GEOLOGICAL SURVEY OF CANADA
BULLETIN 417

ORDOVICIAN TO TRIASSIC CONODONT PALEONTOLOGY OF THE CANADIAN CORDILLERA

Edited by
M.J. Orchard and A.D. McCracken

1991

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

Canada

GEOLOGICAL SURVEY OF CANADA
BULLETIN 417

ORDOVICIAN TO TRIASSIC CONODONT PALEONTOLOGY OF THE CANADIAN CORDILLERA

Edited by
M.J. Orchard and A.D. McCracken

1991

Available in Canada through

authorized bookstore agents and other bookstores

or by mail from

Canada Communication Group - Publishing
Ottawa, Canada K1A 0S9

and from

Geological Survey of Canada offices:

601 Booth Street
Ottawa, Canada K1A 0E8

3303-33rd Street N.W.,
Calgary, Alberta T2L 2A7

100 West Pender Street
Vancouver, B.C. V6B 1R8

A deposit copy of this publication is also available for reference
in public libraries across Canada

Cat. No. M42-417E
ISBN 0-660-14091-8

Price subject to change without notice

COVER DESCRIPTION

Conodonts from the Canadian Cordillera.

Left – one of the oldest conodonts, *Cordylodus proavus* Müller, from the Cambro-Ordovician Rabbitkettle Formation of east-central Yukon Territory (about 505 million years old, hypotype GSC 95112).

Centre – *Palmatolepis crepida* Sannemann, representing the peak of conodont diversity in the Upper Devonian, from the Earn Group of north-eastern British Columbia (about 365 Ma, hypotype GSC 81173).

Right – one of the youngest conodonts, *Misikella posthernsteini* Kozur & Mock, from the Sandilands Formation of Queen Charlotte Islands, British Columbia (about 210 Ma, hypotype GSC 95294).

Final version received for publication: 1990-05-29

Preface

The Canadian Cordillera is a complex of rock units representing the North American craton and accreted allochthonous terranes. The difficulty of correlation within and between terranes and the craton has been overcome in part through paleontological studies. One of the prime fossil tools in this continuing research is the conodont.

This volume is a collection of twelve papers describing aspects of conodont paleontology of the Canadian Cordillera – biostratigraphy, biochronology, paleoecology, evolution, and taxonomy. The last discipline is the basis of all the others, and the creation of 20 new species, 2 new subspecies, 1 new genus, and the 46 plates of conodonts in this volume are a major contribution to taxonomic research. New biostratigraphic zones combined with existing zones provide a comprehensive Ordovician to Triassic temporal standard for sedimentary rocks of western Canada.

Studies such as these increase the precision of correlation both within the Cordillera and with other regions of the world, refine calibration of the geological time scale, and provide the essential framework for mineral and hydrocarbon exploration.

Elkanah A. Babcock
Assistant Deputy Minister
Geological Survey of Canada

Préface

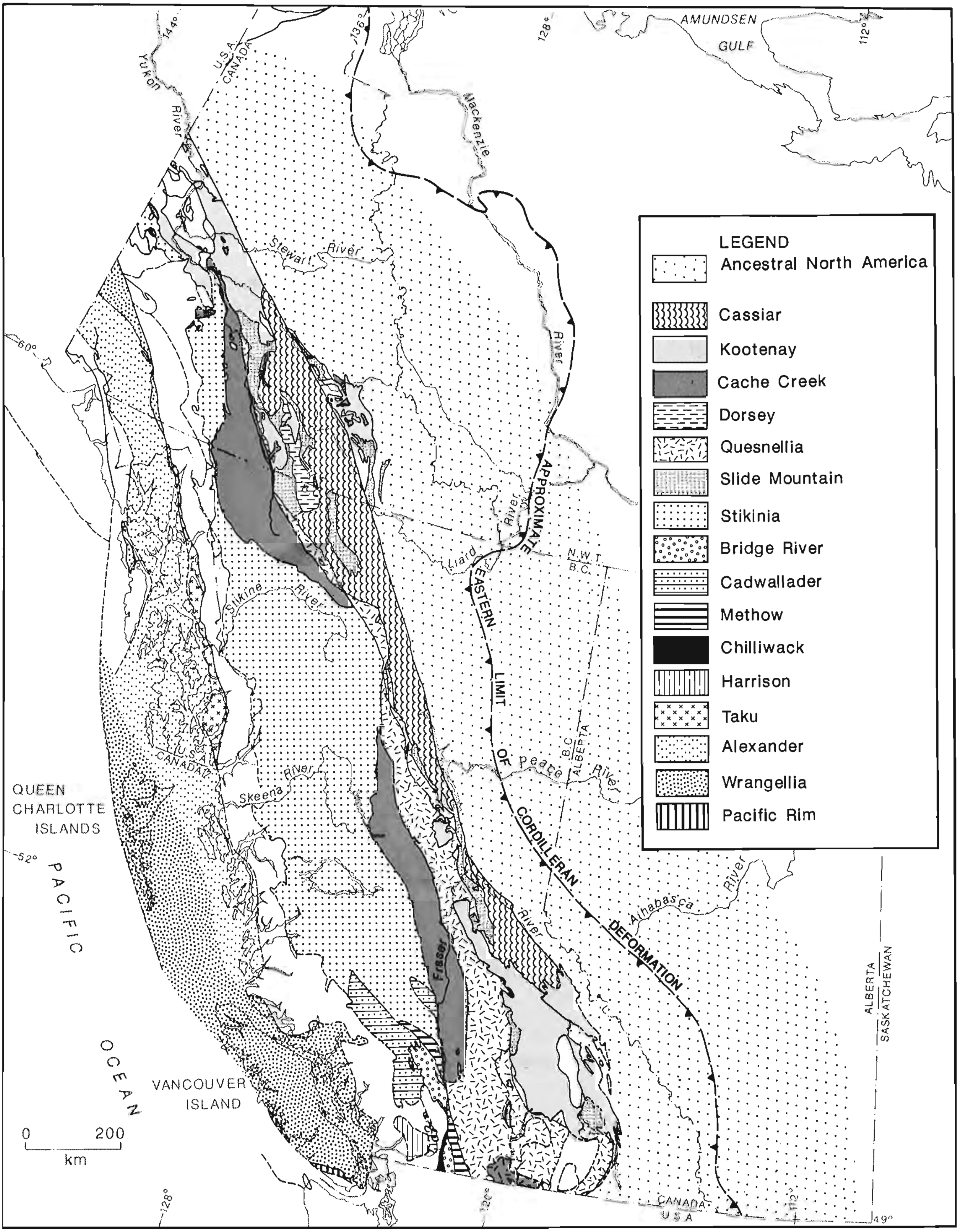
La Cordillère canadienne est un complexe d'unités lithologiques qui correspondent au craton nord-américain et aux terranes allochtones en croissance. Des études paléontologiques ont permis de surmonter partiellement les difficultés que présentent les corrélations à l'intérieur d'un terrane et d'un terrane à l'autre. L'un des principaux fossiles auxquels on fait appel pour réaliser cette étude continue sont les conodontes.

Le présent volume est une collection de douze articles décrivant les détails de la paléontologie des conodontes de la Cordillère canadienne – la biostratigraphie, la biochronologie, la paléoécologie, l'évolution et la taxonomie. La dernière discipline constitue la base de toutes les autres, et la détermination de 20 nouvelles espèces, de deux nouvelles sous-espèces, de un nouveau genre et des 46 planches de conodontes qui figurent dans ce volume représentent une importante contribution à la recherche taxonomique. Les nouvelles zones biostratigraphiques, combinées aux zones existantes, constituent dans l'Ouest canadien un intervalle de référence couvrant toute la période de sédimentation comprise entre l'Ordovicien et le Trias.

Les études de ce type permettent une corrélation plus précise à la fois à l'intérieur de la Cordillère et avec d'autres régions du globe, d'affiner l'étalonnage de l'échelle géologique, et nous offrent un cadre fondamental dans lequel nous pouvons entreprendre l'exploration des gîtes minéraux et des gisements d'hydrocarbures.

Elkanah A. Babcock
Sous-ministre adjoint
Commission géologique du Canada

CONTENTS



Frontispiece. Distribution of Cordilleran tectonostratigraphic terranes in western Canada.

FOREWORD

This volume was compiled to coincide with a joint meeting in Vancouver of the Pander Society (conodont researchers) the first Canadian Paleontology Conference (formerly the Canadian Paleontology and Biostratigraphy Seminar) sponsored by the Paleontology Division of the Geological Association of Canada.

The compilation is a synthesis of Ordovician-Triassic conodont research undertaken in the Canadian Cordillera mostly during the past decade. A frame of reference is the terrane map of western Canada (opposite), which shows the craton and the distribution of heterogenous crustal fragments that have been displaced or have become accreted after the Paleozoic. These studies provide an important contribution in the geological interpretation of the North American Cordillera.

We acknowledge the following for their efforts in expediting the publication of this volume: B. Vanlier (GSC, Vancouver) for assistance with technical editing, the Cartography group (GSC, Calgary) for plate production, S. Irwin (UBC, Vancouver) for technical assistance, and the authors for the relatively efficient production of manuscripts. Final page proofs were seen only by the co-editors because of the tight production schedule, and so we take credit for any errors.

AVANT-PROPOS

La compilation de ce volume a été faite de façon à ce qu'il soit terminé au moment de la réunion conjointe tenue à Vancouver à l'occasion de la Première conférence canadienne de paléontologie de la Pander Society (chercheurs spécialistes des conodontes) (anciennement le Séminaire canadien de paléontologie et de biostratigraphie) parrainée par la Division de paléontologie de l'Association géologique du Canada.

Cette compilation est une synthèse de la recherche entreprise dans la Cordillère canadienne sur les conodontes de l'Ordovicien et du Trias au cours de la décennie qui vient de s'écouler. Un cadre de référence acceptable est la carte des terranes de l'Ouest canadien (page opposée) qui montre le craton et la distribution des fragments crustaux hétérogènes déplacés ou réunis par accrétion après le Paléozoïque. Ces études constituent une importante contribution du point de vue de l'interprétation de la géologie de la Cordillère nord-américaine.

Les auteurs remercient les personnes suivantes de leurs efforts en vue d'accélérer la publication de ce volume: B. Vanlier (CGC, Vancouver), de son aide dans la mise au point technique, le groupe de la Cartographie (CGC, Calgary) de la production des planches, S. Irwin (UBC, Vancouver) de son assistance technique, et les auteurs, de la production relativement efficace des manuscrits. Les corédacteurs seuls ont examiné les épreuves finales du texte, en raison de délais de production serrés, donc nous sommes responsables de toute erreur qui a pu se produire.

Conodonts, time and terranes: an overview of the biostratigraphic record in the western Canadian Cordillera

Michael J. Orchard[1]

Orchard, M.J. 1991: Conodonts, time and terranes: an overview of the biostratigraphic record in the western Canadian Cordillera. In Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417, p. 1-25.

Abstract

Ordovician to Triassic conodont biostratigraphy is described from western Canadian Cordillera, that is within 16 accreted or displaced terranes plus the margin of the North American autochthon. Conodonts of diverse age come from platformal and offshelf strata of Cassiar (including Cariboo) Terrane; pericratonic Kootenay (including Barkerville) Terrane; marginal basin assemblages of Slide Mountain, Dorsey, and Quesnel (Okanagan) terranes; composite island arc assemblages within Quesnel (Harper Ranch), Chilliwack, Cadwallader, Stikine, Taku, Wrangell, and Pacific Rim terranes; oceanic and subduction complexes of Cache Creek and Bridge River terranes; and heterogenous, long ranging Alexander Terrane.

Conodonts of Ordovician age are known from Cassiar, Quesnel (Okanagan) and Alexander terranes; of Silurian age from Cassiar and Alexander terranes; and of Devonian age from Cassiar, Slide Mountian, Quesnel (Okanagan, Harper Ranch), Stikine, and Alexander terranes. Carboniferous–Permian conodont collections, more common and widespread, occur in 12 terranes and are differentiated into 18 faunas. Triassic conodonts occur in 15 terranes with virtually the entire period, including the Permian-Triassic boundary, represented in Cache Creek Terrane.

Résumé

L'auteur décrit la biostratigraphie ordovicienne à triasique des conodontes de la Cordillère occidentale du Canada dans 16 terranes accrétés ou déplacés ainsi que la marge de l'autochtone nord-américain. Des conodontes d'âges divers proviennent de strates de plate-forme et de strates extracôtières dans le terrane de Cassiar (y compris le Cariboo); du terrane péricratonique de Kootenay (y compris le Barkerville); d'assemblages de bassin marginal des terranes de Slide Mountain, de Dorsey et de Quesnel (Okanagan); d'assemblages composites d'arcs insulaires dans les terranes de Quesnel (Harper Ranch), de Chilliwack, de Cadwallader, de Stikine, de Taku, de Wrangel et du Pacific Rim; de complexes océaniques et de complexes de subduction dans les terranes de Cache Creek et de Bridge River; et du terrane hétérogène d'Alexander qui couvre un long intervalle d'âges.

On trouve des conodontes de l'Ordovicien dans les terranes de Cassiar, de Quesnel (Okanagan) et d'Alexander, des conodontes du Silurien dans les terranes de Cassiar et d'Alexander, et des conodontes du Dévonien dans les terranes de Cassiar, de Slide Mountain, de Quesnel (Okanagan, Harper Ranch), de Stikine et d'Alexander. Des collections de conodontes du Carbonifère au Permien, plus fréquents et plus répandus, qui se subdivisent en 18 faunes, se rencontrent dans 12 terranes. Des conodontes du Trias existent dans 15 terranes; les conodontes du terrane de Cache Creek couvrent presque toute la période, y compris la limite permienne-triasique.

---

[1] Geological Survey of Canada, 100 West Pender St., Vancouver, B.C. V6B 1R8

INTRODUCTION

Conodonts from the structurally complex and generally metamorphosed western Canadian Cordillera have been studied for little more than a decade. During this time, conodont research has become increasingly important and continues to have a profound effect on geological interpretations of the region. The growth in conodont study has coincided with the emergence of the terrane concept, which views the western Cordillera as a collage of allochthonous crustal fragments (terranes) that have amalgamated with ancestral North America since the Mesozoic (see Wheeler et al., 1988).

The inception of the terrane concept was strongly influenced by paleontological data (Monger and Ross, 1971), but prior to the routine extraction of conodonts as a complement to systematic regional mapping, the stratigraphic record within most of the tectono-stratigraphic terranes was unknown or poorly constrained. Although considerable biostratigraphic work remains to be done, it is an opportune time to review our current knowledge of terrane biostratigraphy as revealed by the Ordovician–Triassic conodont record.

In this paper, I present a summary of conodont faunas from the western Canadian Cordillera, and adjacent southeast Alaska. The data, much of it unpublished, represent the output from conodont biostratigraphic research in Vancouver since about 1980; they provide a measure of how our understanding of the Cordillera has advanced during this time. The temporal framework presented is a fundamental basis for other work on terrane analysis.

TECTONIC ELEMENTS

In recent years, the western Cordillera has been interpreted as an amalgamation of crustal fragments that record different stratigraphic and tectonic histories. The definition of these tectono-stratigraphic (''accreted'', ''suspect'') terranes has become a focus of multidisciplinary regional studies. The distribution of the principal terranes in western Canada is shown in Figure 1 (derived from compilations by Wheeler and McFeeley, 1987, Wheeler et al., 1988; see also frontispiece, *this volume*); Figure 2 shows 1:250,000 scale map areas cited in the text.

The eastern limit of Cordilleran deformation falls within the craton where the stratigraphic history is relatively well known. The Rocky Mountain early and middle Paleozoic platformal successions pass westward into the Kechika Trough in northeastern British Columbia and the Selwyn Basin in eastern Yukon, the site of slope and basin deposition. After the Middle Devonian, the basins were filled and upper Paleozoic and younger shelf sediments were deposited.

The accreted terranes of the Cordillera lie west of this region, generally across the Rocky Mountain Trench–Tintina transcurrent fault system (Fig. 1). The most easterly, inboard terrane is the **Cassiar** Terrane (= **Cariboo** Terrane in the south), which contains platformal and offshelf strata similar to those of the North American autochthon; it is thought to represent part of the continental margin displaced northward along strike-slip faults.

To the west, the **Kootenay** Terrane (= **Barkerville** Terrane in west-central British Columbia), described as pericratonic, shows early Paleozoic stratigraphic linkages to the craton but its subsequent history differs. Continuing westward, the **Slide Mountain** and **Dorsey** terranes are basin assemblages with diverse sediment and volcanic components, including abundant oceanic ribbon chert and pillow basalt, that are thought to have been deposited in areas marginal to the craton.

Farther west, the most easterly of the surely allochthonous terranes is the **Quesnel (= Quesnellia)** Terrane, the western parts of which (**Harper Ranch** Subterrane) include Paleozoic arc volcanic and clastic rocks. Additional allochthonous arc assemblages are included in the **Chilliwack, Stikine (= Stikinia)**, and **Wrangell** (= **Wrangellia**) terranes, the last two of which also contain significant platform carbonates. The basement of the eastern Quesnel (**Okanagan** Sub-) Terrane is largely an oceanic assemblage. With the exception of the Wrangell Terrane, these former Paleozoic volcanic island arc terranes were superceded by Triassic volcanic arc assemblages, which also typify the basements of the **Cadwallader** and **Pacific Rim** terranes. Triassic volcanic and sedimentary rocks also occur in the **Taku** Terrane, where they overlie Permian limestone, and in the **Harrison** Terrane, where Permian clasts are known.

In the Wrangell Terrane, there are widespread Triassic carbonate platform and slope deposits built on a volcanic basement of oceanic rift basalts. **Cache Creek** and **Bridge River** terranes consist predominantly of upper Paleozoic and lower Mesozoic oceanic volcanics and chert, accretionary prism mélange deposits, and in the former, substantial Permian carbonate buildups containing ''Tethyan'' fossils.

The **Alexander** Terrane contains upper Proterozoic to Triassic volcanic and sedimentary rocks representing diverse depositional environments; of the allochthonous terranes, it is unique in containing a substantial lower Paleozoic sedimentary record.

CONODONT FAUNAS

Conodonts are known from virtually all Cordilleran terranes. Ordovician through Devonian (Fig. 3) collections are relatively rare except in southeast Alaska, where N. Savage (University of Oregon) has documented many collections, particularly of Devonian age. Many unpublished conodont faunas of Ordovician–Devonian age are also known from the disrupted autochthonous margin in the Selwyn Basin–Kechika Trough, and some of these data are the subject of companion papers in this volume.

Carboniferous and Permian conodont collections (Figs. 4, 5) are far more abundant in the terranes than those of the lower Paleozoic, and many correlations are now possible, between terranes and with the autochthonous successions to the east. The Triassic conodont record (Fig. 6) is the most extensive and, through biochronological schemes developed for the region [Orchard, 1991b (*this volume*)], it is possible to produce a highly resolved stratigraphic history.

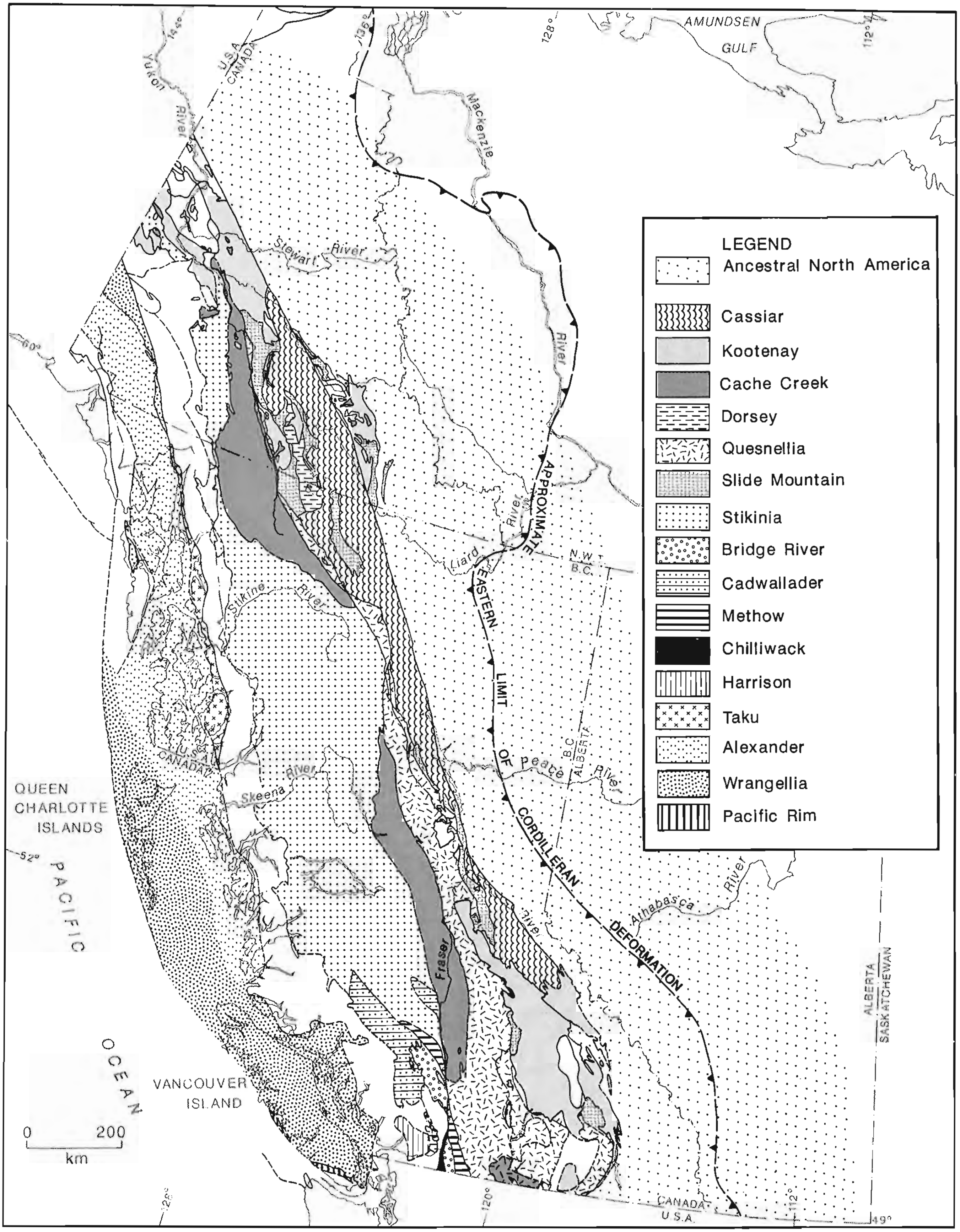


Figure 1. Outline map of western Canada showing distribution of Cordilleran terranes. (From Wheeler and McFeeley, 1987; Wheeler et al., 1988.)

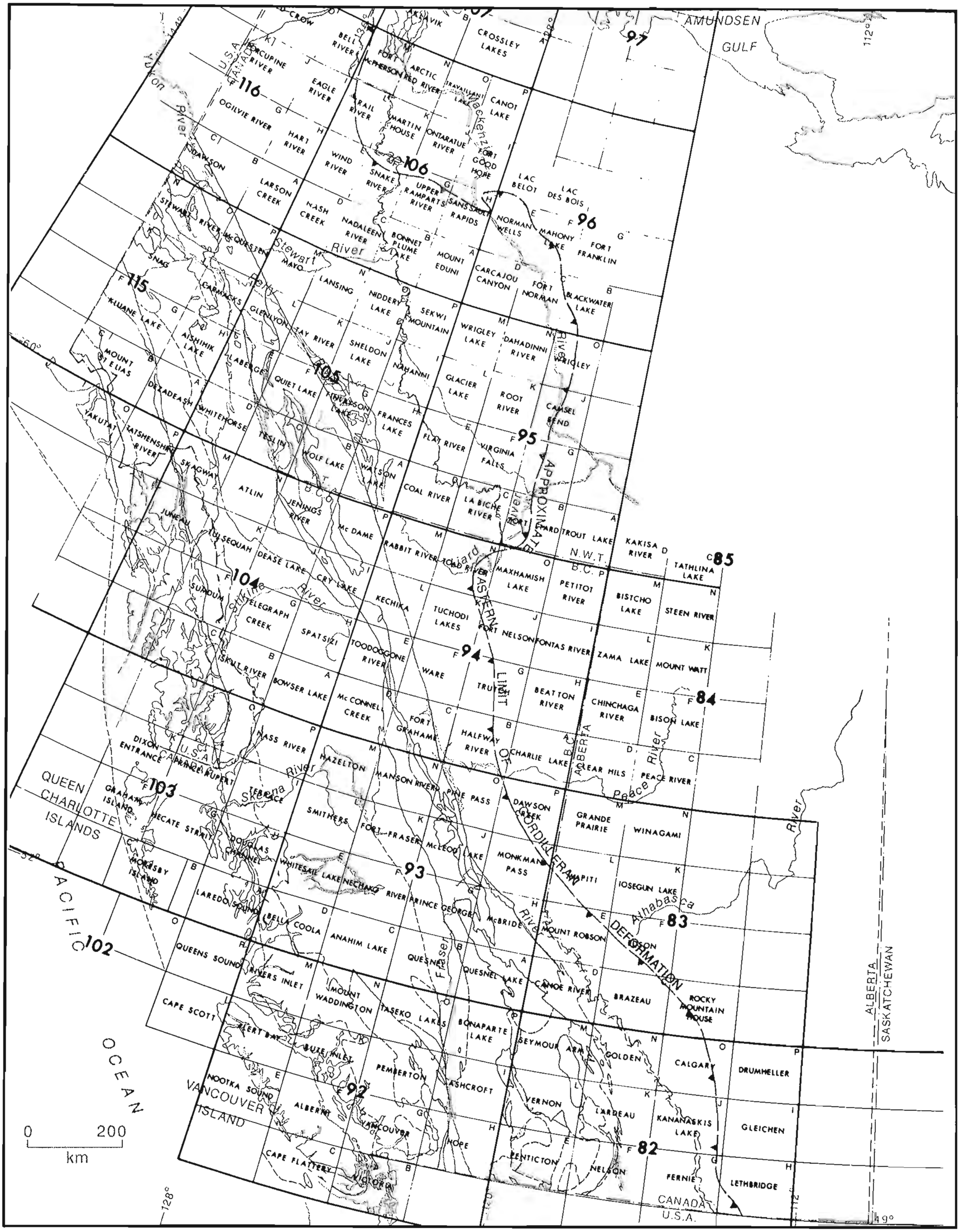


Figure 2. Terrane map of western Canada with overlay showing names of 1:250,000 scale map areas.

In the following account, the conodont biostratigraphic record from the western Cordillera is described chronologically; in the Appendix, the record for each terrane is listed separately. Paleoenvironmental and paleobiogeographic interpretations of the conodonts are noted throughout (see also Orchard *in* Carter et al., in press). The location of cited faunas is recorded by reference to the terranes and the 1:250,000 scale map quadrangles in which they occur.

Ordovician

Ordovician conodonts from the western Cordillera have recently been summarized by Pohler and Orchard (1991), and are included in the review by Barnes et al. [1991 (*this volume*)]. Apart from the marginal areas of the autochthon, Ordovician conodonts are known only from the Alexander, Cassiar, and Quesnel terranes (Fig. 3). In general, as found by Tipnis et al. (1978), in the Selwyn Basin–Kechika Trough, deeper/cooler "North Atlantic Province" conodonts predominate and are juxtaposed against, and in part interfinger with, relatively shallow/warm water North American Midcontinental Province conodonts of the cratonic MacKenzie Platform. Lower, Middle, and Upper Ordovician conodonts are known from the Selwyn Basin (Pohler and Orchard, 1991, Tables. 4-10), but few data are available from sections.

Barnes et al. [1991 (*this volume*)] and McCracken [1991a (*this volume*)] present new data from more easterly and/or northerly, less tectonized areas of Cordilleran Ordovician strata, and review the extent of former studies in the region.

Period/ Age		TERRANE	NORTH AMERICAN AUTOCHTHON	CASSIAR	SLIDE MOUNTAIN	QUESNELLIA	STIKINIA	ALEXANDER
DEVONIAN	Late	FAMENNIAN	●	●	●	●		
		FRASNIAN	●	●		●		●
	Middle	GIVETIAN	●	●				●
		EIFELIAN	●	●			●	●
	Early	EMSIAN	●	●				●
		PRAGIAN	●				●	●
		LOCHKOVIAN	●					●
SILURIAN			●	●				●
ORDOVICIAN			●	●		●		●

GSC

Figure 3. Occurrence of Ordovician–Devonian conodont faunas within Cordilleran terranes.

The Canadian part of the Alexander Terrane (Dezadeash, Tatshenshini River) has yielded few, exclusively coniform and largely Lower Ordovician elements such as *Drepanoistodus* and *Variabiloconus* (Pohler and Orchard, 1991, Table 1) but farther south, A. Harris (pers. comm., 1979) has collected Middle Ordovician *Pygodus* and *Periodon* from the Descon Formation on Prince of Wales Island, and Savage and Savage (1980) report *Periodon* in clasts from a conglomerate on nearby Abbess Island. These "deep-water" taxa occur also in the Road River Formation of the Selwyn Basin–Kechika Trough (e.g., Orchard, 1986), and contrast with "shallow-water" *Phragmodus* fauna from the Kechika Group of the adjacent Cassiar Terrane (Finlayson Lake) in Yukon Territory (Pohler and Orchard, 1991, Table 3).

Ordovician conodonts from the Quesnel Terrane (Penticton; Pohler et al., 1989) occur at a single locality within the Shoemaker Assemblage, which is far removed from any other known Ordovician strata. Consisting principally of *Belodella*? (or *Ansella*), *Belodina*, and *Strachanognathus* (Pohler and Orchard, 1991, Table 2), the fauna occurs within recrystallized limestone surrounded by undated siliciclastic sediments and is loosely constrained as Middle or Late Ordovician in age.

Period/ Fauna	Terrane	NORTH AMERICAN AUTOCHTHON	CASSIAR	KOOTENAY	DORSEY	SLIDE MOUNTAIN	QUESNELLIA	CACHE CREEK	BRIDGE RIVER	CHILLIWACK	STIKINIA	ALEXANDER	WRANGELLIA
CARBONIFEROUS – PERMIAN	18							●					
	17					●	?	●			●		
	16	●				●		●					
	15	●				●	●	●			●		?
	14	●	●			●	●				●		●
	13						●	●			●		●
	12	●		●		●	●	?		●	●		
	11	●				●		●			●		●
	10					?							●
	9		●			●		●					
	8		●		●	●						●	
	7	●	●	?	●	●		●				●	●
	6	●	●	●	●	●	●	●	?	●	●	●	
	5		●	●		●							
	4		●			?					●		
	3	●	●	●		●							
	2	●	●			●	?						
	1	●	●			●							●

Figure 4. Ages of Carboniferous and Permian conodont faunas 1–18 relative to North American and Eurasian Carboniferous and Permian series. In general, nearshore biofacies are to the left, offshore biofacies are to the right.

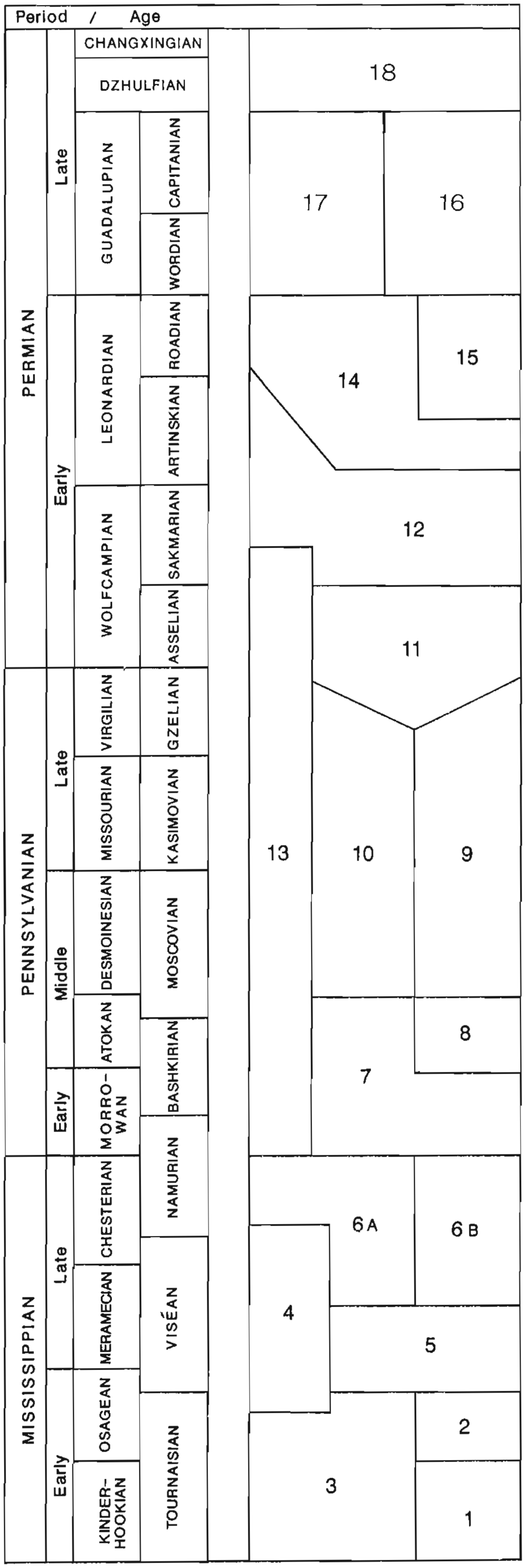


Figure 5. Occurrence of conodont faunas 1–18 within Cordilleran terranes. For relative ages see Figure 4.

Silurian

Silurian conodonts are rare in the Canadian terranes (Fig. 3). A few conodont elements of possible Silurian age are known from the Alexander Terrane (Mount St. Elias, Tatshenshini River) but the only well documented conodont faunas of this age are from the Hecata Limestone in southeast Alaska (Savage, 1985). These diverse faunas are late Llandovery–early Wenlock in age and include several new conodont taxa, which are also known from the northern Cordilleran miogeocline [Norford and Orchard, 1985; Over and Chatterton, 1987; McCracken, 1991b (*this volume*)], Kechika Trough, and equivalent strata in McLeod Lake (Pohler et al., 1989). Small Silurian collections are known from the Cassiar Terrane in Yukon Territory (Quiet Lake), but they are composed exclusively of coniform elements. A review of these data is given by McCracken [1991c (*this volume*].

Devonian

Considerable Devonian conodont data are available from marginal areas of ancestral North America, particularly from east-central Yukon (Nahanni) where several new formations,

TRIASSIC										Period / Age
Early				Middle		Late				
GRIESBACHIAN	DIENERIAN	SMITHIAN	SPATHIAN	ANISIAN	LADINIAN	CARNIAN	NORIAN			
							E	M	L	Terrane
		●	●	●	●	●	●	●	●	NORTH AMERICA AUTOCHTHON
				●	●	●	●	●	●	CASSIAR
						●		●	●	KOOTENAY
					●	●	●	●	●	SLIDE MOUNTAIN
			?	●	●	●	●	●	●	QUESNELLIA
●	●	●	●	●	?	●	●		●	CACHE CREEK
						●	●			BRIDGE RIVER
						●	●	●	●	CADWALLADER
						●				CHILLIWACK
				●						HARRISON
		●	●	●	●	●	●	●	●	STIKINIA
				●		●				TAKU
						●	●	●	●	ALEXANDER
						●	●	●	●	WRANGELLIA
						●	●			PACIFIC RIM

Figure 6. Occurrence of Triassic conodont faunas within Cordilleran terranes.

with complex stratigraphic relationships, have been recognized using data from conodont biostratigraphic studies (Gordey, Abbott, and Orchard, 1982; Orchard, 1984c; Gordey, in press). Some of the Lower–Middle Devonian data are summarized by Uyeno [1991 (*this volume*)] as part of an overview that includes pre-Famennian work on the Rocky and MacKenzie mountains. Upper Devonian conodonts from marginal areas of both Yukon Territory and northern British Columbia are from the Earn Group (Irwin and Orchard, 1989) and are described more fully by Irwin and Orchard [1991 (*this volume*)]. Frasnian–Famennian conodonts from the eastern Cordillera have been described recently by Klapper and Lane (1989), Orchard (1989), and Johnson and Chatterton [1991 (*this volume*)] describe new Famennian data.

Devonian conodonts are known from several areas in the terranes of the western Cordillera, but they are rare outside the Alexander Terrane (Fig. 3). The discovery of Devonian conodonts in both Stikinia and Quesnellia was the first evidence for strata of this age in those terranes, but the geological context of these occurrences remain obscure. Devonian conodonts from the Slide Mountain Terrane supplement reports of Devonian radiolarians from the Sylvester Group and provide a maximum age for that terrane. Details follow.

Lower Devonian

Diverse conodont faunas of Lochkovian, Pragian, and Emsian age have been described from within the Alexander Terrane of southeast Alaska by Savage (1977a, 1977c, 1981, 1982), Savage et al. (1977), and Savage and Gehrels (1984; includes summary). These localities are on Prince of Wales Island and adjacent islands and come principally from the Karheen Formation and overlying (Emsian and younger) Wadleigh Limestone; Lochkovian conodonts have also been recorded from the San Juan Islands in Washington State (Savage, 1984a).

In Canada, Emsian faunules are known from the St. Elias Mountains (Kluane Lake, Tatshenshini River), where *Pandorinellina exigua* Philip is a key element of the fauna, as it is elsewhere in western North America, including the McDame Group of the Cassiar Terrane (Manson River). Younger Emsian faunas from the Alexander Terrane (Dezadeash, Kluane, Mount St. Elias) include *Polygnathus serotinus* Telford and *P. inversus* Klapper and Johnson.

In the Iskut River area of the Stikine Terrane, coralline limestones at the base of the Paleozoic Stikine Assemblage (Read et al., 1989; Anderson, 1989; Brown et al., in press) have yielded Pragian conodonts including *Icriodus steinachensis* Al Rawi. Virtually all of the conodont species known from both the Alexander and Stikine terranes are represented in relatively complete Lower Devonian sequences in the Selwyn Basin [Uyeno, 1991 (*this volume*)]. Conodonts of this age from the accreted terranes are either cosmopolitan or widely dispersed within the Cordilleran region, and have no exotic affinity.

Middle Devonian

Conodonts of probable late Eifelian age are known from the Alexander Terrane in both southeast Alaska (Wadleigh Limestone; Savage, 1977b) and in the St. Elias Mountains in northwest Canada (Tatshenshini River). Species common to both areas are *Polygnathus parawebbi* Chatterton, which appears restricted to the Cordilleran region, and elements close to *P. eiflius* Bischoff and Ziegler and *P. trigonicus* Bischoff and Ziegler. Indeterminate polygnathids of probable Eifelian age also occur in the Stikine Terrane, within the foliated carbonate succession containing Pragian conodonts.

Faunules of definite Givetian age are largely restricted to the St. Elias Mountains where both the *ensensis* (Mount St. Elias) and *varcus* (Tatshenshini River) zones are identified on the basis of their nominate species. *Icriodus*, characteristic of relatively shallow water environments, is common in the Givetian of the Alexander Terrane (Dezadeash, Tatshenshini River) and is also known from the reefoid McDame Group of the Cassiar Terrane (Watson Lake); the genus is also common on the MacKenzie Platform, but rare in the Selwyn Basin. A probable upper Givetian conodont fauna is also reported from the San Juan Islands in northwest Washington State (Savage, 1984a).

Upper Devonian

Upper Devonian conodonts from the Cordilleran terranes are known from the Alexander, Quesnel, Slide Mountain, and Cassiar terranes. Earn Group strata of the miogeocline occur in both the marginal autochthon, and in parautochthonous strata of the Cassiar Terrane (Orchard and Irwin, 1988). The offshore *Palmatolepis* biofacies is ubiquitous throughout the Earn Group and allows precise dating of stratiform mineral deposits that occur within the westerly derived clastic assemblage [Dawson and Orchard, 1982; Orchard and Irwin, 1988; Irwin and Orchard, 1989, 1991 (*this volume*)].

In the Midway area of the Cassiar Terrane (McDame), middle Famennian conodonts occur in Earn Group strata unconformably overlying the karstic surface of the largely Middle Devonian McDame Group (Orchard and Irwin, 1988) and only rare, possibly residual Frasnian conodonts are known at one locality (Jennings River). Elsewhere in the Cassiar Terrane and within the marginal autochthon, sedimentation was apparently continuous during the Upper Devonian, although no Frasnian–Famennian boundary sections are known (Goodfellow et al., 1990).

Palmatolepis-dominated conodont fauna also date Famennian carbonate within the Sylvester Allochthon (McDame), which structurally overlies the Cassiar Terrane in northern British Columbia. These are the oldest sedimentary rocks within the "oceanic" Slide Mountain Terrane and supplement probable Devonian radiolarians identified within chert from the same region (T. Harms, pers. comm., 1991). Chert of this age is uncommon in the terranes, and only one other conodont locality is known, which is within red chert of the Shoemaker Assemblage in the Quesnel Terrane (Penticton) far to the south and more outboard (Fig. 2). A further clast of red chert, with Upper Devonian radiolarians, is reported from a conglomerate near Lytton (Ashcroft) by Cordey (1990, p. 125); its source is undetermined.

The Shoemaker locality (= informal Apex Mountain group of Milford, 1984) lies within the Okanagan Subterrane of the Quesnel Terrane, which consists of a heterogenous assemblage of both oceanic- and arc-derived rock types of diverse age. Apart from the unique Ordovician occurrence noted above, reworked Siluro–Devonian stromatoporoids have been determined by A.E.H. Pedder (Calgary; *in* Read and Okulitch, 1977), and probable Devonian tentaculitids have been found in other clasts collected by G. Ray (identified by E.C. Prosh, Montreal); other dated rocks in the same area are Carboniferous chert and limestone, and Triassic limestone.

Farther east in the Okanagan Subterrane, a second Devonian conodont collection with upper Frasnian *Palmatolepis* has recently been recovered from a coral-bearing limestone near the base of the Knob Hill Group, an ophiolitic assemblage dominated by greenstone and chert (formerly regarded as Carboniferous; Little, 1983; Fyles, 1990).

To the west, within the Harper Ranch Subterrane of the Quesnel Terrane (Ashcroft), a thick section of plant-bearing siliciclastic strata assigned to the long-ranging Harper Ranch Group, has yielded upper Famennian conodonts of the shallow water ''*Icriodus*''–*Polygnathus*–*Apatognathus* biofacies (Orchard, 1987). The conodonts, contained within a thin fossiliferous limestone lying beneath chert-pebble conglomerate, have no described counterpart in the western Cordillera, although associated brachiopods are known from the Palliser Formation in the autochthonous eastern Cordillera, as well as much farther afield (A.W. Norris, pers. comm., 1985). Conodont data show that this is the oldest unit of the western part of the Quesnel Terrane.

Described Upper Devonian conodont faunas from the Alexander Terrane are limited to several Frasnian, *Polygnathus*-dominated collections from the relatively shallow water Wadleigh Limestone of the Coronados Islands (Savage and Funai, 1980), and islands south of Wadleigh Island; *Palmatolepis* and *Ancyrognathus* have also been reported from this formation (Savage, 1987). Several of the species described from these strata have also been found on the MacKenzie Platform of the Northwest Territories (Klapper and Lane, 1985; Orchard, 1988).

Carboniferous – Permian

Conodont faunas of Carboniferous and Permian age are far more widespread in the terranes of the western Cordillera than older faunas; they provide a relatively complete record for the interval, for which, in general, zonal schemes of global applicability have not yet been worked out. Nevertheless, despite poor conodont preservation, a utilitarian zonation consisting of 18 (formerly 17) conodont faunas has been developed for the region (Orchard, in press).

Generalized temporal and spatial relationships of the 18 faunas, based largely on occurrences outside the area of study, are shown in Figure 4. In general, shallow water biofacies are shown on the left and offshore biofacies on the right; a diagonal line separating faunas implies an overlapping age range. Figure 5 shows the representation of the 18 faunas in each of the Cordilleran terranes.

Upper Paleozoic conodonts from the eastern Cordillera occur in well preserved and well exposed sequences that have been described in a preliminary way by Baxter and von Bitter (1984), and Henderson and McGugan (1986). A new summary is given in Higgins et al. [1991 (*this volume*)].

Fauna 1 – the *Siphonodella* fauna

The most distinctive conodont genus for the early–middle Tournaisian (Kinderhookian) is *Siphonodella*, which has a cosmopolitan distribution, typically in offshore areas. The genus, represented by several species, is widespread in the marginal autochthon, where it is known from carbonate buildups of the Kalzas Formation (Glenlyon), the more siliciclastic Tay formation (informal; Tay River), and the quartzitic Tsichu formation (informal; Niddery Lake) [Gordey, in press; Irwin and Orchard, 1991 (*this volume*)].

Fauna 1 is also known from adjacent terranes: the informal Seagull group (''felsic volcanic unit'') in the northern Cassiar Terrane (Quiet Lake); in both the ''Earn Group'' (Cassiar Terrane) and the structurally overlying Sylvester Group (Slide Mountain Terrane) at Midway (McDame, Jennings River, Cry Lake; Fauna III, Orchard and Irwin, 1988); in radiolarian chert of the Antler Formation in the Slide Mountain Terrane (McBride; Struik and Orchard, 1985; Struik, 1988a); and in dark crinoidal limestone lenses within clastics and volcanics of the Eagle Bay Formation of the Kootenay Terrane (Seymour Arm; Orchard *in* Schiarizza and Preto, 1987).

Far to the west, Fauna 1 also occurs in bedded radiolarian chert of the Shaw Creek member (informal) of the Fourth Lake Formation (formerly Cameron River Formation; Massey and Friday, 1988) of the Buttle Lake Group on Vancouver Island (Alberni, Cape Flattery; Brandon et al., 1986), where it is used to date the oldest sediments overlying the Sicker Group arc volcanics in the Wrangell Terrane.

Apart from the Wrangellia occurrence, rocks of this age are not known in the terranes outboard of the marginal basins. Within the Canadian eastern Cordillera, *Siphonodella* faunules occur in the Banff Formation (Baxter and von Bitter, 1984).

Fauna 2 – the *''Hindeodella'' segaformis* fauna

Of several conodont genera restricted to the late Tournaisian in Europe and the early Osagean in North America, one widespread element, *''Hindeodella'' segaformis* Bischoff, is the index to Fauna 2. Although this distinctive element has been reconstructed as part of the apparatus of *Scaliognathus* (Chauff, 1981), the latter genus is known only from one locality, that is within the Tsichu formation in Yukon Territory (Niddery Lake). In contrast, the *segaformis* element is widespread, occurring in association with *Geniculatus*? n. sp. A [Irwin and Orchard, 1991 (*this volume*)] in many faunules from the margin of the autochthon (Sheldon Lake, Niddery Lake), and in the correlative Black Slate formation of the Seagull group (both informal, Quiet Lake) in northern Cassiar Terrane, Greenberry Limestone in southern Cassiar (= Cariboo) Terrane (McBride; Orchard and Struik, 1985; Struik, 1988a), and the Sylvester Allochthon of the Slide Mountain Terrane (McDame; Fauna IV, Orchard and Irwin, 1988).

Other distinctive but less common upper Tournaisian, Fauna 2 genera include *Doliognathus* from the Yukon autochthon [Glenlyon; Irwin and Orchard, 1991 (*this volume*)], and *Eotaphrus* from both the Greenberry Formation (McBride) of southern Cassiar Terrane (Orchard and Struik, 1985), and the Sylvester Allochthon of the Slide Mountain Terrane (McDame, Jennings River). In general, Fauna 2 represents the offshore successor of Fauna 1 and, in common with it, occurs exclusively in areas marginal to the craton. In the eastern Canadian Cordillera, elements of Fauna 2 are found in the upper Banff and the lowest Livingstone formations (Baxter and von Bitter, 1984).

Fauna 3 – the *Pseudopolygnathus* fauna

Pseudopolygnathids, polygnathids and less common gnathodids occur in association with key elements of faunas 1 and 2, but where the former occur alone they are collectively assigned to Fauna 3, interpreted as a relatively shallow water biofacies of latest Devonian through Tournaisian age. Additional taxa in Fauna 3 are species of *Bispathodus*, *Clydagnathus* and ?*Patrognathus*. A single *Pseudopolygnathus* faunule from the Kalzas Limestone in Yukon Territory [Glenlyon; Irwin and Orchard, (*this volume*)] also includes rare upper Tournaisian *Staurognathus*.

In Yukon Territory, faunas 1-3 occur close to stratiform barite deposits (Glenlyon, Niddery Lake, Sekwi Mountain; Dawson and Orchard, 1982; Orchard and Irwin, 1988). Fauna 3 is also known in the Seagull group (Quiet Lake) and Greenberry Limestone (McBride) of the Cassiar Terrane, and the Sylvester Allochthon of the Slide Mountain Terrane (McDame, Cry Lake). The occurrence of *Pseudopolygnathus* alone in the Milford Group of the Kootenay Terrane (Lardeau; Orchard, 1985) represents the oldest conodont faunule known from that unit; it may be a little older than, or coeval with Fauna 1 of the Eagle Bay Formation farther north in Kootenay Terrane (Seymour Arm).

Fauna 4 – the *Mestognathus* fauna

The index for Fauna 4 has been fully described by von Bitter et al. (1986). *Mestognathus* characteristically occurs in low diversity faunules regarded as indicative of restricted nearshore environments, although in one collection from the ?Slide Mountain Terrane (Manson River) it occurs with cosmopolitan siphonodellids (Fauna 1).

Fauna 4 is represented by *Mestognathus praebeckmanni* von Bitter et al. in the Tournaisian Greenberry Formation (McBride; Orchard and Struik, 1985) of the Cassiar Terrane, where it is associated with uncommon *Polygnathus* and ?*Patrognathus*. The younger, Viséan *Mestognathus beckmanni* Bischoff occurs at a single locality in an unnamed unit of the Stikine Terrane (Toodoggone). Elsewhere in western North America, *Mestognathus* is known only from allochthonous strata in the Brooks Range of Alaska, and in Utah (von Bitter et al., 1986).

Fauna 5 – the *Bispathodus* ex gr. *stabilis* fauna

In the western Cordillera, faunas that consist of simple "bispathodids" referred to *Bispathodus* ex gr. *stabilis* (Branson and Mehl), accompanied by hindeodids, and uncommon gnathodids are interpreted as a less restricted correlative of Fauna 4, of early Viséan (late Osagean–early Meramecian) age, even though such elements range beyond the present interval. These low diversity faunas constitute Fauna 5, which is common in parts of the Sylvester Group of northern Slide Mountain Terrane (McDame). The fauna occurs also in the Greenberry Formation (Orchard and Struik, 1985) of southern Cassiar Terrane (McBride), and in parts of the Milford Group (Orchard, 1985) of the Kootenay Terrane (Lardeau).

Fauna 6 – the *Cavusgnathus-Gnathodus* fauna

Upper Viséan–lower Namurian (Chesterian) conodont faunules are the most common and widespread faunules of late Paleozoic age in the western Cordillera. Two biofacies are recognized, although they are commonly mixed and are not differentiated in Figure 5; these are a shallow water *Cavusgnathus–Kladognathus* biofacies (Fauna 6A), and a more offshore *Gnathodus–Lochriea* biofacies (Fauna 6B). The latter fauna is the more diverse and characteristically includes *Gnathodus bilineatus* (Roundy) and *Lochriea commutata* (Branson and Mehl), and less commonly *Gnathodus homopunctatus* Ziegler, *G. texanus* Roundy, *G. girtyi* Hass, *Vogelgnathus campbelli* Rexroad, early *Rhachistognathus* spp., and *Idioprioniodus*.

The *Cavusgnathus* biofacies is best known in the coralline Milford Group of the Kootenay Terrane (Lardeau) where it occurs with a single species of *Gnathodus*, identified as *G. girtyi* by Orchard (1985); this species perhaps had a broader environmental tolerance than other gnathodids.

Cavusgnathus occurs in many other, more diverse upper Mississippian collections from elsewhere. For example, in the quartz arenite–shale and limestone members of the Tsichu formation and correlative units (Niddery Lake, Nahanni, Nash Creek), including the Keno Hill Quartzite (Dawson), of autochthonous Yukon; in the Englishmans Group of the Dorsey Terrane (Teslin); in crinoidal grainstones of the Eagle Bay Formation (Okulitch and Cameron, 1976; Orchard *in* Schiarizza and Preto, 1987) of Kootenay Terrane (Seymour Arm); in coral–brachiopod wackestone of the Harper Ranch Group (Orchard, 1987) in the Quesnel Terrane (Ashcroft); and in the Stikine Assemblage (Brown et al., in press) in northern Stikine Terrane (Iskut River, Telegraph Creek).

A mixed biofacies Fauna 6 represents the oldest Carboniferous conodonts reported from the Alexander Terrane in Canada. It occurs in the metamorphosed Ducie limestone (informal, Prince Rupert; Woodsworth and Orchard, 1985), as well as in the correlative Peratrovich Formation (Faulhaber, 1977) in southeast Alaska.

The offshore, purely *Gnathodus* biofacies is known from the chert member of the Tsichu formation in Yukon (Niddery Lake, Nahanni); in the Black Slate formation of the Seagull group (Finlayson Lake) in the Cassiar Terrane; from oceanic cherts of the Sylvester Group (McDame), Antler Formation (McBride), and Fennell Formation (Bonaparte Lake) of the Slide Mountain Terrane (Orchard, 1986); and as reworked elements in the Alex Allen Formation (McBride; Orchard and Struik, 1985; Struik, 1988a). Offshore Fauna 6B are the oldest conodonts known in limestones of the Cache Creek Complex of northern Cache Creek Terrane (Atlin), which includes the only record of *Lochriea nodosa* (Bischoff) in the western Cordillera.

Small collections of Fauna 6 are known from the Blind Creek Formation of the Quesnel Terrane (Penticton), and from the Chilliwack Group of the Chilliwack Terrane (Hope). The fauna also occurs in the Etherington Formation of the eastern Cordillera (Baxter and von Bitter, 1984).

Fauna 7 – the *Declinognathodus–Idiognathoides* fauna

Conodont faunas indicative of Fauna 7, of late Namurian–early Bashkirian (Early–early Middle Pennsylvanian) age, are characterized by species of *Idiognathoides* and/or *Declinognathodus*. In addition, representatives of the *Idiognathodus–Streptognathodus* plexus are common, whereas species of *Rhachistognathus*, *Neognathodus*, and *Diplognathodus* occur sporadically.

Idiognathoides is ubiquitous in chert of the Slide Mountain Terrane (Orchard, 1986), occurring in the component Anvil Group (Watson Lake), Sylvester Group (McDame), Fennell Formation (Bonaparte Lake, Seymour Arm), Antler Formation (McBride), and correlatives elsewhere (Manson River).

Fauna 7 is common in Yukon, being known from carbonate and chert units assigned to the Mount Christie, Tsichu, and unnamed units in the autochthon (Nash Creek, Niddery Lake, Tay River; Gordey, Abbott and Orchard, 1982), in the Dorsey Terrane (Wolf Lake), and farther west in the Boswell formation (informal, Laberge; Tempelman-Kluit, in prep.). The last occurrence is here referred to the Slide Mountain Terrane, although there is considerable doubt about terrane boundaries in this area.

In the Intermontane Belt of British Columbia, Fauna 7 is known, with *Adetognathus* (see Fauna 13), from massive carbonate of the Cache Creek Complex in central (Fort Fraser, McLeod Lake) and northern (Atlin) Cache Creek Terrane, but not from the type area of the group in the south (Orchard, 1984a) where the oldest sediments are much younger (see below). Neither the Quesnel nor the Stikine terranes include Upper Carboniferous faunas 7-10.

On the west coast, Fauna 7 is known from the Alexander Terrane in metamorphosed limestone of the Dunira Formation (Prince Rupert; Woodsworth and Orchard, 1985), and, much better preserved, in the coeval Klawak Formation and Ladrones Limestone in southeast Alaska (Savage and Barkeley, 1985). In the Wrangell Terrane, Fauna 7 is the oldest fauna in the Fourth Lake Formation of the Buttle Lake Group (Alberni, Victoria; Brandon et al., 1986).

Both faunas 6 and 7 have apparently been reworked into the Alex Allen Formation (Orchard and Struik, 1985) of southern Cassiar Terrane (McBride). The youngest conodonts of the Milford Group in the Kootenay Terrane (Lardeau) are species of *Idiognathodus*, which are tentatively assigned to this fauna (Orchard, 1985).

Fauna 8 – the *Neogondolella clarki–Gondolella laevis* fauna

The occurrence of the nominate species of Fauna 8 is largely within the Middle Pennsylvanian. One or both of the primitive gondolelloids *Neogondolella clarki* (Koike) and *Gondolella laevis* Kosenko and Kozitskaya may occur with elements of Fauna 7, but they are less common. Fauna 8 occurs in the Sylvester Group, Fennell Formation, and Antler Group sedimentary rocks of the oceanic Slide Mountain Terrane (McDame, Cry Lake, Bonaparte Lake, McBride; Orchard, 1986), possibly reflecting a deeper or cooler water habitat for the gondolelloids.

The fauna is also known from the Alex Allen Formation (Orchard and Struik, 1985) in southern Cassiar Terrane (McBride), from Cache Creek limestone in central Cache Creek Terrane (Fort Fraser, McLeod Lake), from an unnamed unit in the Dorsey Terrane (Wolf Lake), and, within the Alexander Terrane, from the Dunira Formation (Prince Rupert; Woodsworth and Orchard, 1985) and correlatives in southeast Alaska (Savage and Barkeley, 1985).

Fauna 9 – the *Gondolella* ex gr. *magna* fauna

I differentiate two upper Middle to Upper Pennsylvanian conodont faunas (9 and 10) characterized by separate complexes of gondolelloid taxa. Fauna 9, the more common one, is recognized by the coarse-ribbed *Gondolella sensu stricto*, collectively referred to *Gondolella* ex gr. *magna* Stauffer and Plummer. These gondolelloids are accompanied by lobate *Streptognathodus* species in the Alex Allen Formation (Orchard and Struik, 1985) of southern Cassiar Terrane (McBride), and within chert of the Fennell and Antler formations of the Slide Mountain Terrane (Bonaparte Lake, McBride; Orchard, 1986).

Fauna 9 occurs in carbonate olistoliths of the eastern belt of the Cache Creek Terrane (Ashcroft; Orchard, 1984a), where *Gondolella* ex gr. *magna* is associated with *Idiognathodus*. Similar faunas have recently been recovered from the central outcrop of the Cache Creek Terrane (McLeod Lake).

Fauna 10 – the *Gondolella* ex gr. *gymna* fauna

This uncommon fauna, the second of late Middle to Late Pennsylvanian age, is characterized by the so-called "naked" gondolellids, here collectively assigned to *Gondolella* ex gr. *gymna* Merrill and King. These species of "*Gondolella*" have a narrow, smooth platform, and often a short posterior process [see Henderson and Orchard, 1991 (*this volume*)].

Gondolella ex gr. *gymna* may occur rarely in faunas 9 and 11, and broad contemporaneity with those faunas is probable. However, the gondolelloids occur alone, or with shallow water *Adetognathus*, in parts of the Fourth Lake Formation of Vancouver Island in southern Wrangell Terrane (Alberni, Victoria; Brandon et al., 1986), where they constitute Fauna 10.

Fauna 11 – the *Streptognathodus* ex gr. *elongatus* fauna

Fauna 11, characterized by *Streptognathodus elongatus* Gunnell and allied species, is close to the Carboniferous–Permian boundary in age. The interval can be subdivided into at least three parts based on the occurrence of neogondolellid species and a new genus of probable Asselian age described by Henderson and Orchard [1991 (*this volume*)].

In east-central Yukon, the Mount Christie formation (informal, Nahanni) has yielded *Streptognathodus elongatus* and the new genus together with a "naked" gondolelloid possibly derived from *Gondolella* ex gr. *gymna*.

A fauna that is probably slightly younger occurs in an unnamed unit in west-central Stikine Terrane (Iskut River), and in the Fourth Lake Formation of southern Wrangell Terrane (Alberni, Victoria), where *Streptognathodus* species and the new genus are associated with neogondolellids close to the Lower Permian *Neogondolella dentiseparata* Chernich and Reshetkova [Brandon et al., 1986; Henderson and Orchard, 1991 (*this volume*)].

The co-occurrence of the streptognathodids and neogondolellids without the new genus constitutes a third variation assigned to Fauna 11. This has been recorded from the Sugar limestone (informal, McBride; Orchard and Struik, 1985; Struik, 1988a) of the Kootenay Terrane (= Barkerville Terrane); the Sylvester Group (McDame), Antler Formation (McBride; Struik and Orchard, 1985) and correlative units (Manson River) of the Slide Mountain Terrane; and within olistoliths of the eastern Cache Creek Complex in the Cache Creek Terrane (Ashcroft; Orchard, 1984a).

Streptognathodus elongatus occurs in the upper Telford Formation of the Canadian eastern Cordillera (Henderson and McGugan, 1986).

Fauna 12 – the *Sweetognathus* fauna

Although the relationships between species of *Sweetognathus* are not fully resolved, the appearance of the genus represents a useful Early Permian datum. In the western Cordillera, the early representative *S. inornatus* Ritter occurs with *Neogondolella bisselli* Clark and Behnken, and Carboniferous holdovers, notably *Adetognathus*, in both the Harper Ranch Group (Orchard, 1984b; Orchard and Forster, 1988) of the Quesnel Terrane (Ashcroft), and in the Chilliwack Group of Chilliwack Terrane (Hope); these occurrences are regarded as Sakmarian in age. Broadly correlative faunas occur at two localities in the Slide Mountain Terrane (McDame, Manson River), where *Sweetognathus* occurs with streptognathodids.

Sweetognathus whitei (Rhodes), which has been regarded as indicative of the Wolfcampian–Leonardian boundary in North America (lower Artinskian), occurs with *Neogondolella bisselli* in the Sugar limestone (Orchard and Struik, 1985) in the Kootenay (= Barkerville) Terrane (McBride); the Harper Ranch Group (Orchard, 1984b; Orchard and Forster, 1988) of the Quesnel Terrane (Ashcroft, Vernon); and the Stikine Assemblage (Iskut River, Telegraph Creek) – including reworked clasts within Jurassic conglomerate of the Hazelton Group (Terrace) – in the Stikine Terrane. In the eastern Cordillera, *S. whitei* is recorded from the Ross Creek Formation (Henderson and McGugan, 1986) in southeastern British Columbia.

Sweetognathids with simple, narrow carinas occur alone, or in poorly preserved and indeterminate collections, in chert of the Mount Christie formation in the Yukon autochthon (Nahanni, Tay River); the Stikine Assemblage of the Stikine Terrane (Iskut River, Terrace); the Fennel Formation of the Slide Mountain Terrane (Seymour Arm); and the eastern mélange belt of Cache Creek Complex in the Cache Creek Terrane (Ashcroft).

The precise age of isolated collections of Fauna 13 is difficult to determine because *Sweetognathus* is known to co-occur in places with the younger *Neostreptognathodus* (see Fauna 14), and sweetognathids of Late Permian age have been reported from Asia, as well as in the Marble Canyon Formation of the Cache Creek Terrane (see Fauna 17).

Fauna 13 – the *Adetognathus* fauna

The long-ranging cavusgnathoid genus *Adetognathus* characterizes Fauna 13, which is age equivalent to faunas 7-12. The genus occurs in low diversity faunas with *Ellisonia* and *Hindeodus* and is regarded as indicative of relatively shallow water environments (see Orchard, 1984b).

Fauna 13 is known from the Harper Ranch Group (Ashcroft); within the Stikine Assemblage of the Stikine Terrane (Smithers, Telegraph Creek); in both the Hasen Creek Formation (Kluane Lake) and Mount Mark Formation (formerly Buttle Lake Formation; Massey and Friday, 1988) in the Wrangell Terrane (Alberni; Brandon et al., 1986); and in massive limestone of the Cache Creek Terrane (Fort Fraser, Atlin). In the last terrane, *Diplognathodus* is associated in several faunas. Fauna 13 collections are not necessarily direct correlatives, but indicative of similar, restricted environments.

Fauna 14 – the *Neostreptognathodus* fauna

Several species of the characteristic upper Lower Permian (Leonardian/Artinskian) conodont *Neostreptognathodus* are recognized in the western Cordillera, where the genus is widely distributed. *Neogondolella bisselli* and younger derivatives are commonly associated, including, in the Harper

Ranch Group of the Quesnel Terrane (Ashcroft), uncommon "Asiatic" neogondolellids, such as *N. gujioensis* Igo (Orchard and Forster, 1988).

Fauna 14 is common throughout the Stikine Terrane (Smithers, Terrace, Toodoggone, Spatsizi, Dease Lake, Iskut River, Telegraph Creek), where several species are known from the Asitka Group and its correlatives. *Neostreptognathodus* occurs rarely in Yukon, being known from one locality in each of the Mount Christie formation on the autochthonous margin (Nahanni), the Starr formation (informal, Quiet Lake; Tempelman-Kluit, in prep.) of the Cassiar Terrane, and the Hasen Creek Formation of northern Wrangell Terrane (Kluane Lake). The genus is also rare in the Slide Mountain Terrane (McDame) of northern British Columbia.

On Vancouver Island (Port Alberni, Victoria), *Neostreptognathodus* (or a homeomorph) occurs in the Buttle Lake Group (upper Sicker Group, Brandon et al., 1986), and is locally the youngest Permian fauna preserved in the Wrangell Terrane. Several species of *Neostreptognathodus* are also present in the Ross Creek Formation, near Fernie, southeastern British Columbia (Henderson and McGugan, 1986), in the eastern Cordillera.

Neostreptognathodus co-occurs with Fauna 13 *Sweetognathus* within the Harper Ranch Group (Orchard and Forster, 1988) of the Quesnel Terrane (Ashcroft), and in the Deadman Bay Volcanics in the San Juan Islands of Washington State (Brandon et al., 1983). Overlap of the two genera is not reported elsewhere in North America, but is known in Asia (Bando et al., 1980); the two faunas (13 and 14) are therefore shown as being partially correlative in Figure 4.

Fauna 15 – the *Neogondolella* ex gr. *idahoensis* fauna

In many Permian faunules, particularly those from oceanic terranes, *Neogondolella* occurs alone. These elements commonly have prominent cusps, strong carinas, and high blades typical of *N. idahoensis* Youngquist, Hawley, and Miller and allied species, and consequently differ from well known pre-middle Artinskian species. These faunules are assigned to Fauna 15, which I regard as a deeper water equivalent of Fauna 14. Fauna 15 is particularly well represented in faunules from chert, but is less common in carbonates.

The fauna is known from the Mount Christie formation of the Yukon autochthon (Glenlyon, Tay River); the Sylvester Group (McDame, Cry Lake; Gordey, Gabrielse and Orchard, 1982), the Antler Formation (McBride; Struik and Orchard, 1985), and the Fennell Formation (Bonaparte Lake, Seymour Arm; Orchard, 1986) of the Slide Mountain Terrane; and from the Kaslo Group of the Kootenay Terrane (Lardeau; Orchard, 1985). The oldest fauna from chert of the eastern belt of the Cache Creek Terrane (Ashcroft, Atlin) is probably of this age.

Fauna 15 occurs in carbonate near the top of the Harper Ranch Group of the Quesnel Terrane (Penticton, Ashcroft; Fauna 5, Orchard and Forster, 1988), in parts of the Stikine Assemblage of the Stikine Terrane (Nass River, Iskut River), and in the Hasen Creek Formation of the Wrangell Terrane (Dezadeash). Recently, a small collection tentatively assigned to this fauna (Hesthammer et al., 1991) has been recovered from Queen Charlotte Islands (Moresby Island); this is the first evidence of Paleozoic strata in this part of the Wrangell Terrane. Fauna 15 is also known from the Kindle Formation in Canadian eastern Cordillera (Toad River).

Fauna 16 – the *Neogondolella* ex gr. *serrata* fauna

Fauna 16 is characterized by the occurrence of the Guadalupian (Upper Permian) *Neogondolella serrata* Clark and Ethington group. In common with the neogondolellids of Fauna 15, members of the group appear to favour an offshore, deep-water setting. The earliest representative of the fauna, *N. serrata*, is known from cherts of the Mount Christie formation in the Yukon autochthon (Tay River), from the Fennell Formation (Bonaparte Lake, Seymour Arm) and correlatives (Manson River) of the Slide Mountain Terrane, and from the Kaslo Group of the Kaslo Terrane (Lardeau; Orchard, 1986).

In the type area of the Cache Creek Terrane in southern British Columbia, the younger *Neogondolella postserrata* Behnken dominates conodont fauna from the largely chert and phyllite matrix of the eastern belt mélange unit (Ashcroft; Orchard, 1984a).

Fauna 17 – the *Neogondolella* ex gr. *phosphoriensis* fauna

A second group of Upper Permian neogondolellids related to *Neogondolella phosphoriensis* Youngquist, Hawley, and Miller are largely coeval with Fauna 16 but apparently occur more commonly within shallow water, fusulinid-bearing limestone. The fauna is known from three terranes: the Marble Canyon Formation in the Cache Creek Complex [Ashcroft; Beyers and Orchard, 1991 (*this volume*)], the Sylvester Group of the Slide Mountain Terrane (Jennings River), and the Stikine Assemblage of the Stikine Terrane (Iskut River, Telegraph Creek).

In most collections of Fauna 17, neogondolellids occur alone or with *Hindeodus*, but in the Marble Canyon Formation of the Cache Creek Terrane they are associated with sweetognathids similar to *Sweetognathus hanzhongensis* Wang from the Maokou Formation of south China, or *S. iranicus* Kozur, Mostler and Rahimi-Yazd from the Abedehian Stage of Iran.

Fauna 18 – the *"Iranognathus"* fauna

In the Canadian Cordillera, post-Guadalupian Permian conodonts are recognized only from the Marble Canyon Formation of southern Cache Creek Terrane [Bonaparte Lake; Beyers and Orchard, 1989, 1991 (*this volume*)]. These collections, grouped as Fauna 18, are characterized by species previously referred to "*Diplognathodus*" (Fauna 17 of Orchard, in press) but now assigned, on the basis of micromorphology, to ?*Iranognathus*.

Fauna 18 also includes hindeodids and rare specimens of *Neogondolella* close to *N. orientalis* Barskov and Koroleva and *N. subcarinata* Sweet. These conodont faunules are younger than any previously described from North America, and are correlated in part with the latest Permian Changxingian Stage of China. These collections are discussed more fully by Beyers and Orchard [1991 (*this volume*)].

Triassic

Triassic conodonts are abundant and widespread throughout the Canadian Cordillera. Those from northeast British Columbia in particular occur with ammonoids through much of the period and provide a biochronology that has broad applications elsewhere in the Cordillera and beyond [Orchard, 1991b (*this volume*)]. In the autochthonous part of Yukon Territory, although the Triassic is commonly absent from beneath a sub-Cretaceous unconformity, conodonts of Early, Middle, and Late Triassic age are known from several areas (Dawson, Nash Creek, Nahanni, Glenlyon, Tay River, Finlayson Lake, and Sheldon Lake). Triassic conodonts from the terranes are common and widespread, and have revealed an equally long stratigraphic record in several areas (Fig. 6).

Lower Triassic

The oldest Triassic conodonts known from the Cordillera are specimens of "*Anchignathodus*" *parvus* Kozur and Pjatakova, which are thought to be of Griesbachian age. They occur in limestone of the Marble Canyon Formation in the Cache Creek Terrane (Bonaparte Lake; Beyers and Orchard, 1989), which we know includes very young Permian limestone (Fauna 18 above).

An erosional hiatus apparently occurs locally between the Permian and Triassic in the Marble Canyon Formation because a few Permian elements are reworked into a largely Dienerian conodont collection from calcareous phyllite in Marble Canyon (Ashcroft; Orchard, 1981, 1984a). Nevertheless, the break in the Marble Canyon Formation at the Permian–Triassic boundary is certainly of lesser duration than elsewhere in western Canada, and probably North America.

Dienerian strata, which are dominated by *Neospathodus dieneri* Sweet, *Neogondolella carinata* Clark, and a large number of "ellisonid" ramiform elements, is missing from the north end of the Marble Range (Bonaparte Lake). There, the oldest Triassic sediments above Upper Permian Fauna 18 are interpreted as Smithian [Beyers and Orchard, 1991 (*this volume*)].

Further evidence of local reworking of the Cache Creek Complex shallow water sediments comes from the south end of the Marble Range where boulder conglomerate with oolitic limestone clasts contains Smithian *Neogondolella milleri* (Müller), *Neospathodus waageni* Sweet, and rare *Platyvillosus*, a taxon better known in lower latitudes (Ashcroft; Orchard and Beyers, 1988).

Farther north in the Marble Range (Bonaparte Lake; Beyers and Orchard, 1989), well bedded, shallow water limestone strata, including algal laminates, were deposited during the Smithian and Spathian. These carbonates contain robust ramiform elements similar to *Hadrodontina* and *Pachycladina*, as well as *Neospathodus homeri* Bender and *N. triangularis* (Bender) [Beyers and Orchard, 1991 (*this volume*)].

The Smithian was evidently a time of widespread deposition in the Cordillera. Conodonts of this age are the oldest known from the Triassic of the autochthon in both British Columbia and Yukon Territory, and from the Stikine Terrane. Collections include *Neospathodus waageni*, *Neogondolella milleri* and *N. mosheri* Kozur and are known from the Toad Formation of northeast British Columbia (Toad River), from a similar sequence of ripple cross-laminated siltstone and fine sandstone of the Jones Lake formation (informal, Nahanni; Gordey, in press), and from more distal, condensed pelitic sequences of Chert Mountain (Dawson; Tempelman-Kluit, 1970) and Rackla River (Nash Creek) in Yukon Territory.

In the Stikine Terrane, the Smithian conodonts *Neospathodus pakistanensis* Sweet and *N. waageni* occur in thin carbonates intercalated with siliceous argillite and siltstone of the Stuhini Group (Dease Lake; Read, 1984). Farther south in this terrane (Terrace), carbonate clasts within the Jurassic Hazelton Group contain the same conodonts, although no Smithian strata are known in situ. Strata with Spathian *Neospathodus homeri* (Bender) in the Stikine Terrane (Dease Lake) attest to the continuation of siliciclastic deposition within the Stuhini Group, which contrasts markedly with the coeval Marble Canyon Formation of the Cache Creek Terrane (Bonaparte Lake).

Poorly preserved neospathodids of probable Early Triassic age have also been extracted from clasts within the basal conglomerate of the Jurassic Ladner Group (possibly derived from the underlying Spider Peak Formation) of the Pasayten Trough (Hope; Ray, 1986, p. 1030), and from clasts in Nicola Group breccias of the Quesnel Terrane (Ashcroft, Hope; Orchard, 1986); these hint at even more widespread Lower Triassic sedimentation.

Middle Triassic

In the Quesnel Terrane (Quesnel Lake, Bonaparte Lake), the "volcaniclastic unit" of Struik (1988b) and correlative "black pelites" contain lower Anisian "*Neogondolella*" *timorensis* (Nogami) and *N. regale* Mosher, which identify the oldest Triassic unit of this terrane. A similar fauna also occurs in siliceous strata of the Tsaybahe (informal) and Stuhini groups of the Stikine Terrane (Dease Lake, Telegraph Creek), and in limestone associated with dark grey slate containing siliceous and carbonaceous concretions in the Perseverance group (informal) of the Taku Terrane (Gehrels et al., in press).

The Anisian apparently marked the end of the carbonate continuum in the Cache Creek Terrane, which persisted from mid-Permian through Spathian time. Middle Triassic conodonts from the Cache Creek Terrane are known principally from chert [Ashcroft; Orchard, 1986; Beyers and Orchard, 1991 (*this volume*)]. There was also approximately contemporaneous deposition of radiolarian ribbon chert interbedded with tuff and some carbonate in a large area of northwest and west-central Stikine Terrane (Cry Lake, Dease Lake, Iskut River, Spatzizi, Telegraph Creek, and Terrace), and in the Camp Cove Formation, the basement unit of the Harrison Terrane (Vancouver).

These conodont localities are characterized by generalized representatives of *Neogondolella constricta* Mosher and Clark and the *N. bulgarica* Budurov and Stefanov–*N. excelsa* (Mosher) group (Orchard, 1986). Radiolarians from chert in Bridge River Terrane (Pemberton) are also of Middle Triassic age (Cordey, 1986, p. 599), although no conodonts of this age have been found.

In southern Quesnel Terrane (Ashcroft), the onset of volcanism has been dated from Middle Triassic neogondolellids that occur in interstitial carbonate within pillowed flows of the Nicola Group near Kamloops (Smith, 1979). Conodonts also prove continuing sedimentation of both pelitic and volcaniclastic units in central Quesnel Terrane (Manson River, Quesnel Lake, Bonaparte Lake; Struik, 1988b, p. 1617). The oldest Triassic conodonts known from the Hoole formation (informal, Tempelman-Kluit, in prep.) in parautochthonous Cassiar Terrane (Finlayson Lake) are also Middle Triassic in age.

The diagnostic upper Ladinian conodont *Budurovignathus* is known from carbonate in the Stikine, Quesnel, and Cassiar terranes as well as from the Liard Formation in northeast British Columbia. In addition, the oldest Triassic sediments of the Wrangell Terrane, immediately beneath the Karmutsen Volcanics on Vancouver Island (Alert Bay), contain a Ladinian *Daonella* macrofauna (Müller et al., 1974), although no conodonts of this age are known from the terrane.

In the Cassiar Terrane (Finlayson Lake, Quiet Lake), late Ladinian strata of the Hoole formation are similar to those of the autochthonous Liard sequences, whereas those from the Quesnel (Ashcroft, Penticton) and Stikine (Telegraph Creek) terranes are, in contrast, intimately associated with volcanics in an island arc assemblage.

In southern Quesnel Terrane (Penticton), the Brooklyn Formation and correlative Olalla limestone (informal; Pohler et al., 1989) contain late Ladinian *Budurovignathus mungoensis* (Diebel) associated with *Neogondolella inclinata* Kovacs. Farther to the west, the same fauna occurs in other carbonates within the dominantly volcanic Nicola Group, including the westernmost exposures of the Quesnel Terrane at Martel (Ashcroft). Many of these limestones occur mixed with volcanics and some include coarse cobble and boulder conglomerate showing multiple phases of reworking; they attest to the instability of the Quesnel Terrane island arc environment during the Ladinian, and later (see below).

Upper Triassic

Upper Triassic conodont bearing strata are preserved in virtually every Cordilleran terrane, as well as in the autochthon. Highly resolved biochronology [Orchard, 1983, 1991a, 1991b (*this volume*); Carter et al., 1989] provides the potential for a relatively detailed piecing together of the Late Triassic history of the Cordillera.

Lower Carnian

Lower Carnian strata, identified most confidently on the basis of *Mosherella newpassensis* (Mosher), are uncommon in the terranes and, outside northeast British Columbia, are proven only in the Hoole formation of the Cassiar Terrane (Finlayson Lake); the same species is recorded (unverified) from limestone of the Nicola Group of the Quesnel Terrane (Ashcroft; Grette, 1978). The occurrence of early species of *Metapolygnathus* in parts of the Shoemaker Assemblage of the Quesnel Terrane (Penticton; Milford, 1984), and in the Stuhini Group of the Stikine Terrane (Dease Lake) also indicate that Lower Carnian strata may be present; each of these occurrences is anticipated from the discovery of upper Ladinian fauna nearby.

In the Wrangell Terrane, the extensive tholeiitic rift lavas of the Karmutsen Volcanics mark a dramatic change in Wrangellian history. The volcanics are bracketed as Lower Carnian but the only conodonts known, from interstratified limestone near the top of the volcanics, are probably Upper Carnian. Conodonts reported by Savage (1983a, 1984b) from San Juan Island in northwest Washington State may also be Early Carnian in age.

Upper Carnian

Upper Carnian platformal carbonates of the Peril Limestone (Queen Charlotte Islands) and Quatsino Formation (Vancouver Island) were deposited on the Karmutsen volcanic basement throughout the Wrangell Terrane; these units are characterized by *Metapolygnathus* ex gr. *polygnathiformis* (Budurov and Stefanov) and *Cornudina*? n. sp. A Orchard (1991a). With the advent of the Upper Carnian *nodosus* Zone, the carbonate platform throughout Queen Charlotte Islands was overtaken by slope and basin deposits of the Peril Formation (Desrochers and Orchard, 1991), although the platformal facies persisted into the Norian in parts of Vancouver Island (Alberni, Alert Bay).

Farther north in the St. Elias Mountains of northwest British Columbia (Tatshenshini River) and Yukon Territory (Kluane Lake), isolated Carnian and Lower Norian conodont collections are also known from the equivalent of the Chitistone Formation in Alaska, but biostratigraphic details of these Wrangellian successions are unknown.

Upper Carnian, *Metapolygnathus*-bearing limestones are the oldest sedimentary rocks in the Ucluth Volcanics, which constitute the basement of Pacific Rim Terrane (Cape Flattery; Brandon, 1984). Upper Carnian conodonts are also the oldest known from the Triassic succession of the Alexander Terrane (Dezadeash), although all Triassic strata in the southern part of the terrane are younger (see below).

In the Stikine Terrane, Upper Carnian conodonts occur in limestone interbedded with interarc volcanics of the Lewes River Group in Yukon Territory (Laberge; Tempelman-Kluit, in prep.), in association with island arc andesitic volcanics and pyroclastics within the Stuhini Group in northern British Columbia (Iskut River, Telegraph Creek, Dease Lake), and in correlative units in central and southern British Columbia (Terrace, Whitesail, Mount Waddington).

Similar Upper Carnian *Metapolygnathus*-bearing volcanic island arc assemblages in the Quesnel Terrane contain limestone intercalated with argillite, volcaniclastic and (calc-alkaline volcanic rocks within the Takla (Manson River) and Nicola groups (Ashcroft; Monger and McMillan, 1984) and in more sediment-dominated sequences such as those of the Hedley area (Hope; Ray et al., 1987).

Nearby, the Cultus Formation of the Chilliwack Terrane (Hope) contains Upper Carnian limestone in association with island arc clastic and volcanic rocks, and the Pioneer Volcanics of the Cadwallader Terrane (Pemberton) also contain Carnian limestone blocks. Similarly, west of Cache Creek, the volcanic–limestone Pavilion Beds (Pemberton) also developed at this time (cf. Rafek, 1980). In the Taku Terrane, the Perseverance group includes Carnian pelitic strata interbedded with basaltic metavolcanic rocks (Gehrels et al., in press).

Less volcanic influx is seen during the Upper Carnian in more northern and eastern parts of the Quesnel Terrane (Quesnel Lake), where fine grained siliciclastic strata of the "black pelite unit" were deposited. Similar sediments characterize the Slocan Group of the Kootenay Terrane (Lardeau; Okulitch and Cameron, 1976; Orchard, 1985), and the only post-Permian sedimentary rocks assigned to the Sylvester Allochthon of the Slide Mountain Terrane (McDame).

Both chert and limestone deposits are Upper Carnian in the oceanic Cache Creek (Ashcroft, Teslin) and Bridge River (Pemberton) terranes, where conodont faunas include *Neocavitella* (known also in the "Tethyan" Baker Terrane of Oregon; collections of M. Nestell, Texas), a taxon which is not known from the autochthon.

Lower Norian

Lower Norian *Epigondolella* species are particularly widespread in the terranes and show that, in general, sedimentary and/or volcanic regimes established during the Upper Carnian continued into the Norian. This is so in the Pardonet Formation of the autochthon (Halfway River), the parautochthonous Hoole formation of the Cassiar Terrane (Quiet Lake), and in the marginal Sylvester Allochthon (McDame).

Similarly, in the Insular Belt, slope and basin sedimentation continued in the Peril–Parsons Bay formations in most areas of the Wrangell Terrane (Queen Charlotte Islands and Vancouver Island), although platformal Quatsino Limestone persisted locally. In the Queen Charlotte Islands, both ?*Neocavitella* and "*Neogondolella*" *hallstattensis* (Mosher) occur in the Lower Norian; neither are known from the autochthon.

In the adjacent Alexander Terrane (Prince Rupert), Lower Norian limestone of the Randall Formation unconformably overlies the Upper Carboniferous (Faunas 7, 8) Dunira Formation (Woodsworth and Orchard, 1985), and marks a Triassic transgression that apparently occurred during the Late Carnian farther north. There, in the Alsek Ranges of St. Elias Mountains, both Upper Carnian and Lower Norian conodonts occur in limy argillaceous strata interbedded with spilitic volcanics and stratiform massive sulphide deposits at Windy–Craggy (Tatshenshini; MacIntyre, 1984), and a basal conglomerate contains derived Devonian conodonts.

Within the Intermontane Belt, multi-generation carbonate conglomerates containing Lower Norian conodonts occur in the Whistle Creek and Hedley sequences of the Quesnel Terrane (Hope; Ray et al., 1987), and in the Hurley Formation of the Cadwallader Terrane (Taseko Lakes, Pemberton; Rusmore, 1987). Elsewhere in the Quesnel Terrane (Ashcroft, Penticton, Quesnel, and Quesnel Lake), the volcanogenic Nicola Group and correlatives commonly contain Lower Norian conodonts representing several zones. The same is true of the Stikine Terrane, where the Stuhini Group includes Lower Norian limestone associated with volcanic rocks in many areas (Dease Lake, Iskut River, Spatsizi, Telegraph Creek).

The Cache Creek (Atlin, Teslin) and Bridge River (Pemberton) terranes continue as sites of chert deposition in the Norian, yet both also include contemporaneous Lower Norian limestone olistoliths and/or lenticular accumulations with conodonts (Cameron and Monger, 1971; misidentified as Ladinian). In common with Carnian faunas, Lower Norian collections from Bridge River include "Tethyan" conodont species, in this case *Epigondolella spatulata* (Hayashi) and *Neogondolella hallstattensis*. Savage (1983b) and Igo et al. (1984) have also reported probable Lower Norian conodonts from, respectively, limestone and chert in the San Juan Islands, Washington State.

Middle Norian

Lowest Middle Norian strata in the Pardonet Formation of autochthonous northeast British Columbia are characterized by *Epigondolella multidentata* Mosher, which is known also from the Jones Lake formation in the Yukon autochthon (Sheldon, Tay River), and the adjacent parautochthonous Hoole formation of the Cassiar Terrane (Quiet Lake), but nowhere else in the western Cordillera. The upper Middle Norian *Epigondolella* n. sp. D of Orchard (1983) [= *E. serrulata* n. sp. Orchard 1991b (*this volume*)] is similarly known only from Yukon Territory (Dawson) and from a pelitic Triassic unit within the Sylvester Allochthon of the Slide Mountain Terrane (McDame). Neither conodont species is known for certain in more distal terranes, nor from outside western Canada, and their presence in these terranes may indicate the proximity of these areas to the North American autochthon in the Middle Norian.

In the Queen Charlotte Islands, Middle Norian conodonts are common in the middle part of the Peril Formation, but only the *Epigondolella* n. sp. C [= *E. spiculata* n. sp. Orchard 1991b (*this volume*)] and *postera* faunas (Orchard, 1983, 1991a) are well known. Elsewhere in the Wrangell Terrane, and in the Alexander (Tatshenshini River), Cadwallader (Pemberton), Quesnel (Ashcroft), and Kootenay (Lardeau; Orchard, 1985) terranes, Middle Norian (mostly *postera* Zone) faunas occur rarely. There are no records of Middle Norian sedimentary rocks in the oceanic Cache Creek and Bridge River terranes.

The scarcity of Middle Norian strata may result from intra-Norian erosion in some areas, although this is only apparent in the Cadwallader Terrane (Taseko Lakes; Umhoefer, 1990) where clasts within the basal red conglomerate of the largely Upper Norian Tyaughton Group contain Lower Norian conodonts. A single Middle Norian conodont collection is known from a conglomerate also in the Stikine Terrane (Telegraph Creek).

Upper Norian

The oldest Upper Norian strata, exemplified by the pelecypod *Monotis* and by the conodont *Epigondolella bidentata* Mosher, are common and widespread in the Cordillera. The fauna occurs throughout the Wrangell Terrane, at the top of the Peril Formation (Queen Charlotte Islands; Orchard, 1991a), within the Parsons Bay Formation (Vancouver Island), and in the probable equivalent of the Alaskan McCarthy Formation (Mount St. Elias).

Elsewhere, *Epigondolella bidentata* occurs in an unnamed unit in the adjacent Alexander Terrane (Tatshenshini); in the Stuhini Group of the Stikine Terrane (Iskut River, Telegraph Creek); in the Tyaughton Group of the Cadwallader Terrane (Taseko Lakes); in sedimentary strata of the Nicola Group, the Hedley sequence and correlatives in the Quesnel Terrane (Ashcroft, Hope, Prince George); in the Slocan Group of the Kootenay Terrane (Lardeau, Nelson); in a unit within the Sylvester Group of the Slide Mountain Terrane (McDame); in the Hoole formation of the Cassiar Terrane (Quiet Lake, Tay River); and, in the autochthon, at or near the top of the Pardonet Formation in the eastern Cordillera, and in correlatives in Yukon Territory (Dawson, Nash Creek). *Monotis* coquinas also occur at most of these localities.

In Cadwallader Terrane, megalodont-bearing limestone with *Epigondolella bidentata* occur immediately below *Monotis*. Similar faunas are known also from reefoid carbonate (also with megalodonts) of the Lewes River Group (Laberge) and the correlative Sinwa Limestone (Skagway, Atlin, Dease Lake), as well as in derived clasts within the overlying Jurassic Inklin Formation. These units are assigned to the Stikine Terrane although they may partially overlap the Cache Creek Terrane. However, in parts of the latter terrane (Fort Fraser), *E. bidentata* (and younger conodonts) occurs in a chert facies.

The definitive middle Upper Norian conodont *Epigondolella mosheri* Kozur and Mostler [Orchard, 1991b (*this volume*)] characterizes the type Amoenum (ammonoid) Zone in the richly fossiliferous *Cassianella* Beds of the Cadwallader Terrane (Taseko Lakes). Conodonts of this age are also known from slope deposits in the lower part of the Sandilands Formation in the Wrangell Terrane (Queen Charlotte Islands), where siliciclastic turbidites replace carbonate rich *Monotis* beds (Desrochers and Orchard, 1991).

The aerially restricted Bocock Limestone in the Peace Reach area (Halfway River) of the craton also contains *Epigondolella mosheri*. Further correlatives are dominantly phyllite in southern Cache Creek Terrane [Ashcroft; Beyers and Orchard, 1991 (*this volume*)], and reefoid buildups in the Lewes River Group of northern Stikine Terrane (Laberge; England, 1980). Local occurrences of coeval shelly limestone (without conodonts) are also known from the Alexander Terrane (Prince Rupert; Woodsworth and Orchard, 1985).

The final chapter in conodont history is documented at three localities [Orchard, 1991b (*this volume*)]. In the Cadwallader Terrane, the type locality of the topmost Norian Crickmayi (ammonoid) Zone occurs in the sandstone and conglomerate of the upper green clastic unit of the upper Tyaughton Group (Taseko Lakes). A single specimen of *Misikella posthernsteini* Kozur and Mock has been recovered from a limestone nodule in this sequence.

In the Wrangell Terrane (Dixon Entrance), the same conodont species has been recovered in association with Crickmayi Zone ammonoids from slope deposits of the Sandilands Formation of the Queen Charlotte Islands. Elsewhere in the Wrangell Terrane, the Sutton Limestone of Vancouver Island (Alberni) includes small coral bioherms of Crickmayi Zone age, but rare conodonts are not specifically diagnostic of the latest Norian.

The third occurrence of *Misikella posthernsteini* is in northern Cache Creek Terrane (Teslin), where conodonts from radiolarian chert prove the continuation of oceanic sedimentation to the Triassic–Jurassic boundary (see also Cordey et al., 1987).

SUMMARY

Ordovician to Triassic conodonts are known from 16 accreted or displaced terranes in the western Canadian Cordillera, as well as the disrupted margin of the North American autochthon. These records are summarized in Figures 3, 5, and 6. The conodonts provide both a temporal framework through which the individual geological history of these areas may be interpreted, and biogeographical signatures that help in identifying the degree of allochthoneity of the terranes.

Ordovician, Silurian, and Devonian conodonts are known from the Alexander and Cassiar terranes, both of which contain strata representing much of the lower Paleozoic. The Cassiar Terrane succession and conodont faunas are of shallow water aspect prior to the Late Devonian, and are clearly related to the North American craton. The Alexander Terrane has a unique stratigraphic record, and contains conodont fauna of both deep and shallow water aspect, which have Cordilleran affinity or are cosmopolitan.

The oldest strata in Quesnellia (Okanagan Subterrane) are Ordovician, and in the Stikine Terrane are Lower Devonian – both are recognized by conodont fauna, are known from single localities, and are enigmatic. Late Paleozoic successions begin in eastern Quesnellia (Harper Ranch Subterrane), and possibly in the Kootenay Terrane, as nearshore siliciclastics of Famennian (Late Devonian) age.

Deep water Famennian strata are the oldest dated in the Slide Mountain Terrane, and these correlate with chert presently regarded as lying within western Quesnellia (Okanagan Subterrane), as well as with Earn Group strata of the miogeocline. Tournaisian (Lower Carboniferous) chert is the oldest paleontologically dated sedimentary rock in Wrangellia, and presently represents the only conodont locality of this age outboard of the Slide Mountain Terrane. Chert in the Slide Mountain Terrane contains conodonts that range from Carboniferous through Guadalupian (Late Permian) in age.

Upper Viséan–Lower Namurian carbonates are the oldest widespread Carboniferous strata known from the volcanic island arc Quesnel, Stikine, Chilliwack, and Alexander terranes, and are also found within the Sylvester Allochthon of the Slide Mountain Terrane. Conodonts of this age are the oldest known currently from limestones of the Cache Creek and Dorsey terranes, and are also widespread in the Yukon Autochthon.

Upper Carboniferous rocks are common in the oceanic Slide Mountain and Cache Creek terranes, and are widespread in the Alexander Terrane, and Yukon authochthon. However, strata of this age are very rare in volcanic island arc terranes of Stikinia and Quesnellia.

The youngest chert in the Slide Mountain Terrane is Guadalupian (Late Permian) in age, the approximate age of the oldest conodonts from chert in the Cache Creek Terrane, where siliceous strata ranges through the Triassic. Data from Bridge River Terrane suggest chert deposition persisted through much of the interval represented by both the Slide Mountain and Cache Creek chert domains.

Lower Permian conodonts from Quesnellia, and Upper Permian conodonts from Cache Creek Terrane carbonates have some asiatic affinity. This is particularly true of the latter, although because of its exceptionally young age, no comparison with cratonal successions can be made. Some conodont differences are due to environment, because different Upper Permian elements occur in chert and carbonate samples from the same terrane.

Uppermost Permian and lowermost Triassic strata are known only from the Cache Creek Terrane. A significant sedimentary and probable tectonic break occurs at this boundary in the Quesnel, Stikine, Taku, and Wrangel terranes. Lower Triassic strata are markedly different between the Cache Creek and Stikine terranes; Middle Triassic strata in both include chert, as do the Harrison and Bridge River terranes.

The oldest Triassic volcanic island arc rock assemblages in the Quesnel, Stikine, and Taku terranes include lower Middle Triassic (Anisian) impure carbonates; these suites continued through the Late Triassic. Oldest Triassic strata in the Cadwallader, Chilliwack, and Pacific Rim terranes are younger, Upper Triassic (Carnian) volcanogenics; in the Kootenay and Slide Mountain terranes they are Carnian pelites.

The Wrangell and Alexander terranes contain Triassic rocks as old as late Ladinian–Early Carnian in age, but are locally no older than Norian above an unconformity in the latter terrane. An intra-Triassic discontinuity occurs in the Cadwallader Terrane, perhaps the Stikine Terrane, and possibly elsewhere. Diverse uppermost Norian strata are known from the Wrangell (slope turbidites, bioherms), Cadwallader (nearshore clastics), and Cache Creek (radiolarian chert) terranes.

Several Upper Triassic conodont species have biogeographically restricted occurrences. The Wrangell, Bridge River, and Cache Creek terranes contain some Tethyan elements; the autochthon, and the Cassiar and Slide Mountain terranes have other species in common that do not occur elsewhere.

ACKNOWLEDGMENTS

I thank all the geologists identified in the Appendix who have contibuted to this paper by collecting conodont samples throughout the Cordillera, and all the technicians, notably P. Krauss, and students who have been involved in conodont processing during the last decade. I thank S. Irwin and T. Oliveric for patiently compiling and drafting the figures. I thank A.D. McCracken and D.J. Tempelman-Kluit for their reviews of an earlier manuscript.

REFERENCES

Anderson, R.G.

1989: A stratigraphic, plutonic, and structural framework for the Iskut River map area, northwestern British Columbia. *In* Current Research, Part E, Geological Survey of Canada, Paper 89-1E, p. 143-151.

Bando, Y., Bhatt, D.K., Gupta, V.J., Hayashi, Sh., Kozer, H., Nakazawa, K., and Wang, Z.H.

1980: Some remarks on the conodont zonation and stratigraphy of the Permian. Recent Researches in Geology, v. 8, p. 1-53.

Barnes, C.R., Ji, Z., and Pohler, S.

1991: A review of Ordovician conodont paleontology of the Canadian Cordillera. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

Baxter, S. and von Bitter, P.H.

1984: Conodont succession in the Mississippian of Southern Canada. *In* Neuvième Congrès International de Stratigraphie et de Géologie du Carbonifère, P.K. Sutherland and W.L. Manger (eds.); Compte Rendu, v. 2, p. 253-264.

Beyers, J.M. and Orchard, M.J.

1989: Permian–Triassic boundary beds in the Cache Creek Group, Marble Range, near Jesmond, Bonaparte Lake map area (92P). *In* Current Research, Part E, Geological Survey of Canada, Paper 89-1E, p. 127-132.

1991: Upper Permian and Triassic conodont faunas from the type area of the Cache Creek Complex, south-central British Columbia, Canada. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

Brandon, M.T.

1984: Deformational processes affecting unlithified sediments at active margins: a field study and a structural model. Unpublished Ph. D. thesis, Department of Geology, University of Washington, Seattle, 159 p.

Brandon, M.T., Cowan, D.S., and Vance, J.A.

1983: The Geology of the San Juan Islands, Washington. Geological Association of Canada/Mineralogical Association of Canada, Canadian Geophysical Union, Joint Annual Meeting, Field Trip No. 5, p. 4-29.

Brandon, M.T., Orchard, M.J., Parrish, R.R., Sutherland Brown, A. and Yorath, C.J.

1986: Fossil ages and isotopic dates from the Paleozoic Sicker Group and associated intrusive rocks, Vancouver Island, British Columbia. *In* Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 683-696.

Brown, D.A., Logan, J.M., Gunning, M.H., Orchard, M.J., and Bamber, E.W.
in press: Stratigraphic evolution of the Paleozoic Stikine assemblage in the Stikine–Iskut River area, northwestern British Columbia (NTS 104 G and 104 B). Canadian Journal of Earth Sciences.

Cameron, B.E.B. and Monger, J.W.H.
1971: Middle Triassic conodonts from the Fergusson Group, northeastern Pemberton map-area (92J), British Columbia. *In* Current Research, Part B, Geological Survey of Canada, Paper 71-1B, p. 94-96.

Carter, E.S., Orchard, M.J., and Tozer, E.T.
1989: Integrated ammonoid-conodont-radiolarian biostratigraphy, Late Triassic Kunga Group, Queen Charlotte Islands, British Columbia. *In* Current Research, Part H, Geological Survey of Canada, Paper 89-1H, p. 23-30.

Carter, E.S., Orchard, M.J., Ross, C.A., Ross, J.R.P., Smith, P.L., and Tipper, H.W.
in press: Part B. Paleontological signatures of terranes. *In* Geology of the Cordilleran Orogen in Canada, H. Gabrielse and C.J. Yorath (eds.); Geological Survey of Canada, Geology of Canada, no. 4 (also Geological Society of America, The Geology of North America, v. G-2).

Chauff, K.M.
1981: Multi-element conodont species from the Osagean (Lower Carboniferous) in Mid-Continent North America and Texas. Palaeontographica, Abt. A, v. 175, p. 140-169.

Cordey, F.
1986: Radiolarian ages from the Cache Creek and Bridge River complexes and from chert pebbles in Cretaceous conglomerates, southwestern British Columbia. *In* Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 595-602.
1990: Radiolarian age determinations from the Canadian Cordillera. *In* Current Research, Part E, Geological Survey of Canada, Paper 90-1E, p. 121-126.

Cordey, F., Mortimer, N., De Wever, P., and Monger, J.W.H.
1987: Significance of Jurassic radiolarians from the Cache Creek Terrane, British Columbia. Geology, v. 15, p. 1151-1154.

Dawson, K. and Orchard, M.J.
1982: Regional metallogeny of the Northern Cordillera: biostratigraphy, correlation and metallogenic significance of bedded barite occurrences in Eastern Yukon and Western District of Mackenzie. *In* Current Research, Part C, Geological Survey of Canada, Paper 82-1C, p. 31-38.

Desrochers, A. and Orchard, M.J.
1991: The Kunga Group (Late Triassic–Early Jurassic), Queen Charlotte Islands, British Columbia: stratigraphic revisions and carbonate sedimentology. *In* Evolution and Hydrocarbon Potential of the Queen Charlotte Basin, British Columbia, G.J. Woodsworth (ed.); Geological Survey of Canada, Paper 90-10, p. 163-172.

England, T.D.J.
1980: A study of Upper Triassic conodonts of the Intermontane Belt, Yukon Territory. Unpublished B.Sc. thesis, University of British Columbia, Vancouver, 70 p.

Faulhaber, J.J.
1977: Late Mississippian (late Osagean through Chesterian) conodonts from the Peratrovich Formation, southeastern Alaska. Unpublished M.Sc. thesis, Department of Geology, University of Oregon, Eugene, 174 p.

Fyles, J.T.
1990: Geology of the Greenwood–Grand Forks area, British Columbia. British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1990-25, 19 p.

Gehrels, G.E., McCelland, W.C., Samson, S.D., Patchett, P.J., and Orchard, M.J.
in press: Geologic and tectonic relations along the western flank of the Coast Mountains Batholith between Cape Fanshaw and Taku Inlet, southeastern Alaska. Tectonics.

Goodfellow, W.D., Geldsetzer, H., McLaren, D.J., Orchard, M.J., and Klapper, G.
1990: Geochemical and isotopic anomalies associated with the Frasnian–Famennian extinction. *In* Rare Events, Mass Extinction and Evolution, E. Buffetaut (ed.); Historical Biology, v. 2, no. 1. Conference Information: second workshop on rare events, 1989, p. 51-72.

Gordey, S.P.
in press: Evolution of northern cordilleran miogeocline, Nahanni map area (105 I), Yukon and Northwest Territories. Geological Survey of Canada, Memoir 428.

Gordey, S., Abbott, J.G., and Orchard, M.J.
1982: Devono–Mississippian (Earn Group) and younger strata in east-central Yukon. *In* Current Research, Part B, Geological Survey of Canada, Paper 82-1B, p. 93-100.

Gordey, S.P., Gabrielse, H., and Orchard, M.J.
1982: Stratigraphy and structure of Sylvester Allochthon, southwest McDame map area, North British Columbia. *In* Current Research, Part B, Geological Survey of Canada, Paper 82-1B, p. 101-106.

Grette, J.F.
1978: Cache Creek and Nicola Group near Ashcroft, British Columbia. Unpublished M.Sc. thesis, University of British Columbia, Vancouver, 88 p.

Henderson, C.M. and McGugan, A.
1986: Permian conodont biostratigraphy of the Isabel Group, southwestern Alberta and southeastern British Columbia. Contributions to Geology, University of Wyoming, v. 24, p. 219-235.

Henderson, C.M. and Orchard, M.J.
1991: *Gondolelloides*, a new Lower Permian conodont genus from western and northern Canada. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

Hesthammer, J., Indrelid, J., Lewis, P.D., and Orchard, M.J.
1991: Permian strata on the Queen Charlotte Islands, British Columbia. *In* Current Research, Part A, Geological Survey of Canada, Paper 91-1A, p. 321-330.

Higgins, A.C., Richards, B.C., and Henderson, C.M.
1991: Conodont biostratigraphy and paleoecology of the uppermost Devonian and Carboniferous of the Western Canada Sedimentary Basin. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

Igo, H., Koike T., Igo, H., Sashida, K., Hisada K., and Isozaki, Y.
1984: On the occurrence of conodonts and radiolarians from the San Juan Islands, Washington and Vancouver Island, British Columbia. Annual report of the Institute of Geoscience, the University of Tsukuba, no. 10, p. 86-91.

Irwin, S.E.B. and Orchard, M.J.
1989: Conodont biostratigraphy of the Earn Group: constraints on Upper Devonian mineral deposits, northern British Columbia and Yukon. *In* Current Research, Part E, Geological Survey of Canada, Paper 89-1E, p. 13-19.
1991: Upper Devonian–Lower Carboniferous conodont biostratigraphy of the Earn Group and overlying units, northern Canadian Cordillera. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

Johnston, D.I. and Chatterton, B.D.E.
1991: Famennian conodont biostratigraphy of the Palliser Formation, Rocky Mountains, Alberta and British Columbia, Canada. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

Klapper, G. and Lane, H.R.
1985: Upper Devonian (Frasnian) conodonts of the *Polygnathus* biofacies, N.W.T., Canada. Journal of Paleontology, v. 59, p. 904-951.
1989: Frasnian (Upper Devonian) conodont sequence at Luscar Mountain and Mount Haultain, Alberta Rockly Mountains. *In* Devonian of the World, N.J. McMillan, A.F. Embry, and D.J. Glass (ed.); Canadian Society of Petroleum Geologists, Memoir 14, p. 469-478 (imprint date 1988).

Little, H.W.
1983: Geology of the Greenwood map-area, British Columbia. Geological Survey of Canada, Paper 79-29, 37 p.

MacIntyre, D.
1984: Geology of the Alsek–Tatshenshini rivers area. *In* Geological Fieldwork, 1983. British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1984-1, p. 173-184.

Massey, N.W.D. and Friday, S.J.
1988: Geology of the Chemainus River–Duncan area, Vancouver Island. *In* Geological Fieldwork, 1987. British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1988-1, p. 81-91.

McCracken, A.D.

1991a: Middle Ordovician conodonts from the Cordilleran Road River Group, northern Yukon Territory, Canada. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

1991b: Taxonomy and biostratigraphy of Llandovery (Silurian) conodonts in the Canadian Cordillera, northern Yukon Territory. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

1991c: Silurian conodont biostratigraphy of the Canadian Cordillera with a description of new Llandovery species. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

Milford, J.C.

1984: Geology of the Apex Mountain group, north and east of the Similkameen River, south-central British Columbia. Unpublished M.Sc. thesis, University of British Columbia, Vancouver, 108 p.

Monger, J.W.H. and McMillan, W.J.

1984: Bedrock geology of Ashcroft (92 I) map area. Geological Survey of Canada, Open File 980.

Monger, J.W.H. and Ross, C.A.

1971: Distributon of fusulinaceans in the western Canadian Cordillera. Canadian Journal of Earth Sciences, v. 8, p. 259-278.

Müller, J.E., Northcote, K.E., and Carlisle, D.

1974: Geology and mineral deposits of Alert Bay–Cape Scott map area (92 L-102 I), Vancouver Island, British Columbia. Geological Survey of Canada, Paper 74-8, 77 p.

Norford, B.S. and Orchard, M.J.

1985: Early Silurian age of rocks hosting lead-zinc mineralization at Howards Pass, Yukon Territory and District of Mackenzie and local biostratigraphy of the Road River Formation and Earn Group. Geological Survey of Canada, Paper 83-18, 35 p.

Okulitch, A.V. and Cameron, B.E.B.

1976: Stratigraphic revisions of the Nicola, Cache Creek, and Mount Ida Groups, based on conodont collections from the western margin of the Shuswap Metamorphic Complex, south-central British Columbia. Canadian Journal of Earth Sciences, v. 13, p. 44-53.

Orchard, M.J.

1981: Triassic conodonts from the Cache Creek Group, Marble Canyon, Southern British Columbia. *In* Current Research, Part A, Geological Survey of Canada, Paper 81-1A, p. 357-359.

1983: *Epigondolella* populations and their phylogeny and zonation in the Norian (Upper Triassic). Proceedings of the Third European Conodont Symposium (ECOS III), University of Lund, Sweden. Fossils and Strata, v. 15, p. 177-192.

1984a: Pennsylvanian, Permian and Triassic conodonts from the Cache Creek Group, Cache Creek, southern British Columbia. *In* Current Research, Part B, Geological Survey of Canada, Paper 84-1B, p. 197-206.

1984b: Early Permian conodonts from the Harper Ranch Beds, Kamloops area, southern British Columbia. *In* Current Research, Part B, Geological Survey of Canada, Paper 84-1B, p. 207-215.

1984c: A preliminary account of the conodont record at the western edge of the Mackenzie Platform (Nahanni map area), northwestern Canada. Geological Society of America, Abstracts with Programs, v. 16(3), p. 135.

1985: Carboniferous, Permian and Triassic conodonts from the central Kootenay Arc: constraints on the age of the Milford, Kaslo and Slocan groups. *In* Current Research, Part A, Geological Survey of Canada, Paper 85-1A, p. 287-300.

1986: Conodonts from western Canadian chert: their nature, distribution and stratigraphic application. *In* Conodonts, Investigative Techniques and Applications, R.L. Austin (ed.); Proceedings of the Fourth European Conodont Symposium (ECOS 1V), Chapter 5, p. 96-121. Ellis-Horwood, Chichester, England.

1987: Conodont biostratigraphy and correlation of the Harper Ranch Group (Devonian–Permian), Ashcroft map area (92 I), southern British Columbia. *In* Current Research, Part A, Geological Survey of Canada, Paper 87-1A, p. 743-749.

1989: Conodonts from the Frasnian–Famennian boundary interval in western Canada. *In* Devonian of the World, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, v. 3, p. 35-52, (imprint date 1988).

1991a: Late Triassic conodont biochronology and biostratigraphy of the Kunga Group, Queen Charlotte Islands, British Columbia. *In* Evolution and Hydrocarbon Potential of the Queen Charlotte Basin, British Columbia, G.J. Woodsworth (ed.); Geological Survey of Canada, Paper 90-10, p. 173-193.

1991b: Upper Triassic conodont biochronology and new index species from the Canadian Cordillera. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

in press: The Carboniferous and Permian conodont record in the Canadian Western Cordillera. Proceedings, 11th International Congress of Carboniferous Stratigraphy, 1987, Beijing, China.

Orchard, M.J. and Beyers, J.

1988: Conodont biostratigraphy of the Cache Creek Group in the Marble Range of south-central British Columbia. *In* Current Research, Part E, Geological Survey of Canada, Paper 88-1E, p. 159-162.

Orchard, M.J. and Forster, P.

1988: Permian conodont biostratigraphy of the Harper Ranch beds, near Kamloops, south-central British Columbia. Geological Survey of Canada, Paper 88-8, p. 1-27.

Orchard, M.J. and Irwin, S.

1988: Conodont biostratigraphy, Midway property, northern British Columbia. *In* Geological Fieldwork, 1987. British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1988-1, p. 249-253.

Orchard, M.J. and Struik, L.C.

1985: Conodonts and stratigraphy of Upper Paleozoic limestones in Cariboo Gold Belt, east-central British Columbia. Canadian Journal of Earth Sciences, v. 22, no. 4, p. 538-552.

Over, D.J. and Chatterton, B.D.E.

1987: Silurian conodonts from the southern Mackenzie Mountains, Northwest Territories, Canada. Geologica et Palaeontologica, v. 21, p. 1-49.

Pohler, S.M.L. and Orchard, M.J.

1991: Ordovician conodonts from the western Canadian Cordillera. Geological Survey of Canada, Paper 90-15, 37 p., (imprint date 1990).

Pohler, S.M.L., Orchard, M.J., and Struik, L.C.

1989: Preliminary biostratigraphy of conodonts from the McLeod Lake map area. *In* Current Research, Part E, Geological Survey of Canada, Paper 89-1E, p. 125-126.

Pohler, S.M.L., Orchard, M.J., and Tempelman-Kluit, D.J.

1989: The oldest sediments in the Intermontane Belt: Ordovician conodonts from Olalla, south-central British Columbia. *In* Current Research, Part E, Geological Survey of Canada, Paper 89-1E, p. 61-67.

Preto, V.A. and Schiarizza, P.

1987: Geology of the Adams Plateau–Clearwater–Vavenby area. British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1987-2, 81 p.

Rafek, M.B.

1980: Triassic conodonts from the Pavilion Beds, Big Bar Creek, central British Columbia. *In* Current Research, Part C, Geological Survey of Canada, Paper 80-1C, p. 129-133.

Ray, G.E.

1986: The Hozameen fault system and related Coquihalla serpentine belt of southwestern British Columbia. Canadian Journal of Earth Sciences, v. 23, p. 1022-1041.

Ray, G.E., Dawson, G.L., and Simpson, R.

1987: The geology and controls of skarn mineralization in the Hedley Gold Camp, southern British Columbia (92 H/8, 82 E/5). *In* Geological Fieldwork, 1986. British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1987-1, p. 65-79.

Read, P.B.

1984: Geology Klastline River (104 G/16 E), Ealue Lake (104 H/13 W), Cake Hill (104 I/4 W), and Stikine Canyon (104 J/1 E), British Columbia. Geological Survey of Canada, Open File 1080.

Read, P.B. and Okulitch, A.V.

1977: The Triassic unconformity of south-central British Columbia. Canadian Journal of Earth Sciences, v. 14, p. 606-638.

Read, P.B., Brown, R.L., Psutka, J.F., Moore, J.M., Journeay, M., Lane, L.S., and Orchard, M.J.

1989: Geology of parts of Snippaker Creek (104 B/10), Forrest Kerr Creek (104 B/15), Bob Quinn Lake (104 B/16), Iskut River (104 G/1) and More Creek (104 G/2). Geological Survey of Canada, Open File 2094.

Rusmore, M.E.
1987: Geology of the Cadwallader Group and the Intermontane–Insular superterrane boundary, southwestern British Columbia. Canadian Journal of Earth Sciences, v. 24, p. 2279-2291.

Savage, N.M.
1977a: Lower Devonian conodonts from the Karheen Formation, southeastern Alaska. Canadian Journal of Earth Sciences, v. 14, p. 278-284.
1977b: Middle Devonian (Eifelian) conodonts of the genus *Polygnathus* from the Wadleigh Limestone, southeastern Alaska. Canadian Journal of Earth Sciences, v. 14, p. 1343-1355.
1977c: Lower Devonian conodonts from Port St. Nicholas, southeastern Alaska. Canadian Journal of Earth Sciences, v. 14, p. 2928-2936.
1981: Lower Devonian conodonts from Kasaan Island, southeastern Alaska. Journal of Paleontology, v. 55, p. 848-852.
1982: Lower Devonian (Lochkovian) conodonts from Lulu Island, southeastern Alaska. Journal of Paleontology, v. 56, p. 983-988.
1983a: Late Triassic (Karnian) conodonts from northern San Juan Island, Washington. Journal of Paleontology, v. 57, p. 804-808.
1983b: Late Triassic (Karnian to Norian) conodonts from Orcas Island, northwest Washington. Journal of Paleontology, v. 57, p. 870-872.
1984a: Devonian conodonts from Jones Island, northwest Washington. Canadian Journal of Earth Sciences, v. 21, p. 1339-1343.
1984b: Late Triassic (Karnian) conodonts from Eagle Cove, southern San Juan Island, Washington. Journal of Paleontology, v. 58, p. 1535-1537.
1985: Silurian (Llandovery–Wenlock) conodonts from the base of the Heceta Limestone, southeastern Alaska. Canadian Journal of Earth Sciences, v. 22, p. 711-727.
1987: New polygnathid conodonts from the Frasnian (Upper Devonian) of southeastern Alaska. Canadian Journal of Earth Sciences, v. 24, p. 2323-2328.

Savage, N.M. and Barkeley, S.J.,
1985: Early to Middle Pennsylvanian conodonts from the Kiwak Formation and the Ladrone Limestone, southeastern Alaska. Journal of Paleontology, v. 59, p. 1453-1477.

Savage, N.M. and Funai, C.A.
1980: Devonian conodonts of probable Early Frasnian age from the Coronados Islands of southeastern Alaska. Journal of Paleontology, v. 54, p. 806-813.

Savage, N.M. and Gehrels, G.E.
1984: Early Devonian conodonts from Prince of Wales Island, southeastern Alaska. Canadian Journal of Earth Sciences, v. 21, p. 1415-1425.

Savage, S.M. and Savage, B.J.
1980: The occurrence of the Ordovician conodont *Periodon* in the Abbess Island Conglomerate, southeastern Alaska. Journal of Paleontology, v. 54, p. 871-873.

Savage, N.M., Churkin, M., Jr., and Eberlein, G.D.
1977: Lower Devonian conodonts from Port St. Nicholas, southeastern Alaska. Canadian Journal of Earth Sciences, v. 14, p. 2928-2936.

Schiarizza, P. and Preto, V.A.
1987: Geology of the Adams Lake Plateau–Clearwater–Vavenby area. British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Survey Branch, Paper 1987-2, 88 p.

Smith, R.B.
1979: Geology of the Harper Ranch Group (Carboniferous–Permian) and Nicola Group (Upper Triassic) northeast of Kamloops, British Columbia. Unpublished M.Sc. thesis, University of British Columbia, Vancouver, 211 p.

Struik, L.C.
1988a: Structural geology of the Cariboo gold mining district, east-central British Columbia. Geological Survey of Canada, Memoir 421, 100 p.
1988b: Regional imbrication within Quesnel Terrane, central British Columbia, as suggested by conodont ages. Canadian Journal of Earth Sciences, v. 25, p. 1608-1617.

Struik, L.C. and Orchard, M.J.
1985: Upper Paleozoic conodonts from ribbon chert delineate imbricate thrusts within the Antler Formation of Slide Mountain Terrane, central British Columbia. Geology, v. 13, p. 794-798.

Tempelman-Kluit, D.J.
1970: Stratigraphy and structure of the "Keno Hill Quartzite" in Tombstone River-Upper Klondike River map-areas, Yukon Territory (116 B/7, B/8). Geological Survey of Canada, Bulletin 180, 102 p.

Tipnis, R.S., Chatterton, B.D.E. and Ludvigsen, R.
1978: Ordovician conodont biostratigraphy of the southern District of MacKenzie, Canada. Geological Association of Canada, Special Paper, no. 18, p. 39-91.

Umhoefer, P.J.
1990: Stratigraphy and tectonic setting of the upper part of the Cadwallader Terrane, southwestern British Columbia. Canadian Journal of Earth Sciences, v. 27, p. 702-711.

Uyeno, T.T.
1991: Pre-Famennian Devonian conodont biostratigraphy of selected intervals in the eastern Canadian Cordillera. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

von Bitter, P.H., Sandberg, C.A., and Orchard, M.J.
1986: Phylogeny, speciation and palaeoecology of the Early Carboniferous (Mississippian) conodont genus *Mestognathus*. Royal Ontario Museum, Life Sciences Contributions, no. 143, 114 p.

Wheeler, J.O. and McFeely, P.
1987: Tectonic assemblage map of the Canadian Cordillera and adjacent parts of the United States of America. Geological Survey of Canada, Open File 1565.

Wheeler, J.O., Brookfield, A.J., Gabrielse, H., Monger, J.W.H., Tipper, H.W., and Woodsworth, G.J.
1988: Terrane map of the Canadian Cordillera. Geological Survey of Canada, Open File 1894.

Woodsworth, G.J. and Orchard, M.J.
1985: Late Paleozoic to Early Mesozoic strata and conodonts in the western Coast Plutonic Complex, British Columbia. Canadian Journal of Earth Sciences, v. 22, p. 1329-1344.

APPENDIX

Conodont biostratigraphic record in the western Cordillera

The following section presents a summary of the conodont biostratigraphic record in each of the Cordilleran terranes, plus the marginal areas of the autochthon. The latter represents one standard for comparison (the "North American Terrane"); it does not include areas of the eastern Cordillera that are the subject of other papers in this volume.

The stratigraphic unit (those that have yet to be formally described are indicated with an *, and a lower case suffix), 1:250,000 scale map area (Fig. 2), and sample collector (in parentheses) are given for each time interval or fauna. References in which conodont faunas have been described or reported are given at the end of each listing.

North American autochthon

This region includes the Selwyn Basin–Kechika Trough and adjacent margin of the MacKenzie Platform during the early to middle Paleozoic, which became the site of platformal clastic deposition during the late Paleozoic and Triassic. For the Ordovican through Devonian, a simple listing of units from which conodont faunas are known are given, many of them based on the Nahanni map area (Gordey, in press). Additional collections are known throughout the length of the Cordilleran autochthonous margin, often from unnamed units, but they are not separated here.

Ordovician

Rabbitkettle, Broken Skull, Haywire*, Duo Lake formations.

Silurian

Duo Lake, Steel*, Whittaker, Sapper* formations.

Devonian

Sapper*, Grizzly Bear, Funeral, Sombre, Arnica, Natla, Landry, Headless, Nahanni, Portrait Lake*, Prevost* formations.

Carboniferous–Permian

Fauna 1. Tay* formation – Glenlyon, Tay River (Gordey).

Faunas 1, 2, 6, 7. Tsichu* formation – Niddery Lake (Abbott, Gordey).

Faunas 1, 3. Kalzas Formation – Glenlyon (Gordey).

Faunas 2, 3. Units with barite – Niddery Lake, Sheldon Lake, Sekwi Mountain (Abbott, Dawson, Gordey, Jonasson, Lydon).

Faunas 6, 7. Unnamed unit – Nash Creek (Dawson).

Faunas 6, 11, 12, 14. Mount Christie* formation – Nahanni (Gordey).

Fauna 7, 12, 15, 16. Mount Christie* formation – Tay River (Gordey).

Fauna 15. Mount Christie* formation – Glenlyon (Gordey); Kindle Formation – Toad River (Read).

Triassic

Smithian–Norian. Toad, Liard, Ludington, Baldonnel, Pardonet, Bocock formations – throughout northeast British Columbia (Gibson, Orchard, Tozer).

Smithian. Jones Lake* formation – Nahanni (Gordey).

Smithian, upper Ladinian, Middle and Upper Norian. Unnamed units – Dawson (Clarke, Orchard).

Smithian, Carnian, Middle Norian. Unnamed units – Nash Creek (Orchard).

Upper Ladinian, Carnian. Jones Lake* formation – Glenlyon (Gordey).

Carnian, Lower, Middle, and Upper Norian. Jones Lake* formation – Tay River (Gordey, Tempelman-Kluit).

?Lower Norian. Unnamed units – Finlayson Lake (Jennings, Mortenson); could be allochthonous.

Lower and Middle Norian. Jones Lake* formation – Sheldon Lake (Gordey, Jennings, Wood).

References

Dawson and Orchard, 1982; Gordey, Abbott, and Orchard, 1982; Orchard, 1984c; Norford and Orchard, 1985; Pohler and Orchard, 1991. See also summaries and references in other papers in this volume.

Cassiar Terrane

Ordovician

Kechika and Sandpile groups – Finlayson Lake, Quiet Lake (Tempelman-Kluit).

Ordovician–Silurian

Kechika and Sandpile groups – Manson River (Ferri).

Devonian

Emsian, Givetian, Frasnian. McDame Group – Manson River (Ferri), McDame (Mundy), Jennings River (Nelson).

Emsian–Eifelian. Unnamed unit – Quiet Lake, Finlayson Lake (Gordey); McLeod Lake (Struik).

Famennian. Earn Group – McDame (Jacubowski, Irwin, Nelson).

Carboniferous – Permian

Fauna 1. Seagull* group, felsic volcanic unit – Quiet Lake (Tempelman-Kluit).

Faunas 1–3. Earn Group – Jennings River (Midway), Cry Lake (Jakubowski, Harms).

Faunas 2, 3, 6. Seagull* group, Black Slate* formation with barite – Quiet Lake, Finlayson Lake (Gordey, Tempelman-Kluit).

Faunas 2–5. Greenberry Formation – McBride (Orchard, Struik).

Faunas 6–9 (mixed). Alex Allen Formation – McBride (Orchard, Struik).

Fauna 14. Starr* formation – Quiet Lake (Tempelman-Kluit); ?unnamed unit – McLeod Lake (Struik).

Triassic

Anisian–Upper Norian. Hoole* formation – Finlayson Lake, Quiet Lake, Tay River, Watson Lake (Abbott, Tempelman-Kluit).

References

Orchard and Struik, 1985; Orchard and Irwin, 1988.

Kootenay Terrane

Carboniferous – Permian

Faunas 1, 6. Eagle Bay Formation – Seymour Arm (Okulitch, Orchard, Petro).

Faunas 3, 5, 6, ?7. Milford Group – Lardeau, Nelson (Klepacki, Orchard, Read, Wheeler).

Fauna 12. Sugar* limestone – McBride (Struik).

Triassic

Carnian, Middle–Upper Norian. Slocan Group – Lardeau, Nelson (Brown, Klepacki, Okulitch, Read, Wheeler).

References

Okulitch and Cameron, 1986; Orchard, 1985; Orchard and Struik, 1985; Orchard *in* Petro and Schiarizza, 1987.

Dorsey Terrane

Carboniferous – Permian

Fauna 6. Englishmans Group – Teslin (Dawson).

Faunas 7, 8. Unnamed unit – Wolf Lake (Abbott).

Slide Mountain Terrane

Devonian

Famennian. Sylvester Group – McDame (Harms, Nelson).

Carboniferous–Permian

Faunas 1, 6–9, ?10, 11, 15. Antler Formation chert – McBride (Struik, Orchard).

Faunas 1?, 6–9, 12, 15, 16. Fennell Formation chert – Bonaparte Lake, Seymour Arm (Schiarizza, Preto).

Faunas 1–3, 5–8, 11, 14, 15, 17. Sylvester Allochthon, limestone and chert – Jennings River, McDame, Cry Lake (Dawson, Gabrielse, Gordey, Harms, Irwin, Jakubowski, Nelson, Psutka).

Faunas 1, ?4, 7, 11, ?12, 15. "Slide Mountain" limestone and chert – Manson River (Ferri, Monger).

Fauna 7. Boswell* formation – Laberge (Tempelman-Kluit). Assignment uncertain.

Faunas 15, 16. Kaslo Group chert – Lardeau (Klepacki).

Triassic

Ladinian. Unnamed unit – Ware (Gabrielse).

Carnian. Unnamed unit – Manson River (Ferri).

Carnian, Lower, Middle and Upper Norian. Unnamed unit – McDame (Dawson, Gabrielse, Nelson).

References

Gordey, Gabrielse and Orchard, 1982; Orchard, 1985, 1986; Orchard *in* Preto and Schiarizza, 1987; Orchard and Irwin, 1988; Struik and Orchard, 1985.

Quesnel Terrane

Ordovician

Shoemaker Assemblage (Milford, Orchard, Pohler, Tempelman-Kluit).

Devonian

Frasnian. Knob Hill Group – Penticton (Fyles).

Famennian. Harper Ranch Group – Ashcroft (Monger, Orchard); Shoemaker Assemblage chert – Penticton (Cordey).

Carboniferous – Permian

Faunas 2?, 6, 12–14, 15. Harper Ranch Group – Ashcroft (Monger, Orchard, Forster).

Fauna 6. Blind Creek Formation – Penticton (Tempelman-Kluit).

Fauna 12. Harper Ranch Group – Vernon (Okulitch).

Fauna 13. Mount Roberts Formation – Nelson (Monger).

Fauna 16. ?Unnamed unit – Penticton (Tempelman-Kluit).

Triassic

Scythian. Clasts in Nicola Group – Ashcroft (Monger), Hope (Ray).

Anisian. "Volcaniclastic unit" – Quesnel Lake (Bloodgood, Struik); "black phyllite unit" – Bonaparte River (Orchard); Nicola Group – Ashcroft (Smith); Takla Group – Manson River (Ferri).

Ladinian. "Pelite unit" – Quesnel Lake (Struik); Brooklyn Formation – Penticton (Fyles, Orchard, Tempelman-Kluit); Nicola Group – Ashcroft (Orchard, Read).

Carnian. Shoemaker Assemblage – Penticton (Milford, Read, Okulitch, Tempelman-Kluit); Nicola Group – Bonaparte Lake (Okulitch), Hope, Ashcroft (Monger, Orchard, Ray, Tempelman-Kluit), Quesnel Lake (Panteleyev); "pelite unit" and "volcaniclastic unit" – Quesnel Lake (Struik); Takla Group – McLeod Lake (Struik).

Lower Norian. Unnamed unit – Vernon (Okulitch); Gloucester* formation – Penticton (Tempelman-Kluit); Nicola Group – Ashcroft, Hope (Monger, Orchard, Ray, Tempelman-Kluit); unnamed units – Quesnel Lake, Quesnel (Panteleyev, Struik).

Middle Norian: Nicola Group – Ashcroft (Moore).

Upper Norian. Hedley sequence – Hope (Ray); unnamed unit – Prince George (Kenyon, Struik).

References

Okulitch and Cameron, 1976; Orchard, 1984b, 1986, 1987; Orchard and Forster, 1988; Pohler, Orchard, and Tempelman-Kluit, 1989.

Cache Creek Terrane

Carboniferous – Permian

Faunas 6, 7, 12?, 15. Cache Creek Complex – Atlin (Bloodgood, Lefebure, Monger).

Fauna 7, 13. Cache Creek Complex – Fort Fraser (Orchard).

Faunas 9, 11, 16. Cache Creek Complex, eastern belt – Ashcroft (Orchard, Shannon).

Faunas 17, 18. Marble Canyon Formation – Ashcroft, Bonaparte Lake (Beyers, Orchard, Shannon).

Triassic

Griesbachian, Dienerian, Smithian, Spathian, Carnian, Lower and Upper Norian. Cache Creek Complex, central and western belt limestone – Ashcroft, Bonaparte Lake (Beyers, Orchard, Shannon).

Anisian, lower Ladinian, Carnian, Lower Norian. Cache Creek Complex chert – Ashcroft (Orchard).

Carnian. Pavilion Beds – Taseko Lakes (Trettin).

Carnian to Lower Norian: Cache Creek Complex chert and limestone – Atlin, Teslin (Bloodgood, Monger, Tempelman-Kluit).

Upper Norian. Cache Creek Complex chert – Fort Fraser (Orchard), Teslin (Jackson, Cordey).

References

Beyers and Orchard, 1989, 1991 (*this volume*); Orchard *in* Monger and McMillan, 1984; Orchard, 1984a, 1986; Orchard and Beyers, 1988; Rafek, 1980.

Bridge River Terrane

Carboniferous – Permian

Fauna 6?. Bridge River Group – Pemberton (Cordey).

Triassic

Carnian, Lower Norian. Bridge River Group – Pemberton (Church, Monger, Orchard, Schiarizza).

References

Cameron and Monger, 1971.

Cadwallader Terrane

Triassic

Carnian. Pioneer Volcanics (limestone blocks) – Pemberton (Church); unnamed unit – Mount Waddington (Woodsworth).

Lower and Middle Norian. Hurley Formation – Pemberton, Taseko Lakes (Church, Rusmore, Schiarriza, Woodsworth).

Lower and Upper Norian. Tyaughton Group (Lower Norian in clasts) – Taseko Lakes (Orchard, Tipper, Umhoefer).

References

Orchard *in* Rusmore, 1987; Orchard *in* Umhoefer, 1990.

Chilliwack Terrane

Carboniferous – Permian

Fauna 6, 12. Chilliwack Group – Hope (Monger, Orchard).

Triassic

Upper Carnian. Cultus Formation – Hope (Danner).

Harrison Terrane

Triassic

Anisian. Camp Cover Formation – Vancouver (Arthur).

Stikine Terrane

Devonian

Pragian, Eifelian. Stikine Assemblage – Iskut River (Anderson, Read).

Carboniferous – Permian

Fauna 4. Unnamed unit – Toodoggone River (Thorstad).

Faunas 6, 11–15, 17. Stikine Assemblage – Iskut River, Telegraph Creek (Anderson, Brown, Gunning, Logan, Psutka, Read).

Faunas 12, 14. Unnamed unit, and clasts in the Hazelton Group – Terrace (Woodsworth).

Faunas 13, 14. Unnamed unit – Smithers (Monger).

Fauna 14. Unnamed units – Toodoggone River (Gabrielse), Spatsizi (Monger, Read), Dease Lake (Read).

Fauna 15. Unnamed unit – Nass River (Psutka).

Triassic

Smithian. Clasts in Hazelton Group – Terrace (Woodsworth); Tsaybahe* group – Dease Lake (Psutka); unnamed chert unit – Terrace (Woodsworth).

Spathian to lower Anisian. Stuhini Group – Dease Lake (Psutka).

Middle Triassic. Stuhini Group chert and limestone – Spatsizi, Dease Lake, Cry Lake, Iskut River, Telegraph Creek (Logan, Psutka, Read); Tsaybahe* group chert – Dease Lake (Read); unnamed chert unit – Terrace (Woodsworth).

Upper Ladinian. Stuhini Group – Telegraph Creek (Read).

Carnian: "Formation G" and Aksala* formation, Lewes River Group – Laberge (Tempelman-Kluit, Tozer); unnamed units – Whitesail Lake, Terrace (Woodsworth), Telegraph Creek (Read); clasts in Hazelton Formation – Terrace (Woodsworth).

Carnian to Lower Norian. Stuhini Group chert and carbonate – Dease Lake, Iskut River, Spatsizi, Telegraph Creek (Brown, Psutka, Read).

Lower Norian. Unnamed unit – Dease Lake (Gabrielse, Monger).

Middle Norian. Hancock* formation – Laberge (Tempelman-Kluit); ?clasts in Takwahoni Formation – Dease Lake (Monger), unnamed conglomerate – Telegraph Creek (Brown).

Upper Norian. Sinwa Formation, and clasts in Inklin Formation – Atlin, ?Dease Lake, Skagway (Dodds, Mihalynuk, Tipper); Hancock* and Povoas* formations – Laberge (Tempelman-Kluit); Stuhini Group – Iskut River, Spatsizi, Telegraph Creek (Brown, Logan, Read).

References

Orchard, 1986; Read et al., 1989; Brown et al., in press.

Taku Terrane

Triassic

Anisian, Carnian. Perseverance* group – southeast Alaska (Gehrels).

References

Gehrels et al., in press.

Alexander Terrane

Ordovician

Descon Formation – southeast Alaska (Harris, Savage); unnamed units – Dezadeash, Tatshenshini (Campbell, Dodds).

Silurian

Hecata Limestone – southeast Alaska (Savage); unnamed units – Kluane, Mount St. Elias (Campbell, Dodds).

Devonian

Lochovian–Pragian. Karheen Formation – southeast Alaska (Savage); unnamed unit – Tatshenshini (Campbell, Dodds).

Emsian–Frasnian. Wadleigh Limestone – southeast Alaska (Savage); unnamed units – Mount St. Elias, Kluane Lake, Dezadeash, Tatshenshini (Campbell, Dodds).

Carboniferous – Permian

Fauna 6. Ducie* limestone – Prince Rupert (Woodsworth, Orchard); Peratrovich Formation – southeast Alaska (Faulhaber, Savage).

Faunas 7, 8. Dunira Formation – Prince Rupert (Woodsworth, Orchard); Klawak Formation and Ladrones Limestone – southeast Alaska (Barkeley, Savage).

Triassic

Carnian to Lower Norian. Unnamed unit – Dezadeash (Brown, Read).

Lower Norian. Unnamed unit – Tatshenshini River (Campbell, Dawson, Dodds, MacIntyre, St. Joe).

Lower to Middle Norian. Randall Formation – Prince Rupert (Orchard, Woodsworth).

Middle to Upper Norian. Unnamed unit – Tatshenshini River (Brown, Dodds).

References

Woodsworth and Orchard, 1985; Orchard, 1986; most papers by Savage and co-authors.

Wrangell Terrane

Carboniferous – Permian

Fauna 1. Shaw Creek member* of Fourth Lake Formation – Alberni, Cape Flattery (Brandon, Massey, Orchard).

Faunas 7, 10, 11, 13, 14. Mount Mark Formation of Buttle Lake Group – Alberni, Victoria (Brandon, Massey, Muller, Orchard, Sutherland Brown, Yorath).

Faunas 13, 14. Hasen Creek Formation – Dezadeash, Kluane Lake (Read).

Fauna 15?. Unnamed unit – Moresby Island (Indrelid).

Triassic

Upper Carnian. Sadler Limestone – Queen Charlotte Islands (Orchard); Chitistone? Formation – Tatshenshini River (Dodds).

Upper Carnian to Lower Norian. Quatsino Limestone – Alberni, Cape Flattery (Desrochers, Massey, Orchard, Sutherland Brown, Tozer, Yorath).

Upper Carnian to Upper Norian. Peril Formation – Queen Charlotte Islands (Orchard).

Lower Norian. Chitistone Formation – Kluane Lake (Read, Brailey).

Upper Norian. McCarthy Formation? – Mount St. Elias (Read).

References

Brandon et al., 1986; Carter et al., 1989; Orchard, 1991a, 1991b (*this volume*); Hesthammer et al., 1991.

Pacific Rim Terrane

Triassic

Carnian, Lower Norian. Ucluth Volcanics – Cape Flattery (Brandon).

References

Brandon, *in* Orchard, 1984.

A review of Ordovician conodont paleontology of the Canadian Cordillera

Christopher R. Barnes[1], Zailiang Ji,[1] and Susanne M.L. Pohler[1]

Barnes, C.R., Ji, Z., and Pohler, S.M.L., 1991: A review of Ordovician conodont paleontology of the Canadian Cordillera. In Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417, p. 27-39.

Abstract

There have been relatively few detailed studies of Ordovician conodonts from the Canadian Cordillera but some major studies are in progress. Much of our knowledge of conodont faunas has arisen through the application of biostratigraphy in support of regional mapping projects. In the Canadian Cordillera part of the Ordovician carbonate platform facies is preserved, as well as the thicker miogeoclinal sequence, the extensional Selwyn Basin, parautochthonous belts, and at least two allochthonous terranes with Ordovician strata that were accreted in post-Paleozoic times.

The carbonate platform conodont faunas are best known from the southern Canadian Rocky Mountains, especially at Wilcox Pass. Data from deeper miogeoclinal equivalents have been recently reported from the McKay Group and overlying Glenogle Formation near the Rocky Mountain Trench. In northern British Columbia, the Yukon Territory and the Northwest Territories, the Mackenzie Mountains region and the Selwyn Basin have yielded a range of faunas spanning shallow platform to deep basin environments. Outboard, Ordovician conodonts have recently been reported from sequences in parautochthonous terranes and in the allochthonous Alexander and Quesnel terranes. The pattern of distribution of conodont faunas belonging to the North Atlantic and Midcontinent realms conforms to earlier models of conodont provincialism and paleoecology. The Canadian Cordillera remains a region of high potential for future research despite difficult logistic problems.

Résumé

On a fait très peu d'études détaillées des conodontes ordoviciens de la Cordillère du Canada, bien que quelques travaux d'envergure soient en cours. Une grande partie de nos connaissances des faunes de conodontes proviennent de l'application de la biostratigraphie à l'appui de projets de cartographie régionale. Dans la Cordillère du Canada, sont conservés une partie du faciès de plate-forme carbonatée de l'Ordovicien ainsi que la séquence miogéoclinale plus épaisse, le bassin d'extension de Selwyn, les zones parautochtones et au moins deux terranes allochtones qui contiennent des strates ordoviciennes et dont l'accrétion est postérieure au Paléozoïque.

Les faunes à conodontes les mieux connues de la plate-forme carbonatée proviennent des Rocheuses du Sud au Canada, notamment du col Wilcox. Récemment, on a recueilli des données sur les équivalents miogéoclinaux plus profonds dans le groupe de McKay et la formation susjacente de Glenogle, près du sillon des Rocheuses. Dans le nord de la Colombie-Britannique, le Yukon et les Territoires du Nord-Ouest, les monts Mackenzie et le bassin de Selwyn ont donné des faunes variées qui proviennent d'une gamme de milieux allant d'une plate-forme peu profonde à un bassin profond. Du côté externe, des conodontes ordoviciens ont été retrouvés récemment dans des terranes parautochtones et dans les terranes allochtones d'Alexander et de Quesnel. La distribution des faunes de conodontes des domaines nord-atlantique et médio-continental correspond aux modèles antérieurs du provincialisme et de la paléoécologie des conodontes. La Cordillère canadienne demeure une région fort intéressante pour les travaux de recherches futurs, malgré l'existence de problèmes logistiques complexes.

---

[1] School of Earth and Ocean Sciences, University of Victoria, P.O. Box 3055, Victoria, B.C. V8W 3P6

INTRODUCTION

Studies of Ordovician conodonts from the Canadian Cordillera are still in their infancy. This paper reviews the present knowledge of Ordovician conodont paleontology. Past studies have tended to fall into two categories: major taxonomic or biostratigraphic studies of particular faunas or stratigraphic units, and brief biostratigraphic determinations of samples collected by Geological Survey scientists during regional mapping projects. The present review paper focuses almost entirely on the former group but includes our current research programs.

The Ordovician was a time of major eustatic sea level change, and the North American craton experienced several progressively larger incursions culminating in almost complete submergence in the Late Ordovician (Lenz, 1982; Barnes, 1984). This resulted in widespread Ordovician deposits, especially platform carbonates, which have been subsequently reduced in area by erosion. Such platformal and miogeoclinal sequences are preserved in outcrop and the subsurface in a northwest-trending belt that extends from southwestern Alberta and northeastern British Columbia into the western part of the Northwest Territories, and Yukon Territory. The platform sequences are mainly preserved in the subsurface and in the Mackenzie Mountains to the east; the miogeoclinal sequences outcrop in the Rocky Mountains and in Selwyn Basin. The main tectonic and paleogeographic elements are shown in Figures 1 to 3.

An intriguing issue for the Cordillera is the location of the continental margin in western Canada during the early Paleozoic. Much of the Cordillera consists of accreted terranes separated by major structural dislocation (Monger et al., 1972, 1982; Monger and Price, 1979; Price, 1986; Struik, 1987). Over the last decade, the definition of each terrane and the details of the internal stratigraphy have become clarified. Most terranes were accreted during the late Paleozoic through early Cenozoic and only a few possess a geological record that embraces the early Paleozoic. In those terranes with an Ordovician stratigraphy, the rocks are commonly highly deformed and metamorphosed and recovery of fossils has been rare. In British Columbia, the Rocky Mountain Trench (extending into the Tintina Trench in the Yukon Territory and Alaska) marks an important tectonic boundary. Significant strike-slip motion of hundreds of kilometres appears to have occurred along the trench system (Gabrielse, 1985). To the east of the trench, Ordovician strata are generally considered to have been deposited on cratonic North America, some being thrust eastward during Mesozoic orogenic phases. Structural and thermal complexity decreases eastward from the trench. Immediately west of the trench a few Ordovician sequences are dated (Reesor, 1973), but these become more highly deformed and much rarer westward into the Omineca Crystalline Belt (Kootenay Terrane). Thus, the nature of the Ordovician continental margin for this segment of North America cannot yet be fully documented. The Selwyn Basin with its deep-water sedimentary facies and minor volcanics (Cecile, 1982) appears to be a local extensional structure inboard of the actual margin. Sears and Price (1978) have argued that a large segment of northwestern North America was rifted away during the late Precambrian and now resides as a terrane in northeastern Siberia. The rifted margin would have presumably defined the lower Paleozoic continental margin, which may lie a few tens of kilometres west of the Rocky Mountain Trench. Bond and Kominz (1984) considered that the Cordilleran miogeocline represents a lower Paleozoic passive margin that was created after a rifting phase in the latest Precambrian to earliest Cambrian.

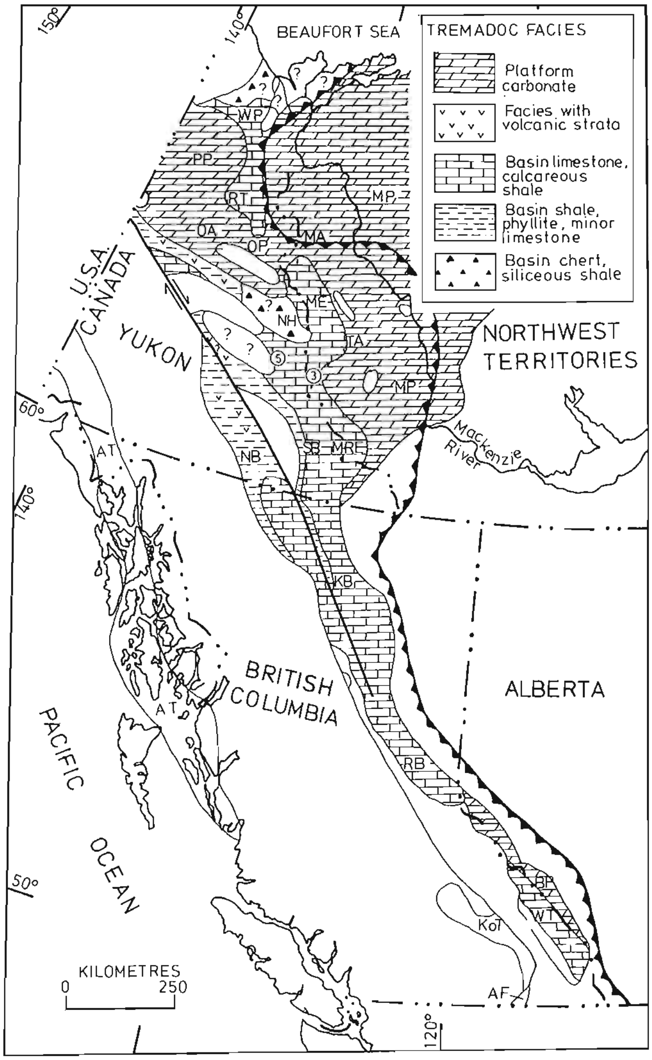


Figure 1. Major paleogeographic features present during the Tremadoc (from Cecile and Norford, in press). WP = White Mountains Platform; PP = Porcupine Platform; RT = Richardson Trough; OA = Ogilvie Arch; MP = Mackenzie Platform; MA = Mackenzie Arch; OP = Ogilvie Platform; ME = Misty Creek Embayment; NH = Niddery High; TA = Twitya Arch; SB = Selwyn Basin; MRE = Meilleur River Embayment; NB = Nasina Basin; KB = Kechika Basin; RB = Robson Basin; BP = White River Trough; AF = Active Formation; KoT = Kootenay Terrane; AT = Alexander Terrane. Numbers in circles refer to conodont publications dealing with Tremadoc conodonts: 3 = Landing et al. (1980); 5 = Pohler and Orchard (1991). Sawtooth line refers to eastern limit of significant tectonic shortening, bold line shows location of the Tintina–Northern Rocky Mountain Trench Fault System.

A general review of the Ordovician geology of the Cordillera has been provided by Douglas et al. (1970) and Cecile and Norford (in press). Regional correlations have been proposed by Barnes et al. (1976, 1981). To conserve space, regional correlation charts are not reproduced herein and the reader is referred to Barnes et al. (1981) for regional stratigraphic details and correlations. Considerations of regional paleogeography have been tackled by Lenz (1982) and Barnes (1984). A review is given below of detailed conodont studies of the major regions and stratigraphic units of the Cordillera for which data are available.

In terms of current research on Ordovician conodont paleontology in the Cordillera, new programs have been established by our group at the University of Victoria, particularly in the southern Canadian Cordillera where many type sections are located, and access for comprehensive collecting is easier. Work on various collections of Ordovician conodonts is being continued at the Geological Survey of Canada (GSC) by A.D. McCracken (Ottawa), G.S. Nowlan (Calgary), and M.J. Orchard (Vancouver). Both the University and GSC teams are involved in geochemical studies of conodonts as well as taxonomic, evolutionary, and biostratigraphic work.

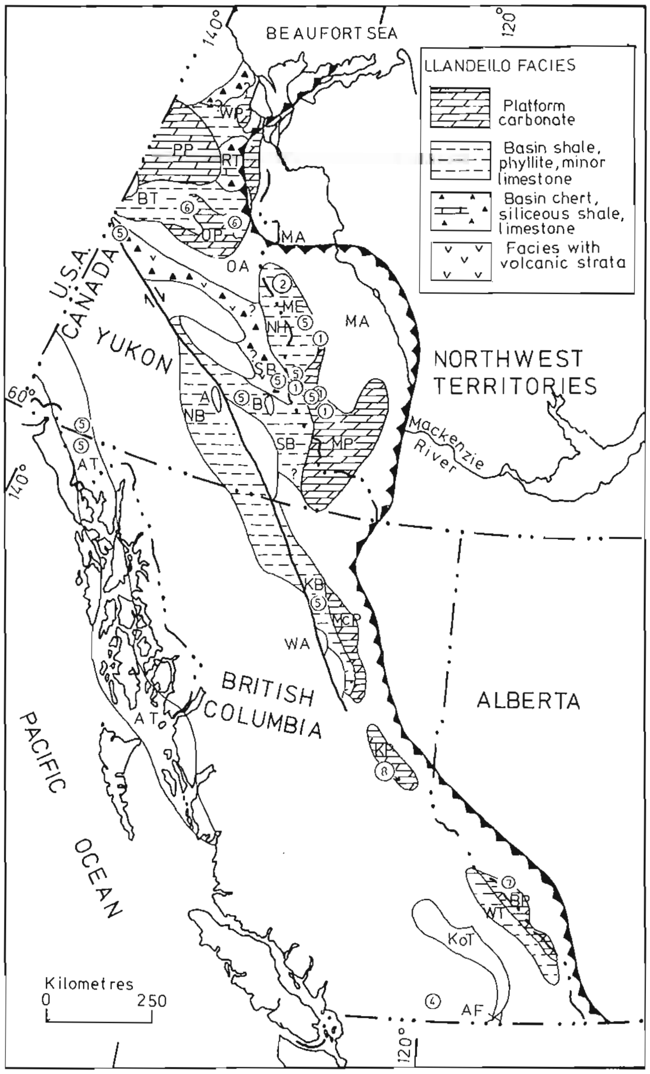


Figure 2. Major paleogeographic features present during the Llandeilo (from Cecile and Norford, in press). BT = Blackstone Trough; A = Positive area A; B = Positive area B; McP = McDonald Platform; KP = Kakwa Platform; WA = Ware Arch. For other abbreviations see Figure 1. Numbers in circles refer to specific conodont publications. Publications and areas dealing only with Tremadoc faunas are listed in Figure 1. Most other samples range in age from Early Ordovician through Middle or Late Ordovician. 1 = Tipnis et al. (1978); 2 = Fritz et al. in Cecile (1982); 4 = Pohler, Orchard, and Tempelman-Kluit (1989); 5 = Pohler and Orchard (1991); 6 = McCracken (1989b); 7 = Ethington and Clark (1965); Derby et al. (1972); 8 = Pohler, Orchard, and Struik (1989).

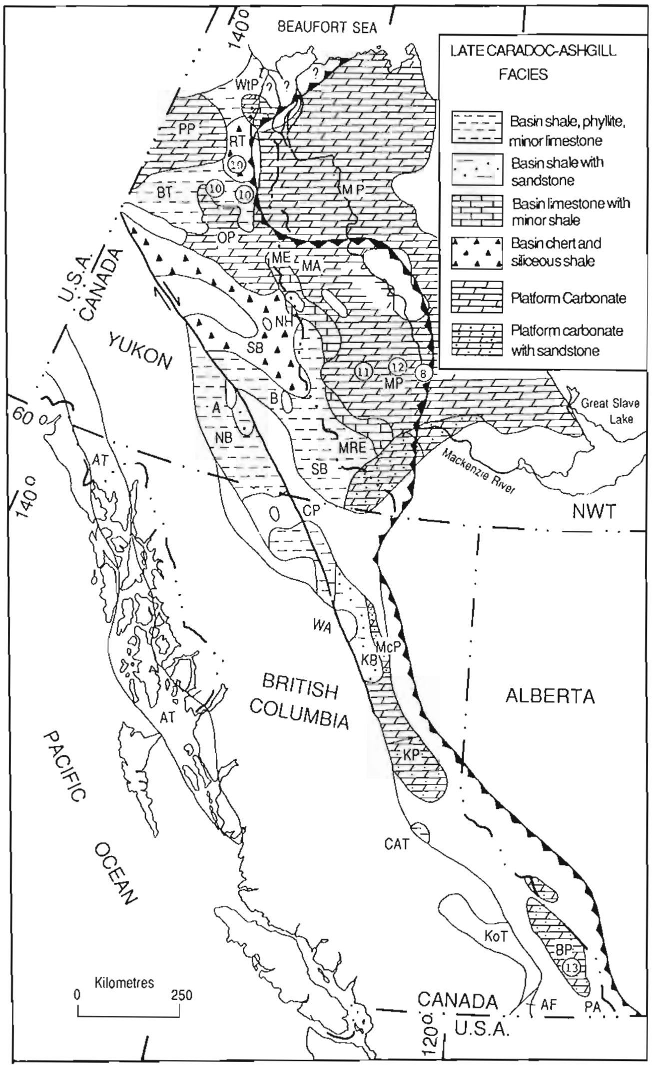


Figure 3. Major paleogeographic features present during the Late Caradoc and Ashgill (from Cecile and Norford, in press). RT = Richardson Trough; BT = Blackstone Trough; A = Positive area A; B = Positive area B; McP = McDonald Platform; KP = Kakwa Platform; WA = Ware Arch; CAT = Cariboo Subterrane; CP = Cassiar Platform; PA = Purcell Arch. For other abbreviations see Figure 1. Numbers in circles refer to publications and/or areas dealing with Upper Ordovician conodonts. 8 = Norford and MacQueen (1975); 10 = McCracken (1987, 1989a); McCracken and Lenz (1987); Lenz and McCracken (1982); 11 = Nowlan et al. (1988); 12 = Mitchell and Sweet (1989); 13 = Norford (1969).

CONODONTS FROM THE CARBONATE PLATFORM, SOUTHERN BRITISH COLUMBIA AND ALBERTA

Survey Peak, Outram, Skoki, and Owen Creek formations

Ordovician sections representing the carbonate platform in southern British Columbia are exposed in the Rocky Mountains. The Survey Peak, Outram, Skoki, and Owen Creek formations at Wilcox Pass, Jasper National Park, Alberta are little deformed, have excellent exposure, and are considered to be a nearly complete sequence (1050 m) of Early and early Middle Ordovician age (Aitken and Norford, 1967; Norford, 1969). The Survey Peak Formation (about 360 m thick) is a series of calcareous shale, mudstone, siltstone, limestone, and limestone-pebble conglomerate. The Outram Formation (about 270 m thick) is composed of dark grey shale, calcareous siltstone, and thick bedded fossiliferous limestone with limestone-pebble conglomerate. The Skoki Formation (about 170 m thick) consists mostly of thick bedded dolostone, with minor, thin beds of limestone in the lower part; chert layers and nodules are common. The Owen Creek Formation (about 250 m thick) is a unit of pale, barren, dense, thick bedded dolostone, with quartz sand, local chert nodules and gastropod coquinas in the lower part.

Detailed biostratigraphic investigation of the Survey Peak, Outram, and lower Skoki formations at Wilcox Pass was carried out by Dean and Martin (1982) and by Dean (1978, 1989). Dean described trilobites from these three formations and showed that much of this sequence is of Early Ordovician age. Ethington and Clark (1965) first described conodonts from the Survey Peak and Outram formations from the same area, but their work was based on limited samples and conodonts. Preliminary information on conodonts from the Cambrian–Ordovician boundary interval was provided by Derby et al. (1972). This was later expanded by Westrop et al. (1981), who recognized two conodont zones (faunas A and B of Ethington and Clark, 1971) in the lower part of the Survey Peak Formation. In 1990, Barnes and Ji collected over 200 conodont samples from the entire Wilcox Pass section, and a detailed study of conodont taxonomy, biostratigraphy, and paleoecology is presently in progress.

Based on preliminary collections, the conodonts recovered from the lower part of the Survey Peak Formation include *Drepanodus pervetus* (Nowlan), *Cordylodus angulatus* Pander, *C. intermedius* Furnish, *C. lindstromi* Druce and Jones, *C. proavus* Müller, *Semiacontiodus nogamii* (Miller), and *Teridontus nakamurai* (Nogami). Few conodonts have so far been recovered from the middle and upper parts of the Survey Peak Formation, but it is considered to be equivalent to the conodont intervals of faunas C and D of Ethington and Clark (1971).

The Outram Formation is mainly characterized by *Acodus comptus* (Branson and Mehl), *A. lanceolatus* (Pander), *A. delicatus* Branson and Mehl, *Bergstroemognathus extensus* (Graves and Ellison), *Drepanodus arcuatus* Pander, *D. concavus* (Branson and Mehl), *Fahraeusodus marathonensis* (Bradshaw), *Oepikodus communis* (Ethington and Clark), *Scolopodus cornutiformis* (Branson and Mehl), *Striatodontus gracilis* (Ethington and Clark), and species of *Periodon*. The fauna of the formation is roughly equivalent to the uppermost part of Fauna D and the lower and middle parts of Fauna E of Ethington and Clark (1971). Some representative species from the Survey Peak and Outram formations are illustrated in Plate 1.

The dominant conodonts recovered from the Skoki Formation include *Acodus comptus, Drepanodus arcuatus, D. concavus, Oepikodus communis, Scolopodus cornutiformis, Striatodontus gracilis,* and several species of *Protopanderodus*. The fauna can be correlated with the upper part of Fauna E to Midcontinent Fauna 2 (Sweet et al., 1971).

Few conodonts have been recovered from the Owen Creek Formation. Several species, such as *Eoneoprioniodus* sp., *Erismodus asymmetricus* (Branson and Mehl), *Multioistodus* sp., *Panderodus* sp. cf. *P. gracilis* (Branson and Mehl), *Phragmodus* sp., and *Polycaulodus bidentatus* Branson and Mehl are present in this formation. The faunas can be tentatively correlated with the Midcontinent faunas 4 to 5 (Sweet et al., 1971; Barnes et al., 1981).

The conodonts of the Survey Peak, Outram, Skoki, and Owen Creek formations have Midcontinent Realm affinities, but there are some strong North Atlantic faunal influxes. Comparisons of faunas from equivalent sections elsewhere indicate that the Wilcox Pass faunas are closely similar to the faunas recovered from the Ibex Area, Western Millard County, Utah (Ethington and Clark, 1981).

Mount Wilson Formation

One of the most profound lithological changes in the Ordovician sequence in the southern Rocky Mountains occurs where the black shales of the Glenogle Formation are overlain by the pure, grey to white quartz sandstone of the Mount Wilson Formation. The latter unit, up to 460 m thick, is a distinctive, resistant, yellow weathering unit produced by easterly derived sands lying conformably to disconformably on the Glenogle, Skoki, and/or Owen Creek formations (Aitken et al., 1972). The Mount Wilson Formation is virtually unfossiliferous although a few undiagnostic conodonts of Middle or Late Ordovician age were recovered from a thin shale at Pinnacle Creek (Norford, 1969).

Beaverfoot Formation

Overlying the Mount Wilson Formation is the Beaverfoot Formation. This unit consists of up to 540 m of resistant, mottled (bioturbated), thick to massive bedded, dolomitic limestone and dolostone. Quartz silt and sand predominate in the lower 28 m (Whiskey Trail Member) which, where present, suggest a conformable contact between the two formations. The carbonates bear a distinctive sequence of coral–brachiopod faunas that range from Late Ordovician to mid-Llandovery in age. Attempts to examine faunal changes across the Ordovician–Silurian boundary are thwarted by a 245 m thick virtually barren dolostone at that level. The

Beaverfoot Formation is overlain by the upper Llandovery Tegart Formation, or locally intersected by the extensive sub-Devonian unconformity.

Norford (1969) recognized a *Bighornia–Thaerodonta* Zone in the lower part of the formation, of Late Ordovician age. A more recent study of the coral faunas and the regional stratigraphy of the Beaverfoot Formation has been completed by Buttler et al. (1988).

Norford (1969, p. 38) reported a conodont-bearing interval near the base of the formation, in the Whiskey Trail Member. These are given as only form-taxa and provide little biostratigraphic precision. Preliminary conodont studies by Barnes and Uyeno for the Beaverfoot, especially near the Ordovician–Silurian boundary, yielded only modest faunas of Midcontinent Realm affinity (Norford, 1988).

ORDOVICIAN CONODONTS FROM THE MIOGEOCLINE, SOUTHERN BRITISH COLUMBIA

McKay Group

In the Western Ranges and Main Ranges of the Rocky Mountains, a thick sequence of Upper Cambrian to Lower Ordovician limestone and shale is assigned to the McKay Group. Early work (e.g., Evans, 1933; Leech, 1958; Raasch and Bruce, 1966; Norford, 1969; Aitken et al., 1972) and a recent study by Mott et al. (1986) have interpreted the sequence as a lateral facies equivalent of the Survey Peak and Outram formations, and of some older strata of the carbonate platform that are exposed in ranges to the east (described above). A deeper miogeoclinal or shale basin setting is envisaged (Bond and Kominz, 1984). Mott et al. (1986) recognized four major lithological units in the McKay Group, each consisting of a lower shale-dominated part and an upper limestone-dominated part. They recorded a thickness of the group of at least 2100 m. Although commonly considered to be a deeper water equivalent of the Survey Peak and Outram formations, parts of the McKay exhibit shallow water indicators (e.g., mud cracks, stromatolites).

The McKay Group is strongly deformed in most sections of the Western and Main ranges. The internal stratigraphy and regional correlations are poorly known. There have been few detailed paleontological studies to build on the initial observations of Evans (1933). Trilobites are abundant at certain levels but have received only interim investigations (e.g., Kobayashi, 1955; Dean, 1988); molluscs, graptolites and brachiopods were reported by Kobayashi (1955) but are less common than trilobites.

Reconnaissance sampling for conodonts in the McKay Group was undertaken by one of us (CRB). Only small collections were recovered with high conodont Colour Alteration Index values (typically CAI 5-6). Samples collected at the Mount Sabine section, near Canal Flats (Aitken et al., 1972) proved to be barren, but these were from the Franconian (Upper Cambrian) part of the section. Other reference samples were taken from a thick bedded carbonate unit in the upper McKay Group near the bridge across the Kicking Horse River, 15 km east of Golden. These samples yielded small collections of fragmentary coniform conodonts, mainly scolopodans, suggesting an age equivalent to Fauna D of Ethington and Clark (1971).

During the 1990 field season, Barnes and Ji collected extensively for conodonts in the McKay Group. Principal collecting sections included Kicking Horse Pass, east of Golden; in the Kootenay National Park, north of Radium; Mount Sabine at Canal Flats; and along the North White River (see Aitken et al., 1972, for details of sections). These samples form the basis of a new detailed study of McKay conodonts, and further collections are planned for 1991.

Glenogle Formation

Overlying the McKay Group with gradational contact is a thick sequence of black shale, locally with quartz siltstone and thin, impure carbonate. Burling (1921, 1922) assigned these to the Glenogle Formation, which attains a thickness of up to 851 m at White River (Norford and Slind, 1990; Norford and Jackson, in press). The Glenogle Formation represents a narrow basinal facies, restricted to British Columbia, which bears graptolites belonging to nine zones of Arenig through early Caradoc age (Larson and Jackson, 1966; Norford and Jackson, in press). The Glenogle appears to have been deposited in an anoxic basin (White River Trough) trending approximately northwest with shallow carbonate facies equivalents to both the west (Purcell Arch) and the east (Bow Platform) (Norford and Slind, 1990). An upper member exhibits an overall shallowing event, probably correlating with the shallowing in the carbonate facies to the east represented by the dolostone of the Owen Creek Formation.

In the North White River area, the Glenogle Formation overlies the McKay Group and in turn is overlain by beds of the lower Skoki Formation. A sequence of graptolite and shelly fossil faunas has helped in the correlation and construction of the regional facies relationships (McKee et al., 1972; Norford and Ross, 1978; Norford and Slind, 1990). We have scanned Glenogle Formation shale surfaces for conodont assemblages without success. Some of the rare carbonate interbeds have yielded conodont faunas that have enabled biostratigraphic ties to be made between the Pacific Province graptolite and North Atlantic Realm conodont zonations. The conodont faunas are currently under detailed study by G.S. Nowlan (GSC, Calgary); some preliminary data are given in Norford and Jackson (in press).

ORDOVICIAN CONODONTS FROM THE MIOGEOCLINE, NORTHERN BRITISH COLUMBIA, YUKON, AND WESTERN NORTHWEST TERRITORIES

The Selwyn Basin (Gabrielse, 1967) occupies most of the Yukon and the western part of the Northwest Territories. It is thought to be an inner miogeoclinal basin with graben-like embayments and troughs. The Selwyn Basin is bordered to the west by the Tintina Fault, to the north by the Ogilvie Arch, to the east by the Niddery High and Mackenzie Platform, and extends southward into the Kechika Basin (Cecile, 1982; Cecile and Norford, in press) (Figs. 1-3).

On an east-to-west transect, three interfingering facies belts can be recognized. The Broken Skull and Sunblood formations in the east comprise the Ordovician shallow-water deposits at the edge of the Mackenzie Platform. Westward, the Sapper formation (informal), the Haywire formation (informal) and in part the Rabbitkettle Formation represent a transitional (slope) facies. The basinal facies is represented by the Rabbitkettle and Duo Lake formations (Cecile, 1982; Gordey, in press). The different facies belts are laterally gradational, and contacts between the successive formations are diachronous.

Rabbitkettle Formation

Conodont faunas from the Rabbitkettle Formation have been reported from several areas in the greater Selwyn Basin. Larger collections are documented from the east-central Selwyn Basin (Nahanni Mountains, and Niddery Lake areas) (Pohler and Orchard, 1991; Gordey, in press), the Misty Creek Embayment (Cecile, 1982), and the southern District of Mackenzie (Tipnis et al., 1978; Landing et al., 1980).

The Rabbitkettle Formation was originally described as an Upper Cambrian to Lower Ordovician succession of dominantly thin bedded, silty limestone (Gabrielse et al., 1973) but later Gordey (in press) assigned rocks as young as Ashgill to the Rabbitkettle Formation. Tipnis et al. (1978) documented Upper Cambrian to lower Tremadoc conodonts from the Rabbitkettle Formation, which they recognized as belonging to the North Atlantic Realm (Pohler and Barnes, 1990). Several species of *Cordylodus* and *Oneotodus* are the dominant faunal elements. North Atlantic Realm conodonts also dominate the Rabbitkettle Formation in the east-central Selwyn Basin (Nahanni and Niddery Lake map areas). Faunas range in age from Late Cambrian to Llandeilo, possibly Caradoc (Pohler and Orchard, 1991).

Fritz et al. (*in* Cecile, 1982) report conodonts and other fossils from the Rabbitkettle Formation in the Misty Creek Embayment ranging in age from Late Cambrian to Early Ordovician. They are similar in composition to those reported by Tipnis et al. (1978) from the Mackenzie Mountains.

Duo Lake Formation (Lower Road River Group)

The Duo Lake Formation (Cecile, 1982) ranges in age from Arenig to Wenlock and, with the younger Steel Formation, comprises the Road River Group, which overlies the Rabbitkettle Formation. The lithotypes (shale, chert, thin bedded limestone and minor volcanic rocks) suggest deposition in a quiet off-shelf setting.

Conodont faunas from the Ordovician units of the Road River Group (i.e., Duo Lake Formation) have been reported from the Ogilvie Mountains in northern Selwyn Basin (Pohler and Orchard, 1991) from the Sheldon Lake area in east-central Selwyn Basin (Pohler and Orchard, 1991), from southern District of Mackenzie (Tipnis et al., 1978) and from northwestern District of Mackenzie and northern Yukon (McCracken and Lenz, 1987). The faunas from the Dawson area in the northern Selwyn Basin range in age from Tremadoc to early Llandeilo, possibly as high as middle Caradoc. Most conodonts are of North Atlantic aspect and the fauna is dominated by *Periodon aculeatus* Hadding and *Pygodus serra* (Hadding). Typical is the occurrence of robust protopanderodids such as *Protopanderodus? giganteus* (Sweet and Bergström).

From the Sheldon Lake area, conodonts as old as Late Cambrian and as young as Llandeilo (*Pygodus anserinus* Zone) have been recovered. Again most faunal components are of North Atlantic aspect. The most common representatives are *Amorphognathus tvaerensis* Bergström, *Periodon* spp., and *Pygodus anserinus* Hadding. A few representatives of the Midcontinent Realm (Pohler and Barnes, 1990) are present, of which *Phragmodus undatus* Branson and Mehl is common. A robust protopanderodan [*Protopanderodus robustus* (Hadding)] is also present in large numbers.

Tipnis et al. (1978) reported conodonts of predominantly North Atlantic type from nine samples of the Road River Group, Nahanni map area. These faunas range from Early to Middle Ordovician in age and are similar in composition to those from the Sheldon Lake area.

Lenz and McCracken (1982), McCracken and Lenz (1987) and McCracken (1987, 1989a,b) discussed Middle to Upper Ordovician conodonts from the Blackstone and Richardson troughs in northern Yukon. McCracken and Lenz (1987) recognized several conodont associations and zones in the Road River Group of that area. The *"Cordylodus" horridus – Spinodus spinatus* association is early Llanvirn in age and contains reworked elements. The *Pygodus serra* Zone of middle to late Llanvirn age comprises genera such as *Ansella, Periodon, Pygodus,* and *Walliserodus.* At Blackstone River, faunas with *Oulodus rohneri* Ethington and Furnish, *Gamachignathus ensifer* McCracken et al., *Noixodontus girardeaudensis* (Satterfield), and *Amorphognathus ordovicicus* Branson and Mehl were assigned to the *G. ensifer* Zone. The fauna is considered to be age equivalent to upper Richmondian strata (i.e., Fauna 12) rather than Gamachian Fauna 13. Fauna 13 appears to be missing in the Ordovician–Silurian boundary interval of the Yukon (Lenz and McCracken, 1982). The *Ozarkodina* n. sp. A–*Icriodella* sp. B association is considered to be late Ashgill in age. McCracken (1989b) discussed seven species of *Protopanderodus* from four sections of the aforementioned region where the genus comprises 12 per cent of the total collection (Llanvirn to Ashgill) and was obviously common in the offshore environments represented by the Road River Group.

Haywire formation

The Haywire formation (Gordey, in press) represents a transitional facies interfingering with the Rabbitkettle and Duo Lake formations basinward and with the Broken Skull and Sunblood formations to the east. The Haywire formation ranges in age from Early Ordovician to Early Silurian. Conodont samples were collected from the Nahanni Mountains

(Pohler and Orchard, 1991; Gordey, in press) and range from Arenig to Ashgill. The successive faunas reported alternate between those dominated by Midcontinent and North Atlantic species. The oldest fauna with *Acodus deltatus* Lindström is of North Atlantic aspect but may be coeval with that of another sample containing Midcontinent Realm species, such as *Protopanderodus leei* Repetski. Faunal shifts continue to occur throughout the sequence. North Atlantic Realm zonal fossils are represented by *Oepikodus evae* (Lindström) and later by *Amorphognathus tvaerensis*. Typical Midcontinent forms are *Multioistodus compressus* Harris and Harris and later *Belodina confluens* Sweet and *Plectodina tenuis* (Branson and Mehl). Many samples contain a mixture of North Atlantic and Midcontinent species.

Transition facies of the Franklin Mountain Formation

Cecile (1982) recognized a facies transitional between basinal (Rabbitkettle and Duo Lake formations) and platformal (Franklin Mountain Formation) rocks in the Misty Creek Embayment. The lithologies were described as dominantly dolostone that basinward interfinger with dolomitic shale, shale, and chert. They range in age from Late Cambrian to Middle Ordovician (Caradoc). Fritz et al. (*in* Cecile, 1982) determined upper Tremadoc(?) to Llandeilo conodonts from this transitional formation. As in the Haywire formation, the transitional facies of the Franklin Mountain Formation contain conodonts of mixed faunal affinity. *Pygodus* sp. occurs with *Plectodina* sp., *Oepikodus evae* with *Oepikodus communis* (Ethington and Clark), and *Drepaniostodus numarcuatus* (Lindström) with *Scolopodus filosus* Ethington and Clark. This mixture enables correlation with both North America and Europe and suggests that an exchange between shelf and basin was not restricted in this area. Other transitional facies in the Misty Creek Embayment are late Middle Ordovician or younger in age and have not yielded significant conodont faunas, or are too young for the scope of this paper.

Farther east, the Selwyn Basin and transitional facies are replaced by the Broken Skull Formation and the younger Sunblood Formation deposited as largely laterally equivalent platform facies.

Sapper formation

The Sapper formation (Gordey, in press) overlies the Road River Group in the west and the Haywire formation in the east. It is considered a transitional facies between the Mackenzie Platform and Selwyn Basin. Conodont collections from the calcareous siltstone and limestone of the Sapper formation are late Middle to Late Ordovician in age with *Aphelognathus politus*, *Amorphognathus* species, *Belodina compressa* (Branson and Mehl), *Drepanoistodus suberectus* and others (Pohler and Orchard, 1991).

CONODONTS FROM THE CARBONATE PLATFORM, NORTHERN BRITISH COLUMBIA, YUKON TERRITORY, AND NORTHWEST TERRITORIES

Broken Skull Formation

The Broken Skull Formation ranges in age from Early to Middle Ordovician. Conodonts have been reported from the Nahanni Mountains, Flat River, and Sekwi Mountain areas (Pohler and Orchard, 1991; Gordey, in press), and the southern District of Mackenzie, especially the Natla River area (Tipnis et al., 1978).

Conodont faunas from the dolostone and thick bedded limestone of the Broken Skull Formation range from Arenig to Caradoc and possibly younger. The faunas are characterized by a mixture of North Atlantic and Midcontinent-type conodonts.

Of the Midcontinent faunal succession, faunas D, E, 1, and possibly 2 were recognized by Tipnis et al. (1978). Pohler and Orchard (1991) found Fauna D and faunas 3-4 (= *Histiodella sinuosa* Zone of Sweet, 1988), together with a large number of long-ranging species. Of the North Atlantic zonation (Lindström, 1971; Bergström, 1971), *Oepikodus evae* and *Pygodus* sp. are notable representatives.

Sunblood Formation

Conodonts from the Sunblood Formation were described by Tipnis et al. (1978). They are Middle Ordovician in age ranging from Whiterockian to Blackriveran, possibly slightly younger. Most faunal elements are of Midcontinental aspect and diagnostic of faunas 3-6 of Sweet et al. (1971). Notable in Fauna 3 are species of *Multioistodus*. Fauna 4 contains a large number of *Paraprioniodus costatus* (Mound); Fauna 5 is dominated by species of *Phragmodus* and *Drepanoistodus suberectus* as is Fauna 6, which in addition is characterized by *Appalachignathus delicatulus* Bergström.

Esbataottine Formation

The Esbataottine Formation (Ludvigsen, 1975) conformably overlies the Sunblood Formation and comprises a series of thinly bedded limestones. Tipnis et al. (1978) described Middle Ordovician conodont faunas (faunas 6-8) of Midcontinent aspect from the Esbataottine Formation, notably *Phragmodus flexuosus* Moskalenko, *Plectodina aculeata* (Stauffer), and *Ansella nevadensis* (Ethington and Schumacher).

Whittaker Formation

The Whittaker Formation (Douglas and Norris, 1961) conformably overlies the Esbataottine Formation. A lower limestone unit and a middle dolostone unit are assigned a Lake

Ordovician age, whereas the overlying upper argillaceous limestone unit is Silurian in age. Tipnis et al. (1978), who first reported conodonts from the Whittaker Formation, found few diagnostic taxa. The authors confirmed faunas 9 and 10, but concluded that a younger age is possible. McCracken and Lenz (1987) discussed Middle Caradoc to Ashgill conodont biofacies of the Whittaker Formation. They argued that most faunal elements are indicative of the Red River Province of Sweet and Bergström (1984) with some representatives of the Ohio Valley Province and the North Atlantic Realm. An inverse relationship between *Phragmodus* and *Plectodina* is indicated.

Nowlan et al. (1988) described conodont faunas from Ordovician–Silurian boundary strata of the Whittaker Formation in the Avalanche Lake area. The Upper Ordovician fauna is diverse and dominated by *Panderodus* species and *Plectodina*. No elements of Gamachian Fauna 13 were recognized and there is a likely hiatus at the Ordovician–Silurian boundary.

Mitchell and Sweet (1989) collected samples from the lower Whittaker Formation and found conodonts of Red River provincial aspect. Analysis of conodont faunas indicates that the lower Whittaker Formation east of Redstone Arch (west flank of Root Basin) spans almost the entire Cincinnatian Series.

Franklin Mountain Formation

The Franklin Mountain Formation (Williams, 1922, 1923) is widely distributed in the eastern Mackenzie and Franklin mountains. The dolostone and argillaceous dolostone were deposited in shallow marine environments of the carbonate platform and range in age from Late Cambrian to Early Ordovician, possibly Middle Ordovician.

The Franklin Mountain Formation is correlative with the Broken Skull Formation in the southern Mackenzie Mountains. A single collection containing Fauna D (upper Tremadoc) was determined from the Franklin Mountain Formation (Norford and Macqueen, 1975).

Mount Kindle Formation

Dolostone of the Mount Kindle Formation (Williams, 1922, 1923) unconformably overlies the Franklin Mountain Formation. The Mount Kindle Formation ranges from Late Ordovician to Early Silurian in age and is correlative with the Whittaker Formation in the southern Mackenzie Mountains.

C.R. Barnes (*in* Norford and Macqueen, 1975) determined a late Middle or Late Ordovician age for conodont collections containing *Phragmodus undatus* and *Plectodina furcata* (Hinde) from the Mount Kindle Formation. Cecile (1982) listed Upper Ordovician conodonts in the transitional Mount Kindle Formation in the Misty Creek Embayment.

ORDOVICIAN CONODONTS FROM ALLOCHTHONOUS TERRANES

Very few Ordovician conodonts are known from the suspect terranes in the western Cordillera. The only localities known to date are in the Alexander Terrane and in the Quesnel Terrane.

Alexander Terrane

The Alexander Terrane (Berg et al., 1972, 1978) is a distinctive assemblage of Paleozoic to Mesozoic age (Schuchert, 1923). It occupies part of southeast Alaska, the Saint Elias Mountains, Yukon Territory and the coastal region of west-central British Columbia (Fig. 1). Ordovician conodonts assigned to *Periodon* were reported from the Abbess Island conglomerate in southeast Alaska by Savage and Savage (1980). The conglomerate is thought to be part of the Descon Formation (Churkin and Eberlein, 1970).

Additional samples containing Ordovician conodonts were collected by C.J. Dodds and associates from the Alsek and Tatshenshini River areas in British Columbia. These are mostly from thin bedded limestones, which have not yet been formally assigned group or formation names (Campbell and Dodds, 1982, 1983). The faunas contain 27 poorly preserved specimens with conodont CAI values ranging from 5-6. On the basis of the occurrence of *Variabiloconus bassleri* (Furnish) and other simple cones, most collections have been assigned an early Ordovician age. The youngest fauna that contains *Protopanderodus* may be Arenig or younger in age (Pohler and Orchard, 1991).

Quesnel Terrane

The Quesnel Terrane (Monger et al., 1982) is characterized by upper Paleozoic and Mesozoic rocks. Ordovician conodonts were found in the problematic Shoemaker Assemblage (Wheeler and McFeely, 1987) near Keremeos. The small fauna with *Belodina compressa* and an enigmatic species of *Ansella* is probably Middle Ordovician in age (Pohler, Orchard, and Tempelman-Kluit, 1989).

Cassiar Platform

The Cassiar Platform (Gabrielse, 1967) is considered a parautochthonous terrane, which was originally situated farther south and displaced along the Tintina Fault to its present location. Two small conodont collections contain *Phragmodus undatus*, *Paroistodus?* sp. and *Protopanderodus* sp., suggesting a Caradoc to Ashgill age for the faunas. The samples were collected from rocks related to the Kechika and Sandpile groups (Pohler and Orchard, 1991).

From the western flank of Kakwa Platform (Figs. 1-3) conodonts from the Ordovician to Silurian Sandpile Group (McLeod Lake map area, central-eastern British Columbia) are noted by Pohler, Orchard, and Struik (1989). The faunas are Early to Lake Ordovician in age and of Midcontinent aspect.

SUMMARY

The Canadian Cordillera contains thick sequences of Lower and Middle Ordovician carbonates ranging from shallow-water platform to deep basinal facies, together with some problematic accreted terrane assemblages. To date few detailed studies have revealed the potential for Ordovician conodont research in the Cordillera. The major limiting factor is one of logistics in mountainous terrain and remote areas, given the weight and volume of conodont samples typically required for detailed research.

Areas in the southern Canadian Cordillera are most accessible and past and current work in the platform carbonates (e.g., Survey Peak, Outram, Skoki, and Owen Creek formations) will provide a benchmark database that can be linked biostratigraphically into trilobite and acritarch zonations. Current studies in progress will trace these faunas westward into the miogeoclinal sequence (McKay Group, Glenogle Formation), although the latter is strongly deformed, both structurally and thermally. The graptolite and conodont zonations will be correlated at several levels in this deeper facies.

In the Yukon Territory and the Northwest Territories, conodont faunas have been described from platform to basinal facies, particularly in the extensional, marginal Selwyn Basin, and the Blackstone and Richardson troughs. Exciting recent discoveries from exotic accreted terranes (Alexander, Quesnel) and from a parautochthonous terrane (Cassiar Platform) have demonstrated the significance of conodont studies in resolving complex structural and tectonic problems.

The pattern of conodont communities, provinces, and realms through time was reviewed by Pohler and Barnes (1990). The limited information on Ordovician faunas of the Canadian Cordillera conforms to the general patterns. The boundary between the North Atlantic and Midcontinent conodont realms typically lies near the basin–platform transition and oscillates laterally with transgressive–regressive phases.

ACKNOWLEDGMENTS

C.R. Barnes acknowledges continued support for conodont research from the Natural Sciences and Engineering Research Council of Canada. Current research in the Cordillera is also supported by grants from the Department of Energy, Mines and Resources, the British Columbia Geological Survey, and the University of Victoria. Special thanks are extended to Drs. M.P. Cecile and B.S. Norford for providing three facies maps modified and reproduced herein as Figures 1-3. Ms. Terry Russell kindly typed the manuscript.

REFERENCES

Aitken, J.D. and Norford, B.S.

1967: Lower Ordovician Survey Peak and Outram formations, southern Rocky Mountains of Alberta. Bulletin of Canadian Petroleum Geology, v. 15, p. 150-207.

Aitken, J.D., Fritz, W.H., and Norford, B.S.

1972: Cambrian and Ordovician biostratigraphy of the southern Canadian Rocky Mountains. 24th International Geological Congress, Montreal. Field excursion A-19, Guidebook, 57 p.

Barnes, C.R.

1984: Early Ordovician eustatic events in Canada. *In* Aspects of the Ordovician System, Bruton, D.L. (ed.). Palaeontological Contributions from the University of Oslo, no. 295, p. 51-63.

Barnes, C.R., Jackson, D.E., and Norford, B.S.

1976: Correlation between Canadian Ordovician zonation based on graptolites, conodonts, and benthic macrofossils from key successions. *In* The Ordovician System. M.G. Bassett (ed.); University of Wales Press and National Museum of Wales, Cardiff, p. 290-226.

Barnes, C.R., Norford, B.S., and Skevington, D.

1981: The Ordovician System in Canada: Correlation chart and explanatory notes. International Union of Geological Sciences, Publication no. 8, 27 p.

Berg, H.C., Jones, D.L., and Richter, D.H.

1972: Gravina–Nutzotin Belt – tectonic significance of an upper Mesozoic sedimentary and volcanic sequence in southern and southeastern Alaska. United States Geological Survey, Professional Paper 800-D, p. D1-D24.

Berg, H.C., Jones, D.L., and Coney, P.J.

1978: Map showing pre-Cenozoic tectonostratigraphic terranes of southeastern Alaska and adjacent areas. United States Geological Survey, Open File Report 78-1085.

Bergström, S.M.

1971: Conodont biostratigraphy of the Middle and Upper Ordovician of Europe and eastern North America. Geological Society of America, Memoir 127, p. 83-161.

Bond, G.C. and Kominz, A.

1984: Constructions of tectonic subsidence curves for the early Paleozoic miogeocline, southern Canadian Rocky Mountains: implication for subsidence mechanisms, age of breakup and crustal thinning. Geological Society of America, Bulletin, v. 95, p. 155-173.

Burling, L.D.

1921: Graptolite localities of western North America, with descriptions of two new formation names (abstract). Geological Society of America, Bulletin, v. 32, p. 127-128.

1922: Cambro-Ordovician section in the Beaverfoot Range near Golden, British Columbia. Geological Magazine, v. 59, p. 452-461.

Buttler, C.J., Elias, R.J., and Norford, B.S.

1988: Upper Ordovician to lowermost Silurian solitary rugose corals from the Beaverfoot Formation, southern Rocky Mountains, British Columbia, and Alberta. *In* Contributions to Canadian Paleontology, Geological Survey of Canada, Bulletin 379, p. 47-91.

Campbell, R.B. and Dodds, C.J.

1982: Geology of the southwest Dezadeash map-area, Yukon Territory. Geological Survey of Canada, Open File Report 831.

1983: Geology of the Tatshenshini River map-area, British Columbia. Geological Survey of Canada, Open File Report 926.

Cecile, M.P.

1982: The Lower Paleozoic Misty Creek Embayment, Selwyn Basin, Yukon and Northwest Territories. Geological Survey of Canada, Bulletin 335, 78 p.

Cecile, M.P. and Norford, B.S.

in press: Ordovician and Silurian; Chapter 4C. *In* The Sedimentary Cover of the Craton: Canada. D.F. Stott and J.D. Aitken (eds.); Geological Survey of Canada, Geology of Canada, no. 5 (also Geological Society of America, The Geology of North America, n. F-1).

Churkin, M., Jr. and Eberlein, G.D.

1970: Paleozoic stratigraphy in the northwest coastal area of Prince of Wales Island, southeastern Alaska. United States Geological Survey, Bulletin 1284, 67 p.

Dean, W.T.

1978: Preliminary report on the stratigraphy and trilobites of the Survey Peak and Outram formations at Wilcox Pass, Jasper National Park, Canada. Geological Survey of Canada, Paper 76-34, 10 p.

1988: Lower Ordovician trilobites from the uppermost McKay Group at its type section, southeastern British Columbia. *In* Contributions to Canadian Paleontology. Geological Survey of Canada, Bulletin 379, p. 1-15.

1989: Trilobites from the Survey Peak, Outram, and Skoki Formations (Upper Cambrian–Lower Ordovician) at Wilcox Pass, Jasper National Park, Alberta. Geological Survey of Canada, Bulletin 389, 141 p.

Dean, W.T. and Martin, F.

1982: The sequence of trilobite faunas and acritarch microfloras at the Cambrian–Ordovician boundary, Wilcox Pass, Alberta, Canada. *In* The Cambrian–Ordovician Boundary: Sections, Fossil Distributions, and Correlations. M.G. Bassett and W.T. Dean (eds.); National Museum of Wales, Geological Series No. 3, Cardiff, p. 131-140.

Derby, J.R., Lane, H.R., and Norford, B.S.

1972: Uppermost Cambrian–basal Ordovician faunal succession in Alberta and correlation with similar sequences in the western United States. 24th International Geological Congress, Section 7, p. 503-512.

Douglas, R.J.W. and Norris, D.K.

1961: Camsell Bend and Root River map-areas, District of Mackenzie, Northwest Territories (95J and 95K). Geological Survey of Canada, Paper 61-13, 36 p.

Douglas, R.J.W., Gabrielse, H., Wheeler, J.O., Stott, D.F., and Belyea, H.R.

1970: Geology of western Canada. *In* Geology and Economic Minerals of Canada. R.T.W. Douglas (ed.); Geological Survey of Canada, Economic Geology Report No. 1, p. 365-488.

Ethington, R.L. and Clark, D.L.

1965: Lower Ordovician conodonts and other microfossils from the Columbia Ice Fields section, Alberta, Canada. Brigham Young University Geology Studies, v. 12, p. 185-206.

1971: Lower Ordovician conodonts in North America. Geological Society of America, Memoir 127, p. 63-82.

1981: Lower and Middle Ordovician conodonts from the Ibex area, Western Millard County, Utah. Brigham Young University Geology Studies, v. 28, part 2, 155 p.

Evans, C.S.

1933: Brisco–Dogtooth map-area, British Columbia. Canadian Department of Mines, Geological Survey Summary Report for 1932, Part AII, p. 106-187.

Gabrielse, H.

1967: Tectonic evolution of the northern Canadian Cordillera. Canadian Journal of Earth Sciences, v. 4, p. 271-298.

1985: Major dextral displacements along Northern Rocky Mountain Trench and related lineaments in north-central British Columbia. Geological Society of America, Bulletin, v. 96, p. 1-14.

Gabrielse, H., Blusson, S.L., and Roddick, J.A.

1973: Geology of Flat River, Glacier Lake and Wrigley Lake map-areas, District of Mackenzie and Yukon Territory. Geological Survey of Canada, Memoir 366, 421 p.

Gordey, S.P.

in press: Evolution of the northern Cordilleran miogeocline Nahanni map area (105 I), Yukon Territory and District of Mackenzie. Geological Survey of Canada, Memoir.

Kobayashi, T.

1955: The Ordovician fossils from the McKay Group in British Columbia, western Canada, with a note on the Early Ordovician palaeogeography. Journal of the Faculty of Science, University of Tokyo, Section II, v. 9, p. 355-493.

Landing, E., Ludvigsen, R., and von Bitter, P.H.

1980: Upper Cambrian to Lower Ordovician conodont biostratigraphy and biofacies, Rabbitkettle Formation, District of Mackenzie. Royal Ontario Museum Life Sciences Contributions, 126, 42 p.

Larson, M.L. and Jackson, D.E.

1966: Biostratigraphy of the Glenogle Formation Ordovician near Glenogle, British Columbia. Bulletin of Canadian Petroleum Geology, v. 14, p. 486-503.

Leech, G.B.

1958: Fernie map-area, west half, British Columbia. Geological Survey of Canada, Paper 58-10, 36 p.

Lenz, A.C.

1982: Ordovician to Devonian sea-level changes in western and northern Canada. Canadian Journal of Earth Sciences, v. 19, p. 1919-1932.

Lenz, A.C. and McCracken, A.D.

1982: The Ordovician–Silurian boundary, northern Canadian Cordillera: graptolite and conodont correlation. Canadian Journal of Earth Sciences, v. 19, p. 1308-1322.

Lindström, M.

1971: Lower Ordovician conodonts of Europe. Geological Society of America, Memoir 127, p. 21-61.

Ludvigsen, R.

1975: Ordovician formations and faunas, southern Mackenzie Mountains. Canadian Journal of Earth Sciences, v. 12, p. 663-697.

McCracken, A.D.

1987: Description and correlation of Late Ordovician conodonts from the *D. ornatus* and *P. pacificus* graptolite zones, Road River Group, northern Yukon Territory. Canadian Journal of Earth Sciences, v. 24, p. 1450-1464.

McCracken, A.D. (cont'd.)

1989a: Preliminary report on Ordovician–Devonian conodont collections from carbonate and fine-grained clastic facies of northern Yukon Territory and northwest District of Mackenzie, N.W.T. *In* Current Research, Part G. Geological Survey of Canada, Paper 89-1G, p. 69-76.

McCracken, A.D. (cont'd.)

1989b: *Protopanderodus* (Conodonta) from the Ordovician Road River Group, Northern Yukon Territory, and the evolution of the genus. Geological Survey of Canada, Bulletin 388, 39 p.

McCracken, A.D. and Lenz, A.C.

1987: Middle and Late Ordovician conodonts and biostratigraphy of graptolitic strata of the Road River Group, northern Yukon Territory. Canadian Journal of Earth Sciences, v. 24, p. 643-653.

McKee, E.H., Norford, B.S., and Ross, R.J. Jr.

1972: Correlation of the *Orthidiella* Zone (shelly facies) with zones of the graptolite facies, Ordovician of Toquima Range, Nevada, and North White River region, southeastern British Columbia. U.S. Geological Survey, Professional Paper 800, Research 1972, Chapter C, p. C145-C156.

Mitchell, C.E. and Sweet, W.C.

1989: Upper Ordovician conodonts, brachiopods, and chronostratigraphy of the Whittaker Formation, southwestern District of Mackenzie, N.W.T., Canada. Canadian Journal of Earth Sciences, v. 26, p. 74-87.

Monger, J.W.H. and Price, R.A.

1979: Geodynamic evolution of the Canadian Cordillera – progress and problems. Canadian Journal of Earth Sciences, v. 16, no. 3, p. 770-791.

Monger, J.W.H., Souther, J.G., and Gabrielse, H.

1972: Evolution of the Canadian Cordillera: a plate-tectonic model. American Journal of Science, v. 272, p. 577-602.

Monger, J.W.H., Price, R.A., and Tempelman-Kluit, D.J.

1982: Tectonic accretion and the origin of the two major metamorphic and plutonic belts in the Canadian Cordillera. Geology, v. 10, p. 70-75.

Mott, J.A., Dixon, J.M., and Helmstaedt, H.

1986: Ordovician stratigraphy and the structural style at the Main Ranges–Front Ranges boundary near Smith Peak, British Columbia. *In* Current Research, Part B. Geological Survey of Canada, Paper 86-1B, p. 457-465.

Norford, B.S.

1969: Ordovician and Silurian stratigraphy of the Southern Rocky Mountains. Geological Survey of Canada, Bulletin 176, 90 p.

1988: The Ordovician–Silurian boundary in the Rocky Mountains, Arctic Islands and Hudson Platform, Canada. *In* A Global Analysis of the Ordovician–Silurian Boundary. L.R.M. Cocks and R.B. Rickards (eds.); Bulletin of the British Museum (Natural History), Geology Series, v. 43, p. 259-263.

Norford, B.S. and Macqueen, R.W.

1975: Lower Paleozoic Franklin Mountain and Mount Kindle Formations, District of Mackenzie: their type sections and regional development. Geological Survey of Canada, Paper 74-34, 37 p.

Norford, B.S. and Ross, R.J., Jr.

1978: New species of brachiopods and trilobites from the Middle Ordovician (Whiterock) of southeastern British Columbia. Geological Survey of Canada, Bulletin 267, p. 1-11.

Norford, B.S. and Slind, O.L.

1990: Cambrian and Ordovician geology of the southern Rocky Mountains; Bow Lake to the Columbia Icefields. CSPG 1990 Annual Convention, Basin Perspectives Field Trip Guidebook, 55 p.

Norford, B.S. and Jackson, D.E.

in press: Ordovician stratigraphy and graptolite faunas of the Glenogle Formation, southeastern British Columbia. Geological Survey of Canada, Bulletin.

Nowlan, G.S., McCracken, A.D., and Chatterton, B.D.E.

1988: Conodonts from Ordovician–Silurian boundary strata, Whittaker Formation, Mackenzie Mountains, Northwest Territories. Geological Survey of Canada, Bulletin 373, 99 p.

Pohler, S.L. and Barnes, C.R.

1990: Conceptual models in conodont paleoecology. Courier des Forschungs-Instituts Senckenberg, v. 118, p. 409-440.

Pohler, S.L. and Orchard, M.J.

1991: Ordovician conodont biostratigraphy, western Canadian Cordillera. Geological Survey of Canada, Paper 90-15, 37 p. (imprint 1990).

Pohler, S.L., Orchard, M.J., and Struik, L.C.
1989: Preliminary biostratigraphy of conodonts from McLeod Lake map area, British Columbia. *In* Current Research, Part E. Geological Survey of Canada, Paper 89-1E, p. 125-126.

Pohler, S.L., Orchard, M.J., and Tempelman-Kluit, D.J.
1989: Ordovician conodonts identify the oldest sediments in the Intermontane Belt, Olalla, south-central British Columbia. *In* Current Research, Part E. Geological Survey of Canada, Paper 89-1E, p. 61-67.

Price, R.A.
1986: The southeastern Canadian Cordillera: thrust faulting, tectonic wedging and delamination of the lithosphere. Journal of Structural Geology, v. 9, p. 239-254.

Raasch, G.O. and Bruce, C.J.
1966: Notes on Late Cambrian and Early Ordovician biostratigraphy of southeast British Columbia. Bulletin of Canadian Petroleum Geology, v. 14, p. 600.

Reesor, J.E.
1973: Geology of the Lardeau map-area, east-half, British Columbia. Geological Survey of Canada, Memoir 369, 126 p.

Savage, N.M. and Savage, B.J.
1980: The occurrence of the Ordovician conodont *Periodon* in the Abbess Island Conglomerate, southeastern Alaska. Journal of Paleontology, v. 54, p. 871-873.

Schuchert, C.
1923: Sites and nature of the North American geosynclines. Geological Society of America, Bulletin, v. 34, p. 151-230.

Sears, J.S. and Price, R.A.
1978: The Siberian connection: a case for Precambrian separation of the North American and Siberian cratons. Geology, v. 6, p. 267-270.

Struik, L.C.
1987: The ancient western North American margin: an Alpine rift model for the east-central Canadian Cordillera. Geological Survey of Canada, Paper 87-15, 19 p.

Sweet, W.C.
1988: The Conodonta. Oxford Monographs of Geology and Geophysics No. 10, 212 p.

Sweet, W.C. and Bergström, S.M.
1984: Conodont provinces and biofacies of the Late Ordovician. *In* Conodont Biofacies and Provinces. D.L. Clark (ed.); Geological Society of America, Special Paper 196, p. 69-87.

Sweet, W.C., Ethington, R.L., and Barnes, C.R.
1971: North American Middle and Upper Ordovician conodont faunas. *In* Symposium on Conodont Biostratigraphy. W.C. Sweet and S.M. Bergström (eds.); Geological Society of America, Memoir 127, p. 163-193.

Tipnis, R.S., Chatterton, B.D.E., and Ludvigsen, R.
1978: Ordovician conodont biostratigraphy of the southern District of Mackenzie. *In* Western Canadian and Arctic Biostratigraphy. C.R. Stelck and B.D.E. Chatterton (eds.); Geological Association of Canada, Special Paper 18, p. 39-91.

Westrop, S.R., Landing, E., and Ludvigsen, R.
1981: Upper Cambrian and Lower Ordovician trilobite and conodont biostratigraphy, Wilcox Peak, Jasper National Park, Alberta. Second International Symposium on the Cambrian System, Guidebook for Field Trip 2: The Cambrian System in the Southern Canadian Rocky Mountains, Alberta and British Columbia, p. 51-52.

Wheeler, J.O. and McFeely, P.
1987: Tectonic assemblage map of the Canadian Cordillera and adjacent parts of the United States of America. Geological Survey of Canada, Open File Report 1565.

Williams, M.Y.
1922: Exploration east of Mackenzie River between Simpson and Wrigley. *In* Geological Survey of Canada, Summary Report, 1921, Part B, p. 56-66.
1923: Reconnaissance across northeast British Columbia and the geology of the northern extension of Franklin Mountain, Northwest Territories. *In* Geological Survey of Canada, Summary Report, 1922, Part B, p. 65-87.

PLATE 1

Lower Ordovician conodonts from the Survey Peak and Outram formations, Wilcox Pass, Alberta (see Dean, 1989, for details of section locations). All specimens are hypotypes and are housed in the National Type Collection of Invertebrate and Plant Fossils at the Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8.

Figure 1. *Drepanodus pervetus* (Nowlan).
Putty shale member of Survey Peak Formation, GSC loc. C-89288.

a element, GSC 101149, x48.

Figures 2–5. *Cordylodus intermedius* Furnish.
Basal silty member of Survey Peak Formation. GSC loc. C-89267.

2. *a* element, GSC 101150, x100.
3. *a* element, GSC 101151, x100.
4. *e* element, GSC 101152, x100.
5. *e* element, GSC 101153, x120.

Figures 6–9. *Teridontus nakamurai* (Nogami).
Putty shale member of Survey Peak Formation, GSC loc. C-89288.

6. *a* element, GSC 101154, x94.
7. *a* element, GSC 101155, x132.
8. *e*? element, GSC 101156, x132.
9. *e* element, GSC 101157, x132.

Figures 10–13. *Semiacontiodus nogamii* (Miller).
Basal silty member of Survey Peak Formation, GSC loc. C-89290.

10. *a* element, GSC 101158, x110.
11. *a* element, GSC 101159, x94.
12. *b*? element, GSC 101160, x110.
13. *b*? element, GSC 101161, x120.

Figures 14–17. *Scolopodus cornutiformis* (Branson and Mehl).
Outram Formation, GSC loc. C-69716.

14. *e* element, GSC 101162, x58.
15. *e* element, GSC 101163, x58.
16. *e*? element, GSC 101164, x110.
17. *e*? element, GSC 101165, x72.

Figures 18, 19. *Fahraeusodus marathonensis* (Bradshaw).
Outram Formation.

18. *b*? element, GSC 101166, x120, GSC loc. C-69712.
19. *b*? element, GSC 101167, x 155, GSC loc. C-69722.

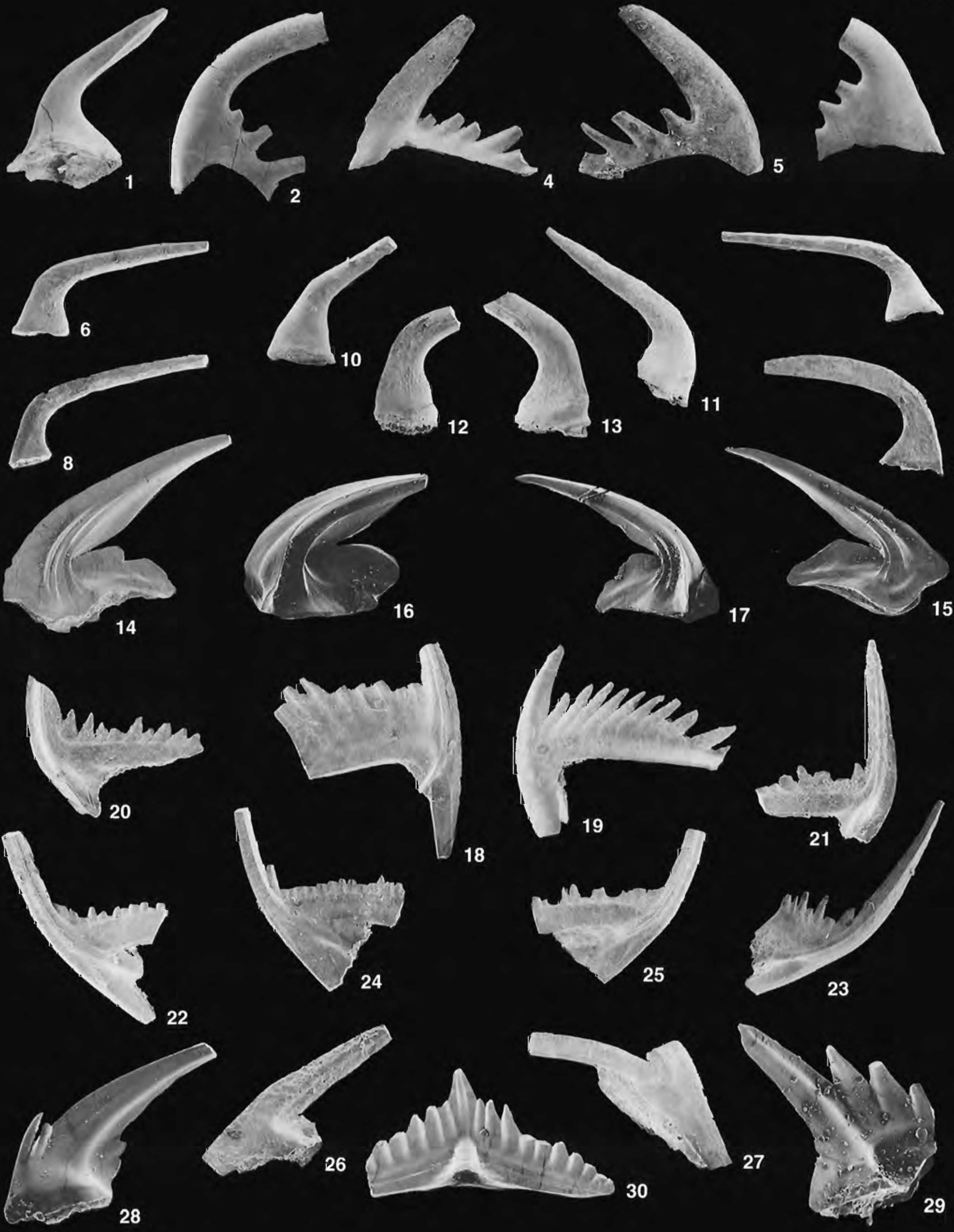
Figures 20–27. *Oepikodus communis* (Ethington and Clark).
Outram Formation, GSC loc. C-69712.

20. *a* element, GSC 101168, x216.
21. *a* element, GSC 101169, x216.
22. *a* element, GSC 101170, x156.
23. *b*? element, GSC 101171, x120.
24. *a*? element, GSC 101172, x130.
25. *a*? element, GSC 101173, x155.
26. *e* element, GSC 101174, x144.
27. *e* element, GSC 101175, x155.

Figures 28–30. *Bergstroemognathus extensus* (Graves and Ellison).
Outram Formation, GSC loc. C-69715.

28. *a*? element, GSC 101176, x94.
29. *b*? element, GSC 101177, x90.
30. *c* element, GSC 101178, x48.

PLATE 1


1
2
4
5
3
6
10
12
13
11
7
8
9
14
16
17
15
20
18
19
21
22
24
25
23
28
26
30
27
29

Middle Ordovician conodonts from the Cordilleran Road River Group, northern Yukon Territory, Canada

Alexander D. McCracken[1]

McCracken, A.D., 1991: Middle Ordovician conodonts from the Cordilleran Road River Group, northern Yukon Territory, Canada. In Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417, p. 41-63.

Abstract

A total of 506 Middle Ordovician conodont specimens was recovered from five samples of carbonate rock collected from within the fine grained clastic Road River Group at three sections of the Canadian Cordillera in northern Yukon.

The "C." horridus–S. spinatus *fauna from the Rock River section occurs below upper Llandeilo or Caradoc graptolites. Conodonts include* Drepanoistodus *sp. cf.* D. basiovalis, Periodon aculeatus, Polonodus tablepointensis*?,* Protopanderodus robustus, P. *sp. aff.* P. varicostatus, *and* Spinodus spinatus. *The presence of* "Cordylodus" horridus *and* Walliserodus ethingtoni *limits this fauna to the lower Llanvirn.*

The W. ethingtoni *fauna from Tetlit Creek comes from a debris-flow deposit. The conodonts are thus poorly preserved and perhaps reworked. At the same level there are Arenig or Llanvirn graptolites; much higher stratigraphically is the Llandeilo–Caradoc* N. gracilis *Zone. Significant conodonts include* P. aculeatus, P. *sp. aff.* P. varicostatus, *and* W. ethingtoni. *The last of these limits the range of the association to lower Llanvirn to Llandeilo.*

A conodont fauna from the Peel River section occurs within the Upper P. tentaculatus *Zone (Llanvirn). Important conodonts are* Ansella nevadensis, Pygodus serra, Drepanoistodus *sp. cf.* D. basiovalis, Periodon aculeatus, Protopanderodus parvibasis, P. robustus, P. *sp. aff.* P. varicostatus, Scalpellodus*?* viruensis, *and* Walliserodus ethingtoni. *This fauna represents the* P. serra *Zone and is probably mid-Llanvirn in age. Although stratigraphically near debris-flow beds, there is no evidence for reworking.*

A higher bed in the same section from between the Middle Ordovician G. teretiusculus *and* N. gracilis *zones yielded two relatively undiagnostic conodonts.*

Résumé

On a extrait en tout 506 spécimens de conodontes dans 5 échantillons de roche carbonatée prélevés dans des sédiments clastiques à grain fin du groupe de Road River qui proviennent de 3 coupes dans la Cordillère canadienne, dans le nord du Yukon.

La faune à «C.» horridus–S. spinatus, *dans la coupe de la rivière Rock, se situe sous les graptolites du Llandeilien supérieur ou du Caradocien. Les conodontes comprennent* Drepanoistodus *sp. cf.* D. basiovalis, Periodon aculeatus, Polonodus tablepointensis*?,* Protopanderodus robustus, P. *sp. aff.* P. varicostatus *et* Spinodus spinatus. *La présence de* «Cordylodus» horridus *et de* Walliserodus ethingtoni *limite l'âge de cette faune au Llanvirnien inférieur.*

La faune à W. ethingtoni, *dans la coupe du ruisseau Tetlit, provient d'un dépôt de coulée de débris. Par conséquent, les conodontes sont mal conservés et pourraient être remaniés. Le même niveau contient des graptolites de l'Arénigien ou du Llanvirnien; la zone à* N. gracilis, *du Llandeilien au Caradocien, est*

---

[1] Geological Survey of Canada, 601 Booth St., Ottawa, Ontario K1A 0E8

stratigraphiquement beaucoup plus élevée. Les principaux conodontes sont les suivants : P. aculeatus, P. *sp. aff.* P. varicostatus *et* W. ethingtoni. *Le dernier indique que l'âge de l'association se situe dans l'intervalle du Llanvirnien inférieur au Llandeilien.*

Une faune à conodontes qui provient de la coupe de la rivière Peel se situe dans la partie supérieure de la zone à P. tentaculatus *(Llanvirnien). Les conodontes importants sont* Ansella nevadensis, *Pygodus* serra, Drepanoistodus *sp. cf.* D. basiovalis, Periodon aculeatus, Protopanderodus parvibasis, P. robustus, P. *sp. aff.* P. varicostatus, Scalpellodus*?* viruensis *et* Walliserodus ethingtoni. *Cette faune représente la zone à* P. serra *et remonte vraisemblablement au Llanvirnien moyen. Bien que, stratigraphiquement, elle se situe près de lits de coulées de débris, elle ne présente aucun indice de remaniement.*

Un lit situé plus haut dans la même coupe, entre les zones à G. teretiusculus *et à* N. gracilis *de l'Ordovicien moyen, a donné deux conodontes relativement non caractéristiques.*

INTRODUCTION

Four samples yielding 506 Middle Ordovician conodont elements (Table 1) were collected from three localities of the Road River Group in the Richardson Mountains of northern Yukon (Figs. 1-4). This group in the Canadian Cordillera ranges in age from Late Cambrian to Early Devonian and is reported by Norford (1964) to have a maximum thickness of 3133 m at the section on Rock River (Fig. 1). The Road River Group is commonly thought of as a graptolitic unit, but is in fact a more complex sequence which, although dominated by black, fine grained clastic and graptolitic strata, also includes rare dark limestone and chert units, and some debris-flow and conglomeratic units. The Road River Group in northern Yukon represents two intersecting depositional basins: the northwest-trending Richardson Trough and the west-trending Blackstone Trough. These deep-water basins were bounded by shallower water platforms in the early Paleozoic. Proximity of the fine grained clastic basins or troughs to these carbonate shelves is shown by debris-flow deposits within strata of the Road River Group, especially in those of the Richardson Trough.

PREVIOUS STUDIES IN NORTHERN YUKON

This report follows several previous summaries and papers dealing with Ordovician–Silurian conodonts and graptolites collected by the author and A.C. Lenz (University of Western Ontario) from 1977-79 from the Road River Group of northern Yukon. Lenz and McCracken (1982) illustrated Upper Ordovician conodonts and graptolites and discussed the integration of graptolite and conodont biostratigraphy, and these authors later (McCracken and Lenz, 1987) defined six conodont "associations" (faunas) and biozones from northern Yukon. Conodonts from the three Middle Ordovician faunas and zones ("*C.*" *horridus*–*S. spinatus* fauna; *W. ethingtoni* fauna; *P. serra* Zone) are discussed and illustrated herein. The other three faunas and zones are Late Ordovician in age.

"Association 2" of McCracken and Lenz (1987), found in an Ashgill debris-flow bed at the Rock River section (Figs. 1, 2) contains conodonts that are not particularly diagnostic; their age could range from early Caradoc to late Ashgill. A more significant find is the Upper Ordovician conodonts from strata at the Peel (Figs. 1, 4) and Blackstone rivers. These two faunas were assigned by Lenz and McCracken (1982) to the Richmondian conodont Fauna 12. These faunas are from within the upper part of the Ashgill *P. pacificus* graptolite Zone and represent the *G. ensifer* conodont Zone (McCracken and Lenz, 1987). At a section near Pat Lake, corroded and

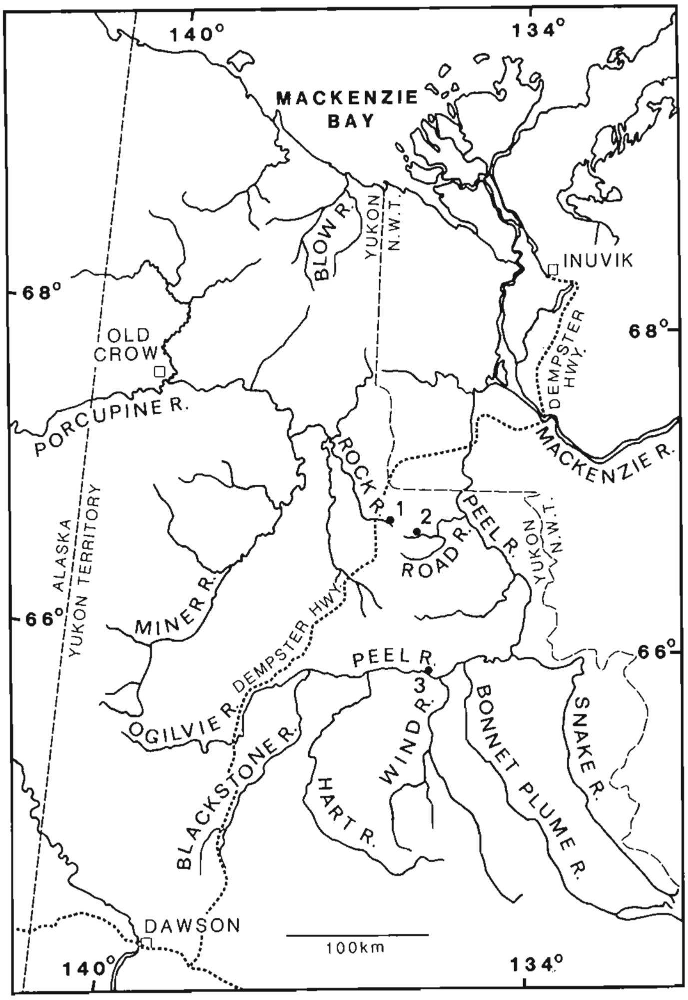


Figure 1. Location of sections: 1. Rock River (66°48'N, 136°16'W); 2. Tetlit Creek (66°44'N, 135°47'W); 3. Peel River (65°53'N, 135°43'W).

Table 1. Distribution of Middle Ordovician conodont species and element abundance from the Road River Group, northern Yukon Territory.

GRAPTOLITE ZONE		upper *tentaculatus*	*teretiusculus-gracilis*	pre-Caradoc	? *gracilis*
SPECIES / SAMPLE		PR77-358m O-104254	PR77-408m O-104255	RR78-13m O-104271	TC78-39m O-104293
Ansella nevadensis					
a element	1	1	0	0	0
b element	2	2	0	0	0
c element	2	2	0	0	0
e element	2	2	0	0	0
f-1 element	2	2	0	0	0
f-2 element	1	1	0	0	0
Coelocerodontus? sp.					
s? (trigoniform) element	1	0	0	0	1
"Cordylodus" horridus	1	0	0	1	0
Dapsilodus? sp. C					
a? (acostate "acodontiform") element	1	1	0	0	0
a (acodontiform) element	1	0	0	1	0
b (distacodontiform) element	3	3	0	0	0
Diaphorodus? sp. A					
cordylodontiform element	2	0	0	2	0
oistodontiform element	2	0	0	2	0
Drepanoistodus sp. cf. *D. basiovalis*					
q (drepanodontiform) element	15	6	0	9	0
r (oistodontiform) element	5	1	1	3	0
Drepanoistodus suberectus					
p (suberectiform) element	1	0	0	0	1
q (homocurvatiform) element	13	0	0	0	13
r (oistodontiform) element	3	0	0	0	3
Drepanoistodus sp. cf. *D. venustus*					
r (oistodontiform) element	4	0	0	3	1
Eoplacognathus? sp. A	4	0	0	4	0
Panderodus sp. cf. *P. feulneri*					
a-c element	2	2	0	0	0
e element	1	1	0	0	0
Panderodus? sp. cf. *P.*? *gibber*					
a/b element	1	1	0	0	0
Panderodus sp. cf. *P. gracilis*					
a-c element	22	7	0	0	15
e element	5	1	0	0	4
Paroistodus? sp.	3	0	1	0	2
Periodon aculeatus					
a-c (periodontiform) element	82	17	0	10	55
e (falodontiform) element	66	19	0	13	34
f (tortiliform) element	24	6	0	4	14
g (prioniodiniform) element	24	6	0	8	10
Phragmodus sp. A					
e (oistodontiform) element	1	0	0	0	1
Plectodina? sp. A	2	0	0	0	2
e/f? element	2	0	0	0	2
g (ozarkodiniform) element	2	0	0	0	2
Polonodus tablepointensis?	1	0	0	1	0
Prioniodus (Oepikodus)? sp. A					
a (gothodontiform) element	1	0	0	1	0
Protopanderodus parvibasis	3	3	0	0	0
Protopanderodus robustus	32	10	0	15	7
Protopanderodus sp. cf. *P. varicostatus*	15	9	0	3	3
Protopanderodus n. sp. A	12	12	0	0	0
Protopanderodus sp. B	2	0	0	0	2
Pygodus serra					
a element	1	1	0	0	0
b element	4	4	0	0	0
c element	3	3	0	0	0
d element	7	7	0	0	0
f element	57	57	0	0	0
g element	7	7	0	0	0
Pygodus sp. cf. *P. serra*					
g element	8	8	0	0	0
Scalpellodus? *viruensis*					
drepanodontiform element	1	1	0	0	0
scadodontiform element	5	5	0	0	0
Spinodus ramosus					
a-1 (cordylodontiform) element	1	0	0	1	0
a-c (undifferentiated) element	1	0	0	1	0
Strachanognathus parvus	11	8	0	0	3
Walliserodus ethingtoni					
a-c element	5	0	0	1	4
Walliserodus? sp.	4	0	0	0	4
Indeterminate oistodontiform element	1	1	0	0	0
Indeterminate element	21	0	0	3	18
TOTAL	506	217	2	86	201

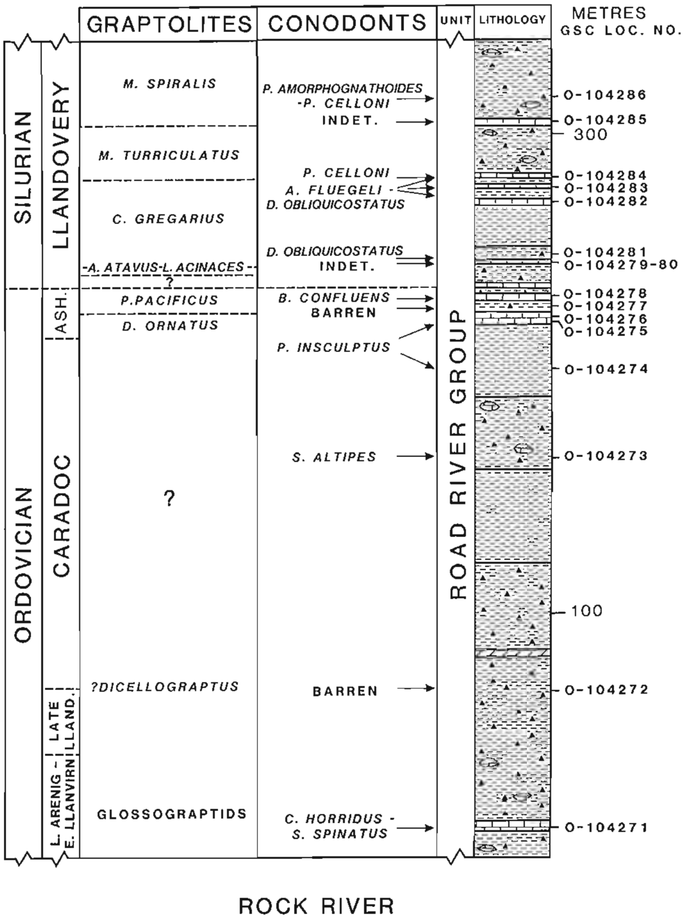


Figure 2. Graptolite–conodont succession at Rock River (loc. 1). Lithology symbols represent in succession chert and shale interbeds with rare limestone lenses, limestone, dolostone, and shale. Stratigraphic measurements are from base of sections in Figs. 2-4. Figure modified from Goodfellow et al. (1991).

rare conodont elements from 15 m of shallow-water biostromal limestone were regarded as Silurian on the basis of what is likely a new species of *Ozarkodina.* McCracken and Lenz (1987) called this collection of conodonts the *Ozarkodina* n. sp. A–*Icriodella* sp. B association. These limestones overlie shales containing graptolites of the *P. pacificus* Zone and underlie the tentative *G. persculptus* Zone (Lenz and McCracken, 1982, placed the base of the ?*G. persculptus* Zone, which at the time defined the base of the Silurian System, at the base of the carbonate unit).

The absence of a recognizable *C.*? *extraordinarius* graptolite Zone between the *P. pacificus* and ?*G. persculptus* zones and the lack of conodont Fauna 13 were thought by Lenz and McCracken (1982) to indicate a widespread stratigraphic hiatus that was probably due to the effects of a glacially induced regression. They suggested this regression prevented migration of faunas and was responsible for local erosion and nondeposition in the basins.

McCracken and Lenz (1987) also discussed Middle to Upper Ordovician conodont biogeography with respect to depositional environments in northern Yukon and southwestern District of Mackenzie. Conodonts from the carbonate or platform facies are characteristic of warm-water regions whereas those from the fine grained clastic or basinal facies contain a mixture of species from both warm- and cold-water regions. The subject of conodont paleoecology was also discussed by McCracken (1989b), who demonstrated that the Ordovician genus *Protopanderodus* was a common component of faunas from the basinal facies but not in the more shallow-water platform facies of the northern Cordillera.

McCracken (1989b) gave details of the evolution of *Protopanderodus* in northern Yukon and other parts of the world and attempted to use the species of *Protopanderodus* as biostratigraphic indices. The survey of *Protopanderodus* species resulted in identifying two phylogenetic lineages that flourished by middle Arenig time. The precursor of *Protopanderodus*, thought to be a biocostate species like *P.* n. sp. A McCracken found in Peel River strata, had probably

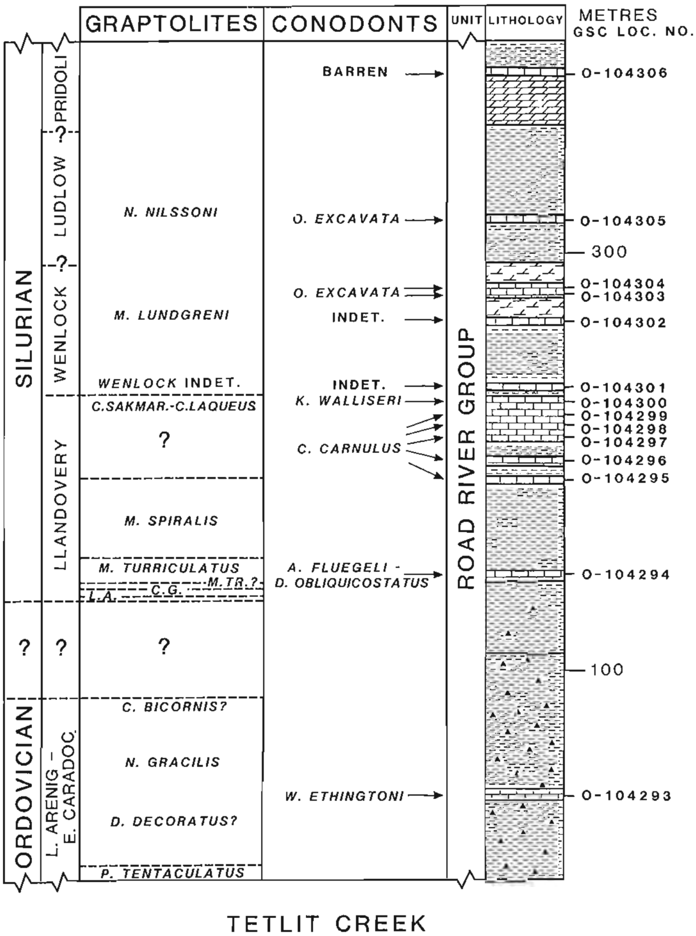


Figure 3. Graptolite–conodont succession at Tetlit Creek (loc. 2). Lithology symbols represent in succession chert and shale interbeds, limestone, shale and chert interbeds, shale, dolomitic shale, and dolostone. Abbreviated graptolite zones are: *L. acinaces, C. gregarius, M. triangularis?, C. sakmaricus.* Figure modified from Goodfellow et al. (1991).

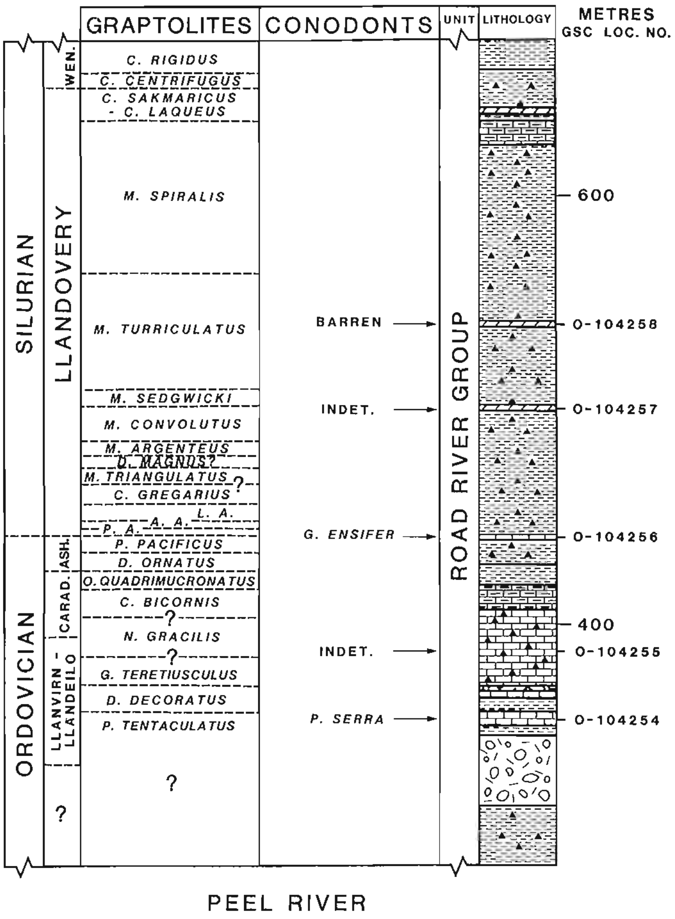


Figure 4. Graptolite–conodont succession at Peel River (loc. 3). Lithology symbols represent in succession chert and shale interbeds, conglomerate, shale, limestone, cherty limestone, shaly limestone, and dolostone. Abbreviated graptolite zones are: *P. acuminatus*, *A. atavus*, *L. acinaces*. Figure modified from Goodfellow et al. (1991).

evolved from a species of *Drepanodus* in early Arenig time. The bicostate lineage terminated in Caradoc time but the multicostate lineage continued until the late Ashgill. Both lineages are represented in faunas at all three sections of the present study.

McCracken (1987) attempted to correlate the uppermost Ordovician conodont and graptolite zones and faunas of northern Yukon, Anticosti Island, Quebec, and the graptolitic stratotype section for the base of the Silurian System at Dobb's Linn, Scotland. He suggested that the *G. ensifer* faunas correlate with Anceps Bands C and D at Dobb's Linn, and that conodont Fauna 13 of Anticosti Island and at the least, the lower part of the Gamachian Stage may correspond to Anceps Band E and the *C.? extraordinarius* Band. The correlation of uppermost Gamachian and the uppermost Ordovician *G. persculptus* Zone was (and is) an enigma.

Formal systematic descriptions and illustrations of the Middle Ordovician conodonts discussed in McCracken and Lenz (1987) are presented herein and represent the final chapter on Ordovician conodonts collected between 1977 and 1979. To date, there has been little mention of the more abundant Silurian conodont elements (over 8500 elements *versus* less than 1000 for all of the Ordovician) collected at the same time (see Appendix); some of this Silurian material is discussed elsewhere in this volume.

I returned to northern Yukon in 1986-88 and collected conodont and macrofossil samples from the Blackstone River section, and from 29 other sections, including six in the adjacent District of Mackenzie of the Northwest Territories. A total of 361 conodont and 71 macrofossil collections was made, representing strata of the Road River Group and its laterally equivalent carbonate units and ranging in age from Ordovician through Devonian. This program was to study conodont evolution in both trough and platform settings, and to continue refining the integrated conodont and graptolite biostratigraphic scheme. Processing of these samples is yet to be completed; in a summary paper, McCracken (1989a) reported over 23,000 conodont elements from about one third of these new samples. Once obtained, the results should add significantly to the knowledge of northern Cordilleran conodonts.

BIOSTRATIGRAPHY

McCracken and Lenz (1987) described Middle to Upper Ordovician conodont biozones and informal associations (faunas) from northern Yukon. Because the ranges of many of the Middle Ordovician conodonts were discussed in their paper, the details will not be repeated here.

The sample from the Rock River section (GSC loc. O-104271) contains conodonts that McCracken and Lenz (1987) referred to as the "*C.*" *horridus–S. spinatus* association. This fauna cannot be precisely located within the graptolite biostratigraphic scheme; all that is known is that glossograptids occur at the same level, and that 56 m higher are upper Llandeilo or Caradoc graptolites. "*Cordylodus*" *horridus* Barnes and Poplawski, which is a lower Whiterockian (uppermost Arenig–lower Llanvirn) species, and the lower Llanvirn–Llandeilo *Walliserodus ethingtoni* (Fåhræus) occur together and thus give an early Llanvirn age for these beds. McCracken and Lenz (1987) suggested that the conodont collection from this Rock River sample may have been reworked, on the basis of typical Tremadoc–lower Arenig conodonts [e.g., *Diaphorodus*? sp. A, *Prioniodus* (*Oepikodus*)? sp. A], as well as on sedimentological evidence.

The *Walliserodus ethingtoni* fauna (conodont "Association 1" of McCracken and Lenz, 1987) from the Tetlit Creek section (GSC loc. O-104293) is delineated below by Arenig–Llanvirn graptolites and above by the Llandeilo–Caradoc *N. gracilis* graptolite Zone. The corroded conodonts occur in a debris-flow deposit of angular-pebble conglomerate. The poor condition of the elements and scarce graptolite data limit the age determination to early Llanvirn to Llandeilo on the basis of *W. ethingtoni*.

The lower condont sample from the Peel River section (GSC loc. O-104254) represents the *Pygodus serra* conodont Zone and occurs within the lowermost part of the Upper *P. tentaculatus* graptolite Zone of Lenz and Jackson (1986) and is therefore probably about mid-Llanvirn in age. This fauna is from within a 1.8 m unit of carbonate rocks, much of which is conglomeratic, and about 12 m above the 30 m of impressive, gorge-forming massive debris-flow carbonate rocks of Llanvirn age. In spite of this, there does not seem to be any evidence for redeposition of conodonts.

The higher sample from the same section (GSC loc. O-104255) contains only two elements, one each of *Drepanoistodus* sp. cf. *D. basiovalis* (Sergeeva) and the nondescript *Paroistodus*? sp. This collection lies between the Middle Ordovician *G. teretiusculus* and younger *N. gracilis* graptolite zones. *Drepanoistodus basiovalis sensu lato* has a long range, from possibly early Arenig to as late as Caradoc (McCracken and Lenz, 1987).

TAXONOMIC REMARKS

Drepanoistodus suberectus (Branson and Mehl) is a well known Ordovician species, and is not illustrated herein. Also not illustrated are the Middle Ordovician species of *Protopanderodus* from northern Yukon: *P. parvibasis* Löfgren, *P. robustus* (Hadding), *P.* sp. aff. *P. varicostatus* (Sweet and Bergström), *P.* n. sp. A McCracken, and *P.* sp. B McCracken. These and other younger Ordovician species of *Protopanderodus* were discussed and illustrated in McCracken (1989b). Rare elements of uncertain affinity (*Paroistodus*? sp., *Walliserodus*? sp.) are not illustrated either. Species that are not well represented in Yukon samples of this study are included in the following section, Taxonomic summaries.

Most specimens are treated in multielement taxonomy; others are classified according to their morphological form, using the "iform" suffix or the abbreviation "*s.f.*" (*sensu formo*). An attempt is made to identify element homologies; these are indicated using the elemental notation system of Barnes et al. (1979).

The numbers prefixed by GSC are type numbers of illustrated specimens (GSC 99602-99693), which are housed in the National Type Collection of Fossil Invertebrates and Plants at the Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8.

TAXONOMIC SUMMARIES

Coelocerodontus? sp. A
(Pl. 1, fig. 16)

Figured specimen. GSC 99621.

Dapsilodus? sp. C
(Pl. 1, fig. 23, Pl. 3, figs. 1, 2, 5, 6)

Remarks. There is variation in the number of costae as seen on: the *a*? (acostate "acodontiform") element; the *a* (acodontiform) element, which is comparable to *Belodus*? *mutatus* Branson and Mehl *s.f.*; and the *b* (distacodontiform) element, which has a multicostate inner face quite like acontiodontiform elements of *Acodus*? *mutatus sensu* Löfgren (1978). The long-based distacodontiform element is similar to "*A.*" *similaris* Rhodes *s.f. sensu* Kennedy et al. (1979).

Figured specimens. GSC 99625, 99670-99673.

Diaphorodus? sp. A
(Pl. 1, figs. 3, 4, 8, 9, 12, 19)

Remarks. The inner face of the oistodontiform element has a sharply curved basal margin and small angle of geniculation. It also has weak carinae at this angle and faint longitudinal striae on the cusp.

The elements of *Diaphorodus*? sp. A are comparable to those of both *Acodus deltatus deltatus* (Lindström) and *A. triangularis* (Furnish), both *sensu* Repetski (1982). The cordylodontiform element shares characters with similar elements of *A. d. deltatus*, and differs from the same element of *A. triangularis* in not being costate. The oistodontiform element has a less anteriorly extended base than in this element of *A. d. deltatus*. Instead, it is more similar to the oistodontiform element of *A. triangularis*.

Figured specimens. GSC 99604-99607.

Drepanoistodus sp. cf. *D. venustus* (Stauffer) *sensu* Löfgren
(Pl. 3, fig. 7)

Figured specimen. GSC 99684.

Eoplacognathus? sp. A
(Pl. 1, figs. 10, 11, 14, 15)

Remarks. The most complete fragment (Pl. 1, fig. 15) has four processes: narrow anterior, short posterolateral, long platform-like posterior, and broken anterolateral. All except the posterolateral process have a row of denticles. The cusp is posterior to the junction of the anterolateral and anterior processes. This fragment and the others have a ''honeycomb'' ornamentation along the upper margins of the platform; this pattern is also present on the denticles of the most complete fragment.

The most complete fragment differs from *Eoplacognathus*? *variabilis* (Sergeeva) of Löfgren (1978; = *Amorphognathus variabilis* of Bergström, 1983) in that the posterolateral process is simply an adenticulate lobe, much shorter than the denticulated posterolateral process of *E.*? *variabilis*. The honeycomb ornamentation is like that found on elements of *E. foliaceus* (Fåhræus) and *E. suecicus* Bergström (cf. Löfgren, 1978).

Figured specimens. GSC 99610-99613.

Panderodus sp. cf. P. *feulneri* (Glenister)
(Pl. 2, figs. 32, 33, 37)

Figured specimens. GSC 99660-99662.

Panderodus? sp. cf. *P.*? *gibber* Nowlan and Barnes
(Pl. 2, fig. 43)

Figured specimen. GSC 99669.

Panderodus sp. cf. *P. gracilis* (Branson and Mehl)
(Pl. 2, figs. 38, 40-42)

Figured specimens. GSC 99664-99667.

Phragmodus sp. A
(Pl. 1, fig. 24)

Figured specimen. GSC 99626.

Plectodina? sp. A
(Pl. 1, figs. 17, 21)

Figured specimens. GSC 99622, 99623.

Prioniodus (*Oepikodus*)? sp. A
(Pl. 1, fig. 5)

Remarks. The single unbowed *a*-2 (gothodontiform) element has an angle between the lateral and posterior processes of about 60 degrees. Striae are prominent on the cusp posterior to the costa and extend to the proximal part of the base and beneath the proximal denticles. Faint oblique striae occur on the anterior margin of the element.

This element is questionably assigned to *Prioniodus* (*Oepikodus*) because of the similarity to P. (*O.*) *communis* (Ethington and Clark). It has a similar erect cusp, prominent lateral process and posterior process denticulation (cf. Repetski, 1982, Pl. 11, figs. 5 b, c).

Figured specimen. GSC 99608.

Indeterminate oistodontiform element
(Pl. 2, fig. 39)

Remarks. The basal outline is narrowly biconvex, and the tip of the basal cavity is perpendicular to the basal margin and extends above the upper margin of the base. The degree to which the cusp is reclined is similar to that of the *e* element of *Phragmodus polonicus* Dzik, but the angle of geniculation is not as sharp.

Figured specimen. GSC 99668.

SYSTEMATIC PALEONTOLOGY

Genus *Ansella* Fåhræus and Hunter, 1985

Type species. *Belodella jemtlandica* Löfgren, 1978.

Remarks. The interpretation of the *Ansella* apparatus used herein is as follows. The *a* (planoconvex *sensu* Löfgren, 1978; acostate denticulate *sensu* Fåhræus and Hunter, 1985) element of *Ansella* species is laterally compressed, has a keeled anterior margin, a straight upper margin beneath the denticles, and a narrow cusp.

The *b* (planoconvex *sensu* Löfgren, 1978; asymmetrical bicostate *sensu* Fåhræus and Hunter, 1985) element has poorly keeled anterior and posterior margins, a concave upper margin and a wide, laterally compressed cusp. The lateral faces are asymmetrically convex; asymmetry may be further exaggerated by the presence and position of carinae or costae. The denticulation on the *b* element is coarse, and more discrete, than that of the *a* element.

The *c* (denticulated triangular; symmetrical bicostate) element is subsymmetrical to symmetrical, with keeled or strongly costate anterolateral margins and a triangular cross-section.

The *e* (oistodontiform; geniculate *sensu* Fåhræus and Hunter, 1985) element is adenticulate and geniculate.

The *f* element has asymmetrically developed lateral faces and an adenticulate to finely denticulate upper margin. The *f* element of *Ansella jemtlandica* (Löfgren) was named the undenticulate biconvex element by Löfgren (1978) and the nondenticulate element by Fåhræus and Hunter (1985). Löfgren's illustrated elements have an upper margin that varies in length and degree of arching, as do the *f* elements from Yukon. The end members within the *f* element (cf. *Belodella jemtlandica* Löfgren, 1978, Pl. 15, fig. 5 *vs*. Pl. 15, fig. 6, and *A. nevadensis*, herein, Pl. 4, fig. 13 *vs*. Pl. 4, fig. 21) alternatively may be regarded as *f* and *g* elements, respectively.

The apparatuses of *Ansella erecta* (Rhodes and Dineley), *A. jemtlandica*, *A. nevadensis* (Ethington and Schumacher), and *A. robusta* (Ethington and Clark) (possibly senior subjective synonym of *A. sinuosa* (Stouge); see Bauer, 1987, p. 12, 13) are compared below.

Ansella nevadensis (Ethington and Schumacher)
Plate 3, figures 3, 4, 8, 9, 13, 14, 19-31

a element

New Genus A ETHINGTON and SCHUMACHER, 1969, p. 478, 479, fig. 12, Textfig. 4J.

b element

Oepikodus copenhagenensis ETHINGTON and SCHUMACHER, 1969, p. 465, Pl. 68, figs. 5, 9, Textfig. 4L.

c element

Roundya n. sp. SWEET and BERGSTRÖM, 1962, p. 1244, 1245, Textfig. 5.

Roundya? sp. A ETHINGTON and SCHUMACHER, 1969, p. 475, Pl. 67, fig. 23.

e element

Oistodus nevadensis ETHINGTON and SCHUMACHER, 1969, p. 467, 468, Pl. 68, figs. 1-4, Textfig. 5C; TIPNIS, CHATTERTON, and LUDVIGSEN, 1978, Pl. 6, fig. 17.

"*Oistodus*" sp. aff. "*O.*" *nevadensis* Ethington and Schumacher. TIPNIS, 1978, Pl. 13.1, fig. 6.

Multielement

Ansella nevadensis (Ethington and Schumacher). FÅHRÆUS and HUNTER, 1985, p. 1175, 1176, Pl. 1, figs. 7, 10 (= *e*, *b* elements), Pl. 2, figs. 11a, b, 13a, b, 14 (= *b*, *e*, *c* elements), Textfigs. 2A-C (= *e*, *c*, *b* elements) (includes synonymy); BERGSTRÖM, 1990, p. 25, Pl. 1, figs. 11-14.

Belodella nevadensis (Ethington and Schumacher). BERGSTRÖM, 1978, Pl. 79, figs. 9, 10 (= *c*, *e* elements); LÖFGREN, 1978, Textfigs. 24J-M (= *e*, *b*, *f*, *a* elements); HARRIS, BERGSTRÖM, ETHINGTON, and ROSS, 1979, Pl. 3, figs. 10-13 (= *c*, *c*, *f*, *e* elements); BERGSTRÖM and ORCHARD, 1985, Pl. 2.2, fig. 2 (= *a* element).

non Belodella sp. A Fåhræus. BERGSTRÖM, 1979, p. 306, figs. 4L-M (= *c*, *e* elements of *A. robusta* or *A. sinuosa*).

non Belodella sp. STOUGE *in* STOUGE and BOYCE, 1983, Pl. 6, figs. 2-8 (figs. 2, 3 = *c*, *f* elements of *A. sinuosa*; figs. 4-8 = *c*, *a*, *e*, *f*, *b* elements of *A. jemtlandica*).

Description. All elements have a triangular basal cavity that extends for the full length of the base. White matter is present in the cusp and denticles. The *a–c* and *f* elements are nongeniculate and denticulate; the *e* element is geniculate and nondenticulate. Cusps are short, proclined on *a–c* and *f* elements, reclined on *e* element. Cusp is flexed slightly to the inner side in *a* element; *b*, *e* and *f* elements are bowed slightly to the inner side. Denticulation in *f* element is weak compared to *a–c* elements.

The acostate *a* element (Pl. 3, figs. 8, 9) is laterally compressed, has a long base with straight anterior, basal and upper (at base of denticles) margins, and a basal cavity that extends anteriorly to about two thirds of element length. Inner face of base is more narrowly convex than outer face. Sharp anterior edge of base develops into a costa on cusp. Posterior portion of upper margin is keeled. Denticles (about 17 or more) are erect, relatively long, fused and have short triangular tips. Micro-ornamentation consists of oblique striae on the anterobasal corner (Pl. 3, fig. 31).

The *b* element (Pl. 3, figs. 3, 4, 23, 24) has an upper margin of base and posterior margin of cusp that form a uniformly concave arch; basal margin is nearly straight to slightly concave. Inner face is slightly convex to planar, outer is more convex. Inner face has costa that is most prominent at midlength of element and diminishes toward posterior and apex of cusp. This face has fine parallel striae between denticles and costa. Outer face is similarly costate except that costa merges posteriorly with carina. Cusp is finely striated; more subtle striae are present anterior of costa, and on base below denticles. Posterior upper margin is adenticulate. Denticles number about 15 or less, are relatively long, proclined, and for the most part discrete.

The *c* element (Pl. 3, figs. 26, 28-30) is symmetrical and has a short base with a long proclined cusp. Anterior and lateral faces of base are concave, producing a basal cross-section that is narrowly triangular. Element has faint striae on posterolateral face of cusp. Anterolateral keels extend for full length of element; cusp is therefore triangular in cross-section. Denticles are long, those toward anterior are longer than those toward posterior. Denticles are fused for most of their length and with discrete triangular tips; they are erect posteriorly, proclined anteriorly, producing a palmate blade of denticles. Anteriormost denticle is fused with posterior edge of cusp. Upper margin is slightly extended past basal margin.

The *e* element (Pl. 3, figs. 25, 27) has basal margin that is only slightly sinuoidal (convex toward anterior corner, concave toward posterior corner). Short upper margin has small geniculation angle between cusp and base and a strong inflection posterior of the angle. Outline of anterior margin is variable, from having a relatively strong inflection (Pl. 3, fig. 25), to being evenly convex (Pl. 3, fig. 27). Cusp has a strong carina on inner face; other side has a weaker carina. Basal cavity does not extend into cusp.

Cross-section of *f* element is like that of *b* element. Upper margin is finely denticulate. Short denticles with triangular tips number about 15 or more, are proclined, relatively long and fused for most of their length. White matter is not present in small denticles of posterior region of upper margin. Both faces of *f*-1 element (Pl. 3, figs. 13, 14, 19, 20) have a weak costa. Micro-ornamentation is like that of *b* element. Upper margin of base on *f*-1 element is straight; on *f*-2 element it is evenly concave. The *f*-2 element (Pl. 3, figs. 21, 22) has basal carina on outer face; inner face lacks costa or carina.

Apparatus of Ansella nevadensis

The reconstruction of *Belodella* (= *Ansella*) *nevadensis* by Löfgren (1978) is followed in part, but a slightly revised interpretation of *A. nevadensis* is summarized in the above synonymy and briefly discussed below.

New Genus A Ethington and Schumacher *s.f.*, regarded as a triangular element by Löfgren (1978, p. 48, 49), has a keeled anterior margin and fused erect denticles. The sharp anterior and posterior margins and a costa on the outer face give this element an asymmetrical cross-section. For these reasons, I consider this the *a* element rather than the *c* element.

Löfgren (1978, p. 49) tentatively equated the bicostate *Oepikodus copenhagenensis* Ethington and Schumacher *s.f.* with the undenticulate biconvex (herein the *f*) element of her *B. jemtlandica* "in spite of its asymmetry" (concavoconvex or planoconvex basal outline). This form species is regarded as the *b* element.

The triangular basal outline and erect cusp with "prominent lateral costae" found on *Roundya*? sp. A Ethington and Schumacher *s.f.* (1969, p. 475) are characteristic of the *c* element of the genus *Ansella*. Carnes (1975) included this form taxon within his interpretation of *B. nevadensis*.

The *e* element of *Ansella* is oistodontiform, and the *f* element is finely denticulate.

Löfgren (1978) considered *Oepikodus*? aff. *O. copenhagenensis s.f.*, as part of *Belodella nevadensis* and to be homologous with the planoconvex element of *B. jemtlandica*. This form species is quite different in denticulation compared to the other elements of *A. nevadensis*. In fact, Fåhræus and Hunter (1985) questionably regarded it as part of their new species *Goverdina alicula*.

Comparison of Ansella *species*

The *a* element of *Ansella nevadensis* is similar to the same element of *A. erecta* (Rhodes and Dineley), *A. jemtlandica* (cf. Löfgren, 1978, Pl. 15, fig. 3), and *A. robusta* (Ethington and Clark), especially with regard to the keeled anterior and posterior margins, and laterally compressed basal outline. However, the denticulation in *A. erecta* (Serpagli, 1967, Pl. 11, figs. 2a-4c), *A. nevadensis*, and *A. robusta* (Bauer, 1987, Pl. 1, fig. 8) is more erect and the cusp is more proclined than in *A. jemtlandica*. There is some variation within the a element of *A. nevadensis* since New Genus A Ethington and Schumacher *s.f.* differs from the Yukon *a* elements in that one lateral face has a costa.

The *b* elements of *Ansella erecta* (Serpagli, 1967, Pl. 11, figs. 1a-c), *A. jemtlandica*, (Löfgren, 1978, Pl. 15, fig. 4), and *A. nevadensis* have relatively coarse denticulation compared to their *f* elements (Löfgren did note the difference in denticulation in her illustrated planoconvex elements, her Pl. 15, figs. 3 and 4 being the *a* and *b* elements, respectively), and are asymmetrically biconvex at the base. The *b* elements of *A. erecta* and *A. jemtlandica* lack lateral costae like those found on the *b* element of *A. nevadensis*.

The *c* element of *Ansella nevadensis* lacks the long base and relatively short denticles found on *c* elements of *Ansella erecta* (Serpagli, 1967, Pl. 11, figs. 5a-6c), *A. jemtlandica* (Löfgren, 1978, Pl. 15, figs. 1A-C, 2), and *A. robusta* (Bauer, 1987, Pl. 1, fig. 1). The high blade-like region of one of the *c* elements of *B. nevadensis* in Harris et al. (1979, Pl. 3, fig. 11) is interpreted to be long and fused denticles. The *c* element of *A. nevadensis sensu* Bergström (1978, Pl. 79, fig. 9) has a long base and long denticles and thus may not be the same species.

The *e* element has a short upper margin and a strong inflection and low angle of geniculation in *A. nevadensis* and *A. jemtlandica* (Löfgren, *ibid.*, figs. 7, 8). The *e* element of *A. erecta* ("*Oistodus*" *pseudorobustus* Serpagli *s.f.*, 1967, Pl. 21, figs. 1a-4d) and *A. nevadensis sensu* Bergström (1978, Pl. 3, fig. 10) differ in that the upper margin is more gently convex. Unlike the basal cavity of the *e* element of *A. jemtlandica*, the cavity tip of this element in *A. erecta* and *A. nevadensis* does not extend into the cusp. The *e* element figured by Bergström (1979, fig. 4M) for *Belodella* sp. A differs from the Yukon element in that the basal margin is more sinuous [= *A. robusta* or *A. sinuosa* (Stouge)?] but it has a similar narrow and carinate cusp, as does the incomplete *e* element of *B. nevadensis sensu* Harris et al. (1979).

The *f* elements of *A. jemtlandica* (cf. Löfgren, 1978, Pl. 15, figs. 5, 6 = *f*-1, *f*-2, respectively) have the same general form as that described here for *A. nevadensis* but are adenticulate or faintly serrated (but without distinct denticles), lack costae, and have a broad carina on each face. The *f* elements of *A. robusta* and *A. sinuosa* are likewise adenticulate, but have lateral costae (cf. Bauer, 1987, Pl. 1, fig. 5).

Löfgren (1978) did not recognize an adenticulate element in Serpagli's (1967) *Belodella erecta*. She suggested that the corresponding element is a denticulate biconvex element.

In their *Ansella nevadensis*, Fåhræus and Hunter (1985) did not identify elements that are herein termed *f* elements, but perhaps these are part of the group they called the asymmetrical bicostate element.

Hypotypes. GSC 99674-99683.

Genus *Cordylodus* Pander, 1856
emend. Bergström and Sweet, 1966

Type species. *Cordylodus angulatus* Pander, 1856.

"*Cordylodus*" *horridus* Barnes and Poplawski
Plate 1, figure 1

Multielement

Cordylodus horridus BARNES and POPLAWSKI, 1973, p. 771, 772, Pl. 2, figs. 16-18.

"*Cordylodus*" *horridus* Barnes and Poplawski. HARRIS, BERGSTRÖM, ETHINGTON, and ROSS, 1979, Pl. 1, fig. 6; NOWLAN and THURLOW, 1984, p. 291, Pl. 1, figs. 4, 7, 8; CRAIG, 1986, Pl. 1, fig. 9.

"*Cordylodus horridus*" Barnes and Poplawski. QIU, 1984, p. 139, Pl. 1, fig. 19.

Cordylodus? *horridus* Barnes and Poplawski. STOUGE *in* STOUGE and BOYCE, 1983, Pl. 7, figs. 7-9; STOUGE, 1984, p. 45, 46, Pl. 1, figs. 1-11 (includes synonymy).

Remarks. Nowlan and Thurlow (1984) believed that this species does not belong to *Cordylodus* and should probably be assigned to a new genus. I follow their example and place the generic name in quotation marks.

Hypotype. GSC 99602.

Genus *Drepanoistodus* Lindström, 1971

Type species. *Oistodus forceps* Lindström, 1955.

Drepanoistodus sp. cf. *D. basiovalis* (Sergeeva)
Plate 3, figures 10-12, 15-18

Oistodus basiovalis SERGEEVA, 1963, p. 96, Pl. 7, figs. 6, 7, Textfig. 3.

Multielement

cf. *Drepanoistodus basiovalis* (Sergeeva). LÖFGREN, 1978, p. 55, 56, Pl. 1, figs. 11-17, Textfigs. 26B, C (includes synonymy); TIPNIS, CHATTERTON, and LUDVIGSEN, 1978, Pl. 9, fig. 21; NOWLAN, 1981, p. 11, Pl. 3, figs. 20-22; STOUGE, 1984, p. 53, Pl. 3, figs. 18-20 (includes synonymy).

Remarks. The *q* (homocurvatiform) elements (Pl. 3, figs. 10, 15-18) have only a slight lateral twist of the cusp and an asymmetrical flare of the base. The anterior margin is variably keeled and the posterior margin may be either slightly keeled or rounded with a faint costa. They are not as recurved as those of *Drepanoistodus basiovalis sensu* Löfgren (1978).

The single *r* (oistodontiform) element (Pl. 3, figs. 11, 12) is characterized by a narrowly rounded anterior basal corner and a cusp that is smoothly convex on the outer face with a weakly developed carina on the other. The basal corner angle is not greater than that of *Drepanoistodus forceps* (Lindström) and is less than that of *D. basiovalis*. The cusp ornamentation is similar to that of the *r* element of *D. basiovalis*.

Figured specimens. GSC 99685-99690.

Genus *Periodon* Hadding, 1913
emend. Bergström and Sweet, 1966

Type species. *Periodon aculeatus* Hadding, 1913.

Periodon aculeatus Hadding
emend. Bergström and Sweet, 1966
Plate 1, figures 13, 20, 22, 25-28
Plate 2, figures 24-27, 31, 34, 35

a–d elements

Periodon aculeatus HADDING, 1913, p. 33, Pl. 1, fig. 14.

Multielement

Periodon aculeatus Hadding. BERGSTRÖM, 1978, Pl. 79, figs. 3-5; FÅHRÆUS and NOWLAN, 1978, p. 482, Pl. 3, figs. ?1, 7-10, 11, ?12, ?13, Textfigs. 5G-L (includes synonymy); LÖFGREN, 1978, p. 74, 75, Pl. 10, figs. 1A, B, Pl. 11, figs. 12-26, Textfig. 28 (in part) (includes synonymy); NOWLAN, 1981, p. 12, Pl. 2, figs. 7-10, Pl. 4, figs. 1-9; AN et al., 1983, p. 120, 121, Pl. 28, figs. 7-9; BURRETT, STAIT, and LAURIE, 1983, p. 183, 184, figs. 8A-H; NI *in* ZENG et al., 1983, Pl. 12, figs. 9-17; QIU, 1984, p. 139, 140, Pl. 1, figs. 1-9; BERGSTRÖM and ORCHARD, 1985, Pl. 2.2, figs. 6, 7; BERGSTRÖM, 1990, Pl. 1, figs. 15, 16.

Periodon aculeatus aculeatus Hadding. NICOLL, 1980, figs. 3A-G.

cf. *Periodon aculeatus*? Hadding. NOWLAN and THURLOW, 1984, p. 293, Pl. 1, figs. 12-14, 17, 18.

cf. *Periodon* sp. cf. *aculeatus* Hadding. SIMES, 1980, fig. 5.

cf. *Periodon* sp. cf. *P. aculeatus* Hadding. TIPNIS, CHATTERTON, and LUDVIGSEN, 1978, Pl. 8, figs. 13-15; KENNEDY, BARNES, and UYENO, 1979, p. 544-546, Pl. 1, figs. 1-8, 35 (includes synonymy).

Periodon aculeatus zgierzensis Dzik. STOUGE *in* STOUGE and BOYCE, 1983, Pl. 6, figs. 9-14; STOUGE, 1984, p. 82, 83, Pl. 16, figs. 1-15 (includes synonymy).

Remarks. As originally defined, the *e* (falodontiform) element of *Periodon aculeatus zgierzensis* Dzik lacks denticles, or has at the most, two denticles on the anterior margin. *Periodon a. zgierzensis* of Stouge (1984) always has anterior denticles, the number varying from two to five, normally being three.

One *e* element (Pl. 1, fig. 22) from the Tetlit Creek section has an angular, adenticulate anterior margin and a relatively long cusp, features which are more characteristic of *Periodon flabellum* (Lindström) than of *P. aculeatus*. All other *e* elements from Tetlit Creek have between one incipient denticle and three distinct denticles.

The illustrated *a* (cordylodontiform) and *b* (cladognathiform) elements (Pl. 1, figs. 13, 20, respectively) from Tetlit Creek have at least six denticles between the cusp and biggest denticle. Most unfigured elements have about have five or six denticles between the cusp and large denticle. This number is within the range of *Periodon aculeatus* rather than *P. flabellum* (cf. Löfgren, 1978, Textfig. 29).

The Tetlit Creek specimens could be assigned to Stouge's broadened interpretation of *Periodon aculeatus zgierzensis*. However, I prefer to follow the conservative interpretation of *P. aculeatus* by Löfgren (1978), because she notes that changes within *Periodon* seem to be gradual and suggests that statistical analyses may be required to separate the subspecies (and species).

Hypotypes. GSC 99614-99620, GSC99653-99659.

Genus *Polonodus* Dzik, 1976

Type species. *Ambalodus clivosus* Viira, 1974.

Polonodus tablepointensis Stouge?
Plate 1, figure 18

Multielement

?*Polonodus clivosus* (Viira). DZIK, 1976, p. 423, Pl. 43, figs. 1a, b, Textfigs. 28c, d.

?*Polonodus tablepointensis* STOUGE, 1984, p. 72, 73, Pl. 12, figs. 13A-C, Pl. 13, figs. 1-5 (includes synonymy).

Description. Single platform element has three processes; longest is between two short broken processes. Short processes diverge at a low angle from point of junction with long process. Processes are flexed slightly to one side and are arched slightly. Ornamentation consists of sharp, concentric ridges with concave upper surfaces and raised edges, medial costae and short denticles. Denticles are centred on margin of ridges; those of long process are slightly recurved toward junction of processes. Costae and raised edge of concentric ridges merge with denticles. Ornamentation is most distinct on distal part of long process. Entire element is basally excavated.

Remarks. The long process is equivalent to the outer lateral process of the polyplacognathiform element of *Polonodus tablepointensis*. The only notable difference is that this process is slightly flexed on the Yukon form but is straight on *P. tablepointensis*. The anterior process of *P. tablepointensis* is curved, but it is also bilobate.

The ornamentation of this element is identical to that of *Polonodus tablepointensis* and the amorphognathiform element of *P. clivosus sensu* Dzik (1976).

Figured specimen. GSC 99624.

Genus *Pygodus* Lamont and Lindström, 1957

Type species. *Pygodus anserinus* Lamont and Lindström, 1957.

Remarks. The multielement apparatus of *Pygodus* consists of *f* (haddingodontiform) and *g* (platform) elements. Bergström (1971) and others suspect that the apparatus of *P. anserinus* also contains hindeodelliform and tetraprioniodontiform (i.e., *c* and *d*) elements. These elements were found in the same Yukon sample as *P. serra* (Hadding), along with *b* (keislognathiform) and a possible *a* (cordylodontiform) element.

The *g* element of *Pygodus anserinus* is narrower, and the four rows of denticles are higher when compared to the same element of *P. serra*. Intermediate forms that have a rudimentary or incipient fourth denticle row have been assigned usually to one or the other species. This report follows Nowlan's (1981) example and gives a conferred species assignment to intermediate forms of platform elements while other *g* elements from the same Yukon sample are assigned to *P. serra sensu stricto*.

The intermediate forms are of biostratigraphic interest as they have been traditionally used to define the boundary between the *P. serra* Zone and the overlying *P. anserinus* Zone. This denticle-row variablity may be evolutionary (cf. Bergström, 1971, p. 97, 149), ecological (cf. Fåhræus, 1982, p. 4-6) or it may reflect an intraspecific variability that is not necessarily temporal on a global scale. If the last statement is true, the use of "intermediate" forms as indicators of the *P. serra–P. anserinus* zonal boundary must be done with caution.

Pygodus serra (Hadding)
Plate 2, figures 4, 6, 7, 9, 11, 12, 14-18, 20-23, 28-30

f element

Arabellites serra HADDING, 1913, p. 33, Pl. 1, figs. 12, 13.

Multielement

Pygodus serra (Hadding). LÖFGREN, 1978, p. 98, Textfigs. 32D-F (includes synonymy); HARRIS, BERGSTRÖM, ETHINGTON, and ROSS, 1979, Pl. 2, fig. 18; NI *in* ZENG et al., 1983, Pl. 12, figs. 3, 5; BERGSTRÖM and ORCHARD, 1985, Pl. 2.2, fig. 15; BERGSTRÖM, 1990, Pl. 1, figs. 23, 24.

Pygodus serrus (Hadding). ?NICOLL, 1980, figs. 3H-L; AN, 1981, Pl. 4, figs. 1-3; ?WANG and WANG, 1981, Pl. 1, fig. 5.

Remarks. For purposes of tabulation, the *a*, *b*, *c*, *d* and *f* elements are arbitrarily included under *Pygodus serra*, rather than *P.* sp. cf. *P. serra*.

The *a* element (Pl. 2, fig. 23) has a denticulate posterior and only one denticulate lateral (inner) process. The opposite side is adenticulate and convex. The same side of the *b* element (Pl. 2, figs. 14, 15, 29) has a sharp adenticulate lateral process that extends for the full length of the element. In other respects, the *a* and *b* elements are similar.

The *c* (Pl. 2, figs. 16, 20, 28, 30) and *d* (Pl. 2, figs. 17, 21, 22) elements are similar to *Roundya pyramidalis* Sweet and Bergström *s.f.* and *Tetraprioniodus lindstroemi* Sweet and Bergström *s.f.*, respectively.

The angle between the two denticulated processes of the *f* element (Pl. 2, figs. 7, 9, 11) is near the maximum limit of the range (55-75 degrees) for *Pygodus serra*, as defined by Bergström (1971).

Only *g* elements (Pl. 2, figs. 4, 6, 12) without the rudimentary fourth denticle row are included within this species.

Hypotypes. GSC 99635-99652.

Pygodus sp. cf. *P. serra* (Hadding)
Plate 2, figures 1-3, 5, 8, 10, 13, 19

f element

cf. *Arabellites serra* HADDING, 1913, p. 33, Pl. 1, figs. 12, 13.

Multielement

Pygodus serrus (Hadding). TIPNIS, CHATTERTON, and LUDVIGSEN, 1978, Pl. 9, figs. 2, 4, 7-9.

Pygodus cf. *P. serrus* (Hadding). NOWLAN, 1981, p. 12, Pl. 2, figs. 14, 16-20.

Remarks. Development of the incipient fourth denticle row in *Pygodus* sp. cf. *P. serra* varies: from only one, to more than one denticle, which forms a rudimentary fourth denticle row, and some elements (Pl. 2, fig. 5) have two incipient denticles on the same inter-row ridge. Fully developed and incipient denticles, and the perpendicular inter-row ridges have a similar papillose micro-ornamentation.

Figured specimens. GSC 99627-99634.

Genus *Scalpellodus* Dzik, 1976
emend. Löfgren, 1978

Type species. *Protopanderodus latus* van Wamel, 1974.

Scalpellodus? *viruensis* Löfgren
Plate 3, figures 32-37

Multielement

Scalpellodus viruensis LÖFGREN, 1978, p. 102, 103, Pl. 5, figs. 1, 2, 7-9.

Remarks. The two illustrated scandodontiform elements show some variation in the length of the base. The micro-ornamentation (striae parallel to the axis of the cusp) on both elements compares to that described by Löfgren (1978).

Nowlan (1981) proposed that *Scalpellodus viruensis* represents the *e* element of *Walliserodus iniquus* (Viira). Since the material is limited, the Yukon elements are questionably referred to as *Scalpellodus* rather than *Walliserodus*.

Hypotypes. GSC 99691-99693.

Genus *Spinodus* Dzik, 1976

Type species. *Cordylodus spinatus* Hadding, 1913.

Spinodus spinatus (Hadding)
Plate 1, figure 2

Cordylodus ramosus HADDING, 1913, p. 31, Pl. 1, fig. 6.

Polygnathus spinatus HADDING, 1913, p. 32, Pl. 1, fig. 6.

a–b elements

Cordylodus spinatus (Hadding). UYENO and BARNES, 1970, p. 106, 107, Pl. 24, figs. 7-11 (includes synonymy); TIPNIS, CHATTERTON, and LUDVIGSEN, 1978, Pl. 8, fig. 16.

Multielement

Cordylodus ramosus Hadding. BARNES and POPLAWSKI, 1973, p. 772, Pl. 4, fig. 6 (includes synonymy); SIMES, 1980, fig. 7.

aff. *Cordylodus* sp. aff. *C. spinatus* (Hadding). LANDING, 1976, p. 631, Pl. 1, fig. 14.

Spinodus ramosus (Hadding). NOWLAN, 1981, p. 15, 16, Pl. 4, figs. 18, 19.

Spinodus spinatus (Hadding). BERGSTRÖM and ORCHARD, 1985, Pl. 2.2, figs. 1, 4; BERGSTRÖM, 1990, Pl. 2, figs. 12, 13.

Remarks. Lindström (1964) recognized a symmetry transition series of three element types based on *C. ramosus* Hadding *s.f.* and *C. spinatus* (Hadding) *s.f.* Uyeno and Barnes (1970) added a fourth element to this series under their *C. spinatus*. Barnes and Poplawski (1973) recognized all four elements in *C. ramosus* from the Mystic Formation of Quebec. These are *a*-1 (cordylodontiform), *a*-2 (ligonodiniform), *b* (cladognathiform) and *c* (hibbardelliform) elements.

Hypotype. GSC 99603.

Genus *Strachanognathus* Rhodes, 1955

Type species. *Strachanognathus parvus* Rhodes, 1955.

Strachanognathus parvus Rhodes
Plate 2, figure 36

Strachanognathus parvus RHODES, 1955, p. 132, 133, Pl. 8, figs. 1-4; PALMIERI, 1978, p. 27, Pl. 6, figs. 27, 28 (only); BERGSTRÖM, 1990, Pl. 1, fig. 10.

Strachanognathus parva Rhodes. PALMIERI, 1978, Textfig. 6(8a-c) (only).

Strachanognathus cf. *S. parvus* RHODES, 1955, p. 133, Pl. 7, fig. 16, Pl. 8, figs. 1-4.

Multielement

Strachanognathus parvus Rhodes. LÖFGREN, 1978, p. 112, 113, Pl. 1, fig. 29 (includes synonymy); KENNEDY, BARNES, and UYENO, 1979, p. 550, Pl. 1, fig. 24; ORCHARD, 1980, p. 26, Pl. 4, figs. 34, 35; NOWLAN, 1981, p. 13, Pl. 3, fig. 18, Pl. 5, fig. 5; LENZ and McCRACKEN, 1982, Pl. 2, fig. 21; STOUGE, 1984, p. 57, Pl. 5, fig. 9; BERGSTRÖM and ORCHARD, 1985, Pl. 2.3, fig. 1.

Remarks. Lenz and McCracken (1982) illustrated a younger (Ashgill) specimen of *Strachanognathus parvus* that has oblique striations on the first denticle. Striae such as these were not observed on the illustrated specimen in the present study.

Hypotype. GSC 99663.

Genus *Walliserodus* Serpagli, 1967

Type species. *Acodus curvatus* Branson and Branson, 1947.

Walliserodus ethingtoni (Fåhræus)
Plate 1, figures 6, 7

Panderodus ethingtoni FÅHRÆUS, 1966, p. 26, Pl. 3, figs. 5a, b.

Walliserodus ethingtoni (Fåhræus). TIPNIS, CHATTERTON, and LUDVIGSEN, 1978, Pl. 9, fig. 23.

Multielement

Walliserodus ethingtoni (Fåhræus). REPETSKI and ETHINGTON, 1977, Pl. 1, fig. 9; AN, 1981, Pl. 3, fig. 16; STOUGE *in* STOUGE and BOYCE, 1983, Pl. 7, figs. 12, 13; NOWLAN and THURLOW, 1984, p. 294, Pl. 2, fig. 15; STOUGE, 1984, p. 64, 65, Pl. 9, figs. 1-9 (includes synonymy); FÅHRÆUS and HUNTER, 1985, p. 1180, 1181, Pl. 3, figs. 11-16, Textfigs. 6A-H (includes synonymy).

Hypotype. GSC 99609.

ACKNOWLEDGMENTS

Financial support to collect and process the samples was provided by a Natural Sciences and Engineering Research Council of Canada grant to Drs. A.C. Lenz (University of Western Ontario) and J.A. Legault (University of Waterloo). Dr. A.C. Lenz is thanked for providing the graptolite identifications used herein. Drs. G.S. Nowlan and T.T. Uyeno (I.S.P.G., Calgary) are thanked for their comments on an earlier version of this paper. Carrie Bolton drafted the figures.

REFERENCES

An Taixiang
1981: Recent progress in Cambrian and Ordovician conodont biostratigraphy of China. *In* Paleontology in China, 1979, C. Teichert, Liu Lu and Chen Peiji (eds.); Geological Society of America, Special Paper 187, p. 209-224.

An Taixiang, Zhang Fang, Xiang Weida, Zhang Youqiu, Xu Wenhao, Zhang Huijuan, Jiang Debiao, Yang Changsheng, Lin Liandi, Cui Zhantang, and Yang Xinchang
1983: The conodonts of North China and the adjacent regions. Science Press of China, 223 p., 33 pl. (In Chinese with English summary.)

Barnes, C.R., Kennedy, D.J., McCracken, A.D., Nowlan, G.S., and Tarrant, G.T.
1979: The structure and evolution of Ordovician conodont apparatuses. Lethaia, v. 12, p. 125-151.

Barnes, C.R. and Poplawski, M.L.S.
1973: Lower and Middle Ordovician conodonts from the Mystic Formation, Quebec, Canada. Journal of Paleontology, v. 47, p. 760-790.

Bauer, J.A.
1987: Conodonts and conodont biostratigraphy of the McLish and Tulip Creek formations (Middle Ordovician) of south-central Oklahoma. Oklahoma Geological Survey, Bulletin 141, 58 p.

Bergström, S.M.
1971: Conodont biostratigraphy of the Middle and Upper Ordovician of Europe and eastern North America. *In* Symposium on Conodont Biostratigraphy, W.C. Sweet and S.M. Bergström (eds.); Geological Society of America, Memoir 127, p. 83-161.
1978: Middle and Upper Ordovician conodont and graptolite biostratigraphy of the Marathon, Texas graptolite zone reference standard. Palaeontology, v. 21, p. 723-758.
1979: Whiterockian (Ordovician) conodonts from the Hølonda Limestone of the Trondheim region, Norwegian Caledonides. Norsk Geologisk Tidsskrift, v. 59, p. 295-307.
1983: Biostratigraphy, evolutionary relationships, and stratigraphic significance of Ordovician platform conodonts. Fossils and Strata, No. 15, p. 35-58.
1990: Biostratigraphic and biogeographic significance of Middle and Upper Ordovician conodonts in the Girvan succession, south-west Scotland. *In* 1st International Senckenberg Conference and 5th European Conodont Symposium (ECOS V), Contributions IV. Papers on conodonts and Ordovician to Triassic conodont stratigraphy, W. Ziegler (ed.); Courier Forschungsinstitut Senckenberg, v. 118, p. 1-43.

Bergström, S.M. and Orchard, M.J.
1985: Conodonts of the Cambrian and Ordovician systems from the British Isles. *In* A Stratigraphical Index of Conodonts, A.C. Higgins and R.L. Austin (eds.); British Micropalaeontological Society Series, Ellis Horwood Limited, Chichester, p. 32-67.

Bergström, S.M. and Sweet, W.C.
1966: Conodonts from the Lexington Limestone (Middle Ordovician) of Kentucky and its lateral equivalents in Ohio and Indiana. Bulletins of American Paleontology, v. 50, no. 229, p. 271-424.

Branson, E.B. and Branson, C.C.
1947: Lower Silurian conodonts from Kentucky. Journal of Paleontology, v. 21, p. 549-556.

Burrett, C., Stait, B., and Laurie, J.
1983: Trilobites and microfossils from the Middle Ordovician of Surprise Bay, southern Tasmania, Australia. Memoirs of the Association of Australasian Palaeontologists, v. 1, p. 177-193.

Carnes, J.B.
1975: Conodont biostratigraphy in the lower Middle Ordovician of the western Appalachian thrust-belts in northeastern Tennessee. Unpublished Ph.D. thesis, The Ohio State University, Columbus, Ohio, 291 p.

Craig, W.W.
1986: Conodont paleontology of Middle and Upper Ordovician strata, Batesville District, Arkansas. *In* Guidebook to the Conodont Paleontology of Uppermost Lower Ordovician Through Silurian Strata, Northeastern Arkansas, W.W. Craig, R.L. Ethington and J.E. Repetski. Pander Society Field Trip, Field Trip No. 5, Annual Meeting of the South Central and Southeastern Sections of the Geological Society of America, Memphis, April, 1986, Department of Geology and Geophysics, University of New Orleans, New Orleans, Louisiana, p. 1-20.

Dzik, J.
1976: Remarks on the evolution of Ordovician conodonts. Acta Palaeontologica Polonica, v. 21, no. 4, p. 395-455.

Ethington, R.L. and Schumacher, D.
1969: Conodonts of the Copenhagen Formation (Middle Ordovician) in central Nevada. Journal of Paleontology, v. 43, p. 440-484.

Fåhræus, L.E.
1966: Lower Viruan (Middle Ordovician) conodonts from the Gullhogen quarry, southern central Sweden. Sveriges Geologiska Undersökning, Avhandlingar och uppsater, Serie C, No. 610, Arsbok, No. 5, 40 p.
1982: Allopatric speciation and lineage zonation exemplified by the *Pygodus serrus–P. anserinus* transition (Conodontophorida, Ordovician). Newsletters on Stratigraphy, v. 11, p. 1-7.

Fåhræus, L.E. and Hunter, D.R.
1985: Simple-cone conodont taxa from the Cobbs Arm Limestone (Middle Ordovician), New World Island, Newfoundland. Canadian Journal of Earth Sciences, v. 22, p. 1171-1182.

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

Goodfellow, W.D., Nowlan, G.S., McCracken, A.D., Lenz, A.C., and Grégoire, D.C.
1991: Geochemical anomalies near the Ordovician–Silurian boundary, northern Yukon Territory, Canada. Historical Biology. (in press)

Hadding, A.
1913: Undre dicellograptusskiffern i Skäne jämte några därmed ekvivalenta bildningar. Lunds Universitets Arsskrift, nf följd, v. 2, No. 15, p. 1-90.

Harris, A.G., Bergström, S.M., Ethington, R.L., and Ross, R.J., Jr.
1979: Aspects of Middle and Upper Ordovician conodont biostratigraphy of carbonate facies in Nevada and southeast California and comparison with some Appalachian successions. Brigham Young University Geology Studies, v. 26, Part 3, p. 7-44.

Kennedy, D.J., Barnes, C.R., and Uyeno, T.T.
1979: A Middle Ordovician conodont faunule from the Tetagouche Group, Camel Back Mountain, New Brunswick. Canadian Journal of Earth Sciences, v. 16, p. 540-551.

Lamont, A. and Lindström, M.
1957: Arenigian and Llandeilian cherts identified in the Southern Uplands of Scotland by means of conodonts, etc. Transactions of the Edinburgh Geological Society, v. 17, pt. 1, p. 60-70.

Landing, E.
1976: Early Ordovician (Arenigian) conodont and graptolite biostratigraphy of the Taconic Allochthon, eastern New York. Journal of Paleontology, v. 50, p. 614-646.

Lenz, A.C. and Jackson, D.E.
1986: Arenig and Llanvirn graptolite biostratigraphy, Canadian Cordillera. *In* Palaeoecology and Biostratigraphy of Graptolites, C.P. Hughes and R.B. Rickards (eds.); Geological Society Special Publication, No. 20, p. 27-45.

Lenz, A.C. and McCracken, A.D.
1982: The Ordovician–Silurian boundary, northern Canadian Cordillera: graptolite and conodont correlation. Canadian Journal of Earth Sciences, v. 19, p. 1308-1322.

Lenz, A.C. and Pedder, A.E.H.
1972: Lower and Middle Paleozoic sediments and paleontology of Royal Creek and Peel River, Yukon, and Powell Creek, N.W.T. 24th International Congress, Montreal, Quebec, Excursion A-14 Guidebook, 43 p.

Lindström, M.
1955: Conodonts from the lowermost Ordovician strata of south-central Sweden. Geologiska Foreningens i Stockholm Forhandlingar, v. 76, p. 517-604.
1964: Conodonts. Elsevier, New York, New York, 196 p.
1971: Lower Ordovician conodonts of Europe. *In* Symposium on Conodont Biostratigraphy, W.C. Sweet and S.M. Bergström (eds.); Geological Society of America, Memoir 127, p. 21-61.

Löfgren, A.
1978: Arenigian and Llanvirnian conodonts from Jämtland, northern Sweden. Fossils and Strata, No. 13, 129 p.

McCracken, A.D.
1987: Description and correlation of Late Ordovician conodonts from the *D. ornatus* and *P. pacificus* graptolite zones, Road River Group, northern Yukon Territory. Canadian Journal of Earth Sciences, v. 24, p. 1450-1464.
1989a: Preliminary report on Ordovician–Devonian conodont collections from carbonate and fine grained clastic facies of northern Yukon Territory and northwest District of Mackenzie, N.W.T. *In* Current Research, Part G. Geological Survey of Canada, Paper 89-1G, p. 69-76.
1989b: *Protopanderodus* (Conodontata) from the Ordovician Road River Group, northern Yukon Territory, and the evolution of the genus. Geological Survey of Canada, Bulletin 388, 39 p.

McCracken, A.D. and Lenz, A.C.
1987: Middle and Late Ordovician conodont faunas and biostratigraphy of graptolitic strata of the Road River Group, northern Yukon Territory. Canadian Journal of Earth Sciences, v. 24, p. 643-653.

Nicoll, R.S.
1980: Middle Ordovician conodonts from the Pittman Formation, Canberra, A.C.T. BMR Journal of Australian Geology and Geophysics, v. 5, p. 150-153.

Norford, B.S.

1964: Reconnaissance of the Ordovician and Silurian rocks of the northern Yukon Territory. Geological Survey of Canada, Paper 63-39, 139 p.

Nowlan, G.S.

1981: Some Ordovician conodont faunules from the Miramichi Anticlinorium, New Brunswick. Geological Survey of Canada, Bulletin 345, 35 p.

Nowlan, G.S. and Thurlow, J.G.

1984: Middle Ordovician conodonts from the Buchans Group, central Newfoundland, and their significance for regional stratigraphy of the Central Volcanic Belt. Canadian Journal of Earth Sciences, v. 21, p. 284-296.

Palmieri, V.

1978: Late Ordovician conodonts from the Fork Lagoons Beds, Emerald area, central Queensland. Geological Survey of Queensland, Publication 369, Palaeontological Paper 43, 55 p.

Pander, C.H.

1856: Monographie der fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements. Akademie der Wissenschaften, St. Petersburg, p. 1-91.

Qiu Hongrong

1984: Some Middle Ordovician conodonts of North Atlantic Province type in Weili County Xinjiang. Bulletin of the Institute of Geology, Chinese Academy of Geological Sciences, No. 9, Geological Publishing House, Beijing, p. 137-144. (In Chinese with English summary.)

Repetski, J.E.

1982: Conodonts from El Paso Group (Lower Ordovician) of westernmost Texas and southern New Mexico. New Mexico Bureau of Mines and Mineral Resources, Memoir 40, 121 p.

Repetski, J.E. and Ethington, R.L.

1977: Conodonts from graptolite facies in the Ouachita Mountains, Arkansas and Oklahoma. *In* Symposium on the Geology of the Ouachita Mountains, Volume 1, Stratigraphy, Sedimentology, Petrography, Tectonics, and Paleontology, 1977, C.G. Stone (ed.); Arkansas Geological Commission, p. 92-106.

Rhodes, F.H.T.

1955: The conodont fauna of the Keisley Limestone. Quarterly Journal of the Geological Society, v. 111, p. 117-142.

Sergeeva, S.P.

1963: Conodonts from the Lower Ordovician in the Leningrad region. Akademia Nauka U.S.S.R., Paleontologischeskiy Zhurnal, 1963, p. 93-108. (In Russian.)

Serpagli, E.

1967: I conodonti dell'Ordoviciano superiore (Ashgilliano) delle Alpi Carniche. Bolletino della Società Paleontologica Italiàna, v. 6, p. 30-111.

Simes, J.E.

1980: Age of the Arthur Marble: conodont evidence from Mount Owen, northwest Nelson. New Zealand Journal of Geology and Geophysics, v. 23, p. 529-532.

Stouge, S.S.

1984: Conodonts of the Middle Ordovician Table Head Formation, western Newfoundland. Fossils and Strata, No. 16, 145 p.

Stouge, S.S. and Boyce, W.D.

1983: Fossils of northwestern Newfoundland and southeastern Labrador: conodonts and trilobites. Mineral Development Division, Department of Mines and Energy, Government of Newfoundland and Labrador, Report 83-3, "The Bug Book", 55 p.

Sweet, W.C. and Bergström, S.M.

1962: Conodonts from the Pratt Ferry Formation (Middle Ordovician) of Alabama. Journal of Paleontology, v. 36, p. 1214-1252.

Tipnis, R.S., Chatterton, B.D.E., and Ludvigsen, R.

1978: Ordovician conodont biostratigraphy of the southern District of Mackenzie, Canada. *In* Western and Arctic Canadian Biostratigraphy, C.R. Stelck and B.D.E. Chatterton (eds.); Geological Association of Canada, Special Paper No. 18, p. 39-91.

Uyeno, T.T. and Barnes, C.R.

1970: Conodonts from the Levis Formation (Zone D1) (Middle Ordovician), Levis, Quebec. Geological Survey of Canada, Bulletin 187, p. 99-123.

Van Wamel, W.A.

1974: Conodont biostratigraphy of the Upper Cambrian and Lower Ordovician of northwestern Oland, southeastern Sweden. Utrecht Micropaleontological Bulletins, Bulletin 10, 126 p.

Viira, V.

1974: Ordovician conodonts of the East Baltic. Eesti NSV Teaduste Akadeemia Geoloogia Institut, Tallinn, 142 p. (In Russian with English summary.)

Wang Chengyuan and Wang Zhihao

1981: Conodont sequence in China (Cambrian–Triassic System). Twelfth Annual Conference of the Palaeontological Society of China, Selected Papers, p. 105-115. (In Chinese.)

Zeng Qingluan, Ni Shizhao, Xu Guanghong, Zhou Tianmei, Wang Xiaofeng, Li Zhihong, Lai Caigen, and Xiang Liwen

1983: Subdivision and correlation on the Ordovician in the eastern Yantze Gorges, China. Bulletin of the Yichang Institute of Geology and Mineral Resources, Chinese Academy of Geological Sciences, No. 6, p. 22-68.

APPENDIX

Graptolite and conodont collections

The following list gives details of all the Ordovician–Silurian graptolite and conodont collections made in 1977-78 at the sections on Rock River, Tetlit Creek and Peel River. At the left side of the list are the field collection numbers representing the section, year collected, and stratigraphic level in metres above the base of the section. Measurements for samples from the Peel River section were made in feet, and converted to SI units.

Each conodont sample represents at least 2 kg of rock, although not all rock samples were completely disintegrated by acid. Additional material (also 2 kg) of some samples were processed; these are denoted below with an asterisk. Graptolite identifications were provided by A.C. Lenz of the University of Western Ontario.

Rock River (66°48'N, 136°16'W; Section 1)

Conodont/graptolite levels and zones

RR78-13 m – glossograptids
RR78-13 m* (GSC loc. O-104271) – conodonts
RR78-69 m (GSC loc. O-104272)
– upper Llandeilo or Caradoc graptolites
– barren of conodonts
RR78-167 m* (GSC loc. O-104273) – conodonts
RR78-207 m* (GSC loc. O-104274) – conodonts
RR78-220 m – *D. ornatus* Zone
RR78-225 m (GSC loc. O-104275) – conodonts
RR78-226 m* (GSC loc. O-104276) – barren of conodonts
RR78-228 m (GSC loc. O-104277) – conodonts
RR78-232 m – *P. pacificus* Zone
RR78-235 m (GSC loc. O-104278) – conodonts
RR78-235 m – *P. pacificus* Zone
RR78-241 m – *A. atavus* or *L. acinaces* zones
RR78-243 m – *L. acinaces* Zone
RR78-244 m – *C. gregarius* Zone
RR78-245 m* (GSC loc. O-104279) – conodonts
RR78-247 m (GSC loc. O-104280) – conodonts
RR78-250 m* (GSC loc. O-104281) – conodonts
RR78-255 m – *C. gregarius* Zone
RR78-275 m (GSC loc. O-104282) – conodonts
RR78-281 m* (GSC loc. O-104283) – conodonts
RR78-282 m – *M. turriculatus* Zone
RR78-285 m (GSC loc. O-104284) – conodonts
RR78-302 m – *M. turriculatus* Zone
RR78-306 m – *M. spiralis* Zone
RR78-308 m (GSC loc. O-104285) – conodonts
RR78-316 m* (GSC loc. O-104286) – conodonts
RR78-345 m – *M. spiralis* Zone
RR78-Section 2/14 m (GSC loc. O-104287) – conodonts
RR78-2/15 m (GSC loc. O-104288) – conodonts
RR78-2/86 m (GSC loc. O-104289) – conodonts
RR78-2/144 m (GSC loc. O-104290) – barren of conodonts
RR78-2/177 m (GSC loc. O-104291) – barren of conodonts
RR78-2/336 m (GSC loc. O-104292) – barren of conodonts

Tetlit Creek (66°44'N, 135°47'W; Section 2)

Conodont/graptolite levels and zones

TC78-1 m – Arenig–Llanvirn graptolites
TC78-39 m* (GSC loc. O-104293) – conodonts
TC78-75 m – *N. gracilis* Zone
TC78-133 m – *L. acinaces* Zone
TC78-136 m – *C. gregarius* Zone
TC78-138 m – *M. triangularis* or *D. magnus*? zones
TC78-139 m – *M. argenteus* Zone
TC78-142 m – *M. convolutus* Zone
TC78-144 m* (GSC loc. O-104294) – conodonts
TC78-144 m – *M. turriculatus* Zone
TC78-148 m – *M. turriculatus* Zone
TC78-168 m – *M. spiralis* Zone
TC78-192 m (GSC loc. O-104295) – conodonts
TC78-192 m – *M. spiralis* Zone
TC78-200 m (GSC loc. O-104296) – conodonts
TC78-212 m (GSC loc. O-104297) – conodonts
TC78-213 m – *C. sakmaricus* – *C. laqueus* Zone
TC78-218 m (GSC loc. O-104298) – conodonts
TC78-222 m* (GSC loc. O-104299) – conodonts
TC78-228 m – *C. sakmaricus* – *C. laqueus* Zone
TC78-230 m (GSC loc. O-104300) – conodonts
TC78-232 m – Wenlock indeterminate graptolites
TC78-233 m – Wenlock indeterminate graptolites
TC78-236 m (GSC loc. O-104301) – conodonts
TC78-270 m* (GSC loc. O-104302) – conodonts
TC78-273 m – *M. lundgreni* Zone
TC78-281 m (GSC loc. O-104303) – conodonts
TC78-286 m (GSC loc. O-104304) – conodonts
TC78-319 m (GSC loc. O-104305) – conodonts
TC78-320 m – *N. nilssoni* Zone
TC78-388 m* (GSC loc. O-104306) – barren of conodonts
TC78-406 m – *M. formosus* Zone

Peel River (65°53'N, 135°42'W; Section 3)

Conodont/graptolite levels and zones

PR77-298.9 m (980 ft.) – Lower *P. tentaculatus* Zone
PR77-354.1 m (1161 ft.) – Upper *P. tentaculatus* Zone
PR77-358.1-362.7 m (1175-1190 ft.) (GSC loc. O-104254) – conodonts
N.B. This sample is from a bed within a 1.8 m unit of carbonate; the original sample number is in reference to the sample levels of the *P. etheridgei* (= Upper *P. tentaculatus*) Zone of Lenz and Pedder (1972, p. 26)
PR77-381.2 m (1250 ft.) – *D. decoratus* Zone
PR77-396.5 m (1300 ft.) – *G. teretiusculus* Zone
PR77-408.4 m (1340 ft.) (GSC loc. O-104255) – conodonts

PR77-410.2 m (1345 ft.) – *N. gracilis* Zone
PR77-452.6 m (1485 ft.) – *P. pacificus* Zone
PR77-452.6 m (1485 ft.)* (GSC loc. O-104256) – conodonts
PR77-453.6 m (1488 ft.) – *P. pacificus* Zone
PR77-454.2 m (1490 ft.) – *P. pacificus* Zone
PR77-454.5 m (1491 ft.) – *P. acuminatus* Zone
PR77-456.9 m (1499 ft.) – *P. acuminatus* Zone
PR77-457.8 m (1502 ft.) – *A. atavus* Zone?
PR77-459 m (1506 ft.) – *A. atavus* Zone
PR77-459.6 m (1508 ft.) – *A. atavus* Zone
PR77-460.6 m (1511 ft.) – *L. acinaces* Zone
PR77-463 m (1519 ft.) – *L. acinaces* Zone
PR77-469.4 m (1540 ft.) – *C. gregarius* Zone
PR77-472.7 m (1551 ft.) – *C. gregarius* Zone
PR77-475.5 m (1560 ft.) – *C. gregarius* or *M. triangulatus* zones
PR77-482.5 m (1583 ft.) – *M. triangulatus* Zone
PR77-487.4 m (1599 ft.) – *M. triangulatus* Zone
PR77-489.2 m (1605 ft.) – *M. triangulatus* or *D. magnus*? zones
PR77-490.7 m (1610 ft.) – *M. argenteus* Zone
PR77-495.9 m (1627 ft.) – *M. convolutus* Zone
PR77-508.4 m (1668 ft.) – *M. convolutus* Zone
PR77-509 m (1670 ft.) (GSC loc. O-104257) – barren of conodonts
PR77-513.6 m (1685 ft.) – *M. sedgwicki* Zone
PR77-515.1 m (1690 ft.) – *M. sedgwicki* Zone
PR77-516.3 m (1694 ft.) – *M. turriculatus* Zone
UPR79-516.6 m (1695 ft.)** (GSC loc. O-105095) – conodonts
PR77-544.1 m (1785 ft.) (GSC loc. O-104258) – barren of conodonts
PR77-559.3 m (1835 ft.) – *M. turriculatus* Zone
PR77-570.9 m (1873 ft.) – *M. spiralis* Zone
PR77-629.4 m (2065 ft.) – *M. spiralis* Zone
PR77-630.9 m (2070 ft.) – *M. spiralis* or *C. sakmaricus–C. laqueus* zones
PR77-635.5 m (2085 ft.) – *C. sakmaricus–C. laqueus* Zone
PR77-642.5 m (2108 ft.) – *C. sakmaricus–C. laqueus* Zone

Plates 1 to 3

PLATE 1

All are lateral views and from GSC loc. O-104271, except where noted.

Figure 1. "*Cordylodus*" *horridus* Barnes and Poplawski.
Cordylodontiform element, GSC 99602, x40, hypotype.

Figure 2. *Spinodus spinatus* (Hadding).
Cordylodontiform (*a*-1) element, GSC 99603, x20, hypotype.

Figures 3, 4, 8, 9, 12, 19. *Diaphorodus*? sp. A.
3, 4. Cordylodontiform element, outer, inner views, figured specimen GSC 99604, x70, x80.
8, 9. Cordylodontiform element, outer, inner views, figured specimen GSC 99605, x70, x65.
12,19. Oistodontiform elements, ?inner, inner views, figured specimens GSC 99606, x80, GSC 99607, x70.

Figure 5. *Prioniodus* (*Oepikodus*)? sp. A.
Gothodontiform (*a*) element, outer view, figured specimen GSC 99608, x55.

Figures 6, 7. *Walliserodus ethingtoni* (Fåhræus).
Symmetrical (*c*) element, hypotype GSC 99609, x55, x50.

Figures 10, 11, 14, 15. *Eoplacognathus*? sp. A.
Platform (*g*?) elements, upper views, figured specimens GSC 99610, x25, GSC 99611, x40, GSC 99612, x45, GSC 99613, x50.

Figures 13, 20, 22, 25-28. *Periodon aculeatus* Hadding.
13. a element, GSC 99614, x30.
20. b (cladognathiform) element, GSC 99615, x45.
22, 25-28. *e* (falodontiform) elements, hypotypes GSC 99616, x70, GSC 99617 (specimen lost), GSC 99618, x45, GSC 99619, x60, GSC 99620,Specimens in figures 22, 26-28 are from GSC loc. O-104293, and in figure 25 from GSC loc. O-104254.

Figure 16. *Coelocerodontus*? sp. A.
Trigoniform (*s*?) element, posterior view, figured specimen GSC 99621, x35, GSC loc. O-104293.

Figures 17, 21. *Plectodina*? sp. A.
17. e or *f* (cyrtoniodontiform or prioniodiniform) element, inner view, figured specimen GSC 99622, x45, GSC loc. O-104293.
21. g (ozarkodiniform) element, figured specimen GSC 99623, x85, GSC loc. O-104293.

Figure 18. *Polonodus tablepointensis* Stouge?
Platform fragment, upper view, figured specimen GSC 99624, x40.

Figure 23. *Dapsilodus*? sp. C.
Acodontiform (*a*) element, figured specimen GSC 99625, x45.

Figure 24. *Phragmodus* sp. A.
Oistodontiform (*e*) element, figured specimen GSC 99626, x50, GSC loc. O-104293.

PLATE 1

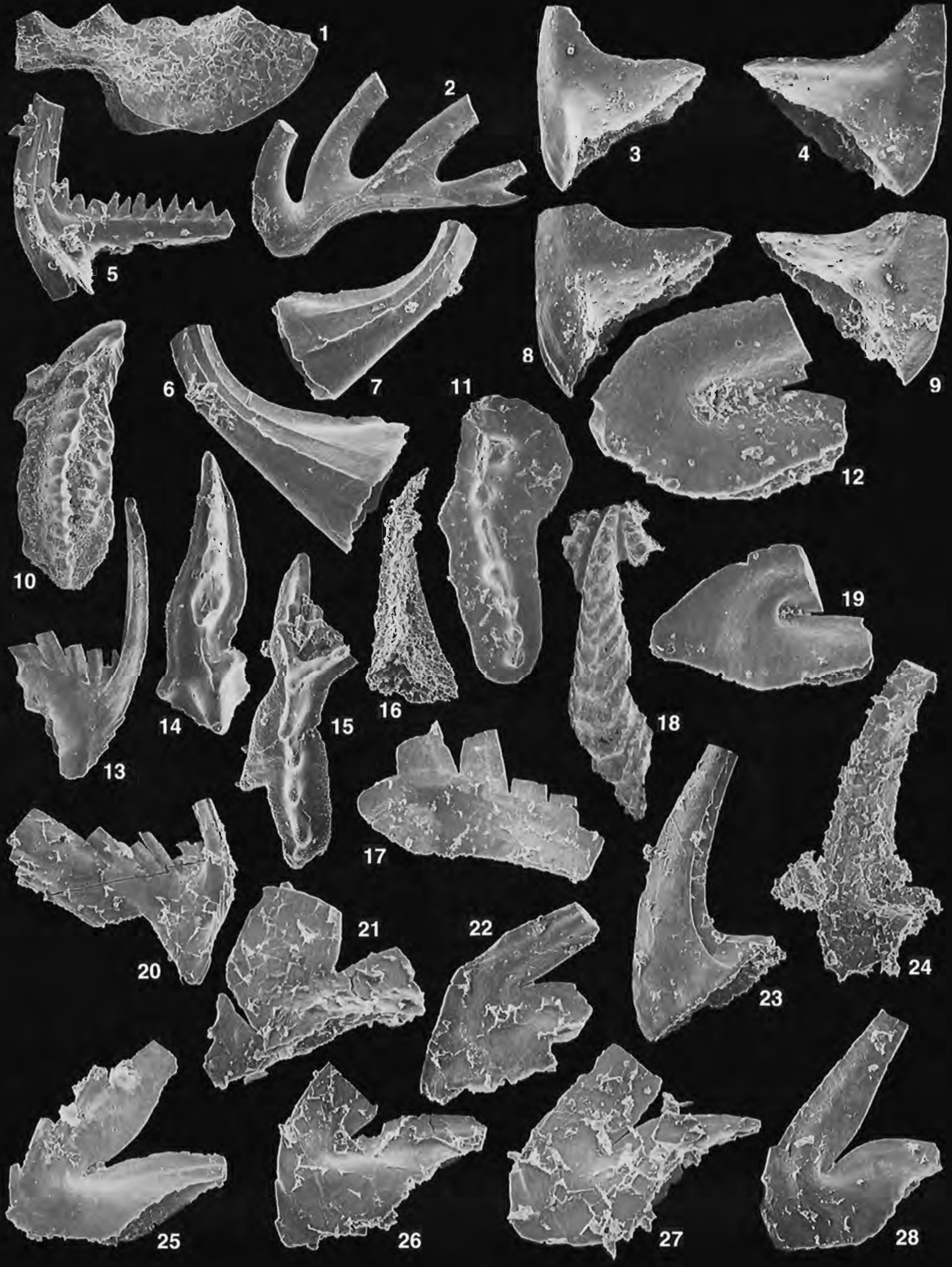


PLATE 2

All specimens are from GSC loc. O-104254, except where noted.

Figures 1-3, 5, 8, 10, 13, 19. *Pygodus* sp. cf. *P. serra* (Hadding).
Platform (*g*) elements, upper views, figured specimens GSC 99627, x30, GSC 99628, x50, GSC 99629, x35, GSC 99630, x35, GSC 99631, x30, GSC 99632, x35, GSC 999633, x30, GSC 99634, x35.

Figures 4, 6, 7, 9, 11, 12, 14-18, 20-23, 28-30. *Pygodus serra* (Hadding).
4, 6, 12. *g* elements, upper view, hypotype GSC 99635, x40, lower view, hypotype GSC 99636, x30, upper view, hypotype GSC 99637, x25.
7, 9, 11. *f* elements, outer view, hypotype GSC 99638, x30, inner view, hypotype GSC 99639, x25, outer view, hypotype GSC 99640, x25.
14, 15, 18, 29. *b* elements, lateral views, hypotypes GSC 99641 (specimen lost), GSC 99642, x35, postero-upper view, GSC 99643 (specimen lost), posterior view, GSC 99644 (specimen lost).
16, 28. *c* elements, posterior views, hypotypes GSC 99645, x35, GSC 99646, x30.
17, 21, 22. *d* elements, lateral views, hypotypes GSC 99647, GSC 99648, GSC 99649, x35.
20, 30. *c* elements, lateral views, hypotypes GSC 99650, x35, GSC 99651, x40.
23\. *a* element, lateral view, hypotype GSC 99652 (specimen lost).

Figures 24-27, 31, 34, 35. *Periodon aculeatus* Hadding.
24, 35. *e* (falodontiform) elements, lateral views, hypotypes GSC 99653, x25, GSC 99654, x20.
25\. *c* (hibbardelliform) element, lateral view, hypotype GSC 99655, x25.
26, 31. *b* (cladognathiform) elements, lateral views, hypotypes GSC 99656, x20, GSC 99657, x30.
27\. *f* (tortiliform) element, lateral view, hypotype GSC 99658, x25.
34\. *a* (cordylodontiform) element, outer view, hypotype GSC 99659, x25.

Figures 32, 33, 37. *Panderodus* sp. cf. *P. feulneri* (Glenister).
32\. *e* element, lateral view, figured specimen GSC 99660, x35.
33, 37. *a/b* elements; outer view, figured specimen GSC 99661, x25, inner view, figured specimen GSC 99662, x30.

Figure 36. *Strachanognathus parvus* Rhodes.
Cordylodontiform element, lateral view, hypotype GSC 99663, x25.

Figures 38, 40-42. *Panderodus* sp. cf. *P. gracilis* (Branson and Mehl).
38, 41, 42. *a/b* elements, outer view, figured specimen GSC 99664, inner views, figured specimens GSC 99665, GSC 99666, x35.
40\. *e* element, lateral view, figured specimen GSC 99667, x35.

Figure 39. Indeterminate oistodontiform element.
Lateral view, figured specimen GSC 99668, x70.

Figure 43. *Panderodus*? sp. cf. *P.*? *gibber* Nowlan and Barnes.
Inner view, *a/b* element, figured specimen GSC 99669, x65.

PLATE 2

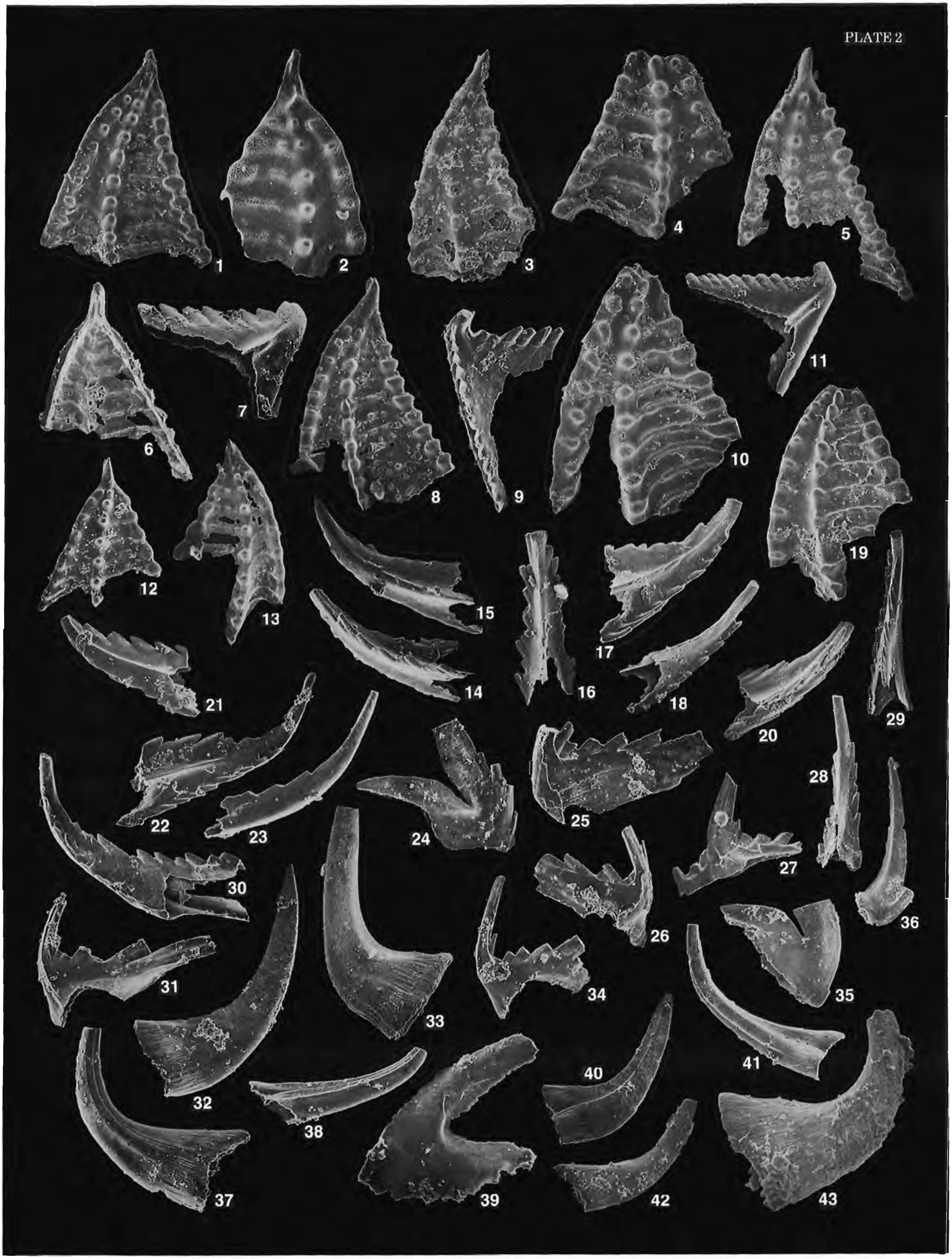

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43

PLATE 3

All specimens are from GSC loc. O-104254, except where noted.

Figures 1, 2, 5, 6. *Dapsilodus*? sp. C.
1. *b* (distacodontiform) element, inner view, figured specimen GSC 99670, x60.
2. Acostate *a*? element, lateral view, figured specimen GSC 99671, x55.
5. Short-based *b* element, lateral view, figured specimen GSC 99672, x60.
6. Long-based *b* element, lateral view, figured specimen GSC 99673, x60.

Figures 3, 4, 8, 9, 13, 14, 19-31. *Ansella nevadensis* (Ethington and Schumacher).
3, 4, 23, 24. *b* elements, outer, inner views, hypotype GSC 99674, x40, x35, outer, inner views, hypotype GSC 99675, x40.
8, 9, 31. *a* element, outer, inner, outer views, hypotype GSC 99676, x80, x70, x450.
13, 14, 19, 20. *f*-1 elements, outer, inner views, hypotype GSC 99677, x40, outer, inner views, hypotype GSC 99678, x40, x35.
21, 22. *f*-2 element, inner, outer views, hypotype GSC 99679, x40, x45.
25, 27. *e* elements, hypotypes GSC 99680, x40, GSC 99681, x60.
26, 28-30. *c* elements, posterior, lateral views, hypotype GSC 99682, x40, x35, posterior, lateral views, hypotype GSC 99683, x50, x45.

Figure 7. *Drepanoistodus* sp. cf. *D. venustus* (Stauffer) *sensu* Löfgren.
Oistodontiform (*r*) element, lateral view, figured specimen GSC 99684 (specimen lost) GSC loc. O-104293.

Figures 10-12, 15-18. *Drepanoistodus* sp. cf. *D. basiovalis* (Sergeeva).
10, 15-18. *q* (drepanodontiform) elements, lateral views, figured specimens GSC 99685, x35, GSC 99686, x35, GSC 99687, x20, GSC 99688 x40, GSC 99689, x20.
11, 12. *r* (oistodontiform) element, inner, outer views, figured specimen GSC 99690, x75, x80.

Figures 32-37. *Scalpellodus*? *viruensis* Löfgren.
32, 33, 36, 37. Scandodontiform elements, inner, outer views, hypotype GSC 99691, x40, inner, outer views, hypotype GSC 99692, x50, x40.
34, 35. Drepanodontiform element, outer, inner views, hypotype GSC 99693, x40, x35.

PLATE 3


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37

Taxonomy and biostratigraphy of Llandovery (Silurian) conodonts in the Canadian Cordillera, northern Yukon Territory

Alexander D. McCracken[1]

McCracken, A.D., 1991: Taxonomy and biostratigraphy of Llandovery (Silurian) conodonts in the Canadian Cordillera, northern Yukon Territory. In Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417, p. 65-95.

Abstract

The lack of key taxa for lower to mid-Llandovery conodont zones necessitates establishing new conodont biozones for northern Yukon Territory's fine grained clastic Road River Group. These zones are the Dapsilodus obliquicostatus, Aspelundia petila *and* A. fluegeli *zones. All are defined on the first occurrence of the nominate species. The base of the* Dapsilodus obliquicostatus *Zone could correspond to strata as low as the* O.? nathani *Zone on the basis of data from elsewhere. The* Aspelundia petila *and* A. fluegeli *zones in outer shelf and basinal environments probably correspond to the lower and upper parts of the* D. kentuckyensis *Zone, respectively.*

The Aspelundia-Dapsilodus *fauna of northern Yukon inhabited an offshore environment. The abundance, wide distribution, and delicate nature of the elements suggests this fauna was pelagic.*

The major species of the Aspelundia-Dapsilodus *fauna are:* A. fluegeli *(Walliser),* A. petila *(Nicoll and Rexroad),* D. obliquicostatus *(Branson and Mehl), and* Walliserodus blackstonensis *n. sp.* Decoriconus fragilis *(Branson and Mehl),* W. curvatus *(Branson and Branson),* W. sancticlairi *Cooper, and* W.? *n. sp. B are some of the minor components of this relatively low diversity fauna. These species are given formal treatment under Systematic Paleontology.*

Résumé

Vu l'absence de taxons clés pour les zones à conodontes du Llandovérien inférieur et moyen, il est nécessaire d'établir de nouvelles biozones à conodontes pour le groupe clastique, à grain fin, de Road River, dans le nord du Yukon. Ces zones sont les suivantes : zone à Dapsilodus obliquicostatus, *zone à* Aspelundia petila *et zone à* A. fluegeli. *Elles sont toutes définies en fonction de l'apparition de leur espèce nominative. À en juger par des données provenant d'ailleurs, la base de la zone à* Dapsilodus obliquicostatus *pourrait correspondre à des strates qui sont aussi basses que la zone à* O.? nathani. *Les zones à* Aspelundia petila *et à* A. fluegeli *correspondent vraisemblablement aux parties supérieure et inférieure, respectivement, de la zone à* D. kentuckyensis, *dans des milieux de plate-forme externe et de bassin.*

Dans le nord du Yukon, la faune à Aspelundia–Dapsilodus *vivait vraisemblablement dans un milieu extracôtier. L'abondance de ses éléments, leur vaste répartition géographique et leur nature délicate portent à croire qu'il s'agissait d'une faune pélagique.*

La faune à Aspelundia–Dapsilodus, *dont la diversité est relativement faible, comprend les espèces majeures suivantes :* A. fluegeli *(Walliser),* A. petila *(Nicoll et Rexroad),* D. obliquicostatus *(Branson et Mehl) et* Walliserodus blackstonensis *n. sp.; elle comporte aussi d'autres espèces moins importantes, notamment* Decoriconus fragilis *(Branson et Mehl),* W. curvatus *(Branson et Branson),* W. sancticlairi *Cooper et* W.? *n. sp. B. Une description formelle de ces espèces est donnée dans la section sur la paléontologie systématique.*

---

[1] Geological Survey of Canada, 601 Booth St., Ottawa, Ontario K1A 0E8

INTRODUCTION

The Road River Formation comprises up to 3130 m of dark graptolitic shale, siltstone, carbonate, chert, and debris-flow deposits, which range in age from Late Cambrian to Early Devonian. Over 9400 conodonts were recovered from 67 samples collected during 1977-79 at five well exposed sections in Yukon Territory (Fig. 1); these samples range in age from Middle Ordovician [McCracken, 1991a (*this volume*)] to Late Ordovician (Lenz and McCracken, 1982; McCracken and Lenz, 1987; McCracken, 1987, 1989), and Early Silurian [(McCracken, 1991b (*this volume*)]. Of this total, over 8500 elements are Silurian in age. Conodonts from Llandovery strata at three of these five sections (Appendix; Tables 1-3) provide correlations with zones in the graptolite biostratigraphic scheme used in the northern Canadian Cordillera (Fig. 2).

The three sections (Figs. 3-5) are within the linear and relatively narrow Blackstone and Richardson basinal troughs, which are west and north-northwest trending, respectively. Strata of these troughs are laterally equivalent to carbonate rocks of the Mackenzie Platform (to the east), Ogilvie Arch (south) and Porcupine Platform (northwest), representing more shallow and nearshore subtidal environments. Graded, slumped and truncated units, pebble to boulder conglomerate, irregular bedding surfaces, and reworked conodont faunas attest to gravity flow from platform margins and the emplacement of debris flow deposits.

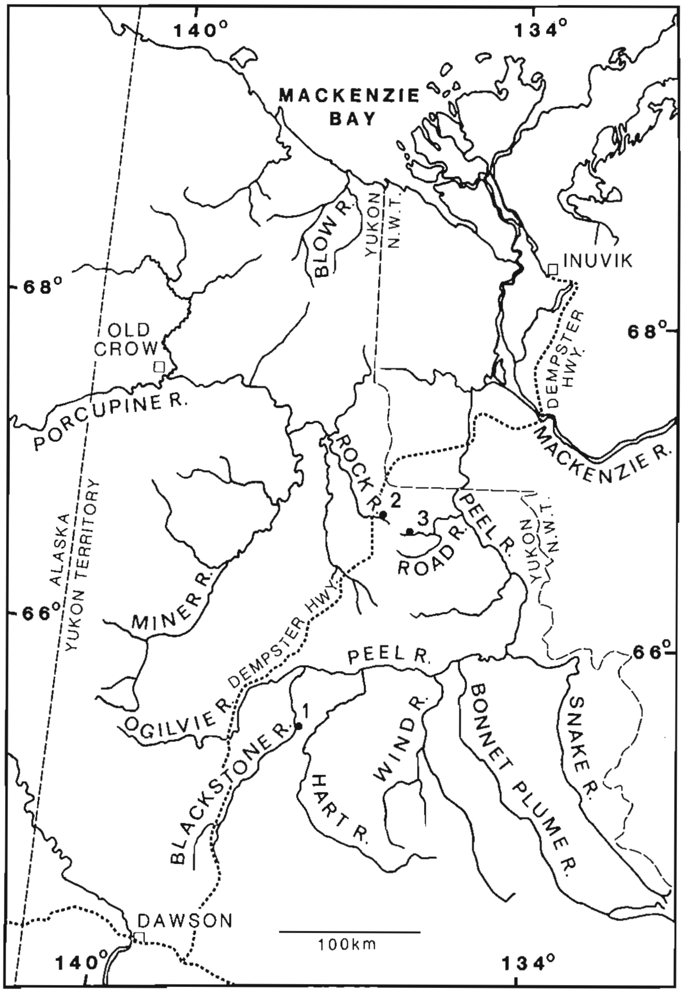


Figure 1. Location of sections: **1.** Blackstone River (65°26′N, 137°20′W); **2.** Rock River (66°48′N, 136°16′W); **3.** Tetlit Creek (66°44′N, 135°47′W).

BIOSTRATIGRAPHY

Data on lower to mid-Llandovery conodont biostratigraphic schemes for northwestern Canada are limited, particularly for strata below the *P. celloni* conodont Zone. This is true for both carbonate shelf and basin facies. For example, pre-*P. celloni* Zone conodonts from southwestern District of Mackenzie are assigned to the undifferentiated "*discreta/kentuckyensis/nathani* Zone" by Over and Chatterton (1987, p. 14). Below these beds is an interval of undiagnostic Silurian conodonts (Nowlan et al., 1988). Correlation of these strata with the graptolite biostratigraphic scheme at present is impossible. Although the graptolite scheme in the equivalent basin facies is well documented (e.g., Lenz and McCracken, 1989), the paucity of conodont-bearing beds confounds attempts to integrate the two biostratigraphic schemes. When found, lower Llandovery conodont faunas often cannot be correlated with the standard zonal scheme based on carbonate shelf faunas; they lack the key species because of paleoecological factors. For this same reason, Armstrong (1990, p. 29, 30) was forced to establish new pre-*P. celloni* Zone biostratigraphic units for the outer shelf and slope facies in North Greenland. Two of his zones will be useful in correlation of the basin facies of northwestern Canada. A third lower Llandovery zone based on a coniform species is proposed below.

SYSTEM	SERIES	N. CORDILLERA GRAPTOLITE ZONES	N. CORDILLERA CONODONT ZONES		STANDARD CONODONT ZONES
SILURIAN	Llandovery	*C. sakmaricus-C. laqueus*	*P. amorphognathoides*		*P. amorphognathoides*
		M. spiralis	*P. celloni*		*P. celloni*
		M. turriculatus			
		M. sedgwicki	*A. fluegeli*	?	*D. staurognathoides*
		M. convolutus			
		M. argenteus			
		?D. magnus	*?A. petila*	*?D. kentuckyensis*	*D. kentuckyensis*
		M. triangularis			
		C. gregarius			
		L. acinaces			
		A. atavus	*?D. obliquicostatus*		
		P. acuminatus		?	*O.? nathani*

Figure 2. Llandovery conodont and graptolite succession, northern Yukon Territory.

Dapsilodus obliquicostatus conodont Zone

The *Dapsilodus obliquicostatus* conodont Zone is a first appearance biozone (Hedberg, 1976) and thus is based on the earliest occurrence of the species. In the three northern Yukon sections where the species occurs, its lowest occurrence is at the 245 m level (GSC loc. O-104279) of the Rock River section within the *C. gregarius* graptolite Zone. This thin carbonate bed represents a debris-flow deposit and contains reworked Ashgill conodonts as well as a few lower Llandovery representatives [this mixed fauna is more fully described in McCracken, 1991b (*this volume*)]. Two metres above this bed, and still within the same graptolite zone is another carbonate bed (GSC loc. O-104280) with only a few elements of *D. obliquicostatus* (Branson and Mehl) and *Walliserodus curvatus* (Branson and Branson). These two species also occur higher at 250 m (GSC loc. O-104281) with *Dapsilodus* sp. B and *Decoriconus fragilis* (Branson and Mehl). There is no evidence (either lithic, or from mixed faunas) for debris flow in these latter two beds.

The oldest occurrence of *Dapsilodus obliquicostatus* is probably much lower than the *C. gregarius* Zone on the basis of the occurrence of *D. obliquicostatus* in the Canadian Arctic Archipelago (*D. kentuckyensis* or *O.*? *nathani* conodont zones; unpublished data).

The highest occurrences of *D. obliquicostatus* in the northern Yukon sections are at the 212 m and 230 m (GSC loc. O-104297, O-104300, respectively) levels in the Tetlit Creek section. The lower of these two levels probably represents the *P. amorphognathoides* conodont Zone (although the nominate species is not present) and occurs with *Carniodus carnulus* Walliser and *Pterospathodus procerus* (Walliser) (*sensu* Männik and Aldridge, 1989). This bed is 1 m below graptolites of the uppermost Llandovery *C. sakmaricus*—*C. laqueus* graptolite Zone. At the higher Tetlit Creek bed, *D. obliquicostatus* is found with *Kockelella ranuliformis*

Table 1. Silurian conodont species abundance from graptolitic strata of the Road River Group, Blackstone River, northern Yukon

SECTION		BLACKSTONE RIVER	
GRAPTOLITE ZONE		*turriculatus*	
SPECIES / SAMPLE		O-104269 90.2m	O-104270 98.5m
Aspelundia spp.	1,185	986	199
Astropentagnathus araneum	64	0	64
Astropentagnathus irregularis	137	0	137
Astropentagnathus indet. el.	11	0	11
Aulacognathus bullatus	2	0	2
Aulacognathus nelsoni	1	0	1
Dapsilodus obliquicostatus	688	684	4
Decoriconus fragilis	4	4	0
Distomodus kentuckyensis?	24	0	24
D. sp. cf. *D. kentuckyensis*	22	9	13
Oulodus n. sp. A	5	0	5
Oulodus? n. sp. B	12	0	12
Ozarkodina sp. aff.			
O. polinclinata	12	5	7
Ozarkodina sp. B	6	4	2
Panderodus spp.	218	90	128
Pterospathodus celloni			
celloniform element	74	0	74
angulatiform, pennatiform el.	41	0	41
Pterospathodus retroramus	44	0	44
Pterospathodus? indet. el.	20	0	20
Walliserodus blackstonensis	1,583	1,583	0
Walliserodus curvatus	47	32	15
Walliserodus sancticlairi	56	56	0
Walliserodus? n. sp. B	8	8	0
Walliserodus spp.	1,021	1,021	0
N. Gen. B n. sp. A	74	0	74
TOTAL	4,110	3,496	614

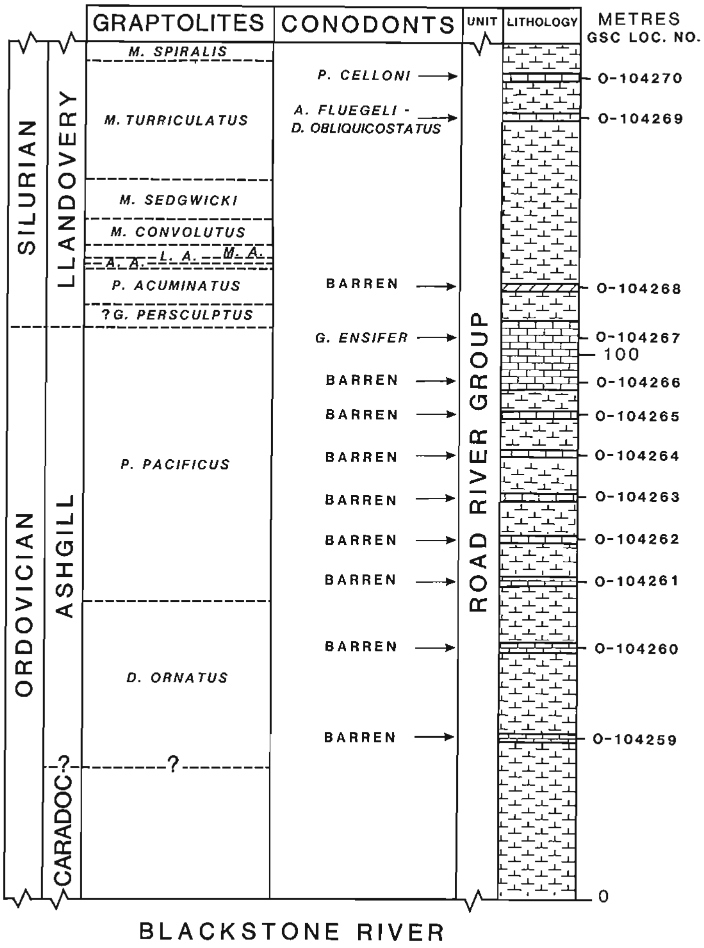


Figure 3. Graptolite–conodont succession at Blackstone River (section 1). Lithological symbols represent calcareous shale and limestone. Abbreviated graptolite zones are: *A. atavus (A.A.)*, *L. acinaces (L.A.)*, *M. argenteus (M.A.)*. Stratigraphic measurements are from base of sections in Figures 3-5. Figure modified from Goodfellow et al. (1991).

Table 2. Silurian conodont species abundance from graptolitic strata of the Road River Group, Rock River, northern Yukon

SECTION		ROCK RIVER										
GRAPTOLITE ZONE		*gregarius*			*gregarius-turriculatus*		*turriculatus*		*spiralis*		Unknown	
SPECIES / SAMPLE		O-104279 245m	O-104280 247m	O-104281 250m	O-104282 275m	O-104283 281m	O-104284 285m	O-104285 308m	O-104286 316m	O-104287 2/14m	O-104288 2/15m	O-104289 2/86m
Aspelundia spp.	47	0	0	0	4	23	20	0	0	0	0	0
Astropentagnathus araneum	1	0	0	0	0	0	1	0	0	0	0	0
Astropentagnathus irregularis	51	0	0	0	0	0	48	0	3	0	0	0
Aulacognathus bullatus	11	0	0	0	0	0	11	0	0	0	0	0
Dapsilodus obliquicostatus	77	4	5	13	1	54	0	0	0	0	0	0
Dapsilodus? sp. B	51	0	0	2	0	0	49	0	0	0	0	0
Decoriconus fragilis	2	0	0	2	0	0	0	0	0	0	0	0
D. sp. cf. *D. kentuckyensis*	17	0	0	0	0	0	16	0	1	0	0	0
Distomodus staurognathoides	24	0	0	0	0	0	9	0	15	0	0	0
Distomodus spp.	3	0	0	0	0	2	0	0	0	0	1	0
Icriodella sp. A	3	3	0	0	0	0	0	0	0	0	0	0
Oulodus n. sp. A	7	0	0	0	0	0	7	0	0	0	0	0
Oulodus? n. sp. B	1	0	0	0	0	0	1	0	0	0	0	0
Ozarkodina excavata n. ssp. A	65	0	0	0	0	0	3	0	0	0	0	62
Ozarkodina manitoulinensis	3	3	0	0	0	0	0	0	0	0	0	0
Ozarkodina sp.	2	0	0	0	0	0	0	0	2	0	0	0
Panderodus unicostatus	42	0	0	0	0	20	0	0	0	0	4	18
Panderodus sp.	2	0	0	0	0	0	0	2	0	0	0	0
Panderodus spp.	78	0	0	0	0	0	44	0	34	0	0	0
Pseudooneotodus bicornis	2	0	0	0	0	0	0	0	0	0	2	0
Pterospathodus celloni												
celloniform element	7	0	0	0	0	0	7	0	0	0	0	0
angulatiform, pennatiform el.	5	0	0	0	0	0	5	0	0	0	0	0
Pterospathodus procerus	8	0	0	0	0	0	0	0	8	0	0	0
Pterospathodus retroramus	11	0	0	0	0	0	11	0	0	0	0	0
Walliserodus blackstonensis	7	0	0	0	0	5	2	0	0	0	0	0
Walliserodus curvatus	7	1	1	1	0	4	0	0	0	0	0	0
Walliserodus sancticlairi	7	0	0	0	0	7	0	0	0	0	0	0
Walliserodus spp.	2	0	0	0	2	0	0	0	0	0	0	0
N. Gen. B n. sp. A	8	0	0	0	0	0	8	0	0	0	0	0
Indeterminate elements	5	0	0	3	0	0	1	0	0	1	0	0
TOTAL	508	11	6	21	3	92	222	2	63	1	7	80

Table 3. Silurian conodont species abundance from graptoliti strata of the Road River Group, Tetlit Creek, northern Yukon

SECTION		TETLIT CREEK											
GRAPTOLITE ZONE		*turriculatus*	*spiralis*	*spiralis-sakmaricus-laqueus*		*sakmaricus-laqueus*		*sakmaricus-laqueus-*?Wenlock	?Wenlock-*lundgreni*			*lundgreni-*?*nilssoni*	
SPECIES / SAMPLE		O-104294	O-104295	O-104296	O-104297	O-104298	O-104299	O-104300	O-104301	O-104302	O-104303	O-104304	O-104305
		144m	192m	200m	212m	218m	222m	230m	236m	270m	281m	286m	319m
Aspelundia spp.	53	15	2	21	9	6	0	0	0	0	0	0	0
Astropentagnathus irregularis	1	0	1	0	0	0	0	0	0	0	0	0	0
Apsidognathus tuberculatus	14	0	9	4	0	1	0	0	0	0	0	0	0
Aulacognathus bullatus	2	2	0	0	0	0	0	0	0	0	0	0	0
Belodella silurica	3	0	0	0	3	0	0	0	0	0	0	0	0
Carniodus carnulus	175	0	7	36	128	2	2	0	0	0	0	0	0
Dapsilodus obliquicostatus	122	2	0	0	7	0	0	24	0	0	0	89	0
Dapsilodus spp.	4	0	0	1	0	0	0	0	3	0	0	0	0
Distomodus kentuckyensis?	6	6	0	0	0	0	0	0	0	0	0	0	0
D. sp. cf. *D. kentuckyensis*	3	1	1	1	0	0	0	0	0	0	0	0	0
Distomodus staurognathoides	6	0	0	0	0	6	0	0	0	0	0	0	0
Distomodus spp.	7	0	6	0	1	0	0	0	0	0	0	0	0
Kockelella ranuliformis	11	0	0	0	0	0	0	11	0	0	0	0	0
Kockelella walliseri?	11	0	0	0	0	0	0	11	0	0	0	0	0
Kockelella spp.	9	0	0	0	0	0	0	0	0	0	0	5	4
Oulodus n. sp. A	220	0	0	192	25	3	0	0	0	0	0	0	0
Oulodus spp.	7	0	0	0	0	0	2	0	1	3	1	0	0
Ozarkodina excavata n. ssp. A	221	0	0	0	0	0	0	46	0	0	2	139	34
Ozarkodina sp. C	90	0	0	33	45	3	3	6	0	0	0	0	0
Ozarkodina sp.	3	1	2	0	0	0	0	0	0	0	0	0	0
Ozarkodina spp.	12	0	0	0	0	0	0	2	3	0	0	0	7
Panderodus recurvatus	7	0	0	0	0	7	0	0	0	0	0	0	0
Panderodus unicostatus	377	0	0	0	0	8	31	146	0	0	0	160	32
Panderodus sp.	8	3	0	0	0	0	0	0	2	3	0	0	0
Panderodus spp.	521	0	12	400	109	0	0	0	0	0	0	0	0
Pseudooneotodus bicornis	7	0	0	0	0	0	0	7	0	0	0	0	0
Pseudooneotodus tricornis	1	0	0	0	0	0	0	1	0	0	0	0	0
Pterospathodus procerus	216	0	16	46	128	18	5	3	0	0	0	0	0
Pterospathodus? indet. el.	76	0	0	17	58	1	0	0	0	0	0	0	0
Walliserodus blackstonensis	2	0	2	0	0	0	0	0	0	0	0	0	0
Walliserodus curvatus	9	8	0	0	0	0	1	0	0	0	0	0	0
Walliserodus sancticlairi	89	0	1	25	62	1	0	0	0	0	0	0	0
Walliserodus? n. sp. B	2	0	0	0	2	0	0	0	0	0	0	0	0
Indeterminate elements	16	0	0	12	0	3	0	1	0	0	0	0	0
TOTAL	2,258	23	57	767	568	53	44	258	9	6	3	393	77

(Walliser), *K. walliseri* (Helfrich)? and *P. procerus*. This fauna is possibly exotic; ranges of *K. walliseri* and *P. procerus* are not known to overlap elsewhere. This fauna is 2 m above graptolites of the *C. sakmaricus*—*C. laqueus* Zone and the same distance below an indeterminate Wenlock graptolite fauna.

Aspelundia *conodont zones*

Armstrong's (1990) *Aspelundia* conodont biozones from North Greenland are used herein; the only modification being the change in name of the earlier *A. expansa* Zone to the *A. petila* Zone because the former species name is a junior subjective synonym (see Systematic Paleontology).

The limited number of collections in northern Yukon make it impossible to precisely date the first occurrence of either species. However, some graptolite data are available to give an approximate correlation of the *A. fluegeli* conodont Zone.

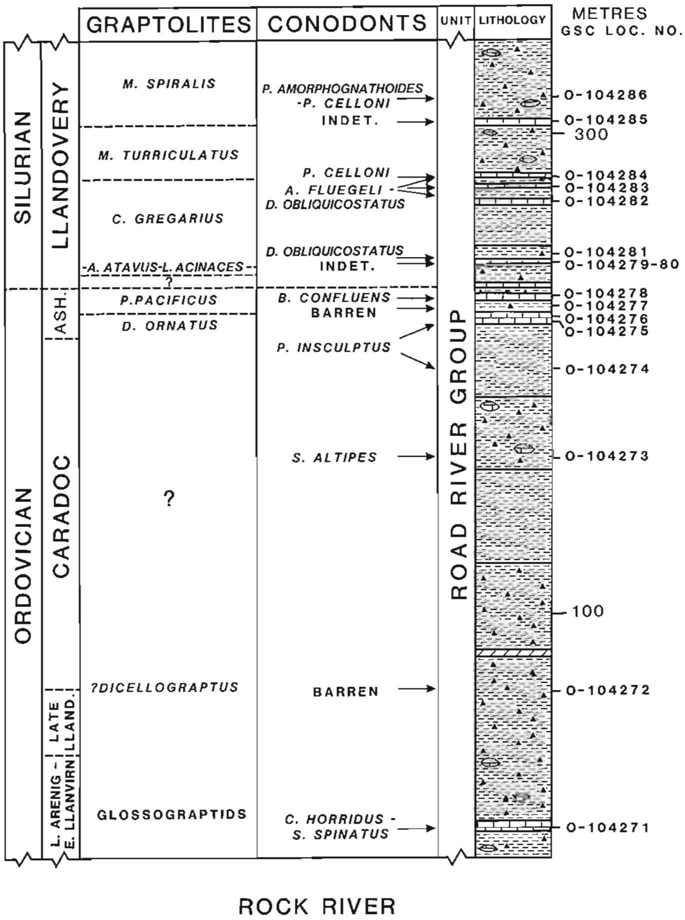


Figure 4. Graptolite–conodont succession at Rock River (section 2). Lithological symbols represent chert and shale interbeds, with rare limestone lenses, limestone, dolostone, and shale. Stratigraphic measurements are from base of sections in Figures 4-6. Figure modified from Goodfellow et al. (1991).

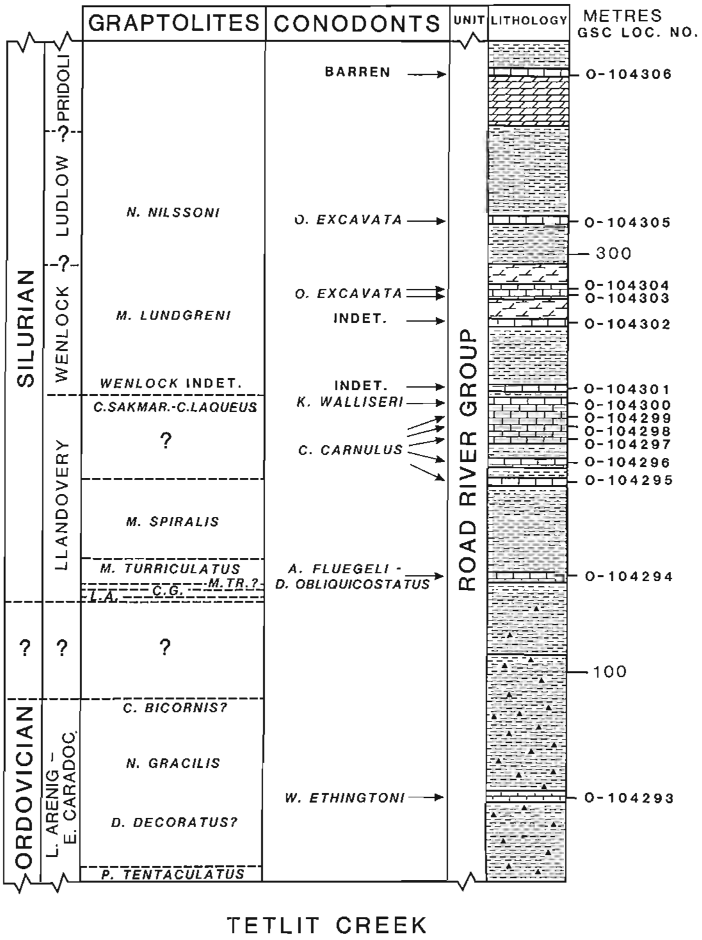


Figure 5. Graptolite–conodont succession at Tetlit Creek (section 3). Lithological symbols represent chert and shale interbeds, limestone, shale and chert interbeds, shale, dolomitic shale, and dolostone. Abbreviated graptolite zones are: *L. acinaces (L.A.), C. gregarius (C.G.), M. triangularis? (M.TR.?), C. sakmaricus (C. SAKMAR.)*. Figure modified from Goodfellow et al. (1991).

Aspelundia petila *conodont Zone*

The *Aspelundia petila* conodont Zone is a first appearance biozone equivalent to Armstrong's (1990) *A. expansa* conodont Zone. This zone is not yet recognized in northern Yukon because the only occurrences of the nominate species are in samples containing *A. fluegeli* (Walliser), the index species to the *A. fluegeli* Zone.

Aspelundia petila (Nicoll and Rexroad) has an earlier first occurrence than *A. fluegeli*. The lower limit of *A. petila* in outer shelf to basin environments is probably within the lower *D. kentuckyensis* Zone, the upper limit is in the *P. amorphognathoides* Zone (see Occurrences under Systematic Paleontology).

Aspelundia fluegeli *conodont Zone*

The *Aspelundia fluegeli* conodont Zone is a first appearance biozone. *Aspeludia fluegeli* in shelf environments ranges from at least the *P. celloni* Zone to the *P. amorphognathoides* Zone; in offshelf environments the first appearance is probably in mid- to upper *D. kentuckyensis* Zone (see Occurrences under Systematic Paleontology).

Other species in the fauna from the *A. fluegeli* Zone at the Blackstone River section include *Aspelundia petila*, *D. obliquicostatus*, *Decoriconus fragilis*, *Distomodus* sp. cf. *D. kentuckyensis* Branson and Branson *sensu* Cooper (1975), *Panderodus* spp., *Ozarkodina* sp. aff. *O. polinclinata* (Nicoll and Rexroad) *sensu* Cooper (1975), *O.* sp. B, *Walliserodus blackstonensis* n. sp. (herein), *W. curvatus*, *W. sancticlairi* Cooper, and *W.*? n. sp. B.

In terms of the standard conodont biostratigraphic scheme, the base of the *D. obliquicostatus* Zone is probably within the *O.*? *nathani* Zone, the bases of the *A. petila* and *A. fluegeli* zones in outer shelf and basinal environments are probably within the lower and upper parts of the *D. kentuckyensis* Zone, respectively. The tops of all three zones are defined by the base of the succeeding zones.

LLANDOVERY CONODONT PALEOECOLOGY

Work of Aldridge and Mabillard (1981) has shown the preference of the Silurian *Panderodus unicostatus* (Branson and Mehl) for shallow shelf environments. Their study across the Welsh Borderland shelf–basin transition showed a definite decrease in abundance of the species toward the basin edge. Other studies confirm this preference (e.g., Uyeno and Barnes, 1983; Mabillard and Aldridge, 1983). In northwestern Canada, Silurian carbonate and fine grained clastic facies show the same relationship—*Panderodus* represents 25 per cent of the total in the Silurian part of the Selwyn Basin carbonate shelf margin sections studied by Nowlan et al. (1988) but 16 per cent in northern Yukon basinal facies (this study).

Other Silurian genera and species have been used previously in paleoecological studies, and some of these can be considered in the interpretation of northern Yukon faunas. The faunas of the *P. amorphognathoides* Zone in the Welsh Basin represent offshore environments and are characterized by *Carniodus*, *Decoriconus*, *Pterospathodus amorphognathoides* Walliser and *Panderodus* sp. cf. *P. recurvatus* (Rhodes) (Aldridge and Mabillard, 1981). The shelf-edge area contains peaks in abundance of *Dapsilodus obliquicostatus*. The faunas of the more nearshore environments in Wales include species of *Apsidognathus*, *Icriodella*?, *Kockelella*, *Ozarkodina*, *Oulodus*, and *P. unicostatus* (Mabillard and Aldridge, 1983).

Llandovery faunas from the intermediate to nearshore environment of Gaspésie, Quebec, are dominated by *Panderodus* but characterized by *Apsidognathus* and *Pterospathodus* [but not *P. celloni* (Walliser) or *P. amorphognathoides*], and *Ozarkodina*. The scarcity of *P. celloni* and *Carniodus carnulus* in eastern Canada is probably a result of conditions that were too shallow (Nowlan, 1983). Aldridge (1976) and Le Fèvre et al. (1976) also concluded that *P. celloni* is more common in strata of the more offshore environments.

The Llandovery shallow water, high energy or littoral environments are characterized by *Icriodella* (Aldridge, 1976; Nowlan, 1983) and *Distomodus* (Le Fèvre et al., 1976). *Icriodella* is very rare in Yukon shale facies, but species of *Distomodus* are more common; some elements were perhaps introduced through debris flows from nearby shelf areas.

Most of the Llandovery Jupiter Formation of Anticosti Island, Quebec strata was interpreted as representing a low energy, moderately deep, open marine carbonate shelf environment (Uyeno and Barnes, 1983). In these strata, *Aspelundia* is absent (it first occurs in highest beds of the *D. staurognathoides* conodont Zone on Anticosti Island, well above its suggested earliest occurrence elsewhere). Present are *Dapsilodus obliquicostatus* and *Panderodus unicostatus*, plus *Decoriconus fragilis*, *Distomodus staurognathoides* (Walliser), *Ozarkodina aldridgei* Uyeno and Barnes, *Panderodus recurvatus*, *Pseudooneotodus*, and *Walliserodus sancticlairi*. Uppermost beds of this formation represent a shallowing phase, and contain *A. petila* (*Oulodus*? *fluegeli* subsp. A Uyeno and Barnes, 1983), *Aulacognathus*, *Distomodus*, *Icriodella*, *Ozarkodina*, and *P. unicostatus*. *Dapsilodus obliquicostatus* is absent from these and higher Anticosti beds. In the succeeding Chicotte Formation, *A. petila* is more rare and occurs with *Apsidognathus*, *Astropentagnathus*, *Carniodus*, *Distomodus*, *Ozarkodina*, *Pterospathodus amorphognathoides*, *P. celloni*, *P. procerus*, and *W. sancticlairi*. Even in its most prolific level on Anticosti Island, *A. petila* comprises less than 3 per cent of the fauna (calculated from Uyeno and Barnes, 1983, Tables 3, 4).

One of the more common coniform conodonts in the basinal environments is *Dapsilodus obliquicostatus*. Barrick (1981) and Aldridge and Mabillard (1981) have suggested this species was an offshore or oceanic animal. Barrick drew an analogy of *D. obliquicostatus* to planktic foraminifers, that is, the species may have been of high productivity and favoured offshore or oceanic environments. In northern Yukon, this species, along with species of *Aspelundia* and *Walliserodus blackstonensis* n. sp., form a large part of what is herein called the *Aspelundia–Dapsilodus* fauna. At the Blackstone River section, this fauna has a relatively low diversity (12 species), and comprises about 60 per cent *Walliserodus* (mostly *W. blackstonensis*), 22 per cent *Aspelundia* (both species), and 15 per cent *Dapsilodus obliquicostatus* (cf. Table 1, GSC loc. O-104269). The dominance of this fauna by these species, and the minor presence of *Panderodus* (2%) and other *Walliserodus* species, certainly reflect environmental factors, albeit unknown.

Aspelundia represents almost the same proportion of the fauna in a higher sample (GSC loc. O-104270) in strata on Blackstone River. This more diverse *Astropentagnathus–Pterospathodus* fauna comprises six species of *Astropentagnathus* [24%; including a new species figured in McCracken, 1991b (*this volume*)] and *Pterospathodus* [21%; including a new species similar to *P. amorphognathoides*; figured in McCracken, 1991b (*this volume*)], two species of *Aspelundia* (23%), plus species of *Panderodus* (15%), *Distomodus* (4%), *Oulodus* (2%), *Walliserodus* (2%), *Ozarkodina* (1%), and *Dapsilodus* (<1%) (total of 17 species). Aldridge and Jeppsson (1984) suggested that *Dapsilodus obliquicostatus*, *Decoriconus fragilis* and *Aspelundia fluegeli* (their *Oulodus*? *fluegeli*) were pelagic and used their delicate conodont apparatuses to grasp small planktonic organisms. Like *Dapsilodus obliquicostatus*, *A. fluegeli*, *A. petila*, and *W. blackstonensis* may also have been of high productivity and favoured oceanic environments.

The *Aspelundia–Dapsilodus* fauna is a characteristic fauna of offshore environments. Armstrong (1990, p. 35) found similar faunas at Kap Schuchert in North Greenland. These are "prolific, low diversity conodont faunas containing *Aspelundia*, *Dapsilodus* and *Decoriconus* almost to the exclusion of other genera". The North Greenland and northern Yukon *Aspelundia–Dapsilodus* faunas differ in that *Decoriconus fragilis* is extremely rare in northern Yukon whereas *Walliserodus blackstonensis* n. sp. is extremely rare in North Greenland. Over and Chatterton (1987) reported similar faunas from the lowest member of the Whittaker Formation of southwestern District of Mackenzie. These beds were interpreted as slope/deep shelf carbonates and are laterally equivalent to the Road River Group. One of their (1987, p. 18) samples contained what was called a "dwarf fauna of *O.*? *fluegeli*". The term "dwarf fauna" may equally apply to the northern Yukon faunas. All elements of the fauna are small, thin walled and delicate. Over and Chatterton (*ibid.*) noted their dwarf fauna occurred in a bed devoid of a shelly component. Directly above this sample was a "normal *Oulodus* suite" as well as a shelly fauna. Over and Chatterton (1987) suggested this dwarf fauna was the result of less than favourable levels of environmental parameters such as nutrients, oxygen or salinity.

SYSTEMATIC PALEONTOLOGY

Conodont Colour Alteration Index (CAI) values (Epstein et al., 1977) are: Blackstone River (4), Rock River (4.5-5), Tetlit Creek (4.5). Element totals for species from these localities are given in Tables 1-3. The element nomenclature is from Barnes et al. (1979). All illustrated specimens are assigned Geological Survey of Canada (GSC) type numbers and are housed in the National Type Collection of Invertebrate and Plant Fossils at the Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8.

Genus *Aspelundia* Savage, 1985
emend. Armstrong, 1990

Type species. Aspelundia capensis Savage, 1985.

Remarks. Armstrong's (1990) emended diagnosis of *Aspelundia* was based on his large collections from North Greenland. His revised generic concept contained seven morphotypes. I recognize the same elements and hence the generic concept of Armstrong (1990) and this study is the same; we do differ though in the interpretation of some of the elements and their morphotypes. His Sc, M, Sd, Pb and Pa elements correspond herein to the *a*, *e*-1, *e*-3, *f* and *g* morphotypes. The Sb_1 and Sb_2 of Armstrong (1990) were not differentiated in this study—they are both called the *b* morphotype. Armstrong did not identify an element equivalent to the very rare *e*-2 element (it has a short denticulated anterior process).

Like Armstrong (1990), I distinguish two species from the Llandovery collections. There is a strong urge to either regard both forms as representing one species that has significant morphological variation, or as subspecies, but there does appear to be some differences in their ranges in addition to morphological differences.

As one of the first revisers of the multielement species herein called *Aspelundia fluegeli*, Klapper and Murphy (1975) chose the form species *Neoprioniodus planus* Walliser *s.f.* as the nominate species of "*N*". *planus*. Their synonymy of this species listed only *N. planus s.f.*, but their remarks clearly show the multielement species contains *e* and *f* elements. The *f* element "somewhat resembles one of the illustrated specimens of *Lonchodina fluegeli* Walliser (1964, pl. 32, fig. 24) (holotype of the form species) and is the same as that of Aldridge (1972, pl. 8, fig. 7). Other elements of the "*N*"; *planus* apparatus have not been identified" (Klapper and Murphy, 1975, p. 55). These workers listed only 37 elements of "*N*". *planus*, so it is not surprising they could not complete the apparatus.

Sweet and Schönlaub (1975) also used *Neoprioniodus planus s.f.* as the name-bearing type in their reconstruction of *Ozarkodina plana*, which was based on 146 elements from Austria. The *a*, *b*, *c*, *e* and *f* elements of their species are assignable to *Aspelundia* species of the Yukon study. Sweet and Schönlaub (1975) assigned their species to *Ozarkodina* because of a few associated spathognathodontiform (*g*) elements. They included an element like *Lonchodina fluegeli s.f.* in the apparatus of *Ozarkodina plana*, although this form species was not mentioned in their synonymy or text. Aldridge (1979) noted that the Sc and Pb (*a* and *g*) elements of Sweet and Schönlaub's species possibly belonged to *Ozarkodina excavata* (Branson and Mehl) or its ancestor (the *a* element is included in *A. fluegeli*).

Mirza (1976), in an unpublished thesis on conodonts from the Canadian Arctic Archipelago, reconstructed an incomplete apparatus of *Ozarkodina fluegeli* that also included *Neoprioniodus planus s.f.* Mirza based his interpretations on more than 500 elements, and placed these within an *Ozarkodina* apparatus that contained N elements and a five-part symmetry transition series (apparatus was reconstructed using the terminology of Klapper and Philip, 1971). The *f* and *g* elements were not identified but they are present in the elements of Mirza's symmetry series.

Aldridge (1979) assigned 62 elements from the upper Llandovery of Greenland to *Oulodus*? *fluegeli*. He (*ibid.*, p. 15) tentatively included "ligonodiniform" elements in the apparatus but noted that the discrete peg-like nature of the denticles of the ligonodiniform element did not compare closely to the denticulation of the other elements. I suggest that these elements are not part of this species.

Aldridge (1979) and Uyeno and Barnes (1983) tentatively assigned elements to *Oulodus*? *fluegeli* because the denticulation departed from the generic diagnosis of Sweet and Schönlaub (1975). The Yukon interpretations are based on the study of over 1500 elements. Although most of the specimens of *A. fluegeli* have closely spaced denticles, some do conform to the diagnosis of *Oulodus*, and in the other species, *A. petila*, the discrete denticulation is a diagnostic character. However, I have followed Armstrong's (1990) assessment of these forms and assign them to the emended *Aspelundia*.

As shown above, two trivial names, *planus* and *fluegeli*, have been used for the same apparatus. First revisers [Article 24(b) of the International Code of Zoological Nomenclature] Klapper and Murphy (1975) or Sweet and Schönlaub (1975) used *planus* as the species name and thus have precedence over subsequent authors who used the species name *fluegeli*. Armstrong noted that it is difficult to distinguish *Neoprioniodus planus s.f.* from the equivalent element of *Ozarkodina polinclinata sensu* Cooper (Bischoff, 1986, listed this element of *O. polinclinata* in his *Oulodus planus*). Because of the difficulties surrounding the *N. planus s.f.* element, I follow Armstrong's (1990) lead and regard it as a *nomen dubium*. Thus the species is herein called *A. fluegeli*. *Aspelundia planus borenoensis* (Bischoff, 1986) from the *P. amorphognathoides–P. latus* Assemblage Zone of Australia differs from both *A. fluegeli* and *A. petila* in having high processes and relatively more, and longer, denticles. This subspecies deserves species status (i.e., *A. borneoensis*), but it may be a junior subjective synonym of *A. capensis* Savage (which may include elements of *Pandorinellina plana sensu* Savage, 1985) from the *P. amorphognathoides* Zone of southwestern Alaska.

Aspelundia fluegeli (Walliser)

Plate 1, figures 5, 6, 10, 13, 14, 17, 19-24, 26, 27, 31, 32
Plate 2, figures 3, 4, 7, 8, 10, 11, 13-15, 17-25, 29, 32

Material. Hypotypes GSC 101005-101040.

a element

?*Hindeodella* sp. WALLISER, 1964, p. 36, Pl. 32, fig. 29.

?*Ligonodina variabilis* NICOLL and REXROAD, 1969, p. 39, Pl. 4, figs. 12-14 (*D. kentuckyensis–P. amorphognathoides* zones); Miller, 1978, Pl. 2, fig. 1 (only).

b element

Trichonodella asymmetrica Nicoll and Rexroad. MILLER, 1978, Pl. 2, fig. 9.

c element

Diadelognathus nicolli Aldridge. MILLER, 1978 (in part), Pl. 3, fig. 17 [only; fig. 16 is tentatively included under *A. petila* (Nicoll and Rexroad) below].

Hibbardella trichonodelloides (Walliser). ALDRIDGE, 1972, p. 182, Pl. 6, figs. 17, 18; MILLER, 1978, Pl. 3, figs. 12-14.

(?)*Roundya trichonodelloides* WALLISER, 1964, p. 72, Pl. 6, fig. 2, Pl. 31, figs. 22-25.

Trichonodella trichonodelloides (Walliser). LINK and DRUCE, 1972, p. 101, 102, Pl. 11, figs. 7-10, Textfig. 66.

?*Triconodella* cf. *trichonodelloides* Walliser. LEE, 1982, p. 107, Pl. 3, fig. 21.

e element

Neoprioniodus planus WALLISER, 1964, p. 51, Pl. 4, fig. 10, Pl. 6, fig. 3, Pl. 29, figs. 12, 13, 15; ?REXROAD, 1967, p. 39, Pl. 3, fig. 11; IGO and KOIKE, 1968, p. 12, Pl. 1, figs. 15, 18, Pl. 3, fig. 21; MILLER, 1978, Pl. 2, fig. 13.

cf. *Neoprioniodus multiformis* WALLISER, 1964, p. 50, 51, Pl. 8, fig. 10, Pl. 29, figs. 14, 16-25, Text-fig. 5a.

f element

Lonchodina fluegeli WALLISER, 1964, p. 44, Pl. 6, fig. 4, Pl. 32, figs. 22-24; ALDRIDGE, 1972, p. 190, 191, Pl. 8, fig. 6; ?MILLER, 1978, Pl. 3, fig. 22.

Plectospathodus sp. A IGO and KOIKE, 1968, p. 16, Pl. 1, figs. 13, 16, 19, 22.

g element

?*Lonchodina detorta* WALLISER, 1964, p. 43, 44, Pl. 9, fig. 20, Pl. 30, figs. 34-37.

Lonchodina detorta Walliser. ALDRIDGE, 1972, p. 190, Pl. 8, fig. 6.

Multielement

Aspelundia fluegeli (Walliser). ARMSTRONG, 1990, p. 53-55, Pl. 3, figs. 1-9, 11, 12 (includes synonymy; *A. fluegeli–P. amorphognathoides* zones).

"*Neoprioniodus*" *planus* Walliser. KLAPPER and MURPHY, 1975, p. 55, Pl. 10, figs. 23-25 (*P. celloni* Zone).

Oulodus fluegeli (Walliser). SAVAGE, 1985, p. 718, 719, Textfigs. 10A-S (*P. amorphognathoides–K. ranuliformis* zones).

Oulodus? *fluegeli* (Walliser). ALDRIDGE, 1979 (in part), p. 14, 15, Pl. 2, figs. 6-10 (*non* fig. 11, may be *a* element of unknown *Oulodus* species; *P. celloni* Zone); ALDRIDGE and MOHAMED, 1982, Pl. 2, figs. 26, 27; upper *P.* celloni–*P. amorphognathoides* zones); ALDRIDGE and JEPPSSON, 1984, Textfig. 3g-h; ORCHARD *in* NORFORD and ORCHARD, 1985, p. 11, Pl. 1, figs. 2, 9, 10, 12-14, 16-18, 20, 21 (?*D. kentuckyensis* or *P. celloni* zones); NAKREM 1986, Textfig. 7(b,e,h,i) (*P. celloni* Zone); OVER and CHATTERTON, 1987, p. 23, Pl. 1, figs. 30-38 (undifferentiated lower Llandovery *O.? nathani–I. discreta–D. kentuckyensis* to lower *P. amorphognathoides* zones).

Oulodus? cf. *O.? fluegeli* (Walliser). UYENO and BARNES, 1983 (in part), p. 19, Pl. 1, figs. 1-5 (*non* fig. 6, may be an element of *Ozarkodina* species).

Ozarkodina plana (Walliser). SWEET and SCHÖNLAUB, 1975 (in part), p. 52, Pl. 1, figs. 1, 4 (= *f*, *c* elements; *non* fig. 2 = *g* element of *Ozarkodina* species; figs. 3, 5, 6 may = *b*, *a* and *e* elements of *A. petila*, herein; *P. celloni* Zone).

Oulodus planus planus (Walliser). BISCHOFF, 1986 (in part), p. 78-84, Pl. 19, figs. 39-41 (*M. griestoniensis*, *P. celloni* zones), Pl. 20, figs. 2, 7, 17, 18, 28, 29, 38, 42, Pl. 21, figs. 1, 2, 8, 9 (*C. cyphus–M. triangularis* zones; *D. pseudopesavis–O. masurenensis* Assemblage Zone), Pl. 20, figs. 20, 35, Pl. 21, figs. 5, 7, 10, 11 (*M. turriculatus* Zone; *A. antiquus–D. staurognathoides* Assemblage Zone) (only; other illustrated elements assigned to *A. petila* below).

Remarks. Most elements of *Aspelundia fluegeli* have been described by other writers. The two species of *Aspelundia* from northern Yukon are compared below under the discussion of *A. petila*.

Aldridge (1979, p. 14, 15) briefly summarized the characters of the elements of his *Oulodus*? *fluegeli*. I do not include his "ligonodiniform" element because it is eoligonodiniform in form and may belong to a species of *Oulodus*.

Both Over and Chatterton (1987), and Armstrong (1990) noted the variable nature of the posterior process of the *a* element (cf. *a*-1 and *a*-2 elements; Pl. 1, figs. 22, 21, respectively). Over and Chatterton (1987, p. 23, Pl. 1, fig. 38) called these forms transitional Sc-Sb elements. Armstrong also noted some of these elements have the distal tip of the process directed anteriorly (1990, p. 54, Pl. 3, fig. 12).

It was reported in Aldridge's (1979, p. 14) study that the cusp of the *c* (his Sa) element may develop into a "denticulated posterior bar"; this element is herein regarded as a *b* rather than a *c* element. Armstrong (1990) also found that some of his elements (Sb_1, herein *b*) have a short posterior process that bears two or three compressed denticles (Armstrong's Sb_2 element lacks a posterior process). The "posterior process" of *b* elements in the northern Yukon material of this study is adenticulate. However, in other localities in the Canadian Cordillera, denticulated *b* elements of *Aspelundia fluegeli* are found [see McCracken, 1991b (*this volume*)].

Some elements of ?*Roundya trichonodelloides s.f.* have the outline of the *c* element of *Aspelundia fluegeli*, but have a short denticulated posterior process (cf. Walliser, 1964, Pl. 31, figs. 22, 25). In Yukon elements, the *c* elements lack a denticulated posterior process.

The *e*-2 elements have not been previously described as part of the apparatus. This element (Pl. 1, fig. 10) has a short anterior process that bears at least two short, discrete denticles. The cusp is nearly erect, and is immediately anterior of the basal flare. These very rare elements may be homologous (for example) to the *e*-2 elements of Ordovician species of *Oulodus*. Elements of the younger *Neoprioniodus multiformis s.f.* are variable, with either an adenticulate or denticulate anterior margin (cf. Walliser, 1964, Pl. 29, figs. 15, 19) and thus are similar to the *e*-1 and *e*-2 elements of *Aspelundia fluegeli* in Yukon. Armstrong (1990) recognized elements comparable to the *e*-1 and *e*-3 elements; his were called M and Sd elements.

Ozarkodina plana of Sweet and Schönlaub (1975) includes a *c* element with a Y-shaped divergence of processes, and an *f* element with confluent denticles and a twisted posterior process. These *c* and *f* elements are comparable to the same elements of *Aspelundia fluegeli*. The *a*, *b* and *e* elements of *O. plana* have a denticulation that is more similar to *A. petila* than to *A. fluegeli*.

Miller (1978) suggested that some of his form species represent *Ozarkodina plana sensu* Sweet and Schönlaub (1975). Six of his form species are included herein under *Aspelundia fluegeli*. The *f* element from Miller (1978) is queried because it has denticles that are not closely packed. It may be more correct to assign *Lonchodina fluegeli s.f.* of Miller to *A. petila* (below).

Uyeno and Barnes (1983) described the rare *Oulodus*? cf. *O.? fluegeli* as an apparatus composed of elements with V-shaped denticle interspaces. They noted that this feature is more characteristic of the genus *Ozarkodina* than *Oulodus*. Their (1983) apparatus also includes a *c* element that has downwardly directed lateral processes and is therefore unlike reconstructions of the two Yukon *Aspelundia* species. The *b*, *f* and *g* elements from Uyeno and Barnes (1983) are comparable to the *A. fluegeli* of this present study.

Occurrence. Elements assignable to *Aspelundia fluegeli* were recorded from the base of the *P. celloni* Zone in the Carnic Alps by Walliser (1964) and from the *I. inconstans* (= *P. celloni*) to lower *P. amorphognathoides* zones in the Welsh Borderland (Aldridge, 1972).

In California, *Aspelundia fluegeli* is found between the *Spathognathodus* (= *P.*) *celloni* and *P. amorphognathoides* zones (Miller, 1978). *Aspelundia fluegeli* occurs in the upper *P. celloni* and *P. amorphognathoides* zones of the Oslo region, Norway (Aldridge and Mohamed, 1982). In southwestern Northwest Territories, *A. fluegeli* ranges from the undifferentiated lower Llandovery (called *discreta*/*kentuckyensis*/*nathani* Zone) where it occurs with the relatively long-ranging *Ozarkodina hassi* (Pollock et al.), to the *P. amorphognathoides* Zone (Over and Chatterton, 1987). Ranges of *A. fluegeli* and its form species components in other localities are given in the above synonymy. Except for localities in northern Yukon, Greenland and Australia, *A. fluegeli* has an apparent range of *P. celloni–P. amorphognathoides* zones. These three localities probably represent similar depositional environments, that is, outer slope to basin, and this may be the reason for the earlier appearance of *Aspelundia* in these environments compared to shelf areas.

The earliest occurrence of *Aspelundia fluegeli* in the three northern Yukon sections is likely in the lowest part of the *M. turriculatus* graptolite Zone, if not lower. At the Blackstone River section the lower of the two conodont-bearing carbonate beds (GSC loc. O-104269) is mid-point within this graptolite zone, but at the Tetlit Creek section it occurs at the same level as the first appearance of graptolites of this zone (GSC loc. O-104294), which is 2 m above the *M. convolutus* graptolite Zone. At the Rock River section, the first known occurrence of *A. fluegeli* is at 275 m (GSC loc. O-104282), which is 20 m above the *C. gregarius* Zone and 5 m below graptolites of the *M. turriculatus* Zone. That is, the base of the *A. fluegeli* Zone is somewhere between, or within one of, the *M. convolutus* and *M. turriculatus* zones. *Aspelundia fluegeli* ranges at least as high as uppermost Llandovery *C. laqueus–C. sakmaricus* Zone at the Tetlit Creek section (GSC loc. O-104298).

The *Aspelundia fluegeli* Zone is best represented in the Blackstone River section. The sample (GSC loc. O-104269; 90.2 m) has a great abundance of conodont elements, but a relatively low diversity. Besides *Aspelundia fluegeli* and *A. petila*, other species are *Dapsilodus obliquicostatus*, *Decoriconus fragilis*, *Distomodus* sp. cf. *D. kentuckyensis sensu* Cooper, *Ozarkodina* sp. aff. *O. polinclinata sensu* Aldridge, *Ozarkodina* sp. B, *Panderodus* spp., *Walliserodus blackstonensis* n. sp., *W. curvatus*, *W. sancticlairi* Cooper, and *W.*? n. sp. B.

Paleoecological factors obviously influenced the composition of this fauna, and this may be why species of *Astropentagnathus* and *Aulacognathus*, found 8.3 m higher in the next conodont bed (GSC loc. O-104270) at the Blackstone River section and representing the *P. celloni* Zone, are absent from this fauna. Even a trace of offshore species such as *Carniodus carnulus*, *Pterospathodus celloni* (both in the higher conodont bed), and *P. amorphognathoides* is also notably absent from this fauna of over 5000 conodont elements. This suggests that the first occurrence of *A. fluegeli* predates that of *P. celloni*. Thus the *A. fluegeli* Zone at the Blackstone River section is equated to the upper *D. staurognathoides* Zone and is terminated well before the full range of the nominate species by the first appearance of the succeeding *P. celloni* Zone.

Armstrong (1990) suggested the base of the *Aspelundia fluegeli* Zone in North Greenland corresponds to the *M. argenteus* graptolite Zone. This base corresponds to a level within the lower part of the *D. kentuckyensis* Zone (Armstrong, 1990, p. 33, fig. 24) and therefore represents one of the oldest occurrences of *A. fluegeli*. Armstrong thus equated the *A. petila* (his *A. expansa*) Zone with the *O.*? *nathani* Zone of Anticosti Island. His conodont data that define this base are from a 55 m thick reference section of the Cape Schuchert Formation. Graptolites from about 10 m below the top of the formation are from the *M. turriculatus* Zone. Thus data from this reference section indicate only that the base of the *A. fluegeli* Zone is either within or below the *M. turriculatus* Zone. Armstrong correlated his reference section with the type section of the Cape Schuchert Formation, which contains graptolites of the *M. argenteus* Zone in the lower part, and of the *M. convolutus* Zone 2 m below the top. The early Aeronian age for the base of the *A. fluegeli* Zone was determined by equating the level of the *M. argenteus* Zone graptolites of the type section with "10-20 m above the base of the reference section"—*A. fluegeli* (Walliser) occurred first at 20 m above the base (Armstrong, 1990, p. 28). From this, the base of the *A. fluegeli* Zone may be as low as the *M. convolutus* or underlying *M. argenteus* zones (mid- to upper part of the *D. kentuckyensis* Zone). *Aspelundia fluegeli* in Greenland ranges into the *Pterospathodus amorphognathoides* Zone (Armstrong, 1990).

Bischoff (1986) recorded *Oulodus planus planus* from the *C. cyphus* to *M. griestoniensis* graptolite zones of midwestern New South Wales in Australia. These graptolite zones correspond approximately to the *C. gregarius* to *M. spiralis* graptolite zones of northern Yukon (Lenz, 1982); thus the lower limit of *Aspelundia* is probably within the lower part of the *D. kentuckyensis* Zone. Some of the illustrated elements of *O. planus planus sensu* Bischoff have herein been assigned to *A. fluegeli*, the remainder to *A. petila*. Bischoff's elements from the Cobbler's Creek and Liscombe Pools sections correspond to the *M. turriculatus* and *M. griestoniensis* zones respectively, and so have a combined age range of *D. staurognathoides–P. celloni* zones; that is within the common range of *A. fluegeli* and *A. petila*. The remaining illustrated elements of Bischoff's *O. p. planus* lower the ranges of both *Aspelundia* species. Diagnostic elements (e.g., *c*, *f*, *g* elements) of *A. fluegeli* and *A. petila* occur in Bischoff's Bridge Creek section, strata which he correlated with the upper parts of the *C. cyphus* Zone. This correlation was supported by a graptolite fauna in higher beds that were assigned to the upper *M. triangulatus* graptolite Zone. Thus in Australia at least, *A. fluegeli* and *A. petila* have a lower limit than anywhere else—at least within the *M. triangulatus* Zone and perhaps the *C. cyphus* Zone. In Australia, the two *Aspelundia* zones apparently are concurrent.

In offshore environments the lower limit of *Aspelundia fluegeli* is probably in the mid- to upper part of the *D. kentuckyensis* Zone. *Aspelundia fluegeli* in shelf environments ranges from at least the *P. celloni* Zone to the *P. amorphognathoides* Zone.

Aspelundia petila (Nicoll and Rexroad)

Plate 1, figures 1-4, 7-9, 11, 12, 15, 16, 18, 25, 28-30
Plate 2, figures 1, 2, 5, 6, 9, 12, 16, 26-28, 30, 31

<u>a element</u>

Ligonodina petila NICOLL and REXROAD, 1969, p. 38, 39, Pl. 5, figs. 20-22 (*P. celloni–P. amorphognathoides* zones).

?*Ligonodina silurica* Branson and Mehl. MILLER, 1978, Pl. 2, figs. 2, 3 (*P. celloni–P. amorphognathoides* zones).

b element

?*Diadelognathus nicolli* Aldridge. MILLER, 1978 (in part), Pl. 3, fig. 16 (only; fig. 17 is included above under *A. fluegeli* (Walliser); *P. celloni–P. amorphognathoides* zones).

?*Trichonodella* sp. NICOLL and REXROAD, 1969 (in part), p. 65, Pl. 4, fig. 15 (only; *P. celloni* Zone).

c element

Trichonodella n. sp. LEE, 1982, p. 107, 108, Pl. 3, figs. 23, 24.

e element

Neoprioniodus planus Walliser. NICOLL and REXROAD, 1969, p. 41, Pl. 5, figs. 11, 12 (*P. celloni–P. amorphognathoides* zones).

f element

Diadelognathus n. sp. B NICOLL and REXROAD, 1969, p. 30, 31, Pl. 6, figs. 5, 6 (*P. celloni* Zone).

?*Lonchodina fluegeli* Walliser. MILLER, 1978, Pl. 3, fig. 22 (*P. celloni–P. amorphognathoides* zones).

g element

Diadelognathus excertus NICOLL and REXROAD, 1969, p. 28, Pl. 6, figs. 1-4 (*P. celloni–P. amorphognathoides* zones); MILLER, 1978, Pl. 3, fig. 15 (*P. celloni* Zone).

Diadelognathus n. sp. A NICOLL and REXROAD, 1969, p. 30, Pl. 6, figs. 9, 10 (*P. celloni* Zone).

Multielement

Aspelundia expansa ARMSTRONG, 1990, p. 50, 52, Pl. 3, figs. 13-20 (*A. expansa–P. amorphognathoides* zones).

Aspelundia n. sp. B ARMSTRONG, 1990 (in part), p. 56, 58, Pl. 4, figs. 6-8, 10 (only; = *g*, *g*, *f*, *a* elements; *P. celloni* Zone).

?*Aspelundia* n. sp. 1 (Over and Chatterton). ARMSTRONG, 1990, p. 55, Pl. 3, fig. 10 (= *g*? element; *P. celloni* Zone).

Delotaxis petila (Nicoll and Rexroad). BARRICK and KLAPPER, 1976 (in part), p. 69, 70, Pl. 4, figs. 29, 33, 34 (only; = *g*, *a*, *g* elements; *P. celloni* Zone).

Oulodus? *fluegeli* (Walliser). MABILLARD and ALDRIDGE, 1983, Pl. 2, figs. 15, 16 (*P. amorphognathoides* Zone).

Oulodus? *fluegeli* subsp. A UYENO and BARNES, 1983, p. 18, 19, Pl. 7, figs. 11-22 (= *g* elements; specimen in fig. 19 has unusually long posterior process and may be aberrant *b* or *c* element).

Oulodus? sp. cf. *O.*? *fluegeli* (Walliser). ORCHARD *in* NORFORD and ORCHARD, 1985, p. 11, Pl. 2, figs. 8, 9, 12, 15, 16, 23, 24 (*P. celloni* Zone or earlier).

?*Oulodus petila* (Nicoll and Rexroad). ALDRIDGE and MOHAMED, 1982, Pl. 2, fig. 34 (= *a* element; *P. amorphognathoides* Zone); KLEFFNER, 1985, Pl. 2, figs. 45-50 *P. celloni–P. amorphognathoides* zones); NAKREM, 1986, Textfig. 8h (*P. celloni* Zone).

Oulodus petilus pacificus SAVAGE, 1985, p. 719, 720, Textfigs. 11A-L (*P. amorphognathoides–K. ranuliformis* zones); OVER and CHATTERTON, 1987, p. 24, Pl. 5, figs. 27-32 (upper *P. amorphognathoides* Zone).

Oulodus planus planus (Walliser). BISCHOFF, 1986 (in part), p. 78-84, Pl. 20, figs. 1, 3-6, 19, 22, 24, ?26, ?27, 30, 31, 37, 40, 43, 44, Pl. 21, figs. 3, 4, 6, 12 (*C. cyphus–M. triangularis* zones; *D. pseudopesavis–O. masurenensis* Assemblage Zone), Pl. 20, figs. 21, 23, 25, 33, ?34, 36 (*M. turriculatus* Zone; *A. antiquus–D. staurognathoides* alpha Assemblage Zone), Pl. 20, fig. ?32 (*M. sedgwickii* or *M. turriculatus* zones; *A. antiquus–D. staurognathoides* alpha Assemblage Zone), Pl. 20, figs. 39, 41 (locality and age unknown) (only; other illustrated elements assigned to *A. fluegeli* above).

Oulodus? n. sp. 1 OVER and CHATTERTON, 1987, p. 23, 24, Pl. 5, figs. 11-17 (*P. amorphognathoides* Zone).

?*Ozarkodina plana* (Walliser). SWEET and SCHÖNLAUB, 1975, p. 52, Pl. 1, figs. 3, 5, 6 (= *b*, *a*, *e* elements; *non* fig. 2: may = *g* element of *Ozarkodina* species; *non* figs. 1, 4: may = *f*, *c* elements of *O. fluegeli*, herein; *P. celloni* Zone).

Description. Elements share many of the characters found in equivalent elements of *Aspelundia fluegeli* but main differences are the discrete denticles and expanded basal cavities. Other differences are outlined below.

The *a* (eoligonodiniform) element has a cusp that is oval in cross-section. The *a*-1 element (Pl. 1, figs. 1, 7, 11, 16) has an inner lateral process that is slightly deflected downward and a posterior process that is only slightly bowed laterally and downward. The *a*-2 element (Pl. 1, figs. 4, 8, 12) has an inner anterolateral process, and a posterior process that is distally bowed moderately to the inner side and deflected moderately downward. Denticles are discrete; proximal and extreme distal denticles are smaller, narrower than other denticles. Denticles on anterolateral or lateral processes are slightly recurved posteriorly and toward cusp. There are up to about seven denticles on the posterior process and about five on the other. Interspaces between denticles of all processes are U-shaped. Denticles near distal end of posterior process are longer than others.

The *b* element (Pl. 1, figs. 25, 28-30) is similar to the *c* element. Denticles on outer lateral process are more narrow and peg-like than those on inner process. There are fewer denticles on inner (about 3 or 4) compared to outer process (about 5 or 6). Inner process denticles are nearly erect and separated by V- to U-shaped interspaces. Central to distal denticles on inner process are larger than other denticles on inner process. Denticles on outer process are nearly erect, slightly curved, and have U-shaped interspaces.

The *c* element (Pl. 2, figs. 26-28, 30, 31) is characterized by lateral processes that are bowed posteriorly forming a W-shape when viewed from the upper or lower sides (cf. Pl. 2, fig. 30). Cusp is laterally compressed at base to level of white matter. Costae on anterolateral margins of cusp bound a convex anterior margin to tip of cusp. Anterior margin of cusp is not proximally narrow. Cusp and its base are slightly to markedly deflected toward inner lateral process. Angle of posterior corner is about 90°. A slight posterior flare of the base reduces this angle.

Processes of *c* element diverge anteriorly at about 90° or more from anterolateral margins of cusp. Denticles are discrete, peg-like, subcircular in cross-section, have costate lateral margins, and number about five or six on each process. Most elements have denticles that are smaller proximally and larger distally. Denticles have U-shaped interspaces. Basal cavity is deepest beneath anterior part of cusp. The posterior process has a slightly flared basal excavation in some elements.

The *e* element has a posterior process with between five and seven long denticles. Denticles are discrete and have V- or U-shaped interspaces. Two submorphotypes of *e* elements are present and follow definitions of *e*-1 and *e*-2 elements (cf. Pl. 1, figs. 2, 9, 15, 18, and Pl. 1, fig. 3, respectively) described above for *Aspelundia fluegeli*.

The *f* element (Pl. 2, figs. 1, 2, 5, 6, 9) has a cusp that is subcircular in cross-section and has sharp anterior and posterior edges. Denticles on processes are separated with V- or U-shaped interspaces. Those of posterolateral process are longer and wider than those on anterior process. Some elements have denticles on posterolateral process that are basally confluent. On average, there are about four on the anterior and six on the posterolateral processes. Torsion of posterolateral process on the *f* element is similar to that on the *f* element of *Aspelundia fluegeli* (Pl. 2, fig. 5): angle between this and anterior process is about 100° (Pl. 2, figs. 1, 2). One *f* element (Pl. 2, fig. 6) has a short broken and denticulated outer lateral process. This may be a second *f* morphotype.

The *g* element (Pl. 2, figs. 12, 16) has a cusp that is slightly recurved. Base of inner lateral process and cusp is straight. In lower or upper view, angle between plane of processes is 90° or less. Inner process has up to about seven long, and relatively wide, discrete denticles that have V- or U-shaped interspaces. Outer process of *g* element is about same length or longer than inner and has up to about ten denticles. These denticles are inclined or slightly curved posteriorly, discrete, with V- or U-shaped interspaces. Basal cavity flare is widest beneath cusp.

Remarks. The reconstructions of *Aspelundia fluegeli* and *A. petila* follow those of Aldridge (1979) and Uyeno and Barnes (1983) (among others), respectively, and are supported by abundant material from northern Yukon. The form of the elements is quite similar, and there is some morphological gradation between elements of the two species. However, most elements are distinguishable. All elements differ in denticulation; the *a* position of each species is represented by different morphotypes; and the *c*, *f*, and *g* elements of each have a distinctive divergence of processes.

The denticles on elements of *Aspelundia fluegeli* are generally more closely packed, wider and more numerous than those of *A. petila*. These features result in denticles that are slightly to moderately confluent with V-shaped interspaces between them on elements of *A. fluegeli*, and discrete with U-shaped interspaces in *A. petila*. There are exceptions to this generalization: U-shaped interspaces occur on some elements of *A. fluegeli*, and some denticles in *A. petila* are basally fused and thus have V-shaped interspaces. Denticles of *A. fluegeli* are more compressed than those of *A. petila*, which tend to be more peg-like.

The base of elements in *Aspelundia fluegeli* is less excavated and thinner than in *A. petila*. This results in elements of *A. petila* being more opaque basally than elements of a similar size in the other species. The flare of the basal cavity is commonly more developed in *A. petila* than in *A. fluegeli*, particularly in the *b*, *c*, *f*, and *g* elements.

The *a* elements of *Aspelundia fluegeli* and *A. petila* are ligonodiniform and eoligonodiniform, respectively. The anterior process of the former is more anteriorly directed; on the latter it is more laterally directed. Both species have two submorphotypes in the *a* position. These may be homologous to the subdivision found in Ordovician species of *Oulodus* (cf. McCracken and Barnes, 1981).

The *b* and *c* elements differ in the angle between the lower and posterior margins of the cusp. With the lower margin oriented horizontally, this angle is seen to be less in elements of *Aspelundia petila* than in *A. fluegeli*. This difference is due to the common occurrence of a posteriorly directed basal flare on elements of *A. petila*. The cusp of these elements in *A. fluegeli* is distinctively subtriangular due to prominent lateral costae, and subcircular with subdued costae in *A. petila*.

The denticulated processes of the *c* elements in *Aspelundia fluegeli* are characteristically directed toward the anterior, forming a V-shape. The processes on this element of *A. petila* are directed more downward and laterally, and bowed posteriorly. This divergence results in a W-shaped outline when viewed from either the upper or lower direction (as opposed to the Y-outline of *A. fluegeli*).

The *e*-1 (which has an adenticulate anterior corner) and very rare *e*-2 (denticulate anterior corner) elements occur in both species. These submorphotypes are homologous to the *e*-1 and *e*-2 elements of Ordovician genera such as *Gamachignathus* (McCracken et al., 1980) and *Oulodus* (McCracken and Barnes, 1981), which also differ in anterior margin denticulation. The rare *e*-3 element was identified only in *Aspelundia fluegeli*; this may be due to a greater element abundance of this species. Both *e*-1 and *e*-2 elements of each species can be distinguished by the denticulation of the posterior process.

The *f* and *g* elements differ in degree and direction of process divergence, although an overlap in the range of divergence angle is noted. From a lower or upper view, the processes of the *f* element diverge at apparent angles of 100° for *Aspelundia petila* and 100-140° for *A. fluegeli*. The processes of the *g* element diverge at apparent angles of greater than 90° in *A. fluegeli* and less than 90° in *A. petila*. One form of *f* element of *A. petila* that has an additional process occurs in other collections (cf. Pl. 2, figs. 1, 6, and *Diadelognathus* n. sp. B Nicoll and Rexroad 1969 *s.f.*, Pl. 6, fig. 6).

Delotaxis petila was reconstructed by Barrick and Klapper (1976) from elements of the *P. celloni* Zone of the Clarita Formation in Oklahoma. Some of these elements can be compared to elements of *Aspelundia petila*. The Sc element of *D. petila* and the *a* element of *A. petila* are identical. The figured M and Sb elements (Barrick and Klapper, 1976 compared these respectively to *Diadelognathus* n. sp. B *s.f.* and *D.* n. sp. A *s.f.* of Nicoll and Rexroad, 1969) are comparable to elements herein regarded as *g* elements (cf. Barrick and Klapper, 1976, Pl. 2, figs. 29, 34 *vs.* Pl. 2, figs. 16, 12, herein). The Sa element of *D. petila* (equated to *Diadelognathus compressus* Nicoll and Rexroad *s.f.* by Barrick and Klapper) has no known counterpart in *A. petila*; the *e* element of *A. petila* (*Neoprioniodus planus s.f.*) is not recognized in *D. petila* or in any other species from the Clarita Formation figured by Barrick and Klapper (1976).

Uyeno and Barnes (1983, p. 18) noted that *Oulodus petila* in Cooper (1980) and *O. petilus* in Uyeno and Barnes (1981, p. 181) are probably the same taxa as their (1983) *Oulodus? fluegeli* subsp. A Uyeno and Barnes. They noted that the holotype of *Ligonodina petila s.f.* was available as the subspecies name but hesitated designating this because it had previously been used by Barrick and Klapper (1976, p. 69-70) for a species of *Delotaxis*.

Elements of *Oulodus? fluegeli* subsp. A Uyeno and Barnes has a discrete style of denticulation similar to that of *Aspelundia petila*. Their (*ibid.*, Pl. 7, fig. 12) *b* element is comparable to one of the two varieties of *b* elements in this taxon. It has a lower margin that is flared and posteriorly convex, and a cusp that has a convex posterior margin. One of their *g* elements (*ibid.*, Pl. 7, fig. 19) has processes that diverge in the fashion of a *g* element, but it also has a long base beneath the cusp. This element could be an aberrant form of an *a*, *b*, or *c* element.

Occurrence. Ranges of *Aspelundia petila* and its form species components at other localities are given in the above synonymy.

Aspelundia petila includes *Oulodus? fluegeli* subsp. A of Uyeno and Barnes, which ranges from the uppermost *D. staurognathoides* Zone to about the middle of the *I. inconstans* (= *P. celloni*) Zone on Anticosti Island. *Aspelundia petila* occurs on Anticosti Island at its lower levels with *Aulacognathus bullatus* (Nicoll and Rexroad), a species that apparently is restricted to the *P. celloni* Zone (Uyeno and Barnes, 1983). Over and Chatterton (1987) record this form from the upper *P. amorphognathoides* Zone of the southwestern Northwest Territories.

The lower limit of *Oulodus petila sensu* Cooper (1980; not illustrated) is somewhere above the base of the *D. staurognathoides* Zone and below the *Pterospathodus* extinction datum plane. *Aspelundia petila* from Norway is recorded only from strata of the *P. amorphognathoides* Zone (Aldridge, 1974; Aldridge and Mohamed, 1982).

The lower range limit of *Aspelundia petila* is best known from North Greenland, where it is from the *A. expansa* to *P. amorphognathoides* zones, and from Australia, where it is found in strata equivalent to the *C. gregarius* to *M. spiralis* zones of northern Yukon (see Biostratigraphy). The range of *A. petila* thus is likely from somewhere within the *D. kentuckyensis* to *P. amorphognathoides* zones (see discussion under Occurrences for *A. fluegeli* above).

Material. Hypotypes GSC 101041-101068.

Genus *Dapsilodus* Cooper, 1976

Type species. *Distacodus obliquicostatus* Branson and Mehl, 1933.

Dapsilodus obliquicostatus (Branson and Mehl)

Plate 4, figures 11, 13, 14, 16-28, 30-32, 35, 40

?*Acodus inornatus* Ethington. NEHRING-LEFELD, 1985, p. 632, Pl. 3, fig. 2, Textfigs. 6(9, 10).

Distacodus obliquicostatus BRANSON and MEHL, 1933, p. 41, Pl. 3, fig. 2; ?MILLER, 1976, Textfig. 8(12); MILLER, 1978, Pl. 1, fig. 18; LEE, 1982, p. 74, 75, Pl. 4, figs. 23, 24; ?NEHRING-LEFELD, 1985, Pl. 3, fig. 4, Textfig. 5(10).

Multielement

Dapsilodus obliquicostatus (Branson and Mehl). ALDRIDGE DORNING and SIVETER, 1981, Pl. 2.1, figs. 6-8; UYENO and BARNES, 1983, p. 16, Pl. 9, figs. 11, 12 (includes synonymy); OVER and CHATTERTON, Pl. 6, figs. 1, 2; ALDRIDGE and JEPPSSON, 1984, Textfig. 3a-c; NAKREM, 1986, Textfig. 7I. ARMSTRONG, 1990, p. 70, 71, Pl. 7, figs. 7-12.

?*Dapsilodus* sp. ORCHARD *in* NORFORD and ORCHARD, 1985, Pl. 1, fig. 5.

Remarks. Oblique striations or costae are present on the anterior margins of the elements. The *a* element has a subdued costa on one face; the other face is either acostate or has a much weaker costa. The *b* morphotype is variable. The base length may be either relatively short or long, and in some elements it is posteriorly extended. The end members displaying a variation in basal length may be homologous to the *b*-1 and *b*-2 submorphotypes found in the Ordovician *Besselodus borealis* Nowlan and McCracken (*in* Nowlan et al., 1988).

Occurrence. Dapsilodus obliquicostatus has not been reported in strata older than the upper part of the *D. staurognathoides* Zone on Anticosti Island (Uyeno and Barnes, 1983). The one element described and illustrated by Aldridge (1972) from the Welsh Borderland occurs about this same level. *Dapsilodus obliquicostatus* also occurs in the Wenlock of Wales (Aldridge et al., 1981). Link and Druce (1972) record this taxon from Ludlow and Gedinne strata of New South Wales, Australia.

In Indiana and Kentucky, *Dapsilodus obliquicostatus* is found in the *N.* (= *P.*) *celloni* Zone and younger strata (Nicoll and Rexroad, 1969). This species is restricted to the *K. ranuliformis* to *K. variabilis* conodont zones in Oklahoma (Barrick, 1977). There are differences in the level of first appearance of *D. obliquicostatus*, a fact possibly reflecting environmental control, as suggested by Barrick (1981).

Dapsilodus obliquicostatus in the northern Yukon study area is found from the lower Llandovery *C. gregarius* Zone (Rock River) to the upper Wenlock–lower Ludlow *M. lundgreni–N. nilssoni* graptolite zones (Tetlit Creek). Over and Chatterton (1987) reported *D. obliquicostatus* from the lowest Silurian beds in southwestern District of Mackenzie. These may be as old as the *Oulodus*? *nathani* Zone. In North Greenland, the species ranges from lower–middle Llandovery to the upper Llandovery (Armstrong, 1990).

Material. Hypotypes GSC 101069-101087.

Dapsilodus? sp. B

Plate 4, figures 29, 34, 36-38

Description. Distacodontiform (*a-b*) element (Pl. 4, figs. 36-38) has a short base, long recurved cusp and asymmetrically opposed lateral costae. Lower margin varies in lateral view; either slightly convex from anterior to posterior, or posteriorly convex and anteriorly straight. Forms with the latter basal profile retain part of their basal filling (Pl. 4, figs. 36, 37). Faint longitudinal striae parallel costae. Coarser oblique striae present along anterior margin.

The *e* (acodontiform) element (Pl. 4, figs. 29, 34) is bowed to inner acostate side. Posterior part of inner face has faint longitudinal striae; anterior margin has coarse oblique striae. Outer costate face lacks striae.

Remarks. These elements occur in two northern Yukon samples. One of these (GSC loc. O-104284) contains *Distomodus staurognathoides* and other species indicative of the mid- to upper Llandovery. A singular (and anomalous) occurrence of an element similar to *Oistodus venustus* Stauffer *s.f.* with this material raises the question whether or not these elements are part of Ordovician *Paroistodus*? and represent contamination, either via a debris flow or laboratory techniques.

The *a-b* elements have a short, bell-shaped base like the *a-b* elements of *Paroistodus*? sp. A Nowlan and McCracken (*in* Nowlan et al., 1988). The *e* elements are comparable to acodontiform elements of both the Ordovician *Paroistodus*? and *Scabbardella*.

The elements of *Dapsilodus*? sp. B differ from those of *Paroistodus*? sp. A in that they have oblique and longitudinal striae. This ornamentation is present on *D. obliquicostatus* and *Besselodus*, the possible ancestor to the genus, but not *Paroistodus*?. Löfgren (1978) has reported longitudinal striae on her Llanvirn *Acodus*? *mutatus* (Branson and Mehl) elements, and one of her illustrated elements has oblique ornamentation.

The acodontiform and distacodontiform elements may comprise a nearly complete apparatus of a species of *Dapsilodus*. However, the presence of an oistodontiform element similar to Ordovician forms makes the generic assignment questionable.

Occurrence. *Dapsilodus*? sp. B occurs at Rock River from the *C. gregarius* to *M. turriculatus* zones.

Material. Figured specimens GSC 101088-101092.

Genus *Decoriconus* Cooper, 1975

Type species. *Paltodus costulatus* Rexroad, 1967.

Decoriconus fragilis (Branson and Mehl)

Plate 4, figures 33, 39

<u>*a element*</u>

Drepanodus aduncus Nicoll and Rexroad. LEE, 1982, p. 79, 80, Pl. 3, figs. 27, 28.

<u>*b-c element*</u>

Paltodus fragilis BRANSON and MEHL, 1933, p. 43, Pl. 3, fig. 6.

<u>*Multielement*</u>

Decoriconus fragilis (Branson and Mehl). ALDRIDGE, DORNING and SIVETER, 1981, Pl. 2.1, figs. 3-5; UYENO and BARNES, 1983, p. 16, 17, Pl. 9, figs. 1-10, 13-16 (includes synonymy); ALDRIDGE and JEPPSSON, 1984, Textfig. 3d-f; KLEFFNER, 1987, Textfig. 7(19, 20); OVER and CHATTERTON, 1987, Pl. 6, fig. 3; ARMSTRONG, 1990, p. 71, 72, Pl. 7, figs. 13-17 (includes synonymy; *A. fluegeli* Zone).

Remarks. Only *b* and *c* elements are known from the Yukon collections. As originally diagnosed, *Decoriconus fragilis* differs from the older *D. costulatus* (Rexroad) by having an extra morphotype, the *a* (drepanodontiform) element. This difference was questioned by McCracken and Barnes (1981) and discussed by Nowlan et al. (1988). Armstrong (1990) emended the diagnosis of *D. fragilis* to include a third morphotype.

Cooper (1976) noted that the elements of *Decoriconus fragilis* are larger and more robust than those of *D. costulatus*. Barrick (1977) found that the *b* elements of both species are nearly identical but the *c* element of *D. fragilis* differs in being more flattened and symmetrical and lacking striae.

Occurrence. *Decoriconus fragilis* in northern Yukon ranges from the *C. gregarius* (at Rock River) to *M. turriculatus* (at Blackstone River) zones. It has a range from lower

Llandovery (possibly as old as *O.? nathani* Zone on the basis of its occurrence in southwestern District of Mackenzie; Over and Chatterton, 1987) to Upper Silurian (Cooper, 1980).

Material. Hypotypes GSC 101093, 101094.

Genus *Walliserodus* Serpagli, 1967

Type species. *Acodus curvatus* Branson and Branson, 1947.

Walliserodus blackstonensis n. sp.

Plate 3, figures 1-42

non Acodus bicostatus BRANSON and MEHL, 1933, p. 42, Pl. 3, fig. 1; REXROAD and CRAIG, 1971, p. 686, Pl. 82, figs. 18, 19 (includes re-illustration of holotype).

Etymology. From Blackstone River, where the holotype, and most other elements of the species were collected by the author and A.C. Lenz (University of Western Ontario).

Multielement

Walliserodus bicostatus (Branson and Mehl). ARMSTRONG, 1990, p. 122, 124, Pl. 21, figs. 1-5.

?*Walliserodus* sp. ORCHARD *in* NORFORD and ORCHARD, 1985, Pl. 2, fig. 21.

Diagnosis. A species of *Walliserodus* having five element morphotypes. Elements are characterized by their relatively wide bases, narrow recurved cusps, keeled margins and on all but one morphotype, costate ornamentation.

Description. All elements have white matter in cusp, keels and costae. Basal cavity is deep in all elements, extending to point of cusp recurvature.

The *a* (curvatiform) element (Pl. 3, figs. 1-9) lacks lateral costae and has a short, triangular and wide base. Cusp is wide, straight, long, compressed, and erect to slightly recurved. Recurvature is at two thirds length of element. Cusp is bowed to inner side, twisted so that inner face is posterolaterally directed. Anterior and posterior edges are sharp; edges on base are keeled. Anterior keel may curve inward producing a concave inner face. Rarely, edge of keel faces posteriorly. Inner face of base planar. Outer face convex; some elements have a wide, low median carina. Basal and lower margins straight to slightly convex.

Two forms of *b* (deboltiform) elements differ according to number of costae. The *b*-1 element (Pl. 3, figs. 10-12, 18) is similar to the *a* element except for the following differences: element is less inwardly bowed, base is slightly longer and not as wide basally, keels are not deflected laterally, and inner face is planar with a weak medial depression. This medial depression is reflected in inner basal outline; outer outline is convex. Outer face has sharp medial costa. In some specimens, this costa is keel-like and nearly perpendicular to anteroposterior plane. Face anterior to costa is slightly concave to slightly convex; face posterior to costa is slightly concave.

The *b*-2 element (Pl. 3, figs. 13, 15-17) is similar to the *b*-1 element, except that the base is higher and the cusp is proclined. Costa on outer face is keel-like and may be medial or near keeled anterior margin. Some elements develop a second sharp costa between anterior margin and other costa. Inner face has a costa near the anterior margin that extends from the base to point of cusp recurvature where it merges with anterior keel.

The *c* (dyscritiform) element (Pl. 3, figs. 14, 19-27) has a long base like that of the *b*-2 element and a proclined cusp, concave anterior face and keeled anterolateral margins. Basal outline is triangular. Two varieties are: symmetrical and slightly asymmetrical elements. Symmetrical *c* element (Pl. 3, figs. 21, 25) is unbowed and has a keeled posterior margin on base. Posterior margin of cusp is convex with sharp posterolateral costae. These continue toward the base where they merge at mid-height to form a posterior keel. Keeled anterolateral costae on base extend anteriorly beyond anterior face. Each costa is immediately paralleled by a sharp costa that is slightly directed posteriorly. These lateral costae extend to tip of cusp, bounding a slightly convex anterior margin. Anterolateral costae do not extend beyond point of recurvature. Lateral faces are planar or slightly concave. Upper and lower margins of base are straight.

The slightly asymmetrical *c* element (Pl. 3, figs. 22, 23, 26, 27) has a cusp directed toward inner side. Distal part of posterior margin on base may be straight or may also be directed inward. Inner and outer lateral costae near anterior margin are like those of symmetrical *c* element. Anterolateral costae may be subdued or as prominent as on symmetrical element. Inner side lacks posterolateral costa. Posterior keel is deflected to inner side and extends to tip of cusp as sharp costa. Cusp has cross-section like that of symmetrical element: costae are present at each corner.

The *d* (multicostatiform) element (Pl. 3, figs. 29, 32, 34-37, 39-42) varies in length of base and number of costae. Element has keeled anterior and posterior margins, proclined cusp, and a nearly straight or slightly concave upper margin. Unbowed elements have a sharp lateral costa near anterior margin on one side that extends for length of element. Immediately anterior to this is a shorter costa. This face may also have a costa near the posterior margin that extends from tip of cusp to about mid-length. Other face has at least two sharp costae: one near the anterior, the other near the posterior margins. Secondary costa may develop slightly posterior to more anterior costa.

The *e* (unicostatiform) element (Pl. 3, figs. 28, 30, 31, 33, 38) has a proclined cusp, sharp anterior and posterior margins, and lacks lateral costae. Straight unbowed form of this element has a low wide base. Cusp is laterally compressed and only slightly twisted to inner side. Base on both sides is nearly flat with shallow and wide medial depression. Anterior margin is keeled in some elements. Basal outline is asymmetrical, subrectangular with rounded edges. Other elements (Pl. 3, figs. 30, 31) are similar, except that bases are longer and less wide, and cusp is more twisted and inclined in posterolateral direction.

Remarks. All element positions and morphotypes are readily comparable to those of *Walliserodus curvatus* and other species of *Walliserodus*. The *e* element is termed "unicostatiform", even though it is acostate, to conform to the descriptive terminology of *W. curvatus*. Both this *e* element and that of the Ordovician *W. amplissimus* (Serpagli), another species with an acostate *e* element, have the outline of *A. unicostatus* Branson and Branson *s.f.* All elements have a degree of variability, particularly the *b* through *d* elements.

The *a* element differs from the *a* element of *Walliserodus curvatus* in lacking lateral costae. In this regard, it is comparable to the *a* element of *W. sancticlairi* (below). It differs in that the base is shorter and wider, and the cusp is more recurved. The robust elements of *W. sancticlairi* in Barrick (1977) and Uyeno and Barnes (1983) are more robust than Cooper's type material but still do not approach the extremes found in the *a* elements of *W. blackstonensis* n. sp.

The *b*-1 element is comparable to the *b* element of both *Walliserodus curvatus* and *W. sancticlairi* in the sense that only the outer side has a costa. This element, however, has a wider and shorter base. The *b*-2 element may have comparable elements in both of the above species. It is essentially a *c* element that is markedly asymmetrical. It also differs from *b* elements in other species in its basal proportions.

The *c* element is characterized by its anteriorly directed anterolateral keels and concave anterior face. The *c* elements of *Walliserodus curvatus* and *W. sancticlairi* are similar to each other in that their anterolateral costae do not extend beyond the anterior face. Also, the anterior face in these *c* elements is more convex. The costae of the *c* element in this new species are better developed than in the other named species.

The morphology of the *d* element in *Walliserodus curvatus*, *W. sancticlairi* and this new species is variable. In *W. blackstonensis* n. sp., the *d* element is characterized by a relatively wide base. The *d* element may be even more variable in ornamentation than is recorded herein.

The *e* element lacks a lateral costa as is found in *Walliserodus curvatus*. Its short wide base distinguishes it from the *e* element of *W. sancticlairi*.

There is no question that the species called *Walliserodus bicostatus* by Armstrong (1990) and the northern Yukon species are the same (cf. Pl. 3, figs. 1, 20, herein, *vs.* Pl. 21, figs. 5, 1, of Armstrong). The form species *Acodus bicostatus* Branson and Mehl *s.f.* is not a synonym of *W. blackstonensis* n. sp. because the holotype (well illustrated by Rexroad and Craig, 1971) is asymmetrical with an outer face having a bicostate carina, and a bicostate (lower) margin. It has the asymmetry of the *b* morphotype, but none of the elements of *W. blackstonensis* n. sp. have the bicostate lateral carina.

Occurrence. At Rock River, *Walliserodus blackstonensis* n. sp. is found in the interval of the *C. gregarius–M. turriculatus* zones, the *M. turriculatus* Zone at Blackstone and Rock rivers, and the *M. spiralis* Zone at Tetlit Creek. Armstrong (1990) found only a few elements assignable to *W. blackstonensis* n. sp. at only two localities in Washington Land in North Greenland. One of these samples, from the Cape Schuchert Formation, occurs in the *A. fluegeli* Zone, the other, from the Kap Godfred Hansen Formation, is from the *P. celloni* Zone. The limited data suggest *W. blackstonensis* is a mid- to upper Llandovery species.

Material. Holotype GSC 101111, paratypes GSC 101095-101110, 101112-101133, unfigured paratypes GSC 101134-101136.

Walliserodus curvatus (Branson and Branson)

Plate 4, figure 12

a element

Acodus curvatus BRANSON and BRANSON, 1947, p. 554, Pl. 81, fig. 20.

Multielement

Walliserodus curvatus (Branson and Branson). COOPER, 1975, p. 995, 996, Pl. 1, figs. 10, 11, 16-21 (includes synonymy); KLEFFNER, 1985, Pl. 2, figs. 35, 36; NOWLAN and McCRACKEN *in* NOWLAN, McCRACKEN and CHATTERTON, 1988, p. 41, 42, Pl. 19, fig. 16 (includes synonymy); ARMSTRONG, 1990, p. 124-126, Pl. 21, figs. 6-15 (includes synonymy).

Remarks. Armstrong (1990) emended the diagnosis of *Walliserodus curvatus* to comprise five element morphotypes (*sym. p*, *ap*, *sq*, *r*). The emended diagnosis is probably not necessary because all five elements have previously been recognized; other writers simply have different interpretations of element homologies (e.g., Cooper, 1976 uses the terminology of Sweet and Schönlaub, 1975; Nowlan et al., 1988 use the terminology of Barnes et al., 1979). For example, the *ap* and *r* elements of *W. curvatus sensu* Armstrong are the *e* and *a* elements of the same species *sensu* Nowlan et al. (1988).

Occurrence. Walliserodus curvatus is found from the *C. gregarius* Zone (at Rock River) to the *M. turriculatus* Zone at Blackstone River and Tetlit Creek. One element was identified from the uppermost Llandovery *C. sakmaricus–C. laqueus* Zone at Tetlit Creek. Elsewhere, it ranges from the lowermost Llandovery (Nowlan et al., 1988) to the *P. amorphognathoides* Zone.

Material. Hypotype GSC 101137.

Walliserodus sancticlairi Cooper

Plate 4, figures 3-10, 15

Multielement

Walliserodus sancticlairi COOPER, 1976, p. 214, 215, Pl.1, figs. 8-11, 16, 21; UYENO and BARNES, 1983, p. 26, Pl. 7, figs. 1-3, 5, 6 (includes synonymy); KLEFFNER, 1987, Fig. 6(15-18).

Walliserodus cf. *W. sancticlairi* Cooper. ARMSTRONG, 1990, p. 126, 127, Pl. 21, figs. 16-24 (*P. celloni – P. amorphognathoides* zones).

Remarks. Armstrong (1990) distinguished *Walliserodus sancticlairi* of Cooper (1976) from his *W.* cf. *W. sancticlairi* on the basis of differences in the costae of the *sym. p* element, the laterally acostate *q* elements, and the addition of a strongly recurved *r* element. The *a* (curvatiform) element (Pl. 4, figs. 6, 9) is similar to the *r* element of Armstrong's species; other elements are also comparable and thus his species is included under *W. sancticlairi.*

The *a* element of *Walliserodus sancticlairi* lacks the costate inner face found on the same element of *W. curvatus.* Cooper (1976) added that this element is straighter in lateral view (except for the sharply curved cusp) than the *a* element of *W. curvatus.* Barrick (1977) suggested that Cooper's illustrated form represented an extreme end member of a series that also includes relatively low, robust forms that are curved near mid-height (cf. Barrick, 1977, Pl. 1, fig. 18; Uyeno and Barnes, 1983, Pl. 7, fig. 2). Barrick further reported that some of these elements have a weak costa on the posterior margin of the inner face. He (1977) noted a gradual loss of the robust forms in younger strata. Northern Yukon elements are comparable to the short, robust elements of Barrick (1977) and Uyeno and Barnes (1983); their base is short and subcircular with only a slight lateral compression.

The *b* (deboltiform) element (Pl. 4, figs. 3-5) of *Walliserodus sancticlairi* is comparable to the *b* element of *W. curvatus,* except that some lack a costa on the outer face (Cooper, 1976). This difference is more common in younger strata (Barrick, 1977).

The *c* elements of *Walliserodus sancticlairi* (Pl. 4, fig. 10) and *W. curvatus* differ only in the arrangement of costae about the posterior margin. The *c* element from northern Yukon has a sharp costate posterior margin that becomes lateral at midpoint and is paralleled on the opposite face by a costa, giving the cusp a square cross-section. In this sense it may differ from the previously described forms.

The *d* (multicostatiform; Pl. 4, fig. 7) and *e* (unicostatiform; Pl. 4, figs. 8, 15) elements of *Walliserodus sancticlairi* are comparable to the same elements of *W. curvatus* except that the latter may lack the distinctive costa on one face. The *d* element also varies stratigraphically. Barrick (1977) found that the lateral costae are medial on older, and more anterior on younger, forms. He stated that the stratigraphic variation in elements of *W. sancticlairi* was so gradual that it was difficult to distinguish with confidence younger from older forms.

Walliserodus sancticlairi is compared to *W. blackstonensis* n. sp. (above) under the remarks on the latter.

Occurrence. Walliserodus sancticlairi is not well known: in Oklahoma it ranges from the *P. amorphognathoides* through most of the *K. amsdeni* conodont zones (Barrick and Klapper, 1976); in Illinois, from the *P. amorphognathoides* Zone to at least the *O. saggita* conodont Zone (Cooper, 1976); and on Anticosti Island, from the uppermost *I. discreta–I. deflecta* (= *D. kentuckyensis*) conodont Zone to middle *I. inconstans* (= *P. celloni*) Zone (Uyeno and Barnes, 1983). In North Greenland, *W. sancticlairi* ranges from the *P. celloni* to *P. amorphognathoides* zones (Armstrong, 1990). It occurs from the *C. gregarius* Zone (at Rock River) to a level between the *M. spiralis* Zone and *C. sakmaricus–C. laqueus* Zone at Tetlit Creek. Thus, the presently known range of *W. sancticlairi* is from middle Llandovery to upper Wenlock.

Material. Hypotypes GSC 101138-101146.

Walliserodus? n. sp. B

Plate 4, figures 1, 2

Remarks. The rare, geniculate elements share the wide base and cusp of *a* elements of *Walliserodus blackstonensis* n. sp. described above. They are not included under *W. blackstonensis* n. sp. because oistodontiform elements are unknown in species of *Walliserodus.* The elements may simply be a rare abberation of the much more abundant form of *a* element of *W. blackstonensis* n. sp. (both species occur in samples from GSC loc. O-104269 and O-104297).

Occurrence. Walliserodus? n. sp. B is found in the *M. turriculatus* Zone at Blackstone River and at a level between the *M. spiralis* Zone and *C. sakmaricus–C. laqueus* Zone at Tetlit Creek.

Material. Figured specimens GSC 101147, 101148.

ACKNOWLEDGMENTS

Financial support to collect and process the samples was provided by a Natural Sciences and Engineering Research Council of Canada grant to Drs. A.C. Lenz (University of Western Ontario) and J.A. Legault (University of Waterloo). Dr. A.C. Lenz is thanked for providing the graptolite identifications used herein. Drs. C.R. Barnes (University of Victoria) and T. Uyeno (GSC, Calgary) are thanked for their comments on an earlier version of this paper. Carrie Bolton (GSC, Ottawa) drafted the figures.

REFERENCES

Aldridge, R.J.
1972: Llandovery conodonts from the Welsh Borderland. British Museum of Natural History (Geology), Bulletin, v. 22, no. 2, p. 125-231.
1974: An *amorphognathoides* Zone conodont fauna from the Silurian of the Ringerike area, south Norway. Norsk Geologisk Tidsskrift, v. 54, p. 295-303.
1976: Comparison of macrofossil communities and conodont distribution in the British Silurian. *In* Conodont Paleoecology, C.R. Barnes (ed.); Geological Association of Canada, Special Paper 15, p. 91-104.
1979: An upper Llandovery conodont fauna from Peary Land, eastern North Greenland. Grønlands Geologiske Undersøgelse, Rapport No. 91, p. 7-23.

Aldridge, R.J., Dorning, K.J., and Siveter, D.J.
1981: Microfossil distribution across the Welsh Wenlock Shelf. *In* Microfossils from Recent and Fossil Shelf Seas, J.W. Neale and M.D. Brasier (eds.); Ellis Horwood Limited, Chichester, England, p. 18-30.

Aldridge, R.J. and Jeppsson, L.

1984: Ecologic specialists among Silurian conodonts. Special Papers in Palaeontology, no. 32, p. 141-149.

Aldridge, R.J. and Mabillard, J.E.

1981: Local variations in the distribution of Silurian conodonts; an example from the *amorphognathoides* interval of the Welsh Basin. *In* Microfossils from Recent and Fossil Shelf Seas, J.W. Neale and M.D. Brasier (eds.); Ellis Horwood Limited, Chichester, England, p. 10-17.

Aldridge, R.J. and Mohamed, I.

1982: Conodont biostratigraphy of the early Silurian of the Oslo Region. *In* Field Meeting, Oslo Region, 1982, D. Worsley (ed.); International Union of Geological Sciences, Subcommission on Silurian Stratigraphy, Paleontological Contributions from the University of Oslo, no. 278, p. 109-120.

Armstrong, H.A.

1990: Conodonts from the Upper Ordovician–Lower Silurian carbonate platform of North Greenland. Grønlands Geologiske Undersøgelse, Bulletin 159, 151 p.

Barnes, C.R., Kennedy, D.J., McCracken, A.D., Nowlan, G.S., and Tarrant, G.T.

1979: The structure and evolution of Ordovician conodont apparatuses. Lethaia, v. 12, p. 125-151.

Barrick, J.E.

1977: Multielement simple-cone conodonts from the Clarita Formation (Silurian), Arbuckle Mountains, Oklahoma. Geologica et Palaeontologica, v. 11, p. 47-68.

1981: Wenlockian (Silurian) conodont biostratigraphy and biofacies, Wayne Formation, central Tennessee. Geological Society of America, Abstracts with Programs, v. 13, no. 6, p. 270 (abstract).

Barrick, J.E. and Klapper, G.

1976: Multielement Silurian (late Llandoverian–Wenlockian) conodonts of the Clarita Formation, Arbuckle Mountains, Oklahoma, and phylogeny of *Kockelella*. Geologica et Palaeontologica, v. 10, p. 59-100.

Bischoff, G.C.O.

1986: Early and Middle Silurian conodonts from midwestern New South Wales. Courier Forschungsinstitut Senckenberg, v. 89, p. 1-337.

Branson, E.B. and Branson, C.C.

1947: Lower Silurian conodonts from Kentucky. Journal of Paleontology, v. 21, p. 549-556.

Branson, E.B. and Mehl, M.G.

1933: Conodont studies. University of Missouri Studies, v. 8, p. 1-349.

Cooper, B.J.

1975: Multielement conodonts from the Brassfield Limestone (Silurian) of southern Ohio. Journal of Paleontology, v. 49, p. 984-1008.

1976: Multielement conodonts from the St. Clair Limestone (Silurian) of southern Illinois. Journal of Paleontology, v. 50, p. 205-217.

1980: Toward an improved Silurian conodont biostratigraphy. Lethaia, v. 13, p. 209-227.

Epstein, A.G., Epstein, J.B., and Harris, L.D.

1977: Conodont color alteration—an index to organic metamorphism. United States Geological Survey, Professional Paper, 995, 27 p.

Goodfellow, W.D., Nowlan, G.S., McCracken, A.D., Lenz, A.C., and Grégoire, D.C.

1991: Geochemical anomalies near the Ordovician–Silurian boundary, northern Yukon Territory. Historical Biology (in press).

Hedberg, H.D. (ed.)

1976: International Guide. A Guide to Stratigraphic Classification Terminology, and Procedure. International Subcommission on Stratigraphic Classification of IUGS Commission on Stratigraphy. John Wiley and Sons, New York, 200 p.

Igo, H. and Koike, T.

1968: Ordovician and Silurian conodonts from the Langkawi Islands, Malaya, Part II. Geology and Palaeontology of Southeast Asia, v. 4, p. 1-21.

Klapper, G. and Murphy, M.A.

1975: Silurian–Lower Devonian conodont sequence in the Roberts Mountains Formation of central Nevada. University of California Publications in Geological Sciences, v. 111, 87 p. (imprint 1974).

Klapper, G. and Philip, G.M.

1971: Devonian conodont apparatuses and their vicarious skeletal elements. Lethaia, v. 4, p. 429-452.

Kleffner, M.A.

1985: Conodont biostratigraphy of the Stray "Clinton" and "Packer Shell" (Silurian, Ohio subsurface) and its bearing on correlation. *In* The New Clinton Collection—1985, J. Gray, A. Maslowski, W. McCullough, and W.E. Shafer (eds.); The Ohio Geological Society, Columbus, Ohio, p. 219-229, 2 pls.

1987: Conodonts of the Estill Shale and Bisher Formation (Silurian, southern Ohio). Ohio Journal of Science, v. 87(3), p. 78-89.

Lee, Ha-young

1982: Conodonts from the Hoedongri Formation (Silurian) western Jeongseon area, Kangweon-do, South Korea. Journal of the National Academy of Sciences, Republic of Korea, Natural Science Series, v. 21, p. 45-131.

Le Fèvre, J., Barnes, C.R., and Tixier, M.

1976: Paleoecology of Late Ordovician and Early Silurian conodontophorids, Hudson Bay Basin. *In* Conodont Paleoecology, C.R. Barnes (ed.); Geological Association of Canada, Special Paper No. 15, p. 69-89.

Lenz, A.C.

1982: Llandovery graptolites of the northern Canadian Cordillera: *Petalograptus, Cephalograptus, Rhaphidograptus, Dimorphograptus*, Retiolitidae, and Monograptidae. Life Sciences Contributions 130, Royal Ontario Museum, 154 p.

Lenz, A.C. and McCracken, A.D.

1982: The Ordovician–Silurian boundary, northern Canadian Cordillera: graptolite and conodont correlation. Canadian Journal of Earth Sciences, v. 19, p. 1308-1322.

1989: Silurian graptolite–conodont reference sections, northern Yukon and south-western Northwest Territories. *In* A Global Standard for the Silurian System, C.H. Holland and M.G. Bassett (eds.); National Museum of Wales, Geological Series no. 9, p. 177-183.

Link, A.G. and Druce, E.C.

1972: Ludlovian and Gedinnian conodont stratigraphy of the Yass Basin, New South Wales. Bureau of Mineral Resources of Australia, Bulletin, v. 134, p. 1-136.

Löfgren, A.

1978: Arenigian and Llanvirnian conodonts from Jämtland, northern Sweden. Fossils and Strata, no. 13, 129 p.

Mabillard, J.E. and Aldridge, R.J.

1983: Conodonts from the Coralliferous Group (Silurian) of Marloes Bay, South-West Dyfed, Wales. Geologica et Palaeontologica, v. 17, p. 29-43.

Männik, P. and Aldridge, R.

1989: Evolution, taxonomy and relationships of the Silurian conodont *Pterospathodus*. Palaeontology, v. 32, p. 893-906.

McCracken, A.D.

1987: Description and correlation of Late Ordovician conodonts from the *D. ornatus* and *P. pacificus* graptolite zones, Road River Group, northern Yukon Territory. Canadian Journal of Earth Sciences, v. 24, p. 1450-1464.

1989: Preliminary report on Ordovician–Devonian conodont collections from carbonate and fine grained clastic facies of northern Yukon Territory and northwest District of Mackenzie, N.W.T. *In* Current Research, Part G. Geological Survey of Canada, Paper 89-1G, p. 69-76.

1991a: Middle Ordovician conodonts from the Cordilleran Road River Group, northern Yukon Territory, Canada. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

1991b: Silurian conodont biostratigraphy of the Canadian Cordillera with a description of new Llandovery species. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

McCracken, A.D. and Barnes, C.R.

1981: Conodont biostratigraphy and paleoecology of the Ellis Bay Formation, Anticosti Island, Québec, with special reference to the Late Ordovician–Early Silurian chronostratigraphy and the systemic boundary. Geological Survey of Canada, Bulletin 329, Part 2, p. 51-134.

McCracken, A.D. and Lenz, A.C.

1987: Middle and Late Ordovician conodont faunas and biostratigraphy of graptolitic strata of the Road River Group, northern Yukon Territory. Canadian Journal of Earth Sciences, v. 24, p. 643-653.

McCracken, A.D., Nowlan, G.S., and Barnes, C.R.
1980: *Gamachignathus*, a new multielement conodont genus from the latest Ordovician, Anticosti Island, Québec. *In* Current Research, Part C. Geological Survey of Canada, Paper 80-C, p. 103-112.

Miller, R.H.
1976: Revision of Upper Ordovician, Silurian, and Lower Devonian stratigraphy, southwestern Great Basin. Geological Society of America, Bulletin, v. 87, p. 961-968.
1978: Early Silurian to Early Devonian conodont biostratigraphy and depositional environments of the Hidden Valley Dolomite, southeastern California. Journal of Paleontology, v. 52, p.323-344.

Mirza, K.
1976: Late Ordovician to Late Silurian stratigraphy and conodont biostratigraphy of the eastern Canadian Arctic Islands. Unpublished M.Sc. thesis, University of Waterloo, Waterloo, Ontario, 302 p.

Nakrem, H.A.
1986: Llandovery conodonts from the Oslo Region, Norway. Norsk Geologisk Tidsskrift, v. 66, p. 121-133.

Nehring-Lefeld, M.
1985: Conodonts of the *amorphognathoides* Zone (Silurian) from eastern part of the Podlasie Depression. Kwartalnik Geologiczny, v. 29, p. 625-652 (in Polish with English summary).

Nicoll, R.S. and Rexroad, C.B.
1969: Stratigraphy and conodont paleontology of the Salamonie Dolomite and the Lee Creek Member of the Brassfield Limestone (Silurian) in southeastern Indiana and adjacent Kentucky. Indiana Geological Survey, Bulletin 40, 73 p., 7 pl. (imprint 1968)

Norford, B.S. and Orchard, M.J.
1985: Early Silurian age of rocks hosting lead–zinc mineralization at Howards Pass, Yukon Territory and District of Mackenzie; local biostratigraphy of Road River Formation and Earn Group. Geological Survey of Canada, Paper 83-18, 35 p.

Nowlan, G.S.
1983: Early Silurian conodonts of eastern Canada. Fossils and Strata, No. 15, p. 95-110.

Nowlan, G.S., McCracken, A.D., and Chatterton, B.D.E.
1988: Conodonts from Ordovician–Silurian boundary strata, Whittaker Formation, Mackenzie Mountains, Northwest Territories. Geological Survey of Canada, Bulletin 373, 99 p.

Over, D.J. and Chatterton, B.D.E.
1987: Silurian conodonts from the southern Mackenzie Mountains, Northwest Territories, Canada. Geologica et Palaeontologica, v. 21, p. 1-49.

Rexroad, C.B.
1967: Stratigraphy and conodont paleontology of the Brassfield (Silurian) in the Cincinnati Arch area. Indiana Geological Survey, Bulletin 38, 64 p., 4 pl.

Rexroad, C.B. and Craig, W.W.
1971: Restudy of conodonts from the Bainbridge Formation (Silurian) at Lithium, Missouri. Journal of Paleontology, v. 45, p. 684-703.

Savage, N.M.
1985: Silurian (Llandovery–Wenlock) conodonts from the base of the Heceta Limestone, southeastern Alaska. Canadian Journal of Earth Sciences, v. 22, p. 711-727.

Serpagli, E.
1967: I conodonti dell'Ordoviciano superiore (Ashgilliano) delle Alpi Carniche. Bolletino della Società Paleontologica Italiàna, v. 6, p. 30-111.

Sweet, W.C. and Schönlaub, H.P.
1975: Conodonts of the genus *Oulodus* Branson and Mehl, 1933. Geologica et Palaeontologica, v. 9, p.41-59.

Uyeno, T.T. and Barnes, C.R.
1981: A summary of Lower Silurian conodont biostratigraphy of the Jupiter and Chicotte formations, Anticosti Island, Québec. *In* Field Meeting, Anticosti-Gaspé, Québec, 1981, v. II: Stratigraphy and Paleontology, P.J. Lespérance (ed.); Subcommission on Silurian Stratigraphy, Ordovician–Silurian Boundary Working Group, Département de géologie, Université of Montréal, p. 173-184.
1983: Conodonts of the Jupiter and Chicotte Formations (Lower Silurian), Anticosti Island, Quebec. Geological Survey of Canada, Bulletin 355, 49 p.

Walliser, O.H.
1964: Conodonten des Silurs. Abhandlungen des Hessischen Landesamtes für Bodenforschung, Heft 41, 106 p.

APPENDIX

Graptolite and conodont collections

The following lists all of the Ordovician–Silurian graptolite and conodont collections made in 1977-78 at the sections on Blackstone River, Rock River, and Tetlit Creek. On the left hand side are the field collection numbers representing the section, year collected, and stratigraphic level in metres above the base of the section. Samples from the Blackstone River section were collected using measurements in feet (in parentheses); these have been converted to SI units.

Each conodont sample represents at least 2 kg of rock, although not all rock samples were completely disintegrated by acid. Additional material (also 2 kg) of some samples were processed; these are denoted with an asterisk (*). Graptolite identifications were provided by A.C. Lenz of the University of Western Ontario.

Blackstone River (65°26′N, 137°20′W; Section 1)

Conodont/graptolite levels and zones

BR77-2/6.1 m (20 ft.) – *D. ornatus* Zone
BR77-2/32 m (105 ft.) (GSC loc. O-104259) – barren of conodonts
BR77-2/48.8 m (160 ft.) (GSC loc. O-104260) – barren of conodonts
BR77-2/49.7 m (163 ft.) – *D. ornatus* Zone
BR77-2/51.8 m (170 ft.) – *D. ornatus* Zone
BR77-2/54.9 m (180 ft.) – *D. ornatus* Zone
BR77-1 (immediately overlies section BR77-2)
BR77-1/6.1 m (20 ft.) – *D. ornatus* Zone
BR77-1/6.1 m (20 ft.) (GSC loc. O-104261) – barren of conodonts
BR77-1/13.7 m (45 ft.) (GSC loc. O-104262) – barren of conodonts
BR77-1/21.3 m (70 ft.) (GSC loc. O-104263) – barren of conodonts
BR77-1/29 m (95 ft.) (GSC loc. O-104264) – barren of conodonts
BR77-1/33.5 m (110 ft.) – *P. pacificus* Zone
BR77-1/36.6 m (120 ft.) – *P. pacificus* Zone
BR77-1/36.6 m (120 ft.) (GSC loc. O-104265) – barren of conodonts
BR77-1/42.7 m (140 ft.) (GSC loc. O-104266) – barren of conodonts
BR77-1/50.3 m (165 ft.) (GSC loc. O-104267) – conodonts
BR77-1/53.3 m (175 ft.) – (?)*G. persculptus* Zone
BR77-1/58.8 m (193 ft.) – (?)*P. acuminatus* Zone
BR77-1/60.7 m (199 ft.) (GSC loc. O-104268) – barren of conodonts
BR77-1/61.3 m (201 ft.) – (?)*P. acuminatus* Zone
BR77-1/61.9 m (203 ft.) – (?)*A. atavus* Zone
BR77-1/62.2 m (204 ft.) – (?)*A. atavus* Zone
BR77-1/62.5 m (205 ft.) – *L. acinaces* Zone
BR77-1/65.5 m (215 ft.) – *M. argenteus* Zone
BR77-1/66.4 m (218 ft.) – *M. convolutus* Zone
BR77-1/70.4 m (231 ft.) – *M. convolutus* Zone
BR77-1/72.2 m (237 ft.) – *M. sedgwicki* Zone
BR77-1/77.7 m (255 ft.) – *M. sedgwicki* Zone
BR77-1/80.2 m (263 ft.) – *M. turriculatus* Zone
BR77-1/90.2 m (296 ft.) (GSC loc. O-104269) – conodonts
BR77-1/98.5 m (323 ft.) (GSC loc. O-104270) – conodonts
BR77-1/99 m (325 ft.) – *M. turriculatus* Zone
BR77-1/103.6 m (340 ft.) – *M. spiralis* Zone

Rock River (66°48′N, 136°16′W; Section 2)

Conodont/graptolite levels and zones

RR78-13 m – Glossograptids
RR78-13 m* (GSC loc. O-104271) – conodonts
RR78-69 m (GSC loc. O-104272)
- upper Llandeilo or Caradoc graptolites
- barren of conodonts

RR78-167 m* (GSC loc. O-104273) – conodonts
RR78-207 m* (GSC loc. O-104274) – conodonts
RR78-220 m – *D. ornatus* Zone
RR78-225 m (GSC loc. O-104275) – conodonts
RR78-226 m* (GSC loc. O-104276) – barren of conodonts
RR78-228 m (GSC loc. O-104277) – conodonts
RR78-232 m – *P. pacificus* Zone
RR78-235 m (GSC loc. O-104278) – conodonts
RR78-235 m – *P. pacificus* Zone
RR78-241 m – *A. atavus* or *L. acinaces* Zone
RR78-243 m – *L. acinaces* Zone
RR78-244 m – *C. gregarius* Zone
RR78-245 m* (GSC loc. O-104279) – conodonts
RR78-247 m (GSC loc. O-104280) – conodonts
RR78-250 m* (GSC loc. O-104281) – conodonts
RR78-255 m – *C. gregarius* Zone
RR78-275 m (GSC loc. O-104282) – conodonts
RR78-281 m* (GSC loc. O-104283) – conodonts
RR78-282 m – *M. turriculatus* Zone
RR78-285 m (GSC loc. O-104284) – conodonts
RR78-302 m – *M. turriculatus* Zone
RR78-306 m – *M. spiralis* Zone
RR78-308 m (GSC loc. O-104285) – conodonts
RR78-316 m* (GSC loc. O-104286) – conodonts
RR78-345 m – *M. spiralis* Zone
RR78-Section 2/14 m (GSC loc. O-104287) – conodonts
RR78-2/15 m (GSC loc. O-104288) – conodonts
RR78-2/86 m (GSC loc. O-104289) – conodonts
RR78-2/144 m (GSC loc. O-104290) – barren of conodonts
RR78-2/177 m (GSC loc. O-104291) – barren of conodonts
RR78-2/336 m (GSC loc. O-104292) – barren of conodonts

Tetlit Creek (66°44′N, 135°47′W; Section 3)

Conodont/graptolite levels and zones

TC78-1 m – Arenig–Llanvirn graptolites
TC78-39 m* (GSC loc. O-104293) – conodonts
TC78-75 m – *N. gracilis* Zone

TC78-133 m – *L. acinaces* Zone
TC78-136 m – *C. gregarius* Zone
TC78-138 m – *M. triangularis* or (?)*D. magnus* Zone
TC78-139 m – *M. argenteus* Zone
TC78-142 m – *M. convolutus* Zone
TC78-144 m* (GSC loc. O-104294) – conodonts
TC78-144 m – *M. turriculatus* Zone
TC78-148 m – *M. turriculatus* Zone
TC78-168 m – *M. spiralis* Zone
TC78-192 m (GSC loc. O-104295) – conodonts
TC78-192 m – *M. spiralis* Zone
TC78-200 m (GSC loc. O-104296) – conodonts
TC78-212 m (GSC loc. O-104297) – conodonts
TC78-213 m – *C. sakmaricus–C. laqueus* Zone
TC78-218 m (GSC loc. O-104298) – conodonts
TC78-222 m* (GSC loc. O-104299) – conodonts
TC78-228 m – *C. sakmaricus–C. laqueus* Zone
TC78-230 m (GSC loc. O-104300) – conodonts
TC78-232 m – Wenlock indeterminate graptolites
TC78-233 m – Wenlock indeterminate graptolites
TC78-236 m (GSC loc. O-104301) – conodonts
TC78-270 m* (GSC loc. O-104302) – conodonts
TC78-273 m – *M. lundgreni* Zone
TC78-281 m (GSC loc. O-104303) – conodonts
TC78-286 m (GSC loc. O-104304) – conodonts
TC78-319 m (GSC loc. O-104305) – conodonts
TC78-320 m – *N. nilssoni* Zone
TC78-388 m* (GSC loc. O-104306) – barren of conodonts
TC78-406 m – *M. formosus* Zone

Plates 1 to 4

PLATE 1

Figures 1-4, 7-9, 11, 12, 15, 16, 18, 25, 28-30. *Aspelundia petila* (Nicoll and Rexroad).

1, 7, 11, 16. *a*-1 elements, inner views, hypotypes GSC 101041, x90, GSC 101042, x60, GSC 101043, x60, GSC 101044, x50, GSC loc. O-104269, except GSC 101042 from GSC loc. O-104270.

2, 9, 15, 18. *e*-1 elements, lateral views, hypotypes GSC 101045, x120, GSC 101046, x65, GSC 101047, x85, GSC 101048, x95, GSC loc. O-104269.

3. *e*-2 element, lateral view, hypotype GSC 101049, x65, GSC loc. O-104269.

4, 8, 12. *a*-2 elements, inner views, hypotypes GSC 101050, x65, GSC 101051, x50, GSC 101052, x60, GSC loc. O-104269.

25, 28-30. *b* elements, posterior views, hypotypes GSC 101053, x90, GSC 101054, x70, GSC 101055, x85, GSC 101056, x65, GSC loc. O-104269.

Figures 5, 6, 10, 13, 14, 17, 19-24, 26, 27, 31, 32. *Aspelundia fluegeli* (Walliser).

5, 6, 19, 24. *e*-1 elements, lateral views, hypotypes GSC 101005, x70, GSC 101006, x90, GSC 101007, x70, GSC 101008, x70, GSC loc. O-104269.

10. *e*-2 element, lateral view, hypotype GSC 101009, x70, GSC loc. O-104269.

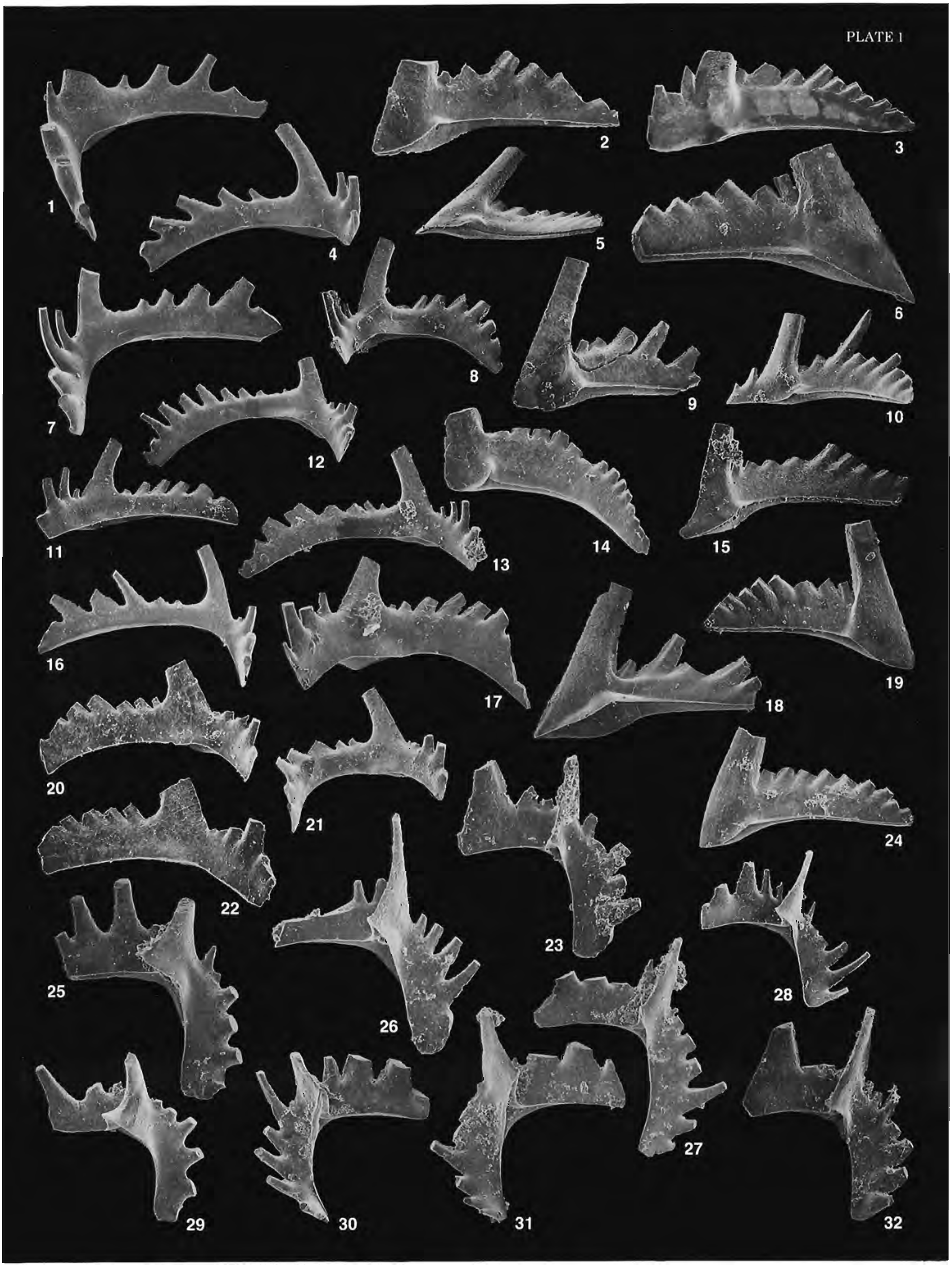
13, 17, 20, 21. *a*-2 elements, inner views, hypotypes GSC 101010, x50, GSC 101011, x100, GSC 101012, x70, GSC 101013, x55, GSC loc. O-104269.

14. *e*-3 element, lateral view, hypotype GSC 101014, x85, GSC loc. O-104269.

22. *a*-1 element, inner view, hypotype GSC 101015, x90, GSC loc. O-104269.

23, 26, 27, 31, 32. *b* elements, posterior views, hypotypes GSC 101016, x100, GSC 101017, x110, GSC 101018, x85, GSC 101019, x90, GSC 101020, x90, GSC loc. O-104269.

PLATE 1



1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32

PLATE 2

Figures 1, 2, 5, 6, 9, 12, 16, 26-28, 30, 31. *Aspelundia petila* (Nicoll and Rexroad).

1, 2, 5. *f* elements, inner-upper views, hypotypes GSC 101057, x 65, GSC 101058, x125, inner-lower view, hypotype GSC 101059, x115, GSC loc. O-104269.

6. *f* element (?second morphotype), inner-upper view, hypotype GSC 101060, x65, GSC loc. O-104269.

9. *f* element, inner lateral-lower view, hypotype GSC 101061, x60, GSC loc. O-104269.

12, 16. *g* elements, posterior and anterior views, hypotypes GSC 101062, x105, GSC 101063, x70, GSC loc. O-104269.

26-28, 30, 31. *c* elements, anterolateral view, hypotype GSC 101064, x70, posterolateral view, hypotype GSC 101065, x70, anterolateral view, hypotype GSC 101066, x150, posterolateral views, hypotypes GSC 101067, x90, GSC 101068, x85, GSC loc. O-104269.

Figures 3, 4, 7, 8, 10, 11, 13-15, 17-25, 29, 32. *Aspelundia fluegeli* (Walliser).

3, 4, 10, 11. *g* elements, antero-upper views, hypotypes GSC 101021, x105, GSC 101022, x75, GSC 101023, x90, GSC 101024, x110, GSC loc. O-104269.

7, 8, 13, 14. *g* elements, anterior views, hypotypes GSC 101025, x95, GSC 101026, x95, posterior views, hypotypes GSC 101027, x70, GSC 101028, x70, GSC loc. O-104269.

15, 17, 19, 22, 24. *f* elements, inner lateral-upper view, hypotype GSC 101029, x90, inner lateral-lower view, hypotype GSC 101030, x55, inner lateral-upper view, hypotype GSC 101031, x90, inner view, hypotype GSC 101032, x155, inner lateral-lower view, hypotype GSC 101033, x90, GSC loc. O-104269.

18, 20,21, 23, 25, 29, 32. *c* elements, antero-upper view, hypotype GSC 101034, x55, anterolateral view, hypotype GSC 101035, x50, lateral-upper view, hypotype GSC 101036, x90, lateral view, hypotype GSC 101037, x110, antero-upper views (specimen lost, hypotype GSC 101038), hypotypes GSC 101039, x70, GSC 101040, x90, GSC loc. O-104269.

PLATE 2

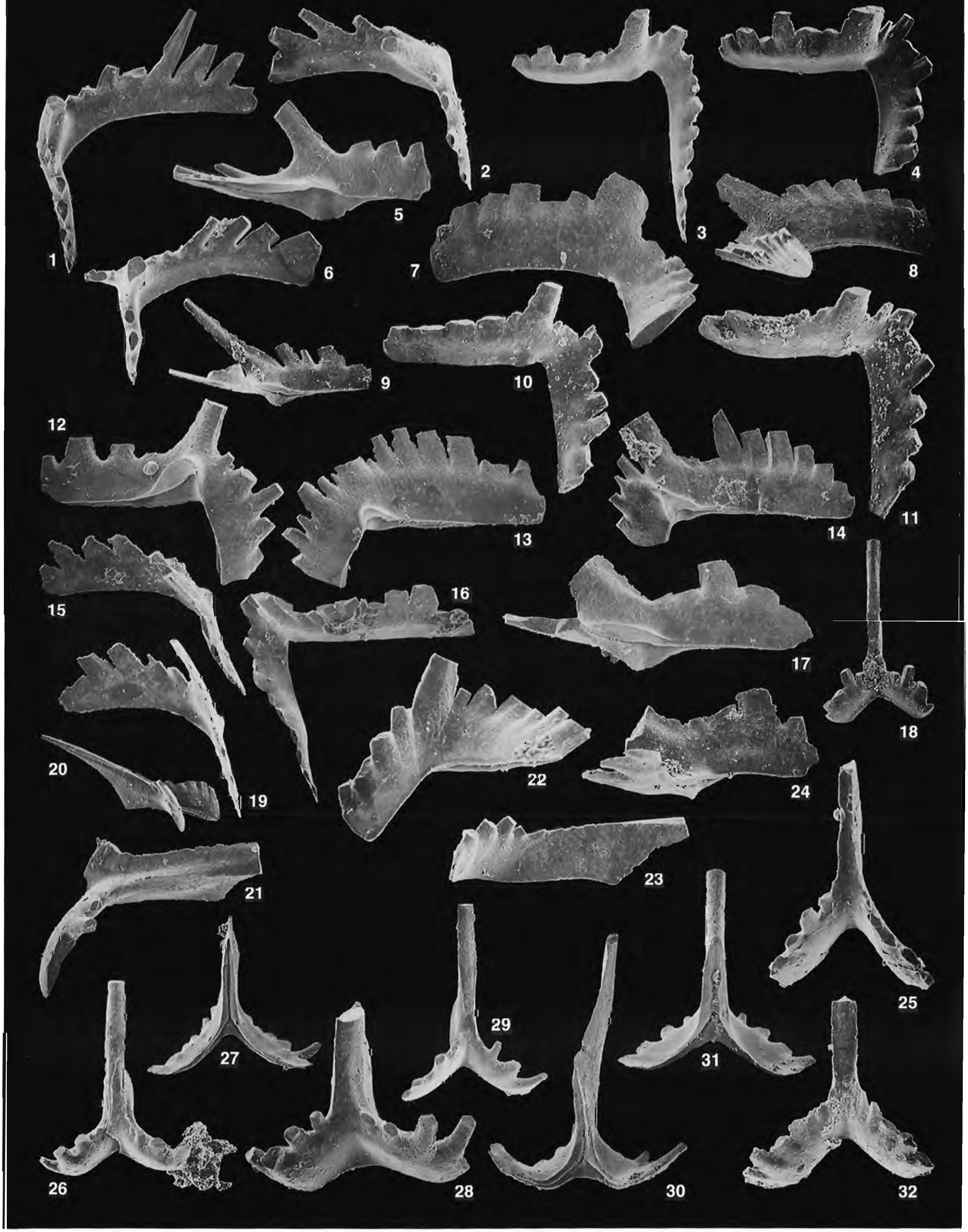

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32

PLATE 3

Figures 1-42. *Walliserodus blackstonensis* n. sp.

1-3. *a* elements, inner views, paratypes GSC 101095, x90, GSC 101096, x90, GSC 101097, x75, GSC loc. O-104269.

6, 4, 5, 7, 9. *a* elements, outer views, paratypes GSC 101098, x75, GSC 101099, x55, GSC 101100, x90, GSC 101101, x90, GSC 101102, x80, GSC 101103, x70, GSC loc. O-104269.

10, 11, 18. *b*-1 elements, outer views, paratypes GSC 101104, x90, GSC 101105, x65, GSC 101106, x80, GSC loc. O-104269.

12. *b*-1 element, inner view, paratype GSC 101107, x80, GSC loc. O-104269.

13, 16, 17. *b*-2 elements, inner views, paratypes GSC 101108, x65, GSC 101109, x90, GSC 101110, x110, GSC loc. O-104269.

14, 19, 20, 24. *c* elements, lateral views, holotype GSC 101111 x70, paratypes GSC 101112, x120, GSC 101113, x60, GSC 101114, x100, GSC loc. O-104269.

15. *b*-2 element, outer view, paratype GSC 101115, x60, GSC loc. O-104269.

21, 25. Symmetrical *c* element, posterior and lateral views, paratype GSC 101116, x80, GSC loc. O-104269.

22, 27. Slightly asymmetrical *c* element, posterior and lateral views, paratype GSC 101117, x80, GSC loc. O-104269.

23, 26. Slightly asymmetrical *c* element, posterior and lateral views, paratype GSC 101118, x80, GSC loc. O-104269.

28, 30, 31, 33, 38. *e* elements, lateral views, paratypes GSC 101119, x95, GSC 101120, x65, GSC 101121, x65, GSC 101122, x70, GSC 101123, x70, GSC loc. O-104269.

29, 32, 34-37, 39-42. *d* elements, lateral views, paratypes GSC 101124, x55, GSC 101125, x125, GSC 101126, x85, GSC 101127, x55, GSC 101128, x85, GSC 101129, x90, GSC 101130, x55, GSC 101131, x75, GSC 101132, x85, GSC 101133, x85, GSC loc. O-104269.

PLATE 3

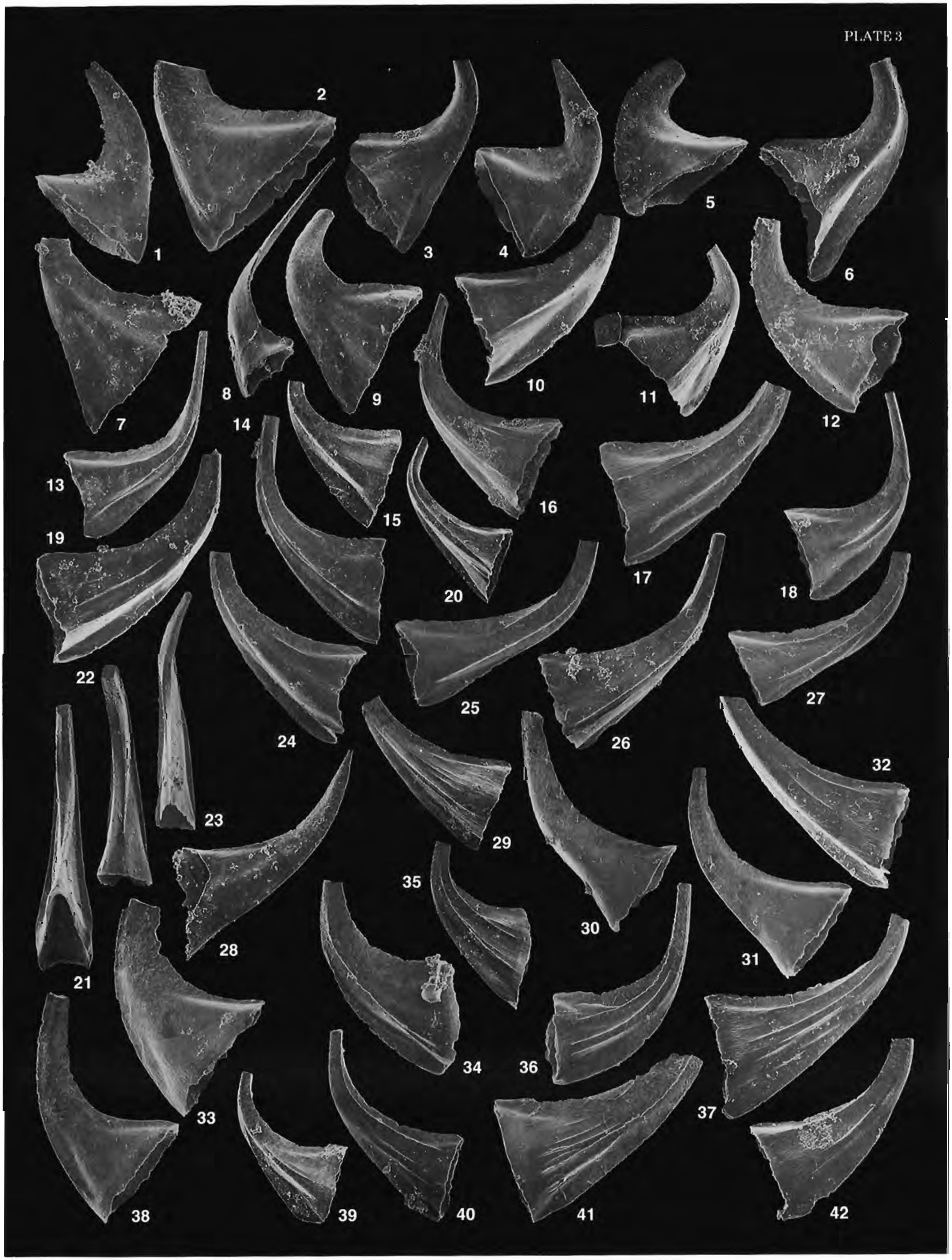

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42

PLATE 4

Figures 1, 2. *Walliserodus*? n. sp. B.

Outer and inner views, *a*? (oistodontiform) elements, figured specimens GSC 101147, x140, GSC 101148, x120, GSC loc. O-104297.

Figures 3-10, 15. *Walliserodus sancticlairi* Cooper.

3, 5. *b* elements, inner views, hypotypes GSC 101138, x70, GSC 101139, x65, GSC loc. O-104269.
4. *b* element, outer view, hypotype GSC 101140, x55, GSC loc. O-104269.
6, 9. *a* elements, inner views, hypotypes GSC 101141, x65, GSC 101142, x75, GSC loc. O-104269.
7. *d* element, lateral view, hypotype GSC 101143, x95, GSC loc. O-104269.
8, 15. *e* elements, lateral views, hypotypes GSC 101144, x45, GSC 101145, x105, GSC loc. O-104269.
10. *c* element, lateral view, hypotype GSC 101146, x90, GSC loc. O-104269.

Figure 12. *Walliserodus curvatus* (Branson and Branson).

e element, lateral view, hypotype GSC 101137, x75, GSC loc. O-104269.

Figures 11, 13, 14, 16-28, 30-32, 35, 40. *Dapsilodus obliquicostatus* (Branson and Mehl).

11. *a* element, lateral view, hypotype GSC 101069, x100, GSC loc. O-104297.
13, 28, 32. *c* elements, lateral views, hypotypes GSC 101070, x150, GSC 101071, x140, GSC 101072, x125, GSC loc. O-104269, except specimen in figure 32, from GSC loc. O-104297.
14, 24. *b* element, lateral views, hypotype GSC 101073, x105, x115, GSC loc. O-104269.
16, 19-21. *b* elements, lateral views, hypotypes GSC 101074, x65, GSC 101075, x115, GSC 101076, x115, GSC 101077, x130, GSC loc. O-104269.
17, 18. *e* elements, outer and inner views, hypotypes GSC 101078, x65, GSC 101079, x65, GSC loc. O-104269.
22, 23. *b* element, lateral views, hypotype GSC 101080, x95, x75, GSC loc. O-104269.
25, 35. *b* elements, lateral views, hypotypes GSC 101081, x95, GSC 101086, x145, GSC loc. O-104269 and GSC loc. O-104279, respectively.
26, 27, 30, 31, 40. *b* elements, lateral views, hypotypes GSC 101082, x145, GSC 101083, x140, GSC 101084, x90, GSC 101085, x125, GSC 101087, x130, GSC loc. O-104297.

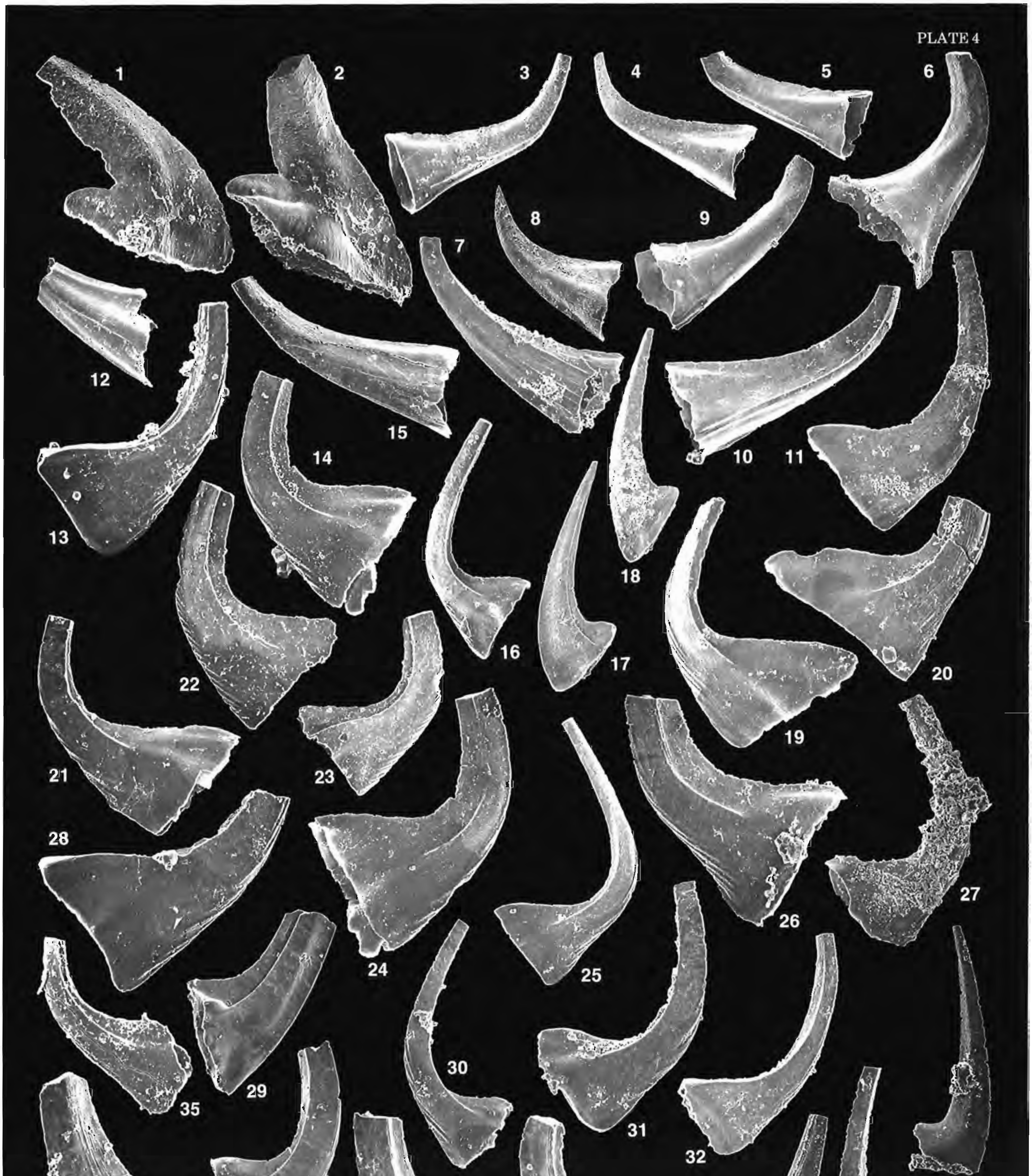
Figures 33, 39. *Decoriconus fragilis* (Branson and Mehl).

33. *b* element, lateral view, hypotype GSC 101093, x75, GSC loc. O-104269.
39. *c* element, lateral view, hypotype GSC 101094, x85, GSC loc. O-104269.

Figures 29, 34, 36-38. *Dapsilodus*? sp. B.

29, 34. *e* elements, inner and outer views, figured specimens GSC 101088, x85, GSC 101089, x105, GSC loc. O-104284.
36-38. *a-b* elements, outer, inner and inner views, figured specimens GSC 101090, x80, GSC 101091, x90, GSC 101092, x110, GSC loc. O-104284.

PLATE 4


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40

Silurian conodont biostratigraphy of the Canadian Cordillera with a description of new Llandovery species

Alexander D. McCracken[1]

McCracken, A.D., 1991: Silurian conodont biostratigraphy of the Canadian Cordillera with a description of new Llandovery species. In Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417, p. 97-127.

Abstract

Silurian (Llandovery–Pridoli) conodont faunas are found at twelve localities in four regions of the Canadian Cordillera. These are: Richardson and Ogilvie mountains in Yukon Territory (Pat Lake, Rock, and Blackstone rivers, Tetlit Creek), Selwyn Mountains (Howards Pass, Yukon, and Northwest Territories), Mackenzie Mountains (Avalanche and Glacier lakes, South Nahanni River, Northwest Territories), and the northeastern (Kechika River), east-central (McLeod Lake), and southeastern (Mount Tegart, Pedley Pass) Rocky Mountains of British Columbia.

The following faunas and zones are described: Ozarkodina *n. sp. A*–Icriodella *sp. B fauna (lower Llandovery on the basis of conodonts, but Upper Ordovician on the basis of graptolites); ?*Oulodus*?* nathani*;* Distomodus kentuckyensis*;* D. staurognathoides, ?Dapsilodus obliquicostatus*; ?*Aspelundia petila*;* A. fluegeli *(all lower Llandovery);* Pterospathodus celloni *(mid–upper Llandovery);* P. amorphognathoides *(upper Llandovery–lower Wenlock);* Ozarkodina *sp. cf.* O. douroensis *fauna (Wenlock);* Kockelella patula *(Wenlock);* Ancoradella ploeckensis *or* Polygnathoides siluricus *(Ludlow);* Ozarkodina bohemica *(Wenlock–Ludlow?);* Polygnathoides siluricus *(Ludlow);* Pelekysgnathus arcticus *fauna (Ludlow–Pridoli);* Ozarkodina eosteinhornensis–Icriodus woschmidti *(Pridoli–lower Lochkovian).*

Two new species, Astropentagnathus araneum *n. sp. and* Pterospathodus retroramus *n. sp., from within the* P. celloni *Zone of northern Yukon, are formally described.*

Résumé

Des faunes à conodontes du Silurien (Llandovérien–Pridolien) se rencontrent à 12 sites dans 4 régions de la Cordillère canadienne. Ces régions (et leurs sites) sont les suivants : monts Richardson et Ogilvie (lac Pat, rivières Rock et Blackstone, ruisseau Tetlit), au Yukon; chaîne Selwyn (col Howards), au Yukon et dans les Territoires du Nord-Ouest; monts Mackenzie (lacs Avalanche et Glacier, rivière Nahanni-Sud), dans les T.N.-O.; et parties nord-ouest (rivière Kechika), centre est (lac McLeod) et sud-est des Rocheuses (mont Tegart, col Pedley), en Colombie-Britannique.

L'auteur décrit les faunes et les zones suivantes : faune à Ozarkodina *n. sp. A*–Icriodella *sp. B (Llandovérien inférieur d'après les conodontes, mais Ordovicien supérieur d'après les graptolites); ?*Oulodus*?* nathani*;* Distomodus kentuckyensis*;* D. staurognathoides, ?Dapsilodus obliquicostatus*; ?*Aspelundia petila*;* A. fluegeli *(Llandovérien inférieur);* Pterospathodus celloni *(Llandovérien moyen à supérieur);* P. amorphognathoides *(Llandovérien supérieur au Wenlockien inférieur); faune à* Ozarkodina *sp. cf.* O. douroensis *(Wenlockien);* Kockelella patula *(Wenlockien);* Ancoradella ploeckensis *ou* Polygnathoides siluricus *(Ludlowien);* Ozarkodina bohemica *(Wenlockien–Ludlowien?);* Polygnathoides siluricus *(Ludlowien); faune à* Pelekysgnathus arcticus *(Ludlowien au Pridolien);* Ozarkodina eosteinhornensis–Icriodus woschmidti *(Pridolien–Lochkovien inférieur).*

L'auteur présente une description formelle de Astropentagnathus araneum *n. sp. et de* Pterospathodus retroramus *n. sp., qui font partie de la zone à* P. celloni *du nord du Yukon.*

---

[1] Geological Survey of Canada, 601 Booth St., Ottawa, Ontario K1A 0E8

INTRODUCTION

Much of the research on Silurian conodont biostratigraphy in the Canadian Cordillera has been reconnaissance in nature. Many of the age determinations are included in unpublished reports, or cited within published studies. Areas of basin and platform margin strata that have received attention in recent years are: 1) Richardson and Ogilvie mountains of northern Yukon Territory; 2) Mackenzie Mountains in southwestern District of Mackenzie, Northwest Territories; 3) Selwyn Mountains in southeastern Yukon and southwestern District of Mackenzie; and 4) Rocky Mountains of British Columbia.

Silurian conodonts from the southern Mackenzie Mountains and the Rocky Mountains have been studied as a complement to regional mapping by M.J. Orchard and T.T. Uyeno. Over 150 of these samples from basin and platform strata were given to the author for incorporation into his current research on Ordovician–Silurian conodonts of the northern Canadian Cordillera (see McCracken, 1989). Of these collections, 43 representative samples (Appendix) from 12 localities are discussed in this paper. These represent each of the four regions cited above (Fig. 1).

LITHOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENT

The Road River Group is a thick sequence of dark shale, limestone, and chert that ranges in age from Late Cambrian to Early Devonian. In northern Yukon, these strata are exposed in sections at Rock River, Tetlit Creek, Blackstone River, and Pat Lake (Fig. 1, locs. 1–4). The group correlates with numerous formations representing shallow water carbonate facies, for example, the Sunblood and Whittaker formations of the Mackenzie Mountains, and the Ogilvie, Mount Kindle, and Franklin Mountain formations of the Mackenzie and Porcupine platforms. In the Selwyn Mountains, the Road River Group is overlain by siliceous shale and coarse clastics of the Earn Group. The lead-zinc mineralization of Howards Pass (Fig. 1, loc. 8) occurs in strata of the Road River Group in the Selwyn Basin (Norford and Orchard, 1985). The group also occurs in the Rocky Mountains of the Kechika River area (Fig. 1, loc. 9) in northeastern British Columbia.

Strata of the Whittaker Formation at Avalanche Lake (Fig. 1, loc. 7) in the Mackenzie Mountains comprise interbedded argillaceous limestone, cherty limestone, and calcareous shale, and represent a transitional facies between the type Whittaker Formation and the Road River Group. The Whittaker Formation at Avalanche Lake is succeeded by the Road River Group, which in turn is overlain by, and in part interfingers with, limestone of the Delorme Group (Over and Chatterton, 1987). Further to the northeast in the South Nahanni River area (Fig. 1, loc. 5) of the Mackenzie Mountains are found the siltstone, calcareous siltstone, and limestone of the informally named Sapper formation (Pohler and Orchard, 1991; formalized by Gordey, in press). Strata of the Whittaker Formation and Delorme Group are also found immediately to the east in the Glacier Lake area (Fig. 1, loc. 6). In east-central British Columbia, the Nonda and Sandpile groups consist of dolostone, sandstone and limestone at McLeod Lake (Fig. 1, loc. 10; Struik et al., 1990). Carbonates also dominate the area of Mount Tegart and Pedley Pass (Fig. 1, locs. 11, 12) in southeastern British Columbia, where limestone and dolostone of the Beaverfoot Formation are succeeded by the argillaceous limestone of the Tegart Formation (Norford, 1969).

The sections in northern Yukon are part of the Richardson and Blackstone troughs, which were relatively narrow basins bounded by shallower water platforms. The Blackstone River and Pat Lake sections are within the Blackstone Trough; the Rock River and Tetlit Creek sections are within the Richardson Trough (Lenz and McCracken, 1989).

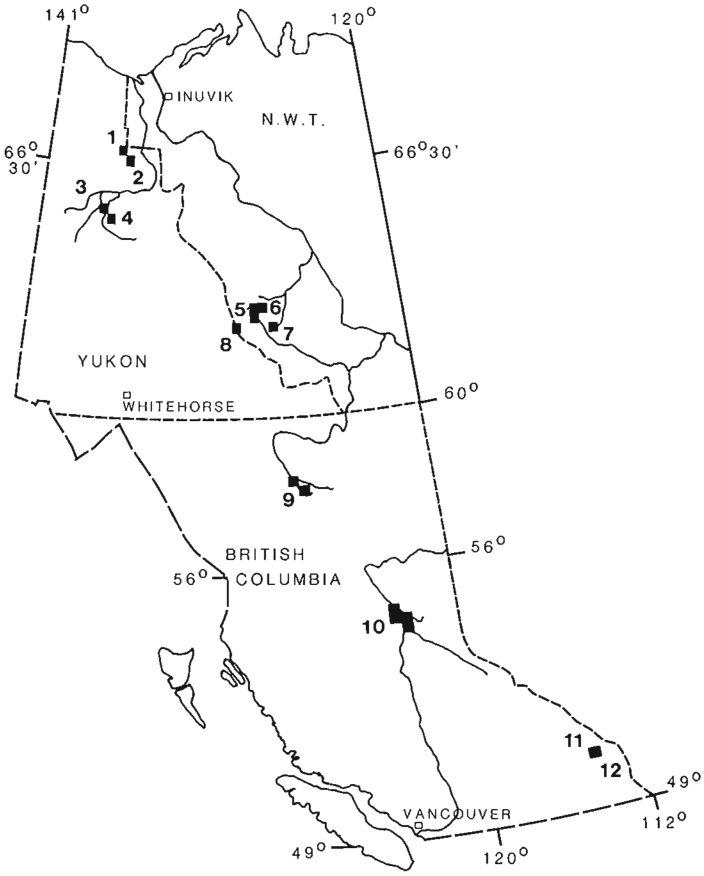


Figure 1. Locality map showing National Topographic System (NTS) map sheet areas. 1) Rock River, NTS 116 I/16, 66°48′N, 136°16′W; 2) Tetlit Creek, NTS 106 L/12, 66°44′N, 135°47′W; 3) Blackstone River, NTS 116 H/6, 65°26′N, 137°20′W; 4) Pat Lake, NTS 116 H/2, 65°09′N, 136°42′W, and Pat Lake South, 65°08′N, 136°38′W; 5) South Nahanni River, NTS 105 I/9, 105 I/16, 62°33′N, 128°07′W to 63°00′N, 128°26′W; 6) Glacier Lake, NTS 95 L/13, 62°58′N, 127°55′W to 62°59.5′N, 127°56′W; 7) Avalanche Lake, NTS 95 L/6, 62°23′N, 127°02′W; 8) Howards Pass, NTS 105 I/6, 62°27.5′N, 127°12′W; 9) Kechika River, NTS 94 L/1, 94 L/7, 58°04′N, 126°06′W to 58°24′N, 126°40′W; 10) McLeod Lake, NTS 93 J/8-10, 93 J/15, 54°28′N, 122°26′W to 54°54′N, 122°46′W; 11) Mount Tegart, NTS 82 J/5, 50°27′N, 122°51′W; 12) Pedley Pass, NTS 82 J/5, 50°27′N, 115°46′W.

Strata at Howards Pass in the Selwyn Mountains represent the Selwyn Basin, whereas those to the east and north at Avalanche and Glacier lakes and South Nahanni River represent the margin between the Silurian shelf carbonate facies of the Mackenzie Platform and the basinal clastic facies of the Selwyn Basin. Strata at Kechika River are part of the Kechika Trough just west of the MacDonald Platform. This trough was a southern extension of the Selwyn Basin and was bordered to the immediate west by the Northern Rocky Mountain Trench and an extension of the Cassiar Platform (Over and Chatterton, 1987; Pohler and Orchard, 1991).

Southeast of Kechika River are the McLeod Lake sections, which are in the region of the upper Llandovery Kakwa Platform (Cecile and Norford, 1985). The Mount Tegart and Pedley Pass area of southeastern British Columbia is in the region of the upper Caradoc–Ashgill Bow Platform of Cecile and Norford (1985). These strata represent a carbonate platform, which was described by Norford (1988) as being a considerable distance from the platform front.

CONODONT BIOSTRATIGRAPHY

Many of the previous studies of conodonts from northwestern Canada have either been preliminary reports, or have dealt with conodonts younger or older than Silurian.

Silurian and Devonian conodont identifications are included in the reports of Norford et al. (1970, 1973), and Pugh (1983, Appendix 1) included conodont data from two drillholes near Tetlit Creek and one near Blackstone River (Fig. 1, locs. 2, 3). Uyeno *in* Pugh (*ibid.*, p. 28-31) identified *Belodella* sp., *Ozarkodina e. excavata* (Branson and Mehl) and *Panderodus* spp. from an interval tentatively assigned to the Mount Kindle Formation. This collection was regarded as Silurian, probably Wenlock to Ludlow in age.

Klapper *in* Lenz and Pedder (1972) identified the gamma morphotype of the Wenlock–Pridoli *Ozarkodina confluens* (Branson and Mehl) and *O. e. excavata*, and the Pridoli *O. r. remscheidensis* (Ziegler) and *Pelekysgnathus* n. sp. A from the Road River Group at Royal Creek in the Wernecke Mountains (east of Blackstone River). The monograph on northern Yukon graptolites and brachiopods by Jackson et al. (1978) included conodont identifications made by B.D.E. Chatterton, G. Klapper and T.T. Uyeno. Their oldest Silurian fauna was called the lower Pridoli *Pelekysgnathus index* associates, on the basis of earlier identifications by Klapper (*Pelekysgnathus* n. sp. A was named *P. index* by Klapper and Murphy, 1975). Younger faunas from Royal Creek included *O. r. remscheidensis*, *O. r. eosteinhornensis* (Walliser), *O.* sp. nov. E, and *O.* sp. nov. X. Because these pre-date the earliest occurrence of *Icriodus woschmidti* Ziegler, Jackson et al. (1978) regarded these collections as upper Pridoli.

Orchard (1984) gave a brief account of the conodonts from the Nahanni area of the Mackenzie Mountains in southeastern Yukon, where reconnaissance samples yielded conodonts ranging in age from Late Cambrian to Early Triassic; his Silurian faunas included taxa of the Llandovery *P. celloni* Zone and upper Llandovery–lower Wenlock *P. amorphognathoides* Zone. Detailed taxonomic reports have been written on the nearby Avalanche Lake faunas by Over and Chatterton (1987) and Nowlan et al. (1988). These faunas are, respectively, Silurian and Late Ordovician–Early Silurian in age; more discussion on them follows. Orchard (*in* Norford and Orchard, 1985) reported on Ordovician to Devonian conodonts from both drill core and outcrop samples from west of Avalanche Lake, at the stratiform lead–zinc deposit of Howards Pass in the Selwyn Mountains of Yukon and Northwest Territories (Silurian faunas are discussed below).

The following faunas and biozones are described herein: *Ozarkodina* n. sp. A–*Icriodella* sp. B fauna (lower Llandovery on the basis of conodonts, but Upper Ordovician on the basis of graptolites); ?*Oulodus*? *nathani*; *Distomodus kentuckyensis*; *D. staurognathoides*; ?*D. obliquicostatus*; ?*Aspelundia petila*; *A. fluegeli* (all lower Llandovery); *Pterospathoides celloni* (mid–upper Llandovery); *P. amorphognathoides*; *Ozarkodina* sp. cf. *O. douroensis* fauna (both upper Llandovery–lower Wenlock); *Kockelella patula* (Wenlock); *Ancoradella ploeckensis* or *Polygnathoides siluricus* (Ludlow); *Ozarkodina bohemica* (Wenlock–Ludlow?); *Polygnathoides siluricus* (Ludlow); *Pelekysgnathus arcticus* fauna (Ludlow–Pridoli); *Ozarkodina eosteinhornensis*–*Icriodus woschmidti* (Pridoli–lower Lochkovian). Figure 2 illustrates the integrated conodont and graptolite biostratigraphic scheme for the Canadian Cordillera. In the following discussion, these are grouped according to geographic region, from northern Yukon to southeastern British Columbia. All zones discussed below are defined by the first occurrence of the nominate species, and all terminate with the beginning of the succeeding zone.

Richardson–Ogilvie Mountains, (Fig. 1, locs. 1-4) Yukon Territory

Ozarkodina n. sp. A–_Icriodella_ sp. B fauna

Strata. Road River Group.

Locality. Pat Lake, loc. 4 (GSC loc. C-085944, C-085946–085949).

Significant conodonts. Ozarkodina n. sp. A (= *O.* sp. Lenz and McCracken).

Other conodonts. Icriodella sp. B, *Panderodus*? *gibber* Nowlan and Barnes, *P.* sp., *Walliserodus* sp.

Associated graptolite zones. Lowest level is 1 m above *P. pacificus* Zone; highest level is 6.3 m below ?*G. persculptus* Zone and 17.3 m below *P. acuminatus* Zone (Lenz and McCracken, 1982).

Remarks. This fauna was interpreted by Lenz and McCracken (1982) as lower Llandovery because of the Silurian aspect of the *Ozarkodina* elements, and because they tentatively identified the traditional basal Silurian *G. persculptus* Zone just above the conodont interval. Since then, the base of the Silurian has been placed at the base of the *P. acuminatus* Zone and thus the underlying ?*G. persculptus* Zone and conodont fauna are regarded as Upper Ordovician.

Equivalent strata from a nearby section (Pat Lake South) have yielded more of the *Ozarkodina* elements collected in 1986. Three of these samples each contain a single Ordovician element. The lowest (GSC loc. C-150617), 3.5 m above the base of the carbonate unit, contains an abraded(?) element of *Belodina*; the second, at 3.9 m (GSC loc. C-150634), includes *Drepanoistodus*; and the third, at 5.3 m (GSC loc. C-150635), contains *Scabbardella*. The two higher Ordovician elements are neither abraded nor corroded. Other elements in these samples represent species of *Icriodella*, *Panderodus*, and *Walliserodus*. The Ordovician elements have the same conodont Colour Alteration Index (CAI) values as the other elements in the samples, so are not obvious contaminants.

?*Dapsilodus obliquicostatus* Zone

Remarks. This zone [McCracken, 1991 (this volume)] in the basin facies has not yet been recognized in the Cordillera. *Dapsilodus obliquicostatus* (Branson and Mehl) was probably a pelagic conodont and a common component of basinal environments. The zone may correlate with the lowermost Llandovery *O.? nathani* Zone of the carbonate platform environment.

?*Aspelundia petila* Zone

Remarks. The ?*A. petila* Zone has not been recognized in the Cordillera, but it is equivalent to the *A. expansa* Zone (Armstrong, 1990) of Greenland (former species name has priority). This zone probably corresponds to the lower part of the *D. kentuckyensis* Zone [McCracken, 1991 (*this volume*)].

Aspelundia fluegeli Zone

Strata. Road River Group.

Locality. Blackstone River, loc. 3 (GSC loc. O-104269).

Significant conodonts. Aspelundia fluegeli (Walliser), *A. petila* (Nicoll and Rexroad), *Dapsilodus obliquicostatus*, *Distomodus* sp. cf. *D. kentuckyensis* Branson and Branson *sensu* Cooper, *Ozarkodina* sp. aff. *O. polinclinata* (Nicoll and Rexroad), *Walliserodus blackstonensis* McCracken (Pl. 5, figs. 16–19, 21, 22).

Other conodonts. Decoriconus fragilis (Branson and Mehl), *Ozarkodina* sp. B, *Panderodus* spp., *Walliserodus curvatus* (Branson and Branson), *Walliserodus sancticlairi* Cooper, *W.*? n. sp. B, *W.* spp.

Associated graptolite zones. Within *M. turriculatus* Zone, 13 m above *M. sedgwicki* Zone, 13.4 m below *M. spiralis* Zone (Lenz, 1982).

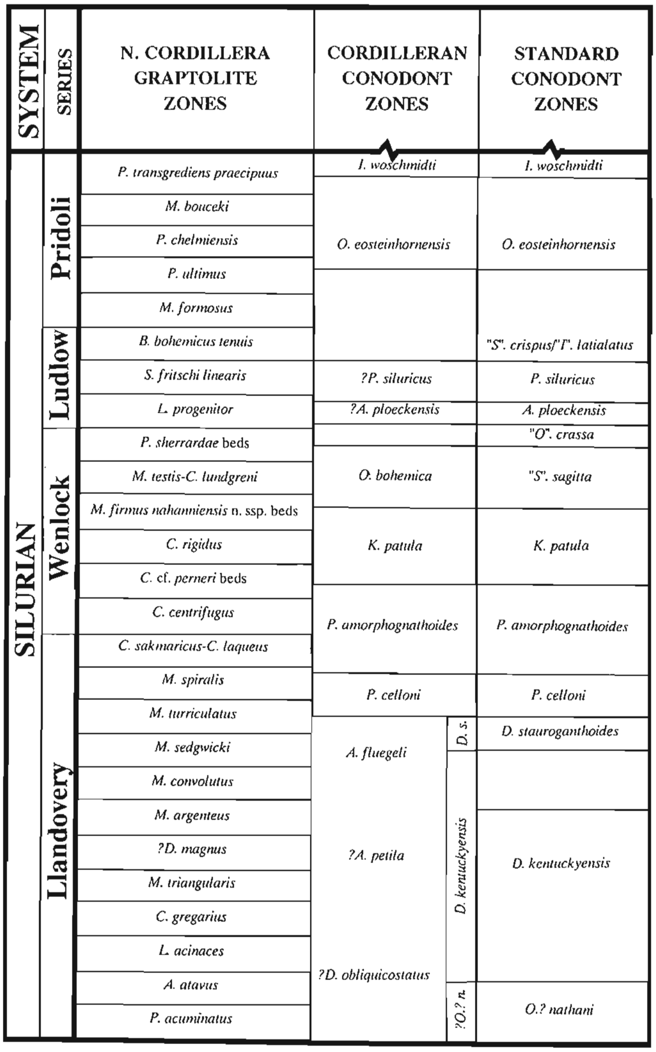
Remarks. The *A. fluegeli* Zone corresponds to the same zone in Greenland (Armstrong; 1990), and is probably equivalent to the upper part of the *D. kentuckyensis* Zone. Further discussion of this and the above two zones, and taxonomic discussion of *Walliserodus blackstonensis*, can be found in McCracken [1991 (*this volume*)].

Pterospathodus celloni Zone

Strata. Road River Group.

Locality. Blackstone River, loc. 3 (GSC loc. O-104270).

Significant conodonts. Astropentagnathus araneum n. sp. (Pl. 2, figs. 1–10), *A. irregularis* Mostler (Pl. 2, figs. 11–19), *Aulacognathus bullatus* (Nicoll and Rexroad) (Pl. 3, figs. 1, 2), *A. nelsoni* Over and Chatterton (Pl. 3, fig. 5), *Ozarkodina* sp. aff. *O. polinclinata*, *P. celloni* (Walliser) (angulatiform, celloniform, and pennatiform elements; Pl. 4, figs. 4–11), *Pterospathodus retroramus* n. sp. (Pl. 4, figs. 24, 25, Pl. 5, figs. 1–5), N. gen. B n. sp. A.



SYSTEM	SERIES	N. CORDILLERA GRAPTOLITE ZONES	CORDILLERAN CONODONT ZONES		STANDARD CONODONT ZONES
SILURIAN	Pridoli	*P. transgrediens praecipuus*	*I. woschmidti*		*I. woschmidti*
		M. bouceki	*O. eosteinhornensis*		*O. eosteinhornensis*
		P. chelmiensis			
		P. ultimus			
		M. formosus			
	Ludlow	*B. bohemicus tenuis*			"*S*". *crispus*/"*T*". *latialatus*
		S. fritschi linearis	?*P. siluricus*		*P. siluricus*
		L. progenitor	?*A. ploeckensis*		*A. ploeckensis*
	Wenlock	*P. sherrardae* beds			"*O*". *crassa*
		M. testis-C. lundgreni	*O. bohemica*		"*S*". *sagitta*
		M. firmus nahanniensis n. ssp. beds	*K. patula*		*K. patula*
		C. rigidus			
		C. cf. perneri beds			
		C. centrifugus	*P. amorphognathoides*		*P. amorphognathoides*
	Llandovery	*C. sakmaricus-C. laqueus*			
		M. spiralis	*P. celloni*		*P. celloni*
		M. turriculatus			
		M. sedgwicki	*A. fluegeli*	*D. s.*	*D. staurognathoides*
		M. convolutus		*D. kentuckyensis*	
		M. argenteus	?*A. petila*		*D. kentuckyensis*
		?*D. magnus*			
		M. triangularis			
		C. gregarius			
		L. acinaces	?*D. obliquicostatus*		
		A. atavus		?*O.*? *n.*	*O.*? *nathani*
		P. acuminatus			

Figure 2. Conodont and graptolite zones and faunas, Yukon Territory, southwestern District of Mackenzie, Northwest Territories, and eastern British Columbia. Graptolite successsion is from Lenz (1980, 1988a, 1988b; pers. comm., 1991) and Lenz and McCracken (1989).

Other conodonts. Aspelundia fluegeli, A. petila, Astropentagnathus indet. elements, *Dapsilodus obliquicostatus, Distomodus kentuckyensis*?, *D.* sp. cf. *D. kentuckyensis sensu* Cooper, *Oulodus*? n. sp. A, *O.*? n. sp. B (Pl. 3, figs. 22, 23), *Ozarkodina* sp. B, *Panderodus* spp., *Pterospathodus* indet. elements, *Walliserodus curvatus*, indet. zygognathiform element.

Associated graptolite zones. Within *M. turriculatus* Zone, 21.3 m above *M. sedgwicki* Zone, 5.1 m below *M. spiralis* Zone (Lenz, 1982).

Remarks. Schönlaub (1975) recorded new form taxa (*Falcodus*? n. sp. *s.f.*, *Synprioniodina typica* n. sp. *s.f.*), which are questionably assigned to N. gen. B n. sp. A, from the lower *P. celloni* Zone. A sample (GSC loc. O-104284) from within the *M. turriculatus* Zone at the Rock River section contains a fauna similar to that from Blackstone River. Species include *Astropentagnathus araneum* n. sp., *A. irregularis, Aulacognathus bullatus, Dapsilodus*? sp. B, *Distomodus* sp. cf. *D. kentuckyensis sensu* Cooper, *D. staurognathoides* (Walliser), *Oulodus*? n. sp. A, *O.*? n. sp. B, *Ozarkodina excavata* n. ssp. A, *Panderodus* spp., *P. celloni, Aspelundia fluegeli, A. petila, Pterospathodus retroramus* n. sp., *Walliserodus blackstonensis*, and N. gen. B n. sp. A.

Pterospathodus amorphognathoides Zone

Strata. Road River Group.

Locality. Tetlit Creek, loc. 2 (GSC loc. O-104297).

Significant conodonts. Carniodus carnulus Walliser, *Pterospathodus procerus* (Walliser), *Oulodus* n. sp. A, *Ozarkodina* sp. C.

Other conodonts. Aspelundia fluegeli, A. petila, Belodella silurica Barrick, *Dapsilodus obliquicostatus, Distomodus* sp., *Panderodus* spp., *Pterospathodus* indet. elements, *Walliserodus sancticlairi, W.*? n. sp. B.

Associated graptolite zones. 20 m above *M. spiralis* Zone, 1m below *C. sakmaricus–C. laqueus* Zone, 20 m below indeterminate Wenlock fauna, 61 m below *C. lundgreni* Zone (Lenz, 1982; unpublished data).

Remarks. Pterospathodus amorphognathoides is not present in the northern Yukon samples. In Oklahoma, the *P. amorphognathoides* Zone is characterized by the first appearance of *Carniodus carnulus* and *P. procerus*. Cooper (1980) noted that the *Pterospathodus* Extinction Datum (base of the *K. ranuliformis* and *K. patula* zones) approximates the level where *Oulodus petila* (= *A. petila*) and *Apsidognathus, Aulacognathus, Carniodus, Distomodus* and *Llandoverygnathus* (= *Pterospathodus*) disappear. All of these genera except *Apsidognathus* and *Aulacognathus* occur in the sample from GSC loc. O-104297. *Apsidognathus tuberculatus* occurs in strata 6 m above and 12–20 m below this sample; *Aulacognathus bullatus* occurs in the older *P. celloni* Zone on Blackstone River.

Oulodus n. sp. A has some similarities to *O. jeannae* Schönlaub of the *P. celloni* Zone, and *O.*? sp. B Mannik (1983), which is probably Wenlock in age. *Ozarkodina* sp. C is comparable to *O.* sp. C Mabillard and Aldridge (1983) from the *P. amorphognathoides* Zone.

The range of the *P. amorphognathoides* Zone is upper Llandovery to lower Wenlock. The fauna from Tetlit Creek occurs 1 m below the uppermost Llandovery *C. sakmaricus–C. laqueus* Zone (Lenz, 1982).

Selwyn Mountains, Howards Pass (Fig. 1, loc. 8), Yukon

?*Distomodus kentuckyensis* Zone

Strata. Shale–chert unit, Road River Group.

Locality. GSC loc. C-087094 (DDH 80: 329.2 m, 341 m).

Significant conodonts. Oulodus? (= *Aspelundia*) *fluegeli, O.*? sp. cf. *O.*? *fluegeli* (= *Aspelundia petila*), *Oulodus*? sp. cf. *O.*? *kentuckyensis* (Branson and Branson).

Other conodonts. Dapsilodus sp., *Distomodus*? sp., ozarkodiniform elements.

Remarks. Orchard (*in* Norford and Orchard, 1985) found similar faunas at GSC loc. C-086324 (DDH 40, 349-350.5 m) and GSC loc. C-087548 (DDH 99, 438.3 m) of the lower Earn Group, and suggested they may either represent this zone or the succeeding *P. celloni* Zone. The fauna from GSC loc. C-086324 also includes *Ozarkodina*?, *Panderodus*, and *Walliserodus*. The early Llandovery age is suggested by *Oulodus*? sp. cf. *O.*? *kentuckyensis*; some of these elements may be part of *Aspelundia petila* (cf. Norford and Orchard, 1985, Pl. 1, fig. 3).

Pterospathodus celloni Zone

Strata. Shale–chert unit, Road River Group.

Locality. GSC loc. C-086423 (DDH 29: 0 m), C-87094 (DDH 80: 266.7 m).

Significant conodonts. Astropentagnathus irregularis, "*Rhynchognathodus*" n. sp. Schönlaub, "*Falcodus*?" n. sp. Schönlaub, *Oulodus*? (= *Aspelundia*) sp. cf. *O.*? *fluegeli, Carniodus* sp.

Other conodonts. Belodella sp., *Distomodus*? sp., *Panderodus* sp., undifferentiated ramiform elements.

Remarks. The elements assigned to the form species of Schönlaub (1971) have been discussed previously (see GSC loc. O-104270). *Astropentagnathus* sp. aff. *A. transitans* (Schönlaub) is found with *Aspelundia fluegeli, Belodella* sp., *Carniodus* sp., and *Panderodus* sp. in a sample (GSC loc. C-087548; DDH 99: 423.7 m) tentatively identified as *P. celloni* Zone (Orchard *in* Norford and Orchard, 1985, p. 6).

The sample from GSC loc. C-102746 (DDH 88: 806 m) includes *A. irregularis* (Pl. 2, fig. 19), *Pterospathodus celloni* and *A. fluegeli*.

Ozarkodina sp. cf. *O. douroensis* fauna

Strata. Shale–chert unit, Road River Group.

Locality. GSC loc. C-087550 (DDH 15: 36.9–38.4 m)

Significant conodonts. Oulodus? sp. cf. *O.*? *fluegeli* (= ?*Aspelundia petila*), *O.* sp. cf. *O. douroensis* Uyeno *sensu* Norford and Orchard.

Other conodonts. Walliserodus sp.

Remarks. This fauna was unnamed in Norford and Orchard (1985). *Ozarkodina douroensis* occurs in the Ludlow *P. siluricus* Zone (Thorsteinsson and Uyeno, 1981), but evidence from the Selwyn Basin suggests this particular fauna is Wenlock in age. Norford and Orchard (1985) reported that the Wenlock *C. rigidus* Zone occurs right at the top of this lithological unit in nearby strata. This sample, if Wenlock or Ludlow in age, would extend the upper limit of *Aspelundia petila*.

Ancoradella ploeckensis or *Polygnathoides siluricus* zones

Strata. Basal Earn Group.

Locality. GSC loc. C-087094 (DDH 80: 76.2 m).

Significant conodonts. Ancoradella ploeckensis Walliser (Pl. 1, fig. 1).

Other conodonts. Undifferentiated ramiform elements.

Remarks. The nominate species of the *A. ploeckensis* Zone ranges into the overlying *P. siluricus* Zone. The presence of this fauna could indicate either zone (Orchard *in* Norford and Orchard, 1985).

Mackenzie Mountains, Glacier Lake (Fig. 1, loc. 6), District of Mackenzie

?*Polygnathoides siluricus–Ozarkodina eosteinhornensis* zones

Strata. Whittaker Formation.

Locality. GSC loc. C-087601.

Significant conodonts. Ozarkodina confluens.

Other conodonts. Ozarkodina? sp.

Remarks. Both alpha and gamma morphotypes of *Ozarkodina confluens* are present (Pl. 3, figs. 24, 25); the gamma morphotype occurs in the *P. siluricus* Zone but is most common in the *P. index* fauna of Nevada (Klapper and Murphy, 1975).

Ozarkodina eosteinhornensis–Icriodus woschmidti zones

Strata. Delorme Formation.

Locality. GSC loc. C-087604.

Significant conodonts. Ozarkodina remscheidensis Ziegler.

Other conodonts. Indet. ramiform elements.

Mackenzie Mountains, South Nahanni River (Fig. 1, loc. 5), District of Mackenzie

Pterospathodus celloni Zone

Strata. Sapper formation (informal), limestone member.

Locality. GSC loc. C-086326.

Significant conodonts. Astropentagnathus irregularis, Pterospathoides celloni.

Other conodonts. Aspelundia fluegeli, Dapsilodus sp., *Panderodus* sp., *Walliserodus* sp.

Remarks. The sample from GSC loc. C-086331 (silty limestone member, Sapper formation) includes a pennatiform element of *Pterospathodus celloni*, plus *Oulodus*? n. sp. B Over and Chatterton? (Pl. 3, figs. 18–20), *Panderodus* spp., and *Pseudooneotodus* sp.

Pterospathodus amorphognathoides Zone

Strata. Sapper formation (informal), silty limestone member.

Locality. GSC loc. C-086330.

Significant conodonts. Apsidognathus tuberculatus (Pl. 1, fig. 2), *Aulacognathus* sp. aff. *A. latus* (Nicoll and Rexroad) *sensu* Over and Chatterton (Pl. 3, fig. 4), *Carniodus carnulus* (Pl. 3, figs. 13, 14), *Distomodus* sp. cf. *D. kentuckyensis sensu* Cooper (Pl. 3, fig. 16), *D. staurognathoides* (Pl. 3, fig. 17), *Pterospathodus procerus* (Pl. 4, figs. 12–19).

Other conodonts. Aspelundia fluegeli (Pl. 1, figs. 16, 17), *A. petila, Oulodus*? n. sp. B Over and Chatterton? (Pl. 3, fig. 21), *Panderodus* sp., *Pseudooneotodus tricornis* (Drygant) (Pl. 4, fig. 3).

Remarks. Similar faunas, plus *Belodella* sp. and *Walliserodus* sp., are found at GSC loc. C-087637 and C-086329. *Apsidognathus tuberculatus* from the former is figured herein (Pl. 1, fig. 3). *Aspelundia fluegeli* is found at both of these localities, and *A. capensis* Savage? (Pl. 1, figs. 18–20) is tentatively identified from GSC loc. C-086329. *Pterospathodus procerus* occurs in GSC loc. C-086329 only. The sample from GSC loc. C-087750 includes *Apsidognathus tuberculatus* (Pl. 1, fig. 4), *A.* n. sp. 3 (Pl. 1, figs. 5–12), *Aspelundia fluegeli* (Pl. 1, figs. 13–15), *Carniodus carnulus* (Pl. 3, figs. 6–12, 15), *Panderodus* sp. (Pl. 4, fig. 1), *Pterospathodus procerus* (Pl. 4, figs. 20–23), *P. rhodesi* (Savage) (Pl. 5, figs. 6-15), and *Walliserodus blackstonensis* (Pl. 5, figs. 20, 23, 24).

Polygnathoides siluricus Zone

Strata. Sapper formation (informal), silty limestone member.

Locality. GSC loc. C-087646.

Significant conodonts. Polygnathoides siluricus Branson and Mehl (Pl. 4, fig. 2).

Other conodonts. Ozarkodina excavata, Panderodus sp.

Remarks. The sample from similar strata at GSC loc. C-086333 yielded *Dapsilodus* sp., *Ozarkodina* sp. cf. *O. confluens* (Pl. 3, fig. 26), *O.* sp. cf. *O. fundamentata* (Walliser)? (Pl. 3, fig. 27), and *Panderodus* sp. The upper range of the fauna from GSC loc. C-086333 is within the *P. siluricus* Zone.

Ozarkodina eosteinhornensis–Icriodus woschmidti zones

Strata. Sapper formation (informal), silty limestone member.

Locality. GSC loc. C-086334.

Significant conodonts. Ozarkodina r. remscheidensis (Ziegler).

Mackenzie Mountains, Avalanche Lake (Fig. 1, loc. 7), District of Mackenzie

?*Oulodus? nathani* Zone

Strata. Informal member 1W, Whittaker Formation.

Locality. AV1:84.5–86 m; AV4B:111.6–112 m.

Significant conodonts. Ozarkodina hassi (Pollock et al.), *Decoriconus costulatus* (Rexroad).

Other conodonts. Dapsilodus? sp. A Over and Chatterton, *Panderodus gracilis* (Branson and Mehl).

Remarks. This zone is Assemblage 5 of Nowlan et al. (1988). Over and Chatterton noted that *Distomodus kentuckyensis* first occurred at AV1:92 m, so these beds perhaps represent the lower Llandovery *O*? *nathani* Zone. Over and Chatterton (1987) assigned these faunas to their "unzoned interval".

Distomodus kentuckyensis Zone

Strata. Informal member 1W, Whittaker Formation.

Locality. Section AV1:92–110 m.

Significant conodonts. Dapsilodus obliquicostatus, Distomodus kentuckyensis, Icriodella discreta Pollock et al., *Oulodus*? *kentuckyensis, O.*? sp. cf. *O.*? *nathani* McCracken and Barnes, *Ozarkodina hassi, O. oldhamensis* (Rexroad).

Other conodonts. Decoriconus fragilis, Oulodus? spp., *Ozarkodina* n. sp. A Over and Chatterton, *O.* n. sp. B Over and Chatterton, *O.* spp., *Panderodus unicostatus, P.* spp., *Walliserodus sancticlari, W.* spp., Gen. et sp. indet. A Over and Chatterton.

Remarks. This zone represents the lower part of the *discreta/kentuckyensis/nathani* Zone of Over and Chatterton (1987), who combined three zones because the nominate species of each occurred at different stratigraphic levels (*Distomodus kentuckyensis* at 92 m, *I. discreta* at 95 m, *O.*? sp. cf. *O.*? *nathani* at 101 m). Over and Chatterton (1987) recognized two distinct faunas in their lower Llandovery strata and suggested the differences were due to a deepening of the basin. Their single composite zone is herein divided into two zones (see below).

Aspelundia fluegeli Zone

Strata. Informal member 1W, Whittaker Formation.

Locality. Section AV1:118.5–174.5 m.

Significant conodonts. Dapsilodus obliquicostatus, Oulodus? (herein = *A.*) *fluegeli, Ozarkodina hassi.*

Other conodonts. Distomodus or *Icriodella*(?), *Decoriconus fragilis, Oulodus*? spp., *Ozarkodina* spp., *Panderodus unicostatus, P.* spp., *Walliserodus sancticlairi, W.* spp.

Remarks. This zone corresponds to the upper part of the *discreta/kentuckyensis/nathani* Zone of Over and Chatterton (1987).

?*Pterospathodus celloni* Zone

Strata. Informal member 3W, Whittaker Formation.

Locality. Section AV1:320 m; AV2:9–17 m.

Significant conodonts. Apsidognathus tuberculatus, Astrolecignathus milleri Over and Chatterton, *Astropentagnathus irregularis, Aulacognathus b. bullatus, Dapsilodus obliquicostatus, Distomodus staurognathoides, Ozarkodina hadra* (Nicoll and Rexroad), *O. gulletensis* (Aldridge), *P. celloni, P. pennatus procerus* (herein = *P. procerus*?).

Other conodonts. Astropentagnathus sp. aff. *A. irregularis, Belodella* sp. A Over and Chatterton, *Dapsilodus* sp., *Aspelundia fluegeli, Oulodus*? n. sp. A Over and Chatterton, *O.*? spp., *Ozarkodina* spp., *Panderodus unicostatus, P.* spp.

Remarks. The occurrence of *Pterospathodus procerus* suggests the *P. amorphognathoides* Zone rather than the *P. celloni* Zone. The element of *P. procerus* illustrated by Over and Chatterton (1987, Pl. 4, fig. 4) is from a level within the *P. amorphognathoides* Zone. They did not illustrate examples of this species from within the *P. celloni* Zone, the presence of which therefore remains in doubt. However, it is notable that elements identified as *P. p. procerus* from the *I.*

inconstans (= *P. celloni*) Zone of Anticosti Island by Uyeno and Barnes (1983, Pl. 8, fig. 1-3) are pennatiform elements of *P. celloni*.

Pterospathodus amorphognathoides Zone

Strata. Informal member 3W, Whittaker Formation.

Locality. Section AV1:336–456 m; AV2:47–160 m; AV4:0–5 m.

Significant conodonts. *Apsidognathus barbarajeanae* (Savage), *Astrolecignathus milleri*, *Astropentagnathus irregularis*, *Aulacognathus kuehni*, *A. chapini* (Savage), *Carniodus carnulus*, *Oulodus*? n. sp. 2 Over and Chatterton, *Ozarkodina hadra*, *O. gulletensis*, *Pseudooneotodus* n. sp. A Over and Chatterton, *Pterospathodus celloni*, *P. pennatus procerus* (herein = *P. procerus*), *P. p. rhodesi* Savage (herein = *P. rhodesi*), *P. amorphognathoides*.

Associated conodonts. *Apsidognathus tuberculatus*, *A.* n. sp. A Over and Chatterton, *Aspelundia fluegeli*, *Astrolecignathus newti* Over and Chatterton, *Aulacognathus b. bullatus*, *A. b.* n. ssp. A Over and Chatterton, *A.* sp. aff. *A. latus*, *A. nelsoni* Over and Chatterton, *Belodella* sp. A Over and Chatterton, *Dapsilodus* spp., *Decoriconus fragilis*, *Distomodus staurognathoides*, *Oulodus*? *petilus pacificus* Savage (herein = *A. petila*), *Oulodus*? n. sp. 1 Over and Chatterton, *O.*? n. sp. A Over and Chatterton, *O.*? spp., *Ozarkodina e. excavata*, *O.* n. sp. C Over and Chatterton, *O.* spp., *Panderodus unicostatus*, *P.* spp., *Pterospathodus* spp., *Pseudooneotodus beckmanni*, *P. bicornis* Drygant, *P. tricornis* Drygant, *Walliserodus* sp., *Spathognathodus* sp. A Over and Chatterton *s.f.*, Gen. et sp. indet. B Over and Chatterton, Gen. et sp. indet. C Over and Chatterton.

Remarks. The lower part of this zone is characterized by *Astropentagnathus irregularis*, *Astrolecignathus milleri*, *Aulacognathus kuehni*, *Aspelundia* species, and *Pterospathodus celloni*, which do not range to the top of this zone. The upper part is represented by *Apsidognathus barbarajeanae*, *Aulacognathus chapini*, *Carniodus carnulus*, *Oulodus*? n. sp. 2, *Ozarkodina hadra*, *Pterospathodus rhodesi*, and *Pseudooneotodus* n. sp. A (Over and Chatterton, 1987). These writers suggested the disappearance of *P. amorphognathoides* near the top of the Whittaker Formation was due to the change to the more clastic environment of the succeeding Road River Group. The palmate elements of N. gen. B n. sp. A resemble those of the Ordovician *Chirognathus* and *Rhipidognathus*. Similar Arctic Island forms occur within the Wenlock *C. rigidus* graptolite Zone (Over and Chatterton, 1987).

Interestingly, this is one of the few reported occurrences of *Pterospathodus amorphognathoides* in Western Canada. Unfortunately, Over and Chatterton (1987) did not illustrate this species. Other collections from this zone (e.g., Savage, 1985; this study) contain *P. procerus* and *P. rhodesi* rather than *P. amorphognathoides*.

Kockelella patula Zone

Strata. Informal member 1D, Delorme Group.

Locality. Section AV2:242–331 m.

Significant conodonts. *K. patula* Walliser.

Associated conodonts. *Kockelella absidata* Barrick and Klapper, *Oulodus*? n. sp. B Over and Chatterton, *O.*? spp., *Ozarkodina e. excavata*, *O.* n. sp. D Over and Chatterton, *O.* spp., *Panderodus unicostatus*, *P.* spp., *Pseudooneotodus bicornis*, N. Gen. B n. sp. A Over and Chatterton, N. Gen. B? n. sp. B Over and Chatterton.

Remarks. The *K. patula* Zone corresponds to the upper part of the *patula*/*ranuliformis* Zone of Over and Chatterton (1987). The lower part of this combined zone is herein referred to as the *P. amorphognathoides* Zone.

The conodonts of the "lower *patula*/*ranuliformis* Zone" are found in member 3W of the Whittaker Formation (AV1:460 m) and member 1D of the Delorme Group (AV4:12 m). These include: *Carniodus carnulus*, *Kockelella ranuliformis* (Walliser), *Ozarkodina hadra*, *O. gulletensis*, *Pterospathodus pennatus procerus* (herein = *P. procerus*), *P. amorphognathoides*. Other conodonts are: *Apsidognathus tuberculatus*, *Aulacognathus bullatus bullatus*, *A. chapini*, *Dapsilodus* spp., *Decoriconus fragilis*, *Distomodus staurognathoides*, *Oulodus*? spp., *Ozarkodina excavata excavata*, *O.* spp., *Panderodus unicostatus*, ?*Pseudooneotodus bicornis*, *P. tricornis*, *Spathognathodus* sp. A *s.f.*

Kockelella ranuliformis and *Aulacognathus chapini* occur within the *P. amorphognathoides* and *K. ranuliformis* zones of Alaska (Savage, 1985). *Kockelella ranuliformis* and *P. bicornis* occur in the *K. ranuliformis* Zone in Oklahoma (Barrick and Klapper, 1976). *Pseudooneotodus bicornis* defines the base of this zone (approximately equal to the base of the *K. patula* Zone, Barrick and Klapper, 1976; Cooper, 1980), but both it and *K. ranuliformis* occur on Anticosti Island in older strata below the *P. amorphognathoides* Zone (Uyeno and Barnes, 1983). Since both *K. ranuliformis* and *P. bicornis* apparently have extended ranges, the *K. ranuliformis* Zone may not be recognizable in areas outside Oklahoma.

Over and Chatterton (1987) reported that over 80 m of shales separate the first occurrence of *Kockelella ranuliformis* and *K. patula* (see below).

Ozarkodina bohemica Zone

Strata. Informal member 1D, Delorme Group (Over and Chatterton, 1987).

Locality. Section AV4:165–231 m.

Significant conodonts. *Kockelella walliseri* (Helfrich), *O. bohemica* Walliser, *O. confluens*.

Associated conodonts. Oulodus? n. sp. C Over and Chatterton, *O.*? spp., *Ozarkodina e. excavata*, *O.* n. sp. D, *O.* spp., *Panderodus unicostatus*, Gen. et sp. indet. D Over and Chatterton, Gen. et sp. indet. E Over and Chatterton.

Pelekysgnathus arcticus fauna

Strata. Road River Group.

Locality. Section AV7:430 m.

Significant conodonts. Ozarkodina confluens, *P. arcticus* Uyeno.

Associated conodonts. Oulodus? spp., *Ozarkodina e. excavata*, *O.* spp., *Panderodus unicostatus*, *P.* spp.

Remarks. Ozarkodina confluens was identified by Over and Chatterton (1987) as the epsilon morphotype of Klapper and Murphy (1975). This fauna was not named by Over and Chatterton (1987).

Rocky Mountains, Kechika River (Fig. 1, loc. 9), British Columbia

?*Aspelundia fluegeli* Zone

Strata. Road River Group.

Locality. GSC loc. C-116712.

Significant conodonts. Dapsilodus obliquicostatus, *Decoriconus fragilis*?, *Distomodus* sp. cf. *D. kentuckyensis sensu* Cooper, *Walliserodus sanctilairi*, *W. blackstonensis.*

Other conodonts. Belodella sp.

Rocky Mountains, McLeod Lake (Fig. 1, loc. 10), British Columbia

Pterospathodus celloni Zone

Strata. Sandpile or Nonda Group.

Locality. GSC loc. C-149713.

Significant conodonts. Aspelundia fluegeli, *P. celloni.*

Other conodonts. Distomodus sp., *Panderodus* spp.

Remarks. The sample from unnamed strata at GSC loc. C-159505 yielded *Aspelundia fluegeli*, *Aulacognathus bullatus*, *Distomodus staurognathoides*, *Pseudooneotodus beckmanni*, and *Panderodus* sp., and based on the presence of *A. bullatus*, represents the *P. celloni* Zone or lower strata (Uyeno and Barnes, 1983; Armstrong, 1990). Sample GSC loc. C-149715 (Sandpile Group) may represent the highest part of the *P. celloni* Zone on the basis of *Carniodus carnulus*. Also present are: *Apsidognathus*? sp., *Aspelundia fluegeli*, *Aulacognathus chapini* (Pl. 3, fig. 3), *Belodella* sp., *Distomodus*? sp., *Oulodus*? sp., and *Panderodus* sp. One sample (GSC loc. C-159575) from the Kechika Group(?) contains *Oulodus*? n. sp. A Over and Chatterton, plus *A. fluegeli*, *Aulacognathus*? sp., and *Panderodus* spp. Over and Chatterton (1987) found that *O.*? n. sp. A ranged from the base of the *P. celloni* Zone into the lower *P. amorphognathoides* Zone.

Pterospathodus amorphognathoides Zone

Strata. Sandpile or Nonda Group.

Locality. GSC loc. C-149711.

Significant conodonts. Carniodus carnulus, *Pterospathodus procerus*, *P. rhodesi.*

Other conodonts. Apsidognathus? sp., *Aspelundia fluegeli*, *Panderodus* sp., *Walliserodus blackstonensis.*

Remarks. A sample from the same zone at GSC loc. C-159504 contains fragments of retiolitid graptolites.

Rocky Mountains, Mount Tegart (Fig. 1, loc. 11), British Columbia

Pterospathodus amorphognathoides Zone

Strata. Tegart Formation.

Locality. GSC loc. C-060933, C-060935.

Significant conodonts. Carniodus carnulus, *Pterospathodus procerus*?

Other conodonts. Aspelundia fluegeli, *Belodella* sp., *Panderodus* sp., ?N. gen. B n. sp. A Over and Chatterton.

Remarks. New gen. B n. sp. A occurs in the Wenlock *patula/ranuliformis* Zone of Over and Chatterton (1987; see above).

Rocky Mountains, Pedley Pass (Fig. 1, loc. 12), British Columbia

Oulodus? *nathani* or *Distomodus kentuckyensis* zones

Strata. Beaverfoot Formation.

Locality. GSC loc. C-060942.

Significant conodonts. Oulodus? *kentuckyensis.*

Other conodonts. Distomodus sp., *Icriodella* sp., *Ozarkodina* sp., *Panderodus* spp., *Walliserodus curvatus*?

Remarks. Samples from higher in this section contain *Ozarkodina hassi*, *O. manitoulinensis* (Pollock et al.), and *O. oldhamensis.*

?Distomodus kentuckyensis Zone

Strata. Beaverfoot Formation.

Locality. GSC loc. C-045575.

Significant conodonts. Ozarkodina sp. cf. *O. polinclinata.*

Other conodonts. Distomodus sp., *Ozarkodina excavata, Panderodus* spp., *Walliserodus curvatus.*

Distomodus staurognathoides Zone

Strata. Beaverfoot Formation.

Locality. GSC loc. C-045583.

Significant conodonts. Aulacognathus bullatus.

Other conodonts. Aspelundia sp., *Oulodus* sp., *Panderodus* sp.

Pterospathodus celloni Zone

Strata. Beaverfoot Formation.

Locality. GSC loc. C-045586.

Significant conodonts. Aulacognathus bullatus, A. latus, Ozarkodina sp. aff. *O. polinclinata, P. celloni.*

Other conodonts. Aspelundia fluegeli, Belodella sp., *Distomodus* sp., *Oulodus*? sp., *Panderodus* spp.

Remarks. Other samples in this zone contain *Aspelundia petila, Pseudooneotodus beckmanni, Walliserodus curvatus, W. blackstonensis.*

Pterospathodus amorphognathoides Zone

Strata. Tegart Formation.

Locality. GSC loc. C-060945.

Significant conodonts. Pterospathodus procerus.

Other conodonts. Aspelundia fluegeli, Panderodus spp., *Pseudooneotodus beckmanni.*

TAXONOMIC REMARKS

Conodont Colour Alteration Index (CAI) values (Epstein et al., 1977) from the following sections are: 1) Rock River (CAI = 4.5–5); 2) Tetlit Creek (4.5); 3) Blackstone River (4); 4a) Pat Lake (5–6); 4b) Pat Lake South (4); 5) South Nahanni River (5); 6) Glacier Lake (4–5); 7) Howards Pass (5); 8) Avalanche Lake (5); 9) Kechika River (5); 10) McLeod Lake (5); 11) Mount Tegart (4); 12) Pedley Pass (2.5). Sample levels with graptolite collection data and element totals for species from the first three localities are given in McCracken [1991 (*this volume*)].

Most conodont taxa identified below are multielement; the few form species mentioned within the text have the abbreviation *s.f.* (*sensu formo*). The element nomenclature is from Barnes et al. (1979). All illustrated specimens are assigned Geological Survey of Canada (GSC) type numbers and are housed in the National Type Collection of Invertebrate and Plant Fossils at the Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8.

Ancoradella ploeckensis Walliser

(Pl. 1, fig. 1)

Hypotype. GSC 66004.

Apsidognathus tuberculatus Walliser

(Pl. 1, figs. 2–4)

Hypotypes. GSC 101182-101184.

Apsidognathus n. sp. 3

(Pl. 1, figs. 5–12; Figs. 3, 4)

Remarks. The entire upper surface of most elements is covered with microreticulation polygons about 5-20 μm in diameter. Even denticles are ornamented in some (e.g., Figs. 3, 4). A rough estimation of polygon diameter in the lyriform elements is about 10 μm across the widest part, increasing to about twice that toward the distal end.

Figured specimens. GSC 101185-101192.

Aspelundia fluegeli (Walliser)

(Pl. 1, figs. 13-17)

Hypotypes. GSC 101193-101197.

Aspelundia capensis Savage?

(Pl. 1, figs. 18-20)

Hypotypes. GSC 101198-101200.

Astropentagnathus irregularis Mostler

(Pl. 2, figs. 11-19; Fig. 7)

Remarks. Microreticulation (polygons about 10 μm in diameter) covers the platform surfaces of the *f* and *g* elements.

Hypotypes. GSC 101211-101219.

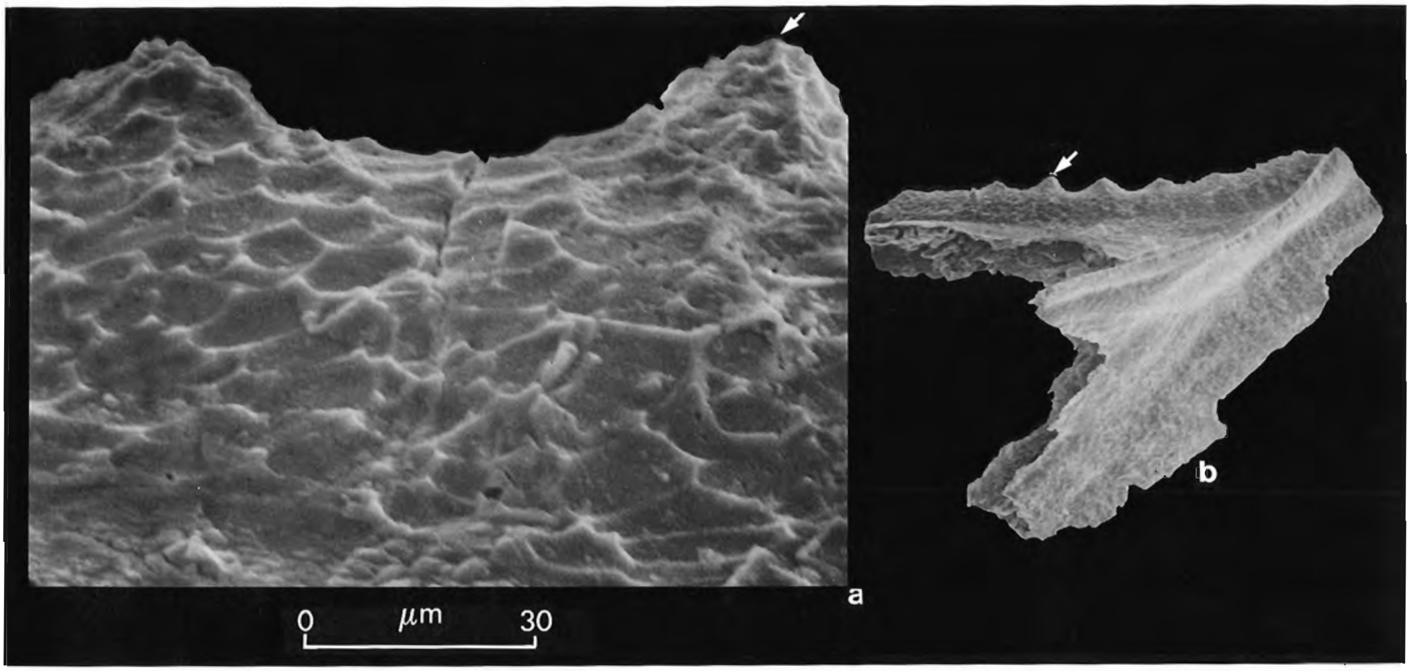


Figure 3. *Apsidognathus* n. sp. 3: *a* element, lateral views, GSC 101190 (same specimen as in Pl. 1, fig. 11). **a)** x1000. **b)** x90. Arrows indicate identical features in both figures.

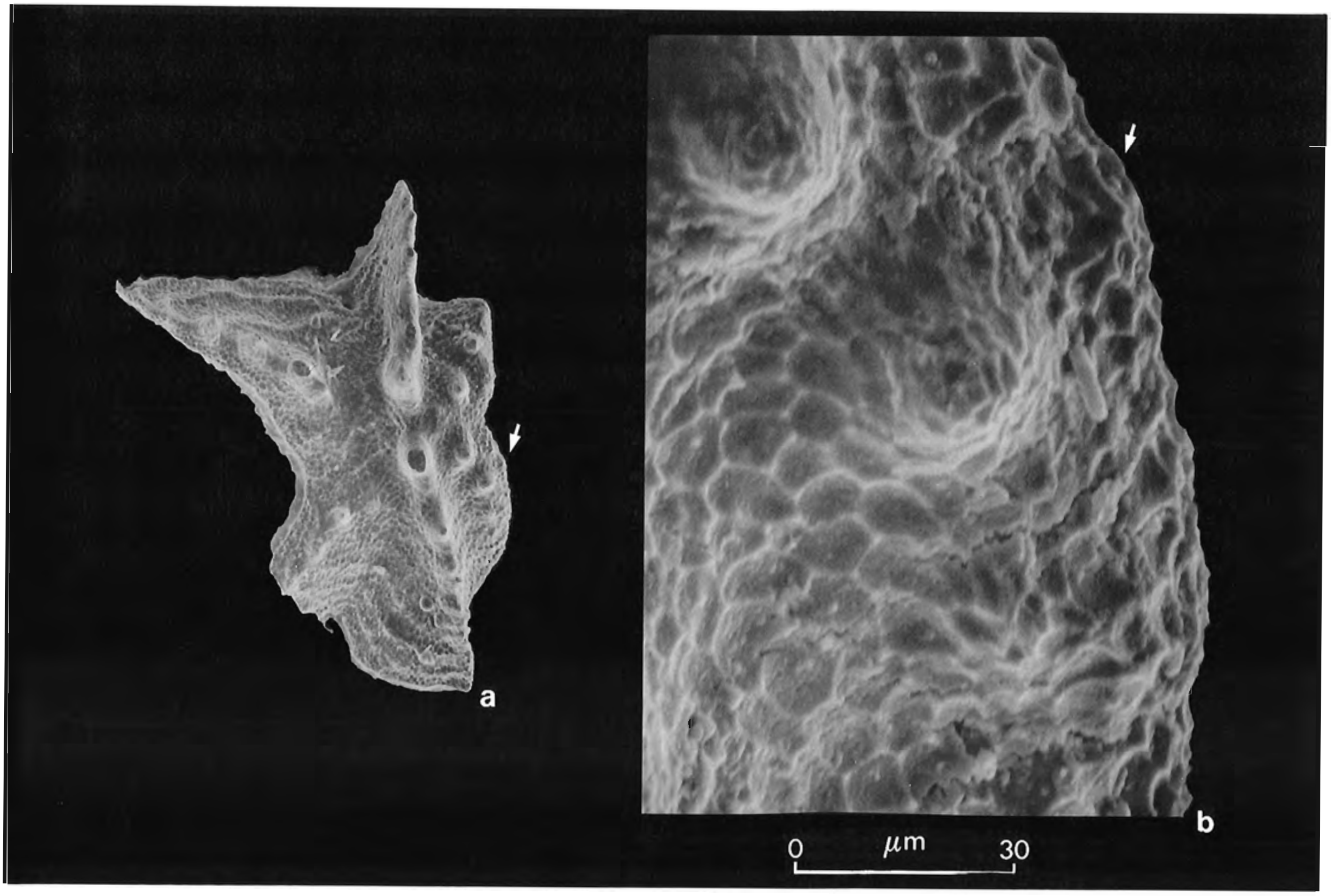


Figure 4. *Apsidognathus* n. sp. 3: *g* element, upper views, GSC 101186 (same specimen as in Pl. 1, fig. 9). **a)** x120. **b)** x1000. Arrows indicate identical features in both figures.

Aulacognathus bullatus (Nicoll and Rexroad)

(Pl. 3, figs. 1, 2)

Hypotypes. GSC 101220, 101221.

Aulacognathus chapini (Savage)

(Pl. 3, fig. 3)

Hypotype. GSC 101222.

Aulacognathus sp. aff. *A. latus* (Nicoll and Rexroad) sensu Over and Chatterton

(Pl. 3, fig. 4)

Remarks. An unfigured *g* element has a smooth upper surface but radiating striations on denticle nodes; some of these striations merge into a pattern of reticulation (5-10 µm).

Figured specimen. GSC 101223.

Aulacognathus nelsoni Over and Chatterton

(Pl. 3, fig. 5)

Hypotype. GSC 101224.

Carniodus carnulus Walliser

(Pl. 3, figs. 6-15)

Remarks. Microreticulation (polygons about 5 µm in diameter) covers along upper margin of process ledges, and longitudinal striations on cusp and denticles.

Hypotypes. GSC 101225-101234.

Distomodus sp. cf. D. kentuckyensis Branson and Branson *sensu* Cooper

(Pl. 3, fig. 16)

Figured specimen. GSC 101235.

Distomodus staurognathoides (Walliser)

(Pl. 3, fig. 17)

Hypotype. GSC 101236.

Oulodus? n. sp. B Over and Chatterton?

(Pl. 3, figs. 18-21)

Remarks. The elements from the *P. celloni* and *P. amorphognathoides* zones at South Nahanni River have widely spaced denticles similar to those found by Over and Chatterton (1987) in the younger *patula*/*ranuliformis* Zone at Avalanche Lake.

Figured specimens. GSC 101237-101240.

Oulodus? n. sp. B

(Pl. 3, figs. 22, 23)

Remarks. The *b* and *c* elements of Armstrong's (1990) *Oulodus* spp. indet. group 5 from Greenland (pre-*P. celloni* Zone) are like those elements (unfigured) of *Oulodus*? n. sp. B from northern Yukon. The other elements (*g* element in Armstrong, *a*, *e*, *f*, of the Yukon species) are rare and cannot be compared.

Figured specimens. GSC 101241, 101242.

Ozarkodina confluens (Branson and Mehl)

(Pl. 3, figs. 24, 25)

Hypotypes. GSC 101243, 101244.

Ozarkodina sp. cf. *O. confluens* (Branson and Mehl)

(Pl. 3, fig. 26)

Figured specimen. GSC 101245.

Ozarkodina fundamentata (Walliser)?

(Pl. 3, fig. 27)

Hypotype. GSC 101246.

Panderodus sp.

(Pl. 4, fig. 1)

Remarks. Micro-ornamentation consists of anastomosing longitudinal striations on base.

Figured specimen. GSC 101247.

Polygnathoides siluricus Branson and Mehl

(Pl. 4, fig. 2)

Hypotype. GSC 101248.

Pseudooneotodus tricornis (Drygant)

(Pl. 4, fig. 3)

Hypotype. GSC 101249.

Pterospathodus celloni (Walliser)

(Pl. 4, figs. 4-11)

Remarks. The three forms of *Pterospathodus celloni* are present in the collections; the angulatiform and celloniform elements characterize the lower part of the *P. celloni* Zone; higher levels are characterized by celloniform and pennatiform elements (Männik and Aldridge, 1989). Micro-ornamentation consists of longitudinal striations on cusp and denticles.

Hypotypes. GSC 101250–101257.

Pterospathodus *procerus* (Walliser)

(Pl. 4, figs. 12-23)

Remarks. Micro-ornamentation consists of longitudinal striations on cusp and denticles, and microreticulation (polygons about 5-10 µm in diameter) and anastomosing longitudinal striations on process surfaces.

Hypotypes. GSC 101258-101269.

Pterospathodus rhodesi (Savage)

(Pl. 5, figs. 6-15)

Remarks. Micro-ornamentation consists of microreticulation along upper margin of process ledges and longitudinal striations on cusp and denticles.

Hypotypes. GSC 101277-101286.

Walliserodus blackstonensis McCracken

(Pl. 5, figs. 16-24)

Remarks. Micro-ornamentation consists of anastomosing longitudinal striations on base.

Hypotypes. GSC 101287-101294.

SYSTEMATIC PALEONTOLOGY

Genus *Astropentagnathus* Mostler, 1967 emend. Bischoff, 1986

Type species. *Astropentagnathus irregularis* Mostler, 1967.

Astropentagnathus araneum n. sp.

Plate 2, figures 1-10; Figures 5, 6

?*Astropentagnathus irregularis* MOSTLER, 1967, p. 298-300, Pl. 1, fig. 4 (only).

Astropentagnathus irregularis Mostler. OVER and CHATTERTON, 1987 (in part), Pl. 2, figs. 2, 6 (only; figs. 3-5, 8, 9 = *A. irregularis*); ORCHARD *in* NORFORD and ORCHARD, 1985 (in part), p. 10, Pl. 2, figs. 2, 3 (only; fig. 6 = *A. irregularis*); MANNIK and VIIRA, 1990, Pl. 17, fig. 24.

Hadrognathus irregularis (Mostler). SCHÖNLAUB, 1971, p. 42, 43, Pl. 1, figs. 4, 11 (only).

Etymology. From the Latin, *araneum*, meaning cobweb. This name refers to the concentric ridges on the basal sheath between the radiating processes of the *g* element (see holotype, Pl. 2, fig. 8).

Diagnosis. Apparatus contains elements that have a basal sheath between most processes; this bears widely spaced growth ridges and microreticulation. The *f* and *g* elements have downwardly directed processes with platforms that are composed of basal sheathing. Anterior process of *f* and *g* elements is blade-like with long denticles. Other elements include *a*?, *b*/*c*, and *e* elements. The reconstruction may not be complete.

Description. A basal sheath is confluent with, and extends between all processes on *a*?, *b*/*c*, and *e* elements, and between some processes on *f* and *g* elements. Sheath has widely spaced growth ridges that parallel lower margin. Lower edge of sheath is narrowly excavated. Upper surface has microreticulation on margins (polygons about 5 µm and larger in diameter), which merge into anastomosing longitudinal striations toward and onto denticles. Most of lower surface is excavated. All elements have white matter in cusp and denticles. Sinistral and dextral forms of all five elements are present.

The *a*? element (Pl. 2, fig. 5) has a long denticulated posterior process, a downwardly and posteriorly directed anticusp or "anterior" process, and an outer, adenticulate lateral process. Anticusp and lateral process taper to a point. Distal end of posterior process is deflected upward, gently in some elements, sharply in others, and, in large elements, it is platform-like. Denticles are numerous (at least 12 on posterior process, 22 on anticusp), relatively short, triangular, and partially confluent. They are inclined toward the anterior and slightly curved toward inner side.

The *b*/*c* (Pl. 2, figs. 1, 4) element has long denticulated posterior and lateral processes. Cusp is short, recurved, and has costae on anterolateral margins that merge with processes. Both lateral processes are directed downward and diverge at about same angle posterolaterally. Anterior margin of cusp at junction of lateral processes is convex. Denticles on lateral process are numerous; one specimen has at least 29. These are inclined toward the anterior and directed laterally. Denticles are short, confluent for most of their length, and have triangular tips. Posterior process has at least eight denticles and a wide adenticulate gap between cusp and first denticle. Denticles of posterior process are shorter than those of lateral process, triangular, and partially overgrown in some specimens. Basal sheath between processes is planar to slightly concave. Asymmetry is due to a slight flexure of cusp and posterior process to inner side.

The *e* element (Pl. 2, figs. 3, 7) has denticles that are slightly to moderately inclined toward short posterior process, which has up to about seven denticles. Anterior process is long with at least 12 denticles. Apical denticle (cusp?) and other denticles are relatively long, thin, confluent, and slightly curved toward inner side. Denticles on anterior process of some elements are inclined inward so that they are nearly horizontal. Outer face of denticle base is convex; inner face slightly to moderately concave. Basal margin on inner side is a narrow to moderately wide platform. Lateral margin of base on outer side is flared beneath cusp. Base nearly straight in most cases, but slightly arched in some elements. Denticle base has micro-ornamentation like that found on sheath of other elements.

The *f* element (Pl. 2, figs. 2, 6) is an arched platform with long anterior and short posterior processes; distal end of posterior process is inwardly bowed in most elements. Inner lateral process is long, perpendicular to anteroposterior plane, and anterior to cusp. All processes are denticulate except for short, flared outer lateral process. This process is opposite to cusp and thus more posterior than inner process. On some elements, posterior margin of inner and anterior margin of outer processes are opposed to each other and perpendicular to anteroposterior plane, giving element a cruciform shape in upper or lower view. All processes are directed downward. Posterior process has ledge-like margins. Lateral processes have margins that are directed downward; anterior process is blade-like. Distal ends of posterior and inner processes are tapered. Cusp is slightly larger than denticles.

Denticles of *f* element have triangular tips, are slightly compressed laterally, and number about 14 on anterior, 9 on inner, and 7 on posterior processes. Denticles on anterior process are relatively long, confluent and erect, with longest situated about two thirds length from cusp. Denticles on posterior and inner processes are short and confluent; those of posterior process are reclined. A relatively wide adenticulate gap is present between proximal denticle of inner and anterior processes. Basal sheath between processes has relatively wide growth ridges. Ridges are also visible in lower

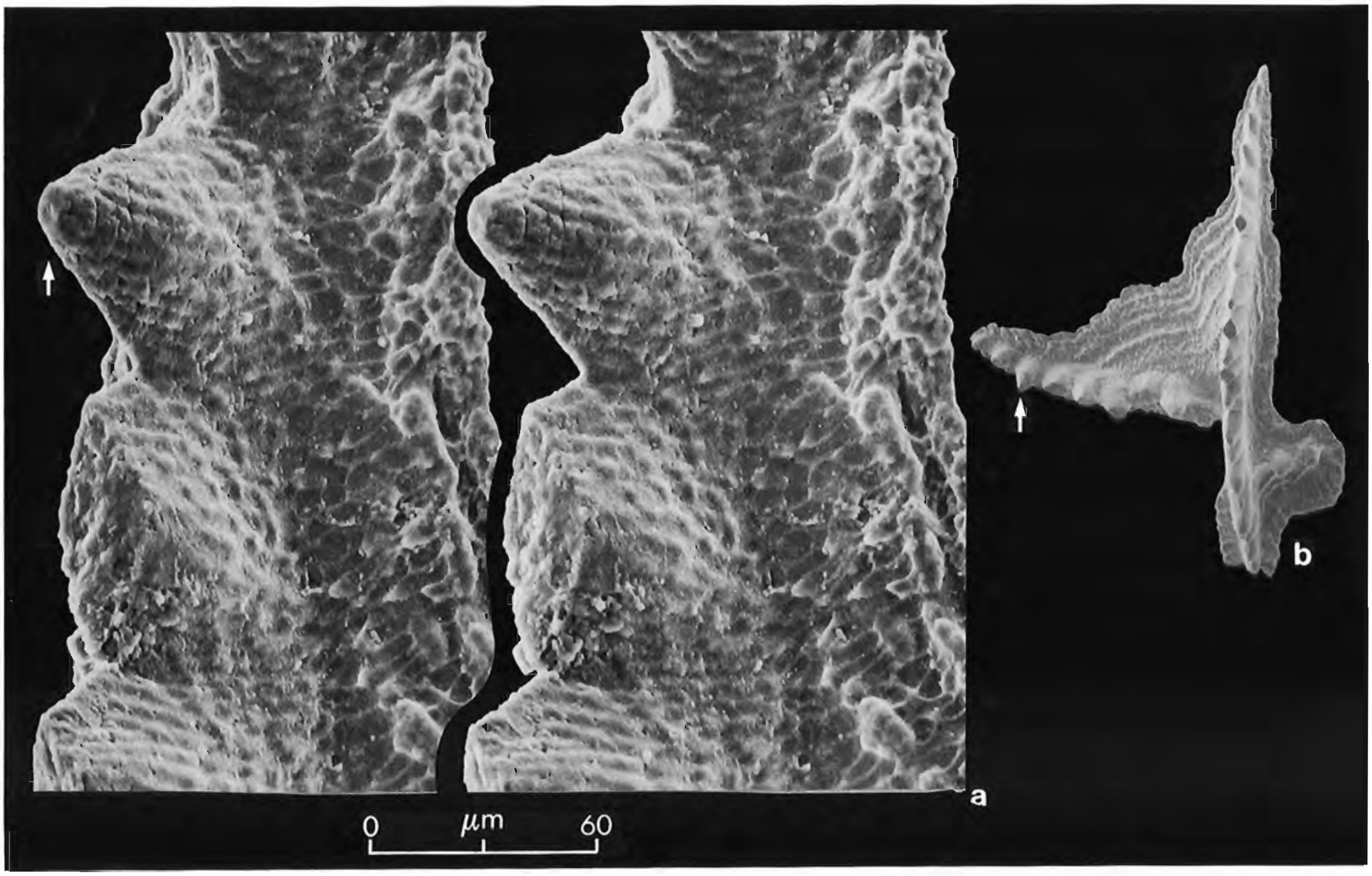


Figure 5. *Astropentagnathus araneum* n. sp.: *f* element, upper views, GSC 101204 (same specimen as in Pl. 2, fig. 6 stereopair). **a)** x500, stereopair (10° and 20° tilt, respectively). **b)** x65. Arrows indicate identical features in both figures.

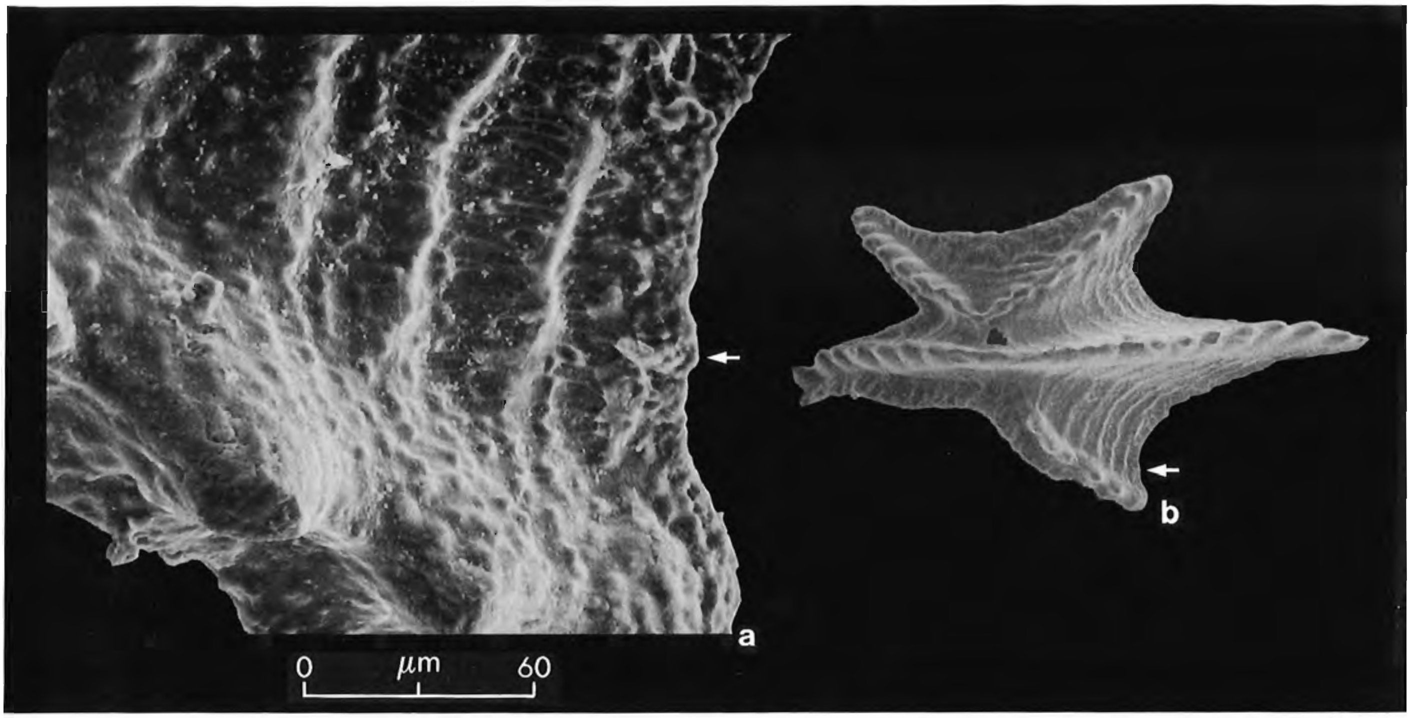


Figure 6. *Astropentagnathus araneum* n. sp.: *g* element, upper views, GSC 101208 (holotype, same specimen as in Pl. 2, fig. 8 stereopair). **a)** x500. **b)** x50. Arrows indicate identical features in both figures.

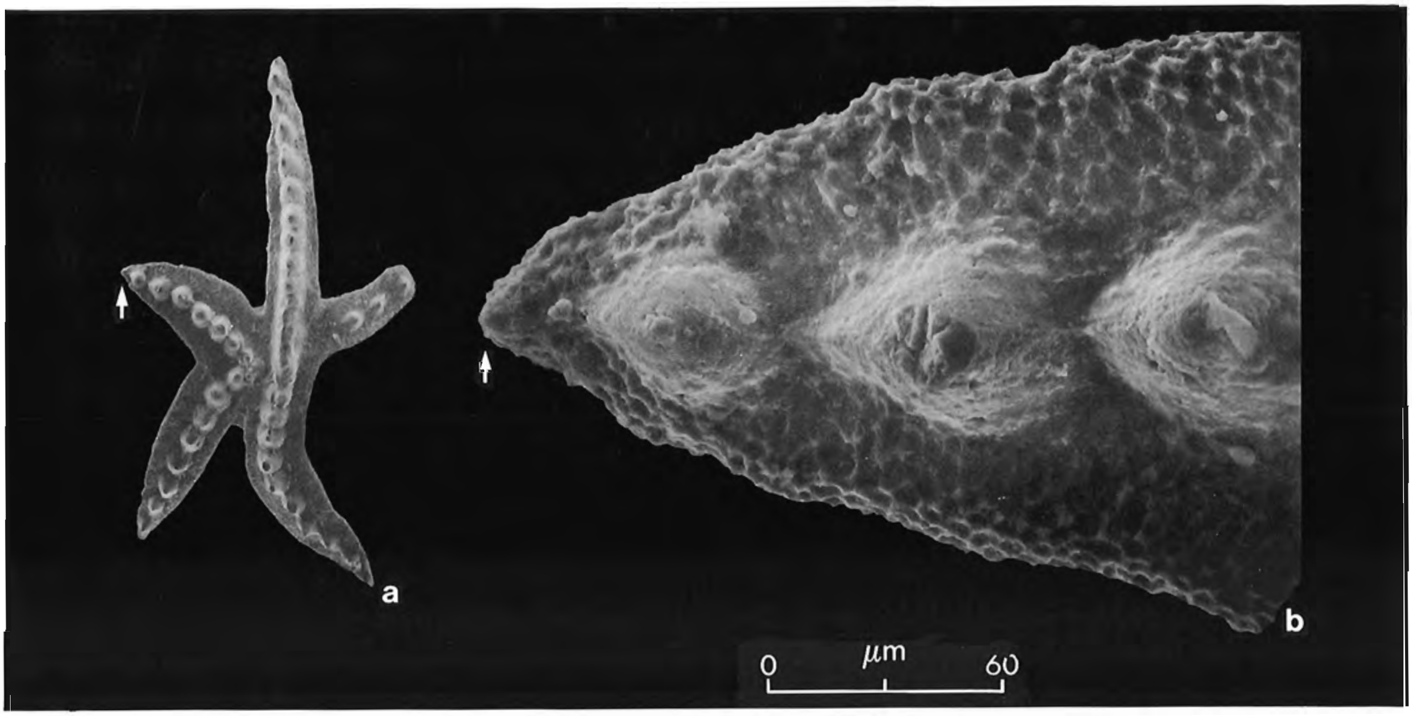


Figure 7. *Astropentagnathus irregularis* Mostler: *g* element, upper views, GSC 101215 (same specimen as in Pl. 2, fig. 15). **a)** x50. **b)**. x500. Arrows indicate identical features in both figures.

view. Lower surface of posterior process is inverted and has a narrow longitudinal groove. Anastomosing longitudinal striations form an interference pattern on denticles (Fig. 5).

The *g* element (Pl. 2, figs. 8-10) has five processes; blade-like anterior process is in line with platform-like posterior process. On small elements, posterior process is more blade-like. Outer bifurcating process is directly opposite inner anterolateral process. All processes are joined at cusp. Anterior process is longest, outer anterolateral is shortest, others are variable in length. All processes are downwardly directed, producing an arched element; inner lateral process is more downwardly directed than others. All lateral processes diverge at about same angle from anteroposterior plane. Posterior process tapers and is inwardly bowed at distal ends; other processes are straight. Anterior process is connected to both inner and outer anterolateral processes via extensive basal sheath. Less extensive sheath also connects outer posterolateral and posterior processes. Growth ridges are present on upper and lower sides of sheath (Fig. 6).

Denticles of *g* element are slightly compressed laterally. Anterior process has up to about 18 relatively long denticles that are confluent except for their triangular tips. Longest denticles are about one-third distance from anterior. Cusp is indistinct and at intersection of processes; cusp and proximal denticles may be lower than other denticles and completely overgrown or fused. Posterior process has up to about 10 denticles that are short, confluent except for their triangular tips; denticles of outer processes are similar. A gap is present between denticles of outer process and cusp. Denticles on inner process are either absent, or present only at distal end forming a short indistinct row. Basal excavation is deepest beneath anterior process. Lower surface beneath posterior and posterolateral processes is inverted with a narrow longitudinal groove.

Remarks. This new species contains elements, particularly the *g* element, that are similar to those of *Astropentagnathus irregularis*. The most striking differences are the basal sheathing, concentric ridges and microreticulation in all elements of *A. araneum* n. sp. This sheathing forms a downwardly directed webbing on the *f* and *g* elements. Platform margins on the same elements of *A. irregularis* are narrow and perpendicular to the denticles.

Mostler (1967, Pl. 1, fig. 4) and Schönlaub (1971, Pl. 1, fig. 4) have illustrated *g* elements that have a similar sheathing and growth lines between the processes. Schönlaub regarded this element as a juvenile form of *Astropentagnathus irregularis*. In the Cordilleran material, these elements are found in the same range of size as those of *A. irregularis*, hence the differences cannot be ascribed to ontogeny. In addition, sinistral and dextral forms can be found in both species. Schönlaub (*ibid.*, fig. 11) also illustrated an *f* element with the same type of ridge ornamentation.

The denticles of the anterior processes of the *f* and *g* elements and the inner lateral process of *Astropentagnathus araneum* n. sp. are longer than those in the same elements of *A. irregularis*. The adenticulate gap between the cusp and denticles of the inner lateral process is much larger on the *f* and *g* elements of this new species than between these elements of *A. irregularis*. The denticles of *A. araneum* n. sp. elements are generally longer, thinner, and more numerous than those of *A. irregularis*.

The *b*/*c* element of *Astropentagnathus irregularis* is more robust and surfaces between processes are convex rather than planar or slightly concave (Bischoff, 1986, Pl. 3, fig. 13). The *e* element of *A. irregularis* (M element *sensu* Bischoff, 1986, Pl. 3, figs. 10-12) is quite different from the *e* element of this species. The former has a prominent cusp and a downwardly directed anterior process.

Elements of these species (from the same sample) also differ in colour. Those of *Astropentagnathus irregularis* are a darker grey than elements of *A. araneum* n. sp., which are more brown than grey (overall CAI = 4). This is presumably due to differences in thickness, and possibly surface micro-ornamentation.

The ridges are perhaps a structural feature, and are similar to those on other thin walled and broad platform elements. For example, see *Apsidognathus tuberculatus* (Pl. 1, fig. 2), *A.* n. sp. 3 (Pl. 1, figs. 5, 9), and Ordovician taxa such as *Polonodus* and *Pygodus*.

Material. Holotype GSC 101208, paratypes GSC 101201–101207, GSC 101209, 101210.

Genus *Pterospathodus* Walliser

Type species. *Pterospathodus amorphognathoides* Walliser.

Pterospathodus retroramus n. sp.

Plate 4, figures 24, 25; Plate 5, figures 1-5; Figure 8

Etymology. From the Latin, *retro-*, meaning backward, and *ramus*, meaning branch. This refers to the way the relative length of the antero- and posterolateral branches of the outer process is the reverse of (''backward'' to) that of the type species of *Pterospathodus*.

Diagnosis. Denticles on anterior and posterior processes of *f* element form a blade, those on outer lateral process form a low ridge. Short inner lateral process is adenticulate. Lateral processes are directed downward; outer lateral process is commonly directed toward posterior. Basal cavity is inverted, forming ledge on processes.

The *g* element is unarched and has anterior, posterior, and outer bifurcated lateral processes. Outer posterolateral process is longer than outer anterolateral. Posterior and outer processes are platform-like with short peg-like denticles; anterior process and denticles are blade-like. Element lacks an inner lateral process, or has only slight adenticulate flare. Apparatus is probably incomplete.

Description. Upper surface is covered with microreticulation; polygons are about 5-10 μm across (Fig. 8). This pattern continues to base of denticles as anastomosing longitudinal striations.

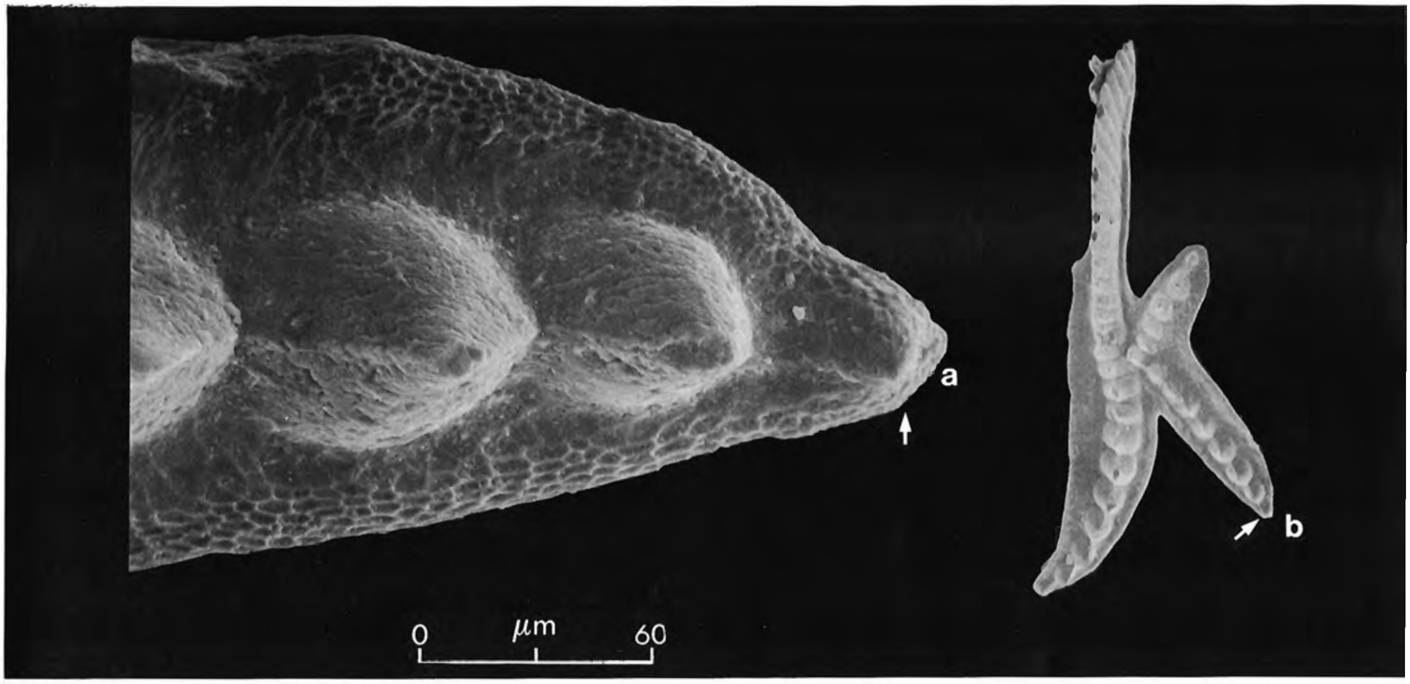


Figure 8. *Pterospathodus retroramus* n. sp.: g element, upper views, GSC 101273 (holotype, same specimen as in Pl. 5, fig. 2). a) x500. b) x50. Arrows indicate identical features in both figures.

The *f* element (Pl. 4, fig. 24, Pl. 5, figs. 1, 3) is an arched ozarkodiniform element that has a long anterior process and a shorter posterior process. Direction of bowing of these processes is variable. Both may be bowed to inner side; or if only posterior process is bowed to this side, anterior process is either straight or slightly bowed to outer side. Outer lateral process is shorter than posterior process; on most elements outer lateral process is posteriorly directed; on some it is directed slightly to anterior. Outer lateral process has platform-like margins, and is distally tapered, although some elements have a lateral process that has a rounded distal end. Side opposite to lateral process either lacks a process or has a short downwardly directed lobe or process. This is slightly anterior to lateral process.

Denticles of anterior and posterior processes of *f* element form a blade. Cusp is wider and longer than denticles, and is at junction of outer lateral and posterior processes. Denticles and cusp contain white matter, are laterally compressed, slightly reclined, confluent, and possess triangular tips. Denticles on distal end of posterior process are short, discrete, and triangular. Denticles number about 9 on posterior, 13 on anterior processes; those on anterior process are higher than those on posterior. A low ridge of two or three denticles on outer process is connected to anterolateral face of cusp base by a sharp costa. Base is completely inverted forming a ledge on processes, and has a narrow groove along each process. Both sinistral and dextral forms of the element are found.

The *g* element (Pl. 4, fig. 25, Pl. 5, figs. 2, 4, 5) is an unarched platform element with a denticulated anterior, posterior, and bifurcated outer lateral process. Distal end of posterior process is curved inward and downward slightly in both sinistral and dextral forms; other processes are straight. Anterior process is longest, posterior process is longer than outer posterolateral, and outer anterolateral is shortest. Posterior and outer processes are platform-like. Anterior process is blade-like, except in large elements, where there is a narrow platform margin or flange. Inner platform edge of posterior process continues anteriorly past cusp to point opposite outer anterolateral process. At this point this platform margin is either straight or forms a short adenticulate lobe.

Denticles on anterior process of *g* element are relatively long, thin, laterally compressed, confluent for most of their length, and with triangular tips. They number about 16; longest denticles are situated about two thirds length from cusp. Denticles on posterior process are about nine in number, are short, peg-like, triangular in profile, and confluent only at their bases. Denticles on outer lateral processes are like those of posterior; anterolateral process has about four, posterolateral about seven denticles. Cusp is indistinguishable. Lower surface is a shallow excavation under platform processes and is narrowly excavated under anterior process. White matter is present in denticles.

Remarks. The *f* element is similar to *Ozarkodina gaertneri* Walliser *s.f.*, the *f* element of *Pterospathodus amorphognathoides*. The *f* element of *P. retroramus* n. sp. differs in that the denticles are more numerous, processes are longer, and the lateral process is denticulated, longer and less downwardly directed.

The *f* element also differs from that of *Astropentagnathus irregularis* (which occurs in the same sample as the type specimens of this species). The *f* element of *A. irregularis* has a longer lateral process that is perpendicular, not oblique, to the anteroposterior plane.

The *g* element is comparable to the same element of *Pterospathodus amorphognathoides*. The distinguishing characteristics are: the outer anterolateral process in *P. retroramus* n. sp. is shorter than the posterolateral process, whereas in *P. amorphognathoides*, these relative lengths are reversed (Männik and Aldridge, 1989).

The *g* element of *Pterospathodus retroramus* n. sp. is also similar to the *g* element of *Astropentagnathus irregularis*. Both have long outer posterolateral and short anterolateral processes, and similar denticulation. They differ in that the *g* element of *Pterospathodus retroramus* n. sp. lacks a well developed inner lateral process and is not arched. It is likely other elements (e.g., *a-c*, *d*, *e*) are part of this new species, but have been mistakenly interpreted as part of *P. celloni*, which occurs in the same sample as this species.

Material. Holotype GSC 101273, paratypes GSC 101270-101272, GSC 101274–101276.

ACKNOWLEDGMENTS

Financial support to collect and process the samples was provided by a Natural Sciences and Engineering Research Council of Canada grant to Drs. A.C. Lenz (University of Western Ontario) and J.A. Legault (University of Waterloo). Dr. A.C. Lenz is thanked for providing the graptolite identifications used herein.

Dr. M.J. Orchard (GSC, Vancouver) provided samples from Kechika River (collected by K. McClay, University of London, U.K.), Glacier Lake and South Nahanni River (samples from both localities were collected by Dr. S. Gordey, GSC, Vancouver), and McLeod Lake (collected by Dr. L.C. Struik, GSC, Vancouver). Dr. T.T. Uyeno (GSC, Calgary) provided the material from Pedley Pass and Mount Tegart, which was originally collected by Dr. B.S. Norford (GSC, Calgary).

Drs. M.J. Orchard and T.T. Uyeno are thanked for their comments on an earlier version of this paper. The figures were drafted by C. Bolton (GSC, Ottawa). A few of the SEM micrographs were provided by P. Krauss (GSC, Vancouver).

REFERENCES

Armstrong, H.A.
1990: Conodonts from the Upper Ordovician–Lower Silurian carbonate platform of North Greenland. Grønlands Geologiske Undersøgelse, Bulletin 159, 151 p.

Barnes, C.R., Kennedy, D.J., McCracken, A.D., Nowlan, G.S., and Tarrant, G.T.
1979: The structure and evolution of Ordovician conodont apparatuses. Lethaia, v. 12, p. 125-151.

Barrick, J.E. and Klapper, G.
1976: Multielement Silurian (late Llandoverian–Wenlockian) conodonts of the Clarita Formation, Arbuckle Mountains, Oklahoma, and phylogeny of *Kockelella*. Geologica et Palaeontologica, v. 10, p. 59-100.

Cecile, M.P. and Norford, B.S.
1985: Ordovician and Silurian paleogeographic maps and cross-sections for western and northwestern Canada. Geological Survey of Canada, Open File 01137.

Cooper, B.J.
1980: Toward an improved Silurian conodont biostratigraphy. Lethaia, v. 13, p. 209-227.

Epstein, A.G., Epstein, J.B., and Harris, L.D.
1977: Conodont color alteration – an index to organic metamorphism. United States Geological Survey, Professional Paper 995, 27 p.

Gordey, S.P.
in press: Evolution of the northern Cordilleran miogeocline Nahanni map area (105I), Yukon Territory and District of Mackenzie. Geological Survey of Canada, Memoir.

Jackson, D.E., Lenz, A.C., and Pedder, A.E.H.
1978: Late Silurian and Early Devonian graptolite, brachiopod and coral faunas from northwestern and Arctic Canada. Geological Association of Canada, Special Paper No. 17, 159 p.

Klapper, G. and Murphy, M.A.
1975: Silurian–Lower Devonian conodont sequence in the Roberts Mountains Formation of central Nevada. University of California Publications in Geological Sciences, v. 111, 87 p. (imprint 1974)

Lenz, A.C.
1980: Wenlock graptolite reference section, Clearwater Creek, Nahanni National Park, Northwest Territories. Canadian Journal of Earth Sciences, v. 17, p. 1075-1086.
1982: Llandoverian graptolites of the northern Canadian Cordillera: *Petalograptus*, *Cephalograptus*, *Rhaphidograptus*, *Dimorphograptus*, Retiolitidae, and Monograptidae. Royal Ontario Museum, Life Sciences Contributions, No. 130, 154 p.
1988a: Upper Silurian and Lower Devonian graptolites and graptolite biostratigraphy, northern Yukon, Canada. Canadian Journal of Earth Sciences, v. 25, p. 355-369.
1988b: Upper Llandovery and Wenlock graptolites from Prairie Creek, southern Mackenzie Mountains, Northwest Territories. Canadian Journal of Earth Sciences, v. 25, p. 1955-1971.

Lenz, A.C. and McCracken, A.D.
1982: The Ordovician–Silurian boundary, northern Canadian Cordillera: graptolite and conodont correlation. Canadian Journal of Earth Sciences, v. 19, p. 1308-1322.
1989: Silurian graptolite–conodont reference sections, northern Yukon and southwestern Northwest Territories. *In* A Global Standard for the Silurian System. C.H. Holland and M.G. Bassett (eds.); National Museum of Wales, Geology Series, No. 9, p. 177-183.

Lenz, A.C. and Pedder, A.E.H.
1972: Lower and Middle Paleozoic sediments and paleontology of Royal Creek and Peel River, Yukon, and Powell Creek, N.W.T. Twenty-fourth International Geological Congress, Montreal, Quebec, Excursion A-14 Guidebook, 43 p.

Mabillard, J.E. and Aldridge, R.J.
1983: Conodonts from the Coralliferous Group (Silurian) of Marloes Bay, south-west Dyfed, Wales. Geologica et Palaeontologica, v. 17, p. 29-43.

Männik, P.
1983: Silurian conodonts from Severnaya Zemlya. Fossils and Strata, No. 15, p. 111-119.

Männik, P. and Aldridge, R.
1989: Evolution, taxonomy and relationships of the Silurian conodont *Pterospathodus*. Palaeontology, v. 32, p. 893-906.

Männik, P. and Viira, V.
1990: Conodonts. *In* Field Meeting, Estonia, 1990, An Excursion Guidebook. D. Kaljo and H. Nestor (eds.); Institute of Geology, Estonian Academy of Sciences, Subcommission on Ordovician Stratigraphy, IUGS Subcommission on Silurian Stratigraphy, IUGS Project "Global Bioevents" IGCP, Tallinn, p. 84-89, pls. 16-18.

McCracken, A.D.
1989: Preliminary report on Ordovician–Devonian conodont collections from carbonate and fine grained clastic facies of northern Yukon Territory and northwest District of Mackenzie, N.W.T. *In* Current Research, Part G, Geological Survey of Canada, Paper 89-1G, p. 69-76.
1991: Taxonomy and biostratigraphy of Llandovery (Silurian) conodonts in the Canadian Cordillera, northern Yukon Territory. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

Mostler, H.
1967: Conodonten aus dem tieferen Silur der Kitzbühler Alpen (Tirol). Annalen des Naturhistorischen Museums in Wien, v. 71, p. 295-303.

Norford, B.S.
1969: Ordovician and Silurian stratigraphy of the southern Rocky Mountains. Geological Survey of Canada, Bulletin 176, 90 p.
1988: The Ordovician–Silurian boundary in the Rocky Mountains, Arctic Islands and Hudson Platform, Canada. *In* A Global Analysis of the Ordovician–Silurian Boundary. L.R.M. Cocks and R.B. Rickards (eds.); Bulletin of the British Museum of Natural History, Geology Series, v. 43, p. 259-263.

Norford, B.S. and Orchard, M.J.
1985: Early Silurian age of rocks hosting lead-zinc mineralization at Howards Pass, Yukon Territory and District of Mackenzie; local biostratigraphy of Road River Formation and Earn Group. Geological Survey of Canada, Paper 83-18, 35 p.

Norford, B.S., Braun, W.K., Chamney, T.P., Fritz, W.H., McGregor, D.C., Norris, A.W., Pedder, A.E.H., and Uyeno, T.T.
1970: Biostratigraphic determinations of fossils from the subsurface of the Yukon Territory and the districts of Mackenzie and Franklin. Geological Survey of Canada, Paper 70-15, 19 p.

Norford, B.S., Brideaux, W.W., Chamney, T.P., Copeland, M.J., Frebold, H., Hopkins., W.S., Jr., Jeletzky, J.A., Johnson, B., McGregor, D.C., Norris, A.W., Pedder, A.E.H., Tozer, E.T., and Uyeno, T.T.
1973: Biostratigraphic determinations of fossils from the subsurface of the Yukon Territory and districts of Franklin, Keewatin and Mackenzie. Geological Survey of Canada, Paper 72-38, 29 p.

Nowlan, G.S., McCracken, A.D., and Chatterton, B.D.E.
1988: Conodonts from Ordovician-Silurian boundary strata, Whittaker Formation, Mackenzie Mountains, Northwest Territories. Geological Survey of Canada, Bulletin 373, 99 p.

Orchard, M.J.
1984: A preliminary account of the conodont record at the western edge of the Mackenzie Platform (Nahanni Map Area), northwestern Canada. Geological Society of America, Abstracts with Programs, v. 16, no. 3, p. 185 (abstract).

Over, D.J. and Chatterton, B.D.E.
1987: Silurian conodonts from the southern Mackenzie Mountains, Northwest Territories, Canada. Geologica et Palaeontologica, v. 21, p. 1-49.

Pohler, S.M.L. and Orchard, M.J.
1991: Ordovician conodont biostratigraphy, western Canadian Cordillera. Geological Survey of Canada, Paper 90-15, 37 p. (imprint 1990)

Pugh, D.C.
1983: Pre-Mesozoic geology in the subsurface of Peel River Map area, Yukon Territory and District of Mackenzie. Geological Survey of Canada, Memoir 401, 61 p.

Savage, N.M.
1985: Silurian (Llandovery–Wenlock) conodonts from the base of the Heceta Limestone, southeastern Alaska. Canadian Journal of Earth Sciences, v. 22, p. 711-727.

Schönlaub, H.P.
1971: Zur Problematik der Conodonten – Chronologie an der Wende Ordoviz/Silur mit besonderer Berücksichtigung der Verhältnisse im Llandovery. Geologica et Palaeontologica, v. 5, p. 35-57.
1975: Conodonten aus dem Llandovery der Westkarawanken (Österreich). Verhandlungen der Geologischen Bundesanstalt, v. 2-3, p. 45-65.

Struik, L.C., Orchard, M.J., Pohler, S., and Norford, B.S.
1990: Paleozoic–Triassic stratigraphy, McLeod Lake map area, central B.C. Geological Association of Canada, Mineralogical Association of Canada Annual Meeting, May 16-18, 1990, Vancouver, B.C., Program with Abstracts, v. 15, p. A126.

Thorsteinsson, R. and Uyeno, T.T.
1981: Stratigraphy and conodonts of Upper Silurian and Lower Devonian rocks in the environs of the Boothia Uplift, Canadian Arctic Archipelago, Part 1. Contributions to stratigraphy. Geological Survey of Canada, Bulletin 292, p. 1-38. (imprint 1980)

Uyeno, T.T. and Barnes, C.R.
1983: Conodonts of the Jupiter and Chicotte Formations (Lower Silurian), Anticosti Island, Quebec. Geological Survey of Canada, Bulletin 355, 49 p.

APPENDIX A

List of GSC localities cited in text

Latitude, longitude, and NTS map sheet number are given in caption to Fig. 1.

Blackstone River (Fig. 1, loc. 3)

O-104269
O-104270

Glacier Lake (Fig. 1, loc. 6)

C-087601
C-087604

Howards Pass (Fig. 1, loc. 8)

C-086324
C-086423
C-087094
C-087548
C-087550
C-102746

Kechika River (Fig. 1, loc. 9)

C-116712

McLeod Lake (Fig. 1, loc. 10)

C-149711
C-149713
C-149715
C-159504
C-159505
C-159575

Mount Tegart (Fig. 1, loc. 11)

C-063933
C-063935

Pat Lake (Fig. 1, loc. 4)

C-085944
C-085946
C-085947
C-085948
C-085949

Pat Lake South (Fig. 1, loc. 4)

C-150617
C-150634
C-150635

Pedley Pass (Fig. 1, loc. 12)

C-045575
C-045583
C-045586
C-060942
C-060945

Rock River (Fig. 1, loc. 1)

O-104284

South Nahanni River (Fig. 1, loc. 5)

C-086326
C-086329
C-086330
C-086331
C-086333
C-086334
C-087637
C-087646
C-087750

Tetlit Creek (Fig. 1, loc. 2)

C-104297

Plates 1 to 5

PLATE 1

Specimens in figure 1 are from Howards Pass; specimens in figures 2 to 20 are from South Nahanni River.

Figure 1. *Ancoradella ploeckensis* Walliser.

g element, lower view, hypotype GSC 66004, x35, GSC loc. C-087094 (same element figured in upper view by Norford and Orchard, 1985, Pl. 2, fig. 1).

Figures 2–4. *Apsidognathus tuberculatus* Walliser

2. *g* element, upper view, hypotype GSC 101182, x25, GSC loc. C-086330.
3. *g* element, upper view, hypotype GSC 101183, x49, GSC loc. C-087637.
4. *g* element, upper view, hypotype GSC 101184, x58, GSC loc. C-087750.

Figures 5–12. *Apsidognathus* n. sp. 3

5, 9. *g* (platform) elements, lateral view, figured specimen GSC 101185, x102; stereopair, 15° and 10° tilt, respectively, upper view, figured specimen GSC 101186, x92, GSC loc. C-087750.
6, 7. Lyriform (scaphate) elements, upper views, figured specimens GSC 101187, x96, GSC 101188, x89, GSC loc. C-087750.
8, 12. *f* elements, upper views, figured specimens GSC 101191, x135, GSC 101192, x177, GSC loc. C-087750.
10. Stelliscaphate element, lateral view, figured specimen GSC 101189, x146, GSC loc. C-087750.
11. *a* element, upper view, figured specimen GSC 101190, x69, GSC loc. C-087750.

Figures 13–17. *Aspelundia fluegeli* (Walliser).

13. *c* element, posterior view, hypotype GSC 101193, x154, GSC loc. C-087750.
14. *f* element, lateral view, hypotype GSC 101194, x65,GSC loc. C-087750.
15. *f* element, lateral view, hypotype GSC 101195, x89, GSC loc. C-087750.
16. *e* element, lateral view, hypotype GSC 101196, x96, GSC loc. C-086330.
17. *a* element, lateral view, hypotype GSC 101197, x116, GSC loc. C-086330.

Figures 18-20. *Aspelundia capensis* Savage?

18. *b* element, posterior view, hypotype GSC 101198, x108, GSC loc. C-086329.
19. *e* element, lateral view, hypotype GSC 101199, x116, GSC loc. C-086329.
20. *c* element, lateral view, hypotype GSC 101200, x89, GSC loc. C-086329.

PLATE 1

PLATE 2

All are from Blackstone River, except specimen in figure 19, which is from Howards Pass.

Figures 1–10. *Astropentagnathus araneum* n. sp.

1, 4. *b/c* elements, lateral view, paratype GSC 101201, x54, upper view, paratype GSC 101202, x54, GSC loc. O-104270.

2, 6. *f* elements, upper views, paratypes GSC 101203, GSC 101204, x50, stereopairs (0° and 10° tilt, respectively), GSC loc. O-104270.

3, 7. *e* elements, inner and outer views, paratypes GSC 101205, x46, GSC 101206, x62, GSC loc. O-104270.

5. *a*? element, lateral view, paratype GSC 101207, x42, GSC loc. O-104270.

8, 9. *g* elements, upper views, holotype GSC 101208, paratype GSC 101209, x39; stereopairs (0° and 10° tilt, respectively), GSC loc. O-104270.

10. *g* element, upper view, paratype GSC 101210, x39, GSC loc. O-104270.

Figures 11–19. *Astropentagnathus irregularis* Mostler.

11–13. *f* elements, upper views, hypotype GSC 101211, x42, stereopair (0° and 10° tilt, respectively), hypotypes GSC 101212, x29, GSC 101213, x42, GSC loc. O-104270.

14–18. *g* elements, upper views, hypotypes GSC 101214, x39, GSC 101215, x39, GSC 101216 stereopair (0° and 10° tilt, respectively); GSC 101217, x62, GSC 101218, x42, GSC loc. O-104270.

19. *g* element, lower view, hypotype GSC 101219, x42, GSC loc. C-102746.

PLATE 2

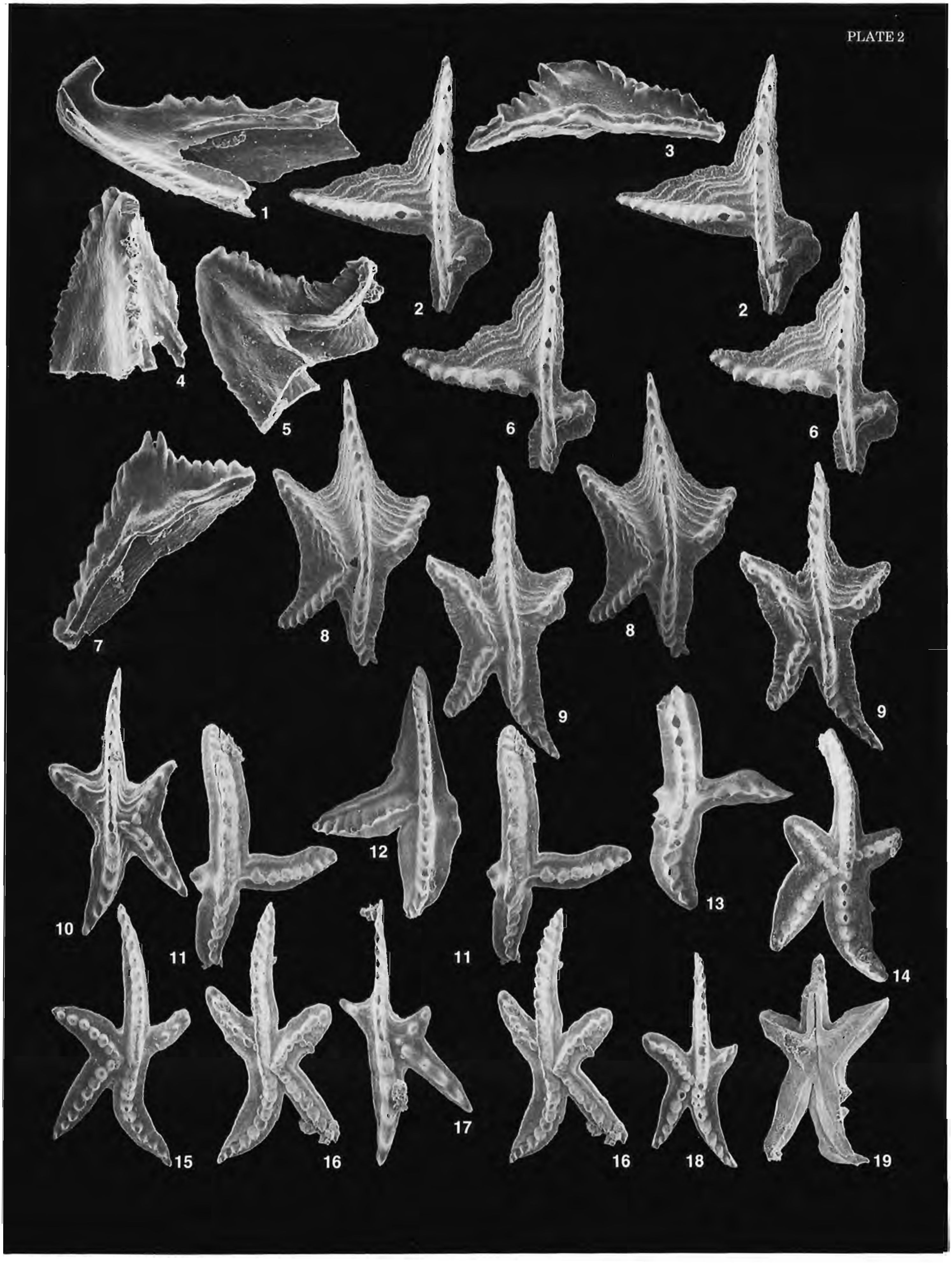


PLATE 3

Specimens in figures 1, 2, 5, 22, and 23 are from Blackstone River; figure 3 from McLeod Lake; figures 4, 6–21, 26, and 27 are from South Nahanni River; figures 24 and 25 are from Glacier Lake.

Figures 1, 2. *Aulacognathus bullatus* (Nicoll and Rexroad).

1. *f* element, lateral view, hypotype GSC 101220, x42.
2. *g* element, upper view, hypotype GSC 101221, x42, GSC loc. O-104270.

Figure 3. *Aulacognathus chapini* (Savage).

g element, upper view, hypotype GSC 101222, x39, GSC loc. C-149715.

Figure 4. *Aulacognathus* sp. aff. *A. latus* (Nicoll and Rexroad) *sensu* Over and Chatterton.

g element, upper view, figured specimen GSC 101223, x33, GSC loc. C-086330.

Figure 5. *Aulacognathus nelsoni* Over and Chatterton.

g element, upper view, hypotype GSC 101224, x31, GSC loc. O-104270.

Figures 6-15. *Carniodus carnulus* Walliser.

6, 7, 10. *f* elements, upper view, hypotype GSC 101225, x89, lateral views, hypotypes GSC 101226, x89, GSC 101227, x89, GSC loc. C-087750.
8. *e*-2 element, anterior view, hypotype GSC 101228, x112, GSC loc. C-087750.
9, 15. *g* elements, lateral views, hypotypes GSC 101229, x123, GSC 101231, x123, GSC loc. C-087750.
14. *g* element, lateral view, hypotype GSC 101230, x193, GSC loc. C-086330.
11. *b* element, anterolateral view, hypotype GSC 101232, x123, GSC loc. C-087750.
12. *a* element, lateral view, hypotype GSC 101233, x112, GSC loc. C-087750.
13. *c* element, anterior view, hypotype GSC 101234, x173, GSC loc. C-086330.

Figure 16. *Distomodus* sp. cf. *D. kentuckyensis* Branson and Branson *sensu* Cooper.

f element, anterior view, figured specimen GSC 101235, x65, GSC loc. C-086330.

Figure 17. *Distomodus staurognathoides* (Walliser).

g element, upper view, hypotype GSC 101236, x27, GSC loc. C-086330.

Figures 18–21. *Oulodus*? n. sp. B Over and Chatterton?

18. *a* element, lateral view, figured specimen GSC 101237, x46, GSC loc. C-086331.
19. *e* element, lateral view, figured specimen GSC 101238, x58, GSC loc. C-086331.
20. *c* element, posterior view, figured specimen GSC 101239, x50, GSC loc. C-086331.
21. *e* element, lateral view, figured specimen GSC 101240, x65, GSC loc. C-086330.

Figures 22, 23. *Oulodus*? n. sp. B McCracken.

22. *f* element, inner view, figured specimen GSC 101241, x50, GSC loc. O-104270.
23. *e* element, lateral view, figured specimen GSC 101242, x53, GSC loc. O-104270.

Figures 24, 25. *Ozarkodina confluens* (Branson and Mehl).

24. *g* element gamma morphotype, hypotype GSC 101243, x92, GSC loc. C-087601.

25. *g* element alpha morphotype, hypotype GSC 101244, x50, GSC loc. C-087601.

Figure 26. *Ozarkodina* sp. cf. *O. confluens* (Branson and Mehl).

g element, figured specimen GSC 101245, x135, GSC loc. C-086333.

Figure 27. *Ozarkodina fundamentata* (Walliser)?

g element, figured specimen GSC 101246, x69, GSC loc. C-086333.

PLATE 3

PLATE 4

Specimens in figures 1–3, 12–23 are from South Nahanni River; specimens in figures 4–11, 24, and 25 are from Blackstone River.

Figure 1. *Panderodus* sp.

Lateral view, figured specimen GSC 101247, x139, GSC loc. C-087750.

Figure 2. *Polygnathoides siluricus* Branson and Mehl.

g element, upper view, hypotype GSC 101248, x64, GSC loc. C-087646.

Figure 3. *Pseudooneotodus tricornis* (Drygant).

Upper-lateral view, hypotype GSC 101249, x85, GSC loc. C-086330.

Figures 4–7. *Pterospathodus celloni* (Walliser).

4, 5. *f* elements, lateral views, hypotypes GSC 101250, x77, GSC 101251, x77, GSC loc. O-104270.
6, 7. *g* (celloniform) elements, lateral views, hypotypes GSC 101252, x50, GSC 101253, x58, GSC loc. O-104270.

Figures 8–11. *Pterospathodus celloni* (Walliser).

8, 11. *g* (angulatiform) elements, upper views, hypotypes GSC 101254, x69, GSC 101255, x69, GSC loc. O-104270.
9. *f* element, lateral view, hypotype GSC 101256, x89, GSC loc. O-104270.
10. *g* (pennatiform?) element, upper view, hypotype GSC 101257, x65, GSC loc. O-104270.

Figures 12–19. *Pterospathodus procerus* (Walliser).

12, 14, 18. *g* elements, upper views, hypotypes GSC 101258, x54, GSC 101259, x54, GSC 101260, x89, GSC loc. C-086330.
13, 19. *f* elements, lateral views, hypotypes GSC 101261, x108, GSC 101262, x89, GSC loc. C-086330.
15. *a* element, lateral view, hypotype GSC 101263, x154, GSC loc. C-086330.
16. *d* (Pc) element, lateral view, hypotype GSC 101264, x108, GSC loc. C-086330.
17. *e* element, lateral view, hypotype GSC 101265, x123, GSC loc. C-086330.

Figures 20–23. *Pterospathodus procerus* (Walliser).

20–22. *g* elements, upper views, hypotypes GSC 101266, x108, GSC 101267, x108, GSC 101268, x108, GSC loc. C-087750.
23. *f* element, lateral view, hypotype GSC 101269, x154, GSC loc. C-087750.

Figures 24, 25. *Pterospathodus retroramus* n. sp.

24. *f* element, lateral view, paratype GSC 101270, x62, GSC loc. O-104270.
25. *g* element, upper view, paratype GSC 101271, x39, GSC loc. O-104270.

PLATE 4

PLATE 5

Specimens in figures 1–5, 16–19, 21, and 22 are from Blackstone River; specimens in figures 6–15, 20, 23, and 24 are from South Nahanni River.

Figures 1–5. *Pterospathodus retroramus* n. sp.

1. *f* element, upper view, stereopair, 10° and 0° tilt, respectively, paratype GSC 101272, x50, GSC loc. O-104270.
2. *g* element, upper view, holotype GSC 101273, x39, stereopair, tilt as for figure 1, GSC loc. O-104270.
3. *f* element, lateral view, paratype GSC 101274, x35, GSC loc. O-104270.

4, 5. *g* elements, upper views, paratypes GSC 101275, x58, GSC 101276, x58, GSC loc. O-104270.

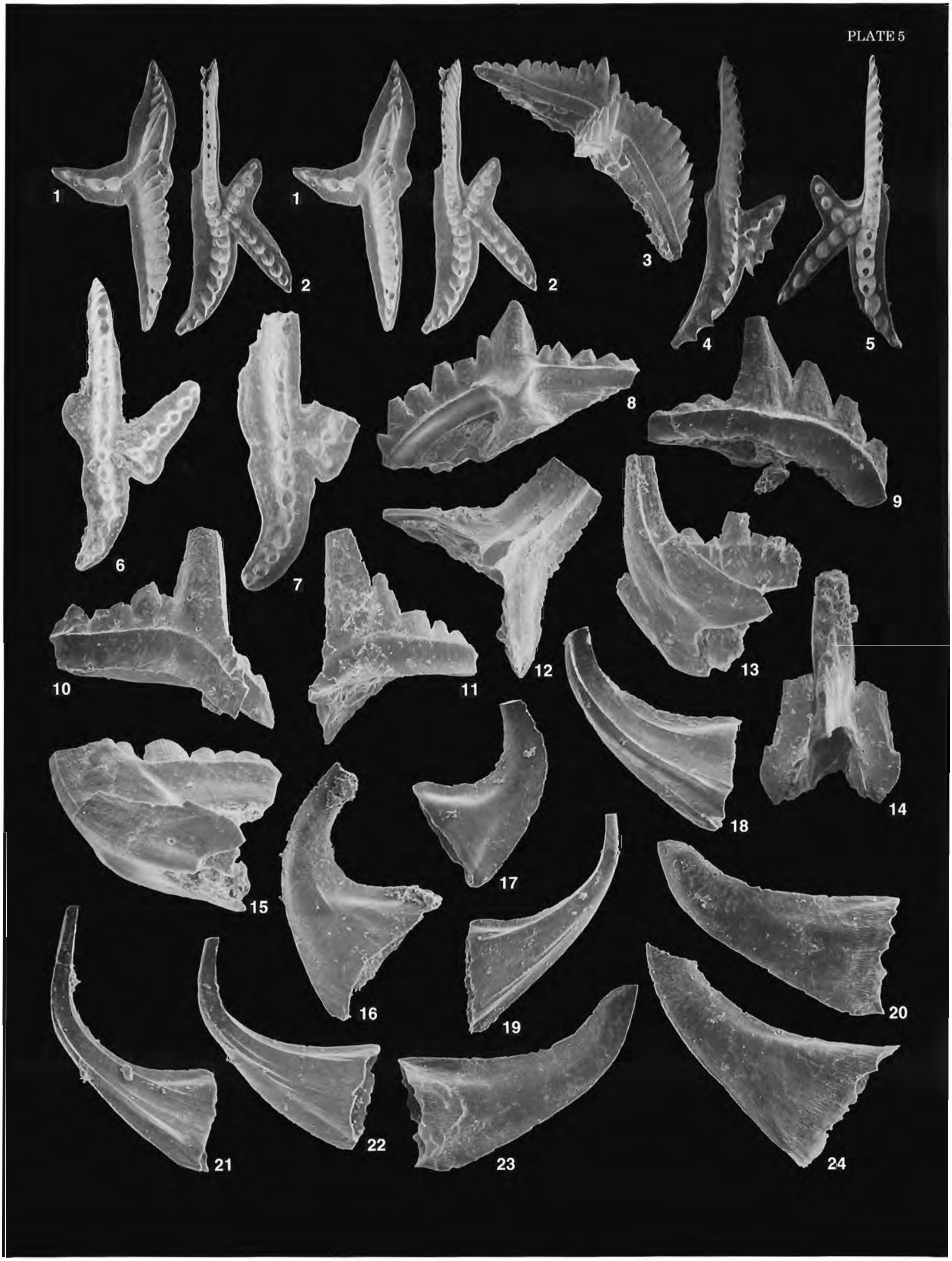
Figures 6–15. *Pterospathodus rhodesi* (Savage).

6, 7. *g* elements, upper views, hypotypes GSC 101277, x47, GSC 101278, x54, GSC loc. C-087750.
8, 9. *f* elements, lateral and posterior views, hypotypes GSC 101279, x62, GSC 101280, x127, GSC loc. C-087750.
10, 11. *d* (Pc) elements, lateral views, hypotypes GSC 101281, x85, GSC 101282, x116, GSC loc. C-087750.
12. *e* element, lateral view, hypotype GSC 101283, x100, GSC loc. C-087750.
13. *b* element, lateral view, hypotype GSC 101284, x200, GSC loc. C-087750.
14, 15. *c* elements, posterior and lateral views, hypotypes GSC 101285, x200; GSC 101286, x135, GSC loc. C-087750.

Figures 16–24. *Walliserodus blackstonensis* McCracken.

16. *a* element, inner view, hypotype GSC 101287, x77, GSC loc. O-104269.
17. *a* element, inner view, hypotype GSC 101288, x65, GSC loc. O-104269.
18. *c* element, lateral view, hypotype GSC 101289, x81, GSC loc. O-104269.
19, 21, 22. *d* elements, lateral views, hypotypes GSC 101290, x62, GSC 101291, GSC 101292, x81, GSC loc. O-104269.
20, 23. *e* element, outer and inner views, hypotype GSC 101293, x116, GSC loc. C-087750.
24. *e* element outer view, hypotype GSC 101294, x104, GSC loc. C-087750.

PLATE 5



Pre-Famennian Devonian conodont biostratigraphy of selected intervals in the eastern Canadian Cordillera

T.T. Uyeno[1]

Uyeno, T.T., 1991: Pre-Famennian Devonian conodont biostratigraphy of selected intervals in the eastern Canadian Cordillera. In Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417, p. 129-161.

Abstract

*A conodont biostratigraphy of the Devonian strata of the eastern Canadian Cordillera is summarized herein. These strata range from Early Devonian, Lochkovian (*hesperius *Zone) to Late Devonian, late Frasnian (approximately Zone 12 of the Montagne Noire, France sequence) in age. The strata are divided into four stratigraphic intervals or "assemblages", A to D. These assemblages, represented by 28 stratigraphic units belong to nine major tectonic and tectono-sedimentological elements. The major elements selected represent the western "continental shelf" and the eastern "cratonic platform". Eighty-three of the more age-diagnostic conodont taxa are illustrated.*

Résumé

*On présente en bref une biostratigraphie des strates dévoniennes de l'est de la Cordillère canadienne, laquelle biostratigraphie se fonde sur des conodontes. Ces strates s'échelonnent du Dévonien inférieur (Lochkovien [zone à *hesperius*]) au Dévonien supérieur (Frasnien supérieur [approximativement zone 12 de la séquence de Montagne Noire, en France]), et se subdivisent en 4 intervalles stratigraphiques, ou «assemblages», soit de A à D, que représentent 28 unités stratigraphiques appartenant à 9 éléments tectoniques et tectono-sédimentologiques majeurs. Les éléments majeurs choisis représentent la partie ouest de la «plate-forme continentale» et la partie est de la «plate-forme cratonique». Quatre-vingt-trois des taxons de conodontes les plus caractéristiques y sont illustrés.*

INTRODUCTION

The major tectono-sedimentological elements and stratigraphic subdivisions of the Devonian strata of the eastern Canadian Cordillera used in this paper are those described by Morrow and Geldsetzer (1989). The eastern limit of the study is at the eastern boundary of the structurally disturbed belt of the Rocky Mountains and of the Franklin and Mackenzie mountains to the north (Fig. 1). A major structural discontinuity in the form of the Rocky Mountain Trench and its northern continuation, the Tintina Trench, divides the Devonian strata into two parts. Devonian strata located east of this discontinuity, although segmented by thrust faults, are readily mappable and form the westward continuation of sediments deposited on the Interior Cratonic Platform. West of the trenches, however, the strata are discontinuous and occur within several pockets of allochthonous or suspect terranes that are separated from one another, thus making mapping difficult.

Devonian strata in the Cordilleran Orogen east of the Rocky Mountain–Tintina Trench cover an area of about 60 000 km^2, with an average total thickness of about 1500 m (Morrow and Geldsetzer, 1989). The Devonian outcrop belt in the Canadian Cordillera north of latitude 60° N is considerably wider than that south of it, because north of this latitude less supracrustal shortening resulted from the Laramide Orogeny (Norris, 1985).

The conodont biostratigraphic summary presented herein is based on 28 representative formations from four major stratigraphic intervals ("assemblages"), and nine major tectono-sedimentological elements. Some of the more

---

[1] Geological Survey of Canada, Institute of Sedimentary and Petroleum Geology, 3303 - 33rd St. NW, Calgary, Alberta T2L 2A7

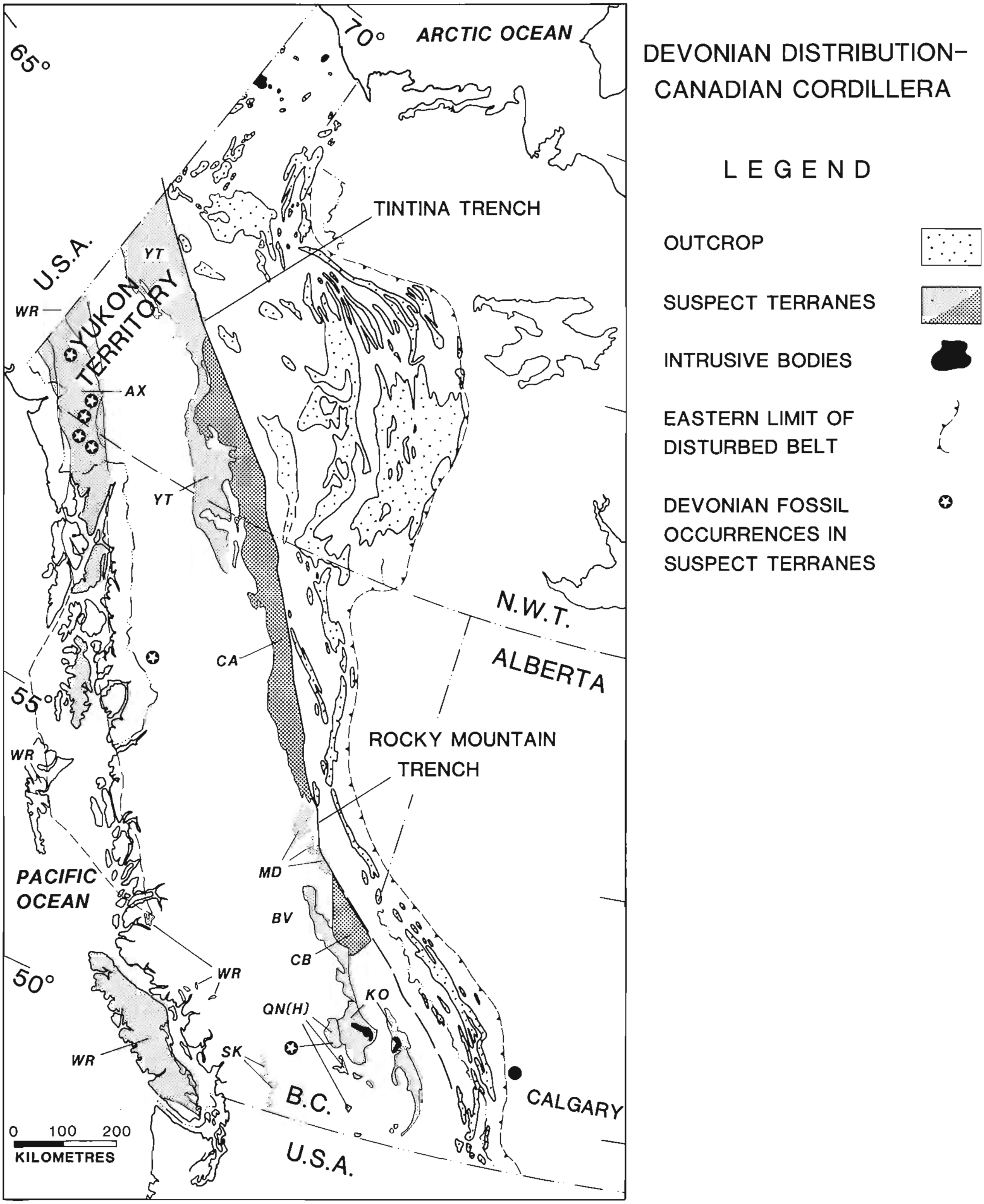


Figure 1. Distribution of Devonian rocks outcropping in the eastern part of the Canadian Cordillera. Allochthonous or suspect terranes west of the Rocky Mountain Trench with Devonian rocks are as follows: Cassiar (CA), Yukon–Tanana (YT), Alexander (AX), Wrangellian (WR), Macleod (MD), Barkerville (BV), Cariboo (CB), Kootenay (KO), Quesnellia (QN,H), and Skagit terranes (SK). (From Morrow and Geldsetzer, 1989).

diagnostic conodonts from different settings in each of these assemblages are illustrated in the accompanying plates (Pls. 1-5).

Major tectonic and tectono-sedimentological elements

Lower and Middle Devonian rocks of the Canadian Cordillera were deposited within two distinct, broadly defined tectonic provinces, the "Continental Shelf" and the "Cratonic Platform" (Morrow and Geldsetzer, 1989). Sedimentary strata of the eastern Cratonic Platform are thin in contrast to the much thicker sequence of the western Continental Shelf, with the boundary between the two probably coinciding with a hinge line separating regions of different rates of subsidence. The Continental Shelf deposits of Early Devonian age are further subdivided into an inner shelf of shallow water carbonate rocks and an outer shelf of sediments deposited in deep water and troughs (Fig. 2). The distribution of the major elements during the Late Devonian is shown in Figure 3.

The inner and outer Continental Shelf and Cratonic Platform are further subdivided into regional tectono-sedimentological elements. These subdivisions were created on the basis of differences in the average rate of uplift or subsidence, and in erosion, nondeposition and rapid or slow sediment accumulation. Thus terms such as "basin", "trough", "shelf", and "platform" are used.

Major stratigraphic subdivisions

The Devonian strata of the eastern Cordillera were subdivided into six groupings of formations, termed "assemblages", by Morrow and Geldsetzer (1989). In descending stratigraphic order they are (Figs. 4, 10):

F. Palliser Assemblage (Famennian)

E. Graminia–Kakisa Assemblage (uppermost Frasnian)

D. Fairholme Assemblage (upper Givetian, *disparilis* Zone to upper Frasnian)

C. Hume–Dunedin Assemblage (Eifelian–mid-Givetian; *costatus* to *varcus* zones)

B. Bear Rock–Stone Assemblage (Pragian–lowermost Eifelian; *sulcatus* to *patulus* zones)

A. Delorme Assemblage (Lochkovian; *hesperius* to *pesavis* zones).

Of these, only the lower four, assemblages A to D, are discussed in this paper. Facies maps of these assemblages are included (Figs. 5-9, 11, 12) to show the approximate distribution and lithotype of the formations.

CONODONT BIOSTRATIGRAPHY

In the following sections, the conodont biostratigraphy is discussed in ascending stratigraphic order, from Assemblage A to D. Each assemblage is further divided into major tectono-sedimentological elements. Taxa that are illustrated in the accompanying plates are marked with an asterisk (*).

*A. Delorme Assemblage (***hesperius** *to* **pesavis** *zones; Figs. 2, 4, 5, Pl. 1)*

Strata of the Delorme Assemblage are characterized by their terrigenous siliciclastic content and a yellowish orange coloration, reflecting the initial onlap of exposed land associated with the Kaskaskia Transgression on the "sub-Devonian" unconformity surface (Morrow and Geldsetzer, 1989). The assemblage, confined to the northern part of the Canadian Cordillera, is prominent across the MacDonald, Mackenzie, and Peel shelves, but is much less evident on the Ogilvie and Porcupine platforms. The platform areas were farther from the cratonic interior, the source of the siliciclastics.

The total thickness of the assemblage varies considerably, and ranges from a feather edge near exposed land, such as the Norman Wells High, to a maximum of more than 1500 m at the edge of the Mackenzie Shelf and in the Root Basin (Morrow and Geldsetzer, 1989).

Southern Mackenzie Shelf

The Mackenzie Shelf, here subdivided into southern and northern parts, occupied a depositional area of the inner shelf, and contains primarily shallow water carbonate rocks. The southern extension of this shelf, in northeastern British Columbia, is referred to as the MacDonald Shelf.

The Vera Formation, a 200 to 300 m thick, brightly coloured, argillaceous, skeletal, lime wackestone, was deposited in the Root Basin, located within the Southern Mackenzie Shelf (Morrow and Cook, 1987). At its type section in the Virginia Falls (95 F) map area, the formation is 271.5 m thick. Its conodont and brachiopod faunas at Cathedral Mountain (61°42′52″N, 125°39′30″W; Sec. 1 of Morrow and Cook, 1987; there the Vera Formation is 200 m thick, and underlain by the Road River Formation) were described by Norris and Uyeno (1981; referred to as "Delorme" Formation in that reference). At GSC locs. C-57249 and C-57259 (23.1–23.2 m and 31.6–31.7 m, respectively, above the base of the formation), the conodont fauna includes: *Icriodus woschmidti hesperius* Klapper and Murphy*, *Ozarkodina remscheidensis remscheidensis* (Ziegler). (Age: *hesperius* Zone.) The associated brachiopods are representative of the *Gypidula pelagica* Zone of Johnson (1977).

Conodonts from the top of the Vera Formation at North Tundra Ridge (61°53′N, 124°55′W), GSC loc. C-60714, include: *Icriodus hadnagyi* Chatterton and Perry*, *Ozarkodina* sp. cf. *O. remscheidensis* (Ziegler). (Age: *eurekaensis* Zone.)

Northern Mackenzie Shelf

At its type area in the Root River (95 K) map area, the Camsell Formation is a variably silty limestone breccia, with some large breccia fragments in a yellow and orange weathering matrix, and some intervals of featureless lime mudstone (Morrow and Hills, *in* Hills et al., 1981). The following collection is from the Camsell Formation at the southern Bonnet Plume (106 B) map area, GSC loc. C-89126 (64°16′N, 130°40′W), some 400 km northwest of the type area: *Amydrotaxis chattertoni* Uyeno*. (Age: *eurekaensis* to *delta* zones.)

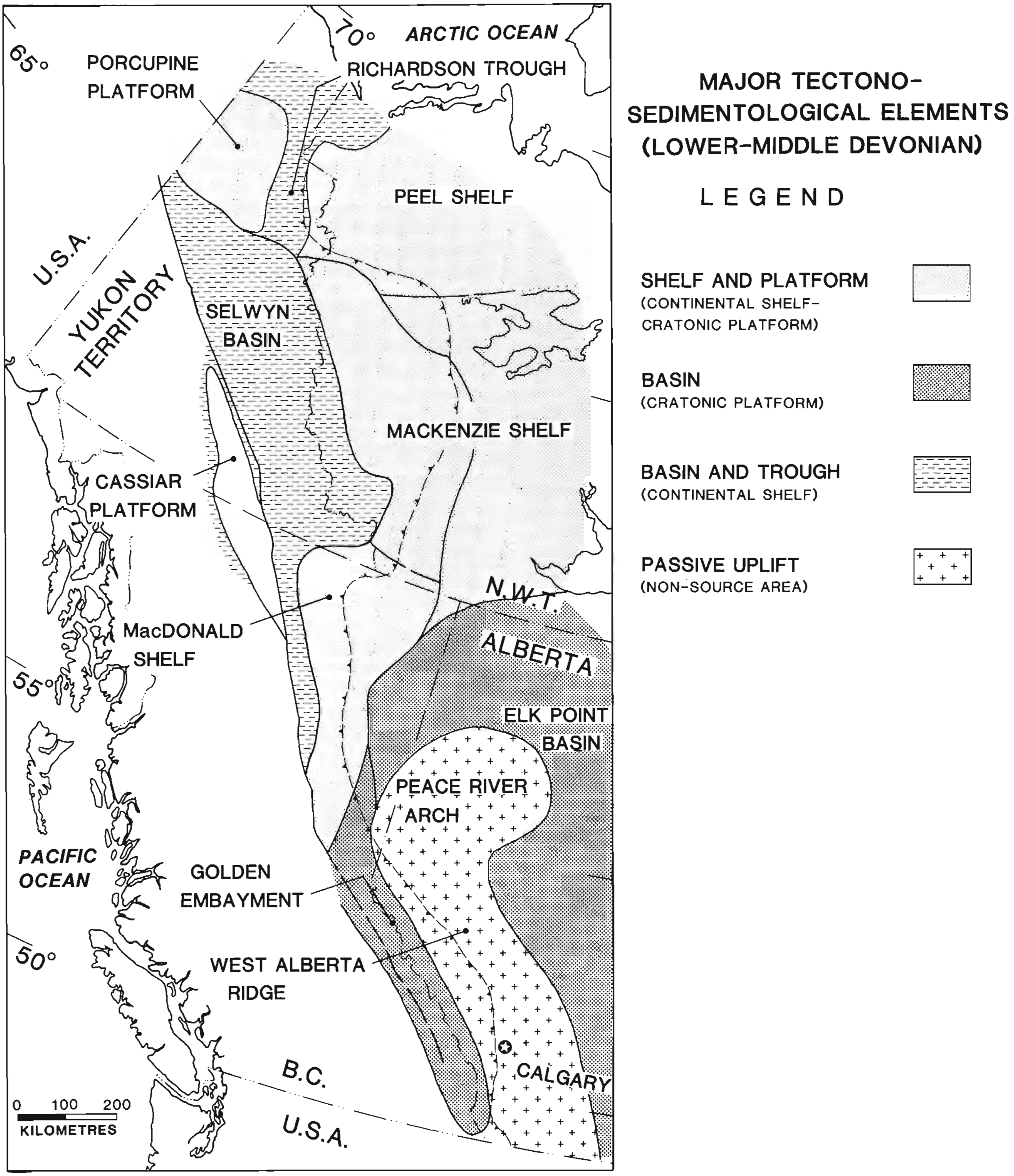


Figure 2. Distribution of major tectono-sedimentological elements of the Lower to Middle Devonian rocks of the Cordillera. Heavy lines indicate the domains of the major tectonic subdivisions of the inner and outer parts of the tectonic shelf, and of the cratonic platform landward of the shelf. (From Morrow and Geldsetzer, 1989).

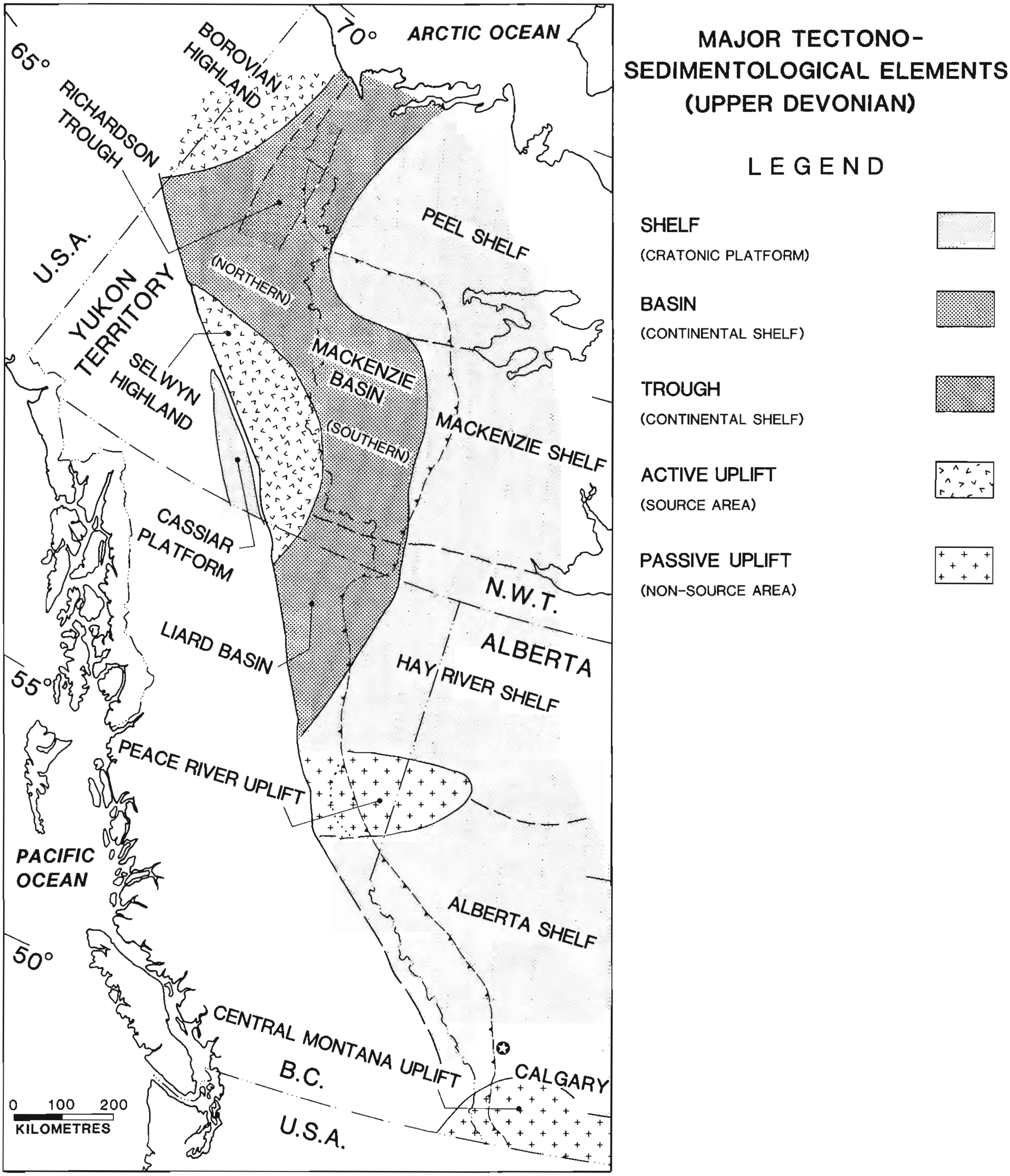


Figure 3. Distribution of the major tectono-sedimentological elements of Upper Devonian rocks of the Cordillera. (From Morrow and Geldsetzer, 1989).

Chatterton and Perry (1977) described conodonts from the Delorme Formation in the Root River (95 K) map area.

Selwyn Basin

The Selwyn Basin, lying west of the Mackenzie Shelf, occupies a depositional area on the outer shelf and primarily contains deeper water shale, limestone, and chert.

The Sapper formation consists of recessive, orange weathering limestone and silty limestone. It is present in an area northeast of the South Nahanni River, and where two members are distinguishable, the upper silty limestone member comprises tan to tan orange weathering silty limestone (Gordey, in press). In the Little Nahanni River (105 I) map area (GSC loc. C-92572; Broken Skull River, 62°47'N, 128°11'W), the silty limestone member yielded the following: *Amydrotaxis johnsoni* (Klapper) beta morphotype *sensu* Klapper and Murphy (1980)*, *Ozarkodina stygia* (Flajs),

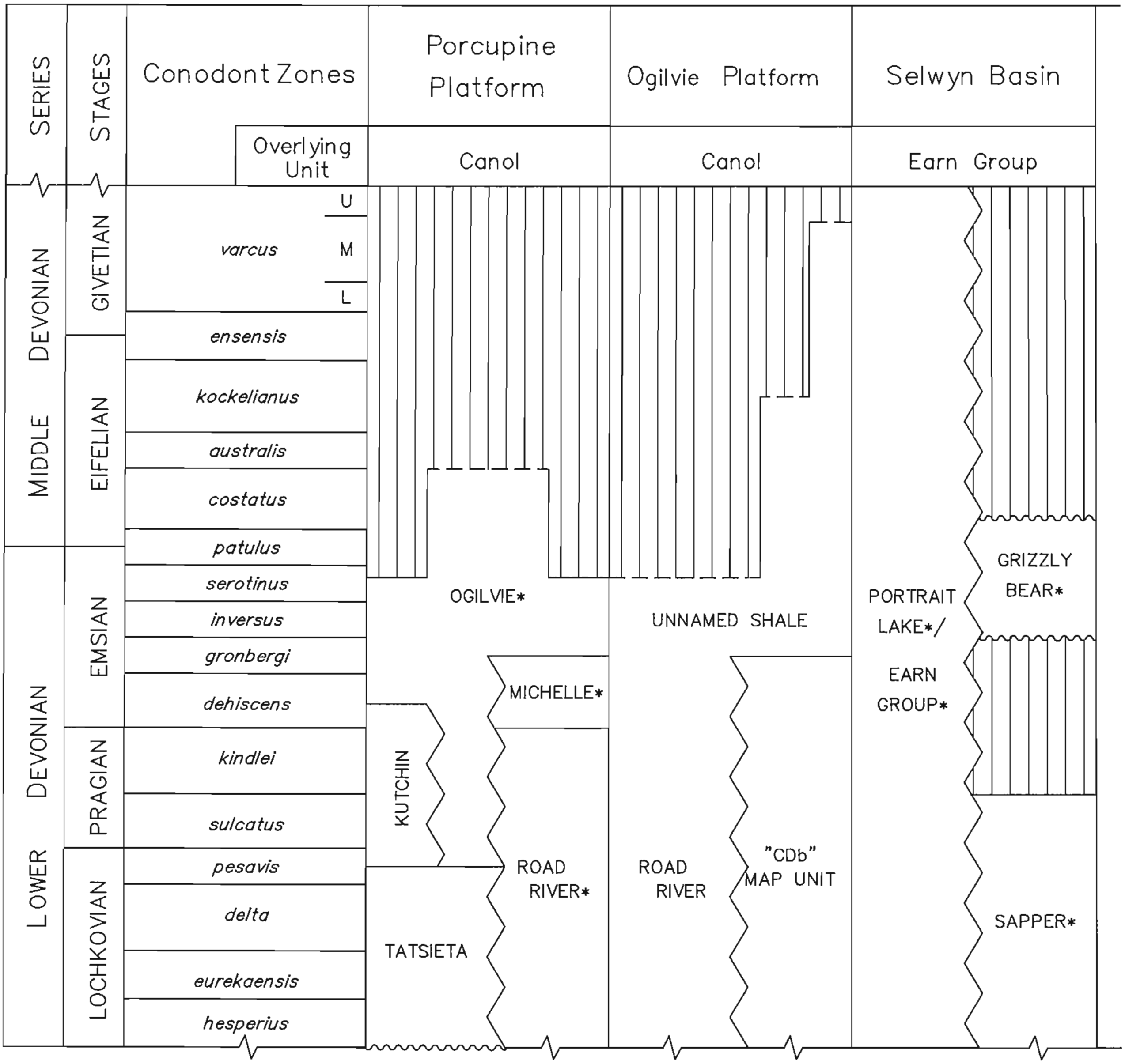


Figure 4. Stratigraphic correlation chart of Devonian formations in the eastern part of the Canadian Cordillera, ranging from the *hersperius* to *varcus* zones. Formations discussed in the text are marked with an asterisk ( ). (In part modified from Morrow and Geldsetzer [1989]; formation names in the Selwyn Basin column are from Gordey [in press], and their approximate positioning is from M.J. Orchard [pers. comm.]; spacing of conodont zonal intervals from Klapper and Johnson *in* Johnson [1990]).

Pandorinellina optima (Moskalenko)*, *Pedavis pesavis pesavis* (Bischoff and Sannemann)*, *Pseudooneotodus beckmanni* (Bischoff and Sannemann). (Age: *pesavis* Zone.)

At GSC loc. C-87829 (62°59′30″N, 128°19′40″W), the following collection was recovered from the silty limestone member: *Ozarkodina remscheidensis remscheidensis* (Ziegler), *O. stygia* (Flajs)*, *Pandorinellina optima* (Moskalenko)*. (Age: *eurekaensis* to *delta* zones.)

In the Kechika River (94 L) map area in north-central British Columbia, a stratigraphic unit that may be referrable to the Road River Formation or Earn Group (GSC loc. C-116707; Driftpile Creek, 58°16′N, 126°12′W), was sampled for conodonts. In the Glenlyon (105 L) map area in the Yukon Territory where the name was introduced, the Earn Group includes Devono-Carboniferous shale, chert, limestone, and chert-pebble conglomerate (Campbell, 1967). In southwestern District of Mackenzie, the Road River Formation is described as consisting of argillaceous limestone and a mixture of shale, chert, and argillaceous limestone (Cecile and Morrow, *in* Hills et al., 1981). The Driftpile Creek collection includes *Icriodus steinachensis* Al-Rawi beta morphotype *sensu* Klapper (*in* Klapper and Johnson, 1980)*, and is dated as *sulcatus* to *kindlei* zones.

The Road River Formation in the Virginia Falls (95 F) map area in southwestern District of Mackenzie (GSC loc. C-52706; South Tundra section, 61°44′N, 124°46′W) yielded the following: *Amydrotaxis sexidentata* Murphy and Matti*,

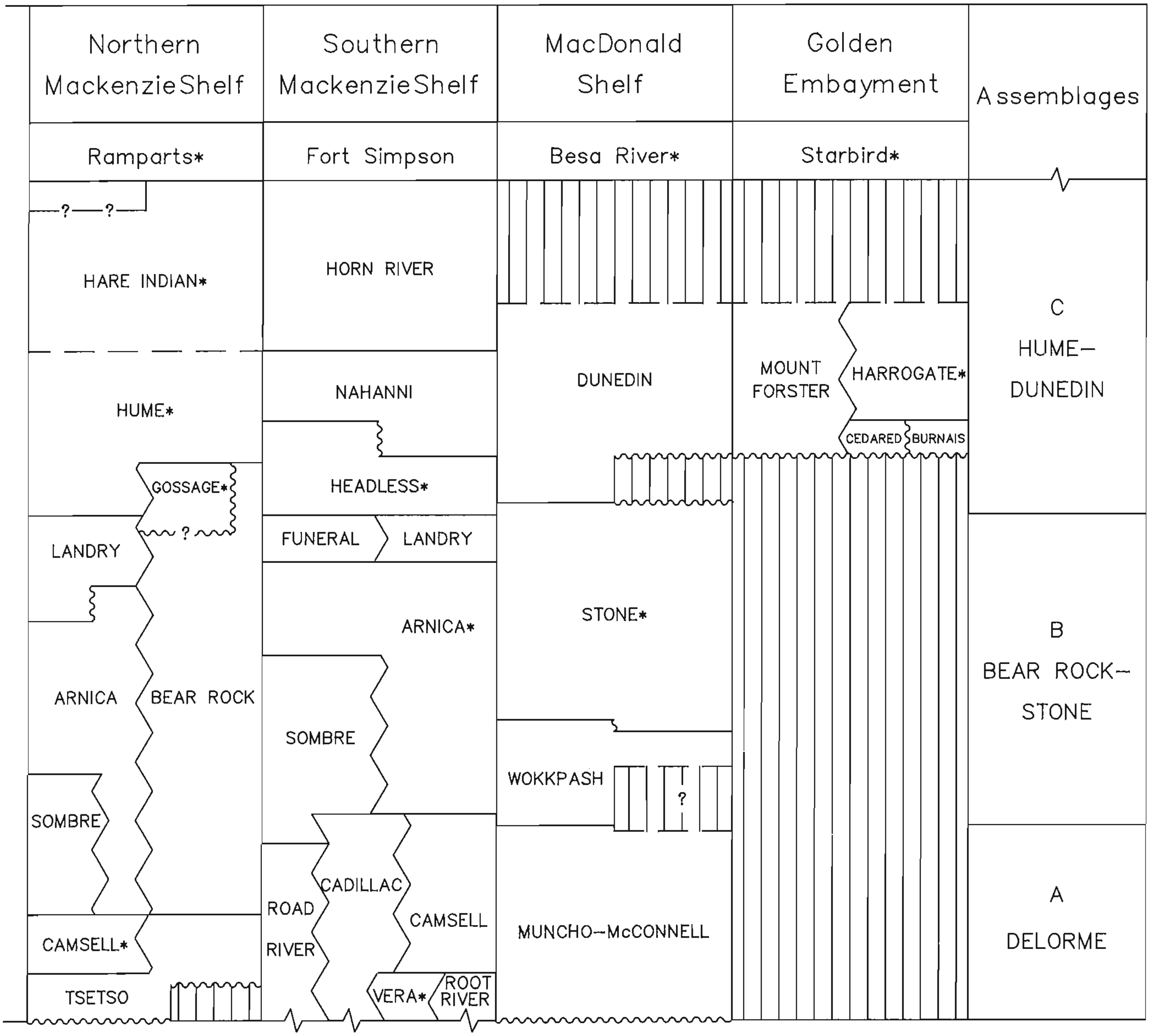


Figure 4 (cont'd.)

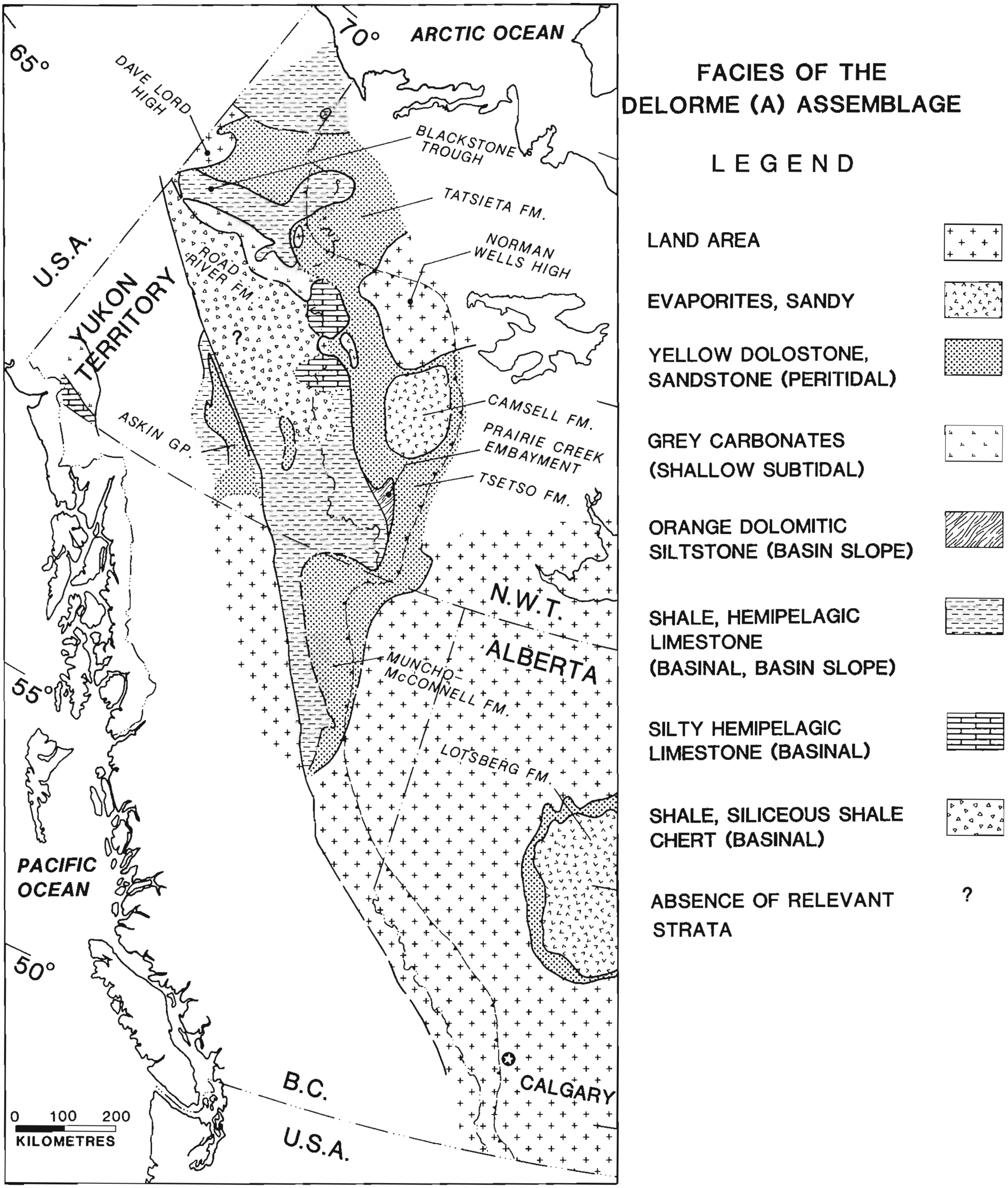


Figure 5. Distribution of the depositional facies of the Delorme Assemblage, *hesperius* to *pesavis* zones. (From Morrow and Geldsetzer, 1989).

Ozarkodina remscheidensis remscheidensis (Ziegler), *Pedavis* sp. cf. *P. pesavis* (Bischoff and Sannemann). (Age: *eurekaensis* Zone.)

Conodonts from the Road River Formation, also in the Virginia Falls (95 F) map area (GSC loc. C-59351; South Manetoe section, 61°38′N, 125°10′W), are: *Eognathodus sulcatus* Philip subsp. indet.*, *Ozarkodina remscheidensis remscheidensis* (Ziegler)*. (Age: lower part of the *sulcatus* Zone.)

Conodonts of the Road River Formation at Royal Creek in the Nash Creek (106 D) map area were described by Klapper (1969).

Porcupine Platform

The Porcupine Platform is located in the west-central part of the Yukon Territory, and is separated from the Peel and Mackenzie shelves by the Richardson Trough. As noted above, its greater distance from the interior craton is reflected in its lower siliciclastic content.

The Road River Formation from the subsurface in the Hart River (116 H) map area (GSC loc. C-13298/8151-8180; SOBC Blackstone Y.T. D-77 well, 65°46′10.77″N, 137°14′54.78″W) yielded the following collection: *Amydrotaxis johnsoni* (Klapper) alpha morphotype *sensu* Klapper and Murphy (1980)*, *Ancyrodelloides delta* (Klapper and Murphy)*, *Ozarkodina stygia* (Flajs). (Age: *delta* Zone.)

Richardson Trough

The deeper water sediments of the Richardson Trough lie between the predominantly carbonate strata of the Peel Shelf to the east and of the Porcupine Platform to the west.

The following collection was obtained from the Road River Formation at the Trail River (106 L) map area (GSC loc. C-104191; Tetlit Creek, 66°42.5′N, 135°48′W) (this locality is close to the type section of the formation, where the unit consists of a thick succession of alternating graptolitic shale, argillaceous limestone and some chert, dolostone, siltstone, and sandstone [Cecile and Morrow, *in* Hills et al., 1981, p. 152-153]): *Ozarkodina paucidentata* Murphy and Matti*, *O. remscheidensis remscheidensis* (Ziegler). (Age: *hesperius* to *eurekaensis* zones.)

*B. Bear Rock–Stone Assemblage (*sulcatus *to* patulus *zones; Figs. 2, 4, 6, 7, Pls. 1, 2)*

The Bear Rock–Stone Assemblage was deposited following the marine transgression that inundated most land areas in the northern Cordillera (Morrow and Geldsetzer, 1989). Clean carbonates and evaporites uncontaminated by land-derived siliciclastic material were deposited. The assemblage, which is still confined to the northern part of the Cordillera, ranges in thickness from a feather edge, where it onlaps the West Alberta Ridge and Peace River Arch, to a maximum of 1700 m at the edge of the Prairie Creek Embayment on the Mackenzie Shelf (Morrow, 1984).

MacDonald Shelf

As noted previously, the MacDonald Shelf is the southern extension of the Mackenzie Shelf, and consists of strata deposited on the inner shelf platform.

A representative unit selected here is the Stone Formation from the Toad River (94 N) map area in north-central British Columbia (GSC loc. O-57339; Caribou Range, 59°42′N, 125°33′W). West of the type area, which is located in the Tuchodi Lakes (94 K) map area, the formation is of shallow subtidal origin, consisting of fine crystalline dolostone with minor interbedded limestone (Taylor, *in* Glass, 1990; *see* also Taylor and MacKenzie, 1970). The formation yielded the following fauna: *Pandorinellina exigua philipi* (Klapper), *Pelekysgnathus* sp. (probably new). (Age: *sulcatus* to *gronbergi* zones.)

Conodonts were obtained from two samples of an unknown stratigraphic unit, from approximately 250 km south of the above locality, in the Ware (94 F) map area. One is from GSC loc. C-79137 (57°07′N, 124°18′W): *Icriodus claudiae* Klapper*, *Pandorinellina exigua philipi* (Klapper)*, *P. steinhornensis praeoptima* (Mashkova) *sensu* Lane and Ormiston (1979)*, *Polygnathus pireneae* Boersma*. (Age: *dehiscens* Zone.)

The second is from GSC loc. C-79088 (57°27′N, 124°47′W): *Eognathodus sulcatus kindlei* Lane and Ormiston*, *Pandorinellina steinhornensis*? of Lane and Ormiston (1979), *Polygnathus pireneae* Boersma*. (Age: *kindlei* Zone.)

Southern Mackenzie Shelf

The Arnica Formation consists of grey, fetid, fine to medium crystalline, thick bedded dolostone (Morrow et al. *in* Hills et al., 1981). From the Root River (95 K) map area (62°30′30″N, 124°49′30″W), GSC loc. C-83240, the following collection was recovered: *Eognathodus sulcatus kindlei* Lane and Ormiston, *Ozarkodina linearis* (Philip)*. (Age: *dehiscens* Zone.)

Conodonts from some units within the Mackenzie Shelf were reported earlier by Chatterton (1979).

Selwyn Basin

From an unassigned unit considered to be a carbonate equivalent to the Road River Formation in the Nash Creek (106 D) map area (central Yukon Territory, 64°44′25″N, 135°09′30″W) GSC loc. C-12895, the following fauna was recovered: *Icriodus taimyricus* Kuzmin*, *Pandorinellina exigua philipi* (Klapper), *Polygnathus* sp. cf. *P. pireneae* Boersma. (Age: *dehiscens* Zone.)

The Portrait Lake formation consists of shale, chert, and minor sandstone and conglomerate (Gordey, in press). At its type section in southeast Niddery Lake (105 O) map area, the formation is 897 m thick. Conodonts were obtained from the formation in the Little Nahanni River (105 I) map area (62°29.5′N, 129°13.6′W) GSC loc. C-76623: *Pandorinellina exigua exigua* (Philip), *P. steinhornensis steinhornensis*

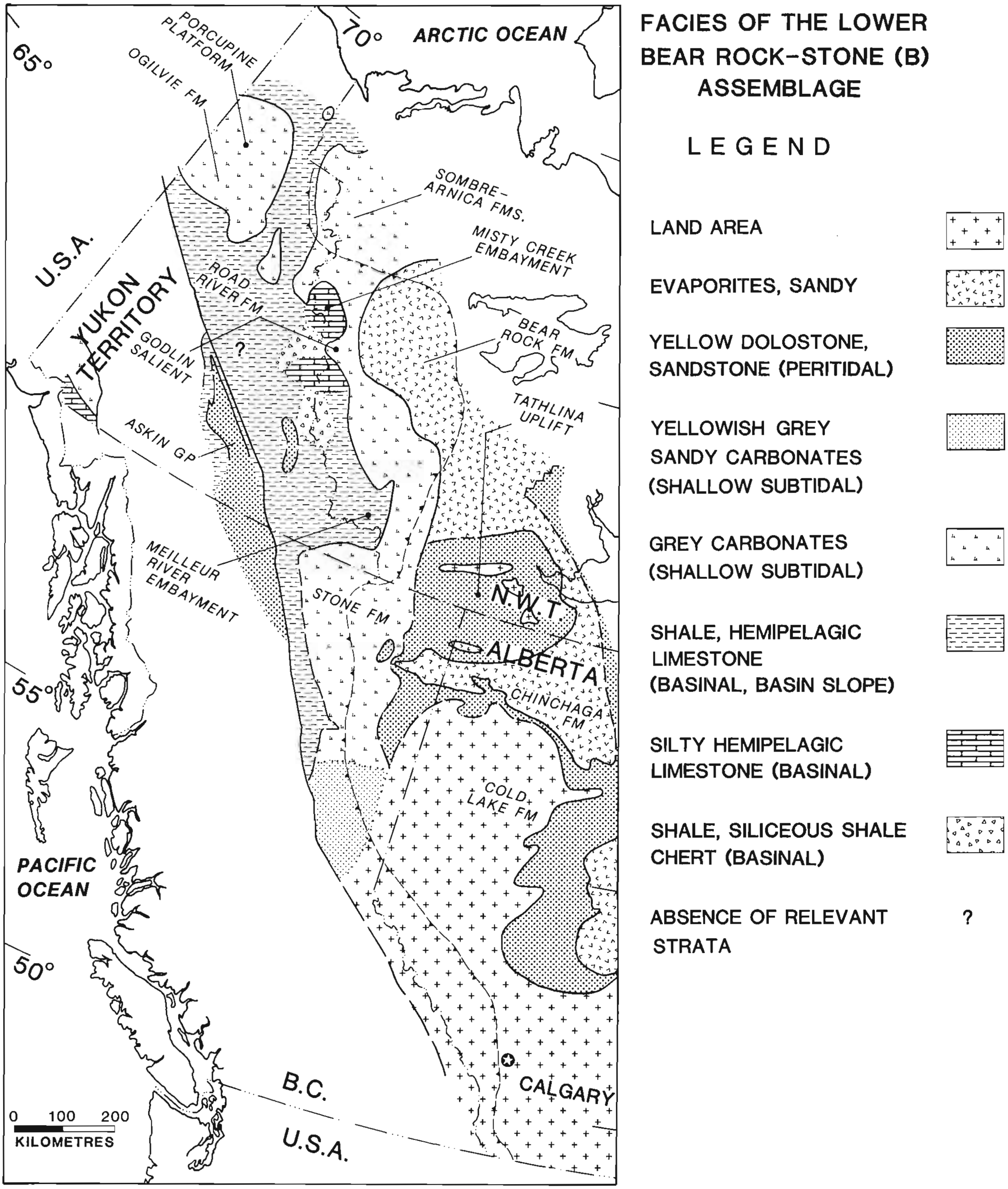


Figure 6. Distribution of the depositional facies of the lower Bear Rock–Stone Assemblage, *sulcatus* to *dehiscens* zones. (From Morrow and Geldsetzer, 1989).

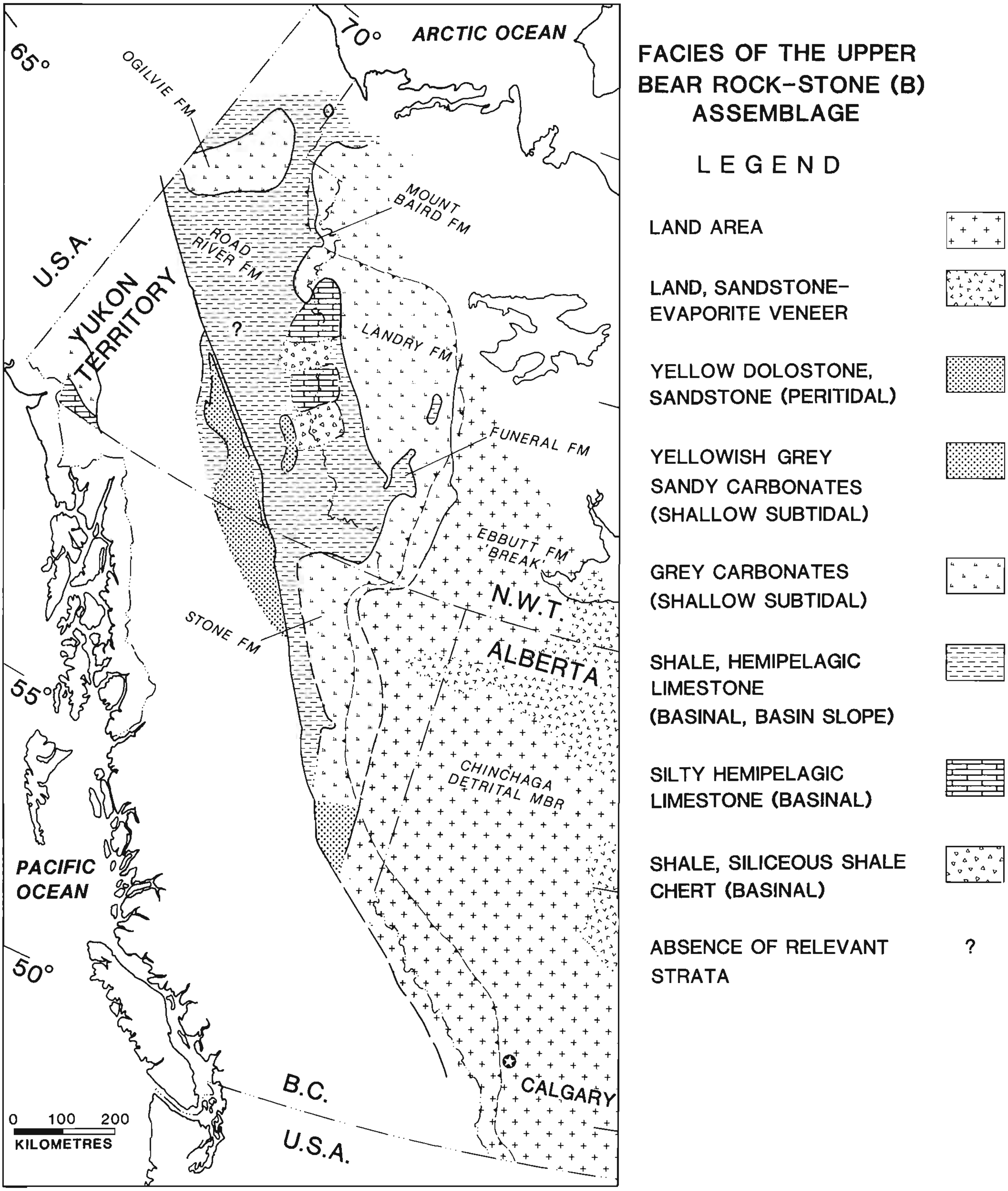


Figure 7. Distribution of the depositional facies of the upper Bear Rock–Stone Assemblage, *gronbergi* to *patulus* zones. (From Morrow and Geldsetzer, 1989).

(Ziegler)*, *Polygnathus gronbergi* Klapper and Johnson*, *P.* sp. aff. *P. laticostatus* Klapper and Johnson*. (Age: *gronbergi* Zone.)

The Grizzly Bear Formation consists of cliff forming, massive, light grey weathering limestone and, in places, dolostone (Gabrielse et al., 1973). At its type section in the Glacier Lake (95 L) map area, it is 256 m thick. From west of the type section in the Little Nahanni River (105 I) map area (62°30.6′N, 128°37.0′W) GSC loc. C-86348, the following collection was obtained: *Pandorinellina exigua exigua* (Philip), *Polygnathus inversus* Klapper and Johnson*, *P. laticostatus* Klapper and Johnson, *Steptotaxis glenisteri* (Klapper). (Age: *inversus* Zone.)

Conodonts of the Road River Formation at Royal Creek in the Nash Creek (106 D) map area were described by Klapper (1969).

Richardson Trough

The following conodont fauna was obtained from the Road River Formation at Trail River (106 L) map area, northern Yukon Territory (*See* Uyeno and Mason, 1975, p. 715, loc. 6, 66°35′N, 135°35′W; referred to as Prongs Creek Formation in that reference; revision, A.W. Norris, pers. comm., 1990): *Pandorinellina* sp. cf. *P. exigua* (Philip), *P. expansa* Uyeno and Mason*, *Polygnathus serotinus* Telford, *Steptotaxis glenisteri* (Klapper). (Age: *serotinus* Zone.)

Porcupine Platform

The Michelle Formation consists of interbedded black, calcareous shales and fossiliferous black, argillaceous and silty limestone and dolostone (Norris, 1968). At its type section in the northern Ogilvie Mountains in the Hart River (116 H) map area, the formation is 167.2 m thick. In the same map area, the following fauna was obtained from the formation at GSC loc. C-128402 (Blackstone River, 65°41′30″N, 137°26′W): *Polygnathus dehiscens dehiscens* Philip and Jackson*, *Steptotaxis? furnishi* (Klapper)*. (Age: *dehiscens* to *gronbergi* zones.)

At GSC loc. C-149438 (65°29′N, 137°57′30″W) the following fauna was obtained: *Eognathodus sulcatus kindlei* Lane and Ormiston, *Pandorinellina exigua philipi* (Klapper), *Polygnathus pireneae* Boersma. (Age: *kindlei* to *dehiscens* zones.)

Also from the Michelle Formation, but to the west in the Ogilvie (116 G) map area (GSC loc. C-150769; north of Ogilvie Crossing, 65°28′N, 138°13′30″W), the following fauna was obtained: *Pandorinellina exigua exigua* (Philip)*, *P. steinhornensis miae* (Bultynck)*, *Pedavis* sp. cf. *P. sherryae* Lane and Ormiston*, *Polygnathus dehiscens* Philip and Jackson. (Age: *dehiscens* Zone.)

Conodonts from the Michelle and Prongs Creek [= Road River] formations were described by Fåhraeus (1971).

The Ogilvie Formation consists in part of skeletal and reefal, resistant limestones, with some scattered argillaceous material, silt, and chert (Norris, 1968). At its type section at Mount Burgess in the Porcupine River (116 J) map area, the formation is 667.5 m thick. In the Hart River (116 H) map area, southeast of the type section, the following fauna was obtained from the formation (GSC loc. C-150952; northwest of Blackstone Lake, 65°13′30″N, 137°56′W; note that this sample is not in sequence with those cited below): *Icriodus taimyricus* Kuzmin*, *Polygnathus dehiscens* Philip and Jackson. (Age: *dehiscens* Zone.)

Additional conodonts from the Ogilvie Formation in the Ogilvie Mountains (65°15′25″N, 136°31′20″W) in the Hart River map area include:

In the interval of 43.6 to 79.3 m below the top of the formation (GSC loc. C-82859 to C-82861, C-82864): *Pandorinellina exigua exigua* (Philip), *P. expansa* Uyeno and Mason, *Polygnathus inversus* Klapper, *Steptotaxis glenisteri* (Klapper)*. (Age: *inversus* Zone.)

In the interval of 15.1 to 32.3 m below the top of the formation (GSC loc. C-82865, C-82867, and C-82869): *Pandorinellina exigua exigua* (Philip), *P. expansa* Uyeno and Mason, *Polygnathus linguiformis bultyncki* Weddige, *P. serotinus* Telford, *Steptotaxis glenisteri* (Klapper). (Age: *serotinus* Zone.)

Note that the *costatus* Zone of the Ogilvie Formation is discussed under Assemblage C.

Conodonts from the Ogilvie Formation were described by Klapper (*in* Perry et al., 1974; in several map areas including 116 F-J, O) and Savage et al. (1985; Ogilvie [116 F] map area). Conodont biostratigraphy aided in interpreting the depositional pattern and history of the Ogilvie Formation between the Blackstone and Hart rivers in the Hart River (116 H) map area (Dubord et al., 1986).

*C. Hume–Dunedin Assemblage (*costatus *to* varcus *zones) (Figs. 2, 4, 8, 9, Pls. 2, 3)*

The Hume–Dunedin Assemblage was deposited during and after a major transgression, which resulted in sedimentation over an area much broader than that previously covered (Morrow and Geldsetzer, 1989). This resulted in the creation of the Elk Point Basin and the Golden Embayment, and in the disappearance of the Peel, Mackenzie, and Porcupine carbonate shelves. The carbonate shelf areas saw the beginning of deeper water siliciclastic deposition.

Porcupine Platform

Conodonts were recovered from higher in the Ogilvie Formation in the Ogilvie Mountains (65°15′25″N, 136°31′20″W) in the Hart River (116 H) map area (continuing from Assemblage B, with the *serotinus, inversus*, and *dehiscens* zones). At GSC loc. C-82870 (0.1 to 0.3 m below the top of the formation), they include: *Icriodus norfordi* Chatterton, *Polygnathus costatus costatus* Klapper*, *P. linguiformis bultyncki* Weddige. (Age: *costatus* Zone.)

Northern Mackenzie Shelf

The continuously exposed section at Powell Creek can be regarded as representative of the Devonian sequence in the Mackenzie Shelf (Hume–Dunedin Assemblage) and later, in

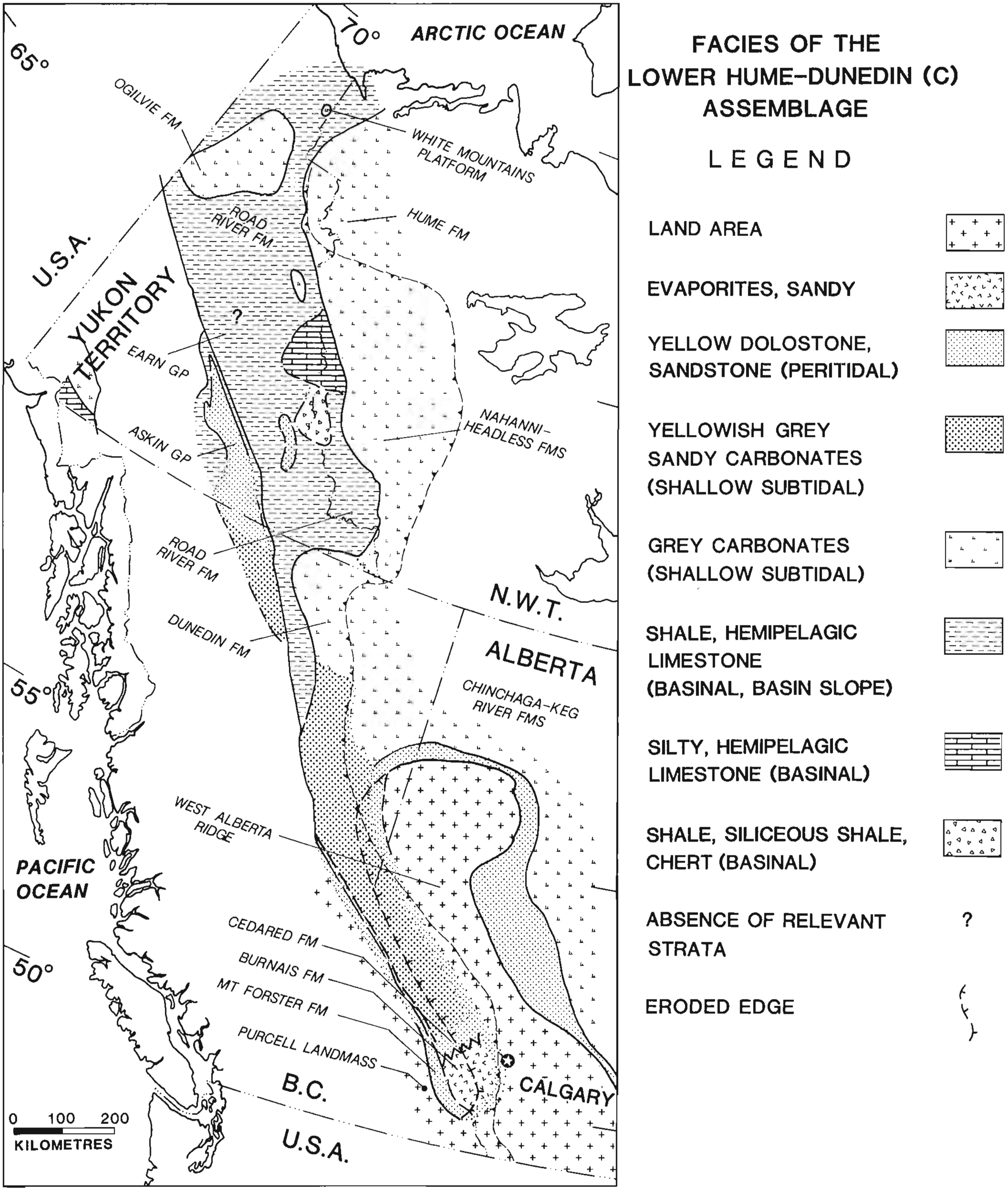


Figure 8. Distribution of the depositional facies of the lower Hume–Dunedin Assemblage, *costatus* to *ensensis* zones. (From Morrow and Geldsetzer, 1989).

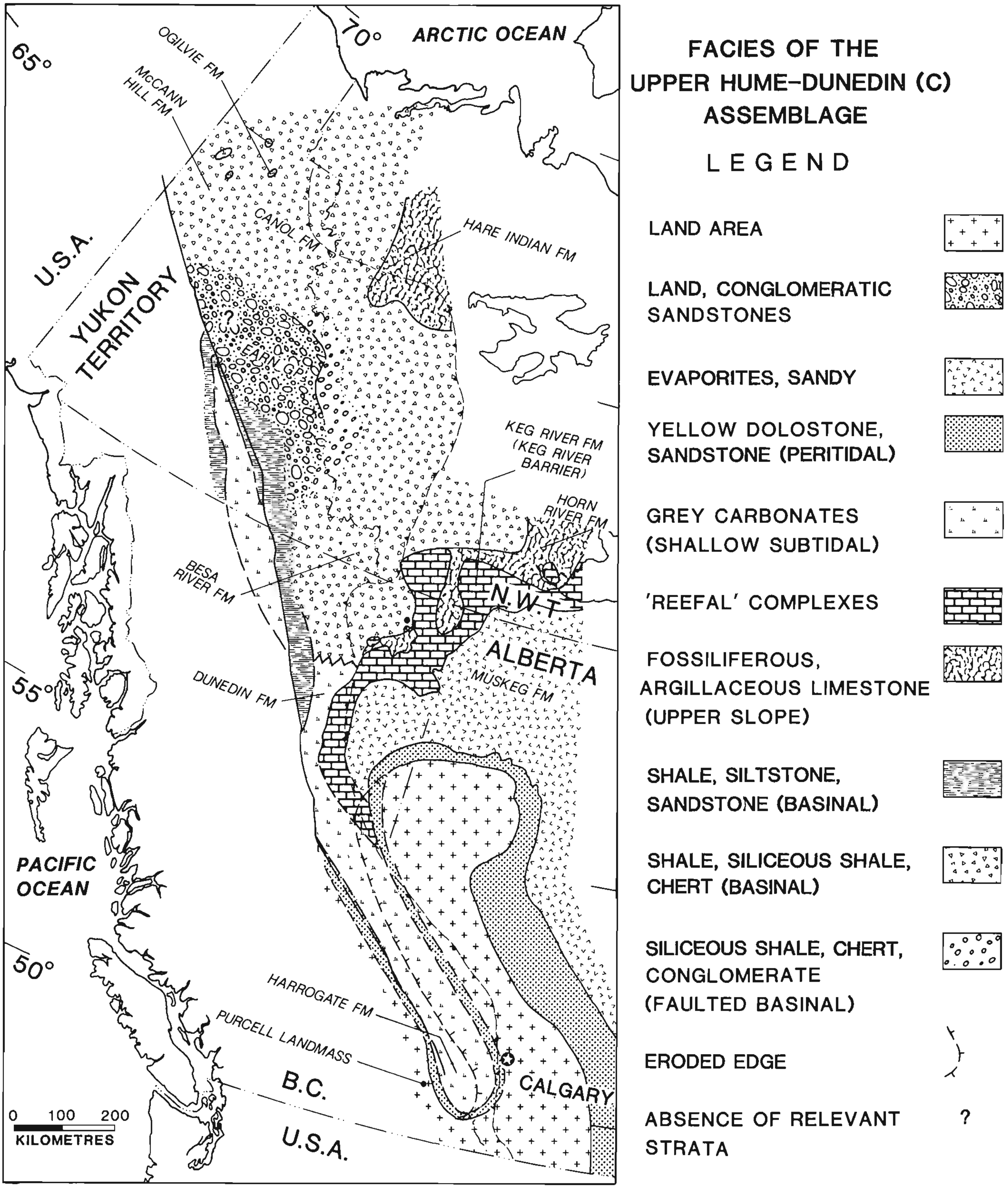


Figure 9. Distribution of the depositional facies of the upper Hume–Dunedin Assemblage, *varcus* to *hermanni* zones. (From Morrow and Geldsetzer, 1989).

the Peel Shelf (Fairholme Assemblage). The succession is exposed along the north side of a small tributary entering the valley of Mountain River from the west. The section is located at latitude 65°16′30″N, longitude 128°46′30″W in the Sans Sault Rapids (106 H) map area. The following is a brief summary of the conodont biostratigraphy at Powell Creek. The reader is referred to Uyeno (*in* Lenz and Pedder, 1972) and Uyeno (1979) for a more complete listing.

The section includes the following Devonian formations (in ascending order):

Bear Rock (limestone and dolostone breccia, 145.1 m)

Gossage (limestone and dolostone, 38.4 m)

Hume (argillaceous and fossiliferous limestone, 138.1 m)

Hare Indian (silty or sandy, variably calcareous shale, 165.8 m)

Ramparts (bioclastic limestone with some thin bedded argillaceous limestone, 30.5 m)

Allochthonous Beds (of MacKenzie, 1971; = "Unnamed beds" of Braun, 1966) (argillaceous limestone and calcareous shale, with limestone blocks derived from the nearby carbonate bank, 16.3 m)

Canol (siliceous, fissile, noncalcareous shale, with limestone concretions, 16.2 m; type section)

Imperial (quartz sandstone with some black, sandy shale, 453+ m).

Of these units, the Bear Rock and Imperial formations were not studied for conodonts and the lower three units, the Gossage, Hume, and Hare Indian formations, fall within the Hume–Dunedin Assemblage. The overlying Ramparts Formation, the Allochthonous Beds, and the Canol Formation are discussed under the Fairholme Assemblage.

The Gossage Formation contains a simple conodont fauna, consisting only of *Pandorinellina* n. sp. A *sensu* Uyeno and Mason (1975)*, and which is now considered to be of *costatus* Zone age (Klapper and Johnson, 1980). The most characteristic fossil in the formation is *Moelleritia canadensis* Copeland, a large smooth ostracode.

The overlying Hume Formation contains two faunas. The lower of these includes *Steptotaxis pedderi* (Uyeno and Mason)* and *Polygnathus parawebbi* Chatterton, and was placed in an approximate *australis* Zone equivalent by Klapper and Johnson (1980). The upper fauna comprises *Polygnathus angusticostatus* Wittekindt*, *P. curtigladius* Uyeno*, and *P. pseudofoliatus* Wittekindt*, of approximate *kockelianus* Zone equivalent (Klapper and Johnson, 1980).

The lower two thirds of the succeeding Hare Indian Formation was either barren of conodonts or yielded only small, undiagnostic collections. The upper part of the formation yielded *Icriodus brevis* Stauffer*, *Polygnathus timorensis* Klapper, Philip and Jackson*, *P. ansatus* Ziegler and Klapper*, and *P. xylus xylus* Stauffer*, suggesting a Middle *varcus* Zone assignment.

Conodonts from some units within the Mackenzie Shelf were reported earlier by Chatterton (1979).

MacDonald Shelf

From an unassigned formation in north-central British Columbia in the Ware (94 F) map area (57°06′N, 124°32′W), GSC loc. C-79343, the following collection was obtained: *Icriodus norfordi* Chatterton*, *Pandorinellina expansa* Uyeno and Mason, *Polygnathus costatus costatus* Klapper*, *P. linguiformis bultyncki* Weddige*, *P. serotinus* Telford*. (Age: *costatus* Zone.)

Golden Embayment

The Golden Embayment straddles the boundary of southeastern British Columbia and southwestern Alberta; its sediments onlap the West Alberta Ridge.

The Harrogate Formation is selected here as representative of this embayment in the Hume–Dunedin Assemblage. At its type section in the Briscoe Range, southeastern British Columbia, the formation is 89 m thick and comprises limestone, shaly limestone, nodular limestone and shale in the lower part, and dolostone in the upper (Norford *in* Glass, 1990).

Conodonts from the Harrogate Formation at North Sinclair Creek (bottom part of the outcrop) in the Lardeau (82 K) map area (50°38′N, 116°04′W), GSC loc. C-53084, include: *Icriodus stelcki* Chatterton*, *Polygnathus linguiformis linguiformis* Hinde, *Polygnathus parawebbi* Chatterton.

A fauna from the formation at the Fairmont Ridge section in the Kananaskis Lakes (82 J) map area (50°21′N, 115°46′W), GSC loc. C-60947, includes: *Polygnathus angusticostatus* Wittekindt*.

The age of the Harrogate Formation is considered to span the *australis* and *ensensis* zones. The reader is referred to Chatterton (1974) for a complete listing and illustration of Harrogate conodonts.

Selwyn Basin

Conodonts from the uppermost part of the Road River "Group" in the Sekwi Mountain (105 P) map area (63°30.2′N, 129°27.1′W, GSC loc. C-87556, (loc. 10 *in* Gordey et al., 1982) are of the *ensensis* Zone. The collection includes *Ozarkodina brevis* (Bischoff and Ziegler), *Polygnathus intermedius* (Bultynck), *P. linguiformis linguiformis* Hinde, *P. parawebbi* Chatterton, *P. pseudofoliatus* Wittekindt, *P.* sp. cf. *P. schwartzi* Chatterton, *P. xylus ensensis* Ziegler and Klapper*, and *P.* n. sp. M of Klapper (*in* Johnson et al., 1980).

The Headless Formation consists of abundantly fossiliferous, argillaceous, dark grey limestone, interbedded with calcareous shale (Douglas and Norris, 1961). In its type area in the Virginia Falls (95 F) map area, the formation is about 61 m thick.

A collection from the Headless Formation in the Virginia Falls map area (Second Canyon, 61°18′N, 124°42′W), GSC loc. C-53037, consists of: *Icriodus* n. sp. A *sensu* Chatterton (1979)*, *Polygnathus parawebbi* Chatterton*, *Steptotaxis pedderi* Uyeno and Mason. (Age: *australis* Zone.)

The following conodonts were recovered from a limestone interval within a volcanic unit in the upper Earn Group, in the Niddery Lake (105 O) map area (63°16.3′N, 130°52.0′W), GSC loc. C-87687 (*see* Gordey et al. (1982) for the geological setting of this collection): *Icriodus* sp. cf. *I. amabilis* Bultynck and Hollard, *Polygnathus angusticostatus* Wittekindt, *Tortodus kockelianus kockelianus* (Bischoff and Ziegler)*. (Age: *kockelianus* Zone.)

*D. Fairholme Assemblage (*disparilis *Zone to upper Frasnian) (Figs. 3, 10-12, Pls. 3-5)*

A widespread regression (the Watt Mountain hiatus) was followed by a major marine transgression (the Taghanic onlap of Johnson, 1970) on the Cratonic Platform, starting about Middle *varcus* Subzone time (e.g., Klapper and Johnson, 1980; Sandberg et al., 1989). The Fairholme Assemblage represents the first part of an extensive record left by this transgression. One of the more notable aspects of this assemblage is the development of prominent reefs populated with stromatoporoids, algae and corals, especially on the Alberta Shelf.

Peel Shelf

The Powell Creek section in the Sans Sault Rapids (106 H) map area (*see* the Hume–Dunedin Assemblage for general discussion of this section) was located on the Peel Shelf during the deposition of the Fairholme Assemblage.

In the following discussion, the zones established by Klapper (1989) in the Montagne Noire in southern France are prefixed "MN", and those of Klapper and Lane (1989) from the southern Rocky Mountains are prefixed "RM".

The upper half of the Ramparts Formation yielded the most varied fauna in the succession, and includes *Palmatolepis disparalvea* Orr and Klapper*, *Polygnathus cristatus* Hinde, *P. dengleri* (Bischoff and Ziegler), *P. disparilis* Ziegler and Klapper, *P. dubius* Hinde, and *Schmidtognathus peracutus* (Bryant). This fauna is assignable to the Upper *disparilis* Subzone.

The lower one third of the succeeding Allochthonous Beds (of MacKenzie, 1971; = "Unnamed beds" of Braun, 1966; = "reef debris" of Morrow and Geldsetzer, 1989) yielded *Skeletognathus norrisi* (Uyeno)*, and is assignable to the *norrisi* Zone, of latest Givetian age. Limestone concretions from the lower part of the overlying Canol Formation have produced, among other species, *Palmatolepis disparilis* Ziegler and Klapper?*, *P. transitans* (Müller)*, *P.* sp.*, *Polygnathus* sp. cf. *P. rugosa* Huddle *sensu* Ziegler (1966)*, and *P. timanicus* Ovnatanova*, suggesting an assignment of this fauna to Klapper's (1989) Zone MN 4. This zone is of early Frasnian age. Conodonts of the intervening MN zones 1 to 3 were not recovered at Powell Creek, but parts of the missing interval are present in the Allochthonous Beds of the Maida Creek G-56 well, as discussed below.

McDermott Maida Creek G-56 well

The Maida Creek G-56 well is located at latitude 65°35′26″N, longitude 128°10′17″W in the same map area (106 H), on the north bank of the Mackenzie River near Carcajou Ridge, and approximately 50 km northeast of the Powell Creek section. The Allochthonous Beds in the well yielded *Ancyrodella alata* Glenister and Klapper late form *sensu* Klapper (1985)*, *A. rugosa* Branson and Mehl*, *A.* sp. cf. *A. rugosa* Branson and Mehl*, *Mesotaxis asymmetrica* (Bischoff and Ziegler)*, *M. ovalis* (Ziegler and Klapper)*, and *Palmatolepis disparata* Ziegler and Klapper*. The presence of *P. disparata* is anomalous, and probably suggests the age of a part of the Ramparts Formation from which the limestone blocks within the Allochthonous Beds were derived; the species has been recorded from the *disparilis* Zone elsewhere (Ziegler and Klapper, 1982). The remainder of the fauna is consistent and is suggestive of MN Zone 3 (Klapper and Johnson *in* Johnson, 1990).

The upper one metre of the underlying Ramparts Formation yielded *Polygnathus* sp. cf. *P. dengleri* Bischoff and Ziegler and *Schmidtognathus peracutus* (Bryant), and has been dated questionably as the Upper *disparilis* Subzone.

Mackenzie Shelf

Conodonts from successions in the area of the Great Slave Lake in southwestern District of Mackenzie were described by Klapper and Lane (1985) and Orchard (1989). The conodonts of the *Polygnathus* biofacies from the Hay River, Twin Falls, uppermost Fort Simpson, Redknife, and Kakisa formations, initially studied by Klapper and Lane (1985), were later correlated by these authors (1989) with RM Zone 2 to RM Faunal Interval 8. Orchard (1989) studied the succession at Trout River; there, the contact between the biostromal carbonate buildup of the Frasnian Kakisa Formation and the shallow water silt/sand deposits of the Famennian Trout River Formation is well exposed.

Liard Basin

The Liard Basin, lying west of the Hay River Shelf in north-central British Columbia, is part of the outer continental shelf and is a southern extension of the Mackenzie Basin.

From a unit that was questionably referred to the Besa River Formation in the Ware (94 F) map area (57°07′N, 124°18′W), GSC loc. C-79138, the following conodonts were recovered: *Icriodus difficilis* Ziegler and Klapper, *Ozarkodina semialternans* (Wirth)*, *Palmatolepis disparilis* Ziegler and Klapper*, *Polygnathus dengleri* Bischoff and Ziegler*, *Schmidtognathus peracutus* (Bryant)*. (Age: Upper *disparilis* Subzone.)

The Besa River Formation consists of dark grey to black, thin bedded, fissile, slightly calcareous to calcareous shale (Hills, *in* Hills et al., 1981). The following collection is from the formation in the Halfway River (94 B) map area (Robb Lake area, 56°56′N, 123°46′W), GSC loc. C-79362: *Polygnathus cristatus* Hinde*, *P. dengleri* Bischoff and Ziegler*, *P. dubius* Hinde*, *P. ordinatus* Bryant*. (Age: Upper *disparilis* subzone.)

Alberta Shelf

The following discussion is based principally on the section at Cold Sulphur Spring (CSS), located about 20 km north of Jasper, Alberta, along Highway 16. Conodonts from this section were previously reported by Clark and Ethington (1965) and by Pollock (1968), with the most recent summary of the stratigraphy of the section provided by Geldsetzer (*in* Norris and Pedder, 1987). A brief summary of the conodont biostratigraphy based on more recent collections was presented by Uyeno (*in* Norris and Pedder, 1987). Data from this section are supplemented by the collections of M. Mallamo from the Banff–Kananaskis area to the south.

The Flume Formation (50.9 m) consists of finely to coarsely crystalline dolostone, in part containing abundant stromatoporoids and *Amphipora*, with a minor amount of dense limestone. At Cold Sulphur Spring, the lowest parts yielded *Icriodus difficilis* Ziegler and Klapper*, *Icriodus subterminus* Youngquist*, *Pandorinellina insita* (Stauffer) (with single large anterior denticle)*, and *Polygnathus alatus* Huddle*. This collection is questionably assigned to the *norrisi* Zone, principally on the basis of the morphotype of *P. insita*. In Utah (Sandberg, 1979) and in central Nevada (Klapper *in* Johnson et al., 1980), the single-denticle morphotype occurs first, in the *norrisi* Zone, and succeeded in the Lower *asymmetrica* Zone by later morphotypes with a multidenticulate anterior blade.

Ancyrodella rotundiloba (Bryant; probably early form of Klapper, 1985) was recovered from the upper part of the Flume Formation at Quartz Hill (Mallamo collection; located at latitude 51°01′30″N, longitude 115°44′40″W, about 260 km southwest of the Cold Sulphur Spring section; here the Flume is a member of the Cairn Formation). This suggests that the Flume Formation/Member ranges into the Lower *asymmetrica* Zone. At Luscar Mountain I section (53°02′36″N, 117°27′W), Klapper and Lane (1989) recorded their RM Zone 1 from the highest parts of the formation, a zone equated with MN Zone 4 by these authors. Mallamo and Geldsetzer (1991) noted the diachronous nature of the base of this unit.

At the Grassi Lakes section at Canmore (one of the stops herein), conodonts were recovered only from the upper part of the Flume Member of the Cairn Formation. The two collections include *Icriodus expansus* Branson and Mehl, *Pandorinellina* sp. cf. *P. insita* (with multidenticulate anterior blade), *Polygnathus* sp. cf. *P. dubius* Hinde, and *P. xylus xylus* Stauffer. At the nearby Mount Rundle section of Mallamo (51°05′00″N, 115°25′00″W), the Flume Member yielded *Icriodus subterminus* Youngquist and *Pandorinellina insita* (with two-denticle anterior blade).

The upper member of the Cairn Formation was sampled for conodonts by Mallamo at several sections, but yielded mostly long-ranging forms. At Mount McDougall (50°54′05″N, 115°02′35″W), the lower half of the member yielded *Mesotaxis* sp. cf. *M.* n. sp. Q of Klapper and Lane (1989), *Polygnathus alatus* Huddle, and *P. aspelundi* Savage

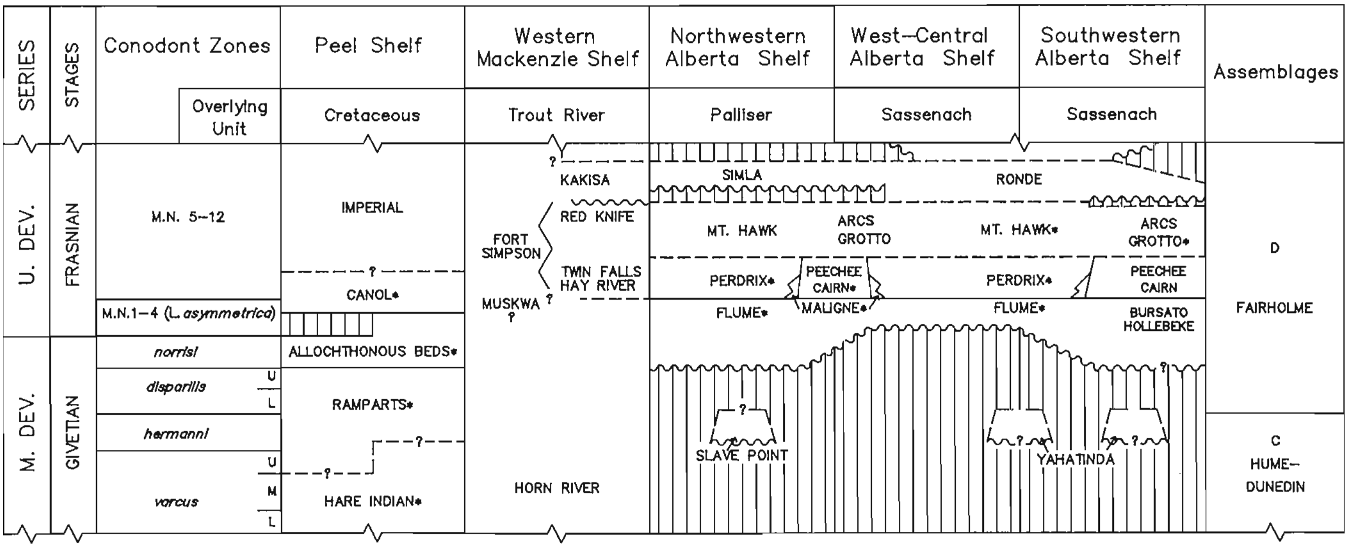


Figure 10. Stratigraphic correlation chart of Devonian formations in the eastern part of the Canadian Cordillera, ranging from the *varcus* Zone to the upper Frasnian. Formations discussed in the text are marked with an asterisk (*). (In part modified from Morrow and Geldsetzer, 1989; names and spacing of conodont zonal intervals from Klapper and Johnson *in* Johnson, 1990).

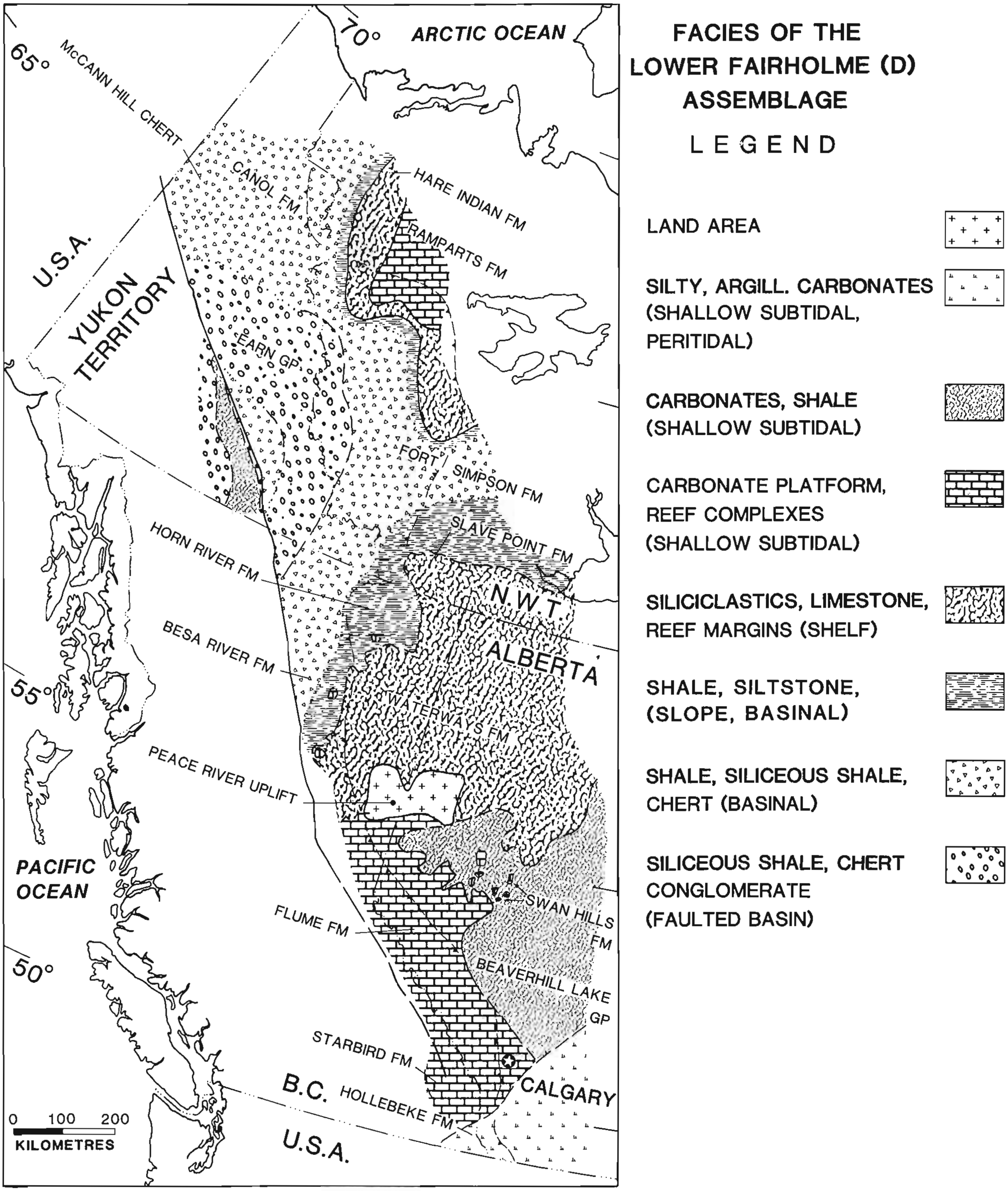


Figure 11. Distribution of the depositional facies of the lower Fairholme Assemblage, *disparilis* Zone to mid-Frasnian. (From Morrow and Geldsetzer, 1989).

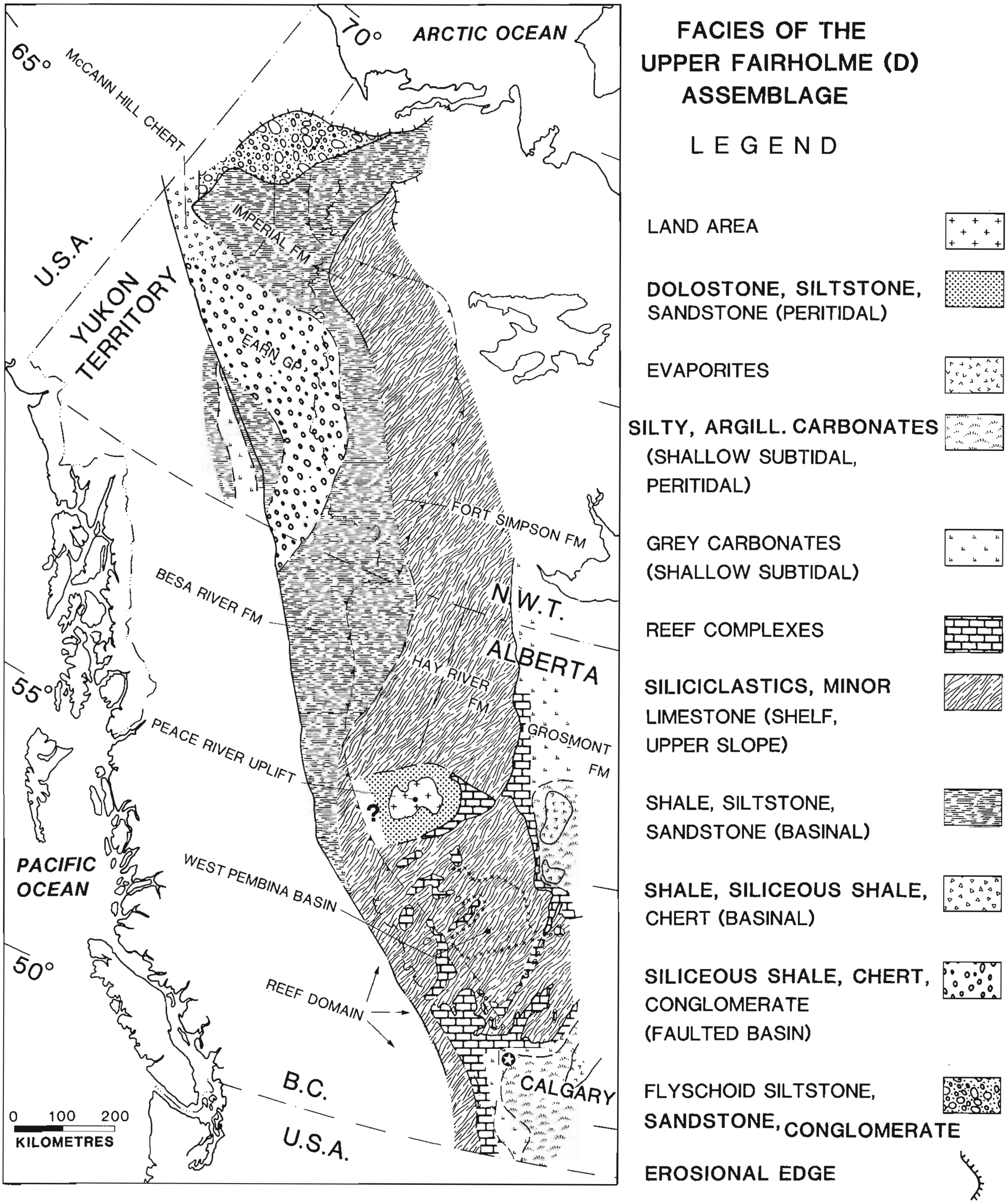


Figure 12. Distribution of depositional facies of the upper Fairholme Assemblage, upper Frasnian. (From Morrow and Geldsetzer, 1989).

and Funai. The first-mentioned is poorly preserved in the collection, but if this can be substantiated, an RM Zone 2 dating is suggested (*see* Klapper and Lane, 1989).

The Maligne Formation (18.9 m) consists of dark grey to black, argillaceous limestone, with some black shale beds in the upper parts. At Cold Sulphur Spring, the lowest part of the formation yielded *Pandorinellina insita* (Stauffer) (with anterior blade consisting of two smaller denticles anterior of the main denticle)*, and is tentatively assigned to the lower part of the former Lower *asymmetrica* Zone. Conodonts from the middle parts of the formation consist of *Mehlina gradata* Youngquist* and *P. insita* (Stauffer) (with multidenticulate anterior blade)*, and are similarly assigned to the lower part of the Lower *asymmetrica* Zone. The highest parts of the formation yielded *Ancyrodella* sp. cf. *A. rugosa* Branson and Mehl*, *Ozarkodina sannemanni* Bischoff and Ziegler subspp. of Pollock (1968)*, *Playfordia primitiva* (Bischoff and Ziegler)*, *Polygnathus angustidiscus* Youngquist*, *P. dubius* Hinde, and *P.* sp. cf. *P. dubius* Hinde*. This collection is questionably dated as MN Zone 3, which falls within the former Lower *asymmetrica* Zone.

The Perdrix Formation consists of black to grey shale with some argillaceous limestone beds. At the roadcut, where only the lower 12.8 m is exposed, the lowest part of the formation yielded *Polygnathus* sp.*. By position, presumably this interval corresponds approximately to RM Zone 1 (Klapper and Lane, 1989). Higher up in the formation are *Icriodus symmetricus* Branson and Mehl*, *Polygnathus timanicus* Ovnatanova*, and *P. webbi* Stauffer*, and the formation is dated as RM Zone 2. RM Zone 1 is equated with MN Zone 4 and forms the highest part of the former Lower *asymmetrica* Zone (Klapper and Lane, 1989). RM Zone 2 is approximated herein to equate with MN zone(s) 5 and/or 6.

At Quartz Hill (*see* above for location), the lower part of the Perdrix Formation yielded *Ancyrodella gigas* Youngquist (form 1 of Klapper, 1989), and the middle and upper parts yielded *A. curvata* (Branson and Mehl) and *Palmatolepis domanicensis* Ovnatanova. On the basis of the established ranges of these species elsewhere (Klapper and Lane, 1989), the lower part is correlated with RM Zones 1 and 2, and the upper beds with RM zones 4A to 5A. Klapper and Lane (1989) recorded ranges of RM zones 1 to 5B and 2 to 5A for the Perdrix Formation at their Luscar Mountain I and Mount Haultain sections, respectively.

The Mount Hawk Formation consists of argillaceous limestone, thin bedded, fossiliferous, medium grey limestone, with some grey mudstone. At Quartz Hill, the middle part of the formation has yielded *Ancyrognathus triangularis* Youngquist, *Palmatolepis kireevae* Ovnatanova, *P. semichatovae* Ovnatanova?, *Polygnathus evidens* Klapper and Lane, and *P. pacificus* Savage and Funai. This collection is dated as RM zones 5A to 5B (*see* Klapper and Lane, 1989). At Fatigue Mountain I and II sections (51°02′40″N, 115°40′40″W, and 51°02′05″N, 115°40′15″W, respectively; Mallamo collections), the lowest part of the Mount Hawk Formation has yielded *Ancyrodella nodosa* Ulrich and Bassler, *Palmatolepis domanicensis* Ovnatanova, and *Polygnathus evidens* Klapper and Lane, a collection that is dated as RM zones 4B to 5A. In the lower to middle parts of the sections are *Ancyrodella curvata* (Branson and Mehl) and *Palmatolepis kireevae*, *P. semichatovae*, and *Polygnathus evidens*, which suggest RM zones 5A to 5B. Klapper and Lane (1989) recorded ranges of RM zones 5B to 7–8 and 5A to 7–8 at their Luscar Mountain I and Mount Haultain sections, respectively.

A succession of conodonts from the Mount Hawk, Ronde, and Sassenach formations at Medicine Lake, located 23 km east of Jasper, Alberta, was reported by Orchard (1989). The Frasnian–Famennian boundary was tentatively placed at the base of the Sassenach Formation. The interval from the upper Mount Hawk to lower Ronde was regarded as Lower to Upper *rhenana* zones (= *gigas* zones in the usage of Ziegler, 1962, 1971; Lower to Upper *rhenana* zones of Ziegler and Sandberg, 1990). Geldsetzer (*in* Norris and Pedder, 1987), in briefly summarizing the section, described the Ronde Formation as consisting of bioturbated dolomitic and calcareous siltstone, and the overlying Sassenach Formation as fossiliferous, silty limestone and calcareous sandstone, in places calcareous shale to shaly limestone.

The Grotto Member of the Southesk Formation is absent at Cold Sulphur Spring. In general terms, it consists of limestone and dolostone with *Amphipora*, corals, and brachiopods. At Sundance Range (51°04′15″N, 115°34′45″W; Mallamo collection), the member yielded *Ancyrodella curvata* and *Polygnathus angustidiscus* Youngquist, and is assigned to RM zones 4A to 5B (*see* Klapper and Lane, 1989) and hence is approximately correlative with the lower part of the Mount Hawk Formation.

Golden Embayment

The Starbird Formation in southeastern British Columbia at Mount Forster (50°36′N, 116°17′W) in the Lardeau (82 K) map area consists of arenaceous limestone and limestone and shale at the base, grading up into limestone at the top (Walker, 1926). At the level of 20 ft (6.1 m) below the "highest fossils" (GSC loc. O-7940; Walker collection), *Pandorinellina insita* (Stauffer) (with multidenticulate anterior blade) was recovered. This is dated as probably Lower *asymmetrica* Zone. From unspecified levels (GSC locs. O-7939 and O-7950), *Mesotaxis asymmetrica* (Bischoff and Ziegler), *Mehlina gradata* Youngquist*, and *Playfordia primitiva* (Bischoff and Ziegler) were retrieved. These collections are dated as probably Lower to Middle *asymmetrica* zones. The associated brachiopods from GSC loc. O-7940 are assigned to the *Eleutherokomma jasperensis* Zone, and those from GSC loc. O-7939 to the *E. leducensis* Zone (A.W. Norris, *in* Norford, 1982); these zones are correlated with the Lower and Middle *asymmetrica* zones, respectively (*see* Braun et al., 1989).

In more recent collections made by B.S. Norford at Mount Forster (*see* Norford, 1982), the Starbird Formation at GSC loc. C-84861 (465–467 m above base of section) contained *Icriodus expansus* Branson and Mehl* and *Pandorinellina insita* (Stauffer) (with a single large anterior denticle). This collection is probably assignable to the *norrisi* Zone (*see* reasoning above).

From the basal part of the Fairholme Group at the Sugar Loaf Ridge section at Fernie (82 G) map area (GSC loc. C-84867; 49°52′N, 115°24′30″W; *see* Norford, 1982), the following collection was obtained: *Icriodus subterminus* Youngquist*, *Polygnathus angustidiscus* Youngquist*. (Age: *norrisi* Zone to Lower *asymmetrica* Zone.) The Fairholme Group encompasses a basal carbonate platform (Flume Formation), carbonate buildup (Cairn Formation with its Flume and Upper members), skeletal and peloid lime sands (Southesk Formation with its Peechee, Grotto, Arcs, and Ronde members), as well as their equivalents of clastic basin fill (Maligne, Perdrix and Mount Hawk formations) (Coppold and Mountjoy *in* Glass, 1990).

ACKNOWLEDGMENTS

I am grateful to Dave Morrow and Helmut Geldsetzer of the Institute of Sedimentary and Petroleum Geology, Geological Survey of Canada, Calgary, for allowing me to reproduce many of the illustrations used in their 1989 paper. Gratitude is also extended to Mike Orchard, of the Geological Survey, Vancouver, for making available several Lower and Middle Devonian conodont collections, and for the loan of prints of some SEM micrographs; some of the collections and prints have been included in the present study. Most of the SEM micrographs were taken by Jenny Wong, and printed by Chris Ryley, both of ISPG. I have further benefitted from careful reviews of the paper by Gilbert Klapper of the University of Iowa, and by Dave Morrow.

REFERENCES

Braun, W.K.
1966: Stratigraphy and microfauna of Middle and Upper Devonian formations, Norman Wells area, Northwest Territories, Canada. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, v. 125, p. 247-264.

Braun, W.K., Norris, A.W., and Uyeno, T.T.
1989: Late Givetian to early Frasnian biostratigraphy of western Canada: the Slave Point–Waterways boundary and related events. *In* Devonian of the World, Proceedings of the Second International Symposium on the Devonian System, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, v. III, Paleontology, Paleoecology and Biostratigraphy, p. 93-111 (imprint 1988).

Campbell, R.B.
1967: Geology of Glenlyon map-area, Yukon Territory. Geological Survey of Canada, Memoir 352, 92 p.

Chatterton, B.D.E.
1974: Middle Devonian conodonts from the Harrogate Formation, southeastern British Columbia. Canadian Journal of Earth Sciences, v. 11, p. 1461-1484.
1979: Aspects of late Early and Middle Devonian conodont biostratigraphy of western and northwestern Canada. *In* Western and Arctic Canadian Biostratigraphy, C.R. Stelck and B.D.E. Chatterton (eds.); Geological Association of Canada Special Paper 18, p. 161-231 (imprint 1978).

Chatterton, B.D.E. and Perry, D.G.
1977: Lochkovian trilobites and conodonts from northwestern Canada. Journal of Paleontology, v. 51, p. 772-796.

Clark, D.L. and Ethington, R.L.
1965: Conodont biostratigraphy of part of the Devonian of the Alberta Rocky Mountains. Bulletin of Canadian Petroleum Geology, v. 13, p. 382-388.

Douglas, R.J.W. and Norris, D.K.
1961: Camsell Bend and Root River map-areas, District of Mackenzie, Northwest Territories, 95J and K. Geological Survey of Canada, Paper 61-13, 36 p.

Dubord, M.P., Morrow, D.W., and Macqueen, R.W.
1986: A shelf-to-basin transition in the Devonian Ogilvie Formation, Yukon Territory. *In* Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 603-608.

Fåhraeus, L.E.
1971: Lower Devonian conodonts from the Michelle and Prongs Creek Formations, Yukon Territory. Journal of Paleontology, v. 45, p. 665-683.

Gabrielse, H., Blusson, S.L., and Roddick, J.A.
1973: Geology of Flat River, Glacier Lake, and Wrigley Lake map-areas, District of Mackenzie and Yukon Territory. Geological Survey of Canada, Memoir 366, Parts I and II, 153 p. and 268 p.

Glass, D.J. (ed.)
1990: Lexicon of Canadian Stratigraphy, western Canada, including eastern British Columbia, Alberta, Saskatchewan and southern Manitoba. Canadian Society of Petroleum Geologists, v. 4, 772 p.

Gordey, S.P.
in press: Evolution of the Northern Cordilleran Miogeocline, Nahanni Map Area (105 I), Yukon Territory and District of Mackenzie. Geological Survey of Canada, Memoir.

Gordey, S.P., Abbott, J.G., and Orchard, M.J.
1982: Devono-Mississippian (Earn Group) and younger strata in east-central Yukon. *In* Current Research, Part B, Geological Survey of Canada, Paper 82-1B, p. 93-100.

Hills, L.V., Sangster, E.V., and Suneby, L.B. (eds.)
1981: Lexicon of Canadian Stratigraphy, Yukon Territory and District of Mackenzie, Canadian Society of Petroleum Geologists, v. 2, 240 p.

Johnson, J.G.
1970: Taghanic onlap and the end of North American Devonian provinciality. Geological Society of America, Bulletin, v. 81, p. 2077-2106.
1977: Lower and Middle Devonian faunal intervals in central Nevada, based on brachiopods. *In* Western North America: Devonian, M.A. Murphy, W.B.N. Berry, and C.A. Sandberg (eds.); University of California Riverside Campus, Museum Contribution 4, p. 16-32.
1990: Lower and Middle Devonian brachiopod-dominated communities of Nevada, and their position in a biofacies–province–realm model (with a section on revision of Middle Devonian conodont zones, by G. Klapper and J.G. Johnson). Journal of Paleontology, v. 64, p. 902-941.

Johnson, J.G., Klapper, G., and Trojan, W.R.
1980: Brachiopod and conodont successions in the Devonian of the northern Antelope Range, central Nevada. Geologica et Palaeontologica, v. 14, p. 77-116.

Klapper, G.
1969: Lower Devonian conodont sequence, Royal Creek, Yukon Territory, and Devon Island, Canada (with a section on Devon Island stratigraphy by A.R. Ormiston). Journal of Paleontology, v. 43, p. 1-27.
1985: Sequence in conodont genus *Ancyrodella* in Lower *asymmetricus* Zone (earliest Frasnian, Upper Devonian) of the Montagne Noire, France. Palaeontographica, Abt. A, v. 188, p. 19-34.
1989: The Montagne Noire Frasnian (Upper Devonian) conodont succession. *In* Devonian of the World, Proceedings of the Second International Symposium on the Devonian System, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, v. III, Paleontology, Paleoecology and Biostratigraphy, p. 449-468 (imprint 1988).

Klapper, G. and Johnson, J.G.
1980: Endemism and dispersal of Devonian conodonts. Journal of Paleontology, v. 54, p. 400-455.

Klapper, G. and Lane, H.R.
1989: Frasnian (Upper Devonian) conodont sequence at Luscar Mountain and Mount Haultain, Alberta Rocky Mountains. *In* Devonian of the World, Proceedings of the Second International Symposium on the Devonian System, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, v. III, Paleontology, Paleoecology and Biostratigraphy, p. 469-478 (imprint 1988).

Klapper, G. and Murphy, M.A.
1980: Conodont zonal species from the *delta* and *pesavis* Zones (Lower Devonian) in central Nevada. Neues Jahrbuch für Geologie und Paläontologie, Monatshefte, Hefte 8, p. 490-504.

Lane, H.R. and Ormistan, A.R.
1979: Siluro–Devonian biostratigraphy of the Salmontrout River area, east-central Alaska. Geologica et Palaeontologica, v. 13, p. 39-96.

Lenz, A.C. and Pedder, A.E.H.
1972: Lower and Middle Paleozoic sediments and paleontology of Royal Creek and Peel River, Yukon, and Powell Creek, N.W.T. Guidebook to Excursion A-14, 24th International Geological Congress, Montreal, Quebec, 43 p.

MacKenzie, W.S.
1971: Allochthonous reef-debris limestone turbidites, Powell Creek, Northwest Territories. Bulletin of Canadian Petroleum Geology, v. 18, p. 474-492 (imprint 1970).

Mallamo, M.P. and Geldsetzer, H.H.J.
1991: The western margin of the Upper Devonian Fairholme Reef Complex, Banff-Kananaskis area, southwestern Alberta. *In* Current Research, Part B, Geological Survey of Canada, Paper 91-1B, p. 59-69.

Morrow, D.W.
1984: Sedimentation in the Root Basin and Prairie Creek Embayment – Siluro-Devonian, Northwest Territories. Bulletin of Canadian Petroleum Geology, v. 32, p. 162-189.

Morrow, D.W. and Cook, D.G.
1987: The Prairie Creek Embayment and lower Paleozoic stratigraphy of the southern Mackenzie Mountains. Geological Survey of Canada, Memoir 412, 195 p.

Morrow, D.W. and Geldsetzer, H.H.J.
1989: Devonian of the eastern Canadian Cordillera. *In* Devonian of the World, Proceedings of the Second International Symposium on the Devonian System, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, v. I, Regional Syntheses, p. 85-121 (imprint 1988).

Murphy, M.A. and Matti, J.C.
1983: Lower Devonian conodonts (*hesperius-kindlei* Zones), central Nevada. University of California Publications, Geological Sciences, v. 123, 83 p. (imprint 1982).

Norford, B.S.
1982: Devonian stratigraphy at the margins of the Rocky Mountain Trench, Columbia River, southeastern British Columbia. Bulletin of Canadian Petroleum Geology, v. 29, p. 540-560 (imprint 1981).

Norris, A.W.
1968: Reconnaissance Devonian stratigraphy of northern Yukon Territory and northwestern District of Mackenzie. Geological Survey of Canada, Paper 67-53, 287 p.

Norris, A.W. and Pedder, A.E.H. (eds.)
1987: Devonian of Alberta Rocky Mountains between Banff and Jasper, A Field Trip Guidebook. Subcommission on Devonian Stratigraphy, Geological Survey of Canada, 85 p.

Norris, A.W. and Uyeno, T.T.
1981: Lower Devonian (Lochkovian) brachiopods and conodonts from the 'Delorme' Formation, Cathedral Mountain, southwestern District of Mackenzie. Geological Survey of Canada, Bulletin 305, 34 p.

Norris, D.K.
1985: Eastern Cordilleran Foldbelt of northern Canada: its structural geology and hydrocarbon potential. American Association of Petroleum Geologists, Bulletin, v. 69, p. 788-808.

Orchard, M.J.
1989: Conodonts from the Frasnian-Famennian boundary interval in western Canada. *In* Devonian of the World, Proceedings of the Second International Symposium on the Devonian System, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, v. III, Paleontology, Paleoecology and Biostratigraphy, p. 35-52 (imprint 1988).

Perry, D.G., Klapper, G., and Lenz, A.C.
1974: Age of the Ogilvie Formation (Devonian), northern Yukon: based primarily on the occurrence of brachiopods and conodonts. Canadian Journal of Earth Sciences, v. 11, p. 1055-1097.

Pollock, C.A.
1968: Lower Upper Devonian conodonts from Alberta, Canada. Journal of Paleontology, v. 42, p. 415-443.

Sandberg, C.A.
1979: Devonian and Lower Mississippian conodont zonation of the Great Basin and Rocky Mountains. *In* Conodont Biostratigraphy of the Great Basin and Rocky Mountains, C.A. Sandberg and D.L. Clark (eds.); Brigham Young University Geology Studies, v. 26, pt. 3, p. 87-106.

Sandberg, C.A., Poole, F.G., and Johnson, J.G.
1989: Upper Devonian of western United States. *In* Devonian of the World, Proceedings of the Second International Symposium on the Devonian System, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, v. I, Regional Syntheses, p. 183-220 (imprint 1988).

Savage, N.M., Blodgett, R.B., and Jaeger, H.
1985: Conodonts and associated graptolites from the late Early Devonian of east-central Alaska and western Yukon Territory. Canadian Journal of Earth Sciences, v. 22, p. 1880-1883.

Taylor, G.C. and MacKenzie, W.S.
1970: Devonian stratigraphy of northeastern British Columbia. Geological Survey of Canada, Bulletin 186, 62 p.

Uyeno, T.T.
1979: Devonian conodont biostratigraphy of Powell Creek and adjacent areas, western District of Mackenzie. *In* Western and Arctic Canadian Biostratigraphy, C.R. Stelck and B.D.E. Chatterton (eds.); Geological Association of Canada Special Paper 18, p. 233-257 (imprint 1978).

Uyeno, T.T. and Mason, D.
1975: New Lower and Middle Devonian conodonts from northern Canada. Journal of Paleontology, v. 49, p. 710-723.

Walker, J.F.
1926: Geology and mineral deposits of Windermere Map- area, British Columbia. Geological Survey of Canada, Memoir 148, 69 p.

Ziegler, W.
1962: Taxionomie und Phylogenie Oberdevonischer Conodonten und ihre stratigraphische Bedeutung. Abhandlungen des Hessischen Landesamtes für Bodenforschung, v. 38, 166 p., 14 pls.
1966: Eine Verfeinerung der Conodontengliederung an der Grenze Mittel–/Oberdevon. Fortschritte in der Geologie von Rheinland und Westfalen, v. 9, p. 647-676 (imprint 1965).
1971: Conodont stratigraphy of the European Devonian. *In* Symposium on Conodont Biostratigraphy, W.C. Sweet and S.M. Bergström (eds.); Geological Society of America, Memoir 127, p. 227-284.

Ziegler, W. and Klapper, G.
1982: The *disparilis* conodont zone, the proposed level for the Middle–Upper Devonian boundary. *In* On Devonian Stratigraphy and Palaeontology of the Ardenno–Rhenish Mountains and Related Devonian Matters, W. Ziegler and R. Werner (eds.); Courier Forschungsinstitut Senckenberg, v. 55, p. 463-492.

Ziegler, W. and Sandberg, C.A.
1990: The Late Devonian standard conodont zonation. Courier Forschungsinstitut Senckenberg, v. 121, 115 p.

Plates 1 to 5

PLATE 1

Conodonts from (A) Delorme and (B) Bear Rock–Stone assemblages. All specimens are hypotypes.

A. Delorme Assemblage

Figures 1, 2. *Icriodus woschmidti hesperius* Klapper and Murphy.
Upper view of I elements, GSC 53470 and 53469, x40, Vera Formation, GSC loc. C-57249, (previously illustrated in Norris and Uyeno, 1981, Pl. 5, figs. 13, 10).

Figure 3. *Icriodus hadnagyi* Chatterton and Perry.
Upper view of I element, GSC 99905, x81, Vera Formation, GSC loc. C-60714.

Figure 4. *Amydrotaxis chattertoni* Uyeno.
Lateral view of Pa element, GSC 99906, x93, Camsell Formation, GSC loc. C-89126.

Figure 5. *Amydrotaxis johnsoni* (Klapper) beta morphotype *sensu* Klapper and Murphy (1980).
Upper view of Pa element, GSC 99907, x21, silty limestone member, Sapper formation, GSC loc. C-92572.

Figure 6. *Pandorinellina optima* (Moskalenko).
Lateral view of Pa element, GSC 99908, x62, silty limestone member, Sapper formation, GSC loc. C-92572.

Figure 7. *Pedavis pesavis pesavis* (Bischoff and Sannemann).
Upper view of I element, GSC 99909, x25, silty limestone member, Sapper formation, GSC loc. C-92572.

Figure 8. *Ozarkodina stygia* (Flajs).
Lateral view of Pa element, GSC 99910, x59, silty limestone member, Sapper formation, GSC loc. C-87829.

Figures 9, 10. *Pandorinellina optima* (Moskalenko).
Lateral and upper views of two Pa elements, GSC 99911 and GSC 99912, x59 and x62, silty limestone member, Sapper formation, GSC loc. C-87829.

Figure 11. *Icriodus steinachensis* Al-Rawi beta morphotype *sensu* Klapper (*in* Klapper and Johnson, 1980).
Upper view of I element, GSC 99913, x40, Road River Formation?, GSC loc. C-116707.

Figure 12. *Eognathodus sulcatus* Philip subsp. indet.
Upper view of Pa element, GSC 99914, x65, Road River Formation, GSC loc. C-59351.

Figure 13. *Ozarkodina remscheidensis remscheidensis* (Ziegler).
Lateral view of Pa element, GSC 99915, x71, Road River Formation, GSC loc. C-59351.

Figure 14. *Amydrotaxis johnsoni* (Klapper) alpha morphotype *sensu* Klapper and Murphy (1980).
Lateral view of Pa element, GSC 99916, x40, Road River Formation, GSC loc. C-13298/8151-8180.

Figure 15. *Ancyrodelloides delta* (Klapper and Murphy).
Upper view of Pa element, GSC 99917, x56, Road River Formation, GSC loc. C-13298/8151-8180.

Figures 16, 17. *Ozarkodina paucidentata* Murphy and Matti.
Lateral view of two Pa elements, GSC 99918 and GSC 99919, x78 and x74, Road River Formation, GSC loc. C-104191.

B. Bear Rock–Stone Assemblage

Specimens in figures 18-22 are from an unknown stratigraphic unit, GSC loc. C-79137.

Figure 18. *Icriodus claudiae* Klapper.
Upper view of I element, GSC 99920, x31.

Figure 19. *Pandorinellina steinhornensis praeoptima* (Mashkova) *sensu* Lane and Ormiston (1979).
Upper view of Pa element, GSC 99921, x62.

Figure 20. *Pandorinellina exigua philipi* (Klapper).
Lateral view of Pa element, GSC 99922, x27.

Figures 21, 22. *Polygnathus pireneae* Boersma.
Upper and lower views of Pa element, GSC 99923, x70.

PLATE 1

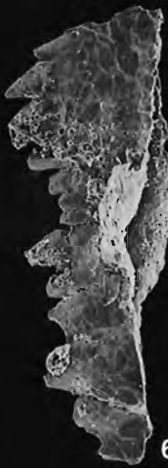

1

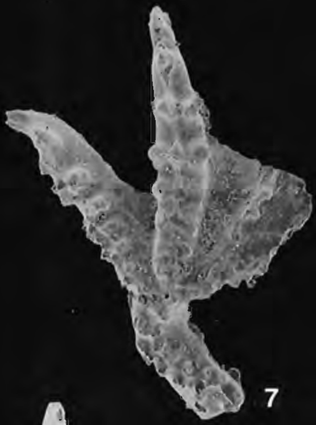

2


3


4

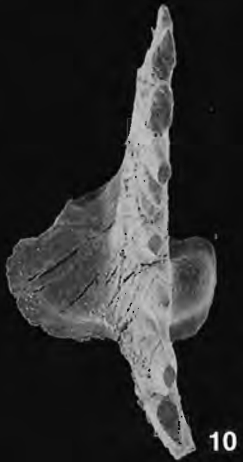

5


6


7

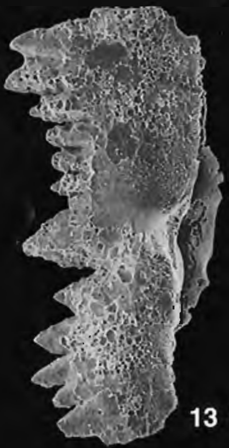

8


9


10


11


12


13


14


15


16


17


18


19


20


21


22

PLATE 2

Conodonts from the (B) Bear Rock–Stone and (C) Hume–Dunedin assemblages.
All specimens are hypotypes, except where noted.

B. Bear Rock–Stone Assemblage (cont'd.)

Figure 1. *Eognathodus sulcatus kindlei* Lane and Ormiston.
Upper view of Pa element, GSC 99924, x41, unknown stratigraphic unit, GSC loc. C-79137.

Figure 2. *Polygnathus pireneae* Boersma.
Lateral view of Pa element, GSC 99925, x78, unknown stratigraphic unit, GSC loc. C-79137.

Figure 3. *Ozarkodina linearis* (Philip).
Upper view of Pa element, GSC 99926, x 71, Arnica Formation, GSC loc. C-83240.

Figure 4. *Icriodus taimyricus* Kuzmin.
Upper view of I element, GSC 99927, x28, unknown stratigraphic unit, GSC loc. C-12895.

Figure 5. *Pandorinellina steinhornensis steinhornensis* (Ziegler).
Lateral view of Pa element, GSC 99928, x40, Portrait Lake formation, GSC loc. C-76623.

Figure 6, 7. *Polygnathus gronbergi* Klapper and Johnson.
Lower and upper views of Pa element, GSC 99929, x38, Portrait Lake formation, GSC loc. C-76623.

Figure 8, 9. *Polygnathus* sp. aff. *P. laticostatus* Klapper and Johnson.
Lower and upper views of Pa element, figured specimen GSC 99930, x38, Portrait Lake formation, GSC loc. C-76623.

Figure 10. *Amydrotaxis sexidentata* Murphy and Matti.
Upper view of Pa element, GSC 99931, x34, Road River Formation, GSC loc. C-52706.

Figures 11, 12. *Polygnathus inversus* Klapper and Johnson.
Lower and upper views of two Pa elements, GSC 99932 and GSC 99933, x66 and x58, Grizzly Bear Formation, GSC loc. C-86348.

Figures 13, 14. *Polygnathus dehiscens dehiscens* Philip and Jackson.
Upper and lower views of Pa element, GSC 99934, x41, Michelle Formation, GSC loc. C-128402.

Figure 15. *Steptotaxis? furnishi* (Klapper).
Upper view of Pa element, GSC 99935, x62, Michelle Formation, GSC loc. C-128402.

Figure 16. *Pandorinellina exigua exigua* (Philip).
Lateral view of Pa element, GSC 99936, x40, Michelle Formation, GSC loc. C-150769.

Figure 17. *Pandorinellina steinhornensis miae* (Bultynck).
Lateral view of Pa element, GSC 99937, x65, Michelle Formation, GSC loc. C-150769.

Figure 18. *Pedavis* sp. cf. *P. sherryae* Lane and Ormiston.
Upper view of I element, figured specimen GSC 99938, x22, Michelle Formation, GSC loc. C-150769.

Figure 19. *Icriodus taimyricus* Kuzmin.
Upper view of I element, GSC 99939, x45, Michelle Formation, GSC loc. C-150952.

Figure 20. *Steptotaxis glenisteri* (Klapper).
Upper view of I element, GSC 99940, x43, Ogilvie Formation, GSC loc. C-82864.

C. Hume – Dunedin Assemblage

Figure 21. *Polygnathus costatus costatus* Klapper.
Upper view of Pa element, GSC 99941, x43, Ogilvie Formation, GSC loc. C-82870.

Figure 22. *Pandorinellina* n. sp. A *sensu* Uyeno and Mason (1975).
Lateral view of Pa element, figured specimen GSC 27884, x40, Gossage Formation, GSC loc. C-3849 (previously illustrated in Uyeno, 1979, Pl. 1, fig. 1).

Figure 23. *Polygnathus curtigladius* Uyeno.
Lateral view of Pa element, GSC 27894, x32, Hume Formation, GSC loc. C-3872 (previously illustrated in Uyeno, 1979, Pl. 1, fig. 30).

Figure 24. *Polygnathus pseudofoliatus* Wittekindt.
Upper view of Pa element, GSC 27893, x40, Hume Formation, GSC loc. C-3872 (previously illustrated in Uyeno, 1979, Pl. 1, fig. 26).

Figure 25. *Steptotaxis pedderi* (Uyeno and Mason).
Upper view of I element, GSC 38398, x40, Hume Formation, GSC loc. C-12116 (previously illustrated in Uyeno and Mason, 1975, Pl. 1, fig. 40).

PLATE 2

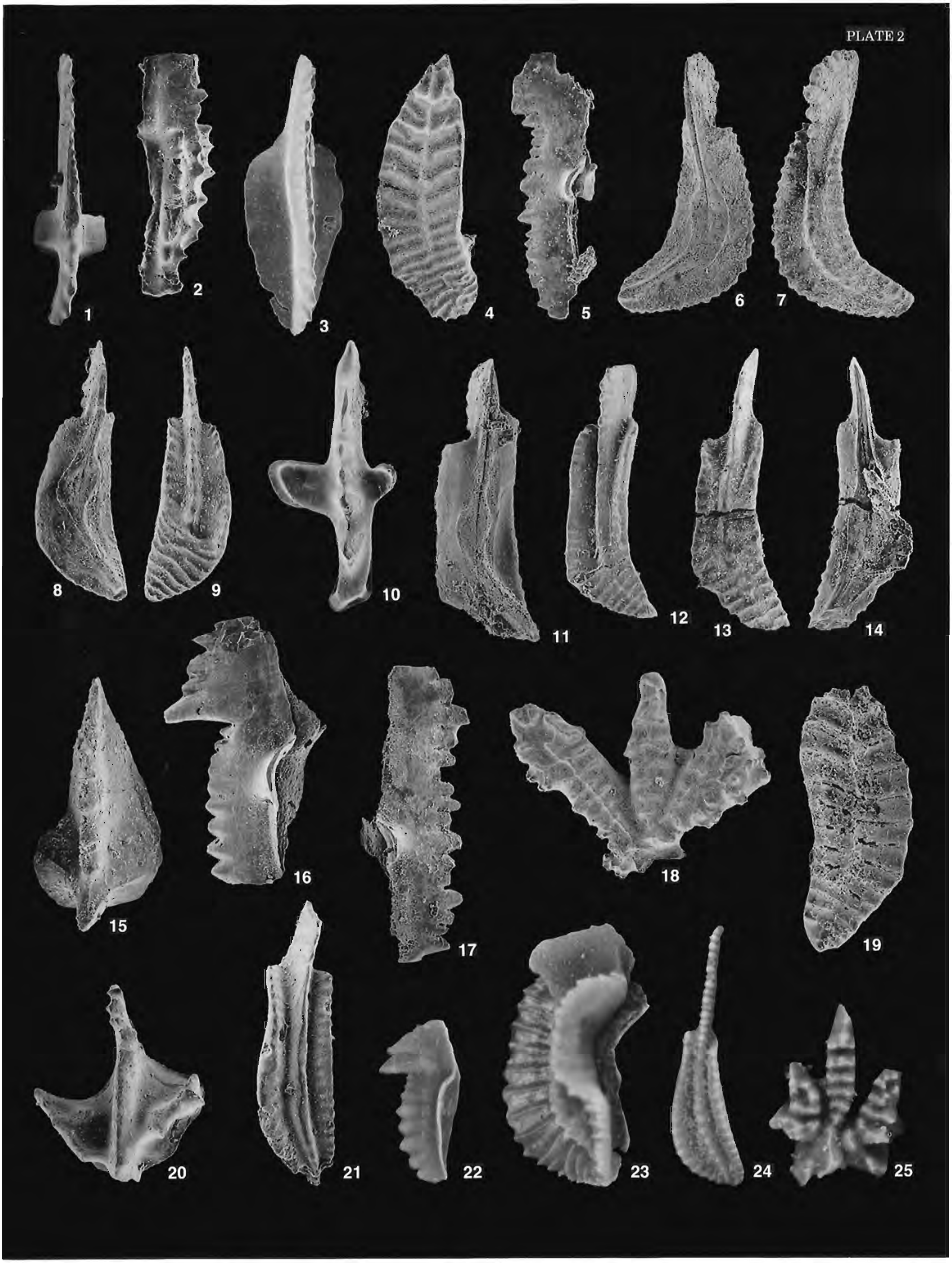


PLATE 3

Conodonts from the (C) Hume–Dunedin and (D) Fairholme assemblages.
All specimens are hypotypes, except where noted.

C. Hume–Dunedin Assemblage (cont'd.)

Figure 1. *Icriodus brevis* Stauffer.
Upper view of I element, GSC 99942, x84, Hare Indian Formation, GSC loc. C-12156.

Figure 2. *Polygnathus ansatus* Ziegler and Klapper.
Upper view of Pa element, GSC 99943, x62, Hare Indian Formation, GSC loc. C-12156.

Figure 3. *Polygnathus timorensis* Klapper, Philip and Jackson.
Upper view of Pa element, GSC 99944, x62, Hare Indian Formation, GSC loc. C-3878.

Figure 4. *Polygnathus xylus xylus* Stauffer.
Upper view of Pa element, GSC 99945, x53, Hare Indian Formation, GSC loc. C-12154.

Figure 5. *Icriodus norfordi* Chatterton.
Upper view of I element, GSC 99946, x60, unknown stratigraphic unit, GSC loc. C-79343.

Figure 6. *Polygnathus costatus costatus* Klapper.
Upper view of Pa element, GSC 99947, x39, unknown stratigraphic unit, GSC loc. C-79343.

Figure 7. *Polygnathus linguiformis bultyncki* Weddige.
Upper view of Pa element, GSC 99948, x31, unknown stratigraphic unit, GSC loc. C-79343.

Figures 8, 9. *Polygnathus serotinus* Telford.
Upper and lower views of Pa element, GSC 99949, x48, unknown stratigraphic unit, GSC loc. C-79343.

Figure 10. *Icriodus stelcki* Chatterton.
Upper view of I element, GSC 99950, x78, Harrogate Formation, GSC loc. C-53084.

Figure 11. *Polygnathus angusticostatus* Wittekindt.
Upper view of Pa element, GSC 99951, x78, Harrogate Formation, GSC loc. C-60947.

Figure 12. *Polygnathus xylus ensensis* Ziegler and Klapper.
Oblique lateral view of Pa element, GSC 99952, x53, Road River 'Group', GSC loc. no. C-87556.

Figure 13. *Icriodus* n. sp. A *sensu* Chatterton (1979).
Upper view of I element, figured specimen GSC 99953, x61, Headless Formation, GSC loc. C-53037.

Figure 14. *Polygnathus parawebbi* Chatterton.
Upper view of Pa element, GSC 99954, x53, Headless Formation, GSC loc. C-53037.

Figure 15. *Tortodus kockelianus kockelianus* (Bischoff and Ziegler).
Upper view of Pa element, GSC 99955, x38, Earn Group, GSC loc. C-87687.

Figure 16. *Pandorinellina expansa* Uyeno and Mason.
Lateral view of Pa element, GSC 38374, x40, Road River Formation, GSC loc. C-29072 (previously illustrated in Uyeno and Mason, 1975, Pl. 1, fig. 12).

D. Fairholme Assemblage

Figures 17, 18. *Palmatolepis disparalvea* Orr and Klapper.
Upper and lower views of Pa element, GSC 27898, x40, Ramparts Formation, GSC loc. C-3883 (previously illustrated in Uyeno, 1979, Pl. 2, figs. 8, 9).

Figure 19. *Skeletognathus norrisi* (Uyeno).
Upper view of Pa element, GSC 46247, x40, Allochthonous Beds, GSC loc. C-3884 (previously illustrated in Uyeno, 1979, Pl. 2, fig. 26).

Figures 20, 21. *Palmatolepis disparilis* Ziegler and Klapper?
Lower and upper views of Pa element, GSC 99956, x78, Canol Formation, GSC loc. C-12171.

Figures 22, 23. *Palmatolepis transitans* (Müller).
Upper and lower views of Pa element, GSC 99957, x53, Canol Formation, GSC loc. C-12171.

Figures 24, 25. *Palmatolepis* sp.
Lower and upper views of Pa element, figured specimen GSC 99958, x43, Canol Formation, GSC loc. C-12171.

Figure 26. *Polygnathus* sp. cf. *P. rugosa* Huddle *sensu* Ziegler (1966).
Upper view of Pa element, figured specimen GSC 99959, x31, Canol Formation, GSC loc. C-12171.

PLATE 3


1


2


3

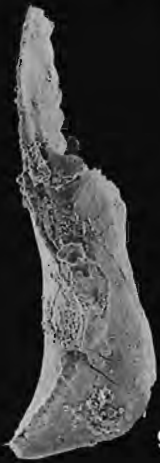

4


5

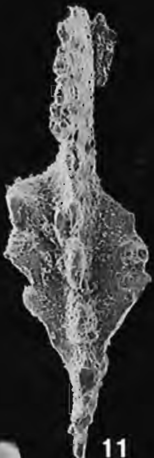

6


7


8


9


10


11


12


13


14


15

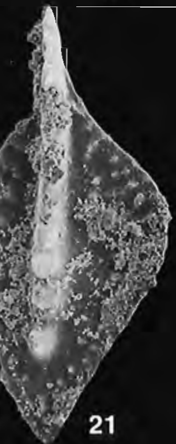

16

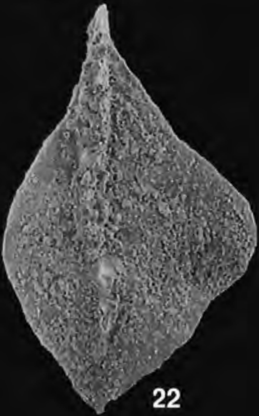

17


18


19

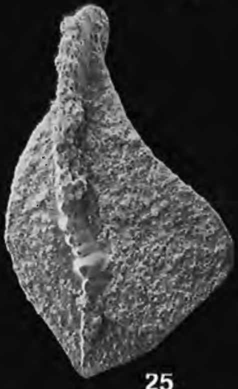

20


21


22


23


24


25


26

PLATE 4

D. Fairholme Assemblage (cont'd.). All specimens are hypotypes, except where noted.

Figures 1, 2. *Palmatolepis* sp.
Lower and upper views of Pa element, figured specimen GSC 99960, x39 (note basal attachment), Canol Formation, GSC loc. C-12171.

Figure 3, 7. *Polygnathus timanicus* Ovnatanova.
Upper views of two Pa elements, GSC 99961 and GSC 99962, x93 and x57, Canol Formation, GSC loc. C-12171.

Figures 4-6. *Ancyrodella alata* Glenister and Klapper late form *sensu* Klapper (1985).
4, 5. Lower and upper views of Pa element, GSC 99963, x39, Allochthonous Beds, GSC loc. C-17977.
6. Upper view of Pa element, GSC 99969, x36, Allochthonous Beds, GSC loc. C-17223.

Figures 8, 9. *Ancyrodella* sp. cf. *A. rugosa* Branson and Mehl.
Lower and upper views of Pa element, figured specimens GSC 99964, x22, Allochthonous Beds, GSC loc. C-17977.

Figures 10, 11. *Ancyrodella rugosa* Branson and Mehl.
Upper and lower views of Pa element, GSC 99965, x27, Allochthonous Beds, GSC loc. C-17977.

Figure 12. *Mesotaxis asymmetrica* (Bischoff and Ziegler).
Upper view of Pa element, GSC 99966, x21, Allochthonous Beds, GSC loc. C-17977.

Figures 13, 16, 17. *Mesotaxis ovalis* (Ziegler and Klapper).
13. Upper view of Pa element, GSC 99967, x39, Allochthonous Beds, GSC loc. C-17977.
16, 17. Upper and lower views of Pa element, GSC 99970, x40, Allochthonous Beds, GSC loc. C-17223.

Figures 14, 15. *Palmatolepis disparata* Ziegler and Klapper.
Upper and lower views of Pa element, GSC 99968, x31, Allochthonous Beds, GSC loc. C-17977.

Figure 18. *Ozarkodina semialternans* (Wirth).
Lateral view of Pa element, GSC 99971, x42, Besa River Formation?, GSC loc. C-79138.

Figures 19, 20. *Palmatolepis disparilis* Ziegler and Klapper.
Upper and lower views of Pa element, GSC 99972, x35, Besa River Formation?, GSC loc. C-79138.

Figure 21. *Polygnathus dengleri* Bischoff and Ziegler.
Upper view of Pa element, GSC 99973, x58, Besa River Formation?, GSC loc. C-79138.

Figure 22. *Schmidtognathus peracutus* (Bryant).
Upper view of Pa element, GSC 99974, x39, Besa River Formation?, GSC loc. C-79138.

Figure 23. *Polygnathus cristatus* Hinde.
Upper view of Pa element, GSC 99975, x32, Besa River Formation, GSC loc. C-79362.

PLATE 4


1


2


3


4


5


6


7


8


9


10


11


12


13


14

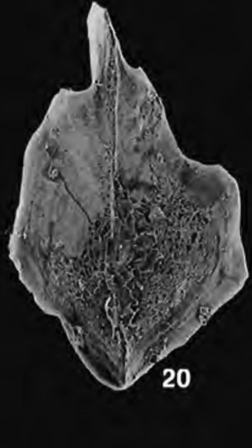

15


16


17


18


19


20


21


22


23

PLATE 5

D. Fairholme Assemblage (cont'd.). All specimens are hypotypes except where noted.

Figure 1. *Polygnathus dengleri* Bischoff and Ziegler.
Upper view of Pa element, GSC 99976, x43, Besa River Formation, GSC loc. C-79362.

Figure 2. *Polygnathus dubius* Hinde.
Upper view of Pa element, GSC 99977, x34, Besa River Formation, GSC loc. C-79362.

Figure 3. *Polygnathus ordinatus* Bryant.
Upper view of Pa element, GSC 99978, x30, Besa River Formation, GSC loc. C-79362.

Figure 4. *Icriodus difficilis* Ziegler and Klapper.
Upper view of I element, GSC 99979, x62, Flume Formation, GSC loc. C-146769.

Figures 5, 24. *Icriodus subterminus* Youngquist.
5. Lateral view of I element, GSC 99980, x62, Flume Formation, GSC loc. C-146770.
24. Upper view of I element, GSC 99996, x78, basal Fairholme Group, GSC loc. C-84867.

Figures 6, 8, 9. *Pandorinellina insita* (Stauffer).
6. Lateral view of Pa element, GSC 99981, x66, Flume Formation, GSC loc. C-146770.
8. Lateral view of Pa element, GSC 99983, x74, Maligne Formation, GSC loc. C-146792.
9. Lateral view of Pa element, GSC 99984, x78, Maligne Formation, GSC loc. C-146797.

Figure 7. *Polygnathus alatus* Huddle.
Upper view of Pa element, GSC 99982, x53, Flume Formation, GSC loc. C-146770.

Figure 10. *Ancyrodella* sp. cf. *A. rugosa* Branson and Mehl.
Upper view of Pa element, figured specimen GSC 99985, x35, Maligne Formation, GSC loc. C-146951.

Figure 11. *Ozarkodina sannemanni variabilis* (Pollock).
Oblique upper view of Pa element, GSC 99987, x43, Maligne Formation, GSC loc. C-146800.

Figure 12. *Playfordia primitiva* (Bischoff and Ziegler).
Lateral view, GSC 99988, x82, Maligne Formation, GSC loc. C-146800.

Figures 13, 25. *Polygnathus angustidiscus* Youngquist.
13. Oblique upper view of Pa element, GSC 99989, x82, Maligne Formation, GSC loc. C-146800.
25. Lateral view of Pa element, GSC 99997, x49, basal Fairholme Group, GSC loc. C-84867.

Figure 14. *Polygnathus* sp. cf. *P. dubius* Hinde.
Upper view of Pa element, figured specimen GSC 99986, x66, Maligne Formation, GSC loc. C-146951.

Figures 15-18. *Polygnathus* sp.
Upper and lower views of two Pa elements, GSC 99990 and GSC 99991, both x97, Perdrix Formation, GSC loc. C-146952.

Figure 19. *Icriodus symmetricus* Branson and Mehl.
Upper view of I element, GSC 99992, x89, Perdrix Formation, GSC loc. C-146953.

Figures 20-22. *Polygnathus timanicus* Ovnatanova.
20, 21. Lower and upper views of Pa element, GSC 99993, x86, Perdrix Formation, GSC loc. C-146953.
22. Upper view of Pa element, GSC 99994, x74, Perdrix Formation, GSC loc. C-146953.

Figure 23. *Polygnathus webbi* Stauffer.
Upper view of Pa element, GSC 99995, x74, Perdrix Formation, GSC loc. C-146953.

Figure 26. *Icriodus expansus* Branson and Mehl.
Upper view of I element, GSC 99998, x74, Starbird Formation, GSC loc. C-84861.

Figure 27. *Mehlina gradata* Youngquist.
Lateral view of Pa element, GSC 99999, x41, Starbird Formation, GSC loc. O-7939.

PLATE 5


1


2


3


4


5


6


7


8


9


10


11


12


13


14


15

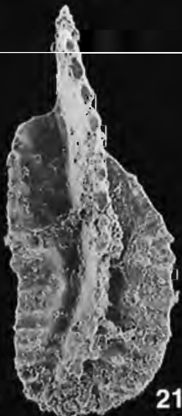

16


17


18


19


20


21


22


23


24


25


26


27

Famennian conodont biostratigraphy of the Palliser Formation, Rocky Mountains, Alberta and British Columbia, Canada

David I. Johnston[1] and Brian D.E. Chatterton[1]

Johnston, D.I. and Chatterton, B.D.E., 1991: Famennian conodont biostratigraphy of the Palliser Formation, Rocky Mountains, Alberta and British Columbia, Canada. In Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417, p. 163-183.

Abstract

Lower to upper Famennian conodont faunas from the Palliser Formation in the Front and Main ranges of Alberta and British Columbia are described and compared with those from well-dated Famennian sequences elsewhere. The Middle crepida *through Upper* marginifera *zones are recognized in the Morro Member of the Palliser Formation. The Lower and Upper* marginifera *zones and possibly the Lower* expansa *Zone are present in the overlying Costigan Member. Zonal indices for the Upper* crepida, *Lower and Upper* rhomboidea *and Lower* marginifera *zones are identified in Palliser strata, whereas the other zones are recognized on the basis of other key taxa.*

Conodont data support the conformable and diachronous nature of the contact between the Costigan and Morro members. The oldest age of this contact is in the upper part of the Upper rhomboidea *Zone, whereas the youngest age is Upper marginifera Zone. The age of the base of the Palliser Formation throughout its outcrop area is tentatively considered to be Middle* crepida *Zone. The youngest age for the top of the Palliser Formation is possibly the Lower* expansa *Zone, whereas the oldest age is the Upper* marginifera *Zone.*

Résumé

Les auteurs décrivent les faunes à conodontes du Famennien inférieur à supérieur de la formation de Palliser, dans les chaînons Front et Main en Alberta et en Colombie-Britannique, et les comparent à celles qui se rencontrent ailleurs dans des séquences famenniennes bien datées. L'intervalle qui englobe la zone moyenne à crepida *et la zone supérieure à* marginifera *est reconnu dans le membre de Morro de la formation de Palliser. Les zones inférieure et supérieure à* marginifera *et possiblement la zone inférieure à* expansa *se rencontrent dans le membre susjacent de Costigan. Des indices de la zone supérieure à* crepida, *des zones inférieure et supérieure à* rhomboidea *et de la zone inférieure à* marginifera *se reconnaissent dans les strates de Palliser, tandis que les autres zones sont reconnues d'après d'autres taxons clés.*

Les données sur les conodontes confirment que le contact entre les membres de Costigan et de Morro est conforme et diachrone. L'âge le plus vieux de ce contact provient de la partie supérieure de la zone supérieure à rhomboidea *et l'âge le plus jeune, de la zone supérieure à* marginifera. *L'âge de la base de la formation de Palliser partout dans sa zone d'affleurement est provisoirement l'âge de la zone moyenne à* crepida. *L'âge le plus jeune du sommet de la formation de Palliser est possiblement l'âge de la zone inférieure à* expansa *et l'âge le plus vieux, celui de la zone supérieure à* marginifera.

---

[1] Department of Geology, University of Alberta, Edmonton, Alberta T6G 2E3

INTRODUCTION

Conodonts have been reported previously from the Palliser Formation by Clark and Ethington (1965) and Richards and Higgins (1988). Mound (1968) discussed the conodonts in the equivalent Wabamun Formation from three boreholes in south-central Alberta.

Previous biostratigraphic zonations of the Palliser Formation have been based on the brachiopod (e.g., McLaren, 1954; Sartenaer, 1969; Raasch, 1989) and ostracode (Lethiers, 1981) succession in this formation. Rare ammonoids, assigned questionably to *Platyclymenia*, have been reported from uppermost Palliser beds by Warren (1927), Taylor (1958) and House and Pedder (1963).

In this report, we discuss Famennian conodonts from the Palliser Formation, and the application of the standard Upper Devonian conodont zones (e.g., Ziegler, 1962, 1971; Ziegler and Sandberg, 1984). Conodont based correlations between the Palliser Formation and other Famennian units in western Canada and the western United States are also discussed.

At present, conodont data are available from thirteen complete, or nearly complete, measured sections of the Palliser Formation in the Rocky Mountains of western Alberta and in eastern British Columbia east of the Rocky Mountain Trench (Fig. 1). Additional conodont data are also available from thirty Palliser sections in which strata at or near the top and/or the base of the formation were sampled (Fig. 1). Conodont biostratigraphy of seven sections of the Palliser Formation, located between the Crowsnest Pass in southwestern Alberta and the Athabasca Valley near Jasper in west-central Alberta (Fig. 1), are the main focus of this report. The thickness and extent of sampling of each section is shown in Figure 2. The location of, and other pertinent stratigraphic information about other relevant sections are provided in the Appendix.

STRATIGRAPHY

The Palliser Formation (Beach, 1943) is generally a prominent cliff-forming unit that outcrops on several thrust sheets in both the Front and Main ranges in western Alberta and eastern British Columbia. Exposures are also found in the Foothills (deWit and McLaren, 1950). This formation outcrops from northwestern Montana (Sandberg et al., 1988) to approximately 55°50′N and 122°W in northeastern British Columbia, where it is apparently truncated by erosion (Geldsetzer, 1982; Geldsetzer et al., 1986) (Fig. 3). The Palliser

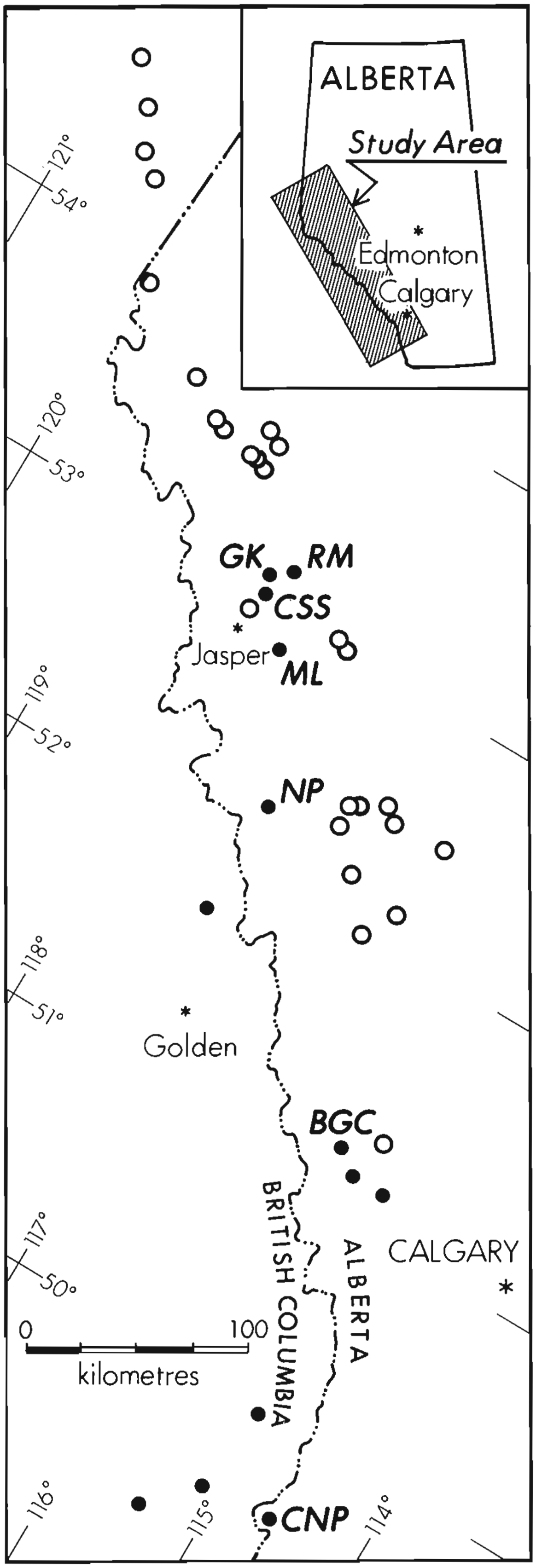


Figure 1. Map showing locations of sections of Palliser Formation sampled for conodonts. Open circles denote sections where only tops and/or bases were sampled, or where section was incompletely sampled. Dots denote sections sampled in detail throughout for conodonts. Abbreviations stand for sections shown in Figure 2. BGC = Banff Golf Course; CNP = Crowsnest Pass; CSS = Cold Sulphur Springs; GK = Mount Greenock; ML = Medicine Lake; NP = Nigel Peak; RM = Roche Miette.

Formation generally thickens to the west. Thicknesses are in the order of 200-300 m in more easterly exposures (e.g., deWit and McLaren, 1950) to as much as 600 m in some westerly exposures (Geldsetzer et al., 1986). However, in some exposures near the Rocky Mountain Trench, the thickness of the Palliser Formation is reduced to 100 m, apparently due to a facies change into a Sassenach-like lithology.

The stratigraphic relationships of the Palliser Formation are shown in Figure 3. The formation is underlain either conformably or disconformably (Fig. 3) by the Famennian Sassenach Formation in most outcrops in southern and south-central Alberta (McLaren and Mountjoy, 1962), in westernmost outcrops in Alberta along the continental divide (e.g., Mountjoy, 1978), and in southeastern British Columbia (Price, 1964; Geldsetzer et al., 1986). In some outcrops, most

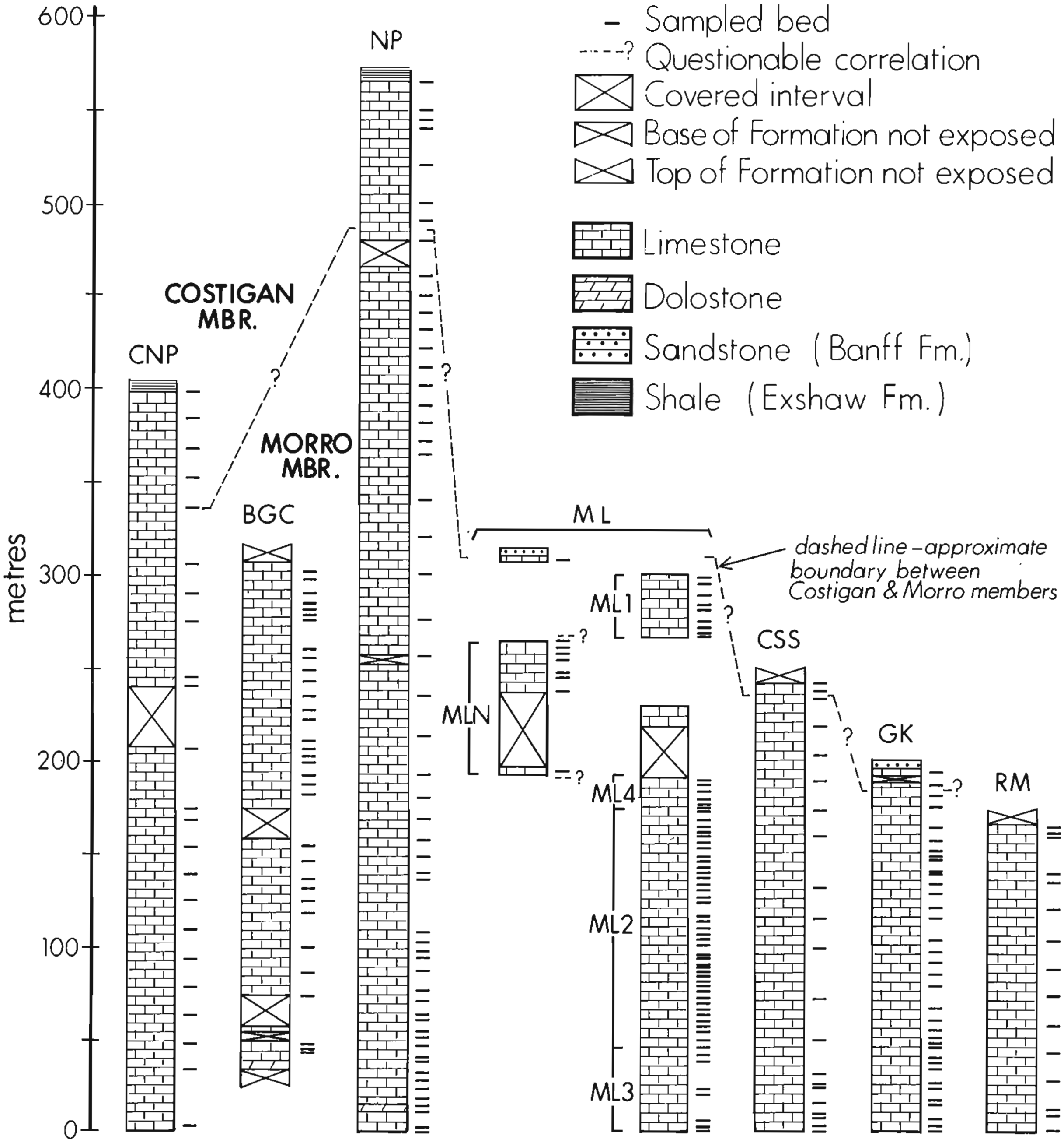


Figure 2. Stratigraphic columns of sections of Palliser Formation indicated by abbreviations in Figure 1. Medicine Lake (ML) section measured in segments (e.g., ML1, ML2, etc.) that are approximately correlated. Lower part of Palliser Formation not measured at Banff Golf Course, so approximate height above base for top of exposed formation shown at this locality. Abbreviations for section as in Figure 1.

notably along the northern margin of the Frasnian Southesk-Cairn reef complex, the Palliser Formation is directly underlain by the Frasnian Ronde Member of the Southesk Formation (Belyea and McLaren, 1964; Mackenzie, 1969). North of the Athabasca Valley, the Palliser Formation is underlain by the Simla Formation, which is equivalent to the Ronde Member (McLaren and Mountjoy, 1962; Geldsetzer, 1982).

The Palliser Formation is probably disconformably overlain by the Exshaw Formation (Fig. 3) in southwestern Alberta, from the Bow Valley northward to approximately halfway between Nigel Peak and Medicine Lake (e.g., Macqueen and Sandberg, 1970, Fig. 2), and in southeastern British Columbia. The Palliser Formation is overlain by the Banff Formation at Medicine Lake, and in sections farther north, except where the formation is overlain by remnants of the Exshaw Formation (Richards and Higgins, 1988). In northeastern British Columbia, the Palliser Formation is overlain by the Besa River Formation (Geldsetzer, 1982).

The Palliser Formation is laterally contiguous with, and lithologically similar to, the limestone of the subsurface Wabamun Formation in Alberta and northeastern

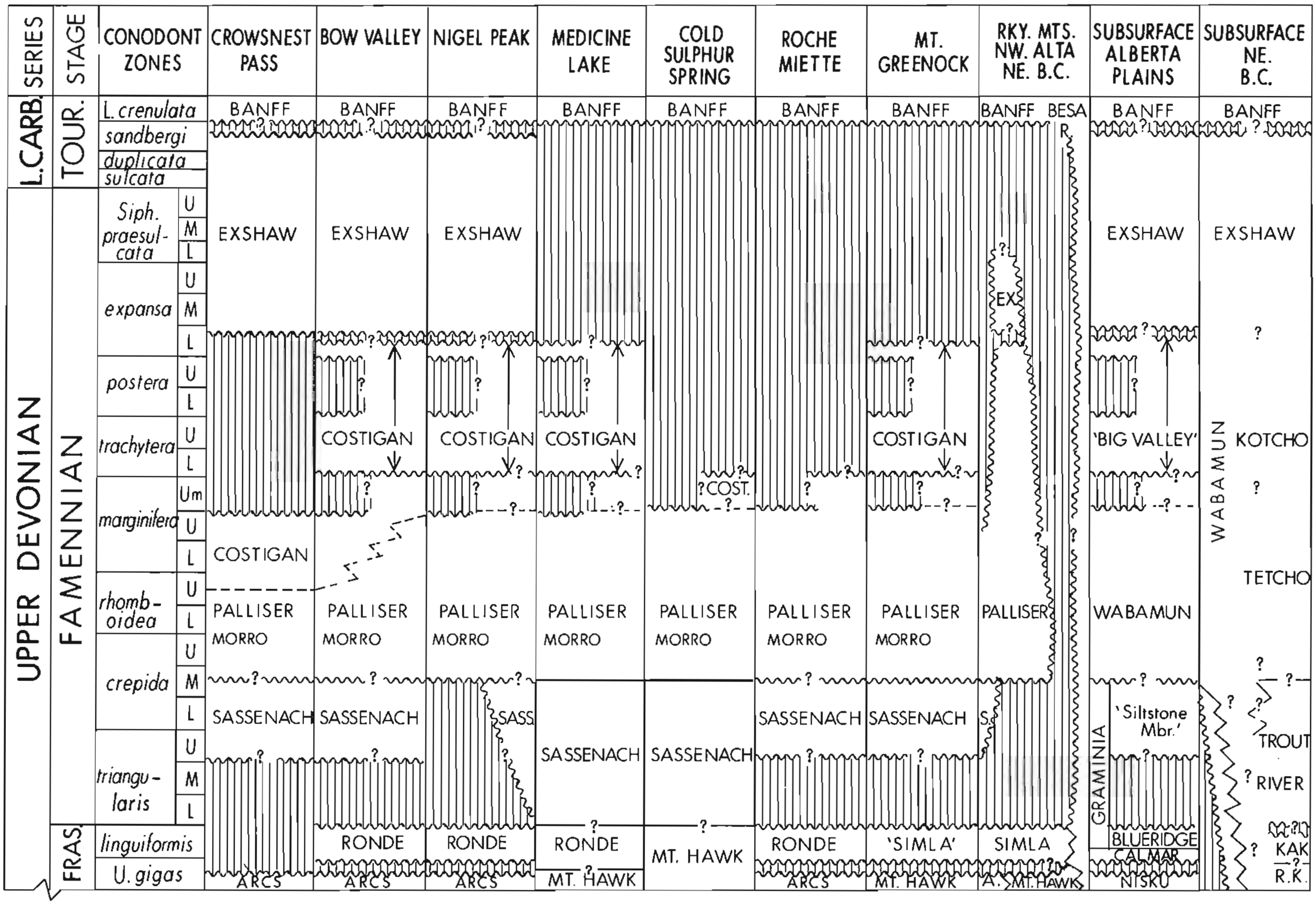


Figure 3. Correlation chart showing Late Devonian and part of Lower Carboniferous conodont zonation and stratigraphic relationships between Palliser Formation and correlative units, and over and underlying formations, compiled from various sources (see below). Banff Golf Course is included in column for the Bow Valley. Lower limit of Sassenach Formation and Siltstone Member of Graminia Formation placed arbitrarily at base of Upper *triangularis* Zone where these units overlie Frasnian carbonate platform strata (quotes around Simla at Mount Greenock denotes possible presence of formation). Continuous solid and wavy lines in lower part of figure indicate conformable and paraconformable contacts, respectively, and question marks indicate uncertainty about either the position or existence of these contacts. Question marks in far right column indicate correlation is uncertain between units in terms of conodont zonation. "Nearshore clastics" (Meijer Drees et al., work in progress) shown by jagged line flanking the Peace River Arch (hachured area in lower left hand corner of column). Age of Exshaw Formation at Crowsnest Pass, Bow Valley, and Nigel Peak, and age of the base of the Banff Formation at all localities is after Richards and Higgins (1988). Wavy lines with question marks joined by double arrow indicate alternative ages for top of Palliser Formation. Abbreviations: A. = Arcs Member; KAK. = Kakisa Formation; R.K. = Redknife. From Belyea and McLaren, 1964; deWit and McLaren, 1950; Geldsetzer, 1982; McLaren, 1955; McLaren and Mountjoy, 1962; Morrow and Geldsetzer, 1988; Price, 1964; Richards and Higgins, 1988.

British Columbia (Fig. 3). The Palliser Formation is also equivalent to the Kotcho and Tetcho formations in the subsurface of northeastern British Columbia (Fig. 3) and the surface and subsurface of the Northwest Territories (e.g., Belyea and McLaren, 1962), and to the evaporite, dolomite and limestone of the Stettler and Big Valley formations (Wonfor and Andrichuk, 1956).

DeWit and McLaren (1950) subdivided the Palliser Formation into an upper Costigan Member and a lower Morro Member. The Costigan Member is present in upper Palliser strata from southwestern Alberta and southeastern British Columbia (Geldsetzer et al., 1986) to at least as far north as the Athabasca River Valley. Eroded remnants occur farther north, in northeastern British Columbia (Geldsetzer, 1982; Geldsetzer et al., 1986). The Costigan Member most commonly consists of thin to thick bedded to massive, silty fossiliferous limestone. In places, particularly the more easterly exposures, this limestone overlies thin to very thick bedded, commonly silty, laminated and brecciated limestone and dolostone in which evaporitic minerals, fenestral fabric, mud-cracks, ripple marks and stromatolites occur (Andrichuk, 1960; Richards and Higgins, 1988; herein). In other Palliser sections (Fig. 2), particularly in more western exposures, the silty fossiliferous limestone of the Costigan Member directly overlies the Morro Member with a gradational contact. The Costigan Member is overlain by either sandstone or black shale belonging to the Banff or Exshaw formations.

The lower Morro Member of the Palliser Formation consists, throughout the entire outcrop area of the formation, of massive, commonly peloidal limestone characterized by bands of dolomitic mottling several centimetres to metres thick. The mottling has been interpreted as dolomitized burrows (Beales, 1953). The Morro Member exhibits varying degrees of dolomitization with some sections being wholly dolomitized (e.g., deWit and McLaren, 1950). In some sections of the Morro Member in the eastern Front Ranges (e.g., Baymag, Devil's Gap, Jura Creek – see Appendix), laminated, peloidal limestone characterized by the occurrence of *Chondrites* occurs near the top, immediately above thick bedded burrow-mottled limestone interbedded with medium to thick bedded microcrystalline dolostone. Sandy or silty beds occur in the lower part of the Morro Member in some sections (deWit and McLaren, 1950; McLaren, 1955).

In the Nigel Peak section (Fig. 2), two other lithofacies, in addition to the typical burrow-mottled limestone, are present. One is characterized by recessive, dark, nodular, thin to medium bedded, sparsely fossiliferous, argillaceous limestone; this is over and underlain by burrow-mottled limestone in the lower part of the Morro Member. The other lithofacies is characterized by thin to thick bedded limestone in which mottling appears to be absent, and occurs in the upper part of the Morro Member below the gradational contact with the Costigan Member. No data are currently available to determine whether the two lithofacies are time-equivalent to similar lithofacies in northwestern Alberta and northeastern and southeastern British Columbia described by Geldsetzer et al. (1986).

Depositional environment

The Palliser Formation has been interpreted by several authors (e.g., Beales, 1956, Andrichuk, 1960), to have been deposited under slightly restricted conditions for much of its history, with open marine conditions being prevalent later during deposition of the Costigan Member. In contrast, both the Palliser and Wabamun formations have been interpreted by others (e.g., Eliuk, 1984; Stoakes, 1987) as part of a prograding, open marine carbonate ramp.

On the basis of available lithological data, we believe that the Palliser Formation in the study area (Fig. 1) was deposited in a variety of environments, ranging from supratidal to deep subtidal. The Morro Member appears to have been deposited initially in generally very shallow subtidal environments, followed by a significant deepening early in its history, and then a return to generally shallower subtidal conditions. The occurrence of laminated peloidal limestone containing *Chondrites* in uppermost Morro strata in sections in the eastern Front Ranges indicates deposition in an intertidal environment. The latter beds are directly overlain by the laminated and brecciated limestone and dolostone of the Costigan Member, which appear to represent very shallow, and/or intertidal or supratidal conditions (Geldsetzer, 1982; Richards and Higgins, 1988). The silty fossiliferous limestone of this member suggests deposition under subtidal conditions, though perhaps not as deep as some parts of the Morro Member because the limestone contains oncolites and relatively shallow water conodont biofacies. In sections of the Palliser Formation farther to the west, conodont data suggest that Morro deposition persisted while contemporaneous deposition of the fossiliferous limestones of the Costigan Member occurred elsewhere (Fig. 3). In the Crowsnest Pass section, relatively deep water conodont biofacies occur in these limestones, which may suggest deposition in a more offshore environment than at the other localities. The cessation of Palliser sedimentation was probably followed by a brief hiatus (Fig. 3) and then by deposition of sandstone and/or black shale of the Banff or Exshaw formations. At Crowsnest Pass, there was apparently a longer hiatus prior to deposition of the Exshaw Formation (Fig. 3).

CONODONT BIOSTRATIGRAPHY

Conodonts from the Palliser Formation are usually common and well preserved, although in some sections, post-depositional (e.g., diagenetic) and tectonic processes have affected their preservation. Colour alteration indices for conodonts in the Palliser Formation range from about 3 to 5. Although conodonts are abundant in some samples and almost always present, large samples (3-5 kg) are usually necessary to obtain a collection of adequate size. Many well known Famennian conodont taxa are present in the Palliser Formation (Plates 1-3), as well as several new species of *Polygnathus* and *Icriodus*. These new species will be described in a future publication.

Conodont zonation

Six, and possibly seven, Upper Devonian standard conodont zones (Ziegler, 1962, 1971) have been recognized in the Palliser Formation and are discussed below. Zonal indices are present for four of these zones, but for the remaining three they are absent, and recognition of the zone is based on the occurrences of other index species. A particular zone is considered to be present when both upper and lower limits can be recognized, as is the case for five zones. The presence of the Middle *crepida* Zone and possibly the Lower *expansa* Zone is based on the recognition of only their upper and lower limits, respectively.

Middle *crepida* Zone

This zone has been recognized in the lower part of the Morro Member in the Medicine Lake, Mount Greenock, Nigel Peak and Roche Miette sections (Fig. 2). Its presence is based on the occurrence of *Palmatolepis wolskajae* Ovnatanova below the first occurrence of *Palmatolepis glabra prima* Ziegler and Huddle. The former species occurs either at, or within, a few metres of the base of the Palliser Formation at all the localities shown in Figure 2. In the Roche Miette section, the presence of the upper part of this zone is indicated by the occurrence of *Palmatolepis delicatula protorhomboidea* Sandberg and Ziegler. Forms identified as *Palmatolepis* sp. cf. *P. delicatula protorhomboidea* at approximately the same stratigraphic level in the Mount Greenock and Nigel Peak sections (Fig. 2) may suggest the presence of this part of the Middle *crepida* Zone at these localities too.

Other significant species of *Palmatolepis* that occur in this zone include *P. circularis* Szulczewski, *P. minuta minuta* Branson and Mehl, *P. quadrantinodosalobata* Sannemann and *P. triangularis* Sannemann, all of which appear above *P. wolskajae* in all the sections shown in Figure 2. *Palmatolepis circularis* occurs with *P. wolskajae* and *P. quadrantinodosalobata* at Mount Greenock, Medicine Lake and Nigel Peak, in all of which the species is moderately abundant within a single bed. *Palmatolepis minuta minuta* is low to moderately abundant and *P. quadrantinodosalobata* highly abundant in this zone. *Palmatolepis triangularis* is rare, with only a few elements found at Medicine Lake and Nigel Peak.

Important species of *Polygnathus* that first appear in this zone in the Palliser Formation include *P. glaber glaber* Ulrich and Bassler, *P. nodocostatus* Branson and Mehl and *P. webbi* Stauffer. Druce (1976) also recorded the first species from as low as the Middle *crepida* Zone in the Canning Basin of Australia. Both *P. nodocostatus* and *P. webbi* range throughout the Palliser Formation, although the latter species, for probable ecological reasons, occurs only in lowermost and uppermost beds of the formation.

The genus *Polylophodonta* is also present in this zone, which extends its stratigraphic range slightly downward. Species include both *P. confluens* Ulrich and Bassler and *P.* sp. cf. *P. linguiformis* Branson and Mehl (*sensu* Sandberg and Ziegler, 1973). Previously, the latter was considered to range only as low as the Upper *crepida* Zone (Sandberg and Ziegler, 1973), whereas *P. confluens* has previously been reported to range no lower than the Upper *rhomboidea* Zone (Druce, 1976).

Species of *Icriodus* and *Pelekysgnathus* that first appear in or are confined to the Middle *crepida* Zone include *I. iowaensis ancylus* Sandberg and Dreesen, *I. iowaensis iowaensis* Youngquist and Peterson, *P. inclinatus* Thomas, and *P. planus* Sannemann. *Pelekysgnathus planus* occurs at the top of this zone at Mount Greenock where it is represented by a single specimen. At Nigel Peak, *P. inclinatus* disappears shortly after its first appearance, only to appear again in upper Palliser strata in this and other sections (see below). *Icriodus iowaensis ancylus* occurs at the base of the Palliser Formation in several sections illustrated in Figure 2 (e.g., Cold Sulphur Spring, Mount Greenock and Nigel Peak), below the first occurrence of *Palmatolepis wolskajae*. *Icriodus i. ancylus* appears to range no higher than the Middle *crepida* Zone in the Palliser Formation. The Palliser sections that have this subspecies and no other diagnostic taxa at their base are no older than Upper *triangularis* Zone, which is the maximum age of the upper part of the Sassenach Formation (Orchard, 1988, p. 38). However, because a Middle *crepida* Zone age can be assigned to the base of the Palliser Formation on the basis of the occurrence of *Palmatolepis wolskajae* with *Icriodus i. ancylus* at the Cold Sulphur Springs section, we consider the maximum age of the base of the Palliser Formation to be the same in sections where only *I. i. ancylus* occurs. Deposition of the Palliser may have commenced in slightly deeper water in the former section than in the latter ones. The contact between this formation and the Sassenach Formation is placed arbitrarily at mid-Middle *crepida* Zone in Figure 3.

Other notable conodonts in this zone are specimens of *Apatognathus varians varians* Branson and Mehl (this genus is used here in the multielement sense, see Nicoll, 1980) at Nigel Peak, the lowest previous stratigraphic occurrence of which was reported from the Upper *marginifera* Zone of the Canning Basin of Australia (Nicoll, 1980). *Mehlina gradata* Youngquist also first appears in the Middle *crepida* Zone in the Palliser Formation, and ranges into the upper part of the formation.

Upper *crepida* Zone

This zone is recognized in the lower part of the Morro Member in the Medicine Lake and Nigel Peak sections (Fig. 2). The lower limit of the zone is placed at the first occurrence of *Palmatolepis glabra prima*, and the upper limit is placed at the first appearance of either *Palmatolepis klapperi* Sandberg and Ziegler or *Palmatolepis poolei* Sandberg and Ziegler. *Palmatolepis wolskajae* disappears shortly above the first appearance of *P. g. prima* in the Upper *crepida* Zone. *Palmatolepis subperlobata* Branson and Mehl has its first appearance in this zone at both Medicine Lake and Nigel Peak. *Pelekysgnathus planus* occurs in this zone in the Nigel Peak section, which represents a slight upward extension of its stratigraphic range compared with the previous upper range in the Middle *crepida* Zone (Sandberg and Dreesen, 1984). *Icriodus alternatus alternatus* Branson and Mehl is found in a single bed in the Roche Miette section that could be old as the Upper *crepida* Zone or as young as the Lower *rhomboidea* Zone. *Palmatolepis quadrantinodosalobata* is very abundant in the Upper *crepida* Zone, and *Palmatolepis minuta minuta* is moderately abundant in some samples.

Lower *rhomboidea* Zone

This zone is present in the lower part of the Morro Member in the Medicine Lake and Nigel Peak sections. Its lower limit defines the upper limit of the underlying Upper *crepida* Zone (see above). The upper limit of this zone is marked by the appearance of *Palmatolepis rhomboidea* Sannemann, which is here considered to mark the base of the overlying Upper *rhomboidea* Zone (see below). This species is absent in the Lower *rhomboidea* Zone in the study area, so in its absence, we regard the occurrences of either *Palmatolepis klapperi* or *P. poolei* to indicate the presence of this zone (see Sandberg, 1979, p. 95, and Dusar and Dreesen, 1984, p. 29). In the Nigel Peak section, *P. poolei* occurs above *P. klapperi*, so that the first occurrence of the latter species is considered to be the base of the Lower *rhomboidea* Zone in this section. The appearance of *P. klapperi* below *P. poolei* and *P. rhomboidea* was also reported by Dreesen and Dusar (1974) from the Famennian of Belgium. At Medicine Lake *P. klapperi* is absent, so that the base of the Lower *rhomboidea* Zone is placed at the single appearance of *P. poolei*. Both these species appear to be restricted to the lowermost part of this zone, with the upper limits of their ranges quite far below the first occurrence of *P. rhomboidea*. The occurrence of several elements identified as *P.* sp. cf. *P. klapperi* a few metres below the first occurrence of *P. rhomboidea* in the Mount Greenock section may indicate the possible presence of this zone at this locality.

Other important taxa that first appear in this zone include *Palmatolepis glabra pectinata* Ziegler and Morphotype 1 of this species (Sandberg and Ziegler, 1973) and *Polygnathus semicostatus* Branson and Mehl. Rare specimens of a lobate morphotype of *Palmatolepis tenuipunctata* Sannemann are also present. Such elements are considered to be more typical of the early phylogenetic history of the species (e.g., Ziegler, 1962, Pl. 4, Figs. 3-11), yet the occurrence of *P. tenuipunctata* in the Lower *rhomboidea* Zone represents a slight upward extension of the stratigraphic range of the species, which is usually considered to range to the top of the Upper *crepida* Zone (e.g., Klapper and Ziegler, 1979, Textfig. 6).

Palmatolepis subperlobata is restricted to the lower part of the Lower *rhomboidea* Zone at Nigel Peak, where the species appears to be represented by a different morphotype than that which occurs in the Upper *crepida* Zone (compare Pl. 1, figs. 20 and 24). The *Palmatolepis glabra* group (Ziegler and Huddle, 1969) are very abundant in the lower part of the Lower *rhomboidea* Zone at Nigel Peak. *Palmatolepis quadrantinodosalobata* is still present in this zone, where it is moderately abundant. Conodont faunas in the remainder of this zone are characterized by either the abundant or exclusive occurrence of *Polygnathus semicostatus.*

Two species of "*Icriodus*", a homeomorph of *Icriodus* (Sandberg and Dreesen, 1984), first appear in the Lower *rhomboidea* Zone. These species are "*I*". *cornutus* Sannemann and "*I*". *chojnicensis* Matyja Morphotype 1 of Sandberg and Dreesen. The occurrence of the latter species in the Lower *rhomboidea* Zone represents a downward extension of its known stratigraphic range, regarded previously as coincident with the base of the Upper *rhomboidea* Zone (Sandberg and Dreesen, 1984). *Icriodus iowaensis iowaensis* appears to range no higher than the Lower *rhomboidea* Zone in the Palliser Formation. *Apatognathus varians klapperi* Druce makes its first appearance in this zone at Nigel Peak.

Upper *rhomboidea* Zone

Definite lower and upper limits of this zone can be recognized in upper Morro beds in the Banff Golf Course, Cold Sulphur Springs, Medicine Lake, and Roche Miette sections (Fig. 2). The lower limit of this zone occurs approximately in the middle of the Morro Member. The base of this zone forms the upper limit of the underlying Lower *rhomboidea* Zone (see above). The first appearance of *Palmatolepis marginifera marginifera* marks the upper limit of this zone, except in the Crowsnest Pass, Mount Greenock, and Nigel Peak sections (see below). The first appearance of *Palmatolepis rhomboidea* is considered to mark the base of the Upper rather the Lower *rhomboidea* Zone in the Palliser Formation because of the much higher first occurrence of this species above the highest occurrences of both *Palmatolepis klapperi* and/or *P. poolei* at both Medicine Lake and Nigel Peak, and because it is the most, or second most, abundant platform element in the lower part of this zone in several sections. Thus, the major requisite for recognition of this zone; the relative abundance of *P. rhomboidea* between the highest occurrence of *P. poolei* and the lowest occurrence of *P. marginifera marginifera* (Sandberg and Ziegler, 1973), appears to be satisfied in the Palliser Formation. It is also for the former reason that we define the base of the zone at the first occurrence of *P. rhomboidea* rather than at the highest occurrence of *P. poolei*, which is normally considered the base of the Upper *rhomboidea* Zone (see Sandberg, 1979).

Palmatolepis rhomboidea is accompanied throughout all or part of its stratigraphic range by *Polygnathus communis communis* Branson and Mehl in three of the sections in Figure 2 (Cold Sulphur Springs, Mount Greenock, and Medicine Lake), but whereas *P. rhomboidea* is confined to the Upper *rhomboidea* Zone, *Polygnathus c. communis* ranges to the top of the Palliser Formation. However, for apparent ecological reasons, the latter species is absent in most of the upper part of the Palliser Formation, except for the uppermost beds. *Palmatolepis stoppeli* Sandberg and Ziegler appears in the upper part of this zone, and in some samples it is very common and is the sole platform element. The stratigraphic ranges of *P. rhomboidea* and *P. stoppeli* do not overlap in our sections except for one questionable occurrence at Nigel Peak.

Palmatolepis quadrantinodosa inflexa Müller occurs in this zone and also in beds that could belong to the upper part of the Lower *rhomboidea* Zone. *Polygnathus pennatulus* Ulrich and Bassler has its only occurrence, and *Apatognathus varians klapperi*, "*Icriodus*" *cornutus* and *Polylophodonta* sp. cf. *P. linguiformis* have their highest occurrence, in this zone. At Mount Greenock, *Palmatolepis quadrantinodosalobata* also ranges into this zone, which supports data of Pavlicek (*in* Metzger, 1989), that show *P. quadrantinodosalobata* has a higher stratigraphic occurrence than the previously reported lowermost Lower *rhomboidea* Zone (Klapper and Ziegler, 1979, Textfig. 6). *Polygnathus semicostatus* occurs in abundance in some samples, mostly in the lower part of this zone.

Lower *marginifera* Zone

This zone has been recognized in both the upper part of the Morro Member and in the lower part of the fossiliferous limestone of the Costigan Member. The lower limit of this zone defines the upper limit of the underlying Upper *rhomboidea* Zone (see above) in most of the sections in Figure 2. An upper limit to this zone has only been recognized in the Crowsnest Pass and Nigel Peak sections. At Nigel Peak, the upper limit of this zone is marked by the appearance of *Bispathodus stabilis* (Branson and Mehl) Morphotype 1 of Ziegler, Sandberg, and Austin; in the Crowsnest Pass section the upper limit is defined by the appearance of *Polygnathus perplexus* (Thomas). In the latter section, an alternate base of the Lower *marginifera* Zone corresponds to the first appearance of *Palmatolepis quadrantinodosa inflexoidea* Ziegler in the fossiliferous limestone unit of the Costigan Member (Fig. 2). This species has been found in only one other bed above its first appearance in this section. The Lower *marginifera* Zone is considered to be present in the remainder of the Costigan Member in the Crowsnest Pass section, excluding the uppermost bed, where the Upper *marginifera* Zone is recognized.

Palmatolepis stoppeli occurs in the lower part of this zone in the Medicine Lake section, and *Palmatolepis marginifera duplicata* Sandberg and Ziegler and *Palmatolepis quadrantinodosa quadrantinodosa* Branson and Mehl occur in the upper part of the zone at Nigel Peak. Both *Pelekysgnathus inclinatus* and *Polygnathus webbi* reappear in the Lower *marginifera* Zone, after being absent in the underlying Upper *crepida* to Upper *rhomboidea* zones, in several sections shown in Figure 2. Both *Polygnathus nodocostatus* and *Polylophodonta confluens* have their highest occurrences in this zone in the Nigel Peak section. *Palmatolepis marginifera marginifera* is very abundant in the lower part of this zone but rare to moderately abundant in the upper part. *Polygnathus semicostatus* is abundant in some samples in this zone.

At Nigel Peak, *Palmatolepis glabra distorta* Branson and Mehl appears in the uppermost part of this zone. Representatives of the "advanced" morphotype of this species (Sandberg and Poole, 1977, p. 163) are present together with more typical specimens. This "advanced" morphotype of *P. g. distorta* also occurs in uppermost exposed Palliser beds belonging to the Morro Member at Banff Golf Course (Fig. 2) that are dated no younger than the Upper *marginifera* Zone but no older than the Lower *marginifera* Zone. Similarly, at Nigel Peak, both *Palmatolepis glabra pectinata* and *Palmatolepis glabra prima* occur in strata overlying the horizon containing the "advanced" morphotype, implying the latter is no younger than the Upper *marginifera* Zone (Klapper and Ziegler, 1979; Ziegler and Sandberg, 1984). Previously, the "advanced" morphotype of *P. g. distorta* was considered by Sandberg and Poole (1977) to occur exclusively in the Lower to Upper *trachytera* zones, so the Palliser occurrences represent a downward extension of its stratigraphic range. This may also suggest that, rather than representing an advanced evolutionary stage of *Palmatolepis glabra distorta*, the "advanced" morphotype of this species may simply represent an ecophenotype.

Upper *marginifera* Zone

Although *Palmatolepis marginifera utahensis* Ziegler and Sandberg, the zonal index for the Upper *marginifera* Zone (Ziegler and Sandberg, 1984), is absent in the Palliser Formation, the zone is recognized in the uppermost bed of the Costigan Member at Crowsnest Pass on the basis of an association of *Palmatolepis glabra pectinata* Morphotype 1 and *Polygnathus perplexus* with *Palmatolepis marginifera marginifera*. *Palmatolepis g. pectinata* Morphotype 1 ranges no higher than the Upper *marginifera* Zone (Klapper and Ziegler, 1979; Ziegler and Sandberg, 1984), whereas *Polygnathus perplexus* has been documented to occur no lower than this zone (Dreesen and Dusar, 1974; Druce, 1976).

The Upper *marginifera* Zone is also present in the Mount Greenock and Nigel Peak sections in beds immediately below the Costigan–Morro contact, which is gradational in these sections (Fig. 2). In the Nigel Peak section, the zone is identified in the stratigraphic interval between the first occurrences of *Bispathodus stabilis* Morphotype 1 and "*Icriodus*" *costatus costatus* (Thomas) Morphotype 1 of Sandberg and Dreesen, in, respectively, the uppermost Morro and the lower Costigan beds. The lower limits of the stratigraphic ranges of *B. stabilis* Morphotype 1 and "*I.*" *c. costatus* are at the bases of the Upper and Uppermost *marginifera* zones, respectively (Sandberg and Dreesen, 1984; Ziegler and Sandberg, 1984).

At Mount Greenock, the presence of this zone is suggested by the occurrence of *Palmatolepis marginifera marginifera* with *Polygnathus perplexus* in uppermost Palliser beds belonging to the Morro Member. The upper limit of this zone is placed at the first occurrence of "*Icriodus*" *raymondi* Sandberg and Ziegler at approximately the base of the Costigan Member in this section. The lower limit of this species range is the base of the Uppermost *marginifera* Zone (Sandberg and Dreesen, 1984).

Lower *expansa* Zone

This zone is tentatively recognized in the Costigan Member in the Medicine Lake and Nigel Peak sections. Its lower limit has been placed at the first appearance of *Bispathodus stabilis* Morphotype 2 of Ziegler, Sandberg, and Austin. The upper limit of this zone may lie in the overlying Exshaw Shale, as suggested by data of Richards and Higgins (1988), or, where the Palliser Formation is overlain by the Banff Formation, part of the zone may be missing due to erosion (Fig. 3). At Medicine Lake, the presence of this zone is suggested by the joint occurrence, just below the Palliser–Banff contact, of *B. stabilis* Morphotype 2 and "*Icriodus*" *raymondi*. The lowest stratigraphic range of the former and the highest stratigraphic range of the latter species overlap in the Lower *expansa* Zone (Sandberg and Dreesen, 1984; Ziegler and Sandberg, 1984). The Lower *expansa* Zone, or younger, is also suggested by the occurrence of *B. stabilis* Morphotype 2 in upper Costigan strata in the eastern Front Ranges of the Bow Valley (see Appendix). The presence of the Lower to Middle *expansa* zones in this area was also suggested by Richards and Higgins (1988).

''*Icriodus*'' *raymondi* occurs with *Bispathodus stabilis* Morphotype 1 in uppermost Palliser strata at Mount Greenock in the Costigan Member. This association suggests the presence of either the Lower *expansa* Zone or the Uppermost *marginifera* Zone (e.g., Sandberg and Dreesen, 1984; Ziegler and Sandberg, 1984). These two possible age assignments for the top of the Palliser Formation are shown for this section in Figure 3.

Some other major taxa present in uppermost Palliser beds that are possibly representative of the Lower *expansa* Zone include *Apatognathus varians varians*, ''*Icriodus*'' *costatus costatus* Morphotype 1, *Polygnathus communis communis*, and *Polygnathus semicostatus*. *Polygnathus c. communis* is common in some samples after being absent in the underlying Palliser strata, which postdate the Upper *rhomboidea* Zone. *Polygnathus semicostatus* is also common. *Mehlina gradata* may occur as high as this zone. The occurrence of ''*I.*'' *c. costatus* Morphotype 1 in this zone may represent a slight upward extension of its stratigraphic range. This morphotype is normally considered to range as high as the Upper *postera* Zone (Sandberg and Dreesen, 1984).

Age of Costigan-Morro contact and uppermost Palliser Formation

From the foregoing discussion it is apparent that the contact between the Costigan and Morro members is diachronous. At Crowsnest Pass, this contact occurs within strata as old as the upper part of the Upper *rhomboidea* Zone. This is shown by the dashed line in Figure 3. In sections where this contact is exposed in the eastern Front Ranges of the Bow Valley, on the McConnell Thrust Sheet (e.g., Baymag, Devil's Gap, Jura Creek – see Appendix), the occurrence of *Palmatolepis stoppeli* in uppermost Morro beds suggests that these beds are the same age. Therefore, both at these localities and at Crowsnest Pass, the upper part of the Upper *rhomboidea* Zone represents the oldest age of the contact between the two members of the Palliser Formation. In all the other sections in Figure 2, strata of this age occur in the upper part of the Morro Member. The lower part of the Costigan Member and the upper part of the Morro Member are shown as facies equivalents in Figure 3 because uppermost exposed Palliser strata at Banff Golf Course still belong to the Morro Member and are no older than Lower *marginifera* Zone, that is younger than uppermost Morro beds in the eastern Front Ranges.

The apparent time equivalence of lower Costigan and upper Morro beds suggests that the contact between these members is conformable, at least in the Crowsnest Pass section and in the Bow Valley. At sections such as Medicine Lake and Mount Greenock, it is not certain whether a hiatus exists between Costigan and Morro beds or whether deposition was continuous between these two members. In the absence of conodont evidence to the contrary, the contact between the Costigan and Morro members is assumed to be conformable in the latter sections too.

At Mount Greenock and Nigel Peak, basal beds of the fossiliferous limestone of the Costigan Member are probably no older than the Upper *marginifera* Zone. The position of the contact (shown by a dashed line with a question mark) between this limestone and the Morro Member in these and the Cold Sulphur Springs and Medicine Lake sections, is placed arbitrarily at the top of this zone in Figure 3. In the Jura Creek section, according to Richards and Higgins (1988), the base of the fossiliferous limestone of the Costigan Member would be no older than the Lower *expansa* Zone. Thus, at Mount Greenock and Nigel Peak, the base of these beds appears to be older than the base of equivalent beds in Palliser sections of the eastern Front Ranges. Based on similarity of conodont faunas, the fossiliferous limestone of the Costigan Member at Jura Creek, which overlies the brecciated and laminated carbonate of this same member, is probably time equivalent to the upper part of the fossiliferous limestone that represents all of the Costigan Member at Nigel Peak (Fig. 3).

The inability to recognize the uppermost *marginifera* through Upper *postera* zones in the Palliser Formation may be due to the lack of suitable paleoenvironments for the zonal indices, but the lack of at least some may be due to the presence of hiatuses that are presently undetected. Regional unconformities recognized in the late Famennian of the western United States encompass the Uppermost *marginifera* Zone and the Lower to Upper *postera* zones (Sandberg and Poole, 1977; Sandberg et al., 1983, 1988), and may also be present in uppermost Palliser strata (Fig. 3). Several obvious disconformities appear to be represented in peritidal carbonates in the lower part of the Costigan Member in the eastern Front Ranges, but these beds are unfossiliferous and undated. In contrast, in Palliser sections in the Athabasca Valley and the section at Nigel Peak, no obvious depositional breaks have been observed by the writers in upper Palliser strata representative of the Costigan Member.

It is evident from the foregoing discussion that the age of the top of the Palliser Formation is not the same everywhere. It has been shown that uppermost Palliser strata in some of the sections in Figure 2 could range as high as the Lower *expansa* Zone (Fig. 3). If this age assignment is accepted, this would be the youngest age of the top of the Palliser Formation determined so far. However, in the Nigel Peak section, uppermost Palliser beds just below the contact with the Exshaw Formation contain the association of *Bispathodus stabilis* Morphotype 2, ''*Icriodus*'' *raymondi* and ''*Icriodus*'' *chojnicensis* Morphotype 2 of Sandberg and Dreesen. The latter element has been considered to range no higher than the Uppermost *marginifera* Zone (Sandberg and Dreesen, 1984). Whether the stratigraphic range of *B. stabilis* Morphotype 2 should be considered to extend downward, or the range of ''*I.*'' *chojnicensis* to extend upward is uncertain, and accounts for the tentative recognition of the Lower *expansa* Zone. The reported occurrence of the rhynchonellid brachiopod *Gastrodetoechia utahensis utahensis* (Kindle) in uppermost Palliser beds at Nigel Peak (Sartenaer, 1969) supports a Lower *expansa* age because, as far as we know, the subspecies is currently known to range from the Lower *trachytera* Zone to possibly as high as the Upper *expansa* Zone (Sartenaer, 1969; Sandberg et al., 1988). Because of the uncertainty, both Lower *expansa* and uppermost *marginifera* zones for uppermost strata of the Palliser Formation are indicated for the Bow Valley, Medicine Lake and Nigel Peak in Figure 3.

In other sections, the age of the top of the Palliser Formation does not appear to be much younger than the lowermost Lower *trachytera* Zone. The Upper *marginifera* Zone is present in the highest bed of the Palliser Formation at Crowsnest Pass. Uppermost exposed beds of the Palliser Formation at Cold Sulphur Springs contain *Palmatolepis glabra distorta*, which suggests an age no younger than the Lower *trachytera* Zone but possibly as old as the Lower *marginifera* Zone for these beds. In the canyon between Morro Peak and Mt. Hawk, not far south of the Cold Sulphur Springs section, Higgins reported (GSC Fossil Report 1-ACH-1983) the occurrence of conodonts, whose known stratigraphic ranges extend no higher than the Uppermost *marginifera* Zone, in a bed just below the contact with the overlying Banff Formation. At Roche Miette, the presence of *Palmatolepis marginifera marginifera* in the uppermost exposed Palliser beds in that section also suggests that the minimum age of the Palliser is no younger than the lowermost Lower *trachytera* Zone. The Morro Member is only recognized in the measured portion of this section. Since only the minimum age for the top of this member is shown in Figure 3, the actual age of uppermost exposed Morro beds at Roche Miette is probably no younger than the highest beds of this member at nearby localities.

Conodont data of Geldsetzer (1982) and the authors' own data suggest, where diagnostic taxa are present, that the top of the Palliser Formation ranges no higher than the *marginifera* Zone in northwestern Alberta and northeastern British Columbia, except where Richards and Higgins (1988) reported the Palliser ranging as high as the *expansa* Zone at Red Deer Creek in northeastern British Columbia.

The age relationships between the Palliser Formation and over and underlying formations, and between the Costigan and Morro members at some localities are summarized in Figure 3. In this figure, we have shown the Costigan Member as having been continuously or discontinuously deposited, with hiatuses shown to correspond to the major unconformities recognized in the Late Famennian of the western United States (see above), although this may not necessarily be the case. If the minimum age for the top of the Palliser Formation is accepted (see above), then the Costigan Member would appear, given its relative thinness (Fig. 2), to be a condensed sequence. It would have been necessary for prolonged breaks in sedimentation and/or very slow deposition to have occurred in order to account for the condensed nature of the member. However, if the maximum age for the top of the Palliser Formation is accepted, there is no need to regard the Costigan Member as condensed. The difficulty encountered in attempting to date uppermost strata of the Palliser Formation illustrates the problem with using probably long-ranging and/or facies-controlled conodont taxa rather than diagnostic species of *Palmatolepis*, which are absent, for this purpose. We are also uncertain whether the fossiliferous limestone assigned to the Costigan Member in the upper part of the Palliser Formation at Crowsnest Pass (Fig. 2) represents an earlier phase of the same depositional episode that resulted in similar limestone being deposited later at the other localities or whether this limestone represents an entirely different episode altogether.

CORRELATIONS

Wabamun Formation

In all but the uppermost strata of the Wabamun Formation in the subsurface of northwestern Alberta and northeastern British Columbia, the occurrence of *Palmatolepis wolskajae*, *P. glabra prima*, *P. klapperi*, *P. rhomboidea*, *P. stoppeli* and *P. marginifera marginifera* (Meijer Drees et al., in prep.; work in progress) from wells in this area indicate that the Wabamun can be correlated with Morro and lower Costigan strata. These taxa also occur in the same order as they do in the Palliser Formation. Correspondingly, the same sequence of standard conodont zones (i.e., Middle *crepida*–Lower *marginifera* zones) are recognized in this portion of the Wabamun Formation. In the uppermost part of the Wabamun Formation, in beds of fossiliferous limestone equated with the Big Valley Formation of Wonfor and Andrichuk (1956) (Fig. 3), the occurrence of *Bispathodus stabilis* Morphotype 2 suggests correlation with the fossiliferous limestone of the Costigan Member. As in the Palliser Formation, the occurrence of *B. stabilis* Morphotype 2 in uppermost Wabamun beds indicates the presence of the Lower *expansa* Zone, but these beds may be older. As in Palliser sections in Figures 2 and 3, it is uncertain whether any significant hiatuses exist between the main part of the Wabamun Formation and its uppermost beds or whether deposition was continuous (Meijer Drees et al., in prep), although the contact between these uppermost beds and underlying strata is assumed to be conformable. The alternative age assignments for the top of the Wabamun Formation and the possible presence of hiatuses have been shown for this formation as they have been shown for the Palliser Formation in Figure 3. Possible disconformities at the contacts between the Graminia and Wabamun formations, and between the latter and the Exshaw Formation, are also shown in Figure 3.

Famennian conodonts illustrated by Mound (1968) from the Calstan Winterburn Province #1 10-4-53-25W4 well near Edmonton, suggest that Wabamun beds sampled in this well, which are equivalent to the Big Valley Formation in southeastern Alberta, are correlative with upper Palliser beds that correspond to the Costigan Member. Specimens of *Pelekysgnathus inclinatus* that Mound (1968, Pl. 69, Figs. 1, 8-11) illustrated are closest to those from the upper Palliser beds. Similarly, *Polygnathus perplexus* (identified by Mound as *Polygnathus nodoundatus* Helms, Pl. 69, figs. 15, 16) is quite common and abundant in uppermost Wabamun or Big Valley beds in this well, and supports the same correlation. This species is also present in Big Valley strata in Wabamun core sampled by Meijer Drees et al. (in prep). Other important taxa that occur in this well include *Polygnathus semicostatus*, and possible *Polygnathus communis communis* and *Palmatolepis glabra distorta* (Mound, 1968).

Earn Group

Conodont data provided by Orchard (1988) and Irwin and Orchard (1989; 1991, *this volume*) may be used to suggest that part of the lower Earn Group, which outcrops in northeastern British Columbia, the Yukon and the Northwest Territories (Gordey, 1988; Irwin and Orchard, 1989, Fig. 2), is correlative with the Palliser Formation. Significant conodont taxa that occur in this unit that suggest correlation with the Palliser Formation include *Palmatolepis glabra distorta*, *P. g. pectinata*, *P. marginifera marginifera*, *P. quadrantinodosalobata* and *P. wolskajae*. Irwin and Orchard (1989) also reported the occurrence of *Palmatolepis glabra lepta* Ziegler and Huddle from the Earn Group. This species has been positively identified from only one of the authors' localities (Meosin Mountain – see Appendix). Further details of the Earn Group conodonts are provided by Irwin and Orchard (1991, *this volume*).

Western United States

Suggested conodont-based correlations between the Palliser Formation and selected Famennian units in the western United States are shown in Figure 4. Correlation of the Morro Member with units such as the "False Birdbear" Member and the upper part of the Logan Gulch Member, has been previously suggested by Sandberg and Poole (1977) and Sandberg et al. (1983, 1988). However, conodont evidence presented herein may be used to suggest that the lowermost beds of the Costigan Member in Palliser sections in the eastern Front Ranges in the Bow Valley and at Crowsnest Pass are also correlative with the upper parts of the "False

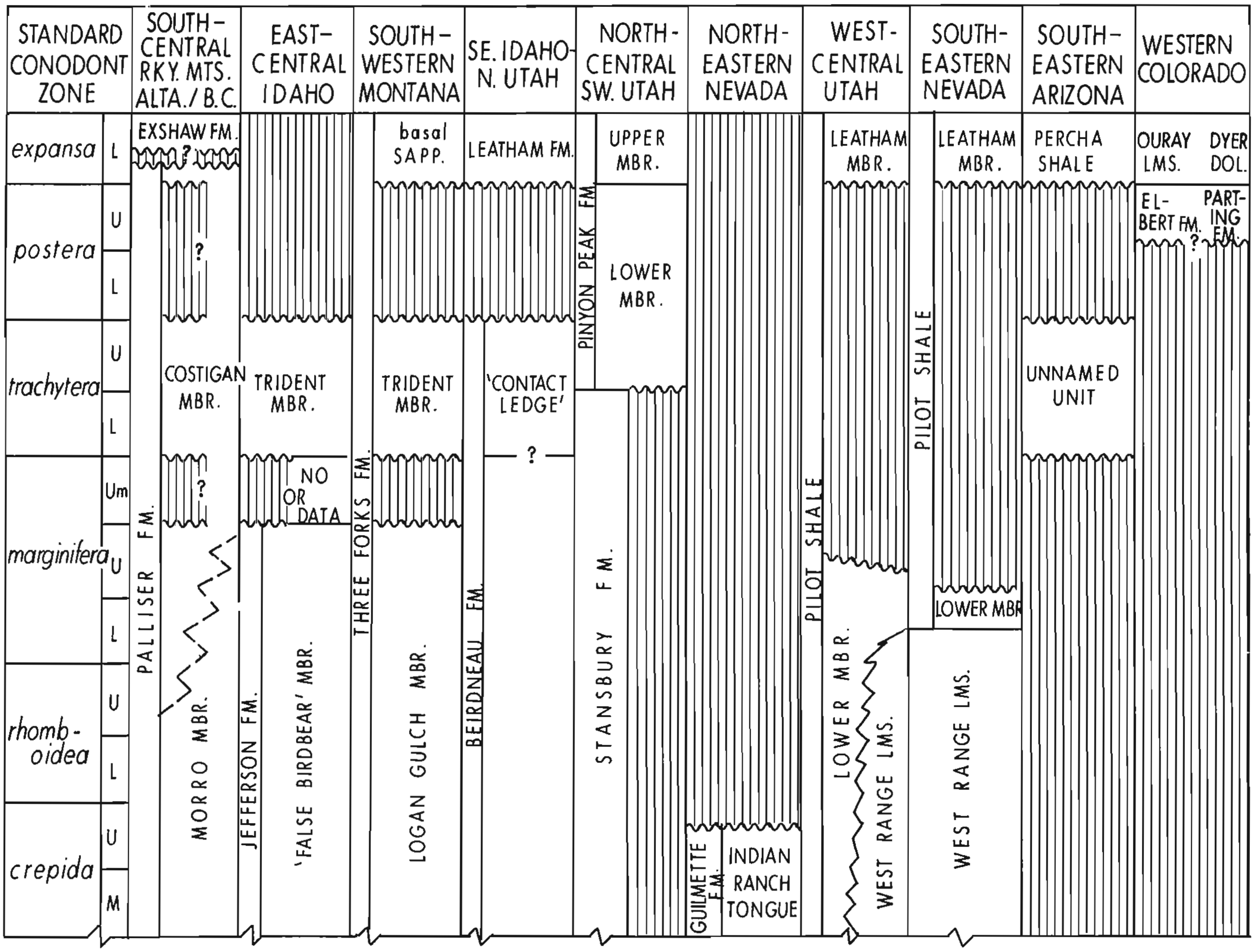


Figure 4. Chart showing correlation of Palliser Formation with other Famennian units in the western United States. Only the minimum age determined for the top of the Palliser Formation indicated in figure. Sources of data for stratigraphic units in western United States: Sandberg and Poole, 1977; Sandberg and Dreesen, 1984; Sandberg et al., 1983, 1988.

Birdbear'' and Logan Gulch members and with the upper part of the lower member of the Pilot Shale, and the West Range Limestone in the western United States (Fig. 4).

Units such as the Trident Member, the ''Contact Ledge'', and the Lower Member of the Pinyon Peak Limestone may be correlative with Costigan beds that lie between strata tentatively dated as no younger than the Uppermost *marginifera* Zone and strata that are dated as Lower *expansa* Zone in the Bow Valley and at Medicine Lake, Mount Greenock, and Nigel Peak (Fig. 3). It has been suggested by Sandberg and Poole (1977) and Sandberg et al. (1988, Fig. 16) that the entire Costigan Member is equivalent to these units in the western United States, which are interpreted as having been deposited during the Lower to Upper *trachytera* zones (Fig. 4). Conodonts such as the ''advanced'' morphotype of *Palmatolepis glabra distorta*, *P. glabra lepta*, *P. marginifera marginifera*, and *Pelekysgnathus inclinatus* occur in the Trident Member in Idaho and the ''Contact Ledge'' in Utah. Elements of this fauna, including the morphotype of *P. g. distorta*, have been found in Costigan beds at some localities (e.g., Cold Sulphur Springs – see above; Cadomin and Nordegg – see Appendix) and in the upper part of the Morro Member at Banff Golf Course and Nigel Peak. However, as discussed above, the authors do not consider the occurrence of the ''advanced'' morphotype of *P. g. distorta* to indicate the definite presence of the *trachytera* Zone in the Palliser Formation, because it has been shown to occur as low as the Lower *marginifera* Zone in the Nigel Peak section.

Although the uppermost part of the Costigan Member is shown as being the same age as the black shale of the basal Sappington Member, the Leatham Formation and Leatham Member, it is possible that the uppermost Costigan Member is slightly older than these units, as depicted with respect to the Exshaw Formation in the first column of Figure 4. In the event that the Palliser Formation is no younger than the Uppermost *marginifera* Zone, the stratigraphic units in the western United States that postdate this zone would not be represented in the Palliser Formation.

CONCLUSIONS

Some of the major conclusions of this paper can be summarized as follows:

1. The Middle *crepida* through Upper *marginifera* zones of the standard Upper Devonian conodont zonation are recognized in the Morro Member. The upper part of the Upper *rhomboidea* Zone through the Upper *marginifera* Zone and tentatively the Lower *expansa* Zone are recognized in the overlying Costigan Member.
2. The contact between the Costigan and Morro members is conformable and diachronous. The maximum age of this contact is the upper part of the Upper *rhomboidea* Zone, and the minimum age recognized so far is the Upper *marginifera* Zone.
3. Whereas the age of the base of the Palliser Formation appears to be virtually the same throughout the outcrop area of this formation, the age of the top of the Palliser Formation differs from area to area. The top of this formation is possibly as young as the Lower *expansa* Zone in some sections while in others it is no younger than the Upper *marginifera* Zone.

ACKNOWLEDGMENTS

The first author wishes to acknowledge H.H.J. Geldsetzer and N.C. Meijer Drees of the Institute of Sedimentary and Petroleum Geology, Calgary (I.S.P.G.), for many valuable discussions on Palliser stratigraphy and for providing much assistance and advice during this project; they also made available some unpublished conodont data identified by A.C. Higgins. The first author also wishes to thank J. Dougherty of I.S.P.G. who arranged for the processing of some of the conodont samples. The assistance of J. Adrain, D. Burr, M. Caldwell, A.V. Csaky, Z. Hadnagy, and P. Tuffnell in the field is gratefully acknowledged. Comments from H.H.J. Geldsetzer, S. Irwin, M. Orchard, and T.T. Uyeno concerning the manuscript are also appreciated.

Both authors wish to thank G. Braybrook for his assistance during SEM photography of conodonts, and F. Dimitrov, who drafted the figures. The Canadian Parks Service, Western Region, is also thanked for allowing the authors to collect conodont samples in Banff and Jasper National parks. Finally, the authors also wish to acknowledge the financial assistance provided by the Department of Energy, Mines and Resources through their Research Agreements Program and the Natural Sciences and Engineering Research Council.

REFERENCES

Andrichuk, J.M.
1960: Facies analysis of Upper Devonian Wabamun Group in west-central Alberta, Canada. American Association of Petroleum Geologists, Bulletin, v. 44, p. 1651-1681.

Beach, H.H.
1943: Moose Mountain and Morley map-areas, Alberta. Geological Survey of Canada, Memoir 236, 74 p.

Beales, F.W.
1953: Dolomitic mottling in Palliser (Devonian) limestone, Banff and Jasper National Parks, Alberta. American Association of Petroleum Geologists, Bulletin, v. 37, p. 2281-2293.
1956: Conditions of deposition of Palliser (Devonian) limestone of southwestern Alberta. American Association of Petroleum Geologists, Bulletin, v. 40, p. 848-870.

Belyea, H.R. and McLaren, D.J.
1962: Upper Devonian formations, southern part of Northwest Territories, northeastern British Columbia and northwestern Alberta. Geological Survey of Canada, Paper 61-29, 74 p.
1964: Devonian correlations near Sunwapta Pass, Banff National Park, Alberta. Bulletin of Canadian Petroleum Geology, v. 12, p. 779-807.

Clark, D.L. and Ethington, R.L.
1965: Conodont biostratigraphy of part of the Devonian of the Alberta Rocky Mountains. Bulletin of Canadian Petroleum Geology, v. 13, p. 382-388.

deWit, R. and McLaren, D.J.
1950: Devonian sections in the Rocky Mountains between Crowsnest Pass and Jasper, Alberta. Geological Survey of Canada, Paper 50-23, 66 p.

Dreesen, R. and Dusar, M.
1974: Refinement of conodont-biozonation in the Famenne type area. *In* International Symposium on Belgian Micropaleontological Limits from Emsian to Viséan, J. Bouckaert and M. Streel (eds.); Belgian Geological Survey, Publication No. 13, 36 p.

Druce, E.C.
1976: Conodont biostratigraphy of the Upper Devonian reef complexes of the Canning Basin, Western Australia. Bureau of Mineral Resources, Bulletin 158, v. 1, 303 p., v. 2, 97 pls.

Dusar, M. and Dreesen, R.
1984: Stratigraphy of the Upper Frasnian and Famennian deposits in the region of Hamoir-sur-Ourthe. Belgian Geological Survey, Professional Paper 1984/5, No. 209, 56 p.

Eliuk, L.S.
1984: A hypothesis for the origin of hydrogen sulphide in Devonian Crossfield Member dolomite, Wabamun Formation, Alberta, Canada. *In* Carbonates in Subsurface and Outcrop, L.S. Eliuk (ed.); 1984 Canadian Society of Petroleum Geologists Core Conference Manual, Canadian Society of Petroleum Geologists, p. 245-289.

Geldsetzer, H.H.J.
1982: Depositional history of the Devonian succession in the Rocky Mountains southwest of the Peace River Arch. *In* Current Research, Part C, Geological Survey of Canada, Paper 82-1C, p. 55-64.

Geldsetzer, H., de Mille, G., Sangster, D.F., Chung, C.F., McDonald, J.A., and Jonasson, I.R.
1986: The Upper Devonian Palliser Formation, Rocky Mountains, B.C. and Alberta: geochemistry and general geology. Geological Survey of Canada, Open File 1021, 51 p.

Gordey, S.P.
1988: Devono-Mississippian clastic sedimentation and tectonism in the Canadian Cordilleran miogeocline. *In* Devonian of the World, Volume II: Sedimentation, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, p. 1-14.

House, M.R. and Pedder, A.E.H.
1963: Devonian goniatites and stratigraphic correlation in western Canada. Palaeontology, v. 6, p. 491-539.

Irwin, S.E.B. and Orchard, M.J.
1989: Conodont biostratigraphy and constraints on Upper Devonian mineral deposits in the Earn Group, northern British Columbia and Yukon. *In* Current Research, Part E, Geological Survey of Canada, Paper 89-1E, p. 13-19.
1991: Upper Devonian-Lower Carboniferous conodont biostratigraphy of the Earn Group and overlying units, northern Canadian Cordillera. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

Klapper, G. and Ziegler, W.
1979: Devonian conodont biostratigraphy. *In* The Devonian System, M.R. House, C.T. Scrutton, and M.G. Bassett (eds.); Special Papers in Paleontology, No. 23, p. 199-224.

Lethiers, F.
1981: Ostracodes de Dévonian terminal de l'ouest du Canada. Systématic biostratigraphie et paléoécologie. Géobios, Mémoire Spécial, No. 5, 236 p.

Mackenzie, W.S.
1969: Stratigraphy of the Devonian Southesk Cairn carbonate complex and associated strata, eastern Jasper National Park, Alberta. Geological Survey of Canada, Bulletin 184, 77 p.

Macqueen, R.W. and Sandberg, C.A.
1970: Stratigraphy, age, and international correlation of the Exshaw Formation, Alberta Rocky Mountains. Bulletin of Canadian Petroleum Geology, v. 18, p. 32-66.

McLaren, D.J.
1954: Upper Devonian rhynchonellid zones in the Canadian Rocky Mountains. *In* Western Canadian Sedimentary Basin – a Symposium, Ralph Leslie Rutherford Volume, D.M. Clark (ed.); American Association of Petroleum Geologists, p. 159-181.
1955: Devonian formations in the Alberta Rocky Mountains between Bow and thabasca rivers. Geological Survey of Canada, Bulletin 35, 59 p.

McLaren, D.J. and Mountjoy, E.W.
1962: Alexo equivalents in the Jasper region, Alberta. Geological Survey of Canada, Paper 62-23, 36 p.

Metzger, R.A.
1989: Upper Devonian (Frasnian–Famennian) conodont biostratigraphy in the subsurface of north-central Iowa and southeastern Nebraska. Journal of Paleontology, v. 63, p. 503-524.

Morrow, D.W. and Geldsetzer, H.H.J.
1988: Devonian of the eastern Canadian Cordillera. *In* Devonian of the World, Volume I: Regional Synthesis, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, p. 85-121.

Mound, M.C.
1968: Upper Devonian conodonts from southern Alberta. Journal of Paleontology, v. 42, p. 444-521.

Mountjoy, E.W.
1978: Upper Devonian reef trends and configurations of the western portion of the Alberta basin. *In* The Fairholme Carbonate Complex at Hummingbird and Cripple Creek, P.C. Jackson (ed.); Guidebook, Canadian Society of Petroleum Geologists, p. 1-30.

Nicoll, R.S.
1980: The multi-element genus *Apatognathus* from the Late Devonian of the Canning Basin, Western Australia. Alcheringa, v. 4, p. 133-152.

Orchard, M.J.
1988: Conodonts from the Frasnian–Famennian boundary interval in western Canada. *In* Devonian of the World, Volume III: Paleontology, Paleoecology and Biostratigraphy, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, p. 35-52.

Price, R.A.
1964: The Devonian Fairholme–Sassenach succession and the evolution of reef front geometry in the Flathead-Crowsnest Pass area, Alberta and British Columbia. Bulletin of Canadian Petroleum Geology, v. 12, p. 427-451.

Raasch, G.O.
1989: Famennian faunal zones in western Canada. *In* Devonian of the World, Volume III: Paleontology, Paleoecology and Biostratigraphy, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, p. 619-631.

Richards, B.C. and Higgins, A.C.
1988: Devonian–Carboniferous boundary beds of the Palliser and Exshaw formations at Jura Creek, Rocky Mountains, southwestern Alberta. *In* Devonian of the World, Volume II: Sedimentation, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, p. 399-412.

Sandberg, C.A.
1979: Devonian and Mississippian conodont zonation of the Great Basin and Rocky Mountains. *In* Conodont Biostratigraphy of the Great Basin and Rocky Mountains, C.A. Sandberg and D.L. Clark (eds.); Brigham Young University Geological Studies, v. 26, p. 87-106.

Sandberg, C.A. and Dreesen, R.
1984: Late Devonian icriodontid biofacies models and alternate shallow-water conodont zonation. *In* Conodont Biofacies and Provincialism, D.L. Clark (ed.); Geological Society of America, Special Paper 196, p. 143-178.

Sandberg, C.A. and Poole, F.G.
1977: Conodont biostratigraphy and depositional complexes of Upper Devonian cratonic-platform and continental-shelf rocks in the western United States. *In* Western North America: Devonian, M.A. Murphy, W.B.N. Berry, and C.A. Sandberg (eds.); University of California, Riverside Campus, Museum Contributions 4, p. 144-182.

Sandberg, C.A. and Ziegler, W.
1973: Refinement of standard Upper Devonian conodont zonation based on sections in Nevada and West Germany. Geologica et Palaeontologica, v. 7, p. 97-122.

Sandberg, C.A., Gutschick, R.C., Johnson, J.G., Poole, F.G., and Sando, W.J.
1983: Devonian to Late Mississippian geologic history of the overthrust belt region, western United States. *In* Geologic Studies of the Cordilleran Thrust Belt, R.B. Powers (ed.); Rocky Mountain Association of Geologists, v. 2, p. 691-719.

Sandberg, C.A., Poole, F.G., and Johnson, J.G.
1988: Upper Devonian of western United States. *In* Devonian of the World, Volume I: Regional Synthesis, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, p. 183-220.

Sartenaer, P.
1969: Devonian (Famennian) rhynchonellid brachiopods from western Canada; Geological Survey of Canada, Bulletin 169, 269 p.

Stoakes, F.A.
1987: Fault-controlled dolomitization of the Wabamun Group, Tangent Field, Peace River Arch, Alberta. *In* Devonian Lithofacies and Reservoir Styles in Alberta, F.F. Krause and O.G. Burrowes (eds.); Guidebook, 13th Canadian Society of Petroleum Geologists Core Conference and Display, Calgary, p. 73-85.

Taylor, P.W.
1958: Further data on Devonian correlations. Journal of the Alberta Society of Petroleum Geologists, v. 6, p. 13-19.

Warren, P.S.
1927: Banff area, Alberta. Geological Survey of Canada, Memoir 153, 94 p.

Wonfor, J.S. and Andrichuk, J.M.
1956: The Wabamun Group in the Stettler area, Alberta. Journal of the Alberta Society of Petroleum Geologists, v. 4, p. 99-111.

Ziegler, W.
1962: Taxionomie und Phylogenie Oberdevonischer Conodonten und ihre stratigraphische Bedeutung. Abhandlungen des Hessischen Landesamtes für Bodenforschung, v. 38, 168 p.

1971: Conodont stratigraphy of the European Devonian. *In* Symposium on Conodont Biostratigraphy, W.C. Sweet and S.M. Bergström (eds.); Geological Society of America, Memoir 127, p. 227-284.

Ziegler, W. and Huddle, J.W.
1969: Die *Palmatolepis glabra*-Gruppe (Conodonta) nach der Revision der Typen von Ulrich und Bassler durch J.W. Huddle. Fortschritte in der Geologie von Rheinland und Westfalen, v. 16, p. 377-386.

Ziegler, W. and Sandberg, C.A.
1984: *Palmatolepis*-based revision of upper part of standard Late Devonian conodont zonation. *In* Conodont Biofacies and Provincialism, D.L. Clark (ed.); Geological Society of America, Special Paper 196, p. 179-194.

Ziegler, W., Sandberg, C.A., and Austin, R.L.
1974: Revision of *Bispathodus* group (Conodonta) in the Upper Devonian and Lower Carboniferous. Geologica et Palaeontologica, v. 8, p. 97-112.

APPENDIX

Measured sections

Baymag – 82 O/3, Canmore (east half), 1:50 000 map sheet, latitude 51°03′45″N, longitude 115°10′43″W. Section located along bend of old Highway 1A, adjacent to Baymag Cement quarry, approximately 1 km west of Exshaw, Alberta. Upper 42.7 m of Palliser Formation measured and sampled by N.C. Meijer Drees and F. DeReuver in 1989, and again in 1990 by N.C. Meijer Drees and D. Johnston. Measured segment includes 42.2 m of Costigan Member and upper 0.5 m of Morro Member.

Cadomin – 83 F, Edson, 1:250 000 map sheet, latitude 53°00′00″N, longitude 117°21′00″W. Section located on Forestry Trunk Road on west side of McLeod River Valley opposite cement quarry. Upper 4 m of Palliser Formation measured and sampled by B.D.E. Chatterton in 1973. Measured segment corresponds to Costigan Member.

Devil's Gap – 82 O/6, Lake Minnewanka, 1:50 000 map sheet, latitude 51°16′00″N, longitude 115°16′00″W. Section located on ridge just northeast of narrows at east end of Lake Minnewanka. Upper 43 m of Palliser Formation measured and sampled by D. Johnston and N.C. Meijer Drees in 1989 and 1990. Measured segment includes 40 m of Costigan Member and upper 3 m of Morro Member.

Jura Creek – 82 O/3, Canmore (east half), 1:50 000 map sheet, two sections. Section 1: latitude 51°04′18″–47″N, longitude 115°08′37″–115°D09′04″W. Section located in canyon cut by Jura Creek at entrance of creek and immediately north of canyon along west side of creek, approximately 2 km northeast of Exshaw, Alberta. Upper 107 m of Palliser Formation measured and sampled by N.C. Meijer Drees, M. Bergeron, and D. Johnston in 1988 and 1989. Measured segment includes 35 m of Costigan Member and upper 72 m of Morro Member. Section 2: latitude 51°05′21″–41″N, longitude 115°08′43″–115°D09′27″W. Section located on north flank of Loder Peak and in gully immediately below, northeast of the type section of the Exshaw Formation and approximately 4 km northeast of Exshaw, Alberta. Entire thickness of Palliser Formation (approximately 300 m) measured by N.C. Meijer Drees, M. Bergeron, and D. Johnston in 1987 and 1988. Measured segment includes 37 m (mostly covered) of Costigan Member, and 263 m of Morro Member.

Meosin Mountain – 93 I, Monkman Pass, 1:250 000 map sheet, latitude 54°17′30″N, longitude 120°20′30″W. Section located on northeast face of Meosin Mountain, northeastern British Columbia. Upper 60 m of Palliser Formation measured and sampled by B.D.E. Chatterton and others in 1973. Costigan and Morro members not differentiated.

Mount Luscar – 83 F, Edson, 1:250 000 map sheet, latitude 53°01′30″N, longitude 117°25′45″W. Section located on peak of Luscar Mountain approximately 7 km west of Cadomin, Alberta. Entire thickness of Palliser Formation (195 m) measured and sampled by D.G. Perry and F.K. Wallace in 1974. Costigan and Morro members not differentiated.

Nordegg – 83 C, Brazeau, 1:250 000 map sheet, latitude 52°29′45″N, longitude 116°00′05″W. Section located immediately below and just west of former railway bridge, approximately 5.5 km northeast of Nordegg, Alberta. Upper 42 m of Palliser Formation measured and sampled by B.D.E. Chatterton in 1973 and D. Johnston and N.C. Meijer Drees in 1987. Measured segment corresponds to Costigan Member.

Sunset Peak – 83 E, Mount Robson, 1:250 000 map sheet, latitude 53°31′50″N, longitude 118°56′00″W. Section located on northwest side of creek valley approximately 2.5 km north of Sunset Peak, Wilmore Wilderness Park, Alberta. Upper 6.2 m of Palliser Formation measured by R. Ludvigsen and others in 1974. Costigan and Morro members not differentiated.

PLATE 1

All specimens figured in this plate and in plates 2 and 3 are housed in the National Type Collection of Invertebrate and Plant Fossils at the Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8. All are upper views of Pa elements, and all are hypotypes, unless stated otherwise.

Figures 1, 3. *Palmatolepis glabra distorta* Branson and Mehl.

1. GSC 100257, x30, from Cadomin, Costigan Member, 3.7 m below top of Palliser Formation, "advanced" morphotype of Sandberg and Poole (1977).
3. GSC 100259, x54, from Nordegg, Costigan Member, 12 m below top of Palliser, typical morphotype of subspecies.

Figure 2. *Palmatolepis glabra lepta* Ziegler and Huddle.

GSC 100258, x65, from Meosin Mountain, approximately 52 m below top of Palliser Formation.

Figure 4. *Palmatolepis glabra prima* Ziegler and Huddle.

GSC 100260, x62, from Medicine Lake (ML2 section), Morro Member, 96 m above base of Palliser Formation.

Figure 5. *Palmatolepis glabra pectinata* Ziegler.

GSC 100261, x60, from Mount Greenock, Morro Member, 128 m above base of Palliser Formation.

Figures 6-8. *Palmatolepis minuta minuta* Branson and Mehl.

6. GSC 100262, x82, from Banff Golf Course, Morro Member, approximately 270 m above base of exposed Palliser Formation.
7. GSC 100263, x92, from Medicine Lake (ML2 section), Morro Member, 96 m above base of Palliser Formation.
8. GSC 100264, x40, lobate morphotype of subspecies, same locality as figure 7, Morro Member, 87 m above base of Palliser Formation.

Figure 9. *Palmatolepis glabra prima* Ziegler and Huddle Morphotype 1 of Sandberg and Ziegler, 1973.

GSC 100265, x63, from Crowsnest Pass, Morro Member, 91.4 m above base of Palliser Formation.

Figure 10. *Palmatolepis klapperi* Sandberg and Ziegler.

GSC 100266, x48, from Nigel Peak, Morro Member, 106.4 m above base of Palliser Formation.

Figure 11. *Palmatolepis glabra prima* Ziegler and Huddle Morphotype 2 of Sandberg and Ziegler, 1973.

GSC 100267, x46, from Nigel Peak, Morro Member, 106.4 m above base of Palliser Formation.

Figure 12. *Palmatolepis glabra pectinata* Ziegler Morphotype 1 of Sandberg and Ziegler, 1973.

GSC 100268, x56, from Medicine Lake, Morro Member, approximately 289 m above base of Palliser Formation.

Figure 13. *Palmatolepis delicatula protorhomboidea* Sandberg and Ziegler.

GSC 100269, x60, from Roche Miette, Morro Member, 27.4 m above base of Palliser Formation.

Figures 14-16. *Palmatolepis quadrantinodosalobata* Sannemann.

14. GSC 100270, x65, intermediate form of species, lower part of Upper *crepida* Zone, from Mount Greenock, Morro Member, 54 m above base of Palliser Formation.
15. GSC 100271, x65, late form of species, Upper *crepida* Zone, resembles Morphotype 1 (Sandberg and Ziegler, 1973) of species, but with anterior portion of outer platform terminating well short of end of free blade, from Medicine Lake (ML2 section), Morro Member, 104 m above base of Palliser Formation.
16. GSC 100272, x66, early form of species, Middle *crepida* Zone, same locality as figure 15, Morro Member, 75 m above base of Palliser Formation.

Figure 17. *Palmatolepis poolei* Sandberg and Ziegler.

GSC 100273, x60, from Nigel Peak, Morro Member, 147.2 m above base of Palliser Formation.

Figure 18. *Palmatolepis tenuipunctata* Sannemann.

GSC 100274, x60, from Nigel Peak, Morro Member, 106.4 m above base of Palliser Formation, lobate morphotype of species.

Figure 19. *Palmatolepis rhomboidea* Sannemann.

GSC 100275, x54, from Medicine Lake (ML2 section), Morro Member, approximately 175 m above base of Palliser Formation.

Figures 20, 24. *Palmatolepis subperlobata* Branson and Mehl.

20. GSC 100276, x60, from Nigel Peak, Morro Member, 106.4 m above base of Palliser Formation.
24. GSC 100280, x36, from Medicine Lake (ML2 section), 90 m above base of Palliser Formation, illustrations of two morphotypes of species, figure 20 is from the Lower *rhomboidea* Zone and figure 24 is from the Upper *crepida* Zone.

Figure 21. *Palmatolepis triangularis* Sannemann.

GSC 100277, x41, from Medicine Lake (ML2 section), Morro Member, 62.5 m above base of Palliser Formation.

Figure 22. *Palmatolepis wolskajae* Ovnatanova.

GSC 100278, x37, from Medicine Lake (ML2 section), Morro Member, 75 m above base of Palliser Formation.

Figure 23. *Palmatolepis circularis* Szulczewski.

GSC 100279, x57, from Medicine Lake (ML2 section), Morro Member, 75 m above base of Palliser Formation.

PLATE 1


1


2


3


4


5


6


7


8


9


10


11


12


13


14


15


16


17


18


19


20


21


22


23


24

PLATE 2

All are upper views of Pa elements and hypotypes unless stated otherwise.

Figures 1, 2. *Bispathodus stabilis* (Branson and Mehl) Morphotype 1 of Ziegler et al., 1974.

1. Lateral view, GSC 100281, x57, from Nigel Peak, Morro Member, 491 m above base of Palliser Formation.
2. GSC 100282, x62, same locality as figure 1, Costigan Member, 551 m above base of Palliser Formation.

Figures 3, 4. *Bispathodus stabilis* (Branson and Mehl) Morphotype 2 of Ziegler, Sandberg and Austin, 1974.

3. GSC 100283, x58, from Nigel Peak, Costigan Member, 541 m above base of Palliser Formation.
4. Lateral view, GSC 100284, x58, from Medicine Lake, Costigan Member, top of Palliser Formation.

Figure 5. *Mehlina gradata* Youngquist.

GSC 100285, x58, from Mount Greenock, Morro Member, base of Palliser Formation.

Figure 6. *Apatognathus varians varians* Branson and Mehl.

Upper view, Sa element, GSC 100286, x83, from Nigel Peak, Costigan Member, 541 m above base of Palliser Formation.

Figure 7. *Apatognathus varians klapperi* Druce.

Upper view, Sa element, GSC 100287, x66, from Nigel Peak, Morro Member, 165 m above base of Palliser Formation.

Figure 8. *Polygnathus semicostatus* Branson and Mehl.

Oblique upper view, GSC 100288, x48, from Medicine Lake, Morro Member, 162 m above base of Palliser Formation.

Figures 9, 10. *Polygnathus webbi* Stauffer.

9. GSC 100289, x60, from Crowsnest Pass, Costigan Member, top of Palliser Formation.
10. Oblique upper view, GSC 100290, x58, from Mount Greenock, Morro Member, base of Palliser Formation.

Figure 11, 12. *Polygnathus communis communis* Branson and Mehl.

11. Lower view, GSC 100291, x95.
12. GSC 100292, x79, both specimens from Medicine Lake (ML2 section), Morro Member, 177 m above base of Palliser Formation.

Figure 13. *Polygnathus glaber glaber* Ulrich and Bassler.

Oblique upper view, GSC 100293, x55, from Mount Greenock, Morro Member, 6.1 m above base of Palliser Formation.

Figure 14. *Polygnathus pennatulus* Ulrich and Bassler.

GSC 100294, x42, from Mount Greenock, Morro Member, 151.5 m above base of Palliser Formation.

Figure 15. *Polygnathus perplexus* Thomas.

GSC 100295, x52, from Cadomin, Costigan Member, 3.7 m below top of Palliser Formation.

Figure 16. *Polygnathus nodocostatus* Branson and Mehl.

Oblique upper view, GSC 100296 (specimen lost), x56, from Nigel Peak, Morro Member, 45 m above base of Palliser Formation.

Figure 17. *Polylophodonta pergyrata* (Holmes).

GSC 100297, x30, from Mount Luscar, 193 m above base of Palliser Formation.

Figure 18. *Polylophodonta* sp. cf. *P. linguiformis* Branson and Mehl *sensu* Sandberg and Ziegler, 1973.

Figured specimen GSC 100298, x30, from Crowsnest Pass, Morro Member, 91 m above base of Palliser Formation.

Figure 19. *Palmatolepis quadrantinodosa quadrantinodosa* Branson and Mehl.

GSC 100299, x53, from Sunset Peak, top of Palliser Formation.

Figure 20. *Polylophodonta confluens* (Ulrich and Bassler).

GSC 100300, x30, from Medicine Lake (ML2 section), Morro Member, 87 m above base of Palliser Formation.

Figures 21, 25. *Palmatolepis marginifera marginifera* Helms.

21. GSC 100301, x53, from Roche Miette, Morro Member, 161.6 m above base of Palliser Formation.
25. GSC 100305, x56, from Cadomin, Costigan Member, 3.7 m below top of Palliser Formation.

Figure 22. *Palmatolepis stoppeli* Sandberg and Ziegler.

GSC 100302, x45, from Cold Sulphur Springs, Morro Member, 73.7 m above base of Palliser Formation.

Figure 23. *Palmatolepis quadrantinodosa inflexa* Müller.

GSC 100303, x60, from Mount Greenock, Morro Member, 151.5 m above base of Palliser Formation.

Figure 24. *Palmatolepis quadrantinodosa inflexoidea* Ziegler.

GSC 100304, x48, from Crowsnest Pass, Costigan Member, 381 m above base of Palliser Formation.

Figure 26. *Palmatolepis marginifera duplicata* Sandberg and Ziegler.

GSC 100306, x57, from Nigel Peak, Morro Member, 355.3 m above base of Palliser Formation.


1


2


3


4


5


6


7


8


9


10


11


12


13

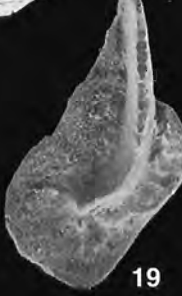

14


15


16


17


18


19


20


21


22


23


24


25


26

PLATE 3

All specimens are hypotypes.

Figures 1-4. "*Icriodus*" *chojnicensis* Matyja Morphotype 2 of Sandberg and Dreesen, 1984.

1. Lateral view, GSC 100307, x85.
2. Upper view of same specimen, x76, from Nigel Peak, Costigan Member, top of Palliser Formation?
3. Oblique upper view, GSC 100308, approx. x70.
4. Lateral view of same specimen, x74, same locality as figures 1 and 2, Costigan Member, 567.2 m above base of Palliser Formation.

Figures 5, 6. "*Icriodus*" *chojnicensis* Matyja Morphotype 1 of Sandberg and Dreesen, 1984.

5. Upper view, GSC 100309, x84.
6. Lateral view, GSC 100310, x75, both specimens from Nigel Peak, Morro Member, 165.2 m above base of Palliser Formation.

Figures 7, 8. "*Icriodus*" *cornutus* Sannemann.

7. Upper view, GSC 100311, x67.
8. Lateral view of same specimen, x84, from Medicine Lake (ML2 section), Morro Member, 110 m above base of Palliser Formation.

Figures 9, 10. "*Icriodus*" *costatus costatus* (Thomas) Morphotype 1 of Sandberg and Dreesen, 1984.

9. Upper view, GSC 100312, x58, from Nigel Peak, Costigan Member, 567.2 m above base of Palliser Formation.
10. Lateral view, GSC 100313, x56, from same locality as figure 9, Costigan Member, 501 m above base of Palliser Formation.

Figure 11. *Pelekysgnathus planus* Sannemann.

Lateral view, GSC 100314, x74, from Mount Greenock, Morro Member, 39.6 m above base of Palliser Formation.

Figures 12-14. *Pelekysgnathus inclinatus* Thomas.

12. Lateral view, GSC 100315, x53, from Nigel Peak, Morro Member, 10.8 m above base of Palliser Formation.
13. Lateral view, GSC 100316, x80, same locality as figure 12, Morro Member, 371 m above base of Palliser Formation.
14. Lateral view, GSC 100317, x80, same locality as figure 12, Morro Member, 491 m above base of Palliser Formation.

Figures 15, 16. *Icriodus iowaensis ancylus* Sandberg and Dreesen.

15. Upper view, GSC 100318, x53.
16. Lateral view of same specimen, x60, from Cold Sulphur Springs, Morro Member, 25.3 m above base of Palliser Formation, abraded specimen of narrow morphotype of subspecies.

Figures 17, 18. "*Icriodus*" *raymondi* Sandberg and Ziegler.

17. Lateral view, GSC 100319, x60.
18. Upper view, GSC 100320, x56, from Medicine Lake, Costigan Member, top of Palliser Formation.

Figures 19, 20. *Icriodus alternatus alternatus* Branson and Mehl.

19. Upper view, GSC 100321, x56.
20. Lateral view of same specimen, x63, from Roche Miette, Morro Member, 42.7 m above base of Palliser Formation.

Figures 21-24. *Icriodus iowaensis iowaensis* Youngquist and Peterson.

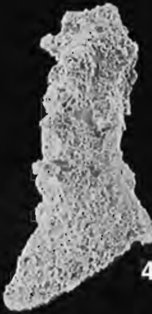
21. Upper view, GSC 100322, x56.
22. Lateral view of same specimen, x64, from Medicine Lake (ML3 section), Morro Member, 41.2 m above base of Palliser Formation, specimen represents typical broad morphotype of subspecies.
23. Oblique upper view, GSC 100323, x55.
24. Lateral view of same specimen, x65, from Cold Sulphur Springs, Morro Member, 70 m above base of Palliser

PLATE 3


1


2


3


4


5


6


7

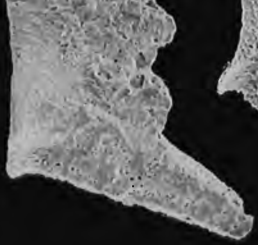

8

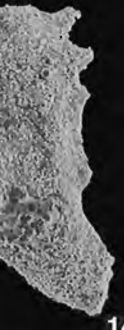

9


10


11


12


13


14


15

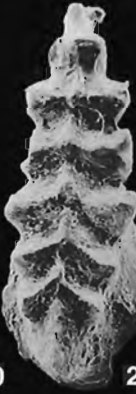

16

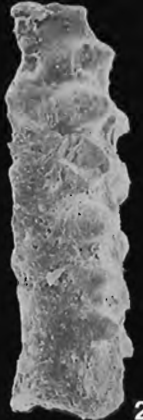

17


18


19


20


21


22


23


24

Upper Devonian – Lower Carboniferous conodont biostratigraphy of the Earn Group and overlying units, northern Canadian Cordillera

S.E.B. Irwin[1] and M.J. Orchard[2]

Irwin, S.E.B., and Orchard, M.J., 1991: Upper Devonian – Lower Carboniferous conodont biostratigraphy of the Earn Group and overlying units, northern Canadian Cordillera. In Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417, p. 185-213.

Abstract

Conodont data provide a biochronological framework for the Upper Devonian – Lower Carboniferous Earn Group and supradjacent strata in northern British Columbia, Yukon, and Northwest Territories. They are used to determine that several sedimentary exhalative deposits are Middle Devonian, middle Frasnian, middle Famennian, and Tournaisian in age, and that a significant unconformity exists at Midway in northern British Columbia, where the middle Famennian Earn Group directly overlies the mostly Givetian McDame Group. Conodont biofacies indicate a relatively deep water setting for the Earn Group.

Conodonts range in age from Middle Devonian through Early Carboniferous but most are Late Devonian in age. Associations indicative of the Frasnian Upper hassi, *Lower* rhenana, *Middle and Uppermost* crepida, *Lower* rhomboidea, *and Lower and Upper* marginifera *zones are recognized. Key zonal conodont species are found in the Earn Group but the zones are not delineated because the species range upward through several zones, and data from sections are minimal. These key species are:* Klapperina disparilis, Mesotaxis falsiovalis, M. asymmetrica, Palmatolepis transitans, P. punctata, P. hassi, P. rhenana rhenana *(all Frasnian)*, P. triangularis, P. minuta minuta, P. crepida, P. glabra pectinata, P. rugosa trachytera, P. perlobata postera *(Famennian)*, Siphonodella duplicata, *and* S. crenulata *(Lower Carboniferous). None of the Upper Devonian faunas ranges within the* linguiformis *through Middle* triangularis *zones (includes Frasnian–Famennian boundary), or the Upper* expansa *through* praesulcata *zones (beneath the Devonian–Carboniferous boundary). The Earn Group conodont fauna data suggest extended age ranges for* P. subrecta, P. quadrantinodosa inflexa, P. q. inflexoidea, *and* P. rugosa trachytera. *Frasnian* Palmatolepis redana *n. sp. and Fammenian* P. quadrantinodosa quincea *n. subsp. are described.*

Résumé

Les données sur les conodontes fournissent un cadre biochronologique pour le groupe d'Earn et les strates susjacentes du Dévonien et du Carbonifère inférieur dans le nord de la Colombie-Britannique et les Territoires du Nord-Ouest. Elles indiquent que plusieurs gisements sédimentaires exhalatifs remontent au Dévonien moyen, au Frasnien moyen, au Famennien moyen et au Tournaisien, et qu'il existe une discordance importante à Midway, dans le nord de la Colombie-Britannique, à l'endroit où le groupe d'Earn du Famennien moyen repose directement sur le groupe de McDame, qui remonte surtout au Givétien. Les biofaciès à conodontes indiquent que le groupe d'Earn s'est déposé en eau relativement profonde.

---

[1] Department of Geological Sciences, University of British Columbia, 6339 Stores Road, Vancouver, B.C. V6T 1Z4

[2] Geological Survey of Canada, 100 West Pender St., Vancouver, B.C. V6B 1R8

Les conodontes s'échelonnent du Dévonien moyen au Carbonifère précoce, mais la plupart d'entre eux remontent au Dévonien tardif. On y reconnaît des associations caractéristiques de la zone supérieure à hassi, *de la zone inférieure à* rhenana, *des zones moyenne et sommitale à* crepida, *de la zone inférieure à* rhomboidea *et des zones inférieure et supérieure à* marginifera, *qui remontent toutes au Frasnien. Des espèces clés de conodontes caractéristiques de zone se rencontrent dans le groupe d'Earn, mais les zones ne sont pas délimitées puisque les espèces se retrouvent vers le haut dans plusieurs zones et que les coupes n'ont fourni qu'un minimum de données. Ces espèces clés sont les suivantes :* Klapperina disparilis, Mesotaxis falsiovalis, M. asymmetrica, Palmatolepis transitans, P. punctata, P. hassi, P. rhenana rhenana *(toutes du Frasnien),* P. triangularis, P. minuta minuta, P. crepida, P. glabra pectinata, P. rugosa trachytera, P. perlobata postera *(Famennien),* Siphonodella duplicata *et* S. crenulata *(Carbonifère inférieur). Aucune des faunes du Dévonien supérieur ne se trouve dans l'intervalle de la zone à* linguiformis *et la zone moyenne à* triangularis *(qui comprend la limite du Frasnien-Famennien), ou de la zone supérieure à* expansa *où se situent les zones à* praesulcata *(sous la limite du Dévonien-Carbonifère). Les données sur les conodontes du groupe d'Earn portent à croire que* P. subrecta, P. quadrantinodosa inflexa, P. q. inflexoidea *et* P. rugosa trachytera *couvrent un intervalle d'âges étendu. Les conodontes* Palmatolepis redana *n. sp. (Frasnien) et* P. quadrantinodosa quincea *n. sp. (Famennien) sont décrits.*

INTRODUCTION

The Devonian and Lower Carboniferous marine clastic rocks of the Earn Group and supradjacent strata in Yukon, Northwest Territories, and northern British Columbia often contain abundant, diverse, and relatively well preserved conodont faunas. The Earn Group marks a significant change in the depositional pattern within the area of the lower to middle Paleozoic Selwyn and Kechika basins. However, due to chaotic sedimentation, considerable regional metamorphic overprint, and relative inaccessibility, little was known about the stratigraphy or the age of the strata, in spite of economically important stratiform mineral deposits that occur within and above the Earn Group. Recent conodont collections from the region provide the biochronological framework that helps our understanding of the depositional history of the Earn Group. Furthermore, conodonts provide tight age constraints for the deposition, frequency, and duration of the sedimentary exhalative sulphide deposits.

This study includes the first systematic account of Upper Devonian and Lower Carboniferous conodont biostratigraphy of the Earn Group. Taxonomic work has focused on the abundant Upper Devonian conodont genus *Palmatolepis*, although many other important Upper Devonian and Lower Carboniferous genera also occur. The existing international Upper Devonian "standard" offshore zonation scheme developed in Germany by Ziegler (1962), and subsequently modified by several authors (Ziegler, 1971; Sandberg and Ziegler, 1973; Ziegler et al., 1976; Ziegler and Klapper, 1982; Ziegler and Sandberg, 1984, 1990; Klapper, 1989; Klapper and Lane, 1989; and Sandberg et al., 1989) is generally applicable to the Earn Group conodonts. Additional revisions for the Middle Devonian proposed by Klapper and Johnson *in* Johnson (1990) are included. Lower Carboniferous zonation after Sandberg and Ziegler (1976), Sandberg et al. (1978), and Lane et al. (1980) was used in a preliminary way for upper- and post-Earn Group conodont taxa.

REGIONAL GEOLOGY

General geology

In northern British Columbia and the territories, from latest Proterozoic through Middle Devonian, deep water clastics, carbonate, and chert were deposited in the Selwyn and Kechika basins (Abbott, 1982). The basins were part of ancestral North America and the Cassiar Terrane, which is believed to be a displaced slice of the miogeocline (Monger and Berg, 1984). On the surrounding platform areas, shallow water carbonate and quartz arenite accumulated during the same time interval. This setting changed dramatically from the Upper Devonian through Lower Carboniferous, with the deposition of transgressive, northerly and westerly derived shale, siltstone, and chert sequences; dispersal of locally derived coarse sediment gravity flows was likely affected by contemporaneous block faulting (Gordey et al., 1987). Several episodes of stratiform barite-zinc-lead-silver mineralization arose from hydrothermal fluids rising upward along such structures and venting onto the sea floor.

Early biostratigraphic studies of the Devono-Carboniferous Earn Group showed that it was typified by a complex internal stratigraphy with unconformities and abrupt changes in thickness, lithology, and facies (Gordey et al., 1982). The rock assemblage is indicative of an active extensional regime arising from either continental rifting and separation, or strike-slip faulting (Abbott et al., 1986). The whole region was structurally deformed during several subsequent episodes of folding, strike-slip and thrust faulting, and minor igneous activity. The study focused on three areas of Earn Group sedimentation, which are discussed below.

Macmillan Pass

The Macmillan Pass region, in the Yukon and Northwest Territories, includes the area around Macmillan Pass and to the west and southeast of the pass (Fig. 1). Strata underlying the Earn Group include upper Proterozoic siliciclastics and Cambro-Ordovician phyllite and slate. Directly below the Earn Group is approximately 450 m of Ordovician through Middle Devonian chert, slate, shale, and silty limestone of the Road River Group. The unconformable Road River–Earn Group contact is diachronous.

In the Macmillan Pass area, the lower Earn Group (*sensu lato* Gordey et al., 1982) is the Portrait Lake formation (informal; Abbott and Turner, 1990), which includes a minimum 300–400 m of chert, chert pebble conglomerate, and siliceous shale, and spans the upper Lower through Upper Devonian. Southeast of Macmillan Pass in the Nahanni map area, Gordey (in press) recognizes the Prevost formation (informal) as an upper division of the Earn Group. This formation, which is not recognized at Macmillan Pass, consists of over 400 m of shale, chert pebble conglomerate, and sandstone.

The Tsichu formation (informal) directly overlies the Prevost formation in the Nahanni map area (Gordey, in press), and the Portrait Lake formation in the Macmillan Pass area (Abbott and Turner, 1990). The Tsichu formation consists of a minimum of 200–600 m of Lower Carboniferous shale, sandstone, and chert conglomerate, and correlates with the Kalzas Formation and Tay formation (informal) southwest of Macmillan Pass (Gordey, in press).

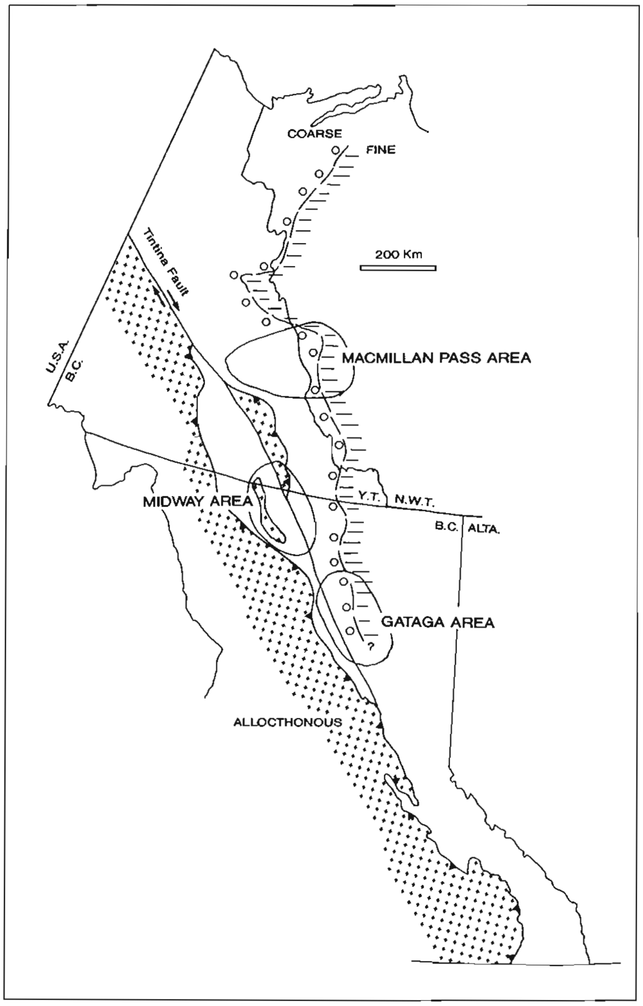


Figure 1. Location of study areas showing the western Canadian autochthonous margin, Tintina Fault, and the margin of Earn Group sedimentation. Modified from Gordey

Midway

Midway is located in northern British Columbia (Fig. 1), on a slice of the western edge of ancestral North America that was displaced at least 450 km northwest along the dextral Tintina fault system during the Middle Jurassic to Early Cenozoic (Gabrielse, 1985). Strata underlying the Earn Group include Lower Cambrian through Lower Devonian siliciclastics and carbonates, and the Middle Devonian McDame Group. The latter consists of approximately 400 m of shallow, marine dolostone and fossiliferous limestone, which contains abundant stromatoporoids, *Amphipora*, the tabulate corals *Syringopora* and *Thamnopora*, and local accumulations of cryptalgal laminates and stromatolites indicative of an intertidal to subtidal environment. The upper McDame Group has undergone significant dissolution; Nelson and Bradford (1987) report up to 200 m of relief at the McDame–Earn contact. This dissolution is related to karstic processes that both pre- and postdate Earn Group deposition; drill core material shows large cavities in the McDame Group infilled with brecciated Earn Group pelite.

At Midway the Earn Group consists of about 700 m of black slate, thin bedded calcareous siltstone, thin to thick bedded sandstone, and chert pebble conglomerate (Nelson and Bradford, 1987). The upper contact of the Earn Group is the complicated basal thrust system of the Sylvester Allochthon, a Devonian to Triassic assemblage that was thrust over the Earn Group during the Middle Jurassic to mid-Cretaceous (Nelson and Bradford, 1987).

Gataga

The Gataga area (Fig. 1) is bordered on the west by the Northern Rocky Mountain Trench dextral strike-slip fault system (Gabrielse, 1985), and on the east by upper Proterozoic age siliciclastics (Taylor and Stott, 1973; McClay et al., 1988). Ordovician to Lower Carboniferous, fine grained siliciclastic strata are underlain by autochthonous upper Proterozoic through Cambro-Ordovician platform to off-shelf siliciclastics and carbonates (McClay and Insley, 1986). All strata in the Gataga area are intensely folded and thrust faulted.

The Road River Group has two subdivisions: a lower graptolitic black shale, chert, and minor limestone, and an upper, resistant dolomitic siltstone and bioturbated siltstone with graptolites directly underlies the Earn Group. The lower Earn Group consists of a thin basal assemblage of thick bedded, chert pebble conglomerate and chert grit, thin bedded laminated siltstone, and silt-banded shale overlain by 400 m of black shale, cherty argillite, and chert. In the southern Gataga area, the lower part of the Earn Group is informally called the "Gunsteel formation" (Jefferson et al., 1983). McClay et al. (1988) reported that 70 m of crinoidal

		Conodont Zone		Defined by the first appearance of:
CARBONIFEROUS	TOURNAISIAN	anchoralis-latus		*Scaliognathus anchoralis*
		typicus		*Gnathodus typicus*
		crenulata	U	*Gnathodus delicatus*
			L	*Siphonodella crenulata*
		sandbergi		*Siphonodella sandbergi*
		duplicata	U	*Siphonodella cooperi*
			L	*Siphonodella duplicata*
		sulcata		*Siphonodella sulcata*
UPPER DEVONIAN	FAMENNIAN	praesulcata	U	*Protognathodus kockeli*
			M	
			L	*Siphonodella praesulcata*
		expansa	U	*Bispathodus ultimus*
			M	*Bispathodus aculeatus*
			L	*Palmatolepis gracilis expansa*
		postera	U	*Palmatolepis gracilis manca*
			L	*Palmatolepis perlobata postera*
		trachytera	U	*Pseudopolygnathus granulosus*
			L	*Palmatolepis rugosa trachytera*
		marginifera	Umt	*Scaphigathus velifer velifer*
			U	*Palmatolepis marginifera utahensis*
			L	*Palmatolepis marginifera marginifera*
		rhomboidea	U	
			L	*Palmatolepis rhomboidea*
		crepida	Umt	*Palmatolepis glabra pectinata*
			U	*Palmatolepis glabra prima*
			M	*Palmatolepis termini*
			L	*Palmatolepis crepida*
		triangularis	U	*Palmatolepis minuta minuta*
			M	*Palmatolepis delicatula platys*
			L	*Palmatolepis triangularis*
	FRASNIAN	linguiformis		*Palmatolepis linguiformis*
		rhenana	U	*Palmatolepis rhenana rhenana*
			L	*Palmatolepis rhenana nasuta*
		jamieae		*Palmatolepis jamieae*
		hassi	U	*Ancyrognathus triangularis*
			L	*Palmatolepis hassi*
		punctata		*Palmatolepis punctata*
		transitans		*Palmatolepis transitans*
		falsiovalis	U	*Mesotaxis asymmetrica*
			L	*Mesotaxis falsiovalis*
? M. DEVONIAN	? GIVETIAN	disparilis	U	*Polygnathus dengleri*
			L	*Klapperina disparilis*
		hermanni	U	*Polygnathus cristatus*
			L	*Schmidtognathus hermanni*

Figure 2. The revised "standard" offshore Upper Devonian conodont zonation. From Ziegler (1962, 1971, 1977); Sandberg and Ziegler (1976); Sandberg et al. (1978, 1989); Klapper and Ziegler (1979); Lane et al. (1980); Ziegler and Sandberg (1984, 1990); Sandberg et al. (1988); Klapper and Johnson, in Johnson (1990). Abbreviations: (Umt) Uppermost, (U) Upper, (M) Middle, and (L) Lower.

grainstone, sandstone, and siltstone with abundant shell debris of Early Carboniferous age were located in the westernmost thrust fault of the Gataga area. This unit was regarded by McClay et al. (1988) as equivalent to the upper Earn Group (*sensu lato* Gordey et al., 1982), and is the youngest strata preserved in the Gataga area.

BIOSTRATIGRAPHY

General remarks

In this report, we employ a form taxonomy in describing the platform conodonts of the Earn Group. This reflects the current state of knowledge, the basis of the standard zonation, and the fact that Earn Group conodont collections include few well preserved nonplatform elements. Recent revisions to Upper Devonian zonation by Ziegler and Sandberg (1990) have used conodonts entirely from the *Palmatolepis* biofacies. Other studies in France (Klapper, 1989) and Alberta (Klapper and Lane, 1989) have developed zonation schemes that employ conodonts that dominate other biofacies. Earn Group conodonts consist almost exclusively of the *Palmatolepis* biofacies, so we have adopted that standard for the Earn Group. Earn Group conodont data provide little sequential information, however, and are generally unsuited for testing zonal schemes.

The Lower Carboniferous, Tournaisian zonation is based largely on *Siphonodella*, a genus that occurs in many of our collections. In total, eight zones (Fig. 2) have been recognized in this interval elsewhere (Sandberg and Ziegler, 1976; Sandberg et al., 1978; Lane et al., 1980). We have not attempted to differentiate our faunas to the zonal level, however, but have included representative taxa to demonstrate the age range of the strata, and the potential for further work.

Results of preliminary conodont biostratigraphic studies within the Earn Group have been presented by Dawson and Orchard (1982), Gordey et al. (1982), Orchard and Irwin (1988), Orchard (1989), and Irwin and Orchard (1989). Prior to these studies, the complex stratigraphy of the Earn Group was very poorly understood, partly due to the lack of diagnostic macrofossils. Several hundred conodont collections of Middle Devonian through Tournaisian age are now known from carbonate lenses within the predominately clastic sediments. The conodonts provide important age constraints on lithofacies variation, intra-Earn Group discontinuities, and sedimentary exhalative mineral deposits. In addition, they provide data on the geographic and stratigraphic range of the existing, as well as some new, taxa.

In the following discussion, individual collections with unique GSC locality numbers are grouped into 56 informal faunas that represent individual, or groups of, conodont collections representative of a specific time interval (Fig. 3, Tables 1-5). Each fauna is designated by a prefix and number reflecting its geographic origin: Macmillan Pass (MP), Midway (M), or Gataga (G).

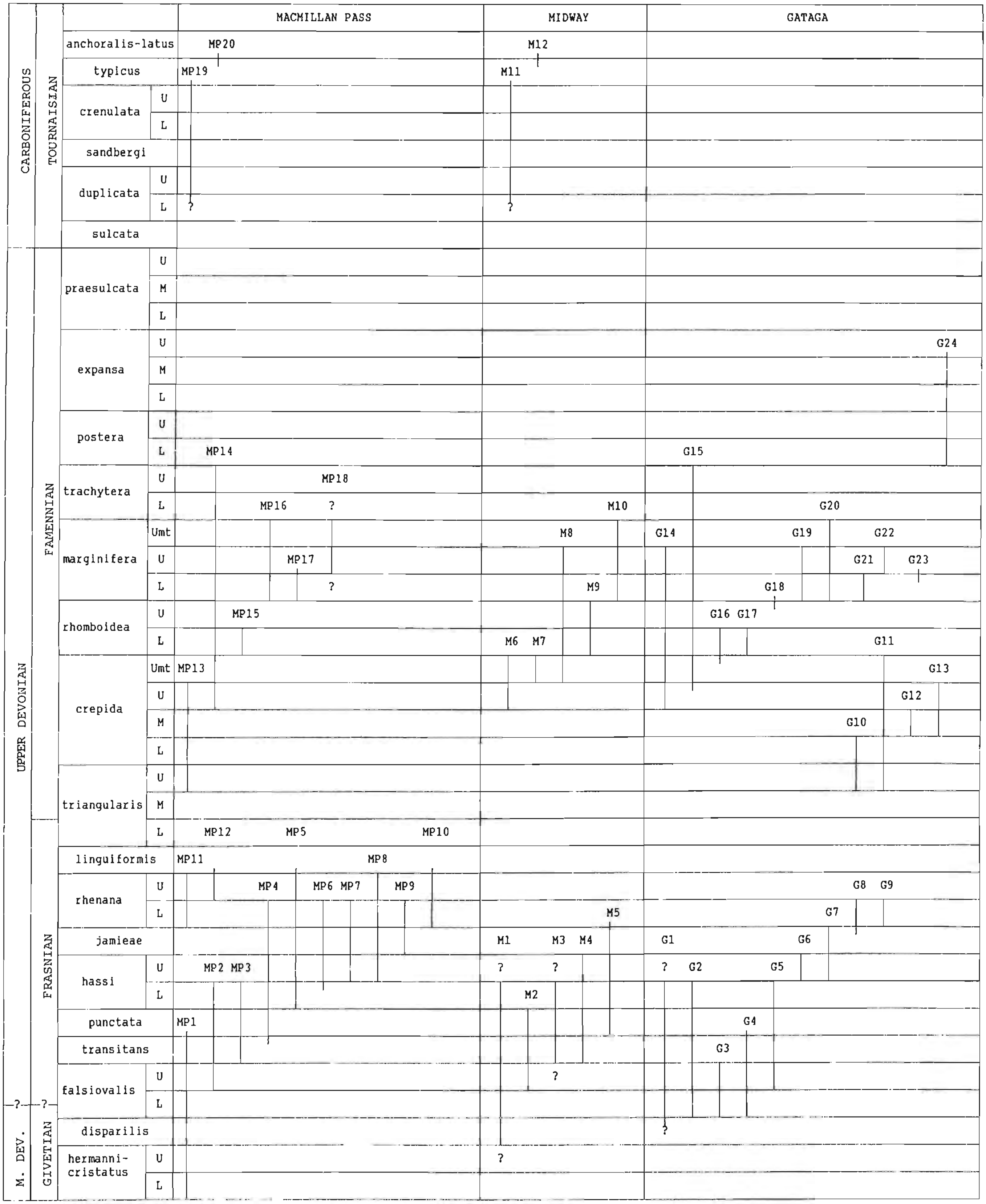


Figure 3. Ranges for Frasnian and Famennian faunas recognized in the Macmillan Pass, Midway, and Gataga areas using the revised international standard Upper Devonian conodont zonation (see Fig. 2).

Macmillan Pass

Twenty conodont faunas from the Macmillan Pass area range in age from Eifelian through Tournaisian. Twelve Middle Devonian and Frasnian faunas (MP1-MP12) contain conodonts with age ranges through the *falsiovalis*, *transitans*, *punctata*, *hassi*, *jamieae*, and *rhenana* zones (Fig. 3). Fauna MP1 (GSC locs. C-087691, C-087686, C-087545, C-087544, C-087542, C-087697; Table 1), broadly dated as Eifelian to lower Frasnian *punctata* Zone, is the oldest conodont fauna found within the Earn Group.

Palmatolepis subrecta Miller and Youngquist occurs with *P. proversa* Ziegler and/or *P. punctata* (Hinde) and/or *P. foliacea* Youngquist in several collections (GSC locs. C-118032, C-118033, C-087560, C-102281, C-087700). The appearance of *P. subrecta* with these species conforms to the age range given by Klapper and Ziegler (1979).

Several new Frasnian species described by Ziegler and Sandberg (1990) are found within the Earn Group in this area: *Palmatolepis ederi* Ziegler and Sandberg in Fauna MP6 (GSC loc. C-118033); *P. rotunda* Ziegler and Sandberg in Fauna MP12 (GSC loc. C-102340); and *P. rhenana rhenana* Bischoff in Fauna MP12 (GSC loc. C-102342). *Palmatolepis redana* n. sp. is described from fauna MP8 (GSC loc. C-118034), of Upper *hassi* through Upper *rhenana* Zone age.

Conodont faunas demonstrate that stratiform barite mineralization occurred during three time intervals in the Macmillan Pass area. The age of the oldest barite, recognized at the Cathy property, is Eifelian to early Frasnian (MP1). The ages of four other barite properties overlap within the Lower *rhenana* Zone: the Gary property barite is confined to the Lower *rhenana* Zone; the Pete barite, which occurs at the same stratigraphic level as the Gary barite, is no older than Lower *rhenana* Zone; the Jeff barite is constrained by fauna from the *rhenana* Zone; and the GHMS barite, southeast of the other properties, is no older than *punctata* Zone. The age of stratiform barite-lead-zinc mineralization at the Jason and Tom properties is no older than the Cathy barite deposit, but is older than the Upper *rhenana* Zone. The stratigraphic position of the Tom and Jason deposits relative to the Cathy, Pete and Gary barites, suggests they probably lie within the Lower *hassi* through Lower *rhenana* zones (Figs. 3, 4).

Famennian conodont faunas from Macmillan Pass (MP13-MP18) are indicative of the Upper *triangularis*, *crepida*, Lower *rhomboidea*, *marginifera*, and possibly *trachytera* zones (Fig. 3, Table 3). The oldest Famennian fauna (MP13) recognized at Macmillan Pass, is indicative of a range within the Upper *triangularis* Zone through Upper *crepida* Zone. Diverse Fauna MP15 includes unique occurrences of *Palmatolepis poolei* Sandberg and Ziegler (GSC locs. C-089929 and C-108160) and *P. quadrantinodosalobata* Morphotype 1 Sandberg and Ziegler (GSC loc.

Table 1. Distribution of Frasnian conodont species and faunal assignment of collections from the Macmillan Pass area of southeast Yukon and southwest Northwest Territories

		Macmillan Pass																												
Frasnian conodont fauna	GSC. Loc.	C-087695	C-087696	C-087697	C-101978	C-101979	C-086425	C-087542	C-087543	C-087544	C-087545	C-118030	C-118032	C-118033	C-118034	C-118035	C-087557	C-087560	C-087686	C-102281	C-102320	C-102321	C-102340	C-102342	C-087691	C-087698	C-087699	C-087700	C-087558	C-102586
Ancyrodella sp.																				1						1				
Ancyrodella curvata						1																								
Ancyrodella gigas																											1			
Ancyrodella ioides																						1								
Ancyrodella nodosa																	1						1						1	
Icriodus sp.					1																							2		
Icriodus symmetricus								1																		3	1			
Palmatolepis sp.							2					7	19	25	2	6	5	15		6	2	20	41	9		1	1	1		6
Klapperina ovalis		1	1						2																					
Mesotaxis asymmetrica		1	1		1				2																					
Palmatolepis ederi														2																
Palmatolepis foliacea													5					4		3										
Palmatolepis hassi												13																	1	1
Palmatolepis proversa							1					20	5	9						3										
Palmatolepis punctata																												1		
Palmatolepis redana n.sp.															3															
Palmatolepis rhenana nasuta							1									1	1	1	.	2		4	2					1	1	1
Palmatolepis rhenana rhenana																		4						3						
Palmatolepis rotunda																							2						1	
Palmatolepis subrecta													9	7	1	2		5		1			8	6		1		2	8	3
Palmatolepis transitans					1																									
Polygnathus sp.		5	3									34	4	21	1	2	7	4		24	4	9	6	3	1	4				2
Polygnathus dubius				1				7																						
Polygnathus linguiformis subsp.										1	4								1				1		1					
ramiform elements		2	16	2	15		7	15	2	4	12	40	40	31	3	50	4	24	8	24	9	37	50	25	6	5	6	20	30	25
Conodont Faunas	(MP)	2	2	1	3	5	7	1	2	1	1	7	9	6	8	10		11	1	11		11	12	12	1		4	11	11	10

99 denotes there are at least 99 elements.

C-089929). Fauna MP18 (Fig. 3, GSC loc. C-108159, Table 3), which represents the youngest Famennian Earn Group at Macmillan Pass, includes *P. rugosa trachytera* Ziegler, which is used to define the base of the *trachytera* Zone, and both *P. quadrantinodosa inflexa* Ziegler and *P. q. inflexoidea* Ziegler, which have not been previously recorded above the Lower *marginifera* Zone.

Upper Devonian conodont faunas with a range inclusive of the Lower and Middle *triangularis*, and *postera* through *praesulcata* zones have not been found at Macmillan Pass.

Lower and middle Tournaisian composite Fauna MP19 (Fauna III, Orchard and Irwin, 1988), recognized by the occurrence of *Siphonodella* spp., occurs in thirty-five collections from the Tsichu, Tay, and Kalzas formations in this region. Several *Siphonodella* species are identified from the Tsichu formation at Macmillan Pass, including *Siphonodella cooperi* Hass (GSC loc. C-089930), *Siphonodella crenulata* (Cooper) (GSC loc. C-108161), *Siphonodella lobata* (Branson and Mehl) (GSC loc. C-108161), and *Siphonodella quadruplicata* (Branson and Mehl) (GSC loc. C-108161).

Table 2. Distribution of Frasnian conodont species and faunal assignment of collections from the Midway and Gataga areas of northern British Columbia

		Midway					Gataga												
Frasnian conodont fauna	GSC. Loc.	C-088250	C-103232	C-143101	C-086357	C-088239	C-118946	C-102874	C-102879	C-102891	C-102892	C-118537	C-118543	C-118550	C-118902	C-118903	C-118908	C-116659	C-116673
Ancyrodella sp.		1	1			1													
Ancyrodella aff. A. binodosa		3																	
Ancyrodella gigas			1																
Ancyrodella ioides																		2	1
Ancyrodella lobata																			1
Ancyrodella nodosa			1																
Ancyrodella rotundiloba											1								
Icriodus sp.			20	3	2	2						1	3						5
Icriodus symmetricus								7		16									
Klapperina disparalis								5											
Klapperina disparalvea								13											
Klapperina disparata								1											
Klapperina ovalis								1		29									
Mesotaxis asymmetrica										19						6			
Mesotaxis falsiovalis										28			5						
Palmatolepis sp.			8	2			2							3	13	21	19	15	
Palmatolepis domanicensis												1							
Palmatolepis aff. P. domanicensis																			16
Palmatolepis foliacea															1			13	
Palmatolepis hassi																2		1	
Palmatolepis plana																		2	
Palmatolepis proversa			1												8			2	
Palmatolepis punctata												2							
Palmatolepis rhenana subsp. indet.																		2	2
Palmatolepis rotunda			2																
Palmatolepis subrecta			1											2			3	18	
Palmatolepis transitans				1						6		5	1						
Palmatolepis aff. P. transitans										1									12
Polygnathus sp.		40	3	1		1		39	6	14	2	1	1	3		3	22	99	5
"Polygnathus" cristatus								1	1										
Polygnathus dengleri								1											
Polygnathus dubius								6											
ramiform elements		30	5	20		40	1	50		50	3	40	40	2	37	99	7	99	99
Conodont Faunas (M) (G)		2	5	4	1	3		3	1	5	4	6	2		8			9	7

99 denotes there are at least 99 elements.

Siphonodella, the offshore successor to the Upper Devonian *Palmatolepis*, is found alone in some collections, but more commonly it is associated with other species, including *Gnathodus punctatus* (Cooper), *Polygnathus communis* Branson and Mehl, *Protognathodus praedelicatulus* Lane, Sandberg and Ziegler, and *Pseudopolygnathus oxpageus* Lane, Sandberg and Ziegler. High diversity faunules such as this are certainly conducive to improved zonal resolution but this has yet to be attempted. In addition, Fauna MP19 occasionally includes *Bispathodus* ex gr. *stabilis* Branson and Mehl, a relatively long-ranging taxon. The Tea barite property, which occurs in an unidentified stratigraphic unit, is associated with Fauna MP19 and represents the third and youngest stratiform barite mineralization in the Macmillan Pass area.

The upper Tournaisian Fauna MP20 (Fauna IV, Orchard and Irwin, 1988), recognized in eight collections from the Tsichu formation, is characterized by "*Hindeodella*" *segaformis* Bischoff (GSC loc. C-108152). The *segaformis* element is common in areas marginal to the craton throughout the Cordillera. In these collections, *Bispathodus* ex gr. *stabilis* and/or *Geniculatus*? n. sp. A (GSC loc. C-108152) occurs, as do fewer *Polygnathus* and *Pseudopolygnathus* species.

Midway

Twelve conodont faunas from the Midway area range in age from Givetian?, Frasnian through Tournaisian, but the most abundant faunas are indicative of the Upper *crepida* Zone through Lower *rhomboidea* Zone (Fig. 3, Tables 2 and 3).

Although most younger collections from the Midway area are dominated by the offshore *Palmatolepis*, faunas from the uppermost McDame Group, predictably, are representative of a relatively shallow water biofacies. The oldest collection, Fauna M1 (GSC loc. C-086357), from Earn Group strata about 100 km north of the Midway property, contains shallow water *Icriodus*. Fauna M2 (GSC loc. C-088250), collected from the McDame Group carbonates underlying the Earn Group contains *Ancyrodella* sp. aff. *A. binodosa* Uyeno and *Ancyrodella* sp., and is dated as Upper *falsiovalis* through

Table 3. Distribution of Famennian conodont species and subspecies and faunal assignment of collections from the Macmillan Pass area of southeast Yukon and southwest Northwest Territories and the Midway area of northern British Columbia

		Macmillan Pass														Midway													
Famennian conodont fauna	GSC Loc.	0-093424	C-086285	C-086286	C-086413	C-087588	C-087589	C-087685	C-087561	C-087562	C-089929	C-089933	C-108159	C-108160	C-142984	C-118253	C-118256	C-157905	C-157906	C-157907	C-157908	C-157909	C-157910	C-157924	C-157928	C-157929	C-157938	C-157939	C-153835
Palmatolepis crepida														1				1		2			2						
Palmatolepis glabra subsp.				1						7	4			2															
Palmatolepis g. acuta											2		2	5		8	1	1		2	2	1			4	1		3	
Palmatolepis g. distorta								19				9	43																
Palmatolepis g. glabra														10		1													
Palmatolepis g. lepta			7								3		7	6		9	6	7	6	8	5	6	3			3	2		
Palmatolepis g. lepta morph. 1								3																					
Palmatolepis g. lepta morph. 2								6				11	14																
Palmatolepis g. pectinata							1	4		10	9		35	3		16	5	1	3	5	2	9	5	6	5	1		6	
Palmatolepis g. prima										6	3		4			10	4	5		5								2	
Palmatolepis gracilis gracilis								2					3																
Palmatolepis klapperi											2			10		3													
Palmatolepis m. marginifera							1	7				8	35														1		
Palmatolepis minuta subsp.									3	10	5			2	1			1										3	
Palmatolepis m. minuta		3				1			1							3	3		1		1	3			2	6			
Palmatolepis m. loba																2	1	2											
Palmatolepis perlobata subsp.						1																2							
Palmatolepis p. schindewolfi						2		2					17								1								1
Palmatolepis poolei											1			14															
Palmatolepis quadrantinodosa subsp.										1																			
Palmatolepis q. inflexa								1					1																
Palmatolepis q. inflexoidea							1						1																
Palmatolepis quadrantinodosalobata											1					1	1												
Palmatolepis q. morph. 1										11																			
Palmatolepis cf. P. regularis		1							1	1	2					2	1				2	2	3	1				1	
Palmatolepis rugosa trachytera					1								6																
Palmatolepis subperlobata									5	7	5			5		8	15	5	1	3	1	11	4					2	
Palmatolepis tenuipunctata										2								1		2	2	2				2			
Palmatolepis triangularis		9			1				1																				
Polygnathus sp.		6	3	2	2			5	1	3	2	2	2	4	1	2	3			1									2
Polyphodonta sp.																												1	
ramiform elements				20	5	5	6		17	5	50	6	30	40	20	99		99	20	50	30	50	15	4	10	10		20	7
Conodont Faunas (MP) (M)		13	14			14	17	17	13	13	15	16	18	15		8	6	6	7	6	7	7	7		9	7			

99 denotes there are at least 99 elements.

punctata zones. Fauna M5 (GSC loc. C-103232) collected from the basal Earn Group south of the Midway property also contains relatively shallow water *Ancyrodella*, *Icriodus*, and *Polygnathus* species in addition to *Palmatolepis* species; this association is dated as *punctata* through *rhenana* zones. An occurrence of *Palmatolepis subrecta* with *P. proversa* in Fauna M5 (GSC loc. C-103232) supports the age range for *P. subrecta* shown by Klapper and Ziegler (1979). Two specimens of *P.* sp. cf. *P. rotunda* also occur in the same collection of Fauna M5.

In the central Midway area, in the vicinity of the Midway property, most of Frasnian time is represented by an unconformity between the McDame and Earn groups. Much of this interval is assumed to have been a period of nondeposition and/or erosion of strata. Fauna M4 (GSC loc. C-143101; Fauna I, Orchard and Irwin, 1988) contains poorly preserved icriodids, palmatolepids, and polygnathids and was collected from dolomitic siltstone within karstic hollows at the McDame/Earn Group contact. This fauna may represent either a component of the insoluble residue left at the top of the McDame Group karst horizon, or an early pulse of Earn Group sedimentation onto this karst surface during *transitans* through Upper *hassi* zone time.

At the Midway property, the reefoid upper McDame Group is directly overlain by Earn Group with abundant Upper through Uppermost *crepida* Zone conodonts of Fauna M6 (GSC locs. C-157905, C-118256, C-157907), and Uppermost *crepida* Zone Fauna M7 (GSC locs. C-157908, C-157906, C-157909, C-157910, C-157929; Fig. 3; Table 3). These large faunas are the oldest Famennian conodonts recovered from the Earn Group in this area, and suggest that the environment was extremely productive, sedimentation rates were very slow, and/or that the conodonts have become concentrated as lag deposits through erosion. The McDame–Earn contact represents not only a significant hiatus but reflects a dramatic increase in water depth on the Cassiar Platform.

In a few collections, there is evidence of faunal mixing. Two Famennian collections, Fauna M8 (GSC loc. C-158253) with a maximum age of Uppermost *crepida* Zone, and Fauna

Table 4. Distribution of Famennian conodont species and subspecies and faunal assignment of collections from the Gataga area of northern British Columbia

		Gataga																														
Famennian conodont fauna	GSC Loc.	C-118539	C-118540	C-118544	C-118547	C-118548	C-118907	C-118914	C-118915	C-118917	C-118923	C-118924	C-118880	C-118884	C-118889	C-118892	C-116954	C-116955	C-116956	C-116957	C-116958	C-116962	C-116965	C-116969	C-116977	C-116979	C-116980	C-116981	C-116983	C-116990	C-116991	C-116992
Palmatolepis clarki																6																
Palmatolepis crepida																6																
Palmatolepis glabra subsp.				3				4	3	5	3	7	5					1	1							2						
Palmatolepis g. acuta														3																		
Palmatolepis g. distorta					3						1	16		66	1					1	6		2								2	4
Palmatolepis g. lepta					4			1	2		2			13	1				7		3		3	1	3							
Palmatolepis g. lepta morph. 1		2			5							5		6			4	1														
Palmatolepis g. lepta morph. 2		2			7	3	7					16		11						11	11								1	2		11
Palmatolepis g. pectinata		7	2		12	2	5		2		13	29		36	3		2			2	13				2			2				8
Palmatolepis g. prima					4	1						4					3	1			1				1							1
Palmatolepis g. prima morph. 2					2						2																					
Palmatolepis klapperi														1																		
Palmatolepis marginifera subsp.								1																								
Palmatolepis m. marginifera		5			15	1	2		8		16	63		41						1	7		3		3		1				2	3
Palmatolepis m. utahensis		2			1						1	10									2						1				1	
Palmatolepis minuta subsp.							3			26						11	1		1						1							
Palmatolepis m. minuta				9	1	2			1			15	44	4																		
Palmatolepis m. loba										5																						
Palmatolepis perlobata subsp.																2																
Palmatolepis p. schindewolfi		1					1			1		12		22					2													
Palmatolepis q. quadrantinodosa											1	1																				
Palmatolepis q. inflexa		1					2																									
Palmatolepis q. inflexoidea											2	13		6					2						1							
Palmatolepis q. quincea n. subsp.							2					1		1											1							
Palmatolepis quadrantinodosalobata				2						4			12			3																
Palmatolepis q. morph. 1				4																												
Palmatolepis cf. P. regularis													2			2																
Palmatolepis stoppeli																			2													
Palmatolepis subperlobata				2						1			11			2	1															
Palmatolepis tenuipunctata																1																
Palmatolepis triangularis																7																
Palmatolepis wolskajae																6																
Polygnathus sp.					7		2					6	6	8		2	2				1	2			2							
Polylophodonta sp.					1						1			2																		
ramiform elements				18	50	10	4	5	30	60	4	99	99	60	6	60			2	8	3			1	60		3		8	2	2	3
Conodont Faunas	(G)	23	14	16	22	20	21	20	19	11	23	23	11	21	19	12	14	14	18	19	22		20	15	21		22	14	15	15	22	19

99 denotes there are at least 99 elements.

M9 (GSC loc. C-157928), with a maximum age of Lower *rhomboidea* Zone, each contain two, presumably derived, specimens of Frasnian *Mesotaxis asymmetrica* (Bischoff and Ziegler).

Fauna M10 (GSC loc. C-157938), indicative of the *marginifera* Zone, represents the youngest Devonian Earn Group identified in the Midway area. The intervals from Upper *rhenana* Zone through Middle *crepida* Zone, including the Frasnian–Famennian boundary, and *trachytera* through *praesulcata* zones are not represented by conodont faunas in the Midway area.

Siphonodella-bearing Fauna M11 (Fauna III, Orchard and Irwin, 1988), equivalent to Fauna MP19, is recognized in fifteen collections from the Earn Group near Midway, including those from the stratiform barite deposits at the Ewen and Perry properties. Fauna M12 (Fauna IV, Orchard and Irwin, 1988) characterized by *''Hindeodella'' segaformis* Bischoff and equivalent in age to Fauna MP20, is recognized in three Earn Group collections at Midway.

Gataga

Twenty-four conodont faunas at Gataga range in age from the upper Givetian *disparilis* Zone through upper Famennian *expansa* Zone. Nine Givetian–Frasnian faunas (G1-G9) and fifteen Famennian faunas (G10-G24) are recognized: these include the index species (Fig. 2) for the Lower and Upper *falsiovalis*, *transitans*, Lower *hassi*, *rhenana*, Lower, Upper, and Uppermost *crepida*, Lower *rhomboidea*, Lower and Upper *marginifera*, and Lower *postera* zones (Fig. 3, Tables 2, 4, and 5), although only the Lower *rhenana*, Middle *crepida*, Lower *rhomboidea*, and Upper *marginifera* zones are specifically identified.

The occurrence of a mixed biofacies taxa in Fauna G4 (GSC loc. C-102892), from a carbonate unit underlying the Earn Group, and Fauna G2 (GSC loc. C-118543) from the Earn Group suggests possible shallow water areas were present in the southernmost Gataga area during the Givetian and early Frasnian. Throughout the later Frasnian, deeper water palmatolepid biofacies were dominant in the Gataga area.

Table 5. Distribution of Famennian conodont species and subspecies and faunal assignment of collections from the Gataga area of northern British Columbia

		Gataga																																
Famennian conodont fauna	GSC Loc.	C-116993	C-116994	C-116997	C-117000	C-116907	C-116909	C-116912	C-116914	C-116669	C-116675	C-116684	C-116693	C-116695	C-116697	C-116698	C-116713	C-116714	C-116715	C-116718	C-116719	C-116720	C-116722	C-116724	C-116730	C-102884	C-176651	C-176684	C-176654	C-176655	C-176656	C-176661	C-176662	C-176663
Palmatolepis glabra subsp.		3				1	2			3	1	3						3								64		1	4					
Palmatolepis g. acuta									1																									
Palmatolepis g. distorta			3				1		7						22	1				4				2	33						3	5	5	
Palmatolepis g. lepta			1	3	1				8					1	1		1								2		6				4	8	13	8
Palmatolepis g. lepta morph. 1							1								1	3							3		5									
Palmatolepis g. lepta morph. 2							1		3				1		1					2			10		10	7								
Palmatolepis g. pectinata		1					4	1	20	9					10	1			1	1		5	1	1	5		3				1	7	11	7
Palmatolepis g. prima																						1												
Palmatolepis gracilis subsp.										1																								
Palmatolepis gracilis gracilis																													1					
Palmatolepis klapperi																								2										
Palmatolepis marginifera subsp.									7																	99								2
Palmatolepis m. marginifera							1		32	1			1		20					1		2	12		38		1				7	16	9	
Palmatolepis m. utahensis									17																4									
Palmatolepis minuta subsp.								2		1					1																			
Palmatolepis m. minuta									7			29																					1	
Palmatolepis perlobata subsp.												3																						
Palmatolepis p. postera																														4				
Palmatolepis p. schindewolfi									23	1					9								1		2		2	2						2
Palmatolepis q. quadrantinodosa									1																									
Palmatolepis q. inflexa									8													1												
Palmatolepis q. inflexoidea									1	2															4						1			
Palmatolepis q. quincea n. subsp.									10																									
Palmatolepis quadrantinodosalobata												10																						
Palmatolepis cf. P. regularis												2																						
Palmatolepis rhomboidea																					4													
Palmatolepis rugosa subsp.																													2	4				
Palmatolepis rugosa ampla																												1	1					
Palmatolepis aff. P. r. trachytera															1																			
Palmatolepis subperlobata												35			1						9								1					
Palmatolepis tenuipunctata												2																						
Palmatolepis triangularis												2																						
Polygnathus sp.											3	2			4				1					1								4		
ramiform elements		1	2	4			7	22	99	12	60	99	5							1	24				50	99	1	1	12	9	3	29	21	20
Conodont Faunas	(G)	14	20	15	15		19	14	23	21		10	19	15	19	19	15	19	14	19	17	19	19	21	23	19	19	24	24	24	21	19	19	19

99 denotes there are at least 99 elements.

Conodonts from the lower Frasnian (Fauna G5, GSC loc. C-102891) occur along strike with the oldest stratiform barite mineralization in the southernmost Gataga area. *Palmatolepis subrecta* occurs in Fauna G9 (GSC loc. C-116659) with *P. proversa* and *P. foliacea*, which is consistent with the age range shown for that species by Klapper and Ziegler (1979); *P. plana* Ziegler and Sandberg also occurs in this collection. Specimens of *P.* sp. aff. *P. domanicensis* Ovnatanova and *P.* sp. aff. *P. transitans* Müller occur in Fauna G7 (GSC loc. C-116673) of Upper *hassi* Zone through *jamieae* Zone age.

Middle Famennian conodont faunas from Gataga are diverse and large collections provided good zonal resolution of the numerous stratiform barite and barite-lead-zinc deposits in the area. Several notable occurrences of new and existing taxa occur within the conodont faunas at Gataga: Fauna G17 (GSC loc. C-116719) includes a unique occurrence of *Palmatolepis rhomboidea* Sannemann; Fauna G18 (GSC loc. C-116956) includes the only occurrence in the Earn Group of *Palmatolepis stoppeli* Sandberg and Ziegler.

Fauna G19 (GSC loc. C-116697) includes a specimen of *Palmatolepis rugosa* sp. aff. *P. r. trachytera*. Fauna G21 (GSC locs. C-118907, C-118884, C-116977), which contains *P.* ex gr. *glabra* and *P. marginifera marginifera* Helms, is indicative of the Lower *marginifera* Zone. Fauna G21 collections and Fauna G23 (C-118924, C-116914) also contain *Palmatolepis quadrantinodosa quincea* n. subsp.

Fauna G21 (GSC loc. C-116724, C-118884), dated as Lower *marginifera* Zone, contains specimens of *Palmatolepis klapperi* Sandberg and Ziegler from Gataga (Table 5). Fauna G23 (GSC locs. C-118539, C-118923, C-118924, C-116914, C-116730), is characterized by *P. marginifera utahensis* Ziegler and Sandberg and *P. quadrantinodosa inflexoidea* and/or *P. q. inflexa*. This co-occurrence implies that the range of both subspecies of *P. quadrantinodosa* extends upward into the Upper *marginifera* Zone, or that the range of *P. m. utahensis* extends downward into the Lower *marginifera* Zone.

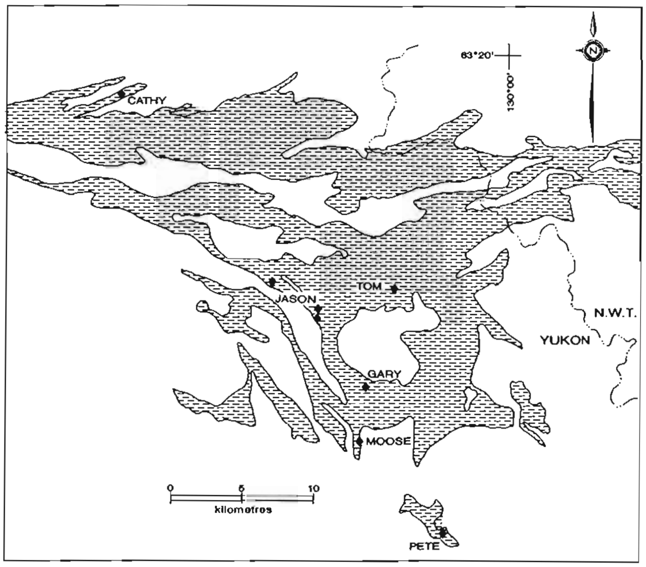


Figure 4. Generalized geological map of the Macmillan Pass area showing the outline of Earn Group outcrop and stratiform mineral properties. Modified from Abbott (1982).

Fauna G24 (GSC locs. C-176654, C-176684, C-176655), of *postera* through *expansa* Zone age, represents the youngest Famennian conodont fauna identified in the entire Earn Group (Fig. 3). Conodonts indicative of the Upper *rhenana* through Middle *triangularis* zones, Upper *expansa* through *praesulcata* zones, and the Tournaisian have not been found at Gataga (Fig. 3).

Stratiform barite mineralization in the Gataga area is dated by faunas as Lower *marginifera* Zone, undifferentiated *marginifera* Zone, and possibly Upper *crepida* or Lower *rhomboidea* zones. Some barite horizons are less tightly constrained by conodont faunas indicating a broad age of Upper *crepida* through Upper *trachytera* zones, no older than the Upper *marginifera* Zone, or Upper *crepida* through Upper *marginifera* zones. Stratiform barite mineralization at Gataga apparently occurred during at least two distinct time intervals within the early and middle Famennian.

Several distinct stratiform barite-lead-zinc sulphide mineral horizons within the Gataga area are also constrained by Famennian conodont faunas. The oldest Famennian level is confined to the Lower *rhomboidea* Zone; a second is constrained by Lower *marginifera* Zone fauna, and a third interval is no older than the Upper *marginifera* Zone. Several other stratiform mineral horizons are dated as no younger than *marginifera* Zone, and no older than the Lower *marginifera* Zone or Upper *crepida* Zone. Assuming an overturned stratigraphic sequence as reported by K.R. McClay (pers. comm., 1990) in the southern Gataga area, stratiform sulphide mineralization is no younger than upper Famennian, Lower *postera* Zone. In the same area a second horizon is no older than middle Famennian, *marginifera* Zone and no younger than upper Famennian, *postera* Zone.

SUMMARY

Conodont faunas of the marginal autochthon in the northern Canadian Cordillera provide a biochronological framework for the region (Fig. 3) and allow a general assessment of the geological history in the area. As shown by both the dominant lithofacies and by conodont biofacies, during the late Givetian and early Frasnian, relatively shallow water conditions prevailed in the southern Midway and Gataga areas. Allowing for restoration of the Tintina fault system, both areas apparently lay close to the margin of the basin. Farther north in the Macmillan Pass area, correlative faunas are dominated by deep water genera of *Klapperina*, *Mesotaxis*, and *Palmatolepis*.

The oldest Earn Group fauna, indicative of the Eifelian to lower Frasnian, occurs at Macmillan Pass (MP1). The presence of lower Frasnian offshore faunas indicates sedimentation of this age in all three areas of study (Fig. 3). Middle and upper Frasnian stratiform barite deposits occur at both Macmillan Pass and Gataga, but stratiform barite-lead-zinc deposits of this age have only been discovered in the former area.

South of the Midway property, the McDame Group Fauna M2 (GSC loc. C-088250), Upper *falsiovalis* Zone through *punctata* Zone age, and Fauna M3 (GSC C-088239), *falsiovalis* Zone age, appears to be conformably overlain by Earn Group sediments of the *punctata* Zone through the Lower *rhenana* Zone (Fauna M5, GSC loc. C-103232). In contrast, at the Midway property, the McDame/Earn Group contact is a distinct karst horizon and generally Middle Devonian shallow water sediments of the McDame Group are directly overlain by mid-Famennian, Upper through Uppermost *crepida* Zone conodonts of Fauna M6 (GSC locs. C-157905, C-118256, C-157907), and Uppermost *crepida* Zone Fauna M7 (GSC locs. C-157908, C-157906, C-157909, C-157910, C-157929; Fig. 3; Table 3). These large faunas are the oldest Famennian conodonts recovered from the Earn Group in the Midway area. A major hiatus embraces the interval from the upper Frasnian *linguiformis* through lower Famennian Lower and Middle *triangularis* zones. These zones are also absent elsewhere, although this may be the result of a lack of carbonate sedimentation.

Well dated faunas of the Lower *rhomboidea* Zone occur at Macmillan Pass and Gataga (MP15, G17). Numerous faunas indicative of the *marginifera* Zone are identified in all three areas, but they are more highly resolved in the Gataga and Macmillan Pass areas (Fig. 3). Several important stratiform sulphide deposits are associated with the Famennian faunas (G17-G22) in the Gataga area only. Upper Famennian *postera* and *expansa* zones are represented by a few small collections of Fauna G24 only in the southern Gataga region. No conodont faunas indicative of the upper Famennian *praesulcata* Zone are recognized in the Earn Group. Tournaisian faunas occur in both Midway and Macmillan Pass areas, and some are associated with barite deposits (MP19-20, M11-12).

The stratigraphic distribution of Earn Group conodonts is demonstrably consistent, for the most part, with the standard Upper Devonian *Palmatolepis* zonation (Ziegler, 1962; Ziegler and Sandberg, 1990). However, three anomalies are notable. In the Macmillan Pass and Gataga areas, *Palmatolepis subrecta* occurs with *P. proversa*, *P. punctata*, and *P. foliacea*, implying an extended range into the *punctata* Zone for the first species. This does not conform to the restricted age range proposed in Ziegler and Sandberg (1990), but with the broader age range given by Klapper and Ziegler (1979).

The appearance at Gataga of *Palmatolepis quadrantinodosa inflexoidea* and/or *P. quadrantinodosa inflexa* within six collections of Upper *marginifera* Zone age, as defined by the occurrence of *P. marginifera utahensis*, provides a younger range for both subspecies than previously described. In the Macmillan Pass area, *Palmatolepis rugosa trachytera* appears in Fauna MP18 of Lower *marginifera* Zone age, as defined by *P. quadrantinodosa inflexa* and *P. q. inflexoidea*, which is an older range for the first subspecies than previously reported.

Several of the new taxa recently introduced by Ziegler and Sandberg (1990) are recognized in the Earn Group faunas; these are *Palmatolepis ederi* (MP6), *Palmatolepis rotunda* (MP11, M5), *Palmatolepis plana* (G9), and *Palmatolepis rhenana rhenana* (MP11-12). *Palmatolepis redana* n. sp. is described from Macmillan Pass area in a small fauna (MP8) indicative of Upper *hassi* Zone through Upper *rhenana* Zone. *Palmatolepis quadrantinodosa quincea* n. subsp. is described from several collections in the Gataga area (G21, G23) that are indicative of the Lower *marginifera* through lower Upper *marginifera* zones.

SYSTEMATIC TAXONOMY

Only new taxa or variations are discussed here. Other generally well known species are illustrated in Plates 1-5, and listed below. All specimens are housed in the National Type Collection of Invertebrate and Plant Fossils at the Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A OE8.

Palmatolepis sp. aff. *P. domanicensis* Ovnatanova
Plate 2, figure 12

aff. 1976 *Palmatolepis domanicensis* n. sp. OVNATANOVA, p. 213-214, Pl. 9, figs. 1, 2.
aff. 1988 *Palmatolepis* sp. aff. *P. domanicensis* Ovnatanova. KLAPPER and LANE, p. 474, Pl. 2, figs. 15-17.

Remarks. These elements are distinguished from *P. domanicensis* by their lack of a posterior carina and by a larger lateral lobe than typical. They are not the same as *P.* sp. aff. *P. domanicensis sensu* Klapper and Lane (1989), which has a smaller, narrower platform and a more distinctly differentiated outer lobe. The present specimens differ from *P. plana* Ziegler and Sandberg (1990) in having an arched platform and down-turned posterior tip.

Occurrence. Sixteen specimens from GSC loc. C-116673, in the Gataga area, in a fauna indicative of the Upper *hassi* through *jamieae* zones. Illustrated specimen GSC 101342.

Palmatolepis glabra lepta Ziegler and Huddle
Plate 4, figure 1

1969 *Palmatolepis glabra lepta* n. subsp. ZIEGLER and HUDDLE, p. 377-386.

Remarks. Palmatolepis glabra lepta is the most common subspecies of *Palmatolepis glabra* within the middle Famennian part of the Earn Group. In addition to typical forms, two variants, Morphotype 1 and Morphotype 2, are differentiated. Both morphotypes often occur with typical *P. g. lepta* and it is possible that they represent earlier growth stages. They are nevertheless differentiated because of their distinctive morphology.

Occurrence. Different combinations of *Palmatolepis glabra lepta* and morphotypes 1 and 2 occur at Macmillan Pass, Midway, and Gataga within fauna of Upper *crepida* through Upper *trachytera* zones (Ziegler and Sandberg, 1984). Illustrated hypotype *P. glabra lepta* GSC 101361.

Morphotype 1 (Pl. 4, fig. 4)

Remarks. Morphotype 1 differs from typical forms in possessing a triangular parapet on the inner anterior platform that is not raised above the plane of the platform. Illustrated hypotype GSC 101364.

Morphotype 2 (Pl. 4, fig. 2)

Remarks. Morphotype 2 is distinguished by the reduced inner anterior platform or parapet and small overall size. Illustrated hypotype GSC 101362.

Palmatolepis quadrantinodosa quincea n. subsp.

Plate 3, figure 12

Etymology. After the quince (pear) shaped outline of the platform.

Holotype. GSC 101354.

Type locality. GSC loc. C-116914, Gataga Creek area, British Columbia.

Type stratum. "Gunsteel formation", Earn Group.

Diagnosis. A subspecies of *Palmatolepis quadrantinodosa* having a shagreen-like, posteriorly broad platform. The outer platform is broad and its margin has a prominent inflexion anterior of the azygous node. The narrow anterior inner platform is slightly raised and has a similar inflexion posterior of the azygous node. The straight anterior carina is deflected anterior of the azygous node and continues as a weak line of nodes posterior of it, occasionally paralleled by a shallow groove, to near the posterior tip. The anterior portion of the inner platform is built up to form a weak ridge parallel to, but separated from, the carina by a groove. The inner platform begins approximately half way between the anterior tip and the azygous node. The outer platform begins close to the anterior end of the carina.

Comparisons. The inner platform ramp of *Palmatolepis quadrantinodosa quincea* n. subsp. is similar to, but much lower and shorter than the equivalent development in *Palmatolepis stoppeli*, *P. marginifera*, and *P. quadrantinodosa quadrantinodosa*.

Occurrence. Sixteen specimens from the Gataga area, GSC locality numbers C-118907, C-118924, C-118884, C-116977, and C-116914. *Palmatolepis quadrantinodosa quincea* occurs within faunas indicative of Lower and lower Upper *marginifera* Zone.

Palmatolepis redana n. sp.

Plate 2, figures 1a, b, 4

Etymology. Referring to the similarity of the platformal build-up to a redan structure.

Holotype. GSC 101333.

Type locality. GSC loc. C-118034, near Tom deposit, Macmillan Pass area, Yukon.

Type stratum. Portrait Lake formation, Earn Group.

Diagnosis. A species of *Palmatolepis* characterized by high anterior platform margins, a straight carina anterior of the central node, and a well developed secondary carina on the outer platform.

Description. The secondary carina lies anterior of the azygous node, is at right angles to the primary carina, and extends out to the raised platform edge. The posterior platform is slightly bulbous, whereas the outer platform has a pronounced anteriorly directed lobe ornamented marginally with a sharp nodose ridge subparallel to the carina. The carina is absent posterior of the central node. The nodose inner platform margin is the same height as the carina anteriorly but diminishes posterior of the central node. A series of subdued nodes outlines the posterior platform margin. There is a small unornamented posterior tip beyond the small nodes. The row of nodes continues around the posterior and onto the outer platform margin to a position opposite the central node. Anterior of this point, the platform margin is raised along the edge of a lobe into a prominent ridge of nodes, equal to the height of the carina. This lobe is directed away from the plane of the carina line at a forty degree angle. The anterior platform margin between the lobe and the main carina is unornamented. A low, sharp secondary carina is developed immediately anterior of the central node. The secondary carina forms a ridge between the main carina and the outer anterior platform margin.

Comparisons. The ornamentation is similar to that of *P. proversa* but is not developed on the outer anterior margin, whereas it is stronger on the inner margin and on the lobe.

Occurrence. Three specimens from GSC loc. C-118034 at Macmillan Pass. The new species occurs with a small fauna indicative of the Upper *hassi* through Upper *rhenana* zones.

Palmatolepis sp. aff. *P. rugosa trachytera* Ziegler

Plate 4, figure 13

aff. 1960 *Palmatolepis rugosa trachytera* n. subsp. ZIEGLER, Pl. 1, fig. 6, Pl. 2, figs. 1-9, Figs. 12, 13.

Remarks. Compared with *P. r. trachytera*, this specimen has a reduced outer lobe, reduced platform nodes, and a broader parapet. The upper surface ornamentation is subdued. Ziegler (1977) noted that the origin of *Palmatolepis rugosa trachytera* is unclear but that it may have evolved from *Palmatolepis marginifera utahensis* or *Palmatolepis rugosa* sp. cf. *P. r. ampla*. Ziegler and Sandberg (1984) noted that specimens with weak outer lobes bear a strong resemblance to a possible *P. marginifera* ancestor. The present specimen may, therefore, represent a younger transitional form between *P. marginifera* and *P. rugosa trachytera*.

Occurrence. One specimen occurs in a single collection from GSC loc. C-116697 at Gataga, dated as Lower through Upper *marginifera* Zone. Figured specimen GSC 101373.

Palmatolepis sp. aff. *P. transitans* Müller

Plate 2, figure 5

aff. 1956 *Palmatolepis transitans* n. sp. MÜLLER, p. 18, Pl. 1 fig. 1.

Remarks. Palmatolepis sp. aff. *P. transitans* differs from *P. transitans* in lacking a posterior carina.

Occurrence. Twelve specimens from GSC loc. C-116173 and one specimen from GSC. loc. C-102891, at Gataga, indicative of the Lower *rhenana* Zone. Illustrated specimen GSC 101336.

ILLUSTRATED SPECIES

The following species are illustrated but not described; all are hypotypes, unless stated otherwise.

Ancyrodella sp. aff. *A. binodosa* Uyeno, Pl. 2, fig. 2, figured specimen GSC 101334.

Bispathodus aculeatus aculeatus (Branson and Mehl), Pl. 5, fig. 7, GSC 101387.

Doliognathus dubius Branson and Mehl, Pl. 5, fig. 16, GSC 101395.

D. latus Branson and Mehl Morphotype 2 Lane, Sandberg, and Ziegler, Pl. 5, fig. 11, GSC 101390.

Geniculatus? n. sp. A, Pl. 5, fig. 1, figured specimen GSC 101380.

Gnathodus punctatus (Cooper), Pl. 5, fig. 2, GSC 101381.

G. semiglaber (Bischoff), Pl. 5, fig. 8, GSC 101388.

"Hindeodella" segaformis Bischoff, Pl. 5, fig. 17, GSC 101396.

Klapperina disparalvea Orr and Klapper, Pl. 1, figs. 3, 4, GSC 101330.

K. ovalis (Ziegler and Klapper), Pl. 1, figs. 7, 8, GSC 81212.

K. disparilis (Ziegler and Klapper), Pl. 1, figs. 9, 10, GSC 101332.

Mesotaxis asymmetrica (Bischoff and Ziegler), Pl. 1, figs. 1, 2, GSC 101329, figs. 11, 12, GSC 101397.

M. falsiovalis Sandberg, Ziegler, and Bultynck, Pl. 1, figs. 5, 6, GSC 101331.

Palmatolepis clarki Ziegler, Pl. 4, fig. 10, GSC 101371.

P. crepida Sannemann, Pl. 2, fig. 15, GSC 81173.

P. ederi Ziegler and Sandberg, Pl. 2, fig. 6, GSC 101337.

P. foliacea Youngquist, Pl. 2, fig. 13, GSC 101343.

P. glabra acuta Helms, Pl. 3, fig. 18, GSC 101360.

P. glabra distorta Branson and Mehl, Pl. 4, fig. 3, GSC 101363.

P. glabra pectinata Ziegler, Pl. 4, fig. 7, GSC 101367.

P. glabra pectinata Ziegler Morphotype 1, Sandberg and Ziegler, Pl. 4, fig. 6, GSC 101366.

P. gracilis gracilis Branson and Mehl, Pl. 4, fig. 5, GSC 101365.

P. hassi Müller and Müller, Pl. 2, fig. 11, GSC 101341.

P. klapperi Sandberg and Ziegler, Pl. 3, fig. 13, GSC 101355.

P. marginifera utahensis Ziegler and Sandberg, Pl. 4, fig. 8, GSC 101368.

P. marginifera marginifera Helms, Pl. 4, figs. 9, 12, GSC 101369, GSC 101370.

P. minuta minuta Branson and Mehl, Pl. 4, fig. 11, GSC 101372.

P. perlobata postera Müller, Pl. 4, fig. 14, GSC 101374.

P. perlobata schindewolfi Müller, Pl. 4, fig. 16, GSC 101376.

P. plana Ziegler and Sandberg, Pl. 2, fig. 3, GSC 101335.

P. poolei Sandberg and Ziegler, Pl. 3, fig. 9, GSC 101351.

P. proversa Ziegler, Pl. 2, fig. 14, GSC 101344.

P. punctata (Hinde), Pl. 2, fig. 9, GSC 101339.

P. quadrantinodosa inflexa Ziegler, Pl. 3, fig. 15, GSC 101357.

P. quadrantinodosa inflexoidea Ziegler, Pl. 3, fig. 17, GSC 101359.

P. quadrantinodosa quadrantinodosa Branson and Mehl, Pl. 4, fig. 19, GSC 101379.

P. quadrantinodosalobata Sannemann, Pl. 3, fig. 14, GSC 101356.

P. quadrantinodosalobata Sannemann Morphotype 1 Sandberg and Ziegler, Pl. 3, fig. 10, GSC 101352.

P. sp. cf. *P. regularis* Cooper, Pl. 3, fig. 16, figured specimen GSC 101358.

P. rhenana nasuta Müller, Pl. 3, fig. 1, GSC 81215.

P. rhenana rhenana Bischoff, Pl. 3, fig. 2, GSC 101345.

P. rhenana subsp. indet., Pl. 3, fig. 5, GSC 101348.

P. rhomboidea Sannemann, Pl. 3, fig. 6, GSC 101349.

P. sp. cf. *P. rotunda* Ziegler and Sandberg, Pl. 2, fig. 10, figured specimen GSC 101340.

P. sp. aff. *P. rugosa ampla* Müller, Pl. 4, fig. 17, figured specimen GSC 101377. Specimen is transitional to *P. rugosa rugosa* Branson and Mehl.

P. rugosa ampla Müller, Pl. 4, fig. 18, GSC 101378.

P. rugosa trachytera Ziegler, Pl. 4, fig. 15, GSC 101375.

P. stoppeli Sandberg and Ziegler, Pl. 3, fig. 8, GSC 101350.

P. subperlobata Branson and Mehl, Pl. 3, fig. 4, GSC 101347.

P. subperlobata subsp. A Helms, Pl. 3, fig. 3, figured specimen GSC 101346.

P. subrecta Miller and Youngquist, Pl. 3, fig. 11, GSC 101353.

P. transitans Müller, Pl. 2, fig. 7, GSC 101338.

P. triangularis Sannemann, Pl. 2, fig. 8, GSC 81165.

P. wolskajae Ovnatanova, Pl. 3, fig. 7, GSC 81168.

Polygnathus communis Branson and Mehl, Pl. 5, fig. 6, GSC 101386.

Protognathodus praedelicatulus Lane, Sandberg, and Ziegler, Pl. 5, fig. 12, GSC 101391.

Pseudopolygnathus oxpageus Morphotype 2 Lane, Sandberg, and Ziegler, Pl. 5, fig. 15, GSC 101394.

Scaliognathus anchoralis Branson and Mehl, Pl. 5, fig. 13, GSC 101392.

Siphonodella crenulata (Cooper), Pl. 5, fig. 3, GSC 101382, fig. 9, GSC 101383.

Siphonodella cooperi Hass, Pl. 5, fig. 5, GSC 101385.

Siphonodella lobata (Branson and Mehl), Pl. 5, fig. 10, GSC 101389.

Siphonodella quadruplicata (Branson and Mehl), Pl. 5, fig. 14, GSC 101393.

Staurognathus sp., Pl. 5, fig. 4, figured specimen GSC 101384.

ACKNOWLEDGMENTS

Financial support for this project was provided to M.J. Orchard at the University of British Columbia by the National Science and Engineering Research Council, and the British Columbia Ministry of Energy, Mines, and Petroleum Resources through the Mineral Development Agreement. The authors thank Dr. T.T. Uyeno (ISPG, Calgary) and Dr. S.P. Gordey (GSC, Vancouver) for their helpful reviews of the manuscript. We also acknowledge the many geologists from the GSC, British Columbia Geological Survey, and various companies (see Locality Register) who were involved in collecting the conodont samples. We are also grateful to the GSC technicians who processed the samples. P. Krauss supervised much of the laboratory work and undertook the conodont photography.

REFERENCES

Abbott, J.G.
1982: Structure and stratigraphy of the Macmillan Fold Belt: evidence for Devonian faulting. *In* Yukon Geology and Exploration 1981; Department of Indian Affairs and Northern Development (Canada), Open File Report, 16 p.

Abbott, J.G., Gordey, S.P., and Tempelman-Kluit, D.J.
1986: Setting of stratiform, sediment-hosted lead-zinc deposits in Yukon and northeastern British Columbia. *In* Mineral Deposits of northern Canadian Cordillera, J.A. Morin (ed.); Canadian Institute of Mining and Metallurgy, Special Volume 37, p. 1-18.

Abbott, J.G. and Turner, R.J.W.
1990: Character and paleotectonic setting of Devonian stratiform-hosted Zn-Pb-barite deposits, Macmillan Fold Belt, Yukon. *In* Mineral Deposits of the Northern Canadian Cordillera, Yukon–Northeastern British Columbia (Field Trip 14), J.G. Abbott and R.J.W. Turner (eds.); Geological Survey of Canada, Open File 2169, p. 99-136.

Dawson, K.M. and Orchard, M.J.
1982: Regional metallogeny of the northern Cordillera: biostratigraphy, correlation and metallogenic significance of bedded barite occurrences in eastern Yukon and western District of Mackenzie. *In* Current Research, Part C, Geological Survey of Canada, Paper 82-1C, p. 31-38.

Gabrielse, H.
1985: Major dextral displacements along Northern Rocky Mountain Trench and related lineaments in north-central British Columbia. Geological Society of America, Bulletin, v. 960, p. 1-14.

Gordey, S.P.
1989: Devono-Mississippian clastic sedimentation and tectonism in the Canadian Cordilleran miogeocline. *In* Devonian of the World, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, p. 1-14 (imprint date 1988).
in press: Evolution of the northern Cordilleràn miogeocline, Nahanni map area (105I), Yukon and Northwest Territories. Geological Survey of Canada, Memoir 428.

Gordey, S.P., Abbott, J.G., and Orchard, M.J.
1982: Devono-Mississippian (Earn Group) and younger strata in east-central Yukon. *In* Current Research, Part B, Geological Survey of Canada, Paper 82-1B, p. 93-100.

Gordey, S.P., Abbott, J.G., Tempelman-Kluit, D.J., and Gabrielse, H.
1987: "Antler" clastics in the Canadian Cordillera. Geology, v. 15, p. 103-107.

Irwin, S.E.B. and Orchard, M.J.
1989: Conodont biostratigraphy and constraints on Upper Devonian mineral deposits in the Earn Group, northern British Columbia and Yukon. *In* Current Research, Part E, Geological Survey of Canada, Paper 89-1E, p. 13-19.

Jefferson, C.W., Kilby, D.B., Pigage, L.C., and Roberts, W.J.
1983: The cirque barite-lead-zinc deposits, northeastern British Columbia. *In* Sediment-hosted Stratiform Lead–Zinc Deposits, D.F. Sangster (ed.); Mineralogical Association of Canada, Short Course Notes, v. 9, p. 121-140.

Johnson, J.G.
1990: Lower and Middle Devonian brachiopod-dominated communities of Nevada, and their position in a biofacies-province-realm model. Appendix 3, revisions of Middle Devonian conodont zones, G. Klapper and J.G. Johnson. Journal of Paleontology, v. 64, no. 6, p. 934-936 and 941.

Klapper, G.
1989: The Montagne Noire Frasnian (Upper Devonian) conodont succession. *In* Devonian of the World, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, p. 449-468 (imprint date 1988).

Klapper, G. and Lane, H.R.
1989: Frasnian (Upper Devonian) conodont sequence at Luscar Mountain and Mount Haultain, Alberta Rocky Mountains. *In* Devonian of the World, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, p. 469-478 (imprint date 1988).

Klapper, R.C. and Ziegler, W.
1979: Devonian conodont biostratigraphy. *In* The Devonian System, Special Papers in Paleontology 23, p. 199-224.

Lane, H.R., Sandberg, C.A., and Ziegler, W.
1980: Taxonomy and phylogeny of some Lower Carboniferous conodonts and preliminary standard post-*Siphonodella* zonation. Geologica et Palaeontologica, v. 14, p. 177-164.

McClay, K.R. and Insley, M.W.
1986: Structure and stratigraphy of the Gataga fold and thrust belt, northeastern British Columbia. *In* Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 259-264.

McClay, K.R., Insley, M.W., Way, N.A., and Anderton, R.
1988: Tectonics and mineralization of the Kechika Trough, Gataga area, northeastern British Columbia. *In* Current Research, Part E, Geological Survey of Canada, Paper 88-1E, p. 1-12.

Monger, J.W.H. and Berg, H.C.
1984: Lithotectonic terrane map of western Canada and southeastern Alaska. *In* Lithotectonic Terrane Maps of North American Cordillera, N.J. Silbering and D.L. Jones (eds.); United States Geological Survey, Open File Report 84-523.

Müller, K.J.
1956: Zur Kenntnis der Conodonten-Fauna des europäischen Devons 1. Die Gattung Palmatolepis. Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft, v. 494, p. 1-77.

Nelson, J. and Bradford, J.
1987: Geology of the area around the Midway deposit, northern British Columbia (104 O/16). *In* Geological Fieldwork, 1986, British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1987-1, p. 181-192.

Orchard, M.J.
1989: Conodonts from the Frasnian–Famennian boundary interval in western Canada. *In* Devonian of the World, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.); Canadian Society of Petroleum Geologists, Memoir 14, p. 35-52 (imprint date 1988).

Orchard, M.J. and Irwin, S.E.B.
1988: Conodont biostratigraphy, Midway property, northern British Columbia (104 O/16). *In* Geological Fieldwork, 1987, British Columbia Ministry of Energy, Mines and Petroleum Resources, Paper 1988-1, p. 249-253.

Ovnatanova, N.S.
1976: New Late Devonian conodonts of the Russian Platform. Paleontology Journal, v. 10, p. 210-219.

Sandberg, C.A. and Ziegler, W.
1973: Refinement of standard Upper Devonian conodont zonation based on sections in Nevada and West Germany. Geologica et Palaeontologica, v. 7, p. 97-122.
1976: Working zonation and refined speciation of *Siphonodella* (Conodonta, Upper Devonian and Lower Carboniferous). Geological Society of America, Abstracts with Programs, no. 8, v. 4, p. 506-507.
1979: Taxonomy and biofacies of important conodonts of Late Devonian *styriacus*-Zone, United States and Germany. Geologica et Palaeontologica, v. 13, p. 173-212.

Sandberg, C.A., Ziegler, W., and Bultynck, P.
1989: New standard conodont zones and early *Ancyrodella* phylogeny across the Middle–Upper Devonian boundary. *In* W. Ziegler (ed.); Courier Forschungsinstitut Senckenberg 110, p. 195-230.

Sandberg, C.A., Ziegler, W., Dreesen, R., and Butler, J.L.
1988: Late Frasnian mass extinction: conodont event stratigraphy, global changes, and possible causes. *In* 1st International Senckenberg Conference and 5th European Conodont Symposium (ECOS V) Contributions 1, W. Ziegler (ed.); Courier Forschungsinstitut Senckenberg 102, p. 263-307.

Sandberg, C.A., Ziegler, W., Leuteritz, K., and Brill, S.M.
1978: Phylogeny, speciation, and zonation of *Siphonodella* (Conodonta, Upper Devonian and Lower Carboniferous). Newsletters on Stratigraphy, no. 7, p. 102-120.

Taylor, G.C. and Stott, D.F.
1973: Tuchodi Lakes map-area, British Columbia. Geological Survey of Canada, Memoir 373, 37 p.

Ziegler, W.
1962: Taxonomie und Phylogenie Oberdevonischer Conodonten und ihre stratigraphische Bedeutung. Hessisches Landesamt für Bodenforschung, Abhandlungen 38, 166 p.
1971: Conodont stratigraphy of the European Devonian. *In* Symposium on Conodont Biostratigraphy, W.C. Sweet and S.M. Bergstrom (eds.); Geological Society of America, Memoir 127, p. 227-284.
1977(ed): Catalogue of Conodonts. E. Schweizerbart'sche Verlagsbuchhandlung, v. III, 574 p.

Ziegler, W. and Huddle, J.W.
1969: Die *Palmatolepis glabra*–Gruppe (Conodonta) nach der Revision der Typen von Ulrich & Bassler durch J.W. Huddle. Forschungs Geologie Rheinland Westfalien, v. 16, p. 377-386.

Ziegler, W. and Klapper, G.
1982: The *disparilis* conodont Zone, the proposed level for the Middle–Upper Devonian boundary. *In* Courier Forschungsinstitut Senckenberg, W. Ziegler and R. Werner (eds.); Devonian Series Boundaries: Results of World-wide Studies, no. 5, p. 463-492.

Ziegler, W., Klapper, G., and Johnson, L.
1976: Redefinition and subdivision of the *varcus* Zone (conodonts, Middle–?Upper Devonian) in Europe and North America. Geologica et Palaeontologica, no. 10, p. 109-140.

Ziegler, W. and Sandberg, C.A.
1984: *Palmatolepis*-based revision of the upper part of the standard Late Devonian conodont zonation. *In* Conodont Biofacies and Provincialism, Geological Society of America, Special Paper 196, D.L. Clark (ed.); p. 179-194.
1990: The Late Devonian standard conodont zonation. Courier Forschungsinstitut Senckenberg, no. 121, 115 p.

APPENDIX

Locality register

Latitude, longitude, location, collector with field number, National Topographic Map sheet number, stratigraphic unit, and age are given for each GSC locality number mentioned in the text. All collections are from the Earn Group and have a CAI value of 5, unless stated otherwise.

Macmillan Pass

Nahanni map area

GSC loc. C-087542. 62°24′N, 128°30′W; GHMS claims. K.M. Dawson, 1980; DY 1772. NTS 105 I. Portrait Lake fm. Age: Eifelian to early Frasnian.

GSC loc. C-087697. 62°24′N, 128°30′W; GHMS claims. K.M. Dawson, 1981; DY1985. NTS: 105 I/7-8. Portrait Lake fm. Age: Eifelian to early Frasnian.

GSC loc. C-087543. 62°24′N, 128°30′W; GMHS claims. K.M. Dawson, 1980; DY 1777. NTS 105 I/7-8. Portrait Lake fm. Age: Upper *falsiovalis* Zone through Lower *hassi* Zone.

Niddery Lake map area

GSC loc. C-087544. 63°16′N, 130°34′W; Cathy property. K.M. Dawson, 1980; 80-DY-1790. NTS: 105 O/7. Age: Eifelian to early Frasnian.

GSC loc. C-087545. 63°16.5′N, 130°34′W; Cathy property. K.M. Dawson, 1980; 80-DY-1792. NTS: 105 O/7. Age: Eifelian to early Frasnian.

GSC loc. C-087560. 63°08.5′N, 130°01.0′W; Central Block; 11 km at 177° from Macmillan Pass. J.G. Abbott, 1981; 81-TOA-41-811.5m. NTS: 105 O/1. Portrait Lake fm. Age: *rhenana* Zone.

GSC loc. C-087562. 63°38.4′N, 130°02.8′W; S.P. Gordey, 1981; 81-GGA-31A-75m. NTS: 105 O. Portrait Lake fm. Age: Upper *triangularis* Zone through Upper *crepida* Zone.

GSC loc. C-087686. 63°14.3′N, 131°31.0′W; Central Block; 24 km at 270° from Macmillan Pass. J.G. Abbott, 1981; 81-TOA-20-8. NTS: 105 O/2. Age: Eifelian to early Frasnian.

GSC loc. C-087691. 63°16.5′N, 130°33′W; Cathy property. K.M. Dawson, 1981; 81-DY-1943. NTS: 105 O/7. Age: Eifelian to early Frasnian.

GSC loc. C-087700. 63°02′N, 130°06′W; Pete claim. K.M. Dawson, 1981; 81-DY-1832. NTS: 105 O/1. Age: *rhenana* Zone.

GSC loc. C-089929. 63°15.3′N, 130°55.8′W; S Block; 30 km at 276 (272?)° from Macmillan Pass. J.G. Abbott, 1982; 82-TOA-11-357m. NTS: 105 O/2. Portrait Lake fm. Age: Lower *rhomboidea* Zone.

GSC loc. C-089930. 63°15.1′N, 130°55.8′W; S Block; 50 (30?) km at 272° from MacMillan Pass. J.G. Abbott, 1982; 82-TOA-11-483m. NTS 105 O. Tsichu fm. Age: early–middle Tournaisian.

GSC loc. C-102281. 63°17′N, 130°47′W; N Block?; 41.5 km at 277° from Macmillan Pass. J.G. Abbott, 1981, 81-TOA-12-6. NTS: 105 O/7. Portrait Lake fm. Age: *rhenana* Zone.

GSC loc. C-102340. 63°04.5′N, 130°17.5′W; S Block; 22.5 km at 215° from Macmillan Pass. J.G. Abbott, 1981; 81-TOA-48-1. NTS: 105 O/1. Portrait Lake fm. Age: Upper *rhenana* Zone to *linguiformis* Zone.

GSC loc. C-102342. 63°04.5′N, 130°14.5′W; S Block; 21.5 km at 211° from Macmillan Pass. J.G. Abbott, 1981; 81-TOA-50-2. NTS: 105 O/1. Portrait Lake fm. Age: Upper *rhenana* Zone to *linguiformis* Zone.

GSC loc. C-108159. 63°15.5′N, 130°28.0′W; 22 km at 275° from Macmillan Pass. J.G. Abbott, 1983; 83-TOA-15-2. NTS: 105 O/1. Portrait Lake fm. Age: possibly Upper through Uppermost *marginifera* Zone.

GSC loc. C-108160. 63°15.5′N, 130°55.0′W; 45 km at 272° from Macmillan Pass. J.G. Abbott, 1983; 83-TOA-17-1. NTS: 105 O/2. Portrait Lake fm. Age: Lower *rhomboidea* Zone.

GSC loc. C-108161. 63°15.3′N, 130°55.0′W; 50 km at 272° from MacMillan Pass. J.G. Abbott, 1982, 82-TOA-17-2. NTS: 105 O. Tsichu fm. Age: early–middle Tournaisian.

GSC loc. C-118032. 63°07′N, 130°09′W; Macmillan Pass, above TOM o/c. K.M. McClay, 1984; 84-MJO-MM-3. NTS: 105 O. Age: *jamieae* through Lower *rhenana* zones.

GSC loc. C-118033. 63°07′N, 130°09′W; Macmillan Pass. Ridge 3 km east of Niddery Camp. K.M. McClay, 1984; 84-MJO-MM-4. NTS: 105 O. Age: upper Lower *hassi* through Lower *rhenana* Zone.

GSC loc. C-118034. 63°07′N, 130°09′W; Macmillan Pass. K.M. McClay, 1984; 84-MJO-MM-5. NTS: 105 O. Age: Upper *hassi* through *rhenana* zones.

GSC loc. C-086426. 63°01′30N, 130°36′30W; Tea barite. I.R. Jonasson/J.W. Lydon, 1979; TE-03005101. NTS: 105 O. Tsichu fm. Age: Tournaisian.

GSC loc. C-089975. 63°01.5′N, 130°37.0′W; S Block; 38 km at 231° from MacMillan Pass. J.G. Abbott, 1982; 82-TOA-53-2. NTS: 105 O/2. Tsichu fm. Age: late Tournaisian.

GSC loc. C-087685. 63°15.3′N, 130°28.5′W; 21.5 km at 276° from Macmillan Pass, north block. J.G. Abbott, 1981; 81-TOA-11-8. NTS: 105 O/1. Portrait Lake fm. Age: Lower *marginifera* Zone.

GSC loc. C-087558. 63°36.6′N, 129°39.4′W; Jeff claim. S.P. Gordey, 1981; 81-GGA-36A1/A2. NTS: 105 P/12. Portrait Lake fm. Age: *rhenana* Zone.

GSC loc. C-108152. 63°11.3′N, 130°17.3′W; 49 km at 277° from MacMillan Pass. J.G. Abbott, 1983; 83-TOA-4-5-343m. NTS: 105 O. Tsichu fm. Age: late Tournaisian.

Glenlyon map area

GSC loc. C-150031. 62°46.79′N, 134°24.88′W; South of Earn Lake. S.P. Gordey, 1986, 86GGAI-77E1. NTS: 105 L. Kalzas Fm. Age: Tournaisian.

GSC loc. C-102600. 62°54.95′N, 134°37.58′W; S.P. Gordey, 1982; 82GGA-59A1. NTS: 105 L/15. Kalzas Fm. Age: late Tournaisian.

Sekwi Mountain map area

GSC loc. C-087563. 63°01.5′N, 129°51.0′W. J.G. Abbott, 1981; 81-TOA-40-2. NTS: 105 P/4. Tsichu fm. Age: late Tournaisian.

Midway

Watson Lake map area

GSC loc. C-086357. 60°32′N, 129°00′W; 6 km west of Mount Hundere (elevation 1579 m). J.G. Abbott, 1973; TOA73-56b. NTS: 105 A. Age: late Givetian through middle Frasnian.

Cry Lake map area

GSC loc. C-088250. 58°46′10N, 128°24′40W; 24 km east of north arm of Cry Lake, 4.8 km at 274° from the southwest end of Blue Sheep Lake, Harm's collection site No. 2. T. Harms, 1983; 83-GAH-72F. NTS: 104 I/16. McDame Group. Age: Upper *falsiovalis* Zone through *punctata* Zone.

GSC loc. C-103232. 58°55′45N, 128°29′20W; 15 km east of Rapid River, unnumbered Harm's collection site, 13.9 km at 263° from junction of Ramhorn Creek and Major Hart River. T. Harms, 1983; 83-GAH-80bF. NTS: 104 I/16. Age: *punctata* Zone into Lower *rhenana* Zone.

GSC loc. C-103233. 58°55′30N, 128°29′50W; 15 km east of Rapid river, 13.9 km at 262° from junction of Ramhorn Creek and Major Hart River. T. Harms, 1983; 83-GAH-81aF. NTS: 104 I/16. Earn Group. Age: early–middle Tournasian.

Jennings River map area

GSC loc. C-118256. 59°55′N, 130°20′W; Discovery area, Midway deposit, 7 km east-northeast of east end of Tootsee Lake between Tootsee and Little Rancheria rivers, (DDH 83-28). W. Jakubowski, 1984; 84MJO-83-28-1AC. NTS: 104 O/16. Age: Upper through Uppermost *crepida* Zone.

GSC loc. C-143101. 59°50′04N, 130°19′36W; southeast of Donegal Mtn. J. Nelson, 1986; 86-JN-03-06-01A. NTS: 104 O/16. McDame Group? Age: *transitans* Zone through *hassi* Zone.

GSC loc. C-143102. 59°59′09N, 130°10′31W; Perry Barite. J. Nelson, 1986, 86JN-05-08. NTS: 104 O/16. Age: early–middle Tournaisian.

GSC loc. C-157905. 59°55′47.1N, 130°20′0.1W; Midway Drill Core 28. S. Irwin, 1987; 87-OF-SI-28-1. NTS: 104 O/16. Age: Upper through Uppermost *crepida* Zone.

GSC loc. C-157906. 59°55′47.1N, 130°20′0.1W; Midway Drill Core 28. S. Irwin, 1987; 87-OF-SI-28-2. NTS: 104 O/16. Age: Uppermost *crepida* Zone.

GSC loc. C-157907. 59°55′47.1N, 130°20′0.1W; Midway Drill Hole 28. S. Irwin, 1987; 87-OF-SI-28-3. NTS: 104 O/16. Age: Upper through Uppermost *crepida* Zone.

GSC loc. C-157908. 59°55′47.1N, 130°20′0.1W; Midway Drill Hole 28. S. Irwin, 1987; 87-OF-SI-28-4. NTS: 104 O/16. Age: Uppermost *crepida* zones.

GSC loc. C-157909. 59°55′47.1N, 130°20′0.1W; Midway Drill Hole 28. S. Irwin, 1987; 87-OF-SI-28-5. NTS: 104 O/16. Age: Uppermost *crepida* Zone.

GSC loc. C-157910. 59°55′47.1N, 130°20′0.1W; Midway Drill Hole 28. S. Irwin, 1987; 87-OF-SI-28-6. NTS: 104 O/16. Age: Uppermost *crepida* Zone.

GSC loc. C-157928. 59°55′42.0N, 130°19′32.4W; Midway Drill Hole 34. S. Irwin, 1987; 87-OF-SI-34-2. NTS: 104 O/16. Age: *rhomboidea* Zone.

GSC loc. C-157929. 59°55′42.0N, 130°19′32.4W; Midway Drill Hole 34. S. Irwin, 1987; 87-OF-SI-34-3. NTS: 104 O/16. Age: Uppermost *crepida* Zone.

GSC loc. C-157938. 59°55′6.8N, 130°19′18.0W; Midway Drill Hole 41. S. Irwin, 1987; 87-OF-SI-41-1. NTS: 104 O/16. Age: *marginifera* Zone.

GSC loc. C-087737. 59°59′N, 130°14′W; 16 km at 050° from the end of Tootsee Lake. B. Hall, 1982; 82MJO-BVH2. NTS 104 O/16. Earn Group. Age: Tournaisian.

Gataga

Ware map area

GSC loc. C-102892. 57°05′52N, 124°33′22W; 0.5 km southwest of Earn showing. D. MacIntyre, 1981; M81-093. NTS: 94 F/2. Age: Lower *falsiovalis* Zone into *punctata* Zone.

GSC loc. C-176654. 57°24′N, 124°54′W; Fluke property. M. Insley, 1989; LF-69, F4. NTS: 94 F/7. Age: *postera* Zone to *expansa* Zone.

GSC loc. C-176655. 57°24′N, 124°54′W; Fluke property. M. Insley, 1989; LF-69, F5. NTS: 94 F/7. Age: *postera* Zone to *expansa* Zone.

GSC loc. C-116659. 57°58′N, 125°50′W; Gataga-Driftpile, TS 462. K.M. McClay, 1986; 86-OFM-G74. NTS: 94 F/13. "Gunsteel fm.". Age: Lower *rhenana* Zone.

GSC loc. C-116914. 57°58′N, 125°45′W; Gataga-Driftpile. TS 268, 1845 m elevation. K.M. McClay, 1986; 86-OFM-G64. NTS: 94 F. "Gunsteel fm.". Age: upper Lower *marginifera* Zone through lower Upper *marginifera* Zone.

GSC loc. C-102891. 57°40′.5N, 125°03.5′W; 9 km north of Kwadacha River. D. MacIntyre, 1981; M81-032. NTS: 94 F/11. "Gunsteel fm.". Age: Upper *falsiovalis* through Lower *hassi* Zone.

GSC loc. C-102874. 57°40′.75N, 124°53′W; 4 km south-southwest of Fern Peak. D. MacIntyre, 1981; M81-005. NTS: 94 F/10. McDame Group. Age: *falsiovalis* Zone.

Kechika map area

GSC loc. C-116673. 58°16′N, 126°12′W; Gataga-Driftpile, R312, 1870 m elevation. K.M. McClay, 1986; 86-OFM-G88. NTS: 94 L/8. "Gunsteel fm.". Age: Upper *hassi* through *jamieae* zones.

GSC loc. C-118902. 58°06′N, 126°00′W; Gataga-Driftpile, TP 51. K.M. McClay, 1985; 85-OFM-20. NTS: 94 K/1. "Gunsteel fm.". Age: Lower *rhenana* Zone.

GSC loc. C-118880. 58°06′N, 126°09′W; Gataga-Driftpile. o/c 605. K.M. McClay, 1985; 85-OFM-58. NTS: 94 L/1. "Gunsteel fm.". Age: *crepida* Zone.

Tuchodi Lakes map area

GSC loc. C-116697. 58°04′N, 125°54′W; Gataga-Driftpile. DDH 80-37. K.M. McClay, 1986; 86-OFM-G112. NTS: 94 K/4. "Gunsteel fm.". Age: Lower through Upper *marginifera* Zone.

GSC loc. C-116719. 58°04′N, 125°54′W; Gataga-Driftpile. DDH 80-35. K.M. McClay, 1986; 86-OFM-G132. NTS: 94 K/4. "Gunsteel fm.". Age: Lower *rhomboidea* Zone.

GSC loc. C-116724. 58°04′N, 125°54′W; Gataga-Driftpile. DDH 80-38. K.M. McClay, 1986; 86-OFM-G137. NTS: 94 K/4. "Gunsteel fm.". Age: Lower *marginifera* Zone.

GSC loc. C-116730. 58°03′N, 125°52′W; Gataga-Driftpile. TS-1339, 1475 m elevation. K.M. McClay, 1986; 86-OFM-G143. NTS: 94 K/4. "Gunsteel fm.". Age: upper Lower *marginifera* Zone–lower Upper *marginifera* Zone boundary.

GSC loc. C-116956. 58°04′15N, 125°54′W; Gataga-Driftpile. DDM 79-30. K.M. McClay, 1986; 86-OFM-G6. NTS: 94 K/4. "Gunsteel fm.". Age: upper Upper *rhomboidea* Zone through lower Lower *marginifera* Zone.

GSC loc. C-176684. 58°06′N, 125°56′W; Gataga-Driftpile. TS 1203, 1345 m elevation. K.M. McClay, 1986; 86-OFM-G99. NTS: 94 K/4. Age: *postera* Zone to *expansa* Zone.

GSC loc. C-118539. 58°07′N, 125°57′W; Gataga-Driftpile. DP 288. K.M. McClay, 1985; 85-OFM-7. NTS: 94 K/4. Age: upper Lower *marginifera* through lower Upper *marginifera* Zone.

GSC loc. C-118884. 58°02′N, 125°55′W; Gataga-Driftpile. FC 461. Limestone in Barite Creek Gataga Project. K.M. McClay, 1985; 85-OFM-62. NTS: 94 K. Age: upper Lower *marginifera* Zone through lower Upper *marginifera* Zone.

GSC loc. C-118907. 58°07′N, 125°56′W; Gataga-Driftpile. DP 347. K.M. McClay, 1985; 85-OFM-25. NTS: 94 K/4. Age: upper Lower *marginifera* Zone through lower Upper *marginifera* Zone.

GSC loc. C-118923. 58°07′N, 125°58′W; Gataga-Driftpile. TP 158. K.M. McClay, 1985; 85-OFM-41. NTS: 94 K/4. Age: upper Lower through lower Upper *marginifera* Zone.

GSC loc. C-118924. 58°04′N, 125°53′00W; Gataga-Driftpile. FC 360. K.M. McClay, 1985; 85-OFM-42. NTS: 94 K/4. Age: upper Lower *marginifera* Zone – lower Upper *marginifera* Zone.

GSC loc. C-116997. 58°04′N, 125°54′W; Gataga-Driftpile. DDH 82-52. K.M. McClay, 1986; 86-OFM-G46. NTS: 94 K/4. "Gunsteel fm.". Age: middle Upper *crepida* Zone through Upper *trachytera* Zone.

GSC loc. C-116958. 58°04.25′N, 125°54′W; Gataga-Driftpile. DDM 79-30. K.M. McClay, 1986; 86-OFM-G8. NTS: 94 K/4. "Gunsteel fm.". Age: Upper *marginifera* Zone.

GSC loc. C-118892. 58°02′N, 125°55′W; Gataga-Driftpile. o/c 895. Mount Waldemar ridge. K.M. McClay, 1985; 85-OFM-70. NTS: 94 K. "Gunsteel fm.". Age: Middle *crepida* Zone.

GSC loc. C-118917. 58°08′N, 125°58′W; Gataga-Driftpile. DP 528. K.M. McClay, 1985; 85-OFM-35. NTS: 94 K/4. "Gunsteel fm.". Age: Uppermost *crepida* Zone into Lower *rhomboidea* Zone.

GSC loc. C-118892. 58°02′N, 125°55′W; Gataga-Driftpile. o/c 895. Mount Waldemar ridge. K.M. McClay, 1985; 85-OFM-70. NTS: 94 K. "Gunsteel fm.". Age: Middle *crepida* Zone.

GSC loc. C-118903. 58°06′N, 125°57′W; Gataga-Driftpile, FC-89a, flycamp 2. K.M. McClay, 1985; 85-OFM-21. NTS: 94 K/4. "Gunsteel fm.". Age: Lower *rhenana* Zone.

PLATE 1

All specimens are from the Earn Group, except where noted.

Figures 1, 2, 11, 12. *Mesotaxis asymmetrica* (Bischoff and Ziegler).

1, 2. Upper and lower views, hypotype GSC 101329, x65, GSC loc. C-102891, Gataga.
11, 12. Lower and upper views, hypotype GSC 101397, x50, GSC loc. C-087543, Macmillan Pass.

Figures 3, 4. *Klapperina disparalvea* Orr and Klapper.

Lower and upper views, hypotype GSC 101330, x50, GSC loc. C-102874, McDame Group, Gataga.

Figures 5, 6. *Mesotaxis falsiovalis* Sandberg, Ziegler, and Bultynck.

Upper and lower views, hypotype GSC 101331, x90, GSC loc. C-102891, Gataga.

Figures 7, 8. *Klapperina ovalis* (Ziegler and Klapper).

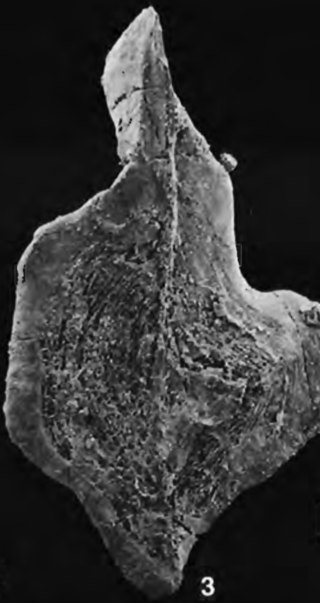
Lower and upper views, hypotype GSC 81212, x50, GSC loc. C-102891, Gataga.

Figures 9, 10. *Klapperina disparilis* (Ziegler and Klapper).

Upper and lower views, hypotype GSC 101332, x50, GSC loc. C-102874, McDame Group, Gataga.


1


2


3


4


5


6


7


8


9


10


11

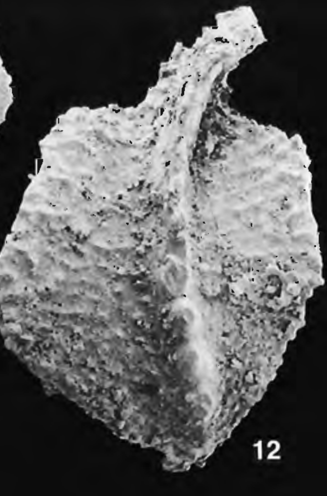

12

PLATE 2

All specimens are from the Earn Group.

Figures 1, 4. *Palmatolepis redana* n. sp.

1. Upper view, stereo-pair of holotype, GSC 101333, x60, GSC loc. C-118034, Macmillan Pass.
4. Left lateral view at a 45° tilt of specimen in figure 1, x60, GSC loc. C-118034, Macmillan Pass.

Figure 2. *Ancyrodella* sp. aff. *A. binodosa* Uyeno.
Upper view, figured specimen GSC 101334, x50, GSC loc. C-088250, Midway.

Figure 3. *Palmatolepis plana* Ziegler and Sandberg.
Upper view, hypotype GSC 101335, x80, GSC loc. C-116659, Gataga.

Figure 5. *Palmatolepis* sp. aff. *P. transitans* Müller.
Upper view, figured specimen GSC 101336, x60, GSC loc. C-102891, Gataga.

Figure 6. *Palmatolepis ederi* Ziegler and Sandberg.
Upper view, hypotype GSC 101337, x90, GSC loc. C-118033, Macmillan Pass.

Figure 7. *Palmatolepis transitans* Müller.
Upper view, hypotype GSC 101338, x60, GSC loc. C-102891, Gataga.

Figure 8. *Palmatolepis triangularis* Sannemann.
Upper view, hypotype GSC 81165, x40, GSC loc. C-118892, Gataga.

Figure 9. *Palmatolepis punctata* (Hinde).
Upper view, hypotype GSC 101339, x60, GSC loc. C-087700, Macmillan Pass.

Figure 10. *Palmatolepis* sp. cf. *P. rotunda* Ziegler and Sandberg.
Upper view, figured specimen GSC 101340, x70, GSC loc. C-103232, Midway.

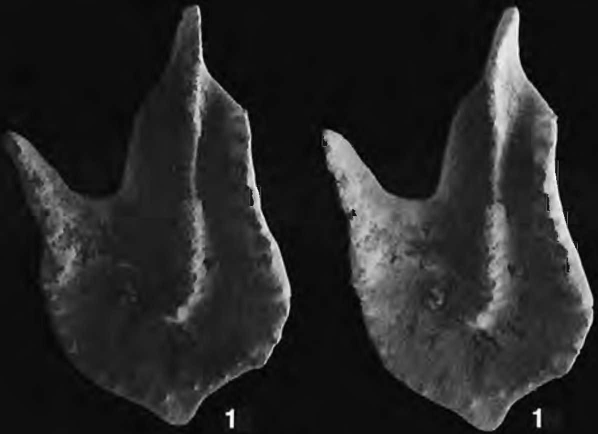
Figure 11. *Palmatolepis hassi* Müller and Müller.
Upper view, hypotype GSC 101341, x40, GSC loc. C-118903, Gataga.

Figure 12. *Palmatolepis* sp. aff. *P. domanicencis* Ovnatanova.
Upper view, figured specimen GSC 101342, x70, GSC loc. C-116673, Gataga.

Figure 13. *Palmatolepis foliacea* Youngquist.
Upper view, hypotype GSC 101343, x60, GSC loc. C-102281, Macmillan Pass.

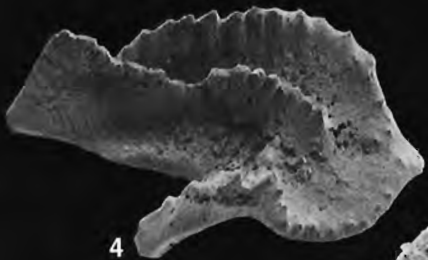
Figure 14. *Palmatolepis proversa* Ziegler.
Upper view, hypotype GSC 101344, x50, GSC loc. C-118902, Gataga.

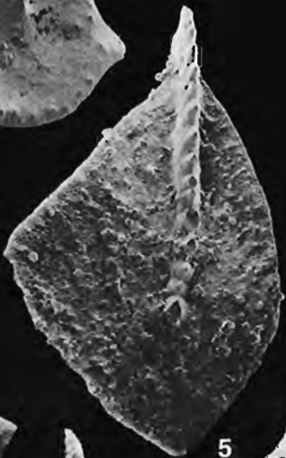
Figure 15. *Palmatolepis crepida* Sannemann.
Upper view, hypotype GSC 81173, x50, GSC loc. C-118892, Gataga.

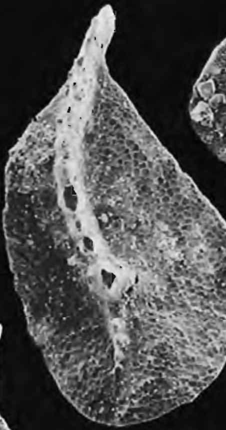

1


2


3

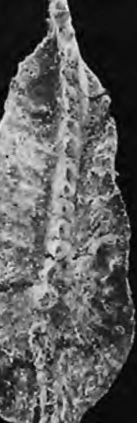

4

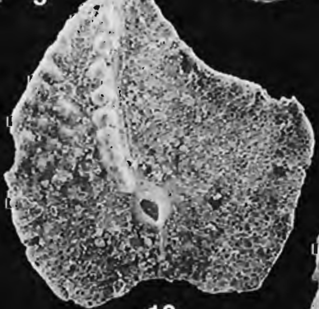

5


6

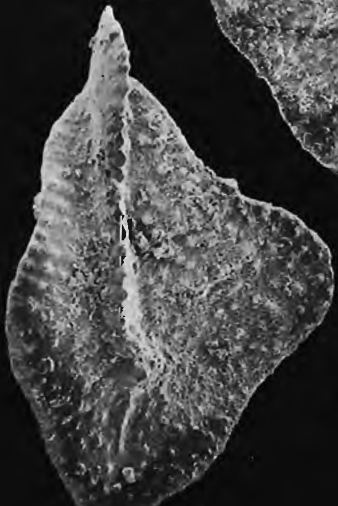

7

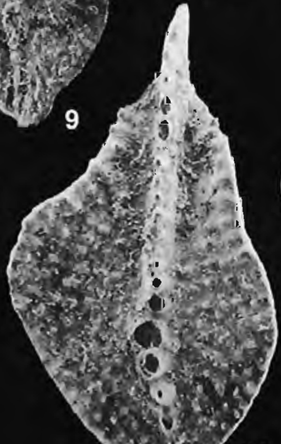

8


9


10


11


12


13


14


15

PLATE 3

All specimens are from the Earn Group.

Figure 1. *Palmatolepis rhenana nasuta* Müller.
Upper view, hypotype GSC 81215, x50, GSC loc. C-087558, Macmillan Pass.

Figure 2. *Palmatolepis rhenana rhenana* Bischoff.
Upper view, hypotype GSC 101345, x45, GSC loc. C-102342, Macmillan Pass.

Figure 3. *Palmatolepis subperlobata* subsp. A Helms.
Upper view, hypotype GSC 101346, x70, GSC loc. C-087562, Macmillan Pass.

Figure 4. *Palmatolepis subperlobata* Branson and Mehl.
Upper view, hypotype GSC 101347, x60, GSC loc. C-118880, Gataga.

Figure 5. *Palmatolepis rhenana* subsp. indet.
Upper view, figured specimen GSC 101348, x50, GSC loc. C-102340, Macmillan Pass.

Figure 6. *Palmatolepis rhomboidea* Sannemann.
Upper view, hypotype GSC 101349, x90, GSC loc. C-116719, Gataga.

Figure 7. *Palmatolepis wolskajae* Ovnatanova.
Upper view, hypotype GSC 81168, x60, GSC loc. C-087562, Macmillan Pass.

Figure 8. *Palmatolepis stoppeli* Sandberg and Ziegler.
Upper view, hypotype GSC 101350, x80, GSC loc. C-108160, Macmillan Pass.

Figure 9. *Palmatolepis poolei* Sandberg and Ziegler.
Upper view, hypotype GSC 101351, x60, GSC loc. C-108160, Macmillan Pass.

Figure 10. *Palmatolepis quadrantinodosalobata* Sannemann Morphotype 1 Sandberg and Ziegler.
Upper view, hypotype GSC 101352, x70, GSC loc. C-087562, Macmillan Pass.

Figure 11. *Palmatolepis subrecta* Miller and Youngquist.
Upper view, hypotype GSC 101353, x60, GSC loc. C-102340, Macmillan Pass.

Figure 12. *Palmatolepis quadrantinodosa quincea* n. subsp.
Upper view, holotype GSC 101354, x60, GSC loc. C-116914, Gataga.

Figure 13. *Palmatolepis klapperi* Sandberg and Ziegler.
Upper view, hypotype GSC 101355, x60, GSC loc. C-108160, Macmillan Pass.

Figure 14. *Palmatolepis quadrantinodosalobata* Sannemann.
Upper view, hypotype GSC 101356, x70, GSC loc. C-118917, Gataga.

Figure 15. *Palmatolepis quadrantinodosa inflexa* Ziegler.
Upper view, hypotype GSC 101357, x50, GSC loc. C-087685, Macmillan Pass.

Figure 16. *Palmatolepis* sp. cf. *P. regularis* Cooper.
Upper view, hypotype GSC 101358, x70, GSC loc. C-116684, Gataga.

Figure 17. *Palmatolepis quadrantinodosa inflexoidea* Ziegler.
Upper view, hypotype GSC 101359, x50, GSC loc. C-118924, Gataga.

Figure 18. *Palmatolepis glabra acuta* Helms.
Upper view, hypotype GSC 101360, x50, GSC loc. C-116914, Gataga.

PLATE 3

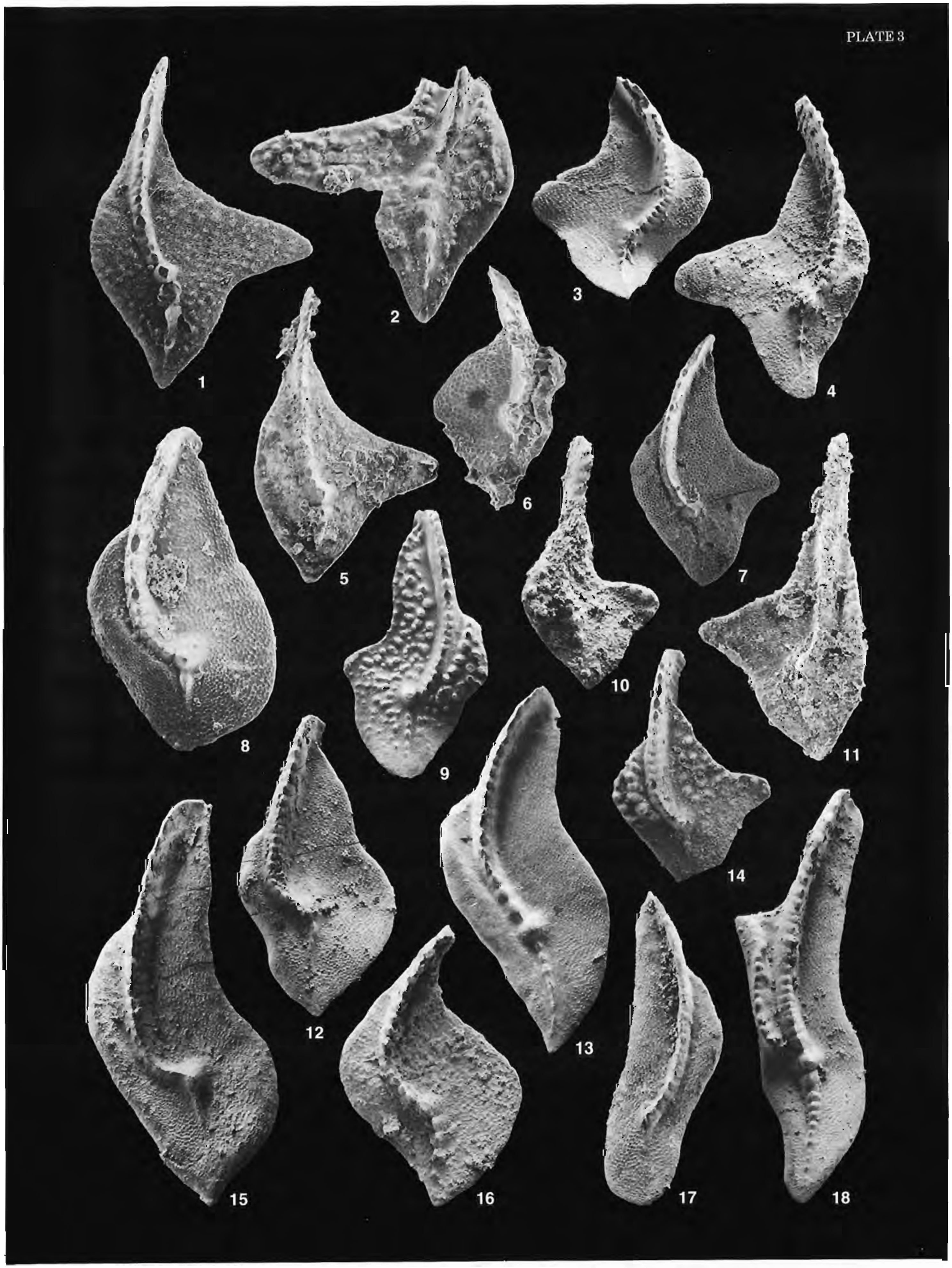


PLATE 4

All specimens are from the Earn Group.

Figure 1. *Palmatolepis glabra lepta* Ziegler and Huddle.
Upper view, hypotype GSC 101361, x40, GSC loc. C-116997, Gataga.

Figure 2. *Palmatolepis glabra lepta* Ziegler and Huddle Morphotype 2.
Upper view, hypotype GSC 101362, x70, GSC loc. C-118924, Gataga.

Figure 3. *Palmatolepis glabra distorta* Branson and Mehl.
Upper view, hypotype GSC 101363, x50, GSC loc. C-108159, Macmillan Pass.

Figure 4. *Palmatolepis glabra lepta* Ziegler and Huddle Morphotype 1.
Upper view, hypotype GSC 101364, x50, GSC loc. C-116697, Gataga.

Figure 5. *Palmatolepis gracilis gracilis* Branson and Mehl.
Upper view, hypotype GSC 101365, x60, GSC loc. C-176654, southern Gataga.

Figure 6. *Palmatolepis glabra pectinata* Ziegler Morphotype 1, Sandberg and Ziegler.
Upper view, hypotype GSC 101366, x65, GSC loc. C-118884, Macmillan Pass.

Figure 7. *Palmatolepis glabra pectinata* Ziegler.
Upper view, hypotype GSC 101367, x50, GSC loc. C-116958, Gataga.

Figure 8. *Palmatolepis marginifera utahensis* Ziegler and Sandberg.
Upper view, hypotype GSC 101368, x60, GSC loc. C-116914, Gataga.

Figures 9, 12. *Palmatolepis marginifera marginifera* Helms.

9. Upper view, hypotype GSC 101369, x60. GSC loc. C-108159, Macmillan Pass.
12. Upper view, hypotype GSC 101370, x60. GSC loc. C-116914, Gataga.

Figure 10. *Palmatolepis clarki* Ziegler.
Upper view, hypotype GSC 101371, x60, GSC loc. C-118892, Gataga.

Figure 11. *Palmatolepis minuta minuta* Branson and Mehl.
Upper view, hypotype GSC 101372, x70, GSC loc. C-118924, Gataga.

Figure 13. *Palmatolepis* sp. aff. *P. rugosa trachytera* Ziegler.
Upper view, figured specimen GSC 101373, x60, GSC loc. C-116697, Gataga.

Figure 14. *Palmatolepis perlobata postera* Müller.
Upper view, hypotype GSC 101374, x60, GSC loc. C-176655, southern Gataga.

Figure 15. *Palmatolepis rugosa trachytera* Ziegler.
Upper view, hypotype GSC 101375, x50, GSC loc. C-108159, Macmillan Pass.

Figure 16. *Palmatolepis perlobata schindewolfi* Müller.
Upper view, hypotype GSC 101376, x50, GSC loc. C-108159, Macmillan Pass.

Figure 17. *Palmatolepis* sp. aff. *P. rugosa ampla* Müller.
Upper view, figured specimen GSC 101377, x60, GSC loc. C-176654, southern Gataga. Specimen is transitional to *P. rugosa rugosa* Branson and Mehl.

Figure 18. *Palmatolepis rugosa ampla* Müller.
Upper view, hypotype GSC 101378, x60, GSC loc. C-176684, southern Gataga.

Figure 19. *Palmatolepis quadrantinodosa quadrantinodosa* Branson and Mehl.
Upper view, hypotype GSC 101379, x60, GSC loc. C-116914, Gataga.

PLATE 4

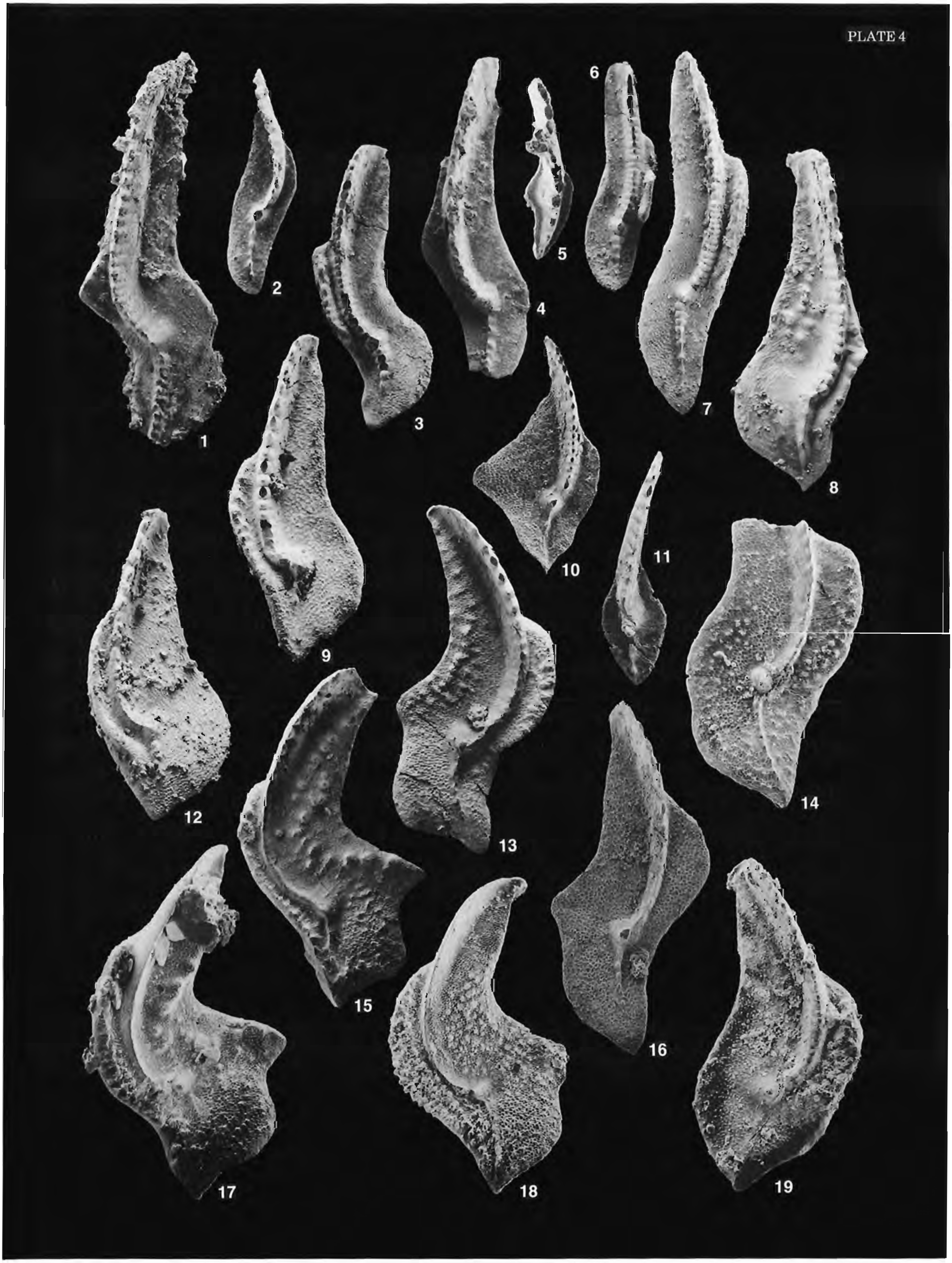


PLATE 5

All specimens are from the Earn Group.

Figure 1. *Geniculatus*? n. sp. A.
Lateral view, figured specimen GSC 101380, x60, GSC loc. C-108152, Macmillan Pass.

Figure 2. *Gnathodus punctatus* (Cooper).
Upper view, hypotype GSC 101381, x60, GSC loc. C-087737, upper Earn Group, Midway.

Figures 3, 9. *Siphonodella crenulata* (Cooper).

3. Upper view, hypotype GSC 101382, x45, GSC loc. C-108161, Macmillan Pass.

9. Upper view, hypotype GSC 101383, x55, GSC loc. C-108161, Macmillan Pass.

Figure 4. *Staurognathus* sp.
Upper view, figured specimen GSC 101384, x60, GSC loc. C-102600, Macmillan Pass.

Figure 5. *Siphonodella cooperi* Hass.
Upper view, hypotype GSC 101385, x50, GSC loc. C-089930, Macmillan Pass.

Figure 6. *Polygnathus communis* Branson and Mehl.
Upper view, hypotype GSC 101386, x60, GSC loc. C-086426, Macmillan Pass.

Figure 7. *Bispathodus aculeatus aculeatus* (Branson and Mehl).
Upper view, hypotype GSC 101387, x90, GSC loc. C-086426, Macmillan Pass.

Figure 8. *Gnathodus semiglaber* (Bischoff).
Upper view, hypotype GSC 101388, x50, GSC loc. C-103233, upper Earn Group, Midway.

Figure 10. *Siphonodella lobata* (Branson and Mehl).
Upper view, hypotype GSC 101389, x35, GSC loc. C-108161, Macmillan Pass.

Figure 11. *Doliognathus latus* Branson and Mehl Morphotype 2 Lane, Sandberg, and Ziegler.
Upper view, hypotype GSC 101390, x60, GSC loc. C-108152, Macmillan Pass.

Figure 12. *Protognathodus praedelicatulus* Lane, Sandberg, and Ziegler.
Upper view, hypotype GSC 101391, x70, GSC loc. C-086426, Macmillan Pass.

Figure 13. *Scaliognathus anchoralis* Branson and Mehl.
Upper view, hypotype GSC 101392, x100, GSC loc. C-089975, Macmillan Pass.

Figure 14. *Siphonodella quadruplicata* (Branson and Mehl).
Upper view, hypotype GSC 101393, x45, GSC loc. C-108161, Macmillan Pass.

Figure 15. *Pseudopolygnathus oxpageus* Morphotype 2 Lane, Sandberg, and Ziegler.
Upper view, hypotype GSC 101394, x60, GSC loc. C-087563, Macmillan Pass.

Figure 16. *Doliognathus dubius* Branson and Mehl.
Upper view, hypotype GSC 101395, x60, GSC loc. C-102600, Macmillan Pass.

Figure 17. *''Hindeodella'' segaformis* Bischoff.
Lateral view, hypotype GSC 101396, x60, GSC loc. C-108152, Macmillan Pass.


1


2


3


4


5

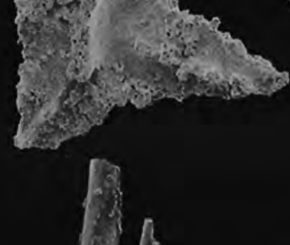

6


7

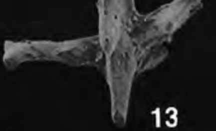

8


9


10


11

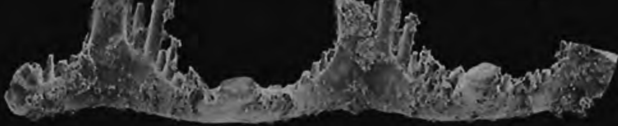

12


13


14


15


16


17

Conodont biostratigraphy and paleoecology of the uppermost Devonian and Carboniferous of the Western Canada Sedimentary Basin

A.C. Higgins[1], B.C. Richards[2], and C.M. Henderson[3]

Higgins, A.C., Richards, B.C., and Henderson, C.J., 1991: Conodont biostratigraphy and paleoecology of the uppermost Devonian and Carboniferous of the Western Canada Sedimentary Basin. In Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417, p. 215-251.

Abstract

A conodont zonation of 18 zones is outlined for the uppermost Devonian and Carboniferous of the Western Canada Sedimentary Basin. The zones are: Devonian Palmatolepis gracilis expansa *and* Siphonodella praesulcata*; Lower Carboniferous* Siphonodella sulcata, S. duplicata, S. sandbergi, *Lower* S. crenulata, *Upper* S. crenulata–S. isosticha, Gnathodus typicus, Scaliognathus anchoralis–Doliognathus latus, Gnathodus texanus, Cavusgnathus, Gnathodus *sp. cf.* G. texanus, G. girtyi collinsoni, G. *g.* simplex, *and* Rhachistognathus muricatus*; and Upper Carboniferous* Rhachistognathus minutus, Streptognathodus oppletus, *and* S. elegantulus? All of these, except the informal Gnathodus *sp. cf.* G. texanus *Zone, introduced here, have been defined elsewhere. The* Siphonodella praesulcata, S. sulcata, *and* S. sandbergi *zones have not been identified with certainty. The Lower Carboniferous* Gnathodus *sp. cf.* G. texanus, G. girtyi collinsoni, G. *g.* simplex *and* Rhachistognathus muricatus *zones, and the Upper Carboniferous zones are reported from the basin for the first time. The Lower Carboniferous conodont zones are correlated with those of foraminifers, corals, and ostracodes to produce a broadly applicable, integrated zonation.*

Many vertical and lateral conodont faunal changes correlate with major lithofacies trends in ramp and platform carbonates. Tournaisian faunas from basin, slope, and outer-shelf-margin lithofacies have the greatest species diversity and show the most rapid vertical changes. Lithofacies-controlled lateral faunal variations in the upper Viséan strata necessitate the use of two zonations: low diversity and long-ranging fauna from protected- and restricted-shelf carbonates are assigned to the broad Cavusgnathus *Zone, whereas those from correlative open-marine deposits are included in the* Gnathodus *sp. cf.* G. texanus *and* G. girtyi collinsoni *zones.*

Résumé

On a déterminé dans le Dévonien sommital et le Carbonifère du bassin sédimentaire de l'Ouest canadien une zonation des conodontes pouvant comprendre jusqu'à 18 zones. Ces zones sont: la zone à Palmatolepis gracilis expansa *du Dévonien et Siphonodella praesulcata; la zone à* Siphonodella sulcata, S. duplicata, S. sandbergi *du Carbonifère inférieur, la zone inférieure à* S. crenulata, *la zone supérieure à* S. crenulata-S. isosticha, Gnathodus typicus, Scaliognathus anchoralis-Doliognathus latus, Gnathodus texanus, Cavusgnathus, Gnathodus *sp. cf.* G. texanus, G. girtyi collinsoni, G. g. simplex *et* Rachistognathus muricatus; *et la zone à* Rachistognatus minutus, Streptognathodus oppletus *et* S. elegantulus*? du Carbonifère supérieur. Toutes ces zones, à l'exception de la zone informelle à* Gnathodus *sp. cf.* G. texanus *présentées pour la première fois ici, ont été définies ailleurs. Les zones à* Siphonodella praesulcata, S. sulcata et S. sandbergi *n'ont pas été identifiées avec certitude. Les zones à* Gnathodus *sp. cf.* G. texanus, G. girtyi

---

[1] BP Research Centre, Sunbury-upon-Thames, Middlesex, United Kingdom TW16 7LN

[2] Geological Survey of Canada, Institute of Sedimentary and Petroleum Geology, 3303 - 33rd Street N.W., Calgary, Alberta T2L 2A7

[3] Department of Geology and Geophysics, University of Calgary, 2500 University Drive N.W., Calgary, Alberta T2N 1N4

collinsoni, G. g. simplex *et* Rachistognathus muricatus *du Carbonifère inférieur, ainsi que des zones du Carbonifère supérieur, ont été signalées dans le bassin de l'Ouest canadien pour la première fois. Les zones à conodontes du Carbonifère inférieur sont corrélées avec les zones à foraminifères, coraux et ostracodes, ce qui permet d'obtenir une zonation intégrée et approximativement applicable à l'ensemble de la région.*

De nombreuses variations verticales et latérales des faunes de conodontes montrent des corrélations avec les grandes directions des lithofaciès dans les carbonates des rampes et plates-formes. Les faunes tournaisiennes des lithofaciès de bassin, de talus continental et de marge de plate-forme externe montrent la plus grande diversité d'espèces et les plus rapides variations verticales. En raison des variations fauniques latérales contrôlées par les lithofaciès dans les strates du Viséen supérieur, il est nécessaire d'employer deux zonations: les faunes peu diverses et de grande longévité qui existent dans les carbonates de plate-forme abritée et de plate-forme à circulation restreinte sont placées dans la grande zone à Cavusgnathus, *tandis que les faunes des sédiments corrélatifs de milieu marin ouvert sont incluses dans les zones à* Gnathodus *sp. cf.* G. texanus *et* G. girtyi collinsoni.

INTRODUCTION

The uppermost Devonian and Carboniferous conodont faunas discussed in this study were collected from the Western Canada Sedimentary Basin (Figs. 1-3), a great wedge of sedimentary rocks that thickens westward from a zero-edge on the Canadian Shield, through the Interior Platform, to the fold and thrust belt of the eastern Cordillera (Fig. 4; Porter et al., 1982; Ricketts, 1989). In the Rocky Mountains and other mountain belts constituting the eastern Cordillera, uppermost Devonian and Carboniferous strata are extensively well exposed as a parautochthonous succession.

Sections in the eastern Cordillera, particularly those of the southeastern Rocky Mountains, are long and commonly lack significant structural and sedimentological breaks. On the Interior Platform, the Carboniferous is an autochthonous subsurface package that extends into southwestern Manitoba and has been penetrated in several salt mine shafts and in thousands of bore holes drilled during hydrocarbon exploration and production.

Biostratigraphic, lithostratigraphic, and sedimentological studies on uppermost Devonian and Carboniferous strata of the Western Canada Sedimentary Basin are at a reconnaissance level in most areas because of the vast extent of the Carboniferous and difficult access in much of the Cordillera. Sufficient biostratigraphic work has been completed, however, to provide a foundation for further study.

Richards (1989b) and Richards et al. (in press) summarized the lithostratigraphy of the succession and outlined the depositional and tectonic histories of the basin using foraminifers, conodonts, and corals for biostratigraphic control. The present study provides additional data on the conodont biostratigraphic scheme presented by Richards et al. (in press), discusses the paleoecology of the conodont faunas, and introduces seven conodont zones not previously reported from the succession.

More than 600, one- to two-kilogram samples from 25 sections of uppermost Devonian to Upper Carboniferous strata were processed for conodonts. Most of the samples were collected by B.C. Richards during regional stratigraphic and sedimentological studies. Although the sampling was at a reconnaissance level, usually at intervals 5-10 m apart, the chosen sections were almost continuously exposed and commonly extended from the uppermost Devonian to the top of the Lower Carboniferous.

Most of the sections sampled are in the Rocky Mountains of western Alberta and east-central British Columbia, but several occur in the Cordillera of northeastern British Columbia and southwestern District of Mackenzie (Appendix). Samples were also obtained from the shaft of a salt mine in southeastern Saskatchewan. The continuity of the sampled sections and their wide geographic distribution allows the recognition of the major elements of a conodont zonation. The study illustrates that local paleoecological factors strongly controlled the diversity and distribution of the conodont faunas, and demonstrates that the integration of biostratigraphy, lithostratigraphy, sedimentology, and tectonics is essential to an understanding of the zonation.

Previous work

The current lithostratigraphic nomenclature and the depositional origins of the major lithofacies have been established by Douglas (1958), Macauley (1958), Halbertsma (1959), Edie (1958), Christopher (1961), Scott (1964), Macqueen and Bamber (1967, 1968), Bamber and Waterhouse (1971), Macqueen et al. (1972), Bamber and Mamet (1978), and Richards (1989a, 1989b). Lithostratigraphic syntheses were presented by Macauley et al. (1964), Douglas et al. (1970), Bamber et al. (1984), Richards (1989b), Henderson (1989), and Richards et al. (in press).

The biostratigraphy of the Lower Carboniferous in the southern part of the Western Canada Sedimentary Basin is now established for several fossil groups (Figs. 2, 3). Zonations are available for conodonts (Baxter, 1972; Baxter and von Bitter, 1984; Richards et al., in press), foraminifers (Mamet, 1976; Bamber and Mamet, 1978; Mamet and Bamber, 1979; Mamet et al., 1986), corals (Nelson, 1960; Sando and Bamber, 1985); ostracodes (Crasquin, 1984), and brachiopods (Nelson, 1958, 1961; Carter, 1987). An integrated zonation based on foraminifers, conodonts, and corals was developed by Sando and Bamber (1985), and modified into a compound zonation (Sando, 1985).

In a recent paper on the Carboniferous and Permian biostratigraphy of northern Yukon Territory and northwest District of Mackenzie, Bamber et al. (1989) presented regional and international correlations of the succession and summarized all available published and unpublished distribution data on conodonts, foraminifers, brachiopods, palynomorphs, corals, and ammonoids.

Of the biozonations developed for the uppermost Devonian and Carboniferous of the Western Canada Sedimentary Basin, the foraminiferal zonation erected by Mamet and Skipp (1970) has been the most widely used in the Western Canada Sedimentary Basin. It has been possible to correlate the latter zonation with that of the conodonts (usually within individual sections) with considerable precision (Richards, 1989b; Richards et al., in press). International correlations have been established principally by using the foraminifers, abundant in most of the shallow marine Carboniferous limestones, and conodonts, which are most varied and abundant in the deeper water limestone lithofacies.

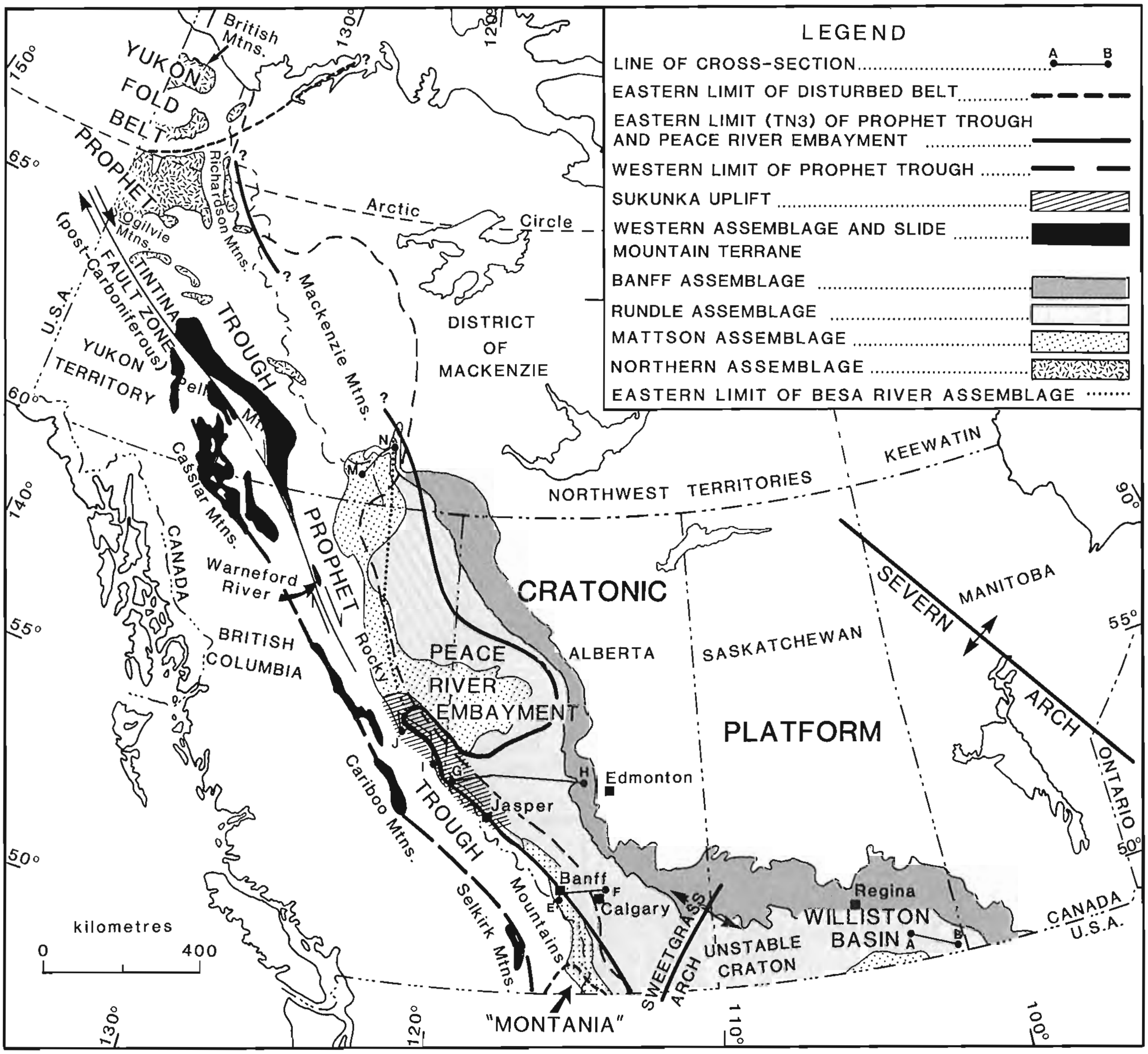


Figure 1. Map of Carboniferous units subcropping beneath Permian and Mesozoic formations in Western Canada Sedimentary Basin, tectonic elements, and lines of cross-section. See Figure 2 for formational composition of Banff, Rundle, and Mattson assemblages and Figure 3 for Carboniferous formations of the Northern Cordillera (modified from Richards, 1989b).

Figure 2. Correlation of Carboniferous lithostratigraphic units, southwestern Manitoba to southwestern District of Mackenzie, with standard chronostratigraphic units and Carboniferous zonal schemes. Dashed lines indicate nature of contact uncertain; question marks indicate position of lines uncertain (modified from Richards et al., in press).

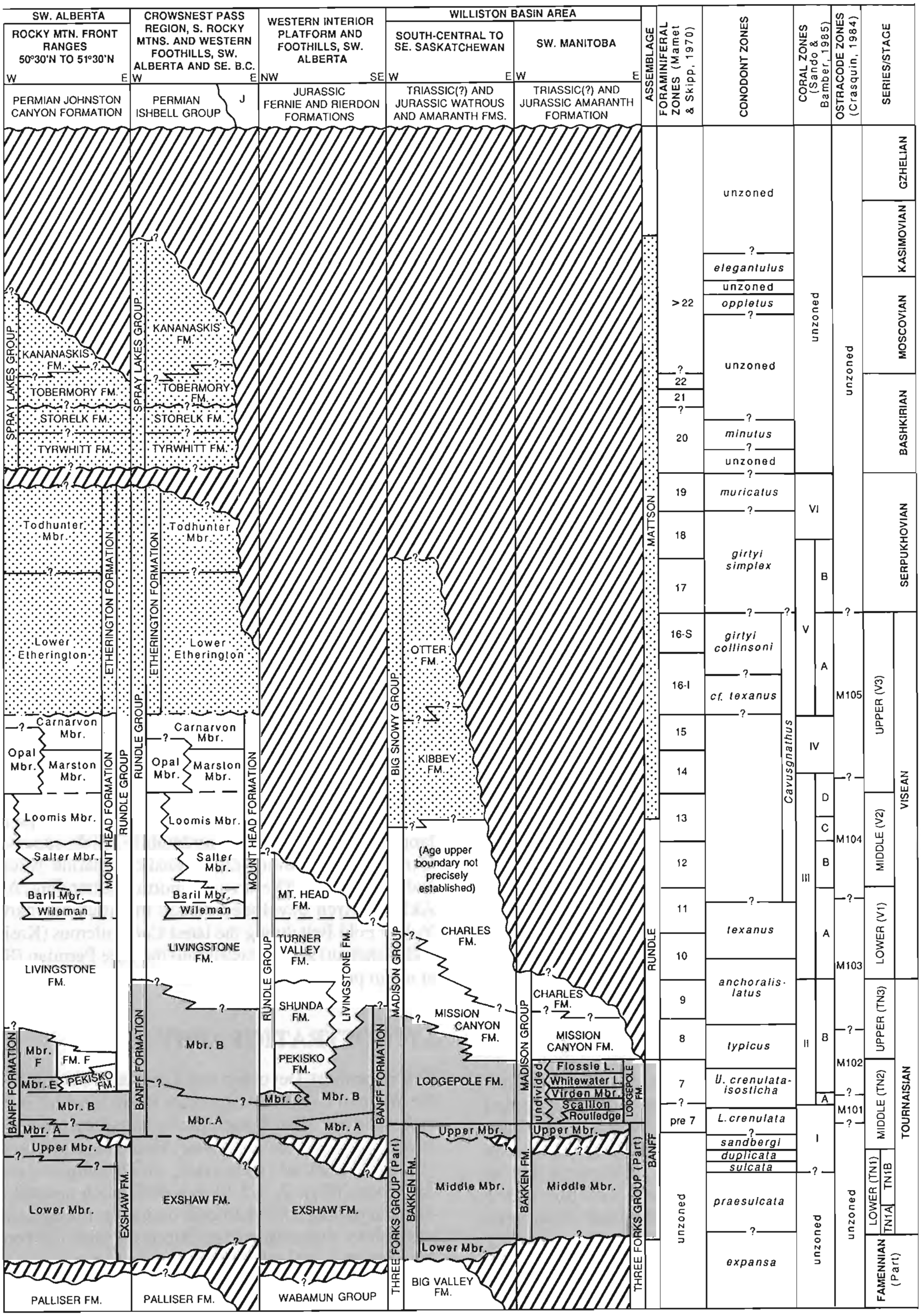


Figure 2 (cont'd.)

DISTRIBUTION AND TECTONIC SETTING

Carboniferous formations are preserved in two main regions (Fig. 1). The southern one, which includes much of the eastern Cordillera and southern to central Interior Platform (Fig. 4), extends from southwestern Manitoba into southwestern District of Mackenzie. The northern area includes the eastern Cordillera of northern Yukon Territory and northwestern District of Mackenzie. Between these regions, erosional remnants are present in the Mackenzie and Selwyn mountains of east-central Yukon and west-central District of Mackenzie. The Lower Carboniferous succession is most complete and best exposed in the southwestern part of the southern region, and the Upper Carboniferous is best represented in northern Yukon (Figs. 2, 3).

During the Carboniferous, the principal tectonic elements in the Western Canada Sedimentary Basin were Prophet Trough, Peace River Embayment, the cratonic platform, Williston Basin, and the Yukon Fold Belt (Fig. 1). The characteristics and Carboniferous tectonic histories of these elements and subordinate features within them were outlined by Richards (1989b) and are, therefore, discussed only briefly below.

Prophet Trough

The name Prophet Trough was introduced by Richards (1989b) for the downwarped and downfaulted western margin of the North American plate of latest Devonian and Carboniferous time. The Prophet Trough was continuous with Antler Foreland Basin of the western United States, and extended from southeastern British Columbia to the Yukon Fold Belt. This pericratonic trough was predominantly an extensional element; however, it developed in the foreland of an ensialic arc or continental margin volcanic/plutonic belt resulting from plate convergence and eastward directed subduction. A broad, partly fault controlled 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 to the east. The western boundary of the trough was an elevated rim, extensively exposed from the Famennian into the early Viséan but subsequently largely transgressed.

Peace River Embayment

The Peace River Embayment (Douglas et al., 1970) of northwestern Alberta and northeastern British Columbia opened northwestward into Prophet Trough and was a broad, fault-controlled re-entrant into the western cratonic platform. The depositional and structural axis of the embayment had an easterly trend coinciding approximately with that of the Upper Devonian Peace River Arch. Regional subsidence accompanied by extensive blockfaulting along northeasterly and northwesterly striking normal faults produced an anomalously thick Lower Carboniferous succession in the embayment, which included an extensive central graben system (Barclay et al., 1990). Embayment development was initiated during the latest Devonian and earliest Carboniferous. The embayment, bounded on its southwestern side by the Sukunka Uplift (Richards, 1989b), continued to occupy an extensive region into the late Serpukhovian but may have been of minor extent during the Late Carboniferous.

Cratonic platform and Williston Basin

The western cratonic platform, which extended northward from the United States to the Yukon and Ellesmerian fold belts (Fig. 1), included the Williston Basin (centred in North Dakota) and a number of broad arches. During the Tournaisian, the Williston Basin was essentially a deep embayment connected to the Prophet Trough and Antler Foreland Basin by a broad seaway, extending from southeastern Alberta into Wyoming. During the early and middle Viséan, the Williston Basin became a topographical basin – a low, broad, northeast-trending uplift (Sweetgrass Arch of Douglas et al., 1970) developed across the seaway in southeastern Alberta and north-central Montana. In the east, Precambrian rocks of the Canadian Shield were exposed along the northwest-trending Severn Arch of Manitoba and the north-trending Wisconsin Arch of Ontario (Porter et al., 1982). These two arches, along with the Transcontinental Arch of the north-central United States, controlled the location of the eastern and northeastern shorelines of the latest Devonian and Carboniferous seas (Richards, 1989b).

Yukon Fold Belt

The Yukon Fold Belt (Bell, 1973) of northern Yukon and Alaska is an orogenic belt resulting from the Frasnian to Tournaisian Ellesmerian Orogeny, named in the Canadian Arctic Archipelago (Thorsteinsson and Tozer, 1970; Trettin, 1973). Topographically high during the Late Devonian and earliest Carboniferous, the fold belt was subsequently onlapped northward by a moderately thick succession of Carboniferous continental to shallow marine siliciclastics and carbonates. The arcuate, northeast-trending Ancestral Aklavik Arch developed across the southern part of the Yukon Fold Belt during the latest Carboniferous (Kasimovian and Gzhelian) and persisted into the Late Permian (Richards et al., in press).

LITHOSTRATIGRAPHY

The uppermost Devonian and Carboniferous succession of the Western Canada Sedimentary Basin is a thick package of carbonate and siliciclastic lithofacies representing the upper Kaskaskia sequence and lower Absaroka sequence of Sloss (1963). Overall, this succession, which comprises numerous formations (Figs. 2, 3, 5-9), is a shallowing-upward, progradational package, but it records numerous transgressions and regressions. Subaerial erosion during the latest Carboniferous, Permian, and subsequent periods removed major parts of the succession, particularly on the Interior Platform and the

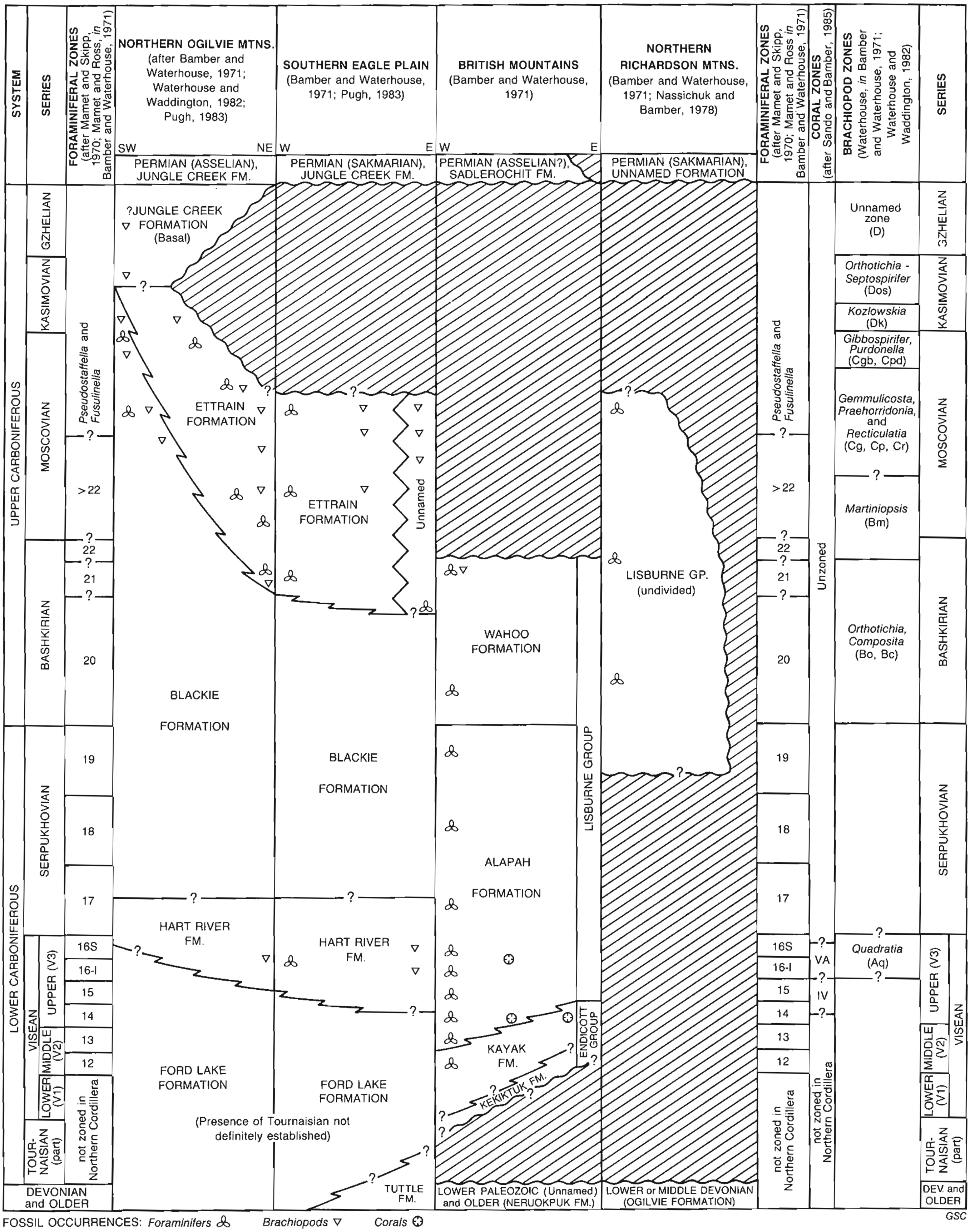


Figure 3. Correlation of Carboniferous lithostratigraphic units in northern Yukon Territory and northwestern District of Mackenzie with standard chronostratigraphic units and Carboniferous zonal schemes. Dashed lines indicate nature of contact uncertain; question marks indicate position of lines uncertain (from Richards et al., in press).

region west of the Rocky Mountain Front Ranges. In areas where the Carboniferous remains, it is generally unconformably overlain by either Permian or Mesozoic strata.

Southwestern Manitoba to southwestern District of Mackenzie

The uppermost Devonian and Carboniferous succession from southwestern Manitoba to southwestern District of Mackenzie was divided by Richards (1989b) into five mappable lithofacies assemblages (Fig. 1). Lithofacies deposited in western Prophet Trough and on its western rim are called the western assemblage. This assemblage, largely removed by deep post-Carboniferous erosion, includes carbonates, volcanics, and remnants of an easterly thinning clastic wedge.

The succession to the east, which includes platform to ramp carbonates and deltaic terrigenous clastics, comprises the Banff, Rundle, and Mattson assemblages (Fig. 2). The Banff, Rundle, and Mattson assemblages resemble the lower, middle, and upper depositional units, respectively of Macauley et al. (1964) and Richards et al. (in press). The Mattson assemblage of Richards (1989b) is here expanded to include the sandstone-dominated Upper Carboniferous succession. Fine grained siliciclastics and cherty to argillaceous carbonates of the Banff assemblage are widely overlain by the carbonate-dominated Rundle assemblage, which in turn is partly overlain by sandstone and subordinate carbonates of the Mattson assemblage. From east-central British Columbia into southwestern District of Mackenzie, the three assemblages overlie and pass basinward into the shale-dominated Besa River assemblage.

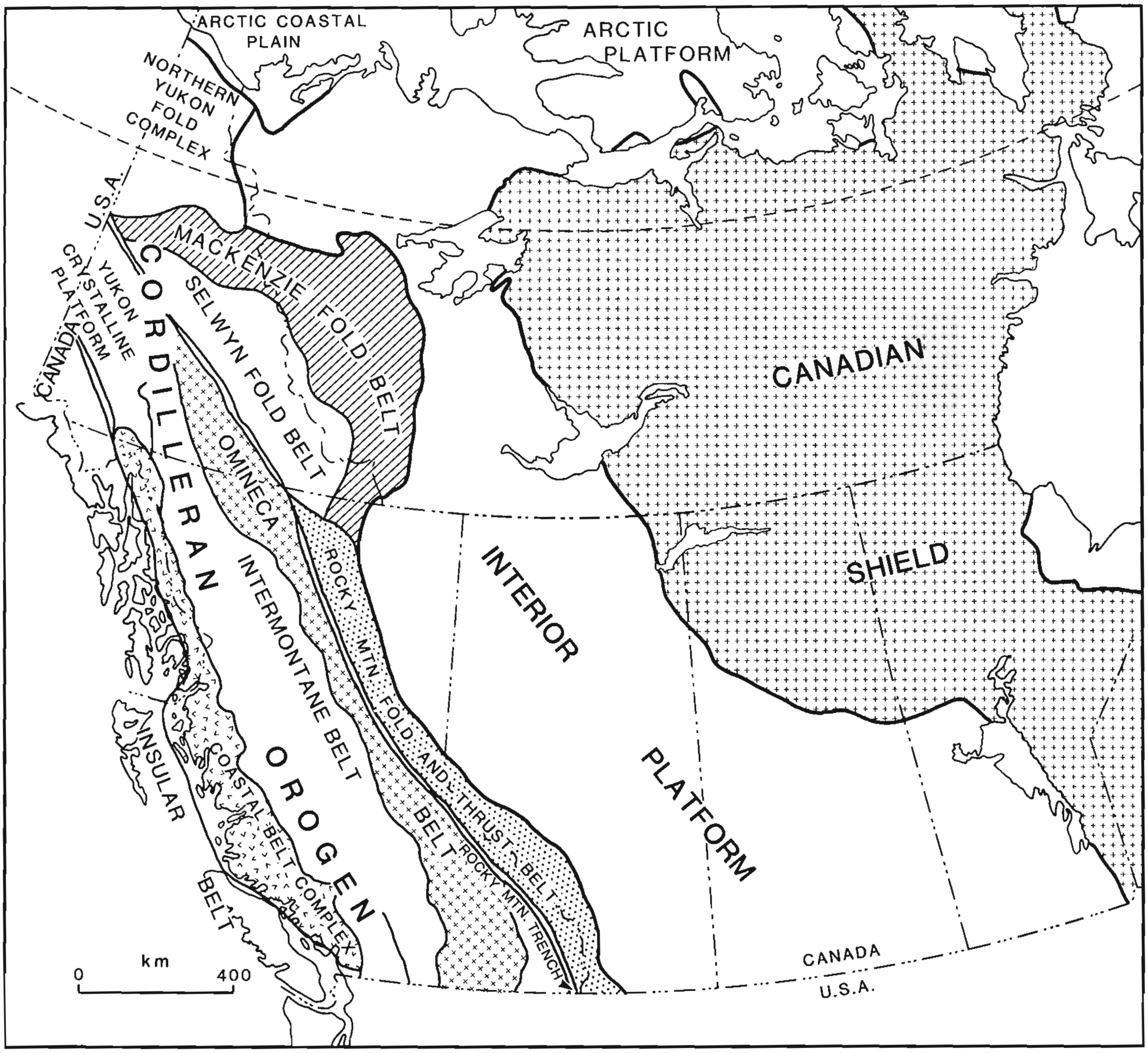


Figure 4. Principal present day geological elements of western Canada (from Douglas et al., 1970).

Banff assemblage

The Banff assemblage comprises carbonates and siliciclastics of the Bakken, Exshaw, Lodgepole, Banff, and Yohin formations (Figs. 2, 5-9). The Bakken constitutes the upper Three Forks Group and the Lodgepole is the lower formation of the lower Madison Group. The Bakken and Lodgepole were deposited in Williston Basin and on the unstable craton of southeastern Alberta and southwestern Saskatchewan, while the Exshaw, Banff, and Yohin formed on the western cratonic platform and in the Prophet Trough, which included the developing Peace River Embayment in the northwest.

In most areas, the Banff assemblage disconformably overlies upper Famennian strata and is overlain by the less widely distributed Rundle assemblage. In most of the Williston Basin, much of the southern Cordillera, and on the Interior Platform of southernmost Alberta, the top of the Banff assemblage becomes younger basinward as the Rundle assemblage grades into it. Elsewhere, the boundary between these two assemblages is generally abrupt and commonly a minor disconformity.

East and north of the subcrop edge of the Rundle assemblage, the Banff assemblage is unconformably overlain by Mesozoic strata. In the Banff assemblage, the oldest Carboniferous deposits generally lie in the Exshaw and Bakken formations, but where these formations are absent or incompletely developed, the oldest Carboniferous strata occur in the Banff Formation.

In the Banff assemblage, the carbonate lithofacies developed on carbonate ramps and to a lesser extent on poorly differentiated carbonate platforms (Figs. 5-8, 11, 12). Most of the siliciclastics are fine grained (shale to sandstone) and were deposited in lower slope and basin settings, but shallow neritic to supratidal siliciclastics are widespread in the middle Bakken, upper Exshaw, upper Banff, and eastern Yohin formations. The shelf lithofacies generally grade southwest-

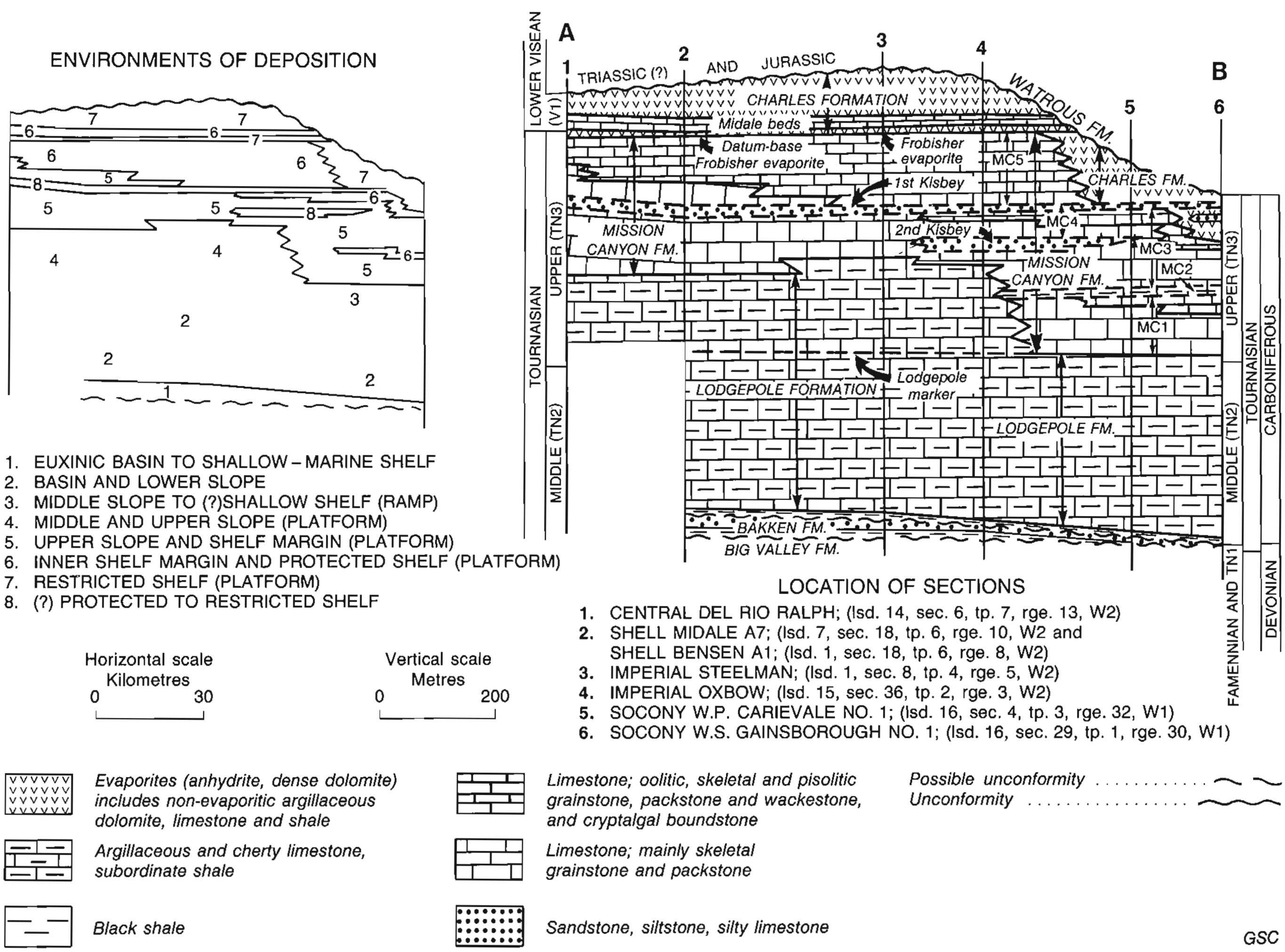


Figure 5. Partly schematic stratigraphic cross-section A–B showing the uppermost Devonian and Lower Carboniferous in eastern Williston Basin, southeastern Saskatchewan, See Figure 1, A–B for line of section (modified from Edie, 1958).

ward (basinward) into slope carbonates and siliciclastics preserved in the Banff assemblage. The slope lithofacies, in turn, grade basinward into shale-dominated basin deposits preserved in the lower part of the assemblage, and in the Besa River assemblage.

Rundle assemblage

The carbonate-dominated Rundle assemblage (Figs. 1, 2) comprises the Mission Canyon and Charles formations of the Madison Group, and all of the Rundle Group, except the Etherington Formation (included in the Mattson assemblage). Deposition of the Rundle Group took place in the Prophet Trough, Peace River Embayment, and on the western cratonic platform, whereas that of the Mission Canyon and Charles formations occurred in the Williston Basin and on the unstable craton to the west.

In the southwest, the principal formations within the Rundle are unnamed formation F and the Livingstone, Pekisko, Shunda, Turner Valley, and Mount Head formations (Figs. 5-8). In the northwest, the Prophet, Debolt, and Flett formations are the main constituents (Fig. 9).

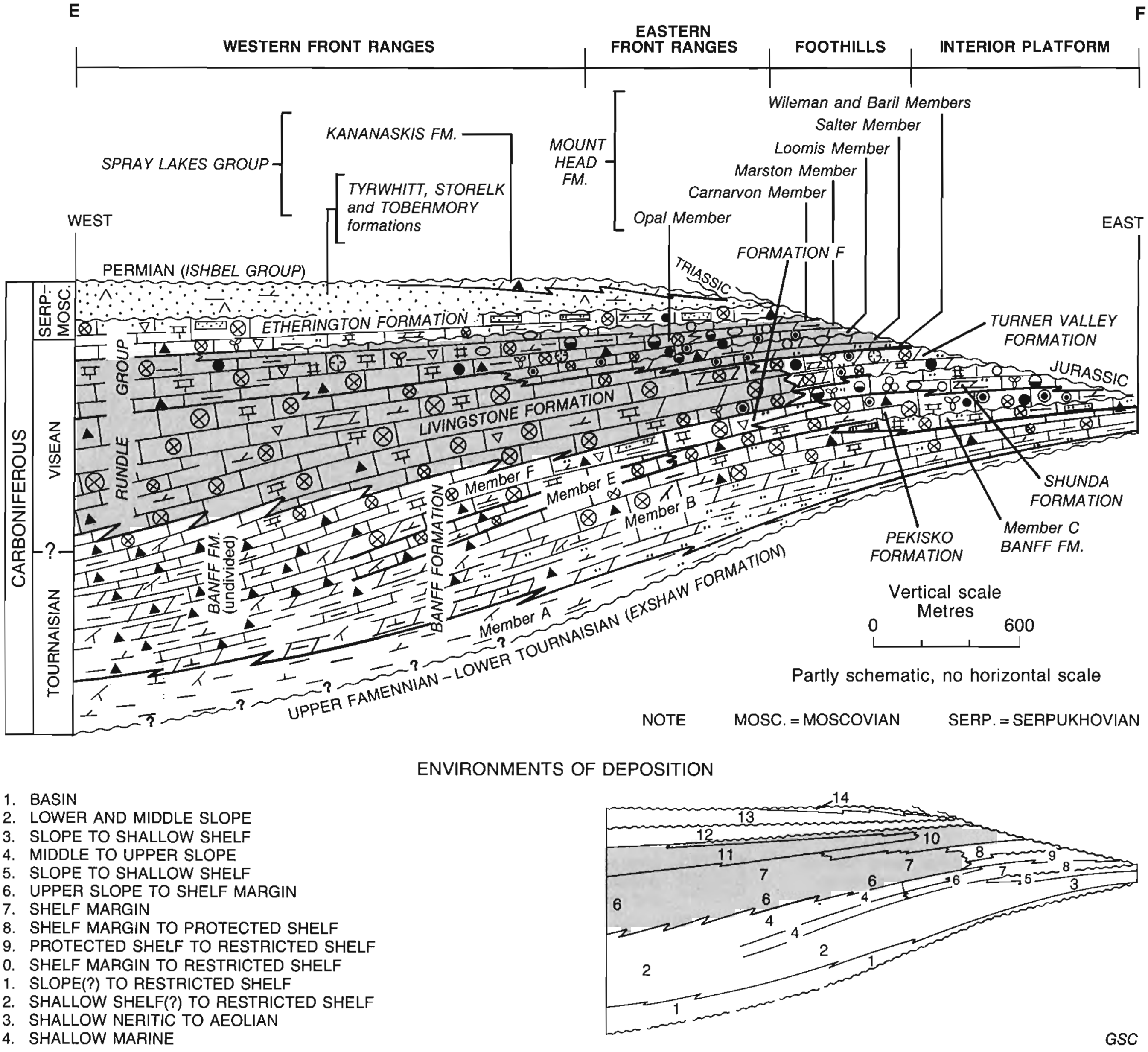


Figure 6. Partly schematic, non-palinspastic stratigraphic cross-section E–F showing the Carboniferous of southwestern Alberta. See Figure 1, E–F for line of section and Figure 7 for legend (from Richards et al., in press).

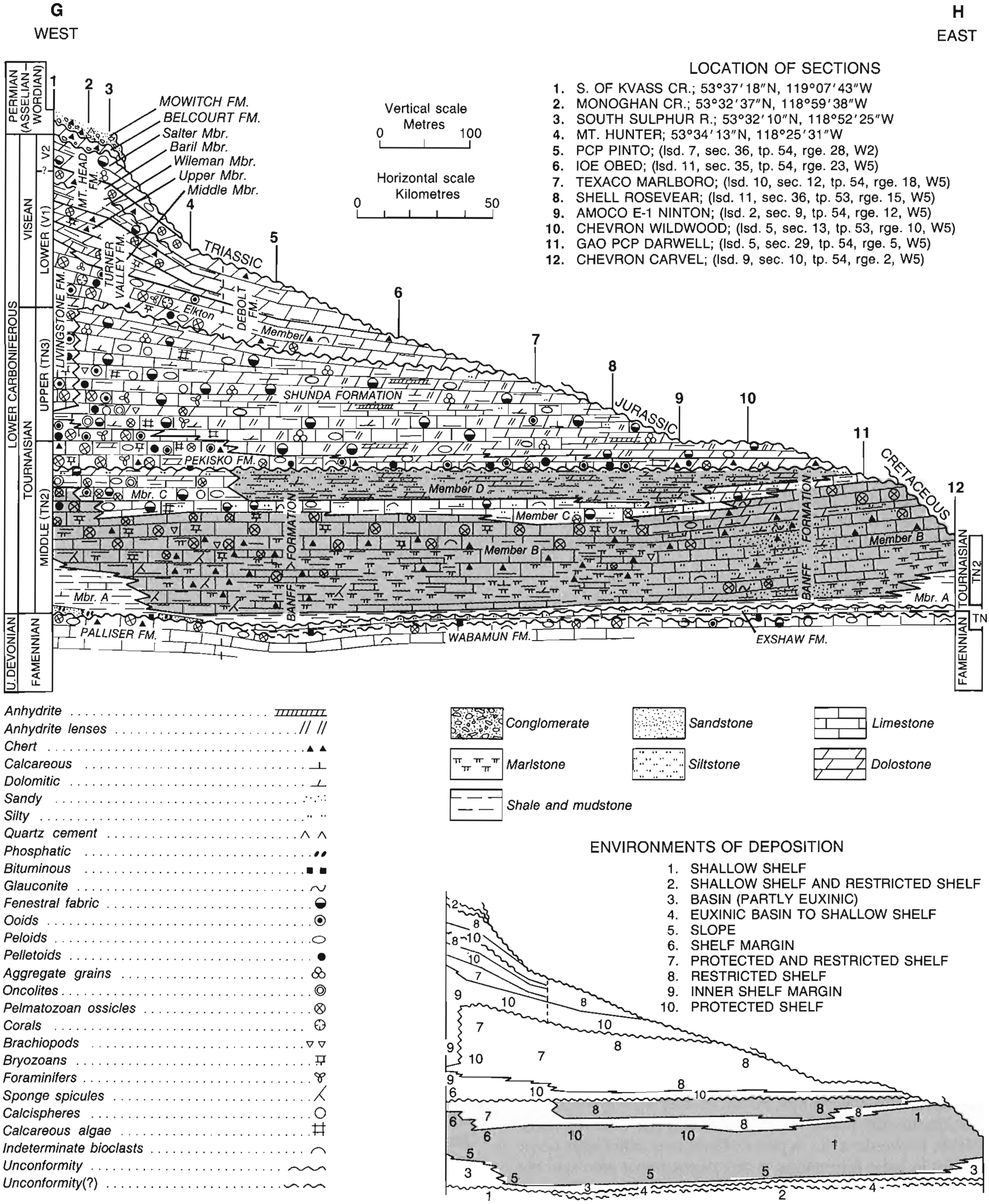


Figure 7. Partly schematic, non-palinspastic stratigraphic cross-section G–H showing the uppermost Devonian and Lower Carboniferous of west-central Alberta. See Figure 1, G–H for line of section (from Richards et al., in press).

The Rundle assemblage generally overlies the Banff assemblage, but from east-central British Columbia to southwestern District of Mackenzie, western deposits of the package overlie and pass basinward into the Besa River assemblage. In most areas, the Rundle assemblage is unconformably overlain by either Permian or Mesozoic strata. It is, however, overlain by the sandstone dominated Mattson assemblage in south-central Saskatchewan, on part of the westernmost Interior Platform, and over wide areas in the eastern Cordillera. The contact between the Rundle and Mattson assemblages may be conformable in Saskatchewan, but it is generally disconformable from southwestern Alberta into the southwestern part of the Peace River Embayment. Farther north, the Rundle assemblage is abruptly, but usually conformably, overlain by the Mattson assemblage at a contact that becomes older northwestward.

Platform and ramp carbonates (Figs. 11, 12) dominate the Rundle assemblage, but in the west the Rundle assemblage includes a great thickness of bedded chert and spiculite preserved mainly in the Prophet Formation. The shelf and shelf-margin lithofacies generally grade southwestward (basinward) into slope deposits preserved in the Prophet Formation and upper part of the Banff assemblage (Figs. 2, 5-9). The slope deposits, in turn, grade basinward into a thick succession of basin facies mainly preserved in the Besa River assemblage and in the lower part of the Banff assemblage.

Mattson assemblage

The Mattson assemblage consists of the Etherington Formation, Stoddart Group (Golata, Kiskatinaw and Taylor Flat formations), Spray Lakes Group (Tyrwhitt, Storelk, Tobermory, and Kananaskis formations), and minor occurrences of the Kibbey and Otter formations of the Big Snowy Group (Figs. 2, 6-9). Sedimentation of the Big Snowy Group took place in the Williston Basin, whereas the remainder of the assemblage was deposited in the Prophet Trough, Peace River Embayment and, at least locally, on the western part of the stable cratonic platform.

The Mattson assemblage, comprising sandstone with subordinate carbonates and shale, overlies the Rundle assemblage. It also overlies and passes basinward into the Besa River assemblage from east-central British Columbia into southwestern District of Mackenzie. In most areas, the Mattson assemblage is unconformably overlain by Permian strata, but east and north of the subcrop edge of the latter, it is unconformably overlain by Triassic to Lower Cretaceous strata.

Lithofacies of the Mattson assemblage were deposited in a complex array of marine to continental environments, including carbonate ramps, deltas, aeolian dune systems, and siliciclastic-dominated marine shelves (Figs. 6-9; Richards, 1989b; Richards et al., in press). Carbonate lithofacies occur locally in most formations in this depositional package, but predominate only in the lower Etherington, Taylor Flat, and Kananaskis formations. Carbonates of the Etherington are probably of ramp origin; those of the other formations do not constitute well defined carbonate buildups. The marine shelf and delta-plain to delta-front lithofacies generally pass basinward (southwestward) into slope deposits preserved in this assemblage. The latter grade basinward into shale-dominated slope and basin deposits occurring mainly in the Golata Formation and Besa River assemblage.

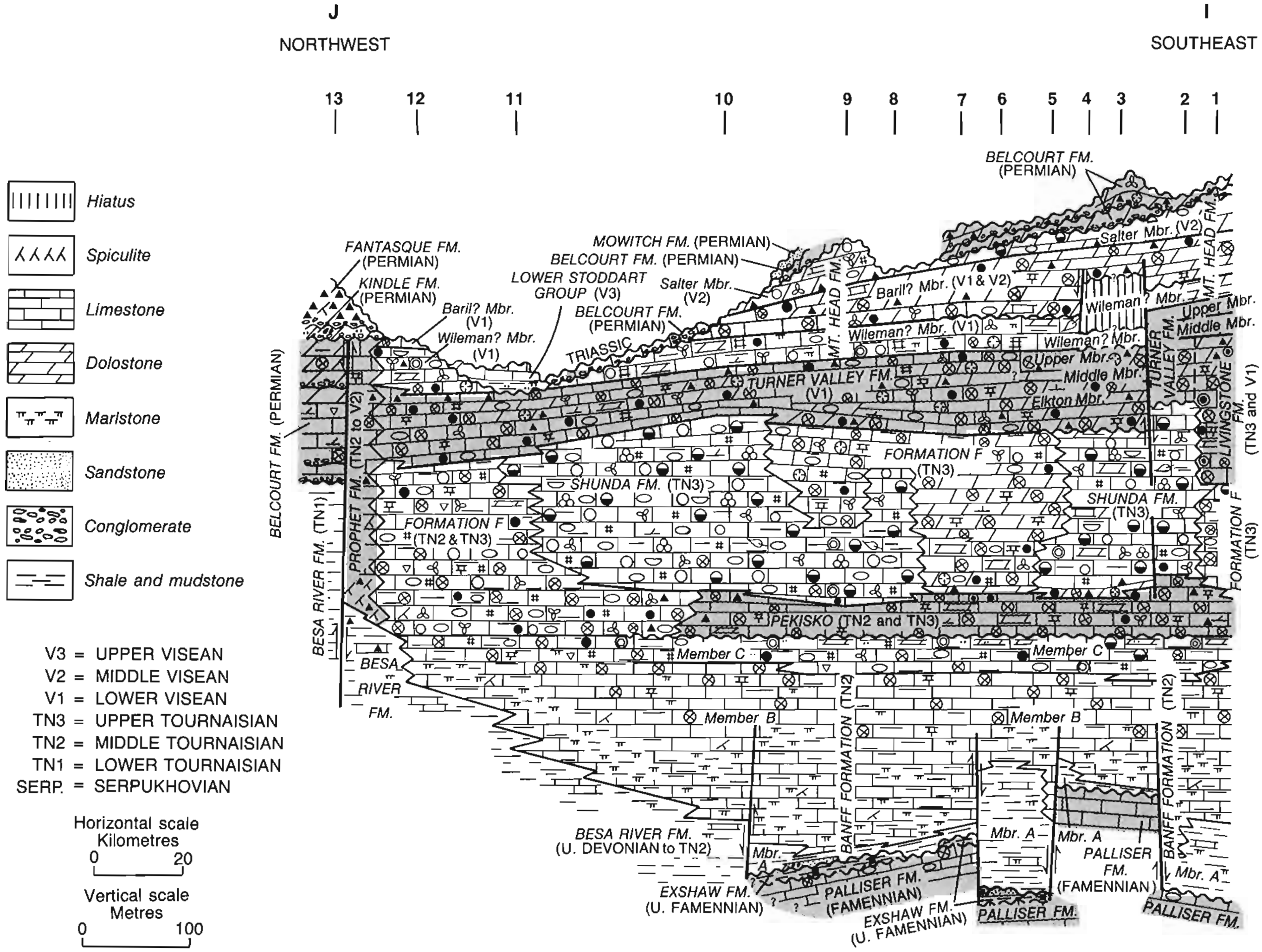
Northern Cordillera – northern Yukon Territory and northwestern District of Mackenzie

The uppermost Devonian and Carboniferous of northern Yukon and northwestern District of Mackenzie (Figs. 1, 3) constitutes most of the northern assemblage of Richards (1989b). That assemblage includes an essentially continuous succession of Viséan to Moscovian carbonates and siliciclastics preserved beneath the regional, sub-Permian unconformity in the northern Cordillera. Younger Carboniferous deposits occur only in the Ogilvie Mountains, where Kasimovian to Gzhelian strata are present and sedimentation may have been locally continuous across the Carboniferous/Permian boundary (Waterhouse and Waddington, 1982). Tournaisian strata have been definitely identified only in the southeast, in southwestern Peel Plateau (Bamber and Waterhouse, 1971). They may however, be present on the western flank of the southern Richardson Mountains (Pugh, 1983) and in the basal siliciclastics of the western British Mountains.

The Carboniferous of the northern Cordillera comprises two separate, but closely related successions (Richards et al., in press). The two successions originally formed part of a continuous depositional complex, but they are now separated geographically by the northeast-trending Ancestral Aklavik Arch (Bamber and Waterhouse, 1971), where they were truncated beneath the regional sub-Permian unconformity. Their distribution was also altered by probable counter-clockwise rotation of northern Yukon and Alaska during the Mesozoic (Sweeney et al., 1978; Nilsen, 1981).

The more completely preserved of the two successions consists of autochthonous and parautochthonous Tournaisian to Gzhelian strata, occurring south of 67°30′N, in the Ogilvie Mountains and Eagle Plain and on the flanks of the southern Richardson Mountains (Fig. 3). This southern array of strata closely resembles the parautochthonous sequence of the southern Brooks Range in Northern Alaska and was deposited in the southeastern part of the same basin. Deposition of this succession took place in the northern Prophet Trough and possibly on the western cratonic platform (Richards et al., in press). The lower part of the southern succession comprises Tournaisian(?) to Bashkirian siliciclastics and carbonates of the Tuttle, Ford Lake, Hart River, and lower Blackie formations. These are generally overlain by Bashkirian to Kasimovian(?) carbonates of the Ettrain Formation, which grade southward and southwestward into shale and carbonates of the upper Blackie Formation. In the Ogilvie Mountains, Kasimovian(?) to Gzhelian terrigenous clastics of the basal Jungle Creek Formation overlie the Ettrain Formation and constitute the top of the Carboniferous System.

The second succession is preserved north of 68°00′N in a southeast-trending discontinuous belt extending from the Alaska/Yukon border into northwestern District of Mackenzie. This package closely resembles the parautochthonous northern



LOCATION OF SECTIONS

1. JARVIS LAKES; 54°06′21″N, 120°12′27″W
2. NW OF MT. HANINGTON; 54°10′46″N, 120°14′45″W
3. MEOSIN MTN.; 54°17′08″N, 120°18′55″W
4. MUINOK MTN.; 54°20′03″N, 120°23′19″W
5. SW OF BELCOURT LAKE; 54°21′54″N, 120°29′58″W
6. RED DEER CR.; 54°27′00″N, 120°35′14″W
7. MT. BECKER; 54°31′02″N, 120°38′46″W
8. ONION LAKE; 54°37′57″N, 120°45′34″W
9. FELLERS CR.; 54°42′19″N, 120°53′06″W
10. ALBRIGHT RIDGE; 54°48′15″N, 121°17 37″W
11. MT. PAULSON; 55°06′32″N, 121°48′23″W
12. WATSON PEAK; 55°13′58″N, 122°05′07″W
13. LEAN-TO CR.; 55°04′33″N, 121°59′40″W

Chert .... ▲▲
Calcareous .... ⊥
Dolomitic .... ∠
Silty .... ״
Phosphatic .... ••
Bituminous .... ■ ■
Fenestral fabric .... ◒
Ooids .... ◉
Peloids .... ⬭
Pelletoids .... ●
Aggregate grains .... ꙮ
Oncolites .... ◎
Pelmatozoan ossicles .... ⊗
Corals .... ⊕
Brachiopods .... ▽
Bryozoans .... ╤
Ostracodes .... ◡
Foraminifers ४
Sponge spicules .... ✕
Calcispheres .... ○
Calcareous algae .... #
Terrestrial plant remains ...... ⌀
Unconformity(?) .... ⌒⌒
Unconformity .... ∿∿
Possible normal faults .... ⇌

ENVIRONMENTS OF DEPOSITION

1. EUXINIC BASIN
2. BASIN (PARTLY EUXINIC)
3. SLOPE
4. UPPER SLOPE AND SHELF MARGIN (PLATFORM)
5. UPPER SLOPE AND SHALLOW SHELF (RAMP)
6. SHALLOW SHELF (RAMP)
7. PROTECTED SHELF AND RESTRICTED SHELF (PLATFORM)
8. SHELF MARGIN AND PROTECTED SHELF (PLATFORM)
9. SHALLOW SHELF AND RESTRICTED SHELF (RAMP)
10. INNER SHELF MARGIN (PLATFORM)
11. PROTECTED SHELF (PLATFORM)
12. RESTRICTED SHELF
13. SLOPE TO SHALLOW SHELF (RAMP IN PART)
14. BASIN? TO SHALLOW SHELF

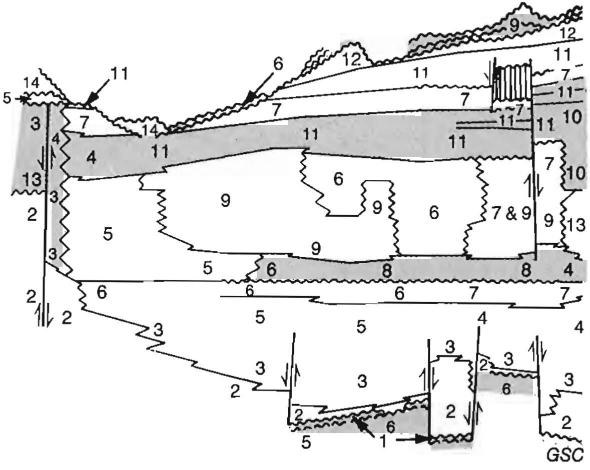


Figure 8. Partly schematic, non-palinspastic stratigraphic cross-section I–J showing the Lower Carboniferous of east-central British Columbia. Locations of late Paleozoic normal faults are based on changes in thickness and lithotype between stratigraphic sections; actual faults not observed. See Figure 1, I–J for line of section (from Richards et al., in press).

Brooks Range succession and that preserved on the Alaskan North Slope and adjacent continental shelf. In the British Mountains, Tournaisian(?) and Viséan terrigenous clastics and subordinate carbonates of the Endicott Group (Kekiktuk and Kayak formations) constitute the lower part of the succession. These lower strata are overlain by carbonates of the Viséan to Bashkirian Lisburn Group (Alapah and Wahoo formations), which are in turn unconformably overlain by Permian strata.

Both the southern and the northern successions of the northern Cordillera consist of a lower interval dominated by continental to basinal terrigenous clastics, and an upper one

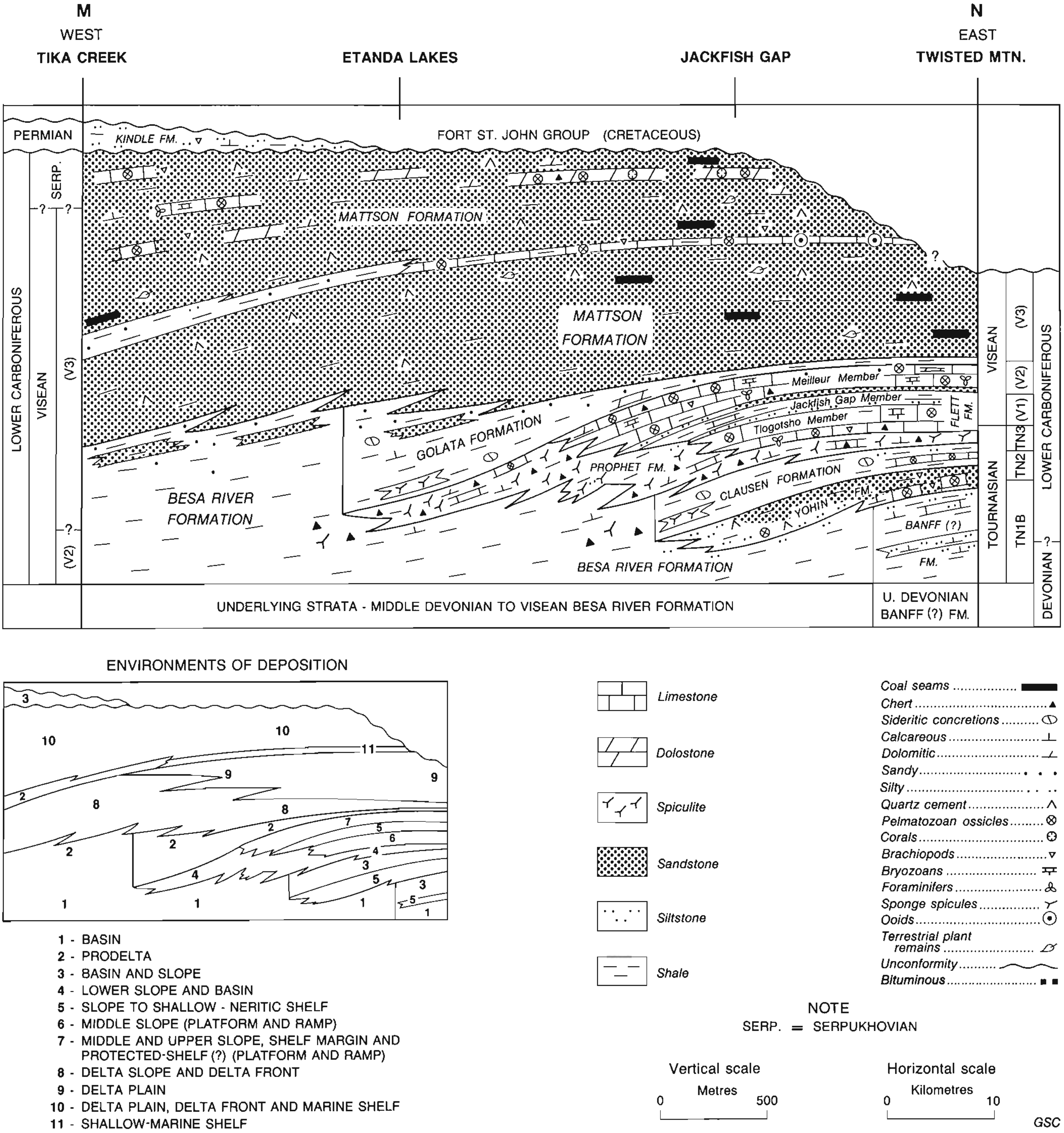


Figure 9. Partly schematic, palinspastic stratigraphic cross-section M–N showing the Lower Carboniferous in the eastern Cordillera of southwestern District of Mackenzie and southeastern Yukon Territory. See Figure 1, M–N for line of section (from Richards et al., in press).

consisting mainly of carbonate platform and ramp lithofacies. In the upper interval, shelf and shelf-margin lithofacies grade westward to southwestward (toward the paleobasin) into slope deposits.

CONODONT BIOSTRATIGRAPHY

Few accounts of the conodont sequence in the Carboniferous of the Western Canada Sedimentary Basin have been published. Baxter (1972) and Baxter and von Bitter (1984) have applied locally a zonal scheme modified from Collinson et al. (1971), which was originally based on the Mississippi valley faunas. The scheme used in the present account for the uppermost Devonian and Lower Carboniferous draws on many sources, including Ziegler and Sandberg (1984), Sandberg et al. (1978) and Lane et al. (1980). In the Upper Devonian and Tournaisian parts of the succession it is applicable internationally. Upper Carboniferous faunas have been recorded by Henderson (*in* Bamber et al., 1989) from northern Yukon Territory but were not assigned to zones. A conodont zonation of up to 18 conodont zones (Figs. 2, 10) is outlined for the uppermost Devonian to Upper Carboniferous of the Western Canada Sedimentary Basin, but three of these, the *Siphonodella praesulcata*, *Siphonodella sulcata* and *Siphonodella sandbergi*, have not yet been identified with certainty. The last two zones lie near the Devonian–Carboniferous boundary, which is located within a highly condensed and possibly incomplete part of the succession. Four of the Lower Carboniferous zones (*Gnathodus* sp. cf. *G. texanus*, *Gnathodus girtyi collinsoni*, *Gnathodus girtyi simplex*, and *Rhachistognathus muricatus*) and three Upper Carboniferous zones (*Rhachistognathus minutus*, *Streptognathodus oppletus*, and *Streptognathodus elegantulus*) are recognized for the first time in the Western Canada Sedimentary Basin.

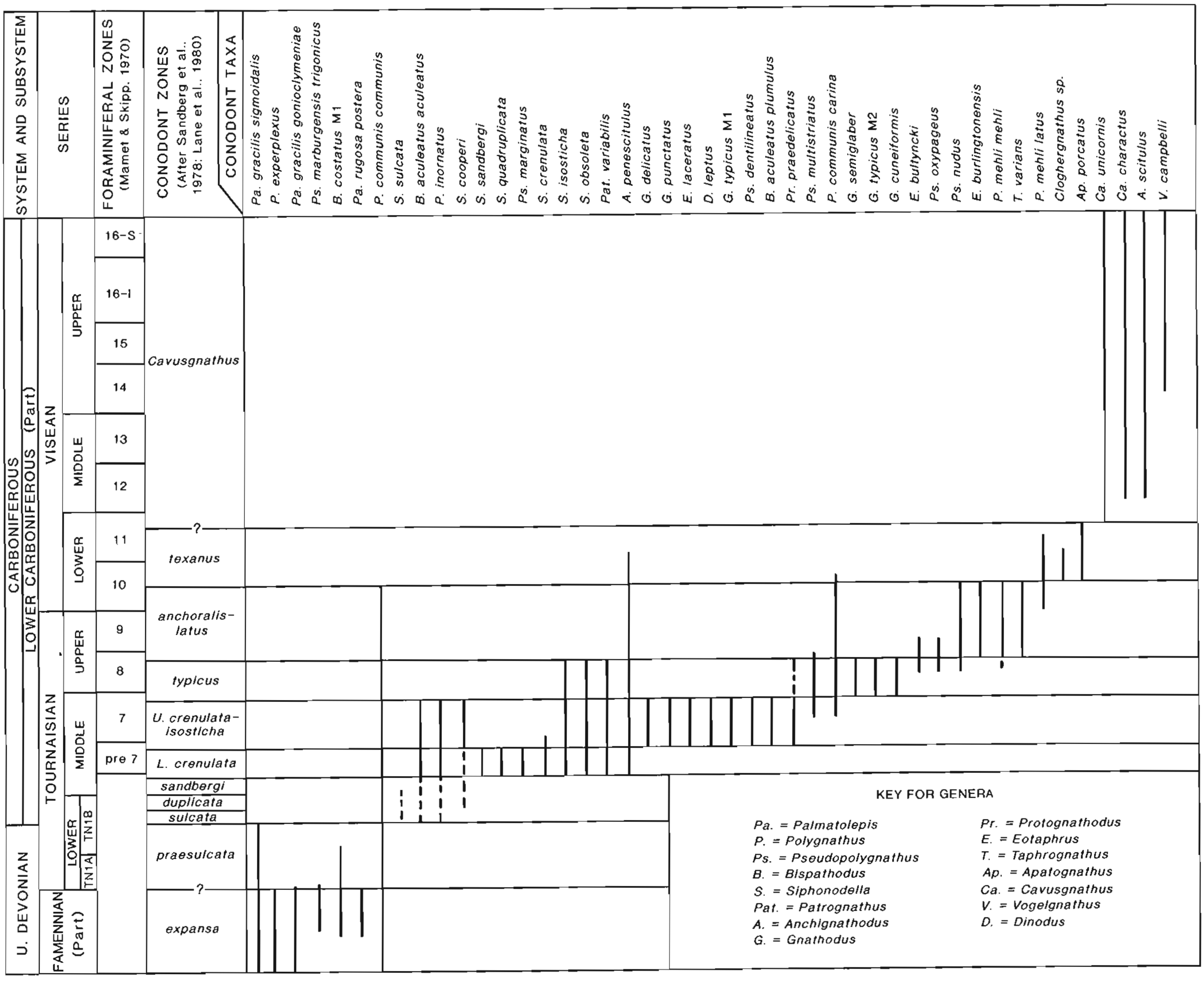


Figure 10. Known stratigraphic ranges of selected conodont species characteristic of the uppermost Devonian and Lower Carboniferous of the Western Canada Sedimentary Basin.

Middle Palmatolepis gracilis expansa *to* Siphonodella praesulcata *zones*

The Middle *expansa* to *praesulcata* zones, of late Famennian and earliest Tournaisian (TN1A and early TN1B) age, are recognized in the upper Famennian to middle Tournaisian Exshaw Formation in both the Rocky Mountains and the subsurface to the east. The Exshaw, which commonly contains the Devonian–Carboniferous boundary, generally comprises a lower black shale member and an upper member dominated by carbonates, sandstone, and siltstone (Richards and Higgins, 1988). In lower part of the black shale member at Jura Creek, southwestern Alberta, the faunas include *Bispathodus costatus* E.R. Branson Morphotype 1 Ziegler, Sandberg and Austin and *Palmatolepis gracilis sigmoidalis* Ziegler. *Bispathodus costatus* Morphotype 1 ranges from the Middle *expansa* to the Middle *praesulcata* Zone, and *P. gracilis sigmoidalis* has an upper range within the Upper *praesulcata* Zone.

Basal beds of the upper member of the Exshaw Formation at Red Deer Creek in the Rocky Mountains of east-central British Columbia (Appendix), yielded a more varied fauna that belongs to the Upper *expansa* Zone and included *Bispathodus jugosus* (Branson and Mehl), *Palmatolepis gracilis expansa* Sandberg and Ziegler, *Palmatolepis gracilis gonioclymeniae* Müller, *Palmatolepis rugosa postera* Ziegler, *Polygnathus communis communis* Branson and Mehl, *Polygnathus experplexus* Sandberg and Ziegler, and *Pseudopolygnathus marburgensis trigonicus* Ziegler (Richards and Higgins, 1988).

Siphonodella sulcata *to* Siphonodella sandbergi *zones*

The *Siphonodella duplicata* Zone has been recognized in the Banff(?) Formation at Bluefish Mountain, southwestern District of Mackenzie (Higgins, *in* Richards, 1989a), but there is no clear evidence of the presence of the *sulcata* Zone, the basal zone of the Carboniferous, in the Western Canada Sedimentary Basin. Similarly, there is no equivocal evidence of the *sandbergi* Zone in the basin.

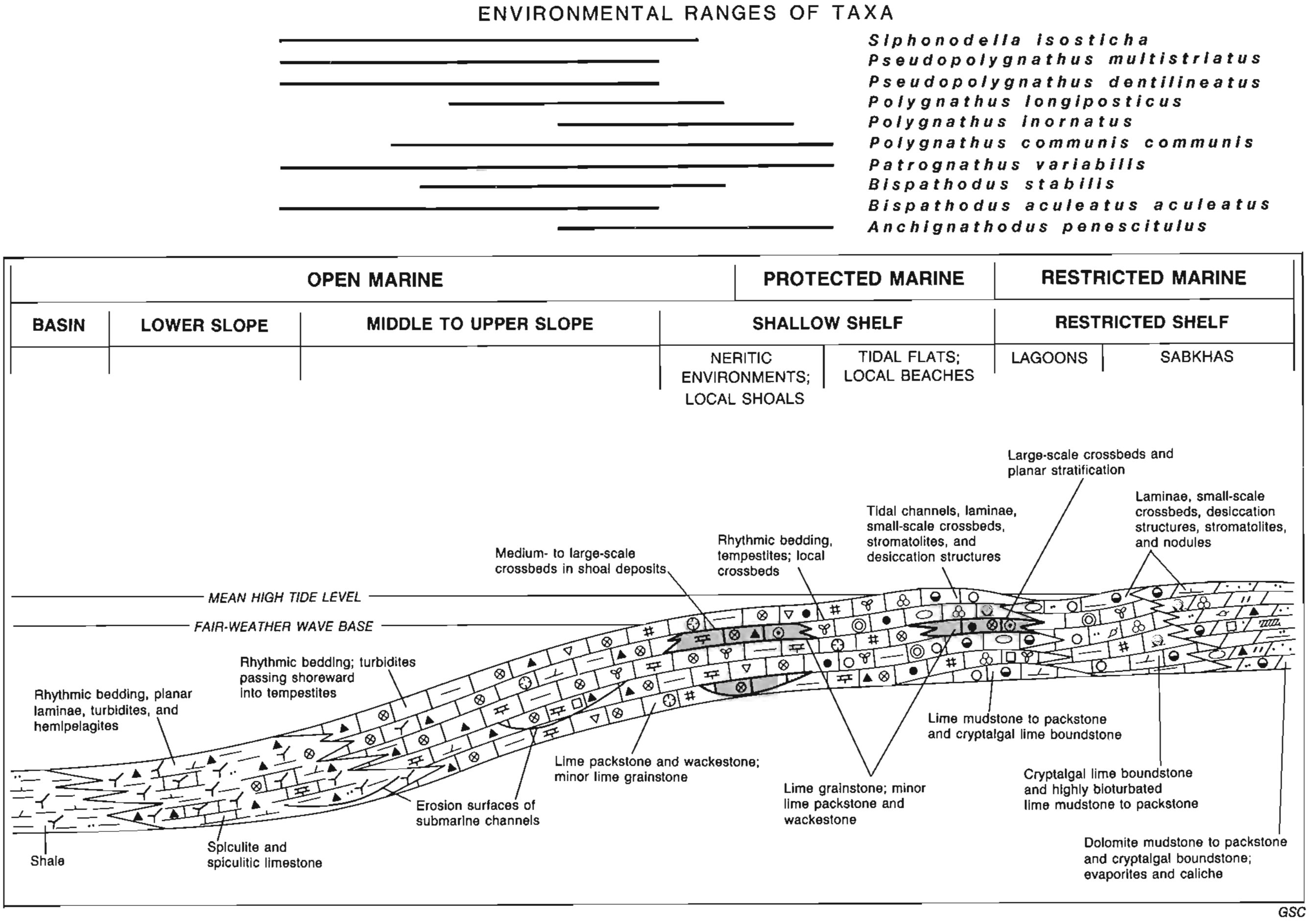


Figure 11. Generalized depositional model of a Carboniferous carbonate ramp showing established environmental ranges of conodont species characteristic of the Upper *crenulata–isosticha* Zone in the Banff assemblage of the Western Canada Sedimentary Basin (modified from Richards, 1989a). See Figure 12 for legend.

The Devonian–Carboniferous boundary must occur within the black shale member of the Exshaw Formation at its stratotype at Jura Creek (Richards and Higgins, 1988), although that section lacks clear evidence of either the *praesulcata* or *sulcata* zones, which bracket the systemic boundary. As stated above, uppermost Devonian conodont faunas assignable to the Middle *expansa* to *praesulcata* zones are present in the lower part of the black shale member at this locality. The highest part of the black shale member at Jura Creek has yielded siphonodellids, including *Siphonodella cooperi* Hass; the same species has been recorded from the overlying siltstone member at Mount Rundle near Banff, Alberta (Macqueen and Sandberg, 1970). *Siphonodella cooperi* has a stratigraphic range from the *duplicata* to *crenulata* zones of Early Carboniferous age. In the absence of sedimentological evidence of an unconformity, the zones are assumed to be present within the sparsely fossiliferous black shale.

In the Williston Basin, the Exshaw Formation has a partial equivalent, the Bakken Formation (Figs. 2, 5). Three informal members constitute the latter: black shale predominates in the lower and upper members, whereas the middle member is mainly sandstone and siltstone. The lower member contains faunas assignable to the *expansa* Zone (Hayes, 1985), the middle member has not been precisely dated, and the upper shale unit, correlative with the widely distributed black shale unit of the basal Banff Formation of Alberta, is referred to the Lower *crenulata* Zone.

Siphonodella sulcata (Huddle), the first appearance of which defines the base of the *sulcata* Zone, has been recorded from the Banff(?) Formation at Bluefish Mountain (Higgins, *in* Richards, 1989a). At that locality it occurs in an assemblage that probably represents the *duplicata* Zone but was questionably assigned to the *sulcata* Zone by Higgins (ibid.). In the Bluefish Mountain assemblage, *S. sulcata* is associated with *Bispathodus aculeatus aculeatus* (Branson and Mehl), *Patrognathus variabilis* Rhodes, Austin, and Druce, *Polygnathus communis communis, P. inornatus* E.R. Branson *P. longiposticus* Branson and Mehl, *Pseudopolygnathus dentilineatus* E.R. Branson, and *P. primus* Branson and Mehl. At a stratigraphic level 9.7 m above the locality yielding this assemblage, the Banff(?) contains a fauna that is within the *duplicata* Zone and includes *Siphonodella duplicata* Morphotype 1 Branson and Mehl. The first appearance of this species defines the base of the *duplicata* Zone (Sandberg et al., 1978).

Lower Siphonodella crenulata *Zone*

The Lower *crenulata* Zone, which is widely represented in the Western Canada Sedimentary Basin, has been recorded from the lower Banff Formation at numerous localities in Alberta and British Columbia (Figs. 2, 6-8). In the south, a minor regional unconformity generally occurs beneath this zone at the base of the Banff Formation, which explains the sudden appearance of large and widespread conodont faunas in the succession. Faunas assignable to the Lower *crenulata* Zone have also been recorded from the Yohin Formation at Twisted Mountain in southwestern District of Mackenzie (Fig. 9; Higgins, *in* Richards, 1989a) and in the upper Bakken and lower Lodgepole formations of the Williston Basin (Hayes, 1985).

The Lower *crenulata* Zone is characterized by *Dinodus fragosus* (E.R. Branson) (Pl. 1, fig. 10), *Elictognathus bialatus* (Branson and Mehl) (Pl. 1, fig. 11), *Pseudopolygnathus marginatus* (Branson and Mehl), *Siphonodella cooperi, S. crenulata* Cooper, *S. isosticha* (Cooper), *S. obsoleta* Hass (Pl. 1, figs. 2, 3, 6), *S. quadruplicata* (Branson and Mehl) (Pl. 1, figs. 5, 7, 9), and *S. sandbergi* Klapper. Other important taxa include: *Anchignathodus penescitulus* (Rexroad and Collinson), *Apatognathus* sp., *Bispathodus aculeatus aculeatus* (Branson and Mehl), and *Polygnathus communis communis*. Samples from this zone commonly contain large faunas of small conodont specimens.

Upper Siphonodella crenulata–Siphonodella isosticha *Zone*

The Upper *crenulata–isosticha* Zone, the base of which is defined by the first appearance of *Gnathodus delicatus* (Branson and Mehl), is widely represented in the Western Canada Sedimentary Basin, where it contains rich and varied faunas. It has been recognized in the Banff and Pekisko formations at many localities from southwestern Alberta into east-central British Columbia. In the Williston Basin it occurs in the Lodgepole Formation. Faunas from this zone include *Anchignathodus penescitulus* (Pl. 2, fig. 8), *Bispathodus aculeatus aculeatus* (Pl. 1, figs. 14, 15), *B. aculeatus plumulus* (Rhodes, Austin, and Druce) (Pl. 1, fig. 17), *Bispathodus spinulicostatus* (E.R. Branson) (Pl. 1, fig. 16), *B.* sp. (Pl. 1, fig. 13), *Clydagnathus* sp., *Gnathodus delicatus, G. punctatus* (Cooper), *Patrognathus variabilis, Polygnathus communis carina* Hass (Pl. 2, figs. 2, 12), *P. inornatus* E.R. Branson, *Protognathodus praedelicatus* Lane, Sandberg, and Ziegler (Pl. 2, fig. 5), *Pseudopolygnathus multistriatus* Mehl and Thomas, and *Siphonodella isosticha* (Pl. 1, figs. 1, 8).

The conodont faunas are a continuation of those in the underlying Lower *crenulata* Zone but are more varied because the intervals sampled include shelf-margin deposits. The latter first occur widely in the Lower Carboniferous succession of the basin at this biostratigraphic level (Figs. 5-8). In the shelf-margin deposits of the basin, which are mostly skeletal and ooid-skeletal lime grainstone, the conodont specimens are usually much larger than those of the slope and basin.

Gnathodus typicus *Zone*

Faunas of the *typicus* Zone occur in the shelf-margin deposits of the Pekisko and Livingstone formations, the protected-shelf to shallow-shelf lithofacies of the Pekisko Formation and overlying lower Shunda Formation (Figs. 6-8), and in lower formation F, which is correlated with the Pekisko and Shunda formations. Siphonodellids are absent, having become extinct. The faunas are dominated by gnathodids and include *Anchignathodus penescitulus, Apatognathus* sp., *Eotaphrus bultyncki* (Groessens), *Gnathodus cuneiformis* Mehl and

Thomas, *G. semiglaber* Bischoff, *G.* sp. cf. *G. typicus* Cooper (Pl. 2, fig. 6), *Polygnathus communis communis*, *P. communis carina*, *P. longiposticus* (Pl. 2, fig. 1), *P. mehli mehli* Thompson, *Protognathodus praedelicatus* Lane, Sandberg, and Ziegler, *Pseudopolygnathus nudus* Pierce and Langenheim, and *P. oxypageus* Lane, Sandberg, and Ziegler.

Scaliognathus anchoralis–Doliognathus latus *Zone*

The *anchoralis–latus* Zone has been recognized at several localities in southwestern Alberta and east-central British Columbia. In these areas, it occurs in the shelf-margin lithofacies of the Livingstone Formation, the shelf deposits of the upper Shunda Formation and overlying lower Turner Valley Formation (Figs. 6-8), and in shallow protected-shelf deposits of upper formation F. The faunas do not include the zonal name-givers *Scaliognathus anchoralis* Branson and Mehl and *Doliognathus latus* Branson and Mehl, but they do include *Eotaphrus burlingtonensis* Pierce and Langenheim (Pl. 1, fig. 12), which is restricted to this zone in other areas (Lane et al., 1980). In addition, *Anchignathodus penescitulus*, *Apatognathus* sp. (Pl. 2, fig. 11), *Eotaphrus bultyncki*, *Gnathodus typicus*, *Polygnathus bischoffi* Rhodes, Austin, and Druce, *P. communis carina*, *P. communis communis*, *P. longiposticus*, *P. mehli* (Pl. 1, fig. 4), *P. mehli latus* Johnson and Higgins, *P. mehli mehli* (Pl. 2, fig. 3), and *Pseudopolygnathus nudus* (Pl. 2, figs. 4, 10) are present.

Gnathodus texanus *Zone*

The *texanus* Zone is recorded from shelf-margin lithofacies of the middle to upper parts of the eastern Livingstone Formation in southwestern Alberta, at Kvass Creek in east-central Alberta, and at Jarvis Lakes, east-central British Columbia. The zone is also known from protected-shelf lithofacies of the Turner Valley Formation from west-central Alberta into east-central British Columbia (Figs. 6-8). The faunas lack the zonal name-giver *Gnathodus texanus* Roundy, generally have low species diversity, and contain few specimens, because environments in which the middle and upper Turner Valley were deposited were probably too shallow and restricted for most conodont animals. Also, the high-energy shelf-margin deposits in the Livingstone are coarse grained bryozoan–pelmatozoan lime grainstone and dolomitized grainstone, commonly unfavourable for conodont preservation. *Taphrognathus varians* Branson and Mehl is present together with *Anchignathodus penescitulus*, *Apatognathus porcatus*, *Apatognathus* sp. (Pl. 2, fig. 11), *Ozarkodina laeviposticus* Rexroad and Collinson, *Polygnathus communis communis*, *P. mehli latus* and, in the upper part of the zone, *Cloghergnathus* spp. (Pl. 2, fig. 9). These taxa are typical of shallow marine lithofacies in other parts of North America; *Cloghergnathus* spp. are characteristic of restricted-shelf lithofacies.

Cavusgnathus *Zone*

The *Cavusgnathus* Zone is a broad biostratigraphic unit recognized in the inner shelf-margin to restricted-shelf lithofacies of the Mount Head Formation at many localities in Alberta and east-central British Columbia. It has also been found locally in shallow- to restricted-shelf deposits of the Etherington Formation near Banff (Figs. 6-8). Faunas from the Mount Head and Etherington formations are typical of shallow marine environments and have few specimens and low species diversity. *Anchignathodus scitulus* (Hinde) (Pl. 2, fig. 7), *Apatognathus* spp., *Cavusgnathus charactus* Rexroad, *C. convexus* Rexroad, *C. unicornis* Youngquist and Miller, and *Vogelgnathus campbelli* (Rexroad) are present, but not in sufficient abundance to be certain of their stratigraphic ranges.

In the outer shelf deposits of the middle to upper Kiskatinaw Formation and overlying Taylor Flat Formation at Mount Greene, northeastern British Columbia, this zonal interval is represented by the *Gnathodus* sp. cf. *G. texanus* (informal, see below) and *G. girtyi collinsoni* zones. In slope carbonates of the Hart River Formation along the Peel River, northern Yukon, correlative upper Viséan conodont assemblages, which include "*Bispathodus stabilis*" (Branson and Mehl), *Gnathodus pseudosemiglaber* Thompson and Fellows, *G. texanus* Roundy, and *Rhachistognathus prolixus* Baesemann and Lane, have been identified at this biostratigraphic level (Bamber et al., 1989).

Species of *Cavusgnathus* were strongly influenced by environmental controls. Cavusgnathids appear in the southern part of the Western Canada Sedimentary Basin somewhat earlier than in other areas, which may reflect the early establishment of favourable shallow marine conditions in the sections sampled. It may also indicate that the succession is more complete than in most other areas where the genus occurs. The broad stratigraphic range of the *Cavusgnathus* Zone indicates a long interval of protected- to restricted-shelf conditions in the eastern Prophet Trough. The shallow marine Viséan and Serpukhovian lithofacies pass basinward into a thick succession of outer shelf, slope, and basin deposits (Figs. 5-9) from which conodonts have yet to be studied.

Gnathodus *sp. cf.* G. texanus *zone*

In the Western Canada Sedimentary Basin, the informal *Gnathodus* sp. cf. *G. texanus* zone is presently recognized from one occurrence (GSC loc. C-171620) of transgressive shelf carbonates in the sandstone- and shale-dominated middle Kiskatinaw Formation at Mount Greene, northeastern British Columbia. Characteristic species include *Cavusgnathus cristatus* Branson and Mehl, ?*Kladognathus* (neoprioniodid elements), "*Bispathodus stabilis*" (Branson and Mehl), and *Gnathodus* sp. cf. *G. texanus* (Pl. 3, fig. 1). This zone is based on the presence of *G.* sp. cf. *G. texanus*, with the upper limit defined by the first appearance of *Gnathodus girtyi girtyi* Hass.

The position of this zone is considerably higher than that of the *texanus* Zone in the lower Viséan (Fig. 2). *Gnathodus texanus* may have a long range, and be absent from the eastern Etherington and Mount Head formations because of unfavourable environmental factors. The presence of *G.* sp. cf. *G. texanus* at Mount Greene could, therefore, reflect the favourable paleogeographic position of the section in the western part of the Peace River Embayment. The appearance of *G.* sp.

cf. *G. texanus* may also have resulted from the return to deeper water shelf conditions after deposition of the regressive deltaic lithofacies characteristic of the lower Kiskatinaw Formation.

A gap within the range of *Gnathodus texanus* has been recognized elsewhere in North America (Thompson and Goebel, 1963; Rexroad and Scott, 1964) leading Lane et al. (1980) to suggest that two homeomorphic forms may exist. The higher occurrence ranges into lower Chesterian strata in the United States and into upper Viséan strata with *Gnathodus bilineatus* (Roundy) in Europe. The upper Viséan zone at Mount Greene is called the *G.* sp. cf. *texanus* zone because of the taxonomic uncertainty.

Gnathodus girtyi collinsoni *Zone*

The *girtyi collinsoni* Zone has been recognized within the lower Taylor Flat Formation at Mount Greene, and from the lower Stoddart Group (formation uncertain) at Peck Creek, northeastern British Columbia. Characteristic species include *Gnathodus girtyi collinsoni* Rhodes, Austin, and Druce (Pl. 3, fig. 2), *G. girtyi girtyi* (Pl. 3, figs. 3-5), *G.* sp. aff. *G. homopunctatus* Ziegler, ?*Kladognathus* [neoprioniodid elements including form species *Neoprioniodus singularis* (Hass)], and *Cavusgnathus cristatus* (both sinistral and dextral Pa elements; Pl. 3, fig. 14). The lower limit is defined by the appearance of *G. girtyi collinsoni* and *G. girtyi girtyi*. The upper limit is defined by the appearance of *G. girtyi simplex* Dunn.

The *collinsoni* Zone was first recognized by Rhodes et al. (1969) and is correlated with the upper Brigantian (uppermost Viséan) in England (Varker and Sevastopulo, 1985). Rhodes et al. (1969) correlated the zone with the *Gnathodus bilineatus–Kladognathus mehli* Zone of Collinson et al. (1962, 1971), which was recognized in mid-Chesterian strata of southern Illinois, Indiana, and western Kentucky.

The faunas from the Stoddart Group are characterized by low-diversity assemblages dominated by *Cavusgnathus*, with occasional specimens of deeper water gnathodid species, suggesting a restricted- or protected-shelf setting. Sedimentological data (silty and sandy, spicule and mixed-skeletal lime wackestone; rhythmically bedded tempestites, lack of subaerial indicators) from the lower Taylor Flat at Mount Greene indicates deposition in the neritic zone and substantial terrigenous influx. At Peck Creek, the lower part of the Stoddart Group includes paleosols, minor unconformities, and wave-formed crossbedding, indicating deposition in shallow neritic to supratidal environments.

Gnathodus girtyi simplex *Zone*

The *girtyi simplex* Zone is recognized within the middle Taylor Flat Formation at Mount Greene and from the lower(?) to middle Taylor Flat at Peck Creek, northeastern British Columbia. Characteristic species include *Gnathodus girtyi simplex* Dunn (Pl. 3, figs. 6, 12), *G. girtyi girtyi*, *G. bilineatus bilineatus* (Pl. 3, fig. 19), ?*Kladognathus* (neoprioniodid elements), and *Rhachistognathus prolixus* Baesemann and Lane (Pl. 3, fig. 10). The lower limit is recognized by the appearance of *G. girtyi simplex* and *R. prolixus*. The upper limit is poorly defined but has been placed at the appearance of *Gnathodus* sp. cf. *G. defectus* Dunn.

Webster (1969) first recognized the *girtyi simplex* Zone in the Indian Springs Formation and overlying lower Bird Spring Formation of southwestern Nevada and correlated it with the upper Chesterian. Dunn (1970) separated the *simplex* Zone of Webster into a lower *G. simplex–Cavusgnathus unicornis* Zone and an upper *Rhachistognathus muricatus* Zone. The *girtyi simplex* Zone, as recognized in the Taylor Flat Formation, correlates with the lower zone of Dunn (1970).

The *girtyi simplex* Zone has been recorded in many other areas including England, where it is correlated with the Pendleian Stage (lower Serpukhovian) (Higgins, 1975, 1985). In areas where the zone is not recognized, the interval is represented by the *Cavusgnathus naviculus* and *C. unicornis* zones of Lane and Straka (1974). According to Baesemann and Lane (1985), *Rhachistognathus prolixus* appears in strata assigned to the *naviculus* Zone. The Taylor Flat rhachistognathids are comparable to early forms of the species that tend to have only one or two nodes on the right platform margin (Tynan, 1980).

The presence of abundant species of *Gnathodus* and the complete lack of any cavusgnathid specimens points to an open marine, outer shelf environment for the middle Taylor Flat Formation at Mount Greene and Peck Creek. An inner- to outer-neritic shelf environment is indicated by the predominance of rhythmically bedded sandstone and sandy carbonate tempestites that locally display wave-formed crossbedding and constitute shallowing- and coarsening-upward sequences.

Uppermost Viséan or Serpukhovian conodont assemblages similar to those from the *girtyi collinsoni* and *girtyi simplex* zones at Mount Greene have been obtained from the lower Blackie Formation of the northern Ogilvie Mountains, northern Yukon (Bamber et al., 1989). The assemblages include *Gnathodus bilineatus*, *G. girtyi collinsoni*, *G. girtyi simplex*, and *Lochriea commutata* (Branson and Mehl).

Rhachistognathus muricatus *Zone*

The *muricatus* Zone is poorly defined in the study area and has been recognized only at Peck Creek where its presence is suggested by the appearance of *Gnathodus* sp. cf. *G. defectus* Dunn (Pl. 3, fig. 9) in the upper Taylor Flat Formation. *Rhachistognathus muricatus* (Dunn) has not been found at this locality, where the *muricatus* Zone extends to the unconformable upper contact of the Taylor Flat. Lane and Straka (1974) recognized the *muricatus* Zone in uppermost Chesterian (upper Serpukhovian) strata in Arkansas and Oklahoma; they indicated that *Gnathodus defectus* is characteristic of the zone. Dunn (1970), who suggested that *Gnathodus defectus* was a descendant of *G. girtyi simplex*, indicated that the appearance of the former species is coincident with that of *Rhachistognathus muricatus*.

Rhachistognathus minutus *Zone*

The *minutus* Zone has been recognized in only one sample from the upper Taylor Flat Formation at Mount Greene (GSC loc. C-171635; 350.5 m above the base of the section, 201.8 m above the base of the formation). Characteristic species include *Rhachistognathus muricatus* (including specimens transitional with *R. primus* Dunn; Pl. 3, figs. 8, 13), *R. websteri* Baesemann and Lane (Pl. 3, fig. 17), *R. minutus havlenai* Baesemann and Lane (Pl. 3, figs, 7, 11), and *Idioprioniodus* sp. According to the range charts of Baesemann and Lane (1985), this assemblage of *Rhachistognathus* species correlates with the *Idiognathoides sinuatus–R. minutus* and *Neognathodus symmetricus* zones of early (but not earliest) Morrowan or early Bashkirian age. The zonal name is shortened here because of the lack of *Idiognathoides* and *Neognathodus*. Davis and Webster (1985) suggested that a *Rhachistognathus* biofacies represents a transitional environment between intertidal environments and normal marine offshore environments.

Faunas similar to those within the *minutus* Zone at Mount Greene have been reported from Bashkirian to lower Moscovian deposits of the lower Ettrain Formation along the Peel River, northern Yukon (Bamber et al., 1989). They include *Rhachistognathus muricatus*, *R. minutus* (Higgins and Bouckaert), and *Adetognathus spathus* (Dunn).

Streptognathodus oppletus *Zone*

The *oppletus* Zone has been recognized in only one sample from the uppermost Taylor Flat Formation at Mount Greene (GSC loc. C-171636; 360.8 m above the base of the section, 3.6 m below the top of the formation). Characteristic species include *Streptognathodus oppletus* Ellison (Pl. 3, fig. 16), *Streptognathodus excelsus*? Stauffer and Plummer, ?*Idiognathoides* sp. aff. *I. marginodosus* Grayson, *Gondolella* sp. cf. *G. gymna* Merrill, *Gondolella* sp. cf. *G. magna* Stauffer and Plummer (Pl. 3, fig. 20), and *Idioprioniodus* sp. *Streptognathodus oppletus* ranges from lower Desmoinesian to Missourian (upper Moscovian to Kasimovian), whereas *S. excelsus* ranges from upper Desmoinesian to Virgilian (upper Moscovian to Gzhelian). The two species of *Gondolella* are typical of Desmoinesian strata (von Bitter and Merrill, 1980). It is difficult to assign a definite age to this assemblage, but a Desmoinesian or late Moscovian age is suggested.

The 10.3 m interval between the localities representing the *minutus* and *oppletus* zones, and the lack of intervening zones, suggests the presence of an unconformity in the upper Taylor Flat Formation. However, this interval could be a condensed succession as it lacks obvious erosional unconformities and contains abundant glauconite and phosphate, indicative of slow sedimentation rates.

Streptognathodus elegantulus*? Zone*

Samples from the uppermost Kananaskis Formation in the Crowsnest Pass area of southeastern British Columbia yielded *Hindeodus minutus* (Ellison), *H. ellisoni* (Merrill) (Pl. 3, fig. 18), *Idiognathodus* sp. cf. *I. delicatus* Gunnell, *Adetognathus lautus* (Gunnell), *Ellisonia* sp., and two fragments of *Streptognathodus* sp. These fragments are tentatively identified as *S. elegantulus* Stauffer and Plummer (Pl. 3, fig. 15), although there are similarities to *S. gracilis* Stauffer and Plummer. Both streptognathid species appear in the upper Desmoinesian (uppermost Moscovian), are particularly abundant in Missourian (Kasimovian) strata, and continue into at least the Virgilian (Gzhelian). According to Merrill (1975), *Hindeodus ellisoni* is characteristic of the Missourian and Virgilian; however, species of *Hindeodus* are typically long ranging in restricted to very shallow marine lithofacies. A latest Moscovian to Kasimovian age is suggested. The dominance of species of *Hindeodus* in the upper Kananaskis Formation suggests deposition in a shallow restricted marine setting.

CONODONT PALEOECOLOGY

Depositional models

The depositional environments of the principal Carboniferous formations in the Western Canada Sedimentary Basin have been discussed by Richards (1989b) and Richards et al. (in press). Many of the interpretations are summarized in schematic cross-sections in Figures 5-9. A ramp and a platform model were developed to illustrate the relationship between environments and lithofacies (Figs. 11, 12). Both models show a series of broad, poorly differentiated facies belts ranging from the basin to the restricted shelf.

The platforms are large buildups with subhorizontal tops and high energy, sand-dominated belts at the shelf slope break. On the platforms, the shelf margin is separated from the main shoreline by a broad, relatively low energy, protected shelf, where deposition occurs in the shallow subtidal and intertidal zones. During transgressions, this was a relatively open marine setting, but at the time of major regressions, the environment commonly resembled that of the restricted shelf.

The ramps are large buildups that prograde gradually away from positive areas and down gentle regional slopes. They lack an obvious break in slope, and the environments of highest energy lie close to the main shoreline. Ramp sedimentation predominated during the early Tournaisian and early middle Tournaisian. On these and younger ramps, the shallow- to restricted-shelf settings were many kilometres wide. From the late middle Tournaisian to the early late Viséan, most of the carbonates formed on platforms, but ramps periodically developed in the Peace River Embayment and in areas where rates of terrigenous influx were high. The shelf-margin barrier was best developed in the southwest from the latest Tournaisian to the latest middle Viséan, when vast restricted shelves were present. From the middle late Viséan into the Moscovian and Kasimovian, rates of terrigenous influx were generally high; consequently, carbonate sedimentation either resulted in ramp development or deposits that were not part of well defined buildups.

The overall Carboniferous regression and development of extensive shelf-margin barriers had a negative effect on post-Tournaisian conodont faunas because the conodont animal evidently preferred open marine environments. The shallow-, restricted-, and protected-shelf settings became inhabited by fewer, less diverse, and more long-ranging conodont species than the open marine environments, and the effectiveness of conodonts as zonal indices diminished in post-Tournaisian strata. This effect was compounded by the general decrease in evolutionary rate of post-Tournaisian conodont faunas.

Relationship of faunas to depositional environment

Von Bitter (1976) described the relationship between conodont faunas and carbonate depositional environments in a study of the Windsor Group (upper Viséan to ?lowermost Serpukhovian) of Nova Scotia. Lithofacies that he considered representative of the most restricted environments (intertidal, lagoon, and oolite shoal) yielded faunas of low diversity

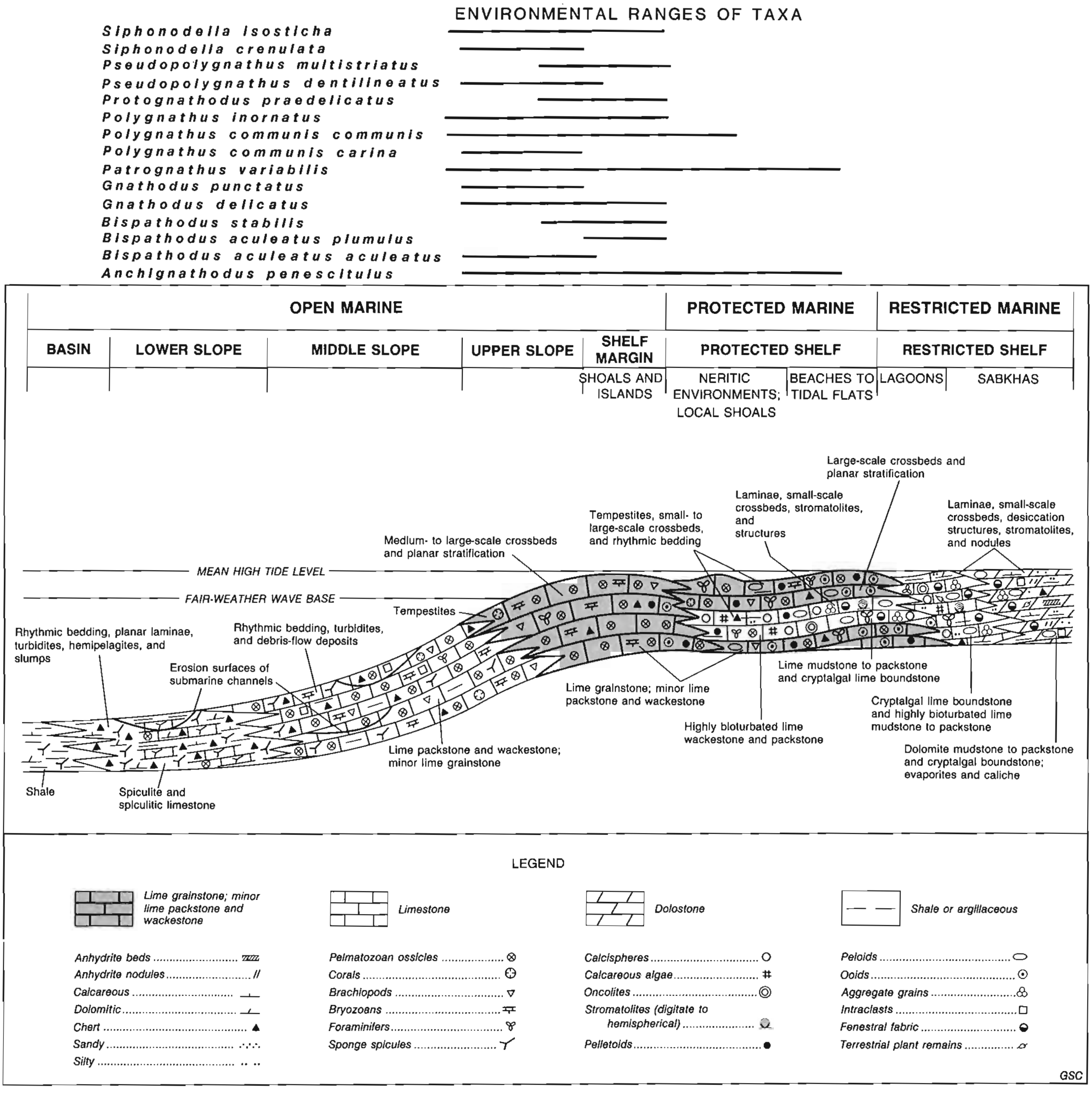


Figure 12. Generalized depositional model of a Carboniferous carbonate platform showing established environmental ranges of conodont species characteristic of the Upper *crenulata–isosticha* Zone in the Rundle assemblage of the Western Canada Sedimentary Basin (modified from Richards, 1989a).

consisting entirely of cavusgnathoids. In slightly deeper water, inner shelf and reef lithofacies, the faunas are more diverse but dominated by specialized forms including cavusgnathoids, taphrognathids and apatognathids. Only in the relatively open marine ?outer shelf deposits, do gnathodids appear in abundance. This pattern is also seen in the Viséan of the Western Canada Sedimentary Basin.

The paleoenvironmental distribution of somewhat older faunas were discussed by Sandberg and Gutschick (1984) for the Osagean/lower Meramecian of Utah. Their environmental model postulated a setting of starved basin (Deseret sub-basin of eastern Antler Foreland Basin) to carbonate platform, showing environmental restriction of conodonts at the generic level. Data from the Western Canada Sedimentary Basin (discussed below) suggest that data analysis at the generic level does not adequately show the relationship between environment and taxa and that, with a few exceptions, the pattern will emerge only with detailed analyses at the specific level (Figs. 11, 12). Only two species, *Polygnathus communis communis* and *Anchignathodus penescitulus* (Pl. 2, fig. 8) are almost ubiquitous, occurring in many environments.

As stated above, the southern Carboniferous succession has been divided into the Banff, Rundle, Mattson, and Besa River assemblages (Figs. 1, 2). These divisions are used below as the basis for analyzing the environments occupied by the Lower Carboniferous conodont faunas. Carboniferous faunas from northern Yukon Territory and those from the Upper Carboniferous of Alberta and British Columbia are generally too poorly known to be assigned to particular environments.

Five hundred and fifty-four Lower Carboniferous samples of 1-2 kg were analyzed from the southern succession. The distribution of the samples, with respect to environment, is as follows:

	Basin	Slope	Shelf margin	Siliciclastic shelf, protected shelf and shallow shelf	Restricted shelf
No. of samples	26	85	176	243	25
% of barren samples	26	7	10	28	80

Up to 500 conodont specimens per kilogram have been recorded from condensed intervals of slope and basin lithofacies in the Lodgepole Formation, but this is atypical and most Carboniferous samples yielded 20 to 50 specimens per kilogram.

Faunas of the Banff assemblage

Conodont faunas from the Banff assemblage were extracted from lithofacies representing several environments including: starved basin to euxinic shelf, aerobic basin, siliciclastic-dominated shelf, carbonate slope, shallow shelf (carbonate ramp), and shelf margin to outer protected shelf (carbonate platform). The siliciclastic-dominated shelf and the starved basin to euxinic-shelf settings are represented by Upper Devonian and Lower Carboniferous taxa, whereas only Lower Carboniferous faunas are known from the other environments.

Faunas from starved, euxinic basins and shelves

Faunas from the starved, euxinic basin and shelf environments were obtained from black shale of the lower Exshaw Formation, which was deposited in the anaerobic to dysaerobic zones of an epeiric sea characterized by high organic productivity in the euphotic zone (Richards and Higgins, 1988). They were also obtained from black shale of the upper Bakken and lower Banff formations.

Typical species in the Upper *expansa* Zone of the lower Exshaw include: *Bispathodus costatus*, *Palmatolepis perlobata*, *P. gracilis sigmoidalis*, *P. rugosa*, and *Polygnathus communis*. *Siphonodella cooperi*, ranging from the Upper *duplicata* to Upper *crenulata–isosticha* zones, occurs in Lower Carboniferous dysaerobic zone shale of the lower Exshaw Formation at Jura Creek, southwestern Alberta.

Typical taxa from the Lower *crenulata* Zone of the basal Banff and upper Bakken formations in Canada include *Siphonodella crenulata*, and *Bispathodus aculeatus aculeatus*. Hayes (1985) reported a diverse assemblage from the Lower *crenulata* Zone in the upper Bakken Formation of North Dakota.

Aerobic basin faunas

Aerobic basin faunas have been recovered only from the Banff(?) Formation at Bluefish Mountain, southwestern District of Mackenzie. The conodonts from that locality were assigned to the ?*sulcata* and *duplicata* zones (Higgins, *in* Richards, 1989a). Typical taxa from the former zone include *Bispathodus aculeatus aculeatus*, *B. aculeatus anteposicornis*, *Polygnathus communis*, *P. inornatus inornatus*, *P. longiposticus*, and *Siphonodella sulcata*. Those within the *duplicata* Zone include *Bispathodus aculeatus aculeatus*, *B. stabilis*, *Polygnathus communis*, *Polygnathus inornatus*, and *Siphonodella duplicata* Morphotype 1.

Slope faunas

Slope faunas have been extracted from the Lodgepole Formation at Esterhazy, Saskatchewan, the Banff(?) Formation at Bluefish Mountain in southwestern District of Mackenzie, and from the Banff Formation at numerous localities from southwestern Alberta into east-central British Columbia. Faunas in the slope lithofacies are more varied than those of the starved basin lithofacies. They occur in dark grey spiculite and lime wackestone of lower slope origin and in rhythmically bedded skeletal lime wackestone, packstone, and grainstone deposited in middle- to upper-slope environments. The major difference between the lower slope and middle- to upper-slope faunas is the smaller size of the lower slope specimens.

Slope faunas within the ?*duplicata* Zone have been recovered only from the Banff(?) Formation at Bluefish Mountain, whereas those of other zones have been collected from the Lodgepole Formation at Esterhazy and the Banff Formation at many localities. The ?*duplicata* Zone is represented by *Bispathodus aculeatus aculeatus*, *B. stabilis*, and *Polygnathus inornatus*. Typical taxa from the Lower *crenulata* Zone are *Dinodus fragosus*, *Elictognathus biolatus*, *Pseudopolygnathus marginatus*, *Siphonodella crenulata*, *S. obsoleta*, *S. quadruplicata*, and *S. sandbergi*. Those from the Upper *crenulata–isosticha* Zone include *Bispathodus aculeatus aculeatus*, *Patrognathus variabilis*, *Polygnathus communis communis*, *P. longiposticus*, *Pseudopolygnathus dentilineatus*, *P. multistriatus*, and *Siphonodella isosticha* (Fig. 11).

Faunas from outer shallow-shelf setting (carbonate ramp)

Faunas from the outer shallow-shelf lithofacies represent the Upper *crenulata–isosticha* Zone (Fig. 11). They were collected from the crossbedded to rhythmically bedded carbonates of the upper Banff Formation at many localities in east-central British Columbia and at Canyon Creek, southwestern Alberta. The shallow-shelf deposits and their conodont faunas closely resemble those of the upper slope and the shelf-margin to outer protected-shelf lithofacies. Typical taxa include *Anchignathodus penescitulus*, *Bispathodus stabilis*, *Neoprioniodus barbatus*, *Patrognathus variabilis*, *Polygnathus communis communis*, *P. inornatus*, *P. longiposticus*, and *Siphonodella isosticha*.

Faunas from aerobic, siliciclastic-dominated shelves

Faunas from aerobic, siliciclastic-dominated shelves have been recovered mainly from sandy, crossbedded, skeletal limestone of the upper Exshaw Formation at Red Deer Creek, east-central British Columbia (Richards and Higgins, 1988), and from tempestites in the Yohin Formation at Bluefish and Twisted mountains, southwestern District of Mackenzie (Higgins *in* Richards, 1989a).

The taxa from the upper Exshaw Formation occur in the Upper *expansa* Zone and include *Bispathodus jugosus*, *Palmatolepis gracilis expansa*, *P. gracilis gonioclymenae*, *P. rugosa postera*, *Polygnathus communis communis*, *P. experplexus*, and *Pseudopolygnathus marburgensis trigonicus*. The assemblages from the Yohin Formation have been assigned to the Lower *crenulata* Zone and include *Anchignathodus penescitulus*, *Bispathodus stabilis*, *Polygnathus communis communis*, and *Polygnathus inornatus*.

Faunas from shelf-margin to outer protected shelf (carbonate platform)

Shelf-margin to outer protected-shelf faunas were extracted from the Upper *crenulata–isosticha* Zone of the upper Banff Formation at several localities in east-central British Columbia and west-central Alberta. During the middle Tournaisian, a poorly differentiated carbonate platform developed in the southeastern part of that area (Figs. 7, 8). The principal taxa are the same as those of outer shallow-shelf lithofacies.

Faunas of the Rundle assemblage

The Rundle assemblage of middle Tournaisian to late Viséan age, records the onset of extensive platform sedimentation (Figs. 5-9) and related establishment of extensive shelf-edge shoals. Conodont faunas have been collected from upper-slope to restricted-shelf environments and show considerable lateral variation; they are best known for the Upper *crenulata–isosticha* Zone in platform lithofacies (Fig. 12).

Faunas of the upper slope

The widely preserved slope deposits of the middle depositional unit have been extensively sampled for conodonts, but only samples from Princess Margaret Mountain, Jarvis Lakes, and Watson Peak (Appendix) have been completely processed. The faunas from these localities, extracted mainly from cherty lime packstone and grainstone that are rhythmically interbedded with marlstone, are from the Pekisko Formation and overlying unnamed formation F. The Upper *crenulata–isosticha*, *typicus*, and Lower *anchoralis–latus* zones are represented.

Principal taxa from the slope deposits within the Upper *crenulata–isosticha* Zone (Fig. 12) are *Anchignathodus penescitulus*, *Gnathodus delicatus*, *G. typicus* Morphotype 1, *Neoprioniodus barbatus*, *Polygnathus communis carina*, *P. communis communis*, *P. inornatus*, *Pseudopolygnathus dentilineatus*, *Siphonodella crenulata*, and *S. isosticha*. Taxa from the *typicus* and Lower *anchoralis–latus* zones include *Anchignathodus penescitulus*, *Eotaphrus bultyncki*, *Polygnathus communis communis*, *Protognathodus praedelicatus*, and *Spathognathodus* sp.

Faunas of the shelf margin

Shelf-margin faunas occur in the Upper *crenulata–isosticha*, *typicus*, *anchoralis–latus*, and *texanus* zones, and have been extracted primarily from the western Pekisko Formation and eastern Livingstone Formation. Western lithofacies of the Turner Valley Formation and Loomis Member of the Mount Head Formation also contain these faunas. The shelf-margin lithofacies, consisting mainly of bryozoan-pelmatozoan lime grainstone with subordinate ooid-skeletal and ooid-lime grainstones, covered a vast belt extending for many hundreds of kilometres along the shelf margin. Toward both the basin and paleoshoreline, the shelf-margin deposits grade into lower energy carbonate lithofacies from which they cannot always be readily differentiated using lithological criteria.

Typical faunas from the Upper *crenulata–isosticha* Zone (Fig. 12) are *Anchignathodus penescitulus, Bispathodus aculeatus aculeatus, B. aculeatus plumulus, B. stabilis, Gnathodus delicatus, G. punctatus, Patrognathus variabilis, Polygnathus inornatus, Protognathodus praedelicatus, Pseudopolygnathus dentilineatus, P. multistriatus*, and *Siphonodella isosticha*. Shelf-margin taxa within the *typicus* Zone include *Eotaphrus bultyncki, Gnathodus cuneiformis, G. typicus, G. semiglaber, Polygnathus longiposticus, P. mehli mehli*, and *Protognathodus praedelicatus*. Typical faunas from the *anchoralis–latus* Zone are *Eotaphrus bultyncki, E. burlingtonensis, Gnathodus typicus, Polygnathus mehli mehli, P. mehli latus*, and *Pseudopolygnathus nudus*. Principal taxa from the *texanus* Zone are *Anchignathodus penescitulus, Neoprioniodus tulensis, Ozarkodina laevipostica, Polygnathus communis communis, P. mehli*, and *Taphrognathus varians*.

Faunas from the protected shelf (platform) and shallow shelf (ramp)

The protected-shelf and shallow-shelf deposits of the Rundle assemblage contain conodont faunas of the Upper *crenulata–isosticha* to *Cavusgnathus* zones. A diverse array of lithofacies ranging from ooid and mixed-skeletal lime grainstone to fenestral, cryptalgal lime boundstone were deposited on the protected shelf and shallow shelf. Protected- and shallow-shelf deposits are widely preserved in numerous formations within the Rundle assemblage (Figs. 7-9). Most specimens representing these environments came from mixed skeletal limestone of probable neritic to outer intertidal origin.

Patrognathus variabilis is the main taxon from the Upper *crenulata–isosticha* Zone. Principal taxa from the *typicus* Zone are *Eotaphrus bultyncki* and *Polygnathus mehli mehli*. The *anchoralis–latus* Zone is generally represented by *Anchignathodus penescitulus, Eotaphrus burlingtonensis, Neoprionodus tulensis, Polygnathus mehli latus*, and *Spathognathodus crassidentatus*. Taxa from the *texanus* Zone include *Anchignathodus penescitulus, Apatognathus porcatus, Cloghergnathus* sp., *Ozarkodina laevipostica*, and *Taphrognathus varians*. The *Cavusgnathus* Zone is represented by *Anchignathodus penescitulus, A. scitulus, Apatognathus porcatus, Cavusgnathus unicornis, C.* spp., *Ozarkodina curvata, O. laevipostica, Polygnathus mehli*, and *Vogelgnathus campbelli*.

Restricted-shelf faunas

Few conodonts occur in the restricted-shelf lithofacies, which includes foraminifer-algal lime wackestone, fenestral cryptalgal lime boundstone, silty dolostone, and evaporites. Most samples processed from this lithofacies are either barren or contain a few specimens that are not zone diagnostic. The known taxa occur in samples from the Shunda Formation of east-central British Columbia; they include *Anchignathodus penescitulus, Apatognathus* sp., and *Spathognathodus elongatus*.

Faunas of the Mattson assemblage

The Mattson assemblage, of late Viséan and Late Carboniferous age, records the widespread development of siliciclastic depositional systems and resulting decline in carbonate platform and ramp development. Conodonts are known from carbonate lithofacies of the Etherington and Kananaskis formations that formed on the shallow shelves of widespread carbonate ramps in southern Prophet Trough. Conodonts have also been extracted from skeletal limestone of the Kiskatinaw and Taylor Flat formations, deposited in western Peace River Embayment in inner- to outer-neritic shelf environments, where deposition of sandstone, siltstone and shale commonly predominated.

Taxa from the Etherington Formation represent the *Cavusgnathus* Zone and include *Anchignathodus scitulus, Cavusgnathus charactus, C. convexus, C. unicornis, Magnilateralla robusta*, and *Vogelgnathus campbelli*. Taxa from the Kananaskis Formation represent the *elegantulus* Zone, and are listed above under conodont biostratigraphy. Faunas from the Kiskatinaw and Taylor Flat formations are more diverse and represent the cf. *texanus, girtyi collinsoni, girtyi simplex, muricatus, minutus*, and *oppletus* zones (discussed above). The Kiskatinaw and Taylor Flat faunas were derived from carbonate units occurring in siliciclastic-dominated successions and represent mainly neritic, open marine shelf environments.

SUMMARY

As documented above, paleoenvironmental control on the uppermost Devonian and Carboniferous conodont faunas is marked in the Western Canada Sedimentary Basin, particularly in the shallow marine lithofacies. All of the principal marine lithofacies have been sampled for conodonts, but none of the zones are represented by faunas that span the complete range of facies. Only the faunas of the Upper *crenulata–isosticha* and *typicus* zones are known from a broad spectrum of lithofacies (Figs. 11, 12) and warrant detailed analysis. In the Lower Carboniferous strata, faunas from slope, outer shelf-margin, and outer shallow-shelf lithofacies had the highest diversity and number of specimens, reflecting conditions ideal for the conodont animal. Samples from the protected-shelf, inner shallow-shelf, and restricted-shelf lithofacies were either barren or contained low diversity faunas with few specimens. Little is known about the paleoenvironmental ranges of the Upper Carboniferous faunas, as they were derived mainly from one principal lithofacies.

Faunas of the Devonian and Lower Carboniferous *expansa* to Lower *crenulata* zones from the starved euxinic basin, starved euxinic shelf, and aerobic basin lithofacies of the Banff assemblage have high species diversity. The Devonian faunas include palmatolepids, polygnathids, and bispathodids; those from the Lower Carboniferous contain siphonodellids in addition to polygnathids, and bispathodids. Pseudopolygnathids, common at this biostratigraphic level in many other parts of the world (Sandberg et al., 1978) have not been observed in the anaerobic basin and shelf lithofacies. Their absence was also noted by Sandberg and Gutschick (1984) from Meramecian and Osagean starved basin deposits in Utah.

Devonian conodont faunas of the Middle *expansa* and *praesulcata* zones from open marine, siliciclastic-dominated shelf deposits resemble those of the correlative starved basin and shelf, in terms of the principal faunal elements. Lower Carboniferous faunas of the *sulcata* to Lower *crenulata* zones from aerobic siliciclastic shelf deposits appear to be less diverse than those from the coeval euxinic deposits and are dominated by polygnathids, bispathodids, and the largely ubiquitous *Anchignathodus penescitulus*. Faunas from slope deposits in the Lower *crenulata* Zone have high species diversity and contain abundant siphonodellids.

The Upper *crenulata–isosticha* Zone occurs in the upper part of the Banff assemblage, deposited mainly on carbonate ramps. It has also been widely recognized in the lower part of the Rundle assemblage, which records the initiation of widespread carbonate platform sedimentation. Slope and shelf faunas have been collected from this zone at numerous localities, but basinal faunas have not been extracted. Faunal changes from the lower- to upper-slope lithofacies are mainly in terms of specimen abundance. Siphonodellids are abundant in the lower and middle slope deposits, become less abundant in the upper slope deposits, and are represented by only *S. isosticha* in the shelf-margin and outer shallow-shelf lithofacies. Siphonodellids are not present in faunas from the protected shelf and inner shallow shelf. Pseudopolygnathids occur in both the slope and shelf-margin lithofacies. Gnathodids are common only in faunas from the shelf-margin lithofacies of the Rundle assemblage. *Gnathodus delicatus* is present in both the upper slope and shelf-margin lithofacies, but *G. punctatus* has been recorded from only the former. *Polygnathus communis carina*, normally occurring in shallow marine deposits (Sandberg and Gutschick, 1984) occurs in lithofacies of the Rundle assemblage that were deposited near the shelf margin. Only *Anchignathodus penescitulus*, *Patrognathus variabilis* and *Polygnathus communis communis* occur in carbonates deposited in the protected-shelf environments of the platform. *Patrognathus variabilis* is also the most widespread species, occurring from lower slope to shelf-margin carbonates of the Banff assemblage, and from upper slope to protected-shelf deposits in the Rundle assemblage.

Faunas of the *typicus* Zone are known from upper slope to restricted marine shelf lithofacies of the Rundle assemblage. The faunas are distinctive but lack high species diversity. *Eotaphrus bultyncki* occurs in upper slope to protected-shelf lithofacies. Polygnathids, represented by *Polygnathus mehli mehli*, occur in the shelf-margin and protected-shelf deposits. Only *Anchignathodus penescitulus* has been identified in the restricted marine deposits.

Faunas of the *anchoralis–latus* Zone occur principally in shelf-margin and protected-shelf lithofacies. *Eotaphrus burlingtonensis* occurs in both environments together with *Anchignathodus penescitulus* and *Polygnathus mehli latus*. *Gnathodus typicus* and *Pseudopolygnathus nudus* are present only in shelf-margin facies.

Most of the faunas of the *texanus* and *Cavusgnathus* zones were derived from the inner shallow-shelf, and protected- to restricted-shelf lithofacies of the Rundle assemblage and lower Mattson assemblage. Consequently, the gnathodid faunas, common in basin, slope, and outer shelf-margin deposits in other parts of the world, are absent. Cavusgnathids, taphrognathids and cloghergnathids are present with *Anchignathodus scitulus* and apatognathids. Upper Viséan and lower Serpukhovian deposits at Mount Greene and Peck Creek, northeastern British Columbia, have richer more diverse faunas assignable to the *Gnathodus* sp. cf. *G. texanus*, *girtyi collinsoni* and *girtyi simplex* zones, which are in part coeval with the *Cavusgnathus* Zone. The Mount Greene faunas represent open marine, environments.

REFERENCES

Baesemann, J.F. and Lane, H.R.
1985: Taxonomy and evolution of the genus *Rhachistognathus* Dunn (Conodonta; late Mississippian to early middle Pennsylvanian). Courier Forschungsinstitut Senckenberg, v. 74, p. 93-136.

Bamber, E.W. and Mamet, B.L.
1978: Carboniferous biostratigraphy and correlation, northeastern British Columbia and southwestern District of Mackenzie. Geological Survey of Canada, Bulletin 266, 65 p.

Bamber, E.W. and Waterhouse, J.B.
1971: Carboniferous and Permian stratigraphy and paleontology, northern Yukon Territory, Canada. Bulletin of Canadian Petroleum Geology, v. 19, p. 29-250.

Bamber, E.W., Macqueen, R.W., and Richards, B.C.
1984: Facies relationships at the Mississippian carbonate platform margin, Western Canada. *In* Part 3: Sedimentology and Geochemistry, E.S. Belt and R.W. Macqueen (eds.); Neuvième Congrès International de Stratigraphie et de Géologie du Carbonifère, 1979, Compte Rendu, v. 3, p. 461-478.

Bamber, E.W., Henderson, C.M., Jerzykiewicz, J., Mamet, B.L., and Utting, J.
1989: A summary of Carboniferous and Permian biostratigraphy, northern Yukon Territory and northwestern District of Mackenzie. *In* Current Research, Part G, Geological Survey of Canada, Paper 89-1G, p. 13-21.

Barclay, J.E., Krause, F.F., Campbell, R.I., and Utting, J.
1990: Dynamic casting and growth faulting: Dawson Creek graben complex, Carboniferous–Permian Peace River Embayment, Western Canada. Bulletin of Canadian Petroleum Geology, v. 38A, p. 115-146.

Baxter, S.
1972: Conodont biostratigraphy of the Mississippian of western Alberta and adjacent British Columbia, Canada. Unpublished Ph.D. thesis, Ohio State University.

Baxter, S. and von Bitter, P.H.
1984: Conodont succession in the Mississippian of Southern Canada. *In* Part 2: Biostratigraphy, P.K. Sutherland and W.L. Manger (eds.); Neuvième Congrès International de Stratigraphie et de Géologie du Carbonifère, Compte Rendu, v. 2, p. 253-264.

Bell, J.S.
1973: Late Paleozoic orogeny in the northern Yukon. *In* Canadian Arctic Geology, J.D. Aitken and D.J. Glass (eds.); Proceedings of the Symposium on the Geology of the Canadian Arctic, Geological Association of Canada–Canadian Society of Petroleum Geologists Symposium, 1973, p. 23-28.

Carter, J.L.
1987: Lower Carboniferous brachiopods from the Banff Formation of western Alberta. Geological Survey of Canada, Bulletin 378, 183 p.

Christopher, J.E.
1961: Transitional Devonian–Mississippian formations of southern Saskatchewan. Saskatchewan Mineral Resources Report 66, 103 p.

Collinson, C., Scott, A.J., and Rexroad, C.B.
1962: Six charts showing biostratigraphic zones, and correlations based on conodonts from the Devonian and Mississippian rocks of the upper Mississippi Valley. Illinois State Geological Survey, Circular 328, 32 p.

Collinson, C., Rexroad, C.B., and Thompson, T.L.
1971: Conodont zonation of the North American Mississippian. *In* Symposium on Conodont Biostratigraphy, W.C. Sweet and S.M. Bergström (eds.); Geological Society of America, Memoir 127, p. 353-394.

Craig, L.C.
1972: Mississippian System. *In* Geologic Atlas of the Rocky Mountain region, W.W. Mallory (ed.); Rocky Mountain Association of Geologists, p. 100-110.

Crasquin, S.
1984: Ostracodes du Dinantien; systématique, biostratigraphie, paléoécologie (France, Belgique, Canada). Thèse de Troisième cycle, l' Université des Sciences et Techniques de Lille, 2 vol., 238 p.

Davis, L.E. and Webster, G.D.
1985: Late Mississippian to early Pennsylvanian conodont biofacies in central Montana. Lethaia, v. 18, p. 67-72.

Douglas, R.J.W.
1958: Mount Head map-area. Geological Survey of Canada, Memoir 291, 241 p.

Douglas, R.J.W., Gabrielse, H., Wheeler, J.O., Stott, D.F., and Belyea, H.R.
1970: Geology of Western Canada. *In* Geology and Economic Minerals of Canada, R.J.W. Douglas (ed.); Geological Survey of Canada, Economic Geology Report no. 1, p. 366-488.

Dunn, D.L.
1970: Middle Carboniferous conodonts from southwestern United States. Journal of Paleontology, v. 44, p. 312-342.

Edie, R.W.
1958: Mississippian sedimentation and oil fields in southwestern Saskatchewan. *In* Jurassic and Carboniferous of Western Canada, A.J. Goodman (ed.); American Association of Petroleum Geologists, John Andrew Allan Memorial Volume, p. 331-363.

Halbertsma, H.L.
1959: Nomenclature of Upper Carboniferous and Permian strata in the subsurface of the Peace River area. Journal of the Alberta Society of Petroleum Geologists, v. 7, p. 109-118.

Hayes, M.D.
1985: Conodonts of the Bakken Formation (Devonian and Mississippian), Williston Basin, North Dakota. The Mountain Geologist, v. 22, no. 2, p. 64-77.

Henderson, C.M.
1989: The lower Absaroka Sequence: Upper Carboniferous and Permian, Chapter 10. *In* Western Canada Sedimentary Basin, A Case History, B.D. Ricketts (ed.); Canadian Society of Petroleum Geologists, p. 203-217.

Higgins, A.C.
1975: Conodont zonation of the Late Viséan–Westphalian strata of the south and central Pennines of Northern England. Geological Survey of Great Britain, Bulletin, v. 53, p. 1-90.
1985: The Carboniferous System: Part 2 – Conodonts of the Silesian Subsystem from Great Britain and Ireland. *In* A Stratigraphical Index of Conodonts, A.C. Higgins and R.L. Austin, (eds.); British Micropalaeontological Society Series, Ellis Horwood Limited, Chichester, p. 210-227.

Lane, H.R. and Straka, J.J., II
1974: Late Mississippian and Early Pennsylvanian conodonts, Arkansas and Oklahoma. Geological Society of America, Special Paper 152, 144 p.

Lane, H.R., Sandberg, C.A., and Ziegler, W.
1980: Taxonomy and phylogeny of some Lower Carboniferous conodonts and preliminary standard post-*Siphonodella* zonation. Geologica et Paleontologica, v. 14, p. 117-164.

Macauley, G.
1958: Late Paleozoic of Peace River Arch, Alberta. *In* Jurassic and Carboniferous of Western Canada, A.J. Goodman (ed.); American Association of Petroleum Geologists, John Andrew Allan Memorial Volume, p. 289-308.

Macauley, G., Penner, D.G., Procter, R.M., and Tisdall, W.H.
1964: Carboniferous. *In* Geological History of Western Canada, R.G. McCrossan and R.P. Glaister (eds.); Alberta Society of Petroleum Geologists, p. 89-102.

Macqueen, R.W. and Bamber, E.W.
1967: Stratigraphy of the Banff Formation and lower Rundle Group (Mississippian), southwestern Alberta. Geological Survey of Canada, Paper 67-47, 37 p.

Macqueen, R.W. and Bamber, E.W. (cont'd.)
1968: Stratigraphy and facies relationships of the upper Mississippian Mount Head Formation, Rocky Mountains and Foothills, southwestern Alberta. Bulletin of Canadian Petroleum Geology, v. 16, p. 225-287.

Macqueen, R.W. and Sandberg, C.A.
1970: Stratigraphy, age, and interregional correlation of the Exshaw Formation, Alberta Rocky Mountains. Bulletin of Canadian Petroleum Geology, v. 18, p. 32-66.

Macqueen, R.W., Bamber, E.W., and Mamet, B.L.
1972: Lower Carboniferous stratigraphy and sedimentology of the southern Rocky Mountains. 24th International Geological Congress, Montreal, Quebec, Guidebook, Field Excursion 17, 62 p.

Mamet, B.L.
1976: An atlas of microfacies in Carboniferous carbonates of the Canadian Cordillera. Geological Survey of Canada, Bulletin 255, 131 p.

Mamet, B.L. and Bamber, E.W
1979: Stratigraphic correlation chart of the lower part of the Carboniferous, Canadian Cordillera and Arctic Archipelago. *In* Palaeontological Characteristics of the Main Subdivisions of the Carboniferous, S.V. Meyen, V.V. Menner, E.A. Reitlinger, A.P. Rotai, and M.N. Solovieva (eds.); Huitième Congrès International de Stratigraphie et de Géologie Carbonifère, 1975; Compte Rendu, v. 3, p. 37-49.

Mamet, B.L., Bamber, E.W., and Macqueen, R.W.
1986: Microfacies of the Lower Carboniferous Banff Formation and Rundle Group, Monkman Pass map-area, northeastern British Columbia. Geological Survey of Canada, Bulletin 353, 93 p.

Mamet, B.L. and Skipp, B.A.
1970: Preliminary foraminiferal correlations of Early Carboniferous strata in the North American Cordillera. *In* Colloque sur la Stratigraphie du Carbonifère; Les Congrès et Colloques de l'Univérsité de Liège, v. 55, p. 327-348.

Merrill, G.K.
1975: Pennsylvanian conodont biostratigraphy and paleoecology of northwestern Illinois. Geological Society of America, Microfiche Publication 3, 130 p.

Nassichuk, W.W. and Bamber, E.W.
1978: Middle Pennsylvanian biostratigraphy, eastern Cordillera and Arctic Islands Canada – a summary. *In* Western and Arctic Canadian Biostratigraphy, C.R. Stelck and B.D.E. Chatterton (eds.); Geological Association of Canada, Special Paper 18, p. 395-413.

Nelson, S.J.
1958: Brachiopod zones of the Mount Head and Etherington formations, southern Canadian Rockies. Royal Society of Canada Transactions, v. 52, sec. 4, p. 45-53.
1960: Mississippian lithostrotionid zones of the southern Canadian Rocky Mountains. Journal of Paleontology, v. 34, p. 107-126.
1961: Mississippian faunas of western Canada. Geological Association of Canada, Special Paper No. 2, 39 p.

Nilsen, T.H.
1981: Upper Devonian and Lower Carboniferous redbeds, Brook Range, Alaska. *In* Sedimentation and Tectonics in Alluvial Basins, A.D. Miall (ed.); Geological Association of Canada, Special Paper 23, p. 187-219.

Porter, J.W., Price, R.A., and McCrossan, R.B.
1982: The Western Canada Sedimentary Basin. Philosophical Transactions of the Royal Society of London, v. A305, p. 169-192.

Pugh, D.C.
1983: Pre-Mesozoic geology in the subsurface of Peel River map area, Yukon Territory and District of Mackenzie. Geological Survey of Canada, Memoir 401, 61 p.

Rexroad, C.B. and Scott, A.J.
1964: Conodont zones in the Rockford Limestone and the lower part of the New Providence Shale (Mississippian) in Indiana. Indiana Geological Survey, Bulletin 30, p. 1-54.

Rhodes, F.H.T., Austin, R.L., and Druce, E.C.
1969: British Avonian (Carboniferous) conodont faunas and their value in local and intercontinental correlation. British Museum (Natural History) Bulletin, Geology Supplement 5, p. 1-313.

Richards, B.C.
1989a: Uppermost Devonian and Lower Carboniferous stratigraphy, sedimentation, and diagenesis, southwestern District of Mackenzie and Southeastern Yukon Territory. Geological Survey of Canada, Bulletin 390, 135 p.
1989b: Upper Kaskaskia Sequence: uppermost Devonian and Lower Carboniferous, Chapter 9. *In* Western Canada Sedimentary Basin, A Case History, B.D. Ricketts (ed.); Canadian Society of Petroleum Geologists, p. 165-201.

Richards, B.C. and Higgins, A.C.
1988: Devonian–Mississippian boundary beds of the Palliser and Exshaw formations at Jura Creek, Rocky Mountains, southwestern Alberta. In Devonian of the World, N.J. McMillan, A.F. Embry, and D.J. Glass (eds.). Canadian Society of Petroleum Geologists, Memoir 14, v. 2, p. 399-412.

Richards, B.C., Bamber, E.W., Higgins, A.C., and Utting, J.
in press: Carboniferous. *In* Sedimentary Cover of the North American Craton: Canada, D.F. Stott and J.D. Aitken (eds.); Geological Survey of Canada, Geology of Canada, no. 6 (also Geological Society of America, The Geology of North America, v. D-1).

Ricketts, B.D.
1989: Introduction, Chapter 1. *In* The Western Canada Sedimentary Basin, A Case History, B.D. Ricketts (ed.); Canadian Society of Petroleum Geologists, p. 1-8.

Sandberg, C.A. and Gutschick, R.C.
1984: Distribution, microfauna, and source-rock potential of Mississippian Delle Phosphatic Member of Woodman Formation and equivalents, Utah and adjacent states. *In* Hydrocarbon Source Rocks of the Greater Rocky Mountain Region, Denver, Colorado, J. Woodward, F.F. Meissner, and J.L. Clayton (eds.); Rocky Mountain Association of Geologists, p. 135-178.

Sandberg, C.A., Ziegler, W., Leuteritz, K., and Brill, S.M.
1978: Phylogeny, speciation, and zonation of *Siphonodella* (Conodonta, Upper Devonian and Lower Carboniferous). Newsletters in Stratigraphy, v. 7, p. 102-120.

Sando, W.J.
1985: Revised Mississippian time scale, western interior region, conterminous United States. United States Geological Survey, Bulletin 01605-A, p. A15-126.

Sando, W.J. and Bamber, E.W.
1985: Coral zonation of the Mississippian System in the Western Interior Province of North America. United States Geological Survey, Professional Paper 1334, 61 p.

Scott, D.L.
1964: Pennsylvanian stratigraphy. Bulletin of Canadian Petroleum Geology, v. 12 (Flathead Valley guidebook issue), p. 460-493.

Sloss, L.L.
1963: Sequences in the cratonic interior of North America. Geological Society of America Bulletin, v. 74, p. 93-114.

Smith, D.L.
1977: Transition from deep- to shallow-water carbonates, Paine Member, Lodgepole Formation, central Montana. *In* Deep-Water Carbonate Environments, H.E. Cook and P. Enos (eds.); Society of Economic Paleontologists and Mineralogists, Special Publication No. 25, p. 187-201.

Sweeney, J.F., Irving, E., and Geuer, J.W.
1978: Evolution of the Arctic Basin. *In* Arctic Geophysical Review, J.F. Sweeney (ed.); Energy, Mines and Resources Canada, Publications of the Earth Physics Branch, v. 45, no. 4, p. 91-100.

Thompson, T.L. and Goebel, L.D.
1963: Preliminary report of conodonts of the Meramecian Stage (Upper Mississippian) from the subsurface of western Kansas. Kansas Geological Survey, Bulletin 165, pt. 1, 16 p.

Thorsteinsson, R. and Tozer, E.T.
1970: Geology of the Arctic Archipelago. *In* Geology and Economic Minerals of Canada, R.J.W. Douglas (ed.); Geological Survey of Canada, Economic Geology Report No. 1, p. 548-590.

Trettin, H.P.
1973: Early Paleozoic evolution of northern parts of Canadian Arctic Archipelago. *In* Arctic Geology, M.G. Pitcher (ed.); American Association of Petroleum Geologists, Memoir 19, p. 57-75.

Tynan, M.C.
1980: Conodont biostratigraphy of the Mississippian Chainman Formation, western Millard County, Utah. Journal of Paleontology, v. 54, p. 1282-1309.

Varker, W.J. and Sevastopulo, G.D.
1985: The Carboniferous System: Part 1 – conodonts of the Dinantian Subsystem from Great Britain and Ireland. *In* A Stratigraphical Index of Conodonts; A.C. Higgins and R.L. Austin (eds.); British Micropalaeontological Society Series, Ellis Horwood Limited, Chichester, p. 167-209.

von Bitter, P.H.
1976: Paleoecology and distribution of Windsor Group (Viséan–?early Namurian) conodonts, Port Hood Island, Nova Scotia, Canada. *In* Conodont Paleoecology, C.R. Barnes (ed.); Geological Association of Canada, Special Paper 15, p. 225-241.

von Bitter, P.H. and Merrill, G.K.
1980: Naked species of *Gondolella* (Conodontophorida): their distribution, taxonomy, and evolutionary significance. Royal Ontario Museum, Life Science Contributions 136, p. 1-56.

Waterhouse, J.B. and Waddington, J.
1982: Systematic descriptions, paleoecology and correlations of the late Paleozoic subfamily *Spiriferellinae* (Brachiopoda) from the Yukon Territory and the Canadian Arctic Archipelago. Geological Survey of Canada, Bulletin 289, 73 p.

Webster, G.D.
1969: Chester through Derry conodonts and stratigraphy of northern Clark and southern Lincoln counties, Nevada. California University Publications, Geological Sciences, v. 79, 121 p.

Ziegler, W. and Sandberg, C.A.
1984: Palmatolepis-based revision of upper part of standard Late Devonian conodont zonation. *In* Pander Society Symposium on Conodont Biofacies and Provincialism, D.L. Clark (ed.); Geological Society of America, Special Paper 196, p. 143-178.

APPENDIX

Locality register

Data for sections discussed in text and detailed locality data for taxa illustrated in plates. Collection levels are in metres, and measured from base of section (except where noted).

Southeastern Saskatchewan

Locality 1

International-Minerals and Chemicals K2 shaft, Esterhazy, Saskatchewan; LSD 7, Sec. 27, Twp. 19, Rge. 32, W1; NTS 62 L/9.

Southeastern British Columbia

Locality 1

Crowsnest Pass area; 49°39′10″N, 114°42′10″W, NTS 82 G/10; southern Rocky Mountains; uppermost Kananaskis Formation, upper Moscovian to Kasimovian.

Southwestern Alberta

Locality 1

Princess Margaret Mountain; section is on southeastern side of Princess Margaret Mountain in deep canyon of unnamed tributary of Bow River; 51°09′08″N, 115°21′26″N, NTS 82 O/3; UTM 5667900N 614900E, zone 11u; section 83RAH7; Fairholme Range, Rocky Mountain Front Ranges.

GSC loc. C-136430 (19.0 m), Pekisko Formation, 16.0 m above base, 13.3 m below top, upper middle Tournaisian.

GSC loc. C-136442 (172.5 m), lower Livingstone Formation, 8.0 m above base, 294.2 m below top, upper Tournaisian.

GSC loc. C-114902 (238.8 m), Livingstone Formation, 74.3 m above base, 227.9 m below top, upper Tournaisian to lower Viséan.

GSC loc. C-114912 (406.4 m), upper Livingstone Formation, 241.9 m above base, 60.3 m below top, lower Viséan.

Locality 2

Ptarmigan Cirque; section measured along northwestern side of cirque on southwestern side of Mount Rae; 50°36′41″N, 114°58′50″W, NTS 82 J/10; UTM 5608300N, 643000E, zone 11u; section 81BR1, Misty Range, Rocky Mountain Front Ranges.

GSC loc. C-91011 (320.0 m), lower Etherington Formation, 10.0 m above base, upper Viséan.

Locality 3

Pigeon Mountain; road cut at base of Pigeon Mountain, south side Highway 1; 51°06′N, 115°13′W, NTS 82 O/3; section 81BR/ACH2; Rocky Mountain Front Ranges.

GSC loc. C-91035 (45.0 m), formation assignment uncertain, either upper Banff Formation or Pekisko Formation, 151.1 m below base of Livingstone Formation, upper middle Tournaisian.

Locality 3

Canyon Creek; section measured along south side of canyon of Canyon Creek, 4.1 km south of summit of Moose Mountain; 50°54′13″N, 114°49′47″W; NTS 82 J/15; UTM 5641200N, 652600E, zone 11u; section 85RAH1; western Rocky Mountain Foothills.

Locality 4

Grotto Mountain; section measured on southeastern side of Grotto Mountain; 51°06′N, 115°19′W, NTS 82 O/3; section 81BR/ACH3; Fairholme Range, Rocky Mountain Front Ranges.

Locality 5

Jura Creek; section measured in canyon of Jura Creek; 51°05′29″N, 115°09′29″W, NTS 82 O/3; UTM 5661500N, 628950E, zone 11u; section 86RAH5; eastern Rocky Mountain Front Ranges.

Willmore Wilderness Provincial Park, west-central Alberta

Locality 1

Mountain South of Kvass Creek; section measured along ridges on east and west sides of large cirque cut into north side of unnamed mountain 5.5 km south of Kvass Creek; 53°37′18″N, 119°07′43″W, NTS 83 E/11; UTM 5943350N, 359150E, zone 10u; section 82RAH3; Rocky Mountain Front Ranges.

GSC loc. C-110174 (254.6 m), lower Livingstone Formation, 25.4 m above base, 169.7 m below top, upper Tournaisian.

Locality 2

Monoghan Creek; section measured up north-facing cliffs at east end of unnamed mountain near headwaters of Monoghan Creek; 53°32′37″N, 118°59′38″W, NTS 83 E/10 and 11; UTM 5934250N, 367850E, zone 11u; section 82RAH4; Rocky Mountain Front Ranges.

GSC loc. C-110194 (116.3 m), middle Banff Formation, 112.8 m above base, 69.2 m below top, middle Tournaisian.

Locality 3

South Sulphur River; section measured up east-facing cliffs on southeastern end of unnamed mountain at junction of the West Sulphur and South Sulphur rivers; 53°32′10″N, 118°52′25″W, NTS 83 E/10; UTM 5933300N, 375800E, zone 11u; section 82RAH2, western Rocky Mountain Front Ranges.

Locality 4

Mount Hunter; section measured up cliffs on east side of Mount Hunter, 53°34′13″N, 118°25′31″W, NTS 83 E/9; UTM 5936400N, 405600E, zone 11u; section 82RAH7; Berland Range, eastern Rocky Mountain Front Ranges.

East-central British Columbia

Locality 1

Jarvis Lakes; section measured up south-facing cliffs on south side of unnamed mountain immediately north of Jarvis Lakes; 54°06′21″N, 120°12′27″W, NTS 93 I/1; UTM 5998700N, 682700E, zone 10u; section 81RAH1; Rocky Mountain Front Ranges.

GSC loc. C-93511 (59.5 m), lower Pekisko Formation, 6.0 m above base, 40.0 m below top, upper middle Tournaisian.

GSC loc. C-93512 (62.5 m), lower Pekisko Formation, 9.0 m above base, 37.0 m below top, upper middle Tournaisian.

GSC loc. C-93544 (72.0 m), Pekisko Formation, 18.5 m above base, 27.0 m below top, upper middle Tournaisian.

Locality 2

Northwest of Mount Hanington (Section A); section measured along ridge on northeastern side of unnamed mountain 6.6 km northwest of Mount Hanington; 54°10′46″N, 120°14′45″W, NTS 93 I/1; UTM 6055500N, 681800E, zone 10u; section 81RAH2; Rocky Mountain Front Ranges.

GSC loc. C-93558 (77.0 m), lower Banff Formation, 165.4 m below top, middle Tournaisian.

GSC loc. C-93559 (82.0 m), lower Banff Formation, 160.4 m below top, middle Tournaisian.

Locality 3

Northwest of Mount Hanington (Section B); section measured up east-facing cliffs on west side of cirque, on north side of unnamed mountain 8.0 km northwest of Mount Hanington; 54°11′02″N, 120°15′32″W, NTS 93 I/1; UTM 6062500 N, 679750E, zone 10u; section 81RAH8, Rocky Mountain Front Ranges.

GSC loc. C-93794 (20.3 m), Turner Valley Formation, position relative to base and top of Turner Valley uncertain, lower Viséan.

Locality 4

Onion Lake section; ridge on east side of unnamed mountain, 2.0 km southeast of Onion Lake; 54°37′57″N, 120°45′34″W, NTS 93 I/10; UTM 605600N, 645500E, zone 10u; section 82RAH1; eastern Rocky Mountain Front Ranges.

GSC loc. C-110139 (420.2 m), basal Turner Valley Formation, 45.4 m below top, uppermost Tournaisian to lowermost Viséan.

Locality 5

Red Deer Creek; section measured at head of deep canyon of unnamed tributary to Red Deer Creek, canyon is cut into unnamed northwest-trending ridge northeast of Red Deer Creek; 54°27′00″N, 120°35′14″W, NTS 93 I/7; UTM 6036350N, 656400E, zone 10u; Hart Ranges, eastern Rocky Mountains.

GSC loc. C-110116 (203.7 m), upper Banff Formation, 193.1 m above base, 49.9 m below top, middle Tournaisian.

Locality 6

Mount Becker (Section A); section measured in high pass between Mount Becker and unnamed mountain immediately west; 54°31′02″N, 120°38′46″W, NTS 93 I/10; UTM 6044900N, 652230E, zone 10u; section 81RAH3; eastern Rocky Mountains.

GSC loc. C-93612 (140.3 m), basal Pekisko Formation, upper middle Tournaisian.

Locality 7

Mount Becker (Section B); section measured up east-facing cliffs at south end of unnamed mountain 1.5 km west of Mount Becker; 54°31′02″N, 120°38′46″W, NTS 93 I/10; UTM 6043440N, 652360E, zone 10u; section 81RAH4; eastern Rocky Mountain Front Ranges.

Locality 8

Watson Peak; section measured along base of northeast-facing cliffs on northeast side of Watson Peak; 55°13′58″N, 122°05′07″W, NTS 93 O/1; UTM 6120850N, 558250E, zone 10u; section 81RAH9; eastern Rocky Mountain Front Ranges.

GSC loc. C-91015 (62.9 m), lower unnamed formation F, 12.7 m above base, 147.3 m below top, upper Tournaisian.

Locality 9

Southwest of Belcourt Lake; section measured up northeast-facing cliffs of cirque headwall on east side of unnamed mountain 10.1 km southwest of Belcourt Lake; 54°21′54″N, 120°29′58″W, NTS 93 I/8; UTM 6126840N, 663500E, zone 10u; Rocky Mountain Front Ranges.

Locality 10

Fellers Creek; section measured along western and eastern ridges of unnamed mountain 4.2 km northwest of summit of Bone Mountain; 54°42′19″N, 120°53′06″W, NTS 93 I/10; UTM 6063800N, 636400E, zone 10u; section 81RAH5, Rocky Mountain Front Ranges.

Locality 11

Albright Ridge; section measured up cliffs on southwestern side of ridge, 6.1 km southeast of Hook Lake; 54°48′44″N, 121°20′00″W, NTS 93 I/14; UTM 6074950N, 607100E, zone 10u; section 81RAH6; Rocky Mountain Front Ranges.

Northeastern British Columbia

Locality 1

Mount Greene; section measured up cliffs on north side of Mount Greene about 1.5 km northeast of main summit; 56°04′37″N, 123°14′46″W; UTM 6177700N, 504150E, zone 10u; NTS 94 B/3; Section 88RAH7; eastern Rocky Mountain Front Ranges.

GSC loc. C-171620 (67.6 m), middle Kiskatinaw Formation, 81.1 m below top, upper Viséan.
GSC loc. C-171625 (196.4 m), lower Taylor Flat Formation, 47.7 m above base, 168.0 m below top, Serpukhovian.
GSC loc. C-171635 (350.5 m), upper Taylor Flat Formation, 201.8 m above base, 13.9 m below top, Bashkirian.
GSC loc. C-171636 (360.8 m), upper Taylor Flat Formation, 212.1 m above base, 3.6 m below top, upper Moscovian.

Locality 2

Unnamed mountain near headwaters of Peck Creek; section measured along ridge at summit of mountain; 55°44′47″N, 122°56′03″W, NTS 93 O/10; UTM 6177700N, 504150E, zone 10u; section 88RAH7; eastern Rocky Mountain Front Ranges.

GSC loc. 171602 (310.7 m), lower Stoddart Group (formation uncertain), 7.9 m above base, 146.9 m below top, upper Viséan to lower Serpukhovian.
GSC loc. C-171606 (367.4 m), Taylor Flat Formation (location of base uncertain), 64.6 m above base Stoddart Group, 90.2 m below top of Taylor Flat, lower Serpukhovian.
GSC loc. 171608 (381.8 m), Taylor Flat Formation (location of base uncertain), 79.0 m above base Stoddart Group, 75.8 m below top of Taylor Flat, Serpukhovian.
GSC loc. 171612 (402.2 m), Taylor Flat Formation (location of base uncertain), 99.4 m above base of Stoddart Group, 55.4 m below top Taylor Flat, Serpukhovian.
GSC loc. C-171613 (408.3 m), Taylor Flat Formation (location of base uncertain), 105.5 m above base Stoddart Group, 49.3 m below top of Taylor Flat, upper Serpukhovian.

Southwestern District of Mackenzie, Northwest Territories

Locality 1

Bluefish Mountain; section measured up cliffs on south side of mountain; 61°07′23″N, 123°29′13″W, NTS 95 G/3; UTM 6776400N, 473700E, zone 10v; section 75MTA/BCR7; southern Franklin Mountains.

Locality 2

Twisted Mountain; section measured on southwestern side of mountain; 61°11′00″N, 123°37′38″W, NTS 95 G/4; UTM 6783100N, 466600E, zone 10v; section 76MTA/BCR9; southern Franklin Mountains.

Plates 1 to 3

All specimens are housed in the National Type Collection of Invertebrate and Plant Fossils at the Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8.

PLATE 1

All figures are scanning electron micrographs. See Appendix for detailed locality data. All specimens are hypotypes, except where noted.

Figures 1, 8. *Siphonodella isosticha* (Cooper).
Jarvis Lakes section, Pekisko Formation, upper middle Tournaisian.

1. Upper surface view, GSC 102177, x32, GSC loc. C-93511.
8. Upper surface view, GSC 102178, x65, GSC loc. C-93512.

Figures 2, 3, 6. *Siphonodella obsoleta* Hass.
Northwest of Mount Hanington (section A), Banff Formation, Middle Tournaisian.

2. Upper surface view, GSC 102179, x65, GSC loc. C-93559.
3. Upper surface view, GSC 102180, x65, GSC loc. C-93559.
6. Upper surface view, GSC 102181, x65, GSC loc. C-93559.

Figure 4. *Polygnathus mehli* Thompson.
Upper surface view, GSC 102182, x65, GSC loc. C-110139, Onion Lake section, basal Turner Valley Formation, uppermost Tournaisian to lowermost Viséan.

Figure 5. *Siphonodella quadruplicata*? (Branson and Mehl)
Upper surface view, GSC 102183, x65, GSC loc. C-93559, northwest of Mount Hanington (Section A), Banff Formation, middle Tournaisian.

Figures 7, 9. *Siphonodella quadruplicata* (Branson and Mehl).
Northwest of Mount Hanington (Section A), Banff Formation, middle Tournaisian.

7. Upper surface view, GSC 102184, x65, GSC loc. C-93559.
9. Upper surface view, GSC 102185, x65, GSC loc. C-93559.

Figure 10. *Dinodus fragosus* (E.R. Branson).
Outer lateral view, GSC 102186, GSC loc. C-93558, northwest of Mount Hanington (Section A), Banff Formation, middle Tournaisian.

Figure 11. *Elictognathus bialatus* (Branson and Mehl).
Inner lateral view, GSC 102187, x65, GSC loc. C-93558, northwest of Mount Hanington (Section A), Banff Formation, middle Tournaisian.

Figure 12. *Eotaphrus burlingtonensis* Pierce and Langenheim.
Upper surface view, cusp partly broken, GSC 102188, x32, GSC loc. C-114902, Princess Margaret Mountain section, Livingstone Formation, upper Tournaisian to lower Viséan.

Figure 13. *Bispathodus* sp.
Upper surface view, figured specimen GSC 102189, x65, GSC loc. C-91035, Pigeon Mountain section, either upper Banff Formation or Pekisko Formation, upper middle Tournaisian.

Figures 14, 15. *Bispathodus aculeatus aculeatus* (Branson and Mehl).
Northwest of Mount Hanington (Section A), Banff Formation, middle Tournaisian.

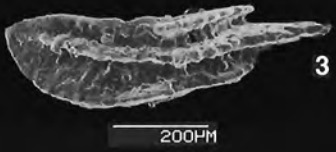
14. Lateral view, GSC 102190, x65, GSC loc. C-93558.
15. Upper surface view, GSC 102191, x130, GSC loc. C-93559.

Figure 16. *Bispathodus spinulicostatus* (E.R. Branson).
Upper surface view, GSC 102192, x65, GSC loc. C-110116, Red Deer Creek section, upper Banff Formation, middle Tournaisian.

Figure 17. *Bispathodus aculeatus plumulus* (Rhodes, Austin, and Druce).
Lateral view, GSC 102193, x65, GSC loc. C-93612, Mount Becker (Section A), basal Pekisko Formation, upper middle Tournaisian.


1

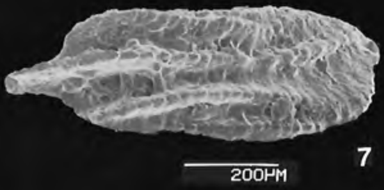

2


3

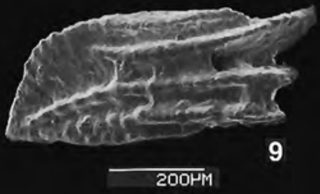

4

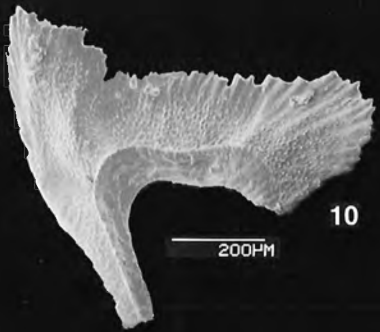

5

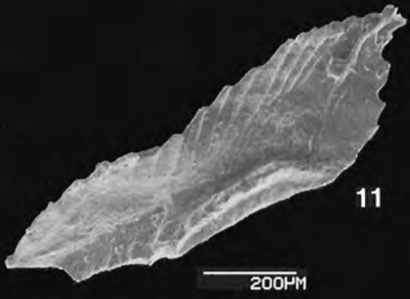

6

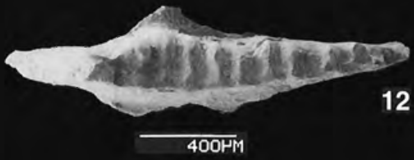

7


8

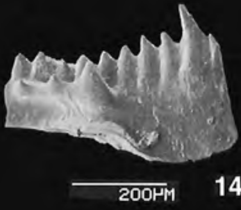

9

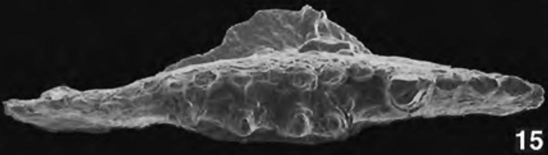

10


11


12


13


14


15


16

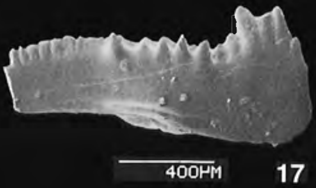

17

PLATE 2

All specimens are hypotypes, except where noted.

Figure 1. *Polygnathus longiposticus* Branson and Mehl.
Upper surface view, GSC 102194, x65, GSC loc. C-136442, Princess Margaret Mountain section, lower Livingstone Formation, upper Tournaisian.

Figures 2, 12. *Polygnathus communis carina* Hass.
Princess Margaret Mountain section, Pekisko Formation, upper Middle Tournaisian.

2. Upper surface view, GSC 102195, x32, GSC loc. C-136430.
12. Upper surface view, GSC 102196, x32, GSC loc. C-136430.

Figure 3. *Polygnathus mehli mehli* Thompson.
Upper surface view, GSC GSC 102290 x65, GSC loc. C-110139, Onion Lake section, basal Turner Valley Formation, uppermost Tournaisian to lowermost Viséan.

Figures 4, 10. *Pseudopolygnathus nudus* Pierce and Langenheim.
Section south of Kvass Creek, lower Livingstone Formation, upper Tournaisian.

4. Upper surface view, GSC 102197, x65, GSC loc. C-110174.
10. Upper surface view, GSC 102198, x65, GSC loc. C-110174.

Figure 5. *Protognathodus praedelicatus* Lane, Sandberg, and Ziegler.
Upper surface view, GSC 102199, x130, GSC loc. C-93544, Jarvis Lakes section, Pekisko Formation, upper middle Tournaisian.

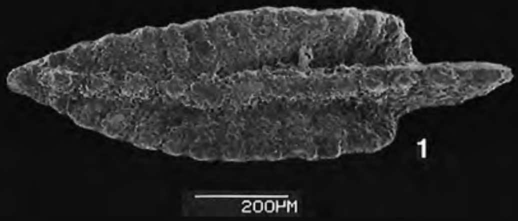
Figure 6. *Gnathodus* sp. cf. *G. typicus* Cooper.
Upper surface view, figured specimen GSC 102200, x130, Watson Peak section, GSC loc. C-91015, lower unnamed formation F, upper Tournaisian.

Figure 7. *Anchignathodus scitulus* (Hinde).
Inner lateral view, GSC 102201, x65, GSC loc. C-91011, Ptarmigan Cirque section, lower Etherington Formation, upper Viséan.

Figure 8. *Anchignathodus penescitulus* (Rexroad and Collinson).
Outer lateral view, GSC 102202, x65, GSC loc. C-110194, Monoghan Creek section, middle Banff Formation, middle Tournaisian.

Figure 9. *Cloghergnathus* sp.
Outer lateral view, figured specimen GSC 102203, x65, GSC loc. C-114912, Princess Margaret Mountain section, upper Livingstone Formation, lower Viséan.

Figure 11. *Apatognathus* sp.
Inner lateral view, figured specimen GSC 102204, x130, GSC loc. C-93794, northwest of Mount Hanington (Section B), Turner Valley Formation, lower Viséan.

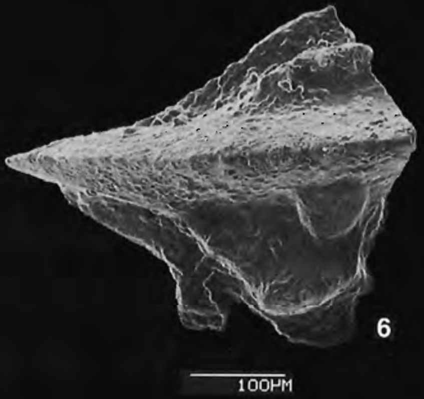

1


2

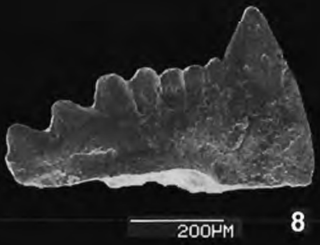

4

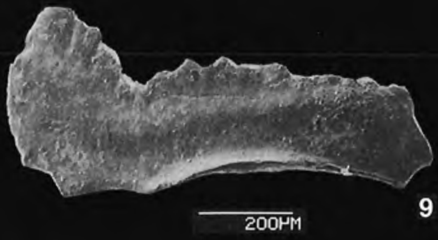

3

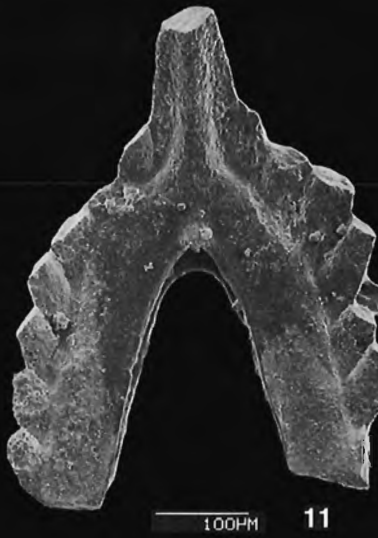

5

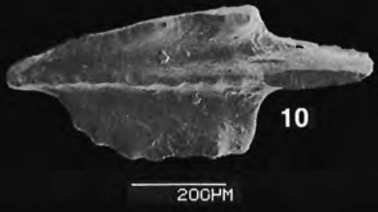

6


7


8


9


11


10


12

PLATE 3

All figures are scanning electron micrographs of Pa elements, and all are hypotypes, except where noted.

Figure 1. *Gnathodus* sp. cf. *G. texanus* Roundy.
Upper surface view, figured specimen GSC 100516, x80, GSC loc. C-171620, Mount Greene section, middle Kiskatinaw Formation, upper Viséan.

Figure 2. *Gnathodus girtyi collinsoni* Rhodes, Austin, and Druce.
Upper surface view, GSC 100517, x100, GSC loc. C-171602, Peck Creek section, lower Stoddart Group, upper Viséan to lower Serpukhovian.

Figures 3-5. *Gnathodus girtyi girtyi* Hass.
Peck Creek section.

3. Upper surface view, GSC 100518, x100, GSC loc. C-171602, lower Stoddart Group, upper Viséan to lower Serpuhkhovian.
4. Upper surface view, GSC 100519, x80, GSC loc. C-171602, lower Stoddart Group, upper Viséan to lower Serpuhkhovian.
5. Upper surface view, GSC 100520, x100, GSC loc. C-171606, Taylor Flat Formation, lower Serpukhovian.

Figures 6, 12. *Gnathodus girtyi simplex* Dunn.
Peck Creek section.

6. Upper surface view, GSC 100521, x100, GSC loc. C-171608, Taylor Flat Formation, Serpukhovian.
12. Upper surface view, GSC 100522, x100, GSC loc. C-171606, Taylor Flat Formation, lower Serpukhovian.

Figures 7, 11. *Rhachistognathus minutus havlenai* Baesemann and Lane.
Mount Greene section, upper Taylor Flat Formation, Bashkirian.

7. Upper surface view, GSC 100523, x80, GSC loc. C-171635.
11. Upper surface view, GSC 100524, x80, GSC loc. C-171635.

Figures 8, 13. *Rhachistognathus muricatus* (Dunn).
Mount Greene section, upper Taylor Flat Formation, Bashkirian.

8. Upper surface view, GSC 100525, x50, GSC loc. C-171635.
13. Upper surface view, GSC 100526, x100, GSC loc. C-171635.

Figure 9. *Gnathodus* sp. cf. *G. defectus* Dunn.
Upper surface view, figured specimen GSC 100527, x100, GSC loc. C-171613, Peck Creek section, Taylor Flat Formation, upper Serpukhovian.

Figure 10. *Rhachistognathus prolixus* Baesemann and Lane.
Upper surface view, GSC 100528, x80, GSC loc. C-171625, Mount Greene section, lower Taylor Flat Formation, Serpukhovian.

Figure 14. *Cavusgnathus cristatus* Branson and Mehl.
Upper surface view, GSC 100529, x80, GSC loc. C-171602, Peck Creek section, lower Stoddart Group, upper Viséan to lower Serpukhovian.

Figure 15. *Streptognathodus elegantulus* Stauffer and Plummer.
Upper surface view, GSC 100530, x120, Kananaskis Formation, Crowsnest Pass, southeastern British Columbia, upper Moscovian to Kasimovian.

Figure 16. *Streptognathodus oppletus* Ellison.
Upper surface view, GSC 100531, x100, GSC loc. C-171636, Mount Greene section, upper Taylor Flat Formation, upper Moscovian.

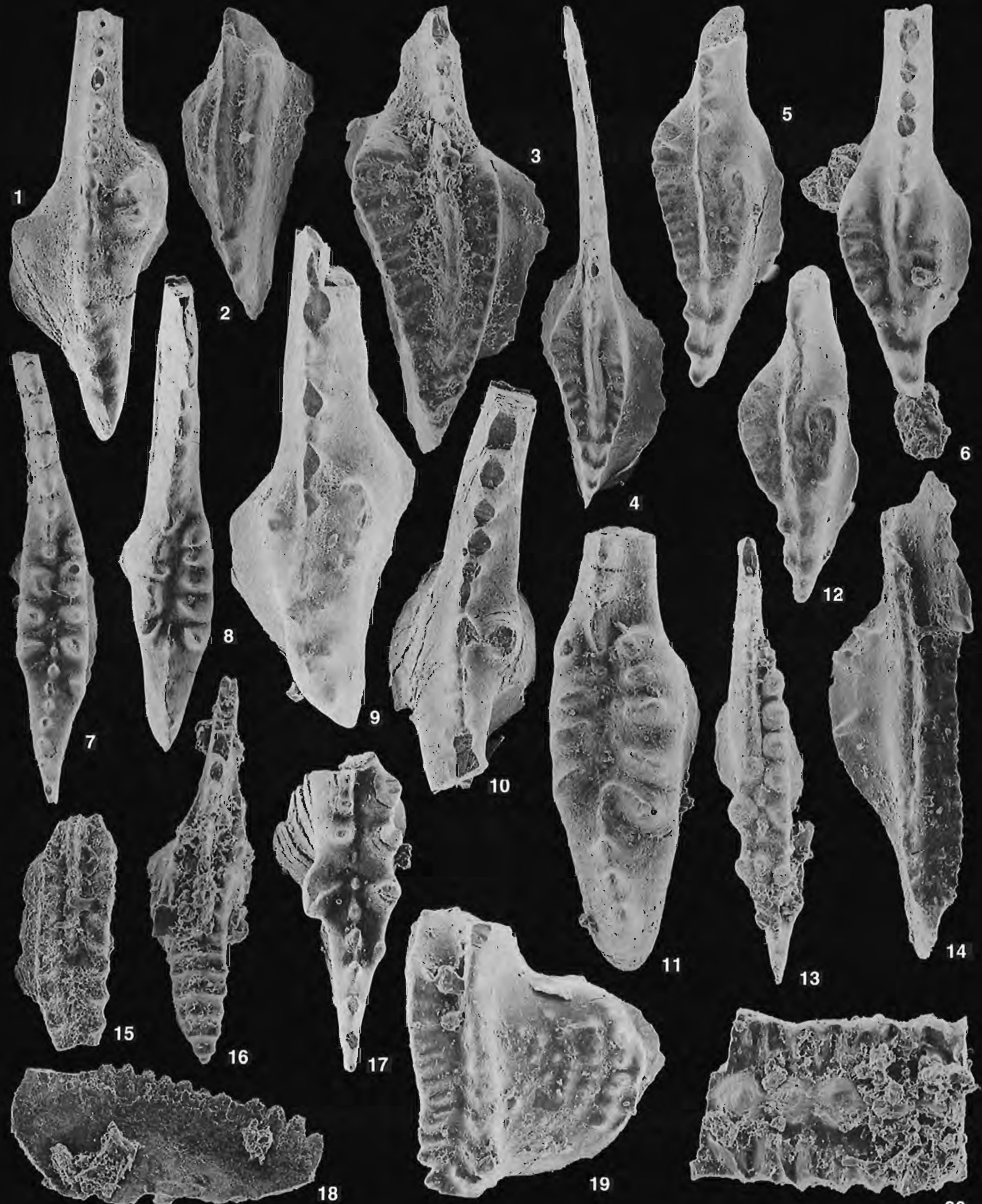
Figure 17. *Rhachistognathus websteri* Baesemann and Lane.
Upper surface view, GSC 100532, x100, GSC loc. C-171635, Mount Greene section, upper Taylor Flat Formation, Bashkirian.

Figure 18. *Hindeodus ellisoni* (Merrill).
Lateral view, GSC 100533, x80, Kananaskis Formation, Crowsnest Pass, southeastern British Columbia, upper Moscovian to Kasimovian.

Figure 19. *Gnathodus bilineatus bilineatus* (Roundy).
Upper surface view, GSC 100534, x100, GSC loc. C-171612, Peck Creek section, Taylor Flat Formation, Serpukhovian.

Figure 20. *Gondolella* sp. cf. *G. magna* Stauffer and Plummer.
Upper surface view, figured specimen GSC 100535, x100, GSC loc. C-171636, Mount Greene section, upper Taylor Flat Formation, upper Moscovian.

PLATE 3



Gondolelloides, a new Lower Permian conodont genus from western and northern Canada

C.M. Henderson[1] and M.J. Orchard[2]

Henderson, C.M., and Orchard, M.J., 1991: Gondolelloides, *a new Lower Permian conodont genus from western and northern Canada. In Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417, p. 253-267.*

Abstract

The new genus Gondolelloides *and two new species,* G. canadensis *and* G. nahanniensis, *are defined on the basis of a very distinctively ornamented segminiplanate element. The species were collected over a wide geographic area in the Canadian Cordillera, as well as in the Canadian and Soviet Arctic. The new genus is known only by its Pa element since co-occurring ramiform elements are sparse and may belong to associated genera; it has not been determined whether* Gondolelloides *has a platform-only or multimembrate apparatus.* Gondolelloides *is thought to have evolved from ''*Gondolella*'' near the Carboniferous–Permian boundary; in six faunules the two genera occur together and are morphologically similar. Two informal new species of ''*Gondolella*'' (''*G.*'' n. sp. A and ''*G.*'' n. sp. B) are described. The new species of* Gondolelloides *are also commonly associated with species of* Neogondolella, Adetognathus *and* Streptognathodus. Gondolelloides *appears to range within a narrow interval in the middle to upper Asselian Stage (Lower Permian), but may range into the Sakmarian.*

Résumé

Le nouveau genre Gondolelloides *n. gen. et deux nouvelles espèces,* G. canadensis *n. sp. et* G. nahanniensis *n. sp., ont été définis en fonction de la présence d'un élément segminiplan à ornementation très distinctive. Cette espèce a été recueillie dans une vaste région de la Cordillère canadienne, ainsi que dans les régions arctiques du Canada et de l'Union soviétique. Le nouveau genre n'est connu que par son élément Pa puisque les éléments ramiformes concomitants sont rares, et pourrait appartenir à des genres connexes; on ne sait pas encore si* Gondolelloides *est pourvu d'un appareil multimembré ou simplement d'un appareil à plate-forme. On pense que* Gondolelloides *s'est différencié de ''*Gondolella*'' près de la limite du Carbonifère et du Permien; chez six faunules, les deux genres apparaissent simultanément et sont morphologiquement semblables. On décrit deux nouvelles espèces informelles de ''*Gondolella*'' (''*G.*'' n. sp. A et ''*G.*'' n. sp. B). Les nouvelles espèces de* Gondolelloides *sont également souvent associées à des espèces des genres* Neogondolella, Adetognathus *et* Streptognathodus. *Il semble que* Gondolelloides *occupe un étroit intervalle de l'étage couvrant l'Assélien moyen à supérieur (Permien inférieur), mais peut se prolonger dans le Sakmarien.*

---

[1] Department of Geology and Geophysics, University of Calgary, Calgary, Alberta T2N 1N4
[2] Geological Survey of Canada, 100 West Pender St., Vancouver, B.C. V6B 1R8

INTRODUCTION

A distinctive, short-ranging Permian conodont genus, *Gondolelloides* n. gen., occurs over a broad area of western and northern Canada as well as Novaya Zemlya, Soviet Arctic. The new genus has been recovered from the upper Telford Formation of southeastern British Columbia (Henderson and McGugan, 1986), from three localities in the Belcourt Formation of northeastern British Columbia, from the Mt. Christie formation (informal) in the Nahanni map area of east-central Yukon Territory (Gordey, in press), from the Hare Fiord Formation of northwestern Ellesmere Island, from the Stikine Assemblage in the Iskut River map area of northwest British Columbia (Brown et al., in press), from two localities in the Buttle Lake Group on Vancouver Island (Brandon et al., 1986), and from two locations in the Kazarkin and Tolbyakh formations on the southern part of Novaya Zemlya, U.S.S.R. The first six localities are part of the North American craton, whereas the other three Canadian occurrences lie within terranes thought to have been accreted to western North America (Fig. 1). All of the occurrences are presented below.

Southeast British Columbia (Loc. 1; Fig. 1)

Gondolelloides canadensis n. gen. et sp. and other species were recovered from a sample (GSC loc. C-126000) of sandy carbonate of outer shelf origin, from near the top of the Telford Formation of southeastern British Columbia (Henderson and McGugan, 1986; Henderson, 1989; Henderson et al., in press). Conodonts associated with *G. canadensis* n. sp. at this locality include *Adetognathus* sp. *B* (similar to *A. paralautus* Orchard) and *A.* sp. C of Henderson 1988, and *Hindeodus* sp. (Table 1). This assemblage was dated as late Sakmarian (Sterlitamakian) by Henderson and McGugan (1986). However, the above adetognathid species have been recognized in older, upper Asselian to Sakmarian strata of southwestern Ellesmere Island (Henderson, 1988; Beauchamp et al., 1989a). *Adetognathus* sp. C of Henderson 1988 has also been recognized from Sakmarian strata in Guizhou Province, China (Kang et al., 1987, Pl. 2, fig. 11, as *Streptognathodus* sp. nov.).

Disconformably overlying the Telford Formation are phosphatic shale and siltstone of the lower Ross Creek Formation, which have yielded *Neogondolella bisselli* Clark and Behnken and *Sweetognathus whitei* (Rhodes), indicating an Artinskian age (early Baigendzhinian) (Henderson and McGugan, 1986; Henderson et al., in press).

Northeast British Columbia (Locs. 2-4; Fig. 1)

Gondolelloides canadensis n. sp. was collected from three sections in northeastern British Columbia by B.C. Richards (Institute of Sedimentary and Petroleum Geology, Calgary). At the first locality (loc. 2), two samples at 47.8 m and 60.7 m (GSC locs. C-163905 and C-163909, respectively) above the base of a section within the lower Belcourt Formation yielded *G. canadensis* n. sp., *Adetognathus lautus* (Gunnell), *A.* sp. A and *A.* sp. B of Henderson 1988, *Ellisonia* sp., *Hindeodus* sp., and *Neogondolella* sp. cf. *N. dentiseparata* Reshetkova and Chernikh (Table 1).

From a second section (loc. 3), two samples at 202.8 m (GSC loc. C-164212) and 208 m (GSC loc. C-164260) above the base of a section of the Belcourt Formation yielded *Adetognathus lautus, Gondolelloides canadensis* n. sp., *G. nahanniensis* n. sp., *Ellisonia* sp., and *Hindeodus* sp.

From the third locality (loc. 4), two samples at 34.5 m (GSC loc. C-164368) and 54.2 m (GSC loc. C-164369) above the base of the Belcourt Formation yielded *Adetognathus* sp. B, *A. lautus*, "*Gondolella*" n. sp. B, *Gondolelloides canadensis* n. sp., *Hindeodus* sp., *Neogondolella* sp. cf. *N. dentiseparata*, and *Streptognathodus* sp. cf. *S. constrictus* Chernikh and Reshetkova.

The conodont faunas from all these sections point strongly to a middle to late Asselian age (Henderson, 1988). Nonfusulinacean foraminifers at these locations also suggest an Early Permian age (probably Asselian; S. Pinard, pers. comm., 1990). The chronostratigraphic correlation of these conodont faunas is discussed further in Henderson (1988).

East-central Yukon Territory (Loc. 5; Fig. 1)

In the northwestern part of Nahanni map area, a sample (GSC loc. C-102654) collected by S.P. Gordey from a one metre thick bed of dark red-brown weathering, light grey, medium crystalline limestone within the Mount Christie formation (informal; Gordey, in press), yielded *Streptognathodus elongatus* Gunnell, "*Gondolella*" n. sp. B, and *Gondolelloides nahanniensis* n. sp. This fauna occurs at 541.5 m in Section 17 of Gordey (*ibid.*), that is about 21 m below the top of the shale (lower) member of the Mount Christie formation, which comprises shale, chert, sandstone, and minor barite. Above, *Sweetognathus* and *Neostreptognathodus pequopensis* Behnken occur in sequence (Orchard, 1987, sample 12).

Ellesmere Island, Canadian Arctic Archipelago (Loc. 6; Fig. 1)

In the Canadian Arctic Archipelago on northwestern Ellesmere Island, *Gondolelloides canadensis* n. sp. was recovered at 262 m above the base of the type section of the Hare Fiord Formation (GSC loc. C-023911), in shaly carbonate of probable basinal to lower slope origin (Thorsteinsson, 1974; Beauchamp et al., 1989b). Associated conodonts from this locality include *Adetognathus* sp. B and species of *Streptognathodus*, including *S. barskovi* Kozur and *S. constrictus*, indicating a middle to late Asselian age.

Succeeding conodont assemblages at this location include *Adetognathus* sp., *Hindeodus* sp., and species of *Neogondolella*, some of which are similar to *N. adentata* Chernikh and Reshetkova or *N. dentiseparata*, whereas others are similar to *N. bisselli* of the Tastubian (lower Sakmarian) to lower Baigendzhinian (Upper Artinskian). A precise dating of these assemblages is difficult because of the wide spacing of samples and the lack of associated faunas, but a Sakmarian age is suggested.

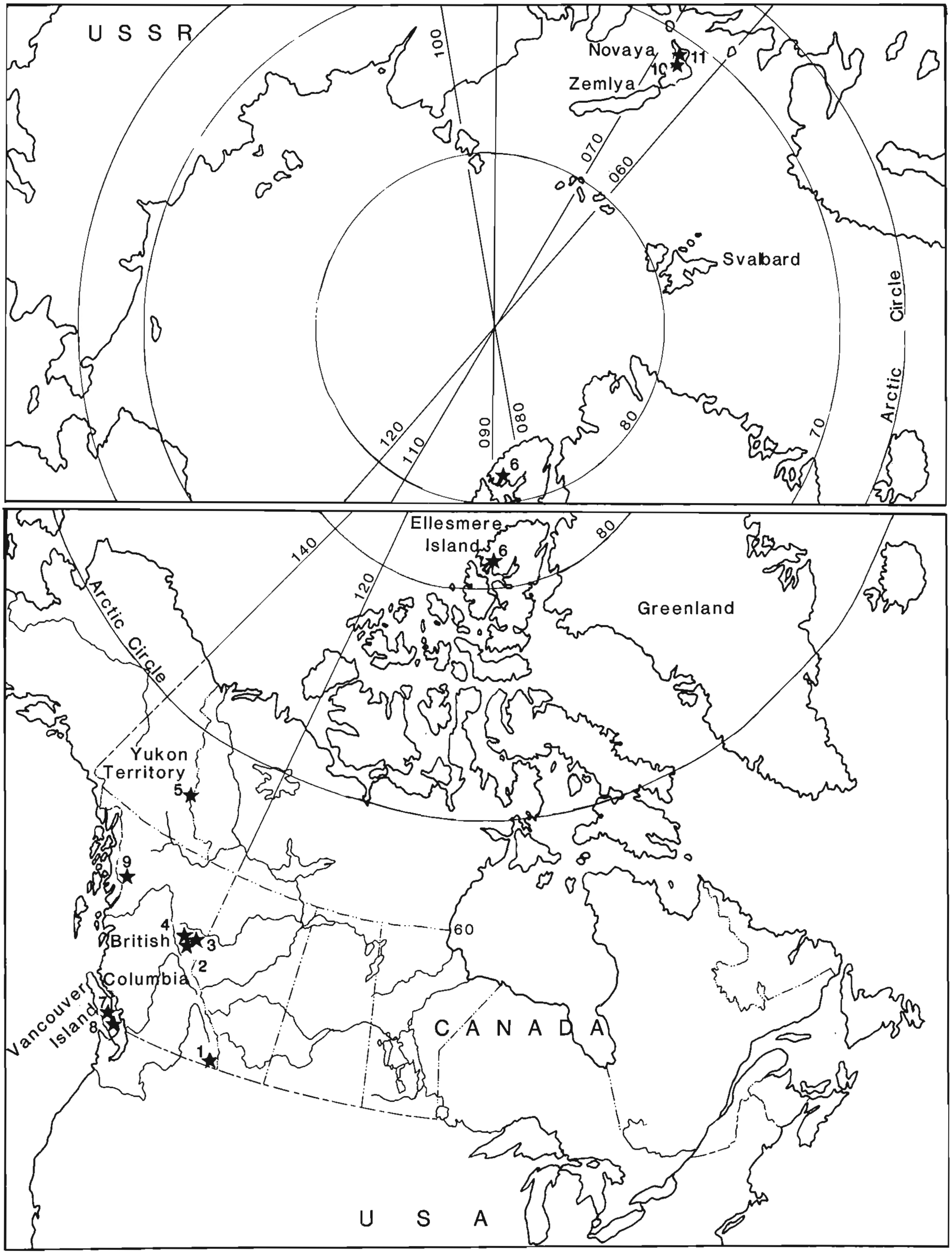


Figure 1. Location map for occurrences of *Gondolelloides*, showing the eleven locations described in the text and listed in Table 1. Latitude and longitude co-ordinates for each of these are: loc. 1 = 49°45′N, 115°W; loc. 2 = 55°04′33″N, 121°59′40″W; loc. 3 = 55°04′42″N, 121°59′23″W; loc. 4 = 55°06′N, 122°01′54″W; loc. 5 = 62°52′36″N, 129°49′42″W; loc. 6 = 81°04′N, 085°30′W; loc. 7 = 49°39′35″N, 125°31′25″W; loc. 8 = 49°10′12″N, 124°32′48″W; loc. 9 = 56°46′07″N, 130°37′17″W; locs. 10, 11 = Soviet Arctic.

Vancouver Island (Locs. 7, 8; Fig. 1)

Gondolelloides is known from two localities within the Buttle Lake Group on Vancouver Island (Alberni map area). The genus was originally found in a sample (GSC loc. C-102165) collected by J.E. Muller (Vancouver) from a small quarry on Buttle Lake road 3.3 km north of Ralph River (loc. 7). A sample of pale grey crinoidal wackestone yielded *G. nahanniensis* n. sp. and *Hindeodus* sp. along with ramiform fragments that had a Colour Alteration Index (Epstein et al., 1977) of 6-7 (Brandon et al., 1986, no. B 19).

Farther south, the new genus was recovered from a sample (loc. 8; GSC loc. C-127686) collected by C.J. Yorath (GSC) from a section along the Cameron River. A sample of dark silty limestone yielded "*Gondolella*" n. sp. A, *Gondolelloides canadensis* n. sp., *Hindeodus* sp., *Neogondolella* sp. cf. *N. dentiseparata*, *Streptognathodus* sp., a neostreptognathodiform Pa element, and ichthyoliths.

Further collections from this section were made in 1985 by Orchard, and the results are presented in Table 1. Additional specimens of *Gondolelloides canadensis* have been recovered from three samples in the upper part of the Fourth Lake Formation and lower part of the Mount Mark Formation. *Gondolelloides canadensis* n. sp. occurs with *Adetognathus* sp. A, *A.* sp. B, "*Gondolella*" n. sp. A, *Hindeodus* sp., a neostreptognathodiform Pa element, *Neogondolella* sp. cf. *N. dentiseparata*, and *Streptognathodus* sp., suggesting a middle to late Asselian age. Higher in the section, *N.* sp. cf. *N. dentiseparata* becomes more abundant prior to being

Table 1. Distribution and frequency of elements of various conodont taxa present in samples pertinent to this study

LOCATION	1.	2. N.E. B.C.			3. N.E. B.C.		4. N.E. B.C.		5.	6.	7.	8. Vancouver Island, B.C.												9.	10. Novaya Zemyla			11. Novaya Zemyla		
FORMATION	T.	Belcourt			Belcourt		Belcourt		Mt. C.	H. F.	B.L.	Buttle Lake Group Fourth Lake								Mt. Mark				?	Kazarkin			Tolbyakh		
Metres above base Section (S) or Formation (F)		16.1 F	47.8 F	60.7 F	203 S	208 S	34.5 F	54.2 F	542 S	262 F			1 S	7.75 S	10 S	25.5 S	29.5 S	37.5 S	43.5 S	1 S	4.5 S	13.5 S	TOP S							
SAMPLE SIZE (kg)		2.0	2.0	2.0	2.4	2.1	2.0	2.0	1.9	0.5	1.0	1.0	6.7	2.0	2.1	4.1	3.5	3.5	3.6	14	5.7	1.9	6.1	0.7						
G.S.C. LOCALITY NUMBER OR FIELD NUMBER / TAXA	C-126000	C-163901	C-163905	C-163909	C-164212	C-164260	C-164368	C-164369	C-102654	C-023911	C-102165	C-127686	C-117760	C-117762	C-117763	C-117766	C-117767	C-117768	C-117769	C-117744	C-117745	C-117747	C-117748	C-102755	101-51	131-45	752-78	601-46	601-47	601-36
Adetognathus lautus		9	P		2		3																							
Adetognathus sp. A		P	5															1			2									
Adetognathus sp. B	P			4				3		1								6			11									
Adetognathus sp. C	P																													
Adetognathus sp. indet.						2										7				1		2								
Ellisonia sp. indet.		4	P	3	P																									
"*Gondolella*" n. sp. A												1	5	6					1							2	1			
"*Gondolella*" n. sp. B								1	2																			1		
Gondolelloides canadensis n. gen. et sp.	3		1	3		1	1	1		2		2						3	2	1				1	3	5	4	5	1	1
Gondolelloides nahanniensis n. gen. et sp.					1				2		1																5			
Hindeodus sp.	P		P		1	1		6			1	2	4	3	1	5		1	2											
Idiognathodus sp. cf. *I. ellisoni*																											1			
Idiognathodus sp. cf. *I. marginodosus*													1																	
Neogondolella sp. cf. *N. dentiseparata*				8				1				11								5	1	10		9	4	17	14	5	3	
Neogondolella sp. cf. *N. bisselli*																							20							
Neostreptognathodiform Pa element												1	2	6					1											
Streptognathodus barskovi										1																			1	
Streptognathodus constrictus										2															2	3				
Streptognathodus sp. cf. *S. constrictus*				1				1																					6	
Streptognathodus elegantulus		1											1	1																
Streptognathodus elongatus									10															20						
Streptognathodus nodulinearis																											1			
Streptognathodus sp. indet.												1								1							1			
ramiform elements *?Idioprioniodus*													P																1	
indeterminate ramiform elements	P	26	P	P	P	P	P	P			P			P		P	2	P	P	P	P	P	P							

P indicates that specimens of that taxa are present but were not counted, or that the material is too fragmented for a meaningful count.
Location numbers refer to locations described in the text.

succeeded by *N.* sp. cf. *N. bisselli.* The latter species suggests that the upper part of the Mount Mark Formation at this locality is probably Sakmarian in age.

Northwest British Columbia (Loc. 9; Fig. 1)

In the Iskut River map area of northwest British Columbia, midway between Forrest Kerr Creek and Iskut River and about 4 km northeast of their confluence, an unnamed unit, consisting of tuffaceous argillite and greywacke with rare conglomerates, has limestone olistoliths near its base (Read et al., 1989). From within one of these olistoliths, a single fragment of *Gondolelloides canadensis* n. sp. along with *Streptognathodus elongatus*, and *Neogondolella* sp. cf. *N. dentiseparata* were recovered from a composite sample (GSC loc. C-102755) of medium grey, fine grained, massive limestone.

Novaya Zemlya, Soviet Arctic (Locs. 10, 11; Fig. 1)

Gondolelloides was recovered from two locations in the southern part of Novaya Zemlya in the Soviet Arctic. These specimens were kindly loaned to the authors by N. Sobolev of Leningrad, who also provided ages for the faunules based on both the conodonts and associated faunas.

At one location (loc. 10), the middle Asselian Kazarkin Formation (samples 101-51, 131-45, 752-78) yielded "*Gondolella*" n. sp. A, *Gondolelloides canadensis* n. sp., *G. nahanniensis* n. sp., *Idiognathodus* sp. cf. *I. ellisoni* Clark and Behnken, *Neogondolella* sp. cf. *N. dentiseparata*, *Streptognathodus constrictus*, and *S. nodulinearis* Chernikh and Reshetkova.

At a second location (loc. 11), the middle to upper Asselian part of the Tolbyakh Formation (samples 601-46, 601-47) yielded "*Gondolella*" n. sp. B, *Gondolelloides canadensis* n. sp., *Neogondolella* sp. cf. *N. dentiseparata*, *Streptognathodus* sp. cf. *S. constrictus*, and *S. barskovi*. At a higher level, in apparently lower Sakmarian strata (N. Sobolev, pers. comm., 1988), a sample yielded a single specimen of *G. canadensis* n. sp.

SYSTEMATIC PALEONTOLOGY

All specimens with GSC type numbers are housed in the National Type Collection of Invertebrate and Plant Fossils at the Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8.

Superfamily GONDOLELLACEA Lindström, 1970

Family GONDOLELLIDAE Lindström, 1970

Genus *Gondolelloides* n. gen.

Type species. Gondolelloides canadensis n. sp. Henderson and Orchard.

Etymology. From its similarity to *Gondolella* in most respects other than the carina.

Diagnosis. The segminiplanate Pa element has an unornamented gondola-shaped platform that is reduced to a flange in some specimens; a smooth textured upper surface completely lacking microreticulation or ridges; a subterminal or terminal cusp; a distinct carina of two longitudinal rows of transversely fused nodes; and a narrow keel with a wide, deep basal groove extending into a prominent basal pit surrounded by a broadly flared loop.

Description. The gondola-shaped segminiplanate Pa element has a variably developed platform that occurs at about mid-height so that the keeled underside is especially prominent. In some specimens, the platform is well developed, but narrow, and extends anteriorly from the cusp to very near the anterior tip; the anterior-most part of the element extends a very short distance as a free blade. In a juvenile form (Pl. 1, figs. 3-6) the platform is not developed but rather a narrow flange extends from the cusp to near the anterior tip. One intermediate sized specimen (Pl. 1, fig. 15) also exhibits a narrow flange; the reason for this flange being separated into two closely spaced, parallel, narrow ridges may be preservational. All surfaces of the platform or flange are smooth.

The cusp is large, laterally compressed, and proclined. At least one accessory denticle occurs posterior of the cusp in juvenile (Pl. 1, fig. 6), intermediate, and mature forms.

The carina consists of two longitudinal rows of nodes that are fused transversely and connected longitudinally by a narrow ridge that extends from the cusp to the anterior tip.

The undersurface is marked by a narrow keel with subparallel elevated ridges and a relatively wide and deep basal groove. This basal groove extends from the anterior tip into a prominent basal pit below the cusp. The keel extends from the anterior tip into an asymmetric-shaped loop below the cusp, and finally as a slight posterior extension below the accessory denticle.

Remarks. The distinctive carina forms the main distinguishing character of *Gondolelloides*, which in other respects is similar to many other gondolellids. The suprageneric classification of the new genus is somewhat uncertain, but it is included within the subfamily Gondolellidae, despite being known from only its Pa element. The smooth surfaced, gondola-shaped platform suggests a phylogenetic relationship with the Pennsylvanian to ?Lower Permian genus *Gondolella* (see also "*Gondolella*" n. sp. A), rather than the Carboniferous to Triassic *Neogondolella*. Sweet (1988) included both *Gondolella* and *Neogondolella* within the family Gondolellidae.

There has been considerable debate about the taxonomic distinctiveness of *Neogondolella* and *Gondolella* (Clark and Mosher, 1966; Sweet, 1970; Kozur, 1974, 1975, 1976; von Bitter and Merrill, 1977, 1980; Bando et al., 1980) to the extent that some workers have placed *Neogondolella* in synonomy with *Gondolella*. In contrast, one of us (MJO) considers *Neogondolella* to be probably polyphyletic; a similar view forms the basis of far reaching revisions by Kozur (1989). We believe that *Neogondolella* should certainly not be submerged in *Gondolella*. In our opinion, the most easily recognized difference between the genera within the upper Paleozoic is the distribution of microreticulation. This feature is present only on the lateral platform surfaces in *Gondolella sensu stricto* but is found over much of the upper surface in *Neogondolella* platform elements (von Bitter, 1976).

Mature specimens of Paleozoic *Neogondolella* have robust, thickened platforms, which generally have abundant microreticulation, and an elongate basal pit exhibiting a tendency toward separation into two small pits separated by a furrow (see Kozur, 1989 for the last feature). In contrast, juvenile specimens of *Neogondolella* are generally thin and delicate, bear less microreticulation (anterior part of platform is often smooth), and have a broadly flaring or funnel-like terminal basal pit, closely resembling *Gondolella* morphology. If *Gondolella* arose from *Neogondolella*, as suggested by von Bitter and Merrill (1977), it may have done so by a process of neoteny. Kozur (1989) stated that such an evolutionary path is excluded by the variations in mature basal pit morphology. In our opinion, the strong similarity between juvenile basal pits of the two genera (Kozur, 1989) clearly points to a probable common phylogenetic origin. However, subsequent evolutionary development apparently followed very different paths.

Neogondolella first appears in the Morrowan [*N. clarki* (Koike)] but subsequent occurrences are rare until the Sakmarian. *Gondolella* appears in the Upper Atokan and is relatively common throughout the remainder of the Upper Carboniferous. The Lower Permian species *G. bella* Stauffer and Plummer from the Asselian, and *G. praebisselli* Kozur and Movschovitsch from the lower Sakmarian, may be reworked; these two species are poorly defined and are very similar to the older *G. magna* Stauffer and Plummer.

During the evolution of the gondolellids, a number of platformed and non-platformed species arose (von Bitter and Merrill, 1977). *Gondolelloides* may have arisen as a last innovation or evolutionary novelty of one lineage. The genus is morphologically similar to "naked" gondolellids (von Bitter and Merrill, 1977) rather than to *Gondolella* sensu stricto, which is characterized by strongly ornate platform margins.

In the Upper Carboniferous, one or more lineages are thought to have developed from antecedents like "*Gondolella*" *laevis* Kosenko and Kozitskaya and "*Gondolella*" *gymna* Merrill and King that bear a vestigial posterior process. In both *Gondolelloides* and its probable precursors, "*Gondolella*" n. sp. A and "*G.*" n. sp. B, a small posterior process is retained, whereas in *Gondolella* sensu stricto this feature was lost at the same time as the development of a broad, sculptured platform.

We are unsure of the precise course of development within the plexus that also includes "neogondolellids" like *Neogondolella clarki*, but Figure 2 is an attempt to show some of the phylogenetic relationships suggested by the present data. The demise of the "*Gondolella*" – *Gondolelloides* lineage may have opened up a niche in the Sakmarian that was subsequently exploited by *Neogondolella*.

Gondolelloides was previously illustrated and discussed by Henderson and McGugan (1986) as Gen. et sp. nov. A [ibid., Fig. 7 (2-3)] and as *Gondolella* sp. B. (ibid., unfigured). The identity of the latter element was unrecognized in the previous work because the double row of nodes was obscured by adhering quartz grains. Occurrence of the new genus was also noted by Orchard (*in* Brandon et al., 1986, p. 696).

The carina of *Gondolelloides* resembles that of several other conodont platform elements—for example, Ordovician *Icriodella*, Silurian *Distomodus*, Devonian *Icriodus*, Carboniferous *Eotaphrus*, and Triassic *Icriospathodus*; it represents a further example of the convergent morphology common in conodont platform elements.

Age relationships of *Gondolelloides* are based on associated conodont species, including species of *Streptognathodus*, *Neogondolella*, and *Adetognathus*. Comparisons with the Soviet Union and with the Sverdrup Basin, Canadian Arctic Archipelago (Henderson, 1988), indicate a middle Asselian to lower Sakmarian age.

Gondolelloides canadensis n. gen. and sp.

Plate 1, figures 1-15; Plate 2, figures 8, 9, 14;
Plate 3, figures 1-3, 5.

1986 Gen. et sp. nov. A HENDERSON and McGUGAN, Fig. 7 (2-3).

1991 unnamed conodont in upper left corner of postage stamp entitled Conodonts, Microfossils, Palaeozoic Era, issued 05 April 1991 by Canada Post (Prehistoric Life in Canada - 2; The Age of Primitive Vertebrates).

Etymology. From its wide distribution in western and Arctic Canada.

Holotype. GSC 64590, Plate 1, figures 7, 11-13.

Type stratum. 262 m above the base of the Hare Fiord Formation.

Type locality. GSC loc. C-023911, Van Hauen Pass area, northwestern Ellesmere Island, Canadian Arctic Archipelago.

Diagnosis. A long, narrow gondola-shaped pectiniform Pa element with a prominent subterminal cusp in mature forms, and a distinct carina of 5 to 13 transversely fused nodes arranged in two longitudinal rows. The carina is low and narrower than the platform in intermediate and mature forms.

Description. The gondola-shaped segminiplanate Pa element has a variably developed platform that is well developed and wider than the carina in intermediate and mature forms (Pl. 1, figs. 2, 9, 12; Pl. 2, figs. 8, 14; Pl. 3, figs. 1, 2), but is lacking or exists as a narrow flange in juveniles (Pl. 1, figs. 4-6). When developed, the platform is narrow (240-325 µm), with a length to width ratio of about 7:1. All surfaces of the platform or flange are smooth, lacking any microreticulation.

The cusp is large (height = 240-525 µm), laterally compressed, and proclined. One posterior accessory denticle is directed posterolaterally to the cusp in the holotype (Pl. 1, figs. 7, 11-13), as well as in juvenile (Pl. 1, figs. 3-6), intermediate (Pl. 1, figs. 8-10) and larger specimens (Pl. 3, figs. 1, 3).

The carina consists of 5 to 13 transversely fused nodes arranged into two longitudinal rows. These nodes are connected medially by a narrow longitudinal ridge that extends from the cusp to the anterior tip. The nodes of the carina are generally of the same diameter (100-225 µm) throughout, but increase in height anteriorly, except for the anteriormost node, which is smaller and lower.

The undersurface is the same as for the genus and is identical to that in species of *Gondolella.*

Remarks. The smooth upper surface of the platform and the lower surface morphology are typical of many species of *Gondolella.* The carina is very distinctive and, as for the genus, provides the main distinguishing feature for this species. The species differs from *Gondolelloides nahanniensis* n. sp. in having a platform that exceeds the width of the carina in later growth stages.

The number of fused nodes comprising the carina increases during ontogeny from 5 at 600 µm, to 7 at 900 µm, to 11 at 1850 µm, and finally to 13 at 2350 µm.

Figured material. Holotype GSC 64590; paratypes GSC 64591, 76321, 94275, 94276, 94281, 94282. Four unnumbered Soviet specimens.

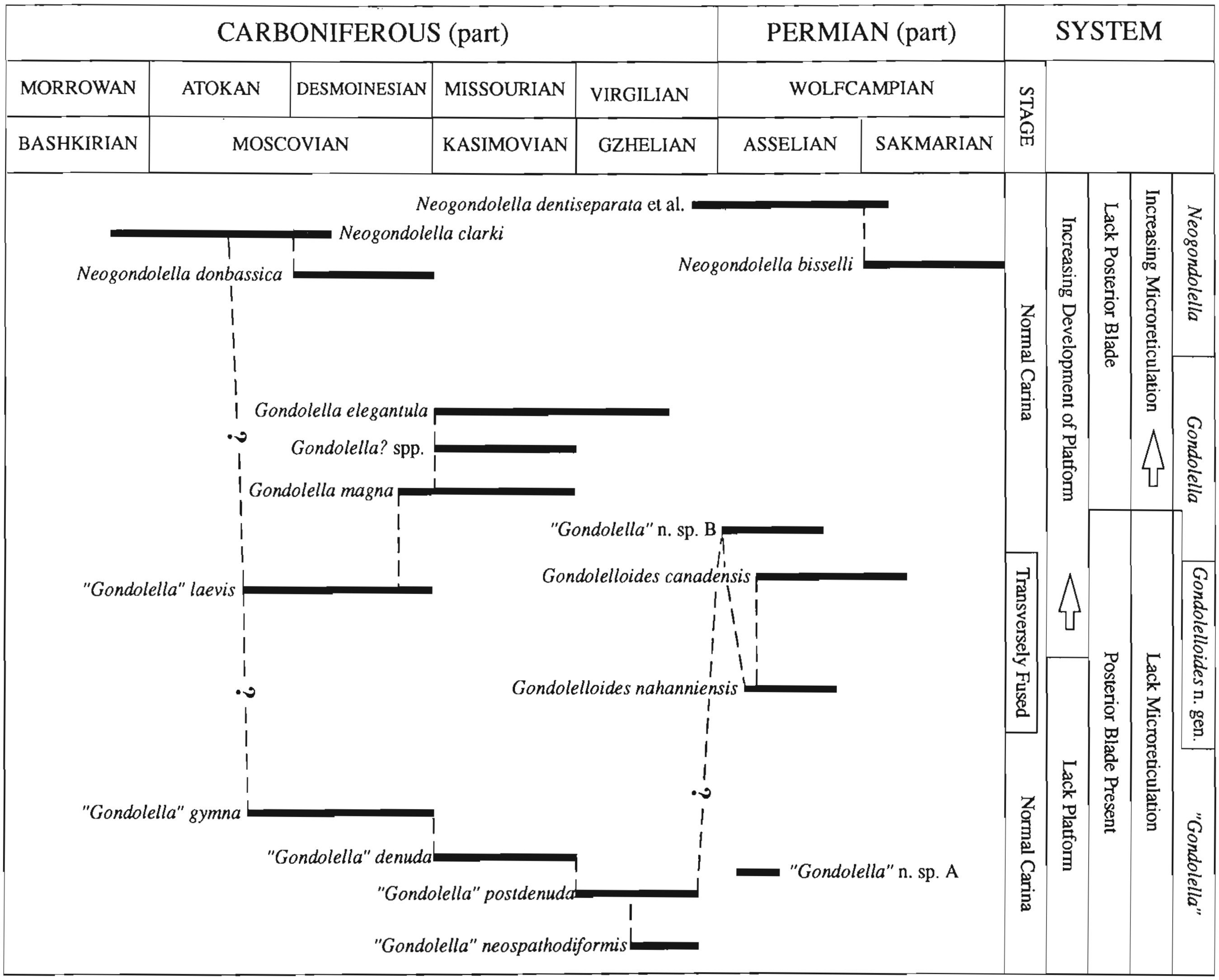


Figure 2. Suggested phylogenetic relationships of various gondolelloids, including species of *Neogondolella, Gondolella* sensu stricto, "*Gondolella*", and *Gondolelloides* n. gen. Ranges for species not named in text are based on von Bitter and Merrill (1977, 1980), and N. Sobolev (pers. comm., 1990). Both North American and Uralian stages are shown.

Gondolelloides nahanniensis n. gen. and sp.

Plate 2, figures 1-5; Plate 3, figure 9

Etymology. From its type locality in Nahanni map area.

Holotype. GSC 94277, Plate 2, figures 1, 2, 4.

Type stratum. About 21 m below the top of the Mount Christie formation (informal).

Type locality. GSC loc. C-102654, 3 km WSW of Mt. Wilson, Nahanni map area, Yukon Territory.

Diagnosis. The segminiplanate Pa element has an unornamented gondola-shaped platform that is equal to or narrower than the width of the carina. The carina is very high throughout the length of the element in mature and intermediate forms.

Remarks. This species differs from *Gondolelloides canadensis* n. sp. by having a higher carina of fused denticles and a less pronounced development of the platform, which is lacking or consists of a narrow flange that is never wider than the carina, even in intermediate and mature specimens.

The only complete specimen of this species has seven fused carinal nodes on an element 880 µm in length, comparable to *Gondolelloides canadensis* n. sp. This characteristic does not, therefore, appear to be valuable for distinguishing the two species of *Gondolelloides*, as it is for species of *Neogondolella* (Behnken, 1975).

Figured material. Holotype GSC 94277; paratype GSC 94278. One un-numbered Soviet specimen.

''*Gondolella*'' n. sp. A

Plate 2, figures 10-13; Plate 3, figures 7, 8

Description. A gondolellid species with a very narrow, unornamented platform, the margins of which taper anteriorly, but are otherwise subparallel for most of their length before merging with a large posteriorly inclined cusp, and disappearing in front of the posterior end of the unit. Posterior of the cusp there is a short, denticulate process.

Remarks. Adhering matrix obscures some details of the available (incomplete) specimens but they nevertheless appear to differ from previously described species of ''*Gondolella*''. However, inadequate material precludes naming of this species at this time. Morphologically, the new species lies close to ''*G.*'' *postdenuda* von Bitter and Merrill (1980) from the Virgilian (upper Pennsylvanian) of Nebraska, Kansas, and Texas, a species that differs most obviously in lacking a significant platform, although the lateral ridge of ''*Gondolella*'' *postdenuda* is in the same position relative to the blade. The two species have closely similar profiles, including ''short and stubby'' denticles, and both may have a denticle posterior of the cusp.

Figured material. Specimens GSC 94283-94285. Two un-numbered Soviet specimens.

''*Gondolella*'' n. sp. B

Plate 2, figures 6, 7, 15, 16; ?Plate 3, figure 6

Description. This gondolellid species has a wide, unornamented platform that is widest at mid-length and tapers both anteriorly and posteriorly. A short laterally deflected and denticulate process is present posterior of the posteriorly directed cusp. In upper view, the carina has an irregular axial trace because of the shape of the elongate, occasionally arcuate, and variably fused denticles. In larger specimens, the posterior denticles are mostly fused. In lateral view, the thick platform is developed at element mid-height. On the underside, a deep, furrowed keel extends the full length of the element and downturns beneath the cusp where there is a broad pit. Upper and lower profiles, as well as the longitudinal axis of the element, are otherwise straight.

Remarks. In many respects, the new species is similar to *Gondolelloides*, which co-occurs in the Yukon and in Novaya Zemlya. The irregularity of the denticles in ''*Gondolella*'' n. sp. B seems to anticipate the lateral broadening that characterizes *Gondolelloides*, and a relationship seems probable. *Gondolelloides* differs in the distinct broadening of the denticles and the lesser tendency to develop a platform. The Soviet specimen (Pl. 3, fig. 6) is questionably assigned to ''*Gondolella*'' n. sp. B because, although the platform margins taper both anteriorly and posteriorly, the denticles are only partly fused posteriorly and are discrete anteriorly. ''*Gondolella*'' *postdenuda* may be the common ancestor to *Gondolelloides*, ''*Gondolella*'' n. sp. A, and ''*G.*'' n. sp. B (Fig. 2).

Figured material. Specimens GSC 94279, 94280. One un-numbered Soviet specimen.

ACKNOWLEDGMENTS

We acknowledge the following geologists for collecting conodont samples discussed in this paper: P. Bender (Marburg), S.P. Gordey (Vancouver), J.E. Muller (Vancouver), B.C. Richards (Calgary), N. Sobolev (Leningrad), and C.J. Yorath (Victoria). We thank Steven Aitken (University of Calgary) for computer drafting of Figure 2 and Table 1. Joanna Beyers and J. Haggart kindly reviewed the manuscript.

REFERENCES

Bando, Y., Bhatt, D.K., Gupta, V.J., Hayashi, S.H., Kozur, H., Nakazawa, K., and Wang, Zhi-hao.

1980: Some remarks on the conodont zonation and stratigraphy of the Permian. Recent Researches in Geology, Hindustan Publishing Corporation, Delhi, India, v. 8, p. 1-53.

Beauchamp, B., Harrison, J.C., and Henderson, C.M.

1989a: Upper Paleozoic stratigraphy and basin analysis of the Sverdrup Basin, Canadian Arctic Archipelago: Part 1, time frame and tectonic evolution. In Current Research, Part G, Geological Survey of Canada, Paper 89-1G, p. 105-113.

1989b: Upper Paleozoic stratigraphy and basin analysis of the Sverdrup Basin,Canadian Arctic Archipelago: Part 2, transgressive–regressive sequences. In Current Research, Part G, Geological Survey of Canada, Paper 89-1G, p. 15-124.

Behnken, F.H.
1975: Leonardian and Guadalupian (Permian) conodont biostratigraphy in western and southwestern United States. Journal of Paleontology, v. 40, p. 376-394.

Brandon, M.T., Orchard, M.J., Parrish, R.R., Sutherland Brown, A., and Yorath, C.J.
1986: Fossil ages and isotopic dates from the Paleozoic Sicker Group and associated intrusive rocks, Vancouver Island, British Columbia. In Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 683-696.

Brown, D.A., Logan, J.M., Gunning, M.H., Orchard, M.J., and Bamber, E.W.
in press: Stratigraphic evolution of the Paleozoic Stikine assemblage in the Stikine–Iskut River area, northwestern British Columbia (NTS 104G and 104B). Canadian Journal of Earth Sciences.

Clark, D.L. and Mosher, L.C.
1966: Stratigraphic, geographic, and evolutionary development of the conodont genus *Gondolella*. Journal of Paleontology, v. 40, p. 376-394.

Epstein, A.G., Epstein, J.B., and Harris, L.D.
1977: Conodont Colour Alteration—An index to organic metamorphism. United States Geological Survey, Professional Paper 995, 27 p.

Gordey, S.P.
in press: Evolution of northern Cordilleran miogeocline, Nahanni map area (105I), Yukon and Northwest Territories. Geological Survey of Canada, Memoir 428.

Henderson, C.M.
1988: Conodont paleontology and biostratigraphy of the Upper Carboniferous to Lower Permian Canyon Fiord, Belcher Channel, Nansen, and Van Hauen Formations and an Unnamed Formation, Southwestern Ellesmere Island, Canadian Arctic Archipelago. Unpublished Ph.D. thesis, University of Calgary, 287 p.
1989: Absaroka Sequence—the Lower Absaroka Sequence: Upper Carboniferous and Permian (Chapter 10). In Basin Analysis—The Western Canada Sedimentary Basin, Ricketts, B. (ed.); Canadian Society of Petroleum Geologists Special Publication, p. 203-217.

Henderson, C.M. and McGugan, A.
1986: Permian conodont biostratigraphy of the Ishbel Group, southwestern Alberta and southeastern British Columbia. Contributions to Geology, University of Wyoming, v. 24, p. 219-235.

Henderson, C.M., Bamber, E.W., Richards, B.C., Higgins, A.C., and McGugan, A.
in press: Sedimentary cover of the craton—Permian. Geology of Canada No. 6. (also Geological Society of America, The Geology of North America, v. D-1).

Kang, Pei-quan, Wang, Cheng-yuan, and Wang, Zhi-hao.
1987: Carboniferous–Permian conodont biostratigraphy in the shelf facies of Ziyun County, Guizhou. Acta Micropalaeontologica Sinica, v. 4, p. 179-192.

Kozur, H.
1974: Beiträge zur Paläoökologie der Triasconodonten. Geologisch Paläontologische Mitteilungen Innsbruck, v. 4(7), p. 1-16.
1975: Beiträge zur Conodontenfauna des Perm. Geologische Paläontologische Mitteilungen Innsbruck, v. 5(4), p. 1-44.
1976: Paleoecology of the Triassic conodonts and its bearing on multielement taxonomy. In Conodont Paleoecology, C.R. Barnes (ed.); Geological Association of Canada, Special Paper 15, p. 313-324.
1989: The taxonomy of the gondolellid conodonts in the Permian and Triassic. Courier Forschungsinstitut Senckenberg, v. 117, p. 409-469.

Orchard, M.J.
1987: Conodonts from western Canadian chert: their nature, distribution and stratigraphic application. In Conodonts: Investigative Techniques and Applications, R.L. Austin (ed.); Ellis Horwood Limited, Chichester, p. 94-119.

Read, P.B., Brown, R.L., Psutka, J.F., Moore, J.M., Journeay, M., Lane, L.S., and Orchard, M.J.
1989: Geology of parts of Snippaker Creek (104B/10), Forrest Kerr Creek (104B/15), Bob Quinn Lake (104B/16), Iskut River (104G/1), and More Creek (104G/2). Geological Survey of Canada, Open File 2094.

Sweet, W.C.
1970: Uppermost Permian and Lower Triassic conodonts of the Salt Range and Trans-Indus Ranges, West Pakistan. *In* Stratigraphic Boundary Problems: Permian and Triassic, West Pakistan, B. Kummel and C. Teichert (eds.); University of Kansas, Department of Geology, Special Publication 4, p. 207-275.
1988: The Conodonta—Morphology, Taxonomy, Paleoecology, and Evolutionary History of a Long Extinct Animal Phylum. Oxford Monographs, Geology and Geophysics, no. 10, Clarendon Press, Oxford, 212 p.

Thorsteinsson, R.
1974: Carboniferous and Permian stratigraphy of Axel Heiberg Island and western Ellesmere Island, Canadian Arctic Archipelago. Geological Survey of Canada, Bulletin 224, 115 p.

von Bitter, P.H.
1976: The apparatus of *Gondolella sublanceolata* Gunnell (Conodontophorida, Upper Pennsylvanian) and its relationship to *Illinella typica* Rhodes. Royal Ontario Museum, Life Sciences Contribution, no. 109, p. 1-44.

von Bitter, P.H. and Merrill, G.K.
1977: Neogondolelliform conodonts of Early and Middle Pennsylvanian age. Royal Ontario Museum, Life Sciences Occasional Paper, no. 29, p. 1-10.
1980: Naked species of *Gondolella* (Conodontophorida): their distribution, taxonomy, and evolutionary significance. Royal Ontario Museum, Life Sciences Contribution, no. 125, p. 1-49.

PLATE 1

All figures are scanning electron micrographs of Pa elements.

Figures 1-15. *Gondolelloides canadensis* n. gen. and sp.

1, 8. Lower surface view (two fragments of single specimen), paratype GSC 76321, x100, GSC loc. C-126000.
2, 9. Upper surface view (same fragments as in figs. 1, 8), x100.
3, 4. Lower and upper views of juvenile specimen, paratype GSC 64591, x100, GSC loc. C-023911.
5. Upper surface view (fig. 4), x50.
6. Oblique upper surface view (figs. 3, 4, 5), x150.
7. Close-up of posterior lower surface of figure 13 showing basal pit, loop, and posterior extension of loop, x300.
10. Oblique upper surface view (specimens in figs. 1, 2, 8, 9 before breakage), x50.
11-13. Oblique lower, upper, and lower surface views of mature specimen, holotype GSC 64590, x 50, GSC loc. C-023911.
14. Lateral view, paratype GSC 94275, x100, GSC loc. C-126000.
15. Oblique lateral view, paratype GSC 94276, x100, GSC loc. C-126000.


1


2


3


4


5


6


7


8


9


10


11


12


13


14

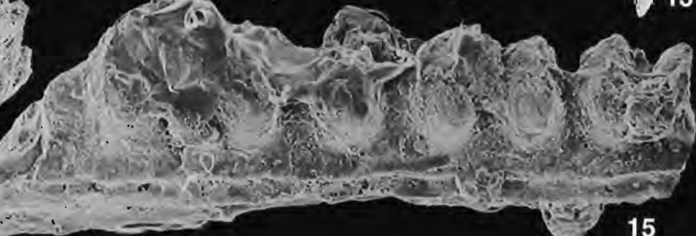

15

PLATE 2

All figures are scanning electron micrographs of Pa elements, x100, unless otherwise indicated.

Figures 1-5. *Gondolelloides nahanniensis* n. gen. and sp.

1. Close-up of medial portion of figure 2, x300.
2, 4. Upper and oblique lateral views of intermediate form, holotype GSC 94277, GSC loc. C-102654.
3. Upper view of anterior element fragment, paratype GSC 94278, GSC loc. C-102654.
5. Oblique lateral view of figure 3.

Figures 6, 7, 15, 16. ''*Gondolella*'' n. sp. B.

6. Upper view of posterior element fragment, figured specimen GSC 94279, GSC loc. C-102654.
16. Lateral view of figure 6.
7. Upper view of posterior element fragment, figured specimen GSC 94280, GSC loc. C-102654.
15. Lateral view of figure 7.

Figures 8, 9, 14. *Gondolelloides canadensis* n. gen. and sp.

8. Upper surface view, paratype GSC 94281, GSC loc. C-127686.
9. Lower surface view of figure 8.
14. Upper surface view of medial element fragment, paratype GSC 94282, GSC loc. C-127686.

Figures 10-13. ''*Gondolella*'' n. sp. A.

10, 13. Upper surface view of posterior part, and lateral view of anterior part of a single specimen, figured specimen GSC 94283, GSC loc. C-127686
11. Oblique lateral view of posterior element fragment, figured specimen GSC 94284, GSC loc. C-117760.
12. Upper surface view of anterior element fragment, figured specimen GSC 94285, GSC loc. C–117762.


1


2

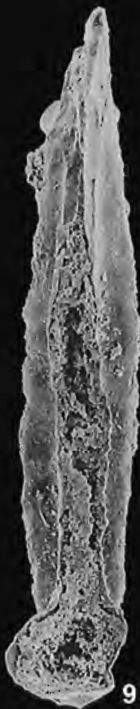

3


4


5


12


8


9


10


11


6


7


13


14


15


16

PLATE 3

All figures are scanning electron micrographs of Pa elements, x100. The figured specimens are all from middle Asselian strata in Novaya Zemlya, U.S.S.R. and are in the care of N. Sobolev at Severmorgeologia Institute, Leningrad. Therefore, they have not been assigned GSC type numbers or GSC locality numbers.

Figures 1-3, 5. *Gondolelloides canadensis* n. gen. and sp.

1, 2. Upper surface views of two specimens, from samples 101-51 and 131-45, respectively.
3. Lower surface view of third specimen, from sample 101-51.
5. Lateral view of fourth specimen, from sample 752-78.

Figure 6. ?"*Gondolella*" n. sp. B.

Upper surface view of specimen, from sample 601-46.

Figures 7, 8. "*Gondolella*" n. sp. A.

Upper surface views of two specimens, from samples 131-45 and 752-78 respectively.

Figure 9. *Gondolelloides nahanniensis* n. gen. and sp.

Upper surface view of specimen, from sample 752-78.

Figures 4, 10, 11. *Neogondolella dentiseparata* Reshetkova and Chernikh.

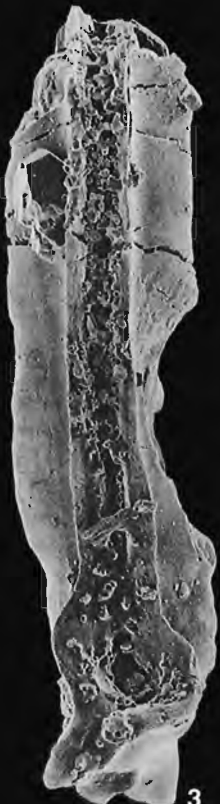
4. Lower surface view of specimen, from sample 131-45.
10, 11. Upper surface views of second and third specimen, from samples 101-51 and 131-45, respectively.

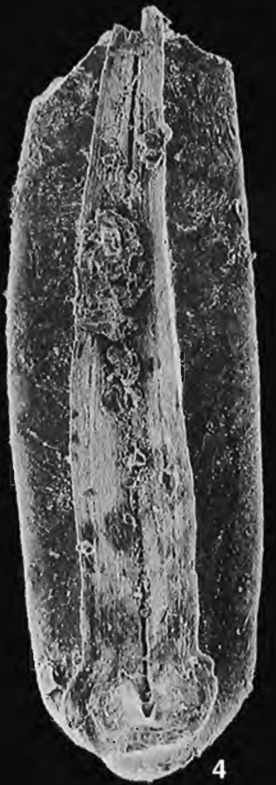
PLATE 3


6


1


2


3


4


5


7


8


9


10


11

Upper Permian and Triassic conodont faunas from the type area of the Cache Creek Complex, south-central British Columbia, Canada

J.M. Beyers[1] and M.J. Orchard[2]

Beyers, J.M. and Orchard, M.J., 1991: Upper Permian and Triassic conodont faunas from the type area of the Cache Creek Complex, south-central British Columbia, Canada. In *Ordovician to Triassic Condont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417, p. 269-297.*

Abstract

Two Upper Permian and nine Triassic conodont faunas are described from the central and western belts of the Cache Creek Complex in its type area, south-central British Columbia. The oldest, Fauna 1, contains Neogondolella phosphoriensis *and species of* Sweetognathus, *and is Guadalupian in age. Fauna 2 consists of three morphotypes of* Iranognathus? *ex gr.* movschovitschi *plus* I.? *n. sp.,* Neogondolella *sp. cf.* N. orientalis, N. subcarinata *subspp., and* N. jesmondi *n. sp., all of which are late Dzhulfian to Dorashamian/Changxingian in age; this is the youngest Permian conodont fauna from North America.*

The Triassic faunas span virtually the entire period. Fauna 3 containing ''Anchignathodus'' parvus *is Griesbachian, and is the first fauna of this age reported from the western Canadian Cordillera. Fauna 4, characterized by* Neogondolella carinata, Neospathodus dieneri, N. peculiaris, *and* N. *sp. cf. N.* pakistanensis, *is a mixed assemblage embracing the middle Dienerian through lower Smithian. Elements of Fauna 5 include* Pachycladina obliqua *and* ''Lonchodina'' nevadensis, *and are Smithian in age.* Neogondolella milleri, Neospathodus novaehollandiae, N. waageni, *and* Platyvillosus costatus *are key taxa of Fauna 6, also of Smithian age. Fauna 7 consists of* Neospathodus homeri *and* N. triangularis *and is Spathian in age. Middle Triassic Fauna 8 is represented by* Neogondolella *ex gr.* excelsa. *Fauna 9 includes* Metapolygnathus nodosus *and ?*Neocavitella *sp. and is Carnian in age. Fauna 10 includes Lower Norian* Epigondolella quadrata, Metapolygnathus primitius, M. pseudoechinatus, *and* Neogondolella navicula. *Middle Upper Norian Fauna 11 contains* Epigondolella bidentata *and* E. mosheri.

Résumé

Les auteurs décrivent deux faunes à conodontes du Permien supérieur et neuf du Trias qui proviennent des zones centrale et occidentale du complexe de Cache Creek, dans sa région type dans le centre sud de la Colombie-Britannique. La faune 1, la plus vieille, contient Neogondolella phosphoriensis *et* Sweetognathus *sp(p.) et remonte au Guadalupien. La faune 2 comporte trois morphotypes d'* Iranognathus? *ex gr.* movschovitschi *ainsi qu'une nouvelle espèce d'* Iranognathus?, Neogondolella *sp. cf.* N. orientalis, N. subcarinata *subspp. et* N. jesmondi *n. sp., qui datent tous du Dzhulfien tardif au Dorashamien-Changxingien. Il s'agit de la plus jeune faune à condontes permienne de l'Amérique du Nord.*

---

[1] Department of Geological Sciences, University of British Columbia, 6339 Stores Road, Vancouver, B.C. V6T 1Z4

[2] Geological Survey of Canada, 100 West Pender St., Vancouver, B.C. V6B 1R8

Les faunes triasiques couvrent presque toute la période. La faune 3, qui contient "Anchignathodus" *parvus, remonte au Griesbachien; c'est la première faune de cet âge reconnue dans la Cordillère occidentale du Canada. La faune 4 se caractérise par la présence de* Neogondolella carinata, *de* Neospathodus dieneri, *de* N. peculiaris *et de* N. *n. sp. cf.* N. pakistanensis*; c'est un assemblage mélangé dont l'âge englobe l'intervalle du Dienérien moyen au Smithien précoce inclusivement. Des éléments de la faune 5 comprennent* Pachycladina obliqua *et* "Lonchodina nevadensis" *et remontent au Smithien. La faune 6 renferme les taxons clés suivants, qui remontent eux aussi au Smithien :* Neogondolella milleri, Neospathodus novaehollandiae, N. waageni *et* Platyvillosus costatus. *La faune 7 comporte* Neospathodus homeri *et* N. triangularis *et date du Spathien. La faune 8 comprend* Neogondolella *ex gr.* excelsa, *du Trias moyen. La faune 9 compte* Metapolygnathus nodosus *et* ?Neocavitella *sp. et remonte au Carnien. La faune 10 se compose d'*Epigondolella quadrata, *de* Metapolygnathus primitius, *de* M. pseudoechinatus *et de* Neogondolella navicula, *du Norien précoce. La faune 11, du milieu du Norien tardif, inclut* Epigondolella bidentata *et* E. mosheri.

PREVIOUS WORK

The Cache Creek Complex is located within the central part of the morpho-tectonic Intermontane Belt of the Canadian Cordillera. It extends almost continuously over a distance of more than 1000 km, from south-central Yukon Territory (lat. 60°), through the Stuart Lake Belt of Armstrong (1949) in central British Columbia, to the type area near the village of Cache Creek in the Interior Plateau of south-central British Columbia (lat. 51°; Ashcroft and Bonaparte Lake map sheets; Fig. 1).

The Cache Creek Complex, until recently considered "mainly of Permian age, but also probably in part of Pennsylvanian age" (Armstrong, 1949, p. 50), was named and described by Selwyn (1872) as "Upper and Lower" groups of the "Cache Creek series". It features a distinctive association of upper Paleozoic and lower Mesozoic chert, argillite, basalt, and minor ultramafic rocks, together with prominent, commonly massive, carbonates. This association suggests an origin in a long-lived ocean basin (Monger, 1977).

Three north–south trending, lithologically distinct outcrop areas have long been recognized in the type area (e.g., Duffell and McTaggart, 1952; Trettin, 1961), for which Trettin (1980) introduced the terms eastern, central, and western belts (Fig. 1). Although these rocks are of subgreenschist metamorphic facies, they have been repeatedly faulted and irregularly folded (Trettin, 1980). Deformation may have occurred in the early Mesozoic, in the Late Jurassic, and in the Tertiary (Travers, 1978; Monger and McMillan, 1989). Only rarely can continuous stratigraphic sections be recognized, and boundaries between the three belts and their constituent units are suspect.

The eastern belt comprises the block-in-matrix mélange of Travers (1978), the Greenstone Unit of Shannon (1981), and may include the aerially extensive limestones near Meadow Lake about 20 km northeast of Jesmond (Fig. 1) (Campbell and Tipper, 1971). Serpentinite bodies noted by Dawson (1879, p. 93B), Campbell and Tipper (1971, p. 67) and Shannon (1982) are also part of the eastern belt.

Blocks in the mélange vary greatly in size, and consist of limestone, chert, basalt, gabbro, and slivers of ultramafic rock in a matrix of chert and argillite (Travers, 1978; Shannon, 1982). The limestone blocks contain Middle to Upper Pennsylvanian and Lower Permian conodonts, but the matrix is Late Permian and Triassic in age (Orchard, 1984). The boundary between the eastern belt and the central belt is a fault (Campbell and Tipper, 1971); Shannon, 1981; Monger and McMillan, 1989).

The central belt consists of a lower unit, called the Mount Soues Division by Trettin (1961), the Marble Canyon Formation (Duffell and McTaggart, 1952), and overlying recessive cherts and argillites. Trettin (1980) mapped these three units

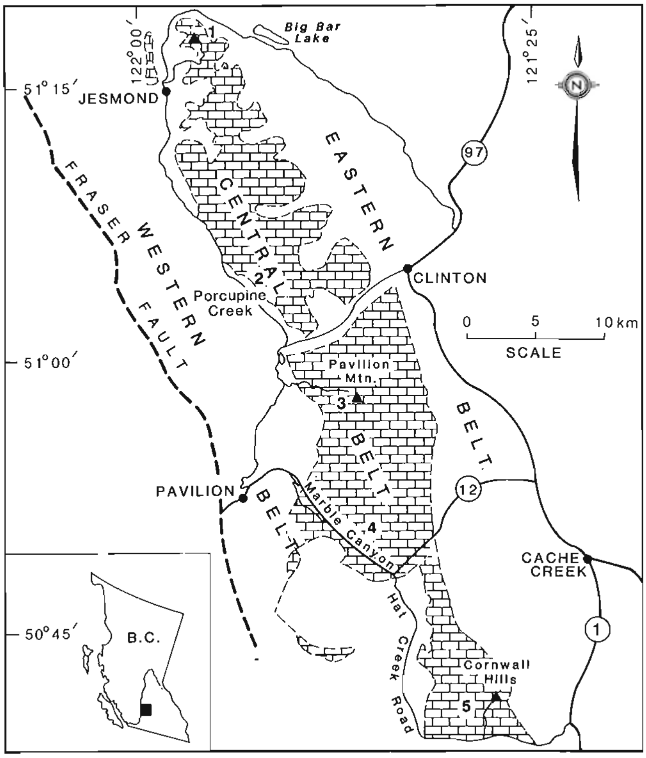


Figure 1. Outcrop area of the southern Cache Creek Complex. Inset shows location in the Canadian Cordillera. Eastern, central and western belts after Trettin (1980). Localities cited in the text: **1.** Jesmond; **2.** Porcupine Creek; **3.** Hat Creek–Marble Canyon; **4.** Pavilion Mountain; **5.** Cornwall Hills. Numbers in circles refer to British Columbia highways.

as map unit 1 (= unit 5 of Campbell and Tipper, 1971; unit bc of Mortimer, 1987), units 2 and 4, and units 3 and 5, respectively.

The Mount Soues Division, made up of volcanics, chert and limestone, is exposed southwest of Clinton and southeast of Porcupine Creek (Fig. 1). It shows lithological similarities with the eastern belt, to which it may belong (Campbell and Tipper, 1971; J.W.H. Monger, pers. comm., 1991). Trettin (1980) thought that the contact between the Mount Soues Division and the Marble Canyon Formation was stratigraphic, although he did not rule out the existence of a thrust fault.

The Marble Canyon Formation typically comprises massive to poorly bedded, dolomitized, recrystallized limestone, with rare chert and argillite. Locally, it contains abundant fusulinids (e.g., Dunbar, 1932; Thompson et al., 1950) and algae (Johnson and Danner, 1966; herein). Lower Triassic limestone has recently been described (Orchard and Beyers, 1988), and Middle Triassic radiolarian chert is known from Cornwall Hills (Fig. 1; Cordey, 1986; Orchard, 1986). Probable Upper Triassic pelecypods (*?Halobia*) were found near there by W.R. Danner in 1981 (pers. comm., 1989).

The nature of the contact between the central and western belts is unclear. Permian limestone of the Marble Canyon Formation appears to abruptly overlie Lower and Upper Triassic strata of the western belt at the western end of Marble Canyon (Orchard, 1981; Monger and McMillan, 1989). However, paleontological data show a general younging of strata in a westerly direction (Danner and Nestell, 1966; Campbell and Tipper, 1971; this report). Also, a decrease in the proportion of interbedded limestone occurs in the area between the two belts (Trettin, 1961; Mortimer, 1987). Furthermore, similar and coeval Triassic strata appear to overlie the Marble Canyon Formation in the southern part of the central belt near Cornwall Hills. Stratigraphic continuity is implied, although structural complexity obscures the relationship between the two belts.

Western belt rocks, originally known as Division I of the Pavilion Group (Trettin, 1961) outcrop west of Marble Range and comprise chert and pelite with minor volcanic rocks and limestone. Farther west, the informal "Pavilion beds" of Trettin (1980; formerly Division II of the Pavilion Group of Trettin, 1961), are characterized by volcanic rocks and volcanic arenite but include thin limestone lenses, chert, conglomerate, and pelite.

Trettin (1980, p. 2) thought the Pavilion strata differed substantially in composition from Cache Creek rocks but Monger (1981) and Orchard (1981) included them in the complex, and Mortimer (1987) regarded them as a more "volcanic/volcaniclastic part" of the western belt and not a separate unit. They have yielded Upper Triassic conodonts (Rafek *in* Trettin, 1980, p. 16; here regarded as Carnian), and Middle Triassic or younger corals (Trettin, 1961, p. 34). Jurassic radiolarians were recently discovered in the western belt, suggesting that Cache Creek sedimentation persisted far longer than had been suspected (Cordey et al., 1987). The Early Tertiary, Fraser River dextral strike-slip fault forms the western boundary of the western belt (Monger and McMillan, 1989).

CONODONT BIOSTRATIGRAPHY

Only collections from the western and central belts of the Cache Creek Complex are considered in this paper (see Appendix). Biostratigraphically significant conodonts were recovered from strata at most of the localities studied. For the purposes of the following discussion, conodont collections have been grouped into eleven conodont faunas (faunas 1-11), some of which are composite in nature. This is a utilitarian approach that results from general lack of stratigraphic sequences, low yields, and fragmental preservation. We provide tabulated numerical data only for key taxa of the Upper Permian (Table 1).

Table 1. Distribution data for *Iranognathus?* and *Neogondolella* in the Jesmond area

	NEOGONDOLELLA								*IRANOGNATHUS ?*								GENUS
	sp. indet.	*? jesmondi*	*jesmondi*	*? subcarinata*	*s.* subsp. *A*	*s. subcarinata*	*? orientalis*	cf. *N. orientalis*	sp. indet.	n. sp. *A*	morphotype ?C	morphotype ?B	morphotype ?A	morphotype C	morphotype B	ex gr. *movschovitschi* morphotype A	SPECIES / SAMPLE
SECTION 2		1							2					1		17	C-149752
	3	3	32						1				1			8	C-101144
			2						2								C-149753
																2	C-149756
		1	29				1		3		1		1			15	C-149757
	2		4														C-157212
SECTION 1											2		1			1	C-149768
	1			1					8		2		6	8		5	C-149769
	1	2	2					1	1	1	1		2			3	C-157204
			1														C-149771
	1	2						1									C-157202
		1															C-149773
SECTION 3	1																C-149781
															1		C-149782
	1												1				C-157217
									2							2	C-157218
															1	2	C-157219
	1								5	1	1		8			11	C-157222
					1				1							7	C-157223
									2			1				5	C-157224
			3	1		2		1	2	1			3	2		12	C-157808
	4		20				1	3					2	4			C-157815

Tabulated samples were collected in sequence in 1986 and 1987; only one reconnaissance sample from previous years has been included.

CHRONOSTRATIGRAPHIC SCALE					CONODONT FAUNAS	CONODONT ZONATION
TRIASSIC	UPPER		NORIAN	U	FAUNA 11	Upper *bidentata*
				M		
				L	FAUNA 10	Upper *primitius*
			CARNIAN	U	FAUNA 9	
				L		
	MIDDLE		LADINIAN		FAUNA 8	
			ANISIAN			
	LOWER	SCYTHIAN	SPATHIAN		FAUNA 7	
			SMITHIAN		FAUNA 6 / FAUNA 5	*milleri* *waageni*
			DIENERIAN		FAUNA 4	
			GRIESBACHIAN		FAUNA 3	*isarcica* *typicalis*
PERMIAN	UPPER		DORASHAMIAN / CHANGXINGIAN		FAUNA 2	*subcarinata*
			DZHULFIAN			*orientalis* *leveni*
		GUADALUPIAN	CAPITANIAN			 *bitteri*
			WORDIAN		FAUNA 1	*phosphoriensis*

Figure 2. Stratigraphic distribution of Cache Creek faunas in the central and western belts of the Cache Creek Complex. Upper Permian conodont zonation modified from Sweet (1988); chronostratigraphy modified from Bamber et al. (1989). Lower Triassic zonation modified from Sweet et al. (1971) and Sweet and Bergström (1986); Upper Triassic zonation from Orchard (1991a; 1991b *this volume*); Triassic chronostratigraphy modified from Sweet et al. (1971).

The ages of faunas 1-11, shown in Figure 2, have been determined by reference to several existing zonal schemes. Of those available for the Lower Triassic, that of Sweet et al. (1971), using data from Pakistan, Kashmir, and Nevada, is used as a standard. This is supplemented by the chronozonal scale of Sweet and Bergström (1986), based on graphic correlation, which takes into account observations made by others in the intervening years, especially in the American Great Basin (e.g., Solien, 1979; Carr and Paull, 1983). Zonation for the Upper Permian is taken from Sweet (1988), and that for the Upper Triassic is from Orchard (1983, 1991a).

Upper Permian

Fauna 1

This fauna comprises species of *Neogondolella*, *Sweetognathus*, and *Hindeodus* and is found west of Clinton and in the Hat Creek--Marble Canyon area (Fig. 1). The fauna is best known in the latter area, where samples contain all three taxa, including Upper Permian *Neogondolella phosphoriensis* (Youngquist, Hawley, and Miller) (e.g., GSC loc. C-116176). Adjacent samples contain only one or two elements of Fauna 1, for example sweetognathids (GSC locs. C-118818, C118499) or the long-ranging *Hindeodus* (GSC locs. C-118121, C-118122). Near Clinton (GSC loc. C-117776), *N. phosphoriensis* occurs alone.

Neogondolella phosphoriensis was first described from the Phosphoria Formation in southeastern Idaho by Youngquist et al. (1951), who suggested a Roadian (late Early Permian) to Wordian (early Late Permian) age for the species. The neogondolellid was also described from the Guadalupian of east Greenland as *N. rosenkrantzi* (Bender and Stoppel, 1965). Detailed study of the conodont succession in the Meade Peak and Rex Chert members of the Phosphoria Formation supports a Wordian (early Guadalupian) age for the species (Behnken et al., 1986); Sweet (1988) showed a range that falls within the *phosphoriensis* and *bitteri* zones (late early to early late Guadalupian). The specimens from Clinton occur with foraminifers *Lepidolina* [formerly *Yabeina* (Goto et al., 1986)] and *?Glomospira*, which further supports a Guadalupian age (Thompson et al., 1950).

The elements of *Sweetognathus* are similar to rare reworked specimens originally found in a mixed, largely Dienerian fauna (Fauna 4, herein) from the eastern wall of Marble Canyon (Orchard, 1981). Orchard (1981) suggested an early Late Permian (Abadehian) age for the reworked elements on the basis of their similarity to *Sweetognathus iranicus* Kozur, Mostler, and Rahimi-Yazd. A similar, slightly older species has been described as *S. hanzhongensis* Wang, but the taxonomy and age of these Upper Permian sweetognathids remains problematic, so we do not identify species here.

Fauna 2

The youngest Permian faunules ("Fauna 1" of Beyers and Orchard, 1989) occur in sections 1-3 and in isolated samples near Jesmond (Fig. 3; Table 1; Appendix); other examples are found above Jesmond Creek (GSC loc. C-157815), and at Section 2 on Pavilion Mountain (GSC loc. C-157847) (Fig. 1). These are combined as Fauna 2, which consists of *Hindeodus typicalis* (Sweet), *Neogondolella jesmondi* n. sp., *N.* sp. cf. *N. orientalis* (Barskov and Koroleva), and *I.?* ex gr. *movschovitschi* (Kozur and Pjatakova), occasionally accompanied by rare *N. subcarinata* Sweet.

Neogondolella subcarinata subcarinata may be present 3 m above the base of Section 1 at Jesmond (GSC loc. C-149769) but is otherwise known only from a locality at a topographically lower outcrop (GSC loc. C-157808), where it is accompanied by several other taxa (see below). A different subspecies, *N. subcarinata* n. subsp. A, was found 32 m above the base of Section 3 (GSC loc. C-157223).

Neogondolella s. subcarinata was originally reported from the Ali Bashi Formation at Kuh-e-Ali Bashi near Julfa, northern Iran (Teichert et al., 1973). The species is known also from the Akhura and Dorasham II sections in nearby Soviet Transcaucasia, and from the section at Kuh-e-Khambast near Abadeh in central Iran (Kozur et al., 1978). At both Kuh-e-Ali Bashi and Dorasham II, *N. s. subcarinata* is accompanied by the ammonoid *Phisonites* (Teichert et al., 1973; Kozur et al., 1978), which defines the base of the Dorashamian stage as established by Rostovtsev and Azaryan (1973).

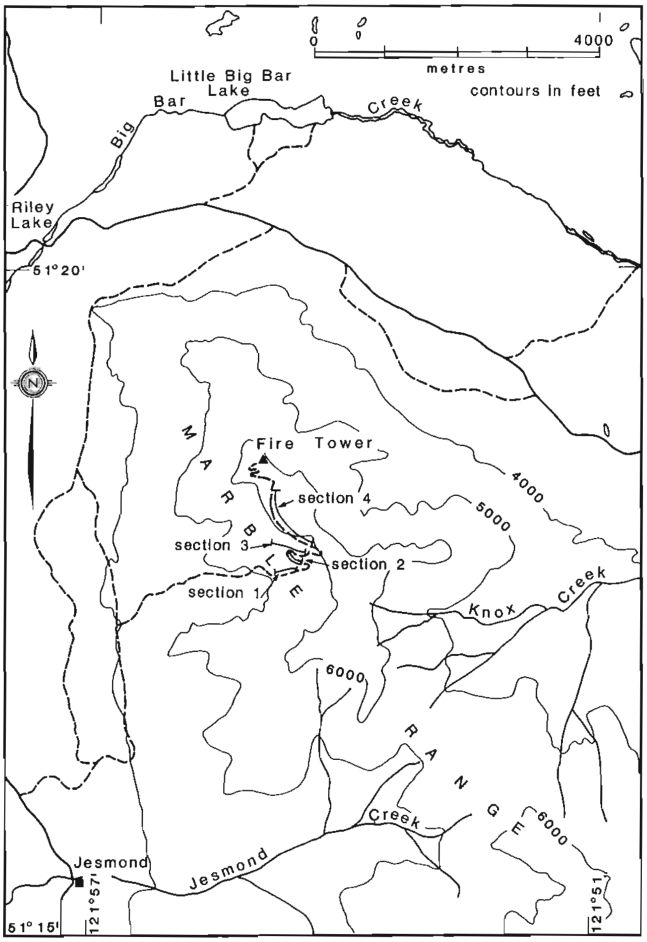


Figure 3. Location of Jesmond sections 1-4.

Several ammonoids that occur in the Dorashamian also occur in the lower Changxingian in south China (Zhao et al., 1981). These data support approximate correlation of the Dorashamian and Changxingian, although *Neogondolella s. subcarinata* is reported, anomalously, from the underlying uppermost Wuchiapingian (Clark and Wang, 1988). *Neogondolella subcarinata* and affiliated taxa range to the top of the Permian as shown by Clark and Wang (1988).

At the Selong section in Nyalam County, Xizang (Tibet), the last occurrence of *Neogondolella subcarinata* coincides with the base of the (Ophiceras) Sakuntala Zone (top of the *Otoceras* bed) in the Triassic "Lower Formation" of the Tulong Group (Yao and Li, 1987). Ding (1986) describes a similar succession for the stratotype section of the Changxingian at Meishan, Changxing County. Whether the extended range of *N. subcarinata* results from an unconformity at the base of the *Otoceras* bed, with a resultant mixed Permian–Triassic fauna (Yao and Li, 1987; Tozer, 1988), is uncertain. In this study, the *subcarinata* Zone is regarded as coinciding with the range of *N. subcarinata* before the appearance of *Otoceras*, a level which corresponds to the traditional base of the Triassic as reviewed by Tozer (1988).

Occurring in greater abundance than any of the other neogondolellids, *Neogondolella jesmondi* is found both near Jesmond and on Pavilion Mountain. At the latter locality (GSC loc. C-157847), 2 m above the base of the predominantly Triassic Section 2, *N. jesmondi* occurs with an element of the *Iranognathus? movschovitschi* group. Near Jesmond, *N. jesmondi* occurs with *N.* sp. cf. *N. orientalis*, *N. s. subcarinata* and with *Iranognathus?* ex gr. *movschovitschi* (GSC loc. C-157808); on the slopes above Jesmond Creek (GSC loc. C-157815) *N. subcarinata* is absent.

Members of the Upper Permian genus *Iranognathus* have previously been described from Iran and China. Wardlaw (1988) also reported "species of *Iranognathus*" from the Salt Range. Two species, *I. unicostatus* and *I. tarazi*, were originally described from Iran by Kozur et al. (1975). Assignment of a third Upper Permian species, *I.? movschovitschi*, to the genus is tentative because, unlike the other two, it is characterized by the absence of ornamentation on the cup. At the type locality of the latter species at Akhura, Kozur (1977) documented a range through *Araxoceras*- and lower *Vedioceras*-equivalent strata of Dzhulfian (Baisalian) age. Kozur (1978) subsequently showed *I.? movschovitschi* ranging through the upper part of the *leveni* Zone and lower part of the *orientalis* Zone (see below).

Iranognathus nudus Wang, Ritter, and Clark, recently described from south China by Wang et al. (1987) and here regarded as a synonym of *I.? movschovitschi*, occurs in cherty limestone of the Shangsi [= Changxing (Clark and Wang, 1988)] Formation in the Qiaoting section near the town of Nanjian, Sichuan Province. The species is found throughout all but the uppermost few metres of the Shangsi Formation, where it is accompanied by *Neogondolella s. changxingensis* Wang and Wang and fewer *N. orientalis* (Wang et al., 1987). The south China occurrence extends the range of *Iranognathus? movschovitschi* upward into the Changxingian (Wang et al., 1987). Co-occurrence of simple iranognathids with *Neogondolella subcarinata* at Jesmond is important because, in the absence of the latter, it strengthens correlation of Fauna 2 with Changxingian strata.

Neogondolella sp. cf. *N. orientalis* is found in isolated samples near Jesmond, as well as in Section 1 and possibly in Section 2. Barskov and Koroleva (1970) originally described *N. orientalis* from the middle *Vedioceras* beds near the Dorasham II railway station. Teichert et al. (1973) recovered it from strata immediately below the Ali Bashi Formation at Kuh-e-Ali Bashi near Julfa, and Kozur et al. (1978) recorded it from *Araxoceras*-bearing beds at Dorasham II and from ?basal *Vedioceras* beds at Kuh-e-Khambast. At these transcaucasian and central Iranian sections, *N. orientalis* occurs at the level at which its predecessor, *N. leveni*, disappears (Kozur et al., 1978). On Hydra, Greece, *N. orientalis* occurs in upper Dzhulfian strata below the base of the Dorashamian (Nestell and Wardlaw, 1987). In south China, the latter species ranges throughout much of the Wuchiaping and Changxing formations (Clark and Wang, 1988), that is Changxingian and older in age. In this paper, the top of the *orientalis* Zone coincides with the first appearance of *N. subcarinata*, which approximates the base of the Changxingian.

Hindeodus typicalis [recorded by some authors as *H. minutus* (Rexroad and Furnish)] is found in the Permian–Triassic boundary interval in northern (Sweet, 1979) and central Iran (Sweet, 1973; Kozur et al., 1978), in the southern Alps of Italy (Perri and Andraghetti, 1987), in Kashmir and Pakistan (Sweet, 1970a, 1970b) and east Greenland (Sweet *in* Teichert and Kummel, 1976). At the Qiaoting section of south China, "*H. minutus*" is present only in the Permian Shangsi Formation, and has not been reported from overlying Triassic strata (Wang et al., 1987). In contrast, in the Great Basin of the United States, *H. typicalis* occurs above the base of the Triassic Dinwoody Formation in southwestern Montana (Schock et al., 1981; R.K. Paull, pers. comm., 1991).

In this paper, the *typicalis* Zone represents the range of *Hindeodus typicalis* above the last occurrence of the Upper Permian *Neogondolella subcarinata*. The zone is superseded by the *isarcica* Zone of the upper Griesbachian above the level of the first Triassic ammonoids (Sweet et al., 1971; Paull, 1982; Sweet and Bergström, 1986).

In summary, the age of Fauna 2 is within the late Dzhulfian through Changxingian interval, or specifically Changxingian where *Neogondolella subcarinata* is present. Both the *orientalis* and *subcarinata* zones may be present. This fauna is the youngest Permian fauna known from North America, and has few parallels anywhere in the world. It is a remarkable attribute of the Cache Creek Complex.

Lower Triassic

Fauna 3

Rare elements of "*Anchignathodus*" *parvus* Kozur and Pjatakova occur with *Hindeodus typicalis* in limestone at the base of a section at Porcupine Creek (Fig. 1) (GSC loc. C-157820; Beyers and Orchard, 1989); this constitutes Fauna 3. Sweet (*in* Ziegler, 1977) has outlined the historical problems attending designation of the former taxon, regarded by some authors as the adenticulate morphotype of *Isarcicella isarcica* (Huckriede) (Morphotype 1 of Sweet *in* Ziegler, 1977). Two outstanding problems remain: stratigraphic range of the several morphotypes, and presence or absence of skeletal components other than Pa elements.

In material described by Staesche (1964), three morphotypes of *Isarcicella isarcica*, denticulate and adenticulate, occurred together in the lower Seis beds of the Werfen Formation in South Tirol. Staesche (ibid.) did not provide distribution data for each of the morphotypes, but Sweet (1970b), who examined this material in Tübingen, concluded that the range of adenticulate and denticulate forms in the Werfen Formation is the same (*in* Ziegler, 1977). Denticulate and adenticulate elements are also found in the lower 4.5 m of the Triassic Elikah Formation at Kuh-e-Ali Bashi (Sweet *in* Teichert et al., 1973), and Paull (1982) reported their co-occurrence in the Lower Triassic Dinwoody Formation of the Terrace Mountains in Utah.

In the Dorasham II, Julfa and Abadeh sections, ''*Anchignathodus*'' *parvus* first occurs above the base of the Triassic in strata containing *Claraia* and *Ophiceras*; the denticulate forms of *Isarcicella isarcica* appear later and range higher (Kozur et al., 1978). At Akhurah the denticulate forms do not occur (Kozur et al., 1978), but Sweet (1970b) recovered them (and adenticulate ones, shown as *A. typicalis* by Sweet *in* Ziegler, 1977) from the Lower Triassic Dolomite Unit of the Kathwai Member of the Mianwali Formation in Pakistan.

At the Selong section in Tibet, ''*Anchignathodus*'' *parvus* is reported from the transitional bed with Upper Permian *Neogondolella subcarinata* and *N. deflecta* (Yao and Li, 1987). As discussed above (see Fauna 2), the transitional bed at Selong apparently contains a mixed fauna and may overlie Permian strata unconformably. It should be noted that the third morphotype of *Isarcicella isarcica*, with a denticle on both sides of the symmetrical blade, is not always present in denticulate populations (Sweet *in* Ziegler, 1977, p. 226).

Whether a gradual change in association of the three morphotypes of *Isacicella isarcica* took place, that is, ''*Anchignathodus*'' *parvus* first occurred alone and was later accompanied by the second morphotype (denticle on one side of an asymmetrical blade), which in turn was associated finally with the third form, can be neither supported nor denied on the basis of available stratigraphic information. In the absence of denticulate forms from Cache Creek, we hesitate to identify *I. isarcica* per se. Nevertheless, except for the Selong occurrence, for which a Permian age could be invoked, all other occurrences of ''*A.*'' *parvus* are clearly Triassic, and are restricted to a well constrained interval in the Lower Triassic. The base of the *isarcicella* Zone of Sweet and Bergström (1986), defined by the first appearance of *Isarcicella isarcica*, falls within the Griesbachian range of *Hindeodus typicalis*.

Fauna 4

Several species of *Neospathodus* and one species of *Neogondolella* make up Fauna 4, a composite of Lower Triassic elements that occurs in Marble Canyon and in Cornwall Hills (Fig. 1). From the east wall of Marble Canyon (GSC loc. C-087055), Orchard (1981) recorded *Neogondolella carinata* (Clark), *Neospathodus dieneri* Sweet and *N. peculiaris* Sweet. Additional elements in this fauna include rare *Neospathodus bicuspidatus* (Müller), *N. robustus* Koike, and *N. waageni* Sweet as well as reworked Permian elements (see above). Fauna 4 elements from Cornwall Hills also include *Neogondolella carinata* (GSC loc. C-118472), *Neospathodus* sp. cf. *N. dieneri* and, in addition, *N.* sp. cf. *N. pakistanensis* Sweet (both GSC loc. C-157860).

Neospathodus dieneri ranges from the base of the Dienerian into the upper Smithian (Sweet et al., 1971). *Neogondolella carinata*, a long-ranging species known from *Phisonites–Paratirolites* beds through Concavum–Tardus ammonoid zones (Sweet *in* Ziegler, 1977), was first described from Lower Triassic strata in Dinner Springs Canyon, Nevada (Clark, 1959); Permian occurrences include the Dorashamian Ali Bashi Formation near Julfa (Teichert et al., 1973). Orchard (1981) briefly discussed the Marble Canyon fauna and concluded, on the basis of its domination by *N. dieneri* and *Neogondolella carinata*, that it was largely middle Dienerian in age. Evidently, the other elements imply a younger, Smithian component, is also present.

The range of *Neospathodus pakistanensis* straddles the Dienerian–Smithian boundary. Originally described from the Salt Range (Sweet, 1970b), the species is also known to occur in Primor'e (Buryi, 1979), on Ellesmere Island with Romunderi Zone ammonoids (Mosher, 1973), and in Idaho (Paull, 1982). The *pakistanensis* Zone of Sweet and Bergström (1986) and Sweet (1988) overlies the lower Dienerian *kummeli–cristagalli* Zone and underlies the Smithian *waageni* Zone. Because *Neospathodus waageni* and *N. pakistanensis* commonly occur together in the western United States, and the distribution of the latter species is more restricted than that of the former, Paull (1988, p. 601) favoured use of the *waageni* Zone only, with ''*N. pakistanensis*, where it is present, defining the basal part of the zone''. In Cornwall Hills, a single specimen of *N.* sp. cf. *N. pakistanensis* occurs in an isolated sample without *N. waageni*; this collection is late Dienerian to early Smithian in age.

Fauna 5

Fauna 5 (''Fauna 3'' of Beyers and Orchard, 1989) is represented by an association of genera in the basal 10.5 m of Section 4 near Jesmond (Fig. 3); some elements of the fauna range to 13 m but co-occur with elements of Fauna 7 (see below). The components of this fauna are exclusively ramiform elements, many of which are too poorly preserved for confident determination. Some are referred to multielement *Pachycladina* and *?Hadrodontina*, and to the form genus ''*Lonchodina*''.

A specimen from basal Section 4 (GSC loc. C-149822) has been assigned to form taxon "*Lonchodina*" *nevadensis* Müller, described originally from the *Meekoceras* bed in Dinner Springs Canyon (Müller, 1956; Clark, 1959). The former element, which has apparently not been included in any later multielement apparatus construction, occurs in the Zafir Formation of Israel and Jordan, where it was included in the *Hadrodontina–Pachycladina* Assemblage Zone of presumably Smithian age (Hirsch, 1975, p. 44). Gedik (1975) placed *Lonchodina* sp. cf. *L. nevadensis* in synonymy with upper Scythian *Hadrodontina anceps* Staesche. Koike (1982, p. 13) gave a late Smithian age for the thin bedded limestone at Gunong Keriang, Malaya, in which *L. nevadensis*, identified as *Parachirognathus* sp. cf. *P. nevadensis*, occurs.

Pachycladina obliqua Staesche, *Pachycladina* sp. aff. *P. obliqua*, and *P.* sp. range throughout the lower part of Jesmond Section 4. Another element from near the base of the section is referred to *P.? sp.* A. A few elements of *P. obliqua* were recovered from sample GSC loc. C-157873 at Cornwall Hills; on Pavilion Mountain (GSC loc. C-157841) and at Jesmond (GSC loc. C-101141) the species is associated with *?Hadrodontina*.

Pachycladina consisted of several form species, first described from South Tirol (Staesche, 1964), which Sweet (*in* Clark, 1981) combined into the seximembrate multielement *P. obliqua*. Perri and Andraghetti (1987) described *P. obliqua* from the upper Scythian Campil, Val Badia, and Cencenighe members of the Werfen Formation. Other occurrences of component elements of *P. obliqua* are in the "late Lower to early Upper Scythian" *Pachycladina–Hadrodontina* Assemblage Zone of the Zafir Formation of Israel and Jordan (Hirsch, 1975), and the upper Smithian limestone in Gunong Keriang, Malaya (as *Parachirognathus*; Koike, 1982). Solien (1979) reported *Pachycladina* form species from Smithian strata in Utah, and Mosher (1973) reported possible Sa elements (*P. symmetrica* of Staesche, 1964) from the Tardus Zone on Ellesmere Island. In summary, Fauna 5 is regarded as Smithian in age.

Fauna 6

Several species of *Neospathodus* and single specimens of *Neogondolella milleri* (Müller) and *Platyvillosus costatus* (Staesche) are grouped as Fauna 6. The fauna is based on isolated samples from Cornwall Hills.

Neospathodus waageni, which was previously reported by Orchard (1984; GSC loc. C-087077) from this area, occurs in the Romunderi and Tardus zones of the British Columbia Toad Formation (Mosher, 1973), and defines a widely recognized zone. The base of the *waageni* Zone, defined by its first occurrence, corresponds to the base of the Smithian as interpreted by Carr and Paull (1983).

The top of the *waageni* Zone is drawn at the first occurrence of *Neogondolella milleri*. Mosher (1973) recorded *N. milleri* from the upper Smithian Tardus Zone in the Toad Formation, and we find it at one locality on Cornwall Hills (GSC loc. C-118479). Carr and Paull (1983) place the top of the *milleri* Zone at the top of the Smithian, although Sweet (1988) recognizes an upper Smithian *triangularis* Zone above a middle Smithian *milleri* Zone.

Two species of *Neospathodus* and *Platyvillosus costatus* were found in a breccia on Cornwall Hills (GSC loc. C-118474). *Neospathodus novaehollandiae* McTavish was first described from the Smithian Locker Shale of the Carnarvon Basin, Western Australia (McTavish, 1973). Subsequently, Goel (1977) reported the species from Dienerian and Smithian strata at Khar in the Spiti District of India. A second species of *Neospathodus*, *N.* sp. A of Orchard (1981) occurs in a further sample from Cornwall Hills (GSC loc. C-157873) with *Pachycladina obliqua*, and also in Marble Canyon (GSC loc. C-087055a; Orchard, 1981), and on Pavilion Mountain (GSC loc. C-157843). The neospathodid is known to occur with Smithian ammonites in limestone olistoliths in Oman (Orchard collections).

Platyvillosus costatus was first described by Staesche (1964) from the Campil beds of South Tirol. It has also been reported from the Taho limestone of southwestern Japan in association with *Furnishius triserratus* (Koike, 1988), and from Nevada in association with the ammonoid *Tirolites* (Sweet et al., 1971). In the zonal scheme of Sweet and Bergström (1986), the range of *P. costatus* is encompassed by the *milleri* Zone of Smithian age. Fauna 6 represents one or more levels within the Smithian.

Fauna 7

Fauna 7 consists of *Neospathodus triangularis* (Bender) and *N. homeri* (Bender) and occurs in strata between 10.5 m and 64 m in Section 4, and in the vicinity of the lookout near Jesmond ("Fauna 3", Beyers and Orchard, 1989).

Neospathodus triangularis is a widespread species described first from the upper Scythian Marmarotrapezakalke on Chios, Greece, as was *N. homeri* (Bender, 1968). Other known occurrences of the latter species include the Campilian beds of the Werfen in South Tirol (Staesche, 1964), the Mianwali Formation in Pakistan (Sweet, 1970b), and the Subrobustus ammonoid zone in the Toad Formation of northern British Columbia (Mosher, 1973). Buryi (1979) recorded the co-occurrence of *N. triangularis* and *N. homeri* in Primor'e, eastern U.S.S.R.

Sweet et al. (1971) showed first occurrences of *Neospathodus homeri* and *N. triangularis* at the base of the Spathian. Carr and Paull (1983) indicated *N. homeri* appeared slightly later in the western United States, just above the base of the Spathian. In the chronozonal arrangement of Sweet and Bergström (1986), the first appearance of *N. triangularis* helps define the base of the *triangularis* Zone. Sweet (1988) showed the first occurrence of *Neospathodus homeri* within the latter zone immediately below the Smithian–Spathian boundary.

As noted by Gedik (1975), the association of *Neospathodus triangularis* with *Parachirognathus* and *Pachycladina* (*Parachirognathus* form species of Gedik) may support a range for *Neospathodus triangularis* downward into the upper Smithian. Conversely, it may mean that the ranges of the other two genera extend into the Spathian, as Perri and Andraghetti (1987) postulated for *Pachycladina*. In the present study *Pachycladina* was not found in samples containing either *Neospathodus triangularis* or *N. homeri*, although two other samples (GSC locs. C-149787, C-149786, Section 4 at Jesmond), overlapping with Fauna 7, contain elements of *Pachycladina* sp. In this paper we interpret Fauna 7 as Spathian in age.

Middle Triassic

Fauna 8

Well bedded chert along the lookout access road on Cornwall Hills yielded neogondolellids referred to *Neogondolella* sp. cf. *N. excelsa* (Mosher) of Middle Triassic age (Orchard, 1986). Cordey (1986) reported Anisian radiolarians from this locality. Probable Anisian conodonts are known from chert near Hat Creek (W.R. Danner, pers. comm., 1985).

Apart from an isolated occurrence of probable Middle Triassic *Neogondolella* sp. aff. *N. excelsa* in a limestone on Cornwall Hills (GSC loc. C-118472), this interval is represented only by chert in the Marble Range. The precise age range of the strata bearing Fauna 8 is undetermined because of the generally poor preservation and low yields.

Upper Triassic

Fauna 9

Species of *Metapolygnathus* and/or probable *Neocavitella* comprise Fauna 9 from Cornwall Hills. Two isolated samples (GSC locs. C-157870, C-157881) each contain an incomplete element of *?Neocavitella*, which was originally described from Julian–Tuvalian (Carnian) strata on Trebevic Mountain in the Yugoslavian Dinarides (Sudar and Budurov, 1979). More complete specimens of this genus occur to the west in Upper Carnian Bridge River strata, which are part of a Mississippian to Jurassic (F. Cordey, pers. comm., 1991) sequence, similar lithologically to the Cache Creek Complex except for the lack of extensive carbonates. It lies a short distance to the west of the Cache Creek type area, separated from it by the Fraser Fault and a belt of Jura-Cretaceous clastic rocks (Monger and McMillan, 1989).

In both Bridge River and Cache Creek rocks, (?)*Neocavitella* is sometimes associated with *Metapolygnathus nodosus* (Hayashi). The latter species, originally described from a mixed fauna in the Adoyama chert in Japan (Hayashi, 1968), occurs in two Cornwall Hills samples (GSC locs. C-157869, C-157870). The metapolygnathid is most common in the Upper Carnian (Orchard, 1991a), to which Fauna 9 is assigned.

Fauna 10

Elements of Fauna 10 are referred to *Neogondolella*, *Metapolygnathus*, and *Epigondolella*, which are collectively Norian in age. The fauna is found in Oregon Jack Creek valley near Cornwall Hills, on Pavilion Mountain, along Porcupine Creek, and in the area north of Porcupine Creek. It was reported from Marble Canyon by Orchard (1981).

An isolated sample (GSC loc. C-117780) on the Oregon Jack Creek road contains a rich and diverse conodont fauna consisting of *Metapolygnathus primitius* (Mosher), *M. pseudoechinatus* Kozur, *M. nodosus*, and *Neogondolella navicula* (Huckriede). This sample is Lower Norian, Upper *primitius* Zone (Orchard, 1991a). Several other collections may be impoverished examples of this assemblage (e.g., GSC loc. C-149985 from Pavilion Mountain).

Limestone interbedded with pelite on Pavilion Mountain (GSC loc. C-117774), and a second locality (GSC loc. C-157824) at a section east of the Griesbachian (Fauna 3) site, contain *Epigondolella quadrata* Orchard in addition to *Neogondolella* and are of a slightly younger Early Norian age (Orchard, 1991b *this volume*). Orchard (1984, GSC loc. C-087079) reported the same epigondolellid from west of Cornwall Hills.

Other poorly preserved Norian collections with indeterminate *Epigondolella* and *Neogondolella* species are from Pavilion Mountain (GSC locs. C-117772, C-149993) and from the area north of Porcupine Creek (GSC loc. C-157813). These collections represent undifferentiated Lower Norian levels.

Fauna 11

The youngest conodont fauna from the Cache Creek Complex is from limestone lenses in siliceous pelite along Porcupine Creek (GSC loc. C-175062). Fauna 11 comprises *Epigondolella bidentata* Mosher, *E. mosheri* (Kozur and Mostler), and *Neogondolella* sp. The association is referred to the Upper *bidentata* Zone of Orchard (1991b *this volume*), which is of middle Late Norian age, approximating the Amoenum Zone of the ammonoid chronology.

SUMMARY

Sedimentary strata of the central and western belts of the Cache Creek Complex in south-central British Columbia are Late Permian and Triassic in age. Eleven conodont faunas are differentiated in this study, two of which are Permian. The other nine span virtually the entire Triassic.

Fauna 1 comprises species of *Sweetognathus*, *Neogondolella* and *Hindeodus* within bedded to massive limestone near the southern entrance of Marble Canyon. One of these species, *Neogondolella phosphoriensis*, occurs also in strata west of Clinton. At both localities, the conodonts are associated with the Guadalupian fusulinids *Lepidolina* and/or *Neoschwagerina*. The fauna is late Wordian to early Capitanian (Guadalupian) in age.

Fauna 2 consists of *Hindeodus typicalis*, *Neogondolella subcarinata* subspp., *N.* sp. cf. *N. orientalis*, *N. jesmondi*, three morphotypes of the *Iranognathus*? *movschovitschi* group, and *I.*? n. sp. A. This fauna is fully represented only in poorly bedded biomicrites along the access road to the

Jesmond fire lookout, but components of it are found on Pavilion Mountain and in a pelmicrite on the hill north of Jesmond Creek. Fauna 2 is interpreted to be at least in part Dorashamian/Changxingian in age, but may be as old as late Dzhulfian. It is the youngest documented Permian conodont fauna in North America.

A gap in the sedimentary record separates Permian from Triassic strata in studied localities of the Marble Range. The oldest Triassic rocks contain Fauna 3 and are found along Porcupine Creek in thin bedded, dolomitic limestone. They are interpreted as Griesbachian in age on the basis of *''Anchignathodus''* *parvus*. This is the first record of Griesbachian strata in the western Canadian Cordillera.

Fauna 4 is typified by *Neogondolella carinata*, *Neospathodus dieneri* and *N. peculiaris*, which are mixed with both older and younger elements in limy pelitic rocks in Marble Canyon. A late Dienerian to early Smithian age is assigned to additional collections from Cornwall Hills, which contain elements of this fauna plus, in one case, *N.* sp. cf. *N. pakistanensis*.

Fauna 5, associated with shallow water, algal laminated micrites near Jesmond, consists solely of ramiform elements. *Pachycladina* and *''Lonchodina''* species date the fauna as Smithian.

Fauna 6, also dated as Smithian, comes from strata, including oolitic breccia, on Cornwall Hills where *Platyvillosus costatus*, *Neogondolella milleri*, *Neospathodus waageni*, *N. novaehollandiae*, and *Neospathodus* n. sp. A are recorded. The latter neospathodid is also recorded from Marble Canyon and Pavilion Mountain.

Fauna 7 occurs near Jesmond in well bedded limestone that includes algal laminates. The fauna is characterized by *Neospathodus homeri* and *N. triangularis*, which in this study are regarded as wholly Spathian in age.

Fauna 8 is virtually restricted to radiolarian chert on Cornwall Hills and in the Hat Creek area. It is Middle Triassic in age on the basis of *Neogondolella* ex gr. *excelsa*.

Three Upper Triassic conodont faunas are found in widespread impure limestone and pelite. The oldest of these, Fauna 9, is Carnian in age and is known only from Cornwall Hills, where species of ?*Neocavitella* and *Metapolygnathus* occur.

Fauna 10 occurs on Pavilion Mountain, in the Porcupine Creek area, Marble Canyon, and west of Cornwall Hills. The fauna embraces several collections dated as Early Norian on the basis of different associations of *Metapolygnathus primitius*, *M. echinatus*, *Neogondolella navicula*, and *Epigondolella quadrata*.

Fauna 11 has so far only been recovered from dominantly pelitic strata along Porcupine Creek. It is identified on the basis of *Epigondolella bidentata* and *E. mosheri*, and is dated as middle Late Norian.

SYSTEMATIC PALEONTOLOGY

The following taxonomy includes a discussion of selected, mostly form species. Species illustrated in Plates 1–5, but not discussed, are listed at the end of this section. Figured specimens are housed in the National Type Collection of Invertebrate and Plant Fossils at the Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8.

Iranognathus? ex gr. *movschovitschi* (Kozur and Pjatakova)

1975 *Diplognathodus movschovitschi* n. sp. KOZUR, Pl. 2, figs. 3-4.
1977 *Diplognathodus*? *movschovitschi* Kozur and Pjatakova. SWEET *in* ZIEGLER, Pl. 1, fig. 5.
1984 '*Diplognathodus*' *movschovitschi* Kozur and Pjatakova. ORCHARD, Pl. 22.2, figs. 3?-4, 8.
1987 *Iranognathus nudus* n. sp. WANG, RITTER, and CLARK, Fig. 6, #8-10.
1989 *Iranognathus* ex gr. *nudus* Wang, Ritter, and Clark. BEYERS and ORCHARD, Pl. 1, figs. 4, 6-7.

Diagnosis. Scaphate elements with a denticulate free blade one third of unit length and a pustulose carina, which is commonly partially fused into a bar. The broadly expanded, subcircular basal cup is unornamented. In profile, the denticulate posterior slope of the carina has a steep terminal edge.

Description. A short free blade, about one third of unit length, carries 4 to 6 discrete denticles diminishing in size posteriorly, except for the anteriormost denticle, which is smaller than the second. The thin, high and often slightly laterally curved carina is partly fused to form a bar, which may arch slightly upward. Posteriorly, the denticulated carina slopes gradually and terminates abruptly in a steep edge. The broadly expanded, usually symmetrical basal cup is oval- to heart-shaped, with its greatest width in the anterior half.

Remarks. Assignment of *I.*? *movschovitschi* to the genus is tentative, because, unlike other species of *Iranognathus*, the species lacks ornamentation on the cup. Elements differ from *Diplognathodus* in lacking a strongly differentiated blade and carina, and in possessing carinal pustules. The micropustules, sometimes obliterated due to recrystallization, indicate a relationship to the sweetognathids.

Wang et al. (1987, p. 1055) stated that *''Iranognathus nudus''* differs from *''Diplognathodus''* *movschovitschi* because the latter ''reportedly lacks the pustulose microstructure that is characteristic of *Iranognathus nudus* n. sp.''. However, the description of *''D.''* *movschovitschi* corresponds closely to *''I. nudus''*, and the two broken specimens available to Kozur and Pjatakova are now known to possess the microornamentation (H. Kozur, pers. comm., 1989). Hence, *movschovitschi* becomes the specific name with priority.

Because the lateral profile of *''Iranognathus nudus''* was not illustrated by Wang et al. (1987), and *''D.''* *movschovitschi* specimens are very poorly preserved, it is not certain that the Marble Canyon Formation material is identical. In upper view, the transcaucasian, Chinese and Canadian specimens show similar free blade to element length relations and basal cavity shape, but a comparison of denticulation and carina profile is precluded. The blister-like nodes on the outer side of the platform reported in some specimens by Wang et al. (1987) are absent in our material.

We recognize three morphotypes in the Marble Canyon Formation, which are differentiated primarily on the basis of carinal fusion (Table 1). Assignment to species level is considered premature because relationships between morphotypes are not understood, and poor preservation means stratigraphic ranges cannot be reliably established. The common occurrence of Morphotype A in the Jesmond area suggests that this form represents the mode of the population in Fauna 2 (see above). For the present, we refer all specimens to the *I.*? *movschovitschi* group.

Morphotype A

Plate 1, figures 1-6

Diagnosis. This morphotype has carinal denticles that are fused into a bar above the widest part of the basal cup. Width of the cup is equal, or almost equal, to length. Micropustules occur either on the bar, on the posterior denticles, or on both.

Remarks. Morphotype A differs from morphotypes B and C by the extensive and uniform distribution of micropustules both on the bar and the denticulate portion of the carina.

Occurrence. Sections 1, 2 and 3, and isolated sample GSC loc. C-157808, Jesmond.

Material. At least 108 specimens. Figured specimens GSC 81236, 95295-95298.

Morphotype B

Plate 1, figures 7-11

Diagnosis. This morphotype has a very short, fused bar located on the posteriormost part of the free blade and above the anteriormost part of the cup. Pustules have so far been recognized only on the denticulate carina, particularly between denticles.

Remarks. Morphotype B is distinguished from Morphotype A by restriction of both micropustules and carinal fusion, which is intermediate between that of morphotypes A and C.

Occurrence. Section 3, Jesmond.

Material. At least 2 specimens. Figured specimens GSC 95299, 95300.

Morphotype C

Plate 2, figures 8, 9, 13, 14

Diagnosis. A small morphotype characterized by a fully denticulate carina. Pustules occur on the sloping posterior part of the carina. The basal cup does not extend to the posterior end of the carina.

Remarks. Juveniles of Morphotype C cannot be distinguished from those of other morphotypes, but later growth stages retain the fully denticulate carina. Morphotype C differs also in lacking carinal fusion, and by posterior restriction of the basal cup.

Occurrence. Sections 1, 2 and 3, and isolated sample GSC loc. C-157808, Jesmond; GSC loc. C-157815, Jesmond Creek.

Material. At least 20 specimens. Figured specimens GSC 95307–95309.

Iranognathus? n. sp. A

Plate 2, figures 10-12, 15

Diagnosis. A species of *Iranognathus*? with a denticulate free blade, stout denticles on the anterior carina, and a short, laterally deflected and fused bar at the posterior end of the carina. Micropustules occur both on the bar and on adjacent denticle(s).

Description. The free blade carries 4 to 5 denticles that decrease in size posteriorly, except for the anteriormost one, which is smaller than the second. The 3 to 4 carinal denticles posterior of the blade are anteroposteriorly extended. At a point two thirds from the anterior end of the element, the carina is laterally deflected and fused into a short bar that terminates above the steep posterior edge. The posteriormost part of the carina is parallel to the anterior part. Two small denticles are located on the posterior edge. The slightly asymmetrical, unornamented basal cup underlies the posterior two thirds of the element and has its greatest width in the anterior half. Small pustules are present on the fused bar and adjacent denticle(s).

Remarks. This species differs from *Iranognathus*? ex gr. *movschovitschi* in the style of denticulation and in the lateral deflection of the fused carinal bar. The distinctive denticulation is reminiscent of *Hindeodus julfensis* (Sweet) but in *I.*? n. sp. A the fused posterior section is flat, rather than arched upward.

Occurrence. Sections 1 and 3, and isolated sample GSC loc. C-157808, Jesmond.

Material. Three specimens. Figured specimens GSC 95310, 95311.

Neogondolella jesmondi n. sp.

Plate 3, figures 6, 7, 9, 10, 13-15

Etymology. From the nearby hamlet of Jesmond.

Holotype. GSC 95317, Pl. 3, figs. 13-15.

Type stratum. At 0.5 m in Section 2, Marble Canyon Formation, Cache Creek Complex.

Type locality. GSC loc. C-101144, Jesmond, near Clinton, south-central British Columbia.

Age. By association in Fauna 2, thought to be late Dzhulfian through Dorashamian/Changxingian.

Occurrence. Sections 1 and 2 (see Table 1), and isolated sample GSC loc. C-157808, Jesmond; isolated sample GSC loc. C-157815, Jesmond Creek; Section 2, Pavilion Mountain.

Diagnosis. A species of *Neogondolella* with a long, slender lachrimiform platform that is widest in the posterior third, a rounded posterior margin, a narrow brim posterior of the distinct cusp, and a high anterior blade.

Description. Platform elements of *Neogondolella jesmondi* are narrow, slightly arched, commonly symmetrical, and generally rounded at the posterior end, which may become subquadrate in late growth stages. Elements are widest in the posterior third, taper gradually to a point one third from the anterior end, and then may narrow more abruptly. There is no free blade, but a high, convex fixed blade that carries 5 to 6 denticles, and passes posteriorly into the 9 to 13 carinal denticles of the mature platform, which are semifused with rounded tips; in mature to overmature specimens the mid-portion of the carina may be fused. The cusp, triangular to circular in cross-section, is discrete and prominent. It is sometimes preceded anteriorly by a very low denticle, anterior of which denticles increase in size toward the blade. The carina is straight or slightly curved, and in some specimens is inturned at the posterior end, in which case the last two denticles may be fused into a cusp, followed anteriorly by a much lower denticle. The platform margins at the posterior end form a variably thickened brim of narrow but variable width. The adcarinal grooves are narrow and of shallow to moderate depth. The platform margins and brim are reticulate except for adcarinal grooves. On the lower surface a fairly wide loop arches around a small, elongate pit, which becomes a narrow groove beneath the blade. The keel is low and longitudinally grooved. In juvenile specimens, the cusp is strongly reclined posteriorly, the brim is absent, and reticulation is restricted to the edge of the platform margin.

Remarks. Distribution data for neogondolellids from the Jesmond area are presented in Table 1. The narrow platform with its brim of variable width is reminiscent of the Upper Permian *Neogondolella serrata* complex, but in *N. jesmondi* the platform achieves greatest width in the posterior third. The new species also differs from the *N. serrata* complex in the shape of the blade, in the carinal denticulation, and from most species in the complex, in the lack of anterior platform serrations. Compared with material from the Changxingian of China (Orchard collections), *N. jesmondi* resembles *N. s. changxingensis* in the narrow, tapered anterior platform, and in the configuration of the blade and carina. However, in *N. jesmondi* the main part of the platform has subparallel margins that extend almost to the posterior end, and the cusp is both prominent and distinct.

Asymmetrical platform terminations occur in some elements of the *Neogondolella jesmondi* population, but they cannot be separated stratigraphically from those with symmetrical terminations.

Material. At least 132 specimens. Figured paratypes GSC 95314–95316, holotype GSC 95317.

Neogondolella sp. cf. *N. orientalis* (Barskov and Koroleva)

Plate 3, figure 1

1970 *Gondolella orientalis* n. sp. BARSKOV and KOROLEVA, Fig. 1, #1-4.
1987 *Neogondolella orientalis* (Barskov and Koroleva). NESTELL and WARDLAW, Fig. 5, #1-9, 11-17; Fig. 6, #2-4, 6, 9, 10, 12-15; Fig. 7, #16-18, 20.

Description. A species of *Neogondolella* with a broad quadrangular to lachrimiform platform, which is widest posterior of the midpoint, a low blade, a pronounced posterior brim, and a very low cusp located toward the inner side of the midline.

Remarks. All of our material is broken anteriorly, and in several specimens only the posteriormost platform is preserved. Nevertheless, the elements show a range in platform shape, similar to that displayed by material from Hydra (Nestell and Wardlaw, 1987).

Occurrence. Jesmond Creek, isolated sample GSC loc. C-157815; Section 1 and isolated sample GSC loc. C-157808 on Jesmond lookout road.

Material. At least 6 specimens. Figured specimen GSC 95312.

Neogondolella phosphoriensis (Youngquist, Hawley and Miller)

Plate 3, figures 8, 11-12

1951 *Gondolella phosphoriensis* n. sp. YOUNGQUIST, HAWLEY and MILLER, Pl. 54, figs. 10-12.
1986 *Neogondolella phosphoriensis* (Youngquist, Hawley and Miller). BEHNKEN, WARDLAW and STOUT, Fig. 5, #1-3, 8-19, 22; Fig. 6, #21-27.

non 1988 *Neogondolella rosenkrantzi* (Bender and Stoppel). CLARK and WANG, Fig. 3, #12.

Description. A species of *Neogondolella* with a wide, oval- to triangular-shaped, regularly tapered platform, round to blunt and often bulbous posterior end, a large elongate cusp which does not project posteriorly, and a moderately high blade, which carries about 4 denticles. The regularly spaced denticles of the carina decrease in size posteriorly and may be fused medially.

Remarks. Neogondolella phosphoriensis may resemble overmature specimens of *N. jesmondi*, but differs in that the blade is lower, the platform wider and thinner, and the cusp elongate and less distinct.

Occurrence. Clinton lookout road, isolated sample GSC loc. C-117776; lower Hat Creek, isolated sample GSC loc. C-116176.

Material. About 10 specimens. Figured hypotypes GSC 95318, 95319, 95350.

Neogondolella subcarinata subcarinata Sweet

Plate 3, figures 4, 5

1973 *Neogondolella carinata subcarinata* n. subsp. TEICHERT, KUMMEL and SWEET, Pl. 13, figs. 12-17; fig. 16E-H, p. 437.
1975 *Gondolella carinata subcarinata* (Sweet). KOZUR, Pl. 2, figs. 9, 10.
1981 *Neogondolella subcarinata subcarinata* Sweet. ZHAO et al., Pl. 5, figs. 1-5, 8, 9.
1988 *Neogondolella subcarinata subcarinata* Sweet. CLARK and WANG, Fig. 3, #26.

Description. A neogondolellid with a short, broad and arched quadrangular platform, a cusp that projects posteriorly, and a narrow posterior brim, which forms a faint buttress. The blade, with 4 denticles, is moderately high and passes into low carinal nodes.

Remarks. The Jesmond material apparently differs from the Dorasham II specimens of *Neogondolella s. subcarinata* illustrated diagrammatically by Sweet (Teichert et al., 1973, fig. 16) in the presence of a slight geniculation point (Pl. 3, fig. 5), resulting in a less evenly downturned anterior platform margin. The geniculation point is similar to that observed in specimens from the Changxingian of south China (Orchard collections), which are also similar in relative lengths of platform and blade; the platform of the Jesmond specimens is more subquadrate.

Specimens of *Neogondolella s. subcarinata* from Jesmond are smaller and more arched than *N. subcarinata* n. subsp. A, do not show the anterior restriction to the same degree, and have a faint buttress beneath the posterior brim. They resemble the new subspecies in overall platform shape, in the proportion of the blade to the rest of the element, and in the posterior inclination of the cusp.

Occurrence. Isolated sample GSC loc. C-157808 and ?Section 1, Jesmond.

Material. Two (?four) specimens. Figured hypotype GSC 95313.

Neogondolella subcarinata n. subsp. A

Plate 3, figures 2-3

1989 *Neogondolella* ex gr. *subcarinata* Sweet. BEYERS and ORCHARD, Pl. 1, fig. 1.

Diagnosis. A subspecies of *Neogondolella subcarinata* with long, broad, subquadrangular platform strongly downturned posteriorly, a distinct cusp and narrow posterior brim, and unevenly developed geniculation points on the anterior platform margins.

Description. Neogondolella subcarinata subsp. A has a high blade with semifused denticles that decrease in height posteriorly, and pass into low, fused carinal nodes. The cusp is discrete, inclined posteriorly, and surrounded by a very narrow brim. The platform is thick, widest at mid-length, has distinct adcarinal grooves, and is sharply downturned near the posterior end. The inner margin narrows abruptly at a geniculation point at about mid-length, the outer margin more gently at a point about one third from the anterior end. Anterior of the geniculation points, both margins taper gradually inward.

Remarks. The strong geniculation point on the inner margin gives the element a superficial resemblance to *Neogondolella leveni*, but it differs from the latter by the greater width of the platform, the offset anterior taper, pronounced arching at the posterior end, size of the denticles adjacent to the cusp, and length of the blade, which is proportionately longer in *N. s.* subspecies A. In addition, the platform margins of the Jesmond element are not strongly upturned and they carry anterior reticulation.

The element resembles *Neogondolella s. subcarinata* from the Changxingian of China (Orchard collections) in the outline of the posteriormost denticles anterior of the cusp, and in the possession of a slight geniculation point on the anterior platform margin. It differs in the relative length of the platform and blade.

Occurrence. Section 3 (GSC loc. C-157223), Jesmond.

Material. One specimen. Figured specimen GSC 81233.

Neospathodus n. sp. A

Plate 5, figure 1

1981 *Neospathodus* sp. A. ORCHARD, p. 358.

Diagnosis. A short species of *Neospathodus* with a straight basal margin, an upturned posterior end, and upright denticles that form a subsymmetrical arcuate crest.

Description. The segminate element is as high as it is long, or nearly so. The robust denticles are fused for two thirds of their length, point straight up, and form an arcuate crest. The cusp, located at the posterior end, is wider but shorter than the anterior denticles. A longitudinal rib occurs a short distance above the straight basal margin. Beneath the posteriormost two denticles, the basal margin is abruptly upturned above a deep basal cavity.

Remarks. Well preserved specimens of the new species have been found in association with Smithian ammonoids in Oman, and will be formally described in a future paper. The occurrence in Cache Creek implies that this is a stratigraphically useful species.

Occurrence. Cornwall Hills, isolated samples GSC loc. C-118474, C-157873 and Pavilion Mountain, Section 2 (GSC loc. C-157843).

Material. Seven specimens. Figured specimen GSC 95330.

Pachycladina? sp. A

Plate 4, figure 12

Description. A *Pachycladina*-like element with a robust, rhomboid blade with nine laterally compressed, posteriorly inclined, short and stout denticles of subequal height. A midlateral rib lies at the upper margin of the lower surface, below the base of the denticles. Growth lines surround a minute basal pit. The lower margin is upturned in a posterior direction. The anterior surface is smooth and distally curved.

Remarks. The upturned lower margin may correspond to the "lip" of *P. obliqua* described by Staesche (1964). *Pachycladina*? sp. A resembles *Parachirognathus geiseri* Clark in outline but differs from it in denticulation and in its distinctly upturned rather than straight lower edge. It differs from *Pachycladina obliqua sensu* Sweet in the subequal height of denticles and, therefore, in the lack of a well differentiated cusp.

Occurrence. 1 m above the base of Section 4, Jesmond (GSC loc. C-149815).

Material. One Sa specimen. Figured specimen GSC 95329.

The following species are not discussed but are illustrated in Plates 1-5:

"Anchignathodus" parvus Kozur and Pjatakova, Pl. 4, figs. 2,3, hypotypes GSC 81239, 81240.

Epigondolella mosheri (Kozur and Mostler), Pl. 5, fig. 21, hypotype GSC 95347.

Epigondolella quadrata Orchard, Pl. 5, fig. 17, hypotype GSC 95343.

Epigondolella triangularis (Budurov), Pl. 5, fig. 18, hypotype GSC 95344.

Hindeodus typicalis (Sweet), Pl. 4, figs. 1, 4, hypotypes GSC 95320, 95321.

"Lonchodina" nevadensis Müller, Pl. 4, fig. 11, hypotype GSC 81235.

Metapolygnathus nodosus (Hayashi), Pl. 5, fig. 22, hypotype GSC 95348.

Metapolygnathus primitius (Mosher), Pl. 5, fig. 19, hypotype GSC 95345.

Metapolygnathus pseudoechinatus Kozur, Pl. 5, fig. 20, hypotype GSC 95346.

Metapolygnathus sp., Pl. 5, fig. 23, figured specimen GSC 95349.

Neocavitella? sp., Pl. 4, figs. 5, 8, figured specimens GSC 95322, 95323.

Neogondolella carinata (Clark), Pl. 5, figs. 15, 16, hypotypes GSC 65880, 95342.

Neogondolella sp. aff. *N. excelsa* (Mosher), Pl. 5, figs. 13, 14, figured specimen GSC 95341.

Neogondolella milleri (Müller), Pl. 5, fig. 11, hypotype GSC 95339.

Neogondolella navicula (Huckriede), Pl. 5, fig. 12, hypotype GSC 95340.

Neospathodus bicuspidatus (Müller), Pl. 5, fig. 8, hypotype GSC 95337.

Neospathodus dieneri Sweet, Pl. 5, fig. 4, hypotype GSC 95333.

Neospathodus homeri (Bender), Pl. 5, fig. 3, hypotype GSC 95332.

Neospathodus novaehollandiae McTavish, Pl. 5, fig. 7, hypotype GSC 95336.

Neospathodus sp. cf. *N. pakistanensis* Sweet, Pl. 5, fig. 2, figured specimen GSC 95331.

Neospathodus peculiaris Sweet, Pl. 5, fig. 9, hypotype GSC 65897.

Neospathodus triangularis (Bender), Pl. 5, fig. 6, hypotype GSC 95335.

Neospathodus waageni Sweet, Pl. 5, fig. 5, hypotype GSC 95334.

Pachycladina obliqua Staesche, Pl. 4, fig. 9, hypotype GSC 95326.

Pachycladina sp. aff. *P. obliqua* Staesche, Pl. 4, fig. 10, figured specimen GSC 95328.

Pachycladina sp., Pl. 4, figs. 7, 13, figured specimens GSC 95325, 95327.

Platyvillosus costatus (Staesche), Pl. 5, fig. 10, hypotype GSC 95338.

Sweetognathus sp(p)., Pl. 2, figs. 1, 2, 7, figured specimens GSC 95301, 95302.

Undetermined ramiform elements, Pl. 2, figs. 3-6; Pl. 4, fig. 6, figured specimens GSC 95303-95306, GSC 95324.

ACKNOWLEDGMENTS

M.J. Orchard acknowledges partial financial support for this project from the National Science and Engineering Research Council. We thank J.W.H. Monger (G.S.C., Vancouver) for his review of an earlier manuscript and discussions of Cache Creek tectonics; R.K. Paull (Milwaukee, WI.) and E.T. Tozer (G.S.C., Vancouver) who also provided useful suggestions; N. Mortimer (D.S.I.R., New Zealand) for guiding us in the Pavilion Mountain area; T. Dickey and R. Manley for assistance in the field; P. Krauss (G.S.C., Vancouver) for S.E.M. photomicroscopy; and T. Oliveric (G.S.C., Vancouver) for drafting.

REFERENCES

Armstrong, J.E.
1949: Fort St. James map-area, Cassiar and Coast districts, British Columbia. Geological Survey of Canada, Memoir 252, 210 p.
Bamber, E.W., Henderson, C.M., Jerzykiewicz, J., Mamet, B.L., and Utting, J.
1989: A summary of Carboniferous and Permian biostratigraphy, northern Yukon Territory and northwest District of Mackenzie. *In* Current Research, Part G, Geological Survey of Canada, Paper 89-1G, p. 13-21.
Barskov, I.S. and Koroleva, N.V.
1970: The first find of Upper Permian conodonts in the U.S.S.R. Doklady Akademii Nauk S.S.S.R., v. 194, p. 933, 934 (in Russian).
Behnken, F.H., Wardlaw, B.R., and Stout, L.N.
1986: Conodont biostratigraphy of the Permian Meade Peak phosphatic shale member, Phosphoria Formation, southeastern Idaho. *In* Western Phosphate Deposits, D.W. Boyd and J.A. Lillegraven (eds.); Contributions to Geology, Phosphoria Issue, v. 24 (2), 38th Annual Meeting of the Rocky Mountains Section of the Geological Society of America, 1985, p. 169-190.
Bender, H.
1968: Zur Gliederung der mediterranen Trias II: die Conodontenchronologie der mediterranen Trias. Annales géologiques des pays helléniques, v. 19, p. 465-540.
Bender, H. and Stoppel, D.
1965: Perm-Conodonten. Geologisches Jahrbuch, v. 82, p. 331-364.
Beyers, J.M. and Orchard, M.J.
1989: Permian-Triassic boundary beds in the Cache Creek Group, Marble Range, near Jesmond, British Columbia. *In* Current Research, Part E, Geological Survey of Canada, Paper 89-1E, p. 127-132.
Buryi, G.I.
1979: Triassic conodonts of Primor'e and their distribution in the Circum-Pacific region (in Russian). *In* Evolyutsiya Organicheskogo Mira Tikhookeanskogo Poyasa: Khronologicheskiye i Paleobiogeograficheskiye Rubezhi, V.A. Krassilov (ed.); Doklady Akademii Nauk, Institute of Geology and Geophysics, Vladivostok, S.S.S.R., International Geological Correlation Programme, Project 106, p. 114-122.
Campbell, R.B. and Tipper, H.W.
1971: Geology of Bonaparte Lake map-area, British Columbia. Geological Survey of Canada, Memoir 363, 100 p.
Carr, T.R. and Paull, R.K.
1983: Early Triassic stratigraphy and paleogeography of the Cordilleran miogeocline. *In* Mesozoic Paleogeography of the West-central United States, M.W. Reynolds and E.D. Dolly (eds.); Society of Economic Paleontologists and Mineralogists, Rocky Mountain Paleogeography 2, p. 39-55.
Clark, D.L.
1959: Conodonts from the Triassic of Nevada and Utah. Journal of Paleontology, v. 33, p. 305-312.
1981: Classification. *In* Treatise on Invertebrate Paleontology, Part W, Miscellanea, Supplement 2, Conodonta, R.A. Robison (ed.); Geological Society of America and University of Kansas Press, Lawrence/Kansas, p. W102-W180.
Clark, D.L. and Wang, C.-y.
1988: Permian neogondolellids from south China: significance for evolution of the *serrata* and *carinata* groups in North America. Journal of Paleontology, v. 62, p. 132-138.
Cordey, F.
1986: Radiolarian ages from the Cache Creek and Bridge River complexes and from chert pebbles in Cretaceous conglomerates, southwestern British Columbia. *In* Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 595-602.
Cordey, F., Mortimer, N., Dewever, P., and Monger, J.W.H.
1987: Jurassic radiolarians from the Cache Creek terrane, British Columbia. Geology, v. 15, p. 1151-1154.
Danner, W.R.
1985: Tethyan exotic terrane, southwestern British Columbia. Field Trip No. 13, Meetings of the Geological Society of America, Cordilleran Section; University of British Columbia, Department of Geological Sciences, 16 p.
Danner, W.R. and Nestell, M.K.
1966: Biostratigraphy of the Cache Creek Group, Pennsylvanian–Permian, in the type area, British Columbia, Canada (abstract). Geological Society of America Annual Meeting, San Francisco, Abstracts with Programs, p. 49-50.
Dawson, G.M.
1879: Report on an exploration from Port Simpson on the Pacific coast to Edmonton on the Saskatchewan, embracing a portion of the northern part of British Columbia and the Peace River country. Geological Survey of Canada, Report of Progress for 1879-80, p. 1B-165B.
Ding, M.H.
1986: Permian–Triassic boundary and conodonts in south China. Memorie della Società Geologica Italiana, v. 34, p. 263-268.
Duffell, S. and McTaggart, K.C.
1952: Ashcroft map-area, British Columbia. Geological Survey of Canada, Memoir 262, 122 p.
Dunbar, C.O.
1932: *Neoschwagerina* in the Permian faunas of British Columbia. Royal Society of Canada, Proceedings and Transactions, v. 26, p. 45-49.
Gedik, J.
1975: Die Conodonten der Trias auf der Kocaeli-Halbinsel (Turkei). Palaeontographica Abt. A, v. 150, p. 99-160.
Goel, R.K.
1977: Triassic conodonts from Spiti (Himachal Pradesh), India. Journal of Paleontology, v. 51, p. 1085-1101.
Goto, H., Maruoka, K., and Ishii, K.-I.
1986: *Lepidolina columbiana* (Permian fusulinid) from British Columbia, Canada. Transactions and Proceedings of the Palaeontological Society of Japan, n. ser., v. 143, p. 422-434.
Hayashi, S.
1968: The Permian conodonts in chert of the Adoyama Formation, Ashio Mountains, central Japan. Earth Science, Japan, v. 22, p. 63-77.
Hirsch, F.
1975: Lower Triassic conodonts from Israel. Israel Geological Survey, Bulletin, v. 66, p. 39-44.
Johnson, J.H. and Danner, W.R.
1966: Permian calcareous algae from northwestern Washington and southwestern British Columbia. Journal of Paleontology, v. 40, p. 424-432.
Koike, T.
1982: Triassic conodont biostratigraphy in Kedah, west Malaya. Geology and Palaeontology of southeast Asia, v. 23, p. 9-51.
1988: Lower Triassic conodonts *Platyvillosus* from the Taho Limestone in Japan. Science Reports of the Yokohama National University, section II, no. 35, p. 61-79.

Kozur, H.

1975: Beiträge zur Conodontenfauna des Perm. Geologische und Paläontologische Mitteilungen, Innsbruck, v. 5(4), p. 1-44.

1977: Beiträge zur Stratigraphie des Perms: Teil I, Probleme der Abgrenzung und Gliederung des Perms. *In* Stratigraphie, Biofazies und Taxonomie des Europäischen Phanerozoikums, Teil IV; Freiberger Forschungshefte, C319, p. 79-121.

1978: Beiträge zur Stratigraphie des Perms: Teil II, Die Conodontenchronologie des Perms. Freiberger Forschungshefte, C334, p. 85-161.

1990: The taxonomy of the gondolellid conodonts in the Permian and Triassic. Courier Forschungsinstitut Senckenberg, v. 117, p. 409-469.

Kozur, H., Mostler, H., and Rahimi-Yazd, A.

1975: Beiträge zur Mikrofauna permotriadischer Schichtfolgen: Teil II, Neue Conodonten aus dem Oberperm und der basalen Trias von Nord- und Zentraliran. Geologische und Paläontologische Mitteilungen, Innsbruck, v. 5(3), p. 1-23.

Kozur, H., Leven, E.Y., Lozowskii, V.R., and Pjatakova, M.V.

1978: Conodontal sequence of Permian and Triassic boundary strata of Transcaucasia. Bulletin of the Moscow Society of Naturalists, Geology Section, v. 53(5), p. 15-23.

McTavish, R.A.

1973: Triassic conodont faunas from Western Australia. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, v. 143, p. 275-303.

Monger, J.W.H.

1977: Upper Paleozoic rocks of the western Canadian Cordillera and their bearing on Cordilleran evolution. Canadian Journal of Earth Sciences, v. 14, p. 1832-1859.

1981: Geology of parts of western Ashcroft map area, southwestern British Columbia. *In* Current Research, Part A, Geological Survey of Canada, Paper 81-1A, p. 185-189.

Monger, J.W.H. and McMillan, W.J.

1989: Geology, Ashcroft, British Columbia. Geological Survey of Canada, Map 42-1989, sheet 1, scale 1:250 000.

Mortimer, N.

1987: Geological map of part of NTS sheet 92I/13, with notes. British Columbia Department of Mines, Open File 87/18.

Mosher, L.C.

1973: Triassic conodonts from British Columbia and the northern Arctic Islands. *In* Contributions to Canadian Paleontology, B.S. Norford and E.J.W. Irish (eds.); Geological Survey of Canada, Bulletin 222, p. 141-193.

Müller, K.J.

1956: Triassic conodonts from Nevada. Journal of Paleontology, v. 30, p. 818-830.

Nestell, M.K. and Wardlaw, B.R.

1987: Upper Permian conodonts from Hydra, Greece. Journal of Paleontology, v. 61, p. 758-772.

Orchard, M.J.

1981: Triassic conodonts from the Cache Creek Group, Marble Canyon, southern British Columbia. *In* Current Research, Part A, Geological Survey of Canada, Paper 81-1A, p. 357-359.

1983: *Epigondolella* populations and their phylogeny and zonation in the Upper Triassic. Fossils and Strata, v. 15, p. 177-192.

1984: Pennsylvanian, Permian and Triassic conodonts from the Cache Creek Group, Cache Creek, southern British Columbia. *In* Current Research, Part B, Geological Survey of Canada, Paper 84-1B, p. 197-206.

1986: Conodonts from western Canadian chert: their nature, distribution and stratigraphic application. *In* Conodonts: Investigative Techniques and Applications, R.L. Austin (ed.); British Micropaleontological Society, Ellis Horwood Limited, Chichester, p. 94-119.

1991a: Late Triassic conodont biochronology and biostratigraphy of the Kunga Group, Queen Charlotte Islands, British Columbia. *In* Evolution and Hydrocarbon Potential of the Queen Charlotte Basin, British Columbia, G.J. Woodsworth (ed.); Geological Survey of Canada, Paper 90-10, p. 173-193.

1991b: Upper Triassic conodont biochronology and new index species from the Canadian Cordillera. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

Orchard, M.J. and Beyers, J.M.

1988: Conodont biostratigraphy of the Cache Creek Group in the Marble Range of south-central British Columbia. *In* Current Research, Part E, Geological Survey of Canada, Paper 88-1E, p. 159-162.

Paull, R.K.

1982: Conodont biostratigraphy of Lower Triassic rocks, Terrace Mountains, northwestern Utah. Utah Geological Association, Publication 10, p. 235-250.

1988: Distribution pattern of Lower Triassic (Scythian) conodonts in the western United States: documentation of the Pakistan connection. Palaios, v. 3, p. 598-605.

Perri, M.C. and Andraghetti, M.

1987: Permian–Triassic boundary and Early Triassic conodonts from the southern Alps, Italy. Rivista Italiana di Paleontologica e Stratigrafia, v. 93, p. 291-328.

Rostovtsev, K.O. and Azaryan, N.R.

1973: The Permian–Triassic boundary in Transcaucasia. *In* The Permian and Triassic Systems and their Mutual Boundary, A. Logan and L.V. Hills (eds.); Canadian Society of Petroleum Geologists, Memoir 2, p. 89-99.

Schock, W.W., Maughan, E.K., and Wardlaw, B.R.

1981: Permian–Triassic boundary in southwestern Montana and western Wyoming. *In* Montana Geological Society Field Conference and Guidebook to Southwest Montana, T.E. Tucker, R.B. Aram, W.F. Brinker, and R.F. Grabb, Jr. (eds.); Montana Geological Society, p. 59-69.

Selwyn, A.R.C.

1872: Journal and report of preliminary explorations in British Columbia. Geological Survey of Canada, Report of Progress for 1871-72, p. 16-72.

Shannon, K.R.

1981: The Cache Creek Group and contiguous rocks near Cache Creek, British Columbia. *In* Current Research, Part A, Geological Survey of Canada, Paper 81-1A, p. 217-221.

1982: Cache Creek Group and contiguous rocks, near Cache Creek, British Columbia. Unpublished M.Sc. thesis, University of British Columbia, Vancouver, 72 p.

Solien, M.A.

1979: Conodont biostratigraphy of the Lower Triassic Thaynes Formation, Utah. Journal of Paleontology, v. 53, p. 276-306.

Staesche, U.

1964: Conodonten aus dem Skyth von Südtirol. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, v. 119, p. 247-306.

Sudar, M.N. and Budurov, K.J.

1979: New conodonts from the Triassic in Yugoslavia and Bulgaria. Geologica Balcanica, v. 9, p. 47-52.

Sweet, W.C.

1970a: Permian and Triassic conodonts from a section at Guryul Ravine, Vihi District, Kashmir. University of Kansas Paleontological Contributions, Paper 49, p. 1-10.

1970b: Uppermost Permian and Lower Triassic conodonts of the Salt Range and Trans-Indus Ranges, West Pakistan. *In* Stratigraphic Boundary Problems: Permian and Triassic of West Pakistan, B. Kummel and C. Teichert (eds.); University of Kansas Paleontological Contributions, Special Publication 4, p. 207-275.

1973: Late Permian and Early Triassic conodonts faunas. *In* The Permian and Triassic Systems and their Mutual Boundary, A. Logan and L.V. Hills (eds.); Canadian Society of Petroleum Geologists, Memoir 2, p. 630-646.

1979: Graphic correlation of Permo-Triassic rocks in Kashmir, Pakistan and Iran. Geologica et Palaeontologica, v. 13, p. 239-248.

1988: The Conodonta. Oxford Monographs on Geology and Geophysics, v. 10, Clarendon Press, Oxford, 212 p.

Sweet, W.C. and Bergström, S.M.

1986: Conodonts and biostratigraphic correlation. Annual Review of Earth and Planetary Sciences, v. 14, p. 85-112.

Sweet, W.C., Mosher, L.C., Clark, D.L., Collinson, J.W., and Hasenmueller, W.A.

1971: Conodont biostratigraphy of the Triassic. *In* Symposium on Conodont Biostratigraphy, W.C. Sweet and S.M. Bergström (eds.); Geological Society of America, Memoir 127, p. 441-465.

Teichert, C. and Kummel, B.

1976: Permian–Triassic boundary in the Kap Stosch area, east Greenland, with Appendix by W.C. Sweet. Meddelelser om Grønland, v. 197, 54 p.

Teichert, C., Kummel, B., and Sweet, W.C.

1973: Permian–Triassic strata, Kuh-e-Ali Bashi, northwestern Iran. Bulletin of the Museum of Comparative Zoology, Harvard University, v. 145, p. 359-472.

Thompson, M.L., Wheeler, H.E., and Danner, W.R.
1950: Middle and Upper Permian fusulinids of Washington and British Columbia. Cushman Foundation for Foraminiferal Research, Contributions, v. 1, p. 40-63.
Tozer, E.T.
1988: Towards a definition of the Permian–Triassic boundary. Episodes, v. 11, p. 251-255.
Travers, W.B.
1978: Overturned Nicola and Ashcroft strata and their relation to the Cache Creek Group, southwestern Intermontane Belt, British Columbia. Canadian Journal of Earth Sciences, v. 15, p. 99-116.
Trettin, H.P.
1961: Geology of the Fraser River Valley between Lillooet and Big Bar Creek. British Columbia Department of Mines and Petroleum Resources, Bulletin 44, 109 p.
1980: Permian Rocks of the Cache Creek Group in the Marble Range, Clinton area, British Columbia. Geological Survey of Canada, Paper 79-17, 17 p.
Wang, C.-y., Ritter, S.M., and Clark, D.L.
1987: The *Sweetognathus* complex in the Permian of China: implications for evolution and homeomorphy. Journal of Paleontology, v. 61, p. 1047-1057.
Wardlaw, B.R.
1988: Permian conodonts from the Salt Range, Pakistan (abstract). Geological Society of America, 22nd Annual Meeting of the North-Central Section, Abstracts with Programs, v. 20(5), p. 393.
Yao, J. and Li, Z.
1987: Permian–Triassic conodont faunas and the Permian–Triassic boundary at the Selong section in Nyalam County, Xizang, China. Kexue Tongbao, v. 32, p. 1555-1560.
Youngquist, W.L., Hawley, R.W., and Miller, A.K.
1951: Phosphoria conodonts from southeastern Idaho. Journal of Paleontology, v. 25, p. 356-364.
Zhao, J.-k., Sheng, J.-z., Yao, Z.-q., Liang, X.-l., Chem, C.-z., Rui, L., and Liao, Z.-t.
1981: The Changhsingian and Permian–Triassic boundary of south China. Bulletin of the Nanjing Institute of Geology and Palaeontology, Academia Sinica, v. 2(2), p. 1-85.
Ziegler, W.
1977: Catalogue of Conodonts, v. 3. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 574 p.

APPENDIX

Locality register

A brief geographical description, latitude, longitude, collector, year of collection, and stratigraphic information are given for each GSC locality number cited in the text. All samples are from the Marble Canyon Formation, unless stated otherwise.

Jesmond: NTS 92 P/5, Bonaparte Lake

Section 1

Jesmond fire lookout access road, section begins 2.87 km from turnoff onto lookout road; between 51°17′41.8″N, 121°54′36.0″W and 51°17′40.9″N, 121°54′30.7″W. Stratigraphic thickness: 61.5 m; J.M. Beyers, 1986, 1987.

GSC loc. C-149768. At 0 m, datum; 1986.

GSC loc. C-149769. At 3 m; 1986.

GSC loc. C-149771. At 49.5 m; 1986.

GSC loc. C-149773. At 53.5 m; 1986.

GSC loc. C-157202. At 51 m; 1987.

GSC loc. C-157204. At 2.5 m, elevation 1606 m (5300 ft.); 1987.

Section 2

Jesmond fire lookout access road, section begins 4.1 km from turnoff onto lookout road, 50 m downhill from second switchback, between 51°17′51.5″N, 121°54′35.8″W and 51°17′47.8″N, 121°54′33.3M″W. Stratigraphic thickness: 7.5 m.

GSC loc. C-101144. At 0.5 m, elevation 1610 m (5600 feet); M.J. Orchard, 1981.

GSC loc. C-118497. At 0.5 m, recollection of GSC loc. C-101144; M.J. Orchard, 1984.

GSC loc. C-149752. At 0 m, datum, elevation 1682 m (5550 feet); J.M. Beyers, 1986.

GSC loc. C-149753. At 0.5 m; J.M. Beyers, 1986.

GSC loc. C-149756. At 3.5 m; J.M. Beyers, 1986.

GSC loc. C-149757. At 3.8 m; J.M. Beyers, 1986.

GSC loc. C-157212. At 6 m; J.M. Beyers, 1987.

Section 3

"Lower section" of Beyers and Orchard (1989), Jesmond fire lookout access road, on hill above second switchback, 4.1 km from turnoff onto lookout road, between 51°17′54.0″N, 121°54′42.2″W and 51°17′50.6″N, 121°54′25.5″W. Stratigraphic thickness: 84 m; J.M. Beyers, 1986, 1987.

GSC loc. C-149781. At 69 m, elevation 1727 m (5700 ft.); 1986.

GSC loc. C-149782. At 74 m; 1986.

GSC loc. C-157217. At 0 m, datum; 1987.

GSC loc. C-157218. At 1 m; 1987.

GSC loc. C-157219. At 3.5 m; 1987.

GSC loc. C-157222. At 28.5 m; 1987.

GSC loc. C-157223. At 32 m; 1987.

GSC loc. C-157224. At 35.5 m; 1987.

Section 4

"Upper section" of Beyers and Orchard (1989), Jesmond fire lookout access road, above third switchback at 4.36 km from turnoff onto lookout road, between 51°17′56.2″N, 121°54′21.5″W and 51°18′16.7″N, 121°54′46.8″W. Stratigraphic thickness: 84 m; J.M. Beyers, 1986.

GSC loc. C-149786. At 13 m, elevation 1800 m (5940 ft.).

GSC loc. C-149787. At 11.5 m.

GSC loc. C-149802. At 3.5 m.

GSC loc. C-149812. At 1 m, elevation 1818 m (6000 ft.).

GSC loc. C-149815. At 1 m (separated along strike).

GSC loc. C-149822. At 4.5 m, elevation 1821 m (6010 ft.).

GSC loc. C-149832. At 8 m.

GSC loc. C-149839. At 10.5 m, elevation 1835 m (6055 ft.).

Isolated samples

The following samples are from the Jesmond area.

GSC loc. C-101141. Section 4. Elevation about 6000 ft. (1829 m); 51°17′N, 121°54′W; M.J. Orchard, 1981.

GSC loc. C-101146. Elevation about 4900 ft. (1485 m); 51°17′N, 121°54′W; M.J. Orchard, 1981.

GSC loc. C-118494. Section 4. 0.6 km from lookout; 51°18′N, 121°54′30″W; M.J. Orchard, 1984.

GSC loc. C-157808. 2.5 km from turnoff onto lookout road, near GSC loc. C-101146; 51°17′44.5″N, 121°54′59.2″W; J.M. Beyers, 1987.

GSC loc. C-157815. On hillside north of Jesmond Creek and west of major north–south gully; elevation 1485 m (4900 ft.); 51°16′13.4″N, 121°54′14.9″W; J.M. Beyers, 1987.

Central Marble Range: NTS 92 P/4, Bonaparte Lake

Isolated samples

GSC loc. C-117776. Lookout access road west of Clinton, 6.5 km from junction with Kelly Lake–Clinton road; 51°06′12.9″N, 121°39′56.3″W; M.J. Orchard, 1986.

GSC loc. C-157813. Road north of Porcupine Creek, 14.5 km north of junction of Kelly Lake and Jesmond roads, elevation 1803 m (5950 ft.); 51°07′25.5″N, 121°51′00.4″W; J.M. Beyers, 1987.

Porcupine Creek road

GSC loc. C-175062. Approximately 3 km from junction with Jesmond road (lies 5.5 km north of junction with Kelly Lake road): 51°04′N, 121°49′W. Western belt strata; M.J. Orchard, 1990.

GSC loc. C-157820. 2.9 km from junction; 51°04′17.6″N, 121°49′19.7″W. At 0 m within 7 m section; J.M. Beyers, 1987.

GSC loc. C-157824. Approximately 3.5 km from junction, elevation 1479 m (4880 ft.); 51°04′26.4″N, 121°49′06.9″W. At 25 m in 42 m section; J.M. Beyers, 1987.

Pavilion Mountain: NTS 92 I/13, Ashcroft

Section 1

Western belt: 5 km east of Hambrook Creek junction, Pavilion Mountain road, between 50°59′04.4″N, 121°42′55.3″W (GSC loc. C-117774) and 50°59′06.2″N, 121°43′06.7″W (GSC loc. C-117772). Stratigraphic thickness: 42.5 m.

GSC loc. C-117772. At 19.5 m; M.J. Orchard, 1986.
GSC loc. C-117774. At 0.5 m; M.J. Orchard, 1986.
GSC loc. C-157841. At 22.5 m; J.M. Beyers, 1987.

Section 2

Western belt: 800 m west of small tower, Pavilion Mountain road, between 50°58′45.3″N, 121°42′08.3″W (GSC loc. C-157847) and 50°58′45.4″N, 121°42′17.3″W (GSC loc. C-149993). Approximately 50 m section; J.M. Beyers.

GSC loc. C-149993. At approximately 40 m; 1986.
GSC loc. C-157843. At approximately 15 m; 1987.
GSC loc. C-157847. At approximately 2 m; 1987.

Isolated sample

GSC loc. C-149985. Western belt: Pavilion Mountain, on straight line between the two microwave towers. 50°58′32.6″N, 121°41′21.5″W; J.M. Beyers, 1986.

Marble Canyon–Hat Creek: NTS 92 I/13, Ashcroft

Section

Highway 12, about 200 m east of Hat Creek turnoff; 50°47′56.9″N, 121°36′22.4″W; M.J. Orchard, 1985.

GSC loc. C-118818. At 2.2 m.
GSC loc. C-118821. At 5.2 m.
GSC loc. C-118822. At 6.7 m.

Isolated samples

GSC loc. C-087055(a, e, g). In roadcut near west end of Marble Canyon, southeast end of Pavilion Lake; 50°51.4′N, 121°43′W; M.J. Orchard, 1980.
GSC loc. C-116176. From Highway 12, in roadcut just east of Hat Creek turnoff; 50°48′N, 121°37′W; M.J. Orchard, 1985.
GSC loc. C-118499. As above; 1984.
GSC loc. C-149969. Off Highway 12 near junction with Hat Creek road, along trail, bearing 192° to junction; elevation 894 m (2950 ft.); 50°48′01.9″N, 121°36′29.8″W; J.M. Beyers, 1986.

Cornwall Hills: NTS 92 I/11, Ashcroft

GSC loc. C-117780. Hat Creek road in Oregon Jack Creek valley, 1.05 km from junction with Cornwall Hills access road; 50°38′29.0″N, 121°29′14.9″W; M.J. Orchard, 1986.

Cornwall Hills Fire lookout, on Tower Access Road:

GSC loc. C-087077. 1.15 km southsouthwest of fire lookout; 50°41′17″N, 121°27′47″W; K.R. Shannon, 1980.
GSC loc. C-118472. 0.19 km from top junction near fire lookout; 50°40′N, 121°28′W; M.J. Orchard, 1984.
GSC loc. C-118474. 0.88 km from top junction; 50°40′N, 121°28′W; M.J. Orchard, 1984.
GSC loc. C-118479. 1.7 km from top junction; 50°40′N, 121°28′W; M.J. Orchard, 1984.
GSC loc. C-157860. 50°41′50.1″N, 121°26′35.5″W; J.M. Beyers, 1987.
GSC loc. C-157869. Elevation 1376 m (6520 ft.); 50°41′40.6″N, 121°27′15.4″W; J.M. Beyers, 1987.
GSC loc. C-157870. Elevation 2021 m (6670 ft.); 50°41′45.0″N, 121°27′17.8″W; J.M. Beyers, 1987.
GSC loc. C-157873. Bearing 106′ to lookout; elevation 2015 m (6610 ft.); 50°41′49.1″N, 121°27′23.5″W; J.M. Beyers, 1987.
GSC loc. C-157881. From bluffs about 15 m above road, bearing 047° to lookout; 50°41′38.4″N, 121°27′47.3″W; J.M. Beyers, 1987.

PLATE 1

Upper Permian conodonts from Cache Creek.

Figures 1-6. *Iranognathus*? ex gr. *movschovitschi* (Kozur and Pjatakova) Morphotype A.

Specimens are recrystallized and have adhering (?)dolomite.

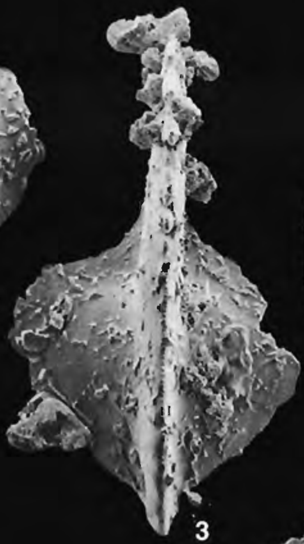
1. Upper view, figured specimen GSC 95295, x100, GSC loc. C-149752.
2. Upper view, figured specimen GSC 95296, x100, GSC loc. C-149752.
3. Upper view, figured specimen GSC 95297, x100, GSC loc. C-149752.
6. Close-up of carina showing pustules, same specimen as figure 3, x400.
4. Lateral view, figured specimen GSC 81236, x90, GSC loc. C-118497.
5. Lateral view, figured specimen GSC 95298, x100, GSC loc. C-149757.

Figures 7-11. *Iranognathus*? ex gr. *movschovitschi* (Kozur and Pjatakova) Morphotype B.

7, 10. Lateral and upper views, figured specimen GSC 95299, x150 and x125, GSC loc. C-157219.
8, 9. Oblique lateral and upper views, figured specimen GSC 95300, x100, GSC loc. C-149782.
11. Close-up of carina, same specimen as figures 8, 9, x400; a. oblique view from the posterior, b. oblique view from the anterior. Note how micropustules are much clearer in the latter view.

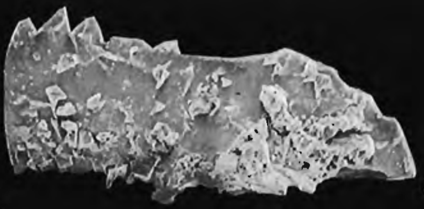
1

2



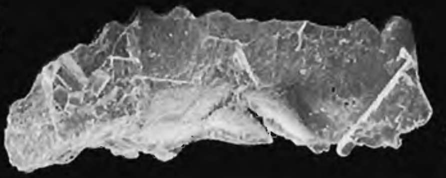
3

4



5

6



7

8

9

10

11a

11b

PLATE 2

Upper Permian conodonts from Cache Creek.

Figures 1, 2, 7. *Sweetognathus* sp(p).

1, 2. Upper and lateral views, figured specimen GSC 95301, x80, GSC loc. C-118818.
7. Upper view of posterior fragment, figured specimen GSC 95302, x100, GSC loc. C-118499.

Figure 3. Undetermined bipennate element.

Upper view, figured specimen GSC 95303, x80, GSC loc. C-101144.

Figure 4. Undetermined alate element.

Upper view, figured specimen GSC 95304, x80, GSC loc. C-101144.

Figure 5. Undetermined digyrate element.

Upper view, figured specimen GSC 95305, x80, GSC loc. C-101144.

Figure 6. Undetermined xaniognathiform element.

Upper view, figured specimen GSC 95306, x80, GSC loc. C-101144.

Figures 8, 9, 13, 14. *Iranognathus*? ex gr. *movschovitschi* (Kozur and Pjatakova) Morphotype C.

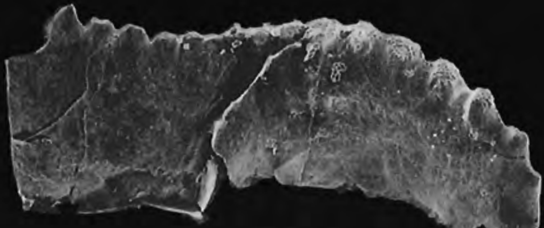
8, 9. Upper view, figured specimen GSC 95307, fig. 8, x250, fig. 9, x150, lateral view, GSC loc. C-157808.
13. Close-up of carina showing pustules, figured specimen GSC 95308, x477, GSC loc. C-149752.
14. Upper view, figured specimen GSC 95309, x250, GSC loc. C-157815.

Figures 10-12, 15. *Iranognathus*? n. sp. A.

10, 11. Lateral and upper views, figured specimen GSC 95310, x125, GSC loc. C-157222.
15. Close-up of carina in oblique lateral view, showing pustules, same specimen as in figures 10, 11, x210.
12. Upper view, figured specimen GSC 95311, x100, GSC loc. C-157204.

PLATE 2


1


2


3


4


5


6


7


8

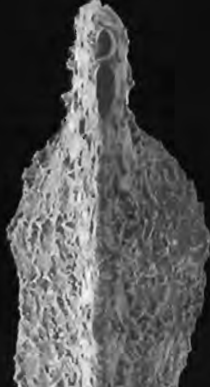

9


10


11


12


13


14


15

PLATE 3

Upper Permian conodonts from Cache Creek.

Figure 1. *Neogondolella* sp. cf. *N. orientalis* (Barskov and Koroleva).

Upper view of figured specimen with anteriormost portion missing, GSC 95312, x70, GSC loc. C-157808.

Figures 2, 3. *Neogondolella subcarinata* n. subsp. A.

Lateral and upper views of figured specimen GSC 81233, x60, GSC loc. C-157223.

Figures 4, 5. *Neogondolella subcarinata subcarinata* Sweet.

Upper and lateral views, hypotype GSC 95313, x60 and x70, GSC loc. C-157808.

Figures 6, 7, 9, 10, 13-15. *Neogondolella jesmondi* n. sp.

6. Upper view, juvenile specimen, paratype GSC 95314, x75, GSC loc. C-101146.
7. Upper view, paratype GSC 95315, x74, GSC loc. C-149757.
9, 10. Upper and lateral views, paratype GSC 95316, x74 and x75, GSC loc. C-149757.
13-15. Upper, lateral, and lower views, holotype GSC 95317, x74, GSC loc. C-101144.

Figures 8, 11, 12. *Neogondolella phosphoriensis* (Youngquist, Hawley and Miller).

8. Posterior fragment, hypotype GSC 95318, x80, GSC loc. C-116176.
11, 12. Upper views, hypotypes GSC 95319, GSC 95350, x60, GSC loc. C-117776.


1


2


3


4


5


6


7


8


9


10


11


12


13


14


15

PLATE 4

Upper Permian and Lower Triassic conodonts from Cache Creek.

Figures 1, 4. *Hindeodus typicalis* (Sweet).

1. Lateral view, hypotype GSC 95320, x80, GSC loc. C-149752.
4. Lateral view, hypotype GSC 95321, x70, GSC loc. C-149752.

Figures 2, 3. *''Anchignathodus'' parvus* Kozur and Pjatakova.

2, 3. Lateral views, hypotypes GSC 81240, GSC 81239, x100, GSC loc. C-157820.

Figures 5, 8. *Neocavitella?* sp.

5. Upper fragment, figured specimen GSC 95322, x140, GSC loc. C-157881.
8. Anterior fragment, figured specimen GSC 95323, x140, GSC loc. C-157870.

Figure 6. Undetermined ramiform element.

Inner view, figured specimen GSC 95324, x70, from GSC loc. C-149815.

Figures 7, 13. *Pachycladina* sp.

7. Sc element, inner view of figured specimen GSC 95325, x70, GSC loc. C-149832.
13. Sb element, oblique-posterior view of figured specimen GSC 95327, x70, GSC loc. C-149832.

Figure 9. *Pachycladina obliqua* Staesche.

Posterior view of Sa element, hypotype GSC 95326, x40, GSC loc. C-149812. Specimen has an anterior lip, similar to that present in forms called ''Variante B'' by Staesche (1964).

Figure 10. *Pachycladina* sp. aff. *P. obliqua* Staesche.

Sc? element, anterior view of figured specimen GSC 95328, x40, GSC loc. C-149802. Note the anterior process in place of the anterior lip of the ''Variante B'' (Staesche, 1964).

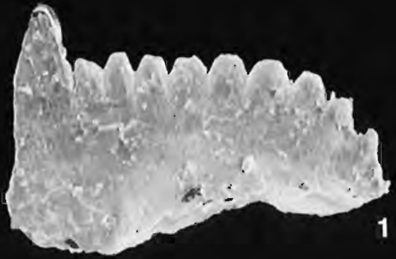
Figure 11. *''Lonchodina'' nevadensis* Müller.

Inner view, hypotype GSC 81235, x50, GSC loc. C-149822.

Figure 12. *Pachycladina*? sp. A.

Sa element, posterior view of figured specimen, GSC 95329, x40, GSC loc. C-149815.

PLATE 4


1


2

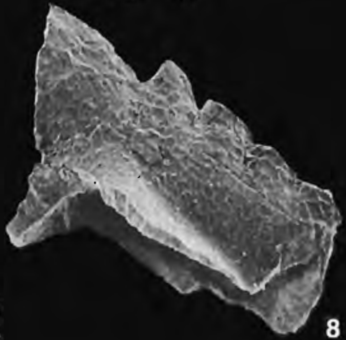

3

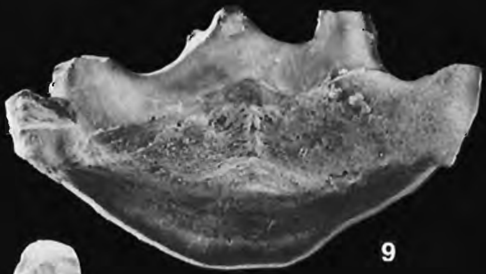

4


5


6


7


8


9


10


11


12

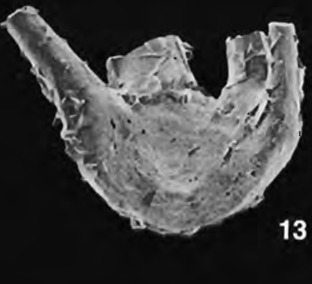

13

PLATE 5

Lower to Upper Triassic conodonts from Cache Creek.

Figure 1. *Neospathodus* n. sp. A.

Lateral view, figured specimen GSC 95330, x70, GSC loc. C-157843.

Figure 2. *Neospathodus* sp. cf. *N. pakistanensis* Sweet.

Lateral view, figured specimen GSC 95331, x140, GSC loc. C-157860.

Figure 3. *Neospathodus homeri* (Bender).

Lateral view, hypotype GSC 95332, x100, GSC loc. C-118494.

Figure 4. *Neospathodus dieneri* Sweet.

Lateral view, hypotype GSC 95333, x80, GSC loc. C-087055(e).

Figure 5. *Neospathodus waageni* Sweet.

Lateral view, hypotype GSC 95334, x80, GSC loc. C-087055(e).

Figure 6. *Neospathodus triangularis* (Bender).

Lateral and oblique lower views of broken specimen showing characteristic heart-shaped basal cavity, hypotype GSC 95335, x100, GSC loc. C-149839.

Figure 7. *Neospathodus novaehollandiae* McTavish.

Lateral view, hypotype GSC 95336, x60, GSC loc. C-118474.

Figure 8. *Neospathodus bicuspidatus* (Müller).

Lateral view, hypotype GSC 95337, x80, GSC loc. C-087055(e).

Figure 9. *Neospathodus peculiaris* Sweet.

Lateral view, hypotype GSC 65897, x120, GSC loc. C-087055(g).

Figure 10. *Platyvillosus costatus* (Staesche).

Oblique upper view, hypotype GSC 95338, x100, GSC loc. C-118474.

Figure 11. *Neogondolella milleri* (Müller).

Upper view, hypotype GSC 95339, x80, GSC loc. C-118479.

Figure 12. *Neogondolella navicula* (Huckriede).

Upper view, hypotype GSC 95340, x80, GSC loc. C-117780.

Figures 13, 14. *Neogondolella* sp. aff. *N. excelsa* (Mosher).

Upper and lateral views, figured specimen GSC 95341, x100, GSC loc. C-118472.

Figures 15, 16. *Neogondolella carinata* (Clark).

Upper views, hypotypes GSC 65880 and GSC 95342, x80, GSC loc. C-087055(g).

Figure 17. *Epigondolella quadrata* Orchard.

Upper view, hypotype GSC 95343, x71, GSC loc. C-157824.

Figure 18. *Epigondolella triangularis* (Budurov).

Upper view, hypotype GSC 95344, x65, GSC loc. C-157824.

Figure 19. *Metapolygnathus primitius* (Mosher).

Upper view, hypotype GSC 95345, x100, GSC loc. C-117780.

Figure 20. *Metapolygnathus pseudoechinatus* Kozur.

Upper view, hypotype GSC 95346, x100, GSC loc. C-117780.

Figure 21. *Epigondolella mosheri* (Kozur and Mostler).

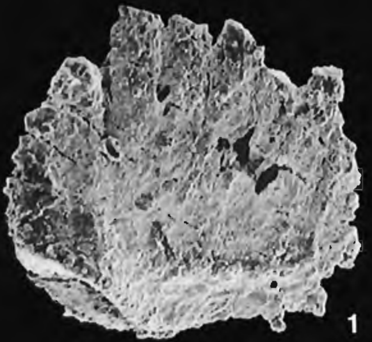
Upper view, hypotype GSC 95347, x76, GSC loc. C-175062.

Figure 22. *Metapolygnathus nodosus* (Hayashi).

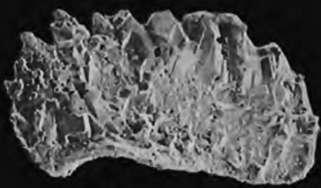
Upper view, hypotype GSC 95348, x100, GSC loc. C-117780.

Figure 23. *Metapolygnathus* sp.

Upper view, figured specimen GSC 95349, x70, GSC loc. C-157870.

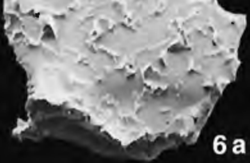

1


2


3


4


5


6a


6b


7

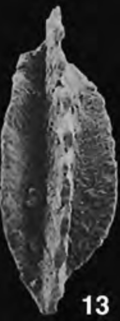

8


9


10

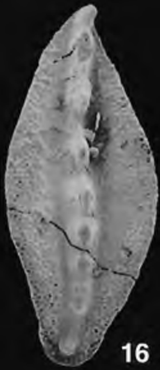

11


12


13

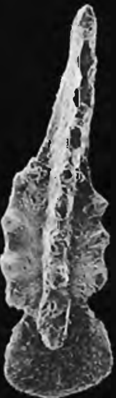

14


15


16


17


18


19


20


21


22


23

Upper Triassic conodont biochronology and new index species from the Canadian Cordillera

Michael J. Orchard[1]

Orchard, M.J., 1991: Upper Triassic conodont biochronology and new index species from the Canadian Cordillera. In *Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417, p. 299-335.*

Abstract

Upper Triassic conodonts from the Canadian Cordillera occur in direct association with ammonoids and age-diagnostic pelecypods in the Pardonet Formation of northeastern British Columbia, the Kunga Group of Queen Charlotte Islands, the Tyaughton Group of south-central British Columbia, and in several isolated areas of Yukon Territory and Northwest Territories. These collections include many new species of Carnian–Early Norian Metapolygnathus *and Norian* Epigondolella, *the following of which are formally described:* M. lindae *n. sp.,* M. samueli *n. sp.,* M. stephanae *n. sp.,* M. zoae *n. sp.,* E. carinata *n. sp.,* E. elongata *n. sp.,* E. englandi *n. sp.,* E. matthewi *n. sp.,* E. quadrata *n. sp.,* E. serrulata *n. sp.,* E. spiculata *n. sp.,* E. transitia *n. sp.,* E. tozeri *n. sp., and* E. triangularis uniformis *n. subsp. The holotypes of other species from Canada,* M. primitius, M. reversus, *and* E. multidentata, *are also re-illustrated and described; other Upper Triassic conodonts belonging to these genera are discussed. Conodont zonation for the Canadian Upper Triassic consists of* polygnathiformis, nodosus *(three subdivisions),* primitius *(two subdivisions),* quadrata, triangularis *(three subdivisions),* multidentata *(two subdivisions),* spiculata, elongata, serrulata, bidentata *(two subdivisions), and* posthernsteini *zones. The calibration of this zonation with the Carnian and Norian ammonoid zonation is presented.*

Résumé

Dans la Cordillère canadienne, des conodontes du Trias supérieur se rencontrent en association directe avec des ammonoïdés et des pélécypodes caractéristiques dans la formation de Pardonet dans le nord-est de la Colombie-Britannique, dans le groupe de Kunga dans les îles de la Reine-Charlotte, dans le groupe de Tyaughton dans le centre sud de la Colombie-Britannique, et à plusieurs endroits dispersés du Yukon et des Territoires du Nord-Ouest. Ces collections comprennent de nombreuses nouvelles espèces de Metapolygnathus *(Carnien-Norien précoce) et d'*Epigondolella *(Norien), dont les suivantes sont décrites formellement :* M. lindae *n. sp.,* M. samueli *n. sp.,* M. stephanae *n. sp.,* M. zoae *n. sp.,* E. carinata *n. sp.,* E. elongata *n. sp.,* E. englandi *n. sp.,* E. matthewi *n. sp.,* E. quadrata *n. sp.,* E. serrulata, *n. sp.,* E. spiculata *n. sp.,* E. transitia *n. sp.,* E. tozeri *n. sp. et* E. triangularis uniformis *n. subsp. Les holotypes d'autres espèces canadiennes,* M. primitius, M. reversus *et* E. multidentata, *sont illustrés de nouveau et décrits; d'autres conodontes du Trias supérieur qui appartiennent à ces genres sont examinés. La zonation des conodontes du Trias tardif canadien englobe les zones à* polygnathiformis, *à* nodosus *(trois subdivisions), à* primitius *(deux subdivisions), à* quadrata, *à* triangularis *(trois subdivisions), à* multidentata *(deux subdivisions), à* spiculata, *à* elongata, *à* serrulata, à bidentata *(deux subdivisions) et à* posthernsteini. *L'auteur présente la corrélation de cette zonation et de la zonation des ammonoïdés du Carnien et du Norien.*

---

[1] Geological Survey of Canada, 100 West Pender St., Vancouver, B.C. V6B 1R8

INTRODUCTION

Triassic strata are preserved throughout the Canadian Cordillera and eastward into the subsurface. The autochthonous successions in northeastern British Columbia are extremely important biochronologically because they represent a substantial part of Triassic time and contain associations of ammonoids and conodonts in relatively simple, tectonically undisturbed stratigraphic sequences. To the west, Triassic strata occur throughout tectono-stratigraphic terranes accreted to the North American margin in later Mesozoic time; some of these terranes are also important in ammonoid–conodont–radiolarian biochronology and calibration (Fig. 1). The fossil zonations that have been, or are being, developed from Canadian Triassic rocks have far reaching significance as global biochronological standards (e.g., Tozer, 1967; in press).

This paper is my third documentation of Cordilleran Triassic conodonts. Previously, I introduced the Norian populations from the Pardonet Formation in northeastern British Columbia and emphasized the calibration of conodont and ammonoid faunas, the breadth of population variation, and the critical importance of scale in comparative study (Orchard, 1983). Later, I outlined the Upper Carnian conodont successions of the Kunga Group on Queen Charlotte Islands, noted the ammonoid calibration, and interpreted the phylogenetic roots of the Norian conodonts (Orchard, 1991a). In this paper, the basis of the Canadian Upper Triassic conodont biochronology is presented in more detail, and new species and subspecies are formally named; many of them have been previously introduced in open nomenclature.

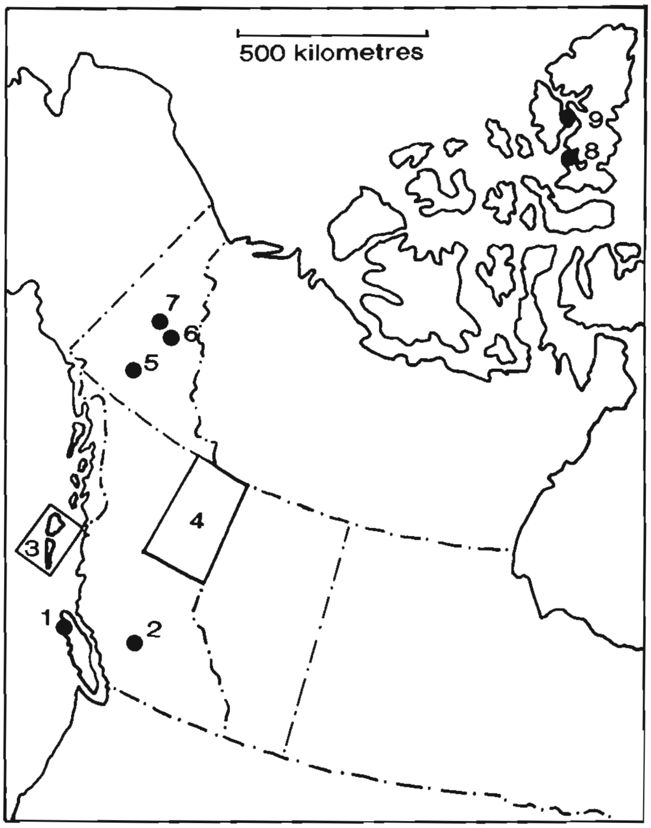


Figure 1. Location of key sections of the Upper Triassic from which biochronologically well constrained conodont faunas are known. 1. Klaskino Inlet, Vancouver Island. 2. Tyaughton Creek, Taseko Lakes. 3. Queen Charlotte Islands (see Orchard, 1991a; Weston et al., 1991 for details). 4. Northeast British Columbia (Fig. 2). 5. Laberge, Yukon. 6. Rackla River, Yukon. 7. Chert Mountain, Dawson, Yukon. 8. Bjorne Peninsula, Ellesmere Island. 9. Buchanan Lake, Axel Heiberg Island.

UPPER TRIASSIC CONODONT BIOCHRONOLOGY

Canadian occurrences of temporally well constrained Upper Triassic conodont collections are summarized below in chronological order. In all cases, the conodonts have either been recovered from the matrix of existing ammonoid collections, or collected concurrently from ammonoid bearing strata, and it is with reference to the ammonoid zonation that the conodont succession is discussed. This calibration of the ammonoid and conodont zonations, which increases the resolving power of Triassic fossils throughout the Cordillera and beyond, represents a decade of collaborative work with E.T. Tozer (GSC, Vancouver), whose guidance has been critical in establishing this framework.

In his pioneering work on Triassic conodonts, Mosher (1968, 1973) also used well controlled ammonoid matrix material from Canada. Mosher was constrained by small sample size, and the lack of data from sections, but his results lay an important foundation and are reviewed and updated below.

The ammonoid zonation referred to throughout this work is derived from Tozer (in press), whose style of citing ammonoid zones I use in the following discussion: standard ammonoid zones begin with an upper case letter, and are not italicized, contrasting with the conodont zones, which may be readily distinguished by the reader. The extent of the conodont record in a number of key sections (Figs. 1, 2) and its calibration with the ammonoid zones is summarized in Figure 3.

The most important sources from which Upper Triassic conodont biochronological data have been derived are the Pardonet Formation of the Peace River area (Fig. 2) for all but the uppermost Norian, the Kunga Group of Queen Charlotte Islands (Orchard, 1991a) for the Upper Carnian and Upper Norian, and the Tyaughton Group of Taseko Lakes area (Fig. 1, Appendix) for the Upper Norian; all areas are in British Columbia.

Previously, a preliminary zonation of the Norian based on conodont populations from the Pardonet Formation (Orchard, 1983), and a formal zonation for the Upper Carnian based largely on the Kunga Group succession of Queen Charlotte Islands (Orchard, 1991a) have been described. Formal definitions of the Norian zones, supported by biostratigraphic details, are in preparation.

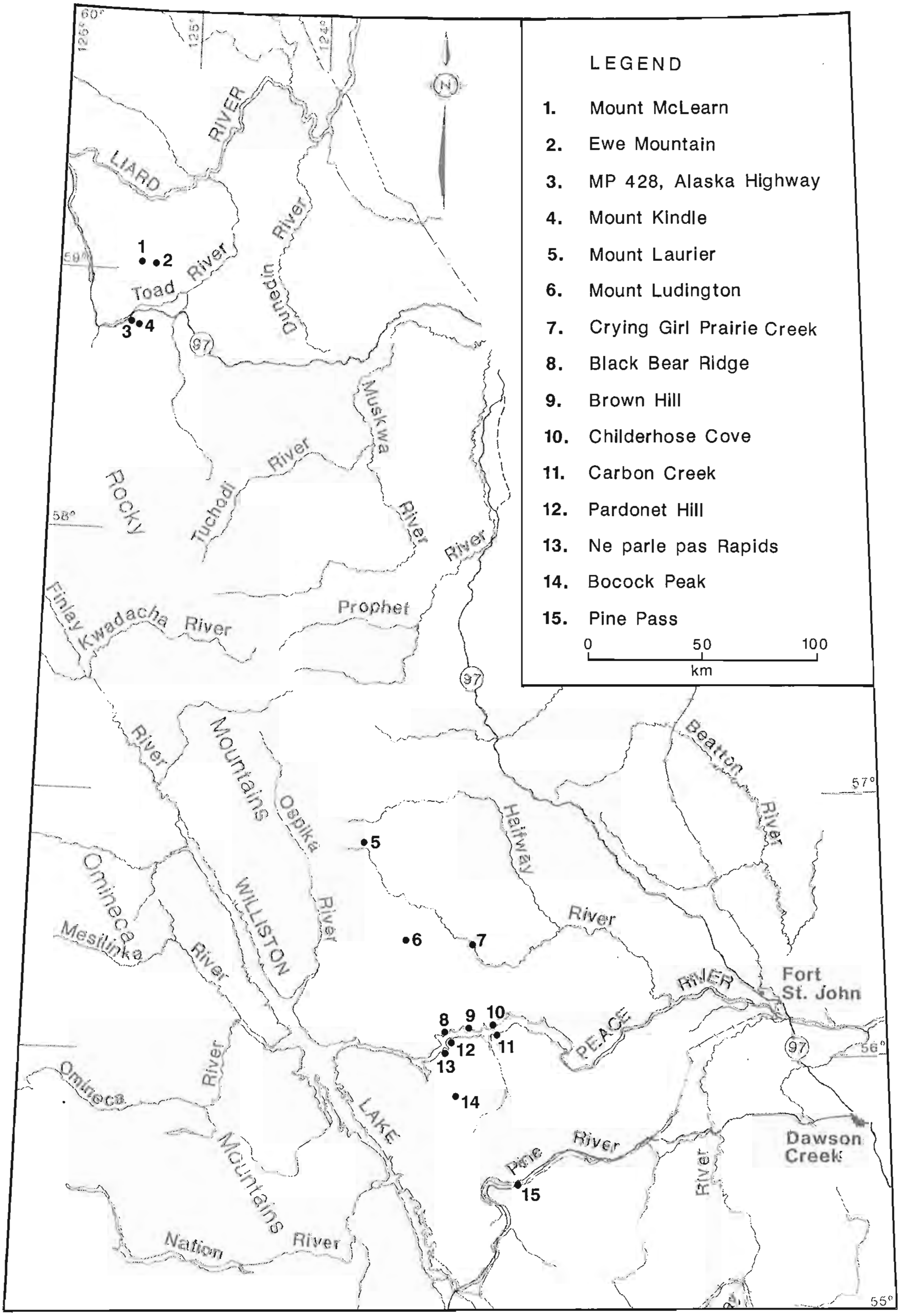


Figure 2. Location of key sections of the Upper Triassic in northeastern British Columbia from which biochronologically well constrained conodont faunas are known.

Below, the occurrences of key conodonts in each of the Upper Triassic ammonoid zones are summarized, and a more detailed conodont zonation of the Norian is outlined. In many cases, conodonts have also been recovered from strata lying between cited collections (GSC locality numbers), but only those faunules that are directly associated with dated ammonoids, or are otherwise critical, are included in the discussion (and Appendix).

The age, or ammonoid zonal assignment of holotypes of conodont species are noted under Systematic Paleontology. Where the holotype is not from Canada, the Canadian occurrence is noted. Concerning the range of the conodont species, the base of Norian conodont zones are defined by the appearance of the name-giver, which also generally dominates the zone. Upper ranges of nominal species, and the ranges of new, less diagnostic species are currently being worked out. The ranges of Upper Carnian species are given in Orchard (1991a).

Lower Carnian

Lower Carnian ammonoid zones begin with the Desatoyense Zone, followed by the Obesum and Nanseni zones. The first of these is best known from Nevada, where Mosherella newpassensis (Mosher) is the key element of the *Trachyceras* beds, as described by Mosher (1968). *Mosherella* Kozur is currently known from both northeastern British Columbia and Yukon Territory, but not in association with ammonoids.

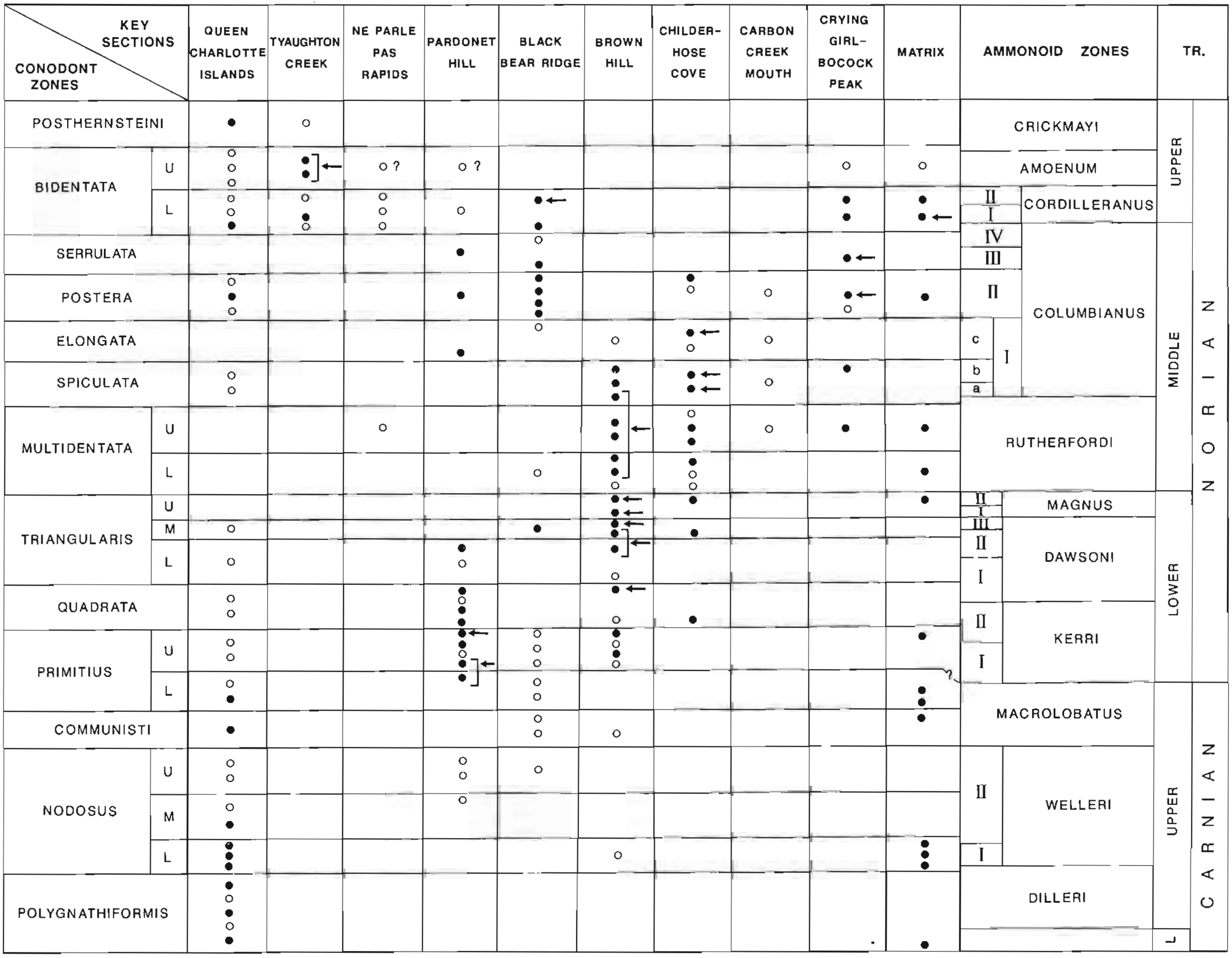


Figure 3. Calibration of Upper Triassic (exclusive of the Lower Carnian) conodont and ammonoid faunas, and the basis of the conodont zonation (left column) for the interval. Solid circles are conodont collections associated directly with ammonoid faunas, the relative position of which shows the zonal assignment in terms of both ammonoid (right column) and conodont zonations. Arrows indicate type localities for ammonoid zones. Open circles are sequential conodont faunas occurring alone and assigned to the conodont zone within which they fall. Key sections are shown in Figures 1 and 2, except Queen Charlotte Islands, which combines all data reported by Orchard (1991a), and the matrix column, which includes matrix samples (see Appendix B) taken from various localities by both the author and by Mosher (1973).

A single, small conodont collection from the Ludington Formation, which was formerly assigned to the Obesum Zone (Mosher, 1973, p. 183), is now referred to the Desatoyense Zone (Tozer, in press). The presence of *Cypridodella scolosculptura* Mosher provides the only link with the Nevadan faunas.

A single conodont described as *Neospathodus* sp. E by Mosher (1973) is known from the type locality of the Obesum Zone. This is of undetermined but potential stratigraphic value; similar segminate elements such as *Mosherella* and *Cornudina*? n. sp. A Orchard (1991a) are short ranging within the Carnian.

Of two small conodont collections reported by Mosher (1973) from the Lower Carnian Nanseni Zone, one (GSC loc. O-26124) is now referred to the Welleri Zone (Tozer, in press; see below). The other, from the type locality of the Nanseni Zone, was reported to contain *Metapolygnathus polygnathiformis* (Budurov and Stefanov). New material from this latter locality fits into the current broad definition of this taxon (Orchard, 1991a), but it is not identical to Upper Carnian material. No formal separation of these elements is attempted at this time, and all are referred to the *polygnathiformis* Zone (*sensu* Orchard, 1991a).

Upper Carnian

The Upper Carnian comprises the Dilleri, Welleri, and Macrolobatus ammonoid zones. Mosher (1973) recovered no conodonts from the Dilleri Zone, but collections are now known from both Vancouver Island and Queen Charlotte Islands. Orchard (1991a) documented several collections from the Kunga Group, where two levels are known: both are characterized by *Metapolygnathus* ex gr. *polygnathiformis*, and are referred to the zone of that name. The older collection (GSC loc. C-157006) also contains *Cornudina*? n. sp. A Orchard (1991a; see Carter et al., 1989), which is apparently confined to this level in Canada. The development of anterior nodes in *Metapolygnathus* Hayashi is first seen in examples from very close to the top of the Dilleri Zone, as is best documented at Sadler Point on Queen Charlotte Islands (Orchard, 1991a).

The Welleri Zone is divided into two ammonoid subzones, I followed by II. Conodonts are known from Subzone I at the type locality on Vancouver Island (GSC loc. O-86284), and from the Alaska Highway (GSC loc. O-42306), where Mosher (1973) reported a generalized *Metapolygnathus polygnathiformis*. New conodonts from the latter locality form the basis of *M. lindae* n. sp., which characterizes the Lower *nodosus* Zone of Orchard (1991a). A similar fauna occurs on Vancouver Island, and beneath Subzone II bearing strata on Kunghit Island on Queen Charlotte Islands (GSC loc. C-157374), which is the reference section for each of the *nodosus* Zone subdivisions.

On Kunghit Island, Welleri Subzone II ammonoids occur with Middle *nodosus* Zone conodonts, identified by *Metapolygnathus zoae* n. sp. at GSC loc. C-157295 (Orchard, 1991a). This key species occurs in the Baldonnel Formation near Pardonet Hill (GSC loc. C-101787) but is not currently known associated with ammonoid fauna in northeastern British Columbia. Welleri Subzone II collections from Mount McLearn (GSC loc. O-42323, O-68179) are characterized by other *M. nodosus* (Hayashi) morphotypes, including some that mimic *Neogondolella* and which resemble *M. reversus* (Mosher). The holotype of the latter species (re-illustrated herein) originated in a collection (GSC loc. O-51650) described by Mosher (1973) from Axel Heiberg Island in the Arctic and is now also assigned to Welleri Subzone II (Tozer, in press). A second Arctic collection (GSC loc. O-26124; formerly referred to the Nanseni Zone), from undifferentiated Welleri Zone, contains similar elements.

The Upper *nodosus* Zone, identified by *Metapolygnathus samueli* n. sp., is nowhere associated with determinable ammonoids, but its relative position in the conodont zonation is clear both at its type locality on Kunghit Island (GSC loc. C-157379), and on Pardonet Hill (GSC loc. C-101786, C-101787) and Black Bear Ridge (GSC loc. C-87955) (Orchard, 1991a). Although Upper *nodosus* Zone conodonts are associated with poorly preserved ammonoids in the Lewes River Group (GSC loc. O-23419) in Yukon Territory, its calibration with the ammonoid zonation is unknown at present.

The youngest ammonoid zone of the Carnian is the Macrolobatus Zone, which is currently undivided. However, conodont collections from this zone can be grouped into two faunas (Orchard, 1991a). Collections from Pardonet Hill reported by Mosher (1973) and duplicated by the author (GSC loc. O-64627, O-64628, O-64616), contain large numbers of *Metapolygnathus primitius* (Mosher), and are now referred to the Lower *primitius* Zone (Orchard, 1991a). On Queen Charlotte Islands, the same conodont zone is recognized in some Macrolobatus faunas (GSC loc. C-157119, C-157123) from the Peril Formation, but others from Kunghit Island (GSC loc. C-157382) are referred to the older *communisti* Zone (Orchard, 1991a). One Macrolobatus Zone collection from Mount McLearn in northeastern British Columbia (GSC loc. O-68202) is also referred to the *communisti* Zone, whereas a second from Mount Laurier (GSC loc. O-94738), although dominated by *M. nodosus* and *M. communisti* Hayashi, contains a few *M. primitius*, to which zone it is therefore assigned.

The transition from *communisti* Zone to *primitius* Zone faunas is best displayed in the lower section at Black Bear Ridge on Peace River, but no well preserved ammonoid faunas occur in this section. Both *Metapolygnathus pseudoechinatus* (Kozur) and *M. stephanae* n. sp. are short-ranging species in the Carnian–Norian boundary interval, the former in both northeastern British Columbia and Queen Charlotte Islands (Orchard, 1991a).

Lower Norian

Conodonts from the Pardonet Formation of the Peace River area (Orchard, 1983) are fully calibrated with ammonoid zones because both fossil groups occur abundantly through most of the formation. The Lower Norian comprises the Kerri, Dawsoni, and Magnus ammonoid zones, each of which has now been subdivided (Tozer, in press).

Within the Kerri Zone, a succession of conodont faunas is known from both subzones I and II at their type locality on Pardonet Hill, and also from Brown Hill (see Appendix). Mosher (1973) reported two collections from the Kerri Zone, both of which are now assigned to Subzone II. Most of these collections are referred to the Upper *primitius* Zone sensu Orchard (1991a), and are dominated by *Metapolygnathus primitius*. This species is often associated with *Neogondolella navicula* (Huckriede), which becomes more common in Subzone II, and with fewer *M. nodosus* and *M. communisti*, which are rare in Subzone II. *Neogondolella navicula*, the appearance of which defines the base of the Upper *primitius* Zone, clearly occurs with Kerri Subzone I ammonoids, but its first appearance is not coincident with the base of the Kerri Zone at Pardonet Hill, where it appears several metres higher (GSC loc. C-101772). The significance of this is uncertain because *Neogondolella* occurs sporadically in the Pardonet Formation, and its absence may reflect some ecological control.

Conodont collections (e.g., GSC loc. O-98509, O-98898) that occur high in the Kerri Zone (above Subzone II collections) at Pardonet Hill carry a different conodont fauna consisting principally of *Epigondolella quadrata* n. sp. (= *E. abneptis* subsp. A of Orchard, 1983). The same conodont fauna is also associated with ammonoids of the overlying Dawsoni Subzone I at Brown Hill (GSC loc. O-97546), and probable correlatives on Pardonet Hill (e.g., GSC loc. O-98896). These represent the *quadrata* Zone (the *abneptis* A Zone of Orchard, 1983, 1991a).

Ammonoids of subzones II and III of the Dawsoni Zone are associated with conodonts referred to *Epigondolella abneptis* subsp. B by Orchard (1983) at Brown Hill (e.g., GSC loc. O-97544, O-97543, O-97542) and Childerhose Cove (GSC loc. O-98538); supplementary material from Black Bear Ridge (GSC loc. O-101033) occurs with undifferentiated Dawsoni Zone ammonoids. Most specimens included in *E. abneptis* subsp. B are now referred to *E. triangularis* (Budurov), which is the nominal species for the *triangularis* Zone (Orchard, 1991a). Two subdivisions of the nominal species are differentiated here. *Epigondolella t. uniformis* n. subsp. appears first and is followed by *E.* sp. aff. *E. spatulata* (Hayashi); both occur prior to confirmed Dawsoni Subzone II levels. Typical *E. t. triangularis* occurs first with Dawsoni Subzone II ammonoids.

Mosher (1973) reports three small collections from undifferentiated Dawsoni Zone at Crying Girl Prairie Creek, where "*Epigondolella abneptis*" occurred with juvenile neogondolellids identified by Mosher as *Neogondolella hallstattensis* (Mosher). This species, which is based on Austrian material, has not been recovered from any other sample from the Pardonet Formation and I regard the record as dubious; the species is, I suspect, biogeographically restricted (Orchard, 1991a).

The Magnus Zone is divided into two subzones, also with type sections at Brown Hill, from which conodonts are known. Mosher's samples included a Subzone II collection from Black Bear Ridge (GSC loc. O-64636), and an undifferentiated faunule from Mount McLearn (GSC loc. O-68191). Both collections are dominated by *Epigondolella triangularis*, and identical elements are typical of all Magnus Zone collections from Brown Hill and from Childerhose Cove (see Appendix). *Epigondolella t. triangularis* is more common in the Magnus Zone than the preceding Dawsoni Zone, and in Magnus Subzone II it is joined by uncommon *E. transitia* n. sp.

On the basis of the occurrence of the several new forms within the range zone of *Epigondolella triangularis* (Orchard, 1991a), the interval is provisionally divided into three parts, in total covering part of the Dawsoni Zone and the whole of the Magnus Zone (Fig. 3). The lower, middle, and upper parts of the *triangularis* Zone are differentiated by the successive appearance of, respectively, *E. t. uniformis*, *E. t. triangularis*, and *E. transitia*.

Middle Norian

The Middle Norian begins with the Rutherfordi Zone, which carries a distinctive conodont population of *Epigondolella multidentata* Mosher at its type locality at Brown Hill (Orchard, 1983). Mosher (1973) recorded two collections, one of which (GSC loc. O-46459) is the type locality for the conodont index species (re-illustrated herein) of the *multidentata* Zone (Orchard, 1983, 1991a). Mosher's report of *Neogondolella navicula* (Huckriede) from this locality is suspect because the successor species *N. steinbergensis* (Mosher) is generally characteristic of the Middle Norian.

Epigondolella multidentata also co-occurs with Rutherfordi Zone ammonoids at Crying Girl Prairie Creek and at Childerhose Cove (see Appendix). At both the latter locality and Brown Hill, *E. tozeri* n. sp. becomes dominant in the higher part of the section, presenting the basis for subdivision of the *multidentata* Zone into lower and upper parts. Mosher's second collection (GSC loc. O-64659) is also characterized by *E. tozeri* and is thought to be younger than the type population of *E. multidentata*. *Epigondolella matthewi* n. sp. is uncommon throughout the *multidentata* Zone.

The Middle Norian Columbianus Zone has undergone considerable refinement since Mosher's work. Four ammonoid subzones are now recognized, and three discrete horizons are recognized in Subzone I (Tozer, in press). Conodonts are known from the type locality of each of the horizons Ia (GSC loc. O-98885), Ib (GSC loc. O-98877), and Ic (GSC loc. O-98542) at Childerhose Cove, and a very large conodont collection is also known from Subzone Ib at Crying Girl Prairie Creek (GSC loc. O-83835). At Brown Hill (GSC loc. O-97525) and near the mouth of Carbon Creek (GSC loc. O-99593), conodonts occur with ammonoid faunas that are referred by Tozer (ibid.) to undifferentiated Columbianus Subzone I. All these collections except that from Subzone Ic carry the typical *Epigondolella* n. sp. C population of Orchard (1983), now referred largely to *E. spiculata* n. sp., the nominal species for the *spiculata* Zone (Orchard, 1991a). At Brown Hill (GSC loc. C-87924), an early example of the *E. spiculata* fauna first occurs high in the Rutherfordi Zone.

The section near Carbon Creek is significant in that it includes a fauna (shown as Lower *postera* Zone by Orchard, 1983, Fig. 12 M, N) dominated by *Epigondolella elongata* n. sp. in a collection (GSC loc. O-99594) from above the *E. spiculata* fauna and beneath the next younger *E. postera* (Kozur and Mostler) fauna. *Epigondolella elongata* also dominates the fauna from the type collection of Columbianus Subzone Ic, as well as in the highest conodont collection on Brown Hill (GSC loc. C-087926, not associated with ammonoids), and with undifferentiated Columbianus I ammonoids on Pardonet Hill (GSC loc. O-98518). These records constitute a new *elongata* Zone (Fig. 3). Elements referred to *E. tozeri* continue through this interval.

Columbianus Subzone II has yielded conodonts at its type locality at Crying Girl Prairie Creek (GSC loc. O-83834), whence Mosher (1973) earlier recovered a single undiagnostic conodont (GSC loc. O-46468). New conodont collections are known from this subzone at Black Bear Ridge (GSC loc. O-98549-98552), Childerhose Cove (GSC loc. O-98540, O-98879), and Pardonet Hill (GSC loc. O-98525), all of which are dominated by *Epigondolella postera* with fewer *E. carinata* n. sp. This ammonoid subzone often contains large numbers of *Neogondolella steinbergensis*, as does a single undifferentiated Columbianus Zone collection from Queen Charlotte Islands (GSC loc. C-157081) (Orchard, 1991a). The *postera* Zone (Orchard, 1983, 1991a) is the most widespread Middle Norian conodont zone in western Canada [Orchard, 1991b (*this volume*)].

Conodont faunas are known from Columbianus Subzone III at its type locality at Crying Girl Prairie Creek (GSC loc. O-97554), from Pardonet Hill (GSC loc. O-98524), and from Black Bear Ridge (GSC loc. O-98548): these are all characterized by *Epigondolella serrulata* n. sp., additional collections of which are known from the pelecypod *Eomonotis* bearing strata at Chert Mountain (GSC loc. C-101889), and on Rackla River (GSC loc. C-97565) in Yukon Territory. These records are assigned to the *serrulata* (=*Epigondolella* n. sp. D) Zone (Orchard, 1983, 1991a).

Conodonts from Columbianus Subzone IV, which is characterized by *Eomonotis pinensis* (Westermann), are relatively uncommon, largely because of the lack of productive lithotypes. An exception is on Pardonet Hill (GSC loc. O-98527) where the *Epigondolella serrulata* fauna is well represented. Elsewhere, a few small, indeterminate epigondolellids occur at this level on Black Bear Ridge (GSC loc. O-98546), but it is not possible to be sure that the *serrulata* Zone occurs there.

Upper Norian

In northeastern British Columbia, the top of the Pardonet Formation is generally characterized by the lowest of three Upper Norian ammonoid zones, the Cordilleranus Zone. This zone, which equates with the range of the pelecypod *Monotis*, has its type locality at Mount Ludington, from which Mosher (1973) reported two small conodont collections (GSC loc. O-68300, O-68304), then referred to the undivided Suessi Zone. Of the three *Epigondolella* species determined by Mosher (1973) in these collections, I consider only *E. bidentata* Mosher to be valid.

The Cordilleranus Zone is now divided into subzones I and II (Tozer, in press). Subzone I, to which Mosher's collections are assigned, has its type locality at Black Bear Ridge, from which large collections (GSC loc. O-98534) of *Epigondolella bidentata* are known. The type locality for Subzone II is near Bocock Peak, where the ammonoids occur with *Monotis ochotica* Keyserling, in contrast with Subzone I faunas that occur with *M. subcircularis* Gabb at this locality. There, conodonts are known from both Subzone I (GSC loc. O-98558), and from beds containing the younger monotids (but no ammonoids) at the top of the Pardonet Formation (GSC loc. C-101137). In addition, conodonts are known from *Monotis* beds at many other localities; these include Ne-Parle-Pas Rapids, Pardonet Hill, and Pine Pass in northeastern British Columbia, Dawson and Nash Creek areas of Yukon Territory, throughout Queen Charlotte Islands (see Orchard et al., 1990), and from scattered localities in the accreted terranes [Orchard, 1991b (*this volume*)]. All of these conodont collections are characterized by the *Epigondolella bidentata* population of Orchard (1983), which includes short and variably ornate forms, but excludes some bidentate elements discussed below. In Yukon Territory, *Neogondolella* is more common at this level. These faunas collectively constitute a lower subdivision of the *bidentata* Zone (Fig. 3).

Mosher (1973) reported no conodonts from post-*Monotis* Upper Norian strata in Canada, although he did report such faunas from Nevada (Mosher, 1968), where the Amoenum and Crickmayi zones are identified in the Gabbs Formation. The type locality for these latest Triassic ammonoid zones is in the Tyaughton Group of the Cadwallader Terrane in Taseko Lakes map area (Tozer, 1979), where the Amoenum Zone is represented by the pelecypod *Cassianella* beds. Conodonts from throughout these beds (GSC loc. C-116137-116142) fall within a broad concept of *Epigondolella* ex gr. *bidentata* (Orchard, 1991a), but include elements that I herein separate as *E. mosheri* (Kozur and Mostler) and *E. englandi* n. sp. I regard the former as diagnostic for an upper division of the *bidentata* Zone, whereas *E. englandi* appears earlier, although it is probably most common in this interval.

The Upper *bidentata* Zone is now also recognized in new collections from: the Lower and basal Middle Gabbs Formation (GSC loc. C-116516-116527); in many post-*Monotis* conodont faunules from the Sandilands Formation on Queen Charlotte Islands (see Orchard et al., 1990); near the base of the aerially restricted Bocock Limestone (GSC loc. C-101138) near Bocock Peak; in formation F (GSC loc. O-23407; Tozer, 1958, locality 15) and correlatives of the Lewes River Group in Laberge map area, Yukon Territory; and, questionably, in the *Rhacophyllites* beds (GSC loc. C-101760) at the top of the Pardonet Formation at Ne-Parle-Pas Rapids on Peace River, and in fissure filling (GSC loc. O-98529) at nearby Pardonet Hill. These samples are regarded as mostly Amoenum Zone in age, but may include basal Crickmayi Zone.

A single specimen of *Misikella posthernsteini* Kozur and Mock has been recovered from the "green sandstone and conglomerate unit" (GSC loc. C-117029) at Tyaughton Creek, the type unit and locality for the Crickmayi Zone. However, the only direct association of the index ammonoid *Choristoceras* and conodonts is in the Sandilands Formation, Queen Charlotte Islands (GSC loc. C-156526), where *M. posthernsteini* also occurs alone (Orchard, 1991a, p. 181). These records constitute the basis for a latest Triassic *posthernsteini* Zone, here differentiated in North America for the first time. A comparable interval is recognized in Europe within the higher parts of the Marshi ammonoid Zone, based on occurrences in both the Koessen beds (Golebiowski, 1986) and Zlambach Formation (Krystyn, 1988).

UPPER TRIASSIC CONODONT TAXONOMY

Through two decades of relatively intensive research on Upper Triassic conodonts, no consensus has yet emerged on an appropriate classification and nomenclature. Disagreement has centred on both the composition of the conodont apparatus, and, more importantly for biostratigraphy, a classification that reflects unambiguous species concepts and demonstrable successional relationships between the platform conodonts. In the absence of well dated, stratigraphic sequences of conodonts, problems arising from homeomorphy, compounded by sparse faunas, poor preservation, and inadequate illustration, have conspired to create the current confusion.

Triassic conodonts from the eastern Cordillera are well preserved, abundant, tightly constrained by ammonoid faunas, and generally occur in relatively stable carbonate sequences. These attributes result in a reliable faunal succession in which the phenomena of homeomorphy and neoteny, and the breadth of intraspecific variation within the conodont populations, can be recognized with more confidence. In contrast, conodonts from the condensed and fissured Hallstatt facies, and the redeposited, poorly preserved chert faunas of the Adoyama Formation in Japan—both important sources of many of the names currently employed in Upper Triassic conodont studies—present many taxonomic problems.

Below, I formally name those species that have been introduced in open nomenclature previously (Orchard, 1983, 1991a), and introduce several others that have biochronological significance. I focus on the stratigraphic origin of holotypes, and on biochronologically significant Canadian occurrences, but I have not attempted a comprehensive synonymy. Such attempts (e.g., Budurov and Sudar, 1990) are of dubious value in the absence of good illustration, thorough description, and well documented stratigraphy. The taxonomic classification that I present is not suprageneric, nor is it multielement—it is a utilitarian approach to defining key pectiniform elements of the Upper Triassic. As briefly discussed earlier (Orchard, 1991a), I recognize two principal Upper Triassic genera of platform conodonts (excluding neogondolellids), the largely Carnian *Metapolygnathus* Hayashi and the wholly Norian *Epigondolella* Mosher.

All Upper Carnian and Norian conodont species based on Canadian material are described below and illustrated in Plates 1-5; stereopairs are provided for holotypes. For most of these species, representative growth stages have been illustrated earlier either in Orchard (1983) for the Norian, or in Orchard (1991a) for the Upper Carnian. The reader is referred to the latter paper for illustration of Canadian examples of Upper Carnian species originally described from Europe and Japan.

SYSTEMATIC TAXONOMY

In the following synonymies I include only original and biochronologically significant Canadian records; I have adopted the Richter notation (see Matthews, 1973) for these records. Diagnoses are new or revised in all cases. Illustrated specimens are housed in the National Type Collection of Invertebrate and Plant Fossils at the Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8.

Genus *Epigondolella* Mosher

1968 *Epigondolella* n. gen. MOSHER, p. 935, 936.
1970 *Tardogondolella* n. gen. BENDER, p. 530.
1972 *Ancyrogondolella* n. gen. BUDUROV, p. 855, 857.
1990 *Mockina* n. gen. KOZUR, p. 423.

Type species. *Polygnathus abneptis* Huckriede, 1958.

Diagnosis. A group of gondolelloid species characterized by a well differentiated free blade, and large, discrete, and sharp anterior platform denticles that at least double the height of the platform. The profile of the lower surface of the elements is clearly stepped upward beyond the blade-platform junction, but may be downturned (in primitive species), straight, or upturned terminally. The cusp is rarely conspicuous. Element growth proceeds through relatively uniform accretion about the posterior platform expansion. A basal pit is generally located beneath the central or anterior part of the platform. Platform microreticulation is characteristically subdued and irregular, particularly in younger species (Orchard, 1983, Fig. 9).

Remarks. Epigondolella is here regarded as a wholly Norian genus, and ornate Carnian species are excluded. The generic diagnosis incorporates in part the distinction used by Krystyn (1980, p. 76) who separated *Metapolygnathus* and *Epigondolella* on the basis of the anterior denticulation: the former with no or weak nodes, and the latter with spine-like nodes. The criterion of recognizing at least a doubling of the overall platform height as diagnostic for *Epigondolella* effectively excludes Upper Carnian (and older) elements formerly assigned to the genus, including *"E". primitia*, which also displays typical *Metapolygnathus* lower profile, growth, pit location and microreticulation. All other species described by Orchard (1983) are retained within *Epigondolella* – I see no basis for discriminating *Ancyrogondolella* Budurov (see *E. triangularis*), nor do I see the value in separating *Mockina* Kozur, species of which are embraced by my new definition of *Epigondolella*.

The original description and illustration of the type species of *Epigondolella*, *E. abneptis*, is inadequate to enable a distinction to be made between several similar species, and, because the holotype is broken and partly lost (see below), the species is here restricted to the holotype. Subspecies of *E. abneptis* are now referred to new species.

Epigondolella abneptis (Huckriede)

vp* 1958 *Polygnathus abneptis* n. sp. HUCKRIEDE, p. 156, 157, Pl. 14, fig. 16 (only).

Holotype. Hu58/176, Philipps University, Marburg; Huckriede, 1958, Pl. 14, fig. 16.

Age of holotype. Within a mixed Lower to Middle Norian fauna (see below).

Type stratum. Hallstatt Limestone.

Type locality. Sommeraukogel, Austria.

Remarks. Huckriede (1958) established this poorly defined species on the basis of material derived from the *Cyrtopleurites bicrenatus* ammonoid Zone of the Hallstatt Limestone at Sommeraukogel. This zone had formerly been established by Mojsisovics (1893) based on ammonoids from unspecified levels within the outcrop. Krystyn (1980, p. 89, 90) noted that all the classical fossil localities originated within "a Fe-oxide rich subsolution facies of the Hangendrotkalk", in which three distinct fossil intervals of Lower (Patens Fauna), Middle (Bicrenatus Fauna), and Upper (Metternichi Fauna) Norian age are now known. According to Krystyn (*ibid.*), the Bicrenatus Lager *sensu* Mojsisovics was several metres thick and included the Lower Norian Patens Fauna and upper Middle Norian Halorites Fauna in addition to a lower Middle Norian Bicrenatus Fauna *sensu stricto*. Huckriede's *Epigondolella abneptis* presumably came from somewhere within this broad interval, but he gives no further information on the precise level of his "10 Proben" at locality 56d (Huckriede, 1958, p. 144). Because conodonts from all of Huckriede's (1958) samples at this locality were referred to *E. abneptis*, it follows that not only was Huckriede's concept of the species likely influenced by an admixture of elements of different ages, but the precise stratigraphic origin of the type specimen is also in doubt. The admixture is in fact evident from Huckriede's material, which I had an opportunity to study in 1982 (courtesy of G. Kaufmann, Marburg). Specimens referred to *Epigondolella abneptis* by Huckriede include, in my interpretation, examples of *E. postera*, *E. quadrata*, *E. spatulata*, *E. spiculata*, and *E. triangularis*. The holotype of the species, at that time in the custody of L. Krystyn (Vienna), occurs on a slide with five other specimens (including Hu58/173, 174, 177, 179, illustrated in Huckriede, 1958, Pl. 14, figs. 12, 13, 16, 17, 19). Assessment of these specimens was difficult because only two were unbroken and two, including the holotype, were incomplete. Only the anterior platform of the holotype remains, and although the original illustration shows an unornamented posterior platform, I do not regard this as sufficient to identify it as conspecific with elements that have subsequently become popularly known as *E. a. abneptis*. In fact, the revised diagnosis of "*E. abneptis*" by Mosher (1973) corresponds to *E. triangularis*.

For the reasons discussed above, I propose that the widely used but stratigraphically ill-defined *Epigondolella abneptis* be restricted to the type specimen. This does not affect its status as the type species of *Epigondolella* because the species is clearly an epigondolellid and as such it retains generic identity. This revision necessitates new names for subspecies of *E. abneptis*. This has been largely taken care of by previous revisors: *E. spatulata* has been recognized as a valid species, and *E. triangularis* largely replaces the informal *E. abneptis* subsp. B of Orchard (Orchard *in* Carter *et al.*, 1989, p. 28). New definition is thus required only for *E. abneptis* subsp. A Orchard = *E. a. abneptis* of authors, herein newly described as *E. quadrata*.

Epigondolella bidentata Mosher

Plate 4, figure 12

vp* 1968 *Epigondolella bidentata* n. sp. MOSHER, p. 936, Pl. 118, figs. 31-35 (only).
v 1973 *Epigondolella bidentata* Mosher. MOSHER, p. 160, Pl. 18, figs. 23, 24, 28.
v 1983 *Epigondolella bidentata* Mosher. ORCHARD, p. 188, 189, Figs. 15 V-X.
v 1989 *Epigondolella bidentata* Mosher. ORCHARD *in* Carter et al., Pl. 1, fig. 13.

Holotype. USNM 159229, US National Museum; Mosher, 1968, Pl. 118, fig. 35.

Age (ammonoid zone) of holotype. Metternichi Zone of Mojsisovics (Mosher, 1968, p. 904) of Late Norian, Late Triassic age.

Type stratum. At 37.8 m (= 124 ft.) above base of grey Hallstatt Limestone.

Type locality. Sample Sb-F1, Steinbergkogel by Hallstatt Salzberg, Austria.

Canadian occurrence. With ammonoids of the Cordilleranus and Amoenum zones, British Columbia and Queen Charlotte Islands. Older occurrences are problematic.

Diagnosis. A small, slender *Epigondolella* with a relatively short platform lying posterior to a pair of prominent, submedially located denticles; smaller accessory nodes may be irregularly developed marginally. The carina is developed to the posterior tip, and typically consists of 3-4, exceptionally 5, nodes beyond the lateral denticle pair; the posterior platform is typically shorter than the anterior blade. A small pit lies beneath the node pair within the posteriorly tapered basal scar.

Comparisons. The relative posterior platform length is shorter and wider than that of *Epigondolella mosheri*, which characteristically has at least 5, commonly more, carinal nodes posterior of the denticle pair. Rare specimens of the current species with five denticles are large, and have a posterior platform that is wide compared with the laterally reduced platform of *E. mosheri*. *Epigondolella englandi* has a consistently broader platform with strong, symmetrically arranged platform nodes. Small growth stages of older *Epigondolella* species may be indistinguishable from *E. bidentata*, but do not attain the same size. This problem was discussed by Orchard (1983, p. 189). Early growth stages of this species may resemble *Parvigondolella* Kozur and Mock but develop a platform and/or lateral nodes with growth.

Remarks. When Mosher (1968) introduced *Epigondolella bidentata*, he figured two mature specimens, one (the holotype) from Austria and the other from Nevada. The holotype originated high in a section of grey Hallstatt Limestone that Tozer (1980, p. 855, Table 2) regarded as belonging to the Amoenum Zone, although the precise level of the diagnostic collection is unknown. The Nevadan specimen subsequently formed the basis of *E. mosheri* (*q.v.*), which, as here interpreted, is typical of the Amoenum Zone. Typical *E. bidentata* faunas, as portrayed by Orchard (1983), characterize the Cordilleranus Zone but identical elements range upward into the Amoenum Zone where they are subordinate to *E. mosheri*. In spite of the restricted definition of *E. bidentata*, the present species concept includes forms that, unlike the holotype, have irregularly developed accessory platform nodes.

Figured material. Hypotype GSC 95281.

Epigondolella carinata n. sp.

Plate 5, figures 4, 5, 10

vp 1983 *Epigondolella postera* (Kozur and Mostler) population. ORCHARD, p. 186-8, Figs. 11A, C (only).

Etymology. Latin, *carina*, referring to the persistent development of an axial carina.

Holotype. GSC 95288, Pl. 5, figs. 4, 5, 10.

Age (ammonoid zone) of holotype. Subzone II, Columbianus Zone of Middle Norian, Late Triassic age.

Type stratum. Pardonet Formation.

Type locality. GSC loc. O-98525, Pardonet Hill, British Columbia.

Diagnosis. A relatively short *Epigondolella* with two large denticles on at least one anterior margin, commonly with one on the other margin, and several others on the tapered to subparallel posterior margins. The blade is short and the carina is low.

Comparisons. This species is introduced for relatively short elements of Middle to Late Norian age that have formerly been included in *Epigondolella postera* or "*E. abneptis*" by previous authors. They differ from *E. postera* in their straight, nonlobate platform, and from *E. tozeri* and *E. serrulata* in their relatively short platforms and fewer anterior nodes. *Epigondolella englandi* has only a single pair of anterior denticles. Very early growth stages of *E. triangularis* (Pl. 3, fig. 4) and the new species may resemble each other but later growth is strongly divergent. The holotype of *E. slovackensis* (Kozur, 1972) differs only in its precipitous posterior blade, whereas that of *E. humboldtensis* Meek has a significantly longer blade.

Remarks. These specimens occur with *Epigondolella postera* but apparently appear earlier, and survive longer. They may be derived from *E. tozeri* through reduction in overall length, relative blade length, and the number of anterior nodes. Reduction to a single pair of anterior nodes occurred in the Upper Norian *E. englandi*. The significance of variations in blade profile and length in otherwise very similar elements is uncertain, but both Budai and Kovács (1986) and Meek (1987) maintain that these are consistent, diagnostic features of their species, respectively, *E. slovackensis* and *E. humboldtensis*.

Figured material. Holotype GSC 95288.

Epigondolella elongata n. sp.

Plate 4, figures 4-6, 15, 20, 21

p 1983 *Epigondolella postera* Kozur and Mostler population. ORCHARD, p. 186-8, Figs. 12M, N (only).

Etymology. Latin, *elongatus*, referring to the relatively elongate platform of the species.

Holotype. GSC 95282, Pl. 4, figs. 15, 20, 21.

Age (ammonoid zone) of holotype. Subzone Ic, Columbianus Zone of Middle Norian, Late Triassic age.

Type stratum. Pardonet Formation.

Type locality. GSC loc. O-98542, Childerhose Cove, Peace River, British Columbia.

Diagnosis. An elongate *Epigondolella* characterized by one to three (and at least two on one side) large denticles on each anterior platform margin, and a generally smooth, long and narrow posterior platform that is about one half of the total unit length. A prominent carina composed of large nodes extends to the posterior end of the platform. A pit is located beneath the anterior third of the platform within a basal scar that extends close to the posterior tip.

Comparisons. The anterior platform node arrangement of the new species is like that of the younger *Epigondolella postera*, which is much shorter and has a broad, markedly lobate posterior platform. *E. matthewi* is much broader posteriorly, commonly has more anterior denticles, and has a carina that often does not extend to the posterior end of the platform. *Epigondolella multidentata* has a similarly shaped platform, but it has more anterior platform nodes and more numerous, posteriorly elevated carinal nodes.

Remarks. This species was formerly included in the *Epigondolella postera* population (Orchard, 1983, Fig. 12), but the species appears earlier and characterizes an interval immediately preceding typical *E. postera*. The new species resembles *E. multidentata* in both blade and lower surface morphology, and is thought to be an early derivative of that species. In common with other Middle to Upper Norian posteriorly unornamented species, a minor accessory node may appear on the posterior platform margin.

Figured material. Holotype GSC 95282, paratype GSC 95277.

Epigondolella englandi n. sp.

Plate 5, figures 9, 11, 13, 19, 20

Etymology. Named for T. England, who first collected and described this species for an undergraduate thesis at the University of British Columbia.

Holotype. GSC 95290, Pl. 5, figs. 11, 13, 19.

Age (ammonoid zone) of holotype. No independent dating on type collection, but regarded as Late Norian, Late Triassic in age. The species occurs in the Queen Charlotte Islands above *Monotis* faunas, and with *Cassianella* at the type locality of the Amoenum Zone in Taseko Lakes.

Type stratum. Lewes River Group.

Type locality. GSC loc. C-87005, 1 km northwest of Hill 4308, near Laurier Creek, Laberge map area, Yukon Territory.

Diagnosis. A small *Epigondolella* with an ovoid platform that has a pair of unequally developed but very high anterior denticles and additional pairs of smaller, but distinct, symmetrically arranged nodes on the posterior platform.

Comparisons. The bidentate platform resembles that of *Epigondolella bidentata* and *E. mosheri* but the new species has a much broader platform and stronger anterior denticles than either of these other Upper Norian species; the strong posterior ornament is the rule rather than the exception, as is the case in the other species. Early growth stages of all three species may be indistinguishable. The platform shape differs from that of rare bidentate elements of the lobate *E. postera.*

Remarks. This species appears to be the final stage in the development of a lineage that starts with the elongate and multidenticulate *Epigondolella tozeri*, gives way to the intermediate tridentate *E. carinata*, and ends with the short bidentate *E. englandi.* Each of these species has unevenly developed anterior denticles, with one denticle being distinctively larger than that on the opposite margin.

Figured material. Holotype GSC 95290, paratypes GSC 95289, GSC 95291.

Epigondolella matthewi n. sp.

Plate 4, figures 8-10

vp	1983	*Epigondolella multidentata* Mosher population. ORCHARD, p. 183, 185, figs. 8M-O (only).
vp	1983	*Epigondolella* n. sp. C population. ORCHARD, p. 185, 186, Fig. 10R (only).

Etymology. Named for my son, Matthew.

Holotype. GSC 95278, Pl. 4, figs. 8-10.

Age (ammonoid zone) of holotype. Rutherfordi Zone of Middle Norian, Late Triassic age.

Type stratum. Pardonet Formation.

Type locality. GSC loc. O-98876, Childerhose Cove, Peace River, British Columbia.

Diagnosis. A posteriorly rounded *Epigondolella* characterized by a relatively broad, biconvex platform that has two to four large denticles on each anterior platform margin and a largely unornamented posterior platform. The blade is composed of relatively few, large denticles that pass into a carina composed of several discrete nodes that usually do not reach the posterior end of the platform.

Comparisons. The species most closely resembles *Epigondolella postera* but is characteristically larger, usually relatively longer, has a more symmetrical posterior platform, and has more anterior nodes. The species is shorter and broader than *E. elongata* and *E. multidentata*, has a less developed posterior carina, and a blade that is shorter and composed of fewer denticles.

Remarks. This species appears near the base of the Middle Norian in association with the more slender and much more common *Epigondolella multidentata.* It persists as an uncommon element of the Rutherfordi Zone faunas and may represent the root stock for the *postera* radiation that occurred low in the Columbianus Zone.

Figured material. Holotype GSC 95278.

Epigondolella mosheri Kozur and Mostler

Plate 4, figures 11, 13, 14

vp	1968	*Epigondolella bidentata* n. sp. MOSHER, p. 936, Pl. 118, fig. 36 (only).
v	1970	*Epigondolella bidentata* Mosher. MOSHER, Pl. 110, figs. 27, 28.
*	1971	*Tardogondolella mosheri* n. sp. KOZUR and MOSTLER, p. 15.
v	1991a	*Epigondolella* ex. gr. *bidentata* Mosher. ORCHARD, Pl. 4, fig. 22.

Holotype. USNM 159234, US National Museum; Mosher, 1968, Pl. 118, fig. 36.

Age (ammonoid zone) of holotype. Probably Amoenum Zone of Late Norian, Late Triassic age.

Type stratum. Uppermost Luning Formation or basal Gabbs Formation.

Type locality. Sample NYL-19, New York Canyon, Nevada.

Canadian occurrence. Within *Cassianella* beds containing Amoenum Zone ammonoids in Tyaughton Creek, and bracketed by *Monotis* and Crickmayi Zone ammonoids on Queen Charlotte Islands.

Diagnosis. A small, typically very slender *Epigondolella* with a relatively long, narrow or incipiently developed platform lying posterior to a pair of prominent denticles, which may be unevenly reduced to little more than a pair of swellings. The carina is prominent throughout, consisting of at least five (as in the holotype), but as many as ten denticles posterior to the lateral denticle pair; this part of the unit is generally longer than the blade and is always narrower than the anterior end of the platform. A small pit lies within a narrow pointed scar at a point beneath the node pair.

Comparisons. This species has been combined with *Epigondolella bidentata* in the past, and their separation is difficult when the elements have not attained a certain minimum length; this is the same problem that impacts on discrimination of *E. bidentata* (*q.v.*) from early growth stages of older species. Certainly, the presence of six or more posterior carinal nodes is only seen in the Upper Norian faunas studied from above the Cordilleranus Zone. The presence of five posterior nodes, as in the holotype, is common in the Amoenum Zone but is only seen in large specimens from the Cordilleranus Zone, where transitional specimens have a broader posterior platform. The species is also similar to *E. elongata*, but it is much smaller, has more carinal nodes, and typically has only two, as opposed to at least three prominent denticles.

Remarks. Kozur and Mostler (1971) established this species on the basis of an illustrated paratype of *Epigondolella bidentata* in Mosher (1968, 1970). Mosher (1973) rejected this separation on the grounds that the element merely showed a continuation of an ontogenetic trend that he had demonstrated in his earlier work. Whereas Mosher (1973) was correct in his observations of growth trends, the relative dimensions of the platform and number of posterior carinal nodes in the holotype of *E. mosheri* are not seen at a comparable growth stage in *E. bidentata*, as the identical magnification of Mosher's specimens reveals. Nevertheless, relatively small specimens from the Amoenum Zone are probably indistinguishable from *E. bidentata* to which, according to new definition, they should be referred. In later growth, there is an emphasis on longitudinal growth in *E. mosheri*, whereas *E. bidentata* tends to broaden; both may have minor accessory platform nodes.

The stratigraphic level of the holotype of *Epigondolella mosheri* is ambiguous: both Luning and Gabbs formations are mentioned in Mosher's work, although the name Luning Formation appears on the USNM slide. I assume the age of the enclosing strata is Amoenum Zone because the index ammonoid *Cochloceras* occurs throughout the Lower Gabbs Formation, and *E. mosheri* is now known to be typical of the same level in Canada.

Figured material. Hypotypes GSC 95279, GSC 95280.

Epigondolella multidentata Mosher

Plate 4, figures 1-3, 7

v* 1970 *Epigondolella multidentata* n. sp. MOSHER, p. 739, Pl. 110, figs. ?19, 22-22, ?26.

v 1973 *Epigondolella multidentata* Mosher. MOSHER, p. 160, Pl. 18, figs. 15, 18-22, ?25-27.

v 1983 *Epigondolella multidentata* Mosher. ORCHARD, p. 183, 185, Figs. 15 J-L.

Holotype. GSC 25055, Mosher, 1970, Pl. 110, figs. 22-24. Re-illustrated in Plate 4, figs. 1-3.

Age (ammonoid zone) of holotype. Rutherfordi Zone of Middle Norian, Late Triassic age.

Type stratum. Pardonet Formation.

Type locality. GSC loc. O-46459, "White Creek", east of Crying Girl Prairie Creek, north of Peace River, British Columbia.

Diagnosis. An *Epigondolella* with an elongate, sometimes sinuous platform that tapers progressively from the broadest part at the anterior end to a pointed or narrowly truncated posterior end. The anterior platform commonly bears three to five high, sharp denticles on each margin, whereas the posterior platform is mostly unornamented apart from a possible accessory node (as in the holotype). The free blade is about one third unit length, consists of up to eight denticles that form a convex crest, descends onto the platform and continues as a prominent, partly fused carina that is conspicuously higher at the posterior end. On the lower surface, the pit lies beneath the anterior part of the platform, whereas the keel tapers to a point close to the posterior end. Microreticulae are relatively weakly developed.

Comparisons. The smooth posterior platform and strong anterior nodes were regarded as diagnostic by Mosher (1970) who, however, did not note the distinctive high, fused posterior carina, here regarded as key to the recognition of the species. *Epigondolella elongata* has a similar platform shape but has fewer anterior nodes, whereas *E. tozeri* has a more ornate platform; both species have more discrete carinal nodes.

Remarks. Epigondolella multidentata appears abruptly at the base of the Middle Norian in the Pardonet Formation, dominating a fauna (summarized as the *E. multidentata* population by Orchard, 1983) that is far more diverse than that immediately preceding it. Mosher (1970, p. 739, 740) thought that the present species developed from similarly shaped specimens of "*E. abneptis*" through posterior node loss, but such elements figured by Mosher are thought to be derivatives rather than ancestors (see *E. tozeri*). I think it is more likely that *E. multidentata* developed from a posteriorly unornamented predecessor, perhaps through retention of morphology seen in juvenile *E. triangularis*.

In the literature, *Epigondolella multidentata* has been given a broader interpretation than can be justified on the basis of topotype collections. I here restrict the species to narrow, elongate specimens with a largely unornamented posterior platform and a very prominent posterior carina. The species is short ranging, and probably biogeographically restricted; I regard records from outside British Columbia as unauthenticated.

Figured material. Holotype GSC 250557, hypotype GSC 95276.

Epigondolella postera (Kozur and Mostler)

Plate 4, figures 16-19

* 1971 *Tardogondolella abneptis postera* n. subsp. KOZUR and MOSTLER, p. 14, 15, Pl. 2, figs. 4-6.

v 1983 *Epigondolella postera* (Kozur and Mostler). ORCHARD, p. 186-188, Figs. 15 P-R.
v 1989 *Epigondolella postera* (Kozur and Mostler). ORCHARD *in* CARTER et al., Pl. 1, fig. 15.
v 1991 *Epigondolella postera* (Kozur and Mostler). ORCHARD, Pl. 4, fig. 21.

Holotype. M VII/25 (repository unknown); Kozur and Mostler, 1971, Pl. 2, figs. 4a-c.

Age of holotype. Of undifferentiated Middle Norian, Late Triassic age.

Type stratum. Hallstatt Limestone.

Type locality. Sommeraukogel, Austria.

Canadian occurrence. With Columbianus Subzone II ammonoids in the Peace River area, British Columbia.

Diagnosis. A relatively short *Epigondolella* with a distinctive anterior denticulation commonly consisting of one prominent denticle on one platform margin and two on the other. The posterior platform is typically unornamented except for the nodes of the carina that may or may not be continuous to the posterior end of the platform. Posterior platform margins are often asymmetrical, with one margin being strongly convex. The blade is short and high, and descends relatively abruptly onto the platform. The pit is located anterior to platform midlength.

Comparisons. This species differs from *Epigondolella elongata* in being much shorter, and having a markedly asymmetrical, lobate posterior platform. Accessory nodes may occur on the posterior margin but specimens are neither as strongly ornate nor as narrow posteriorly as *E. carinata* (*q.v.*). The *E. slovackensis* population described by Budai and Kovács (1986) includes elements that differ from *E. postera* only in the posteriorly precipitous blade. Specimens of *E. postera* may superficially resemble early growth stages of *E. triangularis* but the latter are much smaller, have different blade and platform profiles, and do not have a lobate posterior platform.

Remarks. The morphological breadth of this species is uncertain because topotype collections have not been described. In this paper, my species concept is more restricted than the *E. postera* population of Orchard (1983) for I exclude both elongate elements (= *E. elongata*) and narrow, posteriorly ornate elements (= *E. carinata*).

Figured material. Hypotypes GSC 95283, GSC 95284.

Epigondolella quadrata n. sp.

Plate 2, figures 1-3, 7-9, ?10, ?12

v 1983 *Epigondolella abneptis* subsp. A ORCHARD, p. 179, 181, Figs. 15 D-F.

Etymology. Latin, *quadratus*, referring to the shape of the posterior platform.

Holotype. GSC 95265, Pl. 2, figs. 1-3.

Age (ammonoid zone) of holotype. Subzone II, Kerri Zone of Early Norian, Late Triassic age.

Type stratum. Belemnoid *Aulacoceras* bed, Pardonet Formation.

Type locality. GSC loc. C-101768, Pardonet Hill, British Columbia.

Diagnosis. An *Epigondolella* with a flat, mostly unornamented, commonly rectangular posterior platform with variably pointed, posterolaterally extended corners. In profile, the blade is up to one half unit length, is composed of 9-12 denticles, and rises from both anterior and posterior ends in a low convex crest; the lower surface of the platform is clearly stepped up from the blade but distinctly downturned posteriorly. Carinal nodes, numbering 3-5, are discrete and commonly small except for the posteriormost one, which often dominates the centre of the posterior platform; a small node may occur beyond it. The lateral margins of the anterior platform bear a few large, discrete and sharp denticles that at least double the height of the platform. The lower surface bears a centrally located pit, small surrounding loop, and a basal scar that commonly bifurcates, to some extent, posterior to the pit. Dense microreticulae are largely confined to the posterior platform and are most pronounced peripherally.

Comparisons. As shown by Orchard (1983, Fig. 5), the length to breadth ratio of the platform of this species shows a marked shift compared to its predecessor *Metapolygnathus primitius*, reflecting the relatively shorter and broader platform. Further differences between the latter and the new species are in node prominence and lower surface profile (cf. Pl. 1, fig. 14 and Pl. 2, fig. 3), microreticulation, and the pointed, posterolaterally extended corners of many specimens, which is very rarely seen in *Metapolygnathus*. Some elements of *Epigondolella quadrata* may show a medial constriction reminiscent of its metapolygnathid predecessors (e.g., *E. permica sensu* Krystyn, 1973), particularly when posterolateral expansion is pronounced; however, the anterior nodes are much larger than in *Metapolygnathus*. The profile and lower surface morphology of *E. quadrata* is shared with *E. spatulata* and *E. triangularis*, although these species show decreased posterior downarching, increased bifurcation of the basal scar, and a diminishing relative blade length; most obviously, they differ in posterior ornamentation. Posteriorly smooth Middle Norian elements, which lack a posterior carina (possibly including the holotype of *E. abneptis*) have different profiles.

Remarks. Kozur (1990) regarded this species (formerly *Epigondolella abneptis* subsp. A) as conspecific with the holotype of *Metapolygnathus primitius* (*q.v.*), which it clearly is not. Elements questionably included in this species (Pl. 2, figs. 10, 12) have different posterior platform shapes, but are otherwise very similar.

Figured material. Holotype GSC 95265, paratype GSC 95266, plus hypotype GSC 95267.

Epigondolella serrulata n. sp.

Plate 5, figures 12, 14-18

v 1983 *Epigondolella* n. sp. D ORCHARD, p. 188, 189, Figs. 15 S-U, fig. 13.

Etymology. From the latin *serrula*, saw-like, referring to the sharp platform denticles.

Holotype. GSC 68864, Pl. 5, figs. 17, 18.

Age (ammonoid zone) of holotype. Subzone III, Columbianus Zone of Middle Norian, Late Triassic age.

Type stratum. Pardonet Formation.

Type locality. GSC loc. O-98548, Black Bear Ridge, Peace River, British Columbia.

Diagnosis. A relatively small, elongate *Epigondolella* with a narrowly biconvex, thin and flat platform that tends to taper at both anterior and posterior ends; the middle platform has subparallel margins, or may be broadest at midpoint. At about one third of the platform length from the anterior end of the platform there are commonly a pair of prominent, slightly to strongly outwardly directed denticles; similar but smaller denticles occur on margins of both the anterior and, less commonly, the posterior platform. The free blade is about one quarter unit length, and is composed of four to five denticles that form a convex crest. The carina is composed of large discrete nodes that extend to the posterior end of the unit, and often project beyond it. The lower surface has a small, submedial pit surrounded by a long basal scar with very prominent edges.

Comparisons. The small, outwardly directed platform denticles and relatively thin, flat, delicate platform contrast with *Epigondolella tozeri* in which denticles are larger, relatively upright and more strongly developed at both extremities of the platform. The platform shape of this species also differs from other epigondolellids in having a platform that does not end as abruptly anteriorly. The relatively short length of the free blade is also exceptional compared with other elongate and ornate species of the Middle Norian.

Figured material. Holotype GSC 68864, paratypes GSC 95292, GSC 95293.

Epigondolella spatulata (Hayashi)

Plate 2, figures 4-6, 11

* 1968a,b *Gladigondolella abneptis spatulata* n. subsp. HAYASHI, p. 69, Pl. 2, figs. 5a-c.

Holotype. AD 67/19 (repository unknown); Hayashi, 1968a, Pl. 2, figs. 5a-c.

Age of holotype. Within a mixed Middle–Upper Triassic fauna. The species is Early Norian in age elsewhere in the Tethyan region.

Type stratum. Chert at base of the Adoyama Formation.

Type locality. Near Kuzu-Machi, Tochigi Prefecture, central Japan.

Canadian occurrence. Possibly in Lower Norian strata of the Bridge River and Cadwallader groups of south central British Columbia. No independent ammonoid dating in Canada.

Diagnosis. A relatively short, subcircular *Epigondolella* characterized by a strongly expanded posterior platform that constitutes between two thirds and three quarters of unit length. A pair of large, commonly transversely elongate nodes occur on the short anterior platform margins, posterior to which the platform is abruptly and roundly expanded. Low nodes occur on all platform margins, and may form secondary carinas. The keel is commonly bifurcated posterior to the pit.

Comparisons. This species is shorter and relatively more expanded than both *Epigondolella quadrata* and *E. triangularis.*

Remarks. The holotype of *Epigondolella spatulata* is a relatively small specimen that closely resembles the holotype of the co-occurring *Metapolygnathus echinatus*, which itself has an uncertain identity (Orchard, 1991a). Nevertheless, the popular, although here more restricted concept of the species is adopted in this paper pending a fuller understanding of both the holotype and the variability of typical populations, which I have yet to find in the Canadian Cordillera. The illustrated specimen, from Timor, was kindly provided by L. Krystyn (Vienna) and illustrates what may be typical morphology of the species. Posterior ornamentation is subdued in the present material, but is stronger in similar Lower Norian Tethyan specimens of this species illustrated by Mosher (1968) from the Hallstatt Limestone, and by Koike (1982) from the Taho Limestone in Japan. Similar elements from British Columbia are here referred to *E.* aff. *E. spatulata* (*q.v.*). Many authors have regarded all posteriorly ornate, quadrate elements ("*E. abneptis*") as belonging to *E. spatulata* (e.g., Kozur, 1980, p. 750), a practice that has obscured both biochronological and biogeographic realities.

Figured material. Hypotypes GSC 95268, GSC 95269.

Epigondolella sp. aff. *E. spatulata* Hayashi

Plate 2, figures 13-17

vp 1983 *Epigondolella abneptis* subsp. B population. ORCHARD, p. 181-183, figs. 6 N, S (only).

Remarks. Specimens included here occur in association with *Epigondolella triangularis*, but are much shorter than the latter. They resemble *E. spatulata* in platform outline but they have relatively longer, unexpanded anterior platform margins, and are not as conspicuously expanded posteriorly. These specimens occur in association with ammonoids of both Dawsoni and Magnus zones in northeastern British Columbia and are probably co-eval with *E. spatulata*; separation as a geographic subspecies may be appropriate.

Figured material. GSC 95270, GSC 95271.

Epigondolella spiculata n. sp.

Plate 3, figures 10, 14, 15

v 1983 *Epigondolella* n. sp. C ORCHARD, p. 185, 186, Figs. 15 M-O.

v 1991a *Epigondolella* n. sp. C Orchard. ORCHARD, Pl. 4, figs. 18-20.

Etymology. Latin, *spiculum*, referring to the highly ornate, posterior platform in which projecting sharp denticles produce a characteristic spiky outline.

Holotype. GSC 95274, Pl. 3, figs. 10, 14, 15.

Age (ammonoid zone) of holotype. Subzone Ia, Columbianus Zone of Middle Norian, Late Triassic age.

Type stratum. Pardonet Formation.

Type locality. GSC loc. O-98877, Childerhose Cove, Peace River, British Columbia.

Diagnosis. An *Epigondolella* with an asymmetrical, subrectangular platform that has, in upper view, a pronounced convexity of the outer posterior margin; in profile, the unit has a characteristic flat to convex base with the posterior platform clearly upturned. The blade is one quarter to one third unit length, and is commonly composed of five to seven denticles, which are highest toward the anterior end; it declines strongly to the posterior and ends abruptly on the anterior platform. The discrete nodes of the carina are small at first, but become larger toward the posterior where they are aligned and often connected to a node on the posterior margin that is invariably more prominent than the preceding carinal nodes. Several large anterior denticles occur on each anterior platform margin, and may be higher on one side. Additional sharp nodes are often unevenly developed, with the outer posterior margin being more ornate; these nodes project beyond the platform margin giving the unit a serrated appearance. In lower view, the basal scar is relatively broad and flat, and has only slightly raised edges; the posterior margin of the scar is often obliquely truncated but may be straight or weakly indented; in rare cases, it may be bifurcate but in these examples the indentation does not extend to the pit. The small pit is located slightly to the anterior of the platform midpoint, and a groove extends anteriorly within the tapered scar, which continues as a broad strip beneath the blade. Platform microreticulae are poorly developed.

Comparisons. The new species differs from *Epigondolella triangularis* in the following: the profile of both the lower margin and generally shorter blade; the common asymmetry in both plan view and in denticle development; the depth, width and posterior outline of the basal scar, rarity of a marked bifurcation, and a less pronounced loop surrounding the pit (Orchard, 1983, p. 185); the anterior nodes that tend to be longer, more discrete, sharper, and curved posteriorly; a carina that extends further posteriorly, and tends to be connected to nodes of the posterior margin; and in the common absence of a prominent carinal node on the posterior platform. See also *E. tozeri* and *E. transitia*.

Remarks. This is the species that accounts for many of the Middle Norian records of "*E. abneptis*", and the homeomorphic development may be startling in isolated Middle Norian specimens, particularly when they approach plan view symmetry, which, however, they rarely do.

Figured material. Holotype GSC 95274.

Epigondolella tozeri n. sp.

Plate 5, figures 1-3, 6-8

vp	1970	*Epigondolella abneptis* (Huckriede). MOSHER, Pl. 110, figs. 14,18 (only).
vp	1983	*Epigondolella multidentata* Mosher population. ORCHARD, p. 183, 185, Figs. 8E, F (only).

Etymology. Named for E.T. Tozer (GSC Vancouver).

Holotype. GSC 95287, Pl. 5, figs. 6-8.

Age (ammonoid zone) of holotype. Subzone I, Columbianus Zone of Middle Norian, Late Triassic age.

Type stratum. Pardonet Formation.

Type locality. GSC loc. O-98518, Pardonet Hill, Peace River, British Columbia.

Diagnosis. A strongly denticulate *Epigondolella* with two to four high anterior platform denticles and strong nodes on the tapered to subparallel margins of the pointed to narrowly truncated posterior platform. Discrete carinal nodes extend without significant elevation to the posterior end of the unit. The lower surface has a pit beneath the anterior third of the platform, and a basal scar that is quite broad posteriorly.

Comparisons. The new species differs from *Epigondolella multidentata* in having strong nodes consistently developed posteriorly, and in lacking a high posterior carina. It differs from *E. spiculata* in both the relative symmetry of the posterior platform, and in the strong continuous carina. *Epigondolella serrulata* is consistently smaller, has a thinner, more biconvex platform with smaller, often outwardly directed nodes, and a relatively shorter blade. The platforms of comparable growth stages of *E. triangularis* are posteriorly expanded, broadly truncated, and have no posterior carina.

Remarks. Elements of this species have been previously included in the generalized "*Epigondolella abneptis*" because of the posteriorly ornate platform, or in *E. multidentata* because of the long carinate platform, but neither are appropriate. Mosher (1970, p. 739, 740) regarded these elements as "advanced... *E. abneptis*" from which *E. multidentata* was derived through posterior node loss. However, I think it is more probable that *E. tozeri* developed from *E. multidentata* through the gain of posterior ornament, and/or from *E. triangularis* via *E. transitia* through the complete suppression of one posterolateral lobe. It follows that the species, as currently defined, may include elements with more than one origin, but the type collection is definitely younger than *E. multidentata*.

Growth in this species has some parallels with that of *Epigondolella triangularis* in that small specimens are pointed but posterior nodes added as growth proceeds result in a broadening of the element, and may result in a rectangular posterior end, as in the holotype. However, growth appears to be largely longitudinally directed, with specimens becoming relative longer with increase in size; this contrasts with the emphasis on lateral outgrowth of the posterior platform in *E. triangularis*.

Figured material. Holotype GSC 95287, paratypes GSC 95285, GSC 95286.

Epigondolella transitia n. sp.

Plate 3, figures 11-13

vp 1983 *Epigondolella abneptis* subsp. B population. ORCHARD, p. 181-183, Figs. 6C, E (only).

Etymology. Latin *transitus*, referring to the transitional morphology of the species between typical Lower and Middle Norian *Epigondolella*.

Holotype. GSC 95275, Pl. 3, figs. 11-13.

Age (ammonoid zone) of holotype. Subzone II, Magnus Zone of Early Norian, Late Triassic age.

Type stratum. Pardonet Formation.

Type locality. GSC loc. O-98537, Childerhose Cove, Peace River, British Columbia.

Diagnosis. A strongly ornate *Epigondolella* in which one posterolateral lobe is more strongly developed than the other, thus producing a marked posterior asymmetry. The main anterior carina and one secondary carina on the posterior lobe produces the impression of a continuous carina close to the posterior tip. The lower surface has a central to anteriorly shifted pit, and an asymmetric keel that reflects the asymmetry of the platform and carina development.

Comparisons. The strong asymmetry of the ornate posterior platform distinguishes this species from other Lower Norian species, particularly *Epigondolella triangularis*, which is otherwise very similar and from which the new species clearly developed. Both *E. spiculata* and *E. transitia* have asymmetric posterior platforms, and tend to develop posteriorly continuous carinas, but *E. spiculata* (*q.v.*) is distinguished from the present species by most of the same criteria that separate it from *E. triangularis*. Compare, for example, their lower profiles (Pl. 3, figs. 13, 15). Also, in *E. spiculata*, the inner margin tends to be straight and the posterior outer margin is broadly convex, whereas in *E. transitia* both margins tend to be inturned beyond platform midlength. Furthermore, platform nodes are sharper and more outwardly directed in *E. spiculata* (compare lower views).

Figured material. Holotype GSC 95275.

Epigondolella triangularis (Budurov) *sensu lato*

Plate 3, figures 4-6

* 1972 *Ancyrogondolella triangularis* n. sp. BUDUROV, p. 857, Pl. 1, figs. 3-6.

1983 *Epigondolella abneptis* subsp. B ORCHARD, p. 181-183, Figs. 15 G-I.

Holotype. Bu 2103/1 (repository unknown); Budurov, 1972, Pl. 1, figs. 3-6. Re-illustrated by Budurov and Sudar, 1990, Pl. 6, figs. 3, 4.

Age of holotype. Of undifferentiated Early Norian, Late Triassic age.

Type stratum. "Alaunian limestones".

Type locality. Kalberstein Quarry, southeast of Kalberstein, Berchtesgaden Alps, Bavaria, Germany.

Canadian occurrence. In association with Dawsoni Subzone II through Magnus Zone ammonoids, Lower Norian, northeastern British Columbia.

Description. An *Epigondolella* with a strongly ornate, almost symmetrical platform that is subquadrate to triangular in the posterior half. In profile, the lower surface of the posterior platform is stepped upward from that of the blade but typically downturned terminally. The blade has about seven to nine denticles and commonly has its maximum height at about midlength, although this is variable in young populations; it descends onto the platform and passes into discrete, round carinal nodes that are commonly terminated by a prominent node that lies at the centre of the posterior platform, and which rises above adjacent marginal nodes. Lateral nodes are particularly prominent on the anterior margins and are upright, sharp, and generally discrete; secondary nodes on the posterior platform sometimes merge diagonally into secondary carinae. The lower surface bears a basal scar that surrounds the subcentrally located pit, which is surrounded by a small, relatively prominent loop. The basal scar has a distinct edge and is commonly posteriorly bifurcated with secondary keels extending toward the posterolateral corners; the posterior indentation of the scar commonly extends close to the pit.

Comparisons. Quadrate elements may be confused with some elements of *Epigondolella spiculata* (*q.v.*), but there are many differences: generally, the profile, symmetry, node and carina formation, and basal scar differ. Early growth stages of *E. triangularis* (Pl. 3, figs. 4-6) have pointed platforms and continuous carinas and thus may resemble some Middle Norian species, but larger specimens are quite different. *Epigondolella quadrata* is unornamented posteriorly; *E. transitia* has pronounced posterior asymmetry; *E. spatulata* and related elements are much shorter and have relatively more expanded, subcircular posterior platforms.

Remarks. Epigondolella triangularis dominates the *E. abneptis* subsp. B population of Orchard (1983), but several similar morphotypes are recognized within the former population. There is a trend within the Lower Norian toward increased platform ornament and posterolateral expansion, and decreased relative blade length in this species. On the basis of posterior platform morphology, I herein differentiate two subspecies of *E. triangularis*, which have different stratigraphic ranges. Early growth stages of these subspecies are probably indistinguishable, and the species concept is useful for immature specimens (as illustrated).

Figured material. GSC 68853.

Epigondolella triangularis triangularis (Budurov)

Plate 3, figures 7-9

v 1989 *Epigondolella triangularis* Budurov. ORCHARD *in* CARTER et al., Pl. 1, fig. 12.
v 1991a *Epigondolella triangularis* Budurov. ORCHARD, Pl. 4, fig. 12.

Holotype, type stratum, locality, and age. As for species.

Canadian occurrence. In association with Dawsoni Subzone II through Magnus Zone ammonoids, Lower Norian, northeastern British Columbia.

Diagnosis. A subspecies of *Epigondolella triangularis* in which the posterior half of the platform is bulbous or triangular due to accentuated posterolateral growth.

Comparisons. The laterally expanded, triangular posterior platform typical of large elements is not seen in any Middle Norian species, and in older taxa with a similar platform shape, the posterior is not heavily ornamented.

Remarks. Budurov and Sudar (1990) retained the genus *Ancyrogondolella* for this species based on their interpretation of one posterolateral lobe as lateral in position; in their interpretation, the element is a strongly asymmetric unit. On the contrary, in my view the elements are symmetrically expanded posteriorly, as is evident from the nature of the basal structure. This is not a unique development amongst Upper Triassic platform conodonts – keel bifurcation also occurs in large elements of *E. quadrata*, *E. spatulata*, *Metapolygnathus primitius*, and *M. nodosus* – and generic separation on this basis is not warranted.

Figured material. Hypotype GSC 95273.

Epigondolella triangularis uniformis n. subsp.

Plate 3, figures 1-3

Etymology. Latin, *uniformis*, referring to the uniformly developed, unexpanded posterior platform.

Holotype. GSC 95272, Pl. 3, figs. 1-3.

Age (ammonoid zone) of holotype. Dawsoni Zone of Early Norian, Late Triassic age.

Type stratum. Pardonet Formation.

Type locality. GSC loc. C-101057, Pardonet Hill, Peace River, British Columbia.

Diagnosis. A subspecies of *Epigondolella triangularis* characterized by a relatively uniform development of the posterior platform, which commonly retains subparallel margins throughout growth, and does not become strongly expanded. Posterior ornament is commonly weaker than in the nominal subspecies.

Comparisons. See *Epigondolella triangularis.*

Remarks. This is the first epigondolellid to develop distinct ornamentation on the posterior platform. However, this is not accompanied by strong posterolateral growth as in the nominal subspecies.

Figured material. Holotype GSC 95272.

Genus *Metapolygnathus* Hayashi

1968a *Metapolygnathus* gen. nov. HAYASHI, p. 72.

Type species. *Metapolygnathus communisti* Hayashi, 1968.

Diagnosis. Gondolelloid species that typically have a reduced platform anterior of variably pronounced geniculation points, and relatively coarse and compact platform microreticulation that covers both platform margins and nodes in most species (Orchard, 1983, Fig. 8). Species may be unornamented or show varying degrees of node formation, which can be subdued in some species, well developed in others, but never as pronounced as in *Epigondolella*; nodes are relatively small with a maximum amplitude less than one half of the total platform height. In lateral profile, the lower surface of *Metapolygnathus* is regularly concave and the posterior platform downturned. Growth characteristically proceeds through dual outgrowth of the anterior and, later, posterior portions of the platforms so as to commonly produce a marked submedial to posterior constriction in early to medium growth stages. The carina is always low and does not reach the posterior platform margin, which is characteristically rounded or, in late growth stages, subquadrate. A basal pit is located beneath the posterior half of the platform.

Remarks. As here conceived, *Metapolygnathus* ranges throughout the Carnian and into the basal Norian. Species of *Metapolygnathus* have previously been referred to the genera *Gondolella*, which I regard as a wholly Upper Carboniferous gondolelloid genus, *Neogondolella* and *Paragondolella*, which are more appropriate for Middle Triassic species, and *Epigondolella*, now restricted to Norian species. All Carnian species are now brought to *Metapolygnathus*, regardless of whether they are ornate: the prevalent philosophy of making generic assignments based purely on such a feature, without regard to phyletic relationships, is rejected. All these species share diagnostic characters as described above; of these, lower surface profile, node height, microreticulation, and mode of growth represent new criteria for separation of *Metapolygnathus* and *Epigondolella* species.

Metapolygnathus communisti Hayashi

* 1968 *Metapolygnathus communisti* gen. et sp. nov. HAYASHI, p. 72, Pl. 3, figs. 11a-c.
1968a,b *Gladigondolella abneptis echinatus* n. subsp. HAYASHI, p. 68, 69, Pl. 2, figs. 1a-c.
v 1989 *Metapolygnathus communisti* HAYASHI. ORCHARD *in* CARTER et al., Pl. 1, figs. 7.
v 1991a *Metapolygnathus communisti* HAYASHI. ORCHARD, p. 175, Pl. 2, figs. 14-24.

Holotype. AD67/34 (repository unknown); Hayashi, 1968a, Pl. 3, figs. 11a-c.

Age of holotype. Within a mixed Middle–Upper Triassic fauna. The species is Late Carnian–Early Norian in age elsewhere in the Tethyan region.

Type stratum. Chert at base of the Adoyama Formation.

Type locality. Near Kuzu-Machi, Tochigi Prefecture, central Japan.

Canadian occurrence. In association with ammonoids of the Macrolobatus Zone and less commonly with those of the Kerri Zone, Upper Carnian–Early Norian, Peace River area and Queen Charlotte Islands, British Columbia.

Diagnosis. A *Metapolygnathus* with a weakly- to unornamented, longitudinally and/or laterally reduced platform, particularly in early growth stages; in some small specimens the platform is vestigial. Larger specimens may have a high anterior parapet or geniculation point, but nodes are uncommon. The basal pit is typically more anteriorly located than in older metapolygnathids.

Comparisons. Large specimens are similar to *Metapolygnathus primitius*, but lack the distinct nodes on the anterior platform. As with large specimens of *M. nodosus*, both noded and smooth varieties occur, but in the present species, the pit is more anteriorly located. Small specimens of *M. communisti* (including the holotype of *''Gladigondolella'' echinatus*) show considerable variation in platform development (Orchard, 1991a).

Remarks. As Krystyn (1980, p. 76) noted, *Metapolygnathus communisti* is a mixture of highly evolved smooth (*M. polygnathiformis*) and nodose (*M. nodosus*) specimens with a basal pit migrating toward the centre of the platform. In this respect, the species represents an early development of the basal configuration found in Norian *Epigondolella*, a feature it shares with *M. primitius*.

Metapolygnathus lindae n. sp.

Plate 1, figures 1-3

v 1991a *Metapolygnathus* n. sp. E ORCHARD, p. 176, Pl. 1, figs. 1-6.

Etymology. Named for my wife, Linda.

Holotype. GSC 95194, Orchard, 1991a, Pl. 1, fig. 2, and re-illustrated on Pl. 1, figs. 1-3.

Age (ammonoid zone) of holotype. Subzone I, Welleri Zone of Late Carnian, Late Triassic age.

Type stratum. Ludington or Pardonet Formation (talus block).

Type locality. GSC loc. O-42306, near Mile Post 428 (680 km) on Alaska Highway, Tuchodi Lakes map area, British Columbia.

Diagnosis. An elongate *Metapolygnathus* characterized by a strong posterior platform constriction, generally subdued anterior platform nodes, and a variably reduced anterior platform. The posteriormost platform is often asymmetrically developed and inturned. The anterior platform narrows abruptly in the anterior one quarter to one third, but commonly extends to near the anterior tip of the blade. The low blade descends onto the platform opposite the geniculation points and continues as a row of discrete and round, low nodes. The subterminal cusp is weakly differentiated and occupies a central position within the reduced posterior platform. The lower surface has a subterminal pit surrounded by a well developed loop.

Comparisons. This early derivative of the *Metapolygnathus nodosus* stock is narrower and more elongate than other similarly noded species, and the posterior constriction and asymmetry is more pronounced. *Metapolygnathus communisti* has a more anteriorly located pit. *Metapolygnathus reversus* has a more uniformly developed platform and blade denticles that are more discrete and less differentiated from the carinal nodes.

Remarks. Further reduction of the anterior platform and increased lateral node differentiation is thought to have led to *Metapolygnathus zoae*. An opposite trend results in forms close to *M. reversus*.

Figured material. Holotype GSC 95194.

Metapolygnathus nodosus (Hayashi)

* 1968a,b *Gladigondolella abneptis nodosa* n. subsp. HAYASHI, p. 69, Pl. 2, figs. 9a-c.

v 1989 *Metapolygnathus nodosus* (Hayashi). ORCHARD *in* CARTER et al., Pl. 1, fig. 3.

v 1991a *Metapolygnathus nodosus* (Hayashi). ORCHARD, p. 176, Pl. 2, figs. 8-13; Pl. 3, fig. A.

Holotype. AD/67/23 (repository unknown); Hayashi, 1986a, Pl. 2, figs. 9a-c.

Age of holotype. Within a mixed Middle–Upper Triassic fauna. The species is Late Carnian-Early Norian in age elsewhere in the Tethyan region.

Type stratum. Chert at base of Adoyama Formation.

Type locality. Near Kuzu-Machi, Tochigi Prefecture, central Japan.

Canadian occurrence. Mostly with ammonoids of the Welleri and Macrolobatus zones, rarely with Kerri Zone ammonoids, Upper Carnian–Early Norian, northeastern British Columbia and Queen Charlotte Islands.

Diagnosis. A *Metapolygnathus* with highly variable platform ornamentation ranging from non-nodose (particularly in larger specimens), to weakly nodose (typical), to distinctly but irregularly nodose where the anterior and/or lateral platform margins are incised. Advanced specimens may have discrete, usually irregular anterior nodes, but they are not clearly elevated above the posterior platform margins. Strong posterior platform constriction is typical of early growth stages, whereas in large specimens, the platform fills out and nodes commonly coalesce and become indistinct.

Comparisons. Most closely allied to *Metapolygnathus primitius*, which differs in the relative development of the anterior platform nodes, as illustrated by Orchard (1991a). Nodes of *M. nodosus* are more irregular and develop through incision of the platform margins, which otherwise retain a regular height. In *M. primitius*, the nodes are more discrete and clearly rise above the platform margins, which are depressed posteriorly.

Remarks. Elements presently included in *Metapolygnathus nodosus* have a wide range of both platform shape and node formation. Stratigraphically meaningful subdivision of the species may be possible in future, but discrimination of *M. carpathica* (Mock) does not appear to be practical in my collections.

Metapolygnathus ex gr. *polygnathiformis*

(Budurov and Stefanov)

* 1965 *Gondolella polygnathiformis* sp. nov. BUDUROV and STEFANOV, p. 118, 119, Pl. 3, fig. 7.
v 1989 *Metapolygnathus* ex. gr. *polygnathiformis* Budurov and Stefanov. ORCHARD, *in* CARTER et al., Pl. 1, fig. 4.
v 1991a *Metapolygnathus* ex. gr. *polygnathiformis* Budurov and Stefanov. ORCHARD, p. 176, Pl. 4, figs. 1, 3, 4.

Holotype. BAN, No. 90 (repository unknown); Budurov and Stefanov, 1965, Pl. 3, fig. 7.

Age (ammonoid zone) of holotype. Aon Zone of Early Carnian, Late Triassic age.

Type stratum. Unspecified.

Type locality. South end of village of Snezha, Burgas District, Bulgaria.

Canadian occurrence. With Nanseni and Dilleri Zone ammonoids, Carnian, northeastern British Columbia.

Diagnosis. A group of metapolygnathids with subquadrate platforms with unornamented margins of uniform height. The platform is generally broadest at midlength or anterior of that point. Relatively broad adcarinal troughs, and round, discrete carinal nodes are typical.

Comparisons. During growth, platforms generally develop more uniformly compared with *Metapolygnathus nodosus*, do not develop marginal nodes, and have the broadest part of the platform developed further anteriorly than in typical *M. nodosus*. The presence of a posterior brim in all specimens, the rounder and more discrete carinal nodes, and the narrower lateral zones of platform reticulae may also set the species apart from the younger derivatives.

Remarks. The Lower Carnian type of *Metapolygnathus polygnathiformis* is probably not the same species that has been consistently identified in the Upper Carnian in association with *M. nodosus*. Features outlined above appear to provide a basis for separating them, but more data on Lower Carnian elements are needed.

Metapolygnathus primitius (Mosher)

Plate 1, figures 13-15

v* 1970 *Epigondolella primitia* n. sp. MOSHER, p. 740, 741, Pl. 110, figs. 7-13, 16, 17.
v 1973 *Epigondolella primitia* Mosher. MOSHER, p. 161, Pl. 18, figs. 1-5, 7-11.
v 1983 *Epigondolella primitia* Mosher. ORCHARD, p. 178, 179, Figs. 15 A-C.
v 1989 *Epigondolella primitia* Mosher. ORCHARD *in* CARTER et al., Pl. 1, fig. 16.
v 1991a *Metapolygnathus primitius* (Mosher). ORCHARD, p. 176, Pl. 2, figs. 1-7; Pl. 3, fig. F.

Holotype. GSC 25051, Mosher, 1970, Pl. 110, figs. 8, 11, 12. Re-illustrated in Pl. 1, figs. 13-15.

Age (ammonoid zone) of holotype. Subzone II, Kerri Zone of Early Norian, Late Triassic age.

Type stratum. Pardonet Formation.

Type locality. GSC loc. O-64654, Brown Hill, Peace River, British Columbia.

Diagnosis. A *Metapolygnathus* with the anterior half of the platform having two to five uniformly developed, discrete, roundly terminated nodes of moderate size on each margin. These nodes, when viewed laterally, project above the level of the platform, which is relatively flattened and depressed posterior to the nodes. The platform nodes tend to coalesce in very large specimens. The posterior platform is typically broad, subquadrate, and carries no peripheral nodes. The free blade is well developed being about one third unit length and has a convex upper profile; it descends onto the platform and continues as a row of discrete carinal nodes, the terminal of which is prominent and lies well in front of the posterior margin. Microreticulae cover most of the platform, including the nodes (Orchard, 1983, fig. 3A), and are absent only from the adcarinal area. In profile, the unit is evenly arched, with a slight step at the pit, and downturned posteriorly. The small pit and prominent loop is typically located to the posterior of platform midlength but well in front of the broad, truncated posterior termination of the keel, which may be posterolaterally expanded in very large specimens.

Comparisons. See *Metapolygnathus nodosus* and *Epigondolella quadrata.*

Remarks. This species is the last of the metapolygnathids and shares all of the characters of that genus as newly defined. Kozur's (1990, p. 402, 403) recent assertion that the holotype of *Metapolygnathus primitius* is identical to ''*Epigondolella abneptis*'' (= *E. quadrata*) cannot be upheld, as revealed by new illustration of the holotype: it is clearly not the same as *E. quadrata*, nor does it have the large, sharp denticles and lower profile typical of *Epigondolella* species as newly defined. Similarly, I find no basis in my material for Kozur's separation of older Upper Carnian specimens of *M. primitius* from the Lower Norian populations (including the holotype) based on the number of anterior nodes and the position of the basal pit: in my collections, these features are judged to be intraspecific variables in populations throughout the range of *M. primitius*.

The holotype of *Gladigondolella abneptis permica* Hayashi, from the Adoyama chert in Japan, appears to be very similar to this species and may be a senior synonym. I have chosen not to synonymize them because the nature, variability, and stratigraphic origin of *Metapolygnathus primitius* is well established, whereas that is not true of the species from Japan.

Figured material. Holotype GSC 25051.

Metapolygnathus pseudoechinatus (Kozur)

* 1990 *Epigondolella pseudoechinata* n. sp. KOZUR, p. 430, 431.

v 1991a *Metapolygnathus echinatus* (Hayashi). ORCHARD, p. 175, 176, Pl. 1, figs. 19, 21-6; Pl. 3, fig. E.

Holotype. AD/67/15 (repository unknown); KOVÁCS and KOZUR, 1980, Pl. 11, fig. 4.

Age (ammonoid zone) of holotype. Macrolobatus Zone of latest Tuvalian (Late Carnian), Late Triassic age (Kovács and Kozur, 1980).

Type stratum. Not specified.

Type locality. Sample T-245/A, Alsohegy, northern Hungary.

Canadian occurrence. Above Upper Carnian Welleri Subzone II ammonoids on the Queen Charlotte Islands, and beneath Lower Norian Kerri Zone ammonoids in northeastern British Columbia.

Diagnosis. A *Metapolygnathus* characterized by a long blade up to two thirds total unit length, and a short subquadrate platform that bears small, usually sharp marginal denticles, particularly on the anterior part. Platform microreticulation is typical of *Metapolygnathus* species.

Comparisons. This species is similar to some early growth stages of *Metapolygnathus communisti* but is more ornate, and has a relatively shorter blade. It differs from species of *Epigondolella* in the relative size of platform nodes, platform microreticulation, blade length, and basal profile.

Remarks. As noted earlier (Orchard, 1991a), the holotype of *Metapolygnathus echinatus* was poorly illustrated and of uncertain affinity. Recently, Kozur (1990) concluded that the latter species is an early growth stage of *M. communisti* and established a new name to accommodate those distinctive forms that have previously been referred to "*Epigondolella*" *echinata.* These forms are the end members of the newly recognized Upper Carnian metapolygnathid lineage (Orchard, 1991a) and are unrelated to *Epigondolella.* Derivation from *M. samueli* is easily visualized and the two species occur in sequence in both northeastern British Columbia and Queen Charlotte Islands.

Metapolygnathus reversus (Mosher)

Plate 1, figures 4-6

v* 1973 *Neogondolella reversa* new species MOSHER, p. 169, 170, Pl. 20, figs. 9, 10, 13, 15-17.

Holotype. GSC 29990, Mosher, 1973, Pl. 20, figs. 9, 10, 16. Re-illustrated in Pl. 1, figs. 4-6.

Age (ammonoid zone) of holotype. Subzone II, Welleri Zone of Late Carnian, Late Triassic age.

Type stratum. Jovites bed, Blaa Mountain Formation.

Type locality. GSC loc. O-51650, Buchanan Lake, Axel Heiberg Island, Arctic Archipelago, District of Franklin, Northwest Territories.

Diagnosis. A *Metapolygnathus* with an elongate platform that has a medial constriction within otherwise subparallel margins, a tapered anterior one-quarter platform with indistinct nodes at poorly defined geniculation points, and a rounded posterior one quarter platform with a distinct brim around the subterminal cusp. There is no free blade, and the carina is composed of low, discrete, ovoid denticles that diminish in size toward the medial constriction. The grooved keel expands toward the posterior where a pit is surrounded by a prominent oval loop.

Comparisons. This species differs from other neogondolellid-like Upper Triassic species in having irregular growth of the platform margins, poorly defined but nevertheless present geniculation points, and a metapolygnathid-like lower surface. A reversal during growth from a medially broad to medially restricted platform was cited as diagnostic by Mosher (1973).

Remarks. In addition to its metapolygnathid attributes outlined above, this species is brought to *Metapolygnathus* because its ontogeny essentially involves dual outgrowth of anterior and posterior parts, as is regarded typical of the genus as newly defined. The species is stratigraphically separated from both Ladinian and Norian neogondolellid taxa, and I think it probably developed, possibly from *M. lindae*, through uniform development of the blade/carina denticles and anterior platform. Clearly, its tentative referral to the Middle and Upper Norian ''*Paragondolella*'' *steinbergensis* by Budurov and Sudar (1990, p. 213) is inappropriate because that species has an even, tapered platform and large terminal cusp. Although the platform of the holotype of *M. reversus* appears smooth at low magnification, it does possess remnant microreticulation at the margins; the specimen is apparently corroded and/or recrystallized.

Figured material. Holotype GSC 29990.

Metapolygnathus samueli n. sp.

Plate 1, figures 10-12

v 1991a *Metapolygnathus* n. sp. G ORCHARD, p. 176, Pl. 1, figs. 12-18; Pl. 3, figs. C, D.

Etymology. Named for my son, Samuel.

Holotype. GSC 81244, Pl. 1, figs. 10-12, and also in Orchard, 1991a, Pl. 1, fig. 15, Pl. 3, fig. D.

Age (ammonoid zone) of holotype. Not independently dated at the type locality, but nearby on Kunghit Island, the species occurs above Welleri Subzone II and below Macrolobatus Zone collections of Late Carnian, Late Triassic age.

Type stratum. Peril Formation, Kunga Group.

Type locality. GSC loc. O-157037, west coast of Huston Inlet, Queen Charlotte Islands, British Columbia.

Diagnosis. A relatively long *Metapolygnathus* characterized by small, sharply terminated nodes, usually on all platform margins, but particularly on the anterior two thirds. A constriction occurs in the posterior third of the platform, beyond which the marginal nodes may be less developed. The posterior platform is typically rectangular and may be laterally expanded, particularly in late growth stages. The pit is located close to the posterior end of the basal keel and is surrounded by a prominent loop; the keel may be slightly bifurcate in large specimens. The blade forms a low convex crest in profile.

Comparisons. This is similar to *Metapolygnathus pseudoechinatus*, but that species has a much shorter platform and a relatively long blade. *Metapolygnathus primitius* has larger, more round-tipped nodes which are, furthermore, confined to the anterior platform; the blade is also longer in the latter species, and the lower surface has a more anteriorly located pit. *Epigondolella* species have significantly larger platform denticles (Orchard, 1991a, Pl. 3). In superficially similar *Budurovignathus* species, the basal structure is quite different, with a pit lying more anteriorward within a pointed keel.

Remarks. This species is interpreted as a derivative of *Metapolygnathus zoae* (Orchard, 1991a, Fig. 4). The trend for the anteriormost platform nodes of the latter species to become sharper has been noted (Orchard, 1991a, Pl. 3, fig. C), and in *M. samueli* the posterior platform nodes may resemble those typical of *M. zoae*. Hence, the development and increased differentiation of the platform nodes seems to have been progressive in a posterior direction. In the next younger species, *M. pseudoechinatus*, the overall platform length decreased and the relative blade length increased.

In upper surface morphology, *Metapolygnathus samueli* is homeomorphic after *Budurovignathus diebeli* (Kozur and Mostler) from the Cordevolian (Lower Carnian) of Hungary, which is thought to be the last representative of an upper Ladinian–Lower Carnian lineage. The Upper Carnian lineage (Orchard, 1991a) of which *M. samueli* forms part, is interpreted as being iteratively evolved and unrelated to the older *Budurovignathus.*

Figured material. Holotype GSC 81244.

Metapolygnathus stephanae n. sp.

Plate 1, figures 16-20

v 1991a *Metapolygnathus* n. sp. K ORCHARD, p. 176, Pl. 4, figs. 6,7.

Etymology. Named in memory of Stephanie, late mother of Peter Krauss, GSC conodont technician.

Holotype. GSC 95249, Pl. 1, figs. 18-20, and also in Orchard, 1991a, Pl. 4, fig. 6.

Age (ammonoid zone) of holotype. Macrolobatus Zone of Late Carnian, Late Triassic age.

Type stratum. Peril Formation, Kunga Group.

Type locality. GSC loc. C-157123, Huxley Island, Queen Charlotte Islands, British Columbia.

Diagnosis. A small *Metapolygnathus* with a short blade and equally short, equidimensional platform with upturned margins bearing low anterior nodes.

Comparisons. The short, equidimensional, bowl-like platform is unlike that of any other metapolygnathid. Small elements of *Metapolygnathus communisti* have much longer blades and relatively flat platforms. Early growth stages of *M. nodosus* are more elongate. In other respects, the species resembles *M. nodosus.*

Remarks. This species is a late derivative of *Metapolygnathus nodosus* and has a restricted occurrence about the Carnian–Norian boundary.

Figured material. Holotype GSC 95249, paratype GSC 95264.

Metapolygnathus zoae n. sp.

Plate 1, figures 7-9

v 1991a *Metapolygnathus* n. sp. F ORCHARD, p. 176, Pl. 1, figs. 7-11; Pl. 3, fig. B.

Etymology. Named for my daughter, Zoe.

Holotype. GSC 95203, Pl. 1, figs. 7-9, and also in Orchard, 1991a, Pl. 1, fig. 11, Pl. 3, fig. B.

Age (ammonoid zone) of holotype. Not independently dated at the type locality, but nearby on Kunghit Island, the species occurs above Welleri Subzone II and below Macrolobatus Zone collections of Late Carnian, Late Triassic age.

Type stratum. Peril Formation, Kunga Group.

Type locality. GSC loc. O-157037, west coast of Huston Inlet, Queen Charlotte Islands, British Columbia.

Diagnosis. A relatively elongate metapolygnathid characterized by about four large, well defined but low, circular nodes on each anterior platform margin. The free blade is about one third unit length and in some specimens forms a relatively high convex profile. The basal pit is surrounded by a prominent loop and occupies a position near the posterior end of the narrow keel.

Comparisons. This species differs from *Metapolygnathus nodosus* in having much larger, more prominent and, in upper view, more rounded anterior platform nodes. Viewed in profile, the nodes are much broader but not significantly higher than those of *M. nodosus* (Orchard, 1991a, Pl. 3, fig. B). In advanced specimens, the anteriormost nodes may become sharp, as in *M. samueli.* Platform dimensions may be similar to *M. lindae*, but that species does not possess the distinctive anterior ornament. *Metapolygnathus primitius* has much more differentiated, upstanding anterior nodes.

Remarks. This derivative of *Metapolygnathus lindae* is the first distinctly ornate member of the newly recognized Upper Carnian lineage (see *M. samueli*). The high blade and slightly anterior shifted basal pit of the holotype are variable features in this species, although the blade is often higher than in *M. samueli.*

Figured material. Holotype GSC 95203.

Genus *Misikella* Kozur and Mock

1974a *Misikella* n. gen. KOZUR and MOCK, p. 135, 136.

Type species. *Misikella longidentata* Kozur and Mock, 1974a.

Misikella posthernsteini Kozur and Mock

Plate 5, figure 21

* 1974b *Misikella posthernsteini* n. sp. KOZUR and MOCK, p. 247, 248, figs. 1-4.

Holotype. No catalogue number given; State Museum, Meiningen.

Age of holotype. Alleged *Choristoceras*-bearing strata, "Rhaetian", Late Triassic in age.

Type stratum. "Silica-Decke".

Type locality. Malw Mylnskw vrch, Slovenskw kras, Slowackei.

Canadian occurrence. With Upper Norian Crickmayi Zone ammonoids on the Queen Charlotte Islands, and within correlative strata in the Tyaughton Group of Taseko Lakes area.

Remarks. This very young Triassic species is included here to emphasize the fact that it is known from Canada. The species is characteristic of the latest Triassic in Europe, but my limited material does not yet permit a thorough appraisal. Fåhraeus and Ryley (1989) have proposed different multielement apparatuses for this species and for the type species of *Misikella*, *M. longidentata* Kozur and Mock; they have consequently referred the present species to a new multielement genera, *Axiothea*. I have been unable to reconstruct this apparatus in my material and so I have used the form generic name.

Figured material. Hypotype GSC 95294.

ACKNOWLEDGMENTS

I thank E.T. Tozer (GSC, Vancouver) for his invaluable guidance in establishing relative ages of the conodont faunas, for his companionship in the field, his flow of wisdom on matters Triassic, and his comments on an earlier version of this manuscript. C. Ryley (GSC, Calgary) is also thanked for his helpful review of the manuscript. L. Krystyn (Vienna) kindly provided specimens of *Epigondolella spatulata* from Timor, and showed me the holotype of *E. abneptis*; G. Kaufmann (Marburg) arranged a viewing of additional Upper Triassic conodonts described by Huckriede; J. Repetski (Reston) arranged a loan of Mosher's types of *E. bidentata* and *E. mosheri* from the U.S. National Museum. P. Krauss is thanked for photography, T. Olivieric for drafting, and S. Irwin for help in compilation.

REFERENCES

Bender, H.
1970: Zur Gliederung der Mediterranen Trias II. Die Conodontenchronologie der Mediterranen Trias. Annales Géologiques des Pays Hélleniques, ser. 1, v. 19 (for 1968), p. 465-540.

Budai, T. and Kovács, S.
1986: A Rezi Dolomit retegtani helyzete a Keszthelyi-hegysegben; contributions to the stratigraphy of the Rezi Dolomite Formation [*Metapolygnathus slovackensis* (Conodonta, Upper Triassic) from the Keszthely Mts (W. Hungary)]. Magyar Allami Foldtani Insezet Evi Jelentese Az 1984, p. 175-191.

Budurov, K.
1972: *Ancyrogondolella triangularis* genus and new species (Conodonten). Mitteilungen der Gesellschaft der Geologie und Bergbaustudenten in Österreich, v. 21, p. 853-860.

Budurov, K. and Stefanov, S.
1965: Gattung *Gondolella* aus der Trias Bulgariens. Académie Bulgarien des Sciences, Traveaux géologiques de Bulgare, série Paléontologie, v. 7, p. 115-127.

Budurov, K. and Sudar, M.N.
1990: Late Triassic Conodont Stratigraphy. Courier Forschungsinstitut Senckenberg, v. 118, p. 203-239.

Carter, E.S., Orchard, M.J., and Tozer, E.T.
1989: Integrated ammonoid-conodont-radiolarian biostratigraphy, Late Triassic Kunga Group, Queen Charlotte Islands, British Columbia. *In* Current Research, Part H, Geological Survey of Canada, Paper 89-1H, p. 23-30.

Fåhraeus, L.E. and Ryley, C.C.
1989: Multielement species of *Misikella* Kozur and Mock, 1974 and *Axiothea* n. gen. (Conodonta) from the Mamonia Complex (Upper Triassic), Cyprus. Canadian Journal of Earth Sciences, v. 26, p. 1255-1263.

Golebiowski, R.
1986: Neue Misikellen-Funde (Conodonta) und ihre Bedeutung für die Abgrenzung des Rhat s. str. in den Kossener Schichten, Sitzungsberichten der Österreichische. Akademie der Wissenschaften in Wien, Mathematisch-Naturwissenschaftliche Klasse, v. 195, p. 53-65.

Hayashi, S.
1968a: The Permian conodonts in chert of the Adoyama Formation, Ashio Mountains, central Japan. Earth Science, v. 22, no. 2, p. 63-77.
1968b: Redescription of the new forms proposed in "The Permian conodonts in chert of the Adoyama Formation, Ashio Mountains, Central Japan" 1968 by Shingo Hayashi. Earth Science, v. 22, no. 6, 1 p.

Huckriede, R.
1958: Die Conodonten der Mediterranen Trias und ihr stratigraphischer Wert. Paläontologische Zeitschrift, v. 32, p. 141-175.

Koike, T.
1982: Review of some platform conodonts of the Middle and Late Triassic in Japan. Science Reports of the Yokohama National University, sec. II, no. 29, p. 15-27.

Kovács, S. and Kozur, H.
1980: Stratigraphische Reichweite der wichtigsten Conodonten (ohne Zahnreihenconodonten) der Mittel- und Obertrias. Geologisch Palaontologische Mitteilungen Innsbruck, v. 10, no. 2, p. 47-78.

Kozur, H.
1972: Die Conodontengattung *Metapolygnathus* Hayashi, 1968 und ihr stratigraphischer Wert. Geologisch Paläontologische Mitteilungen Innsbruck, v. 2, no. 11, p. 1-37.
1980: The main events in the Upper Permian and Triassic conodont evolution and its bearing to the Upper Permian and Triassic stratigraphy. Rivista Italiana di Paleontologica e Stratigrafia, v. 85, no. 3-4, p. 741-766.
1990: The taxonomy of the gondolellid conodonts in the Permian and Triassic. Courier Forschungsinstitut Senckenberg, v. 117, p. 409-469.

Kozur, H. and Mock, R.
1974a: Zwei neue Conodonten-Arten aus der Trias des Slowakischen Karstes. asopis pro mineralogii a geologii, v. 19, p. 135-139.

Kozur, H. and Mock, R. (cont'd.)
1974b: *Misikella posthernsteini* n. sp. die jungste Conodontenart der tethyalen Trias. asopis pro mineralogii a geologii, v. 19, p. 245-250.

Kozur, H. and Mostler, H.
1971: Probleme der Conodontenforschung in der Trias. Geologisch Paläontologische Mitteilungen Innsbruck, v. 1, no. 4, p. 1-19.

Krystyn, L.
1973: Zur Ammoniten- und Conodonten-Stratigraphie der Hallstatter Obertrias (Salzkammergut, Österreich). Verhandlungen der Geologischen Bundesanstalt, Austria, no. 1, p. 113-153.
1980: Triassic conodont localities of the Salzkammergut region (northern Calcareous Alps). *In* H.P. Schönlaub (ed.), Second European Conodont Symposium, Guidebook and Abstracts; Abhandlungen der Geologischen Bundesanstalt, Austria, v. 35, p. 61-98.
1988: Zur RHAT-Stratigraphie in den Zlambach-Schichten (vorlaufiger Bericht). Sitzungsberichten der Österreichische Akademie der Wissenschaften in Wien, Mathematisch-Naturwissenschaftliche Klasse, 196/1, p. 21-36.

Matthews, S.C.
1973: Notes on open nomenclature and on synonymy lists. Palaeontology, v. 16, p. 713-719.

Meek, R.H.
1987: A new Late Triassic (Norian) conodont species. Journal of Paleontology, v. 61, no. 1, p. 196-197.

Mojsisovics, E. von
1893: Die Cephalopoden der Hallstätter Kalke. Abhandlungen geologischen Reichsanstalt Wien, vol. 6, pt. 2, p. 1-835.

Mosher, L.C.
1968: Triassic conodonts from western North America and Europe and their correlation. Journal of Paleontology, v. 42, no. 4, p. 895-946.
1970: New conodont species as Triassic guide fossils. Journal of Paleontology, v. 44, no. 4, p. 737-742.
1973: Triassic conodonts from British Columbia and the northern Arctic Islands. Geological Society of Canada, Bulletin 222, p. 141-193.

Orchard, M.J.
1983: *Epigondolella* populations and their phylogeny and zonation in the Upper Triassic. Fossils and Strata, no. 15, Oslo, p. 177-192.

Orchard, M.D. (cont'd.)
1991a: Late Triassic conodont biochronology and biostratigraphy of the Kunga Group, Queen Charlotte Islands, British Columbia. *In* Evolution and Hydrocarbon Potential of the Queen Charlotte Basin, British Columbia, G.J. Woodsworth (ed.); Geological Survey of Canada, Paper 90-10, p. 173-193.
1991b: Conodonts, time and terranes: an overview of the biostratigraphic record in the western Canadian Cordillera. *In* Ordovician to Triassic Conodont Paleontology of the Canadian Cordillera, M.J. Orchard and A.D. McCracken (eds.); Geological Survey of Canada, Bulletin 417 (*this volume*).

Orchard, M.J., Carter, E.S., Tozer, E.T. (paleontological data); Forster, P.J.L., Lesack, K., McKay, K. (compilers); Weston, M., Woodsworth, G.J., Orchard, M.J., Johns, M. (database design)
1990: Electronic database of Kunga Group biostratigraphic data. Geological Survey of Canada, Open File 2284.

Tozer, E.T.
1958: Stratigraphy of the Lewes River Group (Triassic), Central Laberge area, Yukon Territory. Geological Survey of Canada, Bulletin 43, 28 p.
1967: A standard for Triassic time. Geological Survey of Canada, Bulletin 156, 103 p.
1979: Latest Triassic ammonoid faunas and biochronology, western Canada. *In* Current Research, Part B, Geological Survey of Canada, Paper 79-1B, p. 127-135.
1980: Latest Triassic (Upper Norian) ammonoid and *Monotis* faunas and correlations. Rivista Italiana di Paleontologia e Stratigrafia, v. 85, p. 843-876.
in press: Canadian Triassic ammonoid faunas. Geological Survey of Canada, Bulletin.

Weston, M.L., Woodsworth, G.J., Orchard, M.J., and Johns, M.J.
1991: Design of an electronic database for biostratigraphic data. *In* Evolution and Hydrocarbon Potential of the Queen Charlotte Basin, British Columbia, G.J. Woodsworth (ed.); Geological Survey of Canada, Paper 90-10, p. 545-554.

APPENDIX A

Conodont collections

All Canadian Upper Triassic conodont collections that are known to occur in direct association with ammonoids, or age-diagnostic pelecypods, are listed below within the framework provided by the ammonoid zonation. Many key conodont collections occur between diagnostic macrofaunas, but they are excluded from the current list. The collections, which are identified by both GSC locality numbers (prefix O- or C-) form the basis of the calibration described above under biochronology and depicted in Figure 3.

Collections recovered by Mosher (1973, p. 182-85) are indicated in parentheses; all others were recovered by the author. In addition to Mosher's material, collections derived from ammonoid matrix donated by E.T. Tozer are indicated in parentheses ("matrix"). Collections are from the Pardonet Formation, Peace River area, British Columbia, unless stated otherwise.

Lower Carnian

Desatoyense Zone

GSC loc. O-68127, Ludington Formation in the Mount McLearn–Ewe Mountain area (Mosher; formerly assigned to Obesum Zone).

Obesum Zone

GSC loc. O-42308, type locality in Ludington Formation at Ewe Mountain (Mosher).

Nanseni Zone

GSC loc. O-42310, type locality in Ludington Formation at Ewe Mountain (Mosher, matrix); not GSC loc. O-26124 (Mosher), now tentatively referred to Welleri Zone.

Upper Carnian

Dilleri Zone

GSC loc. O-86293, Quatsino Formation at Klaskino Inlet on Vancouver Island (matrix); GSC loc. C-157006, Sadler Limestone at Huston Inlet, Queen Charlotte Islands; GSC loc. C-56561, base of Peril Formation at Sadler Point, Queen Charlotte Islands.

Welleri Zone

Subzone I

GSC loc. O-86284, Quatsino Formation at type locality near Klaskino Inlet, Vancouver Island (matrix); GSC loc. O-42306, possibly Ludington Formation, Mile Post 428 on Alaska Highway (Mosher, matrix); GSC loc. C-157061, Peril Formation at Blue Jay Cove, Queen Charlotte Islands.

Subzone II

GSC loc. O-42385, Pardonet Formation at Mile Post 428 on Alaska Highway (Mosher, matrix); GSC loc. O-51650, Blaa Mountain Formation on Axel Heiberg Island (Mosher); GSC locs. O-42323, O-68179, Baldonnel Formation at Mount McLearn (matrix); GSC locs. C-157063, C-157295, C-157373, Peril Formation at, respectively, Blue Jay Cove, Burnaby Island, Kunghit Island, all Queen Charlotte Islands.

Undifferentiated

GSC loc. O-26124, Schei Point Formation on Ellesmere Island (Mosher, matrix; formerly referred to Nanseni Zone); GSC loc. C-101071, "grey beds" near Mount Kindle.

Macrolobatus Zone

GSC locs. O-64627, O-64628, Pardonet Formation at Pardonet Hill (Mosher); GSC locs. O-64616, O-64628, same locality (matrix); O-68202, Pardonet Formation on Mount McLearn (matrix); GSC loc. O-94738, Ludington Formation on Mount Laurier (matrix); GSC locs. C-157119, C-157123, C-157382, Peril Formation at, respectively, all Queen Charlotte Islands.

Lower Norian

Kerri Zone

Subzone I

GSC locs. O-98513-98515, type locality on Pardonet Hill; GSC loc. O-98880, high on Pardonet Hill; GSC loc. O-97548, Brown Hill.

Subzone II

GSC loc. O-98562, type locality on Pardonet Hill; GSC loc. O-98510, Pardonet Hill; GSC loc. O-64654, Brown Hill (Mosher, matrix); GSC loc. O-68180, Mount McLearn (Mosher); GSC loc. O-97543, Brown Hill.

Undifferentiated

GSC loc. O-98544, Childerhose Cove; GSC locs. O-98509, O-98898, O-98897, all Pardonet Hill (above Subzone II).

Dawsoni Zone

Subzone I

GSC loc. O-97546, type locality on Brown Hill.

Subzone II

GSC locs. O-97544, O-97543, type locality on Brown Hill; GSC loc. O-98538, Childerhose Cove.

Subzone III

GSC loc. O-97542, type locality on Brown Hill.

Undifferentiated

GSC loc. O-46505(a-c), Crying Girl Prairie Creek (Mosher); GSC loc. C-101033, Black Bear Ridge; GSC locs. O-98896, O-98506, C-101056, Pardonet Hill.

Magnus Zone

Subzone I

GSC loc. O-97541, type locality on Brown Hill.

Subzone II

GSC loc. O-97539, type locality on Brown Hill; GSC loc. O-64636, Black Bear Ridge (Mosher); GSC loc. O-98537, Childerhose Cove; GSC locs. O-98874, C-101034, recollection of latter.

Undifferentiated

GSC loc. O-68191, Mount McLearn (Mosher).

Middle Norian

Rutherfordi Zone

GSC locs. O-97529 through O-97536, type locality on Brown Hill; GSC loc. O-64659, Brown Hill (Mosher); GSC loc. O-46459, Crying Girl Prairie Creek (Mosher, matrix); GSC locs. O-98536, O-98876 = C-101037, C-101038, Childerhose Cove; GSC loc. O-97580, Crying Girl Prairie Creek.

Columbianus Zone

Subzone I

GSC locs. O-97525, 97526, 97528, Brown Hill; GSC loc. O-98518, Pardonet Hill; GSC loc. O-99593, near Carbon Creek.

Horizon 1a. GSC loc. O-98885, type locality at Childerhose Cove.

Horizon 1b. GSC locs. O-98877, 98878, = C-101041, 101042, type locality at Childerhose Cove; GSC loc. O-83835, Crying Girl Prairie Creek (matrix).

Horizon 1c. GSC loc. O-98542, type locality at Childerhose Cove.

Subzone II

GSC loc. O-83834 = O-97555, type locality at Crying Girl Prairie Creek; GSC loc. O-46468, Crying Girl Prairie Creek (Mosher); GSC locs. O-98549-98552 = C-101013-101017, Black Bear Ridge; GSC loc. O-98879 = C-101046, O-98540, Childerhose Cove; GSC loc. O-98525, Pardonet Hill.

Subzone III

GSC locs. O-83840 = O-97554, O-97552, type locality at Crying Girl Prairie Creek; GSC locs. O-98522, O-98524, Pardonet Hill; GSC locs. O-98548 = C-101021, Black Bear Ridge; GSC locs. O-97565, C-118949, unnamed unit on Rackla River, Yukon; GSC loc. C-101889, unnamed unit on Chert Mountain, Yukon.

Subzone IV

GSC loc. O-98546 = C-101022, Black Bear Ridge; GSC loc. O-98527, Pardonet Hill.

Undifferentiated

GSC loc. O-99594, near Carbon Creek; GSC locs. O-98535, O-98541, Childerhose Cove.

Upper Norian

Cordilleranus Zone

Subzone I

GSC loc. O-98534 = C-101027, type locality at Black Bear Ridge; GSC locs. O-68300, O-68304, type locality for Cordilleranus Zone at Mount Ludington (Mosher); GSC loc. O-98558, near Bocock Peak (matrix).

Subzone II

GSC loc. C-101032, Black Bear Ridge; GSC loc. C-101137, near Bocock Peak.

*Undifferentiated **Monotis** beds*

GSC loc. C-101110 = C-101028-101031, Black Bear Ridge; GSC locs. O-98504 = C-101764, C-101765, 101766, Ne Parle Pas Rapids; GSC loc. C-101780, Pardonet Hill; GSC loc. C-101788, Pine Pass; GSC loc. C-118950, Rackla River, Yukon; GSC loc. C-101891, Chert Mountain, Yukon. For localities on Queen Charlotte Islands, see Orchard et al., 1990.

Amoenum Zone

Direct associations are rare. The following collections include those that are indirectly dated. GSC locs. C-116137-116142, *Cassianella* beds at type locality at Tyaughton Creek; GSC loc. O-23407, Lewes River Group (formation F) of Laberge map area, Yukon (matrix); GSC loc. C-116516-116526, Lower Gabbs Formation in Nevada, U.S.A.; ?GSC loc. C-101760, post-*Monotis, Rhacophyllites* beds at Ne Parle Pas Rapids; ?GSC loc. O-98529 = C-101781, fissure fill at Pardonet Hill; GSC loc. C-101138, Bocock Limestone near Bocock Peak; numerous samples from Sandilands Formation at Kennecott Point, Queen Charlotte Islands (see Orchard et al., 1990).

Crickmayi Zone

Direct associations are rare. The following collections include those that are indirectly dated. GSC loc. C-117029, "green sandstone and conglomerate unit", near type locality at Tyaughton Creek; GSC loc. C-156526, Sandilands Formation at Kennecott Point, Queen Charlotte Islands; GSC loc. C-116527, basal Middle Gabbs Formation, Nevada, U.S.A.

APPENDIX B

Locality register

Location names, National Topographic System map sheet name and number, latitude and longitude of the localities cited in the text and/or in Appendix A are listed below. See also Figures 1, 2.

Northeastern British Columbia

Mount McLearn, Toad River, 94 N, 59.08°N, 125.45°W.

Ewe Mountain, Toad River, 94 N, 59.08°N, 125.32°W.

Mile Post 428, Alaska Highway, Tuchodi Lakes, 94K, 58.84°N, 125.33°W.

Mount Kindle, Tuchodi Lakes, 94 K, 58.84°N, 125.32°W.

Mount Laurier, Halfway River, 94 B, 56.77°N, 123.45°W.

Mount Ludington, Halfway River, 94 B, 56.46°N, 123.24°W.

Crying Girl Prairie Creek, Halfway River, 94 B, 56.46°N, 122.87°W.

Black Bear Ridge, Halfway River, 94 B, 56.08°N, 123.03°W.

Brown Hill, Halfway River, 94 B, 56.10°N, 122.87°W.

Childerhose Cove, Halfway River, 94 B, 56.10°N, 122.71°W.

Carbon Creek, Halfway River, 94 B, 56.08°N, 122.85°W.

Pardonet Hill, Halfway River, 94 B, 56.07°N, 123.02°W.

Ne Parle Pas Rapids, Halfway River, 94 B, 56.05°N, 123.03°W.

Bocock Peak, Pine Pass, 93O, N, 55.81°N, 122.83°W.

Pine Pass, Pine Pass, 93O, N, 55.45°N, 122.6°W.

Insular Belt

Klaskino Inlet, Alert Bay, 92 L, 50.3°N, 127.73°W.

Huston Inlet, Moresby Island, 103 C, 52.28°N, 131.29°W.

Blue Jay Cove, Moresby Island, 103 C, 52.35°N, 131.26°W.

Burnaby Island, Moresby Island, 103 C, 52.34°N, 131.30° W.

Kunghit Island, Moresby Island, 103 C, 52.07°N, 131.05°W.

Kennecott Point, Graham Island, 103 F, 53.92°N, 133.15°W.

Arctic Islands

Buchanan Lake, Axel Heiberg Island, Eureka Sound N., 49 G, 79.45°N, 87.6°W.

Bjorne Peninsula, Ellesmere Island, Baumann Fiord, 49 C, 77.75°N, 87.75°W.

Yukon Territory

Rackla River, Nash Creek, 106 D, 64.21°N, 134.28°W.

Chert Mountain, Dawson, 116 D, 64.38°N, 138.87°W.

Laberge, 105 E, 61.4°N, 135.05°W.

Southern Interior

Tyaughton Creek, Taseko Lakes, 92O, N, 51.1°N, 123.1°W.

PLATE 1

Figures denoted a and b are stereopairs. All figures (except fig. 4) x80.

Figures 1-3. *Metapolygnathus lindae* n. sp.
Upper, lateral, and lower views, holotype GSC 95194, GSC loc. O-42306, Ludington or Pardonet Formation, Alaska Highway, Lower *nodosus* Zone, Upper Carnian.

Figures 4-6. *Metapolygnathus reversus* (Mosher).
Upper (x100), lower, and lateral views, holotype GSC 29990, GSC loc. O-51650, Blaa Mountain Formation, Axel Heiberg Island, *nodosus* Zone, Upper Carnian.

Figures 7-9. *Metapolygnathus zoae* n. sp.
Upper, lateral, and lower views, holotype GSC 95203, GSC loc. C-157037, Peril Formation, Huston Inlet, Queen Charlotte Islands, Upper *nodosus* Zone, Upper Carnian.

Figures 10-12. *Metapolygnathus samueli* n. sp.
Upper, lateral, and lower views, holotype GSC 81244, GSC loc. C-157037, Peril Formation, Huston Inlet, Queen Charlotte Islands, Upper *nodosus* Zone, Upper Carnian.

Figures 13-15. *Metapolygnathus primitius* (Mosher).
Upper, lateral, and lower views, holotype GSC 25051, GSC loc. O-64654, Pardonet Formation, Brown Hill, Upper *primitius* Zone, Lower Norian.

Figures 16-20. *Metapolygnathus stephanae* n. sp.
Both from Peril Formation, Queen Charlotte Islands.

16, 17. Upper and lateral views, paratype GSC 95264, GSC loc. C-156542, Frederick Island, Upper *primitius* Zone, Lower Norian.

18-20. Lateral, lower, and upper views, holotype GSC 95249, GSC loc. C-157123, Huxley Island, Lower *primitius* Zone, Upper Carnian.

PLATE 1

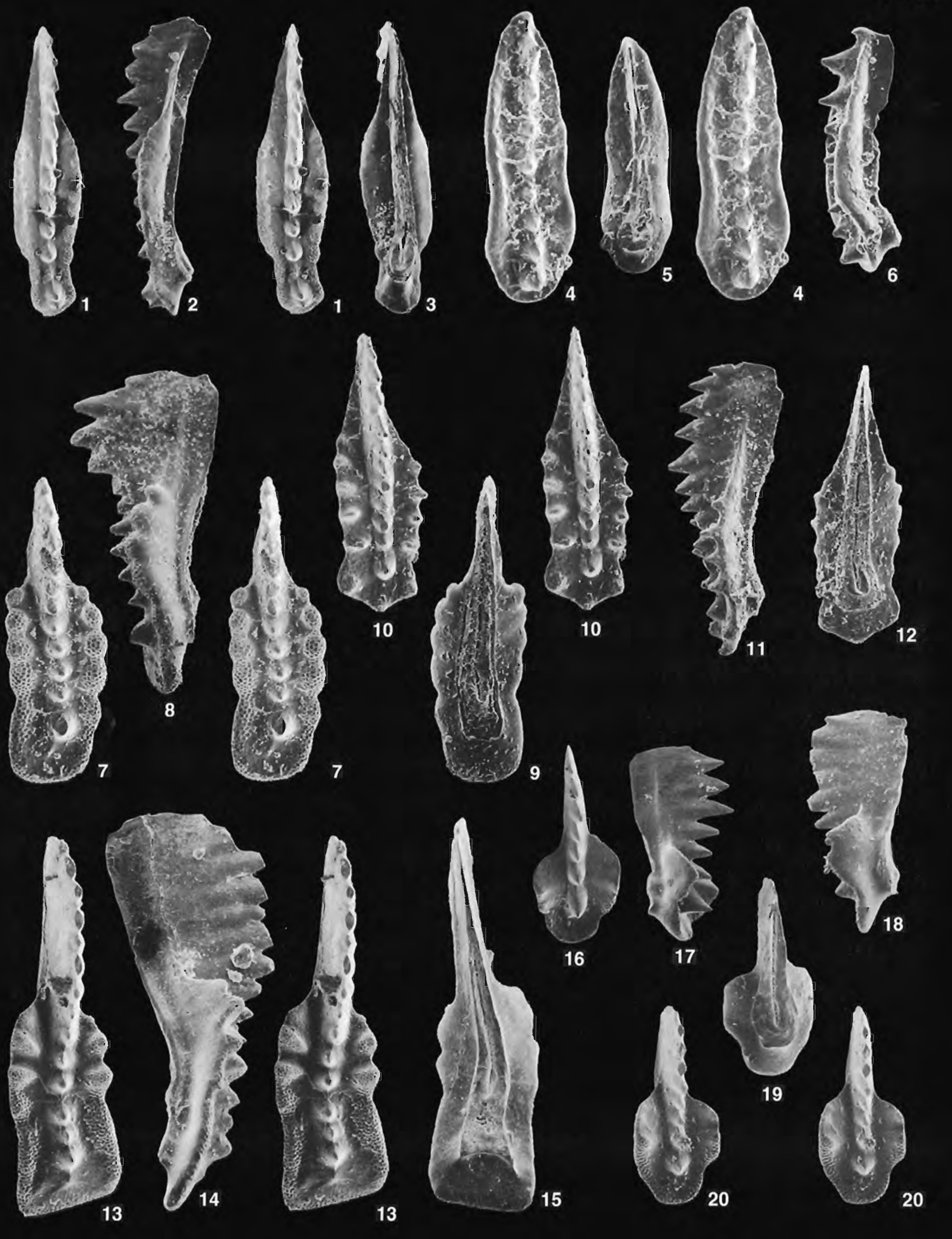


PLATE 2

Figures denoted a and b are stereopairs. All figures x80.

Figures 1-3, 7-9, ?10, ?12. *Epigondolella quadrata* n. sp.
All from Pardonet Formation, Pardonet Hill, *quadrata* Zone, Lower Norian.

1-3. Upper, lower, and lateral views, holotype GSC 95265, GSC loc. C-101768.
7-9. Upper, lateral, and lower views, paratype GSC 95266, GSC loc. C-101150.
?10, ?12. Lower and upper views, posteriorly rounded, slightly broken morphotype, hypotype GSC 95267, GSC loc. C-101768.

Figures 4-6, 11. *Epigondolella spatulata* (Hayashi).
Both are hypotypes from sample F-9, Timor (L. Krystyn collection), Lower Norian.

4-6. Lateral, lower, and upper views, GSC 95268.
11. Upper view, GSC 95269.

Figures 13-17. *Epigondolella* sp. aff. *E. spatulata* (Hayashi).
Both are figured specimens, and from GSC loc. C-87918, Pardonet Formation, Brown Hill, Upper *triangularis* Zone, Lower Norian.

13, 14. Upper and lower views, GSC 95270.

PLATE 2

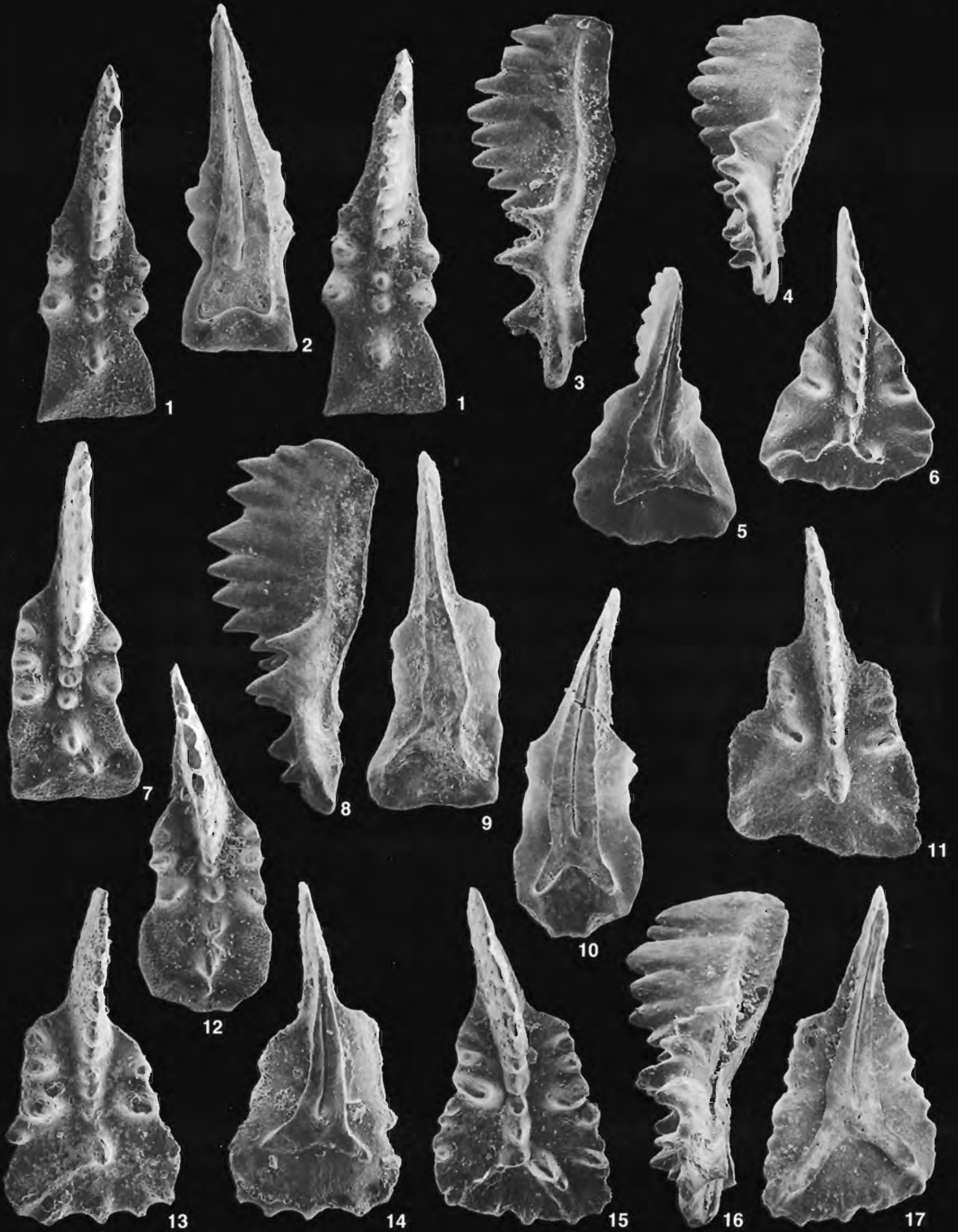


PLATE 3

Figures denoted a and b are stereopairs. All figures x80.

Figures 1-3. *Epigondolella triangularis uniformis* n. subsp.
Upper, lateral, and lower views, holotype GSC 95272, GSC loc. C-101057, Pardonet Formation, Pardonet Hill, Lower *triangularis* Zone, Lower Norian.

Figures 4-6. *Epigondolella triangularis* (Budurov).
Upper, lower, and lateral views, early growth stage, hypotype GSC 68853, GSC loc. C-87915, Pardonet Formation, Brown Hill, Middle *triangularis* Zone, Lower Norian.

Figures 7-9. *Epigondolella triangularis triangularis* (Budurov).
Upper, lateral, and lower views, hypotype GSC 95273, GSC loc. C-101034, Pardonet Formation, Childerhose Cove, Upper *triangularis* Zone, Lower Norian.

Figures 10, 14, 15. *Epigondolella spiculata* n. sp.
Lower, upper, and lateral views, holotype GSC 95274, GSC loc. C-98877, Pardonet Formation, Childerhose Cove, *spiculata* Zone, Middle Norian.

Figures 11-13. *Epigondolella transitia* n. sp.
Upper, lower, and lateral views, holotype GSC 95275, GSC loc. C-98537, Pardonet Formation, Childerhose Cove, Upper *triangularis* Zone, Lower Norian.

PLATE 3

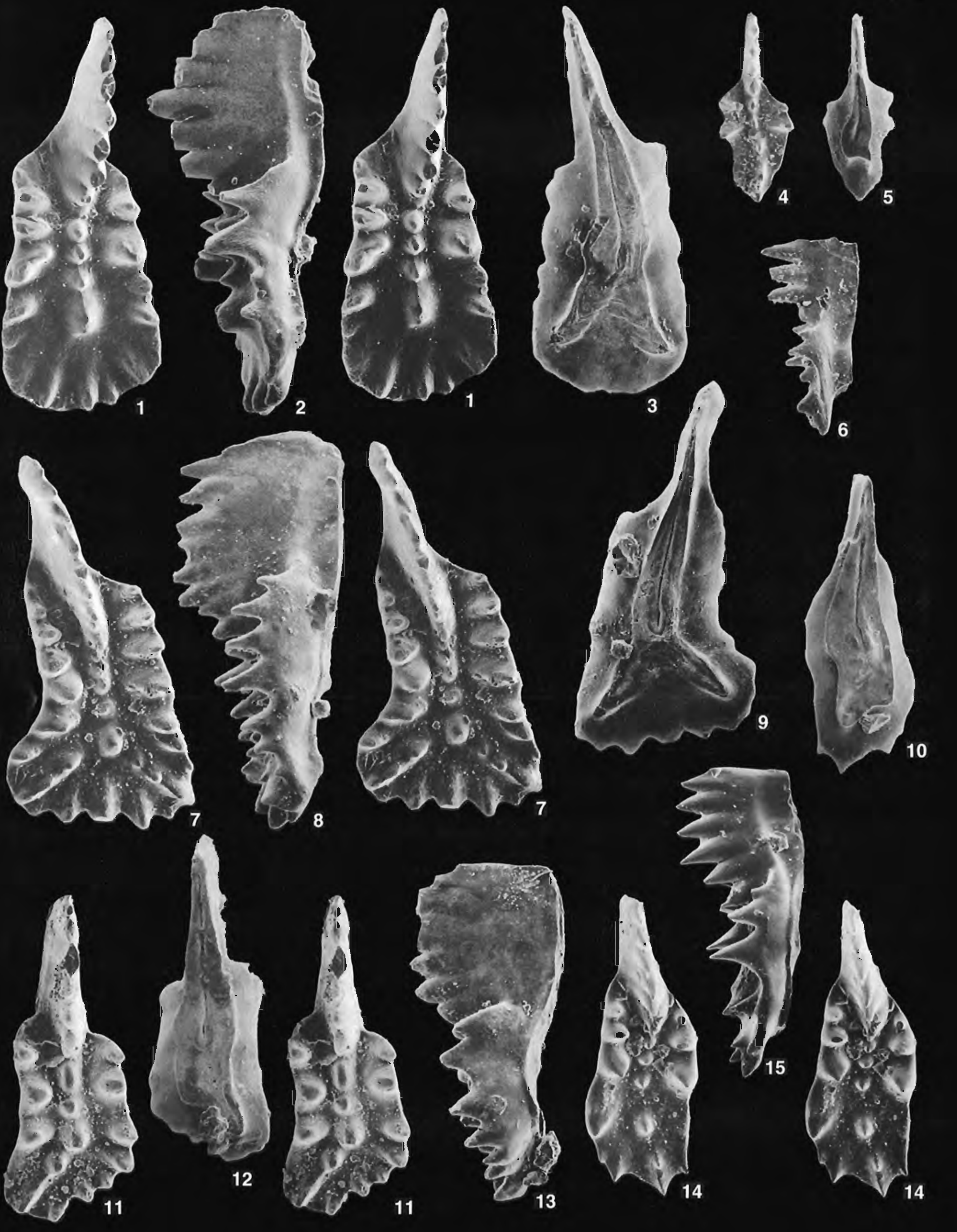


PLATE 4

Figures denoted a and b are stereopairs. All figures x80.

Figures 1-3, 7. *Epigondolella multidentata* Mosher.

1-3. Upper, lower, and lateral views, holotype GSC 25055, GSC loc. C-46459, Pardonet Formation, Crying Girl Prairie Creek, Lower *multidentata* Zone, Middle Norian.

7. Lateral view showing typical high carina, hypotype GSC 95276, GSC loc. C-101037, Pardonet Formation, Childerhose Cove, Lower *multidentata* Zone, Middle Norian.

Figures 4-6, 15, 20, 21. *Epigondolella elongata* n. sp.

4-6. Upper, lower, and lateral views, early growth stage, paratype GSC 95277, GSC loc. O-99594, Pardonet Formation, near Carbon Creek, *elongata* Zone, Middle Norian.

15, 20, 21. Lateral, upper, and lower views, holotype GSC 95282, GSC loc. C-98542, Pardonet Formation, Childerhose Cove, *elongata* Zone, Middle Norian.

Figures 8-10. *Epigondolella matthewi* n. sp.

Upper, lower, and lateral views, holotype GSC 95278, GSC loc. C-98876, Pardonet Formation, Childerhose Cove, Lower *multidentata* Zone, Middle Norian.

Figures 11, 13, 14. *Epigondolella mosheri* Kozur and Mostler.

11. Upper view, hypotype GSC 95279, GSC loc. C-156793, Sandilands Formation, Kennecott Point, Queen Charlotte Islands, Upper *bidentata* Zone, Upper Norian.

13, 14. Upper and lower views, hypotype GSC 95280, GSC loc. C-101138, Bocock limestone, Upper *bidentata* Zone, Upper Norian.

Figures 12. *Epigondolella bidentata* Mosher.

Upper view, hypotype GSC 95281, GSC loc. C-157344, Peril Formation, Rose Inlet, Queen Charlotte Islands, Lower *bidentata* Zone, Upper Norian.

Figures 16-19. *Epigondolella postera* (Kozur and Mostler).

Both from GSC loc. C-101113, Pardonet Formation, Black Bear Ridge, *postera* Zone, Middle Norian.

16, 17,19. Upper, lower, and lateral views, hypotype GSC 95283.

18. Upper view, hypotype GSC 95284.

PLATE 4

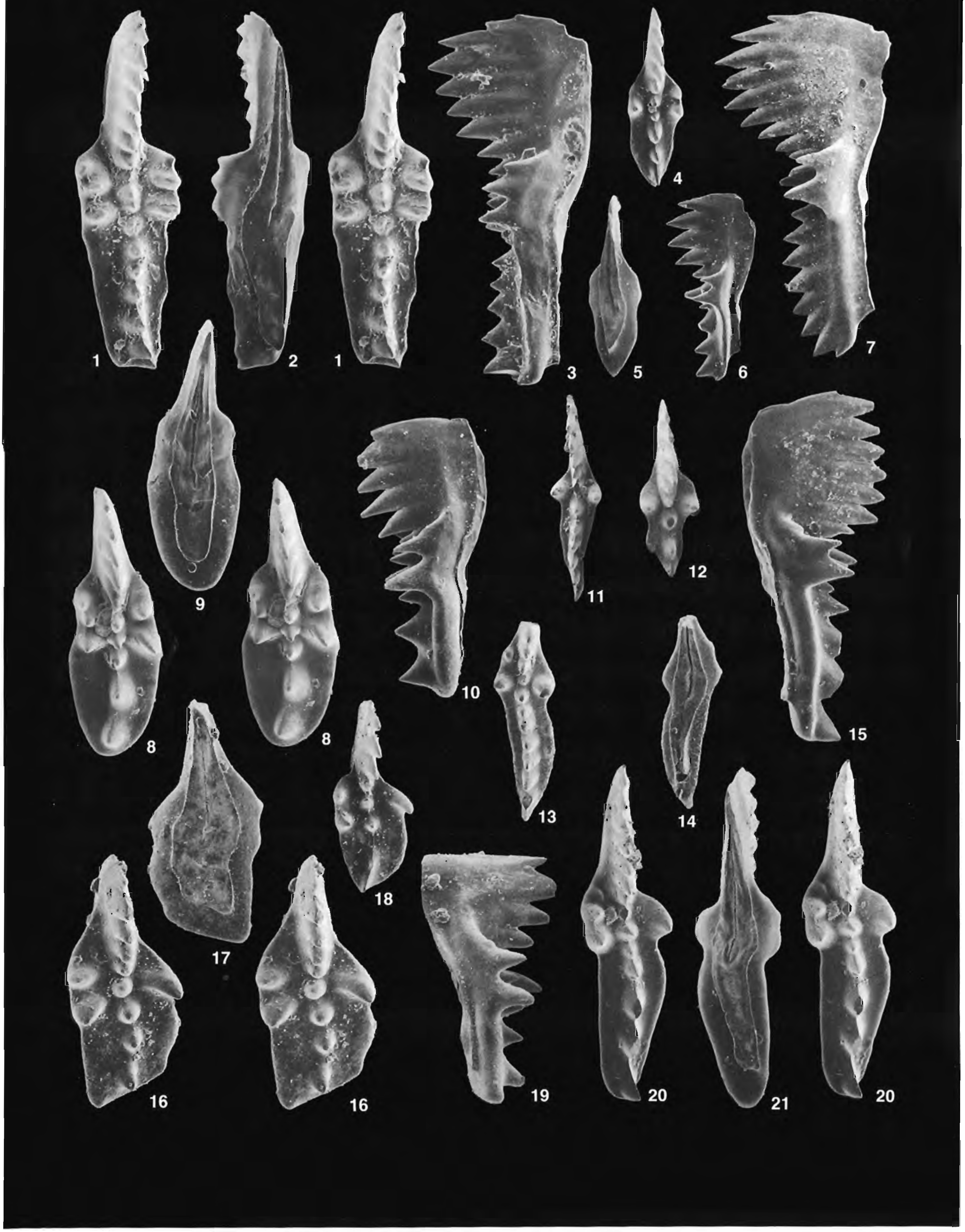


PLATE 5

Figures denoted a and b are stereopairs. All figures x80.

Figures 1-3, 6-8. *Epigondolella tozeri* n. sp.
Three different growth stages from GSC loc. C-98518, Pardonet Formation, Pardonet Hill, *elongata* Zone, Middle Norian.

1, 3. Upper and lower views, paratype GSC 95285.
2. Upper view, paratype GSC 95286.
6-8. Upper, lateral, and lower views, holotype GSC 95287.

Figures 4, 5, 10. *Epigondolella carinata* n. sp.
Upper, lower, and lateral views, holotype GSC 95288, GSC loc. C-98525, Pardonet Formation, Pardonet Hill, *postera* Zone, Middle Norian.

Figures 9, 11, 13, 19, 20. *Epigondolella englandi* n. sp.
Three different growth stages from GSC loc. C-87005, Lewes River Group, Laberge area, Upper *bidentata* Zone, Upper Norian.

9. Upper view, paratype GSC 95289.
11, 13,19. Lateral, upper, and lower views, holotype GSC 95290.
20. Upper view, paratype GSC 95291.

Figures 12, 14-18. *Epigondolella serrulata* n. sp.

12. Upper view, paratype GSC 95292, GSC loc. C-101021, Pardonet Formation, Black Bear Ridge, *serrulata* Zone, Middle Norian.
14-16. Upper, lateral, and lower views, paratype GSC 95293, GSC loc. C-97554, Pardonet Formation, Crying Girl Prairie Creek, *serrulata* Zone, Middle Norian.
17, 18. Upper and lateral views, holotype GSC 68864, GSC loc. O-98548, Pardonet Formation, Black Bear Ridge, *serrulata* Zone, Middle Norian.

Figure 21. *Misikella posthernsteini* Kozur and Mock.
Lateral view, hypotype GSC 95294, GSC loc. C-156526, Sandilands Formation, Kennecott Point, Queen Charlotte Islands, *posthernsteini* Zone, Upper Norian.

PLATE 5