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BIOSTRATIGRAPHY, PALEOECOLOGY AND TAXONOMY OF UPPER DEVONIAN (FAMENNIAN) CONODONTS FROM THE PALLISER FORMATION AND WABAMUN GROUP, ALBERTA AND BRITISH COLUMBIA

by

DAVID IAN JOHNSTON ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY

Edmonton, Alberta
FALL 1994

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August 9, 1994

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled BIOSTRATIGRAPHY, PALEOECOLOGY AND TAXONOMY OF UPPER DEVONIAN (FAMENNIAN) CONODONTS FROM THE PALLISER FORMATION AND WABAMUN GROUP, ALBERTA AND BRITISH COLUMBIA submitted by DAVID IAN JOHNSTON in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY.

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25/July/94

ABSTRACT

Conodont data suggest that the Late Devonian (Famennian) Palliser Formation in the Rocky Mountains of Alberta and British Columbia and Wabamun Group in the subsurface of these two provinces range from the Lower *crepida* to as high as the Lower *expansa* zones. The Morro Member of the Palliser Formation and the Dixonville through to Cardinal Lake units of the Wabamun Group have a maximum age span of Lower *crepida* to Upper *marginifera* zones. The Costigan Member of the Palliser Formation has a maximum age span of Lower *rhomboidea* to possibly Middle *expansa* zones. The age of the Big Valley Formation of the Wabamun Group is Uppermost *marginifera* to Middle *expansa* zones.

Major unconformities encompassing up to four conodont zones occur between uppermost strata of the Palliser Formation and the Wabamun Group and the rest of these units at some localities, whereas in others deposition has been continuous. Major unconformities between the Palliser Formation and overlying units occur in its southeastern and northwestern outcrop areas. A major unconformity occurs between the Wabamun Group and Exshaw Formation along the southern flanks of the Peace River Arch.

Conodont biofacies, together with sedimentologic and stratigraphic evidence, show that a major transgressive-regressive cycle is represented by most of the Palliser Formation and Wabamun Group. These units are comprised of transgressive, highstand and possibly shelf margin systems tracts. Uppermost strata of the Palliser Formation and Wabamun Group may represent part or all of a depositional cycle consisting of either transgressive or transgressive and highstand systems tracts. Several of these transgressive-regressive cycles are correlative with others documented elsewhere along the margin of Euramerica.

Sixteen new conodont species are described in this work. These are: *Icriodus erucisimilis* n. sp., *I. stenoancylus* n. sp., *Mehlina ovata* n. sp., *M.? arcureclinata* n. sp., *M.?*

brevicristata n. sp., *Palmatolepis angulata* n. sp., *P. crista* n. sp., *P. lanceolata* n. sp., *P. ovata* n. sp., *P. parawolskae* n. sp., *Polygnathus crassilabrus* n. sp., *P. dolichopleurus* n. sp., *P. latisemicostatus* n. sp., *P. meijerdreesi* n. sp., *P. paraobliquicostatus* n. sp. and *Polylophodonta medicinelakensis*. n. sp.

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CHAPTER I

INTRODUCTION

This work documents the results of a detailed biostratigraphic, paleoecologic and taxonomic study of conodonts in the Late Devonian Palliser Formation and Wabamun Group. In Chapters II and III the succession of conodont taxa within these units is described for the first time. This succession provides the biostratigraphic framework upon which the correlations described herein between the Palliser Formation and Wabamun Group and between these units and equivalent strata in the western United States and elsewhere are based. Although this work generally confirms previously established correlations between the Palliser Formation and Wabamun Group and coeval units, some correlations have been shown to be in error and have been revised. The conodont biofacies recognized in Chapter IV aid in better understanding the biotic, eustatic and tectonic events that may have affected the conodont faunas and sedimentation in the Palliser Formation and Wabamun Group. Taxonomic study of the conodont faunas of the Palliser Formation and Wabamun Group in Chapter V has resulted in the discovery of sixteen new taxa, of which several may have some biostratigraphic utility and/or paleoecological significance. This study also complements previous conodont work on the Famennian of Western Canada (e.g. Irwin and Orchard, 1991).

PREVIOUS WORK

BIOSTRATIGRAPHIC STUDIES

Conodonts.

Clark and Ethington (1965) reported the presence of poorly preserved or fragmentary conodonts from the Palliser Formation. Mound (1967, 1968) illustrated conodonts from the upper part of Wabamun Group in south-central Alberta and suggested some preliminary correlations of this unit with the

Upper Devonian sequence in northwestern Europe. The preliminary results of conodont investigations from the Palliser Formation were reported by Johnston and Chatterton (1987) and Savoy et al. (1987). Richards and Higgins (1989) showed that uppermost Palliser strata in southwestern Alberta and northeastern British Columbia are late Famennian in age and appear not to differ significantly in age from the overlying Exshaw Formation. Johnston and Chatterton (1991 - Chapter II herein) described the succession of known conodont taxa in the Palliser Formation and showed that the standard Late Devonian conodont zonation (Ziegler and Sandberg, 1990) can be applied to most of this formation. However, their work also illustrated the difficulties encountered in trying to apply this zonation to strata where diagnostic taxa are absent due to environmental influences. Their work and that of Savoy (1990, 1992) also demonstrated the diachroneity of the upper contact of the Palliser Formation. Johnston and Meijer Drees (1993 - Chapter III herein) described the succession of conodont taxa in the Wabamun Group and over- and underlying units in the subsurface of northwestern Alberta and northeastern British Columbia. Meijer Drees and Johnston (1994) discussed the conodont biostratigraphy of the type section of the Palliser Formation and other Palliser sections in the type area of this formation near Banff, Alberta.

Other Fossil Groups.

Warren (1927), Taylor (1958) and House and Pedder (1963) reported the presence of rare ammonoids from uppermost strata of the Palliser Formation. The Palliser Formation has also been zoned on the basis of its brachiopod fauna. Zonations based on rhynchonellids (e.g. McLaren, 1954; Sartenaer, 1969) and cyrtospiriferids (e.g. Crickmay, 1952; Greiner, 1973) have been proposed. Other brachiopod-based zonations in the Palliser Formation and Wabamun Group have been suggested by Warren (194[illegible], Warren and Stelck (1950, 1956), Crickmay (1966) and Raasch (1989).

Lethiers (1978, 1981) studied the ostracod succession in the Big Valley Formation in Alberta and Saskatchewan and in the Palliser Formation and Wabamun Group in Alberta. He (1981) used this succession to zone these and equivalent units in northeastern British Columbia and the southern Northwest Territories. He also discussed these ostracods in terms of their paleoecological significance.

STRATIGRAPHIC STUDIES

Palliser Formation

Beach (1943) first named the Palliser Formation for cliff-forming limestones and dolostones that outcrop in the Bow River valley. DeWit and McLaren (1950) subsequently subdivided the Palliser Formation into an upper Costigan Member and lower Morro Member (Figure I-1). Beales (1953, 1956) described the dolomitic mottling and carbonate microfacies in the Palliser Formation. He (1956) believed that the carbonate sediments in the Palliser Formation may be compared to those on the modern Bahama Bank. Geldsetzer (1982) described the succession and geographic distribution of lithofacies in the Palliser Formation in northwestern Alberta and northeastern British Columbia. Geldsetzer et al. (1986) described the petrographic characteristics and geographic distribution of lithofacies of the Palliser Formation in eastern British Columbia and western Alberta. Meijer Drees and Johnston (1994) designated a type section for the Palliser Formation and redefined the Costigan and Morro members to each include a lower and an upper sub-member.

Wabamun Group

The Wabamun Formation was named by the Geological Staff, Imperial Oil Limited (1950) for a sequence of evaporites, dolostones and limestones in the Edmonton area. Wonfor and Andrichuk (1956) raised the Wabamun Formation to group status in southeastern Alberta and subdivided it into an upper Big Valley Formation and lower Stettler Formation (Figure I-1). Belyea and McLaren (1957) considered the lower part of the Stettler to be a separate formation and named this unit the Crowfoot Formation (Figure I-1). Andrichuk (1960) described the type and distribution of lithofacies in four intervals of the Wabamun Group in south-central Alberta. Workman and Metherell (1969) and Metherell and Workman (1969) described the characteristics of the biostromal Crossfield Member of the Stettler Formation in the Calgary area. Eliuk (1984) and Eliuk and Hunter (1987) elaborated further on the depositional characteristics of the Crossfield Member and equivalent units in the subsurface of the Foothills northwest of Calgary. Nishida (1987) and Stearn et al. (1987) described the characteristics and significance of stromatoporoid buildups in the Wabamun Group near the Peace River Arch. Halbertsma and Meijer Drees (1987) subdivided the Wabamun Group in north-central Alberta into six sequences which were recognized on the basis of their electric log characteristics. Each sequence was interpreted to represent a single carbonate shallowing upward cycle. The lower five sequences were later formally established as members of the Wabamun Group by Halbertsma (in Glass, 1990). Meijer Drees and Johnston (1993) regarded the Wabamun Group as consisting of four informal units overlain by the Big Valley Formation (Figure I-1) in north-central Alberta. They also described the depositional characteristic of the Big Valley Formation and equivalent strata in the surface and subsurface of Alberta.

INTERPRETED DEPOSITIONAL, PALEOGEOGRAPHIC AND TECTONIC SETTING

The portion of Western Canada encompassing the outcrop and subcrop areas of the Palliser Formation and Wabamun Group was situated on the western margin of the Euramerican (= Old Red, Laurussian) continent during the Late Devonian (Figure I-2A). Euramerica is interpreted to have been situated in subtropical to tropical paleolatitudes although opinions differ as to the exact position of this continent at these latitudes (e.g. Gutschick and Sandberg, 1991, fig. 3). In some reconstructions based on paleomagnetic data, Euramerica straddled the paleoequator (e.g. Scotese et al. 1985; Van der Voo, 1988; Ziegler, 1989; Scotese and McKerrow, 1990) (Figure I-2A) whereas in other reconstructions based on the distribution of climatically sensitive lithologies such as evaporites and red beds, this continent is situated entirely in the southern hemisphere just below the equator (e.g. Heckel and Witzke, 1979, Boucot and Gray, 1983, Boucot, 1989, Witzke and Heckel, 1989). In either reconstruction, however, Western Canada would have been situated in the warm arid climatic belt (e.g. Witzke and Heckel, 1989).

The Palliser Formation and Wabamun Group were deposited on the edge of the cratonic platform on the Alberta and Hay River shelves, which were separated by the Peace River Uplift (Figure I-2B). Farther to the west there was a deep trough in which fine grained basinal sediment accumulated. The western side of this trough appears to have been bordered by a tectonic highland (e.g. Kootenay Terrane? - Richards, 1989; Smith et al., 1993) (Figure I-2B), which may have been a source of coarse grained siliciclastics of the Sassenach Formation which underlies the Palliser Formation (Morrow and Geldsetzer, 1989).

The Palliser Formation and Wabamun Group have generally been interpreted to have been deposited in more restricted environments throughout most of their depositional history, because of the predominance of peloidal carbonates and the lack of a diverse macrofauna throughout the bulk of both units. Only the upper part of the Costigan Member in the Palliser Formation and the Big Valley Formation of the Wabamun Group have been interpreted as open marine (e.g. Beales, 1956; Andrichuk, 1960). Geldsetzer (1982) interpreted the Palliser Formation in northwestern Alberta and northeastern British

Columbia to have been initially deposited above (presumably fairweather) wave base. Water depth fluctuated above and below wave base during deposition of the lower part of the formation. In about the middle of the Palliser Formation shallowing to intertidal conditions occurred. Another episode of deepening then followed which resulted in deposition of the upper part of the formation. Evidence in some sections from this area suggest that water depths were very shallow just prior to the termination of Palliser sedimentation (Geldsetzer, 1982).

More recent interpretations have suggested that the Palliser Formation and Wabamun Group formed part of a prograding carbonate ramp (e.g. Eliuk, 1984; Eliuk and Hunter, 1987; Stoakes, 1987; Savoy, 1990, 1992). Halbertsma and Meijer Drees (1987) considered the Wabamun Group in north-central Alberta to have comprised of several packages of prograding then backstepping carbonate barrier to back barrier complexes that shifted their position in response to what they believed were eustatic rises and falls in sea level.

Meijer Drees and Johnston (1993) interpreted the Big Valley Formation as the initial deposits of a major transgression that culminated in the deposition of the black shales of the Exshaw Formation. Meijer Drees et al. (1993) considered the Palliser Formation and its equivalents to represent two transgressive episodes. The first one is represented by the lower part of the Morro Member whereas the second one is represented by the upper fossiliferous carbonates of the Costigan Member. Regressive deposits are represented by the upper part of the Morro Member and lower part of the Costigan Member.

FAMENNIAN CONODONT ZONATION

The Upper Devonian standard conodont zonation was first proposed by Ziegler (1962) and was based primarily on the conodont succession in the Rhenish Schiefergebirge.

Modifications to the Famennian portion of the zonation (Figure I-3) were subsequently made by Sandberg and Ziegler (1973), Sandberg et al. (1978) and Ziegler and Sandberg (1984, 1990). The base of each zone is defined primarily by the first occurrences of species and subspecies[1] of Palmatolepis, although for some zones, particularly in the late Famennian, the lower limits are defined on the first appearance of species or subspecies of other genera (e.g. Scaphignathus, Siphonodella, Bispathodus). As presently defined, each zone (which is each Lower, Middle, Upper, etc. subdivision in Figure I-3) is considered to have an average duration of approximately 500,000 years, with the Famennian having a total duration of approximately 10 million years (Ziegler and Sandberg, 1990). These zones are considered geochronologic units (e.g. Ziegler, 1971; Sandberg et al. 1989b; Ziegler and Sandberg, 1990) although it is the opinion of the writer that zones are biostratigraphic units (e.g. Hedberg, 1976) which represent an interval of time.

In addition to the standard zonation depicted in Figure I-3, an alternate zonation based on species of Icriodus, its homeomorph "Icriodus" and Pelekysgnathus was erected for strata deposited in more nearshore settings (Sandberg and Dreesen, 1984; Figure III-1).

FAMENNIAN CONODONT BIOFACIES

Sandberg (1976) recognized five conodont biofacies from the Lower expansa Zone of the western United States. These biofacies were based on percentages of platform elements in samples collected from different stratigraphic units that were interpreted to represent different but contemporaneous paleotectonic settings (Figure I-4). Each of these biofacies occupied linear belts paralleling a former shoreline with each

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[1] Subspecies of Palmatolepis and other conodont genera are treated as species in Chapters IV and V.

belt showing very little lateral variation. What each biofacies belt shows instead is some degree of overlap with adjacent belts. This overlap was interpreted to have been due to mixing of conodont elements caused by either current activity and/or down slope or storm processes (Sandberg and Dreesen, 1984; Dreesen et al., 1986) or by periodic incursions of ecologic "stragglers" from adjacent biofacies (Sandberg, 1976; Sandberg and Ziegler, 1979).

In a shoreward direction these biofacies were: the palmatolepid-bispathodontid, the palmatolepid-polygnathid, the polygnathid-icriodontid or "icriodontid", the polygnathid-pelekysgnathid and various nearshore biofacies which were recognized in subsequent studies (e.g. Sandberg and Ziegler, 1979; Sandberg and Dreesen, 1984; Sandberg et al. 1989a) (Figure I-4). This sequence of conodont biofacies was also found generally to be valid for different tectonic settings rimming the Euramerican continent in the Famennian (e.g. Dreesen and Thorez, 1980; Matyja, 1987; Sandberg and Dreesen, 1984).

Palmatolepis has been interpreted to have had a pelagic life mode, as had species of Bispathodus and species of Polygnathus belonging to the "nodocostatus - group" (Sandberg, 1976; Sandberg and Ziegler, 1979; = germanus group in Chapter V). Species of Polygnathus belonging to the "semicostatus - group", "Icriodus", Pelekysgnathus and asymmetrical platform taxa typified by genera such as Clydagnathus, Pandorinellina and Scaphignathus are interpreted to have had a nektobenthic life mode (Sandberg and Dreesen, 1984).

In early Famennian strata the palmatolepid-bispathodontid biofacies is the palmatolepid biofacies, since Bispathodus did not evolve until the Upper marginifera Zone (Sandberg and Dreesen, 1984; Figure I-4). A shallow water polygnathid biofacies has been also recognized in Famennian strata of the western United States (Sandberg et al., 1989a) as well as in Belgium (Dreesen et al. 1985a) and in Poland (Matyja, 1987).

An early late Famennian alternognathid biofacies was recognized in shallow water sequences in the western United States (Sandberg et al. 1989a). In late Famennian sequences bordering the European portion of Euramerica, the palmatolepid-bispathodontid biofacies was replaced by the ecologically equivalent pseudopolygnathid (or polygnathid)-bispathodontid biofacies (Dreesen and Thorez, 1980; Matyja, 1987) after the extinction of the palmatolepids in the praesulcata Zone. A deep water bispathodontid biofacies that presumably occurred more offshore than the palmatolepid-bispathodontid biofacies as been recognized in the latest Famennian of Europe (e.g. Weddige et al. 1991) and North America (e.g. Over, 1992).

Biofacies are named on the basis of a single genus or two genera that comprise at least 70 percent of platform elements present (Ziegler and Sandberg, 1990). Conodont faunas in which three genera occur in about equal abundance have been considered to have undergone mixing as a result of storm and/or downslope processes (Sandberg et al. 1988). Possible ecologically controlled groupings of late Famennian conodonts have been recognized through cluster analysis and related statistical techniques by Weddige et al. (1991).

FAMENNIAN EVENT STRATIGRAPHY

All of the events discussed in this section conform to Seilacher's (1984, p. 49) broader definition of event stratigraphy, which is "... the study of rare events" (e.g. biologic, sedimentological) "at any scale." (e.g. from single beds to formations).

Johnson et al. (1985, 1986) recognized two major transgressive-regressive cycles in Euramerica in the Famennian. The first cycle (T-R IIe) began just after the major regression at the end of the Frasnian postdating the major extinction event (Sandberg et al. 1989a) (Figure I-5). The second cycle (T-R IIf) began in the late Famennian, at the base of the Lower expansa Zone. Minor transgressive and regressive pulses occurred during each of these cycles (Figure I-5), which were described in a regional context for the western United States by Johnson and Sandberg (1989). These transgressive and regressive cycles are interpreted to have been controlled at least in part by episodes of glaciation in the South American portion of Gondwanaland (e.g. Caputo, 1985; Caputo and Crowell, 1985). However, doubts have been expressed both about whether the strata upon which this interpretation was based are glaciogenic in origin and about the exact timing of this glaciation i.e. whether this glaciation could only have happened in the Famennian (Boucot, 1989). Sandberg et al. (1983, 1989a) recognized a series of depositional events for the western United States which they dated in terms of an absolute time scale in millions of years before and after the Devonian-Carboniferous boundary (Figure I-5). Dreesen (1989a,b) and Dreesen et al. (1985b, 1989) discussed the Famennian event stratigraphy of the Ardennes and the Rhenish Schiefergebirge and possible correlative events in adjacent areas. House (1985) documented several events on the basis of ammonoid extinctions/originations and sedimentological evidence in strata in northwestern Europe. Narkiewicz (1989) discussed some early Famennian events in southern Poland.

OUTLINE OF PRESENT STUDY

OBJECTIVES

The objectives of this study are as follows:

1. To describe in detail the conodont faunas from the Palliser Formation and Wabamun Group.
2. To correlate sections of the Palliser Formation with each other and with subsurface sections of the Wabamun Group.
3. To correlate the Palliser Formation and Wabamun Group with other conodont-bearing Famennian sequences in North America and other continents.
4. To reconstruct, using sedimentological and conodont data,

the conodont paleoecology of the Palliser Formation and Wabamun Group.

5. To understand regional and global events that have affected the biota and lithologies of the Palliser Formation and Wabamun Group.

An important question that was addressed is what is the age of the Palliser Formation and Wabamun Group. Previous age determinations using other fossil groups have shown that the Palliser Formation ranges from early to late Famennian in age (Sartenaer, 1969; Lethiers, 1981). Geldsetzer (1982) (on the basis of a personal communication of B.D.E. Chatterton) stated that the Palliser Formation ranges from the crepida to marginifera zones in its northern outcrop area. At the time this study commenced no published conodont data existed from the southern outcrop area of this formation. Mound (1968), using conodont data, determined the upper age limit of the Wabamun Group in one well to be no younger than the marginifera Zone.

Another question is: will using conodonts allow the Palliser Formation and Wabamun Group to be zoned biostratigraphically with a greater degree of precision than has been accomplished using other fossil groups? Zoning with rhynchonellid brachiopods allowed Sartenaer (1969) to subdivide the Palliser Formation into only two zones. The lower zone, represented in the Morro Member, was poorly defined. Greiner (1973) recognized two associations of cyrtospiriferid brachiopods in the Palliser Formation, one which characterizes the Morro Member, and the other, the Costigan Member. Like the lower rhynchonellid zone, the association in the Morro Member was poorly defined. The same situation also applies to the brachiopod zonation of Crickmay (1966).

Another question that this study attempted to address is how valid is the standard Late Devonian conodont zonation and how applicable is it to the Palliser Formation and Wabamun

Group? Although most of the zones representing the early and middle Famennian could be recognized in some areas of the adjacent western United States (e.g. Sandberg and Ziegler, 1973) and in Belgium (Dreesen and Dusar, 1974), previous studies in these areas have also shown several late Famennian zones to be absent or unrecognized (e.g. Sandberg and Poole, 1977; Sandberg et al., 1983, 1989a; Dreesen et al., 1986) due to major hiatuses and/or unsuitable environments for zonally diagnostic conodonts. Can zones that are recognized in the western United States and Belgium also be recognized in the Palliser Formation and Wabamun Group? Are the zones not recognized in these areas also not recognizable in the Palliser Formation and Wabamun Group? Do some of the major unconformities which were recognized in the Famennian of the western United States and Belgium also exist in Western Canada?

This study also attempts to test previously proposed Famennian conodont biofacies models (e.g. Sandberg, 1976; Sandberg and Dreesen, 1984) and their applicability to the Palliser Formation and Wabamun Group. The hypothesis that environmental conditions were essentially uniform during the deposition of most of the Palliser Formation and Wabamun Group (e.g. Beales, 1956; Andrichuk, 1960) was tested against a hypothesis which suggests these units were affected by the same eustatic and/or tectonically induced rises and falls in relative sea level that were interpreted to have affected other Famennian stratigraphic units (e.g. Sandberg et al., 1983, 1989a, Matyja, 1987; Dreesen et al., 1989).

It was also hoped that this study would provide the opportunity to test previous reconstructions of apparatuses for some of the major Late Devonian genera that occur in the Famennian (e.g. Icriodus - Klapper and Philip, 1971; Nicoll, 1977, 1982; Palmatolepis - Philip and McDonald, 1975; van den Boogaard and Kuhry, 1979; Pelekysgnathus - Klapper and Philip, 1972; Sandberg and Dreesen, 1934; Polygnathus - Klapper and

Philip, 1971; Nicoll, 1985) as well as come up with apparatus reconstructions for genera in which the apparatuses are unknown (e.g. Polylophodonta). Unfortunately, because of the nature of the collections at the writer's disposal (see Chapter V), these hoped for reconstructions were not realized.

INVESTIGATIVE TECHNIQUES

The main data base for this study is eight measured sections of the Palliser Formation that were sampled in detail for conodonts either by the writer or by B.D.E. Chatterton. These were the Banff Golf Course, Cold Sulphur Springs, Crowsnest Pass, Jura Creek, Medicine Lake, Mount Greenock and Roche Miette sections (Figure I-6, Localities 2, 3, 6, 8-11) which were measured and sampled by B.D.E. Chatterton. The Nigel Peak section (Figure I-6, Locality 7) was measured and sampled by the writer. These sections are located in the Front and Main ranges of the Rocky Mountains in western Alberta (Figure I-6). Additional sections of the Palliser Formation in Alberta and British Columbia were measured and sampled jointly with personnel from the Geological Survey of Canada (Institute of Sedimentary and Petroleum Geology, Calgary) (e.g. Devil's Gap, LaFarge Quarry and Whiteman Gap sections, Figure I-6, Localities 4-6). Also parts of the data base are conodonts from the Wabamun Group from cores in 14 wells in northwestern Alberta and 3 wells in northeastern British Columbia (Figure I-6, Localities 12-24) which were sampled by N.C. Meijer Drees of the Institute of Sedimentary and Petroleum Geology. Additional material from the Palliser Formation came from thirty sections from south-central Alberta to northeastern British Columbia in which only the top and/or base of the formation was sampled or the Palliser Formation was sampled incompletely for conodonts. Additional material, donated by H. Geldsetzer of the Institute of Sedimentary and Petroleum Geology, was also utilized from one section at Wardner, in southeastern British Columbia (Figure I-6, Locality 1), which was originally collected by ESSO Minerals.

Sampled intervals in most sections measured and sampled by the writer were approximately one to two metres to as much as twenty metres apart. Samples were of limestone, although some dolostones were also collected. In general, sample weights from sections sampled by the writer and B.D.E. Chatterton ranged from approximately two to six kilograms, although for the latter only up to four kilograms of rock were processed. Samples were broken up into walnut-size pieces in the field. An accompanying lithological sample was also taken with the majority of conodont samples collected by the writer.

Conodont samples were processed in dilute acetic acid (seven percent) in the solution recommended by Jeppsson et al. (1985). In early processing runs, samples were processed in ten percent acetic acid solutions. Samples were then sieved, and the residues were either picked immediately or further concentrated in tetrabromoethane or sodium polytungstate at a specific gravity of either 2.78 or 2.87. Photography of conodonts was by Scanning Electron Microscope (SEM).

RESPONSIBILITY

Each of the core chapters (i.e. II to V) of this thesis have been written as jointly authored papers which either have been published or will be submitted for publication. Chapters II and III are presented in their published form. There has been no attempt to update them in terms of more recent results. All chapters in this thesis are written in the format of Palaeontographica Canadiana.

The writer is responsible for the writing and nearly all the interpretations presented in Chapter II, as well as for half the photography in Plates II-1 to II-3. B.D.E. Chatterton did most of the collecting and processing of conodont samples and the other half of the photography. Most of the stratigraphic columns of the Palliser Formation depicted in Figure II-2 are based on his field descriptions. He contributed to the discussion of conodont biostratigraphy and commented on various drafts of the text. He also provided the financial and logistical support for the work upon which this chapter and Chapters IV and V are based.

Chapter III was jointly written by the writer and N.C. Meijer Drees, with each contributing about an equal amount to the text. Most of the biostratigraphic interpretations presented are those of the writer. The writer was also responsible for the photography for Plate III-1. He was also responsible for the text-figures and table, with some additions to these made by N.C. Meijer Drees. The text-figures and table were drafted at the Institute of Sedimentary and Petroleum Geology. N.C. Meijer Drees collected all of the conodont samples from the Wabamun Group which were used as data in this chapter and in Chapters IV and V. The samples were processed and picked at the Institute of Sedimentary and Petroleum Geology or by C.F. Minerals, Kelowna and Bio Geo Services, Calgary. Meijer Drees was also responsible for some of the stratigraphic interpretations presented in Chapter III.

The writing of Chapters IV and V and the interpretations presented in these chapters are the responsibility of the writer. The writer is responsible for all the drafting in these chapters and a large part of the photography in Chapter V. B.D.E. Chatterton contributed to discussions of conodont paleoecology and taxonomy and commented of drafts of Chapters IV and V. The stratigraphic columns for sections of the Palliser Formation other than Nigel Peak and Wardner are largely based on his field descriptions, as in Chapter II. The stratigraphic columns of parts of the Wabamun Group presented in Chapter IV are largely based on core descriptions by N.C. Meijer Drees. He also contributed much of the stratigraphic information on the Wabamun Group in Chapters IV and V, and commented on a preliminary draft of Chapter IV. Some of the stratigraphic columns for parts of the Palliser Formation depicted in Figure V-4 are partly based on his field descriptions. The conodont samples from these sections were processed and picked by C.F. Minerals, Kelowna and Bio Geo Services, Calgary.

REPOSITORY OF MATERIAL

Materials upon which this study is based are stored at the National Type Fossil Collections, Geological Survey of Canada, Ottawa, the Institute of Sedimentary and Petroleum Geology, Calgary and the University of Alberta, Edmonton.

<table>
<tr><th>SERIES</th><th>STAGE</th><th>SUBSURFACE N.E. B.C. SOUTHERN N.W.T.</th><th colspan="2">CENTRAL SOUTHERN ROCKY MTNS. ALTA., B.C.</th><th colspan="2">SUBSURFACE CENTRAL NORTHERN ALBERTA</th><th colspan="2">SUBSURFACE SOUTHERN ALBERTA</th><th colspan="2">SUBSURFACE SOUTHERN SASKATCHEWAN</th></tr>
<tr><td rowspan="7">UPPER DEVONIAN</td><td rowspan="7">FAMENNIAN</td><td>EXSHAW FM.</td><td colspan="2">EXSHAW FM.</td><td colspan="2">EXSHAW FM.</td><td colspan="2">EXSHAW FM.</td><td rowspan="7">THREE FORKS GRP.</td><td>BAKKEN FM.</td></tr>
<tr><td rowspan="4">KOTCHO FM.</td><td rowspan="5">PALLISER FM.</td><td rowspan="2">COSTIGAN MBR.</td><td rowspan="5">WABAMUN GRP.</td><td>BIG VALLEY FM.</td><td rowspan="5">WABAMUN GRP.</td><td>BIG VALLEY FM.</td><td>BIG VALLEY FM.</td></tr>
<tr><td>CARDINAL LAKE UNIT</td><td rowspan="4">STETTLER FM.</td><td rowspan="5">TORQUAY FM.</td></tr>
<tr><td rowspan="3">MORRO MBR.</td><td>NORMANDVILLE UNIT</td></tr>
<tr><td>WHITELAW UNIT</td></tr>
<tr><td>?
TETCHO FM.</td><td>DIXONVILLE UNIT</td></tr>
<tr><td>TROUT RIVER FM.</td><td colspan="2">SASSENACH FM.</td><td colspan="2">GRAMINIA FM. (part)</td><td colspan="2">CROWFOOT FM. (part)</td></tr>
</table>

Figure I-1. Correlation chart of Famennian surface and subsurface stratigraphic units in Western Canada.

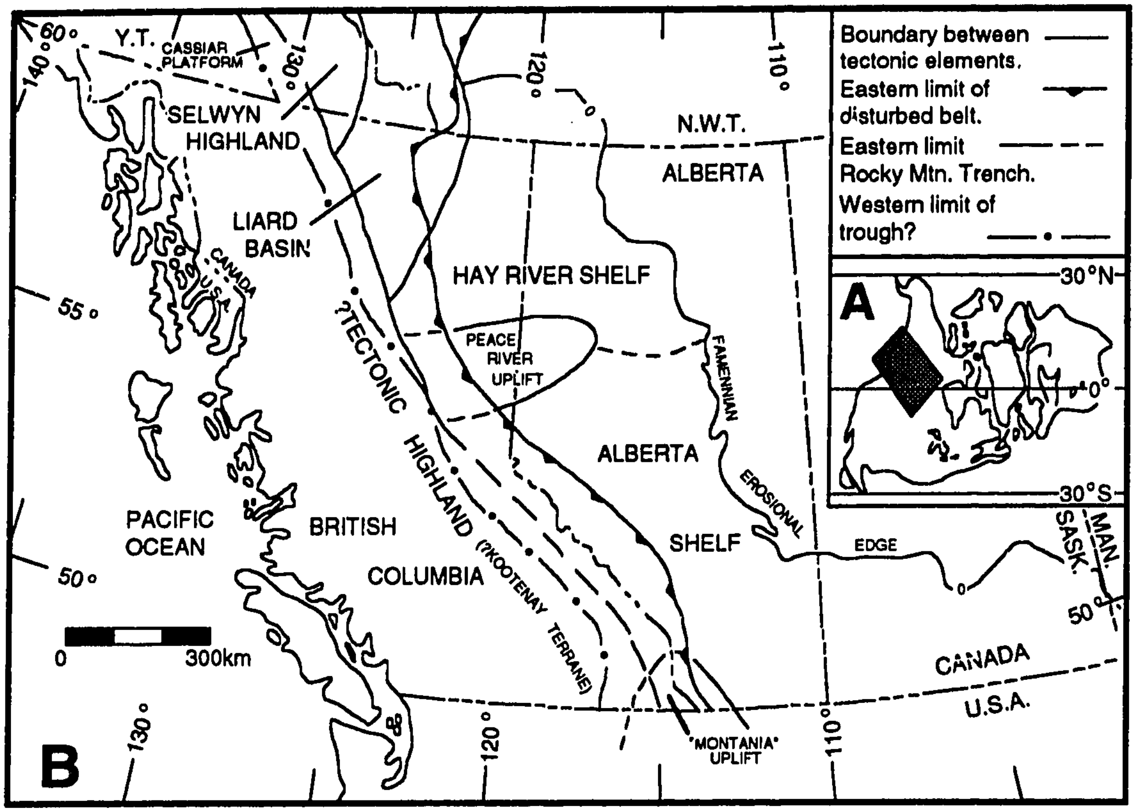


Figure I-2. A) Paleogeographic map showing position of Western Canada (shaded area) relative to the rest of Euramerica in the Famennian. Other continental blocks omitted. Position of Euramerica based on reconstruction in Scotese and McKerrow (1990). B) Famennian paleotectonic elements of Western Canada, modified from Moore (1989), Morrow and Geldsetzer (1989) and Richards (1989). Non-palinspastic position of western limit of trough modified from Richards (1989) to coincide with western boundary of Cassiar Terrane north of 55°. N.W.T. = Northwest Territories; Y.T. = Yukon Territory.

Series	Stage	Standard Conodont Zones	
UPPER DEVONIAN	FAMENNIAN	*praesulcata*	Upper
			Middle
			Lower
		expansa	Upper
			Middle
			Lower
		postera	Upper
			Lower
		trachytera	Upper
			Lower
		marginifera	Uppermost
			Upper
			Lower
		rhomboidea	Upper
			Lower
		crepida	Uppermost
			Upper
			Middle
			Lower
		triangularis	Upper
			Middle
			Lower

Figure I-3. Famennian portion of standard Upper Devonian conodont zonation after Ziegler and Sandberg (1990).

PALEOTECTONIC SETTING	OFFSHORE SHELF TO BASIN		NEARSHORE OPEN MARINE SHELF		VARIOUS NEARSHORE RESTRICTED MARINE + PERITIDAL ENVIRONMENTS	LAND
CONODONT BIOFACIES	I palmatolepid (-bispathodontid)	II palmatolepid-polygnathid	III polygnathid-icriodontid/ "icriodontid"	IV polygnathid-pelekysgnathid	V-X clydagnathid, scaphignathid, polygnathid, etc.	

Figure I-4. Standard Famennian conodont biofacies model much modified after Sandberg and Dreesen (1984, figs. 4 and 8) and from Ziegler and Sandberg (1990). Parentheses around bispathodontid component of biofacies I indicates Bispathodus is not a member of this biofacies until the upper Famennian. Until this time Palmatolepis is the dominant component of this biofacies (e.g. Sandberg and Dreesen, 1984). Icriodontid component of biofacies III represented by species of either Icriodus or "Icriodus".

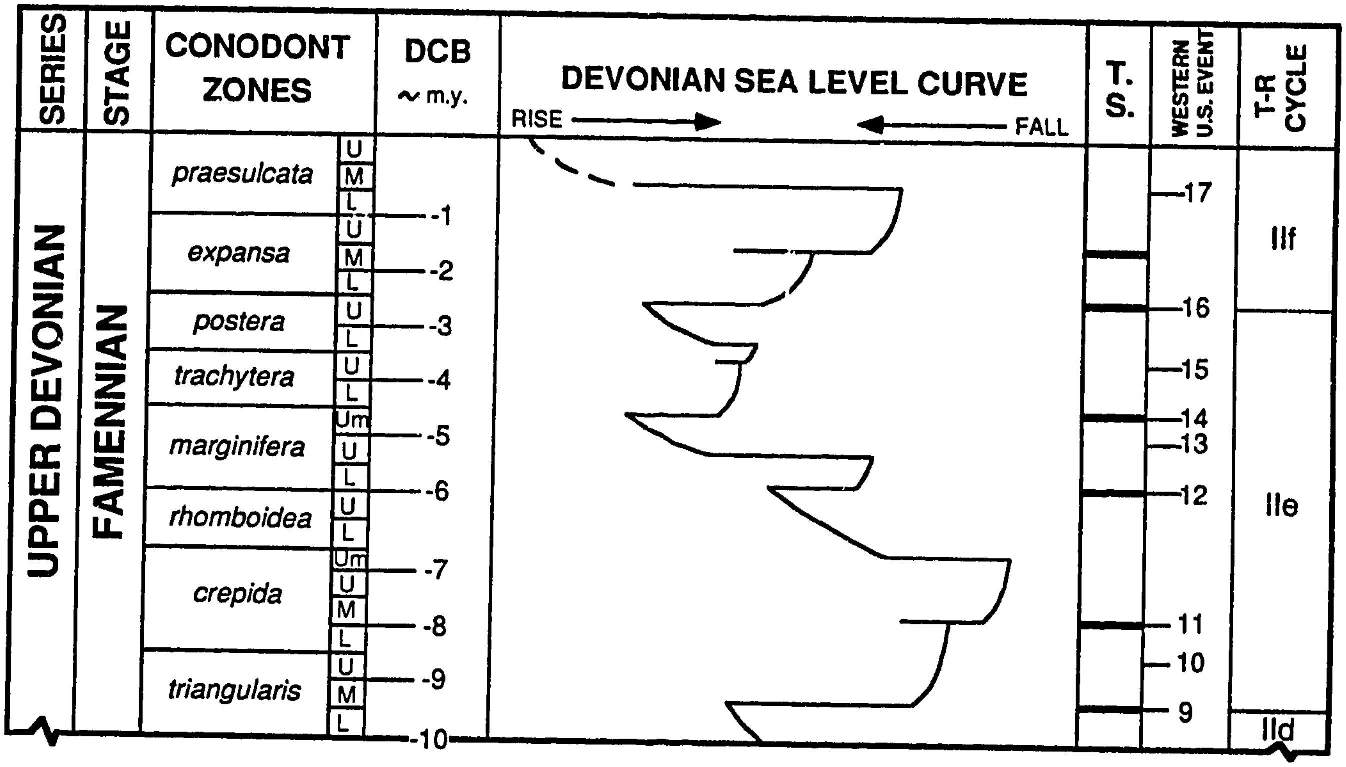
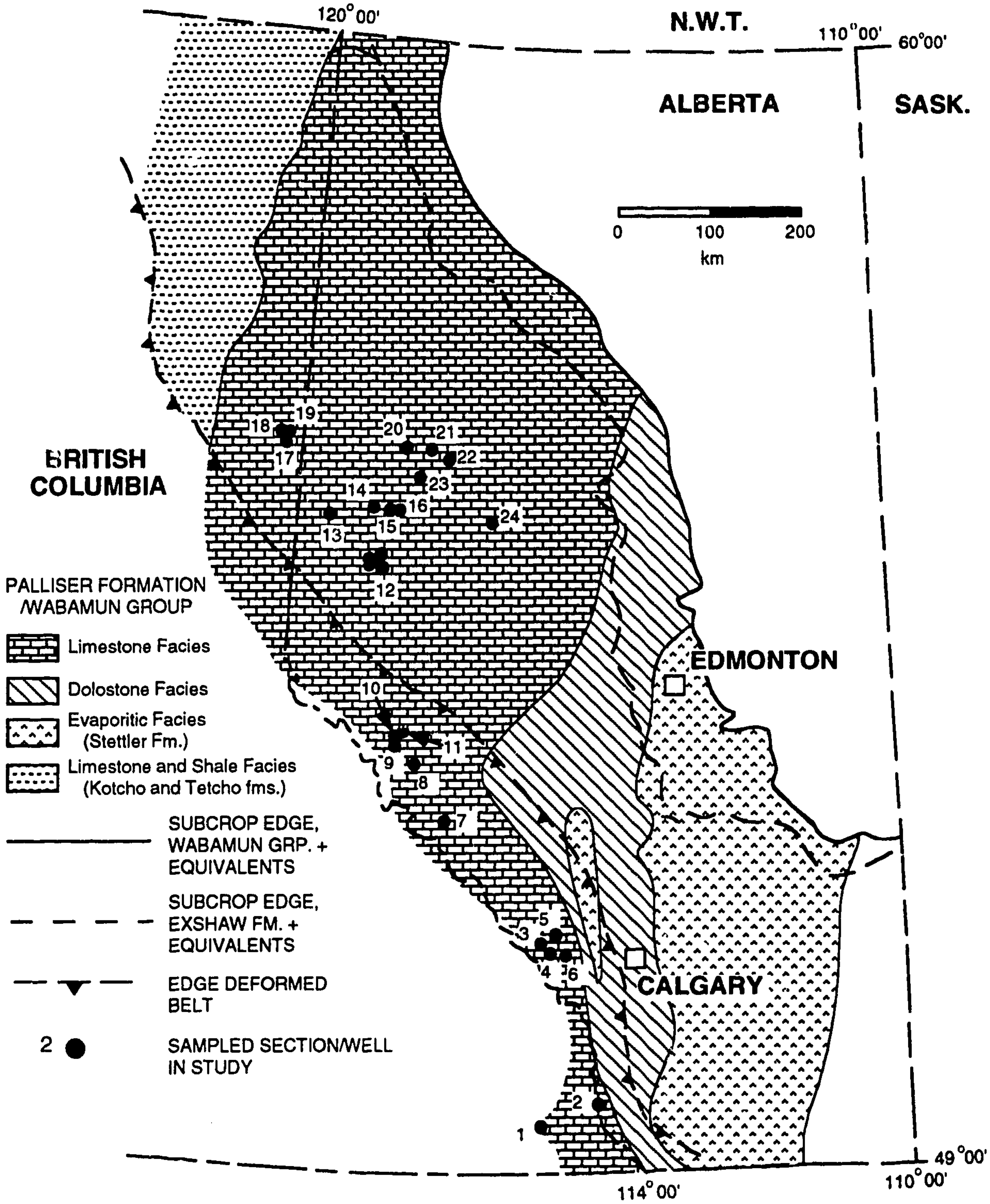


Figure I-5. Famennian portion of Devonian Euramerican sea level curve shown in relation to standard conodont zones and to absolute ages in million of years before Devonian-Carboniferous boundary (DCB) (after fig. 1 in Ziegler and Sandberg, 1990). T.S. = timing of transgressive starts in western United States. T-R = transgressive-regressive cycles (Johnson et al., 1985, 1986, 1991). Western U.S. events discussed in Sandberg et al. (1989a). Sea level curve modified from that in Johnson et al. (1991) to accommodate Uppermost crepida Zone. L = Lower, M = Middle, U = Upper, Um = Uppermost.

Figure I-6. Map showing location of sections of Palliser Formation and wells penetrating the Wabamun Group that comprise the main data base of this study. Map also shows distribution of lithofacies of Palliser Formation and Wabamun Group in Alberta and British Columbia (much modified from Belyea, 1964). Sections of Palliser Formation: 1 - Wardner; 2 - Crowsnest Pass; 3 - Banff Golf Course; 4 - Whiteman Gap; 5 - Devil's Gap; 6 - Jura Creek and LaFarge Quarry; 7 - Nigel Peak; 8 - Medicine Lake; 9 - Cold Sulphur Springs; 10 - Mount Greenock; 11 - Roche Miette. Wells of Wabamun Group: 12 - ARCO Sinclair Gold Creek 7-31-67-5W6, 10-8-67-5W6, 10-31-64-4W6, 10-21-68-4W6 and ARCO Gold Creek 6-36-66-4W6; 13 - Home et al. Beaverlodge 4-23-72-10W6; 14 - Sulpetro et al. Sexsmith 9-33-73-5W6; 15 - Mobil et al. Teepee 6-22-73-3W6; 16 - Dome CDA Smoky Heights 14-22-74-22W6; 17 - Home Pembina Farmington 6-18-80-5W6; 18 - IOE Pacific Parkland 10-26-81-16W6; 19 - Imperial Pacific Parkland 10-28-81-15W6; 20 - Richfield Little Burnt River 6-17-80-1W6; 21 - Canadian Superior Tangent 4-21-80-24W5; 22 - Imperial Normandville 1-16-79-22W5; 23 - Auburn Eaglesham 16-7-77-25W5; 24 - Imperial West Prairie 11-18-72-17W5.



120°00'
N.W.T.
110°00'
60°00'
ALBERTA
SASK.
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100
200
km
BRITISH COLUMBIA
EDMONTON
CALGARY
49°00'
114°00'
110°00'
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PALLISER FORMATION /WABAMUN GROUP
Limestone Facies
Dolostone Facies
Evaporitic Facies (Stettler Fm.)
Limestone and Shale Facies (Kotcho and Tetcho fms.)
SUBCROP EDGE, WABAMUN GRP. + EQUIVALENTS
SUBCROP EDGE, EXSHAW FM. + EQUIVALENTS
EDGE DEFORMED BELT
2 ● SAMPLED SECTION/WELL IN STUDY

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CHAPTER II

FAMENNIAN CONODONT BIOSTRATIGRAPHY OF THE PALLISER FORMATION, ROCKY MOUNTAINS, ALBERTA AND BRITISH COLUMBIA, CANADA[1]

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 ostracod (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 (Figure II-1). Additional conodont data are also available from thirty Palliser sections in which strata at or

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[1] A version of this chapter has been published. Johnston & Chatterton 1991. Geological Survey of Canada Bulletin. 417:163-183.

near the top and/or the base of the formation were sampled (Figure II-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 (Figure II-1), are the main focus of this report. The thickness and extent of sampling of each section is shown in Figure II-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) (Figure II-3). The Palliser 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 II-3. The formation is underlain either conformably or disconformably (Figure II-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 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 (Figure II-3) in southwestern Alberta, from the Bow Valley northwards 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 British Columbia (Figure II-3). The Palliser Formation is also equivalent to the Kotcho and Tetcho formations in the subsurface of northeastern British Columbia (Figure II-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, mudcracks, ripple marks and stromatolites occur (Andrichuk, 1960; Richards and Higgins, 1988; herein). In other Palliser sections (Figure II-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 (Figure II-2), two other lithofacies, in addition to the typical burrow-mottled limestones, 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 limestones 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 (Figure II-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 limestones with Chondrites in uppermost Morro strata in sections in the eastern Front Ranges indicates deposition in intertidal environments. The latter beds are directly overlain by the laminated and brecciated limestones and dolostones 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 whilst contemporaneous deposition of the fossiliferous limestones of the Costigan Member occurred elsewhere (Figure II-3). In the Crowsnest Pass section, relatively deep water conodont biofacies occur in these limestones, which may suggest deposition in a more offshore environments than at the other localities. The cessation of Palliser sedimentation was probably followed by a brief hiatus (Figure II-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 (Figure II-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 (Pls. II-1 to II-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, Late 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 (Figure II-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 II-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 (Figure II-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 II-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* is 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 II-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 II-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 (Figure II-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, text-fig. 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 at Medicine Lake (compare Pl. II-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 (Figure II-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 II-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, text-fig. 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 II-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; and 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 (Figure II-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 II-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 (Figure II-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 (Figure II-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 (Figure II-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 Mt. 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 II-3.

Some other major taxa that are 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 underlying Palliser strata that 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 II-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 II-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 II-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 these limestones 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 II-3. In the Jura Creek section, according to Richards and Higgins (1988), the base of the fossiliferous limestones 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 limestones of the Costigan Member at Jura Creek, which overlie the brecciated and laminated carbonates of this same member, are probably time equivalent to the upper part of the fossiliferous limestone that represents all of the Costigan Member at Nigel Peak (Figure II-3).

The inability to recognize the Uppermost *marginifera* through Upper postera zones in the Palliser Formation may be due to a 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 (Figure II-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. I[illegible]st, in Palliser sections in the Athabasca Valley and [illegible]on at Nigel Peak, no obvious depositional breaks have [illegible] 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 II-2 could range as high as the Lower expansa Zone (Figure II-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 downwards, or the range of "I." chojnicensis to extend upwards 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, so 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 II-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 II-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 II-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 (Figure II-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 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 (Figure II-2) represent an earlier phase of the same depositional episode that resulted in similar limestones being deposited later at the other localities or whether these limestones represent 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) (Figure II-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 II-2 and II-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 II-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 II-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, in 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) 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).

WESTERN UNITED STATES

Suggested conodont-based correlations between the Palliser Formation and selected Famennian units in the western United States are shown in Figure II-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 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 (Figure II-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 (Figure II-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 to have been deposited during the Lower to Upper *trachytera* zones (Figure II-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 shales 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 II-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

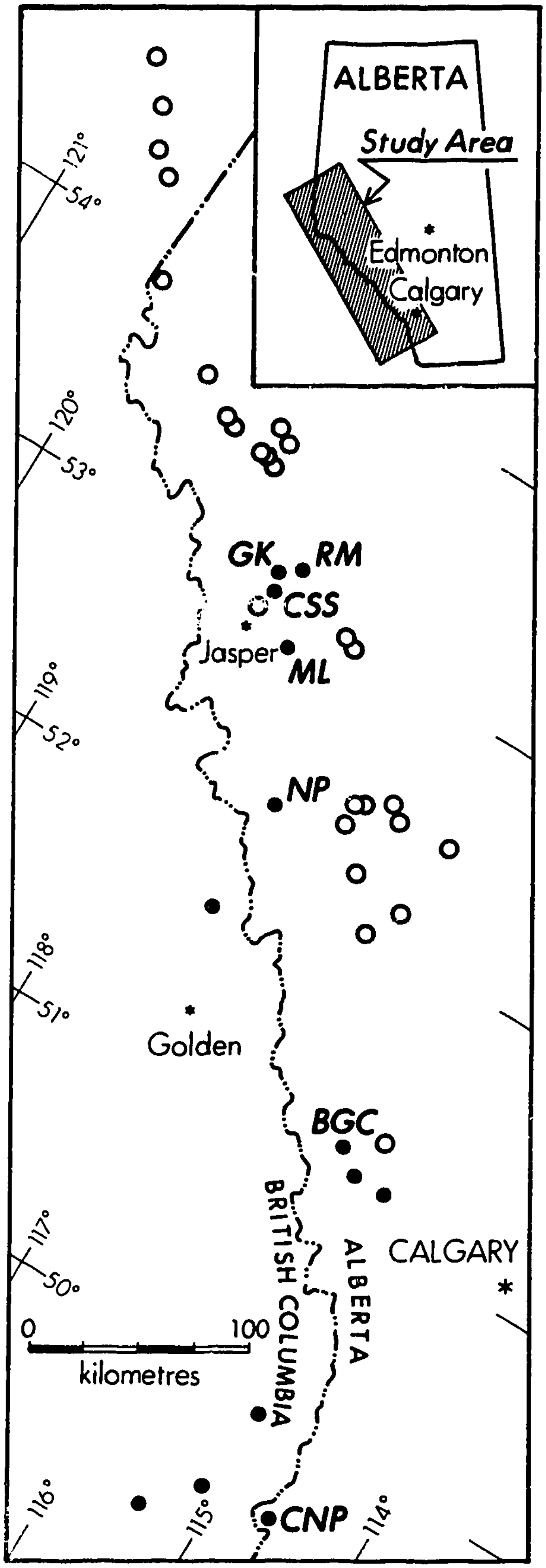
Some of the major conclusions of this paper can be summarized as follows:

1. The Middle crepida through the 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 more or less 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.

Figure II-1. Map showing locations of sections of Palliser Formation sampled for conodonts. Open circles denote sections where only tops and/or bases sampled, or where section 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.



ALBERTA
Study Area
Edmonton
Calgary
121°
54°
120°
53°
119°
52°
118°
51°
117°
50°
116°
115°
114°
GK
RM
CSS
Jasper
ML
NP
Golden
BGC
BRITISH COLUMBIA
ALBERTA
CALGARY
0
100
kilometres
CNP

Figure II-2. Stratigraphic columns of sections of Palliser Formation indicated by abbreviations in Figure II-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 II-1.

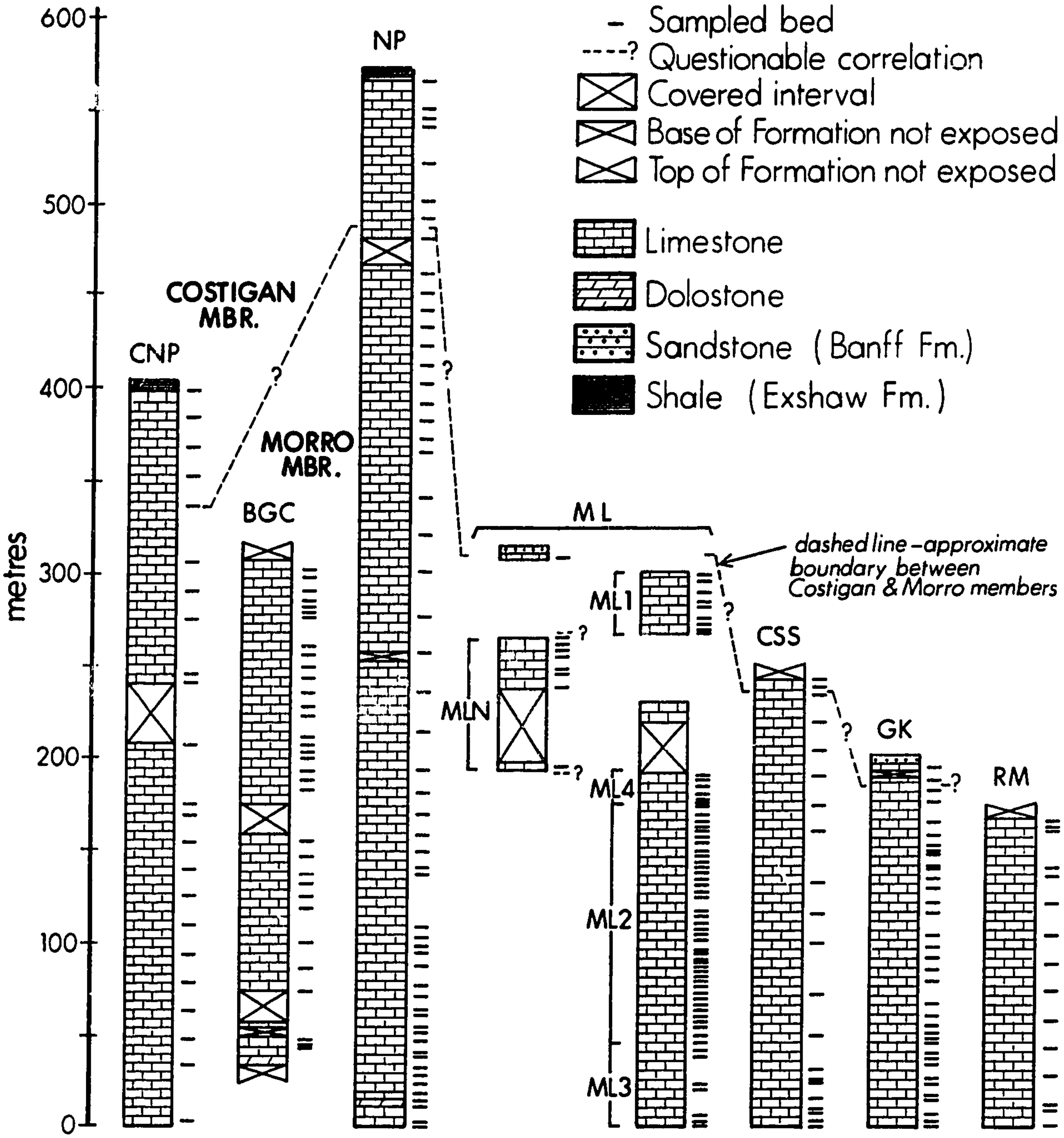
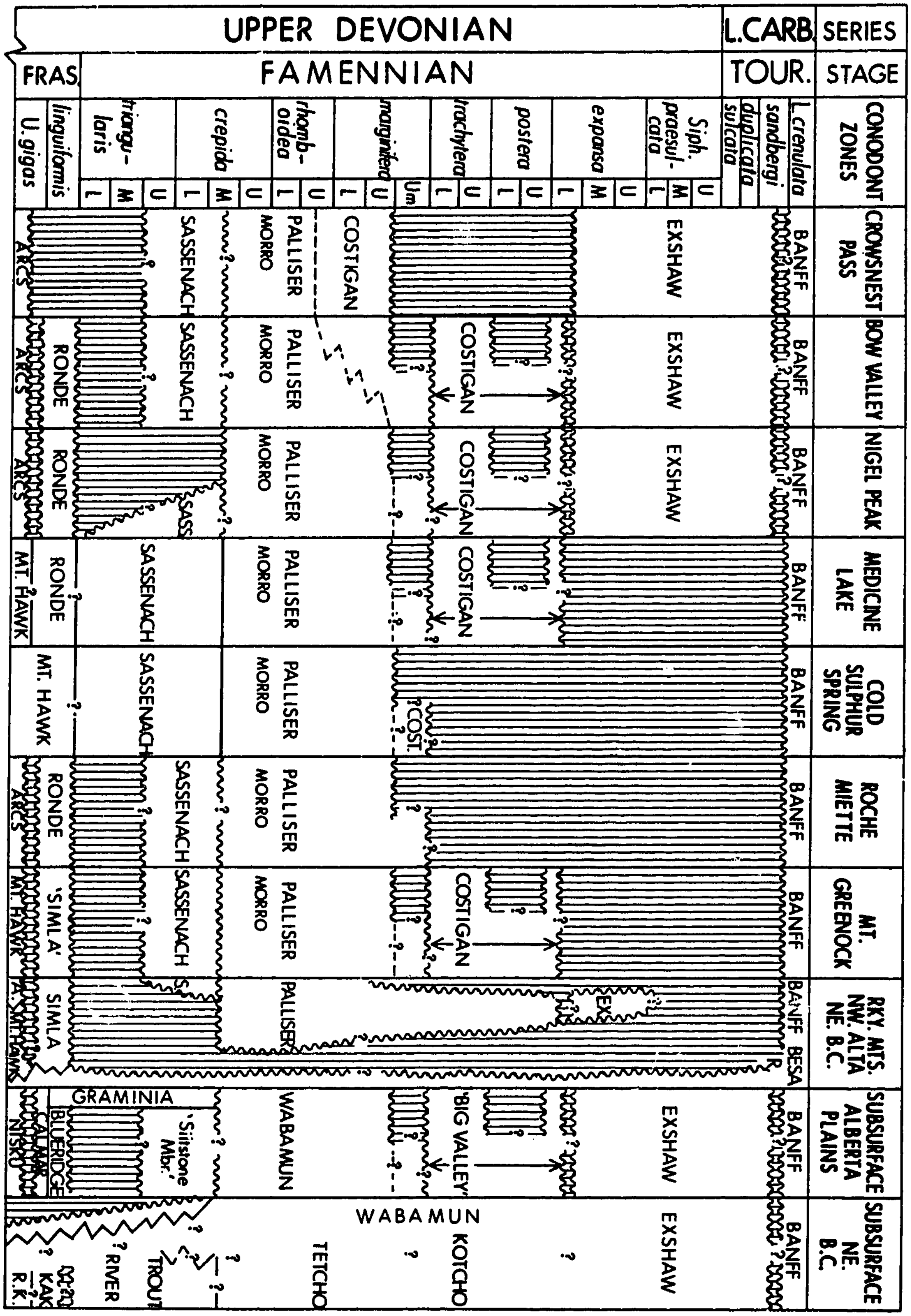

600
500
400
300
200
100
0
metres
- Sampled bed
----? Questionable correlation
Covered interval
Base of Formation not exposed
Top of Formation not exposed
Limestone
Dolostone
Sandstone (Banff Fm.)
Shale (Exshaw Fm.)
CNP
COSTIGAN MBR.
MORRO MBR.
BGC
NP
ML
MLN
ML1
ML4
ML2
ML3
dashed line - approximate boundary between Costigan & Morro members
CSS
GK
RM
?

Figure II-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, while 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., in prep.) shown by jagged line flanking the Peace River Arch (hatchered 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; Sources: 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.


UPPER DEVONIAN
L.CARB.
SERIES
FRAS.
FAMENNIAN
TOUR.
STAGE
CONODONT ZONES
U. gigas
linguiformis
triangu-laris
crepida
rhomb-oidea
marginifera
trachytera
postera
expansa
Siph. praesul-cata
sulcata
duplicata
sandbergi
L. crenulata
L M U
Um
CROWSNEST PASS
BOW VALLEY
NIGEL PEAK
MEDICINE LAKE
COLD SULPHUR SPRING
ROCHE MIETTE
MT. GREENOCK
RKY. MTS. NW. ALTA NE. B.C.
SUBSURFACE ALBERTA PLAINS
SUBSURFACE NE. B.C.
ARCS
RONDE
MT. HAWK
'SIMLA'
SIMLA
A. SMITH/HAWK
SASSENACH
SASS
S
PALLISER
MORRO
COSTIGAN
?COST.
EXSHAW
EX
BANFF
BESA
R
GRAMINIA
CALMAR
BLUERIDGE
NISKU
'Siltstone Mbr.'
WABAMUN
'BIG VALLEY'
TETCHO
KOTCHO
TROUT
RIVER
KAK
R.K.
?

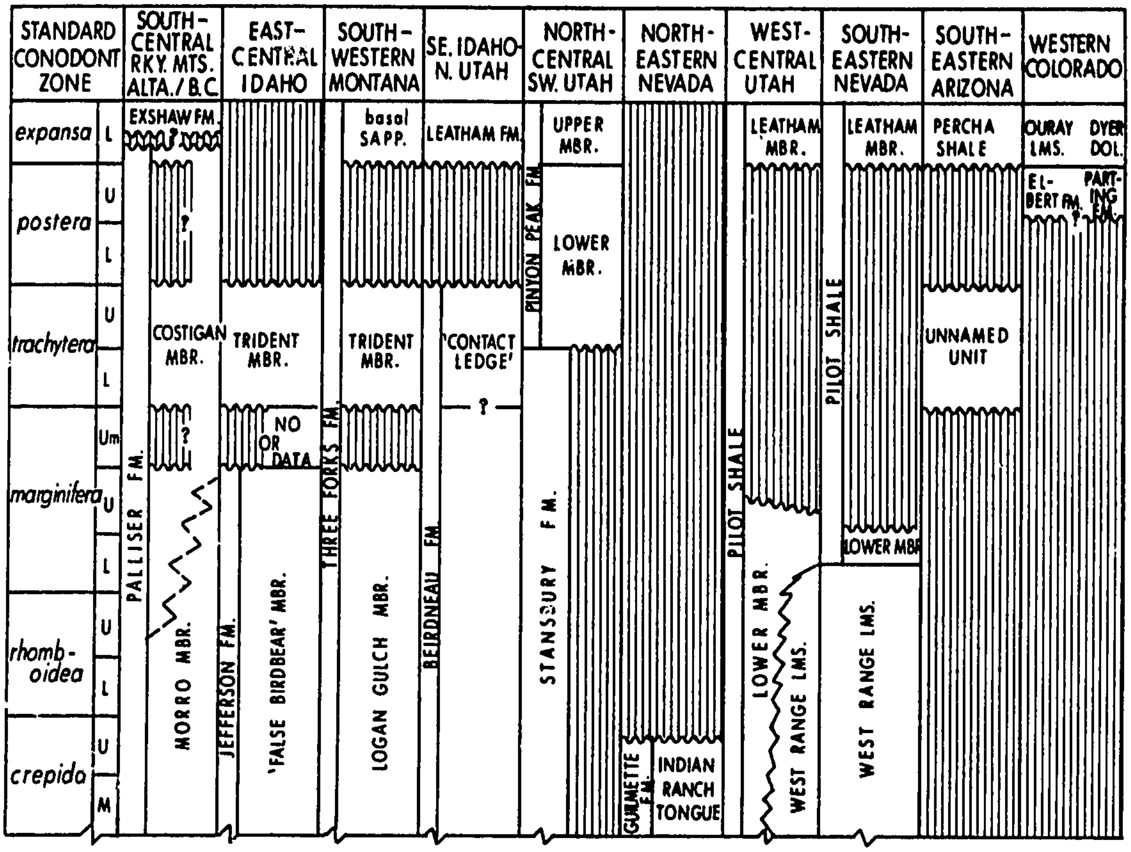


Figure II-4. Chart showing correlation of Palliser Formation with other Famennian units in the western United States. Only the minimum age determined for the top of the Palliser Formation indicated in figure. Sources for data for stratigraphic units in western United States: Sandberg and Poole, 1977; Sandberg and Dreesen, 1984; Sandberg et al., 1983, 1988.

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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° 09' 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° 09' 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 [illegible]3° 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 II-1

All specimens figured in this plate and in Plates II-2 and II-3 are housed in the National Type Collections 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.

Figs. 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 Formation, typical morphotype of subspecies.

Fig. 2. *Palmatolepis glabra lepta* Ziegler and Huddle. GSC 100258, X65, from Meosin Mountain, approximately 52 m below top of Palliser Formation.

Fig. 4. *Palmatolepis glabra prima* Ziegler and Huddle. GSC 100260, X62, from Medicine Lake (ML2 section), Morro Member, 96 m above base of Palliser Formation.

Fig. 5. *Palmatolepis glabra pectinata* Ziegler. GSC 100261, X60, from Mount Greenock, Morro Member, 128 m above base of Palliser Formation.

Figs. 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 Fig. 7, Morro Member, 87 m above base of Palliser Formation.

Fig. 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.

Fig. 10. *Palmatolepis klapperi* Sandberg and Ziegler. GSC 100266, X48, from Nigel Peak, Morro Member, 106.4 m above base of Palliser Formation.

Fig. 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.

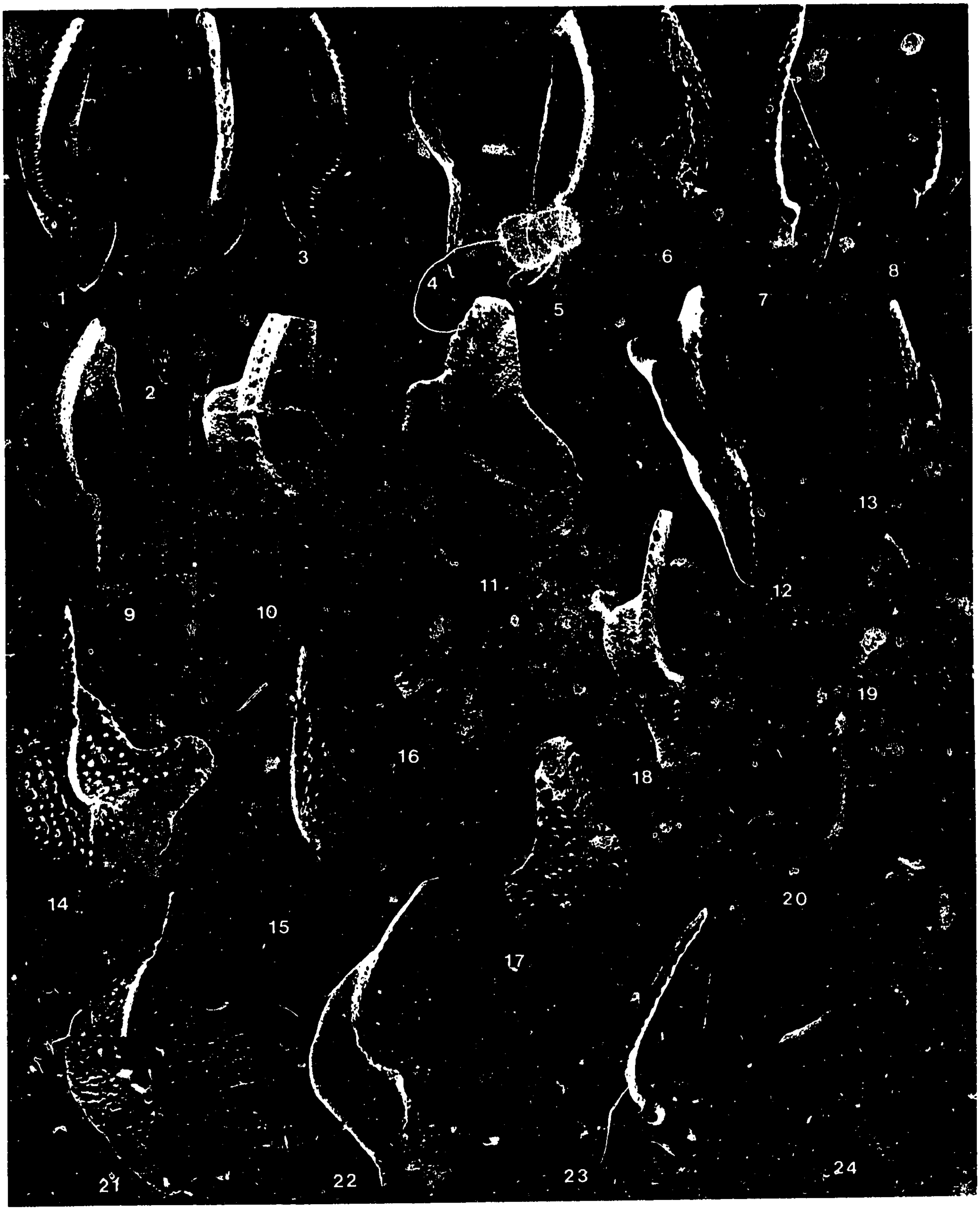
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Fig. 12. *Palmatolepis glabra pectinata* Ziegler Morphotype 1 of Sandberg and Ziegler, 1973. GSC 100268, X56, from Medicine Lake, Morro Member, approximately 289 m above base of Palliser Formation.

Fig. 13. *Palmatolepis delicatula protorhomboidea* Sandberg and Ziegler. GSC 100269, X60, from Roche Miette, Morro Member, 27.4 m above base of Palliser Formation.

Figs. 14-16. *Palmatolepis quadrantinodosalobata* Sannemann. All approximately X65.

14. GSC 100270, 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, 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, early form of species, Middle *crepida* Zone, same locality as Fig. 15, Morro Member, 75 m above base of Palliser Formation.

Fig. 17. *Palmatolepis poolei* Sandberg and Ziegler. GSC 100273, X60, from Nigel Peak, Morro Member, 147.2 m above base of Palliser Formation.

Fig. 18. *Palmatolepis tenuipunctata* Sannemann. GSC 100274, X60, from Nigel Peak, Morro Member, 106.4 m above base of Palliser Formation, lobate morphotype of species.

Fig 19. *Palmatolepis rhomboidea* Sannemann. GSC 100275, X54, from Medicine Lake (ML2 section), Morro Member, approximately 175 m above base of Palliser Formation.

Figs. 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, Fig. 20 is from the Lower *rhomboidea* Zone and Fig. 24 is from the Upper *crepida* Zone.

Fig. 21. *Palmatolepis triangularis* Sannemann. GSC 100277, X41, from Medicine Lake (ML2 section), Morro Member, 62.5 m above base of Palliser Formation.

Fig. 22. *Palmatolepis wolskajae* Ovnatanova. GSC 100278, X37, from Medicine Lake (ML2 section), Morro Member, 75 m above base of Palliser Formation.

Fig. 23. Palmatolepis circularis Szulczewski. GSC 100279, X57, from Medicine Lake (ML2 section), Morro Member, 75 m above base of Palliser Formation.

PLATE II-2

All are upper views of Pa elements and hypotypes unless stated otherwise.

Figs. 1, 2. Bispathodus stabilis (Branson and Mehl) Morphotype 1 of Ziegler, Sandberg and Austin, 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 Fig. 1, Costigan Member, 551 m above base of Palliser Formation.

Figs. 3, 4. Bispathodus stabilis (Branson and Mehl) Morphotype 2 of Ziegler, Sandberg and Austin, 1974. Both X58.
3. GSC 100283, from Nigel Peak, Costigan Member, 541 m above base of Palliser Formation.
4. lateral view, GSC 100284, from Medicine Lake, Costigan Member, top of Palliser Formation.

Fig. 5. Mehlina gradata Youngquist. GSC 100285, X58, from Mount Greenock, Morro Member, base of Palliser Formation.

Fig. 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.

Fig. 7. Apatognathus varians klapperi Druce. Upper view, Sa element, GSC 100287, X66, from Nigel Peak, Morro Member, 165 m above base of Palliser Formation.

Fig. 8. Polygnathus semicostatus Branson and Mehl. Oblique upper view, GSC 100288, X48, from Medicine Lake, Morro Member, 162 m above base of Palliser Formation.

Figs. 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.

Figs. 11, 12. Polygnathus communis communis Branson and Mehl. Both specimens from Medicine Lake (ML2 section), Morro Member, 177 m above base of Palliser Formation.
11. lower view, GSC 100291, X95.
12. GSC 100292, X79.

Fig. 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.

Fig. 14. Polygnathus pennatulus Ulrich and Bassler. GSC 100294, X42, from Mount Greenock, Morro Member, 151.5 m above base of Palliser Formation.

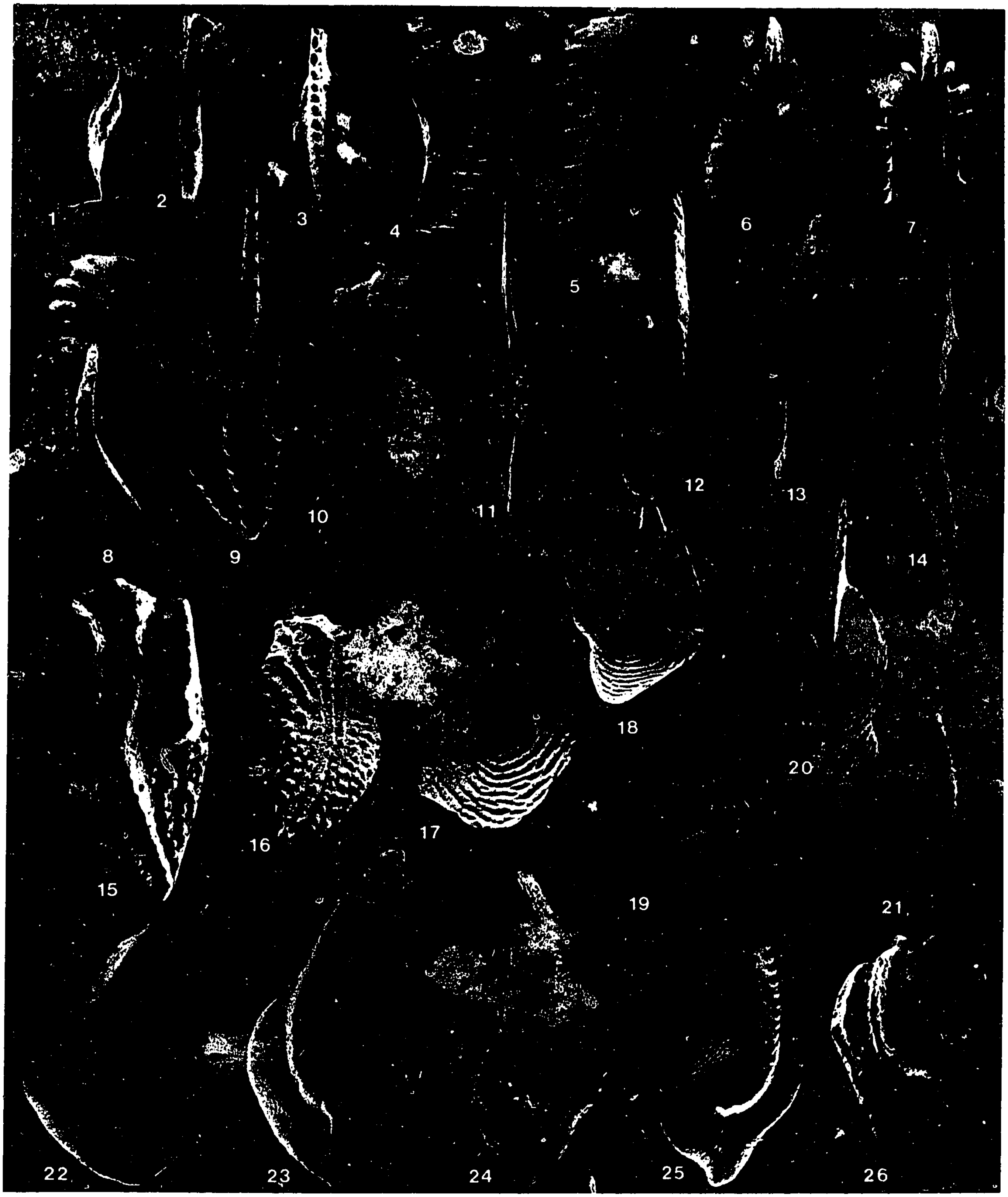
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Fig. 15. *Polygnathus perplexus* Thomas. GSC 100295, X52, from Cadomin, Costigan Member, 3.7 m below top of Palliser Formation.

Fig. 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.

Fig. 17. *Polylophodonta pergyrata* (Holmes). GSC 100297, X30, from Mount Luscar, 193 m above base of Palliser Formation.

Fig. 18. *Polylophodonta* sp. cf. *P. linguiformis* Branson and Mehl *sensu* Sandberg and Ziegler, 1973. GSC 100298, X30, from Crowsnest Pass, Morro Member 91 m above base of Palliser Formation.

Fig. 19. *Palmatolepis quadrantinodosa quadrantinodosa* Branson and Mehl. GSC 100299, X53, from Sunset Peak, top of Palliser Formation.

Fig. 20. *Polylophodonta confluens* (Ulrich and Bassler). GSC 100300, X30. from Medicine Lake (ML2 section), Morro Member, 87 m above base of Palliser Formation.

Figs. 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.

Fig. 22. *Palmatolepis stoppeli* Sandberg and Ziegler. GSC 100302, X45, from Cold Sulphur Springs, Morro Member, 73.7 m above base of Palliser Formation.

Fig. 23. *Palmatolepis quadrantinodosa inflexa* Müller. GSC 100303, X60, from Mount Greenock, Morro Member, 151.5 m above base of Palliser Formation.

Fig. 24. *Palmatolepis quadrantinodosa inflexoidea* Ziegler. GSC 100304, X48, from Crowsnest Pass, Costigan Member, 381 m above base of Palliser Formation.

Fig. 26. *Palmatolepis marginifera duplicata* Sandberg and Ziegler. GSC 100306, X57, from Nigel Peak, Morro Member, 355.3 m above base of Palliser Formation.

PLATE II-3

All specimens are hypotypes.

Figs. 1-4. "*Icriodus*" *chojnicensis* Matyja Morphotype 2 of Sandberg and Dreesen, 1984.
- 1. lateral view, GSC 100307, X89, from Nigel Peak, Costigan Member, top of Palliser Formation?
- 2. upper view of same specimen, X76.
- 3. oblique upper view, GSC 100308, approx. X70, same locality as Figs. 1 and 2, Costigan Member, 567.2 m above base of Palliser Formation.
- 4. lateral view of same specimen, X74.

Figs. 5, 6. "*Icriodus*" *chojnicensis* Matyja Morphotype 1 of Sandberg and Dreesen, 1984. Both specimens from Nigel Peak, Morro Member, 165.2 m above base of Palliser Formation.
- 5. upper view, GSC 100309, X84.
- 6. lateral view, GSC 100310, X75.

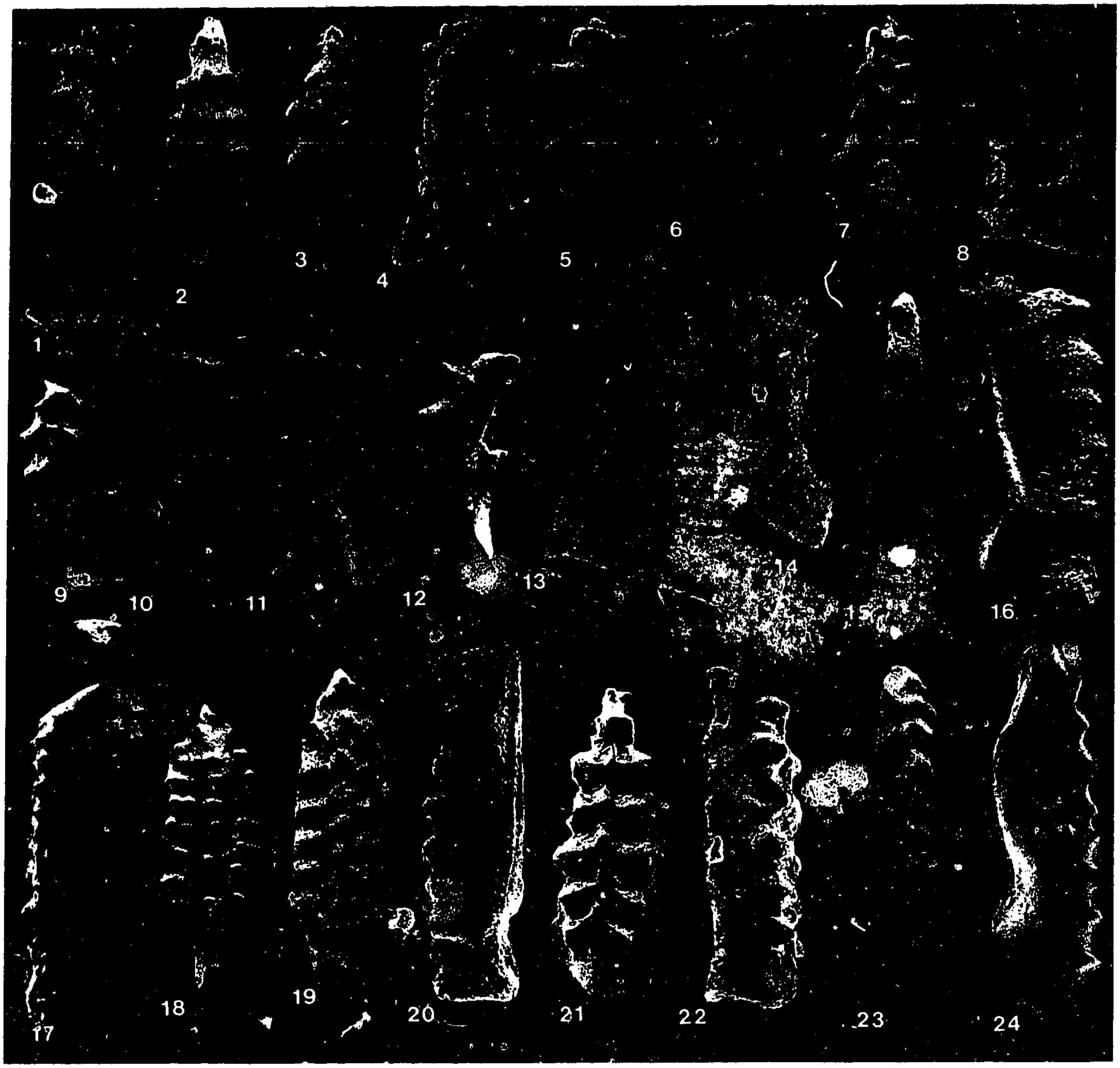
Figs. 7, 8. "*Icriodus*" *cornutus* Sannemann. From Medicine Lake (ML2 section), Morro Member, 110 m above base of Palliser Formation.
- 7. upper view, GSC 100311, X67.
- 8. lateral view of same specimen, X84.

Figs. 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, X5[illegible], from same locality as Fig. 9, Costigan Member, 501 m above base of Palliser Formation.

Fig. 11. *Pelekysgnathus* *planus* Sannemann. Lateral view, GSC 100314, X74, from Mount Greenock, Morro Member, 39.6 m above base of Palliser Formation.

Figs. 12-14. *Pelekysgnathus* *inclinatus* Thomas. Figs. 13 and 14 both X80.
- 12. lateral view, GSC 100315, X53, from Nigel Peak, Morro Member, 10.8 m above base of Palliser Formation.
- 13. lateral view, GSC 100316, same locality as Fig. 12, Morro Member, 371 m above base of Palliser Formation.
- 14. lateral view, GSC 100317, same locality as Fig. 12, Morro Member, 491 m above base of Palliser Formation.

Figs. 15, 16. *Icriodus* *iowaensis* *ancylus* Sandberg and Dreesen. From Cold Sulphur Springs, Morro Member, 25.3 m above base of Palliser Formation,
- 15. upper view, GSC 100318, X53, abraded specimen of narrow morphotype of subspecies.
- 16. lateral view of same specimen, X60.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Figs. 17, 18. "Icriodus" raymondi Sandberg and Ziegler. Both specimens from Medicine Lake, Costigan Member, top of Palliser Formation.

17. lateral view, GSC 100319, X60.
18. upper view, GSC 100320, X56.

Figs. 19, 20. Icriodus alternatus alternatus Branson and Mehl. From Roche Miette, Morro Member, 42.7 m above base of Palliser Formation.

19. upper view, GSC 100321, X56.
20. lateral view of same specimen, X63,

Figs. 21-24. Icriodus iowaensis iowaensis Youngquist and Peterson.

21. upper view, GSC 100322, X56, from Medicine Lake (ML3 section), Morro Member, 41.2 m above base of Palliser Formation, specimen represents typical broad morphotype of subspecies.
22. lateral view of same specimen, X64.
23. oblique upper view, GSC 100323, X55, from Cold Sulphur Springs, Morro Member, 70 m above base of Palliser Formation, specimen represents narrow morphotype (Sandberg and Dreesen, 1984) of subspecies.
24. lateral view of same specimen, X65.

CHAPTER III

UPPER DEVONIAN CONODONTS IN WEST CENTRAL ALBERTA AND ADJACENT BRITISH COLUMBIA[1]

INTRODUCTION

Raasch (1956), Uyeno (1967), Mound (1968) and Pollock (1968) reported on the presence of Devonian conodonts in the subsurface of Western Canada. Clark and Ethington (1965), Pollock (1968), Geldsetzer et al. (1987), Klapper and Lane (1985, 1989), Orchard (1989), Uyeno (1967, 1974), Norris and Uyeno (1981) and Weissenberger (1989) described the Frasnian conodont biostratigraphy of Devonian strata exposed in Alberta and the southern Northwest Territories. The Famennian conodont biostratigraphy of Devonian strata exposed in the Mackenzie and the Rocky Mountains were discussed by Johnston and Chatterton (1987, 1991), Irwin and Orchard (1991), Orchard (1989), Richards and Higgins (1989) and Savoy et al. (1987).

The paleontological work cited above has demonstrated the value of conodonts for regional correlations and age determinations. If one wants to unravel complex relationships a much larger data base is needed than the one available at present.

In west central Alberta the Devonian succession onlaps the Peace River highland, a pre-Devonian erosional remnant of the Peace River Arch (see O'Connell et al., 1991). The geology and detailed stratigraphy of the carbonates of the Winterburn and Wabamun groups that surround and onlap the highland are well known (see Meijer Drees et al., 1993) and samples were systematically taken.

The Wabamun limestones yielded most of the conodonts, but

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[1] A version of this chapter has been published. Johnston & Meijer Drees, 1993. Bulletin of Canadian Petroleum Geology. 41:139-149.

a few conodonts were also obtained from the Winterburn, Woodbend and Beaverhill Lake limestones. A careful search for conodonts on bedding plane surfaces was successful in the shales of the Duvernay and Exshaw formations.

This report on the conodont faunas is only a preliminary one. A more detailed description of the conodonts in the Wabamun and Palliser formations will be published later by the senior author and B.D.E. Chatterton.

CONODONT ZONATION AND BIOFACIES

In this discussion most recent standard conodont zonation for the Late Devonian Epoch is used (see Figure III-1). This zonation was proposed by Ziegler (1962) and has been revised by Sandberg and Ziegler (1973), Sandberg et al. (1988, 1989b), Ziegler (1971) and Ziegler and Sandberg (1984, 1990). The zonation includes 22 zones in the Famennian and 10 zones in the Frasnian. It is based mainly on species of Palmatolepis. Ziegler and Sandberg (1990) considered the zones to have had an average duration of 500,000 years and proposed to change the adjectives to Early, Middle, Late and Latest to emphasize their geochronologic nature. This proposal was not been universally accepted. For example, Irwin and Orchard (1991), in their depiction of the standard offshore Upper Devonian conodont zonation (see Figure III-2), used the adjectives Lower, Middle, Upper and Uppermost for each zone instead. We follow their procedure in Figures III-1 and III-2 of this report.

Another zonation for the Frasnian (not shown on Figure III-1) was proposed by Klapper (1989) and Klapper and Johnson (in Johnson, 1990) for conodont faunas that include species of the genus Palmatolepis and other conodont species.

Both the standard Upper Devonian conodont zonation and Klapper's (1989) zonation were proposed for successions representative of the Palmatolepis biofacies (i.e. successions where Palmatolepis is the most abundant conodont-platform element). These successions are generally interpreted as having been deposited in normal marine and/or deep water environments (Sandberg and Dreesen, 1984) where Palmatolepis is thought to have led a pelagic mode of life (Sandberg, 1976). The standard Upper Devonian conodont zonation has been found to be generally applicable to rock successions that were deposited in a normal marine setting (e.g. Earn Group, Irwin and Orchard, 1991). However, in shallow water and/or nearshore rock successions, characterized by an abundance of Polygnathus, Icriodus and other conodonts and in which Palmatolepis is either absent or scarce, the usefulness of the standard zonation is limited. In Western Canada, both the Frasnian and Famennian successions from several localities are characterized by the abundant and/or only presence of Polygnathus and Icriodus (e.g. Klapper and Lane, 1985, 1989; and Orchard, 1989).

In order to address this problem, Sandberg and Dreesen (1984) proposed an alternative conodont zonation (see Figure III-1) for faunas that lack Palmatolepis. It is based on species of Icriodus, its homeomorph "Icriodus", and Pelekysgnathus. Although this alternative zonation is useful in Upper Devonian strata that were deposited in very shallow water (e.g. Metzger, 1989), it has not been extensively applied.

An effort was made to collect systematically from cores to obtain representative conodont collections from all the Devonian formations. Sampled intervals in core ranged from as little as one metre to as much as five metres.

After it was discovered that many of the limestone samples from the Beaverhill Lake, Woodbend and Winterburn groups yielded little or were barren of conodonts, the decision was made to concentrate the sampling effort on the Wabamun. The absence of many diagnostic conodont taxa that characterize the Frasnian Stage elsewhere in the world may be in part due to unfavourable conditions in the Alberta basin.

It is known that reefal and evaporitic carbonates generally do not contain conodonts (e.g. Seddon and Sweet, 1971).

It is also possible that absence or scarcity of conodonts was in part due to the difficulty of extracting them. Although Weissenberger (1988) reported high recoveries of conodonts from carbonate hardgrounds in the argillaceous basin-fill facies of the Woodbend Group from core and from equivalent strata in outcrop, our samples from calcareous intervals did not sufficiently disintegrate in acid to yield conodonts.

FRASNIAN CONODONT BIOSTRATIGRAPHY

Since only few conodont collections from the Beaverhill Lake, Woodbend and Winterburn strata are available for study and none from the Elk Point, the following discussion includes the results of other conodont paleontologists. Uyeno (1967), Mound (1968) and Pollock (1968) collected conodonts diagnostic of the Lower and Middle asymmetricus zones (see Figure III-1) from Beaverhill Lake strata in the subsurface of central Alberta. Uyeno (1967, 1974) reported on the conodonts of the Waterways and Swan Hills formations in northeastern and central Alberta. Klapper and Lane (1989) and Weissenberger (1989) reported on the Frasnian conodonts from the Devonian in the Alberta Rocky Mountains.

At the present time relatively little is known about the conodonts of the subsurface formations of the Woodbend Group. Conodonts representative of the Lower asymmetricus to Lower gigas zones (see Figure III-1) were collected from the Muskwa Formation in the District of Mackenzie (Uyeno, in Meijer Drees, 1990). The Duvernay Formation in the Imperial Kingman 12-9-49-19W4 well, located southeast of Edmonton, includes conodonts that range from the Upper asymmetricus Zone to the Upper gigas Zone (Uyeno, GSC report 8-TTU-86). The lower part of the Ireton Formation in the Kingman well includes Palmatolepis sp. cf. subrecta Miller and Youngquist, and Pa. sp. aff. Pa. subperlobata Branson and Mehl sensu Klapper and

Lane (1985). This fauna was tentatively assigned to the gigas Zone (Weissenberger, GSC report 01-JAW-1987). The upper part of the Ireton Formation in the IOE Normandville #1 1-16-79-22W5 well includes a form referable to Polygnathus evidens Klapper and Lane (Weissenberger, GSC report 01-JAW-1987). This form suggests that the Lower gigas Zone (Figure III-1) may be represented. The presence of the Lower gigas zone in the Ireton Formation in central Alberta was reported earlier by Mound (1968) and Pollock (1968).

Conodonts obtained from fossiliferous limestone beds in a facies transitional between the upper part of the Ireton Formation and the Peace River carbonate complex of the Leduc Formation in the Pinto 13-19-69-8W6 (at 13102.5 ft.) and Wapiti 4-35-57-13W6 (interval 5038-5043 ft.) wells include, according to T.T. Uyeno (GSC report 02-TTU-91), species respectively of the mid-Frasnian (zones 4a-4b of Klapper and Lane, 1989) and upper Frasnian (possibly Faunal Interval 7 of Klapper and Lane, 1989).

The dolomitized and overlying fossiliferous limestone beds in the upper part of the Winterburn of the Gold Creek 7-31-67-5W6 well (between 11702-11705 ft. and possibly 11639.5-11617 ft.) yielded Polygnathus imparilis Klapper and Lane of the Upper rhenana Zone (see Figure III-1).

FAMENNIAN CONODONT BIOSTRATIGRAPHY

WINTERBURN GROUP

Early Famennian conodonts were obtained from the uppermost, sandy and peloidal limestone beds of the Winterburn Group in the BP Baseline 10-25-65-27W5 well.

In the Baseline well the sandy limestone beds below the Wabamun contain Icriodus alternatus alternatus Branson and Mehl (see Pl. III-1, fig. 10) at a depth of 3392.1 m (Table III-1). This subspecies ranges from the upper Frasnian to lower Famennian (Upper rhenana to Upper crepida zones on Figure III-1). In this borehole Icriodus iowaensis ancylus

Sandberg and Dreesen (see Pl. III-1, figs. 11 and 12) appears in the Winterburn approximately eight metres above the first occurrence of I. a. alternatus (Table III-1). The stratigraphic range of the former subspecies is restricted to the lower part of the Famennian Stage (Lower triangularis to Lower crepida zones on Figure III-2). Both species were reported from the Sassenach and Trout River formations by Orchard (1989).

WABAMUN GROUP

The limestones of the Wabamun Group in west central Alberta and adjacent British Columbia contain a diverse conodont fauna that includes representatives of the Lower crepida to Lower trachytera and Lower expansa zones. The Wabamun in the study area onlaps the erosional remnants of the Peace River Arch and ranges in thickness between 0 and 250 m. The informal subdivision proposed by Halbertsma and Meijer Drees (1987) and Meijer Drees et al. (1993) is used to correlate the cored intervals from which the conodonts were obtained (see Table III-1).

Dixonville Unit

In the Gold Creek 7-31-67-5W6 well the peloidal limestone beds of the Dixonville Unit, that overlie the fossiliferous limestone beds of the Winterburn Group that yielded Polygnathus imparilis, possibly include, between 11607 and 11617 ft., Icriodus iowaensis iowaensis Youngquist and Peterson and, between 11597 and 11607 ft., I. iowaensis ancylus (see Table III-1). The latter species ranges from the Lower triangularis to the Upper crepida zones (see Figure III-1).

The Dixonville Unit was also sampled in the Gold Creek 10-21-68-4W6 well and the basal part (interval 10891-10902 ft.) yielded Icriodus iowaensis ancylus (Higgins, GSC Report 4-ACH-1985).

Samples in the Smokey Heights 14-22-74-2W6 and Parkland 10-28-81-15W6 wells contain *Palmatolepis wolskajae* Ovnatanova (see Pl. III-1, fig. 20) just above the base of the Wabamun Formation. This species occurs between depths 2639 and 2639.3 m in the Smoky Heights well and is accompanied by *Palmatolepis protorhomboidea* Sandberg and Ziegler (see Table III-1). A sample collected 9 m higher in the Smokey Heights well yielded *Pa. glabra prima* Ziegler and Huddle (see Pl. III-1, fig. 14).

In the Parkland 10-28-81-15W6 well the Wabamun Formation overlies the crestal part of the Peace River Highland and is separated from the Precambrian crystalline rocks by a basal transgressive sandstone unit (Meijer Drees et al., 1993, fig. 13). Subsurface correlations and the presence of *Palmatolepis wolskajae* just above the sandstone unit suggest that strata equivalent to the Dixonville are present. *Pa. wolskajae* is joined by *Pa. glabra prima* and *Pa. protorhomboidea* in interval 11128.5 ft. to 11169 ft. (see Table III-1).

The faunas in the Parkland and Smokey Heights wells containing *Pa. wolskajae* without *Pa. glabra prima* are considered representative of the Lower to Middle *crepida* zones (Ziegler and Sandberg, 1990). Here the association of *Pa. glabra prima* and *Pa. wolskajae* in overlying beds in these wells and possibly in the Little Burnt River 6-17-80-1W6 well (interval 7281-7311 ft.) suggests that the lower part of the Upper *crepida* Zone (cf. Sandberg and Ziegler, 1973, table 1; Ziegler and Sandberg, 1990, p. 24) is also present in the Dixonville Unit (see Figure III-2).

The upper part of the Dixonville in the Gold Creek 10-8-67-5W6 well (interval 11900-11851 ft.) did not yield *Palmatolepis glabra prima*. Here *Pa. wolskajae* is considered to indicate the presence of the Lower to Middle *crepida* zones.

Whitelaw Unit

Cores in the basal part of the Whitelaw Unit in the Gold Creek 10-8-67-5W6 (interval 11833-11851 ft.) and 7-31-67-5W6 (interval 11430-11460 ft.) wells also yielded *Palmatolepis wolskajae* and *Pa. protorhomboidea* (see Table III-1). The presence of these conodonts and the absence of *Pa. glabra prima* characterize the Lower to Middle *crepida* zones. The basal part of the Whitelaw Unit in the Gold Creek well may thus be older than the upper part of the Dixonville Unit in the Smoky Heights 14-22-74-2W6 well, and thus the boundary between the Dixonville and Whitelaw units appears to be diachronous.

The middle and upper parts of the Whitelaw unit were sampled in the Sexsmith 9-33-73-5W6, the Gold Creek 10-31-67-4W6 and the Teepee 6-22-73-3W6 wells.

In a Sexsmith sample at depth 3074.5 m, *Palmatolepis glabra prima* occurs without *Pa. wolskajae*. This sample is considered to represent the upper part of the Upper *crepida* Zone. In the Sexsmith sample at depth 3059.5 m *Pa. glabra prima* occurs together with its morphotypes 1 and 2 of Sandberg and Ziegler (1973) and *Pa. tenuipunctata* Sannemann (see Table III-1). These conodonts are shown on Plate III-1, figures 15 16, 23 and 24. *Palmatolepis poolei* Sandberg and Ziegler, indicative of the Lower *rhomboidea* Zone, is also present.

The upper part of the Whitelaw unit in the Sexsmith and Teepee wells contains conodonts characteristic for the Middle and Upper *crepida* to Upper *marginifera* zones.

Palmatolepis glabra prima, Morphotype 1 of this subspecies and *Pa. tenuipunctata* also occur together in the upper part of the Whitelaw Unit in the Gold Creek 10-8-67-5W6 well between 11667 and 11681 ft. (see Table III-1).

Palmatolepis poolei is also present as well in the upper part of the Whitelaw unit in the Gold Creek 10-31-67-4W6 well between depths 10551-10559 ft. and 10604-10613 ft. (see Table III-1). Here the top of the Whitelaw Unit coincides with the top of the Lower *rhomboidea* Zone at the highest occurrence of *Pa. poolei* (see Table III-1).

The Uppermost *crepida* Zone (Ziegler and Sandberg, 1990) in the Gold Creek 10-31 well is present between 10613 ft. to 10649 ft. It is defined by the first occurrence of Pa. glabra prima Morphotype 2 (see Table III-1). Present information suggests that this morphotype does not occur lower than the Uppermost crepida Zone (e.g. Klapper and Ziegler, 1979).

"Shaly" Carbonate Facies. In the Parkland gas field of northeastern British Columbia, the Wabamun Group includes a dark coloured, argillaceous limestone facies that occupies a stratigraphic position somewhere between the Whitelaw and Normandville units (see Meijer Drees et al., 1993, fig. 13). The lower part of the argillaceous facies was sampled in the Parkland 10-28-81-15W6 well. Here the occurrence of Palmatolepis glabra pectinata Ziegler (Pl. III-1, fig. 1) together with Pa. subperlobata Branson and Mehl (Pl. III-1, fig. 17) between 11063 and 11090 ft. (see Table III-1) indicates the presence of the Uppermost crepida and basal part of the Lower rhomboidea zones (see Klapper and Ziegler, 1979, text-fig. 6; Ziegler and Sandberg, 1990).

In the upper part of the "shaly" carbonate facies of the Parkland 10-28-81-15W6 (interval 10932 to 10938 ft.) and 10-26-81-16W6 (interval 11422-11436 ft.) wells, Palmatolepis klapperi Sandberg and Ziegler and Pa. rhomboidea Sannemann (see Pl. III-1, figs. 22 and 13) are the only diagnostic conodonts (see Table III-1). The first species ranges from the Uppermost crepida to the Lower marginifera zones. The second species only occurs in the Lower and Upper rhomboidea zones and the lower part of the Lower marginifera Zone (see Sandberg and Ziegler, 1973; Ziegler and Sandberg, 1990).

Normandville Unit

The strata in the Gold Creek 10-31-67-4W6 well equivalent to the Normandville Unit include the Upper rhomboidea Zone. Palmatolepis klapperi and indeterminate specimens of the Palmatolepis glabra group, Pa. rhomboidea and Polygnathus semicostatus Branson and Mehl (see Pl. III-1, fig. 19) are the only significant conodonts. Palmatolepis klapperi occurs between depths 10474 and 10482 ft. in the middle part of the Normandville unit (see Table III-1). Palmatolepis rhomboidea occurs in the uppermost part of the Normandville Unit between 10426 and 10434 ft. Polygnathus semicostatus, a conodont with a long ranging stratigraphic distribution (see Sandberg and Ziegler, 1979), is also present in the Normandville unit of the Normand 4-15-79-22W5 well between depths 5789 and 5864 ft (see Table III-1).

Cardinal Lake Unit

The occurrence of Palmatolepis stoppeli Sandberg and Ziegler (Pl. III-1, fig. 21) in the middle part of the Cardinal Lake unit of the Gold Creek 10-31-67-4W6 well (interval 10362-10370 ft.) suggests that the uppermost part of the Upper rhomboidea and the basal part of the Lower marginifera zones are present.

The Cardinal Lake Unit was also sampled in the Tangent 4-21-80-24W5 (interval 1853-1865 m) and the Parkland 10-28-81-15W6 (interval 10697-10743 ft.) wells. Table III-1 indicates that in these two wells Palmatolepis stoppeli occurs either with or just below Pa. marginifera marginifera Helms (Pl. III-1, fig. 18).

Faunas including only Pa. stoppeli are assumed to be representative of the uppermost part of the Upper rhomboidea Zone. Faunas containing both Pa. stoppeli and Pa. m. marginifera are interpreted to be representative of the lower part of the Lower marginifera Zone (cf. Ziegler and Sandberg, 1984).

The presence of the Lower marginifera Zone in the Cardinal Lake Unit of the Farmington 6-18-80-15W6 well (See Meijer Drees et al., 1993, fig. 13, section 6) is based on the association of Palmatolepis marginifera marginifera and Pa. quadrantinodosa inflexa Müller between depths of 11825 and 11829 ft.

The presence in the Beaverlodge 4-23-72-10W6 core (interval 11712-11719 ft.) of Bispathodus stabilis (Branson and Mehl) Morphotype 1 of Ziegler, Sandberg and Austin (Pl. III-1, figs. 4, 5) and Palmatolepis marginifera marginifera (see Table III-1) suggests that the uppermost Cardinal Lake unit may include the Upper marginifera to Lower trachytera zones (see Figure III-2).

Big Valley Unit

In the cores of the Eaglesham 16-7-77-25W5 (interval 2018-2022.5 m) and Normandville No. 1 1-16-79-22W5 (interval 5502-5522 ft.) wells the Big Valley Unit (correlative with the Big Valley Formation of Wonfor and Andrichuk, 1956) includes on Table III-1 important conodont taxa such as Alternognathus regularis Ziegler and Sandberg, Bispathodus stabilis morphotypes 1 and 2 of Ziegler, Sandberg and Austin, Pelekysgnathus inclinatus Thomas and Polygnathus perplexus Thomas (see Pl. III-1, figs. 2-9). These species suggest a biostratigraphic position between the Lower expansa and Lower praesulcata zones (see Figure III-2). Zonal indices of the Lower trachytera to Upper postera zones were not recovered.

Mound (1968) also reported Pelekysgnathus inclinatus and Polygnathus perplexus (identified by Mound as Polygnathus nodoundatus Helms, pl. 69, figs. 15 and 16) from the Big Valley part of the Wabamun Group in the Winterburn Province No. 1, 10-4-53-25W4 well near Edmonton.

Johnston and Chatterton (1991) noted the absence of conodonts characteristic of the Uppermost marginifera to Upper postera zones in the upper part of the Costigan Member of the Palliser Formation (more or less equivalent to the Big Valley Formation) and suggested that the absence may be due to the lack of suitable paleoenvironments for the zonal indices or due to the presence of depositional haiti. In the late Famennian of the western United States regional unconformities were recognized that encompass some of these conodont zones (see Sandberg and Poole, 1977; Sandberg et al., 1983, 1989a).

EXSHAW FORMATION

In the southern part of the Peace River region the Exshaw Formation overlies the Big Valley Formation, but in the northern part it erosionally overlies the Cardinal lake Unit (Meijer Drees et al., 1993). This explains the absence of conodonts diagnostic of the Lower expansa to Lower praesulcata zones in the uppermost Wabamun strata of the Beaverlodge 4-23-72-10W6 and Royce 10-28-83-7W6 wells.

In the Peace River area conodonts in the Exshaw Formation include Bispathodus stabilis, Branmehla inornata (Branson and Mehl), Palmatolepis gracilis expansa Sandberg and Ziegler and possibly Pa. perlobata postera Ziegler. Bispathodus stabilis occurs at a depth of 2119.46 m in the Cindy 16-35-77-1W6 well (Uyeno, GSC Fossil Report 6-AWN-89) and Pa. gracilis expansa is present at 5724 ft. in the Lalby No. 1, 1-72-79-22W5 well (Higgins, GSC Fossil Report 9-ACH-86).

Bispathodus stabilis and Branmehla inornata are possibly present in the Peoria 2-35-76-1W6 well at depth of 2179.6 m (see Table III-1). Branmehla inornata and possibly Pa. perlobata postera occur at 11104.5 ft. in the Golata 8-29-83-15W6 well. The presence together of these conodonts in the basal part of the Exshaw Formation suggest a Lower expansa to praesulcata age. This age assignment agrees with that given to the formation at its type section at Jura Creek by Richards and Higgins (1989).

Exshaw conodonts of the same age were reported in the Steveville field in southeastern Alberta by Cooper and Sloss (1943). They were also found in the lower black shale unit of the Bakken Formation in the subsurface of Saskatchewan (Uyeno in Karma and Parslow, 1989) and in North Dakota (Hayes, 1985; Thrasher, 1987) and the Sappington Member of the Three Forks Formation (e.g. Sandberg, 1976; Sandberg and Poole, 1977; Sandberg and Ziegler, 1979; Sandberg et al. 1983, 1989a).

CONCLUSIONS

Information from the literature suggests that the Beaverhill Lake strata in the Peace River region include the Frasnian, Lower to Middle asymmetrica zones (uppermost Upper falsiovalis to punctata zones of Figure III-1). Conodont data for the Woodbend strata are sparse and the lower age limit probably corresponds with the Middle asymmetricus or punctata zones on Figure III-1. The upper age limit of the Woodbend strata is presumably not younger than the Lower to Upper rhenana zones (gigas zones of previous reports). This is the presumed minimum age for the equivalents of the Woodbend in the Rocky Mountains (the Mt. Hawk Formation, Weissenberger, 1989). The Frasnian part of the Winterburn Group remains undefined in terms of the standard conodont zonation.

Conodont data from 91 productive Famennian samples collected in the Peace River region suggest that the Lower to Upper triangularis zones, the Uppermost marginifera Zone, and the Lower trachytera to Upper postera zones are missing. The conodont subspecies diagnostic of the Upper triangularis Zone (i.e. Palmatolepis minuta minuta Branson and Mehl) is present, but it occurs together with conodonts characteristic of the Lower to Upper crepida zones. The presence of Palmatolepis wolskajae in the basal beds of the Wabamun Group suggests that these beds are not older than the Lower crepida Zone (Figure III-2).

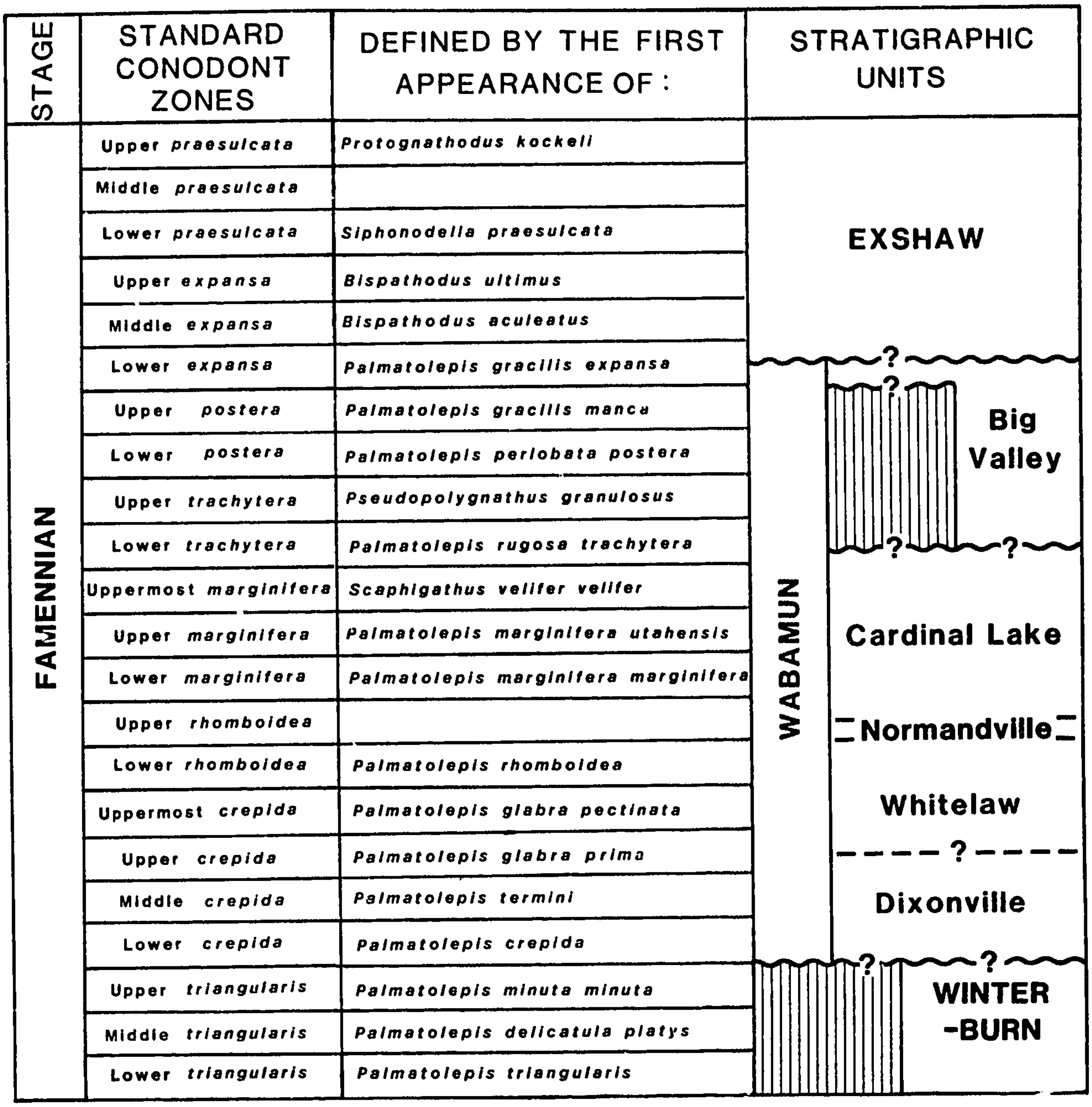
The conodonts diagnostic of the Lower and Middle triangularis zones may be absent because the upper part of the Winterburn Group and the lower part of the Wabamun Group are dominated by nearshore and semi-restricted marine carbonates. It is also possible that diagnostic conodonts are absent because of a hiatus in the sedimentary record (see Figure III-2).

Regional geological evidence indicates that the top of the Winterburn Group in central Alberta marks the end of a regressive sedimentary sequence. Because the nearshore part of a regressive sedimentary or progradational wedge of sediments often includes features related to exposure or erosion, several geologists have postulated the presence of a hiatus in the upper part or at the top of the Winterburn (Morrow and Geldsetzer, 1989). The paucity of biostratigraphic information makes it a matter of speculation whether or not this hiatus coincides with the eustatic fall in sea level postulated by Johnson et al. (1985).

The absence of conodonts diagnostic for the Uppermost marginifera and the Lower trachytera to Upper postera zones in the Wabamun Group can be explained in terms of an unfavourable environment of deposition. It is also possible that the hardground surfaces in the upper part and at the top of the Cardinal Lake unit (Meijer Drees et al., 1993) represent significant discontinuities in deposition (see Figure III-2). In the Peace River region, the Big Valley Formation and the Exshaw Formation both include conodonts of the pelagic expansa Zone. Thus the sharp boundary between the Wabamun limestone and the Exshaw shale does not appear to represent a major hiatus.

Figure III-1. The Upper Devonian standard conodont zonation proposed by Ziegler and Sandberg (1990) compared to the former (Sandberg et al., 1988) and the alternative (nearshore biofacies of Sandberg and Dreesen, 1984) zonations. Abbreviations: L = Lower M = Middle; U = Upper and Um = Uppermost.

SERIES	STAGE	FORMER CONODONT ZONES (PRIOR TO 1988)		STANDARD CONODONT ZONES (PELAGIC BIOFACIES)		ALTERNATIVE ZONES (NEARSHORE BIOFACIES)	
UPPER DEVONIAN	**FAMENNIAN**	U	***Siphonodella praesulcata***	U	***Siphonodella praesulcata***	U	***"Icriodus" costatus***
		M		M			
		L		L			
		U	***expansa***	U	***expansa***		
		M		M		M	
		L		L		L	
		U	***postera***	U	***postera***		
		L		L			
		U	***trachytera***	U	***trachytera***		
		L		L			
		Um	***marginifera***	Um	***marginifera***		
		U		U		U	***"Icriodus" cornutus***
		L		L			
		U	***rhomboidea***	U	***rhomboidea***		
		L		L		M	
		U	***crepida***	Um	***crepida***		
				U			
		M		M			
		L		L			
		U	***triangularis***	U	***triangularis***	L	
		M		M			
		L		L			
	FRASNIAN	Um	***gigas***	***linguiformis***		U	***Pelekysgnathus planus***
		U		U	***rhenana***	L	
		L		L			
		Ancyrognathus triangularis		***jamieae***		***Icriodus symmetricus***	
				U	***hassi***		
		U	***Polygnathus asymmetricus***	L			
		M		***punctata***			
		L		***transitans***			
				U	***Mesotaxis falsiovalis***	unzoned	
M.DEV.		Lm		L			



STAGE	STANDARD CONODONT ZONES	DEFINED BY THE FIRST APPEARANCE OF :
FAMENNIAN	Upper *praesulcata*	*Protognathodus kockeli*
	Middle *praesulcata*	
	Lower *praesulcata*	*Siphonodella praesulcata*
	Upper *expansa*	*Bispathodus ultimus*
	Middle *expansa*	*Bispathodus aculeatus*
	Lower *expansa*	*Palmatolepis gracilis expansa*
	Upper *postera*	*Palmatolepis gracilis manca*
	Lower *postera*	*Palmatolepis perlobata postera*
	Upper *trachytera*	*Pseudopolygnathus granulosus*
	Lower *trachytera*	*Palmatolepis rugosa trachytera*
	Uppermost *marginifera*	*Scaphigathus velifer velifer*
	Upper *marginifera*	*Palmatolepis marginifera utahensis*
	Lower *marginifera*	*Palmatolepis marginifera marginifera*
	Upper *rhomboidea*	
	Lower *rhomboidea*	*Palmatolepis rhomboidea*
	Uppermost *crepida*	*Palmatolepis glabra pectinata*
	Upper *crepida*	*Palmatolepis glabra prima*
	Middle *crepida*	*Palmatolepis termini*
	Lower *crepida*	*Palmatolepis crepida*
	Upper *triangularis*	*Palmatolepis minuta minuta*
	Middle *triangularis*	*Palmatolepis delicatula platys*
	Lower *triangularis*	*Palmatolepis triangularis*

Figure III-2. The Famennian part of the standard offshore Upper Devonian conodont zonation of Ziegler and Sandberg (1990) and the stratigraphy of the Wabamun Group in the Peace River region.

Table III-1. Stratigraphic distribution of diagnostic Frasnian and Famennian conodont species and subspecies from 91 core samples. An X marks the presence, an O indicates the uncertain presence of a species or subspecies. *Bispathodus stabilis* in table refers to definite or possible occurrences of this species where the two morphotypes (i.e. 1 and 2) are not distinguished.

Stratigraphic Units		Well Locations	GSC Catalogue Numbers	Sample Intervals / Conodonts	*Palmatolepis minuta minuta*	*Polygnathus imperalis*	*Icriodus alternatus alternatus*	*I. iowaensis ancylus*	*Palmatolepis wolskajae*	*Pa protorhomboidea*	*Pa glabra prima*	*Pa tenuipunctata*	*Pa subperlobata*	*Pa glabra prima* Morphotype 1	*Pa glabra prima* Morphotype 2	*Pa poolei*	*Polygnathus semicostatus*	*Palmatolepis glabra pectinata*	*Pa klapperi*	*Pa rhomboidea*	*Pa stoppeli*	*Pa marginifera marginifera*	*Pa. quadrantinodosa inflexa*	*Bispathodus stabilis* Morphotype 1	*Bispathodus stabilis*	*Bispathodus stabilis* Morphotype 2	*Palekysgnathus inclinatus*	*Polygnathus perplexus*	*Branmehla inornata*	*Palmatolepis perlobata postera*	*Pa gracilis expansa*	*Alternognathus regularis*
WINTERBURN		1	100138	3392.1 m			X																									
				3384.0-3384.4 m				X																								
				3336.5-3337.5 m				X																								
		2	130391	11702-11705 ft		X																										
				11617-11626 ft		O																										
WABAMUN GROUP	Dixonville			11597-11607 ft				O																								
				11587-11597 ft					X																							
				11560-11570 ft					X																							
		3	100138	10891-10902 ft				X																								
				10875-10883 ft					O																							
		4	14479	2630.0-2630.3 m					X	X																						
				2630.0-2630.5 m	X				X		X																					
				2624.5-2629.5 m	X				X		X																					
				2623.0-2624.5 m	X				X		X	X	X																			
	Dixonville / WN/	5	170478	11170-11220 ft					X																							
				11128.5-11169 ft	X				X	X	X	X	X																			
				11111-11128.5 ft	X				X	X	X	X	X																			
				11063-11090 ft	X						X		X				X	X														
	Dix.	6	186693	7281-7311 ft				O	X		O																					
		7	130936	11875-11900 ft					O																							
				11851-11862 ft					X																							
				11833-11851 ft					X	X																						
	Whitelaw	2	130391	11452-11460 ft						X																						
				11440-11452 ft					X	X																						
				11430-11440 ft					X																							
		6	039547	2743.0-2752.4 m							X						X															
		7	130936	11667-11681 ft							X	X		X			X															
				11656-11667 ft										X			X															
				11645-11656 ft													X															
	Whitelaw / Hor.	9	146877	3074.5 m							X	O																				
				3069.5 m	X						X	X	X	X	X	X	O															
				3057.6 m									X		X																	
				3039.0 m									X																			
				3003.0 m													X															
	Whitelaw	10	146875	10658-10663 ft							X	O		X																		
				10649-10658 ft	X						X	X																				
				10640-10649 ft							X	X			X																	
				10631-10640 ft							X																					
				10622-10631 ft							X	X																				
				10613-10622 ft								X																				
				10604-10613 ft								X				X																
				10598-10603 ft							X	X																				
				10590.5-10598 ft							X	X		X																		
				10587-10590.5 ft							X		X																			
				10581-10587 ft							X				X		X															
				10576-10581 ft							X						X															
				10567-10576 ft													X															
				10559-10567 ft							X																					
	Normandville			10551-10559 ft							X					X	X															
				10530-10538 ft													X															
				10506-10524 ft													X															
				10494-10500 ft													X															
				10484-10494 ft													X															
				10474-10482 ft													X		X													
				10446-10462 ft													X															
				10434-10446 ft													X															
	Cardinal Lake			10426-10434 ft													X			X												
				10417-10426 ft													X			X												
				10401-10417 ft													X			O												
				10394-10401 ft													X															
				10386-10394 ft													X															
				10378-10386 ft													X			X												
				10370-10378 ft													X															
				10362-10370 ft													X				X											
	Nomand.	11	1469784	6834-6864 ft													X															
				6789-6834 ft													X															
		12	170474	11422-11436 ft										X			X	X	X	X												
		5	170475	10932-10938 ft							O						X		X													
	Cardinal Lake			10917-10932 ft							X						X	X	O													
		13	039846	1853-1865 m													X				X											
				1837-1843 m													X					X										
				1831.5-1835.5 m																		X										
		14	170461	11829 ft													X					X	X									
				11825 ft													X					X	X									
				11810-11820 ft													X	X					X									
		5	170476	10732-10743 ft													X	X			X	X										
				10712-10732 ft													O				X											
				10697-10712 ft													X	X			X	X	O									
		15	100141	11756-11765 ft																							X					
				11747-11756 ft																							O					
				11738-11747 ft																												
				11729-11738 ft																		X										
				11719-11729 ft													X					X										
				11712-11719 ft													X					X		X								
	Big Valley	16	130938	5660-5666 m													X										X					
		17	146878	2018.0-2022.3 m													X									X	X	X				
		18	146873	5602-5622 m													X							X		X	X	X				X
EXSHAW		19	170462	11104.5 ft																									X	O		
		20	NA	5774 ft																											X	
		21	NA	2178.6 m																					O			X	O			
		22	174476	2119.46 m																					X							

WELL LOCATIONS

1. Baseline 10-25-65-27W5
2. Gold Creek 7-31-67-5W6
3. Gold Creek 10-21-68-6W6
4. Smokey Heights 14-22-74-2W6
5. Parkland 10-28-81-15W6
6. Little Burnt River 6-17-80-1W6
7. Gold Creek 10-8-67-5W6
8. Teepee 6-22-73-3W6
9. Sexsmith 9-33-73-5W6
10. Gold Creek 10-31-67-4W6
11. Normand 4-15-79-22W5
12. Parkland 10-26-81-16W6
13. Tangent 4-21-80-24W5
14. Farmington 6-18-8-15W6
15. Beaverlodge 4-23-72-10W6
16. West Prairie 11-18-72-17W5
17. Eaglesham 16-7-77-25W5
18. Normandville 1-16-79-22W5
19. Golata 8-29-83-15W6
20. Lalby No. 1, 1-12-79-22W5
21. Peoria 2-35-76-1W6
22. Cindy 16-35-77-1W6

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PLATE III-1

Winterburn (Figs. 10-12) and Wabamun (Figs. 1-9 and 13-24) conodonts. Magnification is X49 and all upper views of hypotypes, unless stated otherwise.

Fig. 1. *Palmatolepis glabra pectinata* Ziegler. GSC 98126, Parkland 10-28-81-15W6, between 11063 and 11090 ft.

Figs. 2, 3. *Alternognathus regularis* Ziegler and Sandberg. Early growth stages, both specimens X58 and from Normandville 1-16-79-22W5 well, between 5502 and 5522 ft.
    2. lateral view, GSC 98127.
    3. GSC 98128.

Figs. 4, 5. *Bispathodus stabilis* (Branson and Mehl) Morphotype 1 of Ziegler, Sandberg and Austin (1974).
    4. GSC 98129, X58, Beaverlodge 4-23-72-10W6 well, between 11712 and 11719 ft.
    5. lateral view, GSC 98130, X68, Normandville 1-16-79-22W5 well, between 5502 and 5522 ft.

Figs. 6, 7. *Bispathodus stabilis* (Branson and Mehl) Morphotype 2 of Ziegler, Sandberg and Austin (1974). Both specimens X58 and from Normandville 1-16-79-22W5 well, between 5502 and 5522 ft.
    6. GSC 98131.
    7. lower lateral view, GSC 98132.

Fig. 8. *Pelekysgnathus inclinatus* Thomas. Lateral view, GSC 98133, X58, Normandville 1-16-79-22W5 well, between 5502 and 5522 ft.

Fig. 9. *Polygnathus perplexus* Thomas. Oblique upper view, GSC 98134, Normandville 1-16-79-22W5 well, between 5502 and 5522 ft.

Fig. 10. *Icriodus alternatus alternatus* Branson and Mehl. GSC 98135, X97, Baseline 10-25-65-27W5 well, 3392.1 m.

Figs. 11, 12. *Icriodus iowaensis ancylus* Sandberg and Dreesen.
    11. GSC 98136, Baseline 10-25-65-27W5 well, between 3336.5 m and 3337.5 m.
    12. lateral view, GSC 98137, Baseline 10-25-65-27W5 well, between 3384 m and 3384.4 m.

Fig. 13. *Palmatolepis rhomboidea* Sannemann. GSC 98138, Parkland 10-26-81-16W6 well, between 11422 and 11436 ft.

Fig. 14. *Palmatolepis glabra prima* Ziegler and Huddle. GSC 98139, Gold Creek 10-31-67-4W6 well, between 10649 and 10658 ft.

Fig. 15. *Palmatolepis glabra prima* Ziegler and Huddle Morphotype 2 of Sandberg and Ziegler 1973. GSC 98140, Sexsmith 9-33-73-5W6 well, 3059.5 m.

Fig. 16. *Palmatolepis glabra prima* Ziegler and Huddle Morphotype 1 of Sandberg and Ziegler 1973. GSC No. 98141, Sexsmith 9-33-73-5W6 well, 3059.5 m.

Fig. 17. *Palmatolepis subperlobata* Branson and Mehl. GSC 98142, Smoky Heights 14-22-74-2W6 well, between 2623 and 2624.5 m.

Fig. 18. *Palmatolepis marginifera marginifera* Helms. GSC 98143, Farmington 6-18-8-15W6 well, 11828 ft.

Fig. 19. *Polygnathus semicostatus* Branson and Mehl. Oblique upper view, GSC 98144, Gold Creek 10-31-67-4W6 well, between 10417 and 10426 ft.

Fig. 20. *Palmatolepis wolskajae* Ovnatanova. GSC 98145, Smokey Heights 14-22-74-2W6 well, between 2630 and 2630.5 m.

Fig. 21. *Palmatolepis stoppeli* Sandberg and Ziegler. GSC 98146, Gold Creek 10-31-67-4W6 well, between 10362 and 10370 ft.

Fig. 22. *Palmatolepis klapperi* Sandberg and Ziegler. GSC 98147, Parkland 10-28-81-15W6 well, between 10932 and 10938 ft.

Figs. 23, 24. *Palmatolepis tenuipunctata* Sannemann. Both specimens from Parkland 10-28-81-15W6 well, between 11111 and 11128.5 ft.

23. GSC 98148, morphotype resembling *Palmatolepis subperlobata*.
24. GSC 98149, elongate morphotype.

CHAPTER IV

CONODONT BIOFACIES IN THE UPPER DEVONIAN (FAMENNIAN) PALLISER FORMATION AND WABAMUN GROUP, ALBERTA AND BRITISH COLUMBIA, CANADA

INTRODUCTION

Environmentally controlled Famennian conodont faunas were first described by Druce (1969, 1973). Sandberg (1976) recognized five conodont biofacies in a nearshore to offshore transect of strata within a single upper Famennian conodont zone in western Euramerica. Additional biofacies in this region were recognized by Sandberg and Ziegler (1979) and Sandberg and Dreesen (1984). Dreesen and Thorez (1980) recognized conodont biofacies that are similar to those of Sandberg (1976) in Famennian strata of the Ardennes, Belgium. Sandberg and Dreesen (1984) integrated their findings with those of previous authors to produce a more refined model of conodont biofacies distributions in the Famennian. Late Famennian conodont biofacies and their relationship to depositional environments were also discussed in Matyja (1987), Sandberg et al. (1989), Weddige et al. (1990) and Over (1992).

In the course of this study of Famennian conodonts from the Palliser Formation and Wabamun Group of Western Canada, it was noted that shifts in relative abundances of conodont taxa occur throughout both units. These shifts seem to be in response to fluctuations in environments. Furthermore, some of these shifts appear to have occurred in phase with similar shifts in conodont relative abundances and/or sedimentological changes documented from Famennian localities elsewhere. Thus, these changes in the Palliser Formation and Wabamun Group can be correlated with both global and regional events.

The purpose of this report is to document shifts in conodont relative abundances, diversities and biofacies of the

Palliser Formation and Wabamun Group and discuss their causes.

NATURE OF THE CONODONT ANIMAL

The first discovered soft-bodied remains of the conodont animal (Briggs et al., 1983) and specimens that were subsequently found (Aldridge et al., 1986, 1993) from the Carboniferous Granton shrimp bed in Scotland, indicate that this animal had a long eel-like body, with probable fin rays posteriorly and large eyes. In several of these specimens conodont apparatuses occur in the anterior, presumably cephalic region of the body (Briggs et al, 1983; Aldridge et al., 1986, 1993). Several of these specimens also show evidence of metamerism in the trunk region and of a notochord, which suggests chordate affinities for conodonts. Metamerism is suggested by the far less well preserved remains of a conodont animal from the Silurian of Wisconsin (Mikulic et al., 1985). Possible vertebrate affinities for conodonts has been argued on the basis of conodont element histology (Sansom et al., 1992).

The life habit suggested by the body form of the Granton specimens is that of an active swimmer (e.g. Aldridge et al., 1986; Sweet, 1988). The morphology of the conodont elements, as well as ontogenetic evidence (e.g. Jeppsson, 1979; Purnell and von Bitter, 1992; Purnell, 1993) suggests that conodonts were also prey-seeking predators (Aldridge et al., 1986; Purnell, 1993). Whether conodonts were nektic pelagic or nektobenthic cannot be deduced from this evidence alone. Klapper and Barrick (1978) showed from examining the distributions of modern benthic and pelagic marine organisms that the life mode of conodonts cannot be inferred from the distribution of their remains in sediments. However, they did suggest that certain conodont species occur only in rocks that were deposited in generally more nearshore environments characterized by fluctuating salinities and temperatures and by low diversity conodont faunas. Conversely, certain other conodont species are found only in rocks that were deposited in open marine environments characterized by normal salinities and temperatures and diverse conodont faunas. However, both distribution patterns could have been caused by a nektic or nektobenthic life mode (Klapper and Barrick, 1978). Klapper and Barrick (1978) also noted that in most cases the distribution of conodont biofacies and lithofacies is not exactly coincident, ruling out that conodonts were infaunal or sessile epifaunal benthos. A pelagic life mode may be inferred for certain species that occur in black shales that are devoid of any evidence of benthos (Klapper and Barrick, 1978; Sweet, 1988). Given the large diversity of conodonts, it was likely that they had a variety of life modes, ranging from wholly nektobenthic to pelagic. It is probable that some species even changed their life mode at different stages of their life history (Sweet, 1988).

METHODS

This study is based on conodont collections from ten sections of the Palliser Formation in western Alberta and southeastern British Columbia (Figure IV-1) and from cored intervals from thirteen wells penetrating the coeval Wabamun Group in northwestern Alberta and northeastern British Columbia (Figure IV-2). Supplemental data are provided by about thirty sections of the Palliser Formation in the Foothills and Rocky Mountains (see Johnston and Chatterton, 1991, fig. 1). Samples are from both the Costigan and Morro members of the Palliser Formation (for the most recent summary of the depositional characteristics of these members, see Meijer Drees and Johnston, 1994), and from the informal Dixonville, Whitelaw, Normandville and Cardinal Lake units and Big Valley Formation of the Wabamun Group (Halbertsma and Meijer Drees, 1987; Johnston and Meijer Drees, 1993).

Discussion of conodont biofacies will focus mainly on the six sections of the Palliser Formation depicted in Figure

IV-3 and on nine cored intervals in the Wabamun Group also depicted in this figure in which conodont abundances from each sample are adequate (see below) to illustrate the succession of conodont biofacies. These sections/cored intervals were also chosen in a manner that shows a shelf to basin transect. Sections of the Palliser Formation at more westerly localities in the Rocky Mountains (Figure IV-1) and subsurface sections of the Wabamun Group northwest of the Peace River Arch (Figure IV-2) are considered to have had a more basinward position than Palliser sections at more easterly localities in the mountains and Wabamun localities south of the Peace River Arch (Figure IV-2). Cored intervals of the Wabamun Group south of the Peace River Arch were also chosen in a manner that best displays the vertical succession of conodont biofacies in this unit.

In this paper, we generally follow the methodology of Sandberg et al. (1988) and Ziegler and Sandberg (1990), who named biofacies on the basis of the most abundant genus or the two most abundant genera that comprise at least 70 percent of platform elements in a particular collection. In some cases, in order to make percentages of platform elements in a particular collection add up to 70 percent, we included morphologically similar elements of a related genus in the count for some genera (e.g. Ziegler and Sandberg, 1984, p. 181). For most of the sections and cored intervals depicted in Figures IV-4 to IV-10, all genera that comprise ten or fewer percent of platform elements in a particular section (e.g. Figure IV-4) are treated as one percentage rather than showing the abundance of each genus individually.

In order to assess what collections should be included in our analysis, we plotted a rarefaction curve of diversity expressed both in terms of number of species and number of genera against number of platform elements, with each point representing a single collection (Figure IV-12). From these plots, it appears that the diversity of collections with twenty or less platform elements is a statistical artifact, because these collections plot before the change in slope in the rarefaction curve. This suggests that collections with less than this number of platform elements should be discarded. Instead we decided to discard only collections with less than ten platform elements. This was done because conodont elements are not abundant in Palliser collections and better coverage could be provided of sections where numerous samples had been collected but most did not contain many specimens (e.g. in the Upper rhomboidea Zone of the Gold Creek 10-31 well; Figure IV-9, sampled continuously through the Wabamun Group). Although the percent error (i.e. uncertainty) of relative abundances in these collections would be high (Patterson and Fishbein, 1989), this situation is less problematic because we are interested in the most abundant genera for defining biofacies.

Here, collections with four or fewer species are considered to have low diversity, those with five to seven species have moderate diversity, and those with eight or more have high diversity. These diversities should be regarded as underestimates, since several genera in our collections had apparatuses that consisted solely of ramiform elements. Because of the state of preservation of the collections at our disposal, we were unable to associate ramiforms of this type with confidence or to rule out that at least some of the ramiform elements belonged in the same apparatus as some of the platform elements. The ramiform elements as a result were left out of our analysis.

We examined our collections to see which may have been hydrodynamically sorted prior to burial. For this, we compared the lengths of various conodont elements of a certain type to the plot of fall velocity versus the length of the same type of elements in McGoff (1991, fig. 4) in spot examinations of collections from several localities. Using this method, these collections appear to have undergone little, if any, post-mortem sorting. This assessment seems to be supported by lithologic data for some of these collections (see below). Also, many of these elements show no sign of mechanical abrasion.

Cluster analysis (Q and R mode analysis using Jaccard similarity coefficient and UPGMA method of clustering, see Jones, 1988, on binary data) was attempted in the early phases of this study to aid in the recognition of biofacies, but the results obtained through this analysis were inconclusive. Although clusters defined on the basis of associations of certain genera could be recognized, the same one or two genera, usually <u>Palmatolepis</u> and\or <u>Polygnathus</u>, occurred in abundance from one sample to another and from one cluster to the next. Thus, no distinct associations biofacies could be recognized using this type of analysis.

A possible reason why this method was unable to distinguish paleocologically significant clusters was that undue emphasis was placed on the less abundant genera in defining clusters. The main problem, however, was that the samples contained too low a diversity of common elements for the method to be effective.

Other reasons commonly cited for the failure of cluster analysis for discriminating biofacies include that similar depositional environments (e.g. in terms of nutrient supply, salinity, temperature, etc.) were being sampled and that post-mortem mixing of conodont assemblages occurred (e.g. Rexroad and Horowitz, 1990). In our collections we would rule out the first hypothesis, because we do have distinct conodont biofacies occurring within specific stratigraphic intervals (Figures IV-3 to IV-10). As for the second hypothesis, we have ruled out significant post-mortem mixing (see above).

We conclude that the failure of cluster analysis is for mathematical/statistical reasons. Our samples contained too low a diversity and too few elements.

CONODONT BIOFACIES

In Figures IV-4 to IV-10, we document conodont relative abundance patterns observed at selected localities of the Palliser Formation and Wabamun Group. For some biostratigraphic intervals at some of these localities, a range of more than one zone is given, because of poor age control. Although the lower limits of the zonal intervals are defined in most cases by the first occurrences of key taxa, we have also used, in several instances, the highest occurrence of taxa both to define the upper limit of a zone or zonal interval and the lower limit of the succeeding zone or zonal interval.

In these figures, we have attempted to classify the biofacies we recognize according to the standard biofacies scheme first introduced by Sandberg (1976) and further refined by Sandberg and Ziegler (1979), Sandberg and Dreesen (1984), Sandberg et al. (1988) and Ziegler and Sandberg (1990) and illustrated in Figure IV-13. According to the biofacies model depicted in this figure, deep water and/or offshore biofacies are represented by biofacies I and II whereas more shallow water and/or nearshore biofacies are represented by biofacies III and IV. Various nearshore biofacies, characterized by faunas dominated by a single genus (e.g. Clydagnathus, Scaphignathus, etc.) are represented by biofacies V-X (Figure IV-13).

Collections representing the polygnathid biofacies (X in Figure IV-13), especially in the Upper rhomboidea and younger zones in Figures IV-3 to IV-10, are considered representative of biofacies III or IV rather than biofacies X, because they were commonly over- and underlain by collections representative of the palmatolepid or palmatolepid-polygnathid biofacies (i.e. biofacies I and II). The collections themselves sometimes contained a significant percentage of Palmatolepis, suggesting environments where this genus occurred in greater abundance were in close proximity.

In several cases assignment of biofacies was equivocal, or assignment to more than one was possible. In other cases, it was not possible to assign a particular collection to any one of these biofacies (indicated by a "-" in Figures IV-4 to IV-10, e.g. the palmatolepid-icriodontid/"icriodontid" biofacies). Collections in which _Bispathodus_ and _Mehlina_ or just the latter genus are the most abundant or next most abundant platform elements are assigned to a standard biofacies on the basis of the next most abundant genera present (e.g. a collection in which _Polygnathus_ and _Icriodus_ are the most abundant genera after _Mehlina_ would be assigned to the polygnathid-icriodontid biofacies - biofacies III in Figure IV-13). This procedure was followed even in the case of so-called "mixed" biofacies (i.e. where the percentages of the two most abundant genera did not add up to 70 percent).

A number of criteria were used to derive the depth curve in Figure IV-3. In this context more nearshore restricted environments are equated with shallow depths and more offshore open marine environments with greater depths. Taxonomic diversity and composition were the primary criteria (e.g. Figures IV-4, IV-6) for deciding whether conodont faunas were nearshore or offshore (i.e. shallow or deep water). High diversity of skeletal grains, the predominance of mudstones or wackestones, and/or high argillaceous content (reflected by nodular bedding) and conodont biofacies (published models) were the secondary criteria used to determine if conditions were more offshore and/or open marine (which would be shown as an excursion of the depth curve to the right in Figure IV-3). Lower diversity of skeletal grains, the predominance of grainstones, packstones and rudstones, the occurrence of cross-stratification and features such as brecciation, cryptalgal lamination and fenestral fabric, were the principle criteria used, in conjunction with low diversity of conodont faunas, to determine if conditions were more nearshore (or supratidal) (shown as an excursion to the left of the depth curve on Figure IV-3). Although these criteria are generally taken to be indicators of water depth, a change in conodont biofacies and/or in lithology could also reflect a change in the environment (e.g. in salinity and temperature) that did not involve any net depth change.

DISCUSSION

ENVIRONMENTAL INTERPRETATION

According to Famennian conodont paleoecological models of Sandberg (1976), Sandberg and Ziegler (1979), Dreesen and Thorez (1980), Sandberg and Dreesen (1984) and Matyja (1987), the progressive change from polygnathid-icriodontid dominated faunas of biofacies III, to palmatolepid or palmatolepid-polygnathid dominated faunas of biofacies I and II, would be interpreted to reflect an increase in water depth and/or distance from shore (Figure IV-13). This is what appears to have happened in lowermost strata of the Palliser Formation and Wabamun Group at localities such as Mount Greenock and Nigel Peak (Figure IV-3). The apparent start of this transgression could have been in the Lower or Middle crepida zones (see below).

In the Cold Sulphur Springs section (Figure IV-3), the occurrence of the palmatolepid-polygnathid biofacies at the base of the Palliser Formation suggests deposition of this unit have commenced in slightly deeper water than the same beds at Mount Greenock and Nigel Peak. However, beds immediately overlying the base at this locality contain conodont faunas characteristic of the polygnathid-icriodontid biofacies, suggesting that there may have been an immediate decrease in water depth right after deposition began. (Figure IV-3).

As conditions became more open marine in the lower Palliser Formation and Wabamun Group, more species of Palmatolepis were added to the fauna. The great abundance and diversity of this genus near and at the top of the interval assigned to the Lower to Middle crepida zones at nearly all localities of the Palliser Formation and Wabamun Group discussed here (Figures IV-3 to IV-5, IV-8), appear to signal the onset of fully open marine conditions.

The persistence of high diversity palmatolepid and palmatolepid-polygnathid biofacies throughout the Upper to Uppermost crepida zones and into the lower part of the Lower rhomboidea Zone at most localities (e.g. Figures IV-4, IV-5, IV-7 to IV-9) suggests the continuation of more open marine conditions through this time interval in both the Palliser Formation and Wabamun Group. This would have marked the time of maximum flooding of the shelf and probably represents the maximum depth of water attained in these units as indicated by our depth curve (Figure IV-3).

The transition from relatively shallow subtidal and/or intertidal conditions at the base of both the Palliser Formation and Wabamun Group to fully marine and/or offshore conditions higher in the lower part of the Morro Member in the former unit and in the Dixonville and Whitelaw units of the latter appears to be supported by lithological evidence at some localities. In the Parkland 10-28 well (Figure IV-7), the lithologies change from interbedded intraclastic, skeletal and peloidal mudstones, wackestones, packstones and grainstones from the base of the cored interval to bioturbated to nonbioturbated mudstones at a depth of about 11128.5 ft. to argillaceous mudstones at a depth of 11063 ft. In the Nigel Peak section there is a gradual change from sandy or silty intraclastic grainstones and rudstones near the base of the formation to mostly intraclastic and peloidal wackestones and grainstones, which pass upward, at about the base of the Upper to Uppermost crepida zones (Figure IV-4), into skeletal wackestones, which in turn pass upward into argillaceous and nodular, skeletal and non-skeletal mud- and wackestones at the base of the Lower rhomboidea Zone.

The relative stratigraphic thinness of the interval represented by the Upper to Uppermost crepida zones, relative to the over- and underlying zones at, for example, the Nigel Peak section (Figure IV-4) and in the Gold Creek 10-31 well (Figure IV-9) could be a reflection of slower sedimentation rates and hence stratigraphic condensation. In sequence stratigraphic terminology the strata deposited in the Palliser Formation and Wabamun Group at this time of maximum transgression would represent a maximum flooding surface at the top of a transgressive systems tract and perhaps the basal deposits of the overlying highstand systems tract (e.g. Van Wagoner et al., 1988; Sarg, 1988; Figure IV-3).

The reversion to palmatolepid-polygnathid and polygnathid biofacies in the upper part of the Lower rhomboidea and the lower Upper rhomboidea zones in the Gold Creek 10-31 well (Figures IV-3, IV-9) and in the Medicine Lake and Nigel Peak sections, (Figures IV-3 to IV-5) may suggest there was a simultaneous, widespread shallowing that affected the entire depositional area of both the Palliser Formation and Wabamun Group. This is shown by an excursion to the left on our depth curve (Figure IV-3).

Lithological and/or stratigraphic data also generally support this interpretation. The Normandville unit in the Wabamun Group consists primarily of grainstones (e.g. Halbertsma and Meijer Drees, 1987, fig. 1; Meijer Drees et al., in prep) and other coarse grained carbonate lithologies. The same lithologies are also present from approximately the same stratigraphic interval in the Palliser Formation at Nigel Peak (Figure IV-4) starting near the top of the Lower rhomboidea Zone in sample NP86-74 where peloids and intraclasts reappear and become the predominant carbonate grains in sample NP86-80. Also, in some intervals, laminated, finely peloidal limestone occurs which may suggest that very shallow subtidal to intertidal conditions existed.

A depth increase near the top of this interval is suggested by the occurrence of moderate to high diversity conodont faunas representative of the palmatolepid-polygnathid biofacies at Mount Greenock (Figure IV-3) and in sampled intervals 10917 ft. to 10932 ft. and 10932 ft. to 10938 ft. in the Parkland 10-28 well (Figure IV-7). The occurrence of fine grained lithologies (e.g. argillaceous mudstones) in these intervals of the latter well (Figure IV-7) appears to suggest quiet water deposition. This in turn may suggest that the "mixed" conodont fauna in the upper interval (Figure IV-7) was the result of special ecological conditions rather than being the result of admixture through storm processes.

Moderate to high diversity conodont collections representative of both the palmatolepid and palmatolepid-polygnathid biofacies, between the first occurrences of *Palmatolepis* *rhomboidea* Sannemann and *P*. *stoppeli* Sandberg and Ziegler in the Upper *rhomboidea* Zone (Figure IV-3), are perhaps indicative of more open marine conditions. Otherwise, in most collections from this portion of the Upper *rhomboidea* Zone, the low to moderate diversity of faunas characteristic of more nearshore polygnathid biofacies (assigned to biofacies III in Figure IV-3), perhaps indicates conditions were not as open marine as in the Upper to Uppermost *crepida* zones or the lower part of the Lower *rhomboidea* Zone. This is the reason for the smaller excursion of our depth curve to the right in the Upper *rhomboidea* Zone than in the Lower to Middle *crepida* to Lower *rhomboidea* zones (Figure IV-3).

In the uppermost part of the Lower *rhomboidea* Zone, the low to moderate diversity of faunas representative of the palmatolepid or the palmatolepid-polygnathid biofacies (Figure IV-3), in which *Palmatolepis* *stoppeli* is the sole palmatolepid, suggests more restricted and/or shallower water conditions. This is a contrary interpretation to that suggested for the depositional setting of the palmatolepid biofacies in Figure IV-13. It is possible that *P*. *stoppeli* may have been an "opportunistic" taxon that intruded and apparently flourished in some cases in more nearshore environments, beyond the ecologic range of most species of Palmatolepis.

Lithological data generally support the interpretation that there is a slight depth increase in about the middle of the Upper rhomboidea Zone. On the basis of sedimentological criteria, the gradational contact between the Normandville and Cardinal Lake units can be viewed as a transition from very shallow subtidal and intertidal to deeper subtidal conditions. This is reflected by an increase in pelmatozoan ossicles as well as the proportion of mud in the lower part of the Cardinal Lake unit. A similar transition is seen in the Nigel Peak section (Figure IV-4) between samples NP86-80 and NPW86-19 from predominantly peloidal grainstone, packstone and wackestone to skeletal mudstone and sparsely skeletal wackestone. In the Parkland 10-26 well and at Wardner (Figures IV-1, IV-2), this interval appears to be marked by fine grained carbonate lithologies (e.g. mudstones and sparsely skeletal wackestones).

Shallowing in the uppermost part of the Upper rhomboidea Zone is indicated by the occurrence of mostly intraclastic and peloidal grainstones, wackestones and packstones. Significantly, there is a change from peloidal wackestones and packstones to laminated and/or cross-bedded peloidal grainstones to packstones, which pass upward into laminated and/or brecciated limestones or dolostones at approximately the top of the Upper rhomboidea zone in Palliser sections in the eastern Front Ranges (see Johnston and Chatterton, 1991). This marks a transition from shallow subtidal and intertidal to peritidal conditions.

The low diversity of conodont faunas representative of the palmatolepid biofacies in the lower part of the Lower marginifera Zone at Medicine Lake (Figure IV-6) appears to also suggest restricted conditions for this part of the Palliser Formation. The faunas are characterized by the abundant and/or exclusive occurrence of a morphotype of

Palmatolepis marginifera with a thickened posterior platform and flattened posterior parapet. This morphotype probably preferred or was only adapted to shallow and perhaps somewhat restricted nearshore environments.

The shift from palmatolepid to palmatolepid-polygnathid biofacies in the Lower *marginifera* Zone at Medicine Lake (Figure IV-6) would appear to suggest, based on the high diversity of sample ML1-40, a transition from restricted to open marine environments. The same interpretation could be suggested for the same part of the Nigel Peak section (Figure IV-4) to explain the occurrence of a high diversity conodont fauna in sample NPW89-2, which is assignable to the palmatolepid-polygnathid biofacies. However, the occurrence of low to moderate diversity faunas (with the latter diversity characteristic of more abundant collections) of the polygnathid biofacies above and below this sample indicates that environmental fluctuations occurred that periodically excluded open marine forms of *Palmatolepis* or caused them to occur in lesser abundance. This is the reason for the excursion to the right of the depth curve being the same magnitude as that shown for the Upper *rhomboidea* Zone (Figure IV-3). The interpretation of more open marine conditions is supported by the occurrence of mainly skeletal wackestones and packstones through this interval.

The reoccurrence of mostly low diversity palmatolepid-dominated faunas above this interval but still within the Lower *marginifera* Zone in the Beaverlodge 4-23 well (Figure IV-10) and in the Medicine Lake (Figure IV-6) and Nigel Peak sections (Figure IV-4) appears to mark a return to restricted conditions (shown as an excursion to the left in Figure IV-3). Here again palmatolepids are represented exclusively by the morphotype of *Palmatolepis marginifera* with the thickened posterior platform and flattened parapet.

In the uppermost part of the Lower *marginifera* Zone in the Nigel Peak section, more diverse faunas of the palmatolepid-polygnathid or palmatolepid-mehlinid biofacies (the latter assigned to biofacies I) characterized by the association of species of the *Palmatolepis glabra* group (e.g. *P. distorta* Branson and Mehl and *P. pectinata* Ziegler) and a slender morphotype of *P. marginifera* with the inner platform parapet extending to the posterior tip (e.g. samples NPW89-11 and 13, Figure IV-4) may suggest that more open marine conditions returned (shown as an excursion to the right in Figure IV-3). The occurrence of this morphotype of *P. marginifera* almost exclusively in these kinds of faunas suggests that it was only adapted to or preferred more open marine environments.

Similar faunas, characterized by the occurrence of *Palmatolepis distorta* in the palmatolepid-polygnathid biofacies, occur at or near the base of the upper fossiliferous limestone unit of the Costigan Member of the Palliser Formation in the Bow and North Saskatchewan river valleys. These faunas, and accompanying sedimentological evidence, indicate a transgression, usually above a pronounced unconformity at the top of restricted shallow subtidal to peritidal carbonates (Meijer Drees and Johnston, 1993, 1994). However, the age of this transgression in these areas would appear to be no older than the Uppermost *marginifera* Zone but no younger than the Upper *trachytera* Zone (see discussion below). These faunas are overlain by those of shallower water conodont biofacies in this unit.

The occurrence of moderate to high diversity faunas of the palmatolepid-polygnathid and polygnathid-bispathodontid biofacies (the latter assigned to biofacies III) in strata no older than the Upper *marginifera* Zone at Crowsnest Pass, Mount Greenock, Nigel Peak and in the Beaverlodge 4-23 well (Figure IV-3) appear to suggest the onset of shallower conditions than those in the highest part of the Lower *marginifera* Zone. This is even despite the generally higher diversity of faunas than in most of the upper part of the latter zone. What this higher diversity may suggest is that conditions, though shallower, were still more open marine than in parts of the Lower marginifera Zone. At Mount Greenock and Nigel Peak, faunas in the Upper marginifera Zone are followed in the next biostratigraphic interval by those characteristic of even shallower water conodont biofacies (Figure IV-3). As a result our depth curve is shown having an excursion to the left in the Upper marginifera Zone (Figure IV-3). However, faunas of the palmatolepid-polygnathid biofacies of this same zone at Crowsnest Pass (Figure IV-3) and elsewhere in southwestern Alberta and southeastern British Columbia (Savoy, 1990; Savoy and Harris, 1993) are overlain by conodont faunas of the deep water palmatolepid-bispathodontid biofacies in the Exshaw Formation of younger Famennian age.

The disproportionately greater thickness and generally regressive nature of strata deposited during the Lower rhomboidea to Upper marginifera zones in the upper part of both the Palliser Formation and the Wabamun Group would seem to indicate that this interval in both units could be considered a highstand systems tract overlain by a shelf margin systems tract (e.g. Van Wagoner et al., 1988; Sarg, 1988) with a sequence boundary in between. Such a boundary is a Type 2 sequence boundary because it appears conformable in Palliser sections to the west in both the Front and Main Ranges (e.g. sections in the Athabasca River valley and Nigel Peak) whereas this boundary is unconformable between normal marine and peritidal carbonates both in the eastern Front Ranges between the lower and upper parts of the Costigan Member and the Big Valley and Stettler formations in the subsurface of southern Alberta (e.g. Richards et al., 1991; Meijer Drees and Johnston, 1993, 1994). However, this systems tract could be represented in part of the peritidal carbonates in more basinward localities in the eastern Front Ranges. There also seems to be a sharp unconformity between the Big Valley Formation and the rest of the Wabamun Group throughout the subsurface of most of central Alberta (Meijer Drees and Johnston, 1993).

The occurrence of faunas dominated by *Polygnathus*, or *Polygnathus* and *Bispathodus*/*Mehlina* or "*Icriodus*" in the Big Valley Formation and in the fossiliferous limestone unit of the Costigan Member of the Palliser Formation reflects a continuation of shallow water conditions (e.g. Figures IV-4, IV-6). The high abundances of "*Icriodus*" and *Pelekysgnathus* at some levels in this interval would appear to be consistent with this interpretation (e.g. Nigel Peak, Figure IV-4). Faunas of similar composition suggesting shallow water conditions have been recovered from uppermost Palliser strata in the Bow Valley area and southeastern British Columbia as well by Savoy (1990) and Savoy and Harris (1993). Lithological evidence points to normal marine conditions for this interval, as shown by the occurrence of skeletal wackestones and packstones. Biostratigraphic evidence from this part of both the Palliser Formation and Wabamun Group may suggest that uppermost strata of both these units may be condensed (Johnston and Chatterton, 1991; Meijer Drees and Johnston, 1994), although the occurrence of shallower water conodont biofacies and carbonate lithofacies may suggest that water depth nevertheless remained shallow over an extended period of time.

However, the occurrence of somewhat more open marine or deeper water conodont faunas and carbonate lithofacies in basal beds of the upper fossiliferous unit of the Costigan Member in the Bow and North Saskatchewan river valleys, suggests that the lower part of this unit was deposited under slightly deeper conditions in some areas than in others during the Uppermost *marginifera* to Upper *trachytera* Zones. At several localities basal beds of this unit indicate an abrupt transition from restricted to open marine environments, although continued shallowing is indicated at this time by the depth curve (Figure IV-3).

The Big Valley Formation and upper Costigan Member are presently interpreted as the initial transgressive deposits (i.e. a transgressive systems tract) of a depositional sequence consisting of these units and the overlying Exshaw Formation (e.g. Richards and Higgins, 1989; Meijer Drees and Johnston, 1993). However, the occurrence of deeper water conodont faunas and lithofacies, that are overlain by rocks containing shallower water conodont faunas, at least at some localities of the upper Costigan Member (e.g. Meijer Drees and Johnston, 1993) suggests that all or part of the Big Valley Formation and the latter unit could represent a separate depositional sequence. According to this scenario, the lower boundary of the overlying sequence occurs either in uppermost beds of these units or at the contact between the Palliser Formation or Wabamun Group and the Exshaw Formation.

The lower age limit of the transgressive (and possible highstand) systems tract is shown as approximately at the base of the Upper marginifera Zone in Figure IV-3, as suggested by the depth curve in this figure. However, the younger age of open marine carbonates of both the upper Costigan Member and Big Valley Formation that abruptly overlie restricted marine carbonates at several localities (Meijer Drees and Johnston, 1993, 1994) suggests a slightly younger lower age limit for this systems tract at these localities.

BIOSTRATIGRAPHIC AND PALEOECOLOGIC IMPLICATIONS

The implications that conodont biofacies have for biostratigraphy are obvious. The most important consequence this has had is for dating the upper and lower contacts of both the Palliser Formation and Wabamun Group. As documented in Johnston and Chatterton (1991) and Johnston and Meijer Drees (1993), the lack of key taxa (Palmatolepis spp.) due to probable unsuitability of environments has hampered precise dating of these contacts.

Environmental effects appear to have been responsible for late first occurrences and/or early last occurrences of taxa. The best example here is the first occurrence of Palmatolepis rhomboidea, which in our localities does not appear until well into the Upper rhomboidea Zone. Elsewhere, its first occurrence has been documented as low as the Lower rhomboidea Zone (e.g. Sandberg and Ziegler, 1973).

It is also apparent from some of the data presented here that certain conodont biofacies may not necessarily be completely diagnostic of a particular depositional environment as depicted in Figure IV-13. For example, the palmatolepid biofacies, which is usually thought to be typical of more offshore environments, appears from our study to have occurred in both near- and offshore environments when such factors as taxonomic diversity and sedimentology are considered.

CORRELATION WITH GLOBAL AND REGIONAL BIOTIC, EUSTATIC AND TECTONIC EVENTS

Although commencement of deposition of the Palliser Formation (and, by extension, the Wabamun Group) is commonly considered to have begun at the start of the Middle crepida Zone (Sandberg et al., 1983, 1989; Johnston and Chatterton, 1991) (western U.S. event 11 in Figure IV-14), the occurrence of early forms of Palmatolepis wolskajae Ovnatanova (i.e. forms conspecific with the holotype) in both the Palliser Formation and Wabamun Group may suggest deposition could have commenced as early as the Lower crepida Zone. (e.g. Johnston and Meijer Drees, 1993). Forms like these have been illustrated from the Lower crepida Zone in Belgium (e.g. Dreesen, 1984) and this species first appears at or near the base of this zone (Ziegler and Sandberg, 1990). It is of interest that at the base of the Lower crepida Zone in the western United States, an episode of slight onlap is recorded at the outer margin of the Pilot Basin at the top of the Devil's Gate Formation at its type section in Nevada (western U.S. event 10, Figure IV-14). This onlap also appears correlative with oolitic ironstone level I on the Ardenne shelf which is considered to mark the start of a transgressive episode (Dreesen, 1982, 1984). The coincidence of these events could suggest a common cause although both are interpreted to have been tectonically induced (Dreesen, 1982, 1984; Sandberg et al., 1989).

The predominance of the deep and/or more open marine palmatolepid or palmatolepid-polygnathid biofacies in the upper part of the Lower to Middle crepida Zone, and in the Upper to Uppermost crepida zones (Figure IV-3) in both the Palliser Formation and Wabamun Group, would appear to suggest that the eustatic rise in sea level postulated for these time intervals (e.g. Sandberg et al., 1989; Dreesen et al., 1989) is represented in these units. Transgressive conditions are recorded from the western and eastern United States (e.g. House, 1985; Sandberg et al., 1989) as well as from Belgium (e.g. Dreesen and Thorez, 1980; Dreesen, 1984) and Poland (e.g. Matyja, 1987, 1989) in northern Europe, where the palmatolepid biofacies is developed ("Famenne/Nenden shales deepening", Dreesen et al., 1989). Transgressive conditions are also tentatively recognized for this time interval in other continental blocks (e.g. Hou, 1986; Talent and Yolkin, 1987).

Our data indicate that deep water conditions persisted into the Lower rhomboidea Zone, at least in more distal localities, rather than indicating that a possible shallowing of depth and/or cessation of deposition occurred in the Uppermost crepida through to the lowermost Lower rhomboidea zones. The start of a regression may be recognized in more proximal localities of the Palliser Formation and Wabamun Group low in the latter zone (e.g. Figures IV-5 and IV-9). Dreesen (1989) suggested that this cessation and\or shallowing of depth preceded deposition of the "Cheiloceras Kalk" facies in the Lower to Upper rhomboidea zones. This facies which was considered by him to be equivalent to oolitic ironstone level IIIa (Figure IV-14) and possibly correlative with other such events in the Rheno-Hercynian basin and adjacent Gondwanaland.

The apparent eustatic drop in sea level, extending from the Lower to Upper rhomboidea zones, is reflected in the change to more shallow water biofacies and lithofacies in the upper part of the Lower rhomboidea Zone and the lower part of the Upper rhomboidea Zone in the study area. (e.g. Figure IV-3). This drop in sea level has been documented in other areas of the Euramerican margin (e.g. Ardenne, northern Polish shelf, Dreesen and Thorez, 1980; Matyja, 1989). However, the occurrence of moderately to highly diverse palmatolepid-dominated faunas in about the middle of the Upper rhomboidea Zone (i.e. from the first appearance of Palmatolepis rhomboidea to the first appearance of P. stoppeli) would suggest that this regression was interrupted by transgressive pulses (e.g. Figure IV-3), perhaps a reflection of fourth and fifth order transgressive and regressive cycles, which may or may not have been tectonically controlled, that are superimposed on the regressive portion of a third order cycle.

Transgressive conditions in the middle part of the Lower marginifera Zone, possibly correlative with western U.S. event 12 and the "Baelen event" in Figure IV-14, may be represented in sample NPW89-2 at Nigel Peak and sample ML1-40 at Medicine Lake. However, no correlative events with the regression and transgression recorded in the upper part of this zone in the study area are evident in Figure IV-14. In contrast, the transition to shallower water conodont biofacies in the Upper marginifera Zone is in agreement with the sea level fall depicted for this zone in Figure IV-14.

Our data suggest that the regional hiatus encompassing the Uppermost marginifera Zone that has been considered to have affected the entire North American craton (Sandberg et al., 1989, western U.S. event 13, Figure IV-14) can be recognized in more easterly localities of the Palliser Formation in the eastern Front Ranges between the upper and lower units of the Costigan Member (see Johnston and

Chatterton, 1991; Meijer Drees and Johnston, 1994). The magnitude of this unconformity decreases in Palliser sections to the west and northwest (Meijer Drees and Johnston, 1994) where deposition appears to have been continuous through this interval.

Beds representative of western U.S. event 14, the transgressive pulse that resulted in the deposition of units such as the Trident Member of the Three Forks Formation, the "contact ledge" of the Bierdneau Formation (Sandberg et al., 1989) and supposedly the upper Costigan Member and the Big Valley Formation, are not recognized at the localities shown in Figure IV-3. Faunas of the palmatolepid-polygnathid biofacies, which contain the morphotype of Palmatolepis distorta that is usually considered present in faunas of the trachytera zone in the western United States (Sandberg and Poole, 1977), occur in strata as low as the upper Lower marginifera Zone at Nigel Peak (Johnston and Chatterton, 1991; Figure IV-4). This morphotype also occurs at the top of the Banff Golf Course section (Figure IV-1), in faunas no younger than the Upper marginifera Zone that are representative of the polygnathid biofacies.

However, the beds in the basal part of the upper fossiliferous unit of the Costigan Member in the Bow and North Saskatchewan river valleys, that contain this morphotype of Palmatolepis distorta, may be representative of western U.S. event 14 since they are dated no older than the Uppermost marginifera Zone and no younger than the Upper trachytera Zone (see above). This interpretation apparently conflicts with the interpretation of shallower water environments for faunas no older than the former zone at Mount Greenock and Nigel Peak (Figures IV-3, IV-4), unless it is accepted that these faunas are laterally equivalent to those that are characteristic of the palmatolepid-polygnathid biofacies at other localities.

Western U.S. event 15, the regression that resulted in extensive erosion of stratigraphic units in the western United

States in the Lower to Upper postera zones, is recognized in easterly localities in the Front Ranges of the Bow Valley below rocks deposited in the initial stages of the transgression of western U.S. event 16 (Sandberg et al., 1989). This hiatus may occur between rocks deposited during this event and those deposited during the preceding western U.S. event 14 (Meijer Drees and Johnston, 1994). At the section of the Costigan Member at Nordegg (Johnston and Chatterton, 1991; Meijer Drees and Johnston, 1993), biostratigraphic data suggest that this hiatus may occur above the Palliser Formation.

No biostratigraphic or visible stratigraphic evidence in the Palliser Formation and Wabamun Group appears to support the existence of the Upper to Lower postera zones hiatus in more basinward localities of these units. In the stratigraphic interval of these units encompassed by these zones, faunas are representative of the polygnathid, polygnathid-"icriodontid" or polygnathid-bispathodontid/mehlinid biofacies which have been assigned to standard biofacies III or IV (Figure IV-3). In the Nigel Peak section, faunas in the upper part of the Costigan Member but below the lower limit of the Lower to Middle? expansa zones are interpreted, in terms of the standard biofacies, of progressing from deeper water biofacies III to shallower water biofacies IV, with the former biofacies returning in the Lower to Middle? expansa zones (Figure IV-4). This is the reason for the depth curve being depicted as having an excursion to the left and then to the right in Figure IV-3. Interpreted this way, the faunas characteristic of biofacies IV could possibly be considered to represent the hiatal period, with sedimentation having continued slowly and/or intermittently through the Lower and Upper postera zones. More work is needed, however, in order to better define the timing of events within this interval in the Palliser Formation and Wabamun Group.

Rocks possibly representative of western U.S. event 16 of Sandberg et al. (1989) marking the beginning of T-R cycle IIf (Figure IV-14) occur in the uppermost parts of the Palliser Formation and Wabamun Group. Conodont faunas of the Lower to Middle? expansa zones from these rocks would either represent shallow water conodont biofacies at the initial stage of the next transgressive phase, characterized by palmatolepid-bispathodontid biofacies in black shales (e.g. Sandberg et al, 1989; Savoy, 1990) or represent conditions just prior to cessation of deposition and a very brief period of probable submarine non-deposition and/or erosion (i.e. a "drowning unconformity" of Schlager, 1989).

It seems that during deposition of the Palliser Formation and Wabamun Group, tectonic activity to the west, which was either compressional (e.g. Smith et al., 1993) and/or tensional (e.g. Gordey et al., 1987) and accompanied by plutonism (e.g. Okulitch, 1985), played a relatively minor role in affecting overall sedimentation patterns in these units. As discussed above, these patterns appear to have been largely affected by eustasy. However, tectonic activity must have been partly responsible for the minor transgressions recorded by us in the Upper rhomboidea Zone and perhaps in the middle of the Lower marginifera Zone, although the latter event may be eustatic, given the possible occurrence of a transgression at about the same time in Belgium (Baelen event, Figure IV-14). Local tectonism is probably the explanation for the non-correspondence of certain transgressive-regressive events observed in western Euramerica and in the Rheno-Hercynian basin, although the general correspondence between deepening and shallowing events in the Palliser Formation and Wabamun Group and equivalent units in the western United States does show that these units were affected by the same events. On the other hand, the apparent synchroneity of transgressive and regressive events interpreted as eustatic in western North America and the Rheno-Hercynian basin could be coincidence as a result of tectonic processes operating independently of each other in widely separated but similar tectonic settings.

CONCLUSIONS

1. Deposition of the Palliser Formation and Wabamun Group, which may have begun in the Lower *crepida*, but certainly by the Middle *crepida* Zone, was initially under very shallow conditions as indicated by sedimentological and stratigraphic evidence, and the occurrence of mainly shallow water conodont biofacies, although deposition could have commenced in slightly deeper water at some localities.

2. Maximum transgression was attained in about the Upper *crepida* to lowermost Lower *rhomboidea* Zone, shown by high diversity *Palmatolepis* faunas appearing in the lower part of the Upper *crepida* Zone. This probably represents the timing of a maximum flooding surface at the top of a transgressive systems tract. This transgression in the Palliser Formation and Wabamun Group appears to have been part of the same eustatic rise in sea level that is recorded in the western United States and northern Europe and possibly in other continental blocks in the early and earliest middle Famennian.

3. Regression followed in the latter part of the Lower *rhomboidea* zone, shown by the occurrence of shallow water conodont biofacies and carbonate lithofacies. Mainly regressive conditions persisted for most of the remainder of the depositional history of the Palliser Formation and Wabamun Group. Periodically, this regressive episode appears to have been punctuated by transgressive events, of either eustatic or tectonic origin, in the Upper *rhomboidea* and the middle and uppermost Lower *marginifera* zones. The last event appears to mark the onset of another depositional cycle. Highstand and/or shelf margin systems tracts are represented in the upper part of the Palliser Formation and Wabamun Group by the upper Morro

and lower Costigan members of the former unit and the Normandville and Cardinal Lake units of the latter.

4. Shallow water conodont biofacies and carbonate lithofacies in uppermost strata of the Palliser Formation and Wabamun Group, of the upper Costigan Member of the former unit and the Big Valley Formation of the latter, may mark either the onset of the next transgressive phase that resulted in the deposition of the black shales of the Exshaw Formation in the _expansa_ Zone or conditions just prior to a brief hiatus before deposition of the latter unit. Uppermost strata of the Palliser Formation and Wabamun Group could thus represent transgressive and/or shelf margin systems tracts of the next depositional sequence or the highstand systems tract of a sequence that includes underlying beds of the Big Valley Formation and upper Costigan Member that contain deeper water conodont biofacies and lithofacies and abruptly overlie restricted carbonates at several localities.

5. Regional environmental conditions appear to have been responsible for the absences of some key zonal taxa. These conditions probably caused late first occurrences of some zonal taxa in the Palliser Formation and Wabamun Group. Other factors (e.g. diversity, taxonomic composition), besides relative abundances, have to be considered when interpreting conodont biofacies.

Figure IV-1. A) Map of Alberta and adjacent portions of Western Canada and the United States showing areas represented in inset maps B-D and in Figure IV-2. Map also shows distribution and thickness of Wabamun Group and equivalents in Alberta and British Columbia (after Belyea, 1964). B) Map showing location of Crowsnest Pass (CNP) and Wardner (WD) sections in area of southwestern Alberta and southeastern British Columbia enlarged from A. Map also shows distribution of Upper Devonian rocks where Palliser Formation is exposed as well as location of Rocky Mountain Trench. Geology after Leech (1958, 1962) and Price (1961). C) Map showing location of sections of the Palliser Formation at Banff Golf Course (BGC), Jura Creek (JC) and Whiteman Gap (WMG) from which conodont faunas were also studied. Map also shows distribution of Upper Devonian rocks where Palliser Formation is exposed in area of southwestern Alberta and adjacent British Columbia enlarged from A. Geology slightly modified from Ollerenshaw (1978). D) Map showing location of Cold Sulphur Springs (CSS), Mount Greenock (GK), Medicine Lake (ML2-4, MLN, ML1) and Nigel Peak (NP) sections. Map also shows location of section of Palliser Formation at Roche Miette (RM) from which conodont faunas were also studied and distribution of Upper Devonian rocks where Palliser Formation is exposed in area of south central Alberta and easternmost British Columbia enlarged from A. Geology after Price et al. (1977).

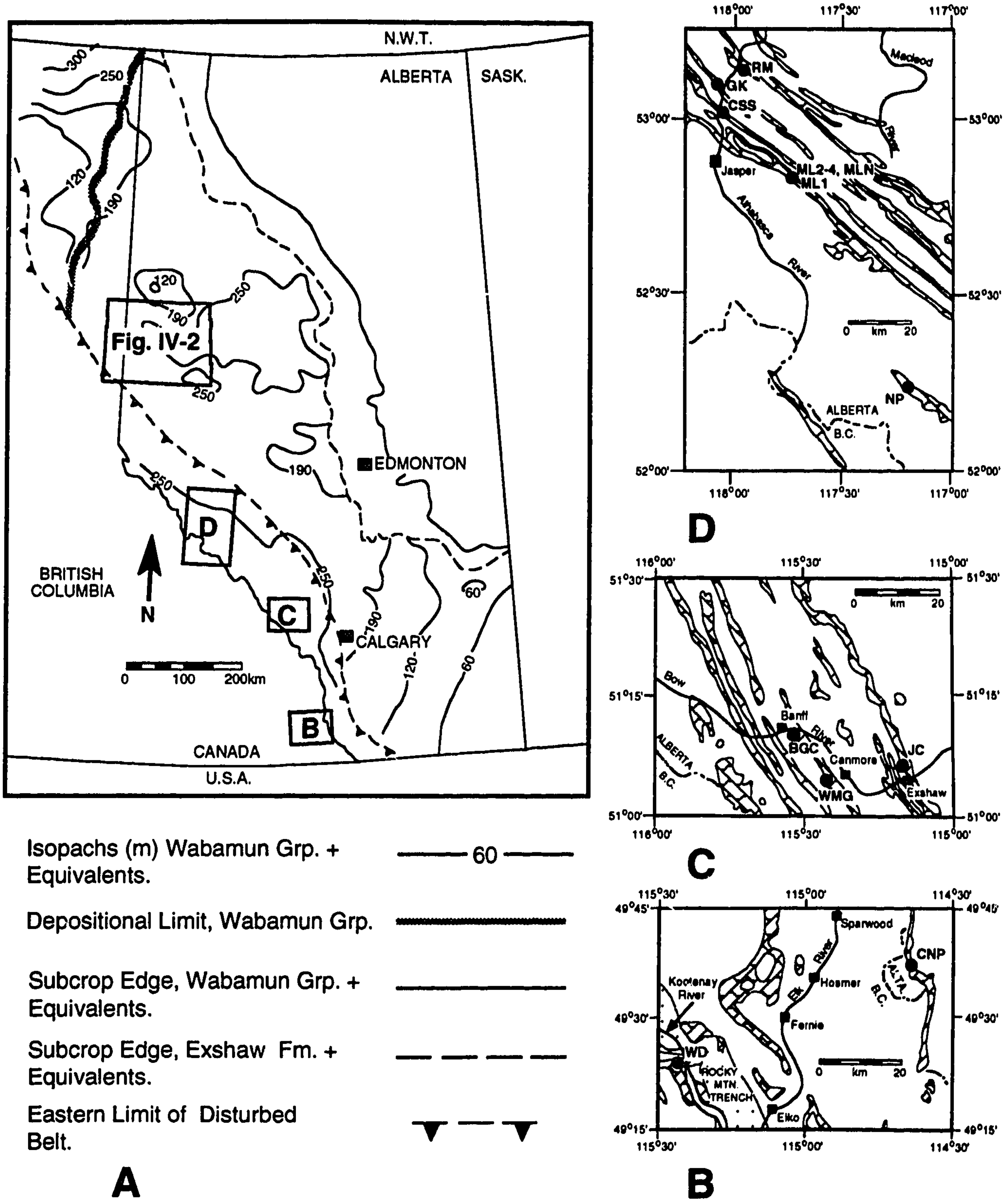
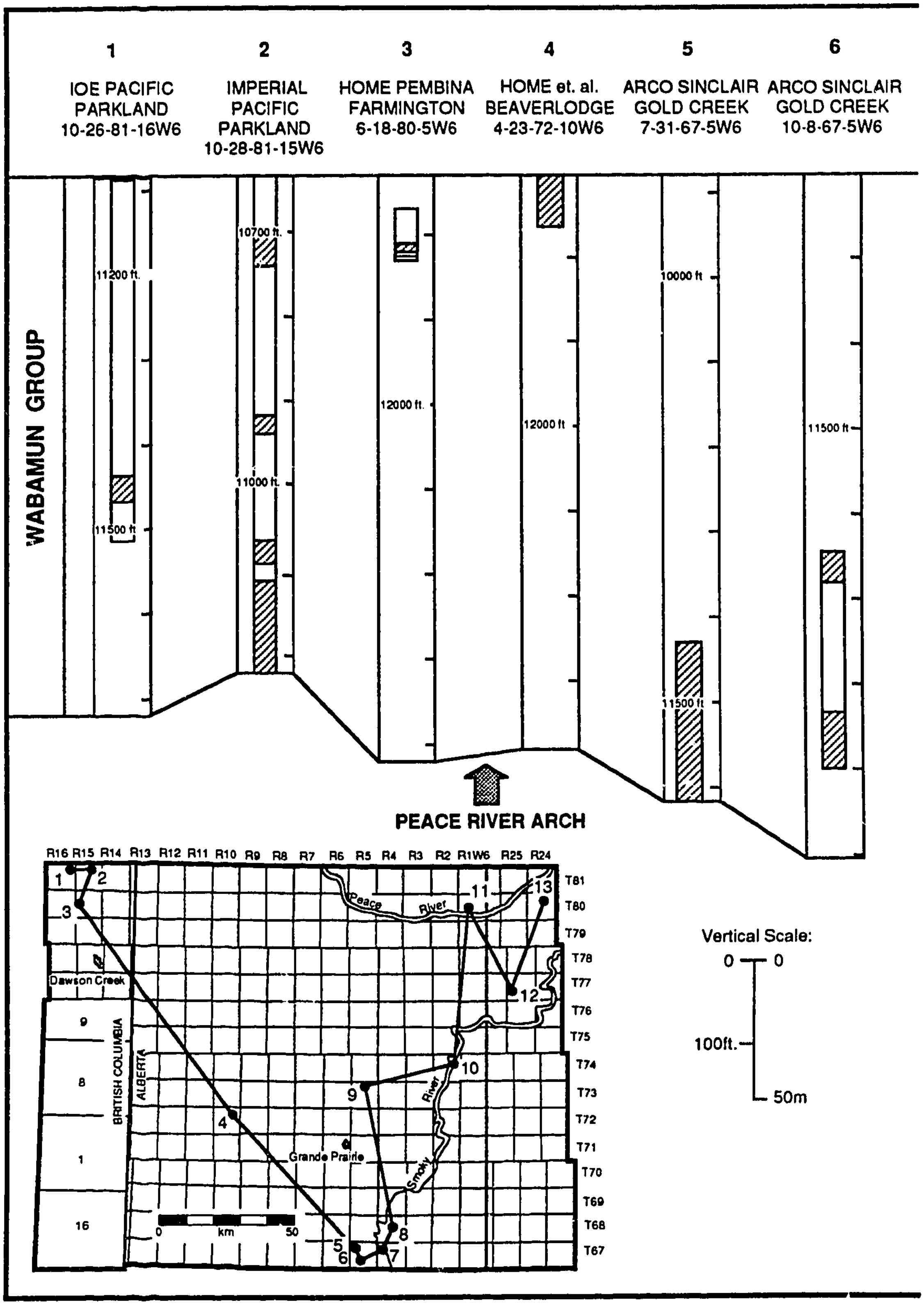

N.W.T.
ALBERTA
SASK.
BRITISH COLUMBIA
N
Fig. IV-2
EDMONTON
CALGARY
CANADA
U.S.A.
0 100 200km
300
250
190
120
60
D
C
B
Isopachs (m) Wabamun Grp. + Equivalents.
60
Depositional Limit, Wabamun Grp.
Subcrop Edge, Wabamun Grp. + Equivalents.
Subcrop Edge, Exshaw Fm. + Equivalents.
Eastern Limit of Disturbed Belt.
A
118°00'
117°30'
117°00'
53°00'
52°30'
52°00'
RM
GK
CSS
Jasper
ML2-4, MLN
ML1
Athabasca River
Medeod River
0 km 20
NP
ALBERTA
B.C.
D
116°00'
115°30'
115°00'
51°30'
51°15'
51°00'
Bow River
Banff
BGC
Canmore
WMG
JC
Exshaw
ALBERTA
B.C.
0 km 20
C
115°30'
115°00'
114°30'
49°45'
49°30'
49°15'
Sparwood
Elk River
Hosmer
Fernie
Kootenay River
WD
ROCKY MTN. TRENCH
Elko
CNP
ALTA.
B.C.
0 km 20
B

Figure IV-2. Cross section showing stratigraphic position of cores in Wabamun Group in northwestern Alberta and northeastern British Columbia in the thirteen wells sampled for conodonts in this study. It includes those with portions that are illustrated in Figures IV-7 to IV-10. Sampled intervals indicated by hatching. Numbers over wells correspond to well location shown in range and township (inset) map, representing area enlarged from Figure IV-1A. Arrow points to approximate position of Peace River Arch in cross section.


1
IOE PACIFIC PARKLAND 10-26-81-16W6
2
IMPERIAL PACIFIC PARKLAND 10-28-81-15W6
3
HOME PEMBINA FARMINGTON 6-18-80-5W6
4
HOME et. al. BEAVERLODGE 4-23-72-10W6
5
ARCO SINCLAIR GOLD CREEK 7-31-67-5W6
6
ARCO SINCLAIR GOLD CREEK 10-8-67-5W6
WABAMUN GROUP
11200 ft.
11500 ft
10700 ft.
11000 ft.
12000 ft.
12000 ft
10000 ft
11500 ft
11500 ft
PEACE RIVER ARCH
R16 R15 R14 R13 R12 R11 R10 R9 R8 R7 R6 R5 R4 R3 R2 R1W6 R25 R24
T81 T80 T79 T78 T77 T76 T75 T74 T73 T72 T71 T70 T69 T68 T67
1 2 3 4 5 6 7 8 9 10 11 12 13
Peace River
Smoky River
Dawson Creek
Grande Prairie
BRITISH COLUMBIA
ALBERTA
9
8
1
16
0 km 50
Vertical Scale:
0 0
100ft.
50m

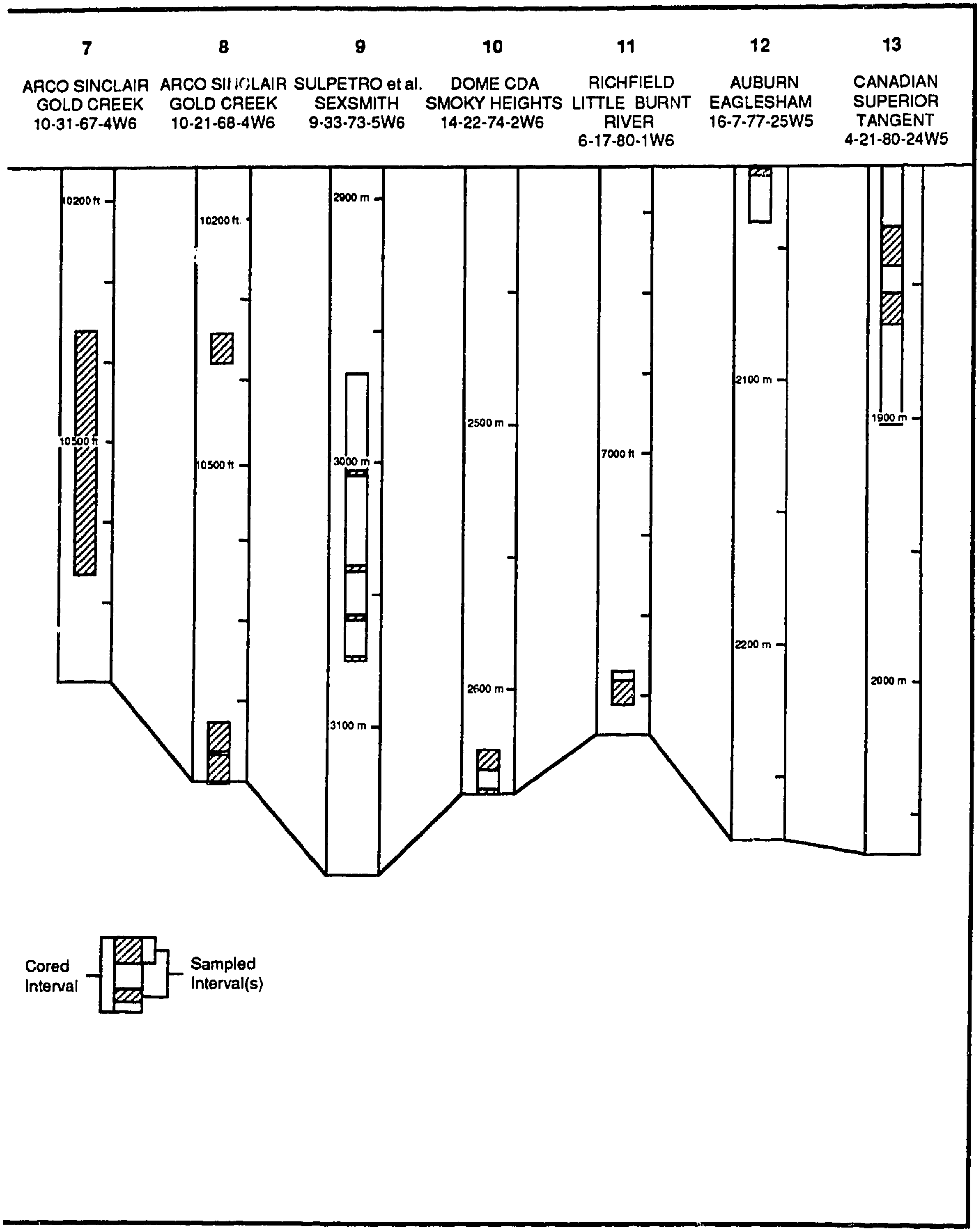

7
ARCO SINCLAIR
GOLD CREEK
10-31-67-4W6
8
ARCO SINCLAIR
GOLD CREEK
10-21-68-4W6
9
SULPETRO et al.
SEXSMITH
9-33-73-5W6
10
DOME CDA
SMOKY HEIGHTS
14-22-74-2W6
11
RICHFIELD
LITTLE BURNT
RIVER
6-17-80-1W6
12
AUBURN
EAGLESHAM
16-7-77-25W5
13
CANADIAN
SUPERIOR
TANGENT
4-21-80-24W5
10200 ft
10500 ft
10200 ft
10500 ft
2900 m
3000 m
3100 m
2500 m
2600 m
7000 ft
2100 m
2200 m
1900 m
2000 m
Cored
Interval
Sampled
Interval(s)

Figure IV-3. Summary diagram showing conodont biofacies occurring in each zone from selected localities shown in Figures IV-1 and IV-2. Some localities have been combined in this figure. Shading for each biofacies proportional to the thickness of strata representative of the zone through which a biofacies occurs. Biofacies indicated by Roman numerals (I, II, III, etc.) which correspond to each of the standard biofacies in Figure IV-13. Gaps in data also shown at each locality. "Depth" curve derived from conodont paleoecological and sedimentological/stratigraphical data, along with sequence stratigraphy, shown at right. Taxonomic diversity of conodont faunas was the primary criterion used to determine whether a deepening or shallowing is represented in a particular biostratigraphic interval. This accounts for the opposite depth interpretation to that suggested by the occurrence of a particular biofacies in some intervals (see text). "<" and "+" in this and all subsequent figures indicate the first and/or only first appearances of *Palmatolepis* *rhomboidea* and *P*. *stoppeli* respectively in Lower *rhomboidea* Zone. "O" and "■" denote in this and all subsequent figures the occurrence of *P*. *duplicata* and highest occurrences of *P*. *inflexa* and/or *P*. *quadrantinodosa* respectively in Lower *marginifera* Zone.

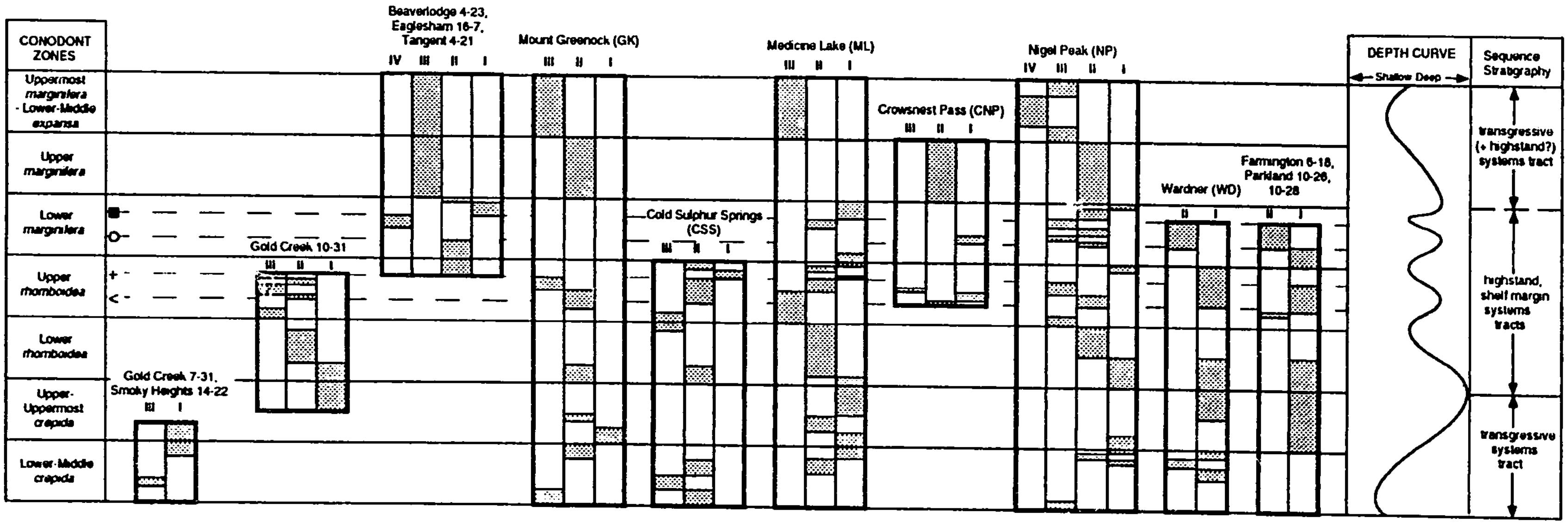

CONODONT ZONES
Uppermost marginifera - Lower-Middle expansa
Upper marginifera
Lower marginifera
Upper rhomboidea
Lower rhomboidea
Upper-Uppermost crepida
Lower-Middle crepida
Gold Creek 7-31, Smoky Heights 14-22
III I
Gold Creek 10-31
III II I
?
Beaverlodge 4-23, Eaglesham 16-7, Tangent 4-21
IV III II I
Mount Greenock (GK)
III II I
Cold Sulphur Springs (CSS)
III II I
Medicine Lake (ML)
III II I
Crowsnest Pass (CNP)
III II I
Nigel Peak (NP)
IV III II I
Wardner (WD)
II I
Farmington 6-18, Parkland 10-26, 10-28
II I
DEPTH CURVE
Shallow Deep
Sequence Stratigraphy
transgressive (+ highstand?) systems tract
highstand, shelf margin systems tracts
transgressive systems tract

Figure IV-4. Diagram depicting plot of relative abundances of conodont platform elements in Palliser Formation at Nigel Peak, Alberta (Figure IV-1D). For this figure and Figures IV-5 to IV-10, lithostratigraphy, lithology, conodont samples used in paleoecologic analysis, diversity and counts of platform elements given at left. Biofacies interpreted according to Sandberg and Dreesen's (1984) standard conodont biofacies (e.g. Figure IV-13), as well as zonation, given at right. "-" denotes biofacies recognized by us that have no equivalent in Sandberg and Dreesen's (1984) scheme. Exact position of boundary between Lower marginifera and Upper rhomboidea zones uncertain. Relative abundances of Polylophodonta combined with those of Polygnathus (indicated as Po.+Polyl. in key below). "Other genera" in this section represented by species of Alternognathus, Skeletognathus and specimens representing a polygnathid-like new genus in sample NP86-80. Key to patterns that stand for each genus in relative abundance plot given at bottom of figure. Key to other patterns and symbols given in Figure IV-11. COST. MBR. = Costigan Member; # sp. = number of species; # Pa, I ele. = number of platform (Pa, I) elements.

Nigel Peak (NP)

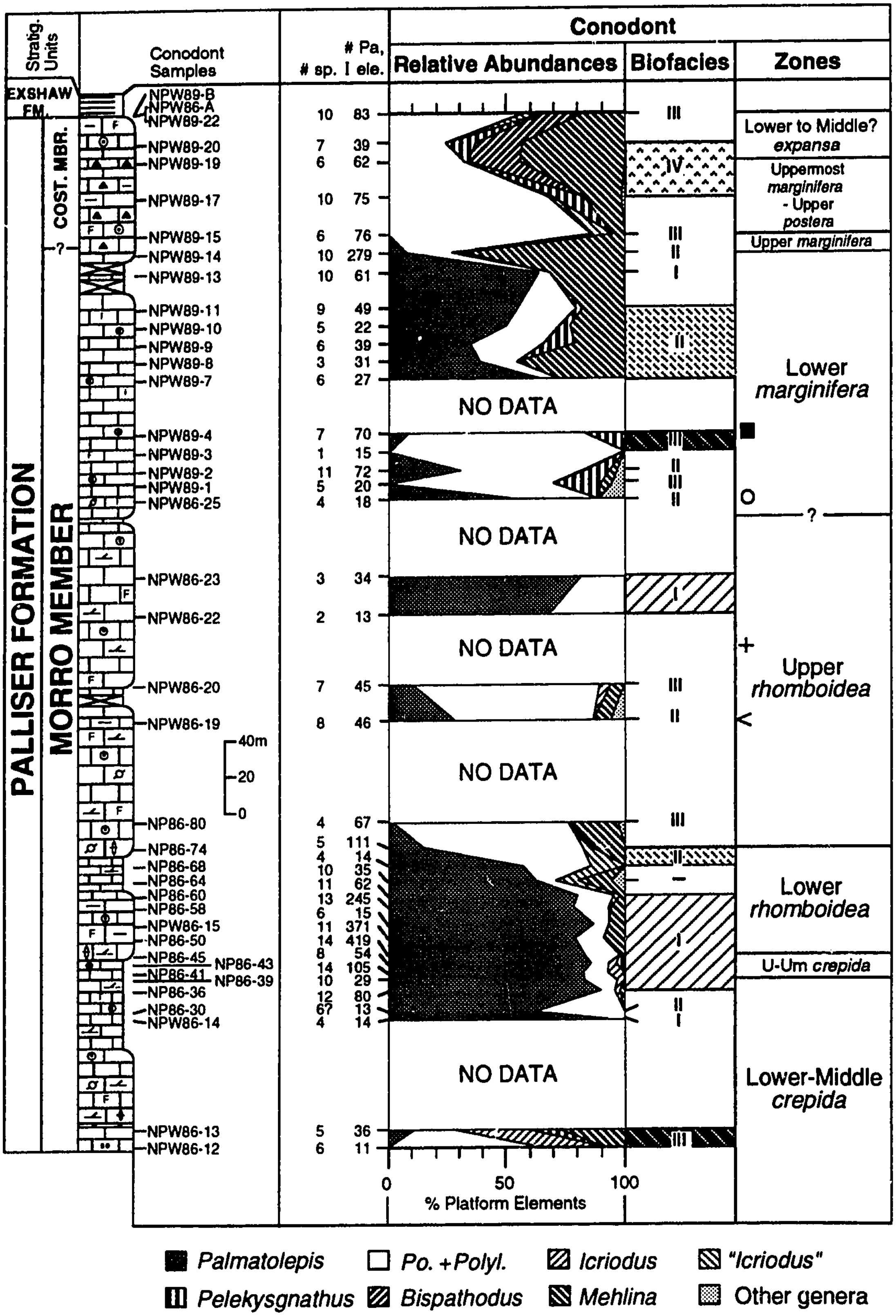
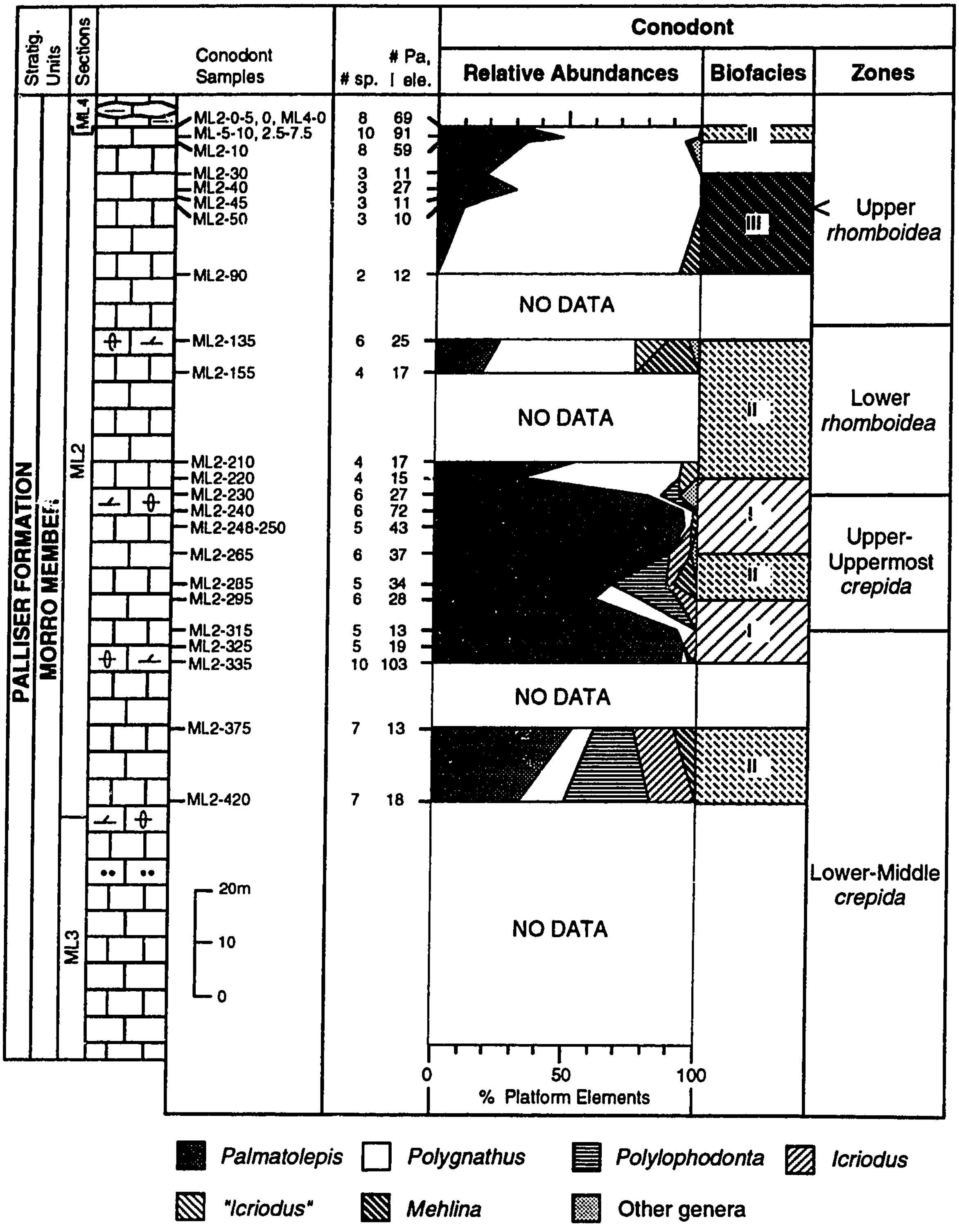
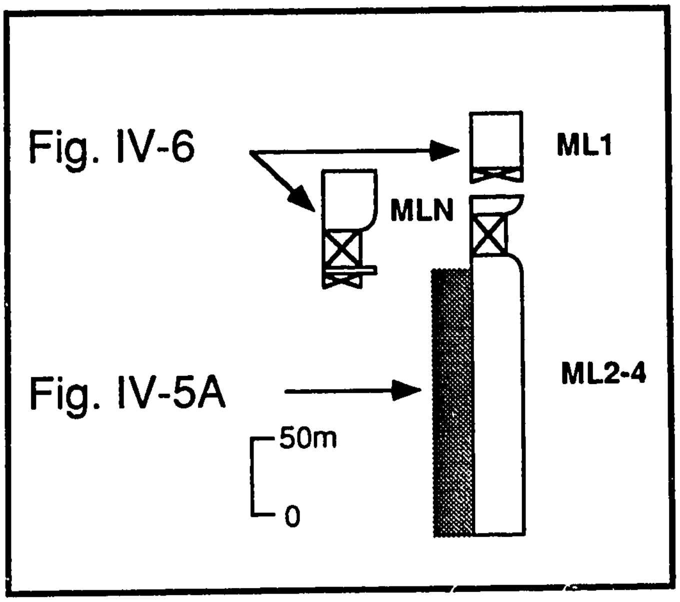


Figure IV-5. A) Diagram depicting plot of relative abundances of conodont platform elements in sections ML2 and 3 in the Palliser Formation at Medicine Lake, Alberta (Figure IV-1D). "Other genera" represented by species of Alternognathus and of several polygnathid-like new genera in this section. Key to patterns that stand for each genus in relative abundance plot given at bottom of figure. Key to other patterns and symbols given in Figure IV-11. # sp. = number of species; # Pa, I ele. = number of platform (Pa, I) elements. B) Schematic diagram showing approximate correlation between measured segments (shown in this figure and in Figure IV-6) of the Palliser Formation at this locality. Portion of sections ML2-4 illustrated in A indicated by shading.

Medicine Lake (ML2-4)



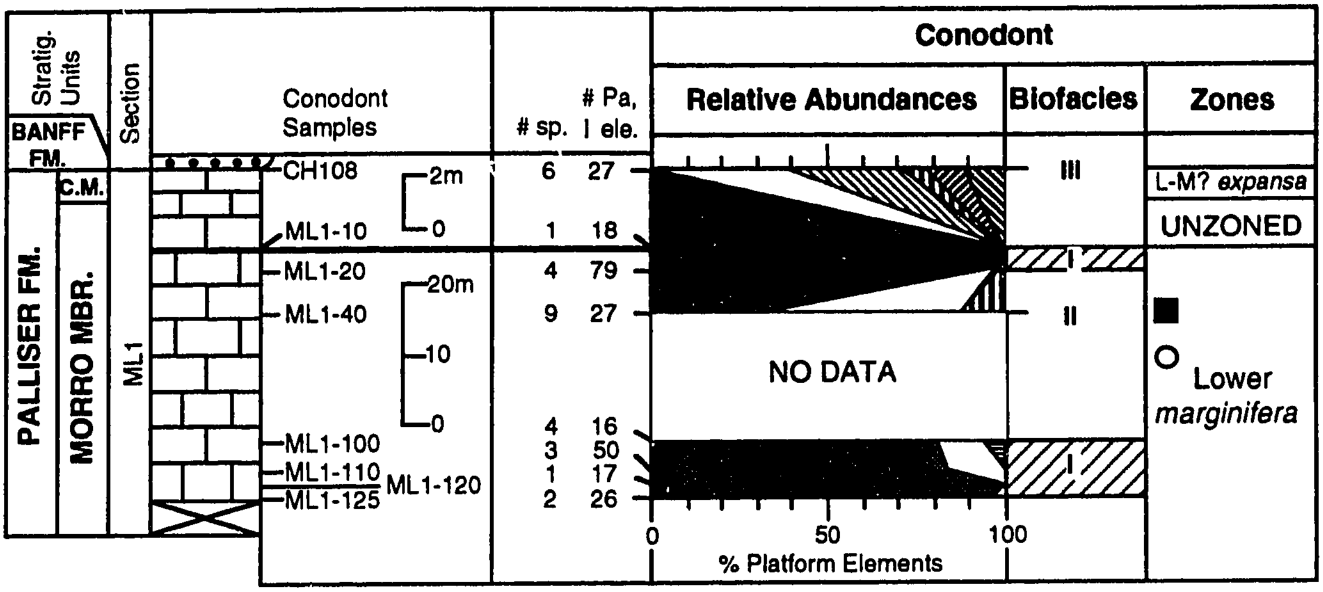
(A)



(B)

Figure IV-6. Diagram depicting plot of relative abundances of conodont platform elements in sections MLN and ML1 in the Palliser Formation at Medicine Lake, Alberta (Figure IV-1D). Stratigraphic correlation of these segments of the Palliser Formation with others at this locality shown in Figure IV-6B. Note change of scale above sample ML1-10. Key to patterns that stand for each genus in relative abundance plots given at bottom of figure. Key to other patterns and symbols given in Figure IV-11. C.M. = Costigan Member; # sp. = number of species; # Pa, I ele. = number of platform (Pa, I) elements.

Medicine Lake 1 (ML1)



Medicine Lake North (MLN)

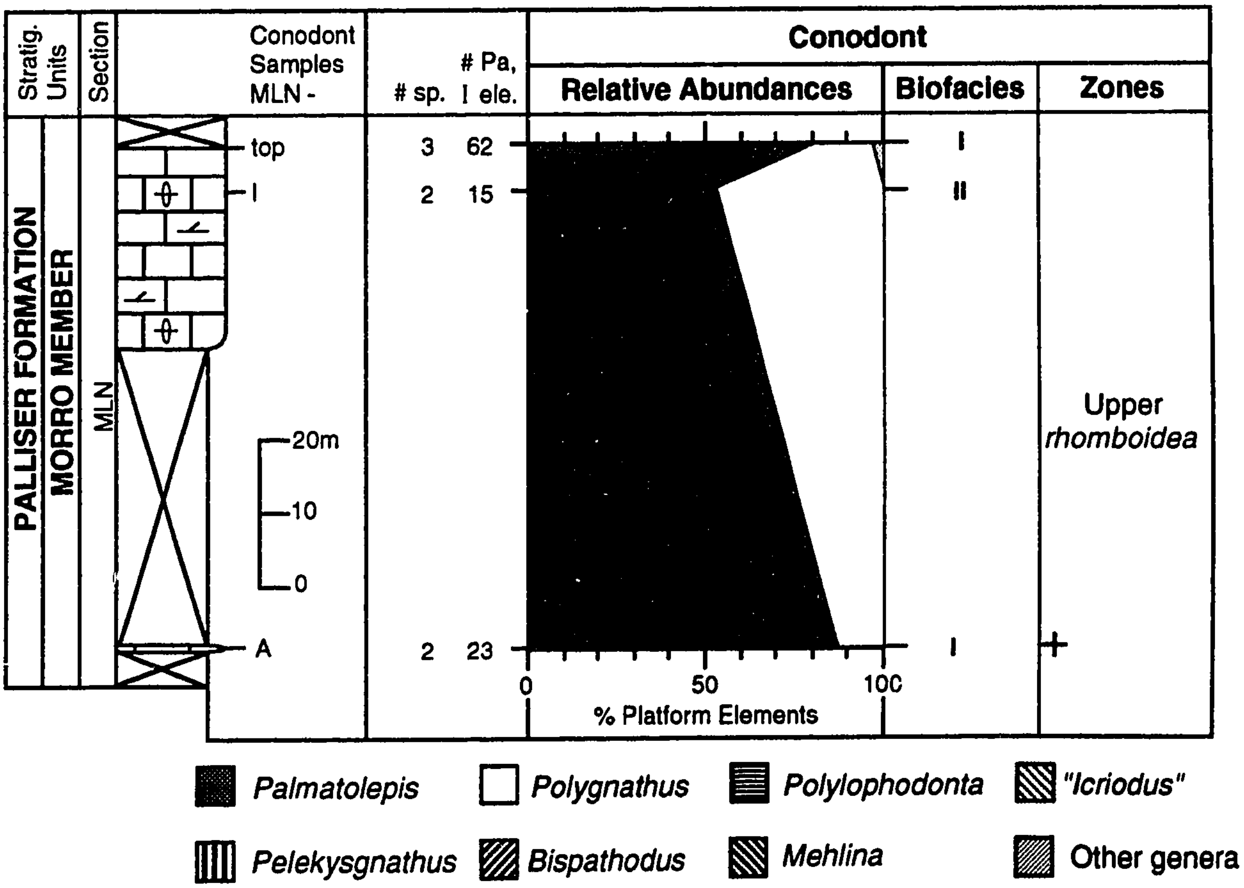


Figure IV-7. Diagram depicting plot of relative abundances of conodont platform elements in the Wabamun Group in the Parkland 10-28 well (Well #2 in Figure IV-2). Sampled intervals indicated as points in plot in this figure and Figures IV-8 to IV-10 to facilitate comparison with relative abundance plots of Palliser localities in Figures IV-4 to IV-6. "Shaly carbonate facies" after Johnston and Meijer Drees (1993). Relative abundances of Polylophodonta combined with those of Polygnathus in this figure (indicated as Po.+Polyl. in key below). "Other genera" in this section represented by species of Alternognathus, "Icriodus", Pelekysgnathus and specimens of a polygnathid-like new genus. Note addition of depth scale on left in this figure and Figures IV-8 to IV-10. Key to patterns that stand for each genus in relative abundance plot given at bottom of figure. Key to other patterns and symbols given in Figure IV-11. # sp. = number of species; # Pa, I ele. = number of platform (Pa, I) elements.

2 - Parkland 10-28

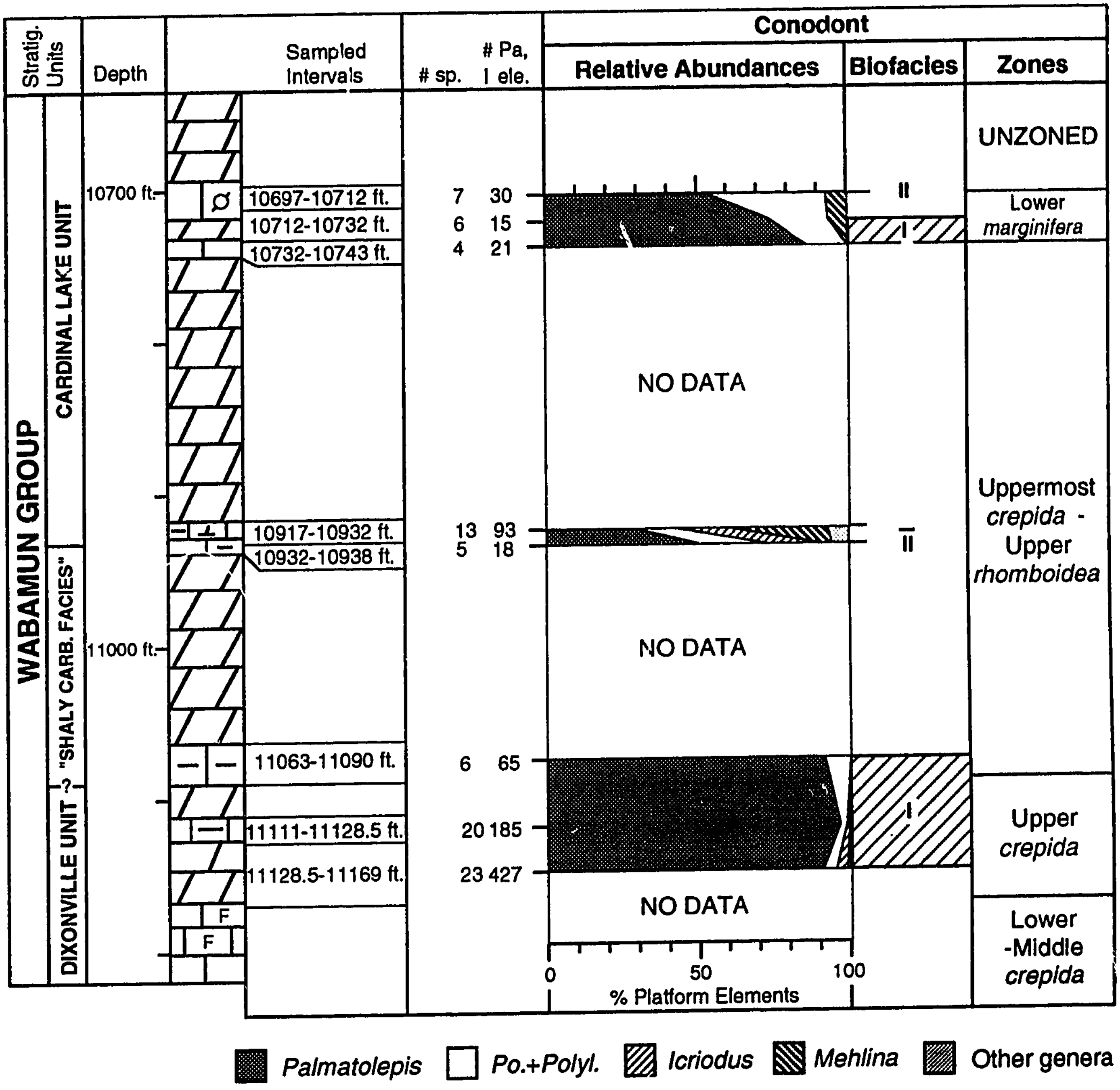
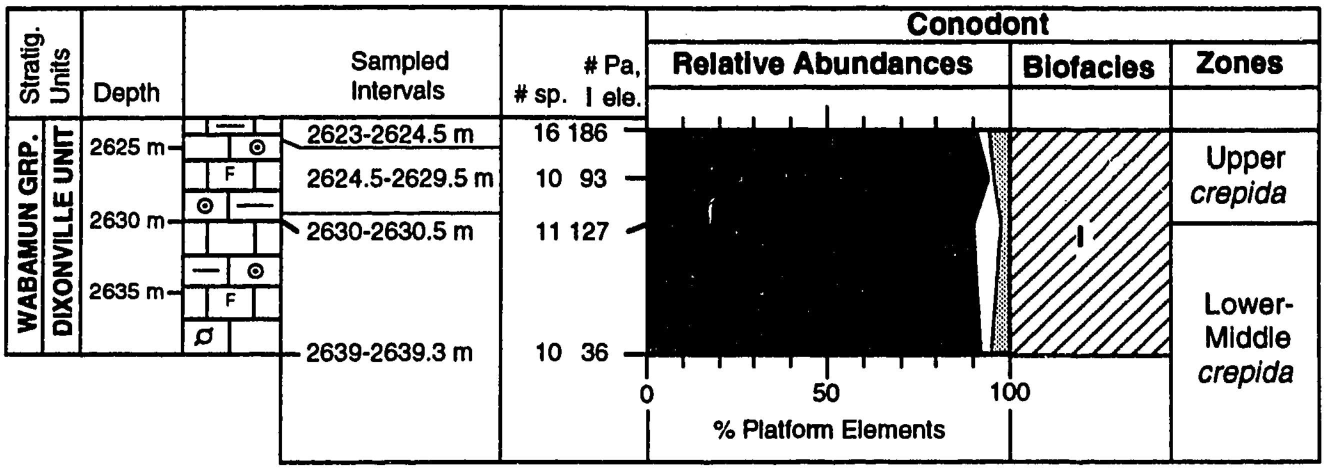


Figure IV-8. Diagram depicting plot of relative abundances of conodont plat[illegible]ments in the Wabamun Group in the Gold Creek 7-31 and [illegible] Heights 14-22 wells (Wells #5 and #10 in Figure IV-2). [illegible]e abundances of <u>Polylophodonta</u> combined with those of <u>Polygnathus</u> for both localities (indicated as <u>Po</u>.+<u>Polyl</u>. in key below). "Other genera" in Smoky Heights 14-22 well include species of <u>Icriodus</u> and <u>Mehlina</u>. Key to patterns that stand for each genus in relative abundance plots given at bottom of figure. Key to other patterns and symbols given in Figure IV-11. DIX. = Dixonville unit; # sp. = number of species; # Pa, I ele. = number of platform (Pa, I) elements.

10 - Smoky Heights 14-22



5 - Gold Creek 7-31

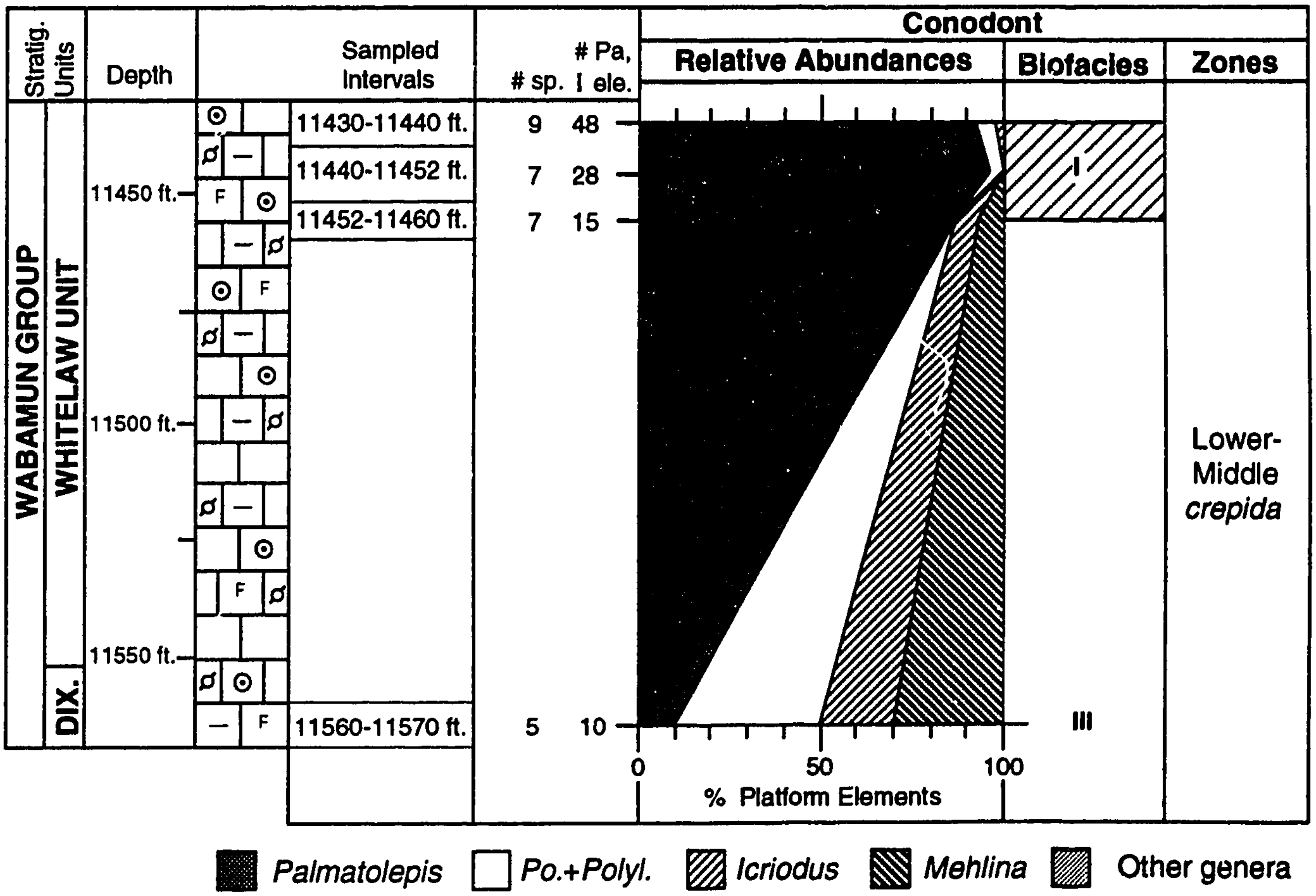
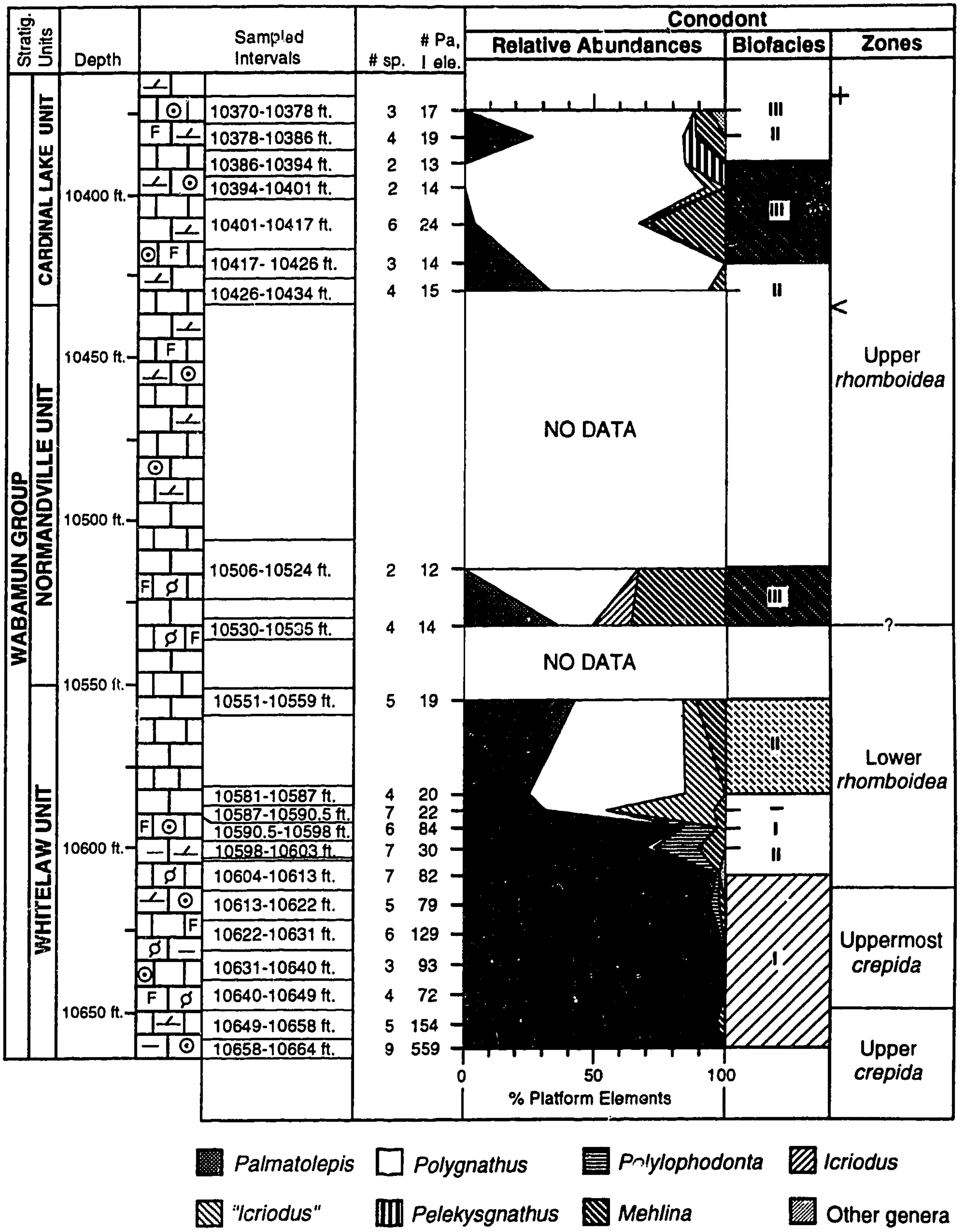


Figure IV-9. Diagram depicting plot of relative abundances of conodont platform elements in the Wabamun Group in the Gold Creek 10-31 well (Well #7 in Figure IV-2). Lithology of cored interval in part after Lethiers (1981). "Other genera" in this well represented by species of <u>Alternognathus</u> and a single specimen of a polygnathid-like new genus. Key to patterns that stand for each genus in relative abundance plot given at bottom of figure. Key to other patterns and symbols given in Figure IV-11. # sp. = number of species; # Pa, I ele. = number of platform (Pa, I) elements.

7 - Gold Creek 10-31



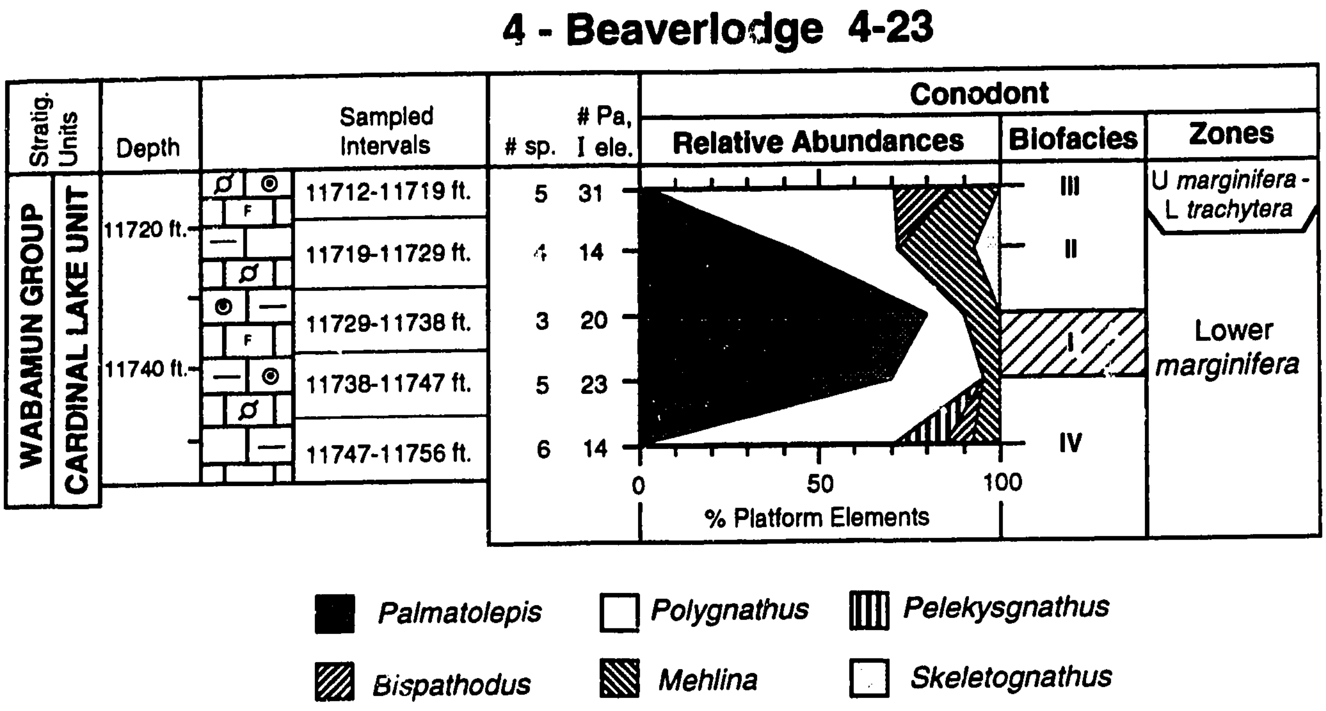


Figure IV-10. Diagram depicting plot of relative abundances of conodont platform elements in the Wabamun Group in the Beaverlodge 4-23 well (Well #4 in Figure IV-2). Key to patterns that stand for each genus in relative abundance plot given at bottom of figure. Key to other patterns and symbols given in Figure IV-11. # sp. = number of species; # Pa, I ele. = number of platform (Pa, I) elements.

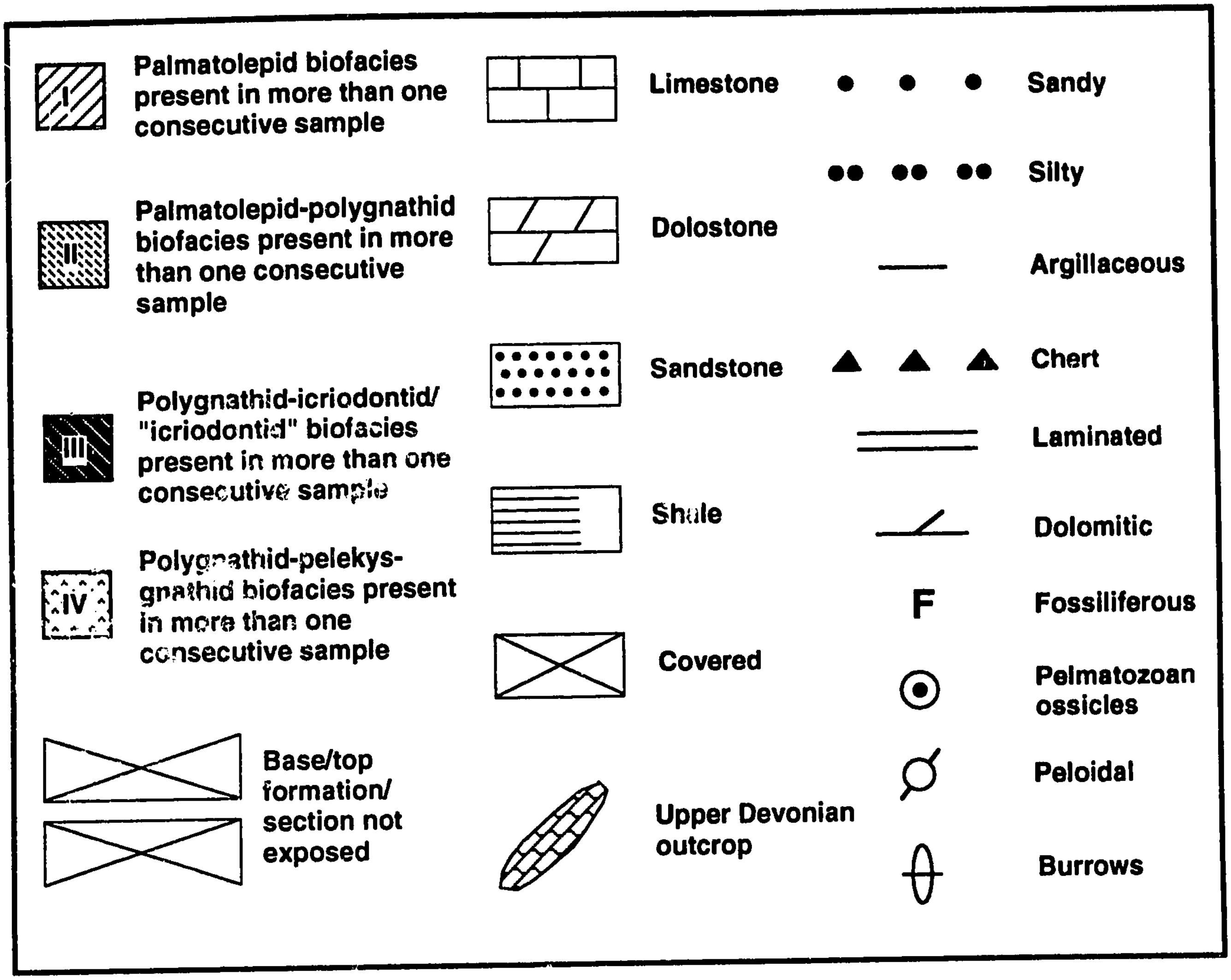
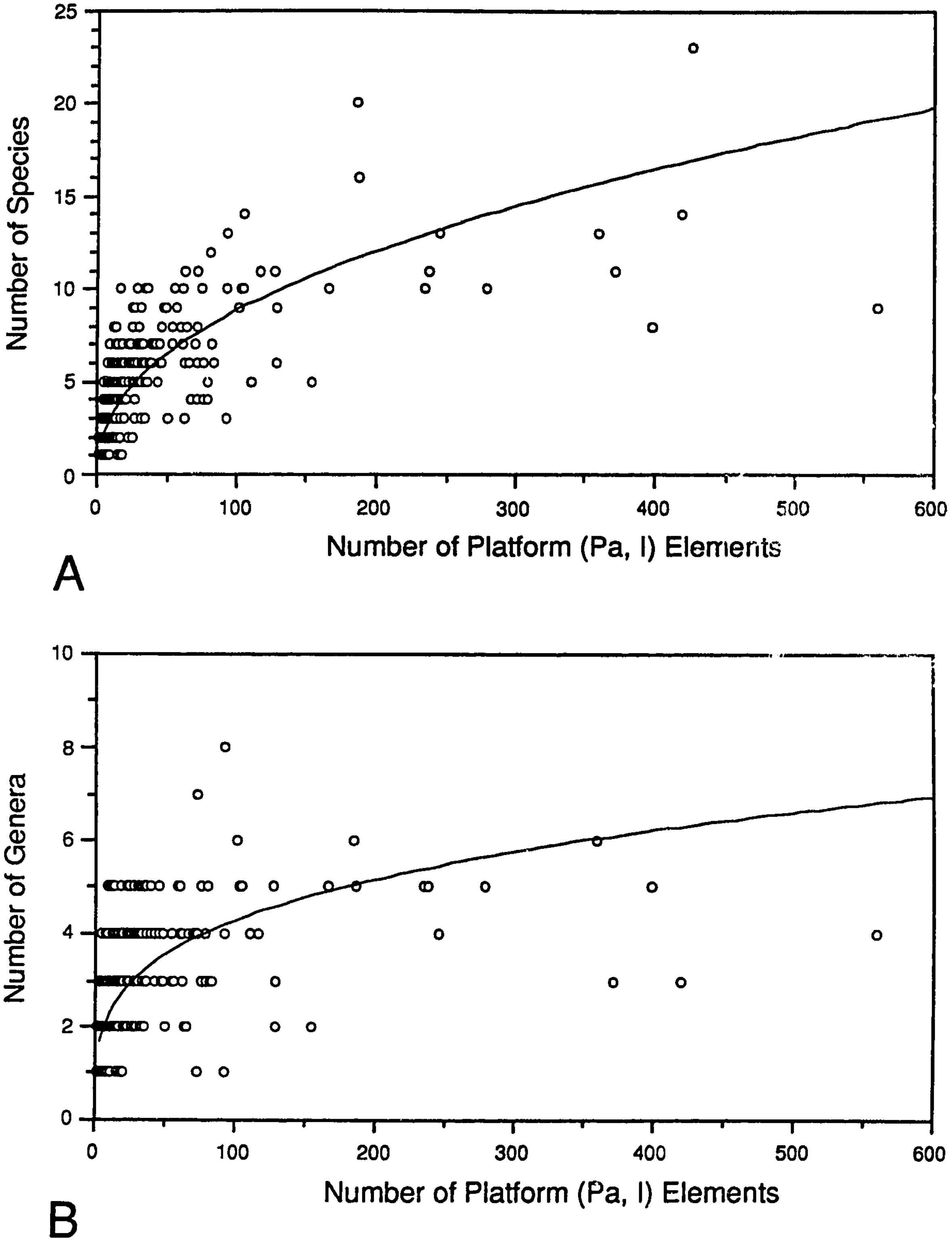


Figure IV-11. Key to lithological and other symbols and patterns used in Figures IV-1 to IV-10.

Figure IV-12. Rarefaction plots for A: number of platform elements versus number of species and B: number of platform elements versus number of genera. Each open circle represents one sample.


25
20
15
10
5
0
Number of Species
0
100
200
300
400
500
600
Number of Platform (Pa, I) Elements
A
10
8
6
4
2
0
Number of Genera
0
100
200
300
400
500
600
Number of Platform (Pa, I) Elements
B

PALEOTECTONIC SETTING	OFFSHORE SHELF TO BASIN		NEARSHORE OPEN MARINE SHELF		VARIOUS NEARSHORE RESTRICTED MARINE + PERITIDAL ENVIRONMENTS	LAND
CONODONT BIOFACIES	I palmatolepid (-bispathodontid)	II palmatolepid-polygnathid	III polygnathid-icriodontid/ "icriodontid"	IV polygnathid-pelekysgnathid	V-X clydagnathid, scaphignathid, polygnathid, etc.	

Figure IV-13. Standard Famennian conodont biofacies much modified from Sandberg and Dreesen (1984) and from Ziegler and Sandberg (1990). Parentheses around bispathodontid component of Biofacies I indicates *Bispathodus* is not a member of this biofacies until the upper Famennian. Until this time *Palmatolepis* is the dominant component of this biofacies (e.g. Sandberg and Dreesen, 1984). Icriodontid component of Biofacies III represented by species of either *Icriodus* or "*Icriodus*".

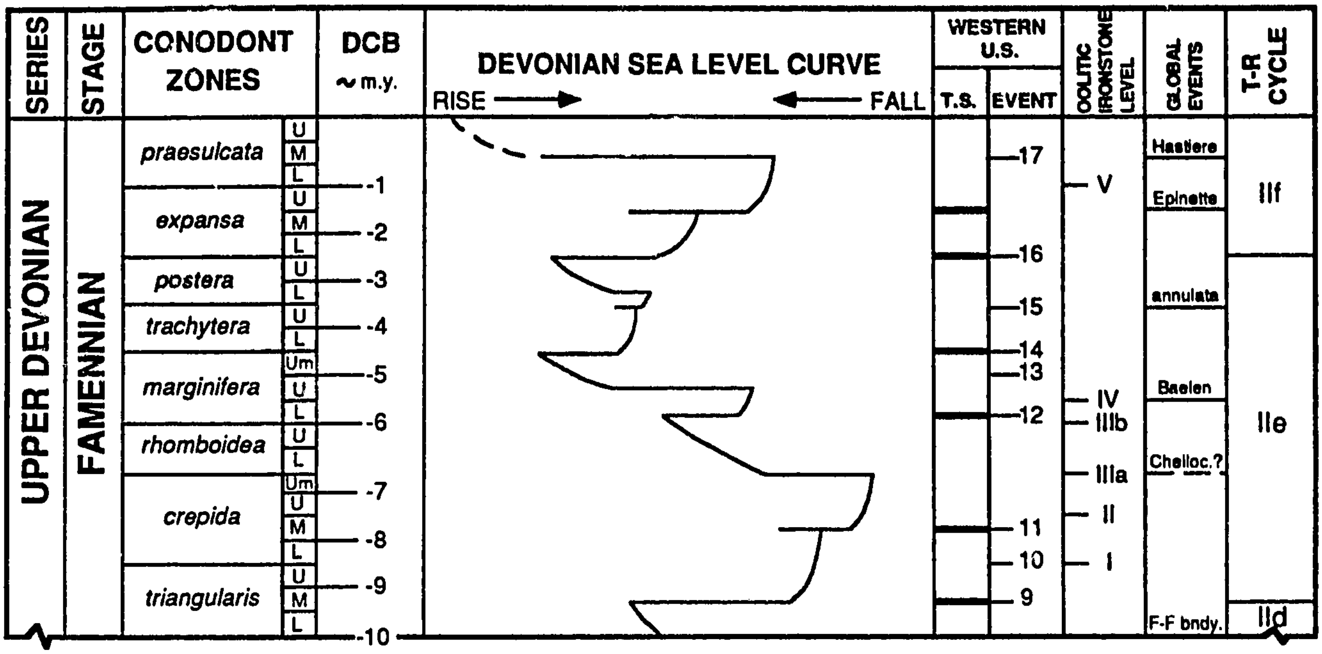


Figure IV-14. Diagram depicting Famennian portion of Devonian sea level curve of Johnson et al. (1985, 1991) plotted against standard conodont zonation, absolute time scale in terms of million of years before Devonian-Carboniferous boundary (DCB), as well as depositional events in the western United States (fourth and fifth columns from the right) (Sandberg et al., 1989), and oolitic ironstone levels in Belgium (third column from the right) (Dreesen, 1982, 1984). All these events are correlated with known and possible global eustatic events described by Dreesen et al. (1989), as well as with Upper Devonian transgressive-regressive (T-R) cycles (Johnson et al., 1985, 1991). F-F bndy. = Frasnian-Famennian boundary event. T.S. = transgressive start in western U.S. Cheiloc.? = Cheiloceras?

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CHAPTER V

TAXONOMY OF UPPER DEVONIAN (FAMENNIAN) CONODONTS OF THE PALLISER FORMATION AND WABAMUN GROUP, ALBERTA AND BRITISH COLUMBIA, CANADA

INTRODUCTION

The first reported occurrence of conodonts from either the Palliser Formation or Wabamun Group was by Clark and Ethington (1965) who recovered a few poorly preserved elements from the Palliser Formation at Mount Rundle and Crowsnest Pass in southwestern Alberta. Shortly after, conodonts were reported from the Wabamun Group by Mound (1967, 1968). These conodonts were recovered from two wells near Edmonton and one near Calgary, Alberta. Core from near the top of the Wabamun Group in one of the wells near Edmonton yielded abundant conodont faunas in the upper part of the cored interval. The occurrence of certain key forms enabled Mound (1967, 1968) to propose tentative correlations with the standard Upper Devonian sequence in Europe. Until recently, Mound's (1968) study was the only published work on conodonts from either the Palliser Formation or Wabamun Group. Most biostratigraphic or paleontological papers on these formations dealt mainly with other fossil groups, most notably brachiopods (e.g. Crickmay, 1952,; McLaren, 1954; Sartenaer, 1969; Greiner, 1973 and Raasch, 1989), although rare occurrences of ammonoids have also been reported (e.g. Warren, 1927; Taylor, 1958; House and Pedder, 1963). The only other micropaleontological works on the Palliser Formation and Wabamun Group were those of Lethiers (1978, 1981), who discussed the biostratigraphy, paleoecology and the taxonomy of Famennian ostracods from the surface and subsurface of Alberta, British Columbia and Saskatchewan.

Beginning in the late nineteen-eighties, a few studies that incorporated conodont data from the Palliser Formation and Wabamun Group were published. The first of these is Sandberg et al.'s (1989b) paper on Late Devonian lithofacies of the western United States, where there was brief mention of conodonts characteristic of the Lower marginifera Zone in the upper part of the Palliser Formation in northwestern Montana. Richards and Higgins (1989) reported the occurrence of Late Famennian conodonts from uppermost beds of the Palliser Formation at Jura Creek, Alberta and from one other locality in northeastern British Columbia. At both localities they (1989) were able to demonstrate, based on conodont evidence, that there was no significant difference in age between uppermost Palliser beds and the overlying Exshaw Formation. Johnston and Chatterton (1991) recently published a preliminary account of the conodont biostratigraphy of the Palliser Formation. In this paper, they demonstrated the presence of a number of the standard Upper Devonian conodont zones, as well as detailing some of the problems encountered in trying to apply the standard zonation to the Palliser Formation. Their work and that of Savoy (1990, 1992) also suggested that the upper contact of the Palliser Formation appears to be diachronous. A preliminary conodont biostratigraphy of the Wabamun Group has also been published, which documents the presence of several of the standard Upper Devonian conodont zones in this unit in the subsurface of northwestern Alberta and northeastern British Columbia (Johnston and Meijer Drees, 1993). Johnston and Meijer Drees (1993) also noted that several zones were either absent or unrecognized. They suggested that the absence or nonrecognition of these zones was perhaps the result of either a lack of suitable environments for diagnostic taxa or the presence of one or several hiatuses.

Meijer Drees and Johnston (1994) designated a type section for the Palliser Formation and discussed the conodont biostratigraphy of this and other sections of this unit in the type area of the formation near Banff, Alberta.

In the present work we treat in more detail herein the conodont taxa from the Palliser Formation and Wabamun Group figured in both Johnston and Chatterton (1991) and Johnston and Meijer Drees (1993). We also describe a number of new taxa. However, discussion is limited to taxonomy, as the biostratigraphy has been published elsewhere.

Most of the data base for this study consists of conodont collections from 12 sections of the Palliser Formation, located in southwestern Alberta and southeastern British Columbia to as far north as the Athabasca River Valley in west-central Alberta (Figure V-1A to V-1D). Most of these sections of the Palliser Formation were sampled at regular intervals throughout for conodonts (e.g. Figures V-2 to V-7). At a few localities, only the upper part of the Palliser Formation was sampled (e.g. Figure V-4). The other part of the data base consists of conodont collections from cored intervals in 17 wells penetrating the Wabamun Group in northwestern Alberta and northeastern British Columbia (Figures V-1, V-8 and V-9) which were collected as part of a regional study of Upper Devonian rocks in this area. Additional collections were also available from about 30 sections of the Palliser Formation (see Johnston and Chatterton, 1991, fig. 1) in which only the base and/or the top of the formation was sampled or the formation was incompletely sampled. Details concerning the number of samples and sampling intervals for each surface and subsurface section are given in the Appendix.

Seven of the sections shown in Figures V-1B to V-1D were sampled by BDEC (Banff Golf Course, Cold Sulphur Springs, Crowsnest Pass, Jura Creek, Medicine Lake, Mount Greenock and Roche Miette) while DIJ sampled the sections at Nigel Peak, Devil's Gap and Whiteman Gap. Material from the section of the Palliser Formation at Wardner in southeastern British Columbia (Figure V-1B) was made available to us by Helmut Geldsetzer of the Geological Survey of Canada. Nick Meijer Dress, also of the Geological Survey of Canada, collected nearly all the conodonts from the Wabamun Group and some from the Palliser Formation either solely or with DIJ.

STRATIGRAPHY

The Palliser Formation was named by Beach (1943) for a sequence of cliff-forming, mottled limestones that outcrop in the Bow River Valley. de Wit and McLaren (1950) subdivided the Palliser Formation into an upper Costigan Member and a lower Morro Member. The Costigan Member consists of silty, thin to thick bedded, fossiliferous limestone. This limestone is either underlain by brecciated and laminated dolostone and limestone and evaporites that are also assigned to this member, or directly by the Morro Member with a gradational contact. The Morro Member is characteristically thick bedded to massive peloidal limestone with bands of burrow-mottling several centimetres to metres thick. This is the most common lithology in exposures of this member, although in exposures at the northwestern and southwestern limits of Palliser outcrop, shaly intervals also occur and mottling is less pronounced (Geldsetzer, 1982; Geldsetzer et al., 1986; Johnston and Chatterton, 1991). The Morro Member is dolomitized to a greater degree in more easterly exposures of the Palliser Formation (de Wit and McLaren, 1950).

The outcrop area of the Palliser Formation extends from northwestern Montana (Sandberg et al., 1989b; Savoy, 1990, 1992) to northeastern British Columbia. Exposures are found in Paleozoic inliers in the Foothills, and in the Front and Main ranges of the Rocky Mountains, as well as in or near the Rocky Mountain Trench (e.g. Figure V-1B). The Palliser Formation generally thickens westward from a thickness of about 300 m in the Foothills and Front Ranges, to as much as 600 m in the western Front and Main Ranges. However, in or near the Rocky Mountain Trench, the thickness of the Palliser Formation decreases to 100 m (Johnston and Chatterton, 1991) (e.g. Figure V-2).

The Wabamun Formation was named for a sequence of carbonates and evaporites in the subsurface of the Edmonton area (Imperial Oil Staff, 1950). Wonfor and Andrichuk (1956) raised the Wabamun to group status in the subsurface of southeastern Alberta, where they recognized an upper Big Valley and a lower Stettler Formation. The Big Valley Formation consists of argillaceous and fossiliferous limestone and shale which overlies mainly carbonates and evaporites of the Stettler Formation. To the northwest the Wabamun Group consists mainly of limestone (Andrichuk, 1960; Meijer Drees and Geldsetzer, 1984; Halbertsma and Meijer Drees, 1987) with shaly interbeds occurring at its northwestern depositional limit (Meijer Drees et al., in prep.).

The Wabamun Group has been subdivided into informal units in several studies (e.g. Andrichuk, 1960), with the most recent subdivision of this group based on the electric log characteristics of particular intervals in this unit (Halbertsma and Meijer Drees, 1987). Five subdivisions have been recognized, which are, in ascending order, the Dixonville, Whitelaw, Normandville and Cardinal Lake units and the Big Valley Formation. The lower four units are more or less correlative with the Morro Member and with the lower peritidal carbonate unit of the Costigan Member in the Palliser Formation (Figure V-10). Lithologically, these units are quite similar, in that they are comprised mainly of peloidal and skeletal mudstones, wackestones, packstones and grainstones (Halbertsma and Meijer Drees, 1987), with a greater proportion of packstones and grainstones in the lower part of the Dixonville unit and throughout the Normandville unit. Tabular stromatoporoids and stromatoporoid reefs occur in the Normandville and Whitelaw units (e.g. Halbertsma and Meijer Drees, 1987; Stearn et al., 1987). These units, which are regarded as informal in this work, were considered members by Halbertsma (in Glass, 1990).

The Big Valley Formation is mainly a glauconitic skeletal wackestone to packstone, with more argillaceous beds in the lower part of this unit. The lower contact of the Big Valley with the underlying Cardinal Lake unit is usually sharp and is apparently erosional. This formation is considered to be correlative with the upper fossiliferous limestone unit of the Costigan Member.

Like the Palliser Formation, the Wabamun Group generally thickens westward. It also thickens northwestward (Figure V-1A) but thins locally over the Peace River Arch. On the north side of the arch the formation thickens again but then decreases in thickness in northeastern British Columbia (Figure V-1A).

The Palliser Formation and Wabamun Group are contiguous with each other and with the shales and limestones of the Kotcho and Tetcho formations in the subsurface of northeastern British Columbia and the southwestern Northwest Territories (Figure V-10). The Palliser Formation and Wabamun Group are also contiguous with the Big Valley and Torquay formations of southern Saskatchewan (Figure V-10). The black shales of the Exshaw Formation overlie the Palliser Formation in south-central and southern Alberta and in southeastern British Columbia whereas in north-central Alberta and northeastern British Columbia, the Palliser Formation is overlain by either the Banff or Besa River formations (Geldsetzer, 1982). The Exshaw Formation overlies the Wabamun Group in the subsurface, except where the latter is truncated along its eastern subcrop area (Figure V-1A).

The Famennian Sassenach Formation underlies the Palliser Formation in south-central and southern Alberta and in southeastern British Columbia (Figure V-10), except at a few localities where the Palliser Formation is underlain by the Frasnian Ronde Member of the Southesk Formation (e.g. Belyea and McLaren, 1964). In north-central Alberta and northeastern British Columbia, the Palliser Formation is underlain by the

Frasnian Simla Formation (Geldsetzer, 1982). In the subsurface the Wabamun Group is underlain by the Graminia Formation (Figure V-10).

According to recent interpretations, the Palliser Formation and Wabamun Group formed part of a basinward-prograding carbonate ramp (Eliuk, 1984; Stoakes, 1987; Savoy, 1990, 1992) that was situated on the northwestern margin of the Euramerican craton (e.g. Witzke and Heckel, 1989). This ramp was bordered by a shale basin to the northwest and west (Richards, 1989; Savoy, 1990, 1992).

For a more complete account of the stratigraphy, lithologic characteristics and interpreted depositional and paleotectonic settings of the Palliser Formation and Wabamun Group, the reader is referred to Beales (1956), Andrichuk (1960), Geldsetzer (1982), Geldsetzer et al. (1986), Halbertsma and Meijer Drees (1987), Johnston and Chatterton (1991) and Meijer Drees and Johnston (1993, 1994).

METHODS

All conodont samples depicted in Figures V-2 to V-7 and Tables V-1 to V-17 were dissolved in a ten percent solution of acetic acid. Those collected by DIJ were dissolved in the solution recommended by Jeppsson et al. (1985). Processing weights ranged from approximately 0.1 kg to as much as 4.0 kg. Insoluble residues were either picked immediately or were further concentrated in tetrabromoethane or sodium polytungstate at specific gravities of 2.78-2.87 for the former and 2.78 for the latter. Photography of conodonts was by scanning electron microscope (SEM).

CONODONT FAUNA

CHARACTERISTICS OF FAUNA

Conodonts were studied from 471 samples collected from surface and subsurface sections of the Palliser Formation and Wabamun Group in Figures V-2 to V-9. Localities of the Palliser

Formation, that are not shown in Figures V-2 to V-7 but which some of the figured specimens and types in Plates V-1 to V-35 came from, are described in the Appendix.

Preservation of conodonts ranged from excellent to very poor. Those conodonts exhibiting poor preservation were either etched or have been recrystallized as a result of diagenesis. Etching appears to have been primarily caused by dolomitization. Fracturing of conodont elements due to tectonism is also common in some collections.

Colour alteration indices (CAI's) ranged from as low as 1.0-1.5 to as high as 5 or more. Faunas from the Palliser Formation generally had higher CAI's, though some faunas in the Wabamun Group were found to have comparable values. Conversely, conodonts faunas at some localities of the Palliser Formation were also found to have low colour alteration indices (about 1.5-3.0).

CONODONT ZONATION

In this report, we apply the Famennian part of the standard Late Devonian conodont zonation (Figure V-11). This zonation was first proposed by Ziegler (1962b). The Famennian part of the zonation was first revised by Sandberg and Ziegler (1973) who added a Lower rhomboidea Zone between the Upper crepida and rhomboidea (now Upper rhomboidea Zone) zones (Figure V-11). The upper (i.e. post marginifera portion) part of the standard zonation was revised by Ziegler and Sandberg (1984). In the most recent revision of this zonation (Ziegler and Sandberg, 1990), an Uppermost crepida Zone has been inserted between the Upper crepida and Lower rhomboidea zones (Figure V-11). These zones are usually defined by the first occurrences of species or subspecies of Palmatolepis (the latter are considered species in this work, see below), although recognition of these zones can be based on the occurrences of taxa other than the zonal indices.

The presence of several standard conodont zones has previously been documented in both the Palliser Formation and Wabamun Group (Johnston and Chatterton, 1991; Johnston and Meijer Drees, 1993), although in some intervals in both these units, it has not been possible to recognize definite lower and/or upper limits of some of these zones. Thus for collections from these intervals their ages and the stratigraphic ranges of taxa in them are expressed in terms of a range of zones (e.g. Lower to Middle crepida zones).

In Tables V-1 to V-17, we have generally followed this procedure, although at some localities only the minimum age span is indicated, because of the lack of evidence of younger zones. In some cases, this narrowed the age span down to a single zone (e.g. the Upper rhomboidea Zone in Tables V-3, V-7, V-14).

SYSTEMATIC PALEONTOLOGY

In the following section, we discuss only the form-taxonomy of platform (Pa and I) elements. Studies of apparatuses and resultant multielement taxonomy have been hampered by collections that either contain too few conodont elements or contain abundant conodont elements but do not have sufficiently low diversity in order to match elements of any particular taxon with each other (see Klapper and Philip, 1971, 1972; Klapper, 1991; Klapper and Foster, 1993). Therefore we have no multielement apparatus reconstructions to propose at this time.

For well known taxa, synonymies emphasize more recently reported occurrences. Only critical earlier references are given in this case. For other taxa that are less known or where our concept differs from that in the literature, extended synonymies are given.

In this section we follow the recommendations of Bengtson (1988) for the usage of the signs "aff.", "cf." and "?" in open nomenclature. Morphologic terminology applied to platform elements follows that in the Treatise (Sweet, in Robison, 1981, pp. W12-W16, W60-W67) and in Sweet (1988). We also follow the suprageneric classification of conodonts of Sweet (1988) with the exception that the Conodonta and Conodonti are considered a class and subclass respectively of the Phylum Chordata (e.g. Purnell and von Bitter, 1992 and see below).

We depart from the practice of most Upper Devonian conodont taxonomists (e.g. Ziegler and Sandberg, 1990) of naming subspecies. We feel that such a practice is unnecessary, and if enough differences exist that warrant the separation of one taxon from another, they should be recognized at the species level. We consider that subspecies should be reserved for contemporaneous allopatric races, of direct interest to paleobiogeographers but of less direct importance to biostratigraphers. As a consequence, all taxa in this work formerly considered subspecies are elevated in rank to species, although some are grouped under some genera in informal taxonomic groups (e.g. species of the "Palmatolepis glabra group") which may or may not represent distinct clades (e.g Helms and Ziegler, 1981, text-fig. 62).

We consider conodont species in the form sense to represent Pa and I elements which possess certain distinguishing morphological features that set these species apart from others of the same genus. These features can be type of ornamentation, blade and carina configuration and denticulation pattern, for example. Conodont genera are regarded as groupings of species which have the same general Pa or I element configuration (e.g. palmatolepid, pelekysgnathid). Genera are also defined on the basis of the other known or assumed elements in the apparatus (e.g. Klapper and Philip, 1971). It has been suggested, however, that species of certain genera can also be identified on the basis of Pb and certain ramiform elements in the apparatus (e.g. Klapper and Foster, 1993).

Phylum CHORDATA Bateson, 1886

Class CONODONTA Pander, 1856
Subclass CONODONTI Branson, 1938
Order PRIONIODONTIDA Dzik, 1976
Family ICRIODONTIDAE Müller and Müller, 1957

Genus *Icriodus* Branson and Mehl, 1938

Type species. *Icriodus expansus* Branson and Mehl, 1938.

Icriodus erucisimilis n. sp.
Pl. V-1, figs. 1-19

1989 *Icriodus iowaensis*, Orchard, p. 50, pl. 5, fig. 20 (only).

Etymology. From the Latin *eruca*, meaning caterpillar and *similis*, meaning like; referring to the caterpillar-like appearance of many specimens of this species.

Types. Holotype GSC 106824, illustrated on Plate V-1, figures 17, 18; paratypes GSC 106812-106823, 106825, illustrated on Plate V-1, figures 1-16, 19.

Material. About 160 specimens.

Diagnosis. A species of *Icriodus* with an unarched to slightly arched and straight to slightly bowed platform, with aligned to slightly offset lateral and medial denticles. These denticles are connected by medial and transverse ridges. The transverse ridges often bifurcate laterally on the sub-rounded and inflated lateral denticles.

Description. Platform elongate, broadening from anterior end to somewhere behind of midlength of element then narrowing posteriorly in mature specimens; platform narrow in juvenile specimens. Platform weakly to moderately arched and moderately bowed to straight.

Lateral denticles pointed to somewhat rounded and/or inflated in mature specimens, forming platform margins that are scalloped in upper view. Lateral denticles either aligned or slightly offset anteriorly from medial denticles. Medial denticles in earliest growth stages elongate, laterally compressed and triangular in lateral view, becoming somewhat lower in height in later growth stages. Medial denticles in all growth stages connected by high, sharp transverse ridges to adjacent lateral denticles or to adjacent lateral and medial denticles by sharp medial and transverse ridges. Medial denticles may form continuous sharp ridge along length of element or several discontinuous ridges. Transverse ridges commonly bifurcate laterally on lateral denticles, may even trifurcate on some large specimens.

Posterior cusp low in intermediate to mature growth stages, high in early growth stages. Posterior cusp connected to medial denticle row by continuation of medial ridge. Latter ridge somewhat sinuous posterior to denticle rows, may have several lateral ridges branching off laterally from it.

Basal cavity flared, with gradual expansion in width posteriorly on some specimens. On other specimens, flaring of basal cavity only restricted to posterior third to quarter of element. In some specimens, a lateral denticle or ridge-like "spur" occurs on the inner postero-lateral margin of the basal cavity.

Remarks. *Icriodus erucisimilis* differs from *I. constrictus* Thomas by having a narrow rather than a broad posterior end of the platform. Both species do share in common, however, bifurcating transverse ridges on the lateral denticles. *Icriodus erucisimilis* differs from *I. iowaensis* Youngquist and Peterson by having lateral denticles that are more rounded and somewhat inflated whereas in the latter species, the lateral denticles generally merge with the medial denticles to form a sharp ridge perpendicular to the axis. A few specimens of

I. iowaensis, however, do show bifurcation of the ridges (Sandberg and Dreesen, 1984).

The low posterior cusp appears to be characteristic of all but the earliest growth stages of *Icriodus erucisimilis*. In the latter case, specimens have an enlarged posterior cusp similar to that encountered in specimens of "*Icriodus*" and *Pelekysgnathus*.

Although most specimens we assign to *Icriodus erucisimilis* generally have symmetrically arranged denticles and ridges in upper view we have one specimen (Pl. V-1, fig. 5) which is asymmetrical with irregular development of denticles and ridges.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-3, V-4, V-6, V-7, V-9 to V-13, V-15, V-16). As presently known, *Icriodus erucisimilis* ranges from the Lower and Middle *crepida* zones to the Upper *crepida* Zone in the Palliser Formation and Wabamun Group.

Icriodus iowaensis Youngquist and Peterson, 1947
Pl. V-1, figs. 20-28

1947	*Icriodus iowaensis* Youngquist and Peterson, p. 247, pl. 37, figs. 22-24, 27-29.
1984	*Icriodus iowaensis iowaensis*, Sandberg and Dreesen, pp. 159, 160, pl. 1, figs. 7-11; pl. 2, figs. 9, 10; pl. 4, fig. 18 (contains synonymy to 1980).
1985	*Icriodus iowaensis*, Klapper and Lane, p. 920, figs. 11.7, 11.10?
1988	*Icriodus iowaensis iowaensis*, Bultynck, p. 28, pl. A2/3, fig. 15.
1988	*Icriodus iowaensis*, Aristov, pp. 69, 70, pl. 10, fig. 3.
1989	*Icriodus iowaensis iowaensis*, Orchard, p. 50, pl. 5, figs. 14, 18, 19, 22, 23.
1989	*Icriodus iowaensis*, Wang and Bai, p. 75, figs. 5.9, 5.11.
1989	*Icriodus iowaensis*, Jia, Xian, Yang, Zhou, Han, Chen, Wang J-X, Wang R-G, Wang S-T, Zhang Z-X and Zhang W-M, p. 88, pl. 3, figs. 16, 17.
?1989	*Icriodus iowaensis*, Metzger, p. 512, fig. 13.8.
1991	*Icriodus iowaensis iowaensis*, Johnston and Chatterton, p. 182, pl. 3, figs. 21-24.
1992	*Icriodus iowaensis iowaensis*, Savage, p. 280, figs. 2.1-2.6.

Types. Figured hypotypes GSC 100322, 100323, 106826-106828.

Diagnosis. See Sandberg and Dreesen (1984, p. 160).

Remarks. We recognize only a few specimens of *Icriodus iowaensis* in our collections. Most specimens with lateral and medial denticles connected by ridges have been assigned to *I. erucisimilis* n. sp. We distinguish specimens of the former species from those of the latter by the rarity or lack of bifurcations of the transverse ridges in *I. iowaensis*.

We have identified both the broad (e.g. Pl. V-1, figs. 20, 21, 24-28) and narrow (e.g. Pl. V-1, figs. 22, 23) morphotypes of *Icriodus iowaensis* recognized by Sandberg and Dreesen (1984). In our collections, both morphotypes are present at the youngest occurrences of this species. This is unlike the pattern of occurrence reported by Sandberg and Dreesen (1984, p. 160) in which the narrow morphotype is the youngest occurring form.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1 to V-3, V-6, V-7, V-9, V-10, V-14). *Icriodus iowaensis* ranges from possibly the Lower to Middle *crepida* zones (e.g. Wardner, Table V-1) to the lowermost part of the Upper *rhomboidea* Zone in the Palliser Formation and Wabamun Group. At some localities, the highest occurrence of this species approximates the uppermost limit of strata that are no younger than the Lower *rhomboidea* Zone. A few scattered specimens that may represent a late form or descendant of this species occur in the remainder of the Upper *rhomboidea* zone.

Icriodus stenoancylus n. sp.

Pl. V-2, figs. 1-4, 5?, 6-11

1991 *Icriodus iowaensis ancylus*, Johnston and Chatterton, p. 182, pl. 3, figs. 15, 16.

Etymology. From the Greek *steno*, meaning narrow, referring to the very narrow platform which is otherwise similar in appearance to that of *Icriodus ancylus* Sandberg and Dreesen.

Types. Holotype GSC 106830, illustrated on Plate V-2, figures 3, 4; paratypes GSC 100318, 106829, 106832-106836, illustrated on Plate V-2, figures 1, 2, 6-11.

Material. About 40 specimens.

Diagnosis. A species of *Icriodus* with a very narrow platform and with a relatively broad, and in some cases, flaring basal cavity. The upper surface has a sinuous to zig-zag medial ridge that connects in many specimens a number of transverse ridges that are irregularly arranged.

Description. Element elongate, generally very narrow in upper view. Element weakly to moderately arched and straight to moderately bowed. Upper surface of element consists of interconnected, poorly to well defined, medial and transverse ridges which are irregularly arranged. Transverse ridges either continuous across platform or extending from medial ridge on only one side. Stratigraphically younger specimens appear to have only transverse ridges developed on the anterior portion of the platform whereas only a sinuous or zig-zag medial ridge occurs posteriorly. Medial ridge connected to low to moderately high posterior cusp. Basal cavity moderately to widely flared posteriorly.

Remarks. *Icriodus stenoancylus* differs chiefly from *I. ancylus* Sandberg and Dreesen by the very narrow width of its platform. Both species appear to have in common the interconnection of medial and lateral denticles by ridges and an upward curvature of the upper side of the platform in lateral view.

Earlier growth stages of *Icriodus stenoancylus* appear similar to specimens of *Pelekysgnathus*, but generally show some trace of transverse ridges.

A questionable specimen of this species (Pl. V-2, fig. 5), which occurs in strata dated as upper part of the Upper *crepida* Zone or younger, may represent a late form or possible descendant of *Icriodus stenoancylus*. It has transverse ridges posteriorly on the upper surface whereas anteriorly there are irregularly arranged nodes.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-6, V-7, V-9 to V-12, V-15, V-16). As presently known, *Icriodus stenoancylus* ranges from the Lower to Middle *crepida* zones to at least as high as the lower part of the Upper *crepida* Zone. A questionable specimen as noted above, occurs slightly higher.

Icriodus aff. *I. alternatus* Branson and Mehl, 1934a
Pl. V-2, figs. 12, 13

aff. 1934a *Icriodus alternatus* Branson and Mehl, pp. 225, 226, pl. 13, figs. 4-6.
1991 *Icriodus alternatus alternatus*, Johnston and Chatterton, p. 182, pl. 3, figs. 19, 2

Types. Figured specimen GSC 100321.

Remarks. Although the specimen we have previously illustrated (see synonymy) has alternating lateral and medial denticles, and the medial denticles appear somewhat lower than those on the lateral margin of the platform, the platform is generally broader relative to its width than typical specimens of *I. alternatus* (e.g. Sandberg and Dreesen, 1984, pl. 2, figs. 5, 11). Also the denticles in our specimen are much lower and rounder, and more robust, than the platform denticles in the latter species.

Occurrence. Palliser Formation (Table V-11). The illustrated specimen comes from strata that are dated as no older than the Lower *crepida* Zone and no younger than the Lower *rhomboidea* Zone (likely no older than the upper part of the Upper *crepida* Zone based on the associated fauna, Table V-11).

Icriodus cf. *I. alternatus* Branson and Mehl, 1934a
Pl. V-2, figs. 14-17

cf. 1934a *Icriodus alternatus* Branson and Mehl, pp. 225, 226, pl. 13, figs. 4-6.

Types. Figured specimens GSC 106837-106839.

Remarks. Although specimens assigned to this taxon have alternating, rounded lateral and medial denticles, a narrow platform and a relatively low posterior cusp, the medial denticles are as high or, in some specimens, higher that the lateral denticles. Typical specimens of Icriodus alternatus Branson and Mehl have medial denticles that are lower than the lateral denticles (Sandberg and Dreesen, 1984). In some of our specimens, the posterior cusp is somewhat enlarged (Pl. V-2, fig. 14), like the posterior cusp in "Icriodus" cornutus Sannemann. However, we do not believe that the cusp size is sufficiently large enough to warrant assignment of these specimens to "Icriodus".

Occurrence. Wabamun Group (Table V-15). Faunas containing Icriodus cf. I. alternatus in the Parkland 10-26 well (Table V-15) are considered to be no older than the Lower rhomboidea Zone but no younger than the Upper marginifera Zone based on the presence of Palmatolepis rhomboidea Sannemann in the fauna. Faunas containing I. cf. I. alternatus in the Parkland 10-28 well (sampled intervals 10717 ft. to 10932 ft., Table V-15) would be considered to be no older that the Uppermost crepida Zone but having possibly the same upper age limit (based on the possible occurrence of P. klapperi Sandberg and Ziegler) as the fauna in the Parkland 10-26 well.

Icriodus sp. A
Pl. V-2, figs. 18-20

Types. Figured specimens GSC 106840-106842.

Remarks. Specimens of Icriodus assigned to this taxon are characterized by a strongly flared basal cavity posteriorly On larger specimens the lateral denticles more or less alternate with the medial denticles. Icriodus sp. A also has a low posterior cusp. Most intact or nearly intact specimens of this taxon are small, and thus could conceivably be early growth stages of other icriodontid taxa present. However, since there are no obvious larger forms to associate it with, we prefer to retain I. sp. A as a separate taxon for the present time.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-15). Icriodus sp. A occurs in strata that are no older than the Lower rhomboidea Zone but no younger than the Lower marginifera Zone.

Genus "Icriodus" sensu Sandberg and Dreesen, 1984

Remarks. Specimens provisionally assigned to Icriodus have enlarged posterior cusps like Pelekysgnathus but also have the triple row of denticles like the former genus (Sandberg and Dreesen, 1984). We concur with Sandberg and Dreesen (1984) that specimens such as these are probably representative of a new genus.

"Icriodus" chojnicensis Matyja, 1972
Pl. V-3, figs. 12, 13

1972	Icriodus chojnicensis Matyja, p. 745, pl. 4, figs. 1-4.
1984	"Icriodus" chojnicensis, Sandberg and Dreesen, pp. 163, 164, pl. 2, figs. 12-14 (contains synonymy).
1987	'Icriodus' chojnicensis, Matyja, p. 375, pl. 22.2, figs. 1-3; p. 376, pl. 22.3, figs. 1, 2.
1988	Icriodus costatus costatus, Aristov, p. 68, pl. 10, figs. 6, 7.
1991	"Icriodus" chojnicensis Morphotype 1, Johnston and Chatterton, p. 182, pl. 3, figs. 5, 6.

Types. Figured hypotypes GSC 100309, 100310.

Diagnosis. See Sandberg and Dreesen (1984, p. 163).

Remarks. We reillustrate two specimens of "Icriodus" *chojnicensis* which have rounded lateral and medial denticles that are characteristic of Sandberg and Dreesen's (1984) Morphotype 1 of this species. One specimen (Pl. V-3, fig. 13) shows the apparent fusion of the two posteriormost denticles on the left side, as well as a discrepancy in the number of denticles between left and right sides of the platform.

Specimens we have previously assigned to Morphotype 2 of this species have been reassigned to "*Icriodus*" cf. "*I.*" *raymondi* Sandberg and Ziegler (see synonymy and Remarks for latter taxon).

Occurrence. Palliser Formation and Wabamun Group (Tables V-6, V-7, V-14). The stratigraphic occurrence of "*I.*" *chojnicensis* in the Palliser Formation and Wabamun Group is restricted to the uppermost part of the Lower *rhomboidea* Zone (e.g. Medicine Lake, Table V-7; Gold Creek 10-31 well, Table V-14; Nigel Peak, Table V-6).

"*Icriodus*" *cornutus* Sannemann, 1955b
Pl. V-3, figs. 1-6

1955b	*Icriodus cornutus* Sannemann, p. 130, pl. 4, figs. 19-21.
1983	*Icriodus cornutus*, Wang and Ziegler, pl. 2, figs. 4, 5.
1984	"*Icriodus*" *cornutus*, Sandberg and Dreesen, pp. 162, 163, pl. 2, fig. 8; pl. 4, figs. 19, 20 (contains synonymy to 1976).
1984	*Icriodus cornutus*, Olivieri, p. 286, pl. 5, fig. 8.
1985	*Icriodus cornutus*, Austin, Orchard and Stewart, p. 158, pl. 4.9, fig. 12.
1985	*Icriodus cornutus*, Ji and Liu, p. 179, pl. 1, figs. 6-8.
1988	*Icriodus cornutus*, Bultynck, p. 29, pl. A2/3, figs. 10, 16.
1990	*Icriodus cornutus*, Perri and Spalletta, p. 60, pl. 1, fig. 3.
1991	"*Icriodus*" *cornutus*, Johnston and Chatterton, p. 182, pl. 3, figs. 7, 8.

Types. Figured hypotypes GSC 100311, 106843, 106844.

Diagnosis. See Sandberg and Dreesen (1984, p. 162).

Remarks. Most smaller specimens that we assign to "*Icriodus*" *cornutus* exhibit the characteristic alternating lateral and medial platform denticles that occur anterior to an enlarged posterior denticle (e.g. Pl. V-3, figs. 3, 6). However, on two larger specimens, the posteriormost lateral denticles are unaligned or slightly offset with respect to one another (e.g. Pl. V-3, figs. 2, 3). This feature makes these specimens somewhat transitional to "I." chojnicensis Matyja.

Occurrence. Palliser Formation and Wabamun Group (Tables V-6, V-7, V-14, V-16). In our collections, "Icriodus" cornutus ranges from the Lower to the Upper rhomboidea zones.

"Icriodus" cf. "I." cornutus Sannemann, 1955b

Pl. V-3, figs. 7-11, 14-16

cf. 1955b	Icriodus cornutus Sannemann, p. 130, pl. 4, figs. 19-21.

Types. Figured specimens GSC 106845-106850.

Remarks. Specimens assigned to this taxon are characterized by irregular denticulation. They include those in which the lateral and medial denticles are both alternating and aligned (e.g. Pl. V-3, fig. 7). We also include in "I." cf. "I." cornutus specimens with complete (Pl. V-3, fig. 11) or partial (Pl. V-3, figs. 8, 9) development of ridges between the denticles, which in one specimen (Pl. V-3, fig. 9) makes the upper side superficially resemble that of Icriodus iowaensis Youngquist and Peterson. In some specimens, lateral denticles are much reduced and/or nearly obsolescent (Pl. V-3, fig. 16).

Occurrence. Palliser and Wabamun formations (Tables V-1, V-3, V-6, V-7, V-13). Specimens assigned to "Icriodus" cf. "I." cornutus range from the Lower to Upper rhomboidea zones.

"Icriodus" costatus (Thomas, 1949)

Pl. V-3, figs. 17-22

1949	Pelekysgnathus costata Thomas, p. 424, pl. 2, fig. 9.
1984	"Icriodus" costatus costatus Morphotype 1 Sandberg and Dreesen, p. 164, pl. 4, figs. 1, 11 (contains synonymy to 1980).
1984	"Icriodus" costatus costatus Morphotype 2 Sandberg and Dreesen, p. 164, pl. 4, fig. 12 (contains synonymy to 1980).

1984	"*Icriodus*" *costatus*, Dusar and Dreesen, p. 55, pl. 4, fig. 8.
?1987	*Icriodus obovatus* Ji, p. 20, pl. 2, figs. 3, 4.
1988	*Icriodus cornutus chojnicensis*, Aristov, p. 67, pl. 10, figs. 1, 2.
1989	*Icriodus costatus costatus*, Metzger, p. 512, figs. 13.9, 13.10.
1991	"*Icriodus*" *costatus costatus* Morphotype 1, Johnston and Chatterton, p. 182, pl. 3, figs. 9, 10.

Types. Figured hypotypes GSC 100312, 100313, 106851, 106852.

Diagnosis. See Sandberg and Dreesen (1984, p. 164).

Remarks. The few specimens of "*Icriodus*" *costatus* in our collections generally correspond to Sandberg and Dreesen's (1984) concept of Morphotype 1 of this species. Specimens of this morphotype have a bowed platform with irregularly arranged ridges on the upper surface (Sandberg and Dreesen, 1984). In one sample (COS89 35.7-36.8m, Table V-5) containing abraded elements of this species, both forms with broad (Pl. V-3, figs. 19, 20) and narrow (Pl. V-3, figs. 17, 18, 21, 22) platforms occur. Both forms, however, are characterized by interconnected ridges.

Occurrence. Palliser Formation and possibly from the Wabamun Group (Tables V-5, V-16, V-17). "*Icriodus*" *costatus* is presently known to range from the Uppermost *marginifera* to the Upper *postera* zones (Sandberg and Dreesen, 1984). However, our data suggest that this species' stratigraphic range can be extended upward at least into the Lower *expansa* Zone (Johnston and Chatterton, 1991). The stratigraphic range of this species may also have a downward extension based on the occurrence of a questionable specimen of "*I.*" *costatus* in the Lower *marginifera* Zone at Nigel Peak (sample NPW89-2, Table V-6).

"*Icriodus*" cf. "*I.*" *raymondi* Sandberg and Ziegler, 1979
Pl. V-3, figs. 23-28; Pl. V-4, figs. 3-7

cf. 1979	*Icriodus? raymondi* Sandberg and Ziegler, pp. 189, 190.
1991	"*Icriodus*" *chojnicensis* Morphotype 2, Johnston and Chatterton, p. 182, pl. 3, figs. 1-4.
1991	"*Icriodus*" *raymondi*, Johnston and Chatterton, p. 182, pl. 3, figs. 17, 18.

Types. Figured specimens GSC 100307, 100308, 100319, 100320, 106853-106855.

Remarks. Specimens assigned to this taxon, although having the prominent posterior cusp and wide platform of "Icriodus" raymondi Sandberg and Ziegler, differ by having at least some lateral and medial denticles that are neither aligned nor alternating with each other. This includes specimens we have previously assigned to "I." raymondi and "I." chojnicensis Matyja Morphotype 2 of Sandberg and Dreesen (see synonymy). Earlier growth stages (e.g. Pl. V-4, figs. 3-7) especially show the irregular arrangement of denticles, whereas in mature specimens, the degree of irregularity of denticle arrangement is somewhat diminished (e.g. Pl. V-3, figs. 27, 28). Mature specimens also exhibit the fusion of denticles on the lateral margins of the platform and between the lateral and medial denticle rows. Fusion of medial denticles is also seen in some of our specimens which results in the formation of short longitudinal ridges (e.g. Pl. V-3, fig. 27; Pl. V-4, figs. 4, 5).

Occurrence. Palliser Formation (Tables V-6, V-8, V-10). "Icriodus" cf. "I." raymondi occurs in strata that are as old as the Upper marginifera Zone and at least as young as the Lower expansa Zone.

Genus Pelekysgnathus Thomas, 1949

Type species. Pelekysgnathus inclinata Thomas, 1949

Pelekysgnathus inclinatus Thomas, 1949
Pl. V-4, figs. 1, 2, 9-12

1949	Pelekysgnathus inclinata Thomas, pp. 424, 425, pl. 2, fig. 10.
1979	Pelekysgnathus australis Nicoll and Druce, pp. 17, 18, pl. 1, figs. 1-17.
1984	Pelekysgnathus inclinatus, Sandberg and Dreesen, pp. 161, 162, pl. 3, figs. 5, 7-9,

	10-19; pl. 4, figs. 7-9 (contains synonymy to 1979).
1984	*Pelekysgnathus inclinatus*, Dusar and Dreesen, p. 55, pl. 4, fig. 6.
1985	*Pelekysgnathus inclinatus*, Austin, Orchard and Stewart, p. 158, pl. 4.9, figs. 6-8.
1987	*Pelekysgnathus inclinatus*, Matyja, p. 376, pl. 22.3, fig. 5; p. 377, pl. 22.4, fig. 6.
1988	*Pelekysgnathus australis*, Aristov, p. 77, pl. 11, figs. 5-7.
1988	*Pelekysgnathus communis*, Aristov, p. 78, pl. 11, figs. 8, 9.
1988	*Pelekysgnathus inclinatus*, Aristov, p. 79, pl. 11, fig. 11.
1988	*Pelekysgnathus isodentatus*, Aristov, p. 79, pl. 12, fig. 16.
1988	*Pelekysgnathus peejayi*, Aristov, p. 80, pl. 11, fig. 1-3.
1988	*Pelekysgnathus proteus*, Aristov, pp. 80, 81, pl. 11, figs. 10, 12-15.
1988	*Pelekysgnathus tridentatus*, Aristov, p. 81, pl. 12, figs. 11, 12 (only).
1988	*Pelekysgnathus* aff. *peejayi* Aristov, p. 115, pl. 11, fig. 4.
1989	*Pelekysgnathus inclinatus*, Metzger, p. 516, figs. 13.23-13.25.
1991	*Pelekysgnathus inclinatus*, Johnston and Chatterton, p. 182, pl. 3, figs. 12-14.
1993	*Pelekysgnathus inclinatus*, Johnston and Meijer Drees, p. 145, pl. 1, fig. 8.

Types. Figured hypotypes GSC 98133, 100315-100317, 106856, 106857.

Diagnosis. See Sandberg and Dreesen (1984, p. 161).

Remarks. Most specimens in our collections conform to the diagnosis of this species. However, a few large specimens (Pl. V-4, figs. 9, 11), appear to have very weak or no development of denticles anterior to the cusp. This feature may be a preservational artifact or phenotypic in nature.

Occurrence. Palliser Formation and Wabamun Group (Tables V-2, V-4 to V-11, V-17). We have only a few scattered occurrences of *Pelekysgnathus inclinatus* in the lower part of the Palliser Formation in the Lower to Middle *crepida* zones (Tables V-6, V-7). The majority of occurrences of this species are in the upper part of the Palliser Formation and Wabamun Group from the Lower *marginifera* to the Lower *expansa* zones.

Pelekysgnathus planus Sannemann, 1955b
Pl. V-4, figs. 8, 13, 14

1955b	*Pelekysgnathus planus* Sannemann, p. 149, pl. 4, figs. 22, 23.
1983	*Pelekysgnathus planus*, Wang and Ziegler, pl. 4, fig. 19.
1984	*Pelekysgnathus planus*, Sandberg and Dreesen, p. 161, pl. 3, fig. 6 (see for synonymy).
1984	*Pelekisgnathus* (sic) *planus*, Olivieri, p. 286, pl. 5, fig. 9.
1989	*Pelekysgnathus planus*, Orchard, p. 41, pl. 1, figs. 1, 2.
1989	*Pelekysgnathus planus*, Ji, p. 300, pl. 4, figs. 30-32 (only).
1991	*Pelekysgnathus planus*, Johnston and Chatterton, p. 182, pl. 3, fig. 11.

<u>Types</u> Figured hypotypes GSC 100314, 106858, 106859.

Diagnosis. See Sandberg and Dreesen (1984, p. 161).

Remarks. The few specimens of *Pelekysgnathus planus* that we have in our collections exhibit a straight lower margin and a single row of denticles that are approximately equal in height on the upper side (e.g. Pl. V-4, figs. 8, 13).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-6, V-10, V-15). *Pelekysgnathus planus* ranges from the Lower to Middle *crepida* zones into the Upper *crepida* Zone.

Pelekysgnathus cf. *P. brevis* Sandberg and Dreesen, 1984
Pl. V-4, figs. 15-20

cf. 1984 *Pelekysgnathus brevis* Sandberg and Dreesen, pp. 160, 161, pl. 3, figs. 1-4.

Types. Figured specimens GSC 106860-106865.

Remarks. Included in this taxon are I elements of *Pelekysgnathus* with erect to semi-erect posterior cusps that have up to several denticles anterior to them. These elements differ from those of *P. brevis* Sandberg and Dreesen by having cusps which appear to be narrow, although one specimen (Pl. V-4, fig. 18), has a broader cusp, but no anterior denticles. On several specimens the anterior denticles are somewhat proclined (e.g. Pl. V-4, figs. 19, 20).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-3, V-6, V-12, V-14, V-15). Most occurrences of *Pelekysgnathus* cf. *P. brevis* are confined to the Lower and Middle *crepida* to the Upper *rhomboidea* zones. However, one specimen (Pl. V-4, fig. 17) occurs in the upper part of the Lower *marginifera* Zone at Nigel Peak (Table V-6).

Order OZARKODINIDA Dzik, 1976

Family ELICTOGNATHIDAE Austin and Rhodes, 1981

Genus *Alternognathus* Ziegler and Sandberg, 1984

Type species. *Alternognathus regularis* Ziegler and Sandberg, 1984.

Alternognathus regularis Ziegler and Sandberg, 1984
Pl. V-5, figs. 7, 8

1971	*Scaphignathus subserratus*, Beinert, Klapper, Sandberg and Ziegler, pp. 82, 83, pl. 1, figs. 1-9, 11, 12.
1984	*Alternognathus regularis* Ziegler and Sandberg, pp. 188, 189 (contains synonymy to 1978).
1985	*Scaphignathus subserratus*, Austin, Orchard and Stewart, p. 152, pl. 4.7, fig. 5.
1990	*Alternognathus beulensis*, Perri and Spalletta, pp. 59, 60, pl. 1, fig. 1.
1991	*Alternognathus beulensis*, Perri and Spalletta, p. 54, pl. 1, fig. 1.
1993	*Alternognathus regularis*, Johnston and Meijer Drees, p. 145, pl. 1, figs. 2, 3.

Types. Figured hypotypes GSC 98127, 98128.

Diagnosis. See Ziegler and Sandberg (1984, p. 188).

Remarks. We reillustrate two specimens of *Alternognathus regularis* (Johnston and Meijer Drees, 1993 - see synonymy) which we believe are conspecific with specimens of early growth stages of this species illustrated in Beinert et al. (1971, pl. 1, figs. 1-4).

Occurrence. Wabamun Group (Table V-17). Our two specimens come from strata that are dated from Uppermost *marginifera* to Upper *expansa* zones. The stratigraphic range of *Alternognathus regularis* has been reported to be from Uppermost *marginifera* to Upper *postera* zones (Ziegler and Sandberg, 1984).

Alternognathus aff. *A. pseudostrigosus* (Dreesen and Dusar, 1974)
Pl. V-5, figs. 1-6, 9, 10?, 11?

aff. 1974 Polygnathus? pseudostrigosus Dreesen and Dusar, p. 20, pl. 1, figs. 17-19 (only); pl. 3, figs. 16, 17, 19-24.

Types. Figured specimens GSC 106866-106870, 106871?

Remarks. Forms assigned to this taxon differ from Alternognathus pseudostrigosus by having a more extensively developed platform in mature specimens (e.g. Pl. V-5, figs. 1, 2). Also, the basal pit appears to lack the characteristic rhomb shape of the latter species. However, A. aff. A. pseudostrigosus does show the asymmetrical development as well as the positioning of the left and right sides of the platform that is characteristic of A. pseudostrigosus. Our mature specimens of A. aff. A. pseudostrigosus also have high free blades like the latter species.

During ontogeny, (e.g. Pl. V-5, figs. 4-6), growth of the platform appears to have begun on the right side, followed by platform growth on the left. Such a growth pattern is characteristic of Alternognathus (Ziegler and Sandberg, 1984). It also appears that during ontogeny the pseudokeel becomes somewhat subdued in mature specimens (e.g. Pl. V-5, fig. 1), whereas it is well developed in earlier growth stages (Pl. V-5, figs. 4, 9).

We also illustrate one specimen (Pl. V-5, figs. 10, 11) from a stratigraphically lower bed which may be an older form of this taxon. It is characterized by the right side of the platform being much longer than the left side of the platform and extending part of the way onto the blade.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-3, V-6, V-7, V-14, V-15). As presently known, the occurrence of Alternognathus aff. A. pseudostrigosus appears to be confined to the Upper rhomboidea Zone.

Alternognathus? sp. A

Pl. V-5, figs. 12-14

Type. Figured specimen GSC 106872.

Remarks. The single specimen of this taxon is questionably assigned to *Alternognathus* based on the possible greater length and degree of development (i.e. width) of the platform on the right side. This specimen has a smooth, though undulatory, upper side of the platform except at the margins where irregular transverse to subparallel ridges are situated (Pl. V-5, fig. 12). The carina is also offset with respect to the blade, like in some specimens of *A. regularis* Ziegler and Sandberg (Beinert et al., 1971), but is still connected to it by a short ridge that is perpendicular to both the blade and the carina (Pl. V-5, fig. 12). On the lower side, the keel is mostly low, with thickening only around the basal pit (Pl. V-5, fig. 13). In this way the lower side appears vaguely similar to that in *A. beulensis* Ziegler and Sandberg (Beinert et al., 1971, pl. 1, fig. 14a).

Occurrence. Wabamun Group (Table V-16). The sample which *Alternognathus*? sp. B comes from is dated Upper *crepida* Zone to possibly as high as the Upper *marginifera* Zone. However, regional biostratigraphic correlations suggest that this sample is probably no younger than the Lower *rhomboidea* Zone (see Johnston and Meijer Drees, 1993).

Family PALMATOLEPIDAE Sweet, 1988

Genus *Palmatolepis* Ulrich and Bassler, 1926

Type species. *Palmatolepis perlobata* Ulrich and Bassler, 1926.

Remarks. Nearly all species of *Palmatolepis* that we have identified have been placed in a number of informal taxonomic groups. Most of these groups correspond with each branch of the *Palmatolepis* phylogeny depicted in Helms and Ziegler (1981, Fig. 62). (e.g. *P. glabra* branch, *P. perlobata* - *P. schindewolfi* branch, etc.). Although we concede that not all taxa placed in a particular group were closely related, we believe that most of the taxa in such a group probably were and thus represent a clade.

"*Palmatolepis circularis* group"

Remarks. We include in this group *Palmatolepis angulata* n. sp., *P.* aff. *P. angulata*, *P. circularis* Szulczewski, *P.* cf. *P. circularis* and *P. wolskajae* Ovnatanova. All these taxa share in common the presence of a triangular to sub-triangular outer lobe and a strongly sigmoidal blade and carina. Another prominent feature of this group is the inflated anterior inner platform. We provisionally include in this group *P.* sp. A, which appears to have affinities with some or all the taxa listed above (see below).

Palmatolepis angulata n. sp.
Pl. V-5, figs. 15-19; Pl. V-6, figs. 4, 5

1973	*Palmatolepis* aff. *P. circularis* Sandberg and Ziegler, pp. 102, 103, pl. 1, figs. 1-12.
1985	*Palmatolepis wolskajae*, Klapper and Lane, p. 930, figs. 15.1, 15.2?, 15.4, 15.5.
?1988	*Palmatolepis wolskajae*, Bultynck, p. 28, pl. A2/3, fig. 2 (only).
1991	*Palmatolepis wolskajae*, Johnston and Chatterton, p. 178, pl. 1, fig. 22.
1993	*Palmatolepis wolskajae*, Johnston and Meijer Drees, p. 145, pl. 1, fig. 20.

Etymology. For the angular outline of the platform.

Types. Holotype GSC 100278, illustrated on Plate V-5, figure 16; paratypes GSC 106873-106876, 106879, 106880, illustrated on Plate V-5, figures 15, 17-19; Plate V-6, figures 4, 5.

Material. About 180 specimens.

Diagnosis. A species of Palmatolepis in which the platform element has a large outer lobe that meets the outer platform at a right or near right angle. A prominent convexity on the posterior outer platform is formed by the junction of the straight anterior and curved posterior portions of the postero-lateral margin. This convexity, along with the usual right angle formed from the junction of the antero-lateral margin of the outer platform and the outer lobe, imparts a somewhat angular outline to the platform. The blade and carina are strongly sigmoidal.

Description. Platform outline elongate to somewhat rounded, with a shagreen-like upper surface. Posterior tip of platform flexed upwards. Swollen anterior inner platform meets blade at obtuse angle. Adcarinal groove between inner platform and blade and carina developed in occasional specimens. Outer platform relatively broad posteriorly, narrow anteriorly, with moderately to extremely elongate outer lobe situated approximately at mid-length of element. Anterior and posterior margins of lobe meet straight lateral margins of outer platform at right or near right angle in most specimens. In some specimens, this angle may be more obtuse at the anterior junction of the outer lobe and platform. Lateral margin of outer platform, posterior to outer lobe, is parallel or subparallel to posterior carina for approximately half the distance between the azygous node and the platform tip. For the remainder of this distance, this margin is either gently or strongly curved inward posteriorly. The straight and curved portions of the postero-lateral margin of the outer platform form a prominent convexity in most specimens.

Blade and carina low posteriorly, becoming higher anteriorly to end of blade. Denticles mostly visible on blade; are nearly confluent to tips. Denticles commonly indistinct on carina. Blade and carina strongly sigmoidal. Ridge-like secondary carina occasionally developed. Strong to weak ridge-like posterior carina developed on most specimens. Azygous node forms low boss on most specimens, whereas in some it is a high, sharp tetragonal structure formed by the junction of the anterior, posterior and secondary carinae.

Underside of element smooth, gently undulating. Crimp relatively narrow; keel low, sigmoidal.

Remarks. *Palmatolepis angulata* differs from *P. wolskajae* Ovnatanova by having a posterior platform which is not as pointed and a more curved blade and carina (compare Pl. V-5, figs. 16-19; Pl. V-6, figs. 4, 5 and Pl. V-6, figs. 6, 7, 9, 11-16). One large specimen (Pl. V-5, fig. 19) occurring in one of our collections does not have as strong a convexity on the lateral margin of the posterior platform although it is similar in most other aspects of its morphology to other specimens of *P. angulata*. Both this species and *P. wolskajae* share in common, however, the swollen anterior inner platform and an outer lobe.

Palmatolepis angulata evolved from *P. wolskajae* or a form close to the latter species by an elongation and enlargement of the outer lobe, the formation of a pronounced junction between the this lobe and the outer platform and by the development of a greater degree of curvature of the blade and carina. The formation of the prominent convexity on the outer platform posterior of the outer lobe is another important feature in the evolution of *P. angulata* from *P. wolskajae*. Transitional specimens between these two species appear to occur at the top of the stratigraphic range of *P. wolskajae* at Cold Sulphur Springs. Here a few specimens (e.g. Pl. V-6, fig. 6) show the partial or complete development of the convexity on the outer margin the posterior platform and the development of an elongate outer lobe.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1 to V-4, V-6, V-7, V-10 to V-13, V-15, V-16). *Palmatolepis* angulata ranges from the upper part of the Lower to Middle crepida zones to the lower part of the Upper crepida Zone.

Palmatolepis aff. P. angulata n. sp.
Pl. V-6, fig. 3

1993 Palmatolepis tenuipunctata, Johnston and Meijer Drees, p. 145, pl. 1, fig. 24.

Types. Figured specimen GSC 98149.

Remarks. A few elongate specimens characterized by a variably developed lateral lobe and a blade and carina configuration similar to Palmatolepis angulata have been assigned to this taxon. The fact that these elements are more elongate, and that the configuration of the anterior part of the inner platform is different from that of the latter species, are the chief reasons why these elements cannot be assigned to P. angulata.

Occurrence. Wabamun Group (Tables V-12, V-13, V-15, V-16). Palmatolepis aff. P. angulata ranges from the Lower to Middle crepida zones to the lower part of the Upper crepida Zone.

Palmatolepis circularis Szulczewski, 1971
Pl. V-6, figs. 1, 2

1967	Palmatolepis inflexa, Nehring, p. 144, pl. 4, fig. 7.
1967	Palmatolepis sp. Wolska, pp. 410, 411, pl. 9, figs. 4-6.
1971	Palmatolepis circularis Szulczewski, pp. 28, 29, pl. 15, figs. 5-7.
1976	Palmatolepis circularis, Bouckaert and Dreesen, p. 580, pl. 1, figs. 8, 9.
1981	Palmatolepis circularis, Helms and Ziegler, p. W98, fig. 62.24.
1985	Palmatolepis circularis, Austin, Orchard and Stewart, p. 150, pl. 4.6, fig. 16.
1987	Palmatolepis circularis, Matyja, p. 374, pl. 22.1, figs. 2, 5?, 8.
1991	Palmatolepis circularis, Johnston and Chatterton, p. 178, pl. 1, fig. 23.

Types. Figured hypotypes GSC 106877, 106878.

Diagnosis. See Ziegler (1973, p. 259).

Remarks. Many of the specimens assigned to this species in our collections have an outline which is similar to the specimen illustrated by Szulczewski (1971, pl. 15, fig. 5), which appears to be more elongate than the holotype.

Occurrence. Palliser Formation and Wabamun Group (Tables V-6, V-7, V-10, V-12, V-15). Specimens of Palmatolepis circularis occur in the upper part of the Lower to Middle crepida zones and in the lower part of the Upper crepida Zone.

Palmatolepis cf. P. circularis Szulczewski, 1971
Pl. V-6, figs. 8, 10

cf. 1971 Palmatolepis circularis Szulczewski, pp. 28, 29, pl. 15, figs. 5-7.

Types. Figured specimens GSC 106883, 106885.

Remarks. Specimens of this taxon differ from Palmatolepis circularis by having a weakly to well defined posterior carina. Otherwise, they resemble the latter species in all other aspects (i.e. the platform outline, blade and carina configuration, etc.).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-6, V-7, V-10, V-12, V-15, V-16). The stratigraphic range of this taxon generally corresponds to that of Palmatolepis circularis.

Palmatolepis wolskajae Ovnatanova, 1969
Pl. V-6, figs. 6, 7, 9, 11-16

1969 Palmatolepis wolskajae Ovnatanova, p. 139, pl. 1, fig. 6.
1984 Palmatolepis wolskajae, Dreesen, p. 210, pl. 1, figs. 6, 9.
1987 Palmatolepis wolskajae, Matyja, p. 374, pl. 22.1, figs. 1, 3.
1988 Palmatolepis wolskajae, Bultynck, p. 28, pl. A2/3, figs. 4, 5 (only).
1989 Palmatolepis wolskajae, Orchard, p. 46, pl. 3, fig. 8.
1991 Palmatolepis wolskajae, Irwin and Orchard, p. 208, pl. 3, fig. 7.

Types. Figured hypotypes GSC 106881, 106882, 106884, 106886-106891.

Diagnosis. See Ziegler (1977, p. 413).

Remarks. Specimens of this species in our collections appear to most closely resemble the holotype although individual specimens are extremely variable in terms of extent of lateral lobe, platform shape, etc.. We also include in this taxon specimens which have traces of the coarse ornamentation (Pl. V-6, figs. 12, 14, 16) that is characteristic of Palmatolepis triangularis Sannemann, the presumed ancestor of P. wolskajae (Ziegler and Sandberg, 1990).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-6, V-7, V-9 to V-13, V-16). Specimens of Palmatolepis wolskajae in our collections generally occur in the lower part of the Lower to Middle crepida zones in these units, with the exception of one locality (Smoky Heights 14-22 well, sampled interval 2639-2639.3 m, Table V-16) where it occurs with P. angulata n. sp. in the upper part of these zones.

Palmatolepis sp. A
Pl. V-7, figs. 6, 11, 12

Types. Figured specimens GSC 106895, 106900, 106901.

Remarks. Only a few specimens are represented of a Pa element of Palmatolepis which is ovoid to slightly rhomboid in shape. There appears to be a small parapet developed on the anteriormost part of the inner platform. There is also a hint of a very small lobe on the outer platform. These elements, because of their unique characteristics, cannot be assigned to any known species at this time. However, these specimens appear to have affinities to taxa we have assigned to the "P. circularis group" in that they have the strongly sigmoidal blade and carina and a similar platform outline.

Occurrence. Palliser Formation (Tables V-7, V-11). As presently known, _Palmatolepis_ sp. A is confined to the Lower to Middle _crepida_ zones.

Palmatolepis _crista_ n. sp.
Pl. V-7, figs. 8-10, 13-20

Etymology. From the Latin _crista_, meaning comb or crest, referring to the comb or crest like appearance of the blade.

Types. Holotype GSC 106905, illustrated on Plate V-7, figures 16-18; paratypes GSC 106897-106899, 106902-106904, 106906, 106907, illustrated on Plate V-7, figures 8-10, 13-15, 19, 20.

Material. About 165 specimens.

Diagnosis. A small species of _Palmatolepis_ with a triangular to slightly lobate platform in which the denticles in the blade and carina ascend anteriorly for most of the length of the element then descend somewhat abruptly in a curve, close to the anteriormost blade margin. This denticulation pattern gives the blade a comb or crest like appearance in lateral view.

Description. Platform triangular to slightly lobate, gently undulatory, with a shagreen-like upper surface. Anterior margin of outer platform begins just posterior to anterior end of blade in mature specimens and well posterior to anterior end of blade in juvenile specimens. Anterior margin of narrow inner platform begins approximately half way between anterior and posterior ends of element. Outer platform widens posteriorly to about opposite azygous node, then narrows towards posterior tip of element. A slight outer lobe is developed in most mature specimens. Posterior tip of element flexed upward.

Blade and carina high, moderately sigmoidal. Denticles on blade and carina nearly confluent to tips; become progressively higher anteriorly then descend somewhat abruptly close to the anteriormost extremity of blade, giving a crest or comb like appearance to the blade in lateral view. Posterior carina weakly to moderately developed.

Lower side of element smooth, gently undulating. Wide crimp occupies approximately half the width between the lateral margin of the element and the keel. Keel high and sharp, moderately sigmoidal anterior of basal pit; keel straight posterior of pit.

Remarks. Palmatolepis crista differs from P. tenuipunctata Sannemann by having denticles that increase then abruptly decrease in height anteriorly whereas, in the latter species, the denticles on the blade are more or less the same height. The inner platform is narrower and its antero-lateral margin does not bulge as prominently in P. crista. Specimens of P. crista differ from most specimens of P. tenuipunctata in our collections (e.g. Pl. V-10, figs. 6-9, 11, 13, 14) by having a less lobate platform.

Specimens of Palmatolepis crista in our collections show a variety of form in terms of platform shape which ranges from lobate (Pl. V-7, figs. 9, 16, 18) to rhomboid (e.g. Pl. V-7, figs. 19, 20).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-7, V-13 to V-16). Palmatolepis crista appears to range from the upper part of the Upper crepida Zone to the Lower rhomboidea Zone. There are also questionable occurrences of this species in strata possibly as young as the Upper rhomboidea Zone (e.g. Table V-15).

"Palmatolepis glabra group"

Remarks. Our treatment of this group generally follows that of most workers (e.g. Ziegler and Huddle, 1969) with the exception that we consider each taxon a separate species (see preamble). We also include in this group *Palmatolepis tenuipunctata* Sannemann and *P*. cf. *P*. *tenuipunctata*, which are morphologically similar to species of this group. The former species is also considered ancestral to all species of the "*P*. *glabra* group" (Sandberg and Ziegler, 1973; Helms and Ziegler, 1981).

Palmatolepis acuta Helms, 1963
Pl. V-7, figs. 1, 2

1963	*Palmatolepis* (*Panderolepis*) *serrata acuta* Helms, pp. 468, 469, pl. 3, figs. 1-4, 6; fig. 2.23.
1976	*Palmatolepis glabra acuta*, Dusar and Dreesen, p. 556, pl. 1, fig. 12.
?1978	*Palmatolepis glabra glabra*, Narkiewicz, p. 440, pl. 9, figs. 8, 9.
1981	*Palmatolepis glabra acuta*, Helms and Ziegler, p. W98, fig. 62.32.
1983	*Palmatolepis glabra acuta*, Wang and Ziegler, pl. 3, fig. 20.
1984	*Palmatolepis glabra acuta*, Olivieri, pp. 292, 293, pl. 6, fig. 6.
?1985	*Palmatolepis glabra distorta*, Austin, Orchard and Stewart, p. 150, pl. 4.6, fig. 20.
1985	*Palmatolepis glabra acuta*, Ji and Liu, p. 180, pl. 2, fig. 35 (only).
?1991	*Palmatolepis glabra acuta*, Irwin and Orchard, p. 208, pl. 3. fig. 18.

Types. Figured hypotypes GSC 106892, 106893.

Diagnosis. See Ziegler (1977, p. 293).

Remarks. Many specimens of this species in our collections were transitional with specimens of *Palmatolepis pectinata* Ziegler Morphotype 1 of Sandberg and Ziegler (1973) by having a weakly diverging inner platform parapet (Pl. V-7, fig. 1). However, these specimens still retain the thorn-like projection on the antero-lateral corner of the inner platform that is characteristic of *P*. *acuta*.

Occurrence. Palliser Formation (Tables V-1, V-2, V-6, V-8, V-10). This species ranges from the Upper *rhomboidea* to the Lower *marginifera* Zone in this formation.

Palmatolepis distorta Branson and Mehl, 1934a

Pl. V-7, figs. 3-5, 7

1934a	*Palmatolepis distorta* Branson and Mehl, pp. 237, 238, pl. 18, figs. 13, 14.
1977	*Palmatolepis glabra distorta*, Ziegler, pp. 297-300, *Palmatolepis* - pl. 6, figs. 4-6 (contains synonymy to 1977).
1979	*Palmatolepis* (*Panderolepis*?) *distorta*, van den Boogaard and Kuhry, pp. 49, 50, fig. 22 (Pa element only).
1981	*Palmatolepis glabra distorta*, Helms and Ziegler, p. W98, fig. 62.33.
1983	*Palmatolepis glabra distorta*, Wang and Ziegler, pl. 3, fig. 17.
1984	*Palmatolepis glabra distorta*, Olivieri, p. 294, pl. 6, figs. 4, 5.
1985	*Palmatolepis glabra distorta*, Austin, Orchard and Stewart, p. 150, pl. 4.6, fig. 19 (only).
1985	*Palmatolepis glabra distorta*, Ji and Liu, p. 180, pl. 2, figs. 11-13, 14?.
1991	*Palmatolepis glabra distorta*, Johnston and Chatterton, p. 178, pl. 1, figs. 1, 3.
1991	*Palmatolepis glabra distorta*, Irwin and Orchard, p. 210, pl. 4, fig. 3.

Types. Figured hypotypes GSC 100257, 100259, 106894, 106896.

Diagnosis. See Ziegler (1977, p. 298).

Remarks. Most large and intermediate size specimens of this species in our collections have the same recessed posterior carina and the lack of an azygous node as specimens of this species from the western United States discussed by Sandberg and Poole (1977, p. 163). A few specimens, however, do have a small azygous node (Pl. V-7, figs. 5, 7). Intermediate size to small specimens of *Palmatolepis distorta* in our collections resemble typical specimens of this species. Johnston and Chatterton (1991) reported the occurrence of specimens of *P. distorta* with a recessed posterior carina and lacking an azygous node from the Lower *marginifera* Zone in the Palliser Formation. Such specimens were considered to be characteristic of the *trachytera* Zone in the western United States (Sandberg and Poole, 1977).

Occurrence. Palliser Formation and Wabamun Group (Tables V-4 to V-6, V-9, V-17). *Palmatolepis distorta* ranges from the Lower *marginifera* to possibly as high as the *trachytera* Zone in some collections from the upper part of the Costigan Member of the Palliser Formation in the Bow Valley (Meijer Drees and Johnston, 1994), from the upper Palliser Formation in the

North Saskatchewan River Valley (authors' unpublished data) and possibly from the uppermost Wabamun Group in the West Prairie 11-18 well (Table V-17).

Palmatolepis klapperi Sandberg and Ziegler, 1973
Pl. V-8, figs. 1-4

?1965	*Palmatolepis* sp. b Bouckaert and Ziegler, pl. 3, figs. 11, 12.
1971	*Palmatolepis quadrantinodosa* aff. *inflexa* Szulczewski, p. 39, pl. 15, fig. 8.
1973	*Palmatolepis klapperi* Sandberg and Ziegler, p. 104, pl. 2, figs. 6, 17-28; pl. 5, fig. 12.
1974	*Palmatolepis klapperi*, Dreesen and Dusar, p. 31, pl. 6, figs. 12-16; fig. 21.
?1978	*Palmatolepis klapperi*, Narkiewicz, p. 441, pl. 8, fig. 11.
1981	*Palmatolepis klapperi*, Helms and Ziegler, p. W98, fig. 62.29.
1991	*Palmatolepis klapperi*, Johnston and Chatterton, p. 178, pl. 1, fig. 10.
1991	*Palmatolepis klapperi*, Irwin and Orchard, p. 208, pl. 3, fig. 13.
1993	*Palmatolepis klapperi*, Johnston and Meijer Drees, p. 145, pl. 1, fig. 22.

Types. Figured hypotypes GSC 106908-106911.

Diagnosis. See Sandberg and Ziegler (1973, p. 104).

Remarks. Typical specimens of *Palmatolepis klapperi* with the flattened ramp on the inner platform and an adcarinal groove or slit between the carina and azygous node and the ramp (Pl. V-8, fig. 1) are present in our collections. In addition, we have specimens with the same general outline but the adcarinal groove or slit is absent (Pl. V-8, figs. 3, 4). Specimens of the latter appear to be the most abundant form of this species in several of our collections. These specimens appear conspecific with the paratypes of *P. klapperi* illustrated by Sandberg and Ziegler (1973) on plate 2, figure 17 (which is reillustrated on pl. 5, fig. 12 at a higher magnification) and figure 23 of their paper. In addition, we have some specimens which appear not to have the typical sinusoidal outline of *P. klapperi* (e.g. Pl. V-8, fig. 2) and the ramp in some of these specimens is not as high as in typical specimens of this species.

In several cases it was difficult to clearly distinguish specimens of *Palmatolepis klapperi* from *P. prima* Ziegler and

Huddle Morphotype 2 of Sandberg and Ziegler from each other. Some specimens of the latter have the typical outline of this morphotype (i.e. like that of the specimens illustrated on pl. 2, fig. 11 of Sandberg and Ziegler, 1973, in which the anterior border of the inner platform does not meet the blade at a near right angle) but also have a thickened inner platform. Dreesen and Dusar (1974) also noted the difficulty in distinguishing *P. prima* Morphotype 2 from *P. klapperi*.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-6, V-10, V-14, V-15). *Palmatolepis klapperi* ranges from the Lower to Upper *rhomboidea* zones in these units.

Palmatolepis lepta Ziegler and Huddle, 1969
Pl. V-8, figs. 5, 6

1962a	*Palmatolepis glabra elongata*. Ziegler, p. 398, pl. 1, fig. 10.
1977	*Palmatolepis glabra lepta*, Ziegler, pp. 301-303, *Palmatolepis* - pl. 7, figs. 1-3 (contains synonymy to 1976).
1978	*Palmatolepis glabra lepta*, Narkiewicz, p. 440, pl. 9, fig. 6.
1979	*Palmatolepis* (*Panderolepis*) *falcata*, van den Boogaard and Kuhry, fig. 21 (Pa element only).
1981	*Palmatolepis glabra lepta*, Helms and Ziegler, p. W98, fig. 62.31.
1983	*Palmatolepis glabra lepta*, Wang and Ziegler, pl. 3, fig. 19.
1983	*Palmatolepis glabra lepta*, Spassov, p. 16, pl. 4, figs. 1, 12.
1984	*Palmatolepis glabra lepta*, Olivieri, pp. 294-296, pl. 6, figs. 7-9.
1985	*Palmatolepis glabra lepta*, Ji and Liu, p. 180, pl. 2, figs. 32-34.
1989	*Palmatolepis glabra lepta*, Irwin and Orchard, p. 17, pl. 1, fig. 5.
1991	*Palmatolepis glabra lepta*, Johnston and Chatterton, p. 178, pl. 1, fig. 2.
1991	*Palmatolepis glabra lepta*, Irwin and Orchard, p. 196, pl. 4, fig. 1.
1991	*Palmatolepis glabra lepta* Morphotype 1 Irwin and Orchard, p. 197, pl. 4, fig. 4.
1991	*Palmatolepis glabra lepta* Morphotype 2 Irwin and Orchard, p. 197, pl. 4, fig. 2.

Types. Figured hypotype GSC 100258, 109912.

Diagnosis. See Ziegler (1977, p. 301).

Remarks. The few specimens of this species we have in our collections (Pl. V-8, fig. 6) appear to be conspecific with those that Irwin and Orchard (1991) included in their concept of *Palmatolepis glabra lepta* Morphotype 2. Their specimens of this morphotype and ours have very narrow and elongate platforms with the inner platform lacking the triangular bulge of typical specimens of *P. lepta*. However, the specimen that we figure, and several others in our collections, appear to be much larger than the specimens that they illustrated (see synonymy).

We also have a few specimens that represent the early form of this species from the Lower *rhomboidea* Zone at Nigel Peak (sample NP86-45, Table V-6) (Pl. V-8, fig. 5).

Occurrence. Palliser Formation (Table V-6). In our collections *Palmatolepis lepta* is confined to the Lower *rhomboidea* Zone (see above).

Palmatolepis pectinata Ziegler, 1962a
Pl. V-8, figs. 7-17

1962a	*Palmatolepis glabra pectinata* Ziegler, pp. 398, 399, pl. 2, figs. 3-5.
1973	*Palmatolepis glabra pectinata* Morphotype 1 Sandberg and Ziegler, p. 104, pl. 2, figs. 4, 12-15; pl. 5, fig. 14.
1973	*Palmatolepis glabra pectinata*, Sandberg and Ziegler, pl. 2, fig. 29.
?1978	*Palmatolepis glabra pectinata*, Narkiewicz, p. 440, pl. 9, figs. 3, 4.
1981	*Palmatolepis glabra pectinata*, Helms and Ziegler, p. W98, fig. 62.30.
1983	*Palmatolepis glabra pectinata*, Wang and Ziegler, pl. 3, fig. 18.
1984	*Palmatolepis glabra pectinata* Morphotype 1, Dreesen, p. 210, pl. 1, fig. 2.
1984	*Palmatolepis glabra acuta*, Olivieri, pp. 292, 293, pl. 4, fig. 16.
1984	*Palmatolepis glabra pectinata*, Olivieri, p. 296, pl. 4, fig. 11; pl. 6, figs. 2, 3.
1985	*Palmatolepis glabra pectinata*, Ji and Liu, p. 180, p. 2, figs. 6-9.
1987	*Palmatolepis glabra pectinata*, Matyja, p. 375, pl. 22.2, fig. 17.
1991	*Palmatolepis glabra pectinata*, Johnston and Chatterton, p. 178, pl. 1, fig. 5.
1991	*Palmatolepis glabra pectinata* Morphotype 1, Johnston and Chatterton, p. 178, pl. 1, fig. 12.
1991	*Palmatolepis glabra pectinata* Morphotype 1, Irwin and Orchard, p. 210, pl. 4, fig. 6.
1991	*Palmatolepis glabra pectinata*, Irwin and Orchard, p. 210, pl. 4, fig. 7.
1993	*Palmatolepis glabra pectinata*, Johnston and Meijer Drees, p. 145, pl. 1, fig. 1.

Types. Figured hypotypes GSC 100261, 100270, 106913-106921.

Diagnosis. See Ziegler (1977, p. 305).

Remarks. In our collections *Palmatolepis pectinata* Morphotype 1 (e.g. Pl. V-8, figs. 13-17) is the most commonly occurring form of this species. This morphotype is connected to typical forms of this species (e.g. Pl. V-8, figs. 7-9) by transitional specimens which have the inner platform parapet terminating close to the anterior end of the platform (e.g.

Pl. V-8, fig. 17). The length of the parapet varies from specimen to specimen (e.g. Pl. V-8, figs. 15-17). Also included in our concept of *P. pectinata* Morphotype 1 are specimens from the Lower *marginifera* Zone which have broad platforms and a recessed posterior carina (Pl. V-8, figs. 13, 14). The inner platform shows a considerable degree of thickening in these specimens, just like specimens of *P. klapperi* Sandberg and Ziegler. Several of our specimens of *P. pectinata* Morphotype 1 are also transitional to *P. acuta* Helms (see Remarks for latter species).

Some of our specimens of *Palmatolepis pectinata* can be also considered transitional to *P. prima* Ziegler and Huddle (e.g. Pl. V-8, fig. 10) (see Remarks for the latter subspecies) and as well as to *P. lepta* Ziegler and Huddle.

Our highest occurrences of *Palmatolepis pectinata* are characterized by specimens which resemble *P. distorta* Branson and Mehl in terms of blade and carina morphology and surface ornamentation (e.g. Pl. V-8, figs. 11, 12) but differ by having a platform which is less curved.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-2, V-4, V-6 to V-8, V-10, V-15). Specimens of *Palmatolepis pectinata* range from the Lower *rhomboidea* to Upper *marginifera* zones in these units. *Palmatolepis pectinata* Morphotype 1 range from the Lower *rhomboidea* to Lower *marginifera* zones.

Palmatolepis prima Ziegler and Huddle, 1969
Pl. V-9, figs. 1-17; Pl. V-10, figs. 1-5

1956	*Palmatolepis glabra*, Bischoff, p. 128, pl. 8, figs. 34, 35.
?1960	*Palmatolepis* (*Palmatolepis*) *distorta*, Clark and Becker, pp. 1669, 1671, pl. 2, fig. 8.
1962a	*Palmatolepis glabra glabra*, Ziegler, p. 397, pl. 1, figs. 11-13.
1962	*Palmatolepis glabra*, Barstenstein and Bischoff, p. 58, pl. 1, fig. 6.
1966	*Palmatolepis tenuipunctata*, Glenister and Klapper, p. 824, p. 89, fig. 4 (only); pl. 92, fig. 10? (only).
?1967	*Palmatolepis glabra* n. subspecies A, Clark and Ethington, p. 52, pl. 4, fig. 18.
1969	*Palmatolepis glabra prima* Ziegler and Huddle, pp. 379, 380.
?1970a	*Palmatolepis tenuipunctata*, Seddon, pl. 12, fig. 12 (only).
1973	*Palmatolepis glabra prima* Morphotype 1 Sandberg and Ziegler, p. 103, pl. 2, figs. 2, 8-10.

1973	*Palmatolepis glabra prima* Morphotype 2 Sandberg and Ziegler, pp. 103, 104, pl. 2, fig. 11.
1973	*Palmatolepis glabra prima*, Sandberg and Ziegler, pl. 2, figs. 1, 7.
?1973	*Palmatolepis glabra acuta*, Sandberg and Ziegler, pl. 2, fig. 5.
1976	*Palmatolepis glabra glabra*, Druce, pp. 152-154, pl. 51, figs. 2-5.
1976	*Palmatolepis tenuipunctata* - *P. klapperi*, Dusar and Dreesen, p. 556, pl. 1, figs. 4, 9.
?1976	*Palmatolepis glabra prima* - *P. glabra pectinata*, Dusar and Dreesen, p. 556, pl. 1, fig. 8.
1976	*Palmatolepis glabra prima*, Dusar and Dreesen, p. 556, pl. 1, fig. 11.
1976	*Palmatolepis glabra prima*, Spassov and Filipović, pp. 8, 9, pl. 1, fig. 13; pl. 2, fig. 3.
1978	*Palmatolepis glabra prima*, Narkiewicz, p. 440, pl. 9, figs. 1, 2, 10.
1978	*Palmatolepis glabra* aff. *prima*, Narkiewicz, p. 440, pl. 9, fig. 5.
1979	*Palmatolepis* (*Panderolepis*) *glabra prima*, van den Boogaard and Kuhry, fig. 19 (Pa element only).
1981	*Palmatolepis glabra prima*, Helms and Ziegler, p. W98, fig. 62.26.
1984	*Palmatolepis glabra prima*, Olivieri, pp. 296, 297, pl. 4, figs. 7, 8; pl. 6, fig. 1.
1984	*Palmatolepis glabra prima* Morphotype 1, Olivieri, p. 297, pl. 4, fig. 9.
1984	*Palmatolepis glabra prima* Morphotype 2, Olivieri, p. 297, pl. 4, fig. 10.
1984	*Palmatolepis glabra prima*, Dusar and Dreesen, p. 53, pl. 2, fig. 2.
1985	*Palmatolepis glabra prima*, Austin, Orchard and Stewart, p. 150, pl. 4.6, figs. 17, 18.
1985	*Palmatolepis glabra glabra*, Ji and Liu, p. 180, pl. 2, figs. 22-27.
1989	*Palmatolepis glabra prima* Morphotype 1, Ji, p. 296, pl. 2, fig. 17.
1989	*Palmatolepis glabra prima*, Ji, p. 296, pl. 2, figs. 18, 19.
1991	*Palmatolepis glabra prima*, Johnston and Chatterton, p. 178, pl. 1, fig. 4.
1991	*Palmatolepis glabra prima* Morphotype 1, Johnston and Chatterton, p. 178, pl. 1, fig. 9.
1991	*Palmatolepis glabra prima* Morphotype 2, Johnston and Chatterton, p. 178, pl. 1, fig. 11.
1993	*Palmatolepis glabra prima*, Johnston and Meijer Drees, p. 145, pl. 1, fig. 14.
1993	*Palmatolepis glabra prima* Morphotype 2, Johnston and Meijer Drees, p. 145, pl. 1, fig. 15.
1993	*Palmatolepis glabra prima* Morphotype 1, Johnston and Meijer Drees, p. 145, pl. 1, fig. 16.

Types. Figured hypotypes GSC 100260, 100265, 106922-106941.

Diagnosis. See Ziegler (1977, p. 309).

Remarks. In addition to typical specimens of *Palmatolepis glabra prima* (e.g. Pl. V-9, figs. 2, 3) exhibiting narrow elongate platforms and rounded antero-lateral margins of the inner platform, we have specimens which are elongate and narrow with angular antero-lateral margins of the inner platform (e.g. Pl. V-9, figs. 5, 6). These forms are connected to typical specimens by transitional forms (e.g. Pl. V-9, fig. 4). We feel that specimens such as these may be conspecific with specimens that are considered to represent early occurrences of *P. acuta* Helms which were reported from the western United States by Clark and Becker (1960), Clark and

Ethington (1967) and Sandberg and Ziegler (1973) (see synonymy). In our opinion, the inner platform parapet is not apparent from the figures of these specimens in each of these papers.

We also have specimens of Palmatolepis prima which are transitional to P. pectinata Ziegler and often show different degrees of upturning of the lateral margin of the anterior inner platform, so that some of our specimens nearly have a parapet developed in this region of the element.

Also included in our concept of Palmatolepis prima are specimens which have a slight lobe developed on the outer platform (Pl. V-9, figs. 7, 8). Specimens such as these have usually been assigned to P. tenuipunctata Sannemann (e.g. specimens figured in Bischoff, 1956; Glenister and Klapper, 1966 - see synonymy). However, we feel that specimens such as these in our collections have much closer affinities to typical P. prima. This close affinity is evident when these specimens are compared with those of this latter species, as opposed to specimens that we have assigned to P. tenuipunctata (e.g. compare Pl. V-9, figs. 7, 8 to Pl. V-10, figs. 6-9, 11, 13, 14). The wide morphological gap between lobate specimens that we assign to P. prima and those we assign to P. tenuipunctata is evident at all but the earliest growth stages of the two taxa. Specimens of P. prima with very small or vestigial lateral lobes are generally present in the very lowest occurrences of this species in the Palliser Formation and Wabamun Group. However, traces of a lateral lobe can be seen occasionally in specimens that occur stratigraphically higher (e.g. Pl. V-9, figs. 13, 16).

We also have in our collections specimens of Palmatolepis prima Morphotype 1 represented (Pl. V-9, figs. 12-17). These are connected to more typical slender forms of this species by intermediate specimens (e.g. Pl. V-9, figs. 9, 10) which includes the specimen we have illustrated previously (see synonymy) and is illustrated in full upper view herein (Pl.

V-9, fig. 10). We also have in our collections specimens that are transitional between P. prima Morphotype 1 and Morphotype 2 of this species (e.g. Pl. V-9, fig. 17; Pl. V-10, fig. 1).

We have a few specimens in our collections in which the proximal part of the carina and azygous node are fused to the inner platform (Pl. V-9, fig. 11). This phenomenon has also been observed in other species of Palmatolepis in the Palliser Formation and Wabamun Group.

As noted under the Remarks for Palmatolepis klapperi Sandberg and Ziegler, some specimens of P. prima Morphotype 2 were assigned with difficulty to this morphotype.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1 to V-4, V-6, V-7, V-10, V-11, V-13 to V-16). Palmatolepis prima ranges from the Upper crepida Zone, which the base of is defined by first appearance of this species, to possibly as high as the Upper marginifera Zone (Table V-6). Morphotype 1 of this species ranges from the upper part of the Upper crepida Zone to possibly as high as the Upper rhomboidea Zone. Palmatolepis prima Morphotype 2 ranges from the Uppermost crepida Zone, which the base of is defined by the first occurrence of this morphotype at one locality (Gold Creek 10-31 well, Table V-14; Johnston and Meijer Drees, 1993), to the Lower rhomboidea Zone. At several localities (e.g. Mount Greenock, Table V-10, Roche Miette, Table V-11) the highest occurrence of this morphotype defines the upper limit of strata that are no younger than this zone.

Palmatolepis tenuipunctata Sannemann, 1955b
Pl. V-10, figs. 6-9, 11, 13, 14

1955b	Palmatolepis tenuipunctata Sannemann, p. 136, pl. 6, fig. 22.
1976	Palmatolepis tenuipunctata, Druce, p. 173, pl. 60, figs. 1-4.
1976	Palmatolepis tenuipunctata, Dusar and Dreesen, p. 562, pl. 4, fig. 5.
1976	Palmatolepis tenuipunctata, Bouckaert and Dreesen, p. 580, pl. 1, figs. 10, 11.
?1978	Palmatolepis cf. tenuipunctata Orchard, p. 946, pl. 115, fig. 16.
1979	Palmatolepis (Manticolepis) tenuipunctata, van den Boogaard and Kuhry, figs. 7, 8 (Pa elements only).
1983	Palmatolepis tenuipunctata, Wang and Ziegler, pl. 4, fig. 5.

1984	*Palmatolepis tenuipunctata*, Dusar and Dreesen, p. 53, pl. 2, fig. 4.
1984	*Palmatolepis subperlobata*, Dusar and Dreesen, p. 53, pl. 2, fig. 5.
1984	*Palmatolepis tenuipunctata*, Olivieri, pp. 301, 302, pl. 6, fig. 13.
1985	*Palmatolepis tenuipunctata*, Delfour and Gigot, p. 338, pl. 1, fig. 7.
?1985	Plates-formes engrénées de *Palmatolepis* Delfour and Gigot, p. 338, pl. 1, figs. 9, 10.
1987	*Palmatolepis tenuipunctata*, Matyja, p. 374, pl. 22.1, fig. 7.
1988	*Palmatolepis tenuipunctata*, Bultynck, p. 26, pl. A2/2, fig. 17.
?1989	*Palmatolepis tenuipunctata*, Ji, p. 296, pl. 2, fig. 14.
1991	*Palmatolepis tenuipunctata*, Johnston and Chatterton, p. 178, pl. 1, fig. 18.
1993	*Palmatolepis tenuipunctata*, Johnston and Meijer Drees, p. 145, pl. 1, fig. 23 (only).

Types. Figured hypotypes GSC 100274, 106942-106944, 106946, 106948, 106949.

Diagnosis. See Ziegler (1973, p. 303).

Remarks. Specimens of *Palmatolepis tenuipunctata* from our collections show a variety of form, ranging from typical specimens (e.g. Pl. V-10, fig. 6) to those in which the outer lobe is strongly developed (e.g. Pl. V-10, figs. 9, 11, 13, 14). Other specimens appear transitional to *P. subperlobata* Branson and Mehl (e.g. Pl. V-10, fig. 7). Strongly lobate specimens, which have previously been considered to represent early forms of this species (e.g. Ziegler, 1962b), are the highest occurring specimens of *P. tenuipunctata* in our sections. These specimens occur in strata as young as the Lower *rhomboidea* Zone, which represents the youngest occurrence of this species reported so far (Johnston and Chatterton, 1991).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-3, V-6, V-7, V-13 to V-16). *Palmatolepis tenuipunctata* ranges from the Upper *crepida* Zone to possibly as high as the Upper *rhomboidea* Zone (sample NP86-80, Table V-6). There is a questionable occurrence of this species in the Lower to Middle *crepida* zones at one locality (Whiteman Gap, Table V-3).

Palmatolepis cf. *P. tenuipunctata* Sannemann, 1955b
Pl. V-10, figs. 10, 12, 15

cf. 1955b Palmatolepis tenuipunctata Sannemann, p. 136, pl. 6, fig. 22.
1991 Palmatolepis subperlobata subsp. A Irwin and Orchard, p. 208, pl. 3, fig. 3.

Types. Figured specimens GSC 106925, 106947, 106950.

Remarks. Specimens in our collections that are assigned to this taxon are similar to Palmatolepis tenuipunctata in terms of outer lobe development, blade and carina denticulation and configuration of the anterior portion of the inner platform. They differ in that their platform outline is more antero-posteriorly compressed than typical specimens of this species. For this reason, our specimens cannot be assigned to P. tenuipunctata with certainty.

Occurrence. Palliser Formation and Wabamun Group (Tables V-7, V-15, V-16). The occurrence of Palmatolepis cf. P. tenuipunctata appears to be in strata that are no older than the Upper crepida Zone and no younger than the Lower rhomboidea Zone. Irwin and Orchard (1991) reported specimens conspecific with ours (see synonymy) from the Uppermost crepida to Lower rhomboidea zones.

"Palmatolepis minuta group"

Remarks. Included in this group are palmatolepids with a moderately to very long free blade, i.e. Palmatolepis lanceolata n. sp., P. minuta Branson and Mehl, P. ovata n. sp., P. parawolskae n. sp. and P. wolskae Szulczewski. We also include in this group a form with a rhomboid platform and moderately long free blade which we name P. sp. B. The first three species listed above and P. wolskae probably comprised part of the same lineage and thus were closely related whereas P. parawolskae may represent part of a separate lineage (e.g. Helms and Ziegler, 1981). As with the Palmatolepis glabra group, all previously recognized subspecies in the P. minuta group are raised in rank to species.

Palmatolepis lanceolata n. sp.

Pl. V-11, figs. 1-7

?1973 *Palmatolepis minuta minuta*, Sandberg and Ziegler, pl. 1, fig. 32.
?1976 *Palmatolepis* sp. nov. B Druce, p. 176, pl. 96, fig. 1.
?1985 *Palmatolepis* sp. B, Ji and Liu, p. 179, pl. 1, figs. 37, 38.

Etymology. For the lanceolate outline of the platform in this species.

Types. Holotype GSC 106951, illustrated on Plate V-11, figures 1, 2, paratypes GSC 106952-106956, illustrated on Plate V-11, figures 3-7.

Material. 70 specimens.

Diagnosis. A species of *Palmatolepis* which has a narrow and lanceolate platform with a pointed posterior end and an elongate free blade. The anteriormost denticles on the free blade descend in a step-wise fashion towards the end of the blade. Carina and free blade slightly offset but subparallel to azygous node and posterior carina.

Description. Platform lanceolate, with shagreen-like upper surface. Platform begins approximately one third the way between anterior margin of free blade and the posterior tip. Anterior margin of outer platform begins farther forward than same margin of inner platform in most specimens. Platform undulatory in front of azygous node. Platform widens to its greatest extent at or just in front of azygous node and then narrows to sharp point posteriorly. Posterior tip flexed upward. Platform slopes laterally downwards from azygous node and carina.

Blade and carina straight, with slight curvature inward anteriorly, slightly offset from but subparallel to azygous node and posterior carina. Carina high, with denticles nearly confluent to tips and continuing onto free blade in same fashion. At anterior end of free blade denticles descend in step-wise fashion towards end of blade. Posterior carina weak, with strongest development just posterior of azygous node; in some specimens posterior carina becomes low ridge that continues to posterior tip.

Lower side smooth, with wide crimp, keel sharp with slight curvature, terminates at basal pit, becomes low ridge posteriorly of pit.

Remarks. *Palmatolepis lanceolata* is distinguished from *P. ovata* n. sp. by its lanceolate platform and elongate free blade. The former species is also distinguished from *P. minuta* Branson and Mehl by its lanceolate platform, which appears to lack any suggestion of an outer lateral lobe. Also, *P. lanceolata* has a much weaker posterior carina, whereas *P. minuta* has a strong posterior carina. The former species lacks the lobe and upturned platform margins of *P. schleizia* Helms.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-6, V-15, V-16). *Palmatolepis lanceolata* ranges from the upper part of the Lower to Middle *crepida* zones to the lower part of the Upper *crepida* Zone in our collections.

Palmatolepis minuta Branson and Mehl, 1934a
Pl. V-11, figs. 8-21

1934a	*Palmatolepis minuta* Branson and Mehl, pp. 236, 237, pl. 18, figs. 1, 6, 7.
1976	*Palmatolepis minuta minuta*, Druce, pp. 159, 160, pl. 66, figs. 1-3.
1976	*Palmatolepis minuta - loba*, Dusar and Dreesen, p. 556, pl. 1, fig. 6.
1976	*Palmatolepis minuta minuta*, Spassov and Filipović, p. 9, pl. 1, fig. 7.
1978	*Palmatolepis minuta minuta*, Orchard, p. 936, pl. 115, figs. 10, 17.
1979	*Palmatolepis* (*Tripodellus*) *minuta flexuosa*, van den Boogaard and Kuhry, p. 41, fig. 12 (Pa element only).
1979	*Palmatolepis* (*Tripodellus*) *minuta minuta* van den Boogaard and Kuhry, p. 42, fig. 13 (Pa element only).
1981	*Palmatolepis minuta minuta*, Helms and Ziegler, p. W99, fig. 62.51.
1983	*Palmatolepis minuta minuta*, Wang and Ziegler, pl. 3, fig. 14.
1984	*Palmatolepis minuta minuta*, Olivieri, p. 298, pl. 4, figs. 1-4.
1985	*Palmatolepis minuta minuta*, Ji and Liu, p. 180, pl. 3, figs. 7-10.
1985	*Palmatolepis minuta minuta*, Ziegler and Wang, p. 36, pl. 4, fig. 19.

1986 *Palmatolepis minuta minuta*, Barca, Gnoli, Olivieri and Serpagli, p. 316, pl. 30, fig. 1.
1988 *Palmatolepis minuta minuta*, Bultynck, p. 28, pl. 3, fig. 12.
1989 *Palmatolepis minuta*, Orchard, p. 44, pl. 2, figs. 17, 19.
1989 *Palmatolepis minuta*, Ji, p. 296, pl. 2, figs. 15, 16.
1991 *Palmatolepis minuta minuta*, Johnston and Chatterton, p. 178, pl. 1, fig. 6 (only).
1991 *Palmatolepis minuta minuta*, Irwin and Orchard, p. 210, pl. 4, fig. 11.

Types. Figured hypotypes GSC 100262, 106957-106965.

Diagnosis. See Ziegler (1977, p. 335).

Remarks. In our collections, we consider specimens of *Palmatolepis minuta* to be those which have a small oval platform that is restricted to the posterior half to third of the element. A slight outer lobe is developed on many specimens (e.g. Pl. V-11, fig. 8) Commonly, the carina and free blade are long and straight, and appear to be offset from, but subparallel to, the azygous node and posterior carina. The platform posterior of the azygous node may be straight (e.g. Pl. V-11, figs. 8, 12) or deflected inwardly (e.g. Pl. V-11, figs. 9-11).

Specimens such as the above appear to be intergradational with elements with much reduced and moderately to strongly deflected posterior platforms, like *Palmatolepis gracilis* Branson and Mehl. Most elements having this appearance are usually quite small so that they probably represent early growth stages of larger elements with broader platforms. However, some specimens like the former are almost the same size as mature specimens of *P. minuta* (compare Pl. V-11, figs. 13, 16-21 with Pl. V-11, figs. 8, 9) but, unlike *P. gracilis*, they do not have the abrupt outward deflection of the keel on the lower side of the element as do other species closely related to this taxon (e.g. Mehl and Ziegler, 1962, pl. 1, figs. 1d, 2b and Sandberg and Ziegler, 1979, pl. 1, figs. 6b, 12, 13, 15 and 17). It is for this reason that we still assign these specimens to *P. minuta*. We do interpret them, however, to be probably close to the ancestor of *P. gracilis*.

Typical specimens of *Palmatolepis minuta* and those possibly ancestral to *P. gracilis* discussed above are common in the lower part of the Palliser Formation and Wabamun Group from approximately the Lower to Middle *crepida* to Uppermost *crepida* or lowermost Lower *rhomboidea* zones. Some of the latter elements may, however, occur in strata perhaps as young as the Upper *rhomboidea* Zone. In sections of the Palliser Formation and Wabamun Group studied by us, late forms of *P. minuta* (e.g. Pl. V-11, fig. 14) are rare in the upper part of the former unit (e.g. Banff Golf Course, Tables V-4 and Nigel Peak, Table V-6) and absent in the same part of the latter unit.

Also included in the concept of *Palmatolepis minuta* for the time being, because of their very small size, are elements with a very strongly deflected posterior platform, and with denticles which are free at their tips (Pl. V-11, fig. 15). Some of these appear to be intergradational with the elements discussed above that we interpret to be early growth stages of *P. minuta*. The elements with the free denticle tips occur mainly in the Nigel Peak section in the Lower *rhomboidea* Zone (Table V-6).

Occurrence. Palliser Formation and Wabamun Group (Table V-1, V-4, V-6, V-7, V-14 to V-16). *Palmatolepis minuta* ranges from the Lower to Middle *crepida* zones to the Upper *marginifera* Zone.

Palmatolepis ovata n. sp.
Pl. V-12, figs. 1-8

?1963	*Palmatolepis minuta*, Abdüsselâmoğlu, p. 6, pl. 1, fig. 3.
1971	*Palmatolepis minuta minuta*, Szulczewski, p. 35, pl. 15, fig. 1 (only).

Etymology. From the ovate outline of the platform.

Types. Holotype GSC 106966, illustrated on Plate V-12, figures

1, 2, paratypes GSC 106967-106971, illustrated on Plate V-12, figures 3-8.

Material. About 150 specimens.

Diagnosis. A species of *Palmatolepis* which has an ovoid platform and a free blade which extends only a half to a third the element length beyond the anterior margin of the platform.

Description. Slightly to moderately undulatory platform with shagreen upper surface which is ovate to somewhat lanceolate in upper view. Anterior margins of the inner and outer platform may begin opposite one another or the outer platform may begin more anterior of the inner platform. Edges of element flattened to slightly upturned, especially along the antero-lateral edge of the inner platform. Posterior tip of platform flat or flexed upward slightly.

Blade and carina straight to gently curved anterior of azygous node, sometimes sharply offset from it, but still connected to azygous node by several denticles. Carina high on platform with denticles nearly confluent to tips, continuing onto free blade. Free blade extends almost one third the element length beyond the anterior margins of the platform. Posterior carina moderately developed, does not extend to posterior tip, commonly followed posteriorly by a groove.

Relatively narrow crimp, occurs a half to a third of the width of the platform from the lateral margin to the keel. Keel strongly developed anterior of pit, more subdued posteriorly.

Remarks. *Palmatolepis ovata* differs from *P. minuta* Branson and Mehl by having a shorter blade and carina length relative to the platform and by lacking an outer lobe. This species differs from *P. lanceolata* n. sp. by having an ovate, less pointed platform and a much shorter free blade. *Palmatolepis ovata* is distinguished from *P. protorhomboidea* Sandberg and Ziegler by lacking a parapet on the anterior portion of the inner platform. However, we also have specimens that are transitional between *P. ovata* and this species (see Remarks for *P. protorhomboidea*).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-3, V-6, V-10, V-12, V-15, V-16). Presently available evidence indicates that *Palmatolepis ovata* has a stratigraphic range from the Lower to Middle *crepida* zones to the lower part of the Upper *crepida* Zone in the Palliser Formation and Wabamun Group. Questionable specimens of this species occur in the Lower *rhomboidea* Zone (e.g. Tables V-6, V-16).

Palmatolepis parawolskae n. sp.

Pl. V-12, figs. 9-16; Pl. V-13, figs. 1-5

1991 *Palmatolepis minuta minuta*, Johnston and Chatterton, p. 178, pl. 1, figs. 7, 8 (only).

Etymology. From the Latin *para* meaning "equal", referring to the close similarity between this species and *Palmatolepis wolskae* Szulczewski.

Types. Holotype GSC 106972, illustrated on Plate V-12, figures 9, 12; paratypes GSC 106973-106982, illustrated on Plate V-12, figures 10, 11, 13-16; Plate V-13, figures 1-5.

Material. About 195 specimens.

Diagnosis. A species of *Palmatolepis* which has an undulatory and lobate rhomboid platform. A prominent to very prominent bulge is present on the anterior portion of the inner platform. A weak to well developed posterior carina is present posterior to the azygous node.

Description. Undulatory rhomboid platform with shagreen-like upper surface. Platform generally comprises three quarters of the length of the element. Anterior margin of the outer platform begins anterior of the same margin the inner platform. Prominent bulge developed on the anterior portion of the inner platform; bulge is nearly parapet in stratigraphically older specimens. Most mature specimens have a poorly to well developed rounded outer lobe. Outer lobe situated anterior of the azygous node. A shallow depression is usually developed just posterior to the outer lobe in most specimens. Posterior tip of platform flexed upward slightly.

Blade and carina moderately sigmoidal with denticles confluent nearly to tips anterior to the azygous node. Posterior carina very weak in most specimens with only one or two nodes behind the azygous node. Narrow shallow depression or groove posterior of carina extends half the distance between the azygous node and the posterior tip.

Basal pit very narrow slit on lower side. Keel low, somewhat sigmoidal. Crimp occurs approximately one-half to one-third the distance from the lateral margin to the keel on the lower surface of the platform.

Remarks. Included in this concept are specimens which do not have as prominent a bulge on the inner platform and which appear to have a somewhat broader and flatter platform (e.g. Pl. V-13, figs. 1, 2). Otherwise, specimens of this species show great variation in terms of the amount of bulging of the inner platform, outer lobe and posterior carina development, etc. Earlier growth stages (e.g. Pl. V-13, figs. 3-5) tend to show somewhat subdued outer lobe development.

Palmatolepis parawolskae is distinguished from P. wolskae Szulczewski by having a weak posterior carina and lacking an extremely large azygous node. Otherwise, it appears to resemble the latter species in most other respects. Palmatolepis parawolskae is distinguished from P. loba Helms by having an undulatory as opposed to a flat platform as in the latter species. In most specimens of *P. parawolskae*, the outer lobe is generally small and not that well differentiated. *Palmatolepis loba* usually has a strong posterior carina extending the full length of the platform between the posterior carina and the tip (see Helms, 1963, pl. 2, fig. 14, Pl. 3, fig. 12, and Szulczewski, 1971, pl. 15, fig. 15) whereas in *P. parawolskae* the posterior carina extends at most only half this distance.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-3, V-4, V-6, V-7, V-10 to V-16). As presently known, *Palmatolepis parawolskae* has a stratigraphic range of Lower to Middle *crepida* zones to Upper *crepida* Zone. Early forms of *P. parawolskae* are restricted to the Lower to Middle *crepida* zones.

Palmatolepis wolskae Szulczewski, 1971
Pl. V-13, figs. 6, 7

1971	*Palmatolepis minuta wolskae* Szulczewski, pp. 36, 37, pl. 15, figs. 2, 12-14.
1976	*Palmatolepis minuta wolskae*, Dusar and Dreesen, p. 556, pl. 1, figs. 5, 7.
1977	*Palmatolepis minuta wolskae*, Ziegler, p. 345, *Palmatolepis* - pl. 9, figs. 12, 13 (contains synonymy to 1977).
1984	*Palmatolepis minuta wolskae*, Dreesen, p. 210, pl. 1, fig. 5.

Types. Figured hypotypes GSC 106983, 106894.

Diagnosis. See Szulczewski (1971, p. 36).

Remarks. Specimens in our collections are close to the holotype of *Palmatolepis wolskae*. There appears to be a very low ridge running from the azygous node to the posterior tip in one of our specimens (Pl. V-13, fig. 6). This ridge is also evident in the specimens of *P. wolskae* illustrated by Dusar and Dreesen (1976) (see synonymy).

Occurrence. Wabamun Group (Table V-15). *Palmatolepis wolskae* is confined to the Upper crepida Zone in our collections.

Palmatolepis sp. B
Pl. V-13, figs. 8-11

Types. Figured specimens GSC 106985-106988.

Remarks. Specimens assigned to this taxon in our collections characteristically have a flat, sub-triangular platform and a long free blade. The posterior carina, if developed, is very weak.

These specimens occur in one of our sections (Wardner, B.C.) and appear similar to juvenile specimens of Palmatolepis subperlobata Branson and Mehl. They differ, however, in that the platform terminates well short of the anterior margin of the free blade, and there is no outer lobe on the platform.

Occurrence. Palliser Formation (Table V-1). As presently known, Palmatolepis sp. B is confined to the Lower to Middle crepida zones.

"Palmatolepis perlobata group"

Remarks. In this group we include Palmatolepis crepida Sannemann, P. perlobata Ulrich and Bassler?, P. cf. P. perlobata and P. schindewolfi Müller. All these forms are characterized by the occurrence of coarse ornamentation on the upper surface that is developed to varying degrees and the scalloped outline of the upper edge of the anterior free blade (see Sannemann, 1955b). Our treatment of this group generally follows that of Helms and Ziegler (1981).

Palmatolepis crepida Sannemann, 1955b
Pl. V-13, fig. 12

1955b	Palmatolepis crepida Sannemann, p. 134, pl. 6, fig. 21; fig. 1.1.
1956	Palmatolepis crepida, Bischoff, p. 128, pl. 8, figs. 31, 32; pl. 10, fig. 9.

1960	*Palmatolepis* (*Palmatolepis*) sp. aff. *crepida*, Clark and Becker, p. 1671, pl. 2, figs. 5, 9, 10 (only).
1962	*Palmatolepis crepida crepida*, Ziegler, p. 55, pl. 6, figs. 12-19; figs. 3a-i, k, l.
1963	*Palmatolepis* (*Palmatolepis*) *crepida*, Helms, p. 478, pl. 1, fig. 25; text-fig. 2.42.
?1963	*Palmatolepis perlobata* n. subsp. a Helms, p. 473, pl. 1, fig. 23.
1967	*Palmatolepis crepida*, Wolska, pp. 387, 388, pl. 6, figs. 1-5; fig. 6.
1969	*Palmatolepis crepida*, Olivieri, pp. 95, 96, pl. 16, figs. 15, 16.
1973	*Palmatolepis crepida*, Sandberg and Ziegler, p. 103, pl. 5, figs. 9-11.
1979	*Palmatolepis* (*Panderolepis*) *crepida*, van den Boogaard and Kuhry, p. 46, fig. 18 (Pa element only).
1981	*Palmatolepis crepida*, Helms and Ziegler, p. W99, fig. 62.63.
1983	*Palmatolepis crepida*, Wang and Ziegler, pl. 8, fig. 14.
1984	*Palmatolepis crepida*, Dusar and Dreesen, p. 53, pl. 2, fig. 1.
1984	*Palmatolepis crepida*, Olivieri, pp. 290-292, pl. 5, figs. 4, 5.
1987	*Palmatolepis crepida*, Matyja, p. 374, pl. 22.1, fig. 6.
1989	*Palmatolepis crepida*, Irwin and Orchard, p. 17, pl. 1, fig. 7.
1989	*Palmatolepis crepida*, Orchard, p. 46, pl. 3, fig. 14.
1991	*Palmatolepis crepida*, Irwin and Orchard, p. 206, pl. 2, fig. 15.

Types. Hypotype GSC 106989.

Diagnosis. See Ziegler (1973, p. 263).

Remarks. The single specimen of this species from Nigel Peak is virtually identical to the specimen illustrated on Pl. 5, fig. 9 in Sandberg and Ziegler (1973) from the Lower *rhomboidea* Zone in the West Range Limestone in Nevada. Our specimen differs slightly in that incipient lateral lobe development on it is not as pronounced as on their specimen. Specimens of *P*. *crepida* similar to ours and to Sandberg and Ziegler's (1973) specimen have also been illustrated by Clark and Becker (1960) and Clark and Ethington (1967) from the western United States and by Wolska (1967) from the Holy Cross Mountains in Poland (see synonymy).

Occurrence. Palliser Formation (Table V-6). *Palmatolepis crepida* is confined to the Lower *rhomboidea* Zone in this formation.

Palmatolepis perlobata Ulrich and Bassler, 1926?
Pl. V-13, fig. 14

?1926	*Palmatolepis perlobata* Ulrich and Bassler, pp. 49, 50, pl. 7, figs. 19, 21, 22 (only).

Types. Figured specimen GSC 106991.

Remarks. The whole and fragmentary specimens assigned to this taxon have a somewhat similar outline to the specimen illustrated by Ziegler (1962b, pl. 8, fig. 1) that he assigned to Palmatolepis perlobata. Our specimens differ by the slight development of ornamentation on the inner platform on an otherwise shagreen-like upper surface.

Occurrence. Wabamun Group (Table V-15). Palmatolepis perlobata? is confined to the Upper crepida Zone.

Palmatolepis cf. P. perlobata Ulrich and Bassler, 1926
Pl. V-13, figs. 13, 15

cf. 1926	Palmatolepis perlobata Ulrich and Bassler, 1926, pp. 49, 50, pl. 7, figs. 19, 21, 22 (only).
?1989	Palmatolepis perlobata perlobata, Orchard, p. 46, pl. 3, fig. 13.
1991	Palmatolepis triangularis, Johnston and Chatterton, p. 178, pl. 1, fig. 21.

Types. Figured specimens GSC 100227, 106990.

Remarks. Specimens assigned to this taxon in our collections exhibit features intermediate between Palmatolepis triangularis Sannemann and P. perlobata. We believe, however, that these specimens are closer to the latter species because they have a large, well differentiated outer lobe. However, even though they have this feature, we do not believe that our specimens are conspecific with P. perlobata. This is because two of the three whole or nearly whole specimens we have (e.g. Pl. V-13, fig. 15) are less elongate than typical specimens of this species. They also do not have a strongly bulging antero-lateral inner platform as does the lectotype of this species and other specimens close to the lectotype that have been illustrated in the literature (e.g. Sannemann, 1955b, pl. 1, fig. 7; Hass, 1959, pl. 50, fig. 14). The third specimen we have (Pl. V-13, fig. 13) resembles elongate forms with a well differentiated outer lobe that have been illustrated by Ziegler (1962, text-figs. 6a-c) and Szulczewski (1971, pl. 14, fig. 14) which were also considered intermediates between P. perlobata and P. triangularis.

Fragmentary palmatolepid elements exhibiting moderate to strong ornamentation on the upper surface and the suggestion or the presence of a large outer lobe are also assigned to this taxon.

Occurrence. Palliser Formation and Wabamun Group (Tables V-7, V-13, V-15, V-16). Specimens of Palmatolepis cf. P. perlobata range from the Lower to Middle crepida zones to Upper crepida Zone.

Palmatolepis schindewolfi Müller, 1956
Pl. V-13, figs. 16-18

1956	Palmatolepis (Palmatolepis) schindewolfi Müller, pp. 27, 28, pl. 8, figs. 22-31; pl. 9, fig. 33; pl. 11, fig. 27?.
1974	Palmatolepis perlobata schindewolfi, Dreesen and Dusar, pl. 7, figs. 15-17.
?1975	Palmatolepis perlobata schindewolfi, van den Boogaard and Schermerhorn, p. 10, pl. 6, figs. 1, 2.
1976	Palmatolepis perlobata perlobata, Druce, pp. 161-163, pl. 67, figs. 2-5.
1976	Palmatolepis perlobata schindewolfi, Bouckaert and Dreesen, p. 580, pl. 1, fig. 7.
1977	Palmatolepis perlobata schindewolfi, Ziegler, pp. 361-364, Palmatolepis - pl. 11, figs. 1-7.
1979	Palmatolepis (Palmatolepis) perlobata schindewolfi, van den Boogaard and Kuhry, p. 55, figs. 27, 28 (Pa elements only).
1979	Palmatolepis perlobata schindewolfi, Sandberg and Ziegler, p. 180, pl. 1, figs. 22-24; pl. 2, fig. 13.
1981	Palmatolepis perlobata schindewolfi, Helms and Ziegler, p. W99, figs. 62.71, 62.72.
1983	Palmatolepis perlobata schindewolfi, Spassov, pp. 16, 17, pl. 5, figs. 11-13.
1983	Palmatolepis perlobata schindewolfi, Wang and Ziegler, pl. 4, fig. 3.
1984	Palmatolepis perlobata schindewolfi, Olivieri, p. 299, pl. 5, figs. 11-13.
1985	Palmatolepis perlobata schindewolfi, Austin, Orchard and Stewart, p. 152, pl. 4.7, fig. 16.
1991	Palmatolepis perlobata schindewolfi, Irwin and Orchard, p. 210, pl. 4, fig. 16.

Types. Figured hypotypes GSC 106992-106994.

Diagnosis. See Ziegler (1977, p. 361).

Remarks. The few specimens of this species in one of our collections (sampled interval 11111 ft. to 11128.5 ft., Table V-15) either have subdued or no ornamentation on the upper surface. The largest specimen (Pl. V-13, fig. 17) exhibits the former feature whereas the other smaller specimens (Pl. V-13, figs. 17, 18) exhibit the latter feature.

Occurrence. Wabamun Group (Table V-15). *Palmatolepis schindewolfi* is confined to the Upper *crepida* Zone.

"*Palmatolepis quadrantinodosa* group"

Remarks. *Palmatolepis duplicata* Sandberg and Ziegler, *P. inflexa* Müller, *P. marginifera* Helms, *P. quadrantinodosa* Branson and Mehl and *P. stoppeli* Sandberg and Ziegler are included in this group which is characterized by forms with rounded to elongate platforms with varying degrees of parapet development. Evolutionary trends within this group have been discussed by Sandberg and Ziegler (1973), Dreesen (1976) and Helms and Ziegler (1981).

Within this group, two subgroups can be recognized. One subgroup is characterized by the occurrence of inner platforms which are flat or that show heightening and thickening (e.g. *Palmatolepis inflexa* and *P. stoppeli*), which is accompanied by nodose ornamentation in some species (e.g. *P. quadrantinodosa*). The other subgroup is characterized by the development of narrow, high and sharp parapets (e.g. *P. duplicata* and *P. marginifera*). As in other groups of Famennian palmatolepids treated in the preceding text, all these taxa have been raised in rank from subspecies to species.

Palmatolepis duplicata Sandberg and Ziegler, 1973
Pl. V-14, figs. 1-4

1973	*Palmatolepis marginifera duplicata*, Sandberg and Ziegler, p. 105, pl. 3, figs. 15-19, 21-25; pl. 5, fig. 15.
?1976	*Palmatolepis marginifera duplicata*, Dreesen, p. 522, pl. 1, figs. 42-44.
1977	*Palmatolepis marginifera duplicata*, Ziegler, pp. 331, 332, *Palmatolepis* - pl. 8, figs. 6-9.
1981	*Palmatolepis marginifera duplicata*, Helms and Ziegler, p. W99, fig. 62.41.
?1985	*Palmatolepis marginifera duplicata*, Ji and Liu, p. 180, pl. 3, figs. 22, 23?.
1991	*Palmatolepis marginifera duplicata*, Johnston and Chatterton, p. 180, pl. 2, fig. 26.

Types. Figured hypotypes GSC 100306, 106995-106997.

Diagnosis. See Sandberg and Ziegler (1973, p. 105).

Remarks. Specimens in our collections generally conform to the diagnosis of Sandberg and Ziegler (1973). However, they differ slightly from the types illustrated by these authors in that our specimens appear to be slightly wider relative to their length. This greater width, however, is judged by us not to be taxonomically significant.

Occurrence. Palliser Formation (Tables V-1, V-6, V-8). *Palmatolepis duplicata* is confined to the Lower *marginifera* Zone in our collections. According to Ziegler and Sandberg (1984), this species ranges from the upper part of the Lower *marginifera* Zone to the lower part of the Upper *marginifera* Zone.

Palmatolepis inflexa Müller, 1956
Pl. V-14, figs. 5-12, 16

1956	*Palmatolepis* (*Palmatolepis*) *inflexa* Müller, p. 30, pl. 10, figs. 5a,b, 8?.
1962b	*Palmatolepis quadrantinodosa marginifera*, Ziegler, pp. 73, 74, pl. 7, fig. 8 (only).
1963	*Palmatolepis* (*Panderolepis*) *inflexoidea*, Helms, p. 482, pl. 3, figs. 5, 7-9, 11.
1973	*Palmatolepis quadrantinodosa inflexoidea*, Sandberg and Ziegler, pl. 4, figs. 1-3.
1975	*Palmatolepis inflexa*, Dreesen, p. 15, pl. 1, fig. 2.
1976	*Palmatolepis* cf. *inflexa*, Dreesen, pp. 516, 517, pl. 1, fig. 1.
1976	*Palmatolepis inflexa inflexa*, Dreesen, p. 518, pl. 1, figs. 52, 53.
1977	*Palmatolepis quadrantinodosa inflexa*, Ziegler, pp. 377, 379, *Palmatolepis* - pl. 12, figs. 3-10 (contains synonymy to 1974).
?1979	*Palmatolepis* (*Conditolepis*) *quadrantinodosa inflexa*, van den Boogaard and Kuhry, p. 52, fig. 24 (Pa element only).
1981	*Palmatolepis quadrantinodosa inflexa*, Helms and Ziegler, p. W98, figs. 62.36-62.38.
1984	*Palmatolepis* cf. *inflexa*, Dusar and Dreesen, p. 54, pl. 3, fig. 7.
?1985	*Palmatolepis quadrantinodosa inflexa*, Ji and Liu, p. 180, pl. 2, figs 15, 19.
1987	*Palmatolepis quadrantinodosa inflexa*, Matyja, p. 375, pl. 22.2, fig. 16.
1991	*Palmatolepis quadrantinodosa inflexa*, Johnston and Chatterton, p. 180, pl. 2, fig. 23.
1991	*Palmatolepis quadrantinodosa inflexoidea*, Johnston and Chatterton, p. 180, pl. 2, fig. 24.
1991	*Palmatolepis quadrantinodosa inflexa*, Irwin and Orchard, p. 208, pl. 3, fig. 15.

Types. Figured hypotypes GSC 100303, 100304, 106998-107703, 107007.

Diagnosis. See Ziegler (1977, p. 377).

Remarks. Specimens with a slight bulge on the anterior portion of the inner platform (Pl. V-14, fig. 11) and those with a flat inner platform (Pl. V-14, fig. 16) are present in our collections. In addition, we also have elongate specimens with bowed-up or flat inner platforms. All these specimens represent each of the three morphotypes of this species recognized by Ziegler (1977, p. 377). One of the specimens we illustrate (Pl. V-14, fig. 7) is a broad specimen which most strongly resembles the specimen of Palmatolepis inflexa illustrated by Ziegler (1962b) on plate 7, figures 4 and 5 of his paper.

Also included in our concept of Palmatolepis inflexa are specimens in our collections (e.g. Pl. V-14, figs. 9, 12) which are conspecific with specimens illustrated in the literature which have been considered P. inflexoidea Ziegler (see synonymy). We believe that our specimens and those cited in our synonymy fit the concept of P. inflexa better because they show a greater degree of curvature than typical specimens of P. inflexoidea. The antero-lateral edge of the inner platform also does not bulge as prominently in our specimens and in those cited in our synonymy as in the latter species. Contrary to Sandberg and Ziegler (1973) and Ziegler (1977), we believe that the azygous node in our specimens and in those we cite in our synonymy is situated more anteriorly than in more typical specimens of P. inflexoidea (i.e. like the holotype). However, some specimens that we assign to P. inflexa could be considered transitional to P. inflexoidea.

We also include in our concept of Palmatolepis inflexa specimens which appear to have a thickened inner platform (Pl. V-14, fig. 10). These forms may be transitional to P. quadrantinodosa Branson and Mehl, because slight ornamentation appears to be developed on one or two specimens. Specimens such as these could thus represent an intermediate stage in the evolution of former species into the latter.

We also illustrate a specimen (Pl. V-14, fig. 5) which appears intermediate in morphology between *Palmatolepis inflexa* and the second morphotype of *P. marginifera* Helms (described herein under the Remarks for the latter species). This specimen has a bowed-up inner platform from which the second morphotype of the latter species could have been derived by a heightening and sharpening of this bulge into a parapet. We have also assigned to *P. inflexa* elements which appear intermediate between this species and *P. duplicata* Sandberg and Ziegler.

Occurrence. Palliser Formation and Wabamun Group (Tables V-2, V-6, V-8, V-10, V-15). *Palmatolepis inflexa* ranges from the Upper *rhomboidea* to the Lower *marginifera* zones in these units.

Palmatolepis marginifera Helms, 1959

Pl. V-14, figs. 13-15, 17, 18; Pl. V-15, figs. 1-6

1959 *Palmatolepis quadrantinodosa marginifera* Helms, pp. 401, 402, pl. 5, figs. 22, 23.
1962a *Palmatolepis quadrantinodosa marginifera*, Ziegler, p. 401, pl. 1, fig. 6; pl. 2, figs. 6-8.
1973 *Palmatolepis marginifera marginifera*, Sandberg and Ziegler, p. 105, pl. 3, figs. 13, 14.
1976 *Palmatolepis marginifera marginifera*, Dreesen, pp. 519, 520, pl. 1, figs. 23, 26-39.
1976 *Palmatolepis marginifera granulosa* Dreesen, pp. 520, 521, pl. 1, figs. 24, 25; fig. 1.
1976 *Palmatolepis marginifera curvata* Dreesen, pp. 521, 522, pl. 1, figs. 40, 41; fig. 2.
1976 *Palmatolepis marginifera granulosa*, Dusar and Dreesen, p. 556, pl. 1, figs. 1-3.
1976 *Palmatolepis marginifera marginifera*, Spassov and Filipović, 1976, p. 9, pl. 1, fig. 12; pl. 2, fig. 6; pl. 3, figs. 11, 12.
1977 *Palmatolepis marginifera marginifera*, Buggisch, p. 61, pl. 1, figs. 1-3.
1977 *Palmatolepis marginifera tuber* Buggisch, pp. 61, 62, pl. 12, figs. 5-10.
1979 *Palmatolepis (Conditolepis) marginifera*, van den Boogaard and Kuhry, pp. 53, 54, fig. 26 (Pa element only).
1981 *Palmatolepis marginifera marginifera*, Helms and Ziegler, p. W98, figs. 62.39, 62.40, 62.42, 62.43 (only).
1983 *Palmatolepis marginifera marginifera*, Wang and Ziegler, pl. 3, fig. 13.
1983 *Palmatolepis marginifera* n. subsp., Wang and Ziegler, pl. 3, figs. 21, 22.
1984 *Palmatolepis marginifera marginifera*, Dusar and Dreesen, p. 54, pl. 3, fig. 2.
1984 *Palmatolepis marginifera curvata*, Dusar and Dreesen, p. 54, pl. 3, fig. 6.
?1984 *Palmatolepis quadrantinodosa* morphotype 1 - *Palmatolepis marginifera*, Dusar and Dreesen, p. 54, pl. 3, fig. 11.
1984 *Palmatolepis marginifera marginifera*, Ziegler and Sandberg, p. 187, pl. 1, fig. 11.
1985 *Palmatolepis marginifera marginifera*, Austin, Orchard and Stewart, p. 150, pl. 4.6, figs. 21, 22?.

1985	Palmatolepis marginifera marginifera, Ji and Liu, p. 108, pl. 3, figs. 19, 21, 24-30.
1987	Palmatolepis marginifera marginifera, Barskov, Alekseev, Kononova and Migdisova, 1987, p. 102, pl. 1, figs. 1-4.
1987	Palmatolepis marginifera marginifera, Matyja, p. 375, pl. 22.2, fig. 10.
1989	Palmatolepis marginifera marginifera, Irwin and Orchard, p. 17, pl. 1, fig. 9.
1991	Palmatolepis marginifera marginifera, Johnston and Chatterton, p. 180, pl. 2, figs, 22, 25.
1991	Palmatolepis marginifera marginifera, Irwin and Orchard, p. 210, pl. 4, figs. 9, 12.
1993	Palmatolepis marginifera marginifera, Johnston and Meijer Drees, p. 145, pl. 1, fig. 18.

Types. Figured hypotypes GSC 98143, 107004-107006, 107008-107014.

Diagnosis. See Sandberg and Ziegler (1973, pp. 105, 106).

Remarks. Two morphotypes of Palmatolepis marginifera, in addition to typical specimens of this species, have been recognized in our collections in upper Palliser and Wabamun strata. We consider typical specimens to be the those that resemble the holotype and the specimens similar to it that are figured on plate 2 of Ziegler (1962a - see synonymy) (i.e. having rounded to nearly circular posterior platforms and a parapet that extends to or just past of azygous node). The specimens figured by Helms (1959 - see synonymy) are considered to belong to our second morphotype of P. marginifera (see below).

The first morphotype is characterized by specimens in which the inner platform parapet widens and flattens posteriorly to become a ramp by the azygous node (e.g. Pl. V-15, figs 4-6). The parapet in some large specimens of this morphotype appears to be restricted mainly to the anteriormost portion of the inner platform. Traces of the parapet are seen in some specimens as a sharp ridge on the outer edge of the inner platform posteriorly (e.g. Pl. V-15, fig. 5). This morphotype is connected to typical specimens of P. marginifera by transitional forms (e.g. Pl. V-14, fig. 13).

In collections where only mature specimens of the first morphotype of Palmatolepis marginifera are present, smaller specimens resemble typical specimens of this species (e.g. Pl. V-15, fig. 1) and specimens intermediate in size are transitional between mature and small specimens (e.g. Pl. V-15, figs 2, 3). In effect, this growth series imitates the transition, seen in mature specimens, from typical representatives of this species to those of the first morphotype. Specimens of *P. marginifera* similar to the first morphotype have been illustrated by Dusar and Dreesen (1984, pl. 3, fig. 2) and Matyja (1972, pl. 4, fig. 13, 1987, pl. 22.2, fig. 10).

Specimens of *Palmatolepis marginifera* that have the inner parapet extending to the posterior tip of which, and having generally more elongate platforms (e.g. Pl. V-14, figs. 14, 15, 17) characterize the second morphotype. This form has been illustrated extensively in the literature (e.g. Ziegler, 1962b, pl. 7, figs. 6, 9; Wolska, 1967, pl. 9, figs. 10-13; Druce, 1976, pl. 55, figs. 1-3; Wang and Ziegler, 1983; Irwin and Orchard, 1989, 1991 - see synonymy for last three references).

The first morphotype of *Palmatolepis marginifera* generally occurs throughout the entire stratigraphic range of this species at many localities. In most collections in which it occurs, it is the sole morphotype of *P. marginifera* present although, in some collections, typical specimens occur with it as well. In the Nigel Peak section, the first morphotype is gradually replaced by the second morphotype of this species up section. It is only in two subsurface sections (e.g. Farmington 6-18 and the Parkland 10-28 wells, Table V-15) that the second morphotype of *P. marginifera* occurs throughout the entire stratigraphic range of this species. There are generally very few joint occurrences of specimens of typical *P. marginifera* and the first morphotype with specimens of the second morphotype of this species in our sections. Given this pattern of occurrence, we believe that specimens of typical *P. marginifera* and those of the first and second morphotype to be probable ecophenotypes of each other.

Forms like the second morphotype of *Palmatolepis marginifera* have been regarded by others (e.g. Ziegler, 1977, p. 325) to represent a late stage in the evolution of this species. The fact that this morphotype occurs with *P*. *stoppeli* Sandberg and Ziegler in the lower Lower *marginifera* Zone of the Parkland 10-28 well (see Table V-15) suggests that it was already present early in the evolutionary history of *P*. *marginifera*. This fact perhaps provides further evidence that this morphotype is an ecophenotype of this species.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-2, V-4 to V-6, V-8 to V-11, V-15, V-17). The first occurrence of *Palmatolepis marginifera* is considered to indicate the presence of the Lower *marginifera* Zone, although this species is known to range as high as the Lower *trachytera* Zone (Ziegler and Sandberg, 1984). In several sections this species ranges at least as high as the Upper *marginifera* Zone.

Palmatolepis quadrantinodosa Branson and Mehl, 1934a

Pl. V-14, fig. 7

1934a	*Palmatolepis quadrantinodosa* Branson and Mehl, pp. 235, 236, pl. 18, figs. 3, 17, 20.
1976	*Palmatolepis quadrantinodosa*, Dreesen, pp. 522, 523, pl. 1, figs. 8, 9.
1976	*Palmatolepis quadrantinodosa* Morphotype 1 Dreesen, pp. 523, 524, pl. 1, figs. 2-7.
1976	*Palmatolepis stoppeli* - *Pa*. *quadrantinodosa* Morphotype 1 Dreesen, p. 525, pl. 1, fig. 10.
1977	*Palmatolepis quadrantinodosa quadrantinodosa*, Ziegler, pp. 371, 372, *Palmatolepis* - pl. 8, figs. 10-16 (contains synonymy to 1976).
1981	*Palmatolepis quadrantinodosa quadrantinodosa*, Helms and Ziegler, p. W99, fig. 62.46.
?1987	*Palmatolepis quadrantinodosa quadrantinodosa*, Matyja, p. 375, pl. 22.2, figs. 9, 11.
1991	*Palmatolepis quadrantinodosa quadrantinodosa*, Johnston and Chatterton, p. 180, pl. 2, fig. 19.
1991	*Palmatolepis quadrantinodosa quadrantinodosa*, Irwin and Orchard, p. 210, pl. 4, fig. 19.

Types. Figured hypotype GSC 107015.

Diagnosis. See Branson and Mehl (1934a, p. 235).

Remarks. All of the few whole specimens of *Palmatolepis quadrantinodosa* we have are close to the holotype. However, in most of the few collections containing this species, specimens are generally fragmentary.

Occurrence. Palliser Formation (Tables V-1, V-6, V-8, V-15, V-17). In this formation the occurrence of *Palmatolepis quadrantinodosa* is considered to indicate the presence of the Lower *marginifera* Zone (cf. Sandberg and Ziegler, 1973).

Palmatolepis stoppeli Sandberg and Ziegler, 1973
Pl. V-15, figs. 8-12, 13?

1962b	*Palmatolepis* sp. Ziegler, pl. 7, figs. 12, 13.
1972	*Palmatolepis* sp. Matyja, p. 747, pl. 4, fig. 12.
1973	*Palmatolepis stoppeli* Sandberg and Ziegler, pp. 106, 107, pl. 3, figs. 1-11; pl. 5, fig. 13.
1974	*Palmatolepis stoppeli*, Dreesen and Dusar, p. 26, pl. 5, figs. 1-7.
1974	*Palmatolepis stoppeli*, Matyja and Zbikowska, p. 681, pl. 6, figs. 11-12.
1975	*Palmatolepis stoppeli*, Dreesen, p. 15, pl. 1, figs 4, 5.
1975	*Palmatolepis stoppeli*, Ziegler, pp. 249, 250, *Palmatolepis* - pl. 5, figs. 5-7.
1976	*Palmatolepis stoppeli*, Dreesen, p. 524, pl. 1, figs. 12-19.
1976	*Palmatolepis stoppeli*, Dusar and Dreesen, p. 562, pl. 4, figs. 7, 10.
?1985	*Palmatolepis stoppeli*, Ji and Liu, p. 180, pl. 3, figs. 11-13.
1987	*Palmatolepis stoppeli*, Matyja, p. 375, pl. 22.2, figs. 14, 15.
1991	*Palmatolepis stoppeli*, Johnston and Chatterton, p. 180, pl. 2, fig. 22.
?1991	*Palmatolepis stoppeli*, Irwin and Orchard, p. 208, pl. 3, fig. 8.
1993	*Palmatolepis stoppeli*, Johnston and Meijer Drees, p. 145, pl. 1, fig. 21.

Types. Figured hypotypes GSC 98146, 107016-107019.

Diagnosis. See Sandberg and Ziegler (1973, p. 106).

Remarks. In our collections a great deal of variation was observed in *Palmatolepis stoppeli*. We have specimens that range from those that have a relatively deep adcarinal groove running from the anterior margin of the inner platform to the azygous node (Pl. V-15, figs. 11, 12) to specimens in which this groove is absent and the proximal portion of the carina and the azygous node are merged with the "ramp" (cf. Sandberg and Ziegler, 1973) on the inner platform (Pl. V-15, fig. 8). Matyja (1987) illustrated a possible specimen of the latter type on plate 22.2, figure 15 of her paper. Intermediate specimens also have no adcarinal groove but the carina and azygous node are still more or less distinct (Pl. V-15, fig.

10).

In a few collections, either specimens with the deep adcarinal groove or those with the posterior carina and azygous node fused to the ramp are the only forms of Palmatolepis stoppeli present. In some collections, both forms may occur together. In most collections, however, either the first two forms and intermediate specimens occur in equal abundance or intermediate specimens are the most abundant form of P. stoppeli. It would appear that none of these forms can be considered to represent different stages in the evolution of this species since they all occur throughout the entire stratigraphic range of this taxon.

Questionably included in P. stoppeli is one specimen recovered from a sample from the Early rhomboidea Zone in the Nigel Peak section (sample NP86-58, Table V-6) which may represent an ancestor of this species. It is characterized by a somewhat diamond-shaped outline and a weak carina which appears to be flush with the ramp in the area of the azygous node (Pl. V-15, fig. 13). No other specimens like it were recovered.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1 to V-6, V-8 to V-11, V-14, V-15, V-17). Definite specimens of Palmatolepis stoppeli occur in the upper part of the Upper rhomboidea Zone and in the lower part of the Lower marginifera Zone. As noted above, a questionable specimen occurs in the Lower rhomboidea Zone.

"Palmatolepis quadrantinodosalobata group"

Remarks. Palmatolepis quadrantinodosalobata Sannemann, Morphotype 1 of this species and P. poolei Sandberg and Ziegler are treated herein as one group because they comprise a single lineage (Sandberg and Ziegler, 1973).

Palmatolepis poolei Sandberg and Ziegler, 1973
Pl. V-15, figs. 14-19, Pl. V-16, figs. 16, 17?, 18?

?1960	*Palmatolepis* (*Palmatolepis*) sp. aff. *crepida*, Clark and Becker, p. 1671, pl. 2, fig. 4 (only).
1973	*Palmatolepis poolei* Sandberg and Ziegler, p. 106, pl. 4, figs. 14-26.
1975	*Palmatolepis* cf. *poolei*, Dreesen and Dusar, pl. 24, fig. 20.
?1983	*Palmatolepis poolei*, Wang and Ziegler, pl. 3, fig. 12.
1984	*Palmatolepis poolei*, Dusar and Dreesen, p. 54, pl. 3, fig. 12.
1984	*Palmatolepis poolei*, Olivieri, p. 299, pl. 4, fig. 20.
1991	*Palmatolepis poolei*, Johnston and Chatterton, p. 178, pl. 1, fig. 17.
1991	*Palmatolepis poolei*, Irwin and Orchard, p. 208, pl. 3, fig. 9.

Types. Figured hypotypes GSC 100273, 107021-107025, 107039.

Diagnosis. See Sandberg and Ziegler (1973, p. 106).

Remarks. Most of our specimens of *Palmatolepis poolei* have the anterior margin of the outer platform terminating well short of the anterior end of the free blade, like specimens illustrated by Sandberg and Ziegler (1973, pl. 4, figs. 21, 24-26). Only in one specimen does the anterior margin of the outer platform almost reach the end of the free blade (Pl. V-15, fig. 15). We found that it was difficult to clearly distinguish juvenile specimens of this species from those of *P. quadrantinodosalobata* Morphotype 1, in collections where the two taxa co-occur.

Questionably included in *Palmatolepis poolei* are specimens in one of our collections (sample NP86-45, Table V-6) which have the same general outline as this species. One specimen, however, (Pl. V-16, fig. 17) has a moderately well developed outer lobe. Another specimen (Pl. V-16, fig. 18) has a reduced outer lobe but the rows of nodes do not have the typical concentric arrangement of nodes that converge on the azygous node on the anterior inner platform.

Occurrence. Palliser Formation and Wabamun Group (Tables V-6, V-7, V-14, V-16). The occurrence of *Palmatolepis poolei* is considered to indicate the presence of the Lower *rhomboidea* Zone, and its first and last occurrence defines the upper and lower limits of this zone in some of our sections (e.g. Nigel Peak, Table V-6; Gold Creek 10-31 well, Table V-14).

Palmatolepis quadrantinodosalobata Sannemann, 1955a
Pl. V-16, figs. 1-11, 14, 15

1955a	*Palmatolepis quadrantinodosalobata* Sannemann, p. 328, pl. 24, fig. 6.
1973	*Palmatolepis quadrantinodosalobata*, Sandberg and Ziegler, p. 105, pl. 4, figs. 33-41.
1973	*Palmatolepis quadrantinodosalobata* Morphotype 1 Sandberg and Ziegler, pp. 105, 106, pl. 4, figs. 27-32.
1976	*Palmatolepis quadrantinodosalobata*, Druce, pp. 166, 167, pl. 56, figs. 1?, 2.
1976	*Palmatolepis* cf. *poolei*, Dusar and Dreesen, p. 562, pl. 4, fig. 4.
1976	*Palmatolepis quadrantinodosalobata*, Bouckaert and Dreesen, p. 580, pl. 1, figs. 3, 4, 5?.
1979	*Palmatolepis* (*Manticolepis*) *quadrantinodosalobata*, van den Boogaard and Kuhry, pp. 35, 36, fig. 6 (Pa element only).
1981	*Palmatolepis quadrantinodosalobata*, Helms and Ziegler, p. W98, fig. 62.18.
1983	*Palmatolepis quadrantinodosalobata*, Wang and Ziegler, pl. 3, fig. 11.
1984	*Palmatolepis quadrantinodosalobata*, Dreesen, p. 210, pl. 1, fig. 7.
1984	*Palmatolepis quadrantinodosalobata*, Dusar and Dreesen, p. 53, pl. 2, fig. 6.
1984	*Palmatolepis quadrantinodosalobata*, Olivieri, pp. 299, 300, pl. 4, figs. 17?, 18; pl. 5, fig. 1.
1985	*Palmatolepis quadrantinodosalobata*, Klapper and Lane, p. 928, fig. 15.6.
1987	*Palmatolepis quadrantinodosalobata*, Matyja, p. 374, pl. 22.1, fig. 4.
?1988	*Palmatolepis triangularis* - *P.quadrantinodosalobata*, Bultynck, pl. A2/1, figs. 5, 6, 17, pl. 2, fig. 12.
?1989	*Palmatolepis* ex. gr. *quadrantinodosalobata*, Orchard, p. 46, pl. 3, fig. 7.
1989	*Palmatolepis quadrantinodosalobata*, Wang and Bai, p. 75, figs. 5.1-5.4.
?1989	*Palmatolepis quadrantinodosalobata*, Metzger, p. 517, fig. 13.31.
1989	*Palmatolepis quadrantinodosalobata*, Ji, pp. 296, 298, pl. 2, figs. 23, 24; pl. 3, figs. 1, 2.
1991	*Palmatolepis quadrantinodosalobata*, Johnston and Chatterton, p. 178, pl. 1, figs. 14-16.
1991	*Palmatolepis quadrantinodosalobata* Morphotype 1, Irwin and Orchard, p. 208, pl. 3, fig. 10.
1991	*Palmatolepis quadrantinodosalobata*, Irwin and Orchard, p. 208, pl. 3, fig. 14.

Types. Figured hypotypes GSC 100270, 100272, 107026-107034, 107037, 107038.

Diagnosis. See Ziegler (1973, p. 295).

Remarks. We recognize both early (Pl. V-16, figs. 1, 4, 5, 6) and late (Pl. V-16, figs. 2, 3, 11) forms of *Palmatolepis quadrantinodosalobata*. These are the same as those illustrated by Sandberg and Ziegler (1973, pl. 4, figs. 33, 34, 38-41). Some of our specimens, occurring just above and below the base of the Upper *crepida* Zone, have lateral lobes that are nearly as wide as the platform (Pl. V-16, fig. 6). We also have specimens with a platform outline like P. subperlobata Branson and Mehl, but with nodes on the anterior part of the inner parapet (Pl. V-16, fig. 10) just like those illustrated by Helms (1963, pl. 1, fig. 12) and Bultynck (1988, pl. A2/3, fig. 13).

We have also found that only our largest specimens of Palmatolepis quadrantinodosalobata Morphotype 1 (Sandberg and Ziegler, 1973), which are few in number, have the anterior margin of the outer platform terminating at or near the end of the free blade (Pl. V-16, figs. 14, 15) like the mature specimens of this morphotype illustrated by Sandberg and Ziegler (1973, pl. 4, figs. 27-31) which are comparable in size with our specimens. The majority of specimens of P. quadrantinodosalobata Morphotype 1 in our collections are smaller, with the anterior margin of the outer platform terminating well short of the anterior end of the blade (Pl. V-16, figs. 7-9), just like the juvenile specimen of this morphotype illustrated by Sandberg and Ziegler (1973, pl. 4, fig. 32). The apparent rarity of large intact specimens of P. quadrantinodosalobata Morphotype 1 that display all the diagnostic features of this taxon could be due to the fact that, in most of our collections, such specimens tend to be fragmentary.

We have previously assigned the specimen illustrated on plate 1, figure 15 in Johnston and Chatterton (1991) to Palmatolepis quadrantinodosalobata. This specimen should be regarded as belonging to Morphotype 1, since it shows the typical concentric arrangement of nodes on the inner parapet and the characteristic platform shape of this morphotype. We also have specimens transitional from typical P. quadrantinodosalobata to Morphotype 1 of this species, like those illustrated by Sandberg and Ziegler (1973, pl. 4, figs. 35-37), in our collections.

We have previously reported the occurrence of Palmatolepis quadrantinodosalobata as high as the Upper rhomboidea Zone (Johnston and Chatterton, 1991, p. 170). In this zone, this species is represented by a mature specimen of Morphotype 1 and another which is transitional to this morphotype.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1 to V-4, V-6, V-7, V-9 to V-16). Palmatolepis quadrantinodosalobata ranges from the Lower to Middle crepida zones to as high as the Upper rhomboidea Zone. Morphotype 1 of this species ranges from the upper part of the Upper crepida Zone into the Upper rhomboidea Zone (Table V-10).

"Palmatolepis rhomboidea group"

Remarks. Included in this group are Palmatolepis rhomboidea Sannemann and P. protorhomboidea Sandberg and Ziegler, which is presumably ancestral to or close to the ancestor of the former species. We also include in this group P. aff. P. protorhomboidea, a form with affinities to the latter species. We include as well a form perhaps conspecific with the ancestral species of all these taxa, i.e. P. delicatula Branson and Mehl. (e.g. Helms and Ziegler, 1981).

Palmatolepis cf. P. delicatula Branson and Mehl, 1934a
Pl. V-16, fig. 19

cf. 1934a Palmatolepis delicatula Branson and Mehl, p. 237, pl. 18, figs. 4, 10.

Type. Figured specimen GSC 107042.

Remarks. The single specimen assigned to Palmatolepis cf. P. delicatula in our collections has generally a similar platform outline to P. delicatula, but it differs in several ways. One difference is that the platform in our specimen is not as thick as typical specimens of P. delicatula (i.e. it is more delicate). Also, the platform, rather than being almost flat, slopes downward away from the azygous node and blade and carina. The platform is also undulatory. It is for these reasons that we cannot assign this specimen to P. delicatula with certainty.

A similar specimen, identified as ?Palmatolepis delicatula was illustrated by Bultynck (1988, pl. A2/3, fig. 3) from the Lower to Middle crepida zone in Belgium. However, the anterior margin of the inner platform meets the blade at a more acute angle in this specimen than in ours. Also, this specimen appears flatter than our specimen.

Occurrence. Palliser Formation (Table V-1). Palmatolepis cf. P. delicatula occurs in the Lower to Middle crepida zones.

Palmatolepis protorhomboidea Sandberg and Ziegler, 1973
Pl. V-16, figs. 12, 13; Pl. V-17, figs. 1, 2?, 3, 7, 8

1973	Palmatolepis delicatula protorhomboidea Sandberg and Ziegler, p. 103, pl. 1, figs. 14-19.
1990	Palmatolepis protorhomboidea, Ziegler and Sandberg, p. 68-69, pl. 17, figs. 8-11 (contains synonymy to 1990).
1991	Palmatolepis delicatula protorhomboidea, Johnston and Chatterton, p. 178, pl. 1, fig. 13.

Types. Figured hypotypes GSC 107035, 107036, 107043, 107045-107049.

Diagnosis. See Ziegler and Sandberg (1990, p. 68).

Remarks. Specimens in our collections show a great deal of variation ranging from those that are close to the holotype of this species (e.g. Pl. V-17, fig. 7) to specimens which have a somewhat more rounded platform (e.g. Pl. V-17, figs. 1, 3). Nevertheless, all specimens retain a moderately to strongly developed parapet on the anterior portion of the inner platform and many have a thickened anterior border of the outer platform (e.g. Pl. V-16, fig. 13).

Specimens which resemble the holotype of Palmatolepis protorhomboidea the most are abundant in two samples in one of our sections (Wardner, samples PL-23-686 and PL-23-687, see Table V-1). However, in sample PL-23-686, some specimens are apparently transitional to Palmatolepis quadrantinodosalobata by showing an elongation of the outer lobe (Pl. V-17, fig. 8). Specimens which are less elongate and more rounded in outline are common in all our other collections that contain P. protorhomboidea.

Some specimens were assigned to Palmatolepis protorhomboidea with question because it was difficult to determine whether the outer margin of the anterior portion of the inner platform was an upturned rim or a parapet. In the former case such specimens could also be assigned to P. ovata n. sp..

A single fragmentary specimen, characterized by a prominent parapet and a thickened anterior margin of the outer platform (Pl. V-17, fig. 2) occurs with Palmatolepis rhomboidea Sannemann in one of our sections (Nigel Peak, sample NPW86-19, Table V-6). This specimen is questionably referred to Palmatolepis protorhomboidea. If this specimen is indeed this species, then this occurrence would appear to represent a range extension of P. protorhomboidea to as high as the Upper rhomboidea Zone (see Johnston and Chatterton, 1991). Palmatolepis protorhomboidea is presently known to range only as high as the Uppermost crepida Zone (Ziegler and Sandberg, 1990).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-6, V-7, V-11 to V-13, V-15, V-16). Specimens of Palmatolepis protorhomboidea ranges from the Lower to Middle crepida zones to the Upper crepida Zone (Parkland 10-28 well, Table V-15). As noted above, this species may range as high as the Upper rhomboidea Zone.

Palmatolepis aff. P. protorhomboidea

Sandberg and Ziegler, 1973
Pl. V-17, figs. 11, 12

aff. 1973	*Palmatolepis delicatula protorhomboidea* Sandberg and Ziegler, p. 103, pl. 1, figs. 14-19.

Types. Figured specimens GSC 107052, 107053.

Remarks. The few specimens assigned to this taxon are characterized by an elongate, ovoid, undulatory platform that has a small, sharp parapet at the anteriormost extremity of the inner platform. These specimens differ sharply from *Palmatolepis protorhomboidea* Sandberg and Ziegler by the relative narrowness of their platforms.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-12). As presently known, *Palmatolepis* aff. *P. protorhomboidea* is confined to the Lower to Middle *crepida* zones.

Palmatolepis rhomboidea Sannemann, 1955a
Pl. V-17, fig. 4-6, 9, 10, 13-15

1955a	*Palmatolepis rhomboidea* Sannemann, p. 329, pl. 24, fig. 14.
1973	*Palmatolepis rhomboidea*, Ziegler, pp. 299-301, *Palmatolepis* - pl. 1, figs. 6, 7 (contains synonymy to 1973).
1974	*Palmatolepis rhomboidea*, Dreesen and Dusar, pl. 7, figs. 11, 12.
?1976	*Palmatolepis rhomboidea*, Spassov and Filipović, p. 10, pl. 1, fig. 14.
1979	*Palmatolepis* (*Conditolepis*) *rhomboidea*, van den Boogaard and Kuhry, pp. 52, 53, fig. 25 (Pa element only).
1981	*Palmatolepis rhomboidea*, Helms and Ziegler, p. W98, fig. 62.16.
1984	*Palmatolepis rhomboidea*, Dusar and Dreesen, p. 54, pl. 3, fig. 3.
1984	*Palmatolepis rhomboidea*, Olivieri, p. 300, pl. 4, figs. 4-6.
1991	*Palmatolepis rhomboidea*, Johnston and Chatterton, p. 178, pl. 1, fig. 19.
1991	*Palmatolepis rhomboidea*, Irwin and Orchard, p. 208, pl. 3, fig. 6.
1993	*Palmatolepis rhomboidea*, Johnston and Meijer Drees, p. 145, pl. 1, fig. 13.

Types. Figured hypotypes GSC 98138, 107046, 107047, 107050, 107051, 107054-107056.

Diagnosis. See Ziegler (1973, p. 299).

Remarks. Several morphotypes of this species, which appear connected by transitional forms, are represented in our collections. Specimens with a platform that is widest anteriorly which tapers to a point posteriorly and with a prominent, rounded bulge (e.g. Pl. V-17, fig. 4) characterize the first morphotype. This particular morphotype is present at either the first or the only occurrence of Palmatolepis rhomboidea in several of our sections. The second morphotype, which usually occurs stratigraphically higher than the first in four of our sections, is more rounded in outline and has a conspicuous, rounded bulge on the anterior part of the inner platform which is almost a parapet in some specimens (e.g. Pl. V-17, fig. 9). Specimens of this morphotype have the strongest resemblance to those of Sandberg and Ziegler's (1973, pl. 1, figs. 24-26) However, our specimens differ from these in that they lack as strong a posterior carina and the platform outline is much rounder.

A third morphotype of Palmatolepis rhomboidea occurs with the second morphotype at Nigel Peak and stratigraphically above it at Medicine Lake. This morphotype is characterized by a slightly more elongate platform and a bulge which is not as pronounced as in the second morphotype (Pl. V-17, figs. 6, 15). Occurring with this third morphotype are specimens which actually appear transitional to the first morphotype.

Two additional morphotypes of Palmatolepis rhomboidea each occur in the Wardner, B.C. section of the Palliser Formation and in the Parkland 10-26 well in the Wabamun Group (see Tables V-1, V-15). Both morphotypes are characterized by mature specimens which generally have a more rectangular platform than specimens of the other morphotypes. In the Wardner section (sample PL-23-689, Table V-1), mature specimens generally have a prominent bulge on the anterior part of the inner platform (Pl. V-17, fig. 14). Mature specimens of P. rhomboidea in the Parkland 10-26 well (sampled interval 11422 ft. to 11436 ft., Table V-15) have a somewhat more subdued bulge (Pl. V-17, fig. 5). In both samples small specimens, and in PL-23-689, a few mature specimens (e.g. Pl.

V-17, fig. 10), are more like the first morphotype in appearance.

The temporal relationship of the morphotypes of Palmatolepis rhomboidea represented in the Parkland 10-26 well and in the Wardner B.C. section to each other and to the first three morphotypes of this species is uncertain. Stratigraphical and sedimentological evidence, however, does suggest that spatially these two morphotypes of P. rhomboidea probably lived in more offshore and/or deeper water environments than the other morphotypes.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-4, V-6, V-7, V-9 to V-11, V-14, V-15). Palmatolepis rhomboidea is confined to the Upper rhomboidea Zone.

Palmatolepis subperlobata Branson and Mehl, 1934a
Pl. V-17, figs. 16-18;
Pl. 18, figs. 7, 8, 12, 13?, 14?, 15-19

1934a	Palmatolepis subperlobata Branson and Mehl, p. 235, pl. 18, figs. 11, 21.
1974	Palmatolepis subperlobata, Dreesen and Dusar, pl. 7, figs. 8-10.
1976	Palmatolepis subperlobata, Druce, pp. 170, 171, pl. 58, fig. 1; pl. 63, figs. 3, 4.
1976	Palmatolepis subperlobata subsp. a, Druce, p. 171, pl. 58, figs. 2, 3?, 5.
1978	Palmatolepis subperlobata, Orchard, p. 936, pl. 115, fig. 2.
1981	Palmatolepis subperlobata, Helms and Ziegler, p. W98, fig. 62.21.
1983	Palmatolepis subperlobata, Wang and Ziegler, pl. 3, figs. ?24-26, 28.
1984	Palmatolepis subperlobata, Olivieri, p. 301, pl. 4, figs. 14, 15.
1985	Palmatolepis subperlobata, Austin, Orchard and Stewart, p. 150, pl. 4.6, fig. 14.
1985	Palmatolepis subperlobata, Ji and Liu, p. 179, pl. 1, figs. 28, 29.
1985	Palmatolepis subperlobata, Ziegler and Wang, p. 36, pl. 4, fig. 11.
1985	Palmatolepis tenuipunctata, Ziegler and Wang, p. 36, pl. 4, figs. 9, 12.
1988	Palmatolepis subperlobata, Bultynck, p. 24, pl. A2/1, figs. 15, 16; pl. A2/2, fig. 18.
1989	Palmatolepis subperlobata, Ji, p. 296, pl. 2, figs. 25-27.
1991	Palmatolepis subperlobata, Johnston and Chatterton, p. 178, pl. 1, figs. 20, 24.
1991	Palmatolepis subperlobata, Irwin and Orchard, p. 208, pl. 3, fig. 4.
1993	Palmatolepis subperlobata, Johnston and Meijer Drees, p. 145, pl. 1, fig. 17.

Types. Figured hypotypes GSC 100280, 107058, 107064, 107065, 107067, 107070-107074.

Diagnosis. See Branson and Mehl (1934a, p. 235).

Remarks. Two morphotypes of this species are presently recognized in our collections (see also Johnston and

Chatterton, 1991). One morphotype is characterized by specimens with the outer lobe more or less situated halfway along the length of the element. Mature specimens of this morphotype are usually much larger than the other morphotype of *Palmatolepis subperlobata* and are much more robust in appearance (e.g. compare Pl. V-17, figs. 17, 18 with Pl. V-18, figs. 7, 8, 12, 15-19). In one large specimen (Pl. V-17, fig. 18), nodes are developed on the anteriormost portion of the inner platform.

The other smaller morphotype also has the outer lobe situated at mid-length (e.g. Pl. V-18, fig. 18). Several specimens may even have the outer lobe situated more posteriorly (Pl. V-18, fig. 15). In a few specimens, the outer lobe may even be directed somewhat posteriorly (Pl. V-18, fig. 17) as well. Included in this morphotype are specimens with very narrow platforms (Pl. V-18, figs. 8, 12, 19). Specimens of this morphotype appear transitional to *Palmatolepis tenuipunctata* Sannemann in terms of the shape of the anterior margin of the inner platform, which appears to meet the blade/carina at a nearly acute angle (Pl. V-18, fig. 7). Elements of this morphotype also exhibit a great degree of variability in terms of outer lobe development, platform width, etc.

Specimens of the first morphotype occur in the Upper to Uppermost *crepida* zones in both the Nigel Peak and Medicine Lake sections and in the Upper *crepida* Zone in the Smoky Heights 14-22 and Parkland 10-28 wells (Tables V-6, V-7, V-15, V-16). In the Nigel Peak section, specimens of the second morphotype occur abundantly in the Lower *rhomboidea* Zone (Table V-6). This morphotype also occurs in abundance in strata dated as Uppermost *crepida* to lowermost Lower *rhomboidea* zones in the Parkland 10-28 well (Table V-15).

It is possible that the first morphotype of *Palmatolepis subperlobata* was ancestral to the second morphotype of this species. Alternatively, these morphotypes may represent ecophenotypes of *P*. *subperlobata*. This latter hypothesis is partly supported by the occurrence of the second morphotype in shaly carbonates in the Nigel Peak section and the Parkland 10-28 well.

We also tentatively include in *Palmatolepis* *subperlobata* specimens which have the same general outline as this species but the anterior margin of the outer platform terminates well short of the anterior end of the free blade (Pl. V-18, fig. 14). We also questionably assign to *P*. *subperlobata* specimens which also have the same general outline as this species but lack a well defined lateral lobe (Pl. V-18, fig. 13).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-4, V-6, V-7, V-11, V-14 to V-16). *Palmatolepis* *subperlobata* ranges from the Lower to Middle *crepida* to Lower *rhomboidea* zones in our collections.

Family POLYGNATHIDAE Bassler, 1925

Remarks. In addition to *Polygnathus* and *Polylophodonta*, we include in this family species assigned to new genera A and B. The assignment of New Genus B to the Polygnathidae is based on its similarity to forms of *Ancyrognathus* that lack a lateral lobe (e.g. *A*. *cryptus* Ziegler, *A*. *sinelaminus* Branson and Mehl) and which probably belong in a separate genus (Klapper, 1990). However, these forms would still be considered to belong to the Polygnathidae, like other species of *Ancyrognathus* with a lateral lobe (Sweet, 1988; Klapper, 1990). One of our species of New Genus B may have a trace of this lateral lobe (see below).

Genus *Polygnathus* Hinde, 1879

Type *species*. *Polygnathus* *dubia* Hinde, 1879.

Remarks. Several groups of species of this genus in our collections are treated under previously recognized categories (e.g. "*nodocostatus*" group of Helms, Sandberg and Ziegler, 1979; = "*germanus* group" herein) which emphasize their close phylogenetic relationship. All other species of this genus, however, are treated alphabetically.

"*Polygnathus communis* group"

Remarks. Included in this group are *Polygnathus communis* Branson and Mehl, *P. glaber* Ulrich and Bassler, *P.* sp. A and *P.* sp. B. We use a slightly modified definition for this group from that employed by Sandberg and Ziegler (1979, p. 188) in that we include *P. glaber*. This species has the same lanceolate to ovate outline of the platform as other species assigned to this group, but lacks the characteristic depression posterior to the basal pit (e.g. Klapper, 1975, p. 75).

Polygnathus sp. A is provisionally included in this group because of the presence of a strong to weak depression posterior to the basal pit in this species and the intergradational nature of some juvenile specimens with the same growth stage of *P. communis* (see below). It is because of the presence of a slight posterior depression in some specimens of *P.* sp. B and its general morphological similarity to *P.* sp. A that we also provisionally include this taxon in this group.

Polygnathus communis Branson and Mehl, 1934b
Pl. V-18, figs. 1-6, 9-11

1934b	*Polygnathus communis* Branson and Mehl, p. 293, pl. 24, figs. 1-4.
1966	*Polygnathus communis*, Klapper, p. 21, pl. 6, figs. 6, 11.
1974	*Polygnathus communis communis*, Dreesen and Dusar, p. 13, pl. 1, figs. 21-29; pl. 4, figs. 3-9; figs. 9, 10.
1975	*Polygnathus communis communis*, van den Boogaard and Schermerhorn, p. 10, pl. 7, figs. 1, 2.
1979	*Polygnathus burtensis*, Nicoll and Druce, p. 28, pl. 15, fig. 2.
1979	*Polygnathus communis collinsoni*, Nicoll and Druce, pp. 28-29, pl. 16, figs. 1-6.

1979	*Polygnathus communis communis*, Nicoll and Druce, p. 29, pl. 15, fig. 1.
1982	*Polygnathus communis communis*, Wang and Ziegler, pl. 1, figs. 2, 3.
1983	*Polygnathus communis communis*, Spassov, p. 17, pl. 1, fig. 20; pl. 2, figs. 13, 14.
1983	*Polygnathus communis communis*, Wang and Ziegler, pl. 8, figs. 3, 4.
?1984	*Polygnathus communis communis*, Austin and Davies, pl. 1, fig. 1.
?1985	*Polygnathus communis communis*, Hayes, p. 75, pl. 2, figs. 9-11.
?1985	*Polygnathus communis communis*, Ji and Liu, p. 179, pl. 1, figs. 9, 10.
1985	*Polygnathus communis communis*, Varker and Sevastopulo, p. 190, pl. 5.1, figs. 12, 16, 17.
1987	*Polygnathus communis communis*, Ji, p. 20, pl. 1, figs. 11, 14, 15.
?1987	*Polygnathus communis communis*, Matyja, p. 377, p. 22.4, fig. 5.
1987	*Polygnathus communis communis*, Yu, Wang, Ruan, Yin, Baoan, Li and Wei, pl. 3, figs. 17-21.
?1989	*Polygnathus depressus* Metzger, pp. 518-520, figs. 14.2-14.6.
1991	*Polygnathus communis communis*, Johnston and Chatterton, p. 180, pl. 2, figs. 11, 12.

Types. Figured hypotypes GSC 100291, 100292, 107059-107063, 107066.

Diagnosis. See Klapper (1966, p. 21).

Remarks. In addition to typical specimens of *Polygnathus communis* (e.g. Pl. V-18, figs. 5, 6, 11), we also have in our collections specimens that have extremely swollen lateral margins of the platform (e.g. Pl. V-18, figs. 1, 3), like those illustrated by Klapper (1966 - see synonymy) and by Nicoll and Druce (1979, pl. 16, figs. 5 and 6). These forms are commonly the largest specimens of this species that occur in collections from uppermost Palliser and Wabamun strata. Specimens of *P. communis* intermediate in size in these same collections typically have nodes developed at the antero-lateral margin of the platform (Pl. V-18, fig. 4).

Specimens of *Polygnathus communis* from the Upper *rhomboidea* Zone generally have a shallower depression posterior to the basal pit (e.g. Pl. V-18, fig. 9). Some of these specimens are also intergradational to those that we have assigned to *P.* sp. A (see Remarks for the latter species). A few specimens we have from this zone also appear to have the rounded and ornamented platforms like specimens illustrated by Metzger (1989 - see synonymy).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-3 to V-10, V-14, V-17). Polygnathus communis ranges from the Upper rhomboidea to at least as high as the Lower expansa Zone in these formations.

Polygnathus glaber Ulrich and Bassler, 1926
Pl. V-19, figs. 1-4, 5?, 6?

1926	Polygnathus glaber Ulrich and Bassler, p. 46, pl. 7, fig. 13.
1968	Polygnathus glabra, Huddle, p. 39, pl. 15, figs. 13-17.
1975	Polygnathus glaber glaber, Klapper, pp. 283, 284, Polygnathus - pl. 5, fig. 1 (contains synonymy to 1969).
?1976	Polygnathus glaber glaber, Druce, p. 190, 191, p. 74, figs. 4, 5; pl. 76, fig. 1 (only).
1983	Polygnathus glaber glaber, Wang and Ziegler, pl. 8, fig. 2.
1984	Polygnathus glaber glaber, Olivieri, p. 292, pl. 8, figs. 1-3.
?1985	Polygnathus glaber glaber, Ji and Liu, p. 179, pl. 1, figs. 11-14.
1991	Polygnathus glaber glaber, Johnston and Chatterton, p. 180, pl. 2, fig. 13.

Types. Figured hypotypes GSC 100293, 107075, 107076.

Diagnosis. See Klapper (1975, p. 283).

Remarks. The few specimens of Polygnathus glaber in our collections range from typical forms (e.g. Pl. V-19, figs. 1, 2) to more elongate forms that have thickened platform margins (e.g. Pl. V-19, figs. 3, 4). Other small and/or fragmentary specimens in our collections are questionably assigned to this species. This includes one specimen from the Parkland 10-28 well (Pl. V-19, figs. 5, 6), which appears to have the same general outline and morphological features as topotype specimens illustrated by Huddle (1968, pl. 15, figs. 14, 15). However, the platform edges in our specimen do not appear as strongly upturned as in Huddle's (1968) specimens.

Occurrence. Palliser Formation and Wabamun Group (Tables V-6, V-10, V-15). Polygnathus glaber ranges from the Lower to Middle crepida zones to possibly as high as the Upper postera Zone in these units.

Polygnathus sp. A
Pl. V-19, figs. 7-17

Types. Figured specimens GSC 107078-107083.

Remarks. Specimens assigned to this taxon have a coarsely ornamented upper side of the platform. They are provisionally assigned to the Polygnathus communis group, however, because of the presence of a depression posterior to the basal pit on the lower side of the platform (Pl. V-19, figs. 8, 10, 13, 17). This taxon is not formally named because of the relatively small number of specimens present in our collections.

In mature specimens, ornamentation ranges from strong transverse ribs and nodes anteriorly to mostly nodes on the posterior half to third of the platform (e.g. Pl. V-19, fig. 7). There is also asymmetrical development of the platform in mature specimens. Platform asymmetry is most pronounced in stratigraphically older specimens (e.g. Pl. V-19, figs. 7-11) but is hardly discernable in younger ones (Pl. V-19, figs. 14-17). The free blade may be long with numerous confluent denticles to short with a few robust denticles. In juvenile specimens (e.g. Pl. V-19, fig. 12), the upper surface is ornamented by nodes.

Stratigraphically older forms of this taxon generally have a deep depression posterior to the basal pit (Pl. V-19, figs. 8, 10) whereas in younger forms this depression is very shallow (Pl. V-19, fig. 17). Early growth stages of the late form have a very shallow depression (Pl. V-19, fig. 13). Earliest growth stages in both early and late forms of this species may have only a few nodes developed along the margin of the platform which, in some specimens, were barely discernable. This made it difficult in some cases to distinguish specimens like these from the same growth stage of Polygnathus communis Branson and Mehl.

Polygnathus sp. A may have been the direct ancestor of P. sp. B. The latter species may have evolved for the former by the loss or reduction of the depression on the lower side of the platform and by the development of strong transverse ornamentation anteriorly.

Occurrence. Palliser Formation and Wabamun Group (Tables V-3, V-7, V-9 to V-11, V-14). As presently known, the stratigraphic range of *Polygnathus* sp. A appears to be confined to the Upper *rhomboidea* Zone.

Polygnathus sp. B
Pl. V-20, figs. 1-10

Types. Figured specimens GSC 107084-107090.

Remarks. The few specimens that we have assigned to this taxon are characterized by a coarsely ornamented upper platform surface much like *Polygnathus* sp. A (see Remarks for that species), However, they either lack (Pl. V-20, fig. 3) or have a very shallow depression posterior to the basal pit. The basal pit also has a thicker rim as does the keel in both juvenile (e.g. Pl. V-20, fig. 7) and mature specimens. These specimens also appear to have stronger transverse ornamentation anteriorly (Pl. V-20, fig. 6). They also have a short to moderately long free blade which has either a few robust or several medium-sized denticles (Pl. V-20, fig. 9).

We retain *Polygnathus* sp. B as a separate taxon from *P.* sp. A, because of the pronounced difference in morphology between mature specimens of both taxa that occur in one sample (compare Pl. V-19, figs. 7, 8 with Pl. V-20, figs. 8, 9). However, because of the possible close phylogenetic relationship between *P.* sp. A and *P.* sp. B, we also provisionally include the latter species in the *Polygnathus communis* group.

Occurrence. Palliser Formation (Tables V-7 to V-10). As presently known, Polygnathus sp. B is confined to the Upper rhomboidea Zone.

Polygnathus crassilabrus n. sp.
Pl. V-20, figs. 11-19; Pl. V-21, figs. 1-5

1972	Polygnathus aff. procerus, Matyja, p. 747, pl. 4, figs. 9, 10.
1987	Polygnathus aff. P. procerus, Matyja, pp. 375, 376, pl. 22.2, fig. 5; pl. 22.3, fig. 4.

Etymology. From the Latin crassus, meaning thick and labrum, meaning lip; referring to the thick-lipped appearance of the platform in upper view.

Typ[illegible] [illegible]ype GSC 107091, illustrated on Plate V-20, figures 11, [illegible] [illegible]types GSC 107092-107097, illustrated on Plate V-20, [illegible] [illegible]3-19, Plate V-21, figures 1-5.

Material. About 1[illegible]5 specimens.

Diagnosis. A species of Polygnathus with an ovoid to elongate platform characterized by thickened upper platform margins separated from the carina by generally deep adcarinal grooves.

Description. Platform ovoid to elongate and narrow. Element nearly straight to moderately bowed and weakly to moderately arched. Platform margins rounded and thickened, separated from the carina by generally deep adcarinal grooves. Widest part of thickened margin situated approximately at mid-length of platform.

Free blade approximately one-half to one-quarter length of element. Denticles on free blade nearly confluent to tips, approximately equal in height and size or increasing in height slightly to about mid-length of the free blade and then decreasing in height anteriorly. Carina fused for most of its length, denticulated only at its anteriormost extremity.

Crimp on lower side of platform occupies approximately half the width of the platform between the lateral margin and the keel. Keel low, basal pit small, elliptical to elongate slit.

Remarks. *Polygnathus crassilabrus* differs from *P. glaber* Ulrich and Bassler by having a much less pointed posterior platform and thickened upper platform margins. *Polygnathus crassilabrus* also lacks the raised, strongly elliptical basal pit of the latter species. *Polygnathus crassilabrus* differs from *P. procerus* Sannemann by having denticles on the free blade that are nearly equal in height and in size. The platform margins of *P. crassilabrus* also appear thicker than the same margins on the holotype of *P. procerus* (Sannemann, 1955b, Pl. 1, fig. 11). *Polygnathus crassilabrus* differs from *P. meijerdreesi* n. sp. by having rounded upper platform margins as opposed to sharp as in the latter species. Denticles on the free blade also tend to be less numerous and robust than in *P. meijerdreesi*. In some collections, juvenile specimens, and in some cases, small mature specimens, of *P. crassilabrus* were distinguished from some specimens of *P. semicostatus* Branson and Mehl with difficulty.

In our collections we note there is a complete gradation between specimens of *Polygnathus crassilabrus* that are moderately bowed and that have an ovoid platform (Pl. V-20, figs. 11, 12, 15, 16) to those which are straight and have an elongate and narrow platform (Pl. V-21, figs. 3-5). Specimens of this species from Poland (see synonymy) resemble the latter forms. In early forms of this species there are faint transverse ridges posteriorly in some specimens (Pl. V-20, fig. 19). Early forms appear to have a shorter free blade with fewer denticles (Pl. V-20, fig. 18).

Occurrence. Palliser Formation and Wabamun Group (Tables V-2 to V-4, V-6, V-8 to V-11, V-15, V-17). As presently known, *Polygnathus crassilabrus* ranges from the upper part of the

Upper rhomboidea Zone to at least the Upper marginifera Zone in most sections. In the Nigel Peak section, it appears to range at least as high as the Uppermost marginifera Zone (sample NPW89-17, Table V-6).

Polygnathus dolichopleurus n. sp.

Pl. V-21, figs. 6-19, 20?, 21, 22; Pl. V-22, figs. 19-21

?1968 Polygnathus nodocostata, Mound, pp. 507, 508, pl. 69, figs. 26, 27.

Etymology. From the Greek dolicho, meaning long and pleura, meaning rib; referring to the prominent longitudinal costae on the upper side of the platform.

Types. Holotype GSC 107102, illustrated on Plate V-21, figures 16-18; paratypes GSC 107098-107101, 107103, 107105, 107114, illustrated on Plate V-21, figures 6-15, 19-21; Plate V-22, figures 19-21.

Material. About 80 specimens.

Diagnosis. A species of Polygnathus with a narrow to broad platform characterized by a series of costae running parallel to the carina for the entire length of the platform. In larger specimens these costae may be highly sinuous and even discontinuous.

Description. Platform elongate and somewhat narrow in juvenile and some mature specimens, broad in mature specimens. In most specimens the platform is wider on the outer side than on the inner side and in some specimens the outer side is more convex, becoming almost lobate anteriorly. Element weakly to moderately bowed in upper view; moderately to strongly arched in lateral view. Upper platform characterized by series of costae parallel to the carina running the entire length of the platform, numbering from one or two to as much as four on either side of the carina. Costae may be straight to somewhat sinuous; costae generally tend to be highly sinuous and even discontinuous in large specimens. Costae generally diverge away from the carina at a low angle anteriorly.

Free blade one-third to one-fourth length of element. Free blade denticles moderately to strongly robust, generally free at their tips. Denticles increase in height and size to about mid-length of free blade then decrease in height anteriorly. Carina continuous ridge to posterior end platform and is usually same height as costae. In many specimens the carina is nodose from about mid-length of the platform to the posterior end.

Crimp on lower side of platform occupies half the width between the platform margin and the keel in juvenile specimens to one-third to one-fourth this width in mature specimens. Keel sharp, somewhat low in most mature specimens. Basal pit fine, elongate slit in most mature specimens to elliptical in juvenile specimens. Basal pit situated just anterior to point of flexure of element on lower side.

Remarks. Mature specimens of Polygnathus dolichopleurus are distinguished from species belonging to the "germanus - group" of Polygnathus (see below) by having elongate costae on the upper side of the platform as opposed to rows of nodes. Juvenile specimens of P. dolichopleurus are distinguished from similar specimens of P. meijerdreesi n. sp. by showing a slight flaring of the outer platform (compare Pl. V-21, figs. 6-15 with Pl. V-23, figs. 6, 12) anteriorly. Denticles on the free blade are also generally more numerous and less robust in P. dolichopleurus. However, some early growth stages of this species were distinguished with difficulty from those of P. meijerdreesi. The latter species was the probable ancestor of P. dolichopleurus (see Remarks for P. meijerdreesi).

In some of our Palliser sections, the lower part of the stratigraphic range of Polygnathus dolichopleurus overlaps with the upper part of the range of P. meijerdreesi, usually several tens of metres above the base of the formation. This would appear to suggest that the former species evolved from the latter late in the life span of the latter species. However, in the Whiteman Gap section, P. dolichopleurus may have its first appearance at the base of the Palliser Formation (Table V-3). This could suggest that the evolution of this species from P. meijerdreesi could have happened at a much earlier time than that suggested by evidence from the other sections.

There appears to be in some of our collections, an intergradation of specimens with more or less straight upper platform costae to specimens with costae that are sinuous, and in some cases, are also discontinuous. In one gerontic specimen (Pl. V-22, fig. 19-21), the upper surface of the platform consists completely of sinuous costae that are continuous and discontinuous, with some connected transversely. On the outer side of the platform, the costae are subradial and may be interspersed with nodes.

Questionably included in this concept are specimens with elongate, narrow platforms with one or two costae to either side of the carina (Pl. V-21, fig. 20).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1 to V-4, V-6, V-7, V-10, V-11, V-15, V-16). As presently known, Polygnathus dolichopleurus appears to range from the Lower to Middle crepida zones to lower part of the Upper crepida Zone.

Polygnathus fallax Helms and Wolska, 1967?
Pl. V-22, figs. 14, 16

?1967 Polygnathus fallax Helms and Wolska, pp. 231, 232, fig. 3.

Types. Figured specimen GSC 107112.

Remarks. The one fragmentary specimen we illustrate appears to have the typical upper platform ornamentation (Pl. V-22, fig. 16) and basal pit configuration (Pl. V-22, fig. 14) of *Polygnathus fallax*. However, because not enough of the specimen is present for a positive identification, we can only questionably assign it to the latter species.

Occurrence. Palliser Formation (Table V-5). The figured specimen comes from strata that range in age from the Uppermost *marginifera* to Upper *trachytera* zones.

Polygnathus aff. *P. fallax* Helms and Wolska, 1967
Pl. V-22, figs. 1-3?, 4-13, 15, 17, 18

aff. 1967 *Polygnathus fallax* Helms and Wolska, pp. 231, 232, fig. 3.

Types. Figured specimens GSC 107106?, 107107-107111, 107113.

Remarks. The few specimens we assign to this taxon differ from *Polygnathus fallax* by having the platform broadest anteriorly instead of medially, although it is lanceolate like in the latter species. The platform is weakly to strongly asymmetrical in most specimens (e.g. Pl. V-22, figs. 5, 8, 10, 11). The basal pit is symmetrical in our specimens as opposed to asymmetrical as in the holotype of *P. fallax* (Helms and Wolska, 1967, fig. 3a). Juvenile specimens have a basal pit which is nearly circular, and with thickened margins (Pl. V-22, fig. 5). The basal pit becomes more elongate with more subdued margins in mature specimens.

The upper platform ornamentation, although fine as in *Polygnathus fallax*, is not developed to as great a degree in our specimens as in the latter species. Most specimens of *Polygnathus* aff. *P. fallax* are straight to gently bowed and weakly arched. However, one specimen shows a greater degree of arching in lateral view (Pl. V-22, fig. 4).

We include in *Polygnathus* aff. *P. fallax* a middle Famennian form (see below) having the same ornamentation and an asymmetrical platform (Pl. V-22, figs. 12, 13). The basal pit has a thickened margin (Pl. V-22, fig. 12). We also tentatively include a specimen that occurs in the same sample as the one just described. The platform in this specimen is highly asymmetrical and the keel is higher and sharper (Pl. V-22, figs. 1-3). The basal pit margins do not appear to be as thick as the same margins in the other specimen (Pl. V-22, fig. 3).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-2, V-6, V-7, V-9, V-12, V-13). As presently known, the majority of specimens of *Polygnathus* aff. *P. fallax* are restricted to the Lower to Middle *crepida* Zone in these units. The youngest specimen assigned to this taxon (see above) as well as the one questionably assigned to it, occur in strata probably assignable to the Upper *rhomboidea* Zone (Table V-2).

"*Polygnathus germanus* group"

Remarks. Our treatment of this group of polygnathids generally follows that of Helms (1961) and Sandberg and Ziegler (1979). In this group are placed polygnathids with broad platforms and variably developed nodes and ridges. In our collections this includes specimens of *Polygnathus germanus* Ulrich and Bassler, *P. perplexus* Thomas and *P.* cf. *P. homoirregularis* Ziegler.

Polygnathus germanus Ulrich and Bassler, 1926
Pl. V-23, figs. 7-10, 17, 22

1926	*Polygnathus germanus* Ulrich and Bassler, p. 46, pl. 7, figs. 11, 12.
1934a	*Polygnathus rhomboidea*, Branson and Mehl, p. 245, pl. 21, fig. 8 (only).
1934a	*Polygnathus nodocostata* Branson and Mehl, pp. 246, 247, pl. 20, figs. 9-13; pl. 21, fig. 15.
1934a	*Polygnathus varinodosa* Branson and Mehl, pp. 249, pl. 20, fig. 15.
1961	*Polygnathus nodocostata incurva* Helms, pp. 686, 687, pl. 1, figs. 14-16; fig. 5.
1961	*Polygnathus nodocostata nodocostata*, Helms, pp. 687, 688, pl. 1, figs. 17, 21, 23; pl. 2, figs. 16-20, 22; fig. 6.
1961	*Polygnathus nodocostata ovata* Helms, pp. 688, 689, pl. 1, figs. 25, 26; pl. 2, figs. 24, 27, 28; fig. 7.
1961	*Polygnathus nodocostata* cf. *ovata* Helms, p. 703, pl. 1, figs. 13, 24.
1968	*Polygnathus germana*, Huddle, pp. 38, 39, pl. 14, figs. 29, 30.

1976	*Polygnathus germanus germanus*, Druce, pp. 188, 189, pl. 74, figs. 1-3, 6.
1976	*Polygnathus nodocostatus nodocostatus*, Dusar and Dreesen, p. 558, pl. 2, fig. 4.
?1983	*Polygnathus nodocostatus ovatus*, Spassov, p. 18, pl. 2, fig. 1; pl. 3, fig. 10.
1984	*Polygnathus nodocostatus*, Olivieri, p. 290, pl. 7, figs. 10-12.
1985	*Polygnathus nodocostatus*, Austin Orchard and Stewart, p. 154, pl. 4.7. figs. 20, 21.
?1985	*Polygnathus nodocostatus nodocostatus*, Klapper and Lane, p. 941, fig. 21.10.
?1987	*Polygnathus* ex. gr. *nodocostatus*, Matyja, p. 376, pl. 22.3. fig. 11.
1991	*Polygnathus nodocostatus*, Johnston and Chatterton, p. 180, pl. 2, fig. 16.

Types. Figured hypotypes GSC 107118-107121, 107128, 107133.

Diagnosis. See Austin et al. (1985, p. 154).

Remarks. Our synonymy reflects our concurrence with Huddle (1968) that *Polygnathus germanus* is the senior subjective synonym of this species over *Polygnathus nodocostatus*.

We are not able to clearly distinguish the three subspecies of *Polygnathus germanus* erected by Helms (1961 - see synonymy). We have found that characteristics of two, and, in a few cases, all three subspecies, can be found in one specimen (e.g. Pl. V-23, fig. 7). Younger occurrences of *P. germanus* are characterized by mature specimens with upper platform nodes somewhat fused to form ridges (Pl. V-23, fig. 10).

Specimens that we interpret as juvenile elements of *Polygnathus germanus* are characterized by much reduced platforms which appear to have grown by addition of denticle rows and by increasing the length of the platform, which in some specimens appears to have occurred at different rates between the outer and inner platform (Pl. V-23, fig. 22). Specimens interpreted as early growth stages in the growth series illustrated by Helms (1961, pl. 2, figs. 19, 20) still appear to have full platform development. Some juvenile specimens that we include in *P. germanus* have needle-like dentition, much like elements of *Skeletognathus* Sandberg, Ziegler and Bultynck and other conodont elements which have been interpreted as pathological specimens (e.g. Müller, in Robison, 1981; Weddige et al., 1991) (Pl. V-23, fig. 17).

Questionably included in our concept of Polygnathus germanus are juvenile specimens from the upper part of the Palliser Formation and Wabamun Group (e.g. samples NPW89-11, 14 at Nigel Peak, Table V-6; sampled intervals 11738 ft. to 11747 ft. in the Beaverlodge 4-23 well, Table V-17) which could belong to other taxa of the Polygnathus germanus group.

Occurrence. Palliser Formation and Wabamun Group (Tables V-2, V-4, V-6, V-10, V-11, V-13, V-15 to V-17). Definite occurrences of specimens of Polygnathus germanus are from strata as low as the Lower to Middle crepida Zone to a least as high as the Upper rhomboidea Zone. Juvenile specimens from the upper Palliser Formation and Wabamun Group (see above) occur in strata as young as the Lower to Upper marginifera zones.

Polygnathus perplexus Thomas, 1949
Pl. V-23, figs. 13-16

1949	Polygnathus perplexa? Thomas, p. 418, Pl. 2, fig. 23.
1961	Polygnathus perplexa, Helms, p. 692, pl. 1, figs. 18, 19; pl. 4, figs. 1-3, 5; fig. 10.
1974	Polygnathus perplexus, Dreesen and Dusar, p. 17, pl. 3, fig. 25.
1976	Polygnathus perplexus, Druce, p. 197, pl. 79, figs. 1, 5.
1978	Polygnathus perplexus, Narkiewicz, p. 440, pl. 7, fig. 7.
1979	Polygnathus perplexus, Sandberg and Ziegler, p. 185, pl. 4, fig. 1.
1983	Polygnathus perplexus, Spassov, p. 19, pl. 1, fig. 21; pl. 3, figs. 18, 19.
1987	Polygnathus perplexus, Ji, p. 20, pl. 1, figs. 18?, 19.
?1987	Polygnathus perplexus, Matyja, p. 376, pl. 22.3, fig. 10.
1988	Polygnathus perplexus, Aristov, p. 92, pl. 4, fig. 10; pl. 5, figs. 1-3.
1989	Polygnathus perplexus, Metzger, p. 520, figs. 15.2-15.14 (only).
1990	Polygnathus perplexus, Perri and Spalletta, p. 67, pl. 7, fig. 4.
1991	Polygnathus perplexus, Johnston and Chatterton, p. 180, pl. 2, fig. 15.
1993	Polygnathus perplexus, Johnston and Meijer Drees, p. 145, pl. 1, fig. 9.

Types. Figured hypotypes GSC 107124-107127.

Diagnosis. See Helms (1961, p. 692).

Remarks. Specimens of Polygnathus perplexus in our collections show the same degree of variation in terms of platform shape, ornamentation, etc. as other specimens of this species illustrated in the literature (see synonymy). In addition, we also note that, in the majority of our specimens, the adcarinal crest is higher and better developed on the inner side of the platform in sinistral specimens (Pl. V-23, fig. 14) whereas in dextral specimens the adcarinal crest is higher and more developed on the outer side of the platform (Pl. V-23, fig. 15). This tendency is also apparent in specimens cited in our synonymy. Only two sinistral specimens from our collections had higher and better developed adcarinal crests on the outer side of the platform (e.g. Pl. V-23, fig. 13). Thus, specimens of P. perplexus are considered to have Class IIIb symmetry of Lane (1968).

We also include in Polygnathus perplexus one specimen in which there are two adcarinal crests that are at a high angle to the carina and in which the carina is deflected slightly inward (Pl. V-23, fig. 16). The latter feature is like that in P. homoirregularis Ziegler except that the deflection of the carina in the latter species is deflected outward (Sandberg and Ziegler, 1979). We retain this specimen in P. perplexus because of the pronouncedly higher adcarinal crest on the outer side of the platform.

Occurrence. Palliser Formation and Wabamun Group (Tables V-2 to V-6, V-8, V-10, V-11, V-17). Our data generally support the first occurrence of Polygnathus perplexus being in the Upper marginifera Zone. The first occurrence of this species in this zone has also been reported elsewhere (Dreesen and Dusar, 1974; Druce, 1976). Polygnathus perplexus ranges at least as high as the Lower expansa Zone in the Palliser Formation and Wabamun Group.

Polygnathus cf. P. homoirregularis Ziegler, 1971
Pl. V-23, fig. 18-21

cf. 1949	Palmatolepis? irregularis Thomas, p. 416, pl. 2, fig. 27.
cf. 1971	Polygnathus homoirregularis Ziegler, pp. 269, 270.

Types. Figured specimens GSC 107129-107132.

Remarks. Specimens of this taxon in our collections differ from *Polygnathus homoirregularis* chiefly in the configuration of the adcarinal crests. In some specimens the adcarinal crests are diagonal, but their point of convergence is either not coincident or posterior to the azygous node instead of anterior of it. One large mature specimen (Pl. V-23, fig. 21) has parallel to subparallel adcarinal crests like *P. subirregularis* Sandberg and Ziegler, but the platform shape and ornamentation is more like *P. homoirregularis*. All our specimens, however, do share in common the outwardly deflected carina with a azygous node at the point of deflection (Pl. V-23, figs. 18-21).

Occurrence. Palliser Formation (Tables V-5, V-6). *Polygnathus* cf. *P. homoirregularis* occurs in strata that are dated as no older than the Uppermost *marginifera* Zone and as young as the Lower *expansa* to Middle *praesulcata* zones.

Polygnathus meijerdreesi n. sp.

Pl. V-23, figs. 1-16, 11, 12; Pl. V-24, figs. 1-3, 4-6?

?1989 *Polygnathus* ex gr. *brevilaminus*, Orchard, pp. 44, 48, pl. 2, fig. 12 (only); pl. 4, fig. 11 (only).

Etymology. This species is named for N.C. Meijer Drees.

Types. Holotype GSC 107115, illustrated on Plate V-23, figures 1-3; paratypes GSC 107116, 107117, 107122, 107123, 107134, 107135, illustrated on Plate V-23, figures 4-6, 11, 12, Plate V-24, figures 1-3.

Material. About 100 specimens.

Diagnosis. A species of *Polygnathus* with an elongate platform that has thickened, costate margins on the upper side which are separated from the carina by deep adcarinal grooves. A short posterior process is usually developed in most specimens.

Description. Platform elongate in mature specimens, with thickened, costate lateral margins on upper side, usually separated from carina by deep adcarinal groove for nearly entire length of element. Element weakly bowed and arched in most specimens. Platform on inner side slightly longer than on outer side. Short posterior process usually developed in most specimens.

Free blade length approximately one-third that of element. Denticles on free blade usually large and robust, relatively few in number, generally erect. Denticles also increase in height and size to approximately mid-length of free blade then decrease in these parameters anteriorly. Carina usually fused for most of its length in mature specimens, consists of one or two nodes at posterior tip of element.

Crimp on lower side of platform occupies one-third to one-half the width between the platform margin and the keel. Keel sharp in most specimens. Basal pit narrow slit to slightly elliptical, continues as basal groove onto lower side of free blade.

Remarks. Polygnathus meijerdreesi differs from P. procerus Sannemann by having more robust denticles on the free blade. The latter species has more rounded platform margins and wider adcarinal grooves than P. meijerdreesi. The differences between P. meijerdreesi and P. crassilabrus n. sp. are discussed under the Remarks for the latter species.

The platform is reduced in length and sometimes in width in gerontic specimens (Pl. V-23, fig. 11; Pl. V-24, figs. 1, 2). The posterior process is usually elongate in these specimens as well (Pl. V-24, figs 1, 2). Gerontic specimens are also moderately arched. Several accessory costae may be developed on the platform margin in these specimens. The anterior extremity of free blade in gerontic specimens is directed outward and the denticles on the free blade may be slightly reclined posteriorly to erect at mid-length to slightly proclined anteriorly (Pl. V-24, fig. 3). The carina is usually fused along the anterior two-thirds of the platform, and differentiates into several discrete denticles on an elongate posterior process (Pl. V-23, figs. 2, 4, 6, 12).

Because of the close similarities of intermediate to small specimens of Polygnathus meijerdreesi to those of P. dolichopleurus n. sp., the former species is thought to be the probable sister taxon of the latter. The latter species may have evolved from a form very similar to the former by a widening of the platform along with an increase of the number of costae on the upper side of the platform.

Tentatively included in our concept of P. meijerdreesi is one large specimen with a large free blade followed by a short platform characterized by a carina consisting of robust nodes and by costate and thickened outer margins (Pl. V-24, figs. 4-6).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-3, V-6, V-7, V-9 to V-13, V-16). Presently available evidence suggests that Polygnathus meijerdreesi may range perhaps as low as the Upper triangularis Zone (Orchard, 1989 - see synonymy; writers' own data) in the Sassenach and Trout River formations to the Lower to Middle crepida zones.

Polygnathus planirostratus Dreesen and Dusar, 1974?
Pl. V-24, figs. 7, 8

?1974 Polygnathus planirostratus Dreesen and Dusar, p. 18, pl. 1, figs. 12-16; pl. 2, figs. 13-20; fig. 12.

Type. Figured specimen GSC 107137.

Remarks. The small size and the poor preservation of the one specimen we have in our collections precludes its positive identification as Polygnathus planirostratus. Otherwise, the illustrated specimen is strongly bowed which is typical for this species. It also shows somewhat the upturned anterior margins and transverse ribbing posteriorly that is especially characteristic of one morphotype of this species (see Dreesen and Dusar, 1974).

Occurrence. Palliser Formation (Table V-6). The figured specimen comes from strata that are dated no older than the Uppermost marginifera Zone and no younger than the Upper postera Zone.

"Polygnathus semicostatus group"

Remarks. In this group we include Polygnathus latisemicostatus n. sp., P. paraobliquicostatus n. sp. and P. semicostatus Branson and Mehl. Our concept of this group generally follows that of Sandberg and Ziegler (1979). Taxa of this group characteristically have highly arched platforms with transverse ridges across the posterior third of the element.

Polygnathus latisemicostatus n. sp.
Pl. V-24, figs. 9-19

Etymology. From the Latin latus, meaning broad, referring to the broad platform in this species which is otherwise similar in morphology to that of Polygnathus semicostatus Branson and Mehl.

Types. Holotype GSC 107138, illustrated on Plate V-24, figures

9-11; paratypes GSC 107139-107143, illustrated on Plate V-24, figures 12-19.

Material. About 90 specimens.

Diagnosis. A species of Polygnathus with a broad, strongly bowed platform characterized by strong transverse ridges on the posterior half and a carina which extends to about mid-length of the platform. The carina is flanked by a pair of adcarinal ridges.

Description. Platform broad. Element moderately bowed and moderately to strongly arched. Platform broadest at about middle and narrows both anteriorly and posteriorly. Platform forms rostrum anteriorly. Posterior end of platform either pointed or rounded. Platform ornamented by sharp transverse ridges that are mostly continuous posterior to the carina. On the inner side of the platform the ridges are aligned oblique to the carina anteriorly, although in some specimens the anterior ends of these ridges may be aligned parallel to subparallel to the carina. On the outer side the ridges are short and are aligned parallel or oblique to the carina anteriorly. In larger elements these ridges may split into several rows of nodes aligned transversely on the anteriormost portion of the platform.

Free blade occupies one-third to one-quarter length of element. Denticles on free blade generally somewhat robust, relatively few in number. Carina partly fused, usually extends to approximately mid-length of the platform. Carina flanked by pair of adcarinal ridges which form part of rostrum anteriorly. Ridges separated from carina by deep adcarinal groove.

Crimp generally occupies half the width between lateral margins of platform and keel except in large specimens where it occupies a third to a quarter of this width. Keel generally low to absent in some specimens. Basal pit elliptical, usually on slightly raised portion of keel anterior to point of flexure of the element.

Remarks. Polygnathus latisemicostatus is distinguished from P. semicostatus Branson and Mehl by having a platform which is quite broad relative to its length, adcarinal ridges and a rostrum. As noted in the Remarks for P. semicostatus, some specimens of this species are transitional to P. latisemicostatus. Polygnathus latisemicostatus is distinguished from species of Polylophodonta by having a carina extending to about mid-length of the platform, instead of being restricted to the anteriormost portion.

The adcarinal ridges are usually sharp in most specimens, However, in one large specimen (Pl. V-24, figs. 15, 17-19), the adcarinal ridges have differentiated into a row of nodes. The tendency for the adcarinal ridges to differentiate into rows of nodes was seen in several large specimens.

Occurrence. Palliser Formation and Wabamun Group (Tables V-4, V-6, V-8, V-10, V-17). As presently known, Polygnathus latisemicostatus ranges from the Upper rhomboidea Zone to the Lower marginifera Zone.

Polygnathus paraobliquicostatus n. sp.
Pl. V-25, figs. 1-10

1976 Polygnathus obliquicostatus, Druce, p. 196, pl. 78, fig. 5.

Etymology. From the Latin para, meaning equal; referring to the similarity of this species to Polygnathus obliquicostatus Ziegler.

Types. Holotype GSC 107145, illustrated on Plate V-25, figures 2, 3; paratypes GSC 107144, 107146-107150, illustrated on Plate V-25, figures 1, 4-10.

Material. 230 specimens.

Diagnosis. A species of *Polygnathus* with a rounded but elongate platform ornamented by sharp transverse ridges which on the inner anterior portion of the platform are oblique to the carina. A weak rostrum is developed in most specimens.

Description. Platform elongate. Element moderately to strongly arched and bowed. Platform broad posteriorly; narrows anteriorly to weak rostrum formed by upturned anterior edges of platform. Platform edges thickened in region of carina. Platform ornamented by transverse ridges which extend across the platform posterior to the carina and, in some specimens, form weak chevrons with the apices of these chevrons directed posteriorly. Ridges perpendicular to carina on outer anterior portion of platform, oblique to carina on inner anterior platform.

Free blade occupies one-third to one-half length of element. Denticles on free blade numerous, approximately equal in size and in height. Fused carina extends to just beyond mid-length of platform (farther back in juveniles), and is flanked on either side by narrow adcarinal grooves that deepen anteriorly.

Crimp occupies approximately half the width between the lateral margins and the keel. Keel sharp; basal pit elliptical with somewhat thickened margins, continues as basal groove onto blade.

Remarks. *Polygnathus paraobliquicostatus* differs from *P. obliquicostatus* Ziegler by having a weak as opposed to a strong rostrum. The platform is not as broad as in the latter species and the carina does not extend as far posteriorly along the platform as in the holotype of *P. obliquicostatus* (Ziegler, 1962b, pl. 11, figs. 10, 12). The free blade appears to be generally longer relative to the platform in *P. paraobliquicostatus*. However, given the similar ornamentation and overall morphology of these two species, the latter either could have been or was close to the ancestor of *P. obliquicostatus*.

Some specimens of *Polygnathus paraobliquicostatus* are transitional to *P. semicostatus* (Pl. V-25, fig. 4). Sandberg and Ziegler (1979, pl. 5, fig. 5) illustrated a specimen which had transitional features between the latter species and *P. obliquicostatus*.

Occurrence. Palliser Formation (Tables V-4 to V-6). The stratigraphic distribution of *Polygnathus paraobliquicostatus* appears to be no lower than the Lower *marginifera* Zone and no higher than the Upper *marginifera* Zone. The specimen reported by Druce (1976 - see synonymy) was from the Lower *marginifera* Zone. All but two specimens of this species in our collections come mainly from two samples (samples CH57-420 and 420.5, Table V-4). *Polygnathus obliquicostatus*, the possible descendant of *P. paraobliquicostatus* (see above), ranges from the Lower *postera* to Middle *expansa* zones (Ziegler and Sandberg, 1984).

Polygnathus semicostatus Branson and Mehl, 1934a
Pl. V-25, figs. 11-23, Pl. V-26, figs. 1-15

1934a	*Polygnathus semicostata* Branson and Mehl, pp. 247, 248, pl. 21, figs. 1, 2.
1975	*Polygnathus semicostatus*, Klapper, pp. 317-319, *Polygnathus* - pl. 5, fig. 6 (contains synonymy to 1971).
1976	*Polygnathus semicostatus*, Druce, p. 201, pl. 80, fig. 5.
1978	*Polygnathus semicostatus*, Narkiewicz, p. 440, pl. 7, fig. 4.
1979	*Polygnathus semicostatus*, Sandberg and Ziegler, p. 187, pl. 5, figs. 1-5.
?1979	*Polygnathus semicostatus* Morphotype 1 Sandberg and Ziegler, p. 187, pl. 5, figs. 6, 7.
1982	*Polygnathus semicostatus*, Wang and Ziegler, p. 155, pl. 1, figs. 23, 30, 31.
1983	*Polygnathus semicostatus*, Spassov, p. 19, pl. 1, fig. 19.
1984	*Polygnathus semicostatus*, Dusar and Dreesen, p. 55, pl. 4, figs. 1-3.
1987	*Polygnathus semicostatus*, Matyja, pp. 375, 377, pl. 22.2, figs. 4, 12?; pl. 22.4, fig. 2.
1987	*Polygnathus delicatulus*, Matyja, p. 379, pl. 22.6, fig. 1.
1989	*Polygnathus semicostatus*, Metzger, p. 521, figs. 15.17-15.19, 15.13?.
1991	*Polygnathus semicostatus*, Johnston and Chatterton, p. 180, pl. 2, fig. 8.
1993	*Polygnathus semicostatus*, Johnston and Meijer Drees, p. 145, pl. 1, fig. 19.

Types. Figured hypotypes GSC 10751-107165.

Diagnosis. See Klapper (1975, p. 317)

Remarks. Specimens of Polygnathus semicostatus in our collections generally show the same wide range of variation as that exhibited by specimens illustrated in Dreesen and Orchard (1974, pls. 1 and 2) and in Sandberg and Ziegler (1979 - see synonymy). Many small to intermediate sized specimens have platforms which are flattened posterior to the basal pit, which makes these platforms almost pseudokeeled (e.g. Pl. V-25, figs. 17, 23). This tendency appears to be most prevalent in younger representatives of this species. We also have in our collections specimens which appear transitional to P. latisemicostatus n. sp. (e.g. Pl. V-25, fig. 20) which begin to show the broadening of the platform and incipient formation of the adcarinal ridges that are characteristic of the latter species. In our highest collections from the Palliser Formation and Wabamun Group, we have specimens of semicostatus in which the platform posterior to the carina is much reduced in width (Pl. V-25, figs. 15, 16). These specimens also have a sharp to very sharp keel (Pl. V-25, figs. 15, 16).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1 to V-11, V-13 to V-17). Polygnathus semicostatus ranges from the Lower rhomboidea Zone to at least the Lower expansa Zone in these units.

Polygnathus webbi Stauffer, 1938
Pl. V-26, figs. 16-22; Pl. V-27, figs. 1-7, 13, 14

1938	Polygnathus webbi Stauffer, p. 439, pl. 53, figs. 25, 26, 28, 29.
?1982	Polygnathus normalis, Wang and Ziegler, pl. 1, fig. 1.
?1983	Polygnathus webbi, Wang and Ziegler, pl. 6, figs. 25, 26.
1983	Polygnathus normalis, Spassov, p. 19, pl. 4, fig. 9.
1985	Polygnathus webbi, Klapper and Lane, pp. 944, 945, fig. 16.18 (contains synonymy to 1982).

1984	*Polygnathus webbi*, Olivieri, pl. 18, fig. 7.
1988	*Polygnathus normalis*, Aristov, p. 90, pl. 3, fig. 4.
?1988	*Polygnathus webbi*, Aristov, p. 109, pl. 1, fig. 12.
1989	*Polygnathus* ex gr. *webbi* Orchard, pp. 42, 44, 48, pl. 1, figs. 4, 10; pl. 2, fig. 11?; pl. 4, figs. 6?, 7?.
1991	*Polygnathus webbi*, Uyeno, p. 160, pl. 5, fig. 23.
1991	*Polygnathus webbi*, Johnston and Chatterton, p. 180, pl. 2, figs. 9, 10.
?1992	*Polygnathus webbi*, Savage, p. 289, figs. 4.9-4.12.

Types. Figured hypotypes GSC 100289, 100290, 107166-107172, 107175, 107176.

Diagnosis. See Klapper and Lane (1985, p. 945).

Remarks. Dextral and sinistral specimens of *Polygnathus webbi* in our collections exhibit the same degree of asymmetry as other specimens of this species illustrated from the literature (see synonymy). Specimens from the Lower to Middle *crepida* zones and from the Lower to Uppermost *marginifera* zones commonly have the anterior edge on the right side of the platform significantly higher than the same edge on the left side in both dextral and sinistral specimens. Ornamentation is most strongly developed in mature to gerontic specimens (Pl. V-27, figs. 1-4), with smaller specimens having weak or no ornamentation (e.g. Pl. V-27, figs. 13, 14).

Specimens of *Polygnathus webbi* from the Upper *rhomboidea* Zone, which represent a separate morphotype of this species, differ from those discussed above in that they appear not to have as great a discrepancy in height between right and left anterior platform margins. Most specimens appear to be somewhat narrower, with a higher carina and thicker posterior platform margins (Pl. V-27, figs. 5-7). Ornamentation in these specimens appears to be finer. Our specimens are similar to that illustrated by Glenister and Klapper (1966, pl. 95, fig. 6) which also has these features. These forms appear to be connected to more typical specimens of *P. webbi* by transitional specimens, such as the dextral and sinistral specimens illustrated in Plate V-26, figures 20, 22 that exhibit an incipient thickening of the posterior platform margins. These specimens occur in the uppermost Lower *rhomboidea* Zone (Table V-7).

Occurrence. Palliser Formation and Wabamun Group (Tables V-2 to V-10, V-12, V-13, V-15, V-17). *Polygnathus webbi* ranges from the Lower to Middle *crepida* zones to at least as high as the Uppermost *marginifera* zone in these formations. We have one questionable occurrence of this species in strata dated as Lower to Middle *expansa* Zone (Jura Creek, Table V-5). We also cite in our synonymy questionable occurrences of *P. webbi* in strata that are possibly as young as these zones (Wang and Ziegler, 1982). Sandberg et al. (1988) and Ziegler and Sandberg (1990) consider *P. webbi* to have gone extinct with the majority of species of *Polygnathus* at the mass extinction just prior to the end of the Frasnian. Instead, our data support the upper limit of the stratigraphic range of this species stated by Klapper (1973) which was *velifer* (= Uppermost *marginifera* to *trachytera*) Zone.

Polygnathus aff. *P. lauriformis* Dreesen and Dusar, 1974
Pl. V-27, figs. 8-10

aff. 1974 *Polygnathus lauriformis* Dreesen and Dusar, p. 16, pl. 1, figs. 8-11; pl. 3, figs. 1-12; fig. 11.
?1990 *Polygnathus lauriformis*, Perri and Spalletta, p. 65, pl. 5, fig. 6.

Types. Figured specimens GSC 107173, 107174.

Remarks. The few specimens of *Polygnathus* aff. *P. lauriformis* in our collections have the high, nodose carina characteristic of *Polygnathus lauriformis* (Pl. V-27, figs. 8, 10). However, our specimens differ from those of the latter species by having low, nodose ornamentation on the margins of the upper side of the platform (Pl. V-27, figs. 8, 10) rather than transverse ridges. On the lower side of the platform, the elongate basal pit is set in a high, sharp keel (Pl. V-27, fig. 9) as opposed to an asymmetrical, flattened and wide portion of the keel as in *P. lauriformis* (Dreesen and Dusar, 1974).

Occurrence. Palliser Formation (Tables V-7, V-10, V-11, V-14). Specimens of *Polygnathus* aff. *P. lauriformis* occur in strata no older than the Upper *crepida* Zone but no younger than the Lower *rhomboidea* Zone. *Polygnathus lauriformis* ranges from the Middle *crepida* to the Upper *marginifera* zones (Dreesen and Dusar, 1974).

Polygnathus aff. *P. pennatulus* Ulrich and Bassler, 1926
Pl. V-27, figs. 11, 12, 15-21

aff. 1926 *Polygnathus pennatulus* Ulrich and Bassler, p. 45, pl. 7, fig. 8 (only).
?1989 *Polygnathus pennatulus*, Metzger, p. 520, figs. 15.10, 15.23 (only).
1991 *Polygnathus pennatulus*, Johnston and Chatterton, p. 180, pl. 2, fig. 14.

Types. Figured specimens GSC 100294, 107177-107181.

Remarks. The few specimens of this taxon in our collections characteristically have strong transverse ridges on the upper surface of the platform like *Polygnathus pennatulus*, but, unlike this species, these ridges are most strongly developed anteriorly in mature specimens (Pl. V-27, figs. 11, 17). In one large specimen, the ridges are replaced posteriorly by nodes (Pl. V-27, fig. 17) which is also seen in one of the other mature specimens illustrated (e.g. Pl. V-27, fig. 11). Another important difference is that the platform in our specimens is asymmetrical, usually with a rounded anterolateral corner of the outer platform, although in one specimen this corner is rectangular (Pl. V-27, fig. 15). The anterolateral margins of the platform in our specimens are also not upturned as they are in *P. pennatulus*.

Two specimens (one of which is illustrated in Pl. V-27, figs. 18, 19), from beds slightly older than the one that the other illustrated specimens come from, have less asymmetrical platforms and transverse ridges occurring all the way to the posterior tip. However, as these elements are somewhat smaller than the mature specimens illustrated in Plate V-27, figures 11, 12, 16, 17 from the younger beds, it cannot be ruled out that these specimens could just represent earlier growth stages (e.g. like the specimens illustrated in Pl. V-27, figs. 20, 21 that come from the same bed as the illustrated mature specimens).

Occurrence. Palliser Formation and Wabamun Group (Tables V-10, V-14, V-15). *Polygnathus* aff. *P*. *pennatulus* appears to be restricted to the Upper *rhomboidea* Zone.

Polygnathus aff. *P*. *timanicus* Ovnatanova, 1969
Pl. V-28, figs. 1-5, 8-10

aff. 1969 *Polygnathus timanicus* Ovnatanova, p. 140, pl. 1, figs. 1, 2.

Types. Figured specimens GSC 107182, 107183, 107185, 107136.

Remarks. Rare specimens of this taxon in our collections differ from *Polygnathus* *timanicus* by having extremely constricted posterior platforms, which is in contrast to the broad posterior platform exhibited by the holotype (see synonymy) and by several specimens of this species illustrated in the literature (e.g. Druce, 1976, pl. 80, figs. 1b,c, 3a,b; Klapper and Lane, 1989, pl. 2, figs. 4, 5). Pairs of dextral and sinistral elements are asymmetrical with respect to one another, with the longest and broadest parts of the platform on the inner side of the element in dextral specimens (e.g. Pl. V-28, figs. 2, 10) and on the outer side of the element in sinistral specimens (Pl. V-27, fig. 8). Thus, pairs of dextral and sinistral specimens of *P*. aff. *P*. *timanicus* exhibit Class IIIb symmetry of Lane (1968).

Despite these differences, we still believe that *Polygnathus* aff. *P*. *timanicus* has close affinities with *P*.

timanicus because these taxa share in common the prominent asymmetry in terms of size and position of the two sides of the platform in a single element. On the lower side of these two taxa the basal pit and groove form a trough which gradually narrows anteriorly (Pl. V-27, fig. 3). It is because of these similarities that we believe *P. timanicus* either to have been or was close to the ancestor of *P.* aff. *P. timanicus*.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-3, V-6, V-7, V-13, V-15). *Polygnathus* aff. *P. timanicus* is presently known to range from the Lower to Middle *crepida* zones to the Upper *crepida* Zone.

Polygnathus cf. *P. brevilaminus* Branson and Mehl, 1934a
Pl. V-28, figs. 6, 7, 11-16, 17-20?, 21-24

cf. 1934a *Polygnathus brevilamina* Branson and Mehl, p. 246, pl. 21, figs. 3-6.

Types. Figured specimens GSC 107184, 107187-107191, 107192?, 107193?, 107194, 107195.

Remarks. Most specimens of *Polygnathus* cf. *P. brevilaminus*, although having more or less the same abbreviated platform as *P. brevilaminus*, differ by having a free blade in which denticles are broad and relatively few in number, unlike the latter species in which denticles are narrow and numerous (e.g. Branson and Mehl, 1934a, pl. 21, fig. 4; Anderson and Ozias, 1966, pls. 1-3 - see Klapper and Lane, 1985, p. 934). A few of our specimens, however, have a free blade with narrow and numerous denticles (e.g. Pl. V-28, fig. 6). On the lower side of the platform, the keel, though sharp, appears lower than specimens of *P. brevilaminus* illustrated in Branson and Mehl (1934a, see synonymy) and in Anderson and Ozias (1966, see above). In some specimens, the basal pit is in a shallow depression (Pl. V-28, fig. 7).

In large specimens that we include in our concept of Polygnathus cf. P. brevilaminus, the outer side of the platform shows a greater degree of development (Pl. V-28, figs. 21, 22). The margins of the platform are thickened in some specimens and are more irregular than the same margins in P. brevilaminus. The free blade in lateral view has only a few, broad denticles (Pl. V-28, fig. 23). Overall, these specimens appear generally more robust than large specimens of P. brevilaminus. Large specimens appear to be connected to the smaller ones by specimens that are intermediate in size. It is because of this possible connection between large and small specimens, in addition to the other differences between P. cf. P. brevilaminus and P. brevilaminus discussed above, that we consider these taxa to be possibly separate.

Also questionably included in this concept are a few scattered specimens (e.g. Pl. V-28, figs. 17-20) which occur stratigraphically higher (see below) than those we definitely assign to this taxon and which may represent late forms or possible descendants of Polygnathus cf. P. brevilaminus.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1 to V-3, V-6, V-7, V-9 to V-13, V-15). As presently known, Polygnathus cf. P. brevilaminus ranges from the Lower to Middle crepida zones to the Upper crepida Zone. The possible late forms or descendants (see above) are found in the Upper rhomboidea Zone.

Polygnathus cf. P. padovaniae Perri and Spalletta, 1990
Pl. V-29, figs. 1-5

?1970b	Polygnathus sp. nov. Seddon, p. 753, pl. 16, figs. 15, 16.
cf. 1990	Polygnathus padovanii Perri and Spalletta, p. 66, pl. 6, figs. 1-4; pl. 7, figs. 1,2,3?.

Types. Figured specimens GSC 107196-107198.

Remarks. The spelling of the specific name of Polygnathus padovaniae has been emended in accordance with Article 32 of the International Code of Zoological Nomenclature. The former spelling contravened Article 31 of the Code.

Our specimens differ from those of Polygnathus padovaniae by having the longer side of the platform on the inner side in dextral specimens and on the outer side in sinistral specimens (Pl. V-28, figs. 1, 4). Our specimens share this attribute in common with Polygnathus aff. P. timanicus Ovnatanova (see Remarks for latter taxon) (compare Pl. V-28, figs. 2-4, 8, 10 with Pl. V-29, figs. 1, 3-5) which we believe may be ancestral to or close to the ancestor of Polygnathus cf. P. padovaniae. However, the degree of asymmetry in terms of size of the left and right sides of the platform element is considerably less in both juvenile (Pl. V-29, fig. 5) and mature specimens. Specimens of P. cf. P. padovaniae in our collections also appear to have a basal groove and pit which form a wide trough that narrows anteriorly (Pl. V-29, fig. 3). Like P. aff. P. timanicus, elements of P. aff. P. padovaniae exhibit Class IIIb symmetry of Lane (1968).

In most other respects, Polygnathus cf. P. padovaniae has similar [illegible] and platform morphology as P. padovaniae. Given the older stratigraphic occurrence of P. cf. P. padovaniae (see below), it may represent an immediate ancestor of P. padovaniae, which is presently known to range from the Upper marginifera through to the Lower trachytera zones (Perri and Spalletta, 1990).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-6, V-15). As presently known, Polygnathus cf. P. padovaniae appears to be restricted to the Lower marginifera Zone.

Polygnathus sp. C
Pl. V-29, figs. 6-8

Types. Figured specimens GSC 107199, 107200.

Remarks. The two specimens assigned to this taxon are characterized by highly arched platforms that are triangular in cross-section and pointed posteriorly. A constriction of the platform on the outer antero-lateral margin is characteristic of both specimens. The resultant adcarinal ridge formed by this constriction forms, along with the blade and carina, a funnel-like adcarinal trough that widens anteriorly.

Ornamentation consists of nodes and/or ridges which are confined to the platform margins in the larger and stratigraphically younger specimen (Pl. V-29, fig. 7) and encompasses most of the platform width in the smaller and stratigraphically older specimen (Pl. V-29, fig. 6).

The keel in both specimens is high and sharp, with an elongated narrow basal pit (Pl. V-29, fig. 8).

Occurrence. Palliser Formation (Tables V-7, V-10). As presently known, Polygnathus sp. C ranges from the Lower to Middle crepida zones to at least as high as the Upper crepida Zone.

Polygnathus sp. D
Pl. V-29, figs. 9-13

Types. Figured specimens GSC 107201, 107202.

Remarks. The two specimens, one juvenile (Pl. V-29, figs. 9-11), the other mature (Pl. V-29, figs. 12, 13), appear to generally resemble Polygnathus aff. P. lauriformis by having the same general platform outline and lower side morphology (e.g. having high and sharp keels in juvenile specimens). Given this similarity, we believe P. aff. P. lauriformis may have been, or was close to, the ancestor of P. sp. D.

These two taxa differ chiefly in ornamentation.

Polygnathus sp. D has sharp, continuous transverse ridges as opposed to nodes. The carina is also fused as opposed to consisting of discrete nodes. The platform is also slightly asymmetrical in the mature specimen).

Occurrence. Palliser Formation (Table V-7). *Polygnathus* sp. D appears to be confined to the Upper *rhomboidea* Zone.

Polygnathus? sp. A
Pl. V-29, figs. 14, 15

Types. Figured specimen GSC 107203.

Remarks. The single specimen questionably assigned to *Polygnathus* has asymmetrically positioned sides of the platform like some of the taxa of *Alternognathus* discussed previously, but lacks a pseudokeel and is much more bowed than specimens that we have assigned to this genus. However, it also lacks the fully developed platform of other taxa we have assigned to *Polygnathus*.

Occurrence. Palliser Formation (Table V-7). The single specimen of *Polygnathus* sp. A comes from the Lower to Middle *crepida* zones.

Genus *Polylophodonta* Branson and Mehl, 1934

Type species. *Polygnathus pergyratus* Holmes, 1926

Polylophodonta confluens (Ulrich and Bassler, 1926)
Pl. V-29, figs. 18-21

1926	*Polygnathus confluens* Ulrich and Bassler, pp. 46, 47, pl. 7, figs. 14, 15.
1966	*Polylophodonta confluens*, Glenister and Klapper, pp. 831-833, pl. 94, figs. 10, 11 (contains synonymy to 1962).
1967	*Polylophodonta confluens*, Wolska, p. 418, pl. 17, fig. 7.
1968	*Polylophodonta confluens*, Huddle, p. 42, pl. 17, figs. 1, 2 (only).
1969	*Polylophodonta confluens*, Druce, p. 109, pl. 34, fig. 3.
1974	*Polylophodonta confluens*, Dreesen and Dusar, pl. 4, fig. 21.
1976	*Polylophodonta confluens*, Druce, pp. 206, 207, pl. 18, fig. 1.

?1984 *Polylophodonta* cf. *confluens*, Olivieri, pl. 6, fig. 14.

Types. Figured hypotypes GSC 107206, 107207.

Diagnosis. See Glenister and Klapper (1966, p. 832).

Remarks. Specimens of *Polylophodonta confluens* in our collections most strongly resemble those illustrated by Glenister and Klapper (1966, see synonymy) and by Helms (1961, pl. 3, figs. 13, 14 and 18). Our specimens have either very broad (Pl. V-29, fig. 20) or narrow (Pl. V-29, fig. 18) platforms. Specimens with narrow platforms appear to represent earlier growth stages.

Occurrence. Palliser Formation and Wabamun Group (Tables V-5, V-6, V-17). *Polylophodonta confluens* in these units appears to be mainly confined to the Lower to Upper *marginifera* zones, although it occurs in strata that may be as young as the Upper *trachytera* Zone (West Prairie 11-18 well, Table V-17). Elsewhere the range of this species has been reported as *rhomboidea* to Upper *marginifera* zones (Druce, 1976).

Polylophodonta cf. *P. confluens* (Ulrich and Bassler, 1926)
Pl. V-29, figs. 16, 17

cf. 1926 *Polygnathus confluens* Ulrich and Bassler, pp. 46, 47, pl. 7, figs. 14, 15.

Types. Figured specimens GSC 107204, 107205.

Remarks. Specimens assigned to this taxon have rows of nodes parallel to the carina like *Polylophodonta confluens* on the anterior portion of the outer side of the platform. In all other aspects of blade morphology, platform outline, etc., these specimens resemble this species. However, the ridges, instead of extending transversely across the platform posterior to the carina, extend diagonally from the postero-lateral margin of the outer side of the platform to the antero-lateral margin of the inner side (Pl. V-29, figs. 16, 17).

Occurrence. Palliser Formation (Tables V-2, V-11). The few specimens we have occur in strata assigned to the Lower and Upper *marginifera* zones.

Polylophodonta *medicinelakensis* n. sp.
Pl. V-30, figs. 1-23; Pl. V-31, figs. 1-7

1967	*Polylophodonta* *confluens*, Nehring, p. 153, pl. 3, fig. 9.
?1967	*Polygnathus* *rhomboidea*, Wolska, p. 416, pl. 17, figs. 5, 6 (only).
1973	*Polylophodonta* cf. *P*. *linguiformis* Sandberg and Ziegler, p. 107, pl. 3, fig. 3; pl. 5, fig. 8.
1991	*Polylophodonta* sp. cf. *P*. *linguiformis*, Johnston and Chatterton, p. 180, pl. 2, fig. 18.
1991	*Polylophodonta* *confluens*, Johnston and Chatterton, p. 180, pl. 2, fig. 20.

Etymology. For Medicine Lake, Jasper National Park, Alberta; the type locality of the holotype.

Types. Holotype GSC 100300, illustrated on Plate V-30, figures 10-12; paratypes GSC 100298, 107208-107227, illustrated on Plate V-30, figures 1-9, 13-23; Plate V-31, figures 1-7.

Material. About 100 specimens.

Diagnosis. A species of *Polylophodonta* with a broad to narrow platform characterized by sharp, transverse ridges and nodes on the posterior portion of the platform.

Description. Platform broad to elongate. Element slightly bowed and slightly to moderately arched. Platform of mature specimens broad anteriorly and narrow posteriorly with narrowing occurring approximately at middle of platform. In some specimens the platform is somewhat thickened. Platform ornamented either by sharp continuous or discontinuous transverse ridges posteriorly or by short ridges and nodes in some specimens. Outer extremities of these ridges directed anteriorly slightly in some specimens. On the anterior portion of the platform, these ridges become subparallel to the adcarinal ridges, and become more discontinuous, commonly consisting of rows of nodes. In some specimens nodes and/or ridges are arranged concentrically around the carina and adcarinal ridges. Slight rostrum may occur on some specimens. Posterior tip of platform somewhat pointed to rounded.

Free blade comprises approximately one-quarter to one-third length of element, with laterally compressed denticles confluent to tips. Denticles of free blade more numerous and confluent in stratigraphically younger specimens. Blade on platform usually flanked by diagonal adcarinal ridges which are separated from blade by deep adcarinal trough on outer side of platform in sinistral specimens and on inner side in dextral specimens.

Crimp occupies approximately one-third to one-quarter width from lateral margin of platform to keel. Keel low; usually highest at its anterior- and posteriormost extremities. Basal pit elliptical in mature specimens, usually situated somewhat medially; basal pit more circular in outline in earlier growth stages.

<u>Remarks</u>. Stratigraphically older specimens of <u>Polylophodonta medicinelakensis</u> generally have broad to more narrow, elongate platforms whereas younger representatives of this species mostly have broader, more ovoid platforms (e.g. compare Pl. V-30, figs. 1-6, 8, 9 with Pl. V-30, figs. 16, 17; Pl. V-31, figs. 6, 7). As noted in the description, some representatives of this species may have nodes developed just posterior to the carina (Pl. V-30, figs. 19, 21).

Polygnathid early growth stages grow into mature forms first by addition of ridges that are parallel or subparallel to the carina (Pl. V-30, fig. 7; Pl. V-31, fig. 4) and second by the loss of all but the anteriormost portion of these ridges in the latest growth stages (Pl. V-30, figs. 5, 6; Pl. V-31, figs. 6, 7). The loss of these ridges is accompanied by the superimposition of transverse ornamentation which begins as transverse rows of nodes posteriorly that fuse with growth to form the characteristic sharp ridges of *P. medicinelakensis*.

Polylophodonta medicinelakensis differs from *P. confluens* Ulrich and Bassler by having transverse ornamentation developed only posteriorly. The former species also differs from the latter by lacking the characteristic "horseshoe-like" arrangement (Huddle, 1968) of nodes about the carina as in *P. confluens*. Instead, ridges are directed diagonally away from the carina rather than being parallel to it.

Occurrence. Palliser Formation and Wabamun Group (Tables V-2, V-3, V-6, V-7, V-9 to V-12, V-14 to V-16). As presently known, *Polylophodonta medicinelakensis* ranges from the Lower to Middle *crepida* zones to the Lower *rhomboidea* Zone. Other occurrences of this species (see synonymy) are from approximately the same time interval.

Polylophodonta sp. A
Pl. V-31, figs. 8, 9

Type. Figured specimen GSC 107228.

Remarks. The single specimen we assign to this taxon differs from *Polylophodonta medicinelakensis* n. sp. by having upper platform ornamentation which is comprised of nodes which have a slight concentric arrangement about the carina anteriorly and a more or less random arrangement posteriorly.

Occurrence. Wabamun Group (Table V-12). The figured specimen occurs in strata dated as Lower to Middle *crepida* zones.

New Genus A sp.
Pl. V-34, figs. 17-19

Types. Figured specimen GSC 108929.

Remarks. The few specimens assigned to this taxon in our collections are laterally compressed with a very slight platform development on the outer side of the element (Pl. V-34, figs. 17, 19). The free blade is relatively short with a few large denticles. The denticulation posteriorly is somewhat similar to that of *Polygnathus meijerdreesi* n. sp. in that the posterior part of the carina is comprised of discrete nodes (Pl. V-34, figs. 18, 19).

Occurrence. Palliser Formation (Tables V-2, V-6, V-7). New Genus A sp. ranges from the uppermost part of the Lower *rhomboidea* Zone to the lowermost part of the Upper *rhomboidea* Zone.

New Genus B

Remarks. Taxa assigned to this genus share in common enlarged anterior denticles that are continuous with a weak to robust carina and anterior platform margins that are flush with the anterior end of the element on one or both sides of either a broad or narrow platform. One species (see below) has a suggestion of a postero-lateral lobe, like species of *Ancyrognathus* Branson and Mehl (Klapper, 1990), which New Genus B may have possible affinities with.

New Genus B sp. 1
Pl. V-35, figs. 1, 2

Type. Figured specimen GSC 108930.

Remarks. The single specimen assigned to this taxon has a thick platform with coarse ridges running transversely along the margins. The carina is high and runs posteriorly from a few robust anterior denticles (broken in this specimen). At the posterior end, a secondary carina diverges from the carina (Pl. V-35, fig. 1). The latter feature is more typical of specimens of Ancyrognathus with a lateral lobe (e.g. Klapper, 1990; Ziegler, 1973). There appears to be a slight lateral lobe that accompanies the secondary carina. The keel on the lower side is sharp (Pl. V-35, fig. 2).

Occurrence. Wabamun Group (Table V-14). New Genus B sp. 1 is presently known from the Lower rhomboidea Zone.

New Genus B sp. 2
Pl. V-35, figs. 3, 4

Type. Figured specimen GSC 108931.

Remarks. The few specimens we assign to this taxon, of which we have illustrated the only intact and/or well-preserved specimen, are characterized by a narrow, elongate platform with a few high denticles anteriorly grading into a sharp, fused carina posteriorly. In the illustrated specimen, the right side of the platform is positioned somewhat more anteriorly than the left side, and, on the margins of both left and right sides of the platform, there is slight ornamentation consisting of ridges and/or nodes (Pl. V-35, fig. 3). The manner in which the antero-lateral margin of the left side of the platform terminates cannot be determined since this margin appears broken. The posterior end of the platform is directed downward and there is a somewhat high and sharp keel on the lower side of the platform (Pl. V-35, fig. 4).

Occurrence. Palliser Formation (Tables V-2 to V-4, V-7, V-9, V-11). As presently known, New Genus B sp. 2 occurs in strata ranging in age from no older than the Upper crepida Zone to no younger than the Lower rhomboidea Zone.

New Genus B sp. 3
Pl. V-35, figs. 5-7, 10, 11

Types. Figured specimens GSC 108932, 108934.

Remarks. Specimens assigned to this taxon are characterized by an asymmetrical, ovoid platform in which the outer side of the platform is more extensively developed (i.e. longer). In the gerontic specimen we illustrate (Pl. V-35, figs. 5-7), the platform is thickened and upper side is undulatory with sharp, well defined transverse ridges and/or nodes. The ridges are perpendicular to the carina. The same style of ornamentation appears to be developed somewhat in the smaller mature specimen we illustrate (Pl. V-35, figs. 10, 11).

New Genus B sp. 3 differs from some taxa of this genus by not having as high or as sharp a keel (Pl. V-35, fig. 7). The blade is also partially free on one side of the smaller specimen (Pl. V-35, fig. 10).

Occurrence. Palliser Formation (Tables V-7, V-9 to V-11). As presently known, New Genus B sp. 3 appears to occur in strata no older than the Upper crepida Zone but no younger than the Lower rhomboidea Zone.

New Genus B sp. 4
Pl. V-35, figs. 8, 9, 14

Types. Figured specimens GSC 108933.

Remarks. The single specimen assigned to this species has a platform with ornamentation consisting of nodes which are partly hidden from view by matrix. A well developed carina, though also partly hidden, is present as well. In this specimen, the blade portion is rather high and somewhat triangular in lateral view (Pl. V-35, fig. 8). As in New Genus B sp. 3, the keel is somewhat low.

Occurrence Wabamun Group (Table V-15). New Genus B sp. 4 occurs in strata dated as Uppermost crepida to Upper rhomboidea zones.

New Genus B sp. 5
Pl. V-35, figs. 12, 13, 15-19

Types. Figured specimens GSC 108935-108937.

Remarks. The few specimens we assign to this taxon differ from those previously discussed by having a broad, somewhat rhomboid platform with the margins directed upward, so as to make the element concave on the upper side. The carina is lower than in the other taxa discussed thus far, but is higher both anteriorly and posteriorly than in the middle in our most intact specimen (Pl. V-35, fig. 17). However, like these taxa, this specimen has enlarged denticles anteriorly. On the lower side, the keel is low (Pl. V-35, fig. 18). Unique to these specimens is a shallow depression at about mid-length (Pl. V-35, figs. 13, 18, 19) like polygnathids belonging to the "Polygnathus communis group" (See Remarks under respective taxa for that group).

Occurrence. Palliser Formation (Tables V-7, V-10). Specimens of New Genus B sp. 5 appear to be confined to the Upper rhomboidea Zone.

New Genus B sp. 6
Pl. V-35, figs. 20-22

Types. Figured specimen GSC 108938.

Remarks. The single specimen assigned to this taxon has a broad, somewhat ovoid platform in upper view which has a weak carina (Pl. V-35, fig. 22). Nodose ornamentation occurs on the upper surface of the platform. The platform edges are flexed downwards (Pl. V-35, figs. 20, 21) around the entire margin. The blade portion is adenticulate and fixed and there is a deep outer adcarinal groove, like in species of Polylophodonta Branson and Mehl (see above).

Occurrence. Palliser Formation (Table V-10). New Genus B sp. 6 occurs in strata that are dated as no older than the Upper crepida Zone but no younger than the Lower rhomboidea Zone.

Family SPATHOGNATHODONTIDAE Hass, 1959

Remarks. We have noted in our study of conodont elements assignable to this family how many juvenile specimens in early to middle Famennian strata have expanded basal cavities which, in several species, become basal pits with growth. This appears to be the case with specimens assigned to Mehlina ovata n. sp. (see below). It appears that the expanded basal cavity is a neotenic feature that becomes fixed in mature specimens of Bispathodus, the presumed descendant of Mehlina (Sweet, 1988), later in the Famennian (e.g. Ziegler et al., 1974). The occurrence of carminate pectiniform elements with expanded basal cavities in early to middle Famennian strata was also reported by Druce (1976).

The occurrence of this feature (i.e. expanded basal cavities) in many smaller "spathognathodontid" specimens made the specific assignment of these elements difficult.

We also include in this family Mashkovia and Skeletognathus, which we have specimens that are questionably assigned to the former genus and definitely or questionably assigned to the latter (see below). We base our assignment of these genera to the Spathognathodontidae on the belief that they are more similar, both in terms of their morphology and ontogeny (e.g. Druce, 1976; Aristov et al., 1983; Aristov, 1988; Sandberg et al., 1989a), to other genera assigned to this family than to other Late Devonian conodont genera assigned to other families of the Order Ozarkodinida.

Genus *Bispathodus* Müller, 1962

Type species. *Spathodus spinulicostatus* E.R. Branson, 1934.

Bispathodus stabilis (Branson and Mehl, 1934a)

Pl. V-31, figs 10-21

1934a	*Spathodus stabilis* Branson and Mehl, pp. 188, 189, pl. 17, fig. 20.
1984	*Bispathodus stabilis*, Olivieri, p. 294, pl. 9, figs. 12, 13.
1984	*Bispathodus stabilis*, Austin and Davies, p. 226, pl. 3, fig. 9.
1987	*Mehlina strigosa*, Matyja, p. 379, pl. 22.6, figs. 2, 3.
1987	*Bispathodus stabilis*, Matyja, p. 379, pl. 22.6, fig. 10, 11.
1989	*Bispathodus stabilis*, Metzger, p. 516, figs. 14.10, 14.14, 14.16, 14.20.
?1990	*Bispathodus stabilis* Morphotype 1, Perri and Spalletta, p. 60, pl. 1, figs. 2.
1991	*Bispathodus stabilis*, Perri and Spalletta, pp. 56-58, pl. 2, figs. 2, 3.
1991	*Bispathodus stabilis* Morphotype 1, Johnston and Chatterton, p. 180, pl. 2, figs. 1, 2.
1991	*Bispathodus stabilis* Morphotype 2, Johnston and Chatterton, p. 180, pl. 2, fig. 3, 4.
1992	*Bispathodus stabilis* Morphotype 1, Over, pp. 307, 308, figs. 6.1-6.16, 6.21, 6.26, 6.28 (contains synonymy to 1990).
1993	*Bispathodus stabilis* Morphotype 1, Johnston and Meijer Drees, p. 145, pl. 1, figs. 4, 5.
1993	*Bispathodus stabilis* Morphotype 2, Johnston and Meijer Drees, p. 145, pl. 1, figs. 6, 7.

Types. Figured hypotypes GSC 98132, 100281-100284, 107229-107232.

Diagnosis. See Klapper (1966, p. 23).

Remarks. We recognize both morphotypes 1 and 2 of this species (Ziegler et al., 1974) in our collections (e.g. Pl. V-31, figs. 10-21, see also synonymy), with Morphotype 1 being the most common. We also have a few specimens in which a single denticle is developed on the outer postero-lateral margin of the element (Pl. V-31, figs. 15, 16). Such specimens were also reported by Metzger (1989, fig. 14.10) from the undifferentiated Sheffield-Maple Hill formations in Iowa and Nebraska. Specimens characterized by the occurrence of nodes on the upper surface of the basal cavity were considered to be representative of a third morphotype of Bispathodus stabilis by Sandberg and Ziegler (1979 - their Morphotype 3 of this species).

The characteristic broad basal cavity of Bispathodus stabilis is best developed on small to intermediate size specimens. On larger specimens, the margins of the basal cavity are often broken, and the specimens themselves are commonly fragmentary. Several specimens appear transitional to Mehlina strigosa (Branson and Mehl) by having basal cavity margins that extend only a short distance away from the sides of the element (Pl. V-31, figs. 19, 21).

Occurrence. Palliser Formation and Wabamun Group (Tables V-5, V-6, V-8, V-10, V-17). The first appearance of Bispathodus stabilis defines the base of the Upper marginifera Zone in several of our sections (e.g. Nigel Peak, Table V-6). This species is presently known to range from the base of this zone (Ziegler and Sandberg, 1984). In the Palliser Formation and Wabamun Group, B. stabilis ranges at least as high as the Lower expansa Zone, with the first appearance of Morphotype 2 of this species indicating the presence of this zone (e.g. Johnston and Chatterton, 1991).

Genus Mashkovia Aristov, Gagiev and Kononova, 1983

Type species. Pseudopolygnathus similis Gagiev, 1979.

Mashkovia? sp.
Pl. V-34, figs. 1-5

Types. Figured specimens GSC 108918-108920.

Remarks. The questionably assignment of specimens of this taxon to Mashkovia is based on their similarity to early growth stages of this genus illustrated by Aristov (1988, pl. 7, figs. 5, 6). These specimens and ours share in common a short platform situated at about midlength. This platform has one or several denticles developed on the upper surface. The lower side of our specimens (e.g. Pl. V-34, fig. 2) exhibits the same ancyrodellid-like morphology as specimens of Mashkovia (e.g. Aristov, pl. 7, figs. 3, 6).

Occurrence. Palliser Formation (Table V-5). The occurrence of Mashkovia? sp. is restricted to a nodular limestone unit in the LaFarge Quarry section (Figure V-4 and Table V-5, see also Appendix). Here this unit occurs in an otherwise unfossiliferous sequence of peritidal carbonates that over- and underlie this unit that are no older than the uppermost Upper rhomboidea Zone at the base and no younger than the Uppermost marginifera Zone at the top (Meijer Drees and Johnston, 1994). The earliest stratigraphic occurrence of Mashkovia is in the velifer (= Uppermost marginifera to Upper trachytera) Zone (Aristov et al., 1983, fig. 1).

Genus Mehlina Youngquist, 1945

Type species. Mehlina irregularis Youngquist, 1945 (= Mehlina gradata Youngquist, 1945).

Mehlina gradata Youngquist, 1945
Pl. V-32, figs. 1, 2?, 3, 4

1945	Mehlina gradata Youngquist, p. 363, pl. 56, fig. 3.
1985	Mehlina gradata, Klapper and Lane, p. 921, fig. 12.1 (see for further synonymy).
?1991	Mehlina gradata, Uyeno, p. 160, pl. 5, fig. 27.

Types. Figured hypotypes GSC 107233, 107235, 107236.

Diagnosis. See Youngquist (1945, p. 363).

Remarks. Specimens assigned to *Mehlina gradata* in our collections show the typical zone of recessive basal margin on the lower side of the element. These specimens also have a simple slit-like basal pit. Specimens similar to these but having a thickening around the basal pit have been assigned to *Mehlina* cf. *M*. *gradata* Youngquist (see Remarks for this taxon).

Tentatively included in our concept of *Mehlina gradata* are Pa elements with free blades that are disproportionately longer relative to the rest of the element (Pl. V-32, fig. 2). These elements have, however, the same slit-like basal pit and zone of recessive basal margin like other specimens we have assigned to *M*. *gradata*.

Occurrence. Palliser Formation and Wabamun Group (Tables V-2, V-4 to V-11, V-13, V-14). Specimens of *Mehlina gradata* in our collections have a stratigraphic range of Lower to Middle *crepida* zones to at least as high as the Upper *marginifera* Zone. Questionable occurrences of this species are in strata as young as the Lower to Middle *expansa* zones (e.g. Nigel Peak, Table V-6).

Mehlina cf. *M*. *gradata* Youngquist, 1945
Pl. V-32, figs 5-8

cf. 1945 *Mehlina gradata* Youngquist, p. 363, pl. 56, fig. 3.
1991 *Mehlina gradata*, Johnston and Chatterton, p. 180, pl. 2, fig. 5.

Types. Figured specimens GSC 107237-107240.

Remarks. Although specimens assigned to *Mehlina* cf. *M*. *gradata* have the typical zone of recessive basal margin of *M*. *gradata* Youngquist, they also have a thickening around the rim of the basal pit, which is developed to different degrees in different specimens. We are uncertain if these specimens should be considered a separate taxon since some appear transitional to typical specimens of M. gradata.

We have also included a specimen which exhibits the thickening around the rim of the basal pit and also slight development of a ledge or incipient platform on one side of the element. This is a characteristic that is similarly developed in Mehlina? sp. C (see Remarks for this species).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-2, V-4, V-6, V-7, V-9 to V-12, V-14). As presently known Mehlina cf. M. gradata ranges from the Lower to Middle crepida zones to the Upper marginifera Zone.

Mehlina ovata n. sp.
Pl. V-32, figs. 9-15

Etymology. Referring to the ovoid outline of mature specimens of this species in cross section.

Types. Holotype GSC 107241, illustrated on Plate V-32, figure 9; paratypes GSC 107242-107246, illustrated on Plate V-32, figures 10-15.

Material. 55 specimens.

Diagnosis. A species of Mehlina characterized by mature Pa elements which have an ovoid cross-section which gives them a very robust appearance. One or two ridges running the length of the element may be developed on each side. The basal pit has a thickened rim. The lower margin has an upward curvature.

Description. Element straight to slightly bowed, with some mature specimens showing upward curvature of the anterior and posterior extremities of the element. Early growth stages generally straight. Mature elements lanceolate in cross section at anterior and posterior ends to ovoid in cross section at mid-point of element, whereas early growth stages lanceolate in cross section throughout length of element.

Denticles numerous, generally confluent to tips, erect to semi-erect, although in some specimens anterior denticles slightly reclined and posterior ones slightly proclined. Anteriormost denticles may be enlarged in some specimens.

Zone of recessive basal margin developed on lower side of mature elements extending to just above basal pit, where a sharp, prominent ridge is developed in some specimens. In other specimens a secondary ridge may be developed above this ridge, occurring near the base of the denticles, and is separated from the primary ridge by a very shallow depression. Basal pit surrounded by a thickening of the lamellae in mature specimens. In early growth stages, a basal cavity is developed which becomes progressively reduced with growth to become a basal pit in mature specimens.

Remarks. Mehlina ovata differs from M. gradata Youngquist by having a much broader element, and, as noted in the description, the strong upward curvature of the anterior and posterior extremities that is seen in some specimens. The change from a basal cavity to a basal pit during growth mirrors the growth pattern of other spathognathodontiform taxa that we recognize in our collections.

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-4, V-6, V-7, V-9 to V-13, V-15, V-16). As presently known, Mehlina ovata is restricted to the Lower to Middle crepida zones.

Mehlina strigosa (Branson and Mehl, 1934a)
Pl. V-32, figs. 16-20; Pl. V-33, figs. 1-4

1934a Spathodus strigosus Branson and Mehl, p. 187, pl. 17, fig. 17.

?1976	*Spathognathodus strigosus*, Dusar, p. 540, pl. 2, figs. 11, 12.
1976	*Spathognathodus strigosus*, Druce, p. 216, pl. 89, figs. 4-9.
1982	*Spathognathodus strigosus*, Wang and Ziegler, pl. 2, figs. 11-16.
1983	*Spathognathodus strigosus*, Spassov, p. 21, pl. 3, figs. 3-7, 9 (only).
?1987	*Spathognathodus strigosus*, Ji, p. 20, pl. 2, fig. 18.
1989	*Mehlina strigosa*, Metzger, p. 517, figs. 14.13, 14.15 (see for further synonymy).
1991	*Mehlina strigosa*, Perri and Spalletta, p. 60, pl. 3, fig. 6.

Types. Figured hypotypes GSC 107247-107253.

Diagnosis. See Branson and Mehl (1934a, p. 187).

Remarks. Specimens assigned to *Mehlina strigosa* are characterized by basal cavities that are narrow and that may or may not extend to the posterior tip, or by those in which there is a thickening of the rim of the basal pit (e.g. Pl. V-32, figs. 16-18). Our specimens range from those in which the basal pit or cavity is restricted to the medial portion of the element to those in which the basal cavity or pit extends the entire length of the posterior process of the element (e.g. Pl. V-32, fig. 16).

We include in this concept specimens in which the basal cavity or pit is asymmetrical, as well as symmetrical. Also included are specimens from the lowermost Upper *rhomboidea* Zone which have small, equal sized denticles (Pl. V-33, fig. 3).

Occurrence. Palliser Formation and Wabamun Group (Tables V-1, V-2, V-4 to V-7, V-9, V-10, V-13, V-14, V-16, V-17). The first occurrence of *Mehlina strigosa* appears to be as low as the Upper *crepida* Zone in one of our sections whereas the highest occurrence of this species is in the Lower to Middle *expansa* zones. The lower limit of *M. strigosa* has been previously reported as Lower *marginifera* Zone (e.g. Ziegler and Sandberg, 1984), although older occurrences of this species were reported by Druce (1976).

Mehlina aff. *M. strigosa* (Branson and Mehl, 1934a)

Pl. V-33, figs. 5, 6

aff. 1934a Spathodus strigosus Branson and Mehl, p. 187, pl. 17, fig. 17.
1976 Spathognathodus strigosus, Druce, p. 216, pl. 89, fig. 11 (only).

Types. Figured specimens GSC 107254, 107255.

Remarks. Specimens assigned to this taxon are characterized by free blades which are considerably shorter in proportion to the rest of the element. The lower side of the element posterior to the basal pit is flattened, and tapering to a fine point at the posterior tip. The element is also gently arched with denticles being fused close to the tips (e.g. Pl. V-33, fig. 5).

Occurrence. Palliser Formation and Wabamun Group (Tables V-6, V-10, V-17). As presently known, Mehlina aff. M. strigosa is confined to upper Palliser and Wabamun strata that are dated as Uppermost marginifera to Lower to Middle expansa zones.

Mehlina? arcureclinata n. sp.
Pl. V-33, figs. 7-10

Etymology. From the Latin arcus, meaning an arch or bow and reclinis, meaning leaning backward; referring to the arcuate outline of the lower margin and the reclined posterior denticles.

Types. Holotype GSC 108907, illustrated in Plate V-33, figure 10; paratypes GSC 107256, 107257, 108906, illustrated on Plate V-33, figures 7-9.

Material. About 120 specimens.

Diagnosis. A species possibly related to Mehlina with an arcuate lower margin and reclined posterior denticles.

Description. Element slightly arched and straight to slightly bowed. Element also laterally compressed. Denticles numerous, mostly confluent to tips, erect to semi-erect anteriorly and moderately to strongly reclined posteriorly. Denticles also appear to decrease in height from anterior to posterior ends.

Lower margin gently arcuate, with basal pit situated medially to somewhat behind the mid-point of the element. Basal cavity present in earlier growth stages, and becomes a basal pit with growth. Narrow zone of recessive basal margin present both anteriorly and posteriorly of basal cavity or pit.

Remarks. The tentative assignment of this species to Mehlina is based on the arcuate lower margin of the element and the reclined denticles posteriorly, as opposed to more typical specimens of this genus which are generally arched posterior to the basal pit with more or less erect denticles.

Occurrence. Palliser Formation and Wabamun Group (Tables V-6, V-13, V-15). Mehlina? arcureclinata is presently known to range as low as the Lower rhomboidea Zone whereas the possible upper limits to its stratigraphic range, based on the accompanying fauna, may be as young as the Lower marginifera Zone. However, we favour an upper age limit of probably no younger than the Upper rhomboidea Zone in light of the lack of definite evidence for the presence of the Lower marginifera Zone in these faunas.

Mehlina? brevicristata n. sp.
Pl. V-33, figs. 11-13, 14?

Etymology. From the Latin brevis, meaning short and crista meaning crest or comb; referring to the shortness of the element and the comb- or crest-like appearance of the row of denticles.

Types. Holotype GSC 108908, illustrated in Plate V-33, figure 11; paratypes GSC 108909, 108910, illustrated on Plate V-33, figures 12, 13.

Material. About 170 specimens.

Diagnosis. A species possibly related to *Mehlina* with a short Pa element characterized by the occurrence of few denticles which have a comb-like appearance in lateral view.

Description. Element short, laterally compressed, slightly arched and slightly bowed. Denticles high, mostly free at tips, laterally compressed and reclined and relatively few in number (less than ten, generally five to six). Row of denticles has a comb- or crest-like appearance. Highest denticles situated near anterior end. Free blade encompasses at most only one or two denticles. Basal cavity occupies posterior three-quarters to two-thirds of element, with greatest expansion of cavity on outer side.

Remarks. Specimens of *Mehlina*? *brevicristata* occur in abundance only in one collection in the Nigel Peak section (sample NPW89-14, Table V-6). Possible descendants occur in the same section in a higher sample (sample NPW89-20, Table V-6) where there appears to be hardly a free blade present and the denticles are more numerous, numbering about eight to ten in mature specimens (Pl. V-33, fig. 14).

Occurrence. Palliser Formation (Table V-6). In the one section that *Mehlina brevicristata* occurs, its stratigraphic range is Upper *marginifera* to at least as high as the Lower *expansa* Zone.

Mehlina? sp. A
Pl. V-33, fig. 15

Types. Figured specimens GSC 108912.

Remarks. Specimens assigned to this taxon are characterized by having enlarged, reclined posterior denticles. Denticles are erect anteriorly and on the lower side of the element, there is a large zone of recessive basal margin. The basal pit is a single elongate slit. Since these elements are relatively few in number, we prefer to retain them in open nomenclature at this time.

Occurrence. Palliser Formation (Tables V-6, V-10). Specimens of *Mehlina*? sp. A occur in strata that are late Famennian in age ranging from possibly the Uppermost *marginifera* to the Lower to Middle *expansa* zones.

Mehlina? sp B
Pl. V-33, figs. 16-18

Types. Figured specimens GSC 108913-108915.

Remarks. The large specimen we figure (Pl. V-33, fig. 16) occurs with a fragmentary specimen of approximately the same size with apparently enlarged posterior denticles. These specimens occur with several smaller ones (e.g. Pl. V-33, figs. 17, 18) which appear to show the same arching and enlargement of the posterior denticles. The occurrence of the smaller specimens with the same general taxonomic features caused us to believe that the larger specimens represent a distinct taxon, rather than being pathologic. However, owing to the paucity of these elements, and their occurrence in only one collection (sample PL-23-687, Table V-1), we retain them in open nomenclature.

Occurrence. Palliser Formation (Table V-1). *Mehlina*? sp. B was found in a horizon assigned to the Lower to Middle *crepida* zones.

Mehlina? sp. C

Pl. V-33, figs. 19-21

Types. Figured specimens GSC 108916, 108917.

Remarks. The few specimens assigned to this taxon have what appears to be an incipient platform along the postero-lateral part of the element on one side (Pl. V-33, figs. 19, 20). Otherwise, these specimens show the same general denticle pattern and large zone of recessive basal margin as other specimens we have assigned to *Mehlina*.

Occurrence. Palliser Formation and possibly the Wabamun Group (Tables V-4, V-15). Definite specimens of *Mehlina*? sp. C are confined to strata assignable either to the upper part of the Upper *rhomboidea* Zone or the lower part of the Lower *marginifera* Zone. We have a questionable occurrence of this species in the Lower to Middle *crepida* zones in the Wabamun Group (Table V-15).

Genus *Skeletognathus* Sandberg, Ziegler and Bultynck, 1989

Type species. *Polygnathus norrisi* Uyeno, 1967.

Skeletognathus sp. A

Pl. V-34, figs. 6-9, 10?, 15?, 16?

?1976 *Polygnathus* cf. *P. norrisi* Druce, pp. 195, 196, pl. 78, figs. 1-4.

Types. Figured specimens GSC 108921-108923, 108924?, 108928?

Remarks. Specimens representing early growth stages of this taxon exhibit the strong development of needle-like denticles on the upper part of the platform. (Pl. V-34, figs. 7-9). In all other respects, these elements are spathognathodontid in appearance. Later growth stages (e.g. Pl. V-34, fig. 6) are carminiplanate.

The latest growth stage of *Skeletognathus* sp. A may be represented by a specimen (Pl. V-34, figs. 15, 16) that we questionably include in this taxon. In this specimen there is an overall reduction in the number of denticles like that suggested for mature specimens of *S*. *norrisi* (Uyeno) by Sandberg et al. (1989a, pl. 5, figs. 1 and 2). This specimen, however, is the only one of its type in our collections.

Angulate pectiniform (Pb) elements also occurring in our collections exhibit the same needle-like dentition posteriorly (Pl. V-34, fig. 10). Similar elements were grouped with Pa elements of *Skeletognathus* *norrisi* (Uyeno) by Sandberg et al. (1989a) in a partial apparatus reconstruction for *Skeletognathus*. This similarity of dentition makes us believe that the carminate and carminiplanate Pa elements discussed above and these Pb elements could have occurred in the same apparatus. However, because the stratigraphic ranges of the two types of elements are not coincident (see below), these Pb elements are only questionably assigned to *Skeletognathus* sp. A at this time.

Occurrence. Palliser Formation and Wabamun Group (Tables V-2, V-8, V-9 - Pa elements only). The lower age limit for Pa elements assigned to this taxon is Lower *rhomboidea* Zone. These elements range as least as high as the Lower *expansa* Zone. Pb elements range from the Upper *rhomboidea* to Lower *marginifera* zones.

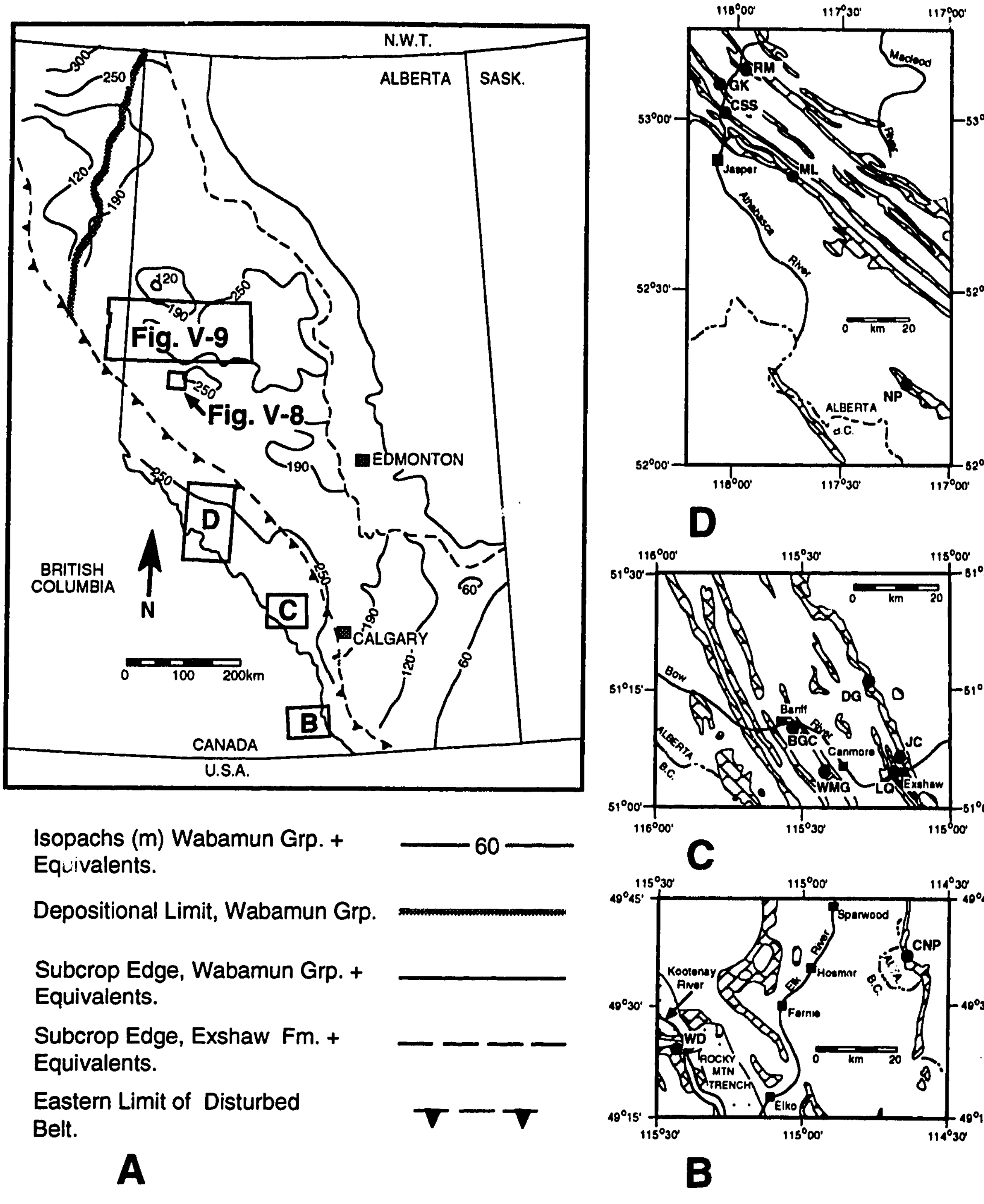
Skeletognathus? sp. A
Pl. V-34, figs. 11-14

Types. Figured specimens GSC 108925-108927.

Remarks. The few specimens of this taxon were questionably assigned to *Skeletognathus* because traces of needle-like denticles can be seen through the subsequent growth lamellae. Otherwise, these specimens have a short platform in which irregular rows of nodes extend between the carina and the outer margin on the upper side (Pl. V-34, figs. 12, 13). There is a long free blade and posterior process in our intact specimen (Pl. V-34, figs. 11, 12).

Occurrence. Palliser Formation (Tables V-2, V-9). *Skeletognathus*? sp. A is presently known to range from the Upper *rhomboidea* to probably as high as the Lower *marginifera* Zone.

Figure V-1. A) Map of part of Western Canada and adjacent United States showing areas represented in inset maps B-D and Figures V-8 and V-9. Map also shows isopachs and subcrop edge for Wabamun Group and equivalent strata and subcrop edge for Exshaw Formation and equivalents (adapted from Belyea, 1964). B) Map showing distribution of Upper Devonian outcrop where Palliser Formation is exposed in area enlarged from A, and location of Crowsnest Pass (CNP) and Wardner (WD) sections in southwestern Alberta and southeastern British Columbia as well as location of Rocky Mountain Trench. Geology after Leech (1958, 1962) and Price (1961). C) Map showing distribution of Upper Devonian outcrop where Palliser Formation is exposed in area enlarged from A, and location of Banff Golf Course (BGC), Devil's Gap (DG), Jura Creek (JC), Lafarge Quarry (LQ) and Whiteman Gap (WMG) sections in southwestern Alberta. Geology modified from Ollerenshaw (1978). D) Map showing distribution of Upper Devonian outcrop where Palliser Formation is exposed in area enlarged from Figure V-1, and location of Cold Sulphur Springs (CSS), Medicine Lake (ML), Mount Greenock (GK) and Roche Miette (RM) sections. Geology after Price et al. (1977).


N.W.T.
ALBERTA
SASK.
300
250
120
190
120
190
250
Fig. V-9
250
Fig. V-8
EDMONTON
190
250
D
BRITISH COLUMBIA
N
250
C
60
190
CALGARY
120
60
0 100 200km
B
CANADA
U.S.A.
Isopachs (m) Wabamun Grp. + Equivalents.
60
Depositional Limit, Wabamun Grp.
Subcrop Edge, Wabamun Grp. + Equivalents.
Subcrop Edge, Exshaw Fm. + Equivalents.
Eastern Limit of Disturbed Belt.
A
118°00'
117°30'
117°00'
53°00'
52°30'
52°00'
RM
GK
CSS
Jasper
ML
Athabasca River
Mcleod River
0 km 20
NP
ALBERTA
B.C.
D
116°00'
115°30'
115°00'
51°30'
51°15'
51°00'
0 km 20
Bow River
DG
Banff
BGC
Canmore
JC
WMG
LQ
Exshaw
ALBERTA
B.C.
C
115°30'
115°00'
114°30'
49°45'
49°30'
49°15'
Sparwood
CNP
Kootenay River
Hosmer
Elk River
Fernie
ALTA.
B.C.
WD
ROCKY MTN TRENCH
0 km 20
Elko
B

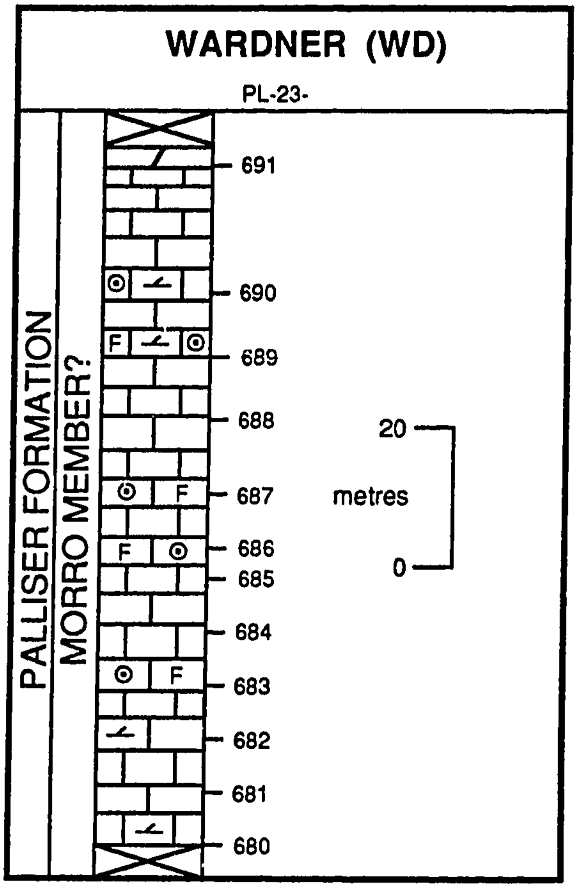


Figure V-2. Stratigraphic column of section of Palliser Formation at Wardner, British Columbia (see Figure V-1B). Sample numbers correspond with those in Table V-1. Only productive samples shown in this and following five figures. See Figure V-12 for explanation of lithological symbols in this figure and Figures V-3 to V-7.

Table V-1. Distribution of conodonts in Wardner (WD) section. For columnar section see Figure V-2. "Apatognathiform" elements refer to conodonts assigned to *Apatognathus* Branson and Mehl and "*Neorhipidognathus*" Mound in this and all subsequent tables. Abbreviations: *rhomb*. = *rhomboidea*; L *m*.? = Lower *marginifera*?; M1 = Morphotype 1 in this and all subsequent tables.

ZONES	Lower - Middle *crepida*								U *crepida* - U *rhomb.*			L m.?
m above base section	0.0	7.6	15.0	23.0	30.5	38.0	43.0	50.0	61.0	70.0	79.0	98.0
WEIGHT (kg.)	0.75	0.65	0.60	0.65	0.65	0.65	0.75	0.75	0.85	0.50	0.85	0.85
SAMPLES / TAXA	PL-23-680	PL-23-681	PL-23-682	PL-23-683	PL-23-684	PL-23-685	PL-23-686	PL-23-687	PL-23-688	PL-23-689	PL-23-690	PL-23-691
Mehlina ovata		1		4	16	1						
Icriodus iowaensis			1?									
Palmatolepis parawolskae			1?			1						
Icriodus erucisimilis				6				1				
Palmatolepis cf. *P. delicatula*				1								
P. minuta				3		2	5	66	34			
P. ovata				4			2		3?			
P. wolskajae				16	5		4					
Pelekysgnathus cf. *P. brevis*				2?						2		
Polygnathus aff. *P. fallax*				1								
P. meijerdreesi				2	3	2						
Palmatolepis sp. B					4	1		5				
Polygnathus aff. *P. timanicus*					1	1		11				
P. cf. *P. brevilaminus*					3?							
Palmatolepis aff. *P. protorhomboidea*						2						
P. cf. *P. perlobata*						1?						
P. subperlobata						1			1			
Icriodus stenoancylus							1					
Mehlina cf. *M. gradata*							3			1		
Palmatolepis protorhomboidea							15	27				
P. quadrantinodosalobata							13	116				
Mehlina? sp. B								25				
Palmatolepis angulata								9				
P. cf. *P. circularis*								3				
P. lanceolata								26				
Pelekysgnathus planus								10				
Polygnathus dolichopleurus								5?				
Mehlina strigosa									6	9		
Palmatolepis crista									1			
P. klapperi									1?			
P. prima M1									15			
P. quadrantinodosalobata M1									54			
P. tenuipunctata									12			
Alternognathus aff. *A. pseudostrigosus*										8	1?	
"*Icriodus*" cf. "*I.*" *cornutus*										5		
Icriodus sp. A										8		
Palmatolepis pectinata										2		5
P. rhomboidea										60		
Polygnathus communis										2		
P. semicostatus										6		46
Palmatolepis stoppeli											10	
P. acuta												1?
P. duplicata												5
P. marginifera												1?
P. quadrantinodosa												6?
Polygnathus cf. *P. padovaniae*												22
Mehlina sp.	1											2
Palmatolepis sp.	1			15	1	3	11	53	2		2	6
Polygnathus sp.				3		1		1				8
Polylophodonta sp.				1								1?
Icriodus sp.						1						
Skeletognathus sp.								1?				1
Pb elements				18	6		3	109	96	44	4	12
ramiform elements	8	5	3	47	21	23	17	604	931	174	22	66
coniform elements	1	6	1	83	38	17	29	44	21	99	13	14
"apatognathiform" elements	7	2	1	84	21	7	6	46	74	26	42	28

Figure V-3. Stratigraphic column of section of Palliser Formation at Crowsnest Pass, Alberta (see Figure V-1B). Approximate position of contact between Costigan and Morro members shown in this and following four figures. Sample numbers correspond with those in Table V-2.

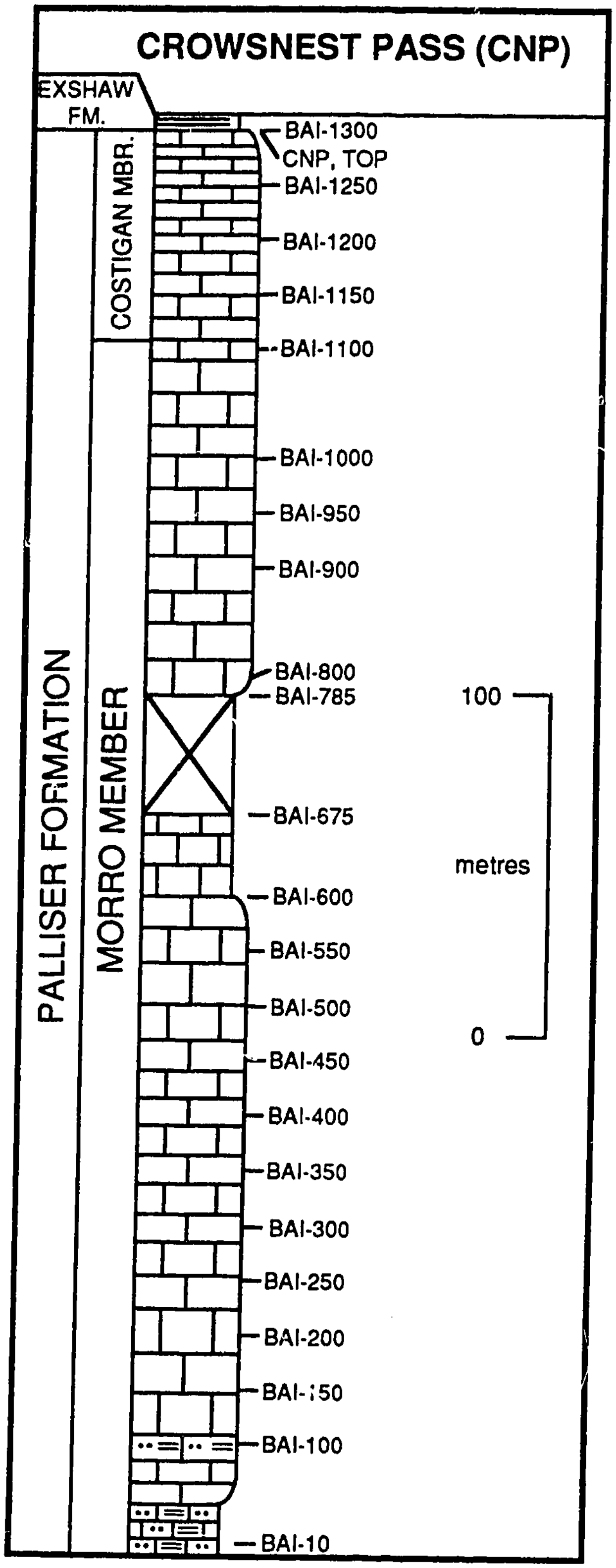
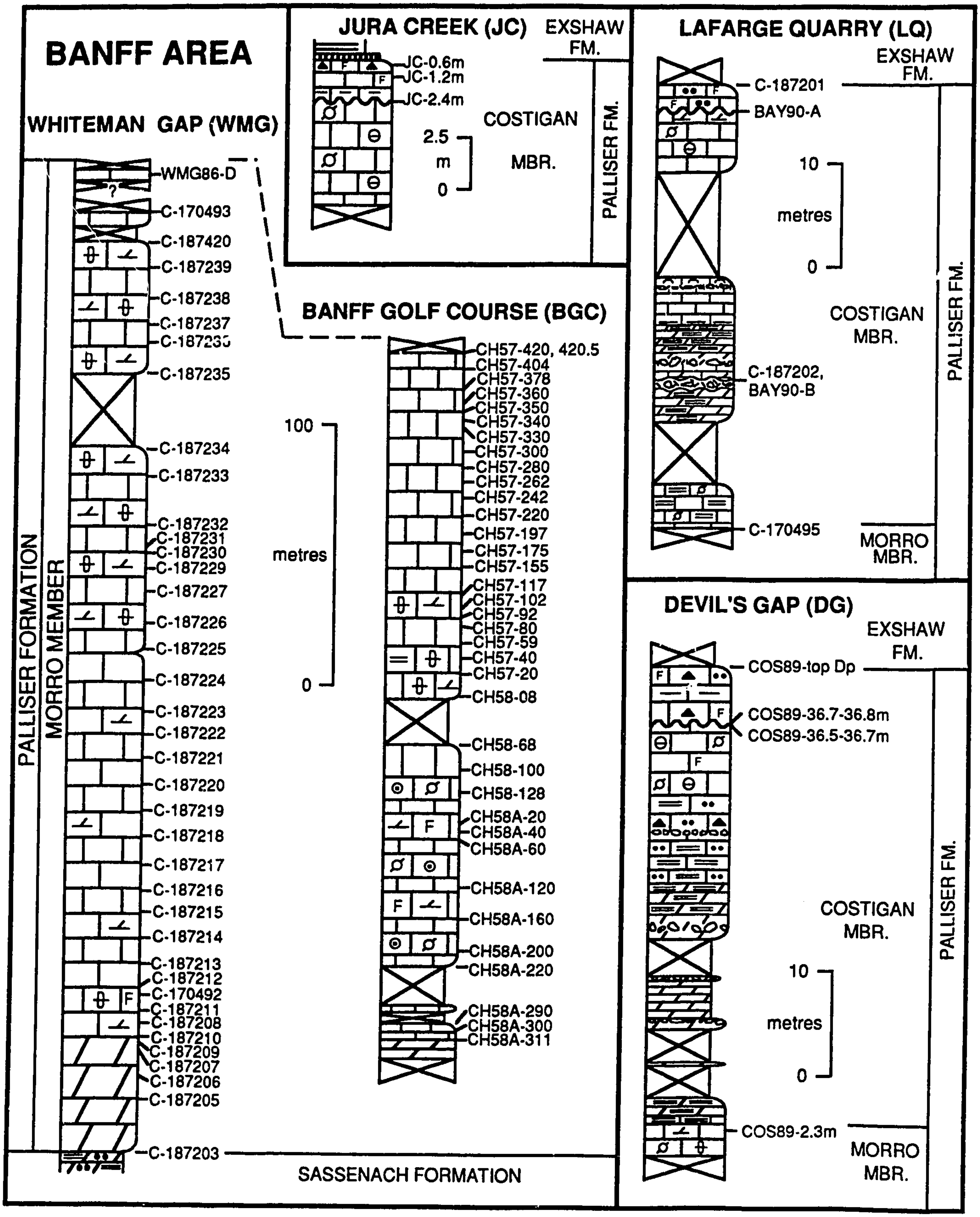

CROWSNEST PASS (CNP)
EXSHAW FM.
COSTIGAN MBR.
PALLISER FORMATION
MORRO MEMBER
BAI-1300
CNP, TOP
BAI-1250
BAI-1200
BAI-1150
BAI-1100
BAI-1000
BAI-950
BAI-900
BAI-800
BAI-785
BAI-675
BAI-600
BAI-550
BAI-500
BAI-450
BAI-400
BAI-350
BAI-300
BAI-250
BAI-200
BAI-150
BAI-100
BAI-10
100
metres
0

Table V-2. Distribution of conodonts in Crowsnest Pass (CNP) section. For columnar section see Figure V-3. Abbreviations: margin. = *marginifera*; U *m*. - L *t*. = Upper *marginifera* to Lower *trachytera*. All other abbreviations as in Table V-1.

ZONES	Lower *crepida* - Upper *rhomboidea*																				Lower *margin.*?		U. *m.* - L. *t.*	
m above base fm.	3.1	30.5	45.7	61.0	76.2	91.4	106.7	121.9	137.2	152.4	167.6	182.9	205.7	239.3	243.8	274.3	289.6	304.8	335.3	350.5	365.8	381.0	396.3	396.3
TAXA / SAMPLES	BAI-10	BAI-100	BAI-150	BAI-200	BAI-250	BAI-300	BAI-350	BAI-400	BAI-450	BAI-500	BAI-550	BAI-600	BAI-675	BAI-785	BAI-800	BAI-900	BAI-950	BAI-1000	BAI-1100	BAI-1150	BAI-1200	BAI-1250	BAI-1300	CNP, TOP
Palmatolepis angulata		6	2																					
P. quadrantinodosalobata		7		1																				
Polygnathus cf. *P. brevilaminus*		1													1?	1?								
Polylophodonta medicinelakensis		3				6																		
Polygnathus dolichopleurus			2	1																				
New Genus B sp. 2					1?																			
Palmatolepis prima M1						1	1?																	
Mehlina cf. *M. gradata*							2											1?					4	
M. gradata							1														1?			
M. strigosa							1																	
Polygnathus semicostatus							4	1	1	6	2	1	5	7	2	9	1	8	2	1	7	1	1	2
Palmatolepis prima										3				4		8								
New Genus A sp.											1?													
Palmatolepis pectinata M1												1?		5	9	13					2			
P. pectinata														3	11						6			
Polygnathus aff. *P. fallax*														1? 1										
Polygnathus germanus														1										
P. webbi														3?	3			1?	1		1			7
Icriodus iowaensis															1?	1?								
Palmatolepis stoppeli																			5	4				
P. acuta																					4			
P. inflexa																					12	2		
Polygnathus crassilabrus																						3	3	3
Skeletognathus sp. A																						1		
S.? sp. A																						1		
Palmatolepis marginifera																							7	6
Pelekysgnathus inclinatus																							2	1
Polygnathus perplexus																								3
Polylophodonta cf. *P. confluens*																								1
Icriodus sp.	1?																							
Polygnathus sp.														1		2								
Palmatolepis sp.															1	11					2	1		
Mehlina sp.																1								2
Alternognathus sp.																	1?							
Pb elements		3	3	1		3	3	3	2	3			9	3	3	3	3	2	2	1	3	1	4	9
ramiform elements		6	1	1	1		10	4	3	11	2		18	9	6	8	5	10	5		10	5	25	37
coniform elements		1				1															5			1
"apatognathiform" elements		6	2		1	2	12	1	4	9	1		26	9	8	8	4	2	2		7	15	30	36

Figure V-4. Stratigraphic columns of sections of Palliser Formation in the area of Banff, Alberta (see Figure V-1C). Top of dolostone unit in Banff Golf Course section correlates with top of same unit at Whiteman Gap. Presumed position of spot sample WMG86-D shown in latter section. All Palliser strata below dashed line connecting top of Banff Golf Course and Whiteman Gap sections included in Morro Member. Only upper part of Palliser Formation shown at Devil's Gap, Jura Creek and LaFarge Quarry sections. For complete sections of this formation at first two localities, see Meijer Drees and Johnston (1994, fig. 3). Sample numbers and/or GSC Locality numbers correspond with those in Tables V-3, V-4 and V-5.


BANFF AREA
WHITEMAN GAP (WMG)
WMG86-D
?
C-170493
C-187420
C-187239
C-187238
C-187237
C-187236
C-187235
C-187234
C-187233
C-187232
C-187231
C-187230
C-187229
C-187227
C-187226
C-187225
C-187224
C-187223
C-187222
C-187221
C-187220
C-187219
C-187218
C-187217
C-187216
C-187215
C-187214
C-187213
C-187212
C-170492
C-187211
C-187208
C-187210
C-187209
C-187207
C-187206
C-187205
C-187203
PALLISER FORMATION
MORRO MEMBER
SASSENACH FORMATION
JURA CREEK (JC)
EXSHAW FM.
JC-0.6m
JC-1.2m
JC-2.4m
2.5
m
0
COSTIGAN
MBR.
PALLISER FM.
BANFF GOLF COURSE (BGC)
100
metres
0
CH57-420, 420.5
CH57-404
CH57-378
CH57-360
CH57-350
CH57-340
CH57-330
CH57-300
CH57-280
CH57-262
CH57-242
CH57-220
CH57-197
CH57-175
CH57-155
CH57-117
CH57-102
CH57-92
CH57-80
CH57-59
CH57-40
CH57-20
CH58-08
CH58-68
CH58-100
CH58-128
CH58A-20
CH58A-40
CH58A-60
CH58A-120
CH58A-160
CH58A-200
CH58A-220
CH58A-290
CH58A-300
CH58A-311
LAFARGE QUARRY (LQ)
EXSHAW FM.
C-187201
BAY90-A
10
metres
0
COSTIGAN MBR.
PALLISER FM.
C-187202,
BAY90-B
C-170495
MORRO MBR.
DEVIL'S GAP (DG)
EXSHAW FM.
COS89-top Dp
COS89-36.7-36.8m
COS89-36.5-36.7m
COSTIGAN MBR.
PALLISER FM.
10
metres
0
COS89-2.3m
MORRO MBR.

ZONES	Lower - Middle *crepida*													? Upper *crepida* - Lower *rhomboidea*											Upper *rhomboidea*								U *margin* - L *trachy.*						
m above base fm.	0.0	20.0	29.3	39.0	41.5	43.5	49.2	54.0	59.9	63.0	72.0	82.0	92.0	100.0	110.0	121.0	131.0	141.0	151.0	160.0	169.0	181.0	193.0	203.0	215.0	224.0	230.0	232.0	241.0	259.5	270.0	299.0	311.0	318.0	328.0	340.0	349.6	361.6	·
WEIGHT (kg.)	1.6	1.5	1.4	1.2	3.0	1.3	1.5	2.4	1.9	1.3	1.9	1.7	2.5	2.7	1.5	1.2	1.5	2.0	2.6	2.7	1.7	2.3	1.5	1.9	1.8	1.6	1.6	1.8	2.0	1.9	1.6	0.6	2.2	1.3	2.1	1.7	1.1	1.6	1.7
GSC LOC. NO./ SAMPLE TAXA	C-187303	C-187205	C-187206	C-187207	C-187209	C-187210	C-187208	C-187211	C-170492	C-187212	C-187213	C-187214	C-187215	C-187216	C-187217	C-187218	C-187219	C-187220	C-187221	C-187222	C-187223	C-187224	C-187225	C-187226	C-187227	C-187229	C-187230	C-187231	C-187232	C-187233	C-187234	C-187235	C-187236	C-187237	C-187238	C-187239	C-187240	C-170493	WMG86-D
Polygnathus dolichopleurus	1?											1	4	3																									
P. meijerdreesi		1																																					
Palmatolepis quadrantinodosalobata						1?		10	6		3		10	17																									
Icriodus erucisimilis							1		3		1?		1	1				1																					
Palmatolepis angulata							4	1				3																											
Polygnathus aff. *P. timanicus*							1																																
Palmatolepis tenuipunctata								1?									2																						
Polygnathus cf. *P. brevilaminus*								1						2?					1?																				
Polylophodonta medicinelakensis								2	1				3				2	2	2																				
Palmatolepis ovata										1		1	1																										
P. parawolskae												1	1?	4																									
P. prima														2?		2																							
New Genus B sp. 2															1?																								
Palmatolepis quadrantinodosalobata M1															3	3	3		1?	5																			
P. prima M1																	3	2?	5?	2?																			
Polygnathus semicostatus																					4		4	4	3	6	6	6	16	2	1	1		3	6	3	1		1?
Icriodus iowaensis																								1															
Pelekysgnathus cf. *P. brevis*																									2														
"*Icriodus*" cf. "*I.*" *cornutus*																										5													
Polygnathus webbi																										1?	3	1?											9
Palmatolepis rhomboidea																														11	4								
Polygnathus communis																															1								
P. sp. A																															1								
Alternognathus aff. *A. pseudostrigosus*																																	1						
Polygnathus crassilabrus																																			1	5		2	9
Palmatolepis stoppeli																																				1	17		
Polygnathus perplexus																																							1
Polygnathus sp.				1?			1					1															1				1		1			1			2
Palmatolepis sp.								4	1			1	1	2								1								1								1	
Mehlina sp.									1				1	1								2																	2?
Icriodus sp.																							2?																
"*Icriodus*" sp.																																2?							
Alternognathus sp.																																					1?		
Pelekysgnathus sp.																																							1
Pb elements							2		3		1?	1	1?	6	2	1	1	1	1	1		6	6	4	2	12	2	3	3				5	2		2	8		7
ramiform elements	1?	2	4		3	1	5	2	4	4	4	3	8	27	1	5	11	6		6	4	9	3	11	9	19	2	10	7	7	4	2	30	12	12	18	22	1	28
coniform elements		3			1			4	16		1	2	7	6	2	2		1	3	2	1	2		1	4	4							5	1			1		19
"apatognathiform" elements	1	5		1	4		14	18	27	6	4	14	33	38	2	3	8	8	2	12	5	22	13	2	8	10	1	8	9	7	2	2	59	28	1	20	12	2	80

Table V-3. Distribution of conodonts in Whiteman Gap (WMG) section. For columnar section see Figure V-4. Abbreviations: trachy. = trachytera. All other abbreviations as in previous tables.

ZONES	Lower *crepida* - Upper *rhomboidea*																										? Lower *marginifera*								? Upper *margin.*?		
m above base section	0.3	3.7	6.7	28.0	34.0	46.3	58.5	76.8	82.9	89.0	95.1	103.6	113.4	131.7	140.2	146.3	152.1	158.5	162.0	165.2	169.8	181.4	187.4	194.2	201.2	207.9	214.0	219.5	225.6	234.7	237.7	240.8	243.8	249.3	257.2	262.0	262.3
TAXA / SAMPLES	CH58A-311	CH58A-300	CH58A-290	CH58A-220	CH58A-200	CH58A-160	CH58A-120	CH58A-60	CH58A-40	CH58A-20	CH58-128	CH58-100	CH58-68	CH58-08	CH57-20	CH57-40	CH57-59	CH57-80	CH57-92	CH57-102	CH57-117	CH57-155	CH57-175	CH57-197	CH57-220	CH57-242	CH57-262	CH57-280	CH57-300	CH57-330	CH57-340	CH57-350	CH57-360	CH57-378	CH57-404	CH57-420	CH57-420.5
Icriodus erucisimilis	2		1																																		
Palmatolepis angulata	6	3																																			
P. quadrantinodosalobata	1	1			1																																
Mehlina ovata		1																																			
Palmatolepis parawolskae				1																																	
P. subperlobata				1?																																	
Polygnathus dolichopleurus				2																																	
Palmatolepis quadrantinodosalobata M1						2?																															
New Genus B sp. 2								1?																													
Palmatolepis prima M1									1	1?																											
Mehlina gradata											1						1?																				
Palmatolepis rhomboidea												3							1?																		
Polygnathus communis													1																								
Palmatolepis pectinata M1														1																							
P. prima														2																							
Polygnathus webbi														1							1	1				1		1?		1	1		1			8	1
P. semicostatus															6	3	3		3	5	5	5	3	1													
P. crassilabrus																	2			1												5	2	2	1		
Mehlina? sp. C																				2			1														
Palmatolepis stoppeli																				16	7	1	3	3	4	1?	1?										
Polygnathus germanus																				1?																	
Mehlina strigosa																											1									6	
Palmatolepis marginifera																											1?			4	4		3	2	1	1	
Polygnathus latisemicostatus																														2?							
Pelekysgnathus inclinatus																																			2		
Polygnathus perplexus																																			1?		
Palmatolepis distorta																																				44	8
P. minuta																																				1	
P. pectinata																																				9	
Polygnathus paraobliquicostatus																																				163	65
Mehlina cf. *M. gradata*																																				1	
Palmatolepis sp.			1	2										2																							
Polylophodonta sp.								1																			1										
Polygnathus sp.										1				2																							1
Icriodus sp.															1																						
Mehlina sp.																	1										1?										
Alternognathus sp.																						1?														1?	1?
Bispathodus sp.																																				1	
Pb elements	2		1?												1		3	2		1	1	3	1				1							1?		37	11
ramiform elements	9	2?		1		1			2			4	3	1	4		5	2	2	16	8	2	2	1?		1	2		1	2		3			1	78	21
coniform elements	4	2	1				1																												3	4	
"apatognathiform" elements	13	5	1	3		1	1					4		2	7	3	1	4		11	3	7	1	1		2				1	2	6	3	2	4	48	6

Table V-4. Distribution of conodonts in Banff Golf Course (BGC) section. For columnar section see Figure V-4. All abbreviations as in previous tables.

Table V-5. Distribution of conodonts in Devil's Gap (DG), Jura Creek (JC) and Lafarge Quarry (LQ) sections. For columnar section of each locality, see Figure V-4. Key to zones: 1 - uppermost Upper rhomboidea to lower Lower marginifera; 2 - Upper rhomboidea to Upper marginifera; 3 - Lower to Upper marginifera; 4 - Lower expansa? to Lower praesulcata; 5 - Uppermost marginifera to Upper trachytera; 6 - Upper marginifera to Lower praesulcata. "-" indicates information not available in this and all subsequent tables. "X" in this and all subsequent tables denotes elements present but not counted. Abbreviations: L-M = Lower to Middle; M2 = Morphotype 2 in this and all subsequent tables. All other abbreviations as in previous tables.

ZONES	1	2		3	4	1	-	5	6	L-M *expansa*		
LOCALITY	LQ					DG				JC		
STRATIGRAPHIC POSITION BELOW TOP FORMATION (b. t. fm.), ABOVE BASE SECTION (a. b. sect.)	42.2 m b. t. fm.	27.9 m b. t. fm.	28.0 m b. t. fm.	2.5 m b. t. fm.	0.6 m b. t. fm.	2.3 m a. b. sect.	35.6 m a. b. sect.	35.7 m a. b. sect.	42.5 m a. b. sect.	2.4 m b. t. fm.	1.2 m b. t. fm.	0.6 m b. t. fm.
WEIGHT (kg.)	2.80	2.60	1.25	2.60	2.70	2.04	2.70	1.82	1.55	-	-	-
SAMPLES / TAXA	C-170495	C-187202	BAY90-B	BAY90-A	C-187201	COS89-2.3m	COS89-36.5-36.7m	COS89-36.7-36.8m	COS89-top Dp	JC-2.4m	JC-1.2m	JC-0.6m
Mehlina gradata	1											
Palmatolepis stoppeli	1					4						
Polygnathus semicostatus	2?				89	2?		X	5	11	33	13
Mashkovia? sp.		5	2									
Palmatolepis distorta				1?				X?				
P. marginifera				4								
Polygnathus paraobliquicostatus				1								
Polylophodonta confluens				2								
Skeletognathus sp. A				1		1						
Bispathodus stabilis M2					11?							
Mehlina strigosa					6?				1	1	4	
Pelekysgnathus inclinatus					2			X			1	1
Polygnathus cf. *P. homoirregularis*					1			X		2		
"Icriodus" costatus								X				
Polygnathus fallax								X?				
Bispathodus stabilis M1									2			2
Polygnathus communis									2		5	5
P. perplexus											1	1
P. webbi											1?	
Mehlina? sp. A												1?
Polygnathus sp.				2	2			X		3		
Mehlina sp.								X			2	
Polylophodonta sp.								X				
Pb elements				20	5	3		X		5	7	3
ramiform elements	9	1	2	9	42	16	2	X	3	15	12	16
coniform elements		6	13	3	17			X		4	2	6
"apatognathiform" elements	14	41	43	42	50	6		X	1	10		5

Figure V-5. Stratigraphic column of section of Palliser Formation at Nigel Peak (see Figure V-1D). Sample numbers correspond to those in Table V-6.

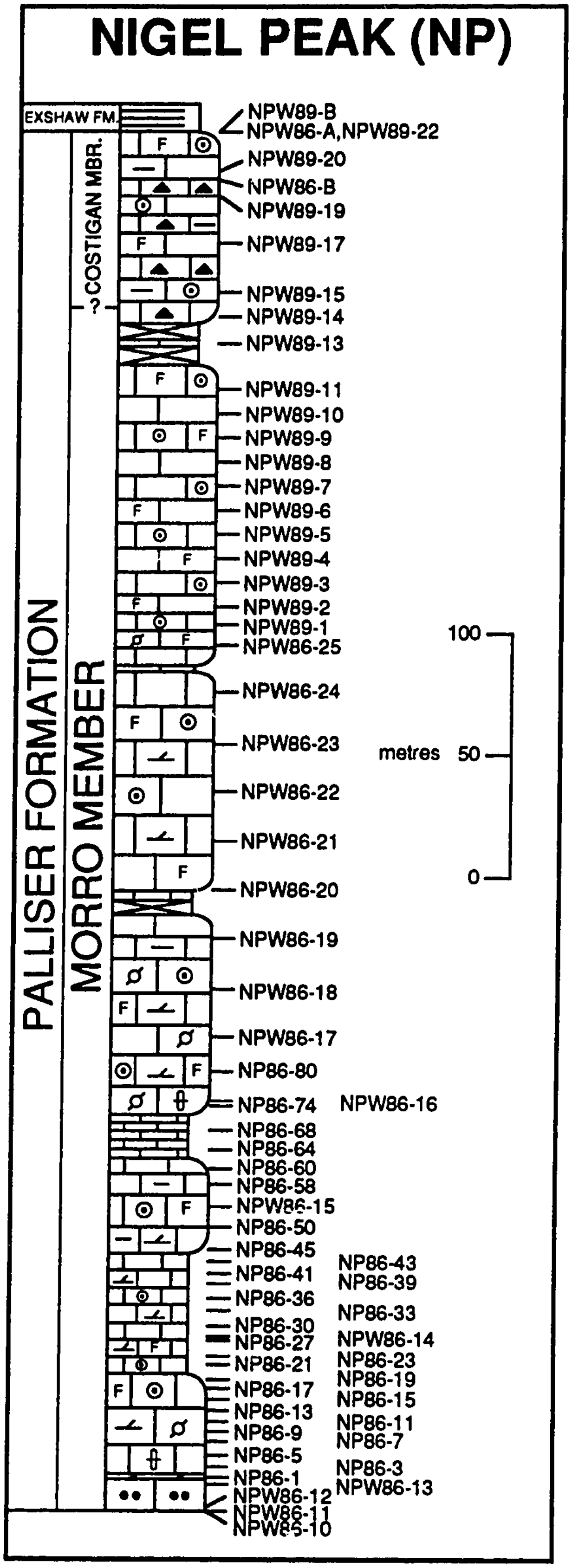
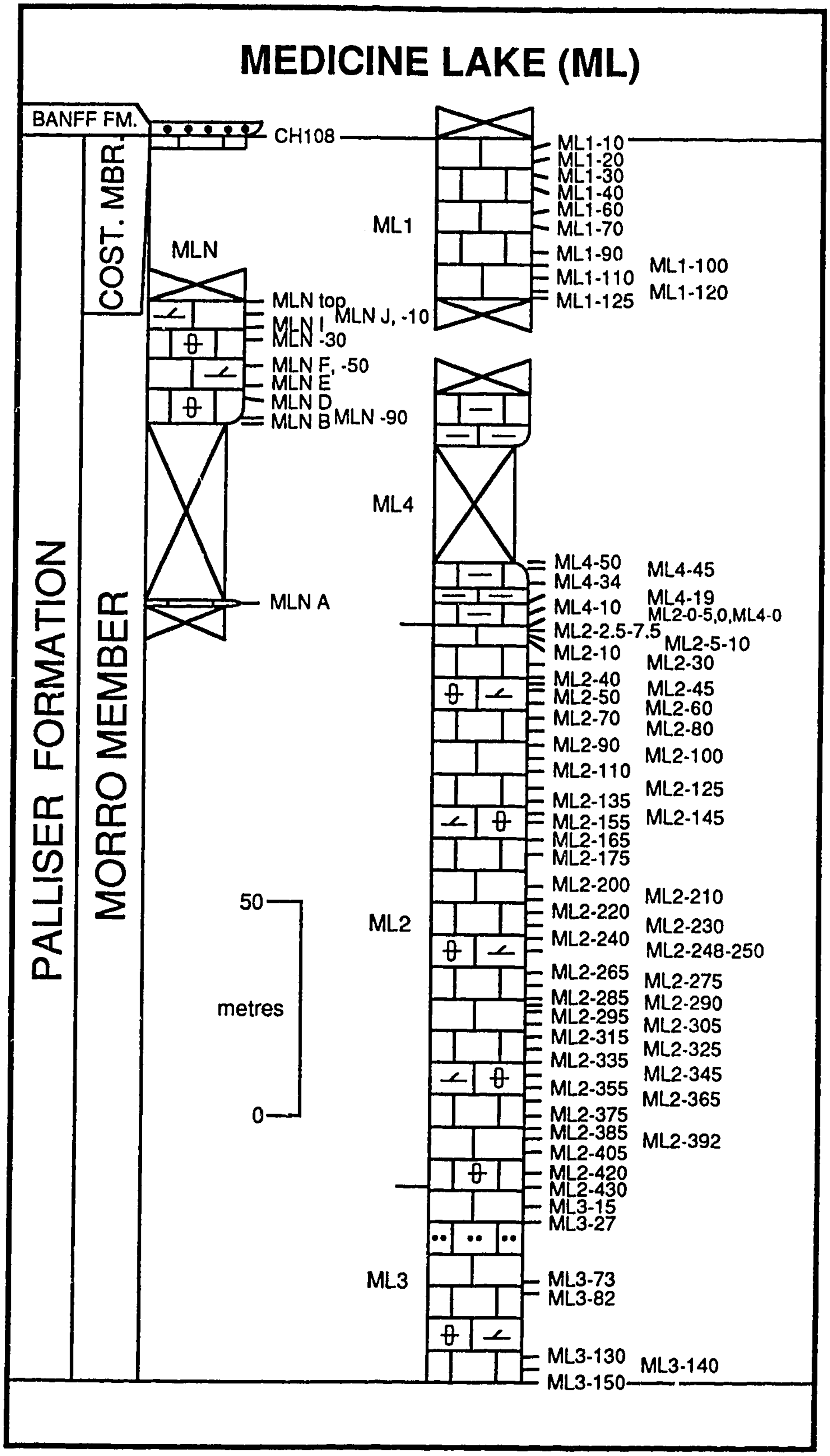

NIGEL PEAK (NP)
EXSHAW FM.
?COSTIGAN MBR.
PALLISER FORMATION
MORRO MEMBER
NPW89-B
NPW86-A,NPW89-22
NPW89-20
NPW86-B
NPW89-19
NPW89-17
NPW89-15
NPW89-14
NPW89-13
NPW89-11
NPW89-10
NPW89-9
NPW89-8
NPW89-7
NPW89-6
NPW89-5
NPW89-4
NPW89-3
NPW89-2
NPW89-1
NPW86-25
NPW86-24
NPW86-23
NPW86-22
NPW86-21
NPW86-20
NPW86-19
NPW86-18
NPW86-17
NP86-80
NP86-74
NPW86-16
NP86-68
NP86-64
NP86-60
NP86-58
NPW86-15
NP86-50
NP86-45
NP86-43
NP86-41
NP86-39
NP86-36
NP86-33
NP86-30
NP86-27
NPW86-14
NP86-21
NP86-23
NP86-19
NP86-17
NP86-15
NP86-13
NP86-11
NP86-9
NP86-7
NP86-5
NP86-3
NP86-1
NPW86-13
NPW86-12
NPW86-11
NPW86-10
F
100
metres 50
0

Table V-6 (in pocket). Distribution of conodonts in Nigel Peak (NP) section. For columnar section see Figure V-5. Abbreviations: U-Um = Upper to Uppermost; Um *m*. - U *p*. = Uppermost *marginifera* to Upper *postera*. All other abbreviations as in previous tables.

Figure V-6. Stratigraphic columns of six measured segments (ML1, ML2, etc.) of section of Palliser Formation at Medicine Lake (see Figure V-1D). Sample numbers correspond to those in Tables V-7 and V-8. See Appendix for further details. COST. MBR. = Costigan Member.



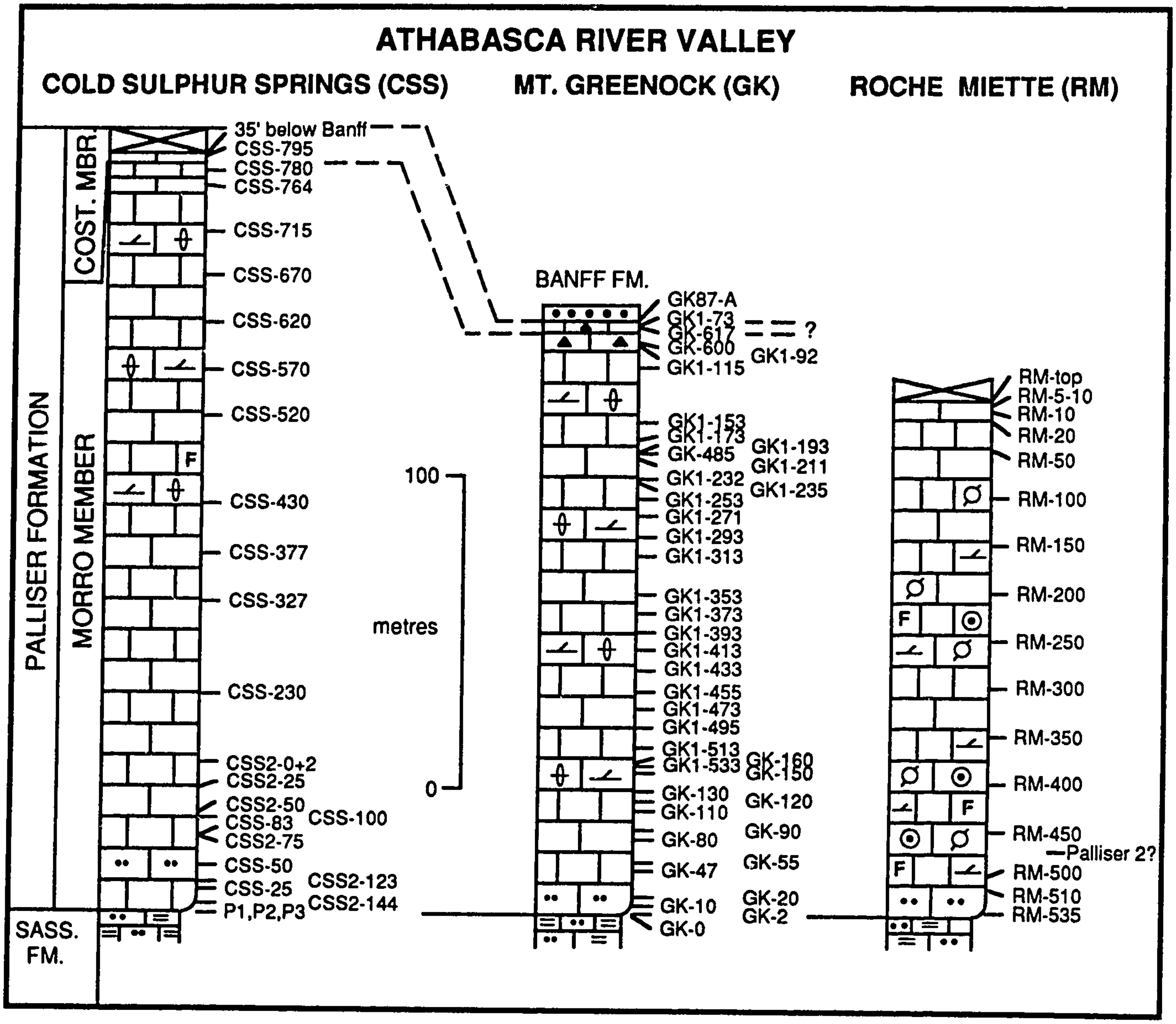
MEDICINE LAKE (ML)

Table V-7 (in pocket). Distribution of conodonts in lower part (ML2-ML4) of Medicine Lake (ML) section. For columnar section see Figure V-6. All abbreviations as in previous tables.

Table V-8. Distribution of conodonts in upper part (MLN, ML1, CH108) of Medicine Lake (ML) section. For columnar section see Figure V-6. Abbreviations: L-M? *exp*. = Lower to Middle? *expansa*; L *m*. - L *t*. = Lower *marginifera* to Lower *trachytera*. All other abbreviations as in previous figures.

ZONES	Upper *rhomboidea*										Lower *marginifera*								L *m.* - L *t.*			L-M? *exp.*
m above base fm.	182.0	224.1	225.6	230.0	233.2	237.8	243.9	246.9	250.0	253.0	254.3	255.9	258.9	261.9	265.0	271.1	274.1	280.2	283.3	286.3	289.4	292.6
SAMPLES / TAXA	MLN A	MLN B	MLN-90	MLN D	MLN E	MLN F, -50	MLN-30	MLN I	MLN J, -10	MLN top	ML1-125	ML1-120	ML1-110	ML1-100	ML1-90	ML1-70	ML1-60	ML1-40	ML1-30	ML1-20	ML1-10	CH108
Palmatolepis stoppeli	20	1				3	2	8	1	50												
Polygnathus semicostatus	3	6	1			3	2	7	3	8	1		2					4				7
P. crassilabrus			2										5	1	2			4		1		
P. sp. L					1?					1												
Skeletognathus sp. A										1?												
Palmatolepis marginifera											25	15	42	13				1	5	76	18	
Polygnathus webbi														1								
Palmatolepis inflexa																2		3				
P. quadrantinodosa																1?		1?				
P. duplicata																	5					
P. acuta																		1				
P. pectinata M1																		3				
Pelekysgnathus inclinatus																		3				
Polygnathus latisemicostatus																		7				
Mehlina gradata																			2			
Bispathodus stabilis M1																						1?
B. stabilis M2																						2
"Icriodus" cf. *"I." raymondi*																						9
Polygnathus communis																						1
P. perplexus																						2
Palmatolepis sp.						1						2										
Polygnathus sp.										2			1?			2			3			1
Polylophodonta sp.														1		1				1		
Mehlina sp.																				1?		3
Pelekysgnathus sp.																						2?
Pb elements	1?	1?	1		1					14	1	2	1	1	2	2		6	2	2	1	11
ramiform elements	4	3	6	2	3	1?	2	6		18	4	2	7	1		2	1	16	8	11	6	19
coniform elements				1?									1			1?		3				4
"apatognathiform" elements	5	2	1	5	1	1?	1	1		29	5	13	45	10	4	3		25	8	26	21	5

Figure V-7. Stratigraphic columns of sections of Palliser Formation in Athabasca River Valley (see Figure V-1D). Position of contact of Costigan and Morro members only shown for Cold Sulphur Springs and Mount Greenock sections. Presumed position of spot sample Palliser 2 (in which conodonts were studied but not counted) shown in Roche Miette section. Sample numbers correspond to those in Tables V-9, V-10 and V-11. COST. MBR. = Costigan Member; SASS. FM. = Sassenach Formation.



ATHABASCA RIVER VALLEY
COLD SULPHUR SPRINGS (CSS)
MT. GREENOCK (GK)
ROCHE MIETTE (RM)
PALLISER FORMATION
COST. MBR.
MORRO MEMBER
SASS. FM.
35' below Banff
CSS-795
CSS-780
CSS-764
CSS-715
CSS-670
CSS-620
CSS-570
CSS-520
F
CSS-430
CSS-377
CSS-327
CSS-230
CSS2-0+2
CSS2-25
CSS2-50
CSS-83
CSS2-75
CSS-100
CSS-50
CSS-25
P1,P2,P3
CSS2-123
CSS2-144
100
metres
0
BANFF FM.
GK87-A
GK1-73
GK-617
GK-600
?
GK1-92
GK1-115
GK1-153
GK1-173
GK-485
GK1-193
GK1-211
GK1-232
GK1-235
GK1-253
GK1-271
GK1-293
GK1-313
GK1-353
GK1-373
GK1-393
GK1-413
GK1-433
GK1-455
GK1-473
GK1-495
GK1-513
GK1-533
GK-160
GK-150
GK-130
GK-110
GK-120
GK-90
GK-80
GK-47
GK-55
GK-10
GK-0
GK-20
GK-2
RM-top
RM-5-10
RM-10
RM-20
RM-50
RM-100
RM-150
RM-200
F
RM-250
RM-300
RM-350
RM-400
F
RM-450
—Palliser 2?
F
RM-500
RM-510
RM-535

Table V-9. Distribution of conodonts in Cold Sulphur Springs (CSS) section. For columnar section see Figure V-7. Key to zones: 1 - Lower _marginifera_ to Lower _trachytera_; 2 - Lower _marginifera_ to Upper _trachytera_; 3 - Lower _marginifera_ to Lower _praesulcata_. All abbreviations as in previous tables.

ZONES	Lower *crepida* - Lower *rhomboidea*															Upper *rhomboidea*							1		2	3
m above base fm.	0.0			3.1	7.6	9.8	15.2	24.4	25.3	30.5	32.0	39.6	48.2	70.1	99.7	114.9	131.1	158.5	173.3	189.0	204.0	217.9	232.9	237.8	242.3	243.2?
SAMPLES TAXA	CSSP1	CSSP2	CSSP3	CSS2-144	CSS-25	CSS2-123	CSS-50	CSS2-75	CSS-83	CSS-100	CSS2-50	CSS-25	CSS2-0+2	CSS-230	CSS-327	CSS-377	CSS-430	CSS-520	CSS-570	CSS-620	CSS-670	CSS-715	CSS-764	CSS-780	CSS-795	35' below Banff
Icriodus erucisimilis	2		1	2	1	1	14	2	1																	
Mehlina ovata	1							3	1	1																
Palmatolepis wolskajae	7		3			1?	7	13	24	1?																
Polygnathus meijerdreesi	2	1	1		2		8	3	4																	
Polylophodonta medicinelakensis		1												5												
Icriodus stenoancylus			1			5	2	3	3																	
Polygnathus webbi				1?	1												2								2	
P. cf. *P. brevilaminus*						5	7	3																		
Mehlina cf. *M. gradata*							2?	1																		
Mehlina gradata							1?								1											
Polygnathus aff. *P. fallax*							1?		3																	
Palmatolepis quadrantinodosalobata													4													
Icriodus iowaensis														1	1											
New Genus B sp. 2														1?												
Palmatolepis quadrantinodosalobata M1														3?												
New Genus B sp. 3															1											
Polygnathus semicostatus															17	7	11	3			9			1	3	2
Palmatolepis rhomboidea																11	12									
Polygnathus sp. A																1	1?									
P. communis																	1									
P. sp. B																	1									
Skeletognathus? sp. A																	1	1			1					
Palmatolepis stoppeli																			16	5	23	8				
Polygnathus crassilabrus																			1		1					
Skeletognathus sp. A																					1					
Palmatolepis marginifera																							7	1		
Pelekysgnathus inclinatus																								1		1
Palmatolepis distorta																									4	
Mehlina strigosa																										3
Icriodus sp.						2																				
Polygnathus sp.						1?				1				2						2	1		2			
Polylophodonta sp.						1		2	3																	
Mehlina sp.									1									1?			1?					
Palmatolepis sp.										1	1															
"*Icriodus*" sp.																1										
Pb elements	3		3?	2?		5	11	6	7	2	1				3		5	3	2		2			1?	4	3
ramiform elements	18	1	13	3	10	15	75	40	54	6	4	1		5	14	10	6	10	5	2	9				5	3
coniform elements	3		5	7	5	4	16	48	30	2	4					4									2	
"apatognathiform" elements	13	2	9	1	4	7	55	28	31	7	4			2	4		2	10	5	1	8	3	2	1	3	

Table V-10. Distribution of conodonts in Mount Greenock (GK) section. For columnar section, see Figure V-7. Abbreviations: Um m. - M e.? = Uppermost marginifera to Middle expansa? All other abbreviations as in previous tables.

ZONES	Lower - Middle *crepida*										Upper *crepida* - Lower *rhomboidea*										Upper *rhomboidea* - Lower *marginifera*															Upper *margin.*			Um *m.* - M *e.?*	
m above base fm.	0.0	0.6	3.1	6.1	14.3	16.8	24.4	27.4	33.5	36.6	39.6	45.7	47.9	48.8	54.0	60.0	66.2	71.6	78.4	84.7	90.6	96.7	102.8	115.0	121.1	127.8	133.3	138.7	139.7	146.1	147.8	151.5	157.6	163.7	175.0	182.3	182.9	188.1	188.1	190.0?
SAMPLES / TAXA	GK-0	GK-2	GK-10	GK-20	GK-47	GK-55	GK-80	GK-90	GK-110	GK-120	GK-130	GK-150	GK1-533	GK-160	GK1-513	GK1-495	GK1-473	GK1-455	GK1-433	GK1-413	GK1-393	GK1-373	GK1-353	GK1-313	GK1-293	GK1-271	GK1-253	GK1-235	GK1-232	GK1-211	GK-485	GK1-193	GK1-173	GK1-153	GK1-115	GK1-92	GK-600	GK-617	GK1-73	GK87-A
Icriodus erucisimilis	2	9	1		2		2				1				3																									
I. stenoancylus	1	1	1		2						1																													
Mehlina cf. *M. gradata*	2																																							
M. gradata	1	1																														1								
Polygnathus meijerdreesi	8	5	1		3		1		1?																															
P. webbi	5	13																																		1		3		
P. cf. *P. brevilaminus*			1 1?										1													1?						1?								
P. glaber				1																																				
Mehlina ovata					1	1																																		
Palmatolepis wolskajae					2	2																																		
Polylophodonta medicinelakensis						1			1?			2		2	1?				5																					
Palmatolepis parawolskae							1				4		4		1																									
P. angulata									3	3			3																											
P. cf. *P. circularis*									2																															
P. circularis									1																															
Polygnathus dolichopleurus									2?		3		3	1																										
Palmatolepis ovata											2																													
P. prima											4		2				1					1				11														
P. quadrantinodosalobata											6	1	2		5														1											
Pelekysgnathus planus											1																													
Polygnathus sp. C														1																										
New Genus B sp. 6															1																									
Palmatolepis prima M1																	4												2											
P. quadrantinodosalobata M1																	1		3										2											
Polygnathus aff. *P. lauriformis*																	1?																							
Palmatolepis prima M2																				1																				
Mehlina strigosa																						1																5	3	24
New Genus B sp. 3																							1?																	
Polygnathus semicostatus																							2	6	2	28	8			14	4	7	4	1?		2			8	125
Palmatolepis inflexa																								1								1								
P. klapperi																								3																
Polygnathus aff. *P. pennatulus*																								1								7								
P. latisemicostatus																								2																
Icriodus iowaensis																									1?															
Palmatolepis rhomboidea																									3		3													
P. acuta																										4														
P. pectinata																										4														
Polygnathus communis																										1													3	115
Polygnathus sp. A																										5	2													
P. sp. B																										3	2			1?										
New Genus B sp. 5																											1													
Polygnathus crassilabrus																														2?			1			5		1		
P. germanus																																	1?							
Palmatolepis stoppeli																																		2						
P. marginifera																																				19	1	12		
Polygnathus perplexus																																				2		2	4	
Bispathodus stabilis M1																																							5	90
"*Icriodus*" cf. "*I*" *raymondi*																																							6	1
Peleksgnathus inclinatus																																							1?	5
Mehlina aff. *M. strigosa*																																								3
M.? sp. A																																								18
Mehlina sp.		1?							1																		1												1	17
Palmatolepis sp.			1								2			1					1		1					6									1		1			
Polygnathus sp.					2					1					1				2?	1						1				2		3								
Icriodus sp.									1		1																													
Bispathodus sp.																																							2?	
"*Icriodus*" sp.																																								1?
Pb elements	2	5?		1?	2	1?			1	2			1		1		1		1?	2		2	1	1		10	6		1	3?	2	9	4	1		2	1?	1	16	X
ramiform elements	21	30	3	8	14	7	4		6	3	11	1?	14	1	2	1?	5	1	14	8	4	3	2	4	1	22	13	7	2	4	1	14	4	1		10	2	11	8	X
coniform elements	22	14	1		8		1	1	2	2	1		2		2				4		1?								2							2			10	X
"apatognathiform" elements	29	33	1?	2	8	2	4	4	3		8	5	6		7		6		10	3	2	2	3	5	5	13	2	3	1	8	1	9	2	6		27	1	17	12	X

Table V-11. Distribution of conodonts in Roche Miette (RM) section. For columnar section see Figure V-7. Abbreviations: U _m_. - L _t_. = Upper _marginifera_ to Lower _trachytera_. All other abbreviations as in previous tables.

ZONES	Lower *crepida* - Lower *rhomboidea*						Upper *rhomboidea*							L *margin.*	U *m.* - L *t.*	
m above base fm.	1.5	9.1	12.2	27.4	42.7	57.9	73.2	88.4	103.6	118.9	134.1	149.9	158.5	161.6	161.6-163	164.6
SAMPLES / TAXA	RM-535	RM-510	RM-500	RM-450	RM-400	RM-350	RM-300	RM-250	RM-200	RM-150	RM-100	RM-50	RM-20	RM-10	RM-5-10	RM-top
Icriodus erucisimilis	2	1?	2	2												
Polygnathus cf. *P. brevilaminus*	1	1		1												
Mehlina ovata		9	1													
Palmatolepis wolskajae		7														
Polygnathus meijerdreesi		3	2	2												
Mehlina gradata			1												1	
Palmatolepis parawolskae			2													
P. sp. A			4													
Polygnathus aff. *P. fallax*			1													
Polylophodonta medicinelakensis			1	1?		1										
Icriodus stenoancylus				1												
Palmatolepis angulata				11												
P. protorhomboidea				1												
P. quadrantinodosalobata				2												
Polygnathus dolichopleurus				4												
Icriodus aff. *I. alternatus*					1											
Palmatolepis prima M1					1											
P. quadrantinodosalobata M1					1											
P. subperlobata					2?											
P. prima M2						3										
Polygnathus aff. *P. lauriformis*						1										
New Genus B sp. 2							1?									
New Genus B sp. 3							1?									
Polygnathus semicostatus							12	5	4		5			1?	1	
Palmatolepis rhomboidea								3								
Polygnathus sp. A								1								
Palmatolepis stoppeli										1						
Polygnathus crassilabrus										2				2	3	
Palmatolepis marginifera														51	5	
Pelekysgnathus inclinatus														1		
Polygnathus germanus														1?		
Polylophodonta cf. *P. confluens*														2		
Mehlina cf. *M. gradata*															1	
Polygnathus perplexus															1	
Polygnathus sp.	1			1												
Polylophodonta sp.	1	1														
Palmatolepis sp.										1		2		2		1
Mehlina sp.														1		
Pb elements	1	6	2	5	1	1?			2	1				9	1?	
ramiform elements	5	21	21	11	4	4	10	4 1?	9	1	3	1?	1	10	8	
coniform elements		11		3												
"apatognathiform" elements	6	17	10	9	4		1?	3	3?	1		1		27	11	2

Figure V-8. Cross section showing stratigraphic position of cored intervals and intervals sampled for conodonts in each core of Wabamun Group from the Gold Creek Field. Location of wells shown in township (T) and range (R) map of area enlarged from Figure V-1A. For depths of sampled intervals see Tables V-12, V-13 and V-14.

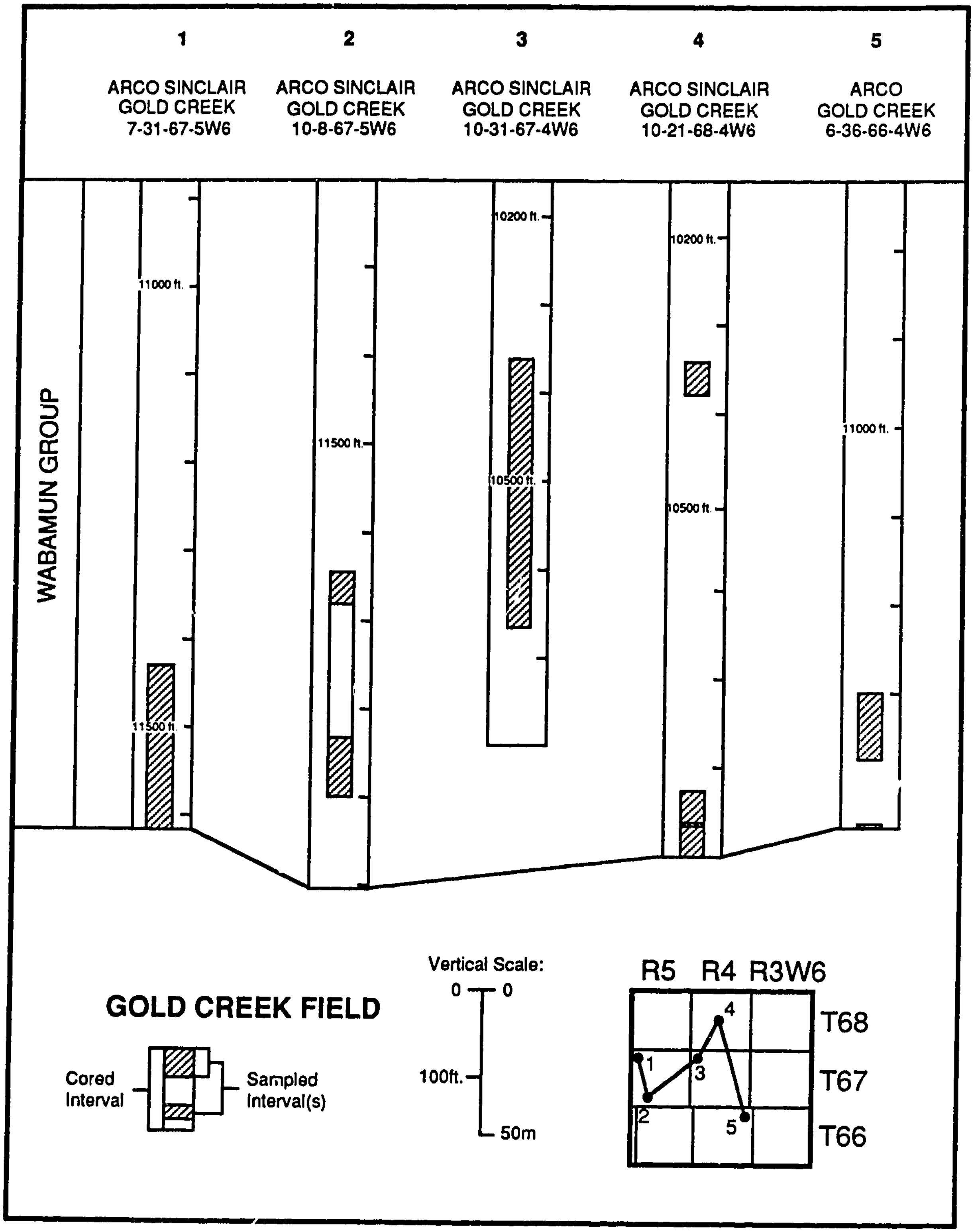

1
ARCO SINCLAIR GOLD CREEK 7-31-67-5W6
2
ARCO SINCLAIR GOLD CREEK 10-8-67-5W6
3
ARCO SINCLAIR GOLD CREEK 10-31-67-4W6
4
ARCO SINCLAIR GOLD CREEK 10-21-68-4W6
5
ARCO GOLD CREEK 6-36-66-4W6
WABAMUN GROUP
11000 ft.
11500 ft.
11500 ft.
10200 ft.
10500 ft.
10200 ft.
10500 ft.
11000 ft.
GOLD CREEK FIELD
Cored Interval
Sampled Interval(s)
Vertical Scale:
0
0
100ft.
50m
R5
R4
R3W6
T68
T67
T66
1
2
3
4
5

Table V-12. Distribution of conodonts in Gold Creek 7-31 well (well no. 1 in Figure V-8). For stratigraphic position of cored interval and well location, see Figure V-8.

STRATIGRAPHIC UNITS	WABAMUN GROUP																	
	DIXONVILLE UNIT							WHITELAW UNIT										
ZONES	Lower - Middle *crepida*																	
GSC LOCALITY NUMBER	C-130391																	
WEIGHT (kg.)	0.800	0.900	0.900	0.725	0.800	0.800	0.700	0.750	0.750	0.775	0.575	0.750	0.600	0.700	0.700	0.700	0.800	0.700
SAMPLED INTERVALS / TAXA	11607-11617 ft.	11597-11607 ft.	11587-11597 ft.	11578-11587 ft.	11570-11578 ft.	11560-11570 ft.	11551-11560 ft.	11538-11551 ft.	11525-11538 ft.	11512-11525 ft.	11496-11512 ft.	11486-11496 ft.	11480-11486 ft.	11472-11480 ft.	11460-i1472 ft.	11452-11460 ft.	11440-11452 ft.	11430-11440 ft.
Icriodus erucisimilis	1	1			1	2								1		1		
Polygnathus meijerdreesi	1	5		2		1?			2						1?			
P. webbi	1?																	
P. cf. *P. brevilaminus*		1?								1?		1?						
Palmatolepis wolskajae			2?			1												
Mehlina cf. *M. gradata*						3												
Polylophodonta sp. A						1												
Polygnathus aff. *P. fallax*								1										
Polylophodonta medicinelakensis									1								1?	3
Pelekysgnathus cf. *P. brevis*										1								
Palmatolepis quadrantinodosalobata															4	5	14	23
Mehlina ovata																1		
Palmatolepis aff. *P. angulata*																1		
P. cf. *P. circularis*																2	1	5
P. parawolskae																1	1	3
P. protorhomboidea																4	5	
P. angulata																	5	4
P. ovata																	1	5
Icriodus stenoancylus																		1?
Palmatolepis aff. *P. protorhomboidea*																		1
P. circularis																		1
Polygnathus sp.	1					2												
Mehlina sp.			1?							1?								
Palmatolepis sp.																		2
Pb elements	1	4	2			2		1	1				1	1?	2	6	7	10
ramiform elements	3	22	12	9	8	19	1	6	8	7?	2	2	3	2	4	36	45	17
coniform elements	2	8	8	2	1	3	1	4	2	11			2		1	6	8	5
"apatognathiform" elements	2	16	5	6	4	12	4	10	3	15	3	5	5	2?	3	20	33	25

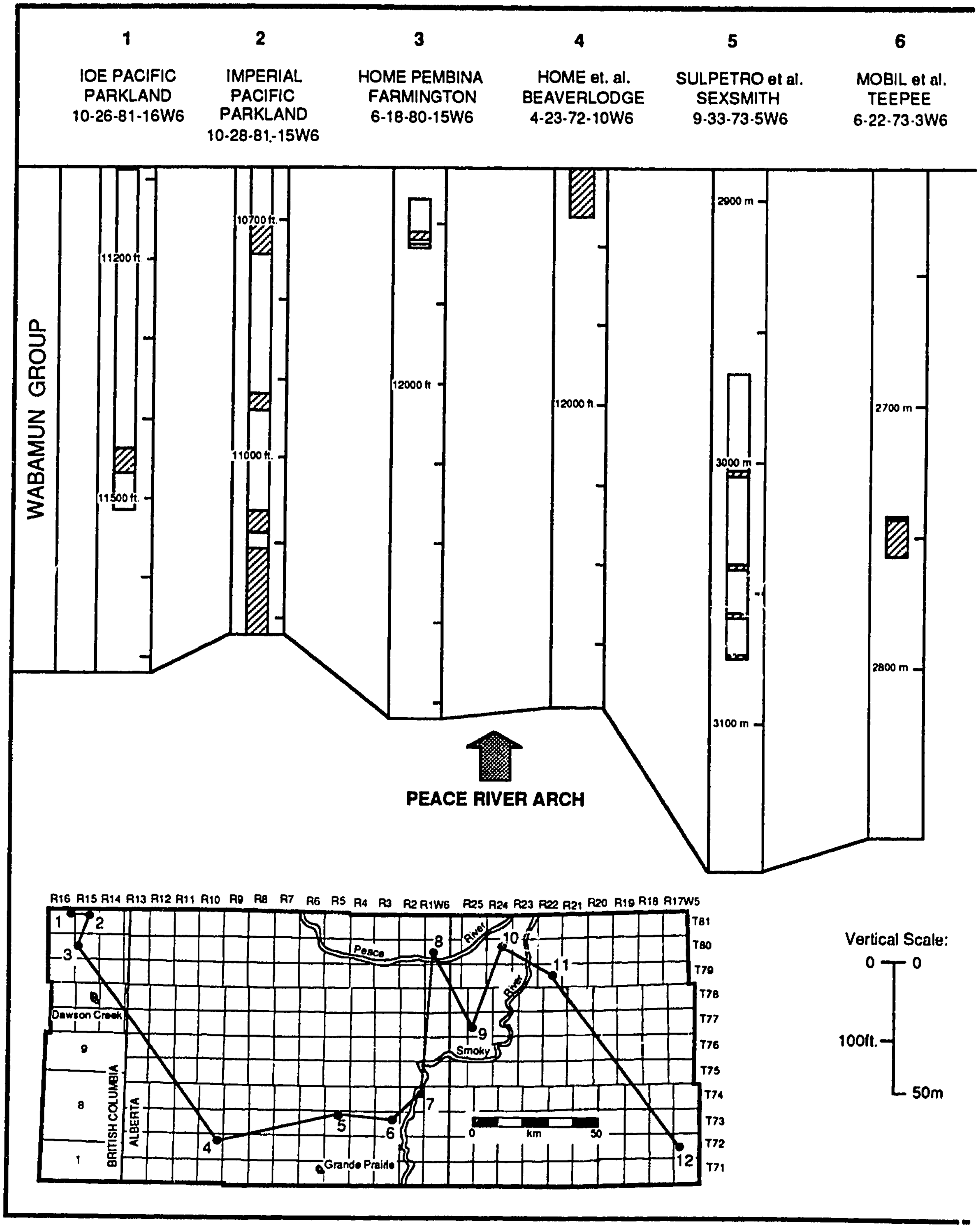
Table V-13. Distribution of conodonts (with corresponding well numbers in parentheses) in Gold Creek 10-21 (4), 6-36 (5), and 10-8 (2) wells. For stratigraphic position of cored intervals and well locations, see Figure V-8. Abbreviations: CARD. L. UNIT = Cardinal Lake unit. All other abbreviations as in previous tables.

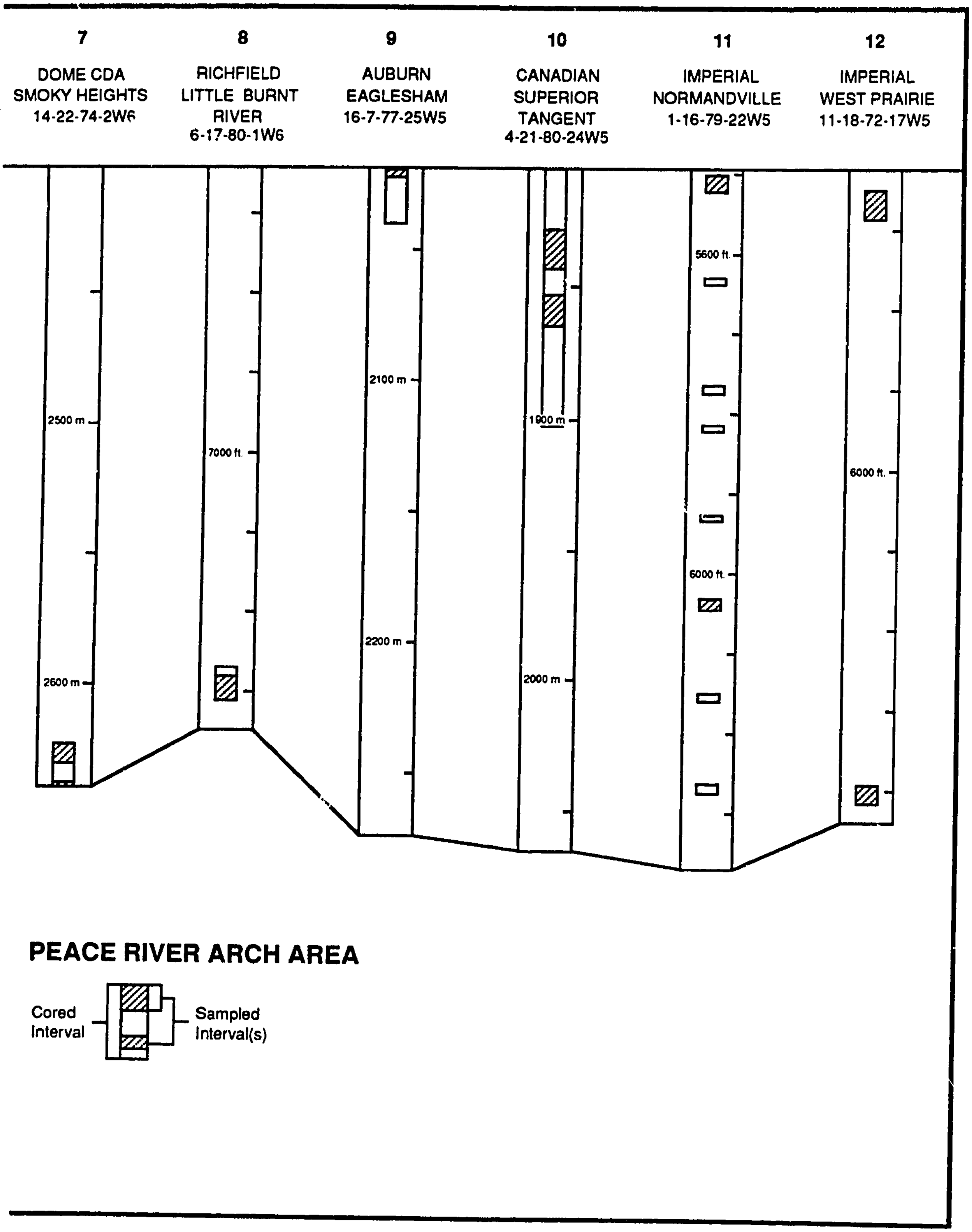
STRATIGRAPHIC UNITS	WABAMUN GROUP																												
	DIXONVILLE UNIT																		WHITELAW UNIT					CARB. L. UNIT					
ZONES	Lower - Middle *crepida*																					U *crepida* - L *rhomboidea*							
																							L - U *rhomboidea*						
WELL NO. (Fig. V-8)	4									5							2							4					
GSC LOCALITY NUMBER	C-100139				C-100137		C-100139			C-130931							C-130936							C-100139					
WEIGHT (kg.)	0.475	0.625	0.475	0.625	0.350	0.425	0.400	0.275	0.500	0.700	0.525	0.500	0.625	0.725	0.550	0.550	0.725	0.700	0.800	0.800	0.900	0.700	0.700	0.400	0.450	0.325	0.425	0.225	0.300
SAMPLED INTERVALS / TAXA	10891-10902 ft.	10883-10891 ft.	10875-10883 ft.	10867-10875 ft.	10855-10863 ft.	10847-10855 ft.	10843-10847 ft.	10835-10843 ft.	10827-10835 ft.	11367-11375 ft.	11355-11367 ft.	11344-11355 ft.	11332.5-11344 ft.	11322-11332.5 ft.	11311-11322 ft.	11300-11311 ft.	11875-11900 ft.	11862-11875 ft.	11851-11862 ft.	11833-11851 ft.	11667-11681 ft.	11656-11667 ft.	11645-11656 ft.	10374-10378 ft.	10370-10374 ft.	10366-10370 ft.	10358-10366 ft.	10350-10358 ft.	10342-10350 ft.
Icriodus erucisimilis	5			2	1						1?		1	2					1?	1									
Polygnathus webbi	1		1?					1?																					
Mehlina ovata			1							1																			
Polygnathus cf. *P. brevilaminus*			1?																										
Mehlina gradata				1																									
Polygnathus meijerdreesi				4				1		2	1		1?																
P. aff. *P. fallax*												1																	
Palmatolepis wolskajae													1				1?												
P. aff. *P. angulata*																2				2									
P. parawolskae																	2?												
P. cf. *P. perlobata*																		1											
P. angulata																			3	5									
P. quadrantinodosalobata																			4	7									
P. protorhomboidea																				6									
Polygnathus aff. *P. timanicus*																				1									
Mehlina strigosa																					2	1							
Palmatolepis crista																					16		2						
P. prima																					2		2						
P. prima M1																					7	3							
P. quadrantinodosalobata M1																					34								
P. tenuipunctata																					1								
Polygnathus germanus																					1								
P. semicostatus																					4	18	9	2		1?	2	2	3
"*Icriodus*" cf. "*I.*" *cornutus*																						4	1						
Mehlina? *arcureclinata*																							1?						
Mehlina sp.			1?	1																		1?							
Palmatolepis sp.			1	1													1		2	3	3								
Polygnathus sp.					2	1									1	1													
"*Icriodus*" sp.																					1?								
Alternognathus sp.																													1?
Pb elements	2		1	2	-	-		2	1	6	1	2	1?			1?	1?	1	4	5	17	9	3	1	2		3	3	4
ramiform elements	8	2?	5	12	-	-	4	5	5	4	5	3	8	2	3?	15	9	5	7	21	46	23	25	9	4	3	6	7	10
coniform elements	11	2	4	1	-	-		3	6	2	3	6	5			4			5	6	72	51	31			1	3	1	4
"apatognathiform" elements	3	3	6	2	-	-	2	5	4	11	8	8	8	3	2	4	7	2	13	24	65	23	14	1	1	3	8	7	10

STRATIGRAPHIC UNITS	WABAMUN GROUP																																		
	WHITELAW UNIT															NORMANDVILLE UNIT													CARDINAL LAKE UNIT						
ZONES	Upper *crepida*		Uppermost *crepida*				Lower *rhomboidea*												? Upper *rhomboidea*																
GSC LOCALITY NUMBER	C-146975																																		
WEIGHT (kg.)	0.662	0.745	0.717	0.661	0.710	0.576	0.652	0.666	0.670	0.556	0.700	0.694	0.691	0.646	0.690	0.707	0.634	0.613	0.613	1.340	0.681	0.636	0.621	0.652	0.655	1.286	0.665	0.626	0.597	0.659	0.691	0.611	0.655	0.697	0.521
SAMPLED INTERVALS / TAXA	10658-10664 ft.	10649-10658 ft.	10640-10649 ft.	10631-10640 ft.	10622-10631 ft.	10613-10622 ft.	10604-10613 ft.	10598-10603 ft.	10590.5-10598 ft.	10587-10590.5 ft.	10581-10587 ft.	10575-10581 ft.	10567-10575 ft.	10559-10567 ft.	10551-10559 ft.	10543-10551 ft.	10535-10543 ft.	10530-10535 ft.	10524-10530 ft.	10506-10524 ft.	10500-10506 ft.	10494-10500 ft.	10484-10494 ft.	10474-10482 ft.	10462-10474 ft.	10446-10462 ft.	10434-10446 ft.	10426-10434 ft.	10417-10426 ft.	10401-10417 ft.	10394-10401 ft.	10386-10394 ft.	10378-10386 ft.	10370-10378 ft.	10362-10370 ft.
Palmatolepis crista	21	22	12	18	14	7	4	4	19	1	1	1																							
P. minuta	1																																		
P. quadrantinodosalobata M1	450	100	50	70	87	53	54	12	30	1?		2?																							
P. parawolskae	10																																		
P. prima	3	3	1								3				4	2?																			
P. prima M1	14	6		1?	3?		6?	4?	14	4?		3		1																					
P. tenuipunctata	1?	2	2		3	4	2	1	4																										
Polylophodonta medicinelakensis	2				1?	3	2	5	11																										
Palmatolepis prima M2			1								1																								
Mehlina strigosa					1									1																					
M. cf. *M. gradata*						2			3									3	4	4															
New Genus B sp. 1							1																												
Palmatolepis poolei							1								4			5?																	
Polygnathus aff. *P. lauriformis*								1																											
"Icriodus" cornutus										9	3		1				2									1					1				
Palmatolepis subperlobata										1																									
Polygnathus semicostatus										5	12	3	5		8	3?		2	2?	8	2?	1	1	3		2	4	7	9	12	13	11	11	15	6
"Icriodus" chojnicensis															1																				
Icriodus iowaensis																1		2?																	
Pelekysgnathus cf. *P. brevis*																			1											1		2	1		
Palmatolepis klapperi																								1											
Polygnathus aff. *P. pennatulus*																								1											
Mehlina gradata																												1		2					
Palmatolepis rhomboidea																												5	3	1?			5		
Polygnathus communis																												1		2					
P. sp. A																													2	1?					
Alternognathus aff. *A. pseudostrigosus*																																		1	
Palmatolepis stoppeli																																			4
Mehlina sp.	2	4?						3		1			1?		2		1?	2							1	2?	1?			5			2	1	
Palmatolepis sp.	53	17		4	20	10	12		3								1							1											
Polygnathus sp.	2																											1							
Pb elements	48	33	16	22	17	7	7	9	25	4	4	6	5	1	11	8	5	8	2	7	3	3	2	3	5	2	3	5	5	11	6	10	10	12	5
ramiform elements	220	105	56	71	127	50	43	33	89	26	34	4	17	3	29	15	18	23	23	15	6	2	9	9	9	18	10	25	19	45	24	45	55	76	64
coniform elements	118	04	18	41	90	40	66	49	88	36	24	17	19	1	21	4	4	5	3	3					1	2	2		1	9	1	5	7	6	2
"apatognathiform" elements	184	117	49	48	45	29	61	49	181	31	22	21	18	10	36	12	11	24	17	21	6	6	10	10	4	7	3	14	6	31	15	38	25	54	26

Table V-14. Distribution of conodonts in Gold Creek 10-31 well (well no. 3 in Figure V-8). For stratigraphic position of cored interval and well location, see Figure V-8. All abbreviations as in previous tables.

Figure V-9. Cross section showing stratigraphic position of cored intervals and intervals sampled for conodonts in each core in Wabamun Group in vicinity of Peace River Arch. Location of wells shown in township (T) and range (R) map of area enlarged from Figure V-1A. Approximate position of Peace River Arch shown by arrow below cross section. For depths of sampled intervals see Tables V-15, V-16 and V-17.


1
IOE PACIFIC
PARKLAND
10-26-81-16W6
2
IMPERIAL
PACIFIC
PARKLAND
10-28-81.-15W6
3
HOME PEMBINA
FARMINGTON
6-18-80-15W6
4
HOME et. al.
BEAVERLODGE
4-23-72-10W6
5
SULPETRO et al.
SEXSMITH
9-33-73-5W6
6
MOBIL et al.
TEEPEE
6-22-73-3W6
WABAMUN GROUP
11200 ft
11500 ft
10700 ft.
11000 ft.
12000 ft
12000 ft.
2900 m
3000 m
3100 m
2700 m
2800 m
PEACE RIVER ARCH
R16 R15 R14 R13 R12 R11 R10 R9 R8 R7 R6 R5 R4 R3 R2 R1W6 R25 R24 R23 R22 R21 R20 R19 R18 R17W5
T81 T80 T79 T78 T77 T76 T75 T74 T73 T72 T71
1 2 3 4 5 6 7 8 9 10 11 12
Peace River
Smoky River
Dawson Creek
Grande Prairie
BRITISH COLUMBIA
ALBERTA
9
8
1
0 km 50
Vertical Scale:
0 0
100ft.
50m



PEACE RIVER ARCH AREA

Table V-15. Distribution of conodonts (with corresponding well numbers in parentheses) in Parkland 10-26 (1), 10-28 (2) and Farmington 6-18 (3) wells. For stratigraphic position of cored intervals and location of wells, see Figure V-9. Abbreviations: L-M _c_. = Lower to Middle _crepida_; _crep_. = _crepida_; DIX. = Dixonville unit; W. = Whitelaw unit; N. = Normandville unit; CL., CARD. L. UNIT = Cardinal Lake unit. All other abbreviations as in previous tables.

STRATIGRAPHIC UNITS	WABAMUN GROUP												
	DIX			W	N	CL	N	CARD L. UNIT					
ZONES	L-M c	Upper crep.		Um crepida - U rhomb.				Lower marginifera					
WELL NO. (Fig. V-9)	2						1	2			3		
GSC LOCALITY NUMBER	C-170475						C-170474	C-170475			C-170451		
WEIGHT (kg.)	2.000	1.800	0.800	1.500	0.400	0.900	1.000	0.800	1.100	1.200	0.700	1.500	0.700
SAMPLED BEDS OR INTERVALS / TAXA	11170-11220 ft.	11128.5-11169 ft.	11111-11128.5 ft.	11063-11090 ft.	10932-10938 ft.	10917-10932 ft.	11422-11436 ft.	10732-10743 ft.	10712-10732 ft.	10697-10712 ft.	11829 ft.	11825 ft.	11810-11820 ft.
Icriodus stenoancylus	1	3											
Mehlina? sp. C	1?												
Palmatolepis angulata	2	26	5										
P. quadrantinodosalobata	1	90	31										
Polygnathus glaber	1?	2											
Icriodus erucisimilis		13	2										
Mehlina ovata		4											
Palmatolepis cf. P. circularis		11											
P. cf. P. perlobata		4											
P. lanceolata		22	4										
P. minuta		33	17	4		6	2						
P. ovata		11	4										
P. parawolskae		39	23										
P. prima		49	36	18		10	2						
P. protorhomboidea		5	5										
P. subperlobata		8	3	28									
P. cf. P. tenuipunctata		6	9										
P. tenuipunctata		13											
P. wolskae		1	1										
Peleksygnathus planus		4											
Polygnathus aff. P. timanicus		4	3										
P. cf. P. brevilaminus		2											
P. dolichopleurus		4											
Mehlina? arcureclinata			1		1	30	26						
Palmatolepis aff. P. angulata			1										
P. circularis			1										
P. perlobata?			2?										
P. schindewolfi			6										
Pelekysgnathus cf. P. brevis			1			4							
Polylophodonta medicinelakensis			2										
Palmatolepis pectinata				9		4	3	2		1			1
Polygnathus germanus				1?			5		1?				
P. semicostatus				5	4	11	7	3	1?	11	5	4	4
Icriodus cf. I. alternatus					3	17	9						
New Genus B sp. 4					1?	1							
Palmatolepis klapperi					7	3?	1						
Alternognathus aff. A. pseudostrigosus						1?							
Palmatolepis crista						3?							
Polygnathus webbi						1							
Icriodus sp. A							14						
Palmatolepis prima M1							7						
P. rhomboidea							35						
Polygnathus aff. P. pennatulus							1						
Palmatolepis marginifera								3		1	5	5	
P. pectinata M1								1					
P. stoppeli								12	10	9			
P. quadrantinodosa									1?				
Polygnathus cf. P. padovaniae									1	1?			
Palmatolepis inflexa										1?	2	4	7
Mehlina cf. M. gradata											1	2	1?
Polygnathus crassilabrus											2	1	2
Mehlina sp.	1		1						1?	2			1?
Polygnathus sp.	1	3									1?		
Polylophodonta sp.	1	2											
Palmatolepis sp.		68	27		2	1	4			4	2		
"*Icriodus*" sp.						1							
Pelekysgnathus sp.												2?	
Pb elements		76	19	1	5	58	86	6	7	10	9	2	1
ramiform elements	7	230	50	20	14	281	223	11	9	51	12	9	10
coniform elements	3?	31	7	2	3	21	15	6	1?	12	3	2	
"apatognathiform" elements	4	23	13		1	2	10	24	18	62	30	18	8

Table V-16. Distribution of conodonts (with corresponding well numbers in parentheses) in Sexsmith 9-33 (5), Teepee 6-22 (6), Smoky Heights 14-22 (7), Little Burnt River 6-17 (8) wells and lower sampled interval (Figure V-9) of Normandville 1-16 (11) well. For stratigraphic position of cored intervals and well locations, see Figure V-9. Abbreviations: DIXON. UNIT = Dixonville unit; WHTL. UNIT = Whitelaw unit. All other abbreviations as in previous tables.

STRATIGRAPHIC UNITS	WABAMUN GROUP											
	DIXON. UNIT					WHTL. UNIT					N.	W.
ZONES	L-M *crep.*		Upper *crepida*			U-Um *crep.*		Lower *rhomb.*			Upper *rhomb.*	
WELL NO. (Fig. V-9)	8	7				11	5					6
GSC LOCALITY NUMBER	C-186693	C-146979				C-146973	C-146977					C-039547
WEIGHT (kg.)	1.300	0.271	0.675	0.695	0.595	0.627	0.061	0.603	0.536	0.645	0.695	1.134
SAMPLED BEDS OR INTERVALS / TAXA	7281-7311 ft.	2639-2639.3 m	2630-2630.5 m	2624.5-2629.5 m	2623-2624.5 m	6032-6046 ft.	3074.5 m	3059.5 m	3057.6 m	3039 m	3003 m	2743-2757.6 m
Icriodus stenoancylus	1		3		3							
Mehlina ovata	1											
Palmatolepis aff. *P. angulata*	7											
P. angulata	5	4	9	4	1							
P. cf. *P. circularis*	24											
P. ovata	27	1	27	17	17			3?				
P. parawolskae	13		9	5	36							
P. quadrantinodosalobata	75	18	31	33	83		9	5				
Polygnathus meijerdreesi	1	1										
Polylophodonta medicinelakensis	1		1	1	2	1	1	2				
Icriodus erucisimilis		1		3	5							
Palmatolepis cf. *P. perlobata*		1										
P. lanceolata		1	3		8							
P. protorhomboidea		4										
P. wolskajae		1										
P. minuta			1	4	2							
P. prima			34	23	12		3	3				1
Polygnathus dolichopleurus			7		3							
Palmatolepis tenuipunctata				1	3		1?	26				
Mehlina strigosa					3							
Palmatolepis cf. *P. tenuipunctata*					4							
P. subperlobata					1		1	2	2	2		
P. quadrantinodosalobata M1						2		135				
P. crista								15				
P. poolei								2				
P. prima M1								21				
P. prima M2								2	5			
Polygnathus semicostatus								5?			2	2
P. germanus									1			
"*Icriodus*" *cornutus*										1	1?	
Alternognathus? sp. A												1
Palmatolepis sp.	9	3						15				
Polygnathus sp.	2		1		2							
Mehlina sp.		1?	1?	2	1	1		1		1		
"*Icriodus*" sp.								1?				
Pb elements	11	4	18	29	48	2		38	2	2	3	4
ramiform elements	75	25	92	152	162	2	7	154	20	6	3	8
coniform elements	18	11	24	27	43	9	1	71	5	3		
"apatognathiform" elements	68	13	73	50	70	3	6	132	10	12	6	18

Table V-17. Distribution of conodonts (with corresponding well numbers in parentheses) in Beaverlodge 4-23 (4), Eaglesham 16-7 (9), Tangent 4-21 (10), West Prairie 11-18 (12) wells and upper sampled interval (Figure V-9) of Normandville 1-16 (11) well. For stratigraphic position of cored intervals and well locations, see Figure V-9. Key to zones: 1 - Upper *marginifera* to Lower *trachytera*; 2 - Uppermost *marginifera*? to Upper *trachytera*; 3 - Uppermost *marginifera* to Upper *expansa*; 4 - Lower to Upper *expansa*. Abbreviations: B.V. Fm. = Big Valley Formation. All other abbreviations as in previous tables.

STRATIGRAPHIC UNITS	WABAMUN GROUP												
	CARDINAL LAKE UNIT											B.V. Fm.	
ZONES	Upper rhomb.		Lower *marginifera*							1	2	3	4
WELL NO. (Fig. V-9)	10				4						12	11	9
GSC LOCALITY NUMBER	C-039546				C-100141						C-130938	C-146973	C-146978
WEIGHT (kg.)	0.887	0.561	0.994	0.600	0.332	0.367	0.361	0.297	0.299	-	0.700	0.573	0.504
SAMPLED INTERVALS	1853-1865 m	1837-1843 m	1831.5-1835.5 m	1828-1829.6 m	11756-11765 ft.	11747-11756 ft.	11738-11747 ft.	11729-11738 ft.	11719-11729 ft.	11712-11719 ft.	5650-5686 ft.	5502-5522 ft.	2018-2022.5 m
Palmatolepis stoppeli	5												
Polygnathus semicostatus	5	1				5	1		4	13	11	19	9
Palmatolepis marginifera		7	4				16	16	6	1			
Polygnathus crassilabrus		1			2	2?	4				5		
P. latisemicostatus		1?		5	5	2							
P. webbi		1									2		
Palmatolepis prima			1										
Polylophodonta confluens				1							1		
Pelekysgnathus inclinatus					2	2						4	1
Polygnathus germanus							1?						
Mehlina cf. *M. gradata*									3				
Skeletognathus sp. A									1			3	1?
Bispathodus stabilis M1										5		4	2
Mehlina strigosa										4?		2	
Polygnathus communis										8		18	1
"Icriodus" costatus											4?		
Palmatolepis distorta											9		
Alternognathus regularis												2	
Bispathodus stabilis M2												4	3
Mehlina aff. *M. strigosa*												2	
Palmatolepis quadrantinodosa												1?	
Polygnathus perplexus												2	1
Mehlina sp.		1				1	1	2			1	3	6
Bispathodus sp.						1?						15	
Polygnathus sp.						1		2			2	4	
Pb elements		8	4	2	8	13	4	7	7	13	9	52	21
ramiform elements	6	8	2	2	25	25	20	12	17	21	34	79	26
coniform elements		3	1			2		1	3	17	10	73	21
"apatognathiform" elements	9	19	8	3	23	45	27	24	11	18	47	107	30

<table>
<tr><th>SERIES</th><th>STAGE</th><th>SUBSURFACE N.E. B.C. SOUTHERN N.W.T.</th><th colspan="2">CENTRAL SOUTHERN ROCKY MTNS. ALTA., B.C.</th><th colspan="2">SUBSURFACE CENTRAL NORTHERN ALBERTA</th><th colspan="2">SUBSURFACE SOUTHERN ALBERTA</th><th colspan="2">SUBSURFACE SOUTHERN SASKATCHEWAN</th></tr>
<tr><td rowspan="7">UPPER DEVONIAN</td><td rowspan="7">FAMENNIAN</td><td>EXSHAW FM.</td><td colspan="2">EXSHAW FM.</td><td colspan="2">EXSHAW FM.</td><td colspan="2">EXSHAW FM.</td><td rowspan="7">THREE FORKS GRP.</td><td>BAKKEN FM.</td></tr>
<tr><td rowspan="4">KOTCHO FM.</td><td rowspan="5">PALLISER FM.</td><td rowspan="2">COSTIGAN MBR.</td><td rowspan="5">WABAMUN GRP.</td><td>BIG VALLEY FM.</td><td rowspan="5">WABAMUN GRP.</td><td>BIG VALLEY FM.</td><td>BIG VALLEY FM.</td></tr>
<tr><td>CARDINAL LAKE UNIT</td><td rowspan="4">STETTLER FM.</td><td rowspan="5">TORQUAY FM.</td></tr>
<tr><td rowspan="3">MORRO MBR.</td><td>NORMANDVILLE UNIT</td></tr>
<tr><td>WHITELAW UNIT</td></tr>
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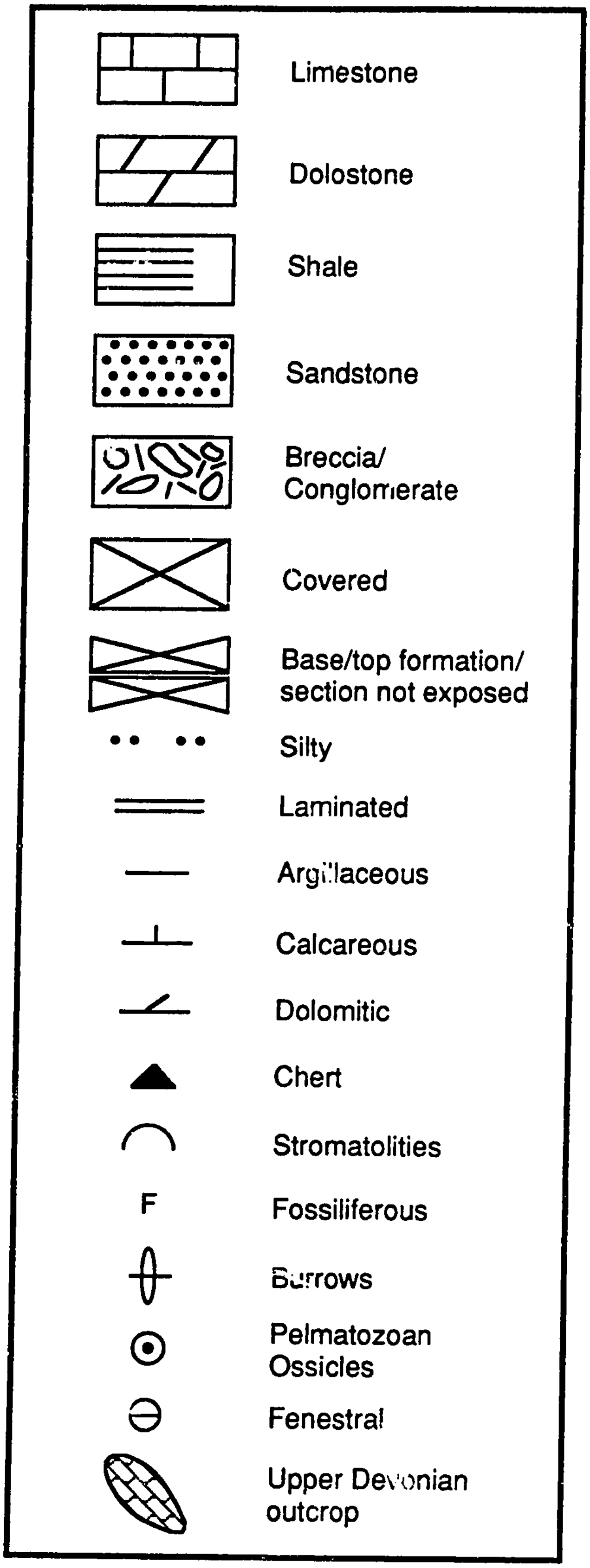
TETCHO FM.</td><td>DIXONVILLE UNIT</td></tr>
<tr><td>TROUT RIVER FM.</td><td colspan="2">SASSENACH FM.</td><td colspan="2">GRAMINIA FM. (part)</td><td colspan="2">CROWFOOT FM. (part)</td></tr>
</table>

Figure V-10. Correlation chart of Famennian stratigraphic units in surface and subsurface of Western Canada. See text for further discussion.

Series	Stage	Standard Conodont Zones	
UPPER DEVONIAN	FAMENNIAN	*praesulcata*	Upper
			Middle
			Lower
		expansa	Upper
			Middle
			Lower
		postera	Upper
			Lower
		trachytera	Upper
			Lower
		marginifera	Uppermost
			Upper
			Lower
		rhomboidea	Upper
			Lower
		crepida	Uppermost
			Upper
			Middle
			Lower
		triangularis	Upper
			Middle
			Lower

Figure V-11. Famennian portion of standard Upper Devonian conodont zonation of Ziegler and Sandberg (1990).

Figure V-12. Explanation of lithologic and other symbols used in Figures V-1 to V-7.


Limestone
Dolostone
Shale
Sandstone
Breccia/ Conglomerate
Covered
Base/top formation/ section not exposed
Silty
Laminated
Argillaceous
Calcareous
Dolomitic
Chert
Stromatolities
F
Fossiliferous
Burrows
Pelmatozoan Ossicles
Fenestral
Upper Devonian outcrop

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APPENDIX

In the following we give a general outline of the depositional features, thicknesses, structural setting and number of samples and sampling intervals of surface and subsurface sections of the Palliser Formation and Wabamun Group depicted in Figures V-2 to V-9. In Figures V-8 and V-9 we show only the position of the cored interval relative to the rest of the Wabamun Group. Sampled intervals in each core are given in the appropriate distribution table for each well (Tables V-12 to V-17). Under the heading "Additional Localities" we provide the location and other pertinent stratigraphic details of some of the localities, other than those shown in Figures V-1 to V-9, that some of the figured specimens and types in Plates V-1 to V-35 came from.

WARDNER

This section, about 100 m thick, is situated on the west side of the Rocky Mountain Trench in southeastern British Columbia (Figure V-1B). All Palliser strata at this locality are tentatively assigned to the Morro Member (Geldsetzer et al., 1986, fig. 14) (Figure V-2). The top and base of the Palliser Formation are covered at this locality (Figure V-2), so that the exact thickness of the formation is not known. Petrographic data from this section suggests that skeletal lime mudstones are the predominant lithologies, with minor skeletal wackestones. A total of 12 samples were taken at approximately 5 to 10 metre intervals (Figure V-2).

CROWSNEST PASS

The Palliser Formation has a total thickness of 396 m at this locality which is on the Lewis Thrust Sheet in southwestern Alberta (Figure V-1B). The upper 60 m of the Palliser Formation is represented by the Costigan Member, with the remaining 336 m by the Morro Member. Both lower and upper contacts of the formation are exposed. The Costigan Member at this locality is an argillaceous, fossiliferous, nodular limestone. The Morro Member is mainly a burrow-mottled, peloidal limestone, although in the lower 10 m of the member sedimentary breccias are present that are interbedded with cross-bedded peloidal limestone. Silty and laminated beds also occur within the lower 30 m of this member (Figure V-3). A total of 29 samples were collected at this locality of which 24 were productive. These samples were spaced at approximately 15 metre intervals (Figure V-3).

BANFF AREA

In this area two sections were sampled on the McConnell Thrust Sheet. One was at Jura Creek just northeast of Exshaw and the other was at Devil's Gap at the east end of Lake Minnewanka approximately 20 km farther to the north (Figure V-1C).

At Jura Creek, approximately the upper seven metres of the Palliser Formation are exposed, all represented by the Costigan Member (Figure V-4). The type section of the Exshaw Formation overlies the Palliser Formation at this locality (Warren, 1937; MacQueen and Sandberg, 1970; Richards and Higgins, 1989). The contact between the two formations is well exposed. The upper 2.5 m of the Costigan Member are represented by fossiliferous limestones. Bedded or nodular chert is conspicuous in this unit. Below are fenestral and peloidal limestones which are in unconformable contact with the fossiliferous limestones (e.g Richards and Higgins, 1989; Meijer Drees and Johnston, 1994). Domal stromatoporoids exposed in cross section occur just below the contact (Meijer Drees and Johnston, 1994). Five samples were taken at this locality at about 0.5 to 1.0 m intervals. Of these five samples, only three were productive (Figure V-4).

At Devil's Gap 47 m of the upper Palliser Formation were measured, with the upper 44 m comprising the Costigan Member and the lower 3 m the uppermost part of the Morro Member. At this locality the contact between the Costigan and Morro members is gradational. The contact between the Exshaw and Palliser formations is not exposed. The lower 31 m of the Costigan Member consists primarily of brecciated and laminated dolostone and limestone which are overlain by a 7 m thick unit of fenestral, peloidal limestone. The latter limestone is overlain with an apparent unconformity by argillaceous and fossiliferous limestone which comprises the remaining six metres of the member (Figure V-4). The upper three metres of the Morro Member is massive, dolomitic, peloidal limestone which grades upward into laminated, peloidal limestone of the basal part of the Costigan Member. A total of eight samples spaced at intervals of two to six metres were collected at this locality. Of these eight samples only five were productive. Only four of these latter samples are shown in Figure V-4.

On the Exshaw Thrust Sheet, the upper 42.7 m of the Palliser Formation was measured just west of Exshaw, Alberta (LaFarge Quarry = Baymag Quarry in Johnston and Chatterton, 1991) (Figure V-1C). The Costigan Member is 42.2 m thick at this locality. Only the uppermost 0.5 m of the Morro Member was measured (Figure V-4). The contact between the Costigan and Morro members is also gradational at this locality and the contact with the Exshaw Formation is not exposed. The Morro Member also passes upward from peloidal, burrow-mottled limestone into laminated, peloidal limestone of the Costigan Member (Figure V-4). Beds of exposed lower Costigan Member above this contact are generally brecciated, laminated, stromatolitic dolostone and limestone. This is with the exception of a 0.7 m thick nodular limestone unit, approximately 14.5 m above the base of the member. In the upper part of the section (Figure V-4), a 6 m thick unit of fenestral, peloidal limestone is overlain by 2.5 m of argillaceous, fossiliferous limestone. Five conodont samples were collected at this locality, one near the base of the section, while two were taken in the nodular limestone in the middle exposed portion of the section (Figure V-4). Two samples were also collected near the top and at the base of the fossiliferous limestone unit at the top of the section (Figure V-4).

Two sections, which together encompass nearly the entire thickness of the Palliser Formation, occur along strike from one another on the Rundle Thrust Sheet. One section was measured and sampled at Whiteman Gap, approximately four kilometres southwest of Canmore, Alberta (Figure V-1C). This section, which is a composite from two segments measured within one kilometre of each other, is 362 m thick, and is all represented by the Morro Member. The lower contact of the Palliser Formation with the Sassenach Formation is exposed. The entire thickness of the formation was not measured at this locality. The lower 44 m of the Palliser Formation is dolostone, whereas the remainder of the formation is dolomitic limestone, with prominent bands of burrow-mottling occurring throughout. A total of 39 conodont samples were collected at this locality, which were nearly all productive. Conodont samples were taken at approximately 10 m intervals to the top of the section (Figure V-4). One spot sample (WMG86-D) near the top of the Palliser Formation was also collected at this locality. The conodont fauna from this sample is tabulated in Table V-3.

The other section, which is a composite of three segments measured within half a kilometre of one another, was measured and sampled near Banff townsite adjacent to the golf course (Figure V-1C). Here a thickness of approximately 270 m was measured, which is all represented by the Morro Member. The top of the dolostone unit in this section is correlated with the top of the dolostone unit of the Whiteman Gap section (Figure V-4). The top of the formation is not exposed at this locality either, although conodont evidence suggests that the highest exposed beds are younger than the highest measured beds at the Whiteman Gap section (see Tables V-3 and V-4).

Burrow-mottled limestone is represented throughout all but the lower eight metres of the section, which is dolostone (Figure V-4). Forty-seven samples were collected at this locality of which 35 were productive. Conodont samples were taken at approximately six metre intervals (Figure V-4).

NIGEL PEAK

This section, located on the Pipestone Pass Thrust Sheet in the Main Ranges of west-central Alberta (Figure V-1D), is a composite of two sections measured in adjacent stream gullies less than one-half a kilometre apart. The Palliser Formation at this locality has a total thickness of about 567 m. The Costigan Member is about 70 m thick (Figure V-5) with the Morro Member comprising the remaining 497 m of the formation. Both lower and upper contacts of the Palliser Formation with the overlying Exshaw and the underlying Sassenach formations are exposed.

At this locality the Costigan Member is a dark grey to black, argillaceous, thin to medium bedded, fossiliferous limestone with chert nodules. Silicified fossils (e.g. brachiopods, stromatoporoids) weather in relief. The Morro Member at this locality is comprised of peloidal, burrow-mottled limestone in part. However, sandy or silty limestone occurs at the base of the member and an interval of dark, recessive, argillaceous, sparsely fossiliferous limestone occurs between 106 and 165 m above the base. In the upper 138 m of the Morro Member, there appears to be a complete absence of burrow-mottling. The occurrence of the dark, recessive, argillaceous nodular limestone in the lower part and the non-burrowed mottled limestone in the upper part of the Morro Member in this section was also noted in Johnston and Chatterton (1991).

A total of 64 samples were processed. These samples were all productive. This section was sampled at 5-10 m to as little as 2 m intervals in the lower 180 m of this section.

For the next 180 m of section, samples were taken at approximately 20 m intervals. For the remainder of the Palliser Formation, the sampling interval was approximately 10 m (Figure V-5).

MEDICINE LAKE

The Medicine Lake section is located on the Chetamon Thrust Sheet. It is depicted as six segments (ML1-ML4, MLN, CH108 - Figure V-6) of which the superpositional relationships of three (ML2-ML4) are known. The other segments (ML1, MLN, CH108) are approximately correlated with each other and with segments ML2-ML4 (Figure V-6). A thickness of about 293 m was measured for the entire formation on Proposal Mountain just southeast of Medicine Lake. Only about the upper metre of the section (CH108) are considered to belong in the Costigan Member; the other segments are assigned to the Morro Member (Figure V-6). The lower contact of the Palliser Formation with the Sassenach Formation is exposed at the base of ML3, which was measured on the ridge just east of Medicine Lake. The upper contact of the Palliser Formation with the Banff Formation is exposed on Proposal Mountain. The Costigan Member at Medicine Lake consists of about a metre of dark, fossiliferous limestone. The Morro Member for the most part consists of thin to thick bedded, peloidal, burrow-mottled limestone. Sandy limestone occurs near the base of the Palliser Formation. A total of 86 conodont samples were collected at this locality which were nearly all productive. Conodont samples were generally taken at about two metre intervals, with some gaps, through all of the measured segments of the formation at this locality (Figure V-6).

ATHABASCA RIVER VALLEY

Three sections of the Palliser Formation were measured in this area (Figure V-1D), on the Colin, Greenock and Miette thrust sheets. The exposed portion of the Palliser Formation at Cold

Sulphur Springs, which is on the Colin Thrust Sheet, is 243 m thick (Figure V-7). Only the uppermost exposed beds are assigned to the Costigan Member, with the rest of the formation assigned to the Morro Member. The lower contact with the Sassenach Formation is exposed both in the roadcut adjacent to Highway 16 and on the hillside about a kilometre south of the highway. The upper contact with the Banff Formation is covered. The Costigan Member at this locality consists of thin bedded, rubbly, fossiliferous limestone that is poorly exposed near the top of the formation. The Morro Member throughout the bulk of the formation is comprised of thin to thick bedded to massive peloidal, burrow-mottled limestone. Sandy and silty limestone beds that decrease in number and thickness up section are found in the lower 50 m of the Palliser Formation. A total of 30 conodont samples were collected at this locality of which 20 were productive. Conodont samples in the middle and upper parts of the formation were taken at about 10 to 15 m intervals. In the lower part of the Palliser Formation, samples were taken at less than one to twelve metre intervals (Figure V-7).

The Mount Greenock section of the Palliser Formation, exposed on the Greenock Thrust Sheet, has an approximate thickness of 190 m (Figure V-7). As at the Cold Sulphur Springs section, only the uppermost few metres of the Palliser Formation are assigned to the Costigan Member, with the rest of the formation assigned to the Morro Member (Figure V-7). The lower contact with the Sassenach Formation is well exposed near the Athabasca River Valley while the upper contact with the Banff Formation is exposed near the top of Mt. Greenock. The Costigan Member in this section is comprised of dark, fossiliferous limestone that is a skeletal wackestone in thin section. The Morro Member is mostly peloidal, burrow-mottled limestones. A total of 45 conodont samples were taken at this locality. Of this number only 37 samples were productive. Conodont samples were taken at roughly three to ten metre intervals (Figure V-7).

The Roche Miette section, which is located on the Miette Thrust Sheet, has a total measured thickness of 165 m. Here the Palliser Formation is all assigned to the Morro Member. The lower contact of the Palliser Formation with the Sassenach Formation is exposed while the upper contact with the Banff Formation is covered. The entire thickness of the Palliser Formation was not measured at this locality. The Morro Member at Roche Miette is mostly peloidal, burrow-mottled limestone. A total of 16 conodont samples were taken at this locality. Nearly all were productive. Samples were spaced at approximately 10-15 m intervals (Figure V-7).

GOLD CREEK FIELD

The five wells depicted in Figure V-8 are located between townships 66 and 68 and ranges 4 and 5 west of the sixth meridian in the subsurface of northwestern Alberta (Figures V-1A, V-8). In this area the Wabamun Group has an average thickness of about 240 m. The Wabamun-Exshaw contact is not cored in any of the wells shown in Figure V-8 although the contact has a prominent gamma log signature. In the Gold Cr [illegible] 7-31, 10-21 and 6-36 wells, the contact between the Wabamun and Winterburn groups has been cored (Figure V-8). In all the five wells only the lower to middle portion of the Wabamun Group is represented by core (Figure V-8). The lithology of the cored intervals in these wells is mostly peloidal limestone. The limestone is often shaly and nodular and skeletal remains such as pelmatozoan ossicles, brachiopods, gastropods and stromatoporoids also occur (Meijer Drees and Geldsetzer, 1984). A total of 82 productive conodont samples were collected from all five wells in the area. Sampled intervals in core ranged in thickness from approximately 1.5 m to as much as 8 m, though the most commonly sampled interval was 2 to 3 m (Tables V-12 to V-14).

PEACE RIVER ARCH AREA

The 12 wells and their cored intervals depicted in Figure V-9 are located in northwestern Alberta and northeastern British Columbia between townships 72 and 81 and between ranges 17 west of the fifth meridian and 16 west of the sixth meridian (Figure V-9). The three wells in northeastern British Columbia occur on the north side of the Peach River Arch whereas the remaining nine wells occur on the south side of the Arch (Figure V-9). The Wabamun Group has an average thickness of approximately 200 m in the three wells in northeastern British Columbia. The thickness of the Wabamun Group in the wells on the south side of the Arch varies between 206 m (e.g. Beaverlodge 4-23 well, Figure V-9) and 267 m (e.g. Normandville 1-16 well, Figure V-9).

Contacts between the Wabamun and Winterburn groups have only been cored in the Smoky Heights 14-22 well on the south side of the Peace River Arch. The lower contact of the Wabamun Group on the north side of the arch is with a clastic unit which is thought to be equivalent to the upper part of the Winterburn Group and the lower part of the Wabamun Group (Meijer Drees et al., in prep.). The upper contact between the Wabamun Group and the Exshaw Formation has been cored in the Beaverlodge 4-23, Eaglesham 16-7 and Tangent 4-21 wells (wells 4, 9 and 10 in Figure V-9). As in the Gold Creek Field, the contact between the Wabamun and Exshaw Formation has a prominent signature on gamma log profiles.

The Wabamun Group on the south side of the Peace River Arch is mostly comprised of peloidal limestone. The occurrence of fossils such as brachiopods, gastropods, pelmatozoan ossicles, ostracods and stromatoporoids have been reported from the Wabamun in this area (e.g Crickmay, 1952; Lethiers, 1981; Halbertsma and Meijer Drees, 1987; Stearn et al., 1987). At the top of the Wabamun Group in wells 8-12 is a fossiliferous, glauconitic and silty limestone which is assigned to the Big Valley Formation (Meijer Drees and

Johnston, 1993). This limestone is not present, however, at the top of the Wabamun formation in the Beaverlodge 4-23 well nor in any of the wells on the north side of the Arch. On the north side of the Peace River Arch, shaly interbeds are found in the lower and middle parts of the Wabamun Group. The upper part of the Wabamun Group is typically peloidal limestone in this area.

A total of 39 conodont samples were collected from the wells in Figure V-9. Nearly all were productive. Sampled intervals in core ranged from 2 up to 15 m, although in some wells single beds were sampled (e.g. Table V-15).

ADDITIONAL LOCALITIES

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.

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.

Persimmon Range

83E, Mount Robson, 1:250,000 map-sheet, Latitude 52° 32' 36" N, Longitude 118° 40' 00" W. Section measured in gap of Persimmon Range at headwaters of South Berland River, approximately 80 kilometres northwest of Jasper, Alberta. Upper 147 m of Palliser Formation measured by R. Ludvigsen and others in 1974. Costigan and Morro members not differentiated.

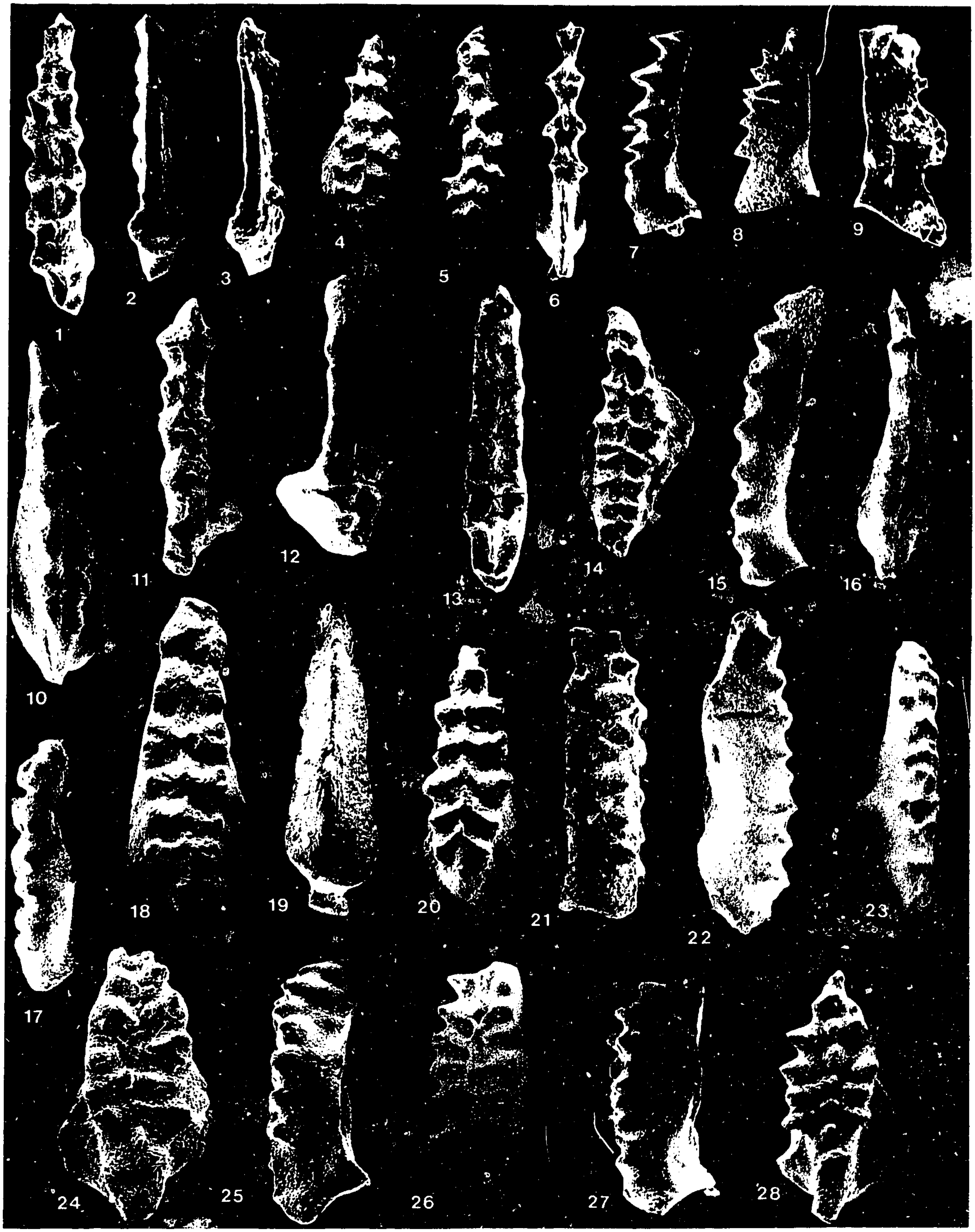
PLATES

The locality and stratigraphic position of each figured or type specimen is given by referring to the appropriate distribution table of the GSC locality, sample, sampled bed or interval in which the specimen occurs.

PLATE V-1

Figs. 1-19. Icriodus erucisimilis n. sp. Specimen illustrated in Figs. 17 and 18 is the holotype; specimens illustrated in Figs. 1-16, 19 are paratypes. All specimens from the Palliser Formation, Morro Member.

1. upper view, GSC 106812, X73 (sample ML2-375, Table V-7).
2. lower view of same specimen, X68.
3. oblique lower view of same specimen, X65.
4. upper view, GSC 106813, X53 (sample CSS-50, Table V-9).
5. upper view, GSC 106814, X54 (sample CSS-50, Table V-9).
6. upper view, GSC 106815, X93, juvenile specimen showing reduction of posterior cusp (compare with Figs. 8 and 9) (sample NPW86-13, Table V-6).
7. lateral view of same specimen, X74.
8. lateral view, GSC 106816, X94, juvenile specimen at more advanced growth stage than Fig. 9 showing addition of second pair of lateral denticles anteriorly (sample NPW86-13, Table V-6).
9. lateral view, GSC 106817, X175, juvenile specimen representing very early growth stage with only first pair of lateral denticles developed anteriorly; also note high posterior cusp (sample NPW86-13, Table V-6).
10. upper view, GSC 106818, X64, juvenile to mature specimen with basal cavity gradually widening posteriorly (sample CSS-P1, Table V-9).
11. upper view, GSC 106819, X87, juvenile specimen showing development of lateral denticle (sample GK-2, Table V-10).
12. upper view, GSC 106820, X45, specimen with lateral "spur" (sample CSS2-75, Table V-9).
13. upper view, GSC 106821, X59, specimen representing late form of species (sample NP86-41, Table V-6).
14. upper view, GSC 106822, X39, mature to gerontic specimen showing bifurcation of ridges (sample CH58A-311, Table V-4).
15. lateral view, GSC 106823, X51, specimen showing strong arching (sample NP86-36, Table V-6).
16. upper view of same specimen showing bowed platform, X50.
17. lateral view, GSC 106824, X41, (sample CSS-50, Table V-9)
18. upper view of same specimen, X53, shows extensive bifurcation of lateral ridges.
19. lower view, GSC 106825, X55, (sample CSS-50, Table V-9).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Figs. 20-28. <u>Icriodus</u> <u>iowaensis</u> Youngquist and Peterson. All specimens are hypotypes and from the Palliser Formation, Morro Member, unless indicated otherwise.

20. upper view, GSC 100322, X65, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 3, figs. 21, 22) (sample ML3-15, Table V-7).
21. lateral view of same specimen, X64.
22. lateral view, GSC 100323, X65, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 3, figs. 23, 24) (sample CSS-230, Table V-9).
23. oblique upper view of same specimen, X51.
24. upper view, GSC 106826, X64, specimen with irregular development of ridges (sample NPW86-16, Table V-6).
25. lateral view, GSC 106827, X53, Wabamun Group, Normandville unit, (sampled interval 10535-10551 ft., Table V-14).
26. oblique upper view of same specimen, X53, shows strong interconnection of ridges.
27. lateral view, GSC 106828, X60, (sample ML2-125, Table V-7).
28. upper view of same specimen, X64, shows interconnection of lateral and medial denticles.

PLATE V-2

Figs. 1-4, 5?, 6-11. *Icriodus stenoancylus* n. sp. Specimen illustrated in Figs. 3 and 4 is the holotype; specimens illustrated in Figs. 1, 2, 5-11 are paratypes. All specimens from the Palliser Formation, Morro Member, unless indicated otherwise.

1. lower view, GSC 106829, X59, small mature specimen (sample CSS-83, Table V-9).
2. lateral view, GSC 100318, X53, same specimen as that identified as *I. iowaensis ancylus* Sandberg and Dreesen by Johnston and Chatterton (1991, pl. 3, figs. 15, 16) (sample CSS-83, Table V-9).
3. upper view, GSC 106830, X45, (sample CSS-P3, Table V-9).
4. lateral view of same specimen, X39.
5. upper view, figured specimen GSC 106831, X64 (sample ML2-265, Table V-7).
6. upper view, GSC 106832, X27, mature to gerontic specimen with broad platform and strongly irregular ridges (sample Palliser 2, Figure V-7).
7. lateral view of same specimen, X27.
8. upper view, GSC 106833, X90, Wabamun Group, Dixonville unit (sampled interval 2630-2630.5 m, Table V-16).
9. upper view, GSC 106834, X39 (sample CSS-83, Table V-9).
10. upper view, GSC 106835, X67, juvenile specimen (sample CSS-123, Table V-9).
11. upper view, GSC 106836, X76, juvenile specimen (sample GK-130, Table V-10).

Figs. 12, 13. *Icriodus* aff. *I. alternatus* Branson and Mehl. Figured specimen GSC 100321, same specimen as that identified as *I. alternatus alternatus* by Johnston and Chatterton (1991, pl. 3. figs. 19, 20), Palliser Formation, Morro Member (sample RMW-400, Table V-11).

12. upper view, X54.
13. lateral view, X63.

Figs. 14-17. *Icriodus* cf. *I. alternatus* Branson and Mehl. All are figured specimens and from the Wabamun Group, Cardinal Lake unit (sampled interval 10917-10932 ft., Table V-15).

14. lateral view, GSC 106837, X170.
15. lateral view, GSC 106838, X140, specimen with slightly arched platform.
16. upper view, GSC 106839, X130.
17. lateral view of same specimen, X135, shows straight platform but low posterior cusp.

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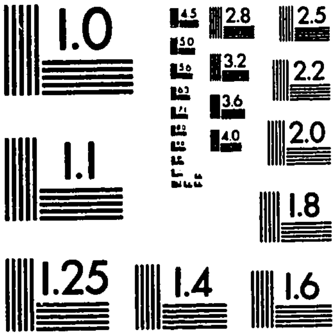

PRECISION℠ RESOLUTION TARGETS


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Figs. 18-20. Icriodus sp. A. All are figured specimens and from the Palliser Formation, Morro Member? (sample PL-23-689, Table V-1).

18. upper view, GSC 106840, X109, specimen showing widely flared basal cavity.

19. upper view, GSC 106841, X124, juvenile specimen with one pair of lateral denticles.

20. lateral view, GSC 106842, X150.

PLATE V-3

Figs. 1-6. "*Icriodus*" *cornutus* Sannemann. All specimens are hypotypes.

1. lateral view, GSC 106843, X81, Wabamun Group, Whitelaw unit (sampled interval 10581-10587 ft., Table V-14).
2. upper view of same specimen, X90.
3. upper view, GSC 106844, X130, Wabamun Group, Whitelaw unit (sampled interval 10581-10587 ft., Table V-14).
4. lateral view of same specimen, X127.
5. lateral view, GSC 100311, X84, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 3, figs. 7, 8), Palliser Formation, Morro Member (sample ML2-220, Table V-7).
6. upper view of same specimen, X63.

Figs. 7-11, 14-16. "*Icriodus*" cf. "*I.*" *cornutus* Sannemann. All are figured specimens and from the Palliser Formation, Morro Member, unless indicated otherwise.

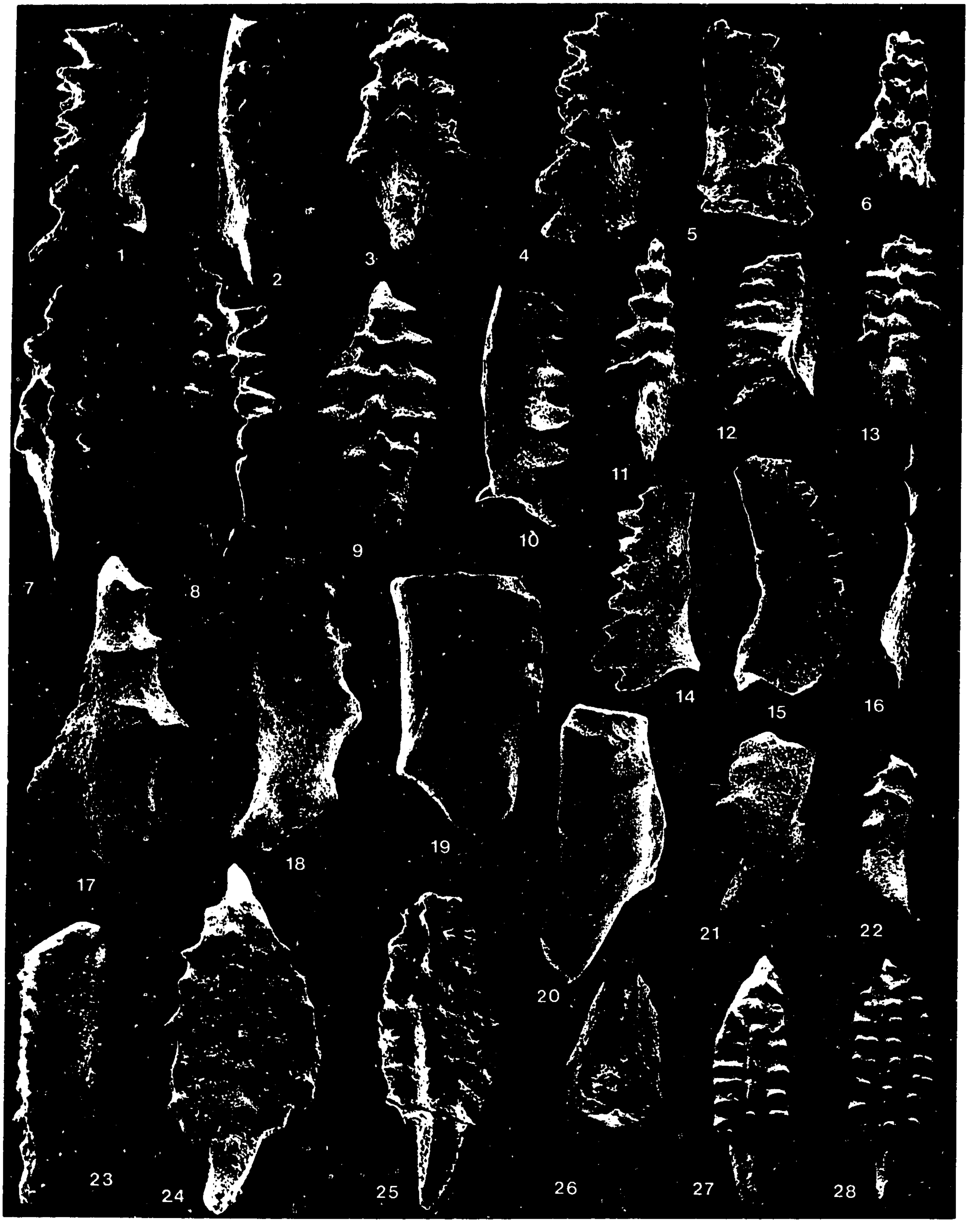
7. upper view, GSC 106845, X93 (sample ML2-135, Table V-7).
8. oblique upper view, GSC 106846, X100 (sample ML2-135, Table V-7).
9. upper view, GSC 106847, X90, Wabamun Group, Whitelaw unit (sampled interval 11656-11667 ft., Table V-13).
10. lateral view of same specimen, X84.
11. upper view, GSC 106848, X69, specimen showing complete fusion of lateral and medial denticles (sample ML2-210, Table V-7).
14. lateral view of same specimen, X63.
15. lateral view, GSC 106849, X90 (GSC Loc. C-187229, Table V-3).
16. upper view, GSC 106850, X105 (GSC Loc. C-187229, Table V-3).

Figs. 12, 13. "*Icriodus*" *chojnicensis* Matyja. Both specimens are hypotypes and from the Palliser Formation, Morro Member (sample NP86-74, Table V-6).

12. lateral view, GSC 100309, X70, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 3, fig. 6).
13. upper view, GSC 100309, X80, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 3, fig. 5).

Figs. 17-22. "*Icriodus*" *costatus* (Thomas). All specimens are hypotypes and from the Palliser Formation, Costigan Member.

17. oblique upper view, GSC 106851, X60 (sample COS89-36.7-36.8 m, Table V-5).
18. lateral view of same specimen, X56.
19. lateral view, GSC 106852, X69, (sample COS89-36.7-36.8 m, Table V-5).
20. upper view of same specimen, X74.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21. lateral view, GSC 100313, X55, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 3, fig. 10) (sample NPW89-15, Table V-6).
22. upper view, GSC 100312, X56, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 3, fig. 9) (sample NPW89-22, Table V-6).

Figs. 23-28. "Icriodus" cf. "I." raymondi Sandberg and Ziegler. All are figured specimens and from the Palliser Formation, Costigan Member.

23. lateral view, GSC 100319, X60, same specimen as that identified as "I." raymondi by Johnston and Chatterton (1991, pl. 3, fig. 17) (sample CH108, Table V-8).
24. upper view of same specimen, X76.
25. upper view, GSC 106853, X69 (sample GK1-73, Table V-10).
26. lower view of same specimen, X55.
27. upper view, GSC 106854, X61 (sample CH108, Table V-8).
28. upper view, GSC 100320, X56, same specimen as that identified as "I." raymondi by Johnston and Chatterton (1991, pl. 3, fig. 18) (sample CH108, Table V-8).

PLATE V-4

All are lateral views unless indicated otherwise.

Figs. 1, 2, 9-12. *Pelekysgnathus inclinatus* Thomas. All specimens are hypotypes.

1. GSC 100315, X53, specimen of early form of species, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 3, fig. 12), Palliser Formation, Morro Member (sample NPW86-13, Table V-6).
2. GSC 100316, X83, specimen of "intermediate" form of species (cf. Sandberg and Dreesen, 1984), same specimen as that illustrated by Johnston and Chatterton (1991, pl. 3, fig. 13), Palliser Formation, Morro Member (sample NPW89-2, Table V-6).
9. GSC 106855, X78, specimen with weak anterior denticle development, Palliser Formation, Costigan Member (sample NPW89-20, Table V-6).
10. GSC 100317, X80, specimen representing "late" form of species, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 3, fig. 14), Palliser Formation, Morro Member (sample NPW89-14, Table V-6).
11. GSC 106857, X50, specimen with adenticulate upper side, Palliser Formation, Morro Member (sample ML1-40, Table V-8).
12. GSC 98133, X74, same specimen as that illustrated by Johnston and Meijer Drees (1993, pl. 1, fig. 8), Wabamun Group, Big Valley Formation, (sampled interval 5502-5522 ft., Table V-17).

Figs. 3-7. "*Icriodus*" cf. "*I.*" *raymondi* Sandberg and Ziegler. All are figured specimens and from the Palliser Formation, Costigan Member.

3. GSC 100308, X74, same specimen as that identified as "*I.*" *chojnicensis* Matyja Morphotype 2 of Sandberg and Dreesen, 1984 by Johnston and Chatterton (1991, pl. 3, figs. 3, 4) (sample NPW86-A, Table V-6).
4. upper view of same specimen, X97.
5. upper view, GSC 106855, X92 (sample GK1-73, Table V-10).
6. GSC 100307, X67, same specimen as that identified as "*I.*" *chojnicensis* Matyja Morphotype 2 of Sandberg and Dreesen, 1984 by Johnston and Chatterton (1991, pl. 3, figs. 1, 2) (sample NPW89-B, Table V-6).
7. upper view of same specimen, X79.

Figs. 8, 13, 14. *Pelekysgnathus planus* Sannemann. All specimens are hypotypes.

8. GSC 100314, X68, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 3, fig. 11), Palliser Formation, Morro Member (sample GK-130, Table V-10).
13. GSC 106858, X145, specimen with somewhat lower posterior cusp than Fig. 8, Palliser Formation, Morro Member? (sample PL-23-687, Table V-1).


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14. GSC 106859, X250, juvenile specimen, Palliser Formation, Morro Member? (sample PL-23-687, Table V-1).

Figs. 15-20. <u>Pelekysgnathus</u> cf. <u>P</u>. <u>brevis</u> Sandberg and Dreesen. All are figured specimens.

15. GSC 106860, X165, specimen with several denticles anterior to cusp, Wabamun Group, Cardinal Lake unit (sampled interval 10917-10932 ft., Table V-15).

16. GSC 106861, X136, specimen with two anterior denticles, Palliser Formation, Morro Member? (sample PL-23-689, Table V-1).

17. GSC 106862, X121, late(?) form of species with single anterior denticle, Palliser Formation, Morro Member (sample NPW89-11, Table V-6).

18. GSC 106863, X143, Wabamun Group, Dixonville unit (sampled interval 11111-11128.5 ft., Table V-15).

19. GSC 106864, X220, Wabamun Group, Cardinal Lake unit (sampled interval 10917-10932 ft., Table V-15).

20. GSC 106865, X140, Palliser Formation, Morro Member (GSC Loc. C-187227, Table V-3).

PLATE V-5

Figs. 1-6, 9, 10?, 11? Alternognathus aff. A. pseudostrigosus (Dreesen and Dusar). All are figured specimens and from the Palliser Formation, Morro Member? (sample PL-23-689, Table V-1), unless indicated otherwise.

1. lower view, GSC 106866, X76, Palliser Formation, Morro Member (sample ML2-10, Table V-7).
2. upper view, GSC 106867, X70.
3. lateral view of same specimen, X64.
4. lower view, GSC 106868, X109, juvenile specimen representing intermediate growth stage.
5. upper view of same specimen, X116.
6. upper view, GSC 106869, X175, juvenile specimen representing very early growth stage.
9. lower view, GSC 106870, X121, small mature specimen showing more advanced stage of platform development than Figs. 4 and 5.
10. upper view, GSC 106871, X150, Wabamun Group, Cardinal Lake unit, (sampled interval 10917-10932 ft., Table V-15).
11. lower view of same specimen, X125.

Figs. 7, 8. Alternognathus regularis Ziegler and Sandberg. Both specimens are hypotypes and X71, Wabamun Group, Big Valley Formation (sampled interval 5502-5522 ft., Table V-17).

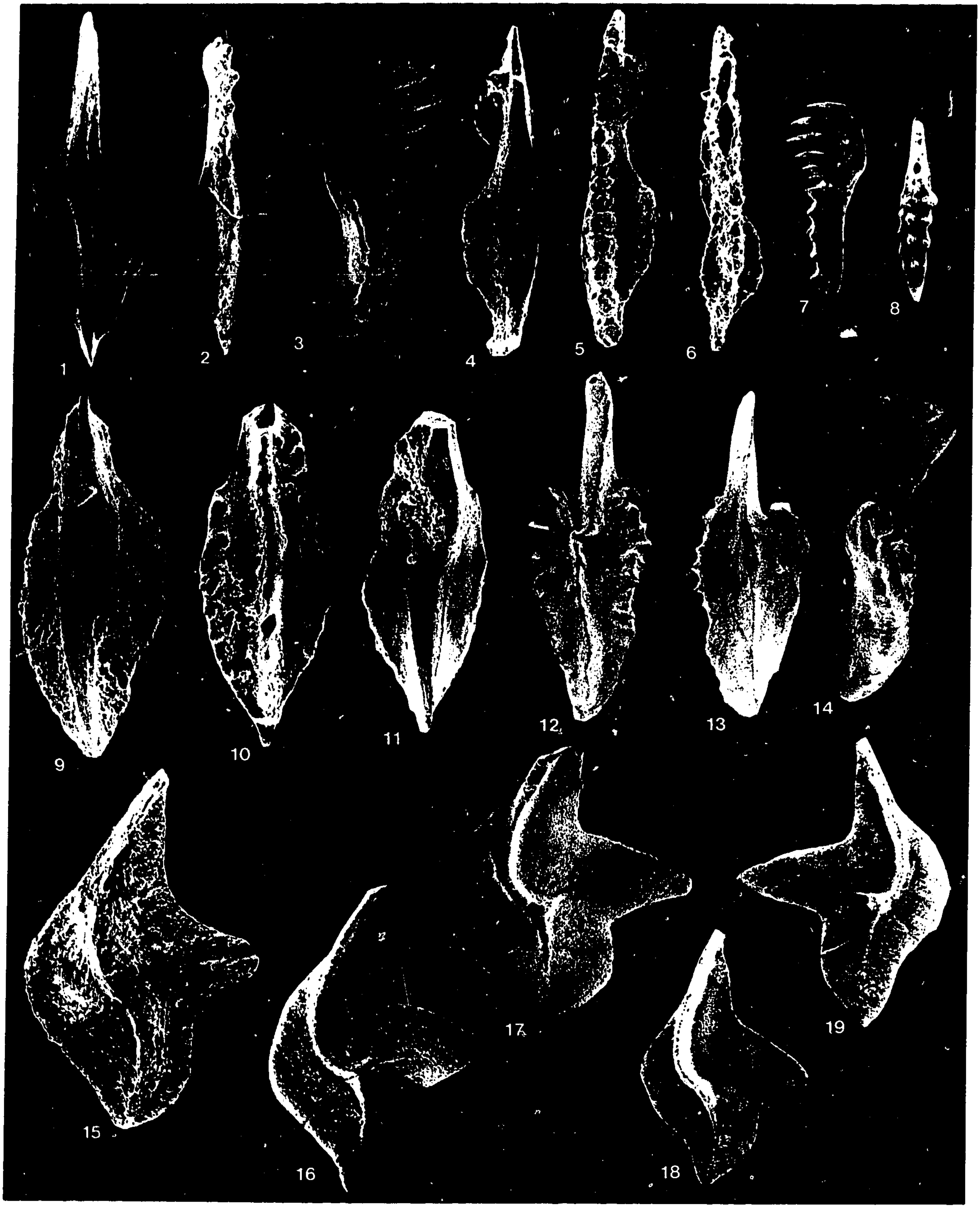
7. lateral view, GSC 98127, same specimen as that illustrated by Johnston and Meijer Drees, (1993, pl. 1, fig. 2).
8. upper view, GSC 98128, same specimen as that illustrated by Johnston and Meijer Drees, (1993, pl. 1, fig. 3).

Figs. 12-14. Alternognathus? sp. A. Figured specimen GSC 106872, Wabamun Group, Whitelaw unit (sampled interval 2743-2757.6 m, Table V-16).

12. upper view, X35, note 90 degree bend in carina.
13. lower view, X32.
14. lateral view, X30.

Figs. 15-19. Palmatolepis angulata n. sp. Specimen illustrated in Fig. 16 is the holotype; specimens illustrated in Figs. 15, 17-19 are paratypes. All specimens from the Palliser Formation, Morro Member, unless indicated otherwise.

15. lower view, GSC 106873, X76 (sample GK-120, Table V-10).
16. upper view, GSC 100278, X37, same specimen as that identified as P. wolskajae Ovnatanova by Johnston and Chatterton (1991, pl. 1, fig. 22) (sample ML2-335, Table V-7).
17. upper view, GSC 106874, X45, specimen representing broader, more rounded morphotype (sample ML2-335, Table V-7).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18. upper view, GSC 106875, X45, elongate specimen with platform outline similar to that of specimens illustrated by Klapper and Lane (1985, figs. 15.1, 15.4, 15.5), Wabamun Group, Dixonville unit (sampled interval 11128.5-11169 ft., Table V-15).
19. upper view, GSC 106876, X28, mature to gerontic specimen, Palliser Formation, Morro Member? (sample PL-23-687, Table V-1).

PLATE V-6

All are upper views of Pa elements.

Figs. 1, 2. Palmatolepis circularis Szulczewski. Both specimens are hypotypes and from the Palliser Formation, Morro Member (sample ML2-335, Table V-7).

1. GSC 106877, X98, juvenile specimen.
2. GSC 106878, X80, specimen with small outer lobe.

Fig. 3. Palmatolepis aff. P. angulata n. sp.. Figured specimen GSC 98149, X52, same specimen as that identified as P. tenuipunctata Sannemann by Johnston and Meijer Drees (1993, pl. 1, fig. 24), Wabamun Group, Dixonville unit, (sampled interval 11111-11128.5 ft., Table V-15).

Figs. 4, 5. Palmatolepis angulata n. sp.. Both specimens are paratypes and from the Palliser Formation, Morro Member (sample ML2-335, Table V-7).

4. GSC 106879, X63, small mature specimen.
5. GSC 106880, X88, juvenile specimen.

Figs. 6, 7, 9, 11-16. Palmatolepis wolskajae Ovnatanova. All specimens are hypotypes and from the Palliser Formation, Morro Member, unless indicated otherwise.

6. GSC 106881, X52 (sample CSS-83, Table V-9).
7. GSC 106882, X57, elongate specimen (sample CSS-83, Table V-9).
9. GSC 106884, X57, juvenile specimen (sample CSS-83, Table V-9).
11. GSC 106886, X54 (sample ML2-420, Table V-7).
12. GSC 106887, X61, Palliser Formation, Morro Member? (sample PL-23-686, Table V-1).
13. GSC 106888, X58, typical specimen (sample CSS-83, Table V-9).
14. GSC 106889, X60, Wabamun Group, Dixonville unit (sampled interval 2639-2639.5 m, Table V-16).
15. GSC 106890, X61, aberrant specimen (sample ML2-420, Table V-7).
16. GSC 106891, X51 (sample NP86-30, Table V-6).

Figs. 8, 10. Palmatolepis cf. P. circularis Szulczewski. Both are figured specimens and approximately X60, Palliser Formation, Morro Member (sample ML2-335, Table V-7).

8. GSC 106883.
10. GSC 106885.

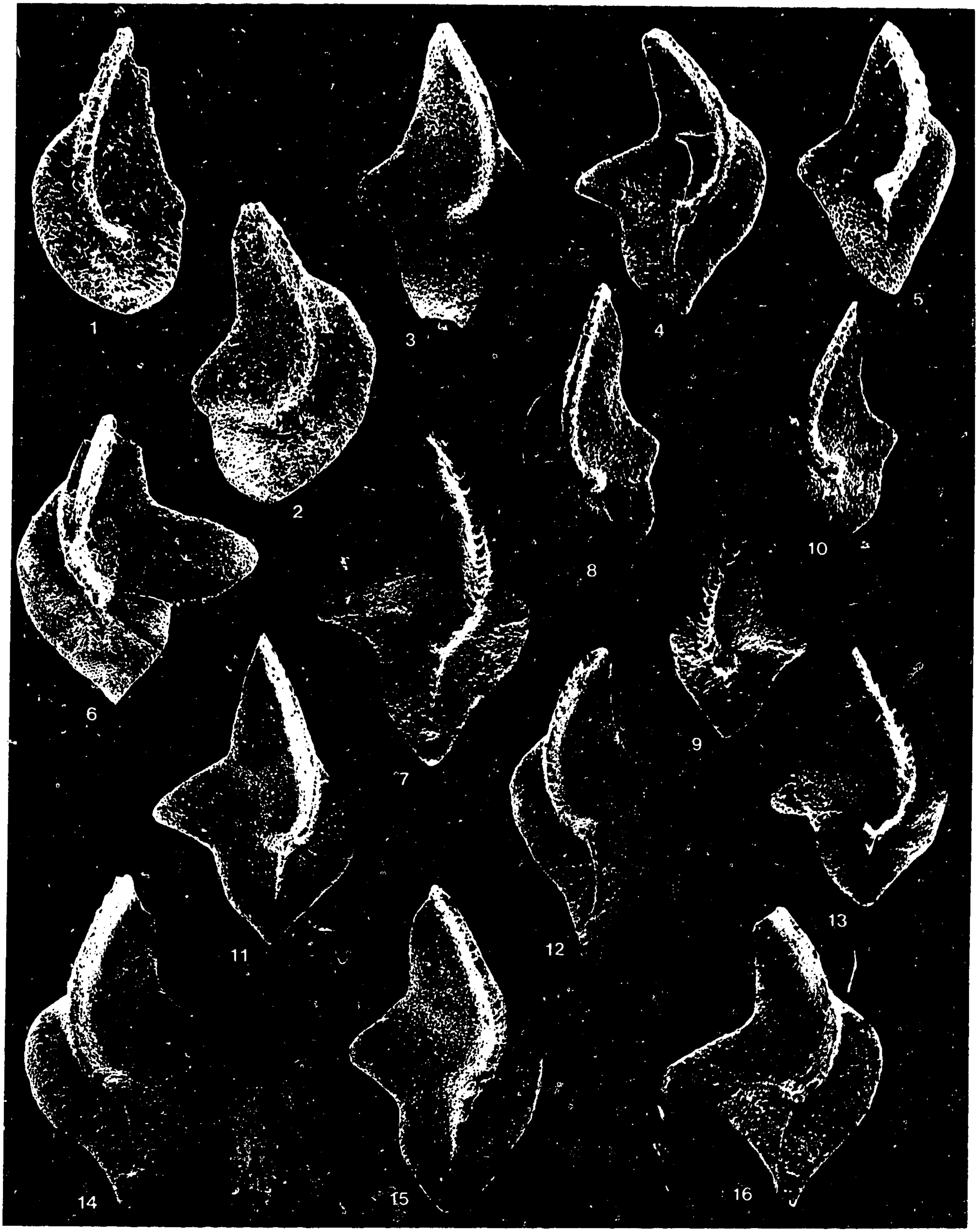
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PLATE V-7

All are upper views of Pa elements unless indicated otherwise.

Figs. 1, 2. *Palmatolepis acuta* Helms. Both specimens are hypotypes and from the Palliser Formation, Morro Member.

1. GSC 106892, X53 (sample GK1-271, Table V-10).
2. GSC 106893, X38, specimen with high, sharp inner platform parapet (sample ML1-40, Table V-8).

Figs. 3-5, 7. *Palmatolepis distorta* Branson and Mehl. All specimens are hypotypes. For locality information concerning specimens illustrated in Figs. 4, 5 and 7, see Appendix.

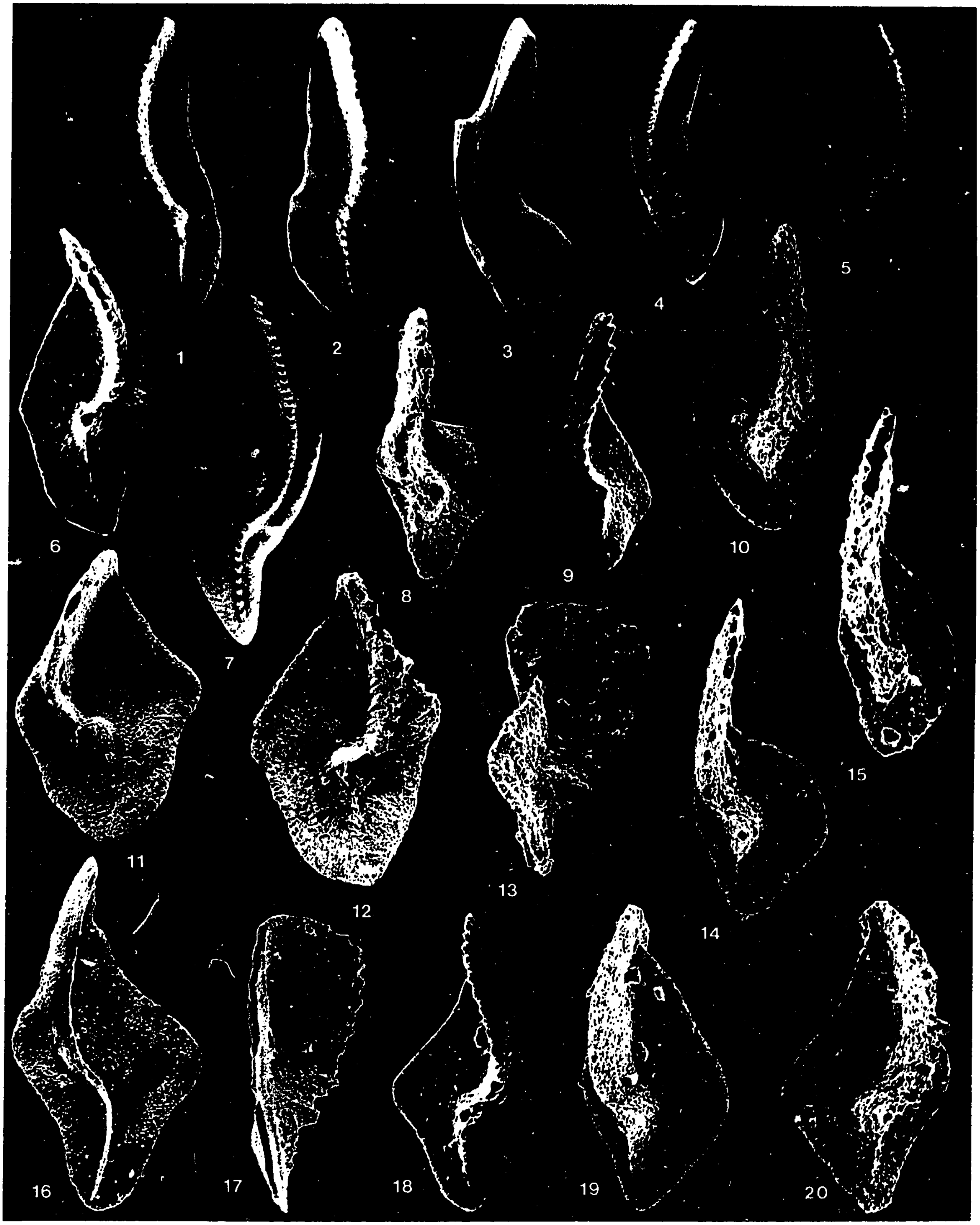
3. GSC 106894, X34, large specimen wth no azygous node and posterior carina nearly absent, Palliser Formation, Morro Member (sample CH57-420, Table V-6).
4. GSC 100257, X30, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 1, fig. 1), from Cadomin, Costigan Member, 3.7 m below top of Palliser Formation.
5. GSC 100259, X54, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 1, fig. 3), from Nordegg, Costigan Member, 12 m below top of Palliser Formation.
7. GSC 106896, X46, specimen with azygous node but recessed posterior carina, from Mount Luscar, 193 m above base of Palliser Formation.

Figs. 6, 11, 12. *Palmatolepis* sp. A. All are figured specimens and from the Palliser Formation, Morro Member.

6. GSC 106895, X120, juvenile specimen (sample ML2-375, Table V-7).
11. GSC 106900, x76, (sample RMW-500, Table V-11).
12. GSC 106901, X100, juvenile to mature specimen (sample ML2-375, Table V-7).

Figs. 8-10, 13-20. *Palmatolepis crista* n. sp. Specimen illustrated in Figs. 16-18 is the holotype; specimens illustrated in Figs. 8-10, 13-15, 19, 20 are paratypes. All specimens from the Wabamun Group, Whitelaw unit, unless indicated otherwise.

8. GSC 106897, X130, juvenile specimen with a reduced platform, (sampled interval 11667-11681 ft., Table V-13).
9. oblique upper view, GSC 106898, X125, specimen representing intermediate growth stage between Figs. 8, 10, 13-15 and Figs. 16-20, Palliser Formation, Morro Member (sample ML2-265, Table V-7).
10. GSC 106899, X160, juvenile specimen with oval platform (sampled interval 11667-11681 ft., Table V-13).
13. lateral view, GSC 106902, X156, juvenile specimen showing blade morphology, Palliser Formation, Morro Member? (sample PL-23-688, Table V-1).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14. GSC 106903, X225, juvenile specimen representing very early growth stage (sampled interval 11667-11681 ft., Table V-13).
15. GSC 106904, X275, juvenile specimen representing earlier growth stage than Fig. 14 (sampled interval 11667-11681 ft., Table V-13).
16. lower view, GSC 106905, X142, Palliser Formation, Morro Member (sample ML2-265, Table V-7).
17. lateral view of same specimen, X117.
18. upper view of same specimen, X119.
19. GSC 106906, X130 (sampled interval 10631-10640 ft., Table V-14).
20. GSC 106907, X130 (sampled bed 3059.5 m, Table V-16).

PLATE V-8

All are upper views of Pa elements and all are hypotypes.

Figs. 1-4. Palmatolepis klapperi Sandberg and Ziegler. All specimens from the Palliser Formation, Morro Member.

1. GSC 106908, X41 (sample NP86-50, Table V-6).
2. GSC 106909, X60 (sample GK1-313, Table V-10).
3. GSC 106910, X43 (sample NP86-45, Table V-6).
4. GSC 106911, X49 (sample NP86-45, Table V-6).

Figs. 5, 6. Palmatolepis lepta Ziegler and Huddle.

5. GSC 106912, X70, Palliser Formation, Morro Member (sample NP86-45, Table V-6).
6. GSC 100258, X63, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 1, fig. 2), from Moosin Mountain, approximately 52 m below top of Palliser Formation (see Appendix for locality information).

Figs. 7-12. Palmatolepis pectinata Ziegler. All specimens from the Palliser Formation, Morro Member, unless indicated otherwise.

7. GSC 106913, X88, late form of species, Palliser Formation, Morro Member? (sample PL-23-691, Table V-1).
8. GSC 106914, X44, typical form of species (sample BAI-900, Table V-2).
9. GSC 106915, X51, specimen with sharp parapet (sample NP86-45, Table V-6).
10. GSC 100261, X58, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 1, fig. 5) (sample GK1-271, Table V-10).
11. GSC 106916, X70 (sample NPW89-14, Table V-6).
12. GSC 106917, X41 (sample CH57-420, Table V-4).

Figs. 13-17. Palmatolepis pectinata Ziegler Morphotype 1 of Sandberg and Ziegler, 1973. All specimens from the Palliser Formation, Morro Member.

13. GSC 106918, X42, broad specimen, with parapet becoming more ramp-like posteriorly (sample NPW89-2, Table V-6).
14. GSC 100268, X54, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 1, fig. 12) (ML1-40, Table V-8).
15. GSC 106919, X72 (sample NP86-50, Table V-6).
16. GSC 106920, X53 (sample BAI-800, Table V-2).
17. GSC 106921, X51 (sample ML2-10, Table V-7).

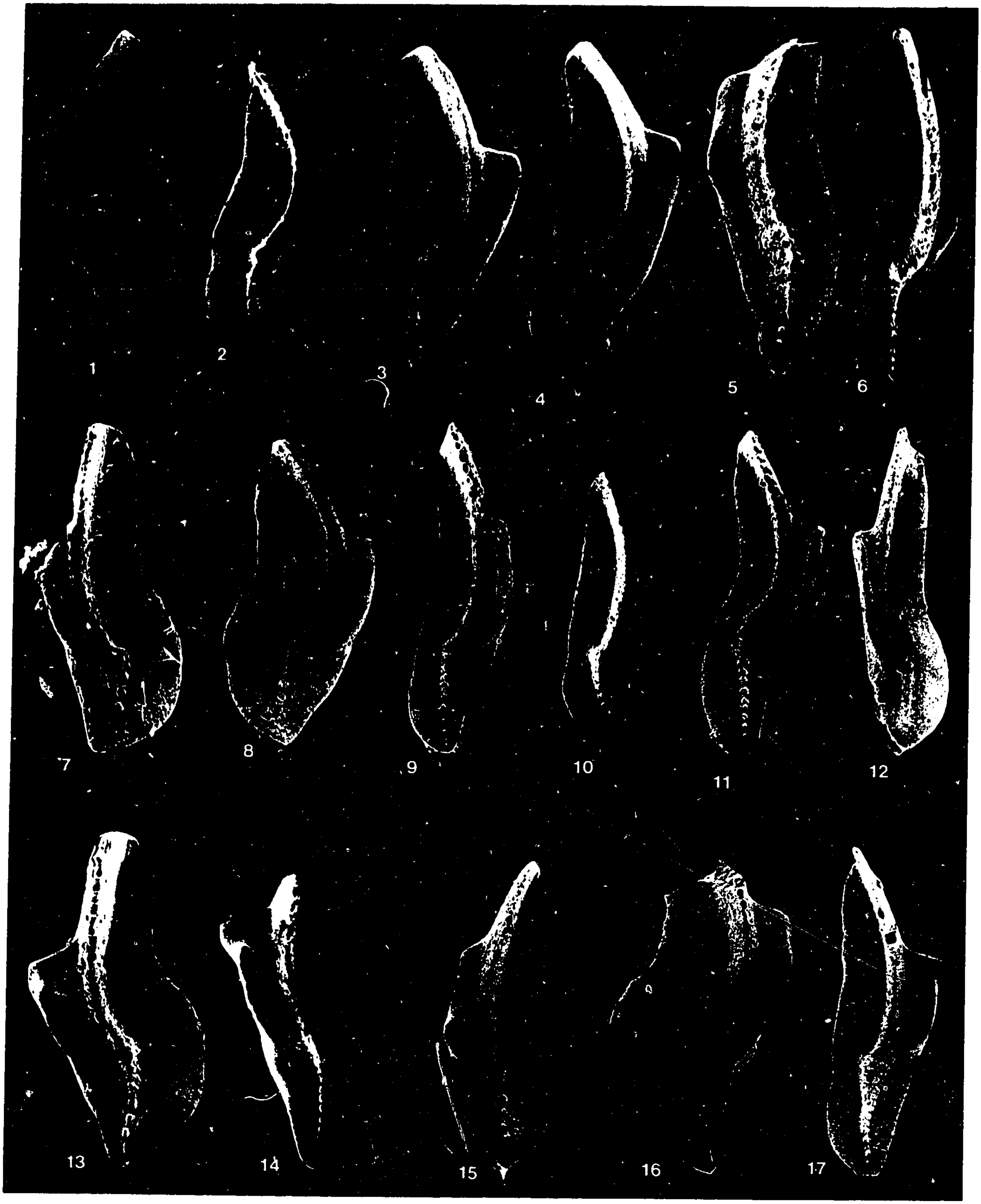
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PLATE V-9

All are upper views of Pa elements and all are hypotypes.

Figs. 1-11. Palmatolepis prima Ziegler and Huddle. All specimens from the Palliser Formation, Morro Member, unless indicated otherwise.

1. GSC 106922, X50, specimen transitional to P. glabra Ulrich and Bassler lacking sharp parapet of latter species, Wabamun Group, Whitelaw unit (sampled interval 11063-11090 ft., Table V-15).
2. GSC 106923, X68, specimen with sinusoidal platform outline and flat anterior inner platform (sample NP86-45, Table V-6).
3. GSC 106924, X56, specimen with slight bulge on anterior inner platform (sample NP86-50, Table V-6).
4. GSC 106925, X60, Wabamun Group, Dixonville unit (sampled interval 11111-11128.5 ft., Table V-15).
5. GSC 106926, X49 (sample NP86-50, Table V-6).
6. GSC 106927, X60 (sample NP86-58, Table V-6).
7. GSC 106928, X60, Wabamun Group, Dixonville unit (sampled interval 11111-11128.5 ft., Table V-15).
8. GSC 106929, X55, Wabamun Group, Dixonville unit (sampled interval 11128.5-11169 ft., Table V-15).
9. GSC 106930, X71 (sample NP86-58, Table V-6).
10. GSC 100260, X76, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 1, fig. 4) (sample ML2-265, Table V-7).
11. GSC 106931, X34 (sample GK1-373, Table V-10).

Figs. 12-17. Palmatolepis prima Ziegler and Huddle Morphotype 1 of Sandberg and Ziegler, 1973. All specimens from the Palliser Formation, Morro Member, unless indicated otherwise.

12. GSC 106932, X29, mature to gerontic specimen, with extended posterior platform and recessed carina (sample NP86-58, Table V-6).
13. GSC 106933, X37 (sample ML2-240, Table V-7).
14. GSC 100265, X63, typical specimen, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 1, fig. 9) (sample BAI-300, Table V-2).
15. GSC 106934, X85, juvenile specimen (sample ML2-240, Table V-7).
16. GSC 106935, X33, Wabamun Group, Whitelaw unit (sampled interval 10658-10664 ft., Table V-14).
17. GSC 106936, X54 (sample ML2-155, Table V-7).

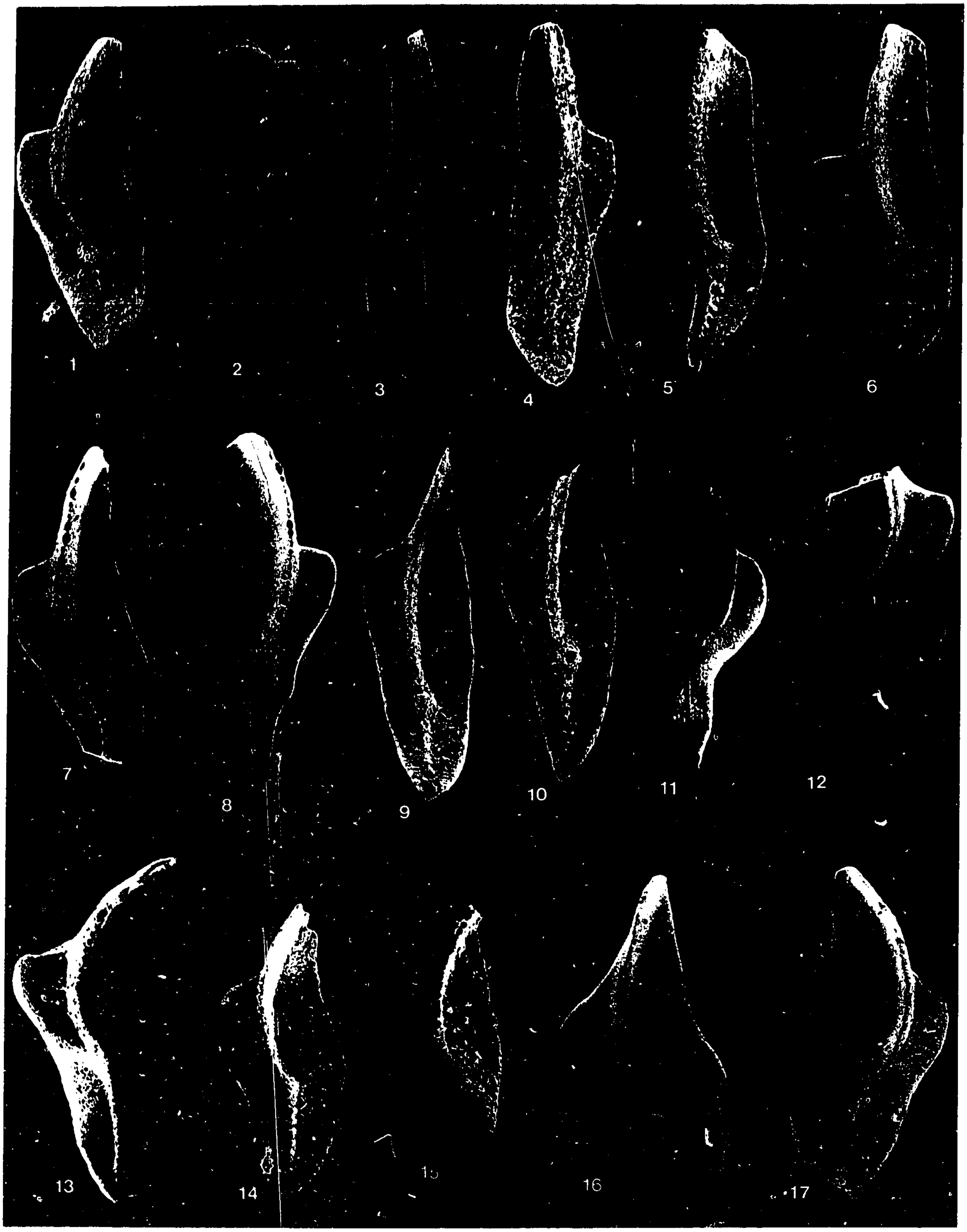
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PLATE V-10

All are upper views of Pa elements.

Fig. 1. Palmatolepis prima Ziegler and Huddle Morphotype 1 of Sandberg and Ziegler, 1973. Hypotype GSC 106937, X68, Palliser Formation, Morro Member (sample NP86-58, Table V-6).

Figs. 2-5. Palmatolepis prima Ziegler and Huddle Morphotype 2 of Sandberg and Ziegler, 1973. All specimens are hypotypes and from the Palliser Formation, Morro Member, unless indicated otherwise.

2. GSC 106938, X46 (sample NP86-45, Table V-6).
3. GSC 106939, X58 (sample NP86-45, Table V-6).
4. GSC 106940, X41, specimen transitional to P. klapperi Sandberg and Ziegler (sample ML2-210, Table V-7).
5. GSC 106941, X40, Wabamun Group, Whitelaw unit (sampled interval 10640-10649 ft., Table V-14).

Figs. 6-9, 11, 13, 14. Palmatolepis tenuipunctata Sannemann. All specimens are hypotypes.

6. GSC 106942, X75, Wabamun Group, Dixonville unit (sampled interval 2623-2624.5 m, Table V-16).
7. GSC 100274, X61, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 1, fig. 18), Palliser Formation, Morro Member (sample NP86-45, Table V-6).
8. GSC 106943, X100, juvenile specimen, Wabamun Group, Dixonville unit (sampled interval 11128.5-11169 ft., Table V-15).
9. GSC 106944, X60, Wabamun Group, Dixonville unit (sampled interval 11128.5-11169 ft., Table V-15).
11. GSC 106946, X80, Wabamun Group, Whitelaw unit (sampled bed 3059.5 m, Table V-16).
13. GSC 106948, X108, Wabamun Group, Whitelaw unit (sampled bed 3059.5 m, Table V-16).
14. GSC 106949, X60, Wabamun Group, Dixonville unit (sampled interval 11128.5-11169 ft., Table V-15).

Figs. 10, 12, 15. Palmatolepis cf. P. tenuipunctata Sannemann. All are figured specimens.

10. GSC 106945, X80, Wabamun Group, Dixonville unit (sampled interval 11128.5-11169 ft., Table V-15).
12. GSC 106947, X109, Palliser Formation, Morro Member, (sample ML2-125, Table V-7).
15. GSC 106950, X80, Wabamun Group, Dixonville unit (sampled interval 2623-2624.5 m, Table V-16).

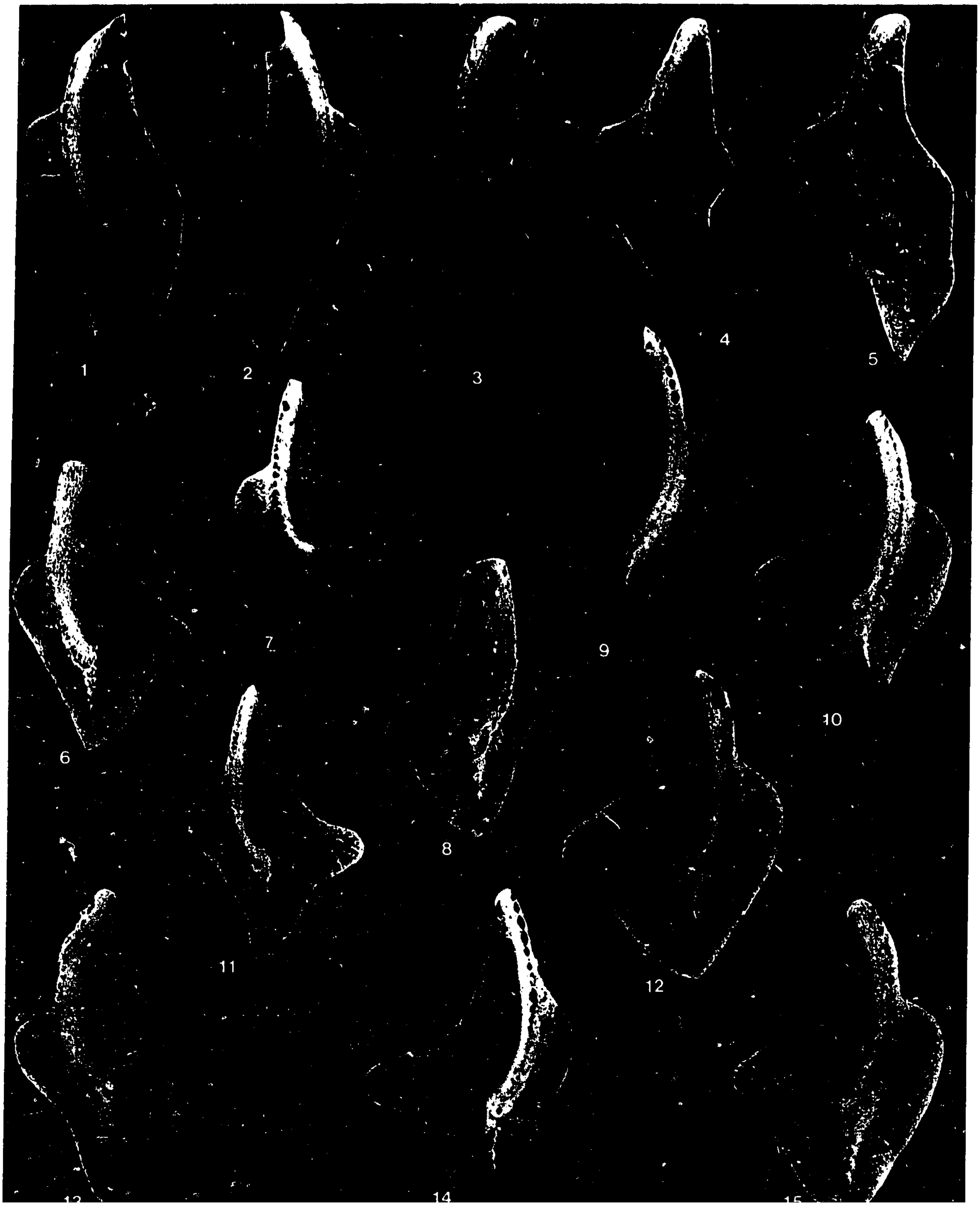
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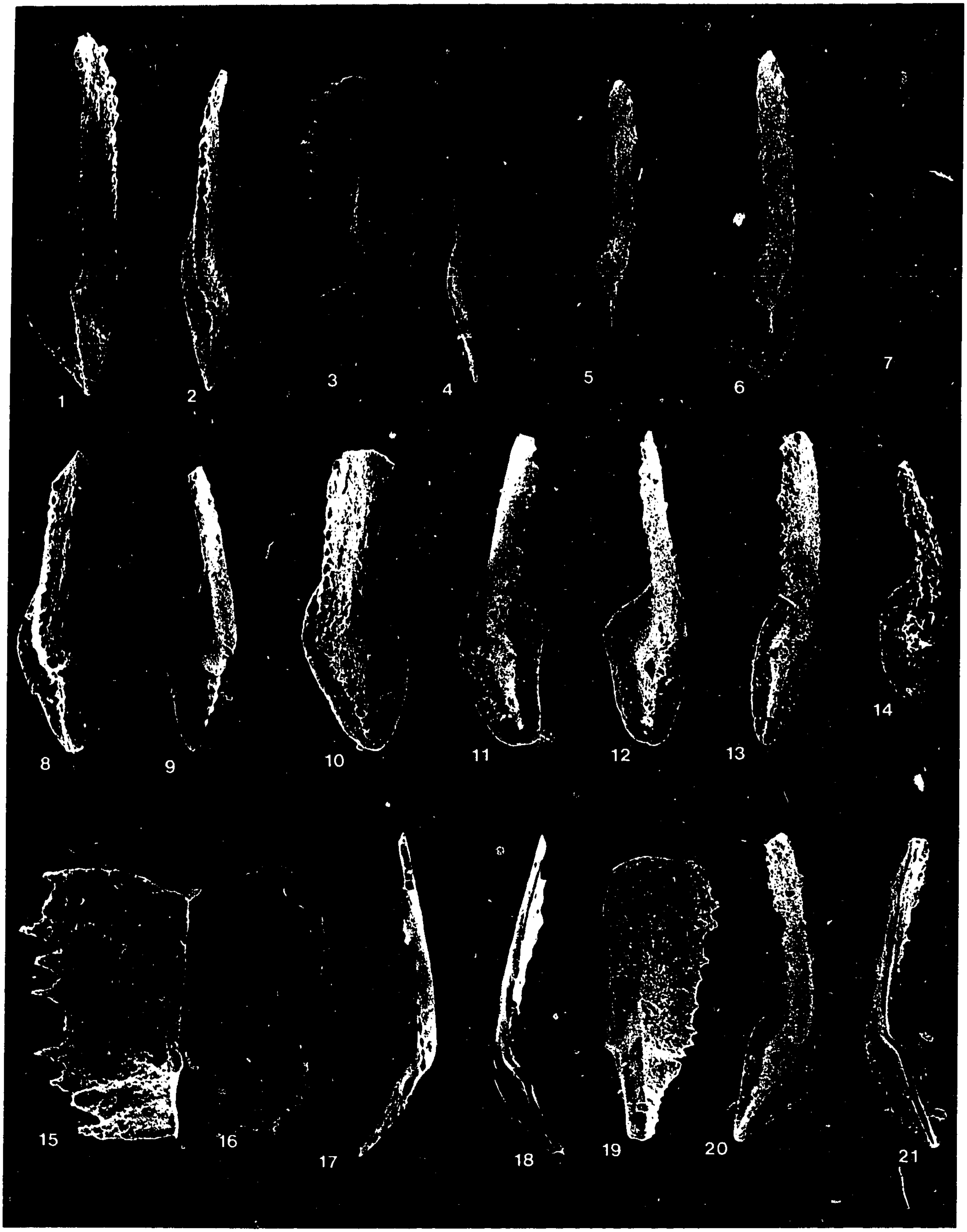
PLATE V-11

Figs. 1-7. Palmatolepis lanceolata n. sp.. The specimen illustrated in Figs. 1 and 2 is the holotype; specimens illustrated in Figs. 3-7 are paratypes. All specimens from the Wabamun Group, Dixonville unit, unless indicated otherwise.

1. lower view, GSC 106951, X85, Palliser Formation, Morro Member (sample NP86-41, Table V-6).
2. upper view of same specimen, X77.
3. lateral view, GSC 106952, X55 (sampled interval 2630-2630.5 m, Table V-16).
4. lateral view, GSC 106953, X65, specimen showing free blade denticles descending in step-wise fashion anteriorly (sampled interval 2623-2624.5 m, Table V-16).
5. upper view, GSC 106954, X80, juvenile to mature specimen (sampled interval 11128.5-11169 ft., Table V-15).
6. upper view, GSC 106955, X130, juvenile specimen (sampled interval 11128.5-11169 ft., Table V-15).
7. upper view, GSC 106956, X160, juvenile specimen representing earlier growth stage than Fig. 6, (sampled interval 11128.5-11169 ft., Table V-15).

Figs. 8-21. Palmatolepis minuta Branson and Mehl. All specimens are hypotypes.

8. upper view, GSC 106957, X83, Palliser Formation, Morro Member (sample ML2-220, Table V-7).
9. upper view, GSC 106958, X95, Palliser Formation, Morro Member? (sample PL-23-687, Table V-1).
10. oblique upper view, GSC 106959, X130, Wabamun Group, Dixonville unit (sampled interval 2623-2624.5 m, Table V-16).
11. upper view, GSC 106960, X140, Wabamun Group, Dixonville unit (sampled interval 11128.5-11169 ft., Table V-15).
12. upper view, GSC 106961, X160, Wabamun Group, Dixonville unit (sampled interval 11128.5-11169 ft., Table V-15).
13. oblique upper view, GSC 106962, X130, Wabamun Group, Normandville unit (sampled interval 11422-11436 ft., Table V-15).
14. upper view, GSC 100262, X82, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 1, fig. 6), Palliser Formation, Morro Member (sample CH57-420, Table V-4).
15. lateral view, GSC 106963, X208, Palliser Formation, Morro Member (sample NP86-58, Table V-6).
16. lateral view, GSC 106964, X140, Wabamun Group, Cardinal Lake unit (sampled interval 10917-10932 ft., Table V-15).
17. upper view of same specimen, X160.
18. lower view of same specimen, X160.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19. lateral view, GSC 106965, X130, Wabamun Group, Normandville unit (sampled interval 11422-11436 ft., Table V-15).
20. upper view of same specimen, X130.
21. lower view of same specimen, X135.

PLATE V-12

All are upper views of Pa elements unless indicated otherwise.

Figs. 1-8. Palmatolepis ovata n. sp. Specimen illustrated in Figs. 1 and 2 is the holotype; specimens illustrated in Figs. 3-8 are paratypes. Figs. 6-8 depict growth series. All specimens from the Palliser Formation, Morro Member.

1. GSC 106966, X128, (sample NP86-41, Table V-6).
2. lower view of same specimen, X133.
3. GSC 106967, X128, specimen with lanceolate platform outline, (sample NP86-39, Table V-6).
4. lower view of same specimen, X146.
5. GSC 106968, X137 (sample NP86-36, Table V-6).
6. GSC 106969, X184, juvenile specimen representing very early growth stage (sample NP86-41, Table V-6).
7. GSC 106970, X161, juvenile specimen representing later growth stage than Fig. 6 (sample NP86-41, Table V-6).
8. GSC 106971, X118 (sample NP86-41, Table V-6).

Figs. 9-16. Palmatolepis parawolskae n. sp. Specimen illustrated in Figs. 9 and 12 is the holotype; specimens illustrated in Figs. 10, 11, 13-16 are paratypes. All specimens from the Palliser Formation, Morro Member, unless indicated otherwise.

9\. GSC 106972, X64, with weak posterior carina (sample ML2-295, Table V-7).

12\. lower view of same specimen, X72.

10\. GSC 106973, X81, early form with more prominent bulge on anterior inner platform (sample ML2-375, Table V-7).

11\. GSC 106974, X91, early form with prominent bulge as above (sample ML2-375, Table V-7).

13\. GSC 106975, X61, elongate specimen (sample CH58A-220, Table V-4).

14\. GSC 100270, X50, same specimen as that identified as P. minuta minuta Branson and Mehl by Johnston and Chatterton (1991, pl. 1, fig. 8) (sample ML2-295, Table V-7).

15\. GSC 106976, X34, Wabamun Group, Dixonville unit (sampled interval 11111-11128.5 ft., Table V-15).

16\. GSC 106977, X71, specimen with less prominent outer lobe than Figs. 9 and 12 (sample ML2-295, Table V-7).

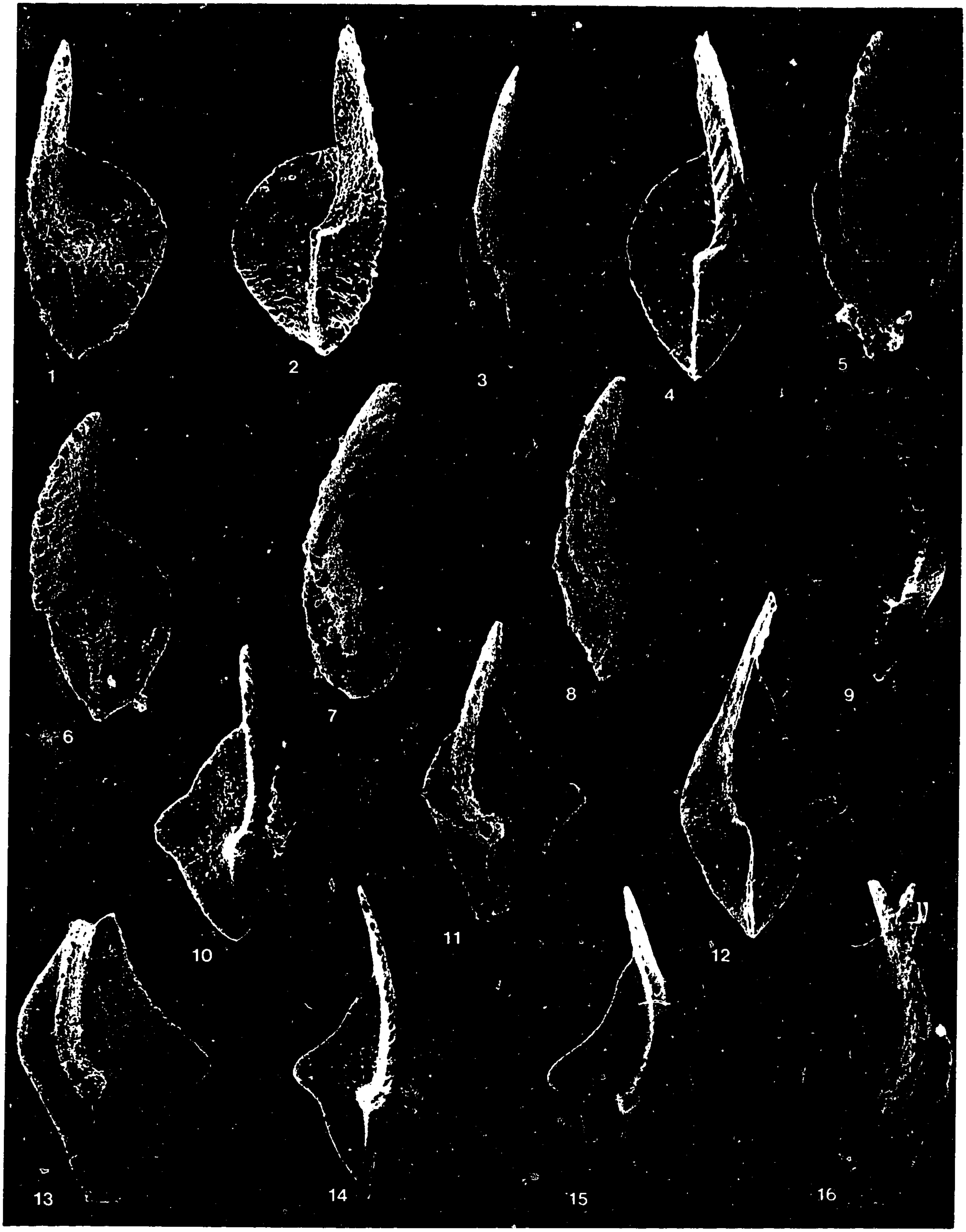
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PLATE V-13

All are upper views of Pa elements.

Figs. 1-5. Palmatolepis parawolskae n. sp. All specimens are paratypes. All specimens from the Wabamun Group, Dixonville unit, unless indicated otherwise.

1. GSC 106978, X45, specimen with reduced posterior carina (sampled interval 11111-11128.5 ft., Table V-15).
2. GSC 106979, X53, specimen with subdued bulge and moderately well developed carina, Palliser Formation, Morro Member (sample NP86-43, Table V-6).
3. GSC 106980, X160, juvenile specimen representing very early growth stage (sampled interval 11128.5-11169 ft., Table V-15).
4. GSC 106981, X100, juvenile specimen representing later growth stage than Fig. 3 (sampled interval 11128.5-11169 ft., Table V-15).
5. GSC 106982, X79, juvenile to mature specimen (sampled interval 11128.5-11169 ft., Table V-15).

Figs. 6, 7. Palmatolepis wolskae Szulczewski. Both specimens are hypotypes and from the Wabamun Group, Dixonville unit.

6. GSC 106983, X100 (sampled interval 11111-11128.5 ft., Table V-15).
7. GSC 106984, X90, specimen with smooth platform posterior to azygous node (sampled interval 11128.5-11169 ft., Table V-15).

Figs. 8-11. Palmatolepis sp. B. All are figured specimens and from the Palliser Formation, Morro Member?.

8. GSC 106985, X153, juvenile specimen (sample PL-23-684, Table V-1).
9. GSC 106986, X147, juvenile specimen with curved free blade and carina (sample PL-23-687, Table V-1).
10. GSC 106987, X106, specimen larger than those in Figs. 8 and 9, with shortened platform (sample PL-23-685, Table V-1).
11. GSC 106988, X111, specimen with shortened platform (sample PL-23-687, Table V-1).

Fig. 12. Palmatolepis crepida Sannemann. Hypotype GSC 106989, X64, Palliser Formation, Morro Member (sample NP86-50, Table V-6).

Figs. 13, 15. Palmatolepis cf. P. perlobata Ulrich and Bassler. All are figured specimens.

13. GSC 106990, X38, Wabamun Group, Dixonville unit (sampled interval 11128.5-11169 ft., Table V-15).
15. GSC 100277, X41, same specimen that was identified as P. triangularis Sannemann by Johnston and Chatterton (1991, pl. 1, fig. 21) (sample ML2-375, Table V-7).

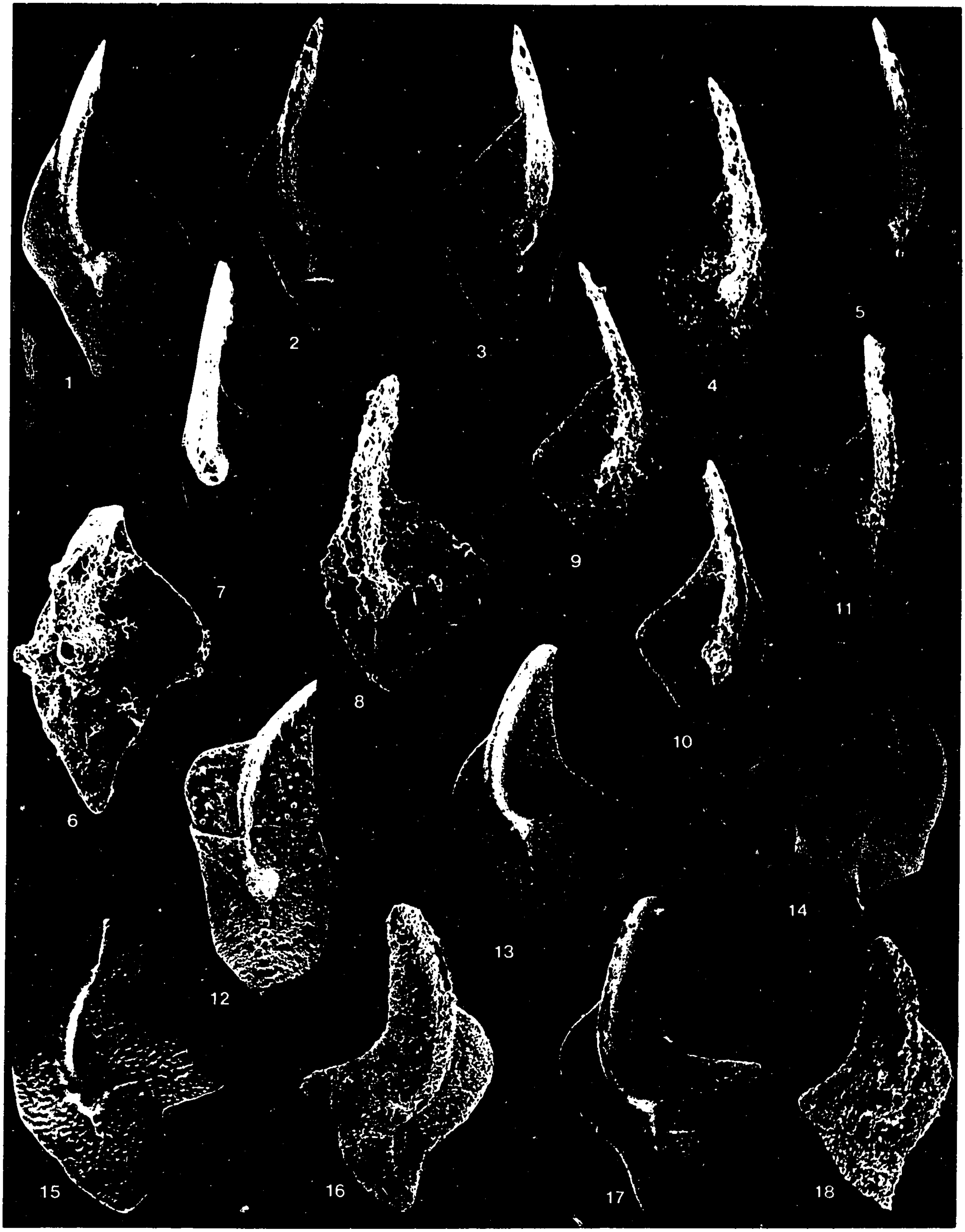
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Fig. 14. Palmatolepis perlobata Ulrich and Bassler? Figured specimen GSC 106991, X45, Wabamun Group, Dixonville unit (sampled interval 11111-11128.5 ft., Table V-15).

Figs. 16-18. Palmatolepis schindewolfi Müller. All specimens are hypotypes and from the Wabamun Group, Dixonville unit (sampled interval 11111-11128.5 ft., Table V-15).

16. GSC 106992, X60, small mature specimen.
17. GSC 106993, X44, mature to gerontic specimen.
18. GSC 106994, X79, juvenile specimen.

PLATE V-14

All are upper views of Pa elements and all are hypotypes.

Figs. 1-4. Palmatolepis duplicata Sandberg and Ziegler. All specimens from the Palliser Formation, Morro Member.

1. GSC 100306, X57, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 2, fig. 26) (sample NPW86-25, Table V-6).
2. GSC 106995, X129, juvenile to mature specimen (sample NPW86-25, Table V-6).
3. GSC 106996, X155, juvenile specimen (sample NPW86-25, Table V-6).
4. GSC 106997, X62 (sample ML1-60, Table V-8).

Figs. 5-12, 16. Palmatolepis inflexa Müller.

5. GSC 106998, X78, Palliser Formation, Morro Member (sample NPW89-4, Table V-6).
6. GSC 106999, X63, Palliser Formation, Costigan Member (sample BAI-1200, Table V-2).
7. GSC 107000, X33, broad specimen (sample BAI-1200, Table V-2).
8. GSC 107001, X79, juvenile specimen (sample BAI-1200, Table V-2).
9. GSC 107002, X38, Wabamun Group, Cardinal Lake unit (sampled bed 11825 ft., Table V-15).
10. GSC 100304, X48, same specimen as that identified as P. quadrantinodosa inflexoidea Ziegler by Johnston and Chatterton (1991, pl. 2, fig. 24), Palliser Formation, Costigan Member (sample BAI-1250, Table V-2).
11. GSC 100303, X60, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 2, fig. 23), Palliser Formation, Morro Member (sample GK1-193, Table V-10).
12. GSC 107002, X36, Wabamun Group, Cardinal Lake unit (sampled interval 11810-11820 ft., Table V-15).
16. GSC 107007, X74, from Meosin Mountain, approximately 30 m below top of Palliser Formation (see Appendix for locality information).

Figs. 13-15, 17, 18. Palmatolepis marginifera Helms.

13. GSC 107004, X54, Palliser Formation, Morro Member (sample GK1-617, Table V-10).
14. GSC 107005, X54, from Nordegg, Costigan Member, 12 m below top of Palliser Formation (see Appendix for locality information).
15. GSC 107006, X70, Palliser Formation, Morro Member (sample ML1-40, Table V-4).
17. GSC 98143, X83, same specimen as that illustrated by Johnston and Meijer Drees (1993, pl. 1, fig. 18), Wabamun Group, Cardinal Lake unit (sampled bed 11828 ft., Table V-15).
18. GSC 107008, X60, typical specimen, Palliser Formation, Morro Member (sample ML1-30, Table V-8).

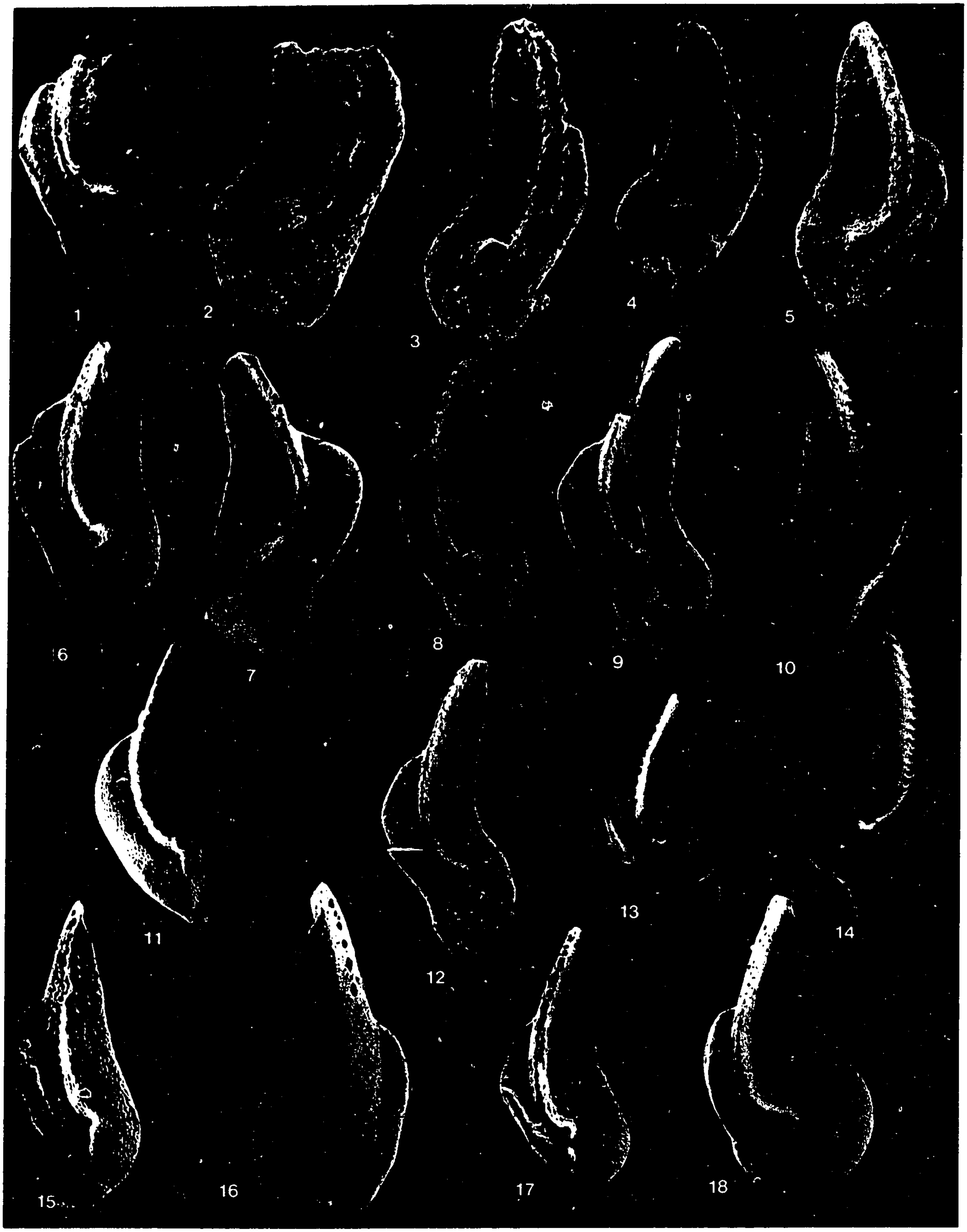
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PLATE V-15

All are upper views of Pa elements.

Figs. 1-6. Palmatolepis marginifera Helms. All specimens are hypotypes and from the Palliser Formation, Morro Member (sample ML1-20, Table V-8).

1. GSC 107009, X104, juvenile specimen.
2. GSC 107010, X80, juvenile specimen, represents later growth stage than Fig. 1.
3. GSC 107011, X64, juvenile specimen, represents later growth stage than Fig. 2.
4. GSC 107012, X39.
5. GSC 107013, X38.
6. GSC 107014, X53.

Fig. 7, Palmatolepis quadrantinodosa Branson and Mehl. Hypotype GSC 107015, X45, Palliser Formation, Morro Member (sample NPW89-4, Table V-6).

Figs. 8-12, 13? Palmatolepis stoppeli Sandberg and Ziegler. Specimens illustrated in Figs. 8-12 are hypotypes. All specimens from the Palliser Formation, Morro Member, unless indicated otherwise.

8. GSC 107016, X61 (sample CSS-570, Table V-9).
9. GSC 107017, X60, specimen with swollen ramp on anterior inner platform (GSC Loc. C-187420, Table V-3).
10. GSC 107018, X59 (sample CSS-570, Table V-9).
11. GSC 98146, X51, specimen with posterior carina, Wabamun Group, Cardinal Lake unit (sampled interval 10362-10370 ft., Table V-14).
12. GSC 107019, X61 (sample MLN A, Table V-8).
13. figured specimen GSC 107020, X61 (sample NP86-58, Table V-6).

Figs. 14-19. Palmatolepis poolei Sandberg and Ziegler. All specimens are hypotypes and from the Palliser Formation, Morro Member, unless indicated otherwise.

14. GSC 107021, X63, specimen with shortened outer platform (sample ML2-30, Table V-7).
15. GSC 100273, X60, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 1, fig. 17) (sample NP86-64, Table V-6).
16. GSC 107022, X61, broad specimen with slight outer lobe (sample NP86-50, Table V-6).
17. GSC 107023, X62 (sample NP86-50, Table V-6).
18. GSC 107024, X70, specimen with reduced outer lobe, Wabamun Group, Whitelaw unit (sampled bed 3059.5 m, Table V-16).
19. GSC 107025, X97, juvenile specimen (sample NP86-60, Table V-6).

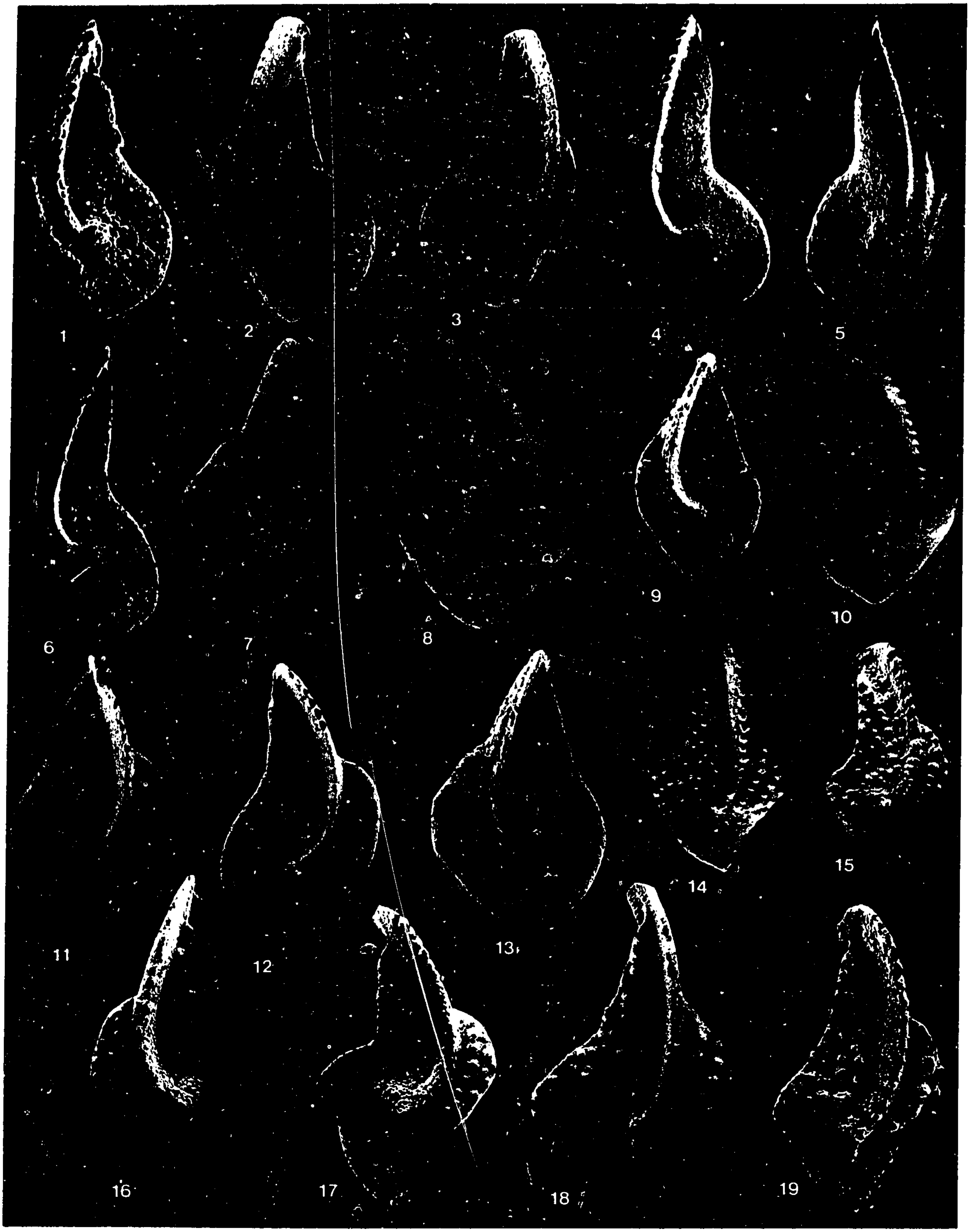
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PLATE V-16

All are upper views of Pa elements.

Figs. 1-6. 10, 11. _Palmatolepis quadrantinodosalobata_ Sannemann. All specimens are hypotypes and from the Palliser Formation, Morro Member, unless indicated otherwise.

1. GSC 107026, X90, specimen with straight free blade, reduced platform and large outer lobe (sample ML2-335, Table V-7).
2. GSC 107027, X64, specimen with broad platform and somewhat subdued outer lobe (sample ML2-295, Table V-7).
3. GSC 107028, X65, slightly smaller specimen with somewhat rounder platform (sample ML2-295, Table V-7).
4. GSC 100272, X66, specimen exhibiting straight free blade and reduced platform and large outer lobe, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 1, fig. 16) (sample ML2-335, Table V-7).
5. GSC 107029, X63, juvenile specimen (sample ML2-335, Table V-7).
6. GSC 107030, X63 (sample ML2-335, Table V-7).
10. GSC 107034, X100, Wabamun Group, Whitelaw unit (sampled interval 11851-11862 ft., Table V-13).
11. GSC 100270, X65, specimen with broad platform with numerous nodes and anteriorly directed outer lobe, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 1, fig. 14) (sample GK1-513, Table V-10).

Figs. 7-9, 14, 15. _Palmatolepis quadrantinodosalobata_ Sannemann Morphotype 1 of Sandberg and Ziegler, 1973. All specimens are hypotypes and from the Palliser Formation, Morro Member, unless indicated otherwise.

7. GSC 107031, X67, small dextral specimen (sample ML2-240, Table V-7).
8. GSC 107032, X70, small sinistral specimen (sample ML2-240, Table V-7).
9. GSC 107033, X70, "early" form of morphotype, showing nodes on inner parapet convergent on azygous node (sample ML2-265, Table V-7).
14. GSC 107037, X55, Wabamun Group, Whitelaw unit (sampled interval 10649-10658 ft., Table V-14).
15. GSC 107038, X66, Palliser Formation, Morro Member? (sample PL-23-688, Table V-1).

Figs. 12, 13. _Palmatolepis protorhomboidea_ Sandberg and Ziegler. Both specimens are hypotypes and from the Palliser Formation, Morro Member (sample ML2-335, Table V-7).

12. GSC 107035, X63, specimen approaching _P. rhomboidea_ Sannemann in outline, with thickened anterior margin of outer platform.
13. GSC 107036, X64.


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16, 17? 18? Palmatolepis poolei Sandberg and Ziegler. All specimens from the Palliser Formation, Morro Member.

16. hypotype GSC 107039, X62, specimen with stronger development of nodes on anterior outer platform (sample NP86-58, Table V-6).

17. figured specimen GSC 107040, X80 (sample NP86-45, Table V-6).

18. figured specimen GSC 107041, X74 (sample NP86-45, Table V-6).

Fig. 19. Palmatolepis cf. P. delicatula Branson and Mehl. Figured specimen GSC 107042, X114, Palliser Formation, Morro Member? (sample PL-23-683, Table V-1).

PLATE V-17

All are upper views of Pa elements.

Figs. 1, 2?, 3, 7, 8. Palmatolepis protorhomboidea Sandberg and Ziegler. Specimens illustrated in Figs. 1, 3, 7, 8 are hypotypes. All specimens from the Palliser Formation, Morro Member, unless indicated otherwise.

1. GSC 107043, X117 (sample ML2-335, Table V-7).
2. figured specimen GSC 107044, X168 (sample NPW86-19, Table V-6).
3. GSC 107045, X113 (sample ML2-335, Table V-7).
7. GSC 107048, X109, Palliser Formation, Morro Member? (sample PL-23-686, Table V-1).
8. GSC 107049, X85, Palliser Formation, Morro Member? (sample PL-23-686, Table V-1).

Figs. 4-6, 9, 10, 13-15. Palmatolepis rhomboidea Sannemann. All specimens are hypotypes.

4. GSC 107046, X64, Palliser Formation, Morro Member (sample CSS-377, Table V-9).
5. GSC 98138, X50, same specimen as that illustrated by Johnston and Meijer Drees (1993, pl. 1, fig. 13), Wabamun Group, Normandville unit (sampled interval 11422-11436 ft., Table V-15).
6. GSC 107047, X114, Palliser Formation, Morro Member (sample ML2-0, Table V-7).
9. GSC 107050, X106, Palliser Formation, Morro Member (sample ML2-10, Table V-7).
10. GSC 107051, X89, Palliser Formation, Morro Member? (sample PL-23-689, Table V-1).
13. GSC 107054, X61, large specimen with rectangular platform outline, Palliser Formation, Morro Member? (sample PL-23-689, Table V-1).
14. GSC 107055, X91, Palliser Formation, Morro Member? (sample PL-23-689, Table V-1).
15. GSC 107056, X115, Palliser Formation, Morro Member (sample ML2-0, Table V-7).

Fig. 11, 12. Palmatolepis aff. P. protorhomboidea Sandberg and Ziegler. Both are figured specimens and from the Palliser Formation, Morro Member? (sample PL-23-685, Table V-1).

11. GSC 107052, X145.
12. GSC 107053, X140.

Figs. 16-18. Palmatolepis subperlobata Branson and Mehl. All specimens are hypotypes and are from the Palliser Formation, Morro Member (sample ML2-285, Table V-7).

16. GSC 107057, X105, juvenile specimen.
17. GSC 107058, X47.
18. GSC 100280, X36, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 1, fig. 24).


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PLATE V-18

All are upper views of Pa elements and all are hypotypes unless indicated otherwise.

Figs. 1-6, 9-11. Polygnathus communis Branson and Mehl.

1. GSC 107059, X83, Wabamun Group, Big Valley Formation (sampled interval 5502-5522 ft., Table V-17).
2. lower view of same specimen, X78.
3. GSC 107060, X88, Palliser Formation, Costigan Member (sample JC-0.6m, Table V-5).
4. GSC 107061, X128, Palliser Formation, Costigan Member, (sample NPW89-22, Table V-6).
5. GSC 107062, X92, Wabamun Group, Big Valley Formation (sampled interval 5502-5522 ft., Table V-17).
6. lower view, GSC 107063, X90, specimen with deep depression posterior to basal pit, from Persimmon Range, 0.3 m below top of Palliser Formation (see Appendix for locality information).
9. lower view GSC 100291, X92, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 2, fig. 11), Palliser Formation, Morro Member (sample ML2-0, Table V-7).
10. GSC 100292, X77, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 2, fig. 12), Palliser Formation, Morro Member (sample ML2-0, Table V-7).
11. GSC 107066, X85, from Persimmon Range, 0.3 m below top of Palliser Formation (see Appendix for locality information).

Figs. 7, 8, 12, 13?, 14?, 15-19. Palmatolepis subperlobata Branson and Mehl. All specimens from the Palliser Formation, Morro Member, unless indicated otherwise.

7. GSC 107064, X100, Wabamun Group, Whitelaw unit (sampled interval 11063-11090 ft., Table V-15).
8. oblique upper view, GSC 107065, X130 (sample NP86-58, Table V-6).
12. GSC 107067, X92 (sample NP86-50, Table V-6).
13. figured specimen GSC 107068, X47 (sample RMW-400, Table V-11).
14. figured specimen GSC 107069, X47 (sample CH57A-220, Table V-4).
15. GSC 107070, X104 (sample NP86-45, Table V-6).
16. GSC 107071, X103, specimen with secondary carina extending onto outer lobe (sample NP86-50, Table V-6).
17. GSC 107072, X108 (sample NP86-45, Table V-6).
18. GSC 107073, X100 (sample NP86-50, Table V-6).
19. GSC 107074, X135 (sample NP86-50, Table V-6).

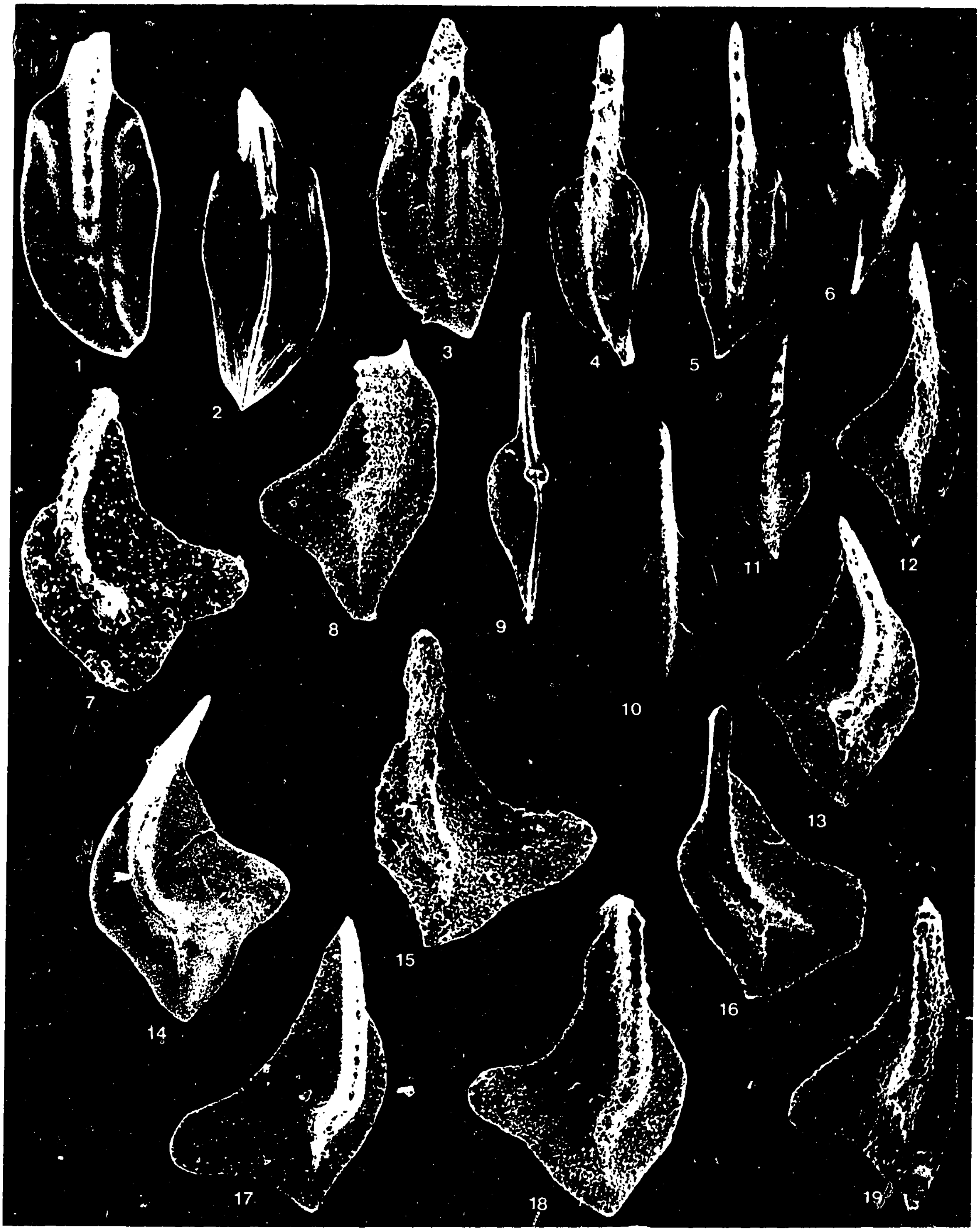
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PLATE V-19

1-4, 5?, 6? *Polygnathus glaber* Ulrich and Bassler. Figs. re hypotypes.
1. upper view, GSC 107075, X123, Palliser Formation, Costigan Member (sample NPW89-17, Table V-6).
2. lower view, GSC 107076, X155, Palliser Formation, Costigan Member (sample NPW89-17, Table V-6).
3. lower view, GSC 100293, X76, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 2, fig. 13), Palliser Formation, Morro Member (sample GK-20, Table V-10).
4. upper view of same specimen, X78.
5. upper view, figured specimen GSC 107077, X100, Wabamun Group, Dixonville unit (sampled interval 11170-11220 ft., Table V-15).
6. oblique lower view of same specimen, X90.

7-17. *Polygnathus* sp. A. All are figured specimens and the Palliser Formation, Morro Member.
7. upper view, GSC 107078, X42 (sample GK1-271, Table V-10).
8. oblique lower view of same specimen, X44.
9. upper view, GSC 107079, X55 (sample ML2-5-10, Table V-7).
10. oblique lower view of same specimen, X62.
11. lateral view of same specimen, X49.
.2. upper view, GSC 107080, juvenile specimen (sample GK1-271, Table V-10).
.3. lower view, GSC 107081, X116, juvenile specimen (sample ML2-2.5-7.5, Table V-7).
.4. upper view, GSC 107082, X39, fragmentary specimen (sample ML2-2.5-7.5, Table V-7).
.5. lateral view of same specimen, X39.
.6. upper view, GSC 107083, X81, juvenile to mature specimen (sample ML2-2.5-7.5, Table V-7).
.7. lower view of same specimen, X81.

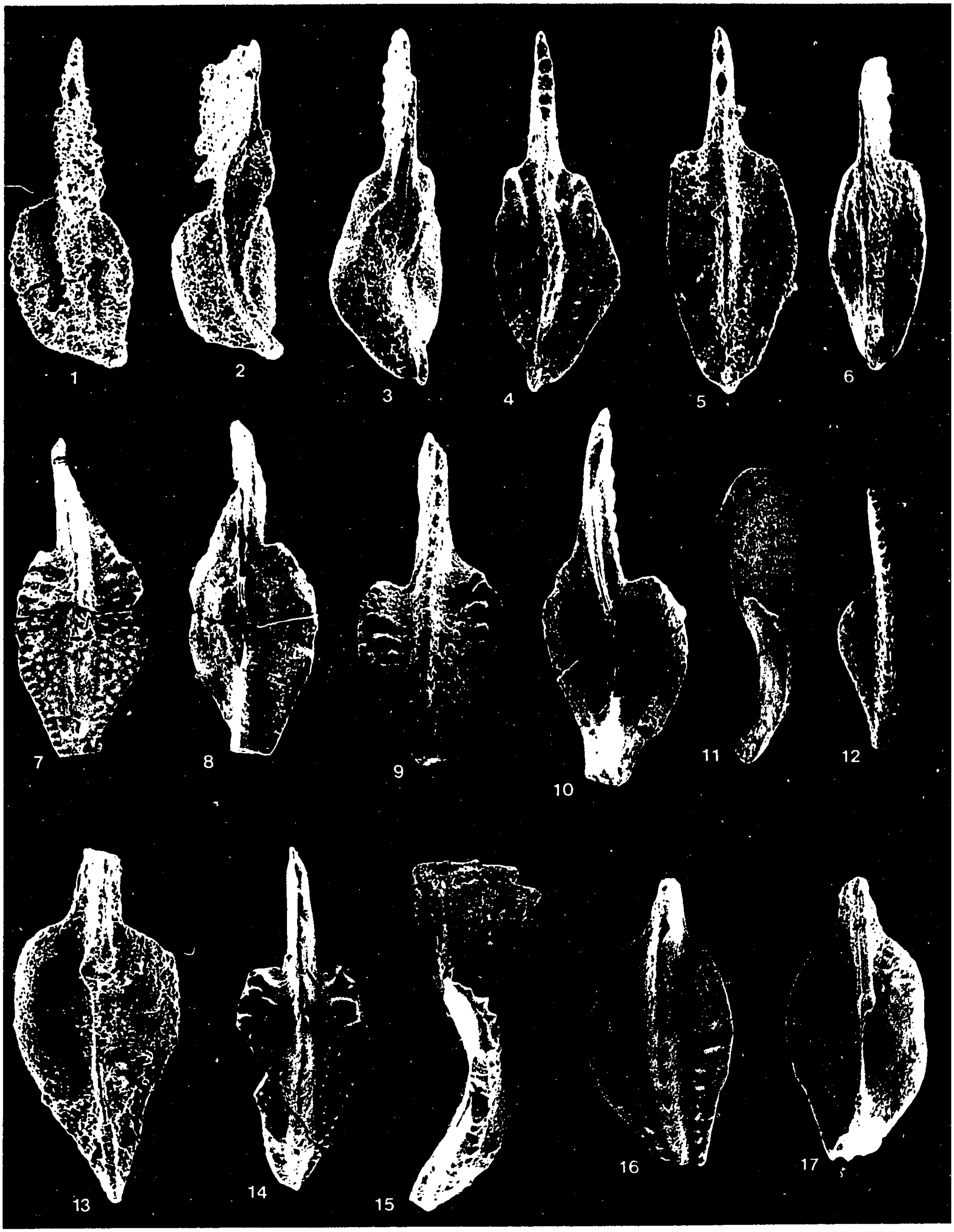
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PLATE V-20

Figs. 1-10. Polygnathus sp. B. All are figured specimens and from the Palliser Formation, Morro Member.

1. upper view, GSC 107084, X108, juvenile specimen (sample GK1-271, Table V-10).
2. upper view, GSC 107085, X54 (sample ML2-0-5, Table V-7).
3. lower view of same specimen, X65.
4. lateral view of same specimen, X59.
5. upper view, GSC 107086, X92, juvenile specimen (sample ML2-10, Table V-7).
6. upper view, GSC 107087, X55 (sample ML2-10, Table V-7).
7. lower view, GSC 107088, X152, juvenile specimen (sample ML2-10, Table V-7).
8. upper view, GSC 107089, X73 (sample GK1-271, Table V-10).
9. lateral view of same specimen, X74.
10. upper view, GSC 107090, X83, juvenile to mature specimen (sample ML2-0, Table V-7).

Figs. 11-19. Polygnathus crassilabrus n. sp. Specimen illustrated in Figs. 11 and 12 is the holotype; specimens illustrated in Figs. 13-19 are paratypes. All specimens from the Palliser Formation, Morro Member.

11. oblique upper view, GSC 107091, X60, (sample RMW-10, Table V-11).
12. lower view of same specimen, X61.
13. lower view, GSC 107092, X94 (sample WMG86-D, Table V-3).
14. upper view of same specimen, X94.
15. lower view, GSC 107093, X74 (sample CH57-350, Table V-4).
16. upper view of same specimen, X78.
17. lower view, GSC 107094, X90 (GSC Loc. C-187239, Table V-3).
18. lateral view of same specimen, X90.
19. upper view of same specimen, X88.


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PLATE V-21

Figs. 1-5. Polygnathus crassilabrus n. sp. All specimens are paratypes and from the Palliser Formation, Morro Member.

1. upper view, GSC 107095, X72, bowed specimen with ovoid to elongate platform (sample CH57-378, Table V-4).
2. upper view, GSC 107096, X91, elongate specimen (sample NPW89-1, Table V-6).
3. lateral view, GSC 107097, X81 (sample ML1-40, Table V-8).
4. upper view of same specimen X85.
5. lower view of same specimen, X96.

Figs. 6-19, 20?, 21, 22. Polygnathus dolichopleurus n. sp. Specimen illustrated in Figs. 16-18 is the holotype; specimens illustrated in Figs. 6-15, 19, 21, 22 are paratypes. All specimens from the Palliser Formation, Morro Member, unless indicated otherwise.

6. lower view, GSC 107098, juvenile specimen, Wabamun Group, Dixonville unit (sampled interval 2630-2630.5 m, Table V-16).
7. upper view of same specimen.
8. lateral view of same specimen, all views X60.
9. lateral view, GSC 107099, X73, juvenile specimen, Wabamun Group, Dixonville unit (sampled interval 2630-2630.5 m, Table V-16).
10. upper view of same specimen, X71.
11. lower view, GSC 107100, X96, juvenile specimen, Wabamun Group, Dixonville unit (sampled interval 2630-2630.5 m, Table V-16).
12. upper view of same specimen, X95.
13. lateral view of same specimen, X96.
14. lower view, GSC 107101, X48, small mature specimen, represents latest stage of growth series depicted by Figs. 6-15 (sample GK1-533, Table V-10).
15. upper view of same specimen, X50.
16. lateral view, GSC 107102, X32, (sample BAI-150, Table V-2).
17. upper view of same specimen, X32.
18. lower view of same specimen, X33.
19. upper view, GSC 107103, X33, (sample NP86-41, Table V-6).
20. oblique upper view, figured specimen GSC 107104, X32 (sample BAI-150, Table V-2).
21. upper view, GSC 107105, X50, (sample ML2-295, Table V-7).
22. oblique lower view of same specimen, X41.

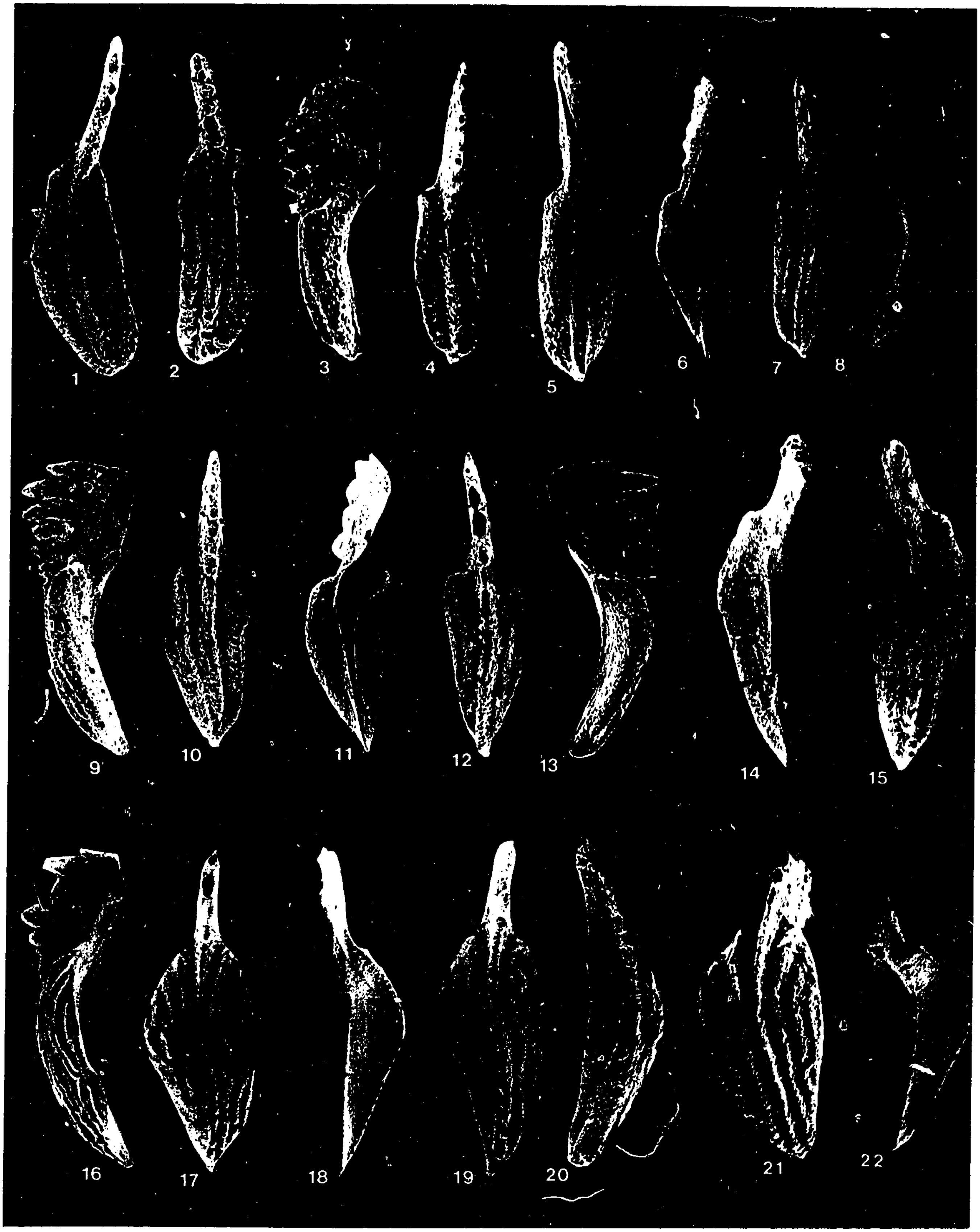
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PLATE V-22

Figs. 1-3?, 4-13, 15, 17, 18. Polygnathus aff. P. fallax Helms and Wolska. All are figured specimens and from the Palliser Formation, Morro Member.

1. upper view, GSC 107106, X69, (sample BAI-785, Table V-2).
2. lateral view of same specimen, X61.
3. lower view of same specimen, X67.
4. lateral view, GSC 107107, X58 (sample CSS-83, Table V-9).
5. lower view, GSC 107108, X106, juvenile specimen (sample NP86-13, Table V-6).
6. lateral view of same specimen, X74.
7. upper view of same specimen, X102.
8. upper view, GSC 107109, X98, juvenile specimen (sample ML2-420, Table V-7).
9. lateral view, GSC 107110, X66 (sample BAI-785, Table V-2).
12. lower view of same specimen, X71.
13. upper view of same specimen, X69.
10. upper view, GSC 107111, X54 (sample RMW-500, Table V-11).
11. lower view of same specimen, X57.
15. lateral view of same specimen, X49.
17. lower view, GSC 107113, X110 (sample CSS-83, Table V-9).
18. upper view of same specimen, X107.

Figs. 14, 16. Polygnathus fallax Helms and Wolska? Figured specimen GSC 107112, Palliser Formation, Costigan Member (sample COS89-36.7-36.8 m, Table V-5).

14. lower view, X86.
16. upper view, X84.

Figs. 19-21. Polygnathus dolichopleurus n. sp. Paratype GSC 107114, gerontic specimen, Palliser Formation, Morro Member (GSC Loc. C-187214, Table V-3).

19. lower view, X21.
20. lateral view, X20.
21. upper view, X22.

PLATE V-23

All are upper views of Pa elements unless indicated otherwise.

Figs. 1-6, 11, 12. _Polygnathus_ _meijerdreesi_ n. sp. Specimen illustrated in Figs. 1-3 is the holotype; specimens illustrated in Figs. 4-6, 11, 12 are paratypes. All specimens from the Palliser Formation, Morro Member, unless indicated otherwise.

1. lower view, GSC 107115, X53, (sample ML2-375, Table V-7).
2. X54.
3. lateral view of same specimen, X60.
4. GSC 107116, X55, Wabamun Group, Dixonville unit (sampled interval 11597-11607 ft., Table V-12).
5. lateral view of same specimen, X60, showing blade morphology like gerontic specimens.
6. GSC 107117, X51, typical specimen (sample RMW-510, Table V-11).
11. GSC 107122, X40 (sample CSS-50, Table V-9).
12. GSC 107123, X56, typical specimen (sample RMW-510, Table V-11).

Figs. 7-10, 17, 22. _Polygnathus_ _germanus_ Ulrich and Bassler. All specimens are hypotypes and from the Palliser Formation, Morro Member.

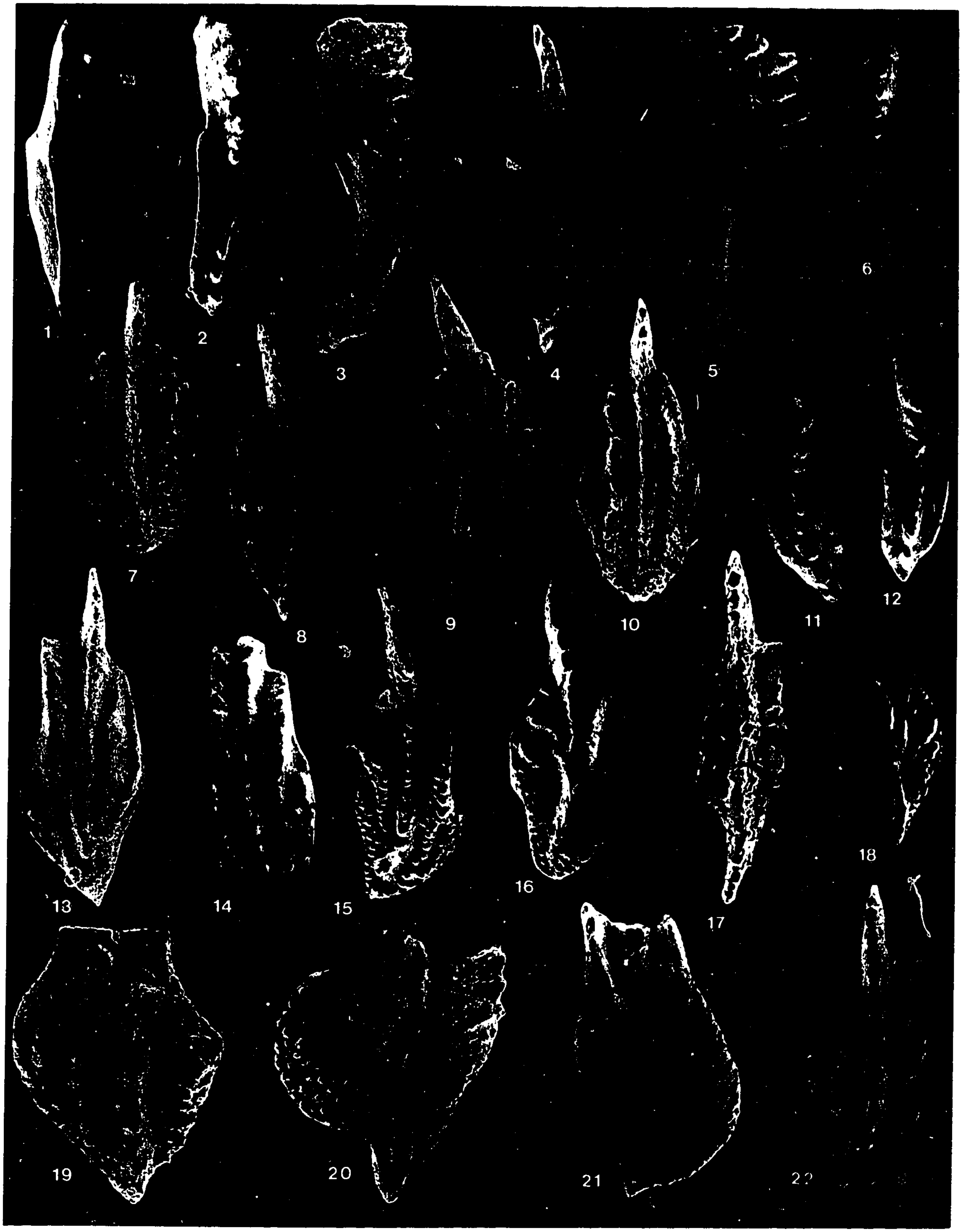
7. GSC 107118, X46 (sample NP86-50, Table V-6).
8. GSC 107119, X49, dextral specimen with parallel rows of nodes (sample NP86-50, Table V-6).
9. GSC 107120, X46, specimen with strong ridges anteriorly (sample NP86-45, Table V-6).
10. GSC 107121, X65 (sample NPW86-19, Table V-6).
17. GSC 107128, X99 (sample NP86-58, Table V-6).
22. GSC 107133, X69, juvenile specimen (sample NP86-58, Table V-6).

Figs. 13-16. _Polygnathus_ _perplexus_ Thomas. All specimens are hypotypes and from the Palliser Formation, Costigan Member, unless indicated otherwise.

13. GSC 107124, X43 (sample NPW89-17, Table V-6).
14. GSC 107125, X53 (sample JC-0.6m, Table V-5).
15. GSC 107126, X44 (sample CNP, TOP, Table V-2).
16. GSC 107127, X35, Palliser Formation, Morro Member (sample GK1-92, Table V-10).

Figs. 18-21. _Polygnathus_ cf. _P_. _homoirregularis_ Ziegler. All are figured specimens and from the Palliser Formation, Costigan Member.

18. oblique upper view, GSC 107129, X26 (sample JC-2.6m, Table V-5).
19. GSC 107130, X115, juvenile specimen (sample COS89-36.7-36.8m, Table V-5).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20. GSC 107131, X73, small mature specimen showing convergence of inner adcarinal crest with carina posterior to azygous node (sample COS89-36.7-36.8m, Table V-5).
21. GSC 107132, X28 (sample NPW89-17, Table V-6).

PLATE V-24

Figs. 1-3, 4-6? Polygnathus meijerdreesi n. sp. Specimens illustrated Figs. 1-3 are paratypes. All specimens from the Palliser Formation, Morro Member.

1. lower view, GSC 107314, X39 (sample NP86-9, Table V-6).
2. upper view, GSC 107135 (sample GK-80, Table V-10).
3. lateral view of same specimen, both views X29.
4. lower view, figured specimen GSC 107136, X25 (sample GK-110, Table V-10).
5. upper view of same specimen, X23.
6. lateral view of same specimen, X25.

Figs. 7, 8. Polygnathus planirostratus Dreesen and Dusar? Figured specimen GSC 107137, Palliser Formation, Costigan Member (sample NPW89-15, Table V-6).

7. lower view, X95.
8. upper view, X98.

Figs. 9-19. Polygnathus latisemicostatus n. sp. Specimen illustrated in Figs. 9-11 is the holotype; specimens illustrated in Figs. 12-19 are paratypes. All specimens from the Palliser Formation, Morro Member. Note broken anterior portion free blade of holotype in Figs. 9 and 11.

9. lateral view, GSC 107138, X73 (sample ML1-40, Table V-8).
10. upper view of same specimen, X75.
11. lower view of same specimen, X62,
12. upper view, GSC 107139, X85, early representative of species (sample GK1-313, Table V-10).
13. upper view, GSC 107140, X159, juvenile specimen (sample NPW89-4, Table V-6).
14. upper view, GSC 107141, X118, juvenile specimen (sample NPW89-4, Table V-6).
15. close-up of upper surface detail of nodes on outer side of anterior platform of specimen illustrated in Figs. 17-19, GSC 107142, X218 (sample NPW89-4, Table V-6).
17. lower view of same specimen, X47.
18. upper view of same specimen, X47, showing broad platform and well defined anterior nodes.
19. lateral view of same specimen, X44.
16. upper view, GSC 107143, X82, specimen showing oblique transverse ridges (sample NPW89-4, Table V-6).

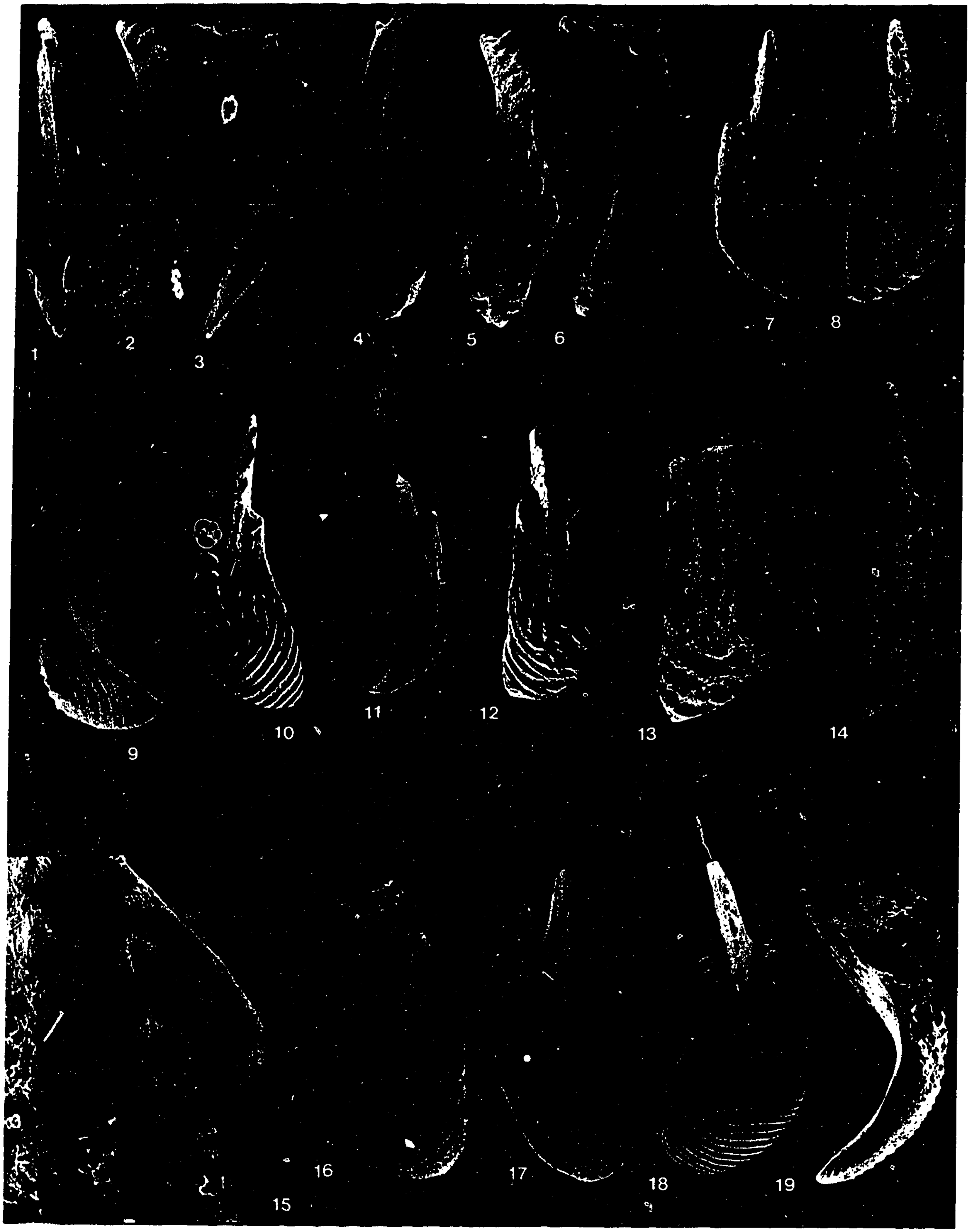
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PLATE V-25

Figs. 1-10. *Polygnathus paraobliquicostatus* n. sp. Specimen illustrated in Figs. 2 and 3 is the holotype; specimens illustrated in Figs. 1, 4-10 are paratypes. All specimens are from the Palliser Formation, Morro Member (sample CH57-420, Table V-4).

1. oblique upper view, GSC 107144, X57, partly corroded specimen showing oblique transverse ridges.
2. lateral view, GSC 107145, X45.
3. upper view of same specimen, X51, shows oblique ridges on upper surface.
4. upper view, GSC 107146, X53.
5. lower view, GSC 107147, X64.
6. lateral view, GSC 107148, X75, shows strong arching of element.
7. upper view of same specimen X69, shows strong bowing of element.
8. upper view, GSC 107149, X40, elongate specimen.
9. upper view, GSC 107150, X128, juvenile specimen showing no ornamentation on upper surface.
10. lower view of same specimen, X124.

Figs. 11-23. *Polygnathus semicostatus* Branson and Mehl. All specimens are hypotypes.

11. lateral view, GSC 107151, X80, Palliser Formation, Costigan Member (sample BAI-1300, Table V-2).
12. upper view of same specimen X88.
13. upper view, GSC 107152, X91, Palliser Formation, Morro Member? (sample PL-23-691, Table V-1).
14. lateral view of same specimen, X87.
15. lower view, GSC 107153, X87, specimen showing less sharp keel than in Fig. 16 (sample PL-23-691, Table V-1).
16. lower view, GSC 107154, X126, narrow specimen with high sharp keel, Wabamun Group, Big Valley Formation (sampled interval 5502-5522 ft., Table V-17).
17. lower view, GSC 107155, X110, Palliser Formation, Costigan Member (sample JC-1.2m, Table V-5).
18. upper view of same specimen, X94.
19. upper view, GSC 107156, X47, gerontic specimen with nodes on anterior platform, Palliser Formation, Morro Member (GSC Loc. C-187237, Table V-3).
20. upper view, GSC 107157, X71, Palliser Formation, Morro Member (sample NPW89-2, Table V-6).
21. upper view, GSC 107158, X71, Wabamun Group, Whitelaw unit (sampled interval 10581-10587 ft., Table V-14).
22. lateral view of same specimen, X58.
23. lower view of same specimen, X71.

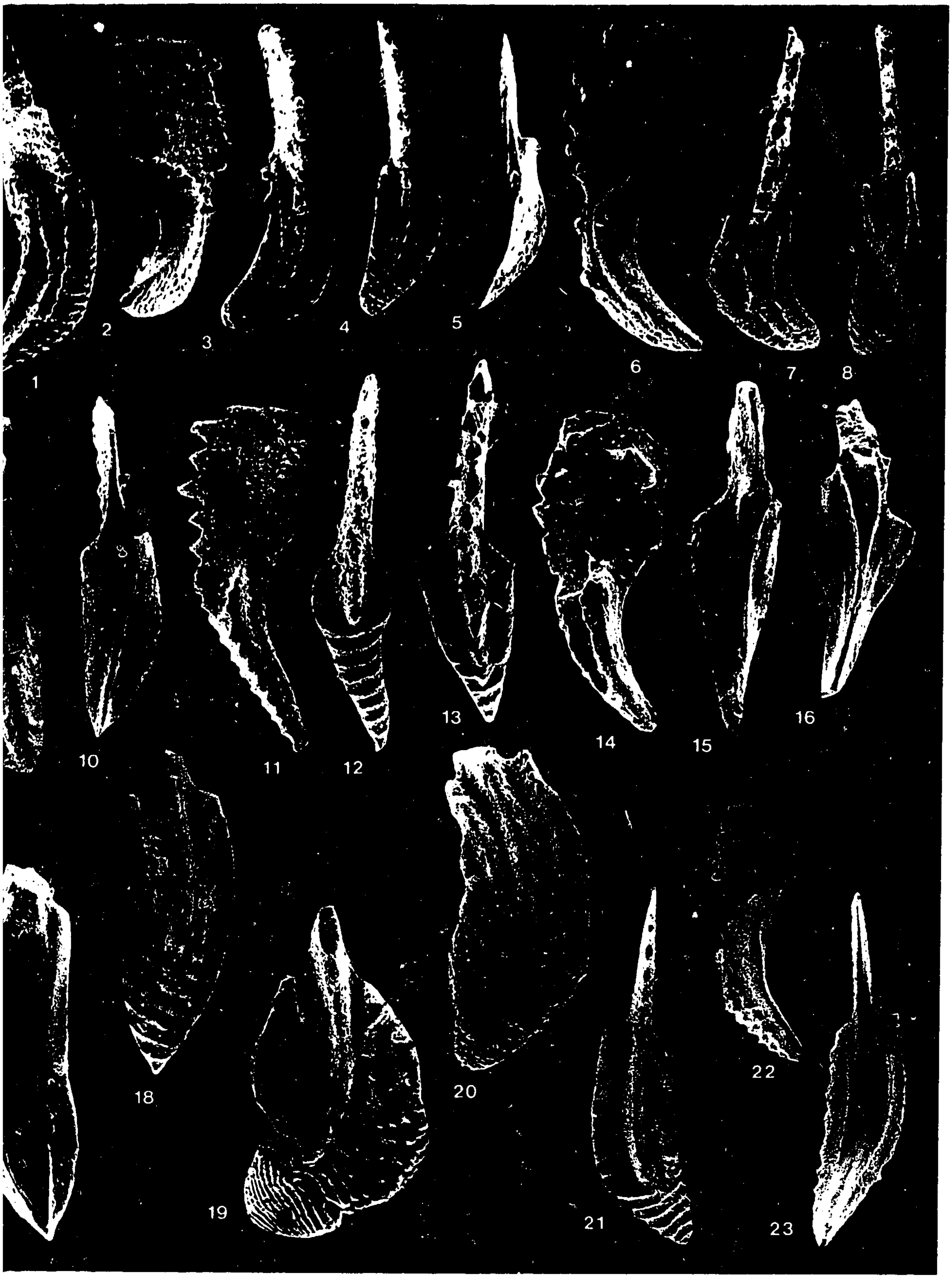
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PLATE V-26

All specimens are hypotypes.

Figs. 1-15. *Polygnathus semicostatus* Branson and Mehl. All specimens from the Palliser Formation, Morro Member.

1. upper view, GSC 107159, X39, elongate specimen with simple scalloped ornamentation anteriorly (sample ML2-220, Table V-7).
2. lower view of same specimen, X36.
3. oblique upper view, GSC 107160, X35, specimen with broad platform that is flattened anteriorly (sample ML2-110, Table V-7).
4. oblique lower view of same specimen, X35.
5. lower view, GSC 107161, X36, specimen with elongate platform (sample ML2-135, Table V-7).
6. upper view of same specimen, X39.
7. upper view, GSC 107163, X64, juvenile specimen with relatively broad platform (sample ML2-220, Table V-7).
8. lateral view, GSC 107163, X46, narrow specimen (sample CSS-377, Table V-9).
9. upper view of same specimen, X49.
10. lower view of same specimen, X45, shows subdued keel.
11. lower view, GSC 107164, X37, specimen with broad platform (sample ML2-10, Table V-7).
12. upper view of same specimen, X43, shows irregular ridge-like ornamentation anteriorly.
13. lateral view of same specimen, X43.
14. lower view, GSC 107165, X88, juvenile specimen (sample ML2-10, Table V-7).
15. upper view of same specimen, X107.

Figs. 16-22. *Polygnathus webbi* Stauffer. All specimens from Palliser Formation, Morro Member.

16. upper view, GSC 107166, X88, juvenile sinistral specimen (sample GK-2, Table V-10).
17. lateral view of same specimen, X79.
18. lower view of same specimen, X85.
19. oblique upper view, GSC 100290, X61, dextral specimen, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 2, fig. 10) (sample GK-0, Table V-10).
20. oblique upper view, GSC 107167, X65, sinistral specimen (sample ML2-210, Table V-7).
21. lateral view, GSC 107168, X54, dextral specimen (sample ML2-210, Table V-7).
22. upper view of same specimen, X54.

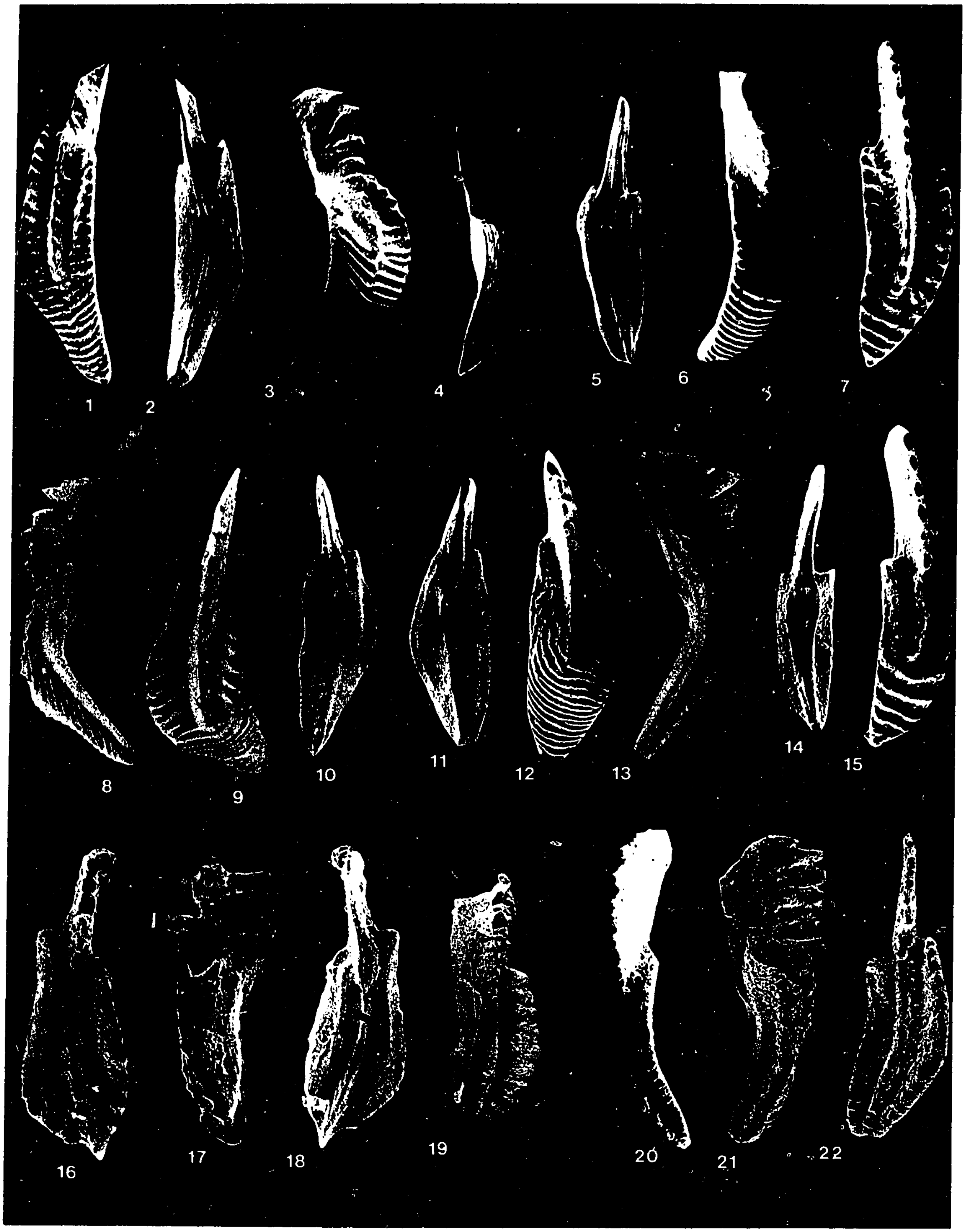
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PLATE V-27

Figs. 1-7, 13, 14. Polygnathus webbi Stauffer. All specimens are hypotypes.

1. upper view, GSC 100289, X58, sinistral specimen, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 2, fig. 9), Palliser Formation, Costigan Member (sample CNP, TOP, Table V-2).
2. upper view, GSC 107169, X43, dextral specimen, Palliser Formation, Morro Member (sample WMG86-D, Table V-3).
3. lateral view of same specimen, X40.
4. lower view, GSC 107170, X60, Palliser Formation, Costigan Member (sample CNP, TOP, Table V-2).
5. lateral view, GSC 107171, X64, sinistral specimen, Palliser Formation, Morro Member (sample CSS-430, Table V-9).
6. upper view of same specimen, X71.
7. upper view, GSC 107172, X75, dextral specimen, Palliser Formation, Morro Member, (sample CH58-08, Table V-4).
13. lateral view, GSC 107175, X56, Palliser Formation, Costigan Member (sample CNP, TOP, Table V-2).
14. upper view, GSC 107176, X57, Palliser Formation, Costigan Member (sample CNP, TOP, Table V-2).

Figs. 8-10. Polygnathus aff. P. lauriformis Dreesen and Dusar. All are figured specimens and from the Palliser Formation, Morro Member (sample ML2-240, Table V-7).

8. upper view, GSC 107173, X86.
9. lower view of same specimen, X70.
10. upper view, GSC 107174, X70, juvenile specimen.

Figs. 11, 12, 15-21. Polygnathus aff. P. pennatulus Ulrich and Bassler. All are figured specimens and from the Palliser Formation, Morro Member.

11. upper view, GSC 100294, same specimen as that identified as P. pennatulus by Johnston and Chatterton (1991, pl. 2, fig. 14) (sample GK1-193, Table V-10).
12. lower view of same specimen, both views X41.
15. upper view, GSC 107177, X48 (sample GK1-193, Table V-10).
16. lateral view, GSC 107178, X37 (sample GK1-193, Table V-10).
17. upper view of same specimen, X39.
18. upper view, GSC 107179, X55 (sample GK1-313, Table V-10).
19. lateral view of same specimen, X54.
20. upper view, GSC 107180, X52, juvenile specimen (sample GK1-193, Table V-10).
21. lower view, GSC 107181, X52, juvenile specimen (sample GK1-193, Table V-10).

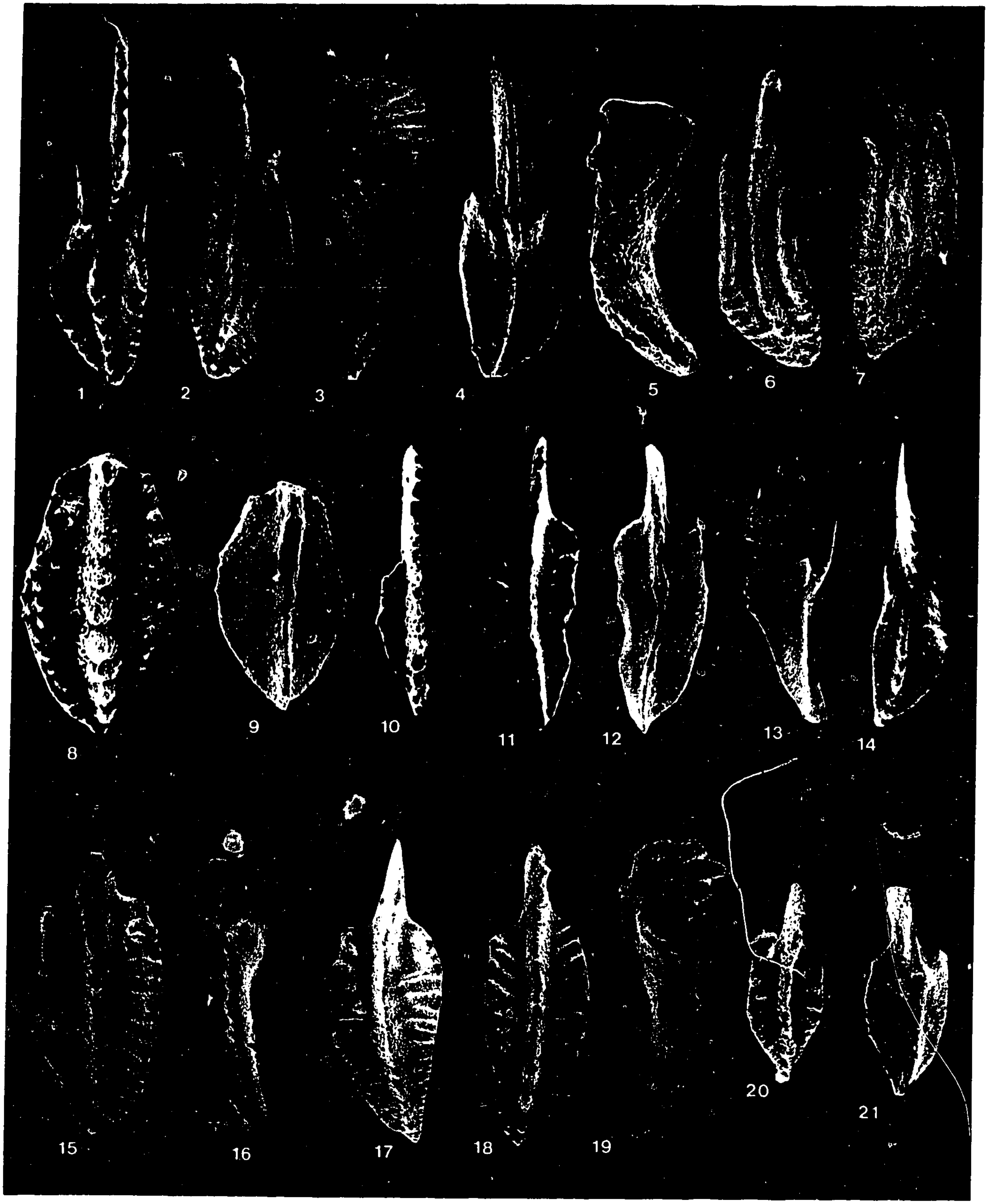
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PLATE V-28

Figs. 1-5, 8-10. Polygnathus aff. P. timanicus Ovnatanova. All are figured specimens and from the Wabamun Group, Dixonville unit, unless indicated otherwise.

1. lateral view, GSC 107182, X180, small dextral specimen (sampled interval 11128.5-11169 ft., Table V-15).
2. upper view of same specimen, X170.
3. lower view, GSC 107183, X131, dextral specimen (sampled interval 11128.5-11169 ft., Table V-15).
4. upper view of same specimen, X146.
5. lateral view of same specimen, X107.
8. upper view, GSC 107185, X146, sinistral specimen (sampled interval 11111-11128.5 ft., Table V-15).
9. lateral view, GSC 107186, X125, dextral specimen, Palliser Formation, Morro Member? (sample PL-23-687, Table V-1).
10. upper view of same specimen, X141.

Figs. 6, 7, 11-16, 17-20?, 21-24. Polygnathus cf. P. brevilaminus Branson and Mehl. All are figured specimens and from the Palliser Formation, Morro Member.

6. lateral view, GSC 107184, X28, specimen with long free blade, note spur on postero-lateral margin (sample CSS-50, Table V-9).
7. oblique lower view of same specimen, X38.
11. lateral view, GSC 107187, X53 (sample RMW-510, Table V-11).
12. lower view, GSC 107188, X39 (sample Palliser 2, Figure V-7).
13. upper view of same specimen, X26.
14. upper view, GSC 107189, X54, specimen with broader platform (sample CSS-50, Table V-9).
15. upper view, GSC 107190, X52, specimen with broader platform (sample CSS-50, Table V-9).
16. upper view, GSC 107191, X46, specimen with less developed platform on right side (sample NP86-36, Table V-6).
17. lateral view, GSC 107192, X42 (sample ML2-40, Table V-7).
18. upper view of same specimen, X46.
19. upper view, GSC 107193, X85 (sample BAI-800, Table V-2).
20. lateral view of same specimen, X79.
21. upper view, GSC 107194, X17, gerontic specimen (sample Palliser 2, Figure V-7).
22. upper view, GSC 107195, X24, gerontic specimen (sample ML2-335, Table V-7).
23. lateral view of same specimen, X20.
24. lower view of same specimen, X20.

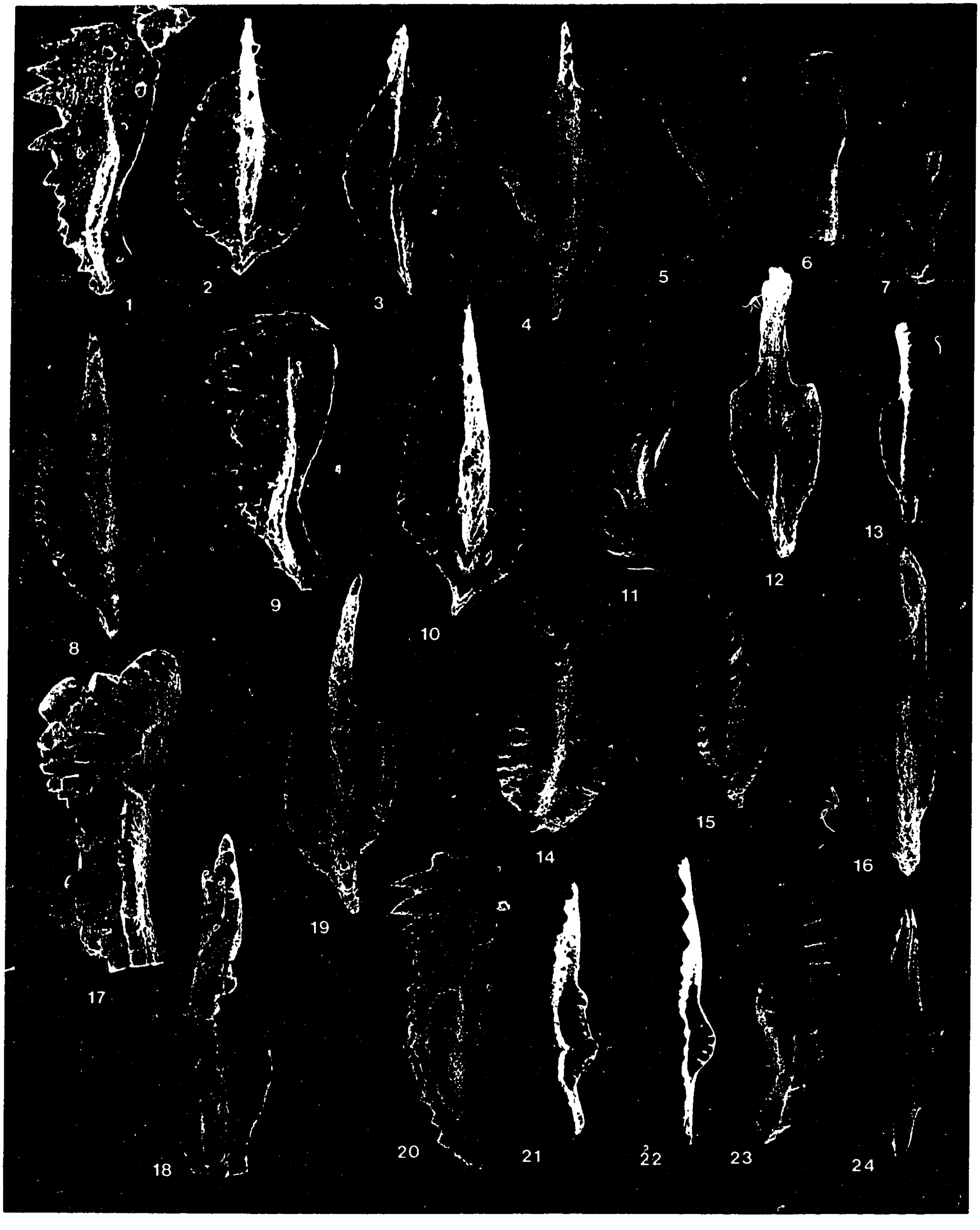
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PLATE V-29

Figs. 1-5. Polygnathus cf. P. padovaniae Perri and Spalletta. All are figured specimens.

1. upper view, GSC 107196, X134, sinistral specimen, Palliser Formation, Morro Member? (sample PL-23-691, Table V-1).
2. lateral view of same specimen, X104.
3. lower view of same specimen, X128.
4. upper view, GSC 107197, X92, dextral specimen, Palliser Formation, Morro Member? (sample PL-23-691, Table V-1).
5. upper view, GSC 107198, X131, Palliser Formation, Morro Member (sample NPW86-25, Table V-6).

Figs. 6-8. Polygnathus sp. C. All are figured specimens and from the Palliser Formation, Morro Member.

6. upper view, GSC 107199, X50 (sample ML2-420, Table V-7).
7. upper view, GSC 107000, X41 (sample GK-160, Table V-10).
8. lower view of same specimen, X45.

Figs. 9-13. Polygnathus sp. D. All are figured specimens and from the Palliser Formation, Morro Member.

9. upper view, GSC 107201, X80, juvenile specimen (sample ML2-0-5, Table V-7).
10. lower view of same specimen, X78.
11. lateral view of same specimen, X72.
12. upper view, GSC 107202, X58, (sample ML2-0-5, Table V-7).
13. lower view of same specimen, X60.

Figs. 14, 15. Polygnathus? sp. A. Figured specimen GSC 107203, Palliser Formation, Morro Member (sample ML3-27, Table V-7).

14. upper view, X50.
15. lateral view, X47.

Figs. 16, 17. Polylophodonta cf. P. confluens Ulrich and Bassler. All are figured specimens.

16. upper view, GSC 107204, X74, small mature specimen, Palliser Formation, Costigan Member (sample CNP, TOP, Table V-2).
17. upper view, GSC 107205, X54, Palliser Formation, Morro Member (sample RMW-10, Table V-11).

Figs. 18-21. Polylophodonta confluens Ulrich and Bassler. All specimens are hypotypes.

18. upper view, GSC 107206, X41, Palliser Formation, Morro Member (sample NPW89-2, Table V-6).
19. lateral view of same specimen, X32.
20. upper view, GSC 107207, X29, Palliser Formation, Costigan Member (sample BAY90-A, Table V-5).
21. lateral view of same specimen, X31.

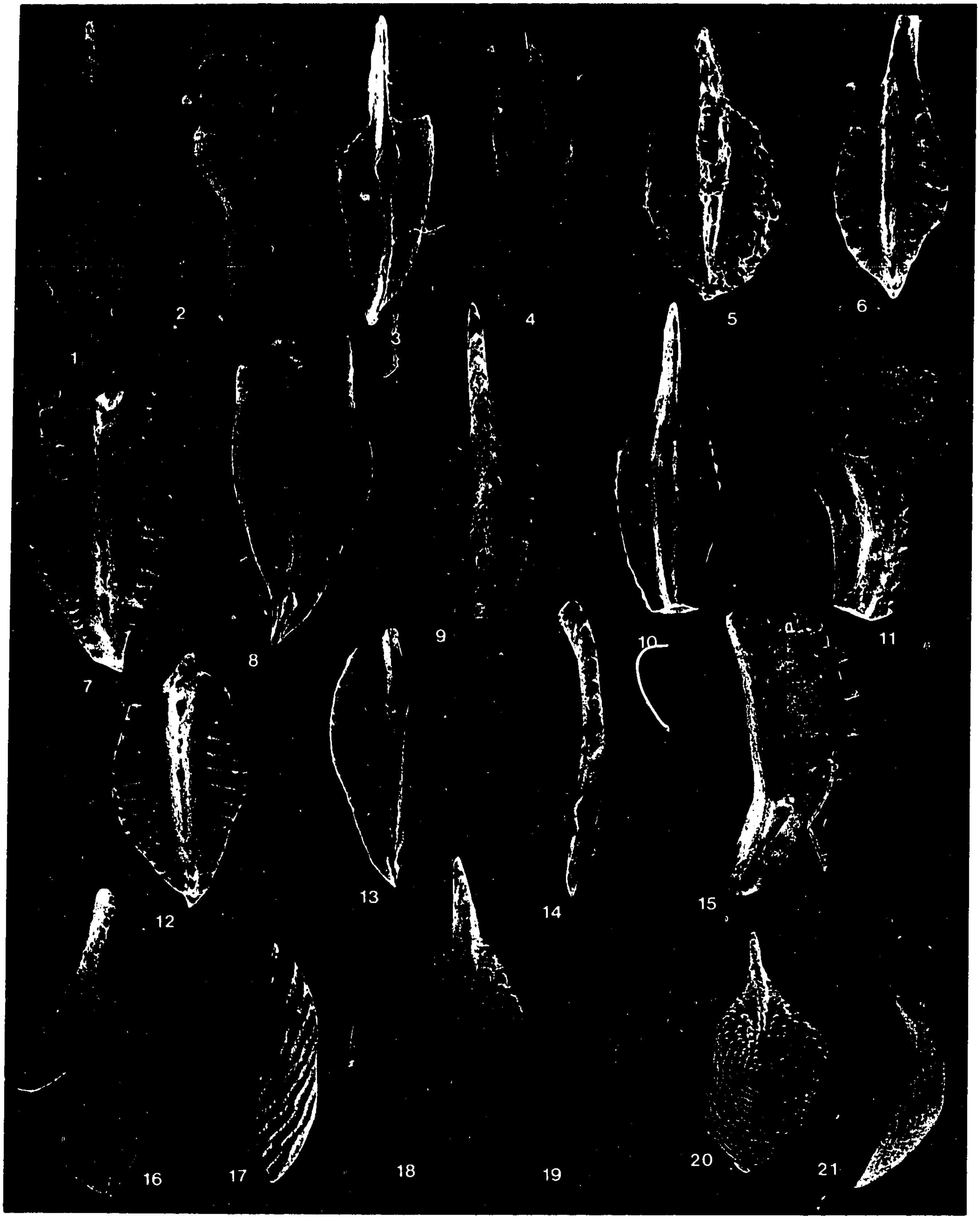
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PLATE V-30

Figs. 1-23. Polylophodonta medicinelakensis n. sp. Specimen illustrated in Figs. 10-12 is the holotype; specimens illustrated in Figs. 1-9, 13-23 are paratypes. All specimens from the Palliser Formation, Morro Member, unless indicated otherwise.

1. lower view, GSC 100298, X28, same specimen as that identified as Polylophodonta sp. cf. P. linguiformis Branson and Mehl sensu Sandberg and Ziegler, 1973 by Johnston and Chatterton (1991, pl. 2, fig. 18) (sample BAI-300, Table V-2).
2. upper view of same specimen, X29.
3. lateral view, GSC 107208, X53 (sample CSS-230, Table V-9).
4. upper view of same specimen, X48.
5. oblique upper view, GSC 107029, X57, juvenile to mature specimen (sample BAI-300, Table V-2).
6. oblique upper view, GSC 107210, X58, juvenile to mature specimen at earlier growth stage than Fig. 5 (sample BAI-300, Table V-2).
7. upper view, GSC 107211, X131, juvenile specimen, Wabamun Group, Whitelaw unit (sampled interval 10604-10613 ft., Table V-14).
8. upper view, GSC 107212, X52, fragmentary specimen (sample CSS-230, Table V-9).
9. upper view, GSC 107213, X50 (sample CSS-230, Table V-9).
10. lateral view, GSC 100300, X38, same specimen as that identified as P. confluens (Ulrich and Bassler) by Johnston and Chatterton (1991, pl. 2, fig. 20) (sample ML2-295, Table V-7).
11. upper view of same specimen, X29.
12. lower view of same specimen, X29.
13. upper view, GSC 107214, X30, (sample GK-160, Table V-10).
14. upper view, GSC 107215, X48, small mature specimen (sample ML2-295, Table V-7).
15. oblique upper view, GSC 107216, X47 (sample ML2-285, Table V-7).
16. upper view, GSC 107217, X35 (sample NP86-36, Table V-6).
17. upper view, GSC 107218, X37, Wabamun Formation, Whitelaw unit (sampled interval 11430-11440 ft., Table V-12).
18. lateral view of same specimen, X32.
19. upper view, GSC 107219, X33 (sample ML2-392, Table V-7).
20. oblique lower view, GSC 107220, X28 (sample ML2-375, Table V-7).
21. upper view of same specimen, X25.


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22. upper view, GSC 107221, X22 (sample ML2-375, Table V-7).
23. upper view, GSC 107222, X26, mature to gerontic specimen (sample ML3-73, Table V-7).

PLATE V-31

Figs. 1-7. Polylophodonta medicinelakensis n. sp. All specimens are paratypes.

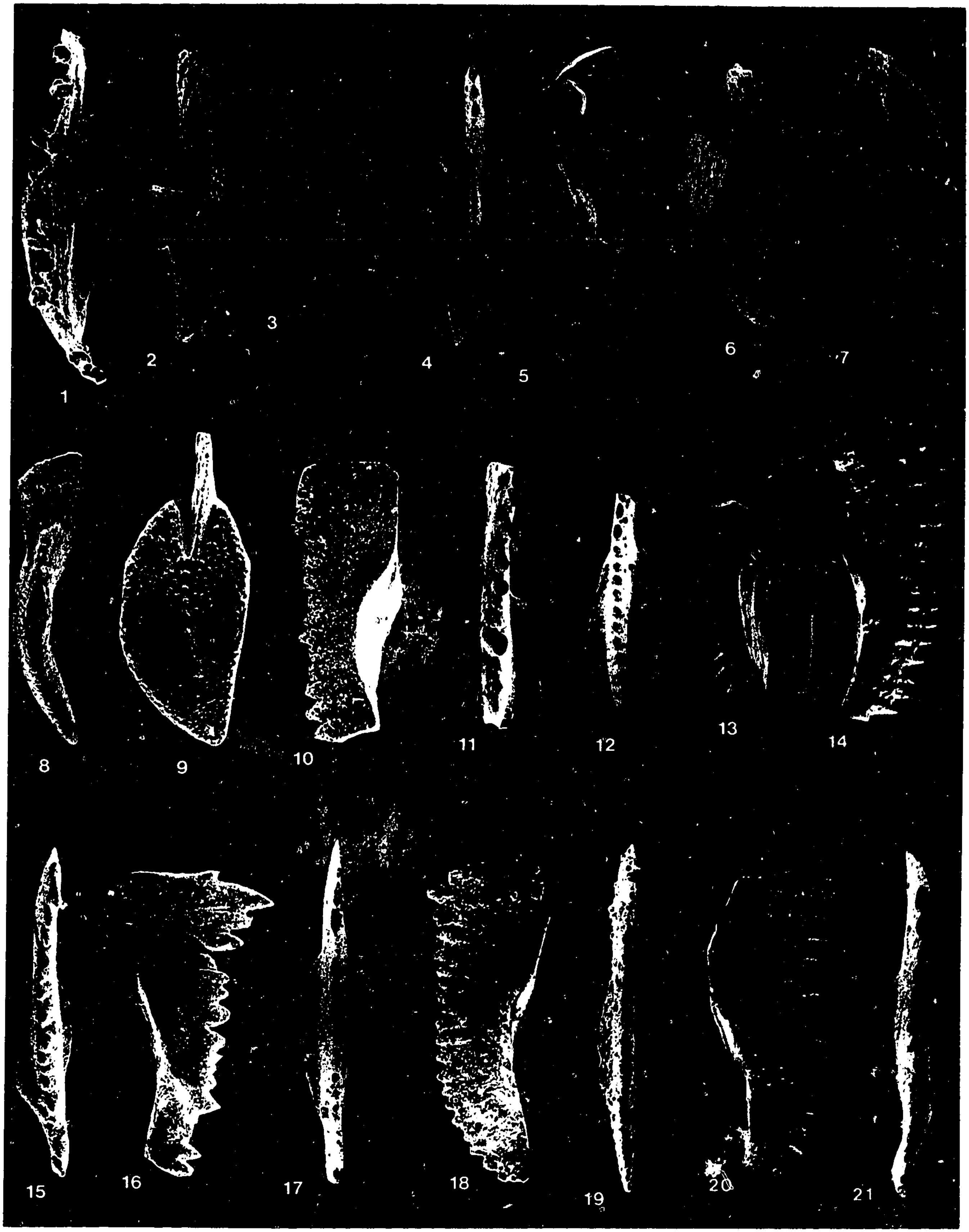
1. lower view, GSC 107223, X160, juvenile specimen at very early growth stage, Palliser Formation, Morro Member (GSC Loc. C-170492, Table V-3).
2. upper view, GSC 107224, X130, juvenile specimen (GSC Loc. C-187211, Table V-3).
3. lateral view of same specimen, X100.
4. upper view, GSC 107225, X78, specimen with incipient adcarinal crests, Wabamun Group, Dixonville unit (sampled interval 11111-11128.5 ft., Table V-15).
5. lateral view of same specimen, X90.
6. upper view, GSC 107226, X90, specimen shows incipient expansion of anterior platform, Wabamun Group, Whitelaw unit (sampled bed 3074.5 m, Table V-16).
7. upper view, GSC 107227, X56, specimen representing more advanced growth stage than Fig. 6 (sample ML2-335, Table V-7).

Figs. 8, 9. Polylophodonta sp. A. Figured specimen GSC 107228, Wabamun Group, Dixonville unit (sampled interval 11560-11570 ft., Table V-12).

8. lateral view, X34.
9. upper view, X38.

Figs. 10, 11, 15-21. Bispathodus stabilis (Branson and Mehl) Morphotype 1 of Ziegler, Sandberg and Austin. All specimens are hypotypes and from the Palliser Formation, Costigan Member, unless indicated otherwise.

10. lateral view, GSC 100281, X84, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 2, fig. 1), Palliser Formation, Morro Member (sample NPW89-14, Table V-6).
11. upper view, GSC 100282, X90, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 2, fig. 2) (sample NPW89-20, Table V-6).
15. upper view, GSC 107229, X67 (sample NPW89-19, Table V-6).
16. lateral view of same specimen, X62.
17. upper view, GSC 107230, X82, specimen with more elongate basal cavity (sample JC-0.6m, Table V-5).
18. lateral view, GSC 107231, X59 (sample GK87-A, Table V-10).
19. upper view of same specimen, X62, shows flared basal cavity on one side.
20. lateral view, GSC 107232, X69 (sample NPW89-19, Table V-6).
21. upper view of same specimen, X77, showing highly asymmetrical basal cavity.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Figs. 12-14. *Bispathodus stabilis* (Branson and Mehl) Morphotype 2 of Ziegler, Sandberg and Austin. All specimens are hypotypes.

12. upper view, GSC 100283, X74, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 2, fig. 3), Palliser Formation, Costigan Member (sample NPW89-19, Table V-6).
13. lower lateral view, GSC 98132, X77, same specimen as that illustrated by Johnston and Meijer Drees (1993, pl. 1, fig. 7), Wabamun Group, Big Valley Formation (sampled interval 5502-5522 ft., Table V-17).
14. lateral view, GSC 100284, X72, same specimen as that illustrated by Johnston and Chatterton (1991, pl. 2, fig. 4), Palliser Formation, Costigan Member (sample CH108, Table V-8).

PLATE V-32

All are lateral views of Pa elements unless indicated otherwise.

Figs. 1, 2?, 3, 4. Mehlina gradata Youngquist. Specimens illustrated in Figs. 1, 3, 4 are hypotypes. All specimens from the Palliser Formation, Morro Member.

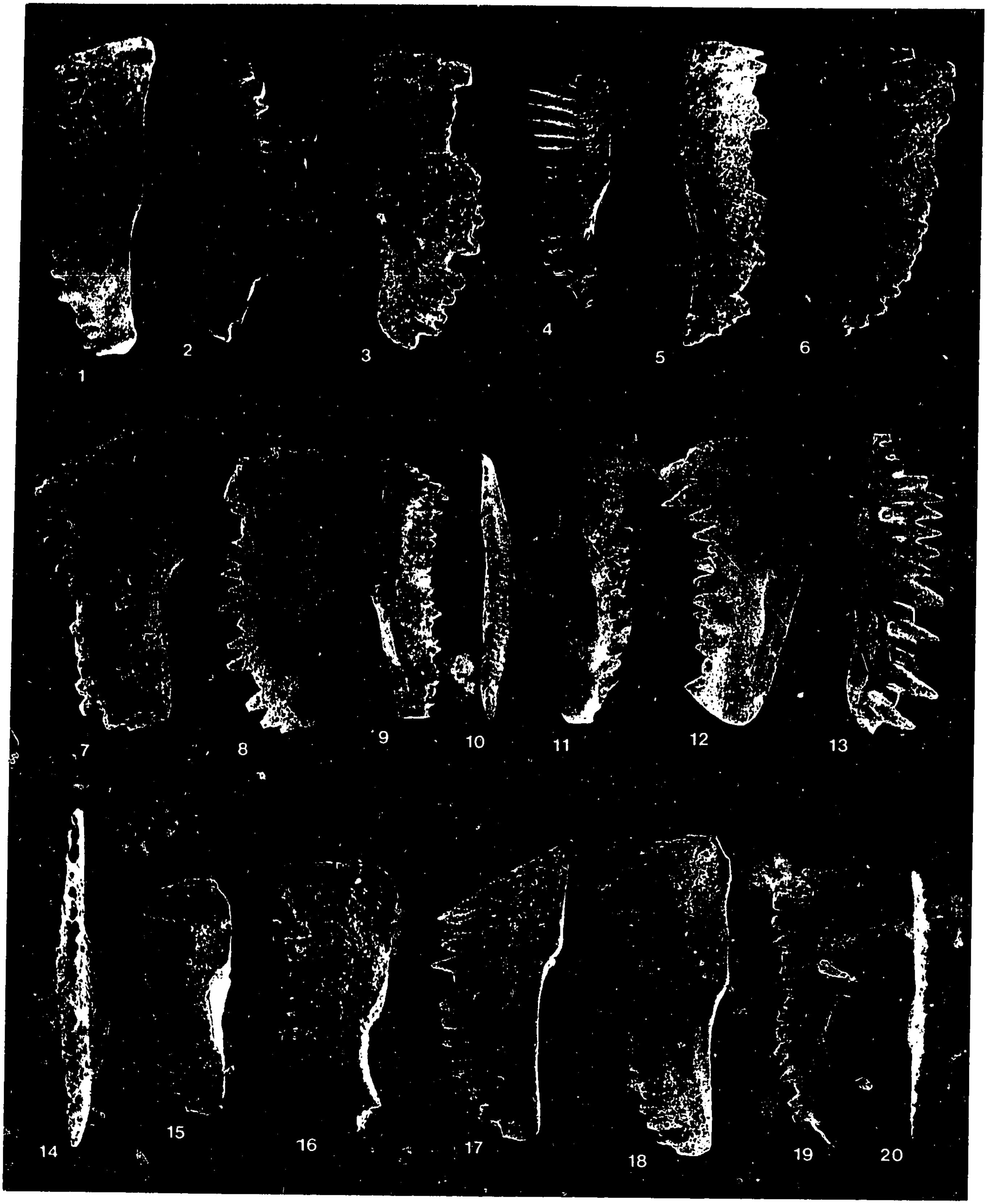
1. GSC 107233, X46, note postero-lateral spur (sample ML2-285, Table V-7).
2. figured specimen GSC 107234, X39 (sample ML2-135, Table V-7).
3. GSC 107235, X55 (sample ML1-30, Table V-8).
4. GSC 107236, X41 (sample GK1-193, Table V-10).

Figs. 5-8. Mehlina cf. M. gradata Youngquist. All are figured specimens.

5. GSC 107237, X71, specimen with slight ledge on margin basal pit, Palliser Formation, Costigan Member (sample BAI-1300, Table V-2).
6. GSC 107238, X35, specimen with large zone of recessive basal margin with slight lip on inner edge of basal pit, Palliser Formation, Morro Member (sample CH57-420, Table V-4).
7. GSC 107239, X76, specimen with large zone of recessive basal margin, with a slight rim on the inner side of basal pit, Palliser Formation, Morro Member? (sample PL-23-686, Table V-1).
8. GSC 107240, X74, specimen showing slight thickening on outside of basal pit, Palliser Formation, Morro Member (sample NPW86-20, Table V-6).

Figs. 9-15. Mehlina ovata n. sp. Specimen illustrated in Fig. 9 is the holotype; specimen illustrated in Figs. 10-15 are paratypes.

9. GSC 107241, X26, specimen shows upturned anterior and posterior extremities, Palliser Formation, Morro Member (sample RMW-510, Table V-11).
10. upper view, GSC 107242, X34, Palliser Formation, Morro Member (sample NP86-11, Table V-6).
11. lateral view of same specimen, X33, showing ridge at upper edge of zone of recessive basal margin.
12. GSC 107243, X53, specimen with anterior and posterior denticles reclined and proclined respectively, Palliser Formation, Morro Member (sample GK-47, Table V-10).
13. GSC 107244, X44, element with posterior end twisted outward, Wabamun Group, Whitelaw unit (sampled interval 11452-11460 ft., Table V-12).
14. upper view, GSC 107245, X95, juvenile specimen with asymmetrical basal cavity, Palliser Formation, Morro Member? (sample PL-23-684, Table V-1).
15. GSC 107246, X83, juvenile specimen, Palliser Formation, Morro Member? (sample PL-23-684, Table V-1).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Figs. 16-20. Mehlina strigosa (Branson and Mehl). All specimens are hypotypes.

16. GSC 107247, X52, specimen with arched posterior, Palliser Formation, Morro Member (sample CH57-420, Table V-4).

17. GSC 107248, X76, specimen with sharp ridge at upper edge of zone of recessive basal margin, Palliser Formation, Morro Member (sample ML2-240, Table V-7).

18. GSC 107249, X60, Palliser Formation, Morro Member? (sample PL-23-688, Table V-1).

19. GSC 107250, X37, specimen with robust denticles mostly free at tips, Palliser Formation, Costigan Member (sample GK87-A, Table V-10).

20. upper view of same specimen, X35.

PLATE V-33

All lateral views of Pa elements unless indicated otherwise.

Figs. 1-4. *Mehlina strigosa* (Branson and Mehl). All specimens are hypotypes.

1. upper view, GSC 107251, X42, Palliser Formation, Costigan Member (sample GK87-A, Table V-10).
2. lateral view of same specimen, X40.
3. GSC 107252, X99, Palliser Formation, Morro Member (sample NP86-80, Table V-6).
4. GSC 107253, X49, highly arched specimen, Palliser Formation, Morro Member (sample CH57-262, Table V-4).

Figs. 5, 6. *Mehlina* aff. *M. strigosa* (Branson and Mehl). Both specimens from the Palliser Formation, Costigan Member.

5. GSC 107254, X84, specimen with short free blade (sample NPW89-19, Table V-6).
6. GSC 107255, X99 (sample GK87-A, Table V-10).

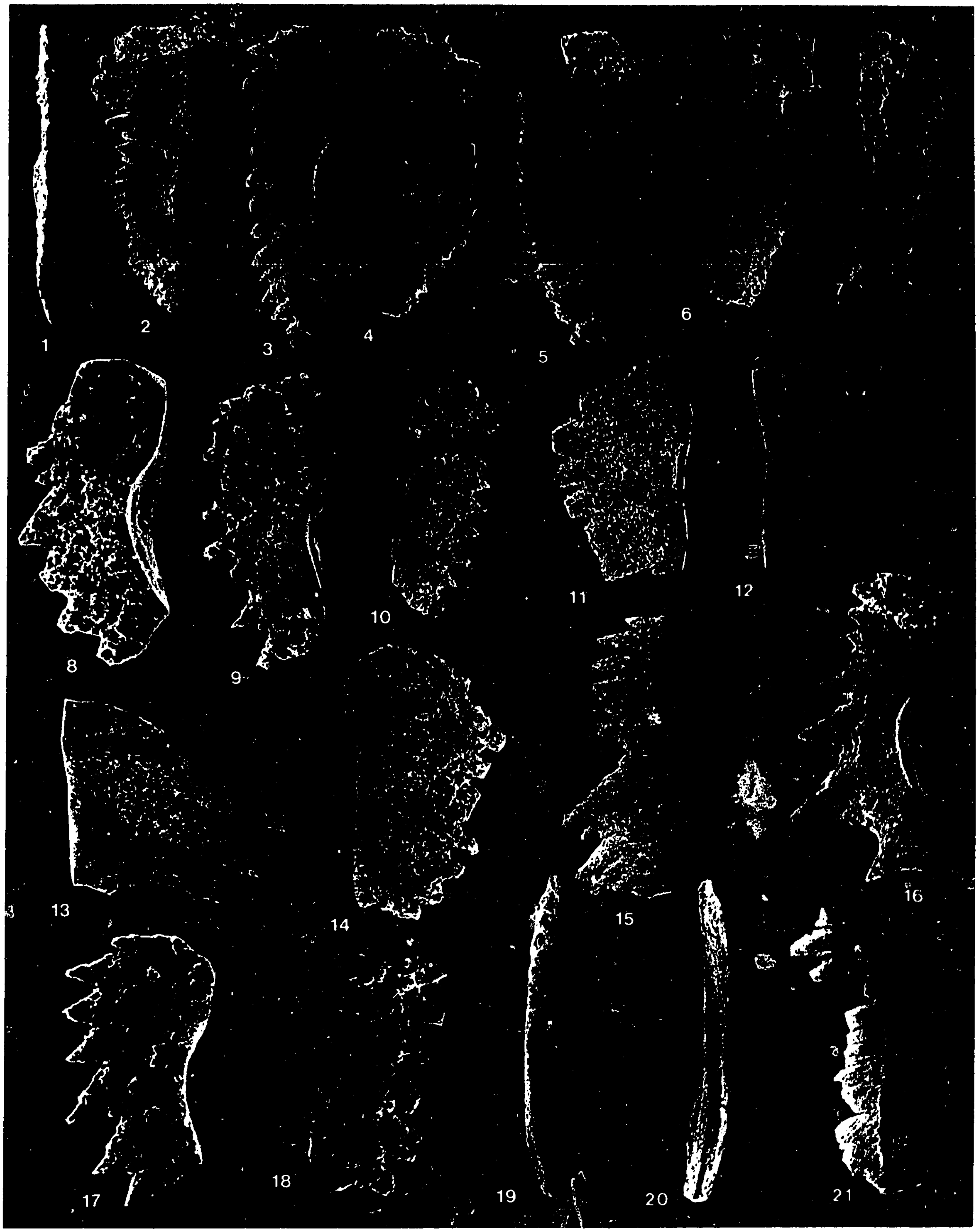
Figs. 7-10. *Mehlina*? *arcureclinata* n. sp. Specimen illustrated in Fig. 10 is the holotype; specimens illustrated in Figs. 7-9 are paratypes. All specimens from the Wabamun Group, Normandville unit, unless indicated otherwise.

7. GSC 107256, X109, stratigraphically older specimen than Figs. 8-10, Palliser Formation, Morro Member (sample NP86-50, Table V-6).
8. GSC 107257, X315, juvenile specimen representing earliest growth stage (sampled interval 11422-11436 ft., Table V-15).
9. GSC 108906, X218, juvenile specimen representing more advanced growth stage than Fig. 8 (sampled interval 11422-11436 ft., Table V-15).
10. GSC 108907, X155, (sampled interval 11422-11436 ft., Table V-15).

Figs. 11-13, 14? *Mehlina*? *brevicristata* n. sp. Specimen illustrated in Fig. 11 is the holotype; specimens illustrated in Figs. 12 and 13 are paratypes. All specimens from the Palliser Formation, Morro Member, unless indicated otherwise.

11. GSC 108908, X102, showing curved lower margin and reclined denticles (sample NPW89-14, Table V-6).
12. GSC 108909, X153, juvenile to mature specimen showing flared basal cavity (sample NPW89-14, Table V-6).
13. GSC 108910, X163, juvenile specimen (sample NPW89-14, Table V-6).
14. figured specimen GSC 108911, X142, Palliser Formation, Costigan Member (sample NPW89-20, Table V-6).

Fig. 15. *Mehlina*? sp. A. Figured specimen GSC 108912, X73, Palliser Formation, Costigan Member (sample GK87-A, Table V-10).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Figs. 16-18. Mehlina? sp. B. All are figured specimens and from the Palliser Formation, Morro Member? (sample PL-23-687, Table V-1).

16. GSC 108913, X124, arched specimen with reclined and enlarged posterior denticles.
17. GSC 108914, X252, juvenile specimen.
18. GSC 108915, X199, juvenile specimen.

Figs. 19-21. Mehlina? sp. C. Both are figured specimens and from the Palliser Formation, Morro Member (sample CH57-102, Table V-4).

19. upper view, GSC 108916, X72.
20. lower view of same specimen, X72.
21. GSC 108917, X71.

PLATE V-34

Figs. 1-5. Mashkovia? sp. All are figured specimens and from the Palliser Formation, Costigan Member.

1. upper view, GSC 108918, X77 (sample BAY90-B, Table V-5).
2. lower view of same specimen, X77.
3. lateral view of same specimen, X74.
4. upper view, GSC 108919, X175, juvenile specimen (GSC Loc. C-187202, Table V-5).
5. upper view, GSC 108920, X175, juvenile specimen (GSC Loc. C-187202, Table V-5).

Figs. 6-9, 10?, 15?, 16? Skeletognathus sp. A. All are figured specimens and from the Palliser Formation, Morro Member, unless indicated otherwise.

6. lower view, GSC 108921, X79 (sample MLN top, Table V-8).
7. upper view, GSC 108922, X112, Palliser Formation, Costigan Member (sample BAY90-A, Table V-7).
8. lateral view of same specimen, X111.
9. lateral view, GSC 108923, X129, specimen with less platform development than Figs. 7 and 8 (sample NPW86-25, Table V-6).
10. lateral view, GSC 108924, X97, Pb element (sample CH57-155, Table V-4).
15. lateral view, GSC 108928, X65 (sample MLN top, Table V-8).
16. upper view of same specimen, X75, shows irregular dentition on platform.

Figs. 11-14. Skeletognathus? sp. A. All are figured specimens and from the Palliser Formation, Morro Member.

11. lateral view, GSC 108925, X78 (sample CSS-670, Table V-9).
12. upper view of same specimen, X84.
13. upper view, GSC 108926, X129 (sample CSS-430, Table V-9).
14. lower view, GSC 108927, X122 (sample CSS-520, Table V-9).

Figs. 17-19. New Genus A sp. Figured specimen GSC 108929, Palliser Formation, Morro Member (sample NP86-80, Table V-6).

17. lower view, X28.
18. lateral view of same specimen, X30.
19. upper view of same specimen, X34.

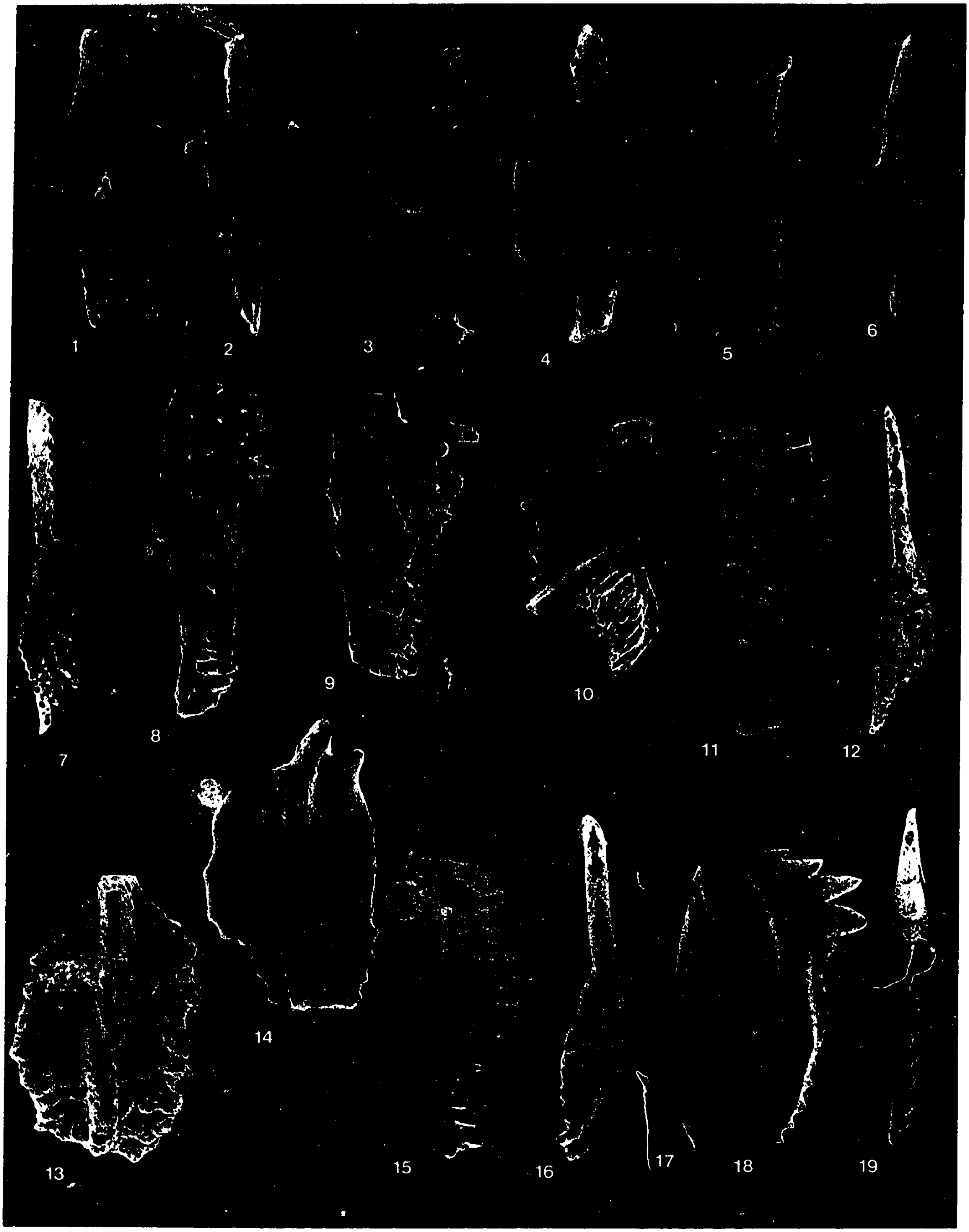
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PLATE V-35

All are figured specimens.

Figs. 1, 2. New Genus B sp. 1. GSC 108930, Wabamun Group, Whitelaw unit (sampled interval 10604-10613 ft., Table V-14).
1. upper view, X18, note secondary carina and lobe on left side near posterior end.
2. lower view, X19.

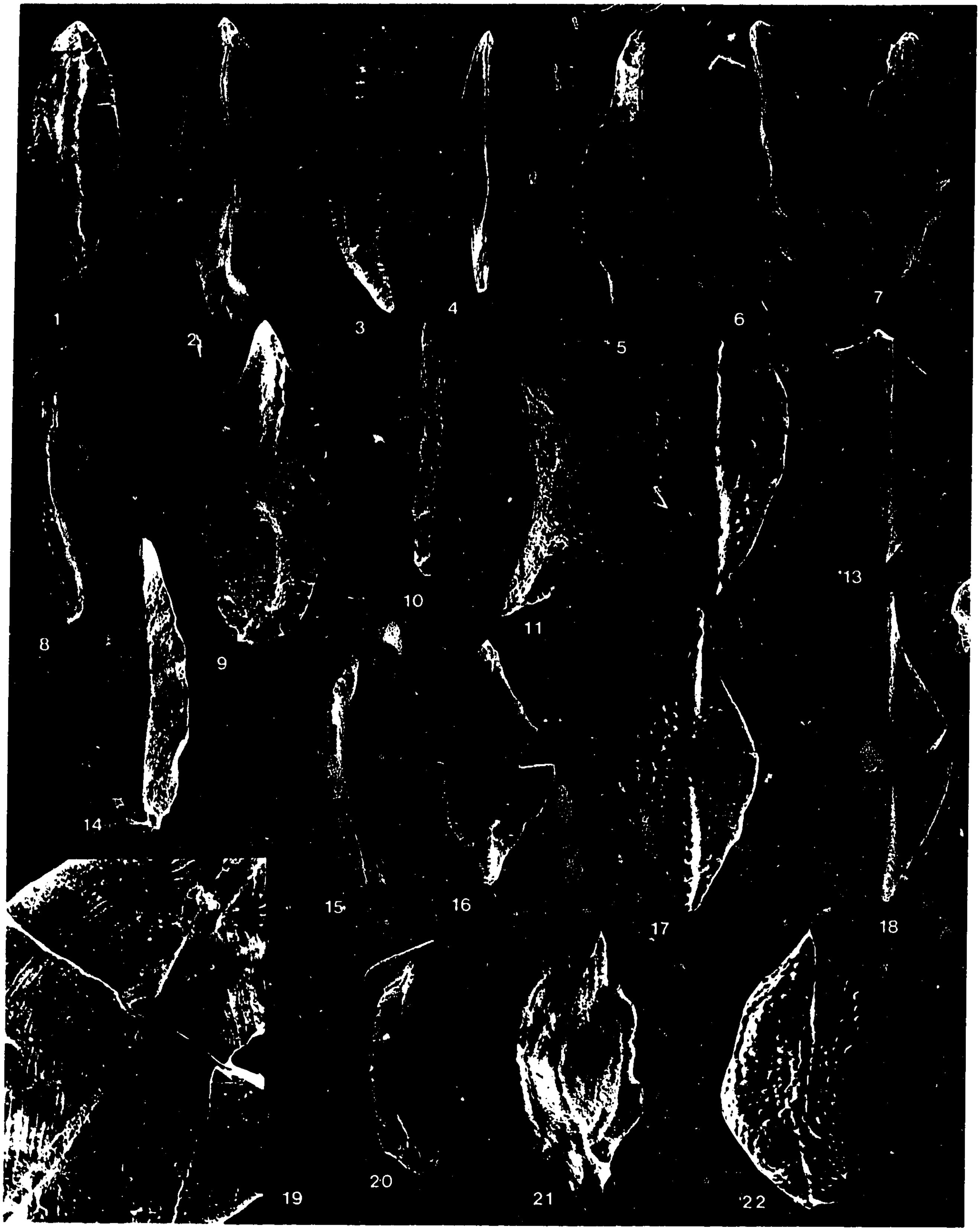
Figs. 3, 4. New Genus B sp. 2. GSC 108931, Palliser Formation, Morro Member (sample ML2-230, Table V-7).
3. oblique upper view, X23.
4. lower view, X22.

Figs. 5-7, 10, 11. New Genus B sp. 3. Both specimens from the Palliser Formation, Morro Member.
5. upper view, GSC 108932, X22, gerontic specimen (sample CSS-327, Table V-9).
6. lateral view of same specimen, X21.
7. lower view of same specimen, X18.
10. upper view, GSC 108934, X35 (sample ML2-60, Table V-7).
11. lateral view of same specimen, X43.

Figs. 8, 9, 14. New Genus B sp. 4. GSC 108933, Wabamun Group, Cardinal Lake unit (sampled interval 10917-10932 ft., Table V-15).
8. lateral view, X25.
9. upper view, X32.
14. lower view, X24.

Figs. 12, 13, 15-19. New Genus B sp. 5. All specimens from the Palliser Formation, Morro Member.
12. upper view, GSC 108935, X50 (sample GK1-253, Table V-10).
13. lower view of same specimen, X46.
15. lateral view, GSC 108936, X32 (sample ML2-10, Table V-7).
16. lower view of same specimen, X26.
17. upper view of same specimen, X33.
19. close-up of view in Fig. 16, X91, shows depression on lower side of element.
18. lower view, GSC 108937, X61, small mature specimen showing lower side morphology (sample ML2-10, Table V-7).

Figs. 20-22. New Genus B sp. 6. GSC 108938, Palliser Formation, Morro Member (sample GK1-513, Table V-10).
20. lateral view, X15.
21. oblique lower view, X18.
22. upper view, X18.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CHAPTER VI

CONCLUSIONS AND DISCUSSION

Chapters II to V present the results of a detailed study of the taxonomy, biostratigraphy and paleoecology of Upper Devonian (Famennian) conodonts from the Palliser Formation and Wabamun Group. The next three sections present the important conclusions of this study plus discussion of these conclusions.

BIOSTRATIGRAPHY

Chapters II and III give an overview of the conodont biostratigraphy of the Palliser Formation and Wabamun Group that was known at the stage of the study that each chapter was written. The most current conodont data suggest that basal strata of both units are no older than Lower crepida Zone. Uppermost strata of the Palliser Formation and Wabamun Group range in age from the Lower to Upper marginifera (Johnston and Chatterton, 1991; Savoy; 1990, Savoy and Harris, 1993) to at least the Lower expansa zones (Figure VI-1). The Morro Member of the Palliser Formation and the Dixonville through to Cardinal Lake informal units in the Wabamun Group range in age from the Lower crepida Zone to at least as high as the Upper marginifera Zone (Figure VI-1), except where the Morro Member is overlain by peritidal carbonates of the lower part of the Costigan Member. There, uppermost Morro beds have a minimum age of Lower marginifera Zone.

The occurrence of several key conodont taxa in the Morro Member of the Palliser Formation and Dixonville to Cardinal Lake units of the Wabamun Group has permitted recognition of several standard Late Devonian conodont zones. Hence, it has been possible to recognize the Upper and Uppermost crepida, the Lower and Upper rhomboidea and the Lower and Upper marginifera zones (Johnston and Chatterton, 1991; Johnston and

Meijer Drees, 1993). No taxa were present that allowed the Lower and Middle *crepida* zones to be differentiated since Ziegler and Sandberg (1990) extended downward the stratigraphic ranges of *Palmatolepis protorhomboidea* Sandberg and Ziegler below the base of the Lower *crepida* Zone and *P. wolskajae* Ovnatanova to the base of this zone. Both species were previously used as indices for the Middle *crepida* Zone (e.g. Johnston and Chatterton, 1991).

The lower age limit of the Costigan Member is no older than the uppermost Upper *rhomboidea* Zone (Figure VI-1). This is apparently the same lower age limit for both fossiliferous marine carbonates assigned to this member at localities such as Crowsnest Pass (Johnston and Chatterton, 1991) and elsewhere in southwesternmost Alberta and southeastern British Columbia (Savoy, 1990, 1992) and for peritidal carbonates of the lower part of this member exposed in the eastern Front Ranges to the north. The upper age limit of these peritidal carbonates is no younger than the Uppermost *marginifera* Zone (Meijer Drees and Johnston, 1994). The minimum upper age limit for the fossiliferous limestone unit of the Costigan Member is Lower to Middle *expansa* Zone (e.g. Richards and Higgins, 1989; Johnston and Chatterton, 1991) which is apparently the same age limit for the Big Valley Formation in the uppermost part of the Wabamun Group in northwestern Alberta (Johnston and Meijer Drees, 1993).

Within the Big Valley Formation of the Wabamun Group and the upper fossiliferous unit of the Costigan Member, no data in the present study indicate the definite presence of the Uppermost *marginifera*, Upper and Lower *trachytera* and Upper and Lower *postera* zones (Johnston and Chatterton, 1991; Johnston and Meijer Drees, 1993). However, evidence from three localities, and possibly one other one, in the present study (Devil's Gap, Table V-5; Nordegg and LaFarge Quarry [= Baymag], Johnston and Chatterton, 1991, p. 177; West Prairie 11-18 well, Table V-17) suggest the presence of strata spanning the Uppermost *marginifera* to Upper *trachytera* zones within the lower part of these units.

The recognition of the Lower and Upper *marginifera* zones in the Costigan Member at Crowsnest Pass (Chapter II, Johnston and Chatterton, 1991) is now considered tentative in the case of the former zone (Table V-2) and is no longer valid in the case of the latter zone. This is because of the taxonomic re-assignment of specimens upon which assignment to the Lower *marginifera* Zone was based and the subsequent discovery that one of the taxa upon which recognition of the Upper *marginifera* zone was based is absent at the top of the Palliser Formation where this zone was supposed to occur. The upper age limit of the fauna at this stratigraphic position is now considered Lower *trachytera* Zone (Table V-2).

Although the biostratigraphic results presented in Chapters II and III generally support conodont and other micro- and macrofossil based age determinations and correlations for the Palliser Formation and Wabamun Group suggested by previous studies (e.g. Sartenaer, 1969; Geldsetzer, 1982; Lethiers, 1981; Sandberg et al., 1983, 1989; Morro and Geldsetzer, 1989; Richards and Higgins, 1989), some differences were noted between these findings and the present work. For example, the Costigan Member was found to be neither exclusively *trachytera* Zone nor *expansa* Zone in age, as suggested by Sandberg et al. (1989) and Richards and Higgins (1989), but strata representative of both zones were found to be present in this unit, even at a single locality (Meijer Drees and Johnston, 1994). No evidence has been found to support the existence of a regional unconformity encompassing the Uppermost *marginifera* Zone, since the contact between the upper and lower parts of the Costigan were found to be conformable within this zone at one locality (Meijer Drees and Johnston, 1994), although there is an abrupt sedimentological contact at this level (Meijer Drees et al., 1993, fig. 20e). A major hiatus exists, however, between uppermost strata of the lower and the upper Costigan Member in more cratonward localities (see below and Figure VI-1).

It was also found, contrary to Morro and Geldsetzer (1989, fig. 15) that strata of expansa Zone age are present at the top of the Palliser Formation in west central Alberta (Figure VI-1), where this formation directly underlies the Banff Formation. These authors suggested that the Palliser Formation ranged no higher than the marginifera Zone in this area. However, biostratigraphic information provided by conodont collections from localities northwest of the Athabasca River near or at the top of the Palliser Formation generally confirm Geldsetzer's (1982) and Morro and Geldsetzer's (1989) assertion that there is a wide discrepancy of ages for the top of the Palliser Formation (Figure VI-1) in this region. This discrepancy is attributed to removal of upper Palliser strata due to pre-Banff erosion (Geldsetzer, 1982; Morro and Geldsetzer, 1989). Biostratigraphic evidence presented in Chapter II (Johnston and Chatterton, 1991) also suggests that the age of the top of the Palliser Formation is older in the southern as well as the northern part of its outcrop area. More detailed documentation of this older age limit for the top of the Palliser Formation in its southern outcrop area was provided by Savoy (1990, 1992). Her results, like those in this study, also showed that the top of this formation gets progressively younger north of this area.

Some new findings include the discovery of the diachronous nature of the contact between the Costigan and Morro Members. This implies that uppermost Morro strata are facies equivalents to both peritidal carbonates assigned to the lower part of the Costigan Member and to fossiliferous carbonates assigned to all of this member in southwestern Alberta and southeastern British Columbia (Johnston and Chatterton, 1991; Savoy, 1990, 1992; Meijer Drees and Johnston, 1994).

Another finding is the possible presence of a significant hiatus between uppermost strata of the Palliser Formation and Wabamun Group and the rest of both units. This hiatus may in some localities encompass up to four conodont zones (Figure VI-1).

Evidence from the present study and subsequent work (e.g. Meijer Drees and Johnston, 1993, 1994) suggests that the stratigraphic position of this hiatus changes from one locality to the next. At Jura Creek, it is apparently between the lower brecciated, laminated peritidal carbonates and the upper fossiliferous open marine carbonates of the Costigan Member and is apparently of greatest magnitude (e.g Richards et al., 1991, fig. 15). At LaFarge Quarry, this hiatus may be entirely within the upper unit of the Costigan Member (Meijer Drees and Johnston, 1994) and is of lesser magnitude. Contacts appear to be erosive or marked by hardgrounds in these first two examples. Recent biostratigraphic work on conodont faunas from this unit at Nordegg (e.g. Meijer Drees and Johnston, 1993) suggests that the hiatus occurs above the Palliser Formation.

The implications of these findings are that the upper part of the Costigan Member and the correlative Big Valley Formation may have had a more complex depositional history than previously suspected (e.g. they could represent more than one depositional event) whereas the depositional histories of the underlying Morro Member in the Palliser Formation and the Dixonville through to Cardinal units in the Wabamun Group are more or less straightforward. Of particular interest is the increase in magnitude of the unconformity within the upper Palliser Formation and Wabamun Group as apparent paleohighs are approached. Uppermost strata of these units thin simultaneously, possibly as a result of erosion and/or stratigraphic condensation.

A southward thinning of the Costigan Member was noted by Savoy (1990, 1992) which may have been against a paleohigh in southwestern Alberta, southeastern British Columbia and northwesternmost Montana (Montania?, see Richards, 1989; Price and Welbon, 1993). The thin development and/or absence of the Big Valley Formation in the subsurface of southwestern Alberta (e.g. Andrichuk, 1960; Penner, 1958) may have been influenced by the existence of this high.

Similar thinning by possible condensation and/or erosional truncation against the Peace River landmass (a paleohigh) was noted by Meijer Drees and Johnston (1993, fig. 6). The thinning and disappearance of the Big Valley Formation towards the Calgary area in the subsurface (presumably a paleohigh) and its reappearance and thickening away from the latter area in southeastern Alberta and southern Saskatchewan is observed in cross sections published by Andrichuk (1960), Richards et al. (1991) and Meijer Drees and Johnston (1993). Still unexplained is the apparent westward truncation of the Big Valley Formation in southern Saskatchewan (e.g. Kent, 1967).

In terms of the alignment of the brachiopod zonation for the Famennian of Western Canada erected by Sartenaer (1969) with the standard Late Devonian conodont zonation, this work does not provide much more insight than previous works, other than to suggest that the lower limit of the *Gastrodetoechia* Zone may align with the Lower to Upper *marginifera* zones. This would be the presumed age of the upper third to quarter of the Morro Member that is depicted as belonging in this zone in figure 1 of Sartenaer (1969). It was also suggested in Chapter II (Johnston and Chatterton, 1991) that the occurrence of *Gastrodetoechia* *utahensis* *utahensis* (Kindle) supported the age assignment of Lower *expansa* Zone over Uppermost *marginifera* Zone for uppermost Palliser strata at Nigel Peak since this subspecies apparently ranges no lower than the Lower *trachytera* Zone. The portion of the *Basilicorhynchus* Zone that occurs in the rest of the Morro Member of the Palliser Formation would presumably correlate with the Lower *crepida* through to the Upper *rhomboidea* and perhaps part(?) of the

Lower *marginifera* Zone.

Conodont data from this study suggest that Raasch's (1989) brachiopod zones DFM 4 and DFM 5 are equivalent to each other in the lower part of the Palliser Formation (Raasch, 1989, fig. 3). Species of zone DFM 5 appear to range at least as high as the Upper *crepida* Zone. Data from this study also suggest that his DFM 6 zone is as young as the *expansa* zone and therefore is partly equivalent to his younger DFM 7 zone. He (Raasch, 1989) suggested that zone DFM 6 was equivalent to the *trachytera* zones and the DFM 7 zone to the *expansa* Zone. However, his suggested alignments of the brachiopod zones with the standard conodont zonation was based on the age of the stratigraphic units in which these zones occur established by indirect correlation with conodont dated units in the western United States (e.g. Sandberg et al., 1983, 1989).

Conodont data from three subsurface localities (Gold Creek 7-31,10-31 and Beaverlodge 4-23 wells) as well as one surface locality (Whiteman Gap) show that Lethiers (1981) proposed alignment of his ostracod zones with the European ammonoid zones (and by extension, the standard Late Devonian conodont zonation) to be in error and that the boundaries between these zones are diachronous. As just one example, the age of the boundary between Lethiers' (1981) DFA 3 and DFA 4 zones is dated as Upper *rhomboidea* Zone in the Gold Creek 10-31 well (Lethiers, 1981, table 5). His suggested alignment for these zones is do III-IV for zone DFA 3 and do V for zone DFA 4 (i.e. from about the Uppermost *marginifera* to Upper *postera* zones for the former zone and Lower to Middle *expansa* zones for the latter zone). In the Beaverlodge 4-23 well (Lethiers, 1981, table 7), the boundary between zones DFA 3 and DFA 4 is dated as Lower *marginifera* Zone, near the base of strata that are Upper *marginifera* through to Lower *trachytera* zones in age (see Table III-1). In both these examples, the alignments of the bases and tops of these zones with the standard conodont zonation are much older than what Lethiers (1981) suggests.

No evidence in this study supports the presence of Strunian (i.e. latest Famennian) strata in the upper part of the Palliser Formation or Wabamun Group.

PALEOECOLOGY

In Chapter IV, conodont relative abundance and sedimentological and stratigraphic data showed that one, and one complete or part of another, major transgressive-regressive cycle can be recognized in the Palliser Formation and Wabamun Group, with several minor cycles occurring in each major cycle. The first cycle encompasses the Morro Member and the lower part of the Costigan Member in the Palliser Formation and the Dixonville through to Cardinal Lake units in the Wabamun Group. The transition from polygnathid-icriodontid biofacies at or near the base of the Palliser Formation and Wabamun Group to palmatolepid biofacies higher in these units suggest that a major transgression occurred from the Lower to Middle crepida to Lower rhomboidea zones. The peak of this transgression was in the Upper crepida to Lower rhomboidea zones as supported by the presence of abundant and diverse palmatolepid faunas as well as the presence of skeletal wackestones and mudstones. The onset of regression may have commenced as early as the lower part of the Lower rhomboidea Zone in more proximal Palliser and Wabamun localities. In more distal localities, such as Nigel Peak (Figure IV-4), the start of the regression was later, in the upper part of this zone.

Conditions were mainly regressive throughout the remainder of the Lower rhomboidea and in the Upper rhomboidea zones. This interval is characterized by low diversity conodont faunas of the polygnathid biofacies. Minor transgressive pulses are documented, recorded by the occurrence of low to moderately diverse conodont faunas of mainly the palmatolepid-polygnathid and occasionally the palmatolepid biofacies. This regressive phase culminated in the deposition of peritidal carbonates of the lower Costigan Member in the eastern Front Ranges and Foothills. Occurring during the latest part of the Upper rhomboidea Zone and the Lower marginifera Zone are low to very low diversity faunas of the palmatolepid biofacies that are characterized by certain species of Palmatolepis that were apparently adapted to more restricted environmental conditions.

It is suggested that this transgressive-regressive episode is the event during which the stromatoporoid mudmounds and reefs of the Crossfield Member in western Alberta and near the Peace River Arch (e.g. Metherell and Workman, 1969; Eliuk, 1984; Eliuk and Hunter, 1987; Stearn, 1988; Stearn et al., 1987) were deposited.

The lower part of the Morro Member of the Palliser Formation and the Dixonville and Whitelaw units of the Wabamun Group are interpreted to represent a transgressive systems tract whereas the upper part of the Morro and/or the lower part of the Costigan Member and Normandville and Cardinal Lake units are interpreted as highstand and shelf margin systems tracts separated by a Type 2 sequence boundary. The major transgressive-regressive cycle represented by these units is interpreted as being in part eustatic in origin since similar shifts of conodont biofacies and lithofacies have been documented elsewhere along the Euramerican margin and possibly on other continental blocks (e.g. Dreesen et al., 1989; Matyja, 1987, 1989; Hou, 1986; Sandberg et al., 1983, 1989).

Part of a second major transgressive-regressive cycle appears to be represented in the Big Valley Formation in the subsurface of Alberta and in the upper fossiliferous portion of the Costigan Member in the Palliser Formation. Here faunas of the palmatolepid-polygnathid biofacies near the base of these units at some localities are replaced upsection by faunas of the polygnathid and other more nearshore biofacies (e.g. Sandberg and Dreesen, 1984) (e.g. Figure IV-4). These units have been interpreted as the initial deposits of the transgression (i.e. a transgressive systems tract) that culminated in the deposition of the black shales of the Exshaw Formation (e.g. Richards and Higgins, 1989; Meijer Drees and Johnston, 1993). Alternatively, all or part of the Big Valley Formation and the upper Costigan Member could represent part of a depositional sequence that includes both transgressive and highstand systems tracts, with only the uppermost beds of both units representing the lower part of another sequence.

This second transgressive-regressive cycle began in the uppermost Lower <u>marginifera</u> Zone and possibly lasted until the Middle <u>expansa</u> Zone, as suggested by the depth curve in Figure IV-3. However, the slightly younger age (i.e. Uppermost <u>marginifera</u> Zone) of basal beds of the Big Valley Formation and upper Costigan Member that abruptly overlie restricted marine carbonates at several localities, suggests that this cycle began later at these localities.

Possible correlation with the transgression that resulted in the deposition of the Trident Member of the Three Forks Form[illegible] its correlatives in the western United States (we[illegible].S. event 14, Sandberg et al., 1989) with that recog[illegible]ed in the lower parts of the Big Valley Formation and upper Costigan Member is suggested.

Western U.S. event 15, the Lower to Upper <u>postera</u> zone regression, is recognized in more proximal localities of the Palliser Formation in the eastern Front Ranges of the Bow River valley. Here it occurs either between the lower and upper units of the Costigan Member or possibly within the upper unit (Meijer Drees and Johnston, 1994). No visible evidence, either faunal or sedimentological, presently exists for this hiatus, however, in more distal localities of the Palliser Formation or Wabamun Group.

Uppermost beds of the Palliser Formation and Wabamun Group are considered to represent part of western U.S. event 16, the initial transgression of T-R cycle IIf (Sandberg et al., 1989).

Another important point that was emphasized in Chapter IV is how other factors besides abundances have to be taken into consideration when interpreting conodont biofacies. Among these are taxonomic diversity and composition of the faunas. In several instances, there were faunas of the palmatolepid biofacies, often monogeneric, comprised of only one species of *Palmatolepis*. These were most notably those faunas containing *P. stoppeli* Sandberg and Ziegler and the morphotype of *P. marginifera* Helms with the thickened platform and flattened posterior parapet, in the upper part of the Palliser Formation and Wabamun Group. The low diversity of these faunas was interpreted as an indicator of restricted conditions. Some of these forms, like *P. stoppeli*, are interpreted as "opportunistic" species because of their abundant occurrence in restricted environments whereas in diverse Famennian conodont faunas they are much less abundant. The morphotype of *P. marginifera* with the thickened platform and flattened posterior parapet is interpreted as only being adapted to restricted conditions, because of its absence in more diverse faunas, although rather similar forms of this species occur in diverse faunas in both Belgium (e.g. Dusar and Dreesen, 1984) and Poland (e.g. Matyja, 1987).

On the other hand, low diversity faunas containing slender forms of *Palmatolepis*, such as *P. gracilis* Branson and Mehl and *P. minuta* Branson and Mehl, like those documented by Sandberg (1976, table 1) and by Savoy and Harris (1993, tables 3 and 4), are interpreted as indicative of more offshore, deep water conditions, because of their occurrence in lithologies suggestive of these conditions (e.g. argillaceous limestones and shales).

The shifting of environments, particularly transgressions, in the Palliser Formation and Wabamun Group has allowed the influx of deeper water faunas that are important for age dating. The exclusion of these forms at some levels by the lack of suitable environments has hampered precise biostratigraphic dating of these intervals. It is noted here that the first appearance of several taxa was delayed in some areas by possible environmental factors, and the appearance, disappearance and then reappearance of certain forms (i.e. the "Lazarus effect" - see Chapter II) was possibly affected by environmental factors in the Palliser Formation and Wabamun Group.

Some of the transgressive-regressive cycles recognized in the Palliser Formation and Wabamun Group are considered of eustatic origin. This appears the case for the major cycle observed in the Morro Member of the Palliser Formation and the Dixonville through to Cardinal Lake units in the Wabamun Group, documented by changes in conodont relative abundances and the transition from more nearshore to more offshore carbonates then back to nearshore carbonates. However, a tectonic overprint is suggested by the minor cycles also observed, which apparently represent fourth and fifth order cycles superimposed on a third order cycle, and the apparent non-synchroneity of some of these cycles with those elsewhere in western North America (e.g. Sandberg et al., 1989) and around the Euramerican continent. Antler orogeny related effects must have influenced the sedimentary environments of this region, perhaps inducing the minor cycles observed in the Palliser and Wabamun sections studied here. These effects also played a role in post-Palliser and Wabamun time by influencing the amount of stratigraphic erosion of these units during a time of uplift and erosion prior to deposition of overlying Carboniferous units, as shown by a wide variation in the ages of the top of the Palliser Formation in its northern outcrop area (Geldsetzer, 1982; Morrow and Geldsetzer, 1989; Figure IV-1).

TAXONOMY

Chapter V presents a detailed taxonomic treatment of the conodont taxa discussed in the previous chapters. As a result, the concepts of some of these taxa have been re-interpreted, although overall this has not greatly affected the biostratigraphic conclusions reached in Chapters II and III. This has, however, caused the age assignments of some collections to be revised, so that some zones that were definitely recognized previously are now only provisionally so or no longer recognized at all.

The only instance where taxonomic re-interpretations have significantly affected the biostratigraphy are in faunas in which *Bispathodus stabilis* (Branson and Mehl) Morphotype 2 of Ziegler, Sandberg and Austin and "*Icriodus*" cf. "*I*." *raymondi* Sandberg and Ziegler occur together. Some specimens of the latter species were formerly assigned to "*I*." *chojnicensis* Matyja Morphotype 2 of Sandberg and Dreesen and as a result of this assignment, it was uncertain whether the faunas in question could be as old as Uppermost *marginifera* Zone or as young as Lower *expansa* Zone since the stratigraphic ranges of *B*. *stabilis* Morphotype 2 and "*I*." *chojnicensis* were not known to overlap (see Chapter II). The re-assignment of specimens to "*I*." cf. "*I*." *raymondi* in collections containing these elements and *B*. *stabilis* Morphotype 2 allows confident assignment of these faunas to the Lower *expansa* or younger zones, whereas they were only tentatively assigned to this interval in Chapter II (Johnston and Chatterton, 1991).

In the course of this work, sixteen new species were named and described. These are: *Icriodus erucisimilis* n. sp., *I*. *stenoancylus* n. sp., *Mehlina ovata* n. sp., *M*.? *arcureclinata* n. sp., *M*.? *brevicristata* n. sp., *Palmatolepis angulata* n. sp., *P*. *crista* n. sp., *P*. *lanceolata* n. sp., *P*. *ovata* n. sp., *P*. *parawolskae* n. sp., *Polygnathus crassilabrus* n. sp., *P*. *dolichopleurus* n. sp., *P*. *latisemicostatus* n. sp., *P*. *meijerdreesi* n. sp., *P*. *paraobliquicostatus* n. sp. and *Polylophodonta medicinelakensis* n. sp. Some of these taxa have very short stratigraphic ranges in the study area and thus should have biostratigraphic utility.

In addition to the new taxa described, some of the more significant taxonomic conclusions are listed below. 1) The recognition of distinct morphotypes of taxa such as Palmatolepis marginifera Helms, P. rhomboidea Sannemann, P. stoppeli and P. subperlobata Branson and Mehl, which appear to have paleoecological significance. 2) The synonymizing of forms assigned to P. inflexoidea Ziegler sensu Sandberg and Ziegler (1973) with P. inflexa Müller, owing to their similarity to the holotype of the latter species rather than to the holotype of P. inflexoidea. It was because of this taxonomic re-assignment that the Lower marginifera Zone is now only tentatively recognized at Crowsnest Pass (see discussion under Biostratigraphy). It is assumed that these forms of P. inflexa occur no lower than the Lower marginifera Zone, whereas the species as a whole ranges as low as the Lower rhomboidea Zone (Sandberg and Ziegler, 1973). 3) That only large specimens of P. quadrantinodosalobata Sannemann Morphotype 1 of Sandberg and Ziegler (1973) have the anterior margin of the outer platform reaching the end of the blade. In smaller specimens this margin terminates well short of the free blade. Previous misidentification of this form (e.g. Johnston and Chatterton, 1991) was because this fact was not recognized. 4) That Polygnathus webbi Stauffer occurs in the Famennian, as stated by Klapper (1973), as well as in the Frasnian. Sandberg et al. (1988) considered this species to have gone extinct at the end of the Frasnian. Another polygnathid that has affinities with Frasnian forms, P. aff. P. timanicus Ovnatanova, has been found to occur in the Palliser Formation and Wabamun Group. This would appear to suggest that there were perhaps more "survivors" of the so-called late Frasnian extinction event (Sandberg et al., 1988) than previously thought and that some lineages that were thought to have been terminated by this event continued into the Famennian. 5) Juvenile specimens with wide basal cavities of different species of Bispathodus and Mehlina are difficult to distinguish from one another and therefore are difficult to identify prior to their largest growth stages. This suggests that late Famennian spathognathodontids with wide basal cavities may have arisen through paedomorphosis since wide basal cavities are a juvenile trait that later became fixed in mature specimens.

Range extensions of taxa in this work, not already noted in Chapter II (Johnston and Chatterton, 1991), include the first occurrence of *Mehlina strigosa* (Branson and Mehl) in the Upper *crepida* Zone, a species previously considered to first appear in the Lower *marginifera* Zone (Ziegler and Sandberg, 1984). A slight upward range extension of *Icriodus iowaensis* Youngquist and Peterson from the Lower to lowermost Upper *rhomboidea* zones is recorded with questionable occurrences of this species higher in the latter zone. A questionable upward range extension into the Upper *rhomboidea* Zone from the Uppermost *crepida* Zone was noted for *Palmatolepis protorhomboidea* Sandberg and Ziegler as well as a possible downward extension of the stratigraphic range of *P. stoppeli* into the Lower *rhomboidea* Zone from the Upper *rhomboidea* Zone.

As explained in the preamble to the systematics section of Chapter V, no complete multielement reconstructions of conodont apparatuses were attempted. Consequently, only a form taxonomy of Pa elements was employed. Although many collections had great abundances of conodont elements, the diversity of Pa and I elements was such that these elements could not be matched with corresponding Pb elements or with ramiform and/or coniform elements with confidence in the way that Klapper and Foster (1993) were able to with specimens of Frasnian *Palmatolepis*. No collections with high abundances but very low diversity are present in the available material. Reconstruction of apparatuses would have been further complicated by the presence of elements of "*Apatognathus*", which probably were part of all ramiform apparatuses.

An attempt was made in Plates V-1 to V-35 of Chapter V to illustrate the degree of intraspecific variability of taxa, where previously in the literature only a few specimens, sometimes just the holotype, of a particular taxon have been figured. This practice does not allow other conodont taxonomists to assess fully how broad or narrow a taxonomic concept is. Thus, it was felt that for certain taxa, not enough illustration of intraspecific variability has been done. Hopefully this has been, in part, rectified in this work.

Finally, the decision to treat all taxa as species rather than to treat them both as species and subspecies, which as been the standard practice of some conodont taxonomists (e.g Sandberg and Ziegler, 1979, pp. 173, 174) is based on the belief if enough differences exist to separate one taxon from another, such differences warrant their recognition as separate species. Given the nature of subspecies in living populations (as geographic races), it would seem impossible to distinguish these from separate species, plus the fact that these forms appear to have been living sympatrically (although time-averaging of samples could give this impression). Also the fact that many of these so-called "subspecies" had a cosmopolitan distribution would argue against their being subspecies in the sense of geographic races. It is also the impression of the writer that these conodont subspecies were being treated, for biostratigraphic purposes, as species (i.e. they were being treated as separate taxa, with distinct hic and stratigraphic distributions).

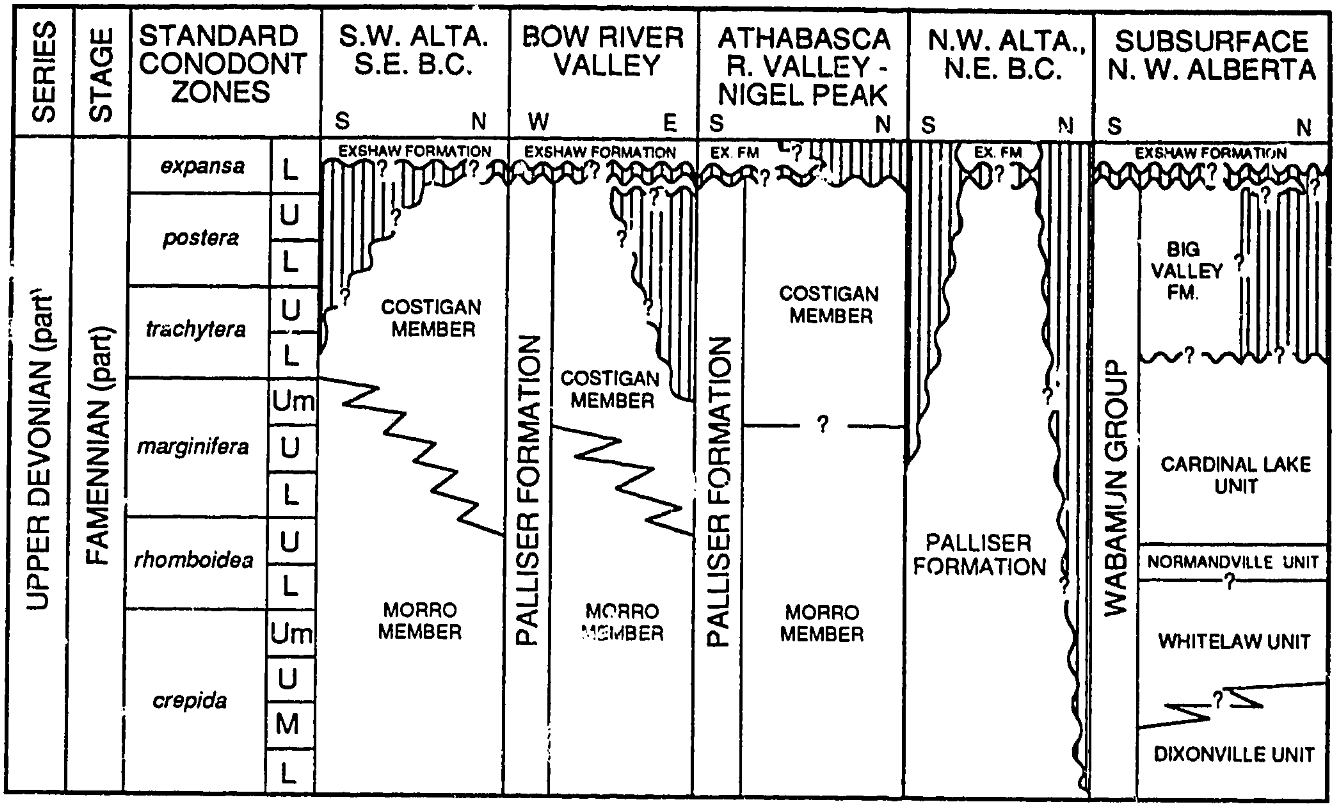

Figure VI-1. Correlation chart showing biostratigraphic relationships of Palliser Formation and Wabamun Group discussed in text. Compiled from several sources, mainly from Johnston and Chatterton (1991, fig. 3), Johnston and Meijer Drees (1993, fig. 2) Meijer Drees and Johnston (1993, 1994) and Savoy (1990, 1992). EX. FM. = Exshaw Formation.

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ZONES	Lower - Middle *crepida*																				Upper - Uppermost *crepida*									Lower *rhomboidea*										Upper *rhomboidea*															
m above base fm.	0.0	3.1	6.1	20.7	23.5	32.9	37.5	41.2	46.0	49.0	54.0	57.0	59.5	62.5	66.0	69.0	72.0	75.0	78.0	81.0	84.0	87.0	88.5	90.0	93.0	96.0	101.0	104.0	107.0	110.0	113.0	116.0	123.5	127.0	130.0	133.0	136.0	139.0	143.0	146.0	149.0	152.5	155.5	159.0	162.0	163.5	165.0	168.0	174.0	175.0	176.0	176.9	176.9	176.9
SAMPLES AXA	ML3-150	ML3-140	ML3-130	ML3-82	ML3-73	ML3-42	ML3-27	ML3-15	ML2-430	ML2-420	ML2-405	ML2-392	ML2-385	ML2-375	ML2-365	ML2-355	ML2-345	ML2-335	ML2-325	ML2-315	ML2-305	ML2-295	ML2-290	ML2-285	ML2-275	ML2-265	ML2-250	ML2-240	ML2-230	ML2-220	ML2-210	ML2-200	ML2-175	ML2-165	ML2-155	ML2-145	ML2-135	ML2-125	ML2-110	ML2-100	ML2-90	ML2-80	ML2-70	ML2-60	ML2-50	ML2-45	ML2-40	ML2-30	ML2-10	ML2-5-10	ML2-2.5-7.5	ML2-0-5	ML2-0	ML4-0
Palmatolepis wolskajae	1?	1	4						5	6	4	3?	1?																																									
Polygnathus meijerdreesi	1	1	1	1					1			1	1?	1		1																																						
Icriodus erucisimilis		1			1		1	1		2				2					1			1																																
Polygnathus aff. *P. fallax*		1								1																																												
P. cf. *P. brevilaminus*				1?	1?		2		1?	1?	1							1										1?																			1?				1?			
odonta medicinelakensis					1							1		2				2				4		7					2																									
Icriodus stenoancylus							2			1								1				1				3?																												
Pelekysgnathus inclinatus							1	1																																														
Polygnathus? sp. A							1																																															
Icriodus iowaensis								1																														1											1?					
Mehlina ovata								1						1				1																																				
Polygnathus webbi								3																							2																			1			7	
P. sp. C										1																																												
almatolepis parawolskae														2						1?		7				1																												
P. cf. *P. perlobata*														2																																								
P. sp. A														3																																								
P. angulata																		15	7	5																																		
P. cf. *P. circularis*																		11	1?																																			
P. circularis																		4	3?																																			
P. protorhomboidea																		20																																				
. quadrantinodosalobata																		42	5	3	5	10			1?	8																												
nathus aff. *P. timanicus*																		1																																				
Palmatolepis prima																				3						2	1			3							1														2			
ygnathus dolichopleurus																				1		5																																
Mehlina gradata																								3											1		2																	
Palmatolepis prima M1																								1?		1	6	7	3	1			1		1																			
P. subperlobata																								22																														
P. crista																										3		1																										
drantinodosalolobata M1																										18	32	60																										
Mehlina strigosa																											1	1																										
matolepis tenuipunctata																											1		3																									
athus aff. *P. lauriformis*																												2																										
New Genus B sp. 2																													2																									
Palmatolepis poolei																													16																									
"*Icriodus*" *cornutus*																														1																								
Palmatolepis minuta																														1																								
lygnathus semicostatus																														9	5	2	5		10		13	2	6	2	11	3		3	7	8	18	8	28	13	10	17	3	8
criodus" cf. "*I.*" *cornutus*																															1						2																	
Palmatolepis prima M2																															9																							
Mehlina cf. *M. gradata*																																			3																			
"*Icriodus*" *chojnicensis*																																					1																	
New Genus A sp.																																					1																	
pis cf. *P. tenuipunctata*																																						1																
New Genus B sp. 3																																												1										
almatolepis rhomboidea																																													1?	2	8	1	17	13	26	4	16	1
Polygnathus sp. A																																													1	1				4	4	1		
P. communis																																																1	1	1	1		2	
aff. *A. pseudostrigosus*																																																	1					
New Genus B sp. 5																																																	2					
matolepis pectinata M1																																																	3				1	
Polygnathus sp. B																																																	6		1	3	3	1
Palmatolepis pectinata																																																			2			
Polygnathus sp. D																																																				2		
kysgnathus cf. *P. brevis*																																																						
Polylophodonta sp.		1								6			1																																									
Palmatolepis sp.				1														4	2		3				1		1								2		5											1		1				
Polygnathus sp.								1			1							1			1						1		1					1											1					2	8			
New Genus B sp.																							1			1																												
Icriodus sp.																								1																											1			
Mehlina sp.																																1									1													
Pb elements				3			3	2		2		1?	1	6		1		8	2	1		2		4		4	10	7	9	10	3	1	1		9		8	2	2		6	2		3	3	2	4	1	14	10	5	4	5	
ramiform elements	1	10	7	7	2		9	2	6	14	20	9	3	28	1	6?	1	31	7	2	2	7	2	17	3	14	18	26	11	13	9	9	13	1	25	2	30	7	15	8	11	6	4	13	14	10	15	1?	22	25	8	8	11	
coniform elements		3	1	5	1		13	4	1	7	2	2	2	4	1	1		21	3	2		11			1	4	7	8	6												1			2?					1			1?		
atognathiform" elements	2	4		3	2	1	7	2	5	17	8	2	5	19		3	3	55	15	5	1?	9		7	2	20	20	45	19	3	2	3	15	1	27	1	21	6	2	1	7	4	1	4	3	4	15	4	15	14	12	5	15	

SAMPLES	NPW86-1	NPW86-11	NPW86-12	NPW86-13	NP86-1	NP86-3	NP86-5	NP86-7	NP86-9	NP86-11	NP86-13	NP86-15	NP86-17	NP86-19	NP86-21	NP86-23	NP86-27	NPW86-14	NP86-30	NP86-33	NP86-36	NP86-39	NP86-41	NP86-43	NP86-45	NP86-50	NPW86-15	NP86-58	NP86-60	NP86-64	NP86-68	NP86-74	NPW86-1	NP86-80	NPW86-1	NPW86-1	NPW86-1	NPW86-2	NPW86-2	NPW86-2	NPW86-2	NPW86-2	NPW86-2	NPW89-1	NPW89-2	NPW89-3	NPW89-4	NPW89-5	NPW89-6	NPW89-7	NPW89-8	NPW89-9	NPW89-1	NPW89-1	NPW89-1	NPW89-1	NPW89-1	NPW89-1	NPW89-1
us aff. P. timanicus	1																				1?																																						
P. meijerdreesi	1	1	1			1			1		3		1	1			1		1																																								
Icriodus erucisimilis			2	11	1						3	5	1		1	3					2	1	6	2																																			
I. stenoancylus			1																				1?																																				
Mehlina ovata			1							1			1			1																																											
Polygnathus webbi			5		2																																3	4	1		2			1	1							3	1	1	1	50	39		
matolepis wolskajae				4									1	2?	1	2	1		2																																								
sgnathus inclinatus				4																																								4	6		11					5				11		10	
cf. P. brevilaminus				5																	2		1	3																																			
hlina cf. M. gradata					4																									5								3																					
Polygnathus glaber									1?																2?																																	3	
P. aff. P. fallax											1																																																
P. germanus												1										1	1		12	13		30	1?	1							2	1																1?		1?			
P. dolichopleurus													1									2	4																																				
olepis parawolskae																	1						10	13																																			
P. minuta																		1			3		3	2	1	15		9	2	3																									2	6			
P. protorhomboidea																		3			4																1?																						
drantinodosalobata																		9			21	6	54	23																																			
P. angulata																					18	7	3																																				
P. cf. P. circularis																					8																																						
P. circularis																					7																																						
P. ovata																					3	3	7						5?																														
a medicinelakensis																					2	1	4																																				
natolepis lanceolata																						1	5																																				
P. prima																						6		1?	27	16	2	9	4	1		1?																							10	1?			
P. subperlobata																						1?	2		93	176	4	55	7	1																													
P. tenuipunctata																								1	1	1		1?	1					1?																									
ekysgnathus planus																								2																																			
hlina? arcureclinata																									10	32	1	15																															
almatolepis klapperi																									98	48	6	6	2																														
P. lepta																									4			3?																															
P. pectinata																									4													1							4										4	8			
P. pectintata M1																									7	12												4							11														
P. poolei																									7 19?	6	1	60	13	7	1	1																											
P. prima M2																									29																																		
tinodosalobata M1																									1			1																															
athus semicostatus																									40	31		6	8	1	1	74		50		1	7	26		2?	4		1?		24		1	1		1	5	7		9			14	41	20
almatolepis crepida																										2																																	
"Icriodus" cornutus																												2	2?		1																												
natolepis prima M1																												40	9	6?	2	15				1																							
P. stoppeli																												1?											4	7	28	3																	
us" cf. "I." cornutus																														3																													
letognathus sp. A																														2							2						2	1	2										1			1	
s" chojnicensis M1																																4																											
Mehlina strigosa																																16		14											2								4?	2	16		3	10	5
Icriodus iowaensis																																	3					2?																					
New Genus A sp.																																		2																									
A. pseudostrigosus																																					1																						
tolepis rhomboidea																																					12																						
P. duplicata																																											10																
s cf. P. padovaniae																																											5												4				
Mehlina gradata																																												1?						3?			1?	1?				2?	
nathus crassilabrus																																												13	7							2						1	
"Icriodus" costatus																																													1?												7	1?	
Palmatolepis inflexa																																													3?		3												
P. marginifera																																													1?		1	4	1?	15	12	13	11	18	4	1			
phodonta confluens																																													1					1									
us latisemicostatus																																														15	51												
is quadrantinodosa																																															2												
P. distorta																																																						9					
nathus cf. P. brevis																																																						1					
paraobliquicostatus																																																						1					
hlina? brevicristata																																																							3?	149			
Palmatolepis acuta																																																							1				
thodus stabilis M1																																																								4			9
thus planirostratus																																																									1?		
P. perplexus																																																									2?	4	
P. homoirregularis																																																										2	
thodus stabilis M2																																																											4
na aff. M. strigosa																																																											18
M.? sp. A																																																											
gnathus communis																																																											
s" cf. "I." raymondi																																																											
Polygnathus sp.		1	1	1							1				1			1	4					1	5		1?			1	3						15	4	1	2					5								4		2	2	10		
Mehlina sp.				10								1									2		1						1				2				3													4?	14	8		6		42			4
elekysgnathus sp.				1?																																									1?								1						1
Palmatolepis sp.																1			6		7		3	6	59	19		7	7	4	5								1	2					3					3		1			13	4			
"Icriodus" sp.																															1																												
Alternognathus sp.																																															1?												
Polylophodonta sp.																																																	1?										
Bispathodus sp.																																																											1
Pb elements		1	1?	13	4					2	7	2		4		1?	1?	5			4	2	12	3	X	X	11	X	X	31	20	47	10	17	3	1?	39	11	3	2?	3	1	13	7	36		93	1	6	6	21	12	7	38	28	270	X	22	32
ramiform elements		5	3	44	9	12	3	2	6	7	20	18	9	18	1?	28	1	27	13	3	33	22	84	24	X	X	27	X	X	83	43	131	8	78	3	2	53	47	28	4	25	2	88	27	96		338	1	12	43	86	69	27	68	100	1617	X	66	12
coniform elements		2		94	11	6	1	1		2	16	18	6	12		6		5	10		27	15	38	19	X	X	20	X	X	45	31	60	7	4			15	8	3		4		6	10	64		50			5	4	12	2	21	8	28	X	30	13
athiform" elements		5	3	115	21	1	12	2		5	28	51	16	27	12	24		68	31	3	56	30	77	32	X	X	19	X	X	35	22	177	10	51	2		49	45	32	10	30		95	32	139		383	2	32	54	63	43	47	166	45	96	X	140	12