CONODONTS FROM A CORE OF THE NITA AND GOLDWYER FORMATIONS (LOWER MIDDLE ORDOVICIAN) OF THE CANNING BASIN, WESTERN AUSTRALIA

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by

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ABSTRACT

The Canning Basin in northern Western Australia includes a thick and areally extensive Lower and Middle Ordovician sequence of dominantly carbonate and shale deposited in an epeiric sea. Ordovician strata outcrop in only two small areas along the northeastern basin margin but have been penetrated in the subsurface by numerous, widely-spaced petroleum exploration drillholes.

Prioniodontacean conodonts from the Lower Ordovician Emanuel Formation in the Prices Creek outcrop area were described by McTAVISH (1973) but descriptions of conodonts from the subsurface formations have not been previously published. This study describes conodonts extracted from a continuous 234m core section through the Middle Ordovician Nita Formation and the underlying upper Goldwyer Formation of the subsurface sequence on the Broome Arch. Approximately 8,700 identifiable conodont elements were recovered from 96 samples with a combined mass of approximately 160kgms. A total of 54 conodont taxa have been identified: 20 multielement genera, including 27 species and 27 form-taxa. New taxa described are as follows: the multielement genus: Onyxodus, the multielement species: Protoprioniodus histion, Onyxodus acuoliratus, Phragmodus polystrophos and Phragmodus spicatus, and the form-species Falodus keramis.

The conodont taxa fall into two, stratigraphically discrete faunas: a lower fauna correlated with Midcontinent

Fauna 4 (SWEET, ETHINGTON and BARNES, 1971) and an upper fauna correlated with the North Atlantic _Eoplacognathus suecicus_ conodont Zone (BERGSTRÖM, 1971) and Midcontinent Fauna 5. The boundary between these two faunas is abrupt (occurring within a 4m thick sample gap) and is correlated with similar conodont faunal changes in: the Majiagou Formation of North China (AN _et_. _al_., 1983), the Bay Fiord Formation of Arctic Canada (NOWLAN, 1976), the Watson Ranch Quartzite of the Ibex Area of Utah (ETHINGTON and CLARK, 1981) and the Antelope Valley Limestone of the Meiklejohn Peak section of Nevada (HARRIS _et_. _al_., 1979).

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INTRODUCTION

The onshore portion of the Canning Basin in northern Western Australia covers an area of approximately 430,000sq. km and contains a predominantly Palaeozoic sedimentary sequence over 10,000m thick in parts (based on seismic and other geophysical data).

Sedimentation commenced in the early Ordovician and persisted through several distinct episodes (FOREMAN and WALES, 1981) until the early Cretaceous. Outcrop in the basin is generally poor and is dominantly of Permian and younger strata except along the northeastern basin margin where the Devonian carbonate sequence is well exposed. Ordovician strata are known in outcrop in only two isolated localities, also on the northeastern margin of the basin (Fig. 1). The more northern of these exposures comprises the type area for the Emanuel and Gap Creek Formations of the Prices Creek Group. Their age was first established by GUPPY and OPIK (1950). The strata are also known in the subsurface in several petroleum and mineral exploration drillholes closeby. Lateral continuity of these strata has not been demonstrated with the Carranya Beds of the southern outcrop area, nor with the subsurface Ordovician strata that are present over most of the rest of the basin to the south and west of the Fitzroy Graben.

The Canning Basin was linked with the Amadeus and Ngalia Basins to the southeast by a shallow seaway in

Ordovician times (WEBBY, 1978). A ridge of Proterozoic sediments that comprises the Sturt Platform presently defines the southeastern limit of the basin.

The Ordovician structure of the basin was interpreted by McTAVISH and LEGG (1976) to consist primarily of two large, shallowly dipping and northwest plunging half-grabens separated by a northwest/southeast trending, mid-basin ridge. Extensional, normal faulting is apparent on many seismic sections in the basin (BENTLEY, 1984).

Knowledge of the subsurface section derives mostly from numerous but widely spaced, petroleum exploration drillholes. Ordovician strata were first recognized in the subsurface in the Roebuck Bay No. 1 and Dampier Downs No. 1 wells by GLENISTER and GLENISTER (1958) on conodont evidence. Rocks of the Prices Creek Group were drilled near the outcrop area as early as 1922-3, but their age was not then established.

At present, there are four main, formally defined Ordovician subsurface rock units. These are in ascending stratigraphic order: Nambeet Formation, Willara Formation, Goldwyer Formation and Nita Formation. Laterally equivalent sandy facies are known in the south of the Kidson Sub-basin; e.g. the Wilson Cliffs Sandstone, which is the only formally named unit. Descriptions and definitions of the Ordovician formations are given in PLAYFORD et. al. (1975).

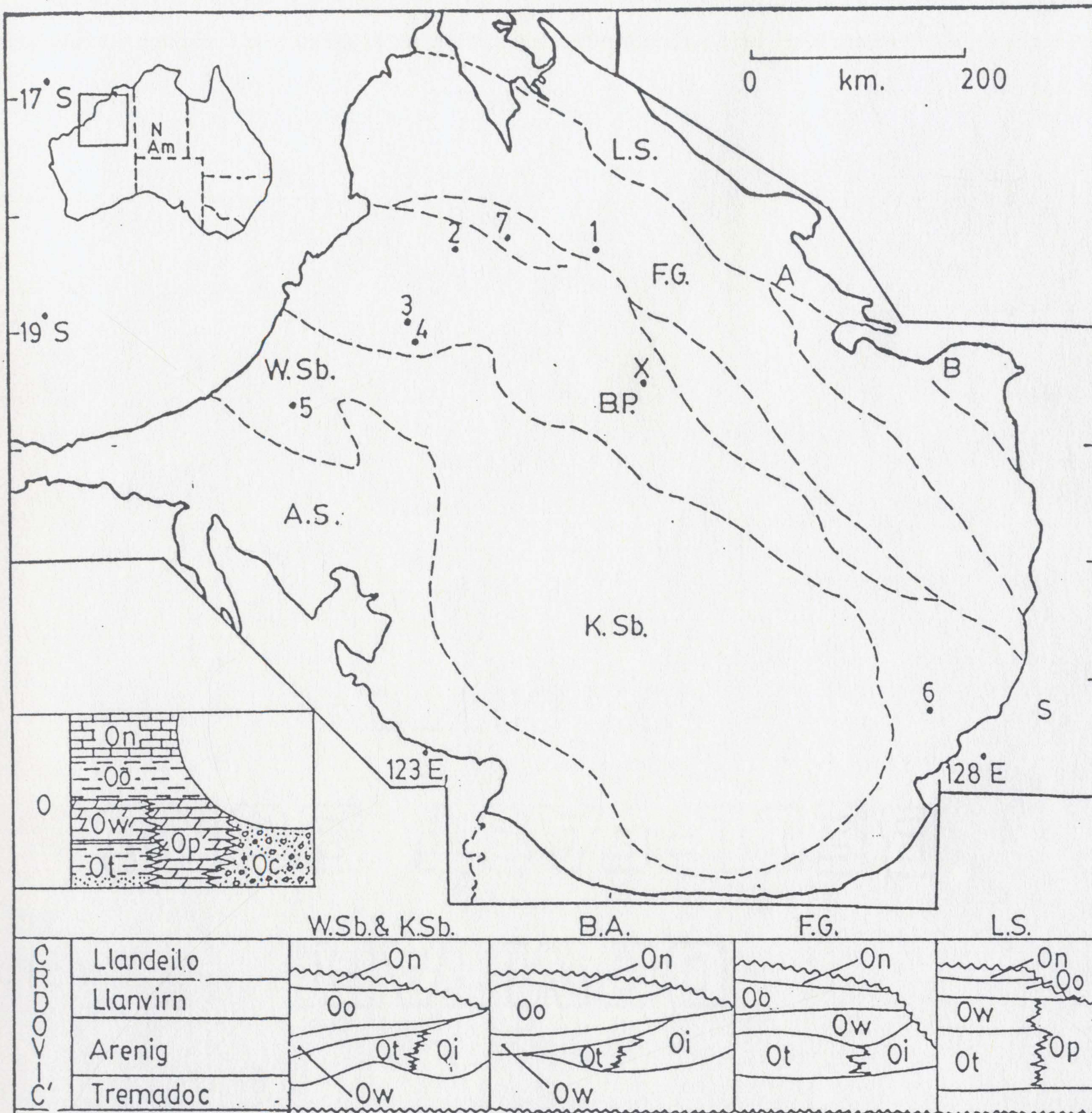
The most comprehensive recent publication concerned with the Ordovician geology of the Canning Basin is by

McTAVISH and LEGG (1976) which includes tabulated but undescribed, informal biostratigraphic zonation schemes (Fig. 2) for conodonts and macrofauna (graptolites and trilobites). The latter scheme has been subsequently revised and updated by LEGG (1976, 1978) but remains informal. There has been no such subsequent revision of the conodont scheme. Poor biostratigraphic control is a major handicap to attempts at resolving the detailed Ordovician palaeogeography of the basin.

This study describes two, stratigraphically discrete, conodont faunas extracted from a continuous core section through the upper Goldwyer and Nita Formations on the Broome Arch in the west central part of the basin: latitude 19°28'22"S, longitude 124°52'06"E (Fig. 1). The uppermost of the two faunas is correlated with the North Altantic _Eoplacognathus suecicus_ conodont zone (BERGSTRÖM, 1971) and the Midcontinent Fauna 5 of SWEET, ETHINGTON and BARNES (1971). The lower fauna is correlated with Midcontinent Fauna 4 (SWEET, ETHINGTON and BARNES, 1971). The boundary between the faunas is abrupt and correlated with a level in Zone OCH of McTAVISH and LEGG (1976). Regional correlations with the Majiagou Formation of North China (AN _et_. _al_., 1983), the Watson Ranch Quartzite of the Ibex Area, Utah (ETHINGTON and CLARK, 1981) and the Antelope Valley Limestone of the Meiklejohn Peak section in Nevada (HARRIS _et_. _al_., 1979) are proposed.

The Nita Formation in the Canning Basin is a major petroleum exploration target and the potential utility of a well-defined Ordovician conodont zonation in assisting exploration is the main impetus behind this preliminary study. The recognition of a major conodont faunal change in the uppermost Goldwyer Formation will assist in mapping the diachroneity of the Nita Formation and in palaeogeographic reconstruction.

Fig. 1 Location map (adapted from YEATES et. al., 1984) with summary of the stratigraphic relationships of the Ordovician rock units for each of the tectonic subdivisions of the basin (inserts).



1. Edgar Range No.1
2. Goldwyer No.1
3. Parda No.1
4. Willara No.1
5. Samphire Marsh No.1
6. Wilson Cliffs No.1
7. Thangoo No.1A
X. Study section

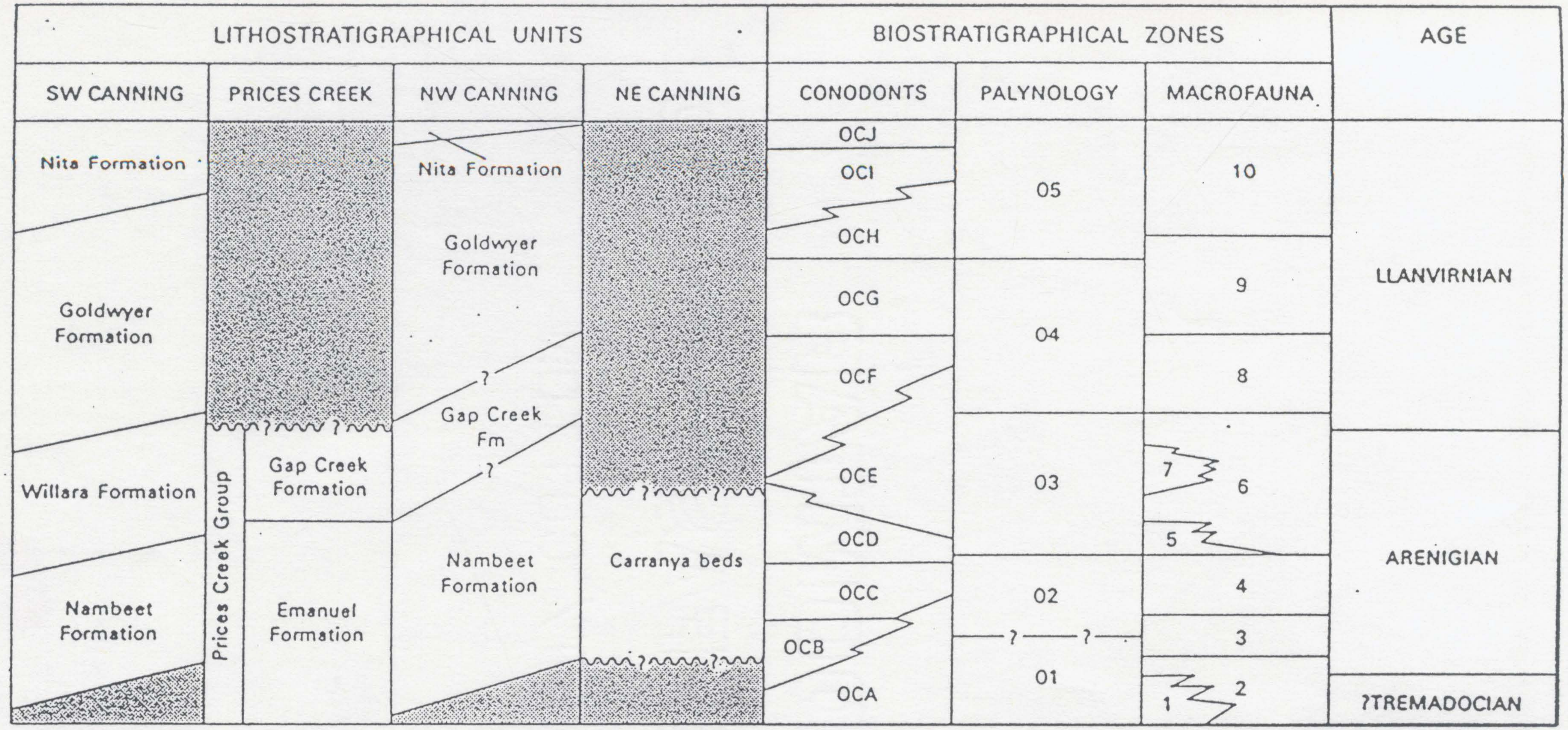
Am Amadeus Basin
N Ngalia Basin

On. Nita Fm.
Oo. Goldwyer Fm.
Ow. Willara Fm.
Ot. Nambeet Fm.
Op. Prices Creek Gp.
Oc. Carranya Beds
Oi. Wilson Cliffs Sst.
S. Sturt Platform

—— Basin margin ---- Tectonic boundary

L.S. Lennard Shelf
F.G. Fitzroy Graben
B.P. Broome Platform
W.Sb. Willara Sub-basin
K.Sb. Kidson Sub-basin
A. Prices Creek Outcrop
B. Carranya Beds Outcrop

Fig. 2 Age and approximate relationships between Ordovician stratigraphic units in the Canning Basin (McTAVISH and LEGG, 1976).


LITHOSTRATIGRAPHICAL UNITS
BIOSTRATIGRAPHICAL ZONES
AGE
SW CANNING
PRICES CREEK
NW CANNING
NE CANNING
CONODONTS
PALYNOLOGY
MACROFAUNA
Nita Formation
Goldwyer Formation
Willara Formation
Nambeet Formation
Prices Creek Group
Gap Creek Formation
Emanuel Formation
Nita Formation
Goldwyer Formation
Gap Creek Fm
Nambeet Formation
Carranya beds
OCJ
OCI
OCH
OCG
OCF
OCE
OCD
OCC
OCB
OCA
05
04
03
02
01
10
9
8
7
6
5
4
3
2
1
LLANVIRNIAN
ARENIGIAN
?TREMADOCIAN

LITHOSTRATIGRAPHIC SETTING

Sedimentation commenced in the Canning Basin in the Early Ordovician (GILBERT-TOMLINSON in JOHNSTONE, 1961) with transgression of the lower, marine sandy facies of the Nambeet Formation southwards over an erosion surface developed on Cambrian and Precambrian basement rocks. The Carranya Beds were also deposited at this time as sandy, intertidal flats (VEEVERS and WELLS, 1961).

The upper part of the subsurface Nambeet Formation is dominantly shaly with minor limestone and sandstone and indicates the onset of deeper water sedimentation as the transgression progressed. The outcropping Emanuel Formation (Fig. 1) is similar in lithology and is partly correlated with these strata (Fig. 2). The type section for the Nambeet Formation is in the Samphire Marsh No. 1 well between 1240m and 2015m.

The subsurface Willara Formation conformably overlies the Nambeet Formation. It is comprised mostly of limestone with a more shaly middle unit recognizable in many well sections. The environment of deposition was mostly shallow, subtidal to intertidal; overall a regional shallowing event or regression is indicated. The outcropping Gap Creek Formation which overlies the Emanuel Formation may correlate with the Willara Formation. The type section for the Willara Formation is in the Willara No. 1 well between 2610m and 3142m.

The Nambeet and Willara formations and the strata outcropping on the north-eastern margin of the basin (Prices Creek Group and Carranya Beds) are older than the cored section of the Goldwyer and Nita formations studied here (Fig. 2). Therefore, they are only briefly discussed.

The Goldwyer Formation overlies the Willara Formation for the most part conformably. It is the most extensively shaly of the subsurface formations and represents the period of maximum transgression. Even so, very shallow subtidal to intertidal conditions are indicated for parts of the Broome Platform. The type section is between 848m and 1060m in the Thangoo No. 1A well located on the northern edge of the Broome Platform. The formation is named after the Goldwyer No. 1 well nearby. The type section is overlain unconformably by Permian strata. A more complete and representative section is that in the Edgar Range No. 1 well to the east (Fig. 1). In this well the formation is 430m in thickness and is divisible into three, informal sub-units: a lower unit (153m) of grey to black, silty shale with few limestone interbeds, a middle unit (100m) of interbedded (50%) black to grey shale and (50%) grey, argillaceous limestone and an upper unit (177m) of grey to black fissile shale with common, thin, nodular limestone interbeds. This three-fold subdivision has been correlated over a wide area in the west-central part of the basin. In the Willara Sub-basin, the formation is more uniformly shaly and southwards into the Kidson Sub-basin, it is increasingly sandy.

Both shale and limestone of the Goldwyer Formation have yielded abundant brachiopods, trilobites, graptolites, conodonts and palynomorphs (acritarchs). These were used by McTAVISH and LEGG, (1976) to infer regional diachroneity of the formation and to interpret an age span from the middle Arenig to the late Llanvirn. The contact with the overlying Nita Formation is conformable and gradational.

The core section studied here includes 168.5m of the upper Goldwyer Formation (460.5m to 629m) and is more carbonate-rich than is typical of the upper, shaly, sub-unit. Dark grey to black, fissile shale is present, mostly in the lower part (refer to Appendix A).

The Nita Formation is the uppermost unit of the subsurface Ordovician section and represents the regression that terminated open marine sedimentation in the basin until the Middle Devonian. The type section is between 1184m and 1270m in the Parda No. 1 well located just to the south of the Admiral Bay Fault along the northern edge of the Willara Sub-basin (Fig. 1). Three informal members are recognized in the type section: an upper member consisting dominantly of dolostone with traces of anhydrite and grey to brown, laminated, dolomitic shale, a middle member of relatively uniform, pale grey limestone with only a few, thin, shale beds and a lower member of interbedded limestone and dark grey to black shale. These three members illustrate the regressive character of the unit.

The Nita Formation is restricted in distribution to the west-central part of the basin where it is unconformably overlain by the Carribuddy Formation. The unconformable nature of this boundary is only apparent on a regional scale (in seismic sections) because of the extremely low angle of discordance. In cores, the boundary appears gradational and originally, the Nita Formation was included as the lowest member (E) of the Carribuddy Formation (KOOP, 1966). It was only recently differentiated by McTAVISH (in PLAYFORD *et. al*., 1975). Fossils from the Nita Formation are few but suggest that the unit is diachronous within the late Llanvirn and possibly into the Llandeilo (McTAVISH and LEGG, 1976).

The Nita Formation in the section studied is 80.9m in thickness (379.6m to 460.5m). Although more dolomite-rich than the type section, the sequence displays a shallowing-up sequence of facies corresponding with that recognized in the Parda No. 1 well (refer to Appendix A).

BIOSTRATIGRAPHY

Previous Work:

Early biostratigraphical studies on the Prices Creek outcrop area resulted in the recognition of five combined faunal "stages" by GUPPY and OPIK (1950). Five divisions based solely on nautiloids were recognized by TEICHERT and GLENISTER (1954). McTAVISH and LEGG (1976) incorporated additional data from the subsurface and tabulated ten informal macrofauna zones based on trilobites and graptolites. The zones were not defined in the accompanying text. LEGG (1976) described the graptolite and trilobite faunas but did not define any zones. Subsequently, LEGG (1978) modified the original scheme, reducing the number of units to six "faunas" but no type localities were nominated.

The only published palynological zonation remains that of COMBAZ and PENIGUEL (1972), comprising five zones based primarily on Chitinozoa. These are labelled 01 to 05 and encompass the entire subsurface Ordovician section (Fig. 2).

Ordovician conodonts were first recognized by GUPPY and OPIK (1950) in rocks of the Prices Creek Group but the first published description of the conodonts from these strata was by McTAVISH (1973). This study was restricted to prioniodontacean conodonts of the Emanuel Formation and outlined a phylogenetic sequence to provide a basis for a biostratigraphical zonation but the work was not continued.

McTAVISH and LEGG (1976) tabulated an informal conodont zonation (Fig. 3) in a similar fashion to the macrofaunal schemes mentioned above (i.e. without description of faunas or definition of the zones in the accompanying text). There have been no further taxonomic publications concerned with the Ordovician conodont faunas of the subsurface section. Faunal lists are included in some petroleum exploration well completion reports but these do not include descriptions or illustrations of taxa. Most of these data pre-date the widespread usage of multielement taxonomy.

Results of this Study:

The collection is divided into two stratigraphically discrete faunas with few taxa shared. There is no obvious major lithological discontinuity in the core to account for the faunal change.

The lower fauna ranges between 629m and 513m and includes the following taxa: Ansella sp. nov., Belodina sp., Bergstroemognathus sp., cf. ?Coleodus sp., aff. Cornuodus sp., Drepanoistodus forceps, Drepanoistodus pitjanti, Falodus keramis sp. nov., Genus and Species nov. A., Histiodella holodentata, Juanognathus leptosomatus, Oepikodus sp. cf. O. communis, Phragmodus spicatus sp. nov., Protopanderodus sp. cf. P. gradatus and Scolopodus sp. cf. S. cornuformis. Not all of these taxa are represented below 613-4m but this is probably due to the low element yields of samples below that level. There is no evidence of phylogenetic change in any of the taxa through the stratigraphic range of the lower fauna and allowing for random sample and minor palaeoecological variation, the overall composition of the fauna is relatively constant.

The presence of Histiodella holodentata indicates biostratigraphic equivalence with Midcontinent Fauna 4 of SWEET, ETHINGTON and BARNES (1971) and the Paraprioniodus costatus - Chosonodina rigbyi - Histiodella holodentata Interval of ETHINGTON and CLARK (1981). The first two named taxa of the latter Interval are not present.

The upper fauna is less diverse. It is dominated by elements of: Phragmodus polystrophos sp. nov., Onyxodus acuoliratus sp. nov. and Drepanoistodus basiovalis. Elements of Ansella sp. and fragments of elements of the genus Eoplacognathus are less common. The fauna ranges of between 509m and 412m. Above 412m, elements of Phragmodus polystrophos, Onyxodus acuoliratus, Ansella sp. and Eoplacognathus are absent. Plectodina sp. cf. P. aculeata is the most common taxon above this level and to the top of the sampled section. This species first appears at 431m and between this level and 412m, the faunal change is gradational and apparently associated with a change in sedimentary facies from a relatively stable, subtidal environment of dominant limestone deposition to a peritidal environment of dominant dolostone deposition.

The most biostratigraphically significant taxa of the upper fauna are Phragmodus polystrophos and the genus Eoplacognathus. Phragmodus polystrophos is synonymous with

?*Phragmodus flexuosus* (MOSKALENKO) of ETHINGTON and CLARK (1981) and indicates a biostratigraphic equivalence with Midcontinent Fauna 5 and the ?*Phragmodus flexuosus* Interval (of the latter authors). Elements of the genus *Eoplacognathus* identifiable at species level are rare. The majority are assigned to *Eoplacognathus suecicus* but a single specimen, from a sample (495-6m) near the base of the upper fauna and with elements of *Eoplacognathus suecicus* identified above and below it, is assigned tentatively to *Eoplacognathus foliaceus*?. *Eoplacognathus suecicus* is the probable evolutionary ancestor of *Eoplacognathus foliaceus* in a lineage recognized by BERGSTRÖM (1971, 1983) in the Baltoscandian and North American Appalachian areas. The two taxa are morphologically distinct and have not been reported previously to cooccur or overlap in stratigraphic range. A correlation with the North Atlantic conodont Province *Eoplacognathus suecicus* Zone is inferred here because of the association of that species with *Phragmodus polystrophos* in Nevada (HARRIS *et*. *al*., 1979).

Contribution to Canning Basin Conodont Biostratigraphy:

The absence of previous description together with changes in conodont nomenclature in recent years make taxa listed in McTAVISH and LEGG's 1976 zonation (Fig. 3) difficult to identify with taxa in this collection. Conodonts described from the Emanuel Formation outcrop area are different and older than those recovered from the section studied here (McTAVISH, 1973). McTAVISH and LEGG (1976) assigned the Emanuel Formation faunas to their zones OCA to OCD (Fig. 2). Based on the interpreted synonymy of Spathognathodus sp. of McTAVISH and LEGG's faunal list with Histiodella holodentata and of Phragmodus sp. cf. P. inflexus with Phragmodus polystrophos, the first appearance of the latter taxon in the mid-part of McTAVISH and LEGG's zone OCH (Fig. 3) is tentatively correlated with the faunal change noted in this study.

Histiodella sp. A of McTAVISH and LEGG may equate with Histiodella sp. A of SWEET, ETHINGTON and BARNES (1971) but this is not believed to be the case. The latter taxon is now widely held to be synonymous with Histiodella holodentata and although some instances of overlap with the stratigraphic range of its putative ancestor, Histiodella sinuosa, have been reported (ETHINGTON and CLARK, 1981, p. 49), Histiodella holodentata has not been reported from stratigraphically below the first occurrence of Histiodella sinuosa. Such a relative stratigraphic distribution would be invoked if the above interpreted synonymy was accepted. Additional support for rejecting this correlation is provided by McTAVISH and LEGG's distinction between (their) Histiodella sp. A and the stratigraphically higher ranging Spathognathodus sp. This latter taxon is more probably synonymous with Histiodella holodentata as McTAVISH and LEGG (1972) referred it to LINDSTRÖM (1960) and also stated that its stratigraphic distribution was reviewed by FÅHRAEUS

(1970). FÅHRAEUS's illustration of the element proves its identity (i.e. with Histiodella holodentata). McTAVISH and LEGG's identification of Histiodella sinuosa is unlikely to be incorrect (a confusion of posteriorly denticulate specimens of the species with longer specimens of Histiodella holodentata is possible when dealing with limited numbers of specimens) because of the biostratigraphic emphasis placed on it by them (McTAVISH and LEGG 1972, p. 468) and because of FÅHRAEUS's (1970) description of the distinguishing criteria of the two species, a discussion with which McTAVISH and LEGG (1972) were familiar.

The lowest occurrence in McTAVISH and LEGG's zonation scheme of any of the taxa present in the lower fauna, is in zone OCE (Fig. 3). The taxa concerned are Scandodus brevibasis (?=Trigonodus larapintinensis of present study), Erismodus spp. (?=Erraticodon balticus) and "Oepikodus" copenhagensis (=Ansella sp. nov.). All of these taxa range through several higher zones and are consequently of little biostratigraphic value.

Zone OCF sees only the introduction of one more possible component of the lower fauna. This is listed as Belodella sp. and may represent an element of the apparatus of Ansella sp. nov.

The base of zone OCG is marked by the introduction of Spathognathodus sp. The correlation of the faunal change in the section studied with the first appearance of

Phragmodus sp. cf. P. inflexus (of McTAVISH and LEGG) in zone OCH implies that the lower fauna correlates with zone OCG and the lower part of zone OCH (Fig. 3).

The base of the upper fauna is not correlated with any stratigraphic level below the base of zone OCH because of the absence of any Phragmodus species. McTAVISH and LEGG (Fig. 3) recognized two species of Phragmodus in zone OCH; Phragmodus sp. A and Phragmodus sp. cf. P. inflexus. If Phragmodus sp. A refers to Phragmodus sp. A of SWEET, ETHINGTON and BARNES (1971) then the base of the upper fauna may not be placed below the base of zone OCH. This is indicated because the latter species is synonymous with Phragmodus flexuosus which does not range below the lower stratigraphic limit of Phragmodus polystrophos sp. nov. (herein). An equation of Phragmodus sp. A of McTAVISH and LEGG with Phragmodus spicatus sp. nov. (herein) and of Phragmodus sp. cf. P. inflexus (ibid.) with Phragmodus polystrophos is preferred. An important taxonomic feature of Phragmodus polystrophos is the incipient denticulation or serration of the lower, anterior edge of the cusp and anticusp of the dichognathiform element. The major criterion for the distinction of Phragmodus inflexus from Phragmodus flexuosus (sensu MOSKALENKO 1973; synonymous with Phragmodus sp. A of SWEET, ETHINGTON and BARNES, 1971) is the presence in the former species of a single, incipient denticle on the anterior margin of the cusp of some specimens of the dichognathiform element. The margin is invariably smooth in

Phragmodus spicatus but is serrated in Phragmodus polystrophos (Pl. 7, Fig. 16b). McTAVISH and LEGG's qualified identification of Phragmodus sp. cf. P. inflexus may indicate the recognition of the presence of more than one incipient denticle in the serrated margin of the dichognathiform element of Phragmodus polystrophos.

Support for this view is provided by the overlapping ranges of Phragmodus sp. A (McTAVISH and LEGG) and Spathognathodus sp. in the lower part of zone OCH. Also, Phragmodus inflexus is generally interpreted as an evolutionary successor to Phragmodus flexuosus and characteristic of Midcontinent Fauna 6 and so occurs above the upper limit of the stratigraphic range of Eoplacognathus suecicus in the Pygodus anserinus Zone and higher. The highest North Atlantic zonal species reported to date from the Canning Basin is Eoplacognathus foliaceus which is listed by McTAVISH and LEGG (Fig. 3) above the upper limit of Phragmodus sp. cf. P. inflexus in zone OCJ.

Inter-Regional Correlation:

The boundary between Midcontinent conodont Faunas 4 and 5 (SWEET, ETHINGTON and BARNES, 1971) marks the extinction of the Whiterockian Histiodella lineage of species and the widespread introduction of Phragmodus flexuosus (sensu MOSKALENKO, 1973) that is characteristic of the early Chazyan (RARING, 1972).

The evidence discussed below suggests that this conodont faunal change took place on all the major cratonic blocks located in palaeoequatorial latitudes in the Eoplacognathus suecicus Zone and that little, if any, overlap of Whiterockian and Chazyan conodont faunas occurred.

In the Canning Basin section studied, the faunal change (i.e. the boundary between the upper and lower faunas) occurs within a four metre sampling gap. There is no obvious lithological evidence within this interval for a major hiatus or sea level change.

Sedimentation throughout the Canning Basin section is interpreted to have been rapid in view of the large stratigraphic interval (ca.100m) of uniform conodont faunas.

There are three sections with detailed published conodont data which correlate well with this Canning Basin section. One of these is in North China and two are in the Midcontinent Conodont Province of the U.S.A.

North China:

AN et. al., (1983) documented conodont faunas from the Majiagou Formation of Hebei, Tangshan and Fengfeng Provinces that correlate well with those in the Canning Basin although Phragmodus polystrophos is not reported. The Fauna 4 assemblage from the lower Majiagou Formation includes the following taxa in common with the lower fauna (synonyms in parentheses): Ansella sp. nov. (Belodella rigida), cf. ?Coleodus sp. (Loxodus dissectus), Histiodella holodentata (Histiodella infrequensa), Tangshanodus tangshanensis and Genus and species indeterminate A

(Ulrichodina sp. aff. U. wisconsinensis). In addition to these, Protopanderodus nogamii (Scolopodus nogamii and Scolopodus euspinus) and Erraticodon balticus (Erraticodon tangshanensis) also occur in both the Fauna 4 assemblage and a stratigraphically higher Fauna 5 assemblage, as they do in the Canning Basin.

The Fauna 5 assemblage is present in the upper Majiagou Formation. It includes Ansella sp. (Belodella rigida), Dapsilodus nevadensis? (Dapsilodus compressus), Eoplacognathus suecicus and Oistodus sthenus. These two faunas are separated stratigraphically by approximately one hundred metres of grey and yellow argillaceous limestone, dolomitic limestone and breccia which yielded only a few elements of Scolopodus flexilis and Scandodus spp. No unconformity is reported in this interval (AN et. al., 1983).

The absence of Phragmodus polystrophos from the upper Majiagou Formation is puzzling in view of the other taxa in common with the Canning Basin. Plectodina onychodonta is characteristic of the fauna of the uppermost part of the upper Majiagou Formation where it first appears approximately 40m above the lowest occurrence of Eoplacognathus suecicus. Plectodina onychodonta has not been identified in the Canning Basin although its ozarkodiniform element is similar to ozarkodiniform A of this study. No elements similar to the other members of the apparatus have been recognized.

Midcontinent Conodont Province U.S.A.:

Phragmodus polystrophos is reported from three localities in the western U.S.A. In the Ibex Area of Utah, it is present in the Crystal Peak Dolomite (ETHINGTON and CLARK, 1981). In Nevada, it is present in the Antelope Valley Formation at Meiklejohn Peak (HARRIS et. al., 1979) and near Steptoe in the Egan Range (ETHINGTON and CLARK 1981, p. 82). This last occurrence is not fully documented.

In the Crystal Peak Dolomite Phragmodus polystrophos occurs in association with a limited fauna in which Dapsilodus nevadensis and possibly New Genus 5 (ETHINGTON and CLARK, 1981) are in common with the upper fauna of the Canning Basin. Histiodella holodentata in the Ibex Area ranges only up to the lowermost strata of the Watson Ranch Quartzite and is thus stratigraphically discrete from Phragmodus polystrophos which is not reported from strata below the Crystal Peak Dolomite. Erraticodon balticus, Protopanderodus nogamii and possibly Ansella sp. nov. are also present in these strata of the Ibex Area. Eoplacognathus suecicus is not reported.

In the Meiklejohn Peak section, Phragmodus polystrophos occurs together with Eoplacognathus suecicus in the lower part of its stratigraphic range. The currently defined, lower stratigraphic limits of these taxa (in that section) are the same; at a level approximately 15m above the highest reported occurrence of Histiodella holodentata. Stratigraphic ranges in the section are defined by 15m sampling intervals (A. G. HARRIS, pers. comm., 1984). Histiodella holodentata is associated with a fauna that includes cf. ?Coleodus sp. and Juanognathus leptosomatus in common with the Canning Basin lower fauna.

A. G. HARRIS (pers. comm., 1984) reports that in the Steptoe section, Phragmodus polystrophos cooccurs with Phragmodus flexuosus through a 30m interval in the Lehmann Formation. Eoplacognathus suecicus is not reported and no stratigraphic overlap is demonstrated with Histiodella holodentata (HARRIS et. al., 1979, p. 12).

Unpublished data (NOWLAN, 1976) from Arctic Canada also records the same faunal change. Phragmodus polystrophos was recovered from samples of the Bay Fiord Formation in the Irene Bay area of Ellesmere Island only above the highest reported occurrence of Histiodella holodentata. In a section through the Bay Fiord Formation on Devon Island, two elements of an ambalodontiform element, probably of Eoplacognathus suecicus, were reported in association with Phragmodus polystrophos. Published information from Arctic Canada (BARNES, 1974, 1977) is not sufficiently detailed and there is only one record of Phragmodus flexuosus (undifferentiated sensu MOSKALENKO, 1973) from the upper Ship Point Formation. No definite Fauna 4 assemblages are reported. Conodont faunas listed from the lower Ship Point Formation and Eleanor River Formation are older.

Appalachian Region:

Detailed published data from several sections in the

Appalachian region document conodont assemblages that are correlated with Midcontinent Fauna 4 and thus with the lower fauna (this study) of the Canning Basin. None of these occurrences are demonstrably younger than the ?Eoplacognathus variabilis Zone. The region is important for correlation of the Midcontinent conodont Faunas with the North Atlantic conodont Zones (BERGSTRÖM, 1971, 1973, 1983) because of the "mixed" faunas which occur. However, from the evidence outlined below, it appears that there are no sections with "mixed" conodont faunas in which continuous sedimentation has been demonstrated across the Fauna 4 and Fauna 5 boundary or that correlate with the Eoplacognathus suecicus Zone. All reports of Phragmodus flexuosus include a cyrtoniodontiform element (i.e. sensu stricto) in the apparatus and range no lower than the Eoplacognathus foliaceus Zone.

Fauna 4 assemblages (with Histiodella holodentata) are recorded from the Deep Kill Shale of New York State (LANDING, 1976), the Levis Formation and Mystic Conglomerate of Quebec (UYENO and BARNES, 1970, BARNES and POPLAWSKI, 1973), the Table Head Formation (FÅHRAEUS, 1970, STOUGE, 1981), and St. George Group (STOUGE, 1982, STOUGE and BOYCE, 1983) of western Newfoundland and the Buchans Group (NOWLAN and THURLOW, 1984) from central Newfoundland.

Of these occurrences only the Levis Formation and the Table Head Formation (FÅHRAEUS, 1970) include conodont faunas with a North Atlantic Zonal index species:

?Eoplacognathus variabilis. The Mystic Conglomerate was reported originally with Eoplacognathus suecicus but this was a misidentification (LANDING, 1976, p. 626). STOUGE (1981, 1984) tentatively correlated the youngest faunas of the topmost Table Head Formation with the Eoplacognathus suecicus Zone. This interpretation was based on the occurrence of Walliserodus ethingtoni, Ansella jemtlandica and Periodon aculeatus. All of these taxa range (at least) well into the ?Eoplacognathus variabilis Zone. LANDING (1976) preferred a correlation of the Deep Kill Shale conodont fauna (from the Paraglossograptus tentaculus Zone) with the Didymograptus hirundo Zone of the British graptolite scheme (Fig. 4), based primarily on the occurrence of Trigonograptus ensiformis. The conodont fauna is strikingly similar with those of the Levis Formation and the Mystic Conglomerate. The conodont fauna of the Buchans Group cannot be correlated directly with any North Atlantic Zone. It is most similar to the faunas of the Mystic Conglomerate, Deep Kill Shale (Paraglossograptus tentaculus Zone) and the Levis Formation. The youngest St. George Group fauna includes the genus Eoneoprioniodus which indicates a stratigraphic level below that of the lower fauna in the Canning Basin.

BERGSTRÖM (1979) described a conodont fauna of Whiterockian aspect from the Hølonda Limestone of the Trondheim Region in the Norwegian Caledonides. The fauna includes Histiodella holodentata, Ansella sp. nov., Erraticodon balticus and cf. ?Coleodus sp. in common with the lower fauna of the Canning Basin and is similar to those faunas of the North American Appalachian region discussed above. BERGSTRÖM preferred a correlation with the Didymograptus bifidus graptolite Zone which indicates a probable equivalence with the North Atlantic ?Eoplacognathus variabilis conodont Zone (Fig. 4).

From the above evidence, it appears that tectonism along the Appalachian chain (associated with the closing of the Iapetus Ocean) at a time equivalent with the upper ?Eoplacognathus variabilis or Eoplacognathus suecicus Zones delayed marine transgression and incursion of the Phragmodus-bearing Chazyan conodont fauna until the time of the Eoplacognathus foliaceus Zone.

Siberian Platform:

Phragmodus flexuosus (undifferentiated sensu MOSKALENKO, 1973) is reported from the base of the Volginskian "Substage" (MOSKALENKO, 1976) in strata exposed along the Podkammennaya Tunguska River together with an undescribed species of Histiodella. No precise details of this possible cooccurrence are published and stratigraphically diagnostic North Atlantic conodonts are not reported. To the south in the area of the Lena and Nepa Rivers, typical Volginskian conodonts cooccur with Cahabagnathus friendsvillensis and Eoplacognathus lindstroemi indicating a stratigraphic level within the Pygodus serra Zone.

Strata of the Volginskian "Substage" overlie the 200m thick Guragirsky "Stage" comprised of unfossiliferous red and variegated dolostones and marls with desiccation cracks and halite psuedomorphs. Below this stage, the Kimajsky "Stage" of subtidal, bioclastic limestones is reported (MOSKALENKO, 1976) to include a conodont fauna correlatable with the Lower Ordovician Fauna D of ETHINGTON and CLARK (1971). An undescribed species of *Histiodella* is reported from the uppermost strata of the "Stage".

Possible Inter-Regional Correlations.

South Korea:

The Jigunsan Formation of Kangweon-do in South Korea contains a conodont fauna (LEE, 1977) that correlates well with that of the upper Majiagou Formation of North China and thus possibly with the upper fauna of the Canning Basin (this study). *Phragmodus polystrophos* is not present and the correlation is based upon the presence of *Plectodina onychodonta*, *Aurilobodus aurilobodus* and *Dapsilodus nevadensis?*. Of these taxa, only *Dapsilodus nevadensis?* is known from the Canning Basin. A polyplacognathiform element in the fauna was tentatively identified by LEE (1977) as *Eoplacognathus foliaceus*. The stratigraphically long-ranging species *Protopanderodus nogamii* and elements of the genus *Ansella* occur in common with the Canning Basin. The Yeongheung Formation (LEE, 1979) includes a similar fauna with *Erraticodon balticus*.

The Maggol Limestone underlies the Jiqunsan

Formation and has a similar conodont fauna with Plectodina onychodonta and Aurilobodus aurilobodus in its upper part. The fauna in the lower part of the formation is not stratigraphically diagnostic. Elements identified as Drepanodus altipes and Coelocerodontus digonius resemble aff. Cornuodus sp. of the lower fauna in the Canning Basin but a reliable identification of this taxon is impossible with the available data. The Fauna 4 and Fauna 5 boundary, if present, must occur in this lower part of the Maggol Formation as the conodont fauna of the underlying Dumugol Formation is comprised of simple cones indicative of an Early Ordovician age.

South America:

The top of the San Juan Formation (SERPAGLI, 1974, Zone E) may be as young as the lower fauna of the Canning Basin. However, a confident correlation is not possible as only two stratigraphically non-diagnostic taxa occur in common (with the Canning Basin section). Protopanderodus nogamii (Panderodus sp. of SERPAGLI) ranges through the two preceeding Zones (C and D) which include taxa (Oistodus multicorrugatus and Periodon flabellum) indicative of a lower stratigraphic position. Belodella sp. A (SERPAGLI s.f.) is not diagnostic of any particular multielement species of Ansella. Other possible taxa in common occur lower in the San Juan Formation. They include Bergstroemognathus sp., aff. Cornuodus sp., Drepanoistodus forceps, Oepikodus sp. cf. O. communis and Protopanderodus sp. cf. P. gradatus. Of these, only Drepanoistodus forceps is present in the San Juan Formation above Zone C. None are present in Zone E.

Tasmania:

BANKS and BURRETT (1980) report Histiodella sinuosa indicative of Fauna 3 or 4 from the Karmberg Limestone and also Phragmodus flexuosus (undifferentiated sensu MOSKALENKO, 1973) from a level just below the base of and in the overlying Cashions Creek Formation. The Karmberg Limestone includes the Wherretts Chert Member in its upper part which is irregular in thickness. The chert is believed to be possibly after anhydrite (B.A. STAIT pers. comm. 1984). The stratigraphic relationship between this chert member and the conodont taxa above is not known. The boundary between the Karmberg Limestone and the Cashions Creek Formation is conformable (WEBBY et. al., 1981).

Fig. 3 Informal Canning Basin conodont zonation of McTAVISH and LEGG (1976, p. 458).

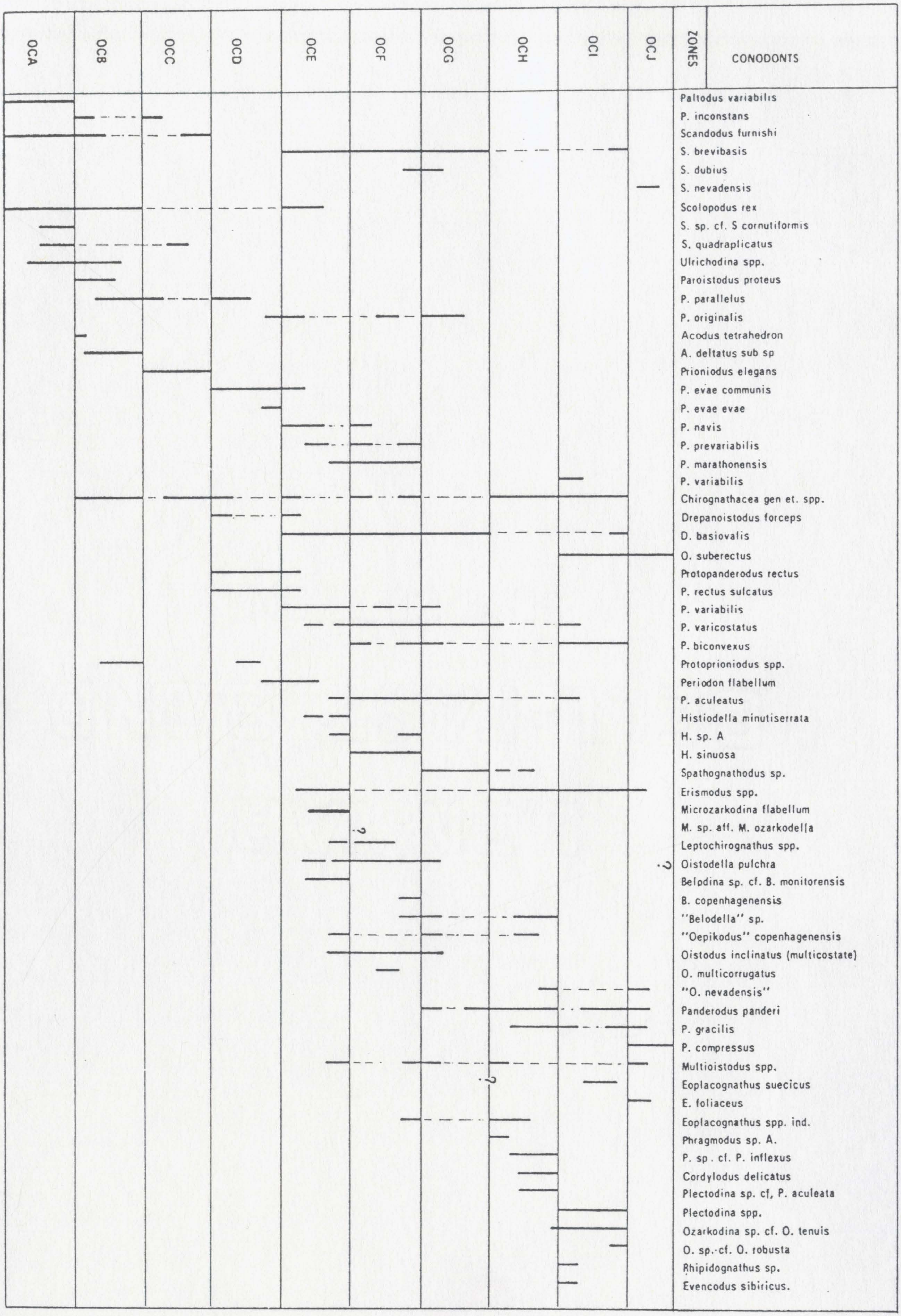
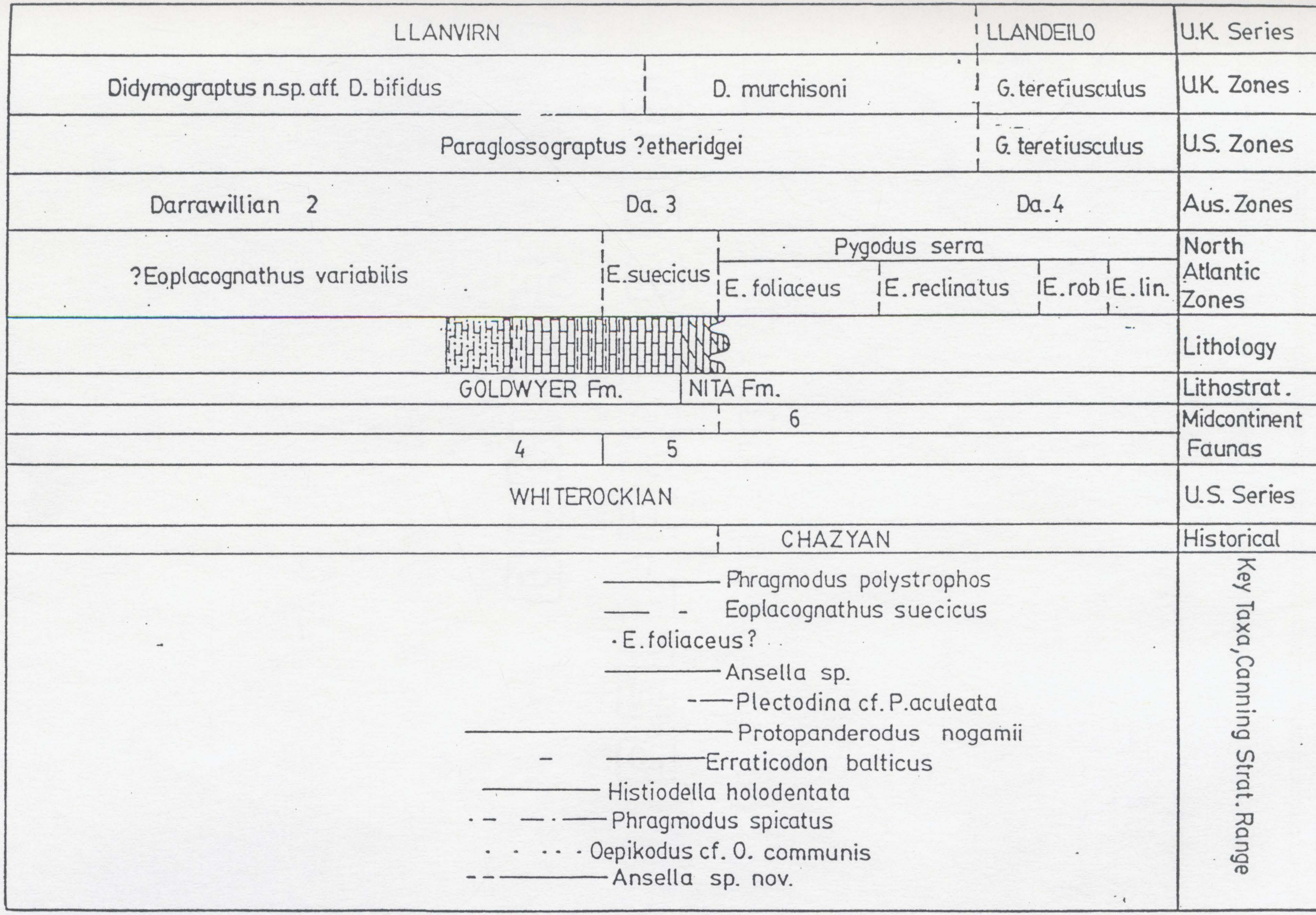

OCA
OCB
OCC
OCD
OCE
OCF
OCG
OCH
OCI
OCJ
ZONES
CONODONTS
Paltodus variabilis
P. inconstans
Scandodus furnishi
S. brevibasis
S. dubius
S. nevadensis
Scolopodus rex
S. sp. cf. S cornutiformis
S. quadraplicatus
Ulrichodina spp.
Paroistodus proteus
P. parallelus
P. originalis
Acodus tetrahedron
A. deltatus sub sp
Prioniodus elegans
P. evae communis
P. evae evae
P. navis
P. prevariabilis
P. marathonensis
P. variabilis
Chirognathacea gen et. spp.
Drepanoistodus forceps
D. basiovalis
O. suberectus
Protopanderodus rectus
P. rectus sulcatus
P. variabilis
P. varicostatus
P. biconvexus
Protoprioniodus spp.
Periodon flabellum
P. aculeatus
Histiodella minutiserrata
H. sp. A
H. sinuosa
Spathognathodus sp.
Erismodus spp.
Microzarkodina flabellum
M. sp. aff. M. ozarkodella
Leptochirognathus spp.
Oistodella pulchra
Belodina sp. cf. B. monitorensis
B. copenhagenensis
"Belodella" sp.
"Oepikodus" copenhagenensis
Oistodus inclinatus (multicostate)
O. multicorrugatus
"O. nevadensis"
Panderodus panderi
P. gracilis
P. compressus
Multioistodus spp.
Eoplacognathus suecicus
E. foliaceus
Eoplacognathus spp. ind.
Phragmodus sp. A.
P. sp. cf. P. inflexus
Cordylodus delicatus
Plectodina sp. cf, P. aculeata
Plectodina spp.
Ozarkodina sp. cf. O. tenuis
O. sp. cf. O. robusta
Rhipidognathus sp.
Evencodus sibiricus.
?
?
?

Fig. 4 Correlation of conodonts from the upper Goldwyer and Nita formations of the Canning Basin with established graptolite and conodont zones (adapted from ROSS _et_. _al_., 1982).


LLANVIRN
LLANDEILO
U.K. Series
Didymograptus n.sp. aff. D. bifidus
D. murchisoni
G. teretiusculus
U.K. Zones
Paraglossograptus ?etheridgei
G. teretiusculus
U.S. Zones
Darrawillian 2
Da. 3
Da. 4
Aus. Zones
?Eoplacognathus variabilis
E. suecicus
Pygodus serra
E. foliaceus
E. reclinatus
E. rob
E. lin.
North Atlantic Zones
Lithology
GOLDWYER Fm.
NITA Fm.
Lithostrat.
6
4
5
Midcontinent Faunas
WHITEROCKIAN
U.S. Series
CHAZYAN
Historical
Phragmodus polystrophos
Eoplacognathus suecicus
E. foliaceus?
Ansella sp.
Plectodina cf. P. aculeata
Protopanderodus nogamii
Erraticodon balticus
Histiodella holodentata
Phragmodus spicatus
Oepikodus cf. O. communis
Ansella sp. nov.
Key Taxa, Canning Strat. Range

SUMMARY AND CONCLUSIONS

The conodont biostratigraphy of the subsurface Lower and Middle Ordovician formations of the Canning Basin in north Western Australia is poorly known. The only published information is that of McTAVISH and LEGG (1976) which lacks description of conodont faunas tabulated in an informal zonation scheme (Fig. 3). This study describes condonts extracted from 96 samples (160kgms of rock) of a 230m (approximately) continuous core section through the Middle Ordovician Nita and (upper) Goldwyer formations on the Broome Arch in the west central part of the basin (Fig. 1).

The study has revealed two stratigraphically discrete conodont faunas each ranging through approximately half of the section (Fig. 5). The lower fauna is correlated with Midcontinent Fauna 4 (SWEET, ETHINGTON and BARNES, 1971) and the upper fauna is correlated with Midcontinent Fauna 5 and with the *Eoplacognathus suecicus* Zone (BERGSTRÖM, 1971). The lower fauna includes the following new conodont species: *Falodus keramis* sp. nov. s.f., *Protoprioniodus histion* sp. nov., *Phragmodus spicatus* sp. nov. Other significant taxa are as follows: *Ansella* sp. nov., cf. ?*Coleodus* sp., *Drepanoistodus forceps*, *Erraticodon balticus*, *Histiodella holodentata*, *Juanognathus leptosomatus*, *Oepikodus* sp. cf. *O. communis*, *Protopanderodus* sp. cf. *P. gradatus*, *Protopanderodus nogamii*, *Scolopodus* sp. cf. *S. cornuformis*, *Trigonodus larapintinensis* and aff. *New*

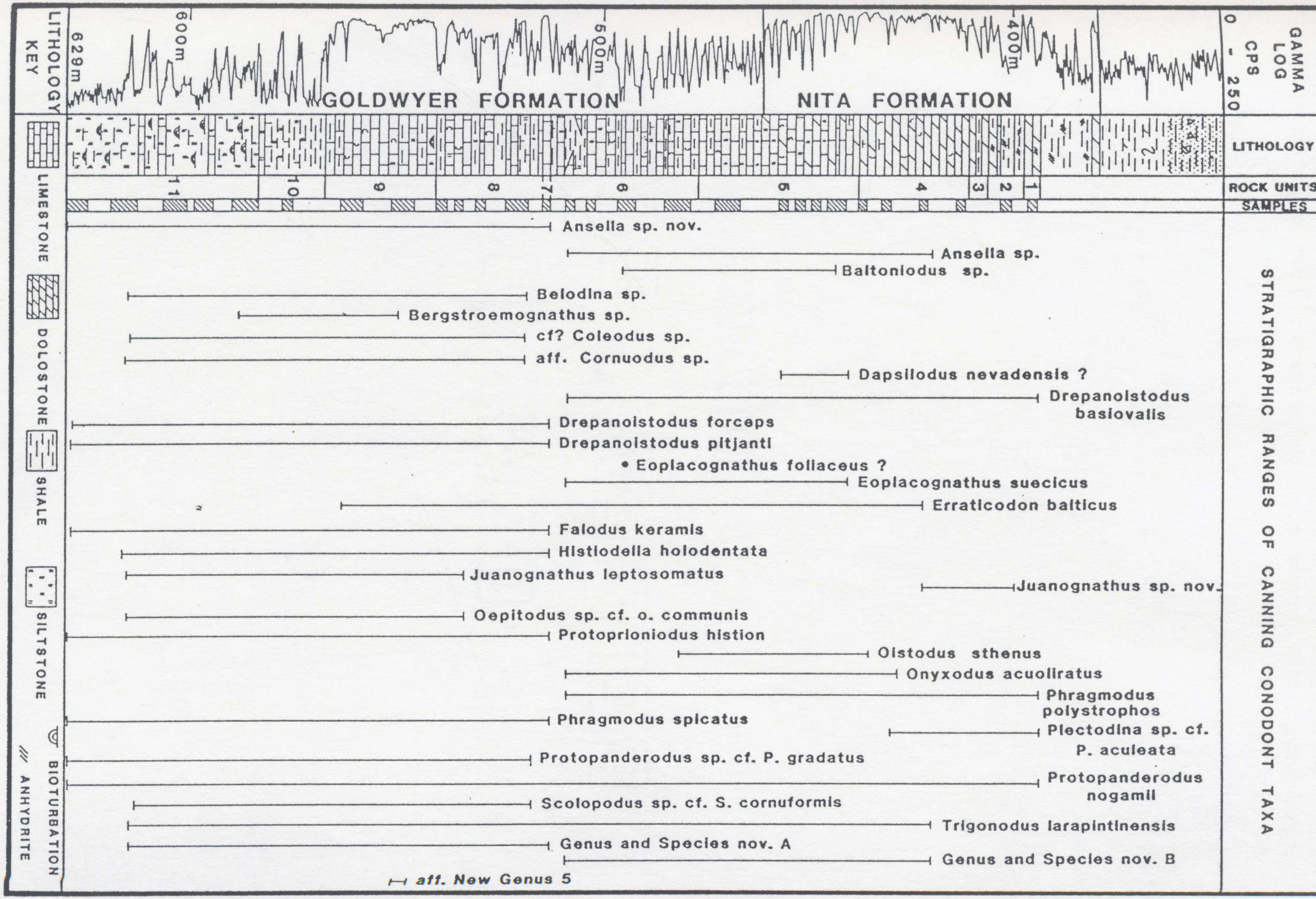
Genus 5.

The upper fauna includes the following new conodont taxa: *Onyxodus acuoliratus* gen. et sp. nov. and *Phragmodus polystrophos* sp. nov. Other significant taxa are as follows: *Ansella* sp., *Dapsilodus nevadensis*?, *Drepanoistodus basiovalis*, *Eoplacognathus foliaceus*?, *Eoplacognathus suecicus*, *Erraticodon balticus*, *Protopanderodus nogamii*, *Trigonodus larapintinensis* and *Oistodus sthenus* s.f. In addition, a change in facies from subtidal limestone to subtidal/intertidal dolostone that occurs towards the top of the section is associated with the incoming of *Plectodina* sp. cf. *P. aculeata*.

These new data have contributed to a better understanding of the apparatuses of the genera *Ansella* *Erraticodon* and *Phragmodus*. In particular, the two new species of *Phragmodus* are significant. *Phragmodus polystrophos* is recognized as distinct from *Phragmodus flexuosus* (MOSKALENKO) and with a lower stratigraphic range, i.e. including the *Eoplacognathus suecicus* Zone and below the lowest reported stratigraphic occurrence of *Phragmodus flexuosus*, in the *Eoplacognathus foliceus* Zone. *Phragmodus spicatus* cooccurs with *Histiodella holodentata* (indicative of Micontinent Fauna 4) and as such, is the stratigraphically lowest ranging species of the genus described to date. The apparatus of *Phragmodus spicatus* includes most of elements recognized in later species; i.e. subcordylodontiform (*a*), phragmodontiform (*b*), trichonodelliform (c), cyrtoniodontiform (e) and dichognathiform (f).

The boundary between the two conodont faunas (upper and lower) in the section, appears to be abrupt (located within a 4m interval sampling gap; Fig. 5) and is correlated with a level within Zone OCH of McTAVISH and LEGG's (1976) informal Canning Basin conodont zonation scheme. Regionally, the boundary is correlated with similar faunal changes in the Majiagou Formation of North China (AN et. al., 1983), the Watson Ranch Quartzite of the Ibex Area of Utah (ETHINGTON and CLARK, 1981) and the Antelope Valley Limestone of the Meiklejohn Peak section in Nevada (HARRIS et. al., 1979). This correlation between three continental blocks that were discrete in Ordovician times indicates that the cause of the faunal change was probably global in extent. The correlation of the upper fauna with the Eoplacognathus suecicus Zone in each of the three localities, suggests that the faunal change was approximately isochronous. The Micontinent Fauna 4 and Fauna 5 boundary is particularly significant as it marks the termination of the characteristically Whiterockian Histiodella lineage of species and its replacement by Phragmodus-bearing conodont faunas of Chazyan aspect.

Fig. 5 Sample distribution and stratigraphic ranges of key conodont taxa through the upper Goldwyer and Nita formations, Canning Basin, Western Australia



LITHOLOGY KEY
LIMESTONE
DOLOSTONE
SHALE
SILTSTONE
BIOTURBATION
ANHYDRITE
629m
600m
500m
400m
GOLDWYER FORMATION
NITA FORMATION
GAMMA LOG
0 - 250 CPS
LITHOLOGY
ROCK UNITS
SAMPLES
11
10
9
8
7
6
5
4
3
2
1
STRATIGRAPHIC RANGES OF CANNING CONODONT TAXA
Ansella sp. nov.
Ansella sp.
Baltoniodus sp.
Belodina sp.
Bergstroemognathus sp.
cf? Coleodus sp.
aff. Cornuodus sp.
Dapsilodus nevadensis ?
Drepanoistodus basiovalis
Drepanoistodus forceps
Drepanoistodus pitjanti
• Eoplacognathus foliaceus ?
Eoplacognathus suecicus
Erraticodon balticus
Falodus keramis
Histiodella holodentata
Juanognathus leptosomatus
Juanognathus sp. nov.
Oepitodus sp. cf. o. communis
Protoprioniodus histion
Oistodus sthenus
Onyxodus acuoliratus
Phragmodus polystrophos
Phragmodus spicatus
Plectodina sp. cf. P. aculeata
Protopanderodus sp. cf. P. gradatus
Protopanderodus nogamii
Scolopodus sp. cf. S. cornuformis
Trigonodus larapintinensis
Genus and Species nov. A
Genus and Species nov. B
aff. New Genus 5

SYSTEMATIC PALAEONTOLOGY

Multielement taxonomy has been used wherever possible. The apparatus and element notation scheme of BARNES et. al., (1979) has been used in conjunction with the descriptive form terminology widely adopted after LINDSTRÖM (1955). This is in preference to the terminology recommended by SWEET (1981, in ROBINSON ed. p. w16-w20) which assumes that most apparatuses include elements homologous with those of basic seximembrate or septimembrate plans. This concept is not necessarily valid for conodonts of the Lower and Middle Ordovician; a time of maximum conodont diversity and rapid evolution. In cases where two distinctive variants of a particular element have been identified in a known apparatus (e.g. the asymmetrical (t) element of *Onyxodus acuoliratus* gen. et. sp. nov.) one has been distinguished by the addition of a "prime-mark" above the designated letter code (e.g. (t) and (t')). Distinguishing criteria are discussed in the systematic description of the relevant taxon.

One new form-species is described: *Falodus keramis* sp. nov. s.f. This species comprises an element with two morphological variants which have been labelled informally as the (x) and (y) morphotypes. Other form species have not been named but are identified either as species in open nomenclature with the assigned suffix s.f. (*sensu formae*

BARNES and POPLAWSKI, 1973) or simply by descriptive form-terms e.g. scandodontiform A.

Taxa are ordered alphabetically in the following systematic discussion.

All specimens are temporarily housed with Western Mining Corporation, 168 Greenhill Road, Parkside, South Australia. Upon completion of studies, all specimens will be lodged with the Western Australian Geological Survey, Perth or the Bureau of Mineral Resources, Canberra.

GENUS ANSELLA FÅHRAEUS and HUNTER, 1985

Type species: Belodella jemtlandica (LÖFGREN), 1978.

Remarks: The elemental terminology of LÖFGREN (1978) was not found to fully describe the elemental variation of the apparatuses described below and is not used. The following terminology is employed: oepikodontiform (symmetrical (a) and asymmetrical (b)); for denticulate elements with a sharp anterior margin to the cusp and prominent basal keel, belodelliform (c); for denticulate elements with a pair of basal keels, a bicostate cusp and a triangular posterior outline, either symmetrical or asymmetrical, oistodontiform (e); drepanodontiform (f); for non-denticulate, asymmetrical elements with the basal cavity expanded only on the outer side giving a plano-convex or sub-triangular basal cross-section and erectiform (g); for non-denticulate elements with a prominent basal keel, basal cavity laterally expanded on both sides and approximately straight-sided and triangular in lateral outline.

Ansella sp. nov.
Pl. 4, figs. 16-18,21-24

?1970 Belodella sp. A FÅHRAEUS, p. 2064, fig. 30.

?1974 Belodella n. sp. s.f. BARNES, p. 230, Pl. 1, fig. 11.

cf.1974 Belodella sp. A SERPAGLI, p. 38-39, Pl. 8, figs. 7a,b, Pl. 20, fig. 10.

cf.1977 Belodella erecta RHODES & DINELEY, LEE, p. 130, Pl. 2, figs. 8,9.

?1977 _Belodella_ _erecta_ RHODES & DINELEY, BARNES, p. 101, Pl. 2, fig. 7.

?1977 _Belodella_ n. sp. s.f. BARNES, p. 101, Pl. 2, figs. 5,6.

?1979 _Belodella_ sp. A (FÅHRAEUS) BERGSTRÖM, p. 306, fig. 41,m.

?1979 _Belodella_ _nevadensis_ (ETHINGTON & SCHUMACHER), HARRIS _et_. _al_., Pl. 3, figs. 10-13.

?1979 ?_Belodella_ _erecta_ RHODES & DINELEY, LEE, p. 43, Pl. 2, fig. 9.

?1979 _Belodella_ nov. sp. BARNES, LEE, p. 44, Pl. 2, figs. 1,2.

?1979 _Oepikodus_ sp. cf. _O_. _copenhagenensis_ (ETHINGTON & SCHUMACHER) LEE, p. 46, Pl. 2, figs. 5,6.

?1980 _Belodella_ _erecta_ RHODES & DINELEY, LEE, p. 6,7, Pl. 2, fig. 12.

?1980 _Oepikodus_ _copenhagenensis_ (ETHINGTON & SCHUMACHER) LEE, p. 7, Pl. 2, fig. 13.

?1981 _Belodella_ _robusta_ ETHINGTON & CLARK, p. 25-26, Pl. 2, figs. 1-4.

?1983 _Belodella_ _rigida_ AN _et_. _al_., p. 77-78, Pl. 18, figs. 12-18, text-fig. 12; 24-27.

Diagnosis: A species of _Ansella_ with an apparatus consisting of symmetrical and asymmetrical oepikodontiform (_a_ & _b_) and belodelliform (_c_) elements in a symmetry transition series, an oistodontiform element (_e_) and drepanodontiform (f) and erectiform (g) elements in a second symmetry transition series in a Type IVB apparatus.

Description: Symmetrical oepikodontiform (a) element is similar to Oepikodus copenhagenensis (ETHINGTON and SCHUMACHER). Cusp is proclined, curved and laterally compressed with sharp, keeled anterior and posterior margins. Lateral faces are convex, each with faint costa located posteriorly. Costae do not project across base as in O. copenhagenensis. Anterior margin of cusp forms smooth, arcuate curve with basal margin. Keel is strongest along anterior of base but fades rapidly near posterior margin. Denticles of upper basal margin are fused and increase in size from posterior to anterior. Denticles are very small and erect posteriorly. Denticle next to cusp is largest and is proclined and fused for much of its length to posterior margin of cusp. Basal cavity is conical, deep and triangular in lateral outline. Apex is adjacent to basal margin in line with downward projection of anteriormost, proclined denticle. Tip of cavity may be downturned. Cavity is laterally expanded on one or both sides with oval posterior outline. Walls of cavity are thin.

Asymmetrical oepikodontiform (b) element is similar to Oepikodus sp. aff. O. copenhagenensis (ETHINGTON and SCHUMACHER). Element differs from a element in marked asymmetry. It is rarely straight but more commonly, strongly laterally curved. Cusp is twisted throughout its length, to appear antero-posteriorly compressed distally, with prominent, tall, sharp lateral costae. Towards base, cusp is rotated so that costae intersect upper and lower margins of base as keels. Anterior keel is continuous along lower basal margin and inwardly deflected. In lower part of cusp, lateral faces bear a prominent, rounded costa or carina. In laterally curved elements, costa is stronger on inner side but never projects far onto base. Denticulation is similar to that of a element but increases more evenly in size from posterior to anterior and more denticles tend to be anteriorly inclined. Anteriormost denticle is largest but not as prominent as in a element and is less fused to cusp. In some specimens, denticle row is sinuously, laterally flexed with sub-erect denticles of sub-equal size, except for anteriormost two or three. Basal cavity is deeper than in a element and expanded only on outer side giving plano-convex cross-section.

Some belodelliform (c) elements are similar to New Genus A (ETHINGTON and SCHUMACHER) but a much greater variety of form is evident than in the original collection of only three specimens. Cusp is proclined to distally erect, and curved. It is antero-posteriorly compressed with semi-circular, smoothly rounded anterior face and prominently keeled posterior margin. Each lateral face bears single, strong, sharp costa. Costae are continuous as keels along lower edge of base to posterior margin. Keels are more or less increasingly strongly flared outwards and downwardly flexed, posteriorly. Upper basal margin is straight and denticulate. Denticle size varies greatly between specimens but in any given element, it is more even than in a and b elements. Largest denticles are located in mid-portion of row. Denticles tend to be uniformly sub-erect or slightly anteriorly inclined. Basal cavity is deep and triangular in lateral outline with apex at base of cusp below anteriormost denticle. Cavity is thin-walled and relatively flat-sided with triangular cross-section and flat base between two basal keels. Most specimens are slightly asymmetrical with one costa on cusp located anteriorly and other costa closer to midline. Relief of costae and basal keels is greatly variable between specimens.

Oistodontiform (e) element is similar to O. nevadensis (ETHINGTON and SCHUMACHER) with reclined cusp, commonly slightly twisted, inner, rounded costa and sharp, anterior and posterior margins. Cusp is commonly inwardly flexed. Base is long posteriorly and slightly expanded inwards, enclosing large basal cavity. Upper basal margin is keeled and gently convex; lower basal margin is sigmoidal in lateral outline.

This element differs from O. nevadensis in consistently having a longer cusp relative to the base; it projects about one base-length beyond the posterior terminus. In this, it more resembles the oistodontiform element of Ansella robusta (ETHINGTON and CLARK).

Non-denticulate elements similar to the f and g elements of this apparatus were not reported by ETHINGTON and SCHUMACHER (1969).

Drepanodontiform (f) element resembles the biconvex element of Ansella robusta (ETHINGTON and CLARK). Element is claw-shaped in lateral outline and laterally compressed. Cusp is short relative to base and proclined with sharp posterior and anterior margins. Anterior margin is keeled in lower portion. Anterior keel is continuous and stronger along basal margin. Keel is deflected slightly inwards and rather blunt-edged. Upper basal margin is sharp. Lateral faces of base may bear narrow, low, rounded costa. If present, costa on inner lateral face is located just above and parallel to base of keel. On outer lateral face, costa is closer to midline. On both faces, costae fade up cusp. Basal cross-section is narrow and asymmetrically triangular in posterior outline with rounded basal corners (rather like the element of Ansella jemtlandica (LÖFGREN) 1978, (Pl. 15, fig. 5b). Basal edge, in posterior outline, connects lateral costae where they intersect posterior margin. Base is thus plano-convex in cross-section. Basal cavity is large, deep and triangular in lateral outline with apex adjacent to antero-basal margin, below posterior margin of cusp.

There is commonly a differentiation of white matter below the upper basal margin suggestive of incipient denticulation but there is no disruption of the smooth line of the upper basal margin.

The erectiform (g) element is unusual and no similar element has been previously reported under Ansella. Cusp is short, straight, strongly proclined and weakly inwardly deflected. Cusp is laterally compressed with sharply keeled anterior and posterior margins. Towards base, each lateral face bears single, broad, low-relief, rounded carina which expands onto base and merges with lateral expansion of basal cavity. Upper and lower basal margins are keeled and lower basal margin forms a nearly straight line with anterior margin of cusp with only weak, rounded, antero-basal flexure. Basal keel may project slightly beyond posterior margin. Upper basal margin is horizontal and straight in lateral outline and meets posterior margin of cusp in very shallow curve of about 160 degrees. Posterior margin of base is straight and vertical. Lateral walls of base are thin and enclose deep, conical basal cavity. Towards upper and lower postero-basal corners, cavity is narrow and laterally compressed but it is laterally expanded along midline of base, slightly more strongly so on inner side. Posterior outline asymmetrically biconvex. Basal cavity is deep and triangular in lateral outline with lower edge parallel to basal margin and junction with upper edge located near midline of element at cusp and base flexure.

Remarks: The synonymy listed for this species is tentative because there are no previously reported apparatuses with the full complement of elements as described here. The synonymy is based on morphologic similarities in <u>c</u>, <u>e</u> and <u>g</u> elements. The taxa differentiated by FÅHRAEUS and HUNTER (1985) as _Ansella nevadensis_, _Ansella jemtlandica_ and _Goverdina alicula_ in Newfoundland, may possibly comprise a single species of _Ansella_ (_Ansella nevadensis_) descended from stratigraphically lower ranging species: _Ansella robusta_ (ETHINGTON and CLARK, 1981), _Ansella rigida_ (AN _et. al._, 1983), _Ansella jemtlandica_ (LÖFGREN, 1978) and _Ansella_ sp. nov. and _Ansella_ sp. from the Canning Basin.

Denticles in some _b_ elements tend to be sub-erect and of sub-equal size as in _A. robusta_. In most specimens they are sloped anteriorly as in _A. jemtlandica_. Denticle size in the _c_ element is extremely variable; ranging from as small as in typical _A. jemtlandica_ to forms several times as large, as in _A. robusta_. Strength of development of the costa on the _f_ element is also variable. Most commonly, costae are readily visible but in a few specimens they are absent. The variability of these characters within this single species indicates that they should be used with caution for taxonomic classification.

Types: Figured specimens, WM00007-13.

Ansella sp.
Pl. 4, figs. 2-3,6-9

Description: The _a_, _b_, _c_ and _f_ elements of this taxon are the same as those of the stratigraphically lower ranging, _Ansella_ sp. nov. The elements show the same range of morphological variation with the exception that no acostate _f_ elements were observed. No _g_ element was observed. The total number of specimens recovered for this species closely approximates the total for Ansella sp. nov. from the lower fauna. Consequently, random sample variation is unlikely to be the cause of the apparent differences between the species noted above.

Types: Figured specimens, WM00014-18,20.

GENUS BALTONIODUS LINDSTRÖM, 1955

Type species: Prioniodus navis LINDSTRÖM, 1955.

?Baltoniodus sp.

Pl. 6, figs. 1-3,5a,b,6,7

aff. 1978 ?Prioniodus (?Baltoniodus) sp. E LÖFGREN, p. 89, Pl. 13, fig. 5.

Description: A species of ?Baltoniodus with an apparatus including keislognathiform (a and/or b), trichonodelliform (c) and tetraprioniodontiform (d) elements in a symmetry transition series and oistodontiform (e), ambalodontiform (f) and amorphognathiform (g) elements; possibly in a Type IVA °apparatus.

Keislognathiform (a/b) element is distinctive with one short, adenticulate, lateral process projecting only slightly below base and a much longer, lateral process bearing two or three, low, widely spaced denticles. This element may fill both the a and b positions in the apparatus but it is also possible that the a element is not represented because of the small size of the collection.

Trichonodelliform (c) element is sub-symmetrical with prominent, denticulate, posterior process and lateral processes similar to larger process of keislognathiform element.

Tetraprioniodontiform (d) element has strongly proclined cusp with four narrowly divergent processes. Posterior process is not as strong as in other ramiform elements but is similar to lateral processes in both height and denticulation. Processes have low, anteriorly inclined, fused denticles and are serrated in outline. Anterior process is a little weaker than others and aligned, keel-like, along anterior and lower margin of base. Basal cavity is deep.

Oistodontiform (e) element has stout cusp with broad carina on inner face. Anterior margin is weakly, sigmoidally curved in outline and posterior margin is shallowly convex. A strong, adenticulate anterior process approaching length of cusp, although not as stout, projects forwards and downwards in line with cusp. Posterior process is quite short.

Ambalodontiform (f) element has prominent, stout cusp. Posterior and lateral processes are long and sub-equally developed. Anterior process is shorter, laterally curved inwards and downwardly deflected at about 45 degrees. It is not recurved beneath cusp. Lateral process is deflected downwards at a lower angle. Processes diverge at approximately 90 degrees. Larger specimens have prominent ledges developed along posterior and lateral processes.

Amorphognathiform (g) element has adenticulate anterior process. Cusp is smaller in relation to stout denticles of posterior and lateral processes. Anterior and lateral processes diverge at about 130 degrees.

Remarks: The apparatus described above is a tentative reconstruction only. The elements are extremely rare in the collection but apart from the oistodontiform element, all the elements described were observed to cooccur.

The single incomplete specimen of the amorphognathiform element is not diagnostic. The oistodontiform element resembles the element illustrated by LÖFGREN (1978, Pl. 13, fig. 5) from the ?E. variabilis Zone. It differs in having a relatively larger cusp. It is certainly more akin in its adenticulate anterior process to later species of the genus (e.g. Baltoniodus prevariabilis FÅHRAEUS).

The ambalodontiform element is unusual for the genus in the development of prominent ledges on the lateral and posterior processes in the larger specimens. In this respect it seems more akin to Eoplacognathus, Amorphognathus and Rhodesognathus. It is tentatively included here because the ledges are not prominent in smaller specimens and the process configuration is different from the ambalodontiform elements herein assigned to Eoplacognathus.

The presence of a good oistodontiform element, the absence of a platform-type amorphognathiform element and also the absence of a holodontiform element (though these might not be expected to be present in such a small collection) mitigate against an assigment to Amorphognathus.

Types: Figured specimens, WM00001-6.

GENUS BELODINA ETHINGTON, 1959

Type species: Belodus compressus BRANSON & MEHL, 1933.

Belodina sp.
Pl. 3, fig. 5

? 1973 Belodina sp. BARNES & POPLAWSKI, p. 770, Pl. 3, fig. 18.

aff.1974 Belodina n. sp. A BARNES, p. 231, Pl. 1, fig. 18.

Description: A belodiniform element with laterally compressed cusp with sharp anterior and posterior, keeled margins. Cusp is straight or inwardly curved and merges with long, high base in smooth, shallow curve giving element a claw-shaped appearance. Anterior keel is continuous along base but terminates short of posterior margin. Keel is blunt along base and inwardly deflected. Posterior keel increases onto base where it is partly or wholly differentiated into several, small, largely fused, sub-erect to posteriorly inclined denticles. Denticles form evenly curved, serrated, upper basal margin. Line of base of denticles and keel is marked by prominent groove along outer face. Posteriormost third of base forms non-denticulate heel with narrow, tightly rounded upper margin just above or in line with denticle tips. Lower basal margin is broadly rounded.

Posterior outline is shaped like an inverted keyhole (i.e. laterally compressed upper portion with parallel flat, inner and outer edges but lower portion expanded with circular outline that includes curve of lower basal margin). Expansion of base rapidly diminishes anteriorly. Base encloses deep, single basal cavity, asymmetrically triangular in lateral outline with lower edge sub-parallel to basal margin and upper edge descending from posterior and upper basal corner down to apex adjacent to basal margin at base of cusp. In some specimens, incipient bifurcation of basal cavity is visible at level of top of basal swelling. Element dominantly albid except for triangular hyaline zone around basal cavity.

Remarks: The small posteriorly sloped denticles are most distinctive. Broadly similar elements have been illustrated from Quebec (BARNES and POPLAWSKI, 1973, Pl. 3, fig. 18) and from the Canadian Arctic (BARNES, 1974, Pl. 1, fig. 18). However, in both illustrated specimens the denticulation is indistinct and in the former instance the denticles are described as anteriorly inclined.

The apparatus to which these elements belongs is unknown. There are no other obviously associated elements and no apparent differentiation of the belodiniform elements into grandiform and compressiform. There is variation between elements in the degree of inward flexure and twisting of the cusp and some specimens are nearly bilaterally symmetrical.

Three specimens of an indeterminate eobelodiniform element (Pl. 3, fig. 4) are present in the collection. Two of these specimens occur together in a single sample, well below the lowest stratigraphic occurrence of the belodiniform element. One specimen is present higher in the section but this is still stratigraphically below the level of all but one of the belodiniform elements. The specimens of the eobelodiniform elements are much larger and more robust than any of the belodiniform elements. It is not possible to confidently group these two elements into a single, typical Belodina apparatus.

Type: Figured specimen, WM00021 and indeterminate eobelodiniform element, WM00023.

GENUS BERGSTROEMOGNATHUS SERPAGLI, 1974

Type species: Oistodus extensus GRAVES & ELLISON, 1941.

Bergstroemognathus sp.
Pl. 5, figs. 16,17,20

Description: Trichonodelliform (c) element is bilaterally symmetrical and arched, with tall, wide, antero-posteriorly compressed, sub-erect cusp, laterally flanked by denticulate processes. Lateral processes each possess between three and seven tall, pointed denticles that decrease in size distally from cusp, from maximum of about two-thirds height of cusp. Denticles are discrete apically but fused basally. Processes are downwards and posteriorly deflected about cusp. Basal cavity is shallow and conical beneath cusp and extends as slit under processes.

There are two variants of trichonodelliform element. One has anterior face of cusp with low, rounded, medial carina which extends downwards as short anticusp. Also, posterior of base is only weakly flared to enclose cavity and lateral processes are only weakly downwardly deflected. In second variant, anticusp is not developed and shallow anterior costa is only weakly developed, if at all but posterior region of base is strongly expanded locally beneath cusp as short, fully excavated, adenticulate process. Lateral processes are strongly, downwardly deflected.

These two variants most probably belong to the same species but whether or not they represent discrete morphotypes in an apparatus or are merely phenotypic variants cannot be determined at this stage. Both variants differ from the trichonodelliform illustrated by SERPAGLI (1974, Pl. 21, fig. 1-7) in their downwardly deflected processes, their flat posterior face to the cusp and uniform curvature in plan.

Only a single good specimen of the prioniodontiform element is preserved. It is similar to that of B. extensus with the only significant difference being a prominent downwards and rounded extension of the basal sheath beneath the cusp on the inner side. The specimen possesses only two anterior denticles though it is possible that there may have been a small, third denticle that is not preserved. The cusp is rather wide and stout. No specimens of a falodontiform element were observed.

Types: Figured specimens, WM00024-6.

GENUS COLEODUS BRANSON & MEHL, 1933

Type species: Coleodus simplex BRANSON & MEHL, 1933.

cf. ?Coleodus sp. s.f. (BARNES & POPLAWSKI, 1973)
Pl. 5, fig. 12

cf. 1973 ?Coleodus sp. s.f. BARNES & POPLAWSKI, p. 771, Pl. 1, fig. 19.

Remarks: Fragments of a hyaline blade comprised of fused and uniformly posteriorly inclined denticles occur commonly in the lower part of the section. The fragments are longitudinally straight but concavo-convex in section with a serrated upper edge. A basal cavity was not preserved in any of the specimens.

Type: Figured specimen, WM00027.

GENUS CORNUODUS FÅHRAEUS, 1966

Type species: Cornuodus erectus FÅHRAEUS 1966.

Discussion: The genus Cornuodus was erected by FÅHRAEUS (1966) in a form sense to include "symmetrical or asymmetrical conodonts lacking edges or costae on a comparatively long base" (ibid. p. 20). SWEET and BERGSTRÖM (1972) regarded the genus as typical of the relatively few monoelemental Ordovician conodont apparatuses. LÖFGREN (1978) reconstructed a bimembrate apparatus for the type species consisting of symmetrical (drepanodontiform) and asymmetrical (scandodontiform) elements; a Type IB apparatus. She regarded Drepanodus longibasis (LINDSTRÖM), as conspecific with the type species and accordingly combined them under the new name Cornuodus longibasis.

In addition to the stated criteria of FÅHRAEUS for the form-distinction of the genus, the presence of asymmetrical scandodontiform elements in the apparatus and the deep, Panderodus-like basal cavity are also characteristic. The lack of grooves distinguishes the genus from Panderodus (ETHINGTON), the lack of surface striation distinguishes it from Scalpellodus (DZIK) and the termination of the basal cavity at the base of the cusp distinguishes it from Coelocerodontus (ETHINGTON).

The apparatus described below and tentatively assigned to this genus does not conform to the generic diagnosis of Cornuodus FÅHRAEUS in that, the upper and lower basal margins are sharp in most specimens and in some, a pronounced keel is developed along the lower basal margin. Otherwise the material does conform to the original generic diagnosis and in apparatus composition it also conforms to the remarks expressed by LÖFGREN (1978). In lateral view many specimens are indistinguishable from the illustrated holotype (FÅHRAEUS 1966, Pl. 2, figs. 8a,b). The similarities with the type species suggest a close relationship and for this reason the specimens are tentatively assigned here. If this is accepted then the generic diagnosis will have to be revised.

aff. Cornuodus sp.
Pl. 1, figs. 4a,b,5,8

?1974 Scandodus tortus VIIRA, p. 118-119, Pl. 5, figs. 31-33, text-fig. 149A,B, fig. 150a-g.

1976 Scalpellodus longibasis (LINDSTRÖM) DZIK, p. 421, text-fig. 13D,E,F.

Description: A species of aff. Cornuodus with sharp upper anterior and posterior margins to the cusp, a sharp upper basal margin and a sharp keel along the lower basal margin.

Both symmetrical s and asymmetrical t elements have erect to proclined, laterally compressed cusp, biconvex in cross-section. Base is long, more or less laterally expanded and encloses deep, simple, conical basal cavity with apex at anterior junction of base and cusp. Basal cavity is triangular in lateral outline. Upper and lower basal margins are moderately divergent posteriorly. Anterior and posterior margins of cusp and base meet in smooth curves.

The s element is bilaterally symmetrical with sharp but non-keeled upper and lower basal margins and base smoothly oval in posterior outline.

The t element is asymmetrical with cusp twisted (anterior inwards) relative to base. Outer lateral face of cusp is slightly more convex than inner. Lower basal margin is sharp or keeled and inwardly deflected and upper basal margin is sharp. Posterior outline of base varies from sub-circular to oval or asymmetrically ellipsoid with sharp apices.

Remarks: Apart from the symmetry transition there are two morphological variants (at least in the _t_ element); one gracile (_t_) and the other robust (_t'_). The gracile variant (_t_) has a long base and slender cusp. The robust variant (_t'_) has a short, more widely laterally expanded base and a short cusp. A similar divergence of form is apparent in the illustrated specimens of the type species _C. erectus_ (FÅHRAEUS, 1966, Pl. 2, figs. 8a,b). The absolute length of the cusp is unknown as the distal portion is broken off in all specimens.

Only one symmetrical specimen is present in the collection. This differs from LÖFGREN's collection of _C. longibasis_ in which symmetrical elements are dominant. Elements of _Scalpellodus longibasis_ of DZIK (1976), were specifically excluded by LÖFGREN in her synonymy of _C. longibasis_, presumably because some of the elements of that species possess sharp edges or low keel development along the basal margin (DZIK 1976, fig. 13d,e,f). LÖFGREN (1978) synonymized these elements with _Scalpellodus gracilis_ (SERGEEVA) of LÖFGREN (1978). DZIK's illustrations, however, show elements similar to those here and they do not show the striation that is diagnostic of the genus _Scalpellodus_ as redefined by LÖFGREN (1978).

Consequently, _Scalpellodus longibasis_ of DZIK (1976) is included here in synonymy and is with this apparatus tentatively assigned to aff. Cornuodus in preference to Scalpellodus.

Types: Figured specimens, WM00028-30.

GENUS DAPSILODUS COOPER, 1976

Type species: Distacodus obliquicostatus BRANSON & MEHL, 1933.

Remarks: The genus Dapsilodus was originally proposed by COOPER (1976, p. 211) in a multielement sense for a Silurian apparatus comprised of "an acodontiform element and a suite of distacodontiform (or acontiodontiform) elements forming a symmetry transition series." No drepanodontiform element was distinguished.

Dapsilodus nevadensis? (ETHINGTON & SCHUMACHER,1969)
Pl. 3, fig. 9,12,13

?1969 Acontiodus nevadensis ETHINGTON & SCHUMACHER, P. 450,452, Pl. 67, figs. 21,22, text-fig. 4C.

?1969 Distacodus aff. D. bigdoeyensis (HAMAR) ETHINGTON & SCHUMACHER, p. 460-1, Pl. 68, fig. 23, text-fig. 4G.

1981 Dapsilodus ?nevadensis ETHINGTON & CLARK, p. 35, Pl. 3, fig. 1.

1983 Dapsilodus compressus ZHANG, (AN et. al.) p. 90, Pl. 26, figs. 10-14.

Remarks: A small collection of six elements is here identified with this taxon. The collection includes an acostate, drepanodontiform (a) element that is not present in the generic diagnosis of COOPER (1976). This was not regarded as sufficient to preclude identification with the genus by ETHINGTON and CLARK (1981) who reported a specimen lacking obvious grooves or costae in their small collection (9 specimens). The apparatus of Dapsilodus compressus (ZHANG) also includes a drepanodontiform element. Acontiodus nevadensis (ETHINGTON and SCHUMACHER, 1969) and Distacodus aff. D. bigdoeyensis (HAMAR) of ETHINGTON and SCHUMACHER (1969) are only tentatively included in the synonymy because of the greater prominence of lateral costae on specimens illustrated by ETHINGTON and SCHUMACHER (1969), compared with Canning specimens. Oistodus sthenus ZHANG (AN et. al., 1983) may be the oistodontiform element of a single apparatus including those elements assigned here. If so, an identification with the genus Acodus may be more appropriate. However, the material at hand is insufficient to confirm such an hypothesis and so Oistodus sthenus has been differentiated as a form-taxon.

Types: Figured specimens, WM00031-3.

GENUS DREPANOISTODUS LINDSTRÖM, 1971

Type species: Oistodus forceps LINDSTRÖM, 1955.

Drepanoistodus basiovalis (SERGEEVA, 1963)

Pl. 3, figs. 21-25

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

1978 Drepanoistodus basiovalis (SERGEEVA) LÖFGREN, p. 55, Pl. 1, figs. 11-17, text-fig. 26B-C.

Remarks: Recognition of this species is based primarily on the morphology of the oistodontiform (r) element. This is because of the general similarity of the homocurvatiform (q) element with those of several other species (of Drepanoistodus). The suberectiform (p) element of this species does differ somewhat from that of D. forceps (which occurs stratigraphically lower in the section) in that its cusp tends to be more strongly laterally compressed and wider.

Curvature, lateral flexure and deflection of the anterior margin in the homocurvatiform (q) element are extremely variable characters.

The oistodontiform (r) element displays quite a wide variation in the taxonomically important characters: genical angle, sharpness of antero-basal junction, base to cusp length ratio, costa development and lateral expansion of the base. The collection includes both forceps-like and suberectus-like specimens.

Types: Figured specimens, WM00045-7, WM00049-50.

Drepanoistodus forceps (LINDSTRÖM, 1955)
Pl. 3, figs. 15,18,19,20

1955 Oistodus forceps LINDSTRÖM, p. 574, Pl. 4, figs. 9-13, text-fig. 3M.

1971 Drepanodus forceps (LINDSTRÖM) LINDSTRÖM, p. 42, text-fig. 8.

1978 <u>Drepanoistodus</u> <u>forceps</u> (LINDSTRÖM) LÖFGREN, p. 53, Pl. 1, figs. 1-6, text-fig. 26A.

1978 <u>Drepanoistodus</u>? cf. <u>D</u>. <u>venustus</u> (STAUFFER) LÖFGREN, p. 56, Pl. 1, figs. 7,8.

Remarks: The oistodontiform (<u>r</u>) element has a relatively much shorter base and a more pronounced, rounded, carina than <u>Oistodus venustus</u> STAUFFER (1935, Pl. 12, fig. 12) from the Glenwood Beds of Minnesota. The cusp of the oistodontiform (<u>r</u>) is twice the length of the base and it is not significantly laterally flexed. The rounded carina of the inner face is a constant feature.

Types: Figured specimens, WM00051-2, WM00054-5.

<u>Drepanoistodus pitjanti</u> COOPER, 1981
Pl. 3, figs. 14,16,17, Pl. 5, fig. 15

Description: Cusp of suberectiform (<u>p</u>) element is sub-erect or weakly recurved and bilaterally symmetrical with a laterally compressed, sub-rhombic cross-section. Cusp is straight with sharp anterior and posterior margins and has one strong, posteriorly facing sharp costa along each lateral face and another weaker, sharp costa developed in parallel along the midline which fades about halfway up cusp. Both costae project a short distance onto base. Base is low and symmetrically laterally expanded as thin sheath with oval basal outline. Anterior and posterior margins of base are sharply and thinly keeled and contiguous with sharp margins of cusp. Anterior margin strongly projects anteriorly beyond line of cusp. Basal cavity is shallow with overturned apex below posterior margin of cusp and base.

Homocurvatiform (q) element is moderately to strongly recurved and varies from near bilaterally symmetrical to moderately asymmetrical with cusp inwardly inclined and anterior margin weakly, inwardly deflected. Cusp is strongly laterally compressed with sharp anterior and posterior margins. Lateral faces are shallowly convex with outer face more prominently so in asymmetrical specimens. Fine, sharp costae fade distally. Costa of inner face is more strongly developed on asymmetrical forms than that of outer face and is more medially located. Base is weakly laterally expanded, most strongly on inner side. Basal cavity is relatively shallow with rounded lateral outline and overturned apex near midline. Anterior margin may be weakly produced beyond line of cusp. Posterior margin of cusp meets upper basal margin in smooth arcuate curve. Lower basal margin is weakly sigmoidal on inner side and smoothly convex downwards on outer side.

Oistodontiform (r) element is robust and with cusp reclined at about 45 degrees. Cusp has straight or weakly curved anterior and posterior margins and has a massive, sharp-edged carina along midline of inner face. Outer face is smooth and shallowly convex. Anterior and posterior margins are sharply keeled and cross-section of cusp is triangular. Base is low and relatively short with cusp projecting well beyond posterior end. Antero-basal junction is tightly rounded. Upper basal margin is short, straight and sharp. Lower basal margin decribes a smooth, downwardly convex arc. Shallow, squat basal cavity has low-relief apex just anterior of genical angle.

Remarks: The oistodontiform (r) element cooccurs with the oistodontiform (r) element of Drepanoistodus forceps but is distinguished from that element by its massive, sharp-edged inner carina and shorter base. There are some poorly preserved specimens with apparently rounded but still massive carinae.

The outer costa of the homocurvatiform (q) element is very weak in some specimens but it is always present. As with other species of Drepanoistodus, the q element displays a high degree of variability in basal flaring, cusp curvature and lateral flexure. It is probable therefore, that the q classification is a simplification, grouping different elements of a more complicated apparatus plan.

Types: Figured specimens, WM00058, WM00056-7, WM00144.

GENUS EOPLACOGNATHUS HAMAR, 1966

Type Species: Ambalodus lindstroemi HAMAR, 1964.

Eoplacognathus foliaceus? (FÅHRAEUS, 1966)
Pl. 6, fig. 29, Pl. 7, fig. 2

1966 Ambalodus foliaceus FÅHRAEUS, p. 18, Pl. 4, fig. 2.

1971 Eoplacognathus foliaceus (FÅHRAEUS) BERGSTRÖM, p. 138, Pl. 1, fig. 8.

1978 Eoplacognathus foliaceus (FÅHRAEUS) LÖFGREN, p. 60, Pl. 15, fig. 21.

Remarks: One specimen of a sinistral ambalodontiform element is tentatively identified with this species. Typically, this element of the E. foliaceus apparatus is distinguished from the comparable element of E. suecicus by its much smaller posterior process. In the specimen recovered, this process is not preserved but the specimen is otherwise intact and the marks of breakage suggest that the process was small. In curvature of the anterior process and denticle row, the specimen much more closely resembles E. foliaceus than E. suecicus. It is certainly distinct from those sinistral ambalodontiform elements in the collection that are assigned to E. suecicus but being of a single, fragmentary specimen, the identification is extremely tentative.

Type: Figured specimen, WM00059.

Eoplacognathus suecicus BERGSTRÖM, 1971
Pl. 6, figs. 28,32,33, Pl. 7, figs. 3,5

1971 Eoplacognathus suecicus BERGSTRÖM, p. 141, Pl. 1, figs. 5,7.

1978 Eoplacognathus suecicus LÖFGREN, P. 59, Pl. 15, figs. 12,16a,b.

Remarks: Several fragments of a polyplacognathiform element and of an ambalodontiform element are assigned with confidence to E. suecicus. A complete specimen of the sinistral ambalodontiform element and several other less well preserved specimens occur stratigraphically above the sinistral ambalodontiform element here assigned to *E. foliaceus*?. Two other specimens assigned to *E. suecicus* occur stratigraphically below.

E. foliaceus and *E. suecicus* are morphologically distinct and there are no previously reported instances of their cooccurrence. In Baltoscandia and the Appalachian region of the U.S.A. typical *E. foliaceus* appears abruptly only above the last appearance of *E. suecicus* and without overlap (BERGSTRÖM, 1983). BERGSTRÖM (*ibid.*, p. 43) states that he has not seen any "actual specimens or illustrations of elements truly transitional" between these two species.

Types: Figured specimens, WM00060-2.

GENUS *ERRATICODON* DZIK, 1978

Type species: *Erraticodon balticus* DZIK, 1978.

Discussion: DZIK (1978) described a seximembrate apparatus for the species, consisting of ozarkodiniform (*a*), hindeodelliform (*b*), trichonodelliform (*c*), neoprioniodontiform (*e*), spathognathodontiform (*f'*) and plectospathodontiform (*f*) elements. He figured (DZIK, 1978, fig. 6) five elements of the apparatus and referred to a specimen illustrated by VIIRA (1974, Pl. 11, fig. 22) as the sixth, spathognathodontiform element. All of the five elements illustrated by DZIK are recognized here. The spathognathodontiform is not recognized. The two Canning specimens which most closely resemble the latter element are incomplete specimens of the prioniodontiform (_f'_) element such as that described in the apparatus of _Erraticodon patu_ (COOPER, 1981) as lonchodiniform. A seventh element is referred to as cardiodelliform (_g_).

Some elements display considerable morphologic variation between samples but it is believed that there is only one species of _Erraticodon_ represented in the collection. The modified (from DZIK) septimembrate apparatus reconstruction described below is probably complete and all the elements included in it have been observed (at least as recognizable fragments) to cooccur.

Erraticodon _balticus_ DZIK, 1978

Pl. 5, figs. 2-10, Pl. 8, figs. 1,2,5,6,8-13

1970 _Chirognathus_ sp. FÅHRAEUS, p. 2064, fig. 3; 1,m.

1975 _Gothodus_ n. sp. LEE, p. 175, Pl. 2, fig. 4.

1975 _Trichonodella_ sp. cf. _T_. _barbara_ (STAUFFER 1935), LEE, p. 181, Pl. 2 figs. 7,8.

1977 _Erismodus_ _horridus_ (HARRIS), BARNES, p. 103, Pl. 2, fig. 8.

cf.1978 _Erraticodon_ _balticus_ DZIK, p. 66, Pl. 15, figs. 1-3,5,6, text-fig. 6.

1979 _Neoprioniodus_ sp. nov. LEE, p. 45-46, Pl. 2, fig. 17.

1979 _Plectodina_ sp. LEE, p. 49, Pl. 2, figs. 4,7,8.

1979 _Erraticodon_ sp. HARRIS _et_. _al_., Pl. 3, figs. 1-5.

1981 _Erraticodon_ aff. _E_. _balticus_ DZIK, ETHINGTON &

CLARK, p. 45, Pl. 4, figs. 15,17,23,24.

Description: An apparatus comprising ozarkodiniform (a), hindeodelliform (b), trichonodelliform (c), neoprioniodontiform (e) and plectospathodontiform (f) elements that closely resemble type elements figured by DZIK (1978), a prioniodontiform (f') similar to that illustrated by COOPER (1981) for Erraticodon patu and a cardiodelliform (g) element.

All elements are hyaline and characterized by long, slender, pointed denticles, recurved cusp and wide, shallow basal cavity with low, sharp peak under cusp. Concave cavity extends under full extent of processes. Denticles are either straight and posteriorly inclined or curved.

Ozarkodiniform (a) element has moderately downwardly and weakly inwardly deflected processes giving element arched and weakly inwardly concave appearance. Anterior process is short and has two or three denticles decreasing in size distally. Posterior process is longer with five or six denticles and is moderately arched about large denticle approaching size of cusp located approximately mid-way along process. In most specimens, the posterior process is broken at a point just anterior of the large denticle.

Hindeodelliform (b) element is broadly similar to ozarkodiniform element but has substantially longer antero-lateral process much more strongly laterally deflected. Posterior process tends to be more strongly twisted inwards and in some specimens denticulation differs by lacking prominent, large denticle in mid-position of process. Denticles gradually increase in size posteriorly to maximum of about half-cusp height and abruptly diminish distally.

Trichonodelliform (c) element is bilaterally symmetrical with symmetrical processes each bearing a single denticle of about one third of cusp height. Processes project laterally from and slightly anteriorly of cusp. Cusp bears hair-like costa on each lateral face located anterior of midline contiguous with lateral proceses. Posterior process straight and untwisted.

Most specimens of the neoprioniodontiform (e) element are simply cyrtonidontiform without anterior denticles. Most have four denticles along posterior process. Cusp is markedly inwardly curved. One specimen was observed with a small, hook-like anterior denticle and an extra, small, fifth posterior denticle partially fused to posterior of cusp.

Plectospathodontiform (f) element has three discrete processes: inner lateral, outer lateral and posterior. Outer lateral process is long and strongly downwardly and posteriorly deflected. Process is weakly curved and has five or six, relatively long denticles. Inner-lateral process is more or less anteriorly and is short; bearing only one or two large denticles. It is also strongly downwardly deflected and forms a relatively high, asymmetric arch about the cusp in conjunction with the outer-lateral process.

posterior process is not preserved intact together with outer lateral process in any specimens. Most commonly, only a short stump is preserved with two or three denticles. Stump projects horizontally, straight back from base of the cusp (i.e. from apex of the arch formed by lateral processes). In one specimen, process is preserved intact and is about as long as outer-lateral process and about equal to cusp height. Process bears four denticles. Two denticles nearest cusp are relatively small but distal pair are much larger, approaching size of cusp. Most distal denticle is outwardly tilted. This "modified" prioniodontiform (f') element is, of all the elements here brought to the genus Erraticodon, most similar to the spathognathodontiform element illustrated by VIIRA (1974) which DZIK (1978) included in the apparatus of Erraticodon balticus. The element is not identical with VIIRA's illustration. It differs from that illustrated by VIIRA (1974, Pl. 11, fig. 22) in having a shorter antero-lateral process and more strongly inwardly inclined posterior denticles and cusp. Both specimens of this element in the collection are incomplete. Each has only two processes preserved and a broken stump indicating a third (Pl. 8, fig. 5). The processes are: posterior, antero-lateral (inner) and inner. Cusp and denticles of posterior process are strongly inwardly curved. Posterior process is robust, outwardly twisted and deflected. Process bears four long, slender, pointed denticles, the middle two of which are the longest at about two-thirds of cusp height. Anterior process is inwardly and downwardly deflected and short with two denticles: a long, robust denticle adjacent to the cusp and two, much smaller distal ones.

Cardiodelliform (g) element is most distinctive. Only one intact specimen was recovered but identifiable fragments were noted from several samples. Element has two denticulate processes; antero-lateral (outer) and posterior. Posterior process is longer and abruptly flexed outwards at about 90 degrees near its mid-length. Antero-lateral process projects outwardly at about 80 degrees from cusp and has three, straight denticles. Process and denticles are inclined posteriorly. Cusp is straight and inwardly inclined. Posterior process bears two or three large denticles in zone of flexure, as big as or slightly bigger than cusp, which curve slightly inwards. Denticles decrease distally in size. An incomplete specimen from sample 603-604M suggests that the relative length and degree of curvature of the posterior process in this element may be quite variable although the denticulation pattern is basically the same.

Remarks: The extra element to the apparatus not included in DZIK's (1978) reconstruction is the cardiodelliform (g) element. There is only one complete specimen of this element in the collection but fragments are relatively common. It is called cardiodelliform because its fragmentary remains closely resemble specimens of the

Ordovician genus Cardiodella.

The apparatus best fits the Type IVB model. Some elements possess basal filling.

The material described above was differentiated by direct comparison, from Erraticodon patu from the Horn Valley Siltstone by the consistent presence of a prominent, large denticle on the posterior process in a, b and c elements (R.S. NICHOLL, pers. comm., 1985). Also, denticles anterior to the cusp in the e element are much more common in Erraticodon patu than in Erraticodon balticus.

Types: Figured specimens, WM00063-4, WM00066-72.

GENUS FALODUS LINDSTRÖM, 1955

Type species: Oistodus prodentatus GRAVES & ELLISON, 1941.

Falodus keramis sp. nov. s.f.
Pl. 4, figs. 11,14

Derivation of name: keramis (Greek); imbricated. This refers to the anterior denticulation pattern.

Diagnosis: A strongly laterally compressed, straight, blade-like falodontiform element with large, steeply reclined cusp, triangular in outline and bearing a broad, low, inner carina. Anterior denticles are invariably strongly fused or absent. Cusp and denticles are albid; base is hyaline.

Description: Cusp is reclined at about 30 degrees, projecting well beyond base. Cusp has prominent mid-rib or carina, either rounded or sharp-edged; the latter giving cusp faceted appearance. Cusp bears thin but high keels along both anterior and posterior margins. Keels taper distally towards the apex of cusp. Cusp is commonly weakly curved inwards distally. Base is extended anteriorly as short process.

There are two variants: (x) and (y). In the (x) variant the anterior process commonly bears six to eight, posteriorly inclined denticles; the largest adjacent to and fused to anterior margin of cusp. Denticles decrease anteriorly both in size and posterior inclination. They are fused for about three-quarters of their length, forming a blade with sharp apices projecting in saw-tooth fashion in a curved, (convex upward), serrated upper edge. In the (y) variant, denticles are not differentiated and anterior process is a smooth-edged, solid blade with upper margin sloping forward gently from cusp tip.

Anterior of process is bluntly rounded from about half-cusp height and commonly slightly deflected downwards. Lower basal margin has a thin basal sheath most strongly developed and weakly laterally flared directly beneath cusp; flaring is stronger on inner side. Sheath encloses shallow basal cavity with nearly straight, lateral outline. Sheath and cavity gradually diminish distally from cusp and cavity becomes a very shallow slit.

Remarks: The adenticulate (y) variant of this form-taxon is basically oistodontiform. There is a complete range of variation between it and the most prominently denticulate (x) variants. Commonly, in non-denticulate and weakly denticulate specimens, only the upper portion of the anterior blade is albid. In weakly denticulate specimens, there is no lateral relief to the denticles which are evident only by serration of the upper margin and a differentiation of the white matter.

McHARGUE's (1982) apparatus reconstructions for species of Histiodella holodentata from the Joins Formation in Oklahoma include oistodontiform elements resembling (in particular) the non-denticulate (y) morphotype of Falodus keramis. Morphologic similarities include the prominent innner carina, postero-basal outline and upper basal margin, basal cavity and white matter distribution. Major differences include the antero-basal outline and the absence of denticulation in any Joins Formation specimens. The main factor influencing the decision to differentiate Falodus keramis as a form-taxon discrete from the apparatus of Histiodella holodentata, is the absence of similar (to Falodus keramis) elements from other collections including abundant Histiodella holodentata (eg. ETHINGTON and CLARK, 1981).

Types: Holotype: WM00075, paratype: WM00076.

GENUS HISTIODELLA HARRIS, 1962

Type species: Histiodella altifrons HARRIS, 1962.

Discussion: Histiodella was erected as a form taxon by HARRIS (1962) who recognized two species: H. altifrons and H. serrata, from the Joins Formation of Oklahoma.

McHARGUE (1982) reconstructed a seximembrate apparatus plan for these species of Histiodella from large collections also from the Joins Formation. Some of the elements of this interpreted apparatus have been reported from other localities (ETHINGTON and CLARK, 1981) but identification of the genus is still dependent primarily on the blade element as this tends to be the most common and distinctive element. In H. holodentata, only a single non-blade element, a trichonodelliform element, has been previously reported and this is extremely rare. ETHINGTON and CLARK (1981) reported only a single, possible, example with a collection of two hundred and fifteen blade elements.

Histiodella holodentata ETHINGTON & CLARK, 1981
Pl. 4, figs. 15,20

1970 Spathognathodus n. sp. (LINDSTRÖM) FÅHRAEUS, p. 2073, text-fig. 3I.

1970 Spathognathodus sp. UYENO & BARNES, P. 117, Pl. 24, figs. 12,13.

1971 Histiodella sp. A SWEET, ETHINGTON & BARNES, p. 167, Pl. 1, fig. 16.

1973 Histiodella sinuosa (GRAVES & ELLISON) BARNES & POPLAWSKI, p. 776, Pl. 1, fig. 18.

1974 Spathognathodus sp. (LINDSTRÖM) VIIRA, p. 125, Pl. 5, figs. 39,40.

1979 Histiodella n. sp. 1 HARRIS et. al., Pl. 1, fig. 9.

1981 Histiodella holodentata ETHINGTON & CLARK,

p. 47-8, Pl. 4, figs. 1,3,4,16.

1983 Histiodella infrequensa AN (AN et. al.), p. 105-106, Pl. 25, figs. 1,2.

1984 Histiodella holodentata ETHINGTON & CLARK NOWLAN & THURLOW, p. 293, Pl. 1, figs. 1,3,5.

Remarks: All but one of the elements assigned here to Histiodella are blades and conform well with the description of H. holodentata ETHINGTON and CLARK (1981) except for two hyaline specimens that were observed. The crimping and flaring of the base and lateral rib development just above the base are all variable features without any discernable pattern of variation through the section. No specimens similar to the slightly younger Histiodella n. sp. 2 of HARRIS et. al. (1979) were observed.

A single specimen of an oistodontiform element occurs which may belong to a multielement H. holodentata apparatus (Pl. 4, figs. 19a,b). This element has a strongly laterally compressed slightly reclined cusp which does not project posteriorly beyond the base. Both lateral faces of the cusp carry a broad, low, rounded carina. Anterior and posterior margins are sharp and straight giving the cusp a triangular lateral outline. The posterior margin is near vertical. The cusp is twisted relative to the base which is locally, inwardly flared below the cusp to enclose a simple, conical basal cavity. The base projects sub-equally about one base-height to the anterior and posterior of the cusp as short, adenticulate processes. This element is tentatively grouped with *H. holodentata* on account of its similar white matter distribution, small, localized basal cavity and similar size. The small basal cavity makes an association with *Falodus keramis* sp. nov. less likely, although the latter taxon may itself be related to *H. holodentata*. The element is quite different from the oistodontiform elements of earlier *Histiodella* species described by McHARGUE (1982).

Falodus keramis sp. nov. is one of two blade-like elements with similar white matter distribution that cooccur here with *Histiodella holodentata*, through the same stratigraphical interval. The other is Genus and Species nov. A. These elements are herein described separately as form-taxa because of the lack of other illustrated reports of their occurrence in association with *H. holodentata*. A falodontiform element was reported by ETHINGTON and CLARK (1981 p. 48), in association with *Histiodella* n. sp. 2 (HARRIS *et*. *al*., 1979) from the Antelope Valley Limestone in central Nevada. It was described as an oistodontiform element with *Falodus*-like anterior denticles, which resembled the oistodontiform elements of *H. altifrons* and *H. sinuosa*. It was not illustrated.

H. infrequensa AN (1983) is tentatively included in synonymy. Specimens with a large cusp (AN *et*. *al*., 1983, Pl. 25, fig. 1) are not similar to any of the *Histiodella* specimens here but are reminiscent of *Falodus keramis* sp. nov. described herein. They differ (from the latter) in having denticles located posteriorly of the cusp.

Types: Figured specimens, WM00077-9.

GENUS *JUANOGNATHUS* SERPAGLI, 1974

Type species: *Juanognathus* *variabilis* SERPAGLI, 1974.

Juanognathus *leptosomatus* (AN),(AN *et*. *al*., 1983)

Pl. 1, figs. 1,2,3,6

1975 aff. *Gen*. *nov*. B COOPER & DRUCE, p. 579, Pl. 4, fig. 30.

1979 *Juanognathus* sp. aff. *J*. *variabilis* (SERPAGLI) HARRIS *et*. *al*., Pl. 1, figs. 3,4, non. fig. 5.

1983 *Aurilobodus* *leptosomatus* AN (AN *et*. *al*.), p. 72-73, Pl. 21, figs. 14-17, Pl. 22, fig. 1.

?1983 *Aurilobodus* *simplex* XIANG & ZHANG (AN *et*. *al*.), p. 74, Pl. 22, fig. 9, non. figs. 10-12.

1984 *Juanognathus* *serpaglii* STOUGE, p. 58-9, Pl. 5, figs. 10-20.

Description: A species of *Juanognathus* consisting of two elements: asymmetrical (*t*) and symmetrical (*s*) in a symmetry transition series in a Type IB apparatus. Elements are antero-posteriorly compressed, proclined, curved cones bearing a single, slightly posteriorly deflected, wing-like costa along each lateral face. Cusp and most of costae are albid. Base and costae below level of upper basal margin are hyaline.

Anterior faces of costae form a moderately convex plane with anterior face of cusp projecting as low-relief rounded, linear swelling. Posterior of cusp is higher in relief along concave, posterior face. Costae project below level of base in an inverted 'V'-shape. Base is relatively small, short and moderately laterally compressed. Upper basal margin is short and straight in lateral outline. Posterior outline is sub-symmetrically 'U'-shaped with upper basal surface somewhat flattened. Anterior face of base is flat or weakly convex and in line with or slightly recessed into anterior plane of element. Lower basal margin is straight in lateral view between antero-basal corner and posterior end of upper basal margin. Base encloses simple, conical basal cavity with apex at base of cusp adjacent to anterior margin. Cavity extends as relatively wide slit under costae.

Asymmetrical (t) elements vary from sub-symmetrical with sub-equally developed costae to strongly asymmetrical with outer costa much higher than inner. In strongly asymmetrical forms, cusp is inwardly curved with edge of inner costa concave or straight (in anterior or posterior view) and that of outer convex.

There are two variants of symmetrical (s) element: one variant (s) is relatively narrow, with simple triangular outline and basal tips of costa projecting downwards below level of base and other variant is tricladiodontiform (s') with distal tips of costae turned upwards and outwards about level with base.

Remarks: HARRIS et. al. (1979) illustrated two specimens of this taxon, one asymmetrical and one symmetrical and assigned these to _Juanognathus_ sp. aff. _J. variabilis_ SERPAGLI (1974). The asymmetrical element is indeed similar to some elements of _J. variabilis_ but the apparatus of the latter taxon differs from this species in having a much greater variety of asymmetrical elements and in lacking a truly symmetrical element (SERPAGLI, 1974, p. 33). The third element that HARRIS _et. al._ (1979) illustrated and assigned to _Juanognathus_ sp. aff. _J. variabilis_ is unlike any in this collection. It is tricladiodontiform but differs from those here in having an angular, outward flexure of the distal tips of the costae. In all three tricladiodontiform (_s'_) elements observed in this collection, this flexure is smoothly curved.

XIANG and ZHANG (AN _et. al._, 1983) have proposed a new genus _Aurilobodus_ including six new species. Of these _A. leptosomatus_ appears to be the same in both element morphology and apparatus composition to this taxon. Similar elements are also present in STOUGE's (1981) collection from the Table Head Group of western Newfoundland.

Types: Figured specimens, WM00080-3.

?_Juanognathus_ sp. nov.
Pl. 1, figs. 16a,b,17,18

Description: Robust, simple cone elements with a single, wide, sharp, flange-like costa along each lateral junction of anterior and lateral faces of cusp. Symmetrical, acontiodontiform (_s_) and asymmetrical (_t_) elements in a symmetry transition series of a Type IB apparatus.

Asymmetrical elements have irregular, wavy, basal outline and strongly twisted cusp giving a contorted appearance.

Cusp of s element is straight, laterally compressed and proclined. Posterior margin is strongly and sharply keeled. Anterior margin, with costae, forms shallowly convex face along entire length of element to lower basal margin. Antero-basal face is recurved under cusp. Upper basal margin is short, straight and sharp and meets posterior margin of cusp in smooth, open curve. Postero-basal outline is triangular with weakly concave lateral edges. Basal cavity is conical and relatively deep.

There are two variants of asymmetrical element: scandodontiform (t) and oistodontiform (t'). Cusp of scandodontiform (t) element is antero-posteriorly compressed and strongly recurved. Anterior and posterior faces are gently convex and meet in sharp, strongly costate, lateral margins. Cusp is outwardly twisted with inner margin rotated into antero-lateral position. Inner costa is wider than outer and strongly posteriorly curved such that inner edge faces posteriorly. Edge of outer costa also faces posteriorly. Costae and anterior face of cusp form single convex face through about 270 degrees. Posterior of cusp resembles broad, low, rounded carina on strongly concave face of element. Inner costa terminates at antero-basal corner in conspicuous, bulbous node. Outer costa terminates at posterior margin of base adjacent to upper basal margin. Base is laterally compressed with irregularly wavy but overall sigmoidal, basal outline caused by inward deflection of anterior portion towards terminal node of inner costa. Basal cavity is relatively deep with shallow extensions under costae.

Oistodontiform (t') variant is similar to scandodontiform variant but has cusp more strongly recurved and has a sharp (geniculate) posterior junction with base. Base is moderately inwardly flared in a narrow zone directly below cusp.

Remarks: Although the collection is small it appears that all elements of an apparatus are represented including an oistodontiform element. SERPAGLI (1974, p. 49) in his generic diagnosis, considered that an oistodontiform element, "may possibly complete the apparatus" although he did not recognise one in either of the two species he described (*J. variabilis* and *J. jaanussoni*). An oistodontiform element is also absent from the apparatuses of the other two species of *Juanognathus* described here (*Juanognathus leptosomatus* and ?*Juanognathus* sp.).

Types: Figured specimens, WM00084-6.

?*Juanognathus* sp.
Pl. 3, figs. 7,8,10,11

?1976 *Acontiodus* sp. LEE, p 162, Pl. 1, fig. 5, text-fig. 2E.

?1977 *Acontiodus* sp. B LEE, p. 130, Pl. 1, figs. 1,2.

Description: This apparatus reconstruction is tentative. A species of ?*Juanognathus* consisting of two elements: symmetrical s and asymmetrical t in a symmetry transition series of a Type IB apparatus. Both elements are bicostate cones. The s element has a single, strong, sharp, flange-like costa along anterior of each lateral face giving cusp T-shaped cross-section. The t element is scandodontiform with a strong, sharp, flange-like, inner-anterior costa and less strong but equally sharp, outer-posterior costa. Elements have albid cusp and hyaline base, bearing faint, fine, longitudinal striae.

Cusp of s and t elements is long, proclined to sub-erect and curved. In s elements, anterior face of cusp lies in shallowly convex, curved plane formed with the two lateral costae. Anterior face continuous to the antero-basal corner. Posterior margin of cusp projects as strong, sharp-edged, thin carina. Edge of costa meets short, sharp, upper basal margin in tight but smooth curve. Posterior outline of base is sub-triangular with apex at sharp, upper basal margin and weakly convex lateral faces. Basal cavity conical and equilaterally triangular in lateral outline with apex adjacent to anterior margin below level of upper basal margin.

The t elements form a transition series with variation in inwards curvature of cusp and development of costae. Those closest to s elements have a posteriorly curved cusp with both costae strongly but asymmetrically developed, with sharp edge of the outer costa facing directly posteriorly approximately at right angles to laterally facing edge of inner costa. In other variants, cusp is inwardly curved and outer costa reduced to a minimum of hair-like development. Inner costa invariably strongly developed but is less inwardly deflected; being more antero-laterally aligned. Outer face of cusp connects both costae in single, smooth, strongly convex curve through 225 to 270 degrees. Inner face of cusp moderately convex and resembles broad, rounded carina between costae. Base is laterally compressed but moderately, postero-laterally flared. Basal cavity is conical and weakly attenuated towards apex at level of the upper basal margin and adjacent to anterior margin.

Remarks: The *s* element of this taxon is similar to that of *?Juanognathus* sp. nov. The latter differs in having a more strongly compressed posterior carina and a base with lateral faces that are weakly concave. The preservation of elements in the single occurrence of *?Juanognathus* sp. nov. prevents comparison of the white matter distribution. The remainder of the apparatus is distinct. There is a wide variation in the degree of robustness of the scandodontiform elements including some distinctive slender, graciliform variants.

There are other scandodontiform elements in the collection with similar white matter distribution and gross morphology. These display a wide range of variation including some intermediate specimens that are difficult to categorize. The nature of their relationship to this taxon cannot be determined with the limited collection at hand and so they are described separately as form-taxa.

Types: Figured specimens, WM00087-90.

GENUS MICROZARKODINA LINDSTRÖM, 1971

Type species: Prioniodina flabellum LINDSTRÖM, 1955.

?Microzarkodina sp.
Pl. 6, figs. 4,8

?1984 Gen. et. sp. indet. C STOUGE, p. 90, Pl. 18, fig. 21

Remarks: Two isolated elements are here tentatively assigned to this genus: trichonodelliform (c) and ozarkodiniform (f). The ozarkodiniform element is unusual in its long posterior process, longer than in other species of Microzarkodina. Some plectospathodontiform elements (e.g. M. flabellum parva, DZIK, 1976, text-fig. 9) have processes approaching this length and also possess only a single denticle antero-laterally of the cusp. However, they are distinguished by their posteriorly expanded basal cavity. The trichonodelliform element is sub-symmetrical and roughly resembles that of M. flabellum (ZIEGLER 1975, v.II, p. 189, Pl. 1, fig. 5).

Types: Figured specimens, WM00092-3.

GENUS OEPIKODUS LINDSTRÖM, 1955

Type species: O. smithensis LINDSTRÖM, 1955.

Oepikodus sp. cf. O. communis
(ETHINGTON and CLARK, 1964)

Pl. 6, figs. 9,10,11,14,15, Pl. 8, figs. 3,4,7

cf.1964 Gothodus communis ETHINGTON & CLARK, p. 690, Pl. 114, figs. 6,14.

1973 Prioniodus evae communis (ETHINGTON & CLARK) McTAVISH, p. 45-6, Pl. 3, figs. 27,29-32,37, text-figs. 6A-E.

1974 Prioniodus (Oepikodus) intermedius SERPAGLI, p. 67,69-73, Pl. 15, figs. 1a-4b, Pl. 27, figs. 1,2,3,5,6,7, non. 4, text-fig. 15D-F.

cf.1981 Oepikodus communis (ETHINGTON & CLARK) ETHINGTON & CLARK, p. 61-2, Pl. 6, figs. 18,22,25.

1982 Oepikodus sp. cf. O. communis (ETHINGTON & CLARK) STOUGE, p. 40, Pl. 6, figs. 17-20.

Remarks: This apparatus is composed of oepikodontiform (a), oistodontiform (e) (falodontiform) and prioniodontiform (f) elements in a Type IVE plan.

Only one small specimen of the prioniodontiform (f) element is present in the collection. This element particularly closely resembles the prioniodontiform (f) element of the type Oepikodus intermedius illustrated by SERPAGLI (1974).

The four specimens of oepikodontiform (a) element also closely resemble O. intermedius illustrated by SERPAGLI (1974). The denticulation of the posterior process is hindeodelliform in all four and thus seems to be a more constant feature of the species in this material and in SERPAGLI's (1974) San Juan and McTAVISH's (1973) Emanuel

Formation collections compared with the "at least occasional enlarged denticles" reported by ETHINGTON and CLARK (1981, p. 62) for specimens from the Pogonip Group. The sub-equal, larger denticles occur at rather irregularly spaced intervals along the posterior process with the number of intermediate, smaller denticles varying between three and seven. It is in the mid-portion of the process that the hindeodellid pattern is most evident.

The oistodontiform (e) element is quite variable in the length of the anterior process and in genical angle. Some specimens are close to those SERPAGLI (1974) regarded as typical of *O. intermedius* although the anterior process is always rather short. Other specimens resemble more the morphology SERPAGLI regarded as typical of *O. communis* (*sensu* ETHINGTON and CLARK, 1964). Generally, they appear intermediate between *O.intermedius* and *O. communis* (*sensu* SERPAGLI, 1974).

All the elements of the apparatus were directly compared with the original specimens of *O. evae communis* of McTAVISH (1973) from the Lower Ordovician Emanuel Formation of the Canning Basin. They are similar and within the range of intraspecific variation proposed by ETHINGTON and CLARK (1981).

SERPAGLI (1974) recognized *O. intermedius* as specifically distinct from *O. communis* (*sensu* ETHINGTON and CLARK, 1964) but in more extensive and abundant Ibex area collections, ETHINGTON and CLARK (1981) found both of the variants used by SERPAGLI to distinguish the two species, to occur together. Consequently, they have revised and broadened their initial concept of O. communis to include forms typical of O. intermedius, which they now regard as a junior synonym. Although the elements here may be included in this broadened concept of O. communis (i.e. sensu ETHINGTON and CLARK, 1981) the identification of the species is tentative because of the apparently narrower range of morphological variation displayed and the particular similarity with Oepikodus intermedius (SERPAGLI, 1974). Also, the cooccurrence of the elements here with Histiodella holodentata and other species typical of Fauna 4 (SWEET, ETHINGTON and BARNES, 1971) is stratigraphically higher than the upper limit of the stratigraphical range of O. communis in the Pogonip Group (ETHINGTON & CLARK, 1981), i.e. up to a stratigraphical level no higher than the Wah Wah Formation, somewhat below the first appearance of H. altifrons and in a species assemblage characteristic of Fauna 1 (SWEET, ETHINGTON and BARNES, 1971). All other reported occurrences of O. communis (ETHINGTON and CLARK, 1981, p. 62) are similarly, stratigraphically lower except for STOUGE (1982) who reported a stratigraphic overlap with Histiodella holodentata in the Aguathuna Formation of western Newfoundland.

Types: Figured specimens, WM00096-100.

GENUS OISTODUS PANDER, 1856

(emend. LINDSTRÖM, 1955, 1971)

Type species: Oistodus lanceolatus PANDER, 1856.

?Oistodus sthenus s.f. ZHANG, 1983
Pl. 4, fig. 1

Remarks: Fifteen specimens are tentatively assigned here by visual comparison with illustrated specimens of AN et. al., 1983 (Pl. 28, figs. 15,16,17) from the Majiagou Formation in North China. In both North China and the Canning Basin, this taxon ranges through the same stratigraphic interval as those elements assigned to Dapsilodus nevadensis? It may comprise a single multielement species with those elements, possibly of the genus Acodus.

Type: Figured specimen, WM00019.

GENUS ONYXODUS gen. nov.

Derivation of name: onyx (Greek); claw, odus (Greek); tooth.
Type species: Onyxodus acuoliratus sp. nov.

Diagnosis: To this genus are assigned those hyaline, non-geniculate distacodontiform (s) and scandodontiform (t) cone elements in a symmetry transition series in a Type IB apparatus. Distacodontiform (s) element is abruptly flexed at junction of base with proclined to sub-erect cusp. Basal cavity is deep and triangular in outline with apex in zone of flexure. Elements are weakly, laterally compressed.

Remarks: Onyxodus differs from Staufferella (SWEET, THOMPSON and SATTERFIELD, 1975) mainly by the absence of basal alae in the symmetrical element, the absence of surface striation and the lack of a (slightly asymmetrical) posteriorly bicarinate element in the apparatus. In addition, symmetrical elements of Onyxodus possess a base that is weakly to moderately laterally compressed and not depressed as in species of Staufferella.

Onyxodus acuoliratus sp. nov.
Pl. 2, figs. 9a,b,10a,b,11

Derivation of name: acutus (Latin); sharp, liratus (Latin); ridge.

aff. 1973 Distacodus vernus MOSKALENKO,
p. 29-30, Pl. 2, figs. 4a,b.

aff. 1973 Drepanodus inventum MOSKALENKO,
p. 32-33, Pl. 2, figs. 7,8a,b.

aff. 1973 Scandodus dulkumaensis MOSKALENKO,
p. 40, Pl. 3, figs. 8a,b,9.

aff. 1973 Scandodus notabilis MOSKALENKO,
p. 41, Pl. 3, figs. 10a,b,11,12.

Diagnosis: A species of Onyxodus with distacodontiform (s) and scandodontiform elements (t) that are slender with straight, proclined to erect cusp but that are abruptly flexed at junction of base with cusp. Distacodontiform (s) element has long base commonly approaching that of cusp. Deep, conical basal cavity has apex in zone of flexure and adjacent to anterior margin.

Description: The s element is symmetrical or sub-symmetrically and sharply bicostate from tip of cusp to basal margin. Anterior face is rounded and posterior margin sharply keeled. Base is relatively long; in many specimens sub-equal in length to cusp.

The t elements have cusp twisted relative to base and are asymmetrical with laterally deflected, sharply keeled, anterior and posterior margins. Length of base is variable from a maximum of a little less than cusp length.

The symmetry transition between s and t elements results from degree of inwards twisting of cusp relative to base and associated degree of displacement of the outer costa posteriorly and inner costa anteriorly. In scandodontiform elements, posterior keel is absent and lateral costae are rotated sufficiently far anteriorly and posteriorly to appear as laterally deflected keels.

Remarks: In more asymmetrical distacodontiform specimens, outer costa and posterior keel are particularly closely adjacent suggesting that the scandodontiform element might result from the merging of these two ridges. However, such merging was not actually observed in any of the specimens and because of this discreteness of the two elements, the s designation is here broadly applied to include both symmetrical and asymmetrical distacodontiform elements. This is preferable to grouping both drepanodontiform and scandodontiform elements under a single, asymmetrical t designation.

Types: Holotype: WM00036, paratypes: WM00038-9.

GENUS PHRAGMODUS BRANSON & MEHL, 1933
(emend. BERGSTROM & SWEET, 1966)
(further emend. herein)

Type species: Phragmodus primus BRANSON & MEHL, 1933.

Discussion: The genus Phragmodus was originally erected by BRANSON & MEHL (1933) to include only those elements which are now recognized as comprising the ramiform (phragmodontiform) symmetry transition series in the revised, multielement concept of the taxon. The emended generic diagnosis of BERGSTRÖM & SWEET (1966, p. 366) defined Phragmodus as, "a multielement conodont genus composed basically of paired phragmodus-like and dichognathus-like elements but developing paired oistodus-like elements in some species." This initial concept was subsequently revised by SWEET (in ZIEGLER, 1981 p. 245) to include "conodonts with a skeletal apparatus of six or seven morphologically distinct types of elements. Pa is dichognathiform or ozarkodiniform. Pb is dichognathiform, M is cyrtoniodontiform or oistodontiform. Sa is hibbardelliform with short, adenticulate lateral processes and a long, arched, posterior process with a denticle at the crest as large as or longer than the cusp. Sb is like Sa, but lateral processes are not symmetrically disposed on either side of the cusp. Sc is cordylodontiform or like Sa and Sb with adenticulate lateral process or laterally deflected anterior process on only one side."

Two species of Phragmodus are described below, each with a five-member apparatus. Thus the generic diagnosis requires further emendment to incorporate these smaller apparatuses. The following is proposed: a conodont genus comprised of a symmetry transition series of ramiform elements (*a*, *b*, *c*), an oistodontiform or cyrtoniodontiform element (*e*), and a dichognathiform element (*f*). Later species also include an extra, different dichognathiform or ozarkodiniform *g* element. The *b* and *c* elements of the symmetry transition series are characterized by a long, arched denticulate posterior process with a denticle or denticles as large as, or larger than the cusp located at the crest of the arch. The *a* element is subcordylodontiform with straight, non-arched process. Cusp of *a* element is weakly costate or acostate. Cusp of *b* element is asymmetrical and either unicostate or bicostate. Cusp of *c* element is roughly bilaterally symmetrical with (sub)equal costae developed.

Early species of *Phragmodus* are poorly documented and the phylogenetic origins of the genus are obscure. It is a biostratigraphically important constituent of Midcontinent faunas.

Phragmodus polystrophos sp. nov.
Pl. 6, figs. 20,21,24-27, Pl. 7, figs. 10,12-16

Derivation of name: *poly* (Greek); many, *strophos* (Greek); twisted.

1970 *Oistodus* sp. cf. *O. abundans* MOSKALENKO,
p. 47, Pl. 1, fig. 2 (only).

1970 <u>Oistodus</u> <u>linguatus</u> (LINDSTRÖM) MOSKALENKO, p. 47, Pl. 1, fig. 4.

1970 <u>Dichognathus</u> <u>brevis</u> BRANSON & MEHL, MOSKALENKO, p. 64-65, Pl. 1, figs. 7a,b.

1970 <u>Phragmodus</u> sp. MOSKALENKO, p. 81, Pl. 13, fig. 5.

1970 <u>Subcordylodus</u> <u>sinuatus</u> STAUFFER, MOSKALENKO, p. 88-89, Pl. 13, fig. 4.

1973 <u>Dichognathus</u> <u>brevis</u>? BRANSON & MEHL, MOSKALENKO, p. 66, Pl. 16, figs. 1,2.

1973 <u>Dichognathus</u> <u>decipiens</u> BRANSON & MEHL, MOSKALENKO, p. 66, Pl. 15, figs. 7-12.

?1973 <u>Gothodus</u> <u>evenkiensis</u> MOSKALENKO, p. 67, Pl. 11, figs. 1-3.

1973 <u>Oistodus</u> <u>abundans</u> BRANSON & MEHL, MOSKALENKO, p. 35-36, Pl. 1, fig. 9 (only).

1973 <u>Phragmodus</u> <u>flexuosus</u> MOSKALENKO, p. 73-74, Pl. 11, figs. 4-6.

1973 <u>Subcordylodus</u> <u>sinuatus</u> (STAUFFER) MOSKALENKO, p. 80-81, Pl. 12, figs. 7-9.

1979 <u>Phragmodus</u> n. sp. A HARRIS <u>et</u>. <u>al</u>., p. 23, text-fig. 13.

1981 ?<u>Phragmodus</u> <u>flexuosus</u> MOSKALENKO, ETHINGTON & CLARK, p. 79-82, Pl. 9, figs. 2-7.

Description: The apparatus is a Type IVC apparatus with a symmetry transition series of: subcordylodontiform (<u>a</u>), asymmetrical (<u>b</u>) and (near) symmetrical trichonodelliform; (<u>c</u>) elements, an oistodontiform (<u>e</u>)

element and one type of dichognathiform (f) element with a serrated lower anterior margin to the cusp. There is a complete spectrum of inter-gradational forms in the symmetry transition series. The apparatus has been adequately described by ETHINGTON and CLARK (1981, p. 79-80) but the following comments are necessary. The oistodontiform (e) element illustrated by ETHINGTON and CLARK (1981) is incomplete with the non-denticulate posterior process missing. Most of the specimens in this collection are in a similar state of preservation but in some, the posterior process is preserved. ETHINGTON and CLARK (1981) may not have recognized this as they did not include in their synonymy, Oistodus linguatus (LINDSTRÖM) as illustrated by MOSKALENKO (1970, Pl. 1, fig. 4) which has the posterior process preserved and is most similar to the element in this collection. MOSKALENKO did not include the element in her original apparatus reconstruction of P. flexuosus. ETHINGTON and CLARK (1981) do not describe the serration of the lower anterior margin of the cusp of the dichognathiform (f) element that is a prominent feature of the element in this collection and which is due to incipient denticulation (Pl. 7, fig. 16b).

Remarks: The name, P. flexuosus, has in the past, been used rather loosely, partly because of confusion arising from there being in fact, two different apparatuses, both of which possess identical phragmodontiform elements in the symmetry transition series. The confusion stems from the original description of MOSKALENKO (1972) who included nine elements from both apparatuses in a single apparatus reconstruction.

HARRIS et. al. (1979) were the first to distinguish the two species. In their study of faunas from the Great Basin and Rocky Mountains regions of the U.S.A. they recognized an apparatus which they identified with P. flexuosus. The apparatus included a cyrtoniodontiform (e) element. They also recognized another Phragmodus apparatus with an oistodontiform (e) element as in Phragmodus polystrophos. They referred to this species as Phragmodus sp. nov. A. The two species are also distinguished by the absence of the incipient denticulation which is present in the dichognathiform element of Phragmodus polystrophos in the two, different dichognathiform elements of Phragmodus flexuosus.

ANITA HARRIS (pers. comm., 1984) reports that in none of the sections studied by her and others (1979) was P. flexuosus (e = cyrtoniodontiform) (unequivocally) found in strata below the Eoplacognathus foliaceus - E. reclinatus transition interval. In the Meiklejohn Peak section Phragmodus polystrophos was recovered from samples through a 160m interval of graded carbonates believed to represent an outer shelf to upperslope environment of deposition. In the lower 90m of this interval, Phragmodus polystrophos cooccurs with Eoplacognathus suecicus BERGSTRÖM (1971). In the upper 70m of the interval, no other biostratigraphically significant taxa were found in association with it. At Steptoe Section in the Egan Range the two Phragmodus species were found to cooccur over a 30m interval in the upper Pogonip, in strata believed to represent a more, inner shelf environment of deposition. MOSKALENKO (1973) may also have found these two species co-existing as she reported (1976) oistodontiform elements and plectodiniform (cyrtoniodontiform) elements from the same "horizon". Despite these two cooccurrences and the possible facies complication in the sections studied by HARRIS et. al., additional data suggest that there may be a biostratigraphically useful, phylogenetic component influencing the relative vertical distributions of these two species.

ETHINGTON and CLARK (1981) report Phragmodus polystrophos (e = oistodontiform) from through the entire type section of the Crystal Peak Dolomite in the Ibex Area (except for the top 50cm). This is above the highest occurrence of Histiodella holodentata ETHINGTON and CLARK (1981). Unfortunately, no biostratigraphically diagnostic taxa were found actually associated with it. In this Australian collection, Phragmodus polystrophos also occurs above the highest occurrence of H. holodentata and is associated with elements of Eoplacognathus suecicus. BERGSTRÖM & CARNES (1976) reported P. flexuosus (e = cyrtoniodontiform) from the Holston Formation of Tennessee in strata of the Pygodus anserinus Zone. All other reports of the species from the Appalachian region are from the Eoplacognathus foliaceus Zone or younger strata.

All these data lend support to the notion of a biostratigraphically useful distribution with Phragmodus polystrophos (e = oistodontiform) appearing before P. flexuosus (e = cyrtoniodontiform) and ranging alone through the Eoplacognathus suecicus Zone.

Types: Holotype: WM00110, paratypes: WM00105, WM00107-8, WM00111-2.

Phragmodus spicatus sp. nov.

Pl. 6, figs. 12,13,17-19a,b,22,23, Pl. 7, figs. 1,4,6-9,11

Derivation of name: spicatus (Latin); having ears. This refers to the lateral denticles present in the triconodelliform (c) element.

Diagnosis: A species of Phragmodus consisting of a ramiform element symmetry transition series (a, b, & c), a crytoniodontiform element (e) and a dichognathiform element (f) in a Type IVC apparatus. There is a complete range of intergradational forms in the ramiform symmetry transition series.

The c element is trichonodelliform with symmetrical, lateral processes, each bearing a single, large, denticle. All elements have an albid cusp and denticles and a hyaline base.

Description: Cusp of subcordylodontiform a element is sub-erect to proclined and curved, slender and acostate. Cusp is moderately laterally compressed with biconvex cross-section and has anterior and posterior margins sharp and weakly keeled. Anterior margin is inwardly deflected. Margins of cusp and base meet in smooth curves. Base is laterally compressed with flat inner face and slightly convex outer face and base encloses deep, triangular (in outline) basal cavity with apex at base of cusp below anteriormost denticle. Straight, upper basal margin is developed posteriorly into long, non-arched and non-curved denticulate process, at least somewhat greater in length than cusp (the absolute length is unknown as the process is never completely preserved). Posterior process is laterally compressed. Basal cavity extends uniformly along process as slit excavated to a depth of about one third to one half of process height. Two to four denticles of the upper basal margin are small, laterally compressed and triangular in outine. They are sub-erect to posteriorly inclined. Anteriormost denticle is in elevated position relative to other and is located at junction of cusp and base. Denticles are closely spaced and may be fused basally. Denticles of posterior process are about double the size of largest denticle of base (at about half-cusp height) and are more discrete. Denticles are all markedly inclined posteriorly.

Cusp of phragmodontiform b element is similar to that of a element but is either unicostate or asymmetrically bicostate (one along each lateral face). Cusp is also less laterally compressed with sub-circular cross-section. Costae are thin, hair-like and located roughly along midline of cusp. Lower part of anterior margin of cusp and base is more prominently keeled basally than in a element and produced basally as an anticusp. Costae may be strongly on and expanded laterally as short flange-like adenticulate processes approximately bisecting base. Posterior process is moderately arched and variably sinuous. Denticulation is similar to that of a element but size and spacing of denticles is more variable. Denticles of posterior process tend to much wider (in an antero-posterior sense) than those of a element. Some elements have a distinctive wider spacing between the denticles. Denticles are variably laterally deflected in sinuous elements.

Trichonodelliform c element is similar to b element with bicostate cusp and arched posterior process. It differs in having a bilaterally symmetrical cusp with rounded anterior margin, no anticusp and two, single-denticle, lateral processes. Posterior process is also relatively straight. Denticles of lateral processes are antero-posteriorly compressed, slightly anteriorly and outwardly inclined and curved in line with anterior margin of cusp. Lateral processes extend slightly beyond lower basal margin. There are normally only two, relatively small denticles along upper basal margin. The third denticle from cusp (first on posterior process) is largest and about as high as cusp. It may also be very wide and sail-like in appearance. Denticles further to posterior of this are similar but slightly smaller.

Cusp of cyrtoniodontiform (e) element is long, sub-erect and strongly laterally compressed with sharp margins. Outer face is shallowly convex and inner face bears a broad, low, medial swelling, most prominent towards base. Anterior margin is moderately curved in lateral outline, but posterior margin is nearly straight. Base is strongly inwardly turned and posteriorly produced as straight, denticulate process. Base possesses inwardly expanded sheath enclosing moderately deep basal cavity with bluntly rounded apex. Basal outline of sheath is sigmoidal. Anterior margin of base is vertical and meets lower basal margin in a sharp right-angle. Upper basal margin is straight and denticulate and meets posterior margin of cusp also in a sharp right-angle. Upper basal margin and posterior process are together, at least as long as cusp with about six or seven closely spaced, relatively long and thin, slightly laterally compressed, strongly posteriorly sloped and sub-equal denticles. Basal sheath continues along posterior process and encloses relatively deep, slit-like continuation of basal cavity.

Cusp of dichognathiform (f) element is stout, sub-erect and strongly laterally compressed with sharp margins; basically similar to that of the e element. Anterior margin projects downwards basally and posteriorly in smooth curve (under cusp) as a prominent adenticulate anticusp. Both lateral process and posterior process are denticulate and diverge at an angle of approximately 135 degrees. Inner basal margins of both processes are connected by flat, (triangular) sheath enclosing large and deep basal cavity. Inner-lateral process is at least as long as cusp and is strongly downwardly deflected, moderately inclined forwards and slightly curved. It bears short, tooth-like, closely spaced denticles tilted anteriorly in line with plane of process. Posterior process is straight near cusp but inwardly curved distally. Its denticles are similar to those of inner-lateral process and may be either erect or inclined posteriorly.

Remarks: The apparatus described here resembles that of P. flexuosus and that of P. inflexus. It differs from both in its unusual (for the genus) trichonodelliform c element with denticulate lateral processes. All the specimens in the collection are small and relatively fragile (compared with Phragmodus polystrophos higher in the section) and in this aspect they thus differ from P. flexuosus and resemble P. inflexus. However, the anterior margin of the base and lower cusp of all specimens of the dichognathiform (f) element is smooth and adenticulate and there is no evidence of a "germ" denticle such as is characteristic of P. inflexus. The dichognathiform element is much less common in this species than in Phragmodus polystrophos (above) and specimens are too few for statistical analysis. There is no apparent pattern in their distribution to indicate a relationship with the remainder of the apparatus described. In fact, despite their relative scarcity, in some samples they occur in isolation from other elements of the apparatus. Their inclusion in the apparatus is thus based primarily on morphological grounds and by apparatus comparison with younger species of *Phragmodus*. There are no other elements with which they are apparently associated. A distributional relationship is apparent between the more numerous *e* element and the ramiform elements.

This new species cooccurs with *Histiodella holodentata* indicative of Midcontinent Fauna 4. This makes it the stratigraphically lowest reported occurrence of the genus *Phragmodus*.

Types: Holotype; WM00117, paratypes; WM00114-6, WM00118-20.

GENUS *PLECTODINA* STAUFFER, 1935

Type species: *Prioniodus aculeatus* STAUFFER, 1930.

Plectodina sp. cf. *P. aculeata* (STAUFFER, 1930)

Pl. 5, figs. 18,19,21-23

Remarks: For comparative convenience the elemental designation of SWEET and SCHÖNLAUB (1975) is used in the discussion of this species with the corresponding letter designation of BARNES *et. al*. (1979) cited in parentheses.

P. aculeata has a distinctive type IVB apparatus consisting of a prioniodiniform M (*e*) element, a dichognathiform Pa (*f*) element, an ozarkodiniform Pb (*g*) element and a cordylodontiform to trichonodelliform, Sa to

Sc, (a, b & c) symmetry transition series. The apparatus is distinguished from other Plectodina species by the combination of a dichognathiform (f) element and a prioniodiniform (e) element which characteristically possesses two sub-equal processes mutually divergent at 90 degrees (SWEET in ZIEGLER, 1981, p. 277). The apparatus recognized here conforms well with this aculeata-plan, although the Sa and Sb (c and b) elements are largely fragmentary and undiagnostic.

The species has been loosely interpreted by many students to include much regional variation in the morphology of the elements. The elements of the apparatus here do not altogether resemble those of any other single reported occurrence.

The regional variation suggests that the present species concept of P. aculeata actually includes a group of probably distinct species or sub-species with a common apparatus plan and for this reason, the apparatus recognized here is only tentatively identified as Plectodina sp. cf. P. aculeata.

There is a large difference in the relative frequency of ozarkodiniform Pb (g) and dichognathiform Pa (f) elements. The former outnumber the latter by approximately 10:1 (46:5) indicating that these elements are not paired. Ozarkodiniform elements are in fact five times more abundant than the next most common element which is the prioniodiniform M (e) element.

Types: Figured specimens, WM00121-5.

GENUS <u>PROTOPANDERODUS</u> LINDSTRÖM, 1971

Type species: <u>Acontiodus</u> <u>rectus</u> LINDSTRÖM, 1955.

Discussion: The genus <u>Protopanderodus</u> was erected by LINDSTRÖM (1971, p. 50) to include, "panderodids with a cusp that is higher than the base. The longitudinal striations of the cusp may be inconspicuous. The cross-section of the cusp may be sub-circular, comma-shaped, lanceolate or <u>Acontiodus</u>-like. Most species include symmetrical as well as asymmetrical elements but there are no oistodontiform elements."

This is rather a broad definition and it has been so interpreted. In addition to the above, the following characters are also considered diagnostic: the apparatus is composed of elements with white matter in a two-element symmetry transition series of the Type IB in which the symmetrical element is acontiodontiform.

<u>Protopanderodus</u> <u>nogamii</u> (LEE) 1975
Pl. 3, figs. 1a,b,6a,b

1967 <u>Scolopodus</u> sp. cf. <u>S</u>. <u>bassleri</u> (FURNISH) IGO & KOIKE, p. 23, Pl. 3, figs. 7,8; text-fig 6B.

1974 <u>Panderodus</u> sp. SERPAGLI, p. 59, Pl. 24, figs. 12,13, Pl. 30, figs. 12,13.

1975 <u>Scolopodus</u> <u>nogamii</u> LEE, p. 179, Pl. 2, fig. 13.

1977 <u>Panderodus</u> <u>striatus</u> (STAUFFER) LEE, p. 138, Pl. 1, figs. 11,13.

1977 Scolopodus nogamii LEE, p. 141, Pl. 2, fig. 12.

1983 Scolopodus euspinus JIANG & ZHANG (AN et. al.), p. 140, Pl. 13, fig. 27, Pl. 14, figs. 1-8.

1983 Scolopodus nogamii LEE, AN et. al., p. 144, Pl. 13, figs. 20-25.

Description: A species of Protopanderodus with two elements; grandiform (p) and reclined (q), in a curvature transition series of a Type IIIB apparatus. Both elements are simple cones with a single, continuous groove along each lateral face of albid cusp and hyaline base. Base and posterior face of lower cusp are finely striated. Cusp of p element is sub-erect to proclined and rarely recurved. Cusp of q element is long, slender and straight or weakly curved. Base of q element is much shorter relative to cusp than that of p element.

Grandiform p element is asymmetrical or less commonly sub-symmetrical with asymmetrically disposed grooves along each face and often with laterally deflected anterior margin. Reclined q element is commonly sub-symmetrical. Both elements may be slightly twisted.

Cusp of p element is long, curved and distally tapered. Anterior face is strongly convex between anterior margins of lateral grooves. Posterior face is narrower, and more strongly convex than anterior. Lateral grooves are thin distally on cusp and widen and deepen slightly towards base. Margins of grooves are broad and rounded on base but a sharp, hair-like costa may line anterior margin of groove along cusp. When present, costa diverges from groove onto base and fades rapidly. Base is relatively long with slightly posteriorly divergent upper and antero-lower margins. Cusp and base approximately define a single, smooth, arcuate curve in lateral outline. Base encloses deep, simple, conical basal cavity, opening posteriorly and with apex adjacent to anterior margin at base of cusp. Posterior outline of base broadly reflects cusp section but is more irregular and rounded. Basal striae are very fine. There is a narrow, non-striate, rounded posterior marginal rim.

Cusp of q element is straight and sub-erect or moderately recurved. Grooves may be aligned along midline of cusp or migrate anteriorly or posteriorly up cusp from a medial position on base. Cross-section of cusp conforms to migration of grooves such that margin distal from grooves is sharp and margin proximal to grooves is broadly rounded and convex or flattened and sub-rectangular, commonly with a faint, hair-like, medial costa. In elements with grooves along midline of cusp both anterior and posterior faces are flat and cusp has square cross-section with rounded corners. Base is much shorter in relation to cusp than in p elements but otherwise similar. Junction of cusp and base is more tightly curved.

Remarks: This species cannot be assigned to Panderodus because of its shallower basal cavity, nor to Scolopodus because of the restricted application of that name to only hyaline forms. It cannot be assigned to Scalpellodus because of its uncompressed cusp, lacking sharp anterior and posterior margins and because of the different striation pattern. The p element is approximately twice as numerous as the q element.

Types: Figured specimens, WM00138, WM00139.

Protopanderodus sp. cf. P. gradatus SERPAGLI, 1974
Pl. 1, figs. 15a,b,19a,b,20,21

Description: Cusp of s element is sub-erect and relatively straight. Cusp meets base in smooth curve and anterior margin of cusp is sharp distally but tightly rounded towards base. Posterior margin is sharply keeled. Sharp, postero-lateral costae face posteriorly giving cusp a tanged, arrowhead-like cross-section. Costae are continuous along entire length of cusp and most of base, terminating just short of posterior margin. Above and adjacent to termination of lateral costae is a short, shallow linear depression. Most specimens also possess another just above the postero-basal corner. Depressions are widest posteriorly and progressively diminish anteriorly along base. Base is laterally compressed with flat sides downwardly divergent from sharp upper margin. Lower basal margin flat-faced. Base is triangular in cross-section.

Cusp of t element has sharp anterior and posterior margins and lateral faces either acostate and smoothly convex, unicostate or bicostate. Costae are sharp or rounded and are separated by narrow grooves or wider, sulcus-like depressions. Costae invariably terminate close to posterior margin of base. Base is laterally compressed with sharp, upper and lower margins and weakly convex lateral faces. Length of base varies from about equal to twice the base height. This variation is not apparently related to symmetry.

The t element describes a symmetry transition series including the following: scandodontiform elements with inwardly deflected anterior margin and either unicostate or bicostate inner face and acostate or unicostate outer face and drepanodontiform elements with non-deflected anterior margin but similar, asymmetrically developed lateral costae. Some drepanodontiform specimens have both lateral faces bicostate and in these, asymmetry is due to the position and relative strength of the costae. No specimens were observed with both faces unicostate (as in s element). Where only one costa was observed on a face, it was always in the postero-lateral position. Where two costae were observed on a face either could be the stronger.

Discussion: The material closely resembles *Protopanderodus gradatus* SERPAGLI (1974) with which it is compared. It differs by including a truly symmetrical, acontiodontiform element with a flat, antero-basal margin. It also includes elements with a significantly longer base (particularly the s element) than any of the specimens illustrated by SERPAGLI (Pl. 15, figs. 5a-8b, Pl. 26, figs. 11-15, Pl. 30, figs. 1a,b, text-fig. 17).

Types: Figured specimens, WM00134, WM00132-3, WM00135.

Protopanderodus sp. A s.f.
°Pl. 1, figs. 10,11,13

Description: A small collection of specimens of fundamentally similar morphology are here assigned to the genus Protopanderodus. The specimens are all basically scandodontiform with proclined to weakly recurved, laterally compressed and inwardly twisted cusp. Base has more or less strong, sharp, inwardly deflected keel along lower margin. Base and cusp meet in smooth curve and have a single, continuous, hair-like shallow groove along the inner face. Base is slightly flared inwards distally and encloses deep, straight, conical basal cavity with apex just above or level with upper basal margin and adjacent to anterior margin.

Cusp is acostate and near symmetrically biconvex in cross-section with sharp, non-keeled anterior and posterior margins. Every specimen but one, possesses a long base and proclined to sub-erect cusp. The exception has a short base and weakly recurved cusp. Base is approximately sub-circular or broadly oval in cross-section with prominent keel developed along lower margin contiguous with sharp anterior margin of cusp. Upper margin of base may bear a weaker, hair-like, sharp keel contiguous with cusp's posterior margin. Keels are most prominent in zone of cusp and base flexure and both rapidly fade distally. In posterior third of base they are occluded by outward flaring of base and are indistinct in posterior outline. Cusp is albid and base is hyaline.

Remarks: The long-based specimens closely resemble the scandodontiform elements of Scalpellodus gracilis (SERGEEVA) LÖFGREN (1978, Pl. 5, figs. 11-13). They differ only in the apparent lack of surface striation and the prominence of the groove.

According to LÖFGREN (1978) Scalpellodus is distinguished mainly from Protopanderodus by more prominent surface striations and by the lack of a symmetrical acontiodontiform element in the apparatus. Consequently, despite the morphological similarity of these specimens with the scandodontiform element of Scalpellodus gracilis, they cannot be assigned to that genus without disregarding one of its main distinguishing criteria. No drepanodontiform elements were found that are associated with this scandodontiform element like those in the apparatus of Scalpellodus gracilis.

The apparent variation in the length of the base is insufficient to define an apparatus, particularly as the collection is small and only a single short-based variant is present. The specimens probably represent part of an apparatus which may include the symmetrical acontiodontiform element assigned to this genus but which is described separately below, as Protopanderodus sp. B s.f.

Types: Figured specimens, WM00127-9.

Protopanderodus sp. B s.f.
Pl. 1, fig. 12

Description: A bilaterally symmetrical acontiodontiform element with long, laterally compressed, slightly recurved cusp. Distally, cusp is straight with apex located above the upper basal margin. Anterior margin of cusp sharp distally but increasingly rounded towards base. Posterior face of cusp is typically acontiodontiform with sharp keel flanked by two posteriorly facing, sharp, postero-lateral costae. Cusp is arrowhead-shaped in cross-section. Costae and posterior keel diminish on base but intersect the posterior margin, though they are faint and not visible in posterior outline. Base is robust and laterally compressed with oval cross-section (about twice as high as wide) and rounded upper and lower margins. In lateral view, upper basal margin is flat and meets cusp in smooth arcuate curve. Antero-basal face slopes posteriorly at about 45 degrees and is straight or only weakly curved below level of upper basal margin. Antero-basal junction is an open, arcuate curve. Posterior margin connects upper basal margin and antero-basal margin in straight, anteriorly sloped edge. Base is of variable length, with upper basal margin from one to two cusp widths in length. Base encloses relatively deep, conical basal cavity with slightly upturned apex adjacent to anterior margin just above level of upper basal margin.

Remarks: This element differs from *Acontiodus rectus* LINDSTRÖM in its longer base and deeper basal cavity and from the *s* element of *Protopanderodus* sp. cf. *P.*

gradatus in its rounded anterior margin to the cusp and base. In basal cavity shape, white matter distribution, variability in length of base and in the optical character of its surface (indicative of microstructure), it resembles Protopanderodus sp. A s.f. and it may be the acontiodontiform element of a single multielement apparatus that includes that scandodontiform element. More material is required for confirmation.

Type: Figured specimen, WM00130.

GENUS PROTOPRIONIODUS McTAVISH, 1973

Type species: Protoprioniodus simplicissimus McTAVISH, 1973

Protoprioniodus histion sp. nov.
Pl. 2, figs. 1-4

Derivation of name: histion (Greek); sail.

Diagnosis: A multielement species of Protoprioniodus consisting of three elements; oistodontiform (a), prioniodontiform (b) and trichonodelliform (c) in a symmetry transition series in a Type IIB apparatus.

All elements have base extended posteriorly into long adenticulate process. Process of oistodontiform (a) element is sickle-shaped (convex upwards) and about half as long as cusp. Prioniodontiform (b) and trichonodelliform (c) elements are non-geniculate and have straight posterior processes approximately equal in length to cusp.

Description: Cusp of oistodontiform (a) element is blade-like, moderately to strongly reclined and variably inwardly curved. Cusp has thin, sharp, straight or weakly curved anterior and posterior margins and a medial rib-like thickening. Base is strongly laterally compressed, with flat outer face. Anterior margin is sharp and in line with anterior edge of cusp. Antero-basal corner is sharply rounded at angle of about 45 degrees. Genical angle varies between 50 and 80 degrees. Base is slightly inwardly expanded beneath cusp and has thin-walled sheath with sinuous basal outline which encloses shallow basal cavity. Basal cavity has anteriorly tilted apex under midline of cusp (at base of medial rib) and extends along posterior process with as shallow slit with smooth, rounded upper outline. Outline of cavity drops sub-vertically to anterior of apex and is strongly concave; intersecting basal margin well short of antero-basal corner.

The prioniodontiform (b) element is highly variable. Cusp is invariably sub-erect and has anterior portion variably inwardly deflected. Specimens with gentle anterior deflection, either curved or angular, have broad, low, rounded carina on outer face of cusp and smooth inner face. Specimens with strong, angular lateral deflection have strong, narrow costa on outer face of cusp along axis of deflection. Costa continues downwards across base, becoming wider, rounded and deflected postero-laterally. Costa projects below lower basal margin as short process. Posterior margin of cusp meets upper basal margin in smooth curve. Posterior process is straight, blade-like, and only slightly tapered distally.

Cusp of trichonodelliform (c) element is proclined and weakly curved, with sharp posterior margin. Cusp is bilaterally symmetrical with single wide, flange-like costa projecting perpendicular to cusp from each side of anterior margin. Costae are continuous from tip of cusp to basal margin, are straight-edged and extend laterally and downwards below lower basal margin. Base is extended posteriorly as adenticulate blade-like process as in (b) element. Posterior margin of cusp and upper basal margin lie in smooth sweeping curve through approximately 120 degrees. Basal cavity is small, shallow and triangular in basal and lateral outline. Cavity extends a short distance under costae and much further along posterior process as in (b) element.

Remarks: Specimens in the collection appear fragile and are often transluscent with a lightly frosted appearance. Extremities are commonly missing. White matter is not always present and even when developed it tends to be rather diffuse. Only one specimen of the b element was observed that can be described as 3-edged and thus, as properly prioniodontiform. Most examples have only gently curved lateral deflection of the anterior of the cusp, but it appears likely that the apparatus includes a complete spectrum of forms (of the b element), exhibiting varying degrees of asymmetry.

Types: Holotype: WM00104, paratypes: WM00101, WM00103, WM00140.

GENUS <u>SCOLOPODUS</u> PANDER, 1856, emend. LINDSTRÖM, 1971

Type species: <u>Scolopodus</u> <u>sublaevis</u> PANDER, 1856.

<u>Scolopodus</u> sp. cf. <u>S</u>. <u>cornuformis</u> SERGEEVA, 1963
Pl. 5, figs. 11,13,14

Remarks: LÖFGREN (1978) described the multielement apparatus of <u>S. cornuformis</u> as composed of a symmetrical cornuform element and a very variable scandodontiform element. She recognized three main variants of the latter. A similar apparatus is recognized here although the fauna is small and the apparatus differs slightly from typical <u>S. cornuformis</u> in the relative weakness of the postero-lateral grooves and in the absence of some of the scandodontiform variants described by LÖFGREN (1978). Apart from this, it conforms well with LÖFGREN's observations.

The cornuform <u>(s)</u> element is more similar to SERGEEVA's (1963) and LÖFGREN's (1978) stratigraphically older material in that the posterior margin is rounded with no medial groove. The postero-lateral grooves are weak and widely spaced and the cusp is long, proclined and relatively straight.

The scandodontiform <u>(t)</u> element varies from forms with two postero-lateral grooves, only slightly asymmetrically distributed, through strongly asymmetrical, bi-grooved forms to forms with only a single postero-lateral groove. With the cornuform <u>(s)</u> element, this represents a symmetry transition series of a Type IB apparatus. Relative length of the cusp to the base is variable but the base never comprises more than about one third of the total length of the element. The cusp varies from straight to weakly curved and from proclined (more common) to sub-erect.

The development of the striation is variable. In all elements, the anterior face of the cusp is smooth (as described by LÖFGREN) but the size of the smooth area varies and in some specimens it extends onto the lateral faces. There is a tendency to development of coarser striae or costae, anteriorly bordering the postero-lateral grooves.

Types: Figured specimens, WM00141-3.

GENUS TANGSHANODUS AN, 1983

Type species: Tangshanodus tangshanensis AN (AN et. al.) 1983

Tangshanodus tangshanensis
Pl. 5, fig. 1

1983 Tangshanodus tangshanensis AN (AN et. al.), p. 151-2, Pl. 20, figs. 1,2 (only).

Remarks: In the lower part of the section, there occurs a single specimen of a hyaline, bilaterally symmetrical, ramiform element (c). It differs from the trichonodelliform (c) element of Erraticodon balticus by lacking single-denticle, lateral processes. It has instead, strongly developed flange-like lateral costae along the cusp. The height of the costae increases down the cusp in a triangular fashion from an apex at the tip of the cusp to about one cusp diameter at the antero-basal junction. The costae terminate in a horizontal line in line with the basal margin. In other respects the element is similar to the trichonodelliform (c) element of Erraticodon balticus.

Type: Figured specimen, WM00074.

GENUS TRIGONODUS NIEPER, 1969
(emend. COOPER, 1981)

Type species: Trigonodus larapintinensis (CRESPIN, 1943)

Trigonodus larapintinensis (CRESPIN, 1943)
Pl. 2, figs. 12-14, 18-20, 22, 23.

Remarks: All the elements comprising the apparatus of Trigonodus larapintinensis have been recognised in the Canning material by direct comparison with Horn Valley Siltstone material (kindly provided by Dr. R.S. Nicoll of the Bureau of Mineral Resources, Canberra, Australia). From this comparison, the symmetrical c (Sa) and oistodontiform e (M) elements figured by COOPER (1981, Pl. 27, figs. 6,16) are questioned. The oistodontiform e (M) element illustrated (COOPER 1981, Pl. 27, fig. 6) may be considered to be a sharply recurved drepanodontiform a (Sc) element. The correct oistodontiform e (M) element was not figured. The symmetrical c (Sa) element illustrated by COOPER (1981, Pl. 27, fig. 16) may possibly not belong to Trigonodus. It appears to lack the prominent posterior keel and sharp, upper basal margin typical of the element in both the Horn Valley and Canning collections (Pl. 2, fig. 12). Only one scandodontiform _g_ (P) element was figured by COOPER (1981, Pl. 21, fig. 17). VAN WAMEL (1974, Pl. 5, figs. 2a,b,3a,b) included two variants in his reconstruction of _Triangulodus brevibasis_; considered to be co-generic by COOPER. The Canning material includes three variants of scandodontiform or suberectiform (P) element; _f_, _g_ and _g'_. One is essentially oistodontiform _g_ with a gently reclined cusp that meets the upper basal margin at a tightly rounded junction; the element is not quite geniculate although some poorly preserved specimens appear so. It also has a relatively deep basal cavity; moderately flared inwards and weakly flared outwards. The anterior margin is significantly curved in a zone just above the level of the upper basal margin. The second type _g'_ has an erect cusp with an essentially straight, contiguous, anterior margin to both the cusp and base. The cusp is slightly inwardly flexed, the basal cavity is relatively shallow and the base is strongly laterally flared on both sides. Neither of these forms is identical to the suberectiform _f_ element illustrated by VAN WAMEL (1974) which has a smoother curvature between cusp and base. Elements similar to it represent the third _f_ type present in the collection.

There is a difference in the relative frequencies of some of the elements between the upper and lower parts of the section. The first two suberectiform _g_ and _g'_ elements described above are rare in the lower part and the scandodontiform _f_ element and the costate elements of the symmetry transition series a, b, c are relatively much more abundant. Although, the collection is small this difference suggests the possibility of two species.

The oistodontiform (M) element is unique among the elements of the apparatus in having a non-triangular and relatively shallow basal cavity. The outline of the cavity is sinuous and the apex is commonly anteriorly overturned.
Types: Figured specimens, WM00145-148, WM00150-1, WM00040-1

aff. New Genus 5 sensu ETHINGTON & CLARK, 1981
Pl. 4, figs. 4,5

Remarks: Five specimens (from two adjacent samples) are comparable with the two elements ETHINGTON and CLARK (1981) recovered from the Crystal Peak Dolomite referred to as New Genus 5. Each specimen, like those of ETHINGTON and CLARK is incomplete; missing the basal portion. The specimens here differ in being asymmetrical with smoothly and strongly convex anterior faces. Also, the posterior costa is particularly tall and strongly laterally compressed and is aligned along the midline at a height of about one half times the width of the element. The basal cavity is conical and deep with the apex roughly on the midline and in the distal half. The cavity is filled in all specimens.

Types: Figured specimens, WM00153-4.

Genus and Species nov. A
Pl. 4, figs. 10,13

Description: Blade-like elements composed of a row of eight or (many) more, partly fused, long, slender, pointed, posteriorly inclined, albid denticles on a hyaline base. Cusp is longer than subordinate denticles but equally slender. Denticles decrease in size distally from cusp. Basal cavity is a very narrow, shallow slit. There are two morphotypes: arched (x) and non-arched (y).

Arched variant (x) has straight cusp, greater in length than the base and strongly reclined from crest of arch. Adjacent denticles may be nearly as long. Number of denticles varies from minimum of eight to in excess of twenty. Denticles and cusp are fused for between one third and two thirds of their length. Degree of fusing is roughly proportional to number of denticles. Cusp and denticles are laterally compressed and sub-rhombic in cross-section with sharp anterior and posterior margins and a broad, low, sharp carina approximately along midline of each lateral face. Degree of posterior inclination of denticles increases posteriorly with anteriormost denticle sub-vertical and posteriormost denticle near horizontal. Anterior denticles are shortest and may be weakly curved.

Non-arched variant (y) is rarer than the first. Anterior two-thirds of base is flat. Posterior third of base is slightly upturned and inwardly flexed. Cusp and denticles are acostate with smoothly convex lateral faces. Cusp is moderately to strongly reclined from flexure point and denticles decrease in size distally from cusp. Anterior denticles are about twice as numerous as posterior denticles and of variable inclination (between specimens) from moderately inclined posteriorly to sub-erect. Posterior denticles are strongly, posteriorly inclined.

Remarks: In white matter distribution and blade-like form this taxon resembles Histiodella holodentata and Falodus histion sp. nov. with which species it cooccurs. In the denticulation pattern and in the total absence of basal flaring, it differs from those two taxa.

The variability in curvature and arching is suggestive of a transition series but the material is insufficient to permit confident recognition of any particular apparatus plan.

Types: Figured specimens, WM00136, WM00137.

Genus and Species nov. B
Pl. 2, figs. 7,8

Description: A few specimens appear to comprise an apparatus of unknown affinity. There are two elements, asymmetrical and symmetrical, which probably represent the b and c elements respectively, of a cordylodontiform-roundyaform symmetry transition series.

Both elements are characterized by a long, relatively stout, sub-erect cusp that is straight distally but curved towards the base. Cusp bears a single, thin, sharp, costa along each lateral face continuous across base to posterior margin. A single short, robust denticle is developed from each lateral costa just below level of upper basal margin. Base is posteriorly expanded and triangular in lateral outline with relatively long, straight, horizontal upper basal margin that, in most cases, also carries a single short, robust denticle. Transition from cusp to base is smoothly curved. Base encloses deep, conical basal cavity with apex located between laterally produced, basal denticles. Cusp and denticles are albid, remainder of element is hyaline.

Cusp of asymmetrical (b) element is slightly antero-posteriorly compressed and twisted distally through about 45 degrees. Anterior and posterior faces are both smoothly convex. A faint, hair-like keel is developed along lower part of posterior face of cusp contiguous with sharp, upper basal margin. Lateral denticles are asymmetrically disposed with one higher and to anterior of other but both lie near midline of lateral faces of base. Lateral costae are expanded posteriorly of denticles as strong, sharp carinae, triangular in section (where they intercept the posterior margin). Lower basal margin is also strongly but bluntly keeled and keel fades rapidly anteriorly. In posterior outline, base is oval with sharp upper and lower apices and a single, prominent, triangular rib projects from each lateral face, either symmetrically or asymmetrically disposed.

Symmetrical (c) element differs in having slightly laterally compressed, untwisted cusp, with broad, shallowly convex anterior face and weakly convex lateral faces that meet posteriorly at sharp posterior margin. Lateral costae are symmetrically located at junctions of lateral faces with anterior face. Lateral denticles are symmetrically positioned along anterior edges of base. Base is triangular in cross-section with flat lower and lateral faces and sharp upper margin. Posterior to denticles, lateral costae are expanded as in asymmetrical element but are located along intersection of lateral faces of base with antero-basal face.

Remarks: Only two elements are recognized here and it is not certain if these represent a complete or incomplete apparatus. Elements are morphologically distinctive.

Types: Figured specimens, WM00094-5.

Genus and Species Indeterminate A
Pl. 4, fig. 25

cf. 1983 Ulrichodina sp. aff. wisconsinensis (FURNISH) AN et. al., p. 160-161, Pl. 22, figs. 13,14.

Remarks: One specimen is assigned here. It differs from Ulrichodina by its low, squat shape, sigmoidally curved anterior and posterior margins and concave basal margin. In lateral view it resembles a shark's dorsal fin.

Type: Figured specimen, WM00152.

Genus and Species Indeterminate B
Pl. 6, figs. 30,31

Description: Two specimens of different morphology are together assigned here. One is sub-symmetrical and nearly flat, the other is asymmetrical and strongly arched. Both are antero-posteriorly compressed, robust, shallowly excavated, hyaline bars sub-equal in size and bearing several albid denticles.

Base of sub-symmetrical element is non-arched and about four times as long as wide, with sharp distal apices. Anterior margin is convex, posterior margin is straight. Mid-portion of base is highest at about one third of length. Height gradually diminishes towards lateral apices. Cusp and denticles lie along sharp, medial ridge with cusp located at high-point of element. Two denticles, each laterally adjacent to cusp are moderately posteriorly inclined and antero-posteriorly compressed, with sharp lateral margins and convex anterior and posterior faces. Denticles are discrete and spaced at intervals of over one denticle width. Distal tips of cusp and denticles are not preserved. Another small denticle is developed on one of the distal apices of the base. A similar denticle may have been present on the other apex but if so, is not preserved.

Asymmetrical element is strongly arched and anteriorly flexed about cusp. Base with blunt distal termini and weakly flexed, lower basal margin appearing as near-continuous, narrow, sharp-edged lip. Denticles differ from those of sub-symmetrical element in being relatively crowded with confluent bases and are also markedly triangular in outline. Size and inclination of denticles is variable. Cusp is located on crest of arch and slightly set back to posterior of other denticles.

Remarks: Together with Cordylodontiform B and

Ozarkodiniform] A (herein), these elements may form part of an Oulodus apparatus.

Types: Figured specimens, WM00157-8.

Cordylodontiform A
Pl. 2, fig. 6

Description: This element conforms closely with the description of Cordylodus intermedius FURNISH (1938) given by DRUCE and JONES (1971, p. 68) except that is is entirely hyaline. It cannot be readily assigned to a multielement apparatus.

Type: Figured specimen, WM00155.

Cordylodontiform B
Pl. 6, fig. 35

Description: Slightly asymmetrical with distally twisted cusp and unequally moderately convex, lateral basal faces. Cusp is weakly recurved and laterally compressed with distal, inward rotation of anterior margin through about 45 degrees. Lateral faces are shallowly convex. Distal, twisted part of cusp has sharp, extremely finely keeled, anterior and posterior margins. Keels fade downwards towards base as cusp becomes less twisted. Anterior and posterior margins are tightly rounded. Base is large with keeled lower margin and weakly convex lateral faces, inner face slightly more strongly so. Large, deep, conical basal cavity is triangular in lateral outline with apex adjacent to anterior margin. Upper edge of basal cavity is straight, horizontal and parallel to upper basal margin which has three moderately posteriorly inclined, laterally compressed, discrete denticles, increasing in size distally from cusp. Margin extends posteriorly into a broken denticulate posterior process. Cusp is albid and base is hyaline.

Remarks: Possibly associated with Genus and Species Indeterminate B (herein) and Ozarkodiniform A in a multielement Oulodus apparatus.

Type: Figured specimen, WM00156.

Dichognathiform A
Pl. 6, fig. 16

Description: Cusp is relatively tall and slender and slightly recurved. It is laterally compressed with sharp anterior and posterior margins. Outer face is convex, inner face is flat or weakly convex and acostate. There may be a low, rounded swelling on inner face of cusp just above junction with base. Anterior margin of cusp projects basally as short, adenticulate anticusp, weakly curved posteriorly. Cusp is inwardly turned at angle of about 15 degrees to posterior process. Posterior and inner processes diverge at about 135 degrees. Both processes appear slightly shorter than cusp and bear two to four relatively large, discrete, peg-like denticles. Inner process is deflected slightly downwards. Denticles of inner process are antero-posteriorly compressed with rounded anterior and posterior faces, sharp lateral margins and are weakly curved posteriorly. Denticles of posterior process are laterally compressed with convex outer face and flat to weakly convex, inner face meeting at sharp anterior and posterior margins. Denticles slope posteriorly and outwards. Basal cavity is wide and large and extends under all processes, including anticusp. Cavity is enclosed by thin, convex upper sheath, triangular in plan, which connects lateral processes. A similarly thin, continuous sheath is present along anterior and outer margins of processes and anticusp. Cusp and denticles are albid, base and processes are hyaline.

Remarks: This element cooccurs in several samples with Phragmodus polystrophos sp. nov. It is not interpreted here as a second dichognathiform element of that apparatus because it is much less abundant in the collection than any element of that species (by a factor of 10) and also because of its distinctive, different morphology. The cusp is longer and relatively more slender with an acostate inner face and it is also recurved and inwardly inclined relative to the posterior process with a smaller anticusp and an invariably smooth, non-serrated, anterior margin. The denticles are relatively much larger and on the posterior process, outwardly inclined.

The inner and posterior processes diverge at about the same angle as in the dichognathiform element of Phragmodus polystrophos.

Type: Figured specimen, WM00034.

Distacodontiform A
Pl. 2, fig. 5

aff. 1955 aff. Oistodus n. sp. LINDSTRÖM,

p. 581, Pl. 3, fig. 26.

Description: A bilaterally symmetrical cone element with slightly curved, sub-erect cusp with thin, sharp costae developed along midline of each lateral face and sharply keeled anterior and posterior margins. Costae and keels continuous to lower basal margin. Lateral costae fade distally up cusp. Base is short, enclosing relatively deep, conical cavity with apex anterior of midline of cusp at level of sharp, upper basal margin. Basal outline is rhombic. Base meets posterior margin of cusp in a tight curve. Cusp is albid and base is hyaline.

Remarks: This element bears some resemblance to *Oistodus* n. sp. LINDSTRÖM (1955). It differs in being non-geniculate, although poorly preserved specimens may appear so, with a less strongly reclined cusp and a deeper basal cavity.

Type: Figured specimen, WM00035.

Oistodontiform A
Pl. 2, fig. 15

Description: Cusp is laterally compressed, recurved at approximately 30 degrees to upper basal margin and weakly flexed inwards distally. Anterior and posterior margins are strongly and sharply keeled and gently curved. Anterior keel is continuous along base to antero-posterior junction and is weakly deflected inwards. Inner face of cusp is weakly concave. Outer face is strongly convex and both faces have broad, low, rounded carina along midline. Base is short (approximately half the length of the cusp) low, and strongly, sub-equally laterally expanded with broad, spindle-shaped, basal plan. Upper basal margin is short, sharp, straight and horizontal. Base encloses shallow, near-radially symmetrical, simple, conical cavity with gently sloping sides. Apex is located on lateral midline level with upper basal margin. Cavity has only short, shallow, constricted and attenuated, anterior and posterior projections towards basal termini. Element is totally hyaline.

Type: Figured specimen, WM00161.

Ozarkodiniform A
Pl. 6, fig. 34

?1983 Plectodina onychodonta AN & XU, (AN et. al.), p. 12, Pl. 24, figs. 3-10.

Description: An ozarkodiniform element with sub-equal, bar-like anterior and posterior processes, weakly inwardly curved and downwardly deflected from cusp. Anterior process has six to nine crowded, partly fused denticles increasingly fused towards cusp and decreasing in size distally. Posterior process has four to six, less crowded and shorter denticles, triangular in lateral outline and decreasing in size distally from cusp. Base and processes are hyaline, cusp and denticles are albid.

Cusp is stout, erect or marginally recurved and weakly laterally compressed with strongly convex lateral faces and sharp or blunt anterior and posterior margins.

posterior margin is straight or recurved in outline. Anterior margin is distally recurved to apex. Base and processes are strongly laterally compressed and crimped below a low, rounded linear swelling along "root-zone" of denticles. Processes are robust and approximately one and a half times length of cusp. Base has low, thin-walled sheath developed along lower basal margin. Sheath is locally outwardly expanded beneath cusp and encloses a shallow sub-symmetrical and sub-vertical, conical basal cavity with sharp apex. Sheath and cavity extend part-way along processes; further posteriorly. They gradually diminish with distance from cusp.

Remarks: Although this element is similar to the ozarkodiniform element of Plectodina onychodonta AN et. al. (1983), no elements similar to the other elements of the apparatus have been recognized. The element may belong to an Oulodus-like apparatus (refer to Remarks on Gen. et sp. Indeterminate B herein).

Type: Figured specimen, WM00159.

Ozarkodiniform B
Pl. 4, fig. 12

Description: A strongly laterally compressed, straight or weakly laterally curved, blade-like ozarkodiniform element with sub-equal, denticulate anterior and posterior processes. Anterior process has three to four closely spaced, partially fused denticles, all smaller than cusp and decreasing in size distally. Posterior process has two to three discrete, sub-equal denticles of about half-cusp height. Denticles are triangular in lateral outline.

Cusp is weakly reclined and strongly laterally compressed with weakly convex, acostate lateral faces meeting anteriorly and posteriorly in sharp margins. Cusp is slightly longer than height of base. Base and processes are strongly laterally compressed and flat-sided. Processes are weakly downwardly deflected. Basal margin has well developed, thin-walled sheath enclosing basal cavity. Lower margin of sheath connects distal apices of processes with straight, horizontal lower margin. Sheath is expanded moderately outwards and weakly inwards in restricted area directly beneath cusp. Basal cavity is shallow; only as deep as sheath except for weak rounded apex beneath cusp. Cusp, denticles and upper portion of base have diffuse white matter. The lower portion of base is hyaline.

Remarks: This element is similar in denticulation pattern and basal sheath to Ozarkodiniform A and also the ozarkodiniform element of P. sp. cf. P. aculeata. It differs in having fewer denticles and in being more strongly laterally compressed and blade-like in plan with little or no lateral deflection of processes.

Type: Figured specimen, WM00160.

Scandodontiform A

Pl. 1, fig. 22

Description: A scandodontiform element with strongly laterally compressed, wide, blade-like, robust cusp. Anterior and posterior margins are sharp and distally attenuated; almost keeled. The anterior margin develops into inwardly deflected keel towards and onto base. Base is moderately inwardly expanded, with deep, simple, conical, basal cavity. Cusp is albid and base is hyaline.

Cusp is sub-erect and curved and more or less inwardly flexed relative to base. In cross-section, cusp is long, narrow, sharp-ended ellipsoid with inner face slightly more convex than outer. Keel is continuous along anterior basal margin to antero-basal corner. Base is short. Length of upper basal margin is less than height. Base height is between a half to a quarter that of cusp. Line of anterior and upper basal margins is roughly contiguous with line of cusp margin curvature. Base is inwardly expanded and encloses simple, conical, basal cavity with apex at lower margin. Outline of cavity is a right-angle with longest edge connecting upper posterior corner of base with apex. Anterior edge is about half of base height in length. Posterior outline of base is oval with a small "pinch" of upper and outer portion where intersected by sharp, upper basal margin.

Remarks: The degree of inward curvature, lateral compression of the cusp and the degree of inner expansion of the base are all quite variable between drepanodontiform and more typical scandodontiform end members. This is suggestive of a symmetry transition series. The more curved and less compressed variants of this element are similar to the scandodontiform of ?Juanognathus sp.

Type: Figured specimen, WM00162.

Scandodontiform B
Pl. 3, fig. 2

Description: Robust, simple, non-geniculate cone element with smoothly recurved cusp. Cusp has sharp sub-equally keeled anterior and posterior margins. Anterior keel is strongly deflected into inner-lateral position. Outer lateral face of cusp is strongly convex. Inner face of cusp is flat with strong, broad, rounded carina along midline. Edges of carina are sharply defined adjacent to keels. Keels project onto base but terminate just short of basal margin. Base is robust, short and low with upper basal margin no longer than diameter of cusp. In rare specimens, base is markedly inwardly rotated relative to cusp. Base encloses simple conical basal cavity with apex at anterior margin at base of cusp and is finely striated except for smooth, rounded rim adjacent to posterior margin.

Remarks: This element has basically the same geometry as the asymmetrical element of ?Juanognathus sp. and Scandodontiform A. It differs from the former in its smaller, less flared base and sub-equal keels and from the latter by its more rounded cusp section. All the specimens in the collection are noticeably large and robust and many possess a basal filling. It is possible that this element is a phenotypic variant of the scandodontiform element of

?*Juanognathus* sp. Striae are present on the bases of both elements. The absence of striae from the cusp distinguishes these elements from those of *Protopanderodus nogamii*.

Type: Figured specimen, WM00163.

Scandodontiform C
Pl. 1, fig. 9

Description: Simple, sub-symmetrical, non-geniculate cone element with sub-erect to weakly recurved cusp. Cusp is laterally compressed with strongly convex inner face and less convex outer face meeting in sharp, low-keeled, anterior and posterior margins. Base is slightly inwardly twisted to cusp and is laterally compressed with broad, oval posterior outline. Upper basal margin is straight in lateral view and about a quarter of length of cusp. Keels of cusp are continuous onto upper and lower basal margins but terminate short of posterior margin. Base encloses deep, conical basal cavity with up-turned apex located at antero-basal margin just below level of upper basal margin.

Remarks: This element is similar to the short-based scandodontiform variant of *Protopanderodus* sp. A s.f. It differs in having a less robust base enclosing a basal cavity with an apex just below the level of the basal margin (i.e. not at or above). It also lacks the inner lateral groove.

Type: Figured specimen, WM00184.

Scandodontiform D

Pl. 1, fig. 7

Description: A scandodontiform element with sub-erect to proclined cusp bearing a prominent, sharp antero-lateral (inner) keel. Base is low and strongly expanded with characteristically sub-circular or broadly oval, basal outline. Cusp is albid and base is hyaline.

Cusp is moderately laterally compressed with an asymmetrically biconvex cross-section. Outer lateral face is smoothly convex. Inner lateral face has strong, broad, rounded carina. Anterior and posterior margins of cusp are strongly keeled, the posterior margin less so. Keels fade onto base and do not reach basal margin. Cusp is straight distally or weakly curved but strongly inwardly flexed towards base. Base encloses simple, shallow, conical basal cavity with apex at base of cusp in line with or just anterior of midline of cusp. Basal outline is characteristically sub-circular but outer lateral face may be somewhat flattened.

Remarks: This element superficially resembles Scolopodus peselephantis LINDSTRÖM (1955) in its round base and white matter distribution (described by ETHINGTON and CLARK, 1981). However, no surface striae were observed nor are any of the specimens postero-laterally grooved.

Type: Figured specimen, WM00165.

Indeterminate element A
Pl. 3, fig. 3

Description: A simple, non-geniculate cone element with strongly proclined, straight, slender cusp. Cusp has broad, round-edged groove along inner lateral face and fainter, linear depression in corresponding position along outer lateral face. Base is short and unflared with parallel margins. Element is very finely striated all over. Cusp is albid and base is hyaline.

Cusp is widest anteriorly with broadly convex anterior face. Posterior to grooves, lateral faces converge towards narrow, sharply rounded posterior margin. Grooves fade on base short of basal margin. Cusp meets base in open curve at angle of about 135 degrees. Base is broadly oval in posterior outline and encloses simple conical basal cavity, asymmetrically triangular in lateral outline. Apex of cavity is adjacent to low, basal margin at about one cusp diameter from posterior margin.

Remarks: This element closely resembles those of *Protopanderodus nogamii* in white matter distribution, cusp cross-section and striation. It is differentiated from that species by its proclined cusp. Only one specimen was observed in the collection whereas elements of *Protopanderodus nogamii* total 509 specimens.

Type: Figured specimen, WM00166.

Indeterminate element B
Pl. 1, fig. 14

Description: Non-geniculate, antero-posteriorly compressed, sub-symmetrical cone element. Cusp is relatively stout, proclined and straight or weakly curved. Anterior face is gently convex and posterior face strongly convex, meeting at sharply costate lateral margins. Base is extremely short, with gently rounded upper basal margin approximately as long as cusp is wide. Anterior face of base is weakly convex and in same plane of curvature as anterior face of cusp. Base is sub-equally and laterally extended as short, sharp, adenticulate processes or alars contiguous with lateral costae of cusp. Lateral processes terminate at sharp apices. Basal cavity shallow and bowl-shaped and restricted to area directly under cusp.

Type: Figured specimen, WM00167.

Indeterminate element C
Pl. 2, figs. 16, 17

Description: Hyaline, simple-cone elements with laterally compressed cusp and base. Cusp is weakly laterally flexed and sub-erect to weakly recurved with sharp anterior and posterior margins. Junction of cusp with upper basal margin is non-geniculate. Base is high with straight, parallel upper and lower margins (in outline) connected by shallowly convex, posterior margin. Antero-basal junction is angular at approximately 80 to 110 degrees. Base encloses anteriorly overturned cavity with apex at mid-height of base and mid-point of diagonal between anterior and posterior cusp and base junctions. Basal cavity extends anteriorly to antero-basal corner.

Types: Figured specimens, WM00042-3.

Indeterminate element D

Pl. 2, fig. 21

Remarks: Two specimens of a hyaline belodiniform element were obtained from different samples in the lower part of the section. One specimen is more robust and compressiform and the other is more grandiform. Both have a similar laterally compressed, conical basal cavity with the apex markedly down-turned. The cusp bears a longitudinal groove along each lateral face, but the groove fades onto the basal region and does not intersect the posterior margin.

Types: Figured specimen, WM00024.

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PLATE 1

All magnifications X60 unless otherwise specified.

Juanognathus leptosomatus (AN)

Fig. 1 (s): posterior, WM00081, 612m.

Fig. 2 (t): posterior, WM00083, 546m.

Fig. 3 (t): posterior, WM00082, 535m.

Fig. 6 (s'): posterior, WM00080, 612m.

aff. Cornuodus sp.

Figs. 4a,b (t): a; outer, b; inner, WM00030, 612m.

Fig. 5 (t'): outer, WM00028, 612m.

Fig. 8 (s): lateral, WM00029, 613m.

Scandodontiform D

Fig. 7: inner, WM00165, 612m.

Scandodontiform C

Fig. 9: outer, WM00184, 612m.

Protopanderodus sp. A s.f.

Fig. 10: inner, long-based specimen, WM00128, 561m.

Fig. 11: inner, short-based specimen, WM00127, 612m.

Fig. 13: inner, keeled specimen, WM00129, 561m.

Protopanderodus sp. B s.f.

Fig. 12: lateral, WM00130, 576m.

Indeterminate element B

Fig. 14: posterior, WM00167, 471m.

Protopanderodus sp. cf. P. gradatus SERPAGLI

Figs. 15a,b (t): a; outer, b; inner, WM00134,612m.

Figs. 19a,b (t): a; outer, b; inner, WM00135,530m.

Fig. 20 (t): inner, WM00133, 576m.

Fig. 21 (s): lateral, WM00132, 534m.

?Juanognathus sp. nov.

Figs. 16a,b X50 (s): a; posterior, b; lateral, WM00084, 422m.

Fig. 17 X50 (t'): inner, WM00086, 422m.

Fig. 18 X50 (t): posterior, WM00085, 422m.

Scandodontiform A

Fig. 22: inner, WM00162, 612m.

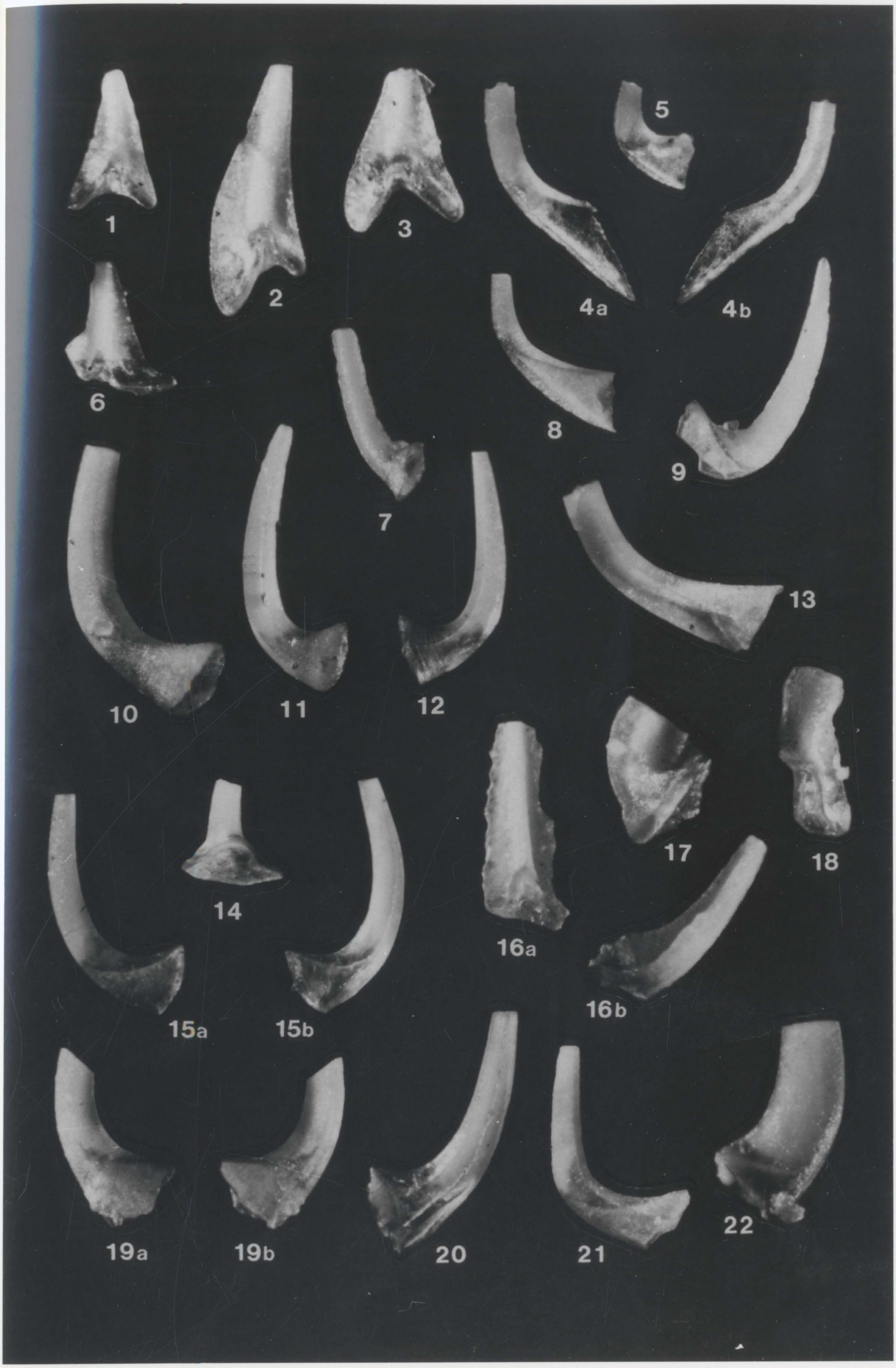

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PLATE 2

All magnifications X60 unless otherwise specified.

Protoprioniodus histion sp. nov.

Fig. 1 (c): posterior, paratype WM00103, 612m.

Fig. 2 (c): lateral, holotype WM00104, 612m.

Fig. 3 (a): inner, paratype WM00101, 585m.

Fig. 4 (b): outer, paratype WM00140, 519m.

Distacodontiform A

Fig. 5: lateral, WM00035, 508m.

Cordylodontiform A

Fig. 6: lateral, WM00155, 575m.

Genus and Species nov. B

Fig. 7 (b): lateral, WM00095, 495m.

Fig. 8 (c): lateral, WM00094, 495m.

Onyxodus acuoliratus sp. nov.

Figs. 9a,b (t'): a; outer, b; inner, paratype WM00039,508m.

Figs. 10a,b (t): a; outer, b; inner, paratype WM00038,508m.

Fig. 11 (s): lateral, holotype WM00036, 508m.

Trigonodus larapintinensis (CRESPIN)

Fig. 12 (c): posterior, WM00150, 447m.

Fig. 13 (g): inner, WM00145, 495m.

Fig. 14 (g'): inner, WM00146, 493m.

Fig. 18 (e): inner, WM00151, 612m.

Fig. 19 (a): inner, WM00147, 495m.

Fig. 20 (b): inner, WM00148, 520m.

Fig. 22 (a): inner, WM00041, 612m.

Fig. 23 (b): inner, WM00040, 613m.

Oistodontiform A

Fig. 15: inner, WM00161, 613m.

Indeterminate element C

Fig. 16: inner, WM00042, 520m.

Fig. 17: inner, WM00043, 520m.

Indeterminate element D

Fig. 21: lateral, WM00024, 585m.


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PLATE 3

All magnifications X60 unless otherwise specified.

Protopanderodus nogamii (LEE)

Figs. 1a,b (q): a; inner, b; outer, WM00138, 493m.

Figs. 6a,b (r): a; inner, b; outer, WM00139, 507m.

Scandodontiform B

Fig. 2: inner, WM00163, 519m.

Indeterminate element A

Fig. 3: inner, WM00166, 612m.

Eobelodiniform element

Fig. 4: inner, WM00023, 612m.

Belodina sp.

Fig. 5: outer, WM00021, 467m.

?Juanognathus sp.

Fig. 7 X50 (s): posterior, WM00087, 561m.

Fig. 8 X50 (t): posterior, WM00088, 561m.

Fig. 10 X50 (t): inner, WM00090, 483m.

Fig. 11 X50 (s): posterior, WM00089, 483m.

Dapsilodus nevadensis? (ETHINGTON & SCHUMACHER)

Fig. 9 (c): inner, WM00031, 456m.

Fig. 12 (a): inner, WM00033,456m.

Fig. 13 (b): inner, WM00032, 448m.

Drepanoistodus pitjanti COOPER

Fig. 14 (q): inner, WM00057, 576m.

Fig. 16 (p): lateral, WM00056, 603m.

Fig. 17 (r): inner, WM00058, 576m.

Drepanoistodus forceps (LINDSTRÖM)

Fig. 15 (q): inner, WM00052, 585m.

Fig. 18 (r): inner, WM00054, 603m.

Fig. 19 (q): inner, WM00055, 576m.

Fig. 20 (p): lateral, WM00051, 585m.

Drepanoistodus basiovalis (SERGEEVA)

Fig. 21 (p): lateral, WM00050, 495m.

Fig. 22 (r): inner, WM00047, 493m.

Fig. 23 (r): inner, WM00049, 495m.

Fig. 24 (q): inner, WM00045, 495m.

Fig. 25 (q): inner, WM00046, 495m.

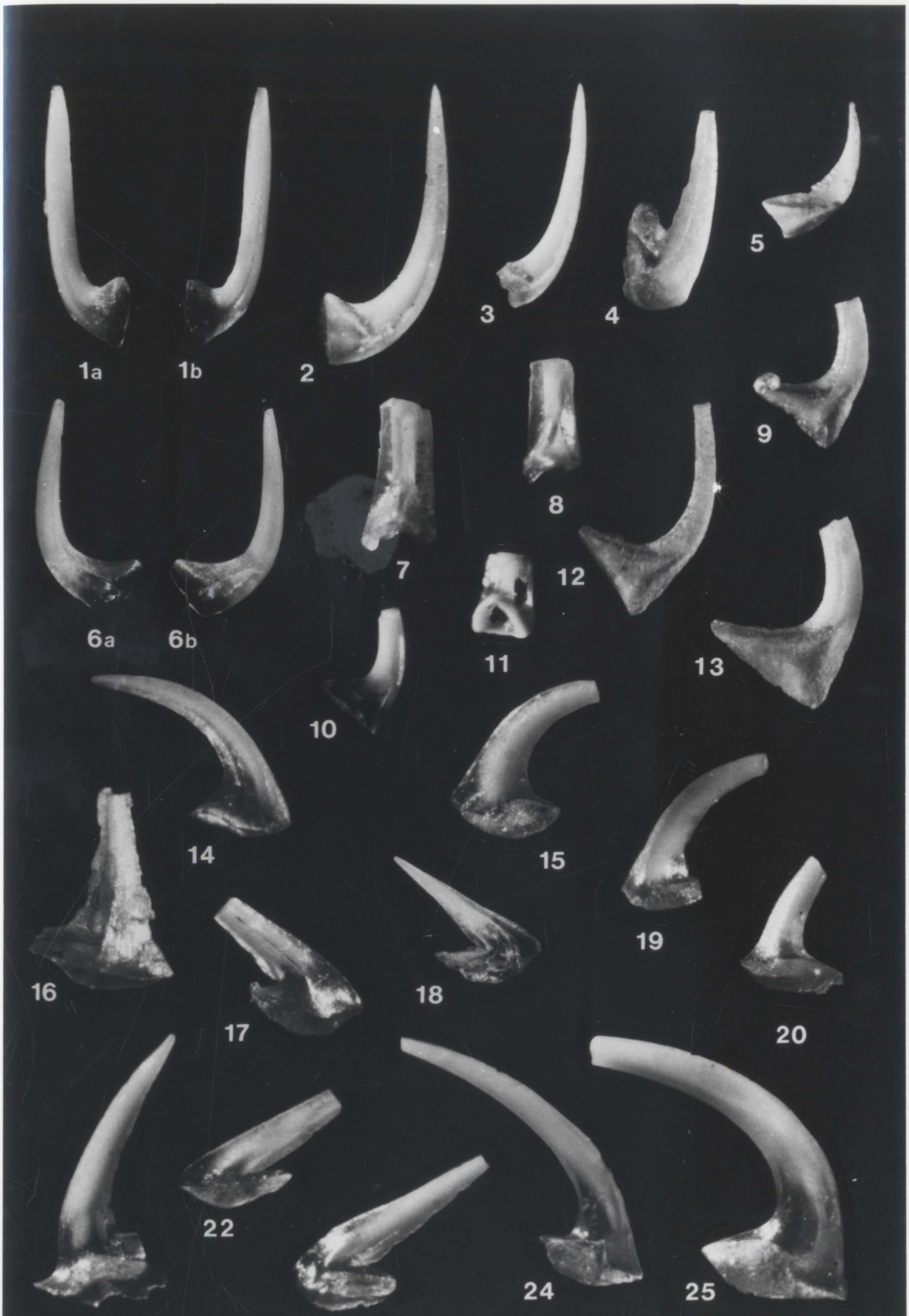
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PLATE 4

All magnifications X60 unless otherwise specified.

Oistodus sthenus s.f. ZHANG

Fig. 1: inner, WM00019, 468m.

Ansella sp.

Fig. 2 (e): inner, WM00020, 468m.

Fig. 3 (f): inner, WM00014, 495m.

Fig. 6 (a): lateral, WM00015, 471m.

Fig. 7 (c): lateral, WM00017, 468m.

Fig. 8 (b): inner, WM00016, 467m.

Fig. 9 (c): lateral, WM00018, 495m.

aff. New Genus 5 sensu ETHINGTON & CLARK

Fig. 4: posterior, WM00154, 549m.

Fig. 5: posterior, WM00153, 549m.

Genus and Species nov. A

Fig. 10 (y): outer, WM00137, 575m.

Fig. 13 (x): inner, WM00136, 548m.

Falodus keramis sp. nov. s.f.

Fig. 11 (x): inner, holotype WM00075, 613m.

Fig. 14 (y): inner, paratype WM00076, 549m.

Ozarkodiniform B

Fig. 12: inner, WM00160, 575m.

Histiodella holodentata ETHINGTON & CLARK

Fig. 15: inner, WM00078, 612m.

Figs. 19a,b: a; inner, b; outer, WM00079, 613m. Possible apparatus component.

Fig. 20: outer, WM00077, 612m.

<u>Ansella</u> sp. nov.

Fig. 16 (<u>a</u>): lateral, WM00009, 519M.

Fig. 17 (<u>b</u>): inner, WM00010, 585M.

Fig. 18 (<u>e</u>): inner, WM00013, 612m.

Fig. 21 (<u>c</u>): lateral, WM00011, 612m.

Fig. 22 (<u>f</u>): inner, WM00008, 612m.

Fig. 23 (<u>c</u>): lateral, WM00012, 588m.

Fig. 24 (<u>g</u>): inner, WM00007, 612m.

Genus and Species indeterminate A

Fig. 25: lateral, WM00152, 576m.

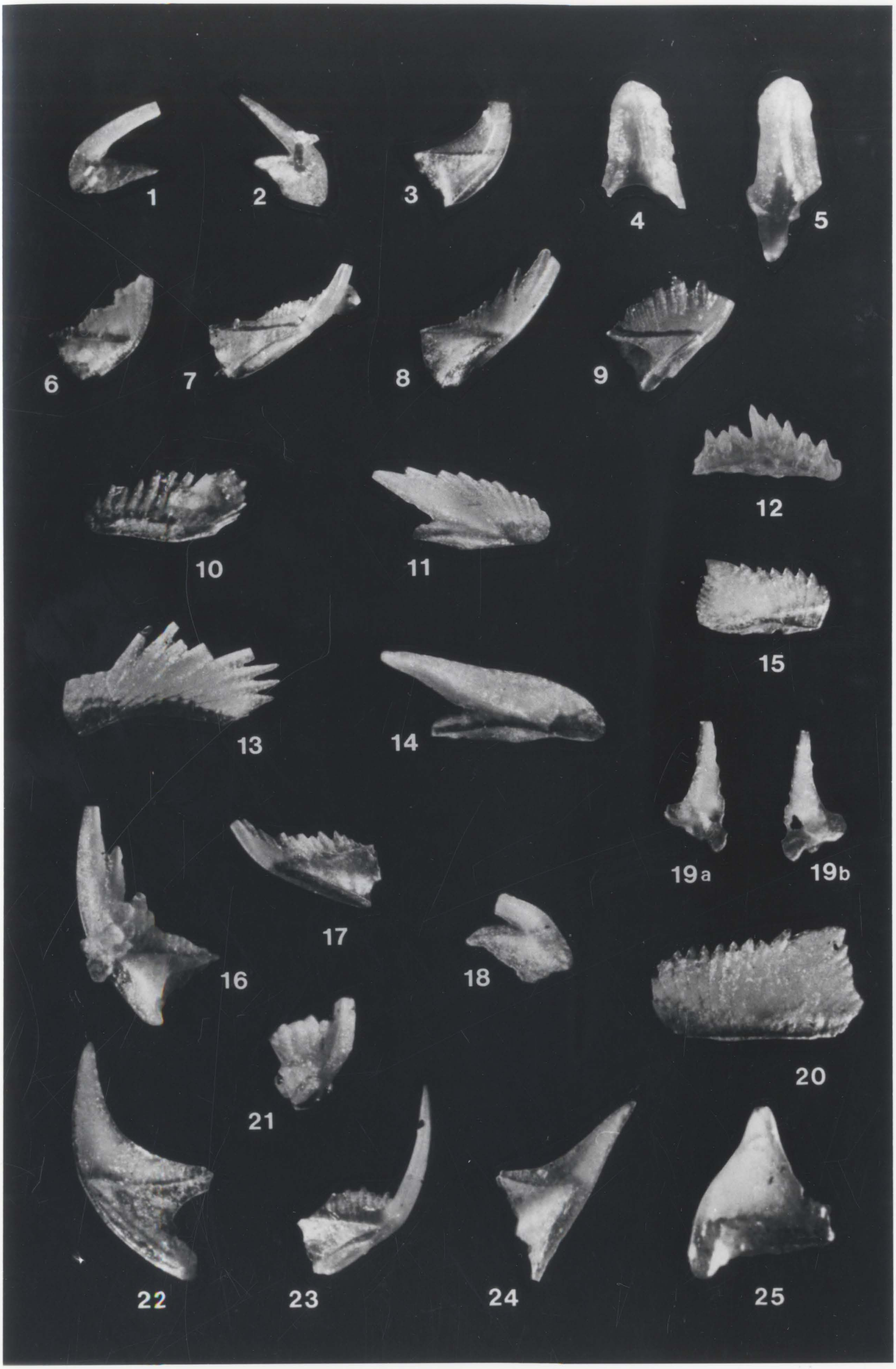
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PLATE 5

All magnifications X60 unless otherwise specified.

Tangshanodus tangshanensis AN

Fig. 1 X40 (c): lateral, WM00074, 548m.

Erraticodon balticus DZIK

Fig. 2 (c): lateral, WM00070, 503m.

Fig. 3 (b): inner, WM00069, 493m.

Fig. 4 (a): outer, WM00068, 503m.

Fig. 5 X70 (f): posterior, WM00071, 503m.

Fig. 6 X40 (f'): inner, WM00063, 431m.

Fig. 7 X70 (g): inner, WM00064, 562m.

Fig. 8 X40 (f): inner, WM00072, 503m.

Fig. 9 X45 (e): inner, WM00066, 503m.

Fig. 10 X45 (e): inner, WM00067, 482m.

Scolopodus sp. cf. S. cornuformis SERGEEVA

Fig. 11 (t): inner, WM00143, 519m.

Fig. 13 (t): inner, WM00142, 519m.

Fig. 14 (s): lateral, WM00141, 519m.

cf. ?Coleodus sp. s.f. BARNES & POPLAWSKI

Fig. 12: inner, WM00027, 612m.

Drepanoistodus pitjanti COOPER

Fig. 15 (q): outer, WM00144, 612m.

Bergstroemognathus sp.

Fig. 16 X35 (f): outer, WM00025, 585m.

Fig. 17 X35 (c): anterior, WM00024, 585m.

Fig. 20 X35 (c): anterior, WM00026, 583m.

Plectodina sp. cf. P. aculeata

Fig. 18 (c): posterior, WM00124, 395m.

Fig. 19 (f): inner, WM00121, 430m.

Fig. 21 (a): inner, WM00123, 395m.

Fig. 22 X30 (g): outer, WM00122, 412m.

Fig. 23 (e): inner, WM00125, 412m.

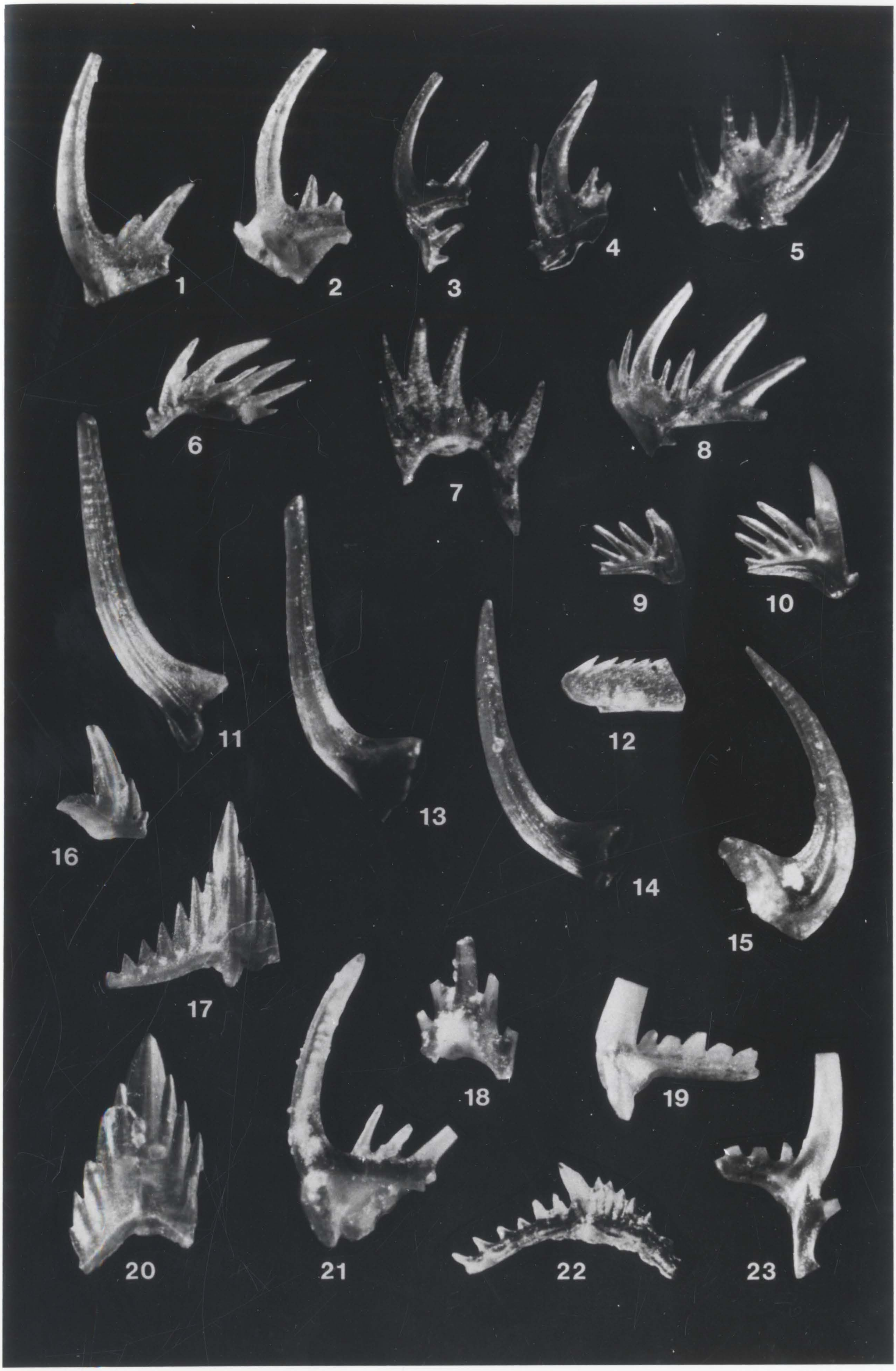
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PLATE 6

All magnifications X60 unless otherwise specified.

?*Baltoniodus* sp.

Fig. 1 (*f*): upper (inner), WM00002, 495m.

Fig. 2 (*d*): postero-lateral, WM00005, 495m.

Fig. 3 (*e*): inner, WM00006, 482m.

Figs. 5a,b (*g*): a; inner, b; outer, WM00001, 495m.

Fig. 6 (*c*): lateral, WM00004, 495m.

Fig. 7 (*b*): inner, WM00003, 495m.

?*Microzarkodina* sp.

Fig. 4 (*c*): anterior, WM00093, 469m.

Fig. 8 (*f*): inner, WM00092, 469m.

Oepikodus sp. cf. *O. communis* ETHINGTON & CLARK

Fig. 9 (*f*): inner, WM00096, 613m.

Fig. 10 (*e*): inner, WM00098, 561m.

Fig. 11 (*e*): inner, WM00099, 535m.

Fig. 14 (*a*): inner, WM00097, 585m.

Fig. 15: lateral, WM00100, 560m.

Phragmodus spicatus sp. nov.

Fig. 12 (*f*): outer, paratype WM00119, 584m.

Fig. 13 (*f*): outer, paratype WM00120, 575m.

Fig. 17 (*a*): inner, paratype WM00114, 575m.

Fig. 18 (*b*): inner, paratype WM00115, 575m.

Figs. 19a,b (*e*): a; outer lateral, b; inner lateral, paratype WM00118, 575m.

Fig. 22 (*c*): lateral, holotype WM00117, 575m.

Fig. 23 (*b*): inner, paratype WM00116, 575m.

Dichognathiform A

Fig. 16 X50: inner, WM00034, 471m.

Phragmodus polystrophos sp. nov.

Fig. 20 X70 (f): inner, paratype WM00111, 495m.

Fig. 21 X50 (f): inner, paratype WM00112, 495m.

ig. 24 X50 (e): inner, holotype WM00110, 495m.

Fig. 25 (c): lateral, paratype WM00108, 495m.

Fig. 26 X50 (b): inner, paratype WM00107, 495m.

Fig. 27 (a): inner, paratype WM00105, 495m.

Eoplacognathus suecicus BERGSTRÖM

Fig. 28 (f): upper plan, WM00060, 480m.

Fig. 32 (g): upper plan, WM00062, 503m.

Fig. 33 (g): upper plan, WM00061, 502m.

Eoplacognathus foliaceus? (FÅHRAEUS)

Fig 29 (f): upper plan, WM00059, 495m.

Genus and species indeterminate B

Fig. 30: posterior, WM00158, 495m.

Fig. 31: upper plan, WM00157, 495m.

Ozarkodiniform A

Fig. 34: inner, WM00159, 495m.

Cordylodontiform B

Fig. 35: outer, WM00156, 495m.


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PLATE 7

All magnifications X100 unless otherwise specified.

Phragmodus spicatus sp. nov.

Fig. 1 (c): lateral, holotype WM00117, 575m.

Fig. 4 (b): inner, paratype WM00115, 575m.

Fig. 6 (b): inner, paratype WM00116, 575m.

Fig. 7 X110 (f): inner, paratype WM00119, 584m.

Fig. 8 (e): inner, paratype WM00118, 575m.

Fig. 9 (a): lateral, paratype WM00114, 575m.

Fig. 11 X110 (f): inner, paratype WM00120, 575m.

Eoplacognathus foliaceus? (FÅHRAEUS)

Fig. 2 X80 (f): upper plan, WM00059, 495m.

Eoplacognathus suecicus BERGSTRÖM

Fig. 3 (f): upper plan, WM00060, 480m.

Fig. 5 X80 (g): upper plan, WM00062, 503m.

Phragmodus polystrophos sp. nov.

Fig. 10 X80 (a): outer, paratype WM00105, 495m.

Fig. 12 (f): inner, paratype WM00111, 495m.

Fig. 13 X80 (e): inner, holotype WM00110, 495m.

Fig. 14 X65 (b): inner, paratype WM00107, 495m.

Fig. 15 X80 (c): lateral, paratype WM00108, 495m.

Fig. 16 (f); a; X100 inner, b; X450 inner, paratype WM00112, 495m.


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PLATE 8

All magnifications X80 unless otherwise specified.

Erraticodon balticus DZIK

Fig. 1 (c): lateral, WM00070, 503m.

Fig. 2 X100 (b): inner, WM00069, 493m.

Fig. 5 X65 (f'): inner, WM00063, 431m.

Fig. 6 (a): inner, WM00068, 503m.

Fig. 8 (f): posterior, WM00071, 503m.

Fig. 9 X65 (e): inner, WM00067, 482m.

Fig. 10 (f): posterior, WM00073, 494m.

Fig. 11 X55 (f): inner, WM00072, 503m.

Fig. 12 (e): inner, WM00066, 503m.

Fig. 13 (g): inner, WM00064, 562m.

Oepikodus sp. cf. O. communis ETHINGTON & CLARK

Fig. 3 X135 (f): inner, WM00096, 613m.

Fig. 4 (e): inner, WM00098, 561m.

Fig. 7 X100 (a): inner, WM00097, 585m.


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Appendix A Core Log.

Lithologic description of samples and defined rock units in studied section; Upper Goldwyer Formation and Nita Formation, Canning Basin.

UNIT 1: 395-397m: Dolostone: light grey, massive with common disseminated anhydrite and few, thin, anhydrite bands.

Samples (total element yield incl. fragments):

395-6(20) anhydritic dolostone
396-7(53) " "

Comments: Possibly lagoonal, shallow subtidal or lower intertidal environment of deposition. Moderate conodont yields suggest seaward access.

UNIT 2: 397-406.7m: Banded dolostone, finely interbedded green claystone and anhydrite. Anhydrite and claystone increase towards top of unit; dolostone and bioturbation decrease. Rare clcm thick anhydrite bands present towards top of unit associated with possible tee-pee structures.

Samples:

401-2(1) anhydritic dolostone
402-3(4) " "
403-4(0) " "
404-5(0) " "

Comments: Further shallowing to upper, intertidal or supra-tidal environment of deposition.

UNIT 3: 406.7-411.25m: Banded dolostone: light grey to greenish-grey. Banding comprised of graded, centimetric cycles of upward clay enrichment. Occasional bioturbation. No fossils.

Samples:

None

Comments: Shallow, subtidal algal laminite.

UNIT 4: 411.25-437.7m: Dolostone: light grey, silty, mottled in parts. Dolomite results from dolomitization overprint of primary limestone with wackestone texture similar to unit 5.

Samples:

412-3(55)	50% silty, bioturbated dolostone, 50% clean dolostone
413-4(91)	light grey dolostone
421-2(36)	50% light grey dolostone, 50% silty bioturbated dolostone
422-3(152)	light grey dolostone
430-1(99)	light grey dolostone with leached packstone band
431-2(14)	light grey dolostone
436-7(5)	" " "

Comments: Slight shallowing but fundamentally a continuation of the environment of deposition of unit 5.

UNIT 5: 437.7-477.5m: Limestone: variably silty and dolomitic. Light grey, sparse biowackestone grading locally into calcareous (dolomitic) siltstone. Occasional biopackstone bands. Limestone commonly bioturbated in more silty intervals. Abundant stylolites and anastomosing stylolitic laminae concentrated in more silty zones and giving core a mottled, nodular aspect. Dolomite content increases up-section. Base gradational with increasing shale.

Samples:

437-8(199)	70% dolostone, 30% stylolitized wackestone
441-2(152)	stylolitized wackestone
442-3(39)	" "
443-4(11)	" "

444-5(309)	50% stylolitized wackestone, 50% silty dolomite
447-8(121)	60% stylolitized wackestone, 40% silty dolomite
448-9(10)	stylolitized wackestone
451-2(87)	" "
452-3(121)	" "
455-6(198)	bioturbated dolomitic siltstone
456-7(76)	stylolitized, silty wackestone with bioturbation
467-8(247)	" " " " "
468-9(160)	" " " " "
469-70(195)	" " " " "
470-1(162)	" " " " "
471-2(103)	" " " " "
472-3(128)	" " " " "

Comments: Relatively uniform, stable, shallow, subtidal environment of deposition; dominantly carbonate muds with minor siliclastic input. Best conodont yields are from heavily stylolitized silty zones and are often associated with bioturbation.

UNIT 6: 477.5-513m: Interbedded <u>limestone</u> (50%), <u>silty claystone</u> (25%), <u>silty</u>, <u>argillaceous</u> <u>limestone</u> (15%) and <u>siltstone</u> (10%). Limestone is light grey to buff, wackestone, silty in parts with abundant stylolites and stylolitic laminae and common skeletal and rarely oolitic, thin packstone beds. Claystone is dark grey and fissile with common siltstone laminae and irregular limestone pods and lenses. Trilobite remains common, few brachiopods and rare graptolite fragments. Silty, argillaceous limestone with irregular texture of limestone pods and lenses intercalated with dolomitic clayey siltstones. Siltstones either laminated or bioturbated.

Unit increasingly calcareous up-section with claystone beds restricted to lower part of unit (below 495m). Silty, argillaceous limestone most common in upper part of unit. Dolomite restricted to silty and argillaceous, stylolitic laminae. Thin packstone bands common throughout.

Samples:

479-80(223)	70% silty, argillaceous limestone, 30% wackestone
480-1(71)	50% silty, argillaceous limestone, 50% wackestone
481-2(97)	" " " " " "
482-3(157)	" " " " " "
483-4(270)	silty, argillaceous limestone with bioturbation
484-5(65)	70% silty, argillaceous limestone with bioturbation, 30% wackestone
492-3(232)	wackestone 493-4(390) wackestone with thin packstone bed with oncolites
494-5(150)	80% dark grey claystone, 20% wackestone
495-6(514)	dark grey claystone
502-3(181)	60% dark grey claystone with limestone pods, 40% wackestone
503-4(267)	70% silty claystone with limestone pods, 30% fissile dark grey claystone with limestone pods
507-8(302)	limestone with silty stylolitic laminae
508-9(123)	" " " " "

Comments: Overall a shallowing-up sequence. A major conodont faunal change occurs near the base of unit below 509m. The common packstone bands are probably storm deposits.

UNIT 7: 513-515m: Limestone: light grey with common stylolites. Sparse wackestone texture with large, recrystallized gastropod remains and occasional brachiopod valves. Low siliciclastic content.

Samples:

513-4(24)	gastropod wackestone
514-5(14)	" "

Comments: Possibly a shallowing event. This is the only unit with gastropods readily visible in hand specimen.

UNIT 8: 515-539.9m: Interbedded limestone (60%), claystone (30%) and calcitic siltstone (10%). Limestone light to medium grey or buff and variably silty and/or argillaceous. Dominant wackestone texture with thin decimetric packstone interbeds, occasionally with oolites. Limestone finely interbedded (decimetric scale) with claystone and calcitic siltstone. Larger cycles of limestone dominated intervals are coarsely interbedded (metric scale) with claystone dominated intervals. Claystone is dark grey and fissile with rare trilobite fragments and common, graded (fining upwards) siltstone lenses and laminae. Siltstone towards top of unit is abundantly bioturbated.

Samples:

519-20(201)	low siliciclastic wackestone
520-1(205)	silty wackestone with thin oolitic packstone bed
521-2(1)	silty wackestone with thin brachiopod cocquinite bed
522-3(2)	finely interbedded silty wackestone and silty claystone
523-4(14)	silty claystone with minor limestone
529-30(50)	50% massive limestone, 50% claystone with siltstone and limestone bands
530-1(141)	claystone with single (20cm) skeletal packstone bed
534-5(75)	low siliciclastic wackestone with thin packstone bands
535-6(143)	50% interbedded claystone and limestone, 50% wackestone
538-9(3)	claystone, thin siltstone and limestone lenses
539-40(48)	" " " " " "

Comments: subtidal deposition in varying water depths.

UNIT 9: 539.9-565.75m: Limestone: light grey to buff, with abundant stylolites. Dominant sparse, brachiopod wackestone texture, silty and bioturbated in parts with occasional oncolite and/or oolite and/or fine skeletal, packstone or grainstone interbeds. Base gradational with underlying claystone unit through thinly interbedded sequence approximately three metres in thickness.

Samples:

546-7(19)	sparse wackestone
547-8(74)	" "
548-9(32)	" "
549-50(126)	packstone with skeletal debris, oolites and oncolites
550-1(13)	60% packstone, 40% sparse wackestone
558-9(13)	sparse wackestone
559-60(15)	" "
560-1(10)	" "
561-2(163)	silty, bioturbated lime mudstone
562-3(39)	sparse wackestone

Comments: Open marine, shallow, carbonate shelf lime wackestones with higher-energy storm events giving rise to common, thin packstone and grainstone beds. Conodont yields of wackestones are generally low suggesting a relatively fast rate of deposition. The silty, bioturbated interval (561-2) with the highest element yield, may indicate an episode of slower deposition.

UNIT 10: 565.75-583.15m: Silty claystone: dark grey with thin limestone interbeds, bands, lenses and nodules. Claystone, fissile with abundant trilobite remains, rare brachiopods and graptolite fragments. Common light grey, coarse, siltstone laminae, more common towards base. Limestone beds, light grey, packstones or grainstones, with skeletal debris, oolites and occasionally oncolites. Stylolites abundant. Fossil nautiloid at 582.85m.

Samples:

575-6(237) dark grey claystone with common limestone lenses
576-7(320) dark grey claystone

Comments: Open marine outer shelf or shallow intra-shelf basin with clay muds. The two samples from this interval yielded relatively high numbers of small conodont elements. The faunal composition of the element assemblage is similar with that of other samples from this lower part of the section but the majority of elements are as a whole markedly smaller than in other samples. This is probably a product of sorting but a palaeoecological cause cannot be ruled out.

UNIT 11: 583.15-629m: Calcitic siltstone: light to medium brownish-grey, heavily bioturbated with irregular burrows and grazing trails mostly less than 5mm in diameter. Fine coarse to fine silt with graded lamination preserved in parts and possible ripple-foresets. Occasional silty limestone interbeds heavily bioturbated and apparently non-fossiliferous (in hand specimen) but with abundant stylolites. Limestone is more common above 614m.

Samples:

583-4(79) bioturbated siltstone
584-5(59) " "
585-6(79) " "

586-7(26)	" "
587-8(9)	" "
588-9(22)	" "
594-5(7)	" "
595-6(7)	" "
596-7(4)	" "
597-8(9)	" "
600-1(4)	" "
601-2(4)	" "
602-3(5)	" "
603-4(41)	" "
605-6(17)	silty limestone
612-3(451)	bioturbated siltstone
613-4(367)	50% bioturbated siltstone, 50% massive limestone bed
614-5(5)	bioturbated siltstone
615-6(2)	" "
616-7(1)	" "
617-8(3)	" "
624-5(2)	" "
625-6(3)	bioturbated siltstone with silty claystone bands
626-7(14)	" " " " " "
627-8(25)	50% bioturbated siltstone, 50% silty limestone with rare brachiopod fragments
628-9(4)	bioturbated siltstone with silty claystone bands

Comments: Clastics dominated, shallow subtidal setting without sessile, benthic epifauna. Generally low conodont yields; better yields from calcitic siltstones and silty limestones. The two, highest-yielding samples mark the base of the lowest carbonate-rich interval.

Appendix B Sampling Method.

SAMPLING

The core provided for study was an NQ diamond drillcore with a diameter of approximately 43mm. Whole core samples were not taken because of a requirement of the Western Australian Department of Mines and Energy for preservation of a continuous section at least one quarter core in width. This fact, combined with the sampling requirements of other studies restricted conodont samples to half-core slabs.

Conodont yields from a nearby core section through approximately the same stratigraphic interval were at best of only twenty-five elements per kilogram (approximately) and were normally considerably less (R.S. NICOLL, pers. comm., 1984). Microlithofacies variation in the core section studied was generally on a decimetric scale so restriction of sampling to specific microlithofacies was not feasible if reasonable element yields were to be expected. A minimum sample size of one metre in length (for half-core slabs) was considered necessary. Ninety-eight such samples were selected from the more uniform sections of lithology in an attempt to avoid major lithofacies boundaries and sample weight was relatively constant at about 1.6kg. Sampling was distributed through the entire section to provide a comprehensive coverage of the various lithofacies.

Appendix C.

Table of faunal distribution

and element abundances.

SPECIES	ELEMENT	508/9	507/8	503/4	502/3	495/6	494/5	493/4	492/3	484/5	483/4	482/3	481/2	480/1	479/80	472/3	471/2	470/1	469/70	468/9	467/8	456/7	455/6	452/3	451/2	448/9	447/8	444/5	443/4	442/3	441/2	437/8	436/7	431/2	430/1	422/3	421/2	413/4	412/3	402/3	401/2	396/7	395/6	TOTAL
	a																		1	1																								2
	b								1	1					3	2				2	3	1	1	2	1			1				2												20
Ansella sp.	c				1	2	1		2					3	4	2		2	3	2	5	2	1	2				2			1	1			2	1	2							41
	e	1		2	1	2			2						2	2			1	2	6	3	2	3	1			1			3	3												37
	f						1																																					1
	a/b						2																	2																				4
	c						1																																					1
?Baltoniodus sp.	d											1																																1
	e						3														1																							4
	f						1																																					1
	g	1				2			5		1		1	1	2	3				1	3	3		1								1												25
Dapsilodus	a																					1								1														2
nevadensis?	b																							1		1	1																	3
	c																					1									1													2
Drepanoistodus	p	1	2	2	1	1	1	1	1						1								2		1			2								2								18
basiovalis	q	12	37	23	9	43	6	28	16	7	17	13	11	9	13	2	4	4	7	14	8	7	8	4	7	2	15	15		3	6	9		1		10	2	4	3			3	3	385
	r	7	9	14	5	8	4	16	3	1	11	4	1	5	2	2	1	2	2	3	4	3	3	5	1	1	3	2				2				3		1						128
Eoplac. foliaceus?	f						1																																					1
Eoplacognathus	f		2											1				1			1										1													6
suecicus	g			1	1		2				1					2			1		1																							9
	a			1	3			2	4						1				1		1		1	F	1							1		1										17
	b	1		3				2				1			1				1		3		2					1			1					1								17
Erraticodon	c			1				1											1									1				1												5
balticus	e	1		2	2						1								2		1			1	1											2								13
	f	1		6	4	1	1	2		1		1	1		4				2		2		2	F							2													30
	g			1+F	1				F			F							F		F			F																				2
	f'																																	1										1
?Juanognathus sp. nov.	s																																			3								3
	t																																			12					1			13
	t'																																			2								2
?Juanognathus	s							2		1	1																			1				1	2	1								9
sp.	t				1			10	2	3	13	3	1	1				1	2		6	3							1			6		1	6	10	3	12	5			?7	3	100
?Microzarkodina	c																		1																									1
sp.	f																		1		1																							2
Oistodus sthenus	e												1		3				1	1		1	1	3				1			1	1	1											15
Onyxodus	s	1		3					1	2	1			1	1		1	1		1	2		2				2	1			2	2				1								24
acuoliratus	t	25	9	1	3			3	6	1	3		2	4	5	2	1	3	3	5	7	2	10	5	10	1	2	8	2	1	5	6			2									137
	t'	16	8	8	2	2		4	7	4	4	4	2	1	6	3	4	4	9	7	15	1	6	16	4	2	8	10	1	1	8	16	1	2	2									188
	a																																					6	1			1	3	11
	b																																										2	2
Plectodina sp. cf.	c																																						1				1	2
P.aculeata	e																																					4	3	1			3	11
	f																																		1				3			1		5
	g																																			2	6	16	9	2		4	2	41
	a	4	20	23	17	62	15	22	20	1	9	5	5	2	10	6	8	4	12	6	9	1	3	4	5		7	16	1		1	4	1		2				1					306
Phragmodus	b	8	47	43	31	(111)	37	45	34	3	15	19	5	6	20	18	15	5	24	13	24	8	11	11	10	1	10	52		4	23	21	1			5								680
polystrophos	c	1	10	7	5	26	4	9	9		2	5	1		2	5	1	1	2	2	5	1	3	3	1		4	9		2	2	4			1									127
	e	3	37	30	22	(107)	22	42	19	6	29	21	13	7	14	11	8	2	20	10	17	4	18	7	4		13	33		4	11	11		2	6									553
	f	7	35	25	18	93	17	50	28	3	24	18	11		14	12	12	4	18	5	18	4	16	8	10		6	38		4	21	20		1	8	4	1	3						556
Protopanderodus	q	1	1	10	1			10	1		9	8	2	6	9	3	1	8	9	12		6	12	3	4	1	1	3		1		3	1			12	1		1			1		141
nogamii	r		3	8	3			6	3		2	3	3	2	5	3		5	2	7		4	2	7				1			3	1		1	2	1	3		1			1		82
	a							5	1	1	1				4						5				1		2	4			1													25
	b					2					2																1	1																6
	c																																											0
Trigonodus	d																																											0
larapintinensis	e														1																													1
	f																																											0
	g					4	1	2	3		1	2	1	1						1	1						1	1			1					1								21
	g'							1		1	3			2									1				1	1								1	1							12
Gen.et.sp.nov.B	b		2			1	1			1	3				3	1																				1								13
	c		3			1	1	1			4				1	1																				1								13
Gen.et.sp.indet.B	s.f.					2																																						2
cordylo'form B.	el.					1																																						1
dicho'form indt.	el.			3				1			2	1			1		2						4					3																17
dist'form indt.	el.	1		2				2						1				1						1																				8
ozarko'form A	el.					9	3	6			6	1			1			1	4	1			2				1	1				2												38
scando'form A	el.	1					2																																					3
scando'form B	el.					4																																						4
indt. form B	el.														1		1											1																3

SAMPLE / SPECIES	ELEMENT	628/9	627/8	626/7	625/6	624/5	617/8	616/7	615/6	614/5	613/4	612/3	605/6	603/4	602/3	601/2	600/1	597/8	596/7	595/6	594/5	588/9	587/8	586/7	585/6	584/5	583/4	576/7	575/6	562/3	561/2	560/1	559/60	558/9	550/1	549/50	548/9	547/8	546/7	539/40	538/9	535/6	534/5	530/1	529/30	523/4	522/3	521/2	520/1	519/20	514/5	513/4	TOTAL
	a										1															1		1										1												1			5
	b										4	2												2	1	1	1		1		1							1						1					1			1	17
Ansella sp. nov.	c		1								10	11					1			1		1		1	4		2	3	5		1					5		3						6	2				5	4		2	68
	e			1							1	7												1	2	3		1	3		1					4								1					2	1		1	29
	f										3	10												1		1			2							1		1		1			1		1				2				24
	g										1	1																																1						1			4
Belodina sp.	p										1																																		1								2
eobelodiniform	el.											1																																						2			3
Bergstroemog.	c																						2				1									1																	4
sp.	f																								1		1																										2
cf. ?Coleodus sp.	s.f.											4			1										2	4	9	1						2				2	2	1			1	1					3				33
	s										1																																										1
aff. Cornuodus sp.	t,											3	1													1		4	4		1									4		2	2	2					2				26
	t'											2																4																									6
Drepanoistodus	p																								1				1																								2
forceps	q										6	2		1								2		1	2		4	5	6															2							1		32
	r			1							6	4										2		2	1		2	3	1		1												1							1	1		26
Drepanoistodus	p			1							1	3		1														1																1					1	1			10
pitjanti	q		3		2						11	18		2					1				1					5			3					1	1			2			1	3		2			3	3			62
	r		1									1																3			1							1		1									1		1		10
	a																													1	2																						3
	b																													1	1																						2
Erraticodon	c																													1			1																				2
balticus	e																													2	5	1																					8
	f																														1		1																				2
	g,																													1	F																						1
	f'																														1																						1
Falodus	x										32	9													1		2	3	4	1	2		1	3	1	3	1	3				1							2	1		2	62
keramis s.f.	y			1							1																								1	4		1				1	3	1			1						14
H.holodentata	f									1	48	31								3				1	4	1	7	17	20		12		1	1	3	22	4	14	1	2		10	3	1	2				14	6		7	136
	?										2																																										2
Juanognathus	t										2																3				1					1			2			2											11
leptosomatus	s,											2																								4						1											7
	s'											1											1			1	1																										4
?Juanognathus	s										1	2			1							1		1		1					3	1							3			4							1				19
sp.	t		3	1			1				6	17		7		1						1			4	1	2	2	2	2	8	1	2		4	6	3	9	3			6		4	3				5	8			112
Oepikodus sp.cf.	a																								1						1					1								1									4
O.communis	e										2																				1					2	1					3											9
	f										1																																										1
Protoprioniodus	a	2	2	1							26	37	5	7							1	2	1	3	13			21	12		8		1			1				2			5	17	2				15	5	2	1	192
histion	b										6	6																3	1							1				1							1			1		1	21
	c										3	9	3	1							1	2	2		1			1	1							1													2		1		28
	a										3																1	8	21		1									1		3			2	2			23	1			66
	b										2																	9	32													3	1	11	1				19	3			81
Phragmodus	c																											1	6														1						2	1			11
spicatus	e		1								2			1										1	1		4	6	22							1						7	1	8	4				18	8		1	86
	f										3															4	1	2	7		1					1				1		2	1										23
Protopanderodus	q		3	1					1		19	30	2	4				4				6		1	7	7	9	21		2	3	2		1	1	4	1	9		1		9	10	12	2	1			2	14	2	3	194
nogamii	r				1						4	15	1				1	1					1		4	2	6	9		1	1				1	4	2	2				3	4	6	2				1	8		2	82
Protopanderodus	s	1					1				2	4																1								2							1		1								13
sp.cf.P.gradatus	t			2							4	12																5			3					4	1					3	2	5	1					4			46
?P.sp.A	s.f.											1																1										1	1				3	1	1								9
?P.sp.B	s.f.,										3	10	1	2																	4					3	1					1	1	5					3	4			38
	s.f.'											1																								1																	2
Scolopodus sp.cf.	s											2																			1							1											1				5
S.cornuformis	t											3																2			2							1				1		3		1			1	7			21
T. tangshanensis	c																																				1																1
	a										4	4									2						2	1	2									2		2			1	1					1				28
	b											3																6	6											6		1	2	1		1			5	1			34
	c																											1	3							1													1				6
Trigonodus	d										1	1																																									2
larapintinensis	e										2	1																2	5											3		1						1	4	1			20
	f										1																	3	13											4					2	2			2				27
	g,										1																	1																					1	1			4
	g'																																												2								2
Genus et.sp.nov.A	x										10	4															2	2	7	1	1		6	2		5	2	1					1								2		46
	y																												1		1			1																		1	4
aff.new gen. 5	s.f.																																			2	3																5
Gen.et.sp.indt.A	el.																											1																									1
cordylo'form A	el.																												5																								5
oisto'form indt.	el.										1																	1																									2
ozarko'form B	el.																												3																								3
scando'form A	el.		1								2	6													3	2	1		1	1	1		1			1	1					1		1						2	1		26
scando'form B	el.																																							1				1						8			10
scando'form C	el.											2																																									2
scando'form D	el.										3	4																																									7
indt.form A	el.										1	1																																									2
indt.form C	el.		1								3	7		1														5	5		1									2									5	9			39
indt.form D	el.																																		1																		1

Sample Totals; Identifiable Elements.

Sample	Total
628-9	3
627-8	16
626-7	9
625-6	3
624-5	0
617-8	2
616-7	0
615-6	1
614-5	1
613-4	247
612-3	296
605-6	13
603-4	27
602-3	2
601-2	1
600-1	2
597-8	5
596-7	1
595-6	4
594-5	6
588-9	17
587-8	8
586-7	15
585-6	53
584-5	30
583-4	61
576-7	166
575-6	202
562-3	14
561-2	75
560-1	5
559-60	14
558-9	10
550-1	12
549-50	87
548-9	22
547-8	53
546-7	12
539-40	35
558-9	0
535-6	66
554-5	46
530-1	99
524-30	29
523-4	10
522-3	2
521-2	1
520-1	150
519-20	107
514-5	11
513-4	22

Sample	Total
508-9	93
507-8	225
503-4	219
502-3	131
495-6	484
494-5	127
493-4	273
492-3	168
484-5	37
483-4	165
482-3	110
481-2	61
480-1	53
479-80	134
472-3	80
471-2	59
470-1	49
469-70	130
468-9	96
467-8	149
456-7	56
455-6	113
452-3	89
451-2	62
448-9	9
447-8	78
444-5	209
443-4	5
442-3	22
441-2	94
437-8	117
436-7	5
431-2	11
430-1	34
422-3	76
421-2	19
413-4	46
412-3	28
402-3	3
401-2	1
396-7	18
395-6	17