EARLY ORDOVICIAN (ARENIG) CONODONTS FROM ST. PAULS INLET AND MARTIN POINT, COW HEAD GROUP, WESTERN NEWFOUNDLAND

DAVID IAN JOHNSTON

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Early Ordovician (Arenig) Conodonts from St. Pauls Inlet and Martin Point, Cow Head Group, Western Newfoundland

by

©David Ian Johnston, B.Sc.

A thesis submitted to the School of
Graduate Studies in partial fulfillment
of the requirements for the degree of
Master of Science

Department of Earth Sciences
Memorial University of Newfoundland

June 1986

St. John's, Newfoundland

ISBN 0-315-37032-7

ABSTRACT

The Middle Cambrian to Middle Ordovician Cow Head Group, western Newfoundland, was deposited at the toe-of-slope and continental rise of a passive margin adjacent to a carbonate platform. Early Ordovician (Arenig) strata are characterized by massive megaconglomerates interbedded with deep-water carbonates and siliciclastics and minor conglomerate. The St. Pauls Inlet and Martin Point sections are interpreted as intermediate and distal facies, respectively, of this sequence. Arenig strata in these and in other Cow Head sections of the St. Pauls Member of the Green Point Formation record the transition from a tectonically passive to a tectonically active margin. In the Middle Ordovician these rocks were thrust over coeval platform strata.

Previous conodont investigations focused entirely on sections on the Cow Head Peninsula. This study is an investigation of the biostratigraphy, paleoecology, and the taxonomy of Arenig conodont faunas from bedded strata of both the St. Pauls Inlet and Martin Point sections. Each section was measured and sampled intensively, with 3.5 kg. samples taken at approximately 1 m intervals. The majority of processed samples were limestones which were dissolved in 10-15% acetic acid, and then sieved, separated, and picked for conodonts. A total of 35,659 conodont elements were recovered from 64 limestone and shale samples.

Apparatuses of *Lenodus* Sergeeva, *Oistodella* Bradshaw, and *Spinodus* Dzik are described. The occurrence of *Oepikodus communis* Ethington and Clark below the first occurrence of *O. evae* (Lindström) supports the hypothesis that these species belong to separate lineages. Morphologic evidence from Cow Head material supports the assignment of elements resembling "*Scolopodus*" *gracilis* Ethington and Clark s.f. to monoelemental species of *Parapanderodus* Stouge. *Periodon flabellum* evolves gradually into *Periodon aculeatus*, with early, intermediate, and late forms of the latter species recognized. The triangulariform element of *Protoprioniodus papiliosus* van Wamel is recognized as belonging in the apparatus

of this species in Cow Head collections. Elements representing an intermediate evolutionary stage of "*Scolopodus*" *peselephantis* Lindström are recognized. A new species is described: *Polonodus*? *peavyi* n. sp..

Five faunal assemblages (A1-A5) are recognized in Arenig rocks at St. Pauls Inlet. An additional late Arenig fauna was recovered from a limestone clast in the Lower Head Formation overlying the Cow Head Group at Martin Point. The early to middle Arenig North Atlantic Province *Paroistodus proteus*, *Prioniodus elegans*, and *Oepikodus evae* zones are recognized in Beds 9-11 at St. Pauls Inlet. In these same beds North American Midcontinent Fauna D and the *Oepikodus communis* Zone are recognized. Fauna 2 is recognized in Beds 13-15. Beds 9-12 are dated using conodonts as uppermost Canadian and Beds 12-15 as Whiterockian. The Arenig-Llanvirn boundary may lie in uppermost Cow Head strata at St. Pauls Inlet. Arenig strata at St. Pauls Inlet can be correlated with those on the adjacent platform and equivalent sequences around the North American craton and in Argentina and Australia. The bases of the *Tetragraptus approximatus* and *Paroistodus proteus* zones coincide in both sections. Conodont-based correlations at St. Pauls Inlet support correlations based on macrofossil evidence.

The size and robustness of conodont elements in bedded carbonates was found to be correlative with grain size. The abrupt turnover from *Oepikodus*-dominated to *Periodon*-dominated faunas is documented in Bed 11 at St. Pauls Inlet. Significant changes in paleoecological patterns and major influxes and extinctions of taxa commonly coincide with each other and with major lithologic changes representing the onset or termination of aerobic, condensed and anaerobic phases in Arenig Cow Head strata. The predominance of deep water taxa in Beds 9, 10, and the lower part of 11, and the predominance of shallower water taxa in upper Bed 11, and Beds 12-15 support the interpretation that lower to middle Arenig Cow Head strata at St. Pauls Inlet are transgressive and middle to upper Arenig strata are regressive.

ACKNOWLEDGEMENTS

I would like to acknowledge a number of individuals who contributed to this work. First, I wish to gratefully acknowledge the enthusiastic guidance and stimulating discussions provided by my supervisors Drs. C.R. Barnes and L.E. Fåhraeus. I would also like to thank Ms. Felicity O'Brien for her advice on technical matters throughout all stages of this project and for her invaluable aid in the field. I would also like to acknowledge the photographic expertise of Mr. Wilf Marsh, who also allowed the use of darkroom facilities. I extend thanks to Ms. Sigrid Neuland who provided field and drafting assistance and to Ms. Beverly Chapman also for drafting work. The assistance and advice of Ms. Carolyn Emerson in operating the SEM is gratefully acknowledged. Fruitful discussion on Cow Head biostratigraphy and sedimentology was provided by Drs. M. Coniglio, N.P. James, R.K. Stevens, and S.H. Williams. I especially extend my warmest regards to Ms. S.L. Pohler for many discussions on Cow Head conodont taxonomy and biostratigraphy.

The financial assistance provided by NSERC is gratefully acknowledged, as well as that provided by the Department of Earth Sciences, Memorial University of Newfoundland. The co-operation of Parks Canada for permission to collect material for the writer's thesis within the environs of Gros Morne National Park is also acknowledged. The writer also wishes to thank Dr. B.D.E. Chatterton, Department of Geology, University of Alberta, for providing the funds, materials, and working facilities for the completion of this project.

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1. INTRODUCTION

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1.1.1 Stratigraphic studies

The Cow Head Group is a sequence of interbedded limestones, shales and siltstones between sometimes massive limestone conglomerate beds (=megaconglomerates: for terminology see James and Stevens, in press). The group has its type section on the Cow Head Peninsula and extends from Daniels Harbour in the north to at least Rocky Harbour in the south (Figure 1). The first modern comprehensive study of the Cow Head Group (Kindle and Whittington, 1958) was undertaken by Schuchert and Dunbar (1934). In this important work they established the stratigraphic nomenclature with descriptions for many of the rock units within this group and for correlative strata. Johnson (1941), using graptolite biostratigraphy, showed that the predominantly argillaceous rocks of Schuchert and Dunbar's Green Point Series were equivalent in age to the predominantly carbonate St. George and Table Head series. He also suggested that the Green Point rocks were perhaps emplaced by thrusting from the east. Oxley (1953) published the first geological map of the Cow Head Group. He further subdivided the Green Point Series into the St. Pauls and Green Point groups on the basis of graptolites. In these studies the Cow Head Breccias were considered to be a different age from the Green Point Group. The age of the breccias was thought to be Middle Ordovician, while the Green Point rocks were considered Early Ordovician (Schuchert and Dunbar, 1934; Oxley, 1953).

A major revision of the stratigraphy of the Cow Head rocks was undertaken by Kindle and Whittington (1958). They showed that the Green Point strata and the Cow Head Breccias are essentially coeval. In addition, they suggested a syndepositional origin of the breccias, which constrasted with earlier tectonic interpretations. Until recently, this paper was the single most comprehensive reference on the Cow Head Group.

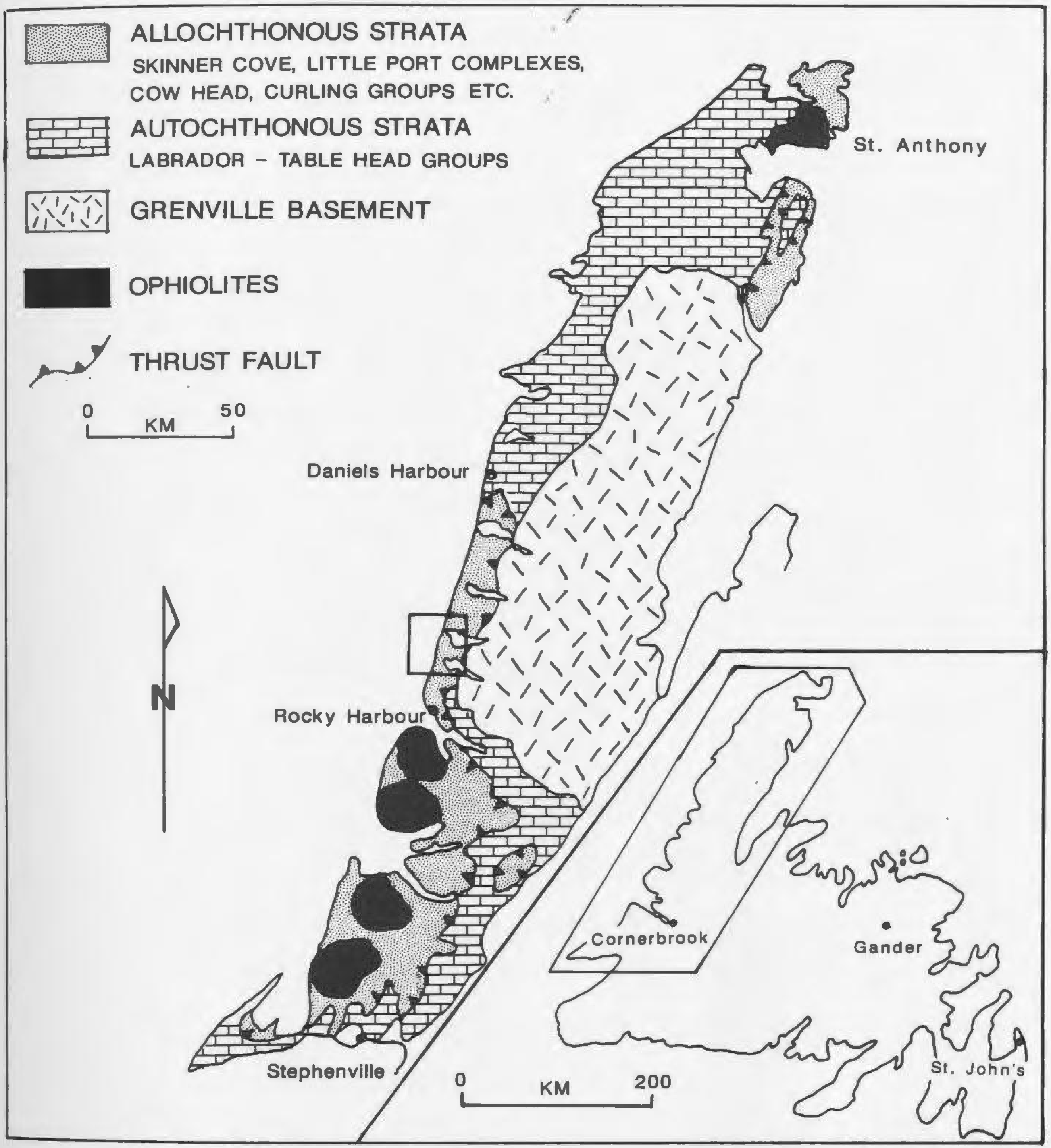


FIGURE 1--Map of western Newfoundland showing major tectonic elements of the Humber Zone (Williams, 1979). Humber Arm Allochthon extends from Daniels Harbour to Stephenville; Hare Bay allochthon by St. Anthony. Study area indicated by rectangle (after James and Stevens, in press).

Rodgers and Neale (1963) suggested that the Cow Head Group and Humber Arm Supergroup (Stevens, 1970) are allochthonous, originating from east of White Bay. A comparison between these units and the Taconic Klippen of New York State suggested that the Cow Head and Humber Arm strata are of deep water origin. Gravity sliding from the east was considered the mechanism of transport which emplaced these rocks atop autochthonous platform strata (Rodgers and Neale, 1963). Stevens (1970) interpreted these allochthonous rocks in terms of a plate tectonic model suggesting that overthrusting came about during the closure of the Proto-Atlantic or Iapetus Ocean. The Cow Head Group was interpreted as accumulating on the slope of a passive continental margin. Carbonate debris flows were derived from the edge of an adjacent carbonate platform.

Nowlan's (1974) study of conodonts from the Cow Head Peninsula used a depositional model similar to that of Stevens (1970). However, Hubert *et al.* (1977) proposed a radically different model in which the continental slope was a series of oblique ridges with slumping occurring off both sides of each ridge. More recent work has attempted to show that depositional patterns in the Cow Head Group can be explained using a simpler model with debris flows originating at the carbonate platform edge and on the upper slope and moving downslope. James and Stevens (in press) and Hiscott and James (1985) demonstrate that the Cow Head Group has a definite proximal to distal polarity from the northwest to the southeast. This northeast to southwest trend is thought to represent the original paleoslope (Hiscott and James, 1985). The most proximal facies are distinguished by megaconglomerates characterized by large blocks commonly of shallow water origin (James and Stevens, in press). These flows commonly downcut into underlying bedded strata. In the more distal facies the megaconglomerates are thinner and finer with the bedded strata more complete. Individual conglomerates can be traced many tens of kilometres from their proximal to distal ends.

Other recent works concerning the authochthonous platformal strata of the St. George and Table Head groups include Knight (1977, 1983), Knight and Boyce (1984), Klappa *et al.* (1980) and Knight and James (in press). The stratigraphy of both units has recently been revised with several new formations proposed. These studies document the effects of eustatic and tectonic events on sedimentation patterns in platformal strata in western Newfoundland from the Early to Middle Ordovician (e.g. Stouge, 1980; Barnes, 1984; Knight and Boyce, 1984).

1.1.2 Biostratigraphic studies

The early biostratigraphic studies of the Cow Head Group were done in conjunction with the stratigraphic studies mentioned above (e.g. Schuchert and Dunbar, 1934; Johnson, 1944, Oxley, 1953). Correlation was largely based upon graptolite occurences with particular reference to the shale sequences of New York State (e.g. the Schaghticoke and Deepkill shales, Ross *et al.*, 1982). Shelly fossils were compared primarly with those of North American cratonic sequences. Kindle and Whittington (1958) attempted to zone the Cow Head Group using trilobites and graptolites. Trilobites were found to be of both Pacific and Atlantic provincial affinity, thus enabling correlation of the Cow Head faunas in terms of both North American and European zonation schemes. The graptolite faunas showed close affinity to those from the Victoria sequence in Australia. Here lay the first hint of the Cow Head Group's potential for correlating the North American-Pacific faunal successions with those of Europe.

Erdtmann's (1971) study of graptolites from the Cow Head Group and adjacent sequences also recognized a distinctive faunal grouping of Pacific and Baltic graptolite associations. He suggested that these associations were separated by some physical barrier, such as an island arc system, in the Early Ordovician and that their present close apposition is explained by the closure of the Iapetus Ocean in the Middle Ordovician (Erdtmann, 1971). The co-occurrence of North American and European shelly fossils, graptolites, and conodonts was again recognized in a recent study by Fortey *et al.* (1982). This work on the Cambro-Ordovician boundary in the Cow Head Group at Broom Point illustrated the difficulties encountered in correlating European and North American series and system boundaries. It is also one of the first attempts to use a number of fossil groups to solve the Cambro-Ordovician boundary problem in the Cow Head Group.

1.1.3 Conodont biostratigraphy and provinciality

Provincialism in Ordovician conodonts was first recognized in work carried out by Sweet *et al.* (1959) and by Sweet and Bergström (1962). Most conodonts in this and previous studies of the Cow Head Group can be assigned to either one of two faunal provinces for the Early Ordovician. These are the Midcontinent and North Atlantic Faunal Provinces (e.g. Barnes and Fåhraeus, 1975). These provinces are characterized by the occurrence of conodont faunas which were adapted to elevated temperatures and salinities (Midcontinent) or normal marine salinities and cooler temperatures (North Atlantic). Conodonts presumably adapted to the former conditions were described from the Midcontinent of North America by workers such as Branson and Mehl (1933), Furnish (1938), Ethington and Clark (1964, 1971), Sweet *et al.* (1971) and others. Conodonts more cosmopolitan in character that were adapted to the latter conditions were described from the Baltic region of Europe by Pander (1856), Lindström (1955), Sergeeva (1962), Viira (1966), and Löfgren (1978). Separate zonation schemes have been erected for each faunal province. Ethington and Clark (1971) erected such a scheme for the Midcontinent while Lindström (1971) suggested one for the North Atlantic Province. Since these zonations were established refinements have been proposed by van Wamel (1974), Löfgren (1978) and Ethington and Clark (1982).

1.1.4 Conodont biostratigraphy in the Cow Head Group and equivalent sequences

Fåhraeus (1970) first recognized conodonts of North Atlantic affinity in the Cow Head and Table Head groups. Conodonts of Midcontinent affinity were seen to predominate in the St. George Group although some North Atlantic forms did occur (Barnes and Tuke, 1970). Both studies showed it was possible to correlate widely strata in western Newfoundland using conodonts. Conodont studies by Fåhraeus (1973) and Bergström *et al.* (1974) of the Long Point Group placed an upper limit on the time of emplacement of the Humber Arm Allochthon. Fåhraeus (1970), Nowlan (1974) and Fåhraeus and Nowlan (1978) described conodonts of Tremadoc to Arenig-Llanvirn age in the Cow Head Group from the Cow Head Peninsula. These studies were of a preliminary nature. Stouge (1982, 1984) studied conodonts of the St. George and Table Head groups. In both studies the intermingling of Midcontinent and North Atlantic faunas was recognized with domination by species of one province over the other in a particular interval reflecting episodes of either shallowing or deepening on the shelf. Thus the shift of relative abundances of Midcontinent versus North Atlantic conodont species was interpreted to reflect eustatic or tectonic events by Stouge.

1.2 Objectives of study

Previous investigations of Arenig conodonts in the Cow Head Group by Fåhraeus (1970), Nowlan (1974), Fåhraeus and Nowlan (1978) focused on small faunas collected from sections representing proximal facies (Shallow Bay Formation, James and Stevens, in press) of this sequence on the Cow Head Peninsula. Fåhraeus and Nowlan (1978) taxonomically described the conodont faunas collected from these strata. To date no published taxonomic descriptions exist of Arenig conodont faunas from distal Cow Head sections. Therefore, the main objective of this study is to investigate the taxonomy of Arenig conodont faunas from distal sections of the Cow Head Group.

A second objective of this study is to test the validity of both North Atlantic and North American Midcontinent faunal and zonation schemes in Cow Head strata. Sections in the Cow Head Group are much more expanded and more continuous than equivalent strata in Balto-Scandia which are highly condensed and marked by many hiatuses (e.g. Tjernvik, 1956; Lindström, 1971; van Wamel, 1974; Löfgren, 1978, 1985). Some of the North Atlantic zonal taxa found in this latter sequence are probably endemic (Lindström, 1984). Thicker Cow Head strata should allow a better assessment of the stratigraphic range of taxa of these zones.

A third objective of this study is to observe how well Midcontinent and North Atlantic faunas can be correlated with each other, using data from both bedded strata and conglomerates and to observe how closely conodont faunas in Cow Head strata compare with graptolite and shelly fossil zonations in this sequence.

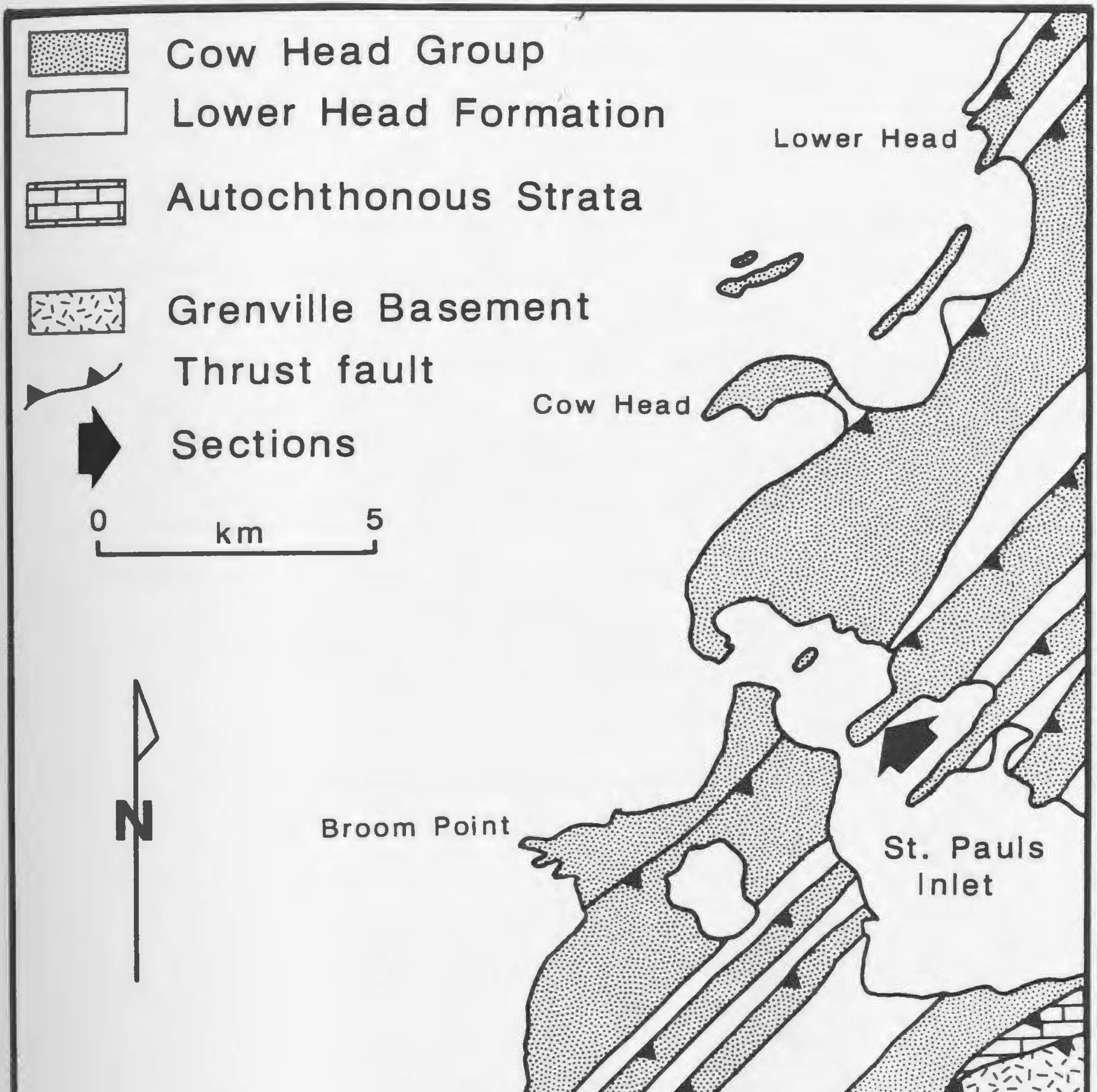
The Arenig marks a crucial stage in the history of the Cow Head Group. Cow Head and platformal strata of this age records the transition from a tectonically passive to an active continental margin with the closure of the Iapetus Ocean (Hiscott and James, 1985; James and Stevens, in press; Stouge, 1982, 1984; Williams, 1979). This margin is also affected by eustatic cycles which are reflected in both platform and slope strata (Barnes, 1984; Fortey, 1984; James and Stevens, in press; Stouge, 1982, 1984). The change in composition and distribution of conodont faunas as a probable result of these eustatic and tectonic events has been documented in platformal strata (Stouge, 1982, 1984). Previous Cow Head conodont studies suggests that slope faunas in proximal facies of this group might also be affected by these events (Fåhraeus and Barnes, 1975; Fåhraeus and Nowlan, 1978). The final objective of this study is to observe whether or not the composition and distribution of conodont faunas in more distal Cow Head facies undergo the same changes as faunas in the proximal facies.

1.3 Location

Both the Martin Point and St. Pauls Inlet sections can be located on the St. Pauls Inlet mapsheet: NTS no. 12H/3, scale: 1:50,000. In the Martin Point section (49° 46' N, 57° 55' W) (Figure 2) the Arenig section is mostly covered on the cliff face. On the cliff top, patches of outcrop mostly of shale and siltstone exist between covered intervals. The entire section is nearly completely exposed on the shore at low tide. Thin conglomerate beds form prominent ribs extending along strike obliquely out to sea. Measuring commenced from the top of a megaconglomerate bed forming part of the most southerly hogback ridge on the shore at this locality. Access to this section is gained from Highway 430, which is about 200 meters from the section.

The St. Pauls Inlet section (49° 51' N, 57° 42' W) (Figure 2) is exposed on the shoreline of a narrow peninsula extending into the inlet which is immediately north of the village of St. Pauls. Measuring of upper Tremadoc and Arenig strata in this section began at the top of a conglomerate bed just below an abutment on the east side of the highway bridge spanning the inlet. Measuring continued to the point formed by Bed 10 (Appendix B) where the section then continues along strike roughly parallel to the shore northeast of the end of the peninsula for approximately one kilometre (Figure 2). Access to the lower part of the

FIGURE 2--Simplified geological map of study area enlarged from Figure 1 showing location of Martin Point and St. Pauls Inlet sections plus other important localities of the Cow Head Group. Note imbricate nature of thrust slices and occurrence of studied sections on separate thrust sheets. Geology after Williams *et al.* (1985).


Cow Head Group
Lower Head Formation
Autochthonous Strata
Grenville Basement
Thrust fault
Sections
0
km
5
N
Lower Head
Cow Head
Broom Point
St. Pauls
Inlet
Martin Point
Western
Brook Pond

section is directly off the highway by the bridge. The upper part is accessible only by trails and a private lane extending in from the highway approximately one-half a kilometre north of the bridge.

1.4 Sampling methods

1.4.1 Field sampling

Each section was measured using a tape measure and Jacob's staff. Measurements were compared to sections to be published in James and Stevens (in press). Thicknesses for the St. Pauls Inlet and Martin Point sections came within 20% and 15% respectively of those obtained by these authors. Each section was sampled for conodonts at an interval of approximately one metre stratigraphic thickness where possible or from small outcrops between covered intervals. Bedded limestone, conglomerate, siltstone, and shale were sampled. Individual boulders were sampled in conglomerate beds and limestone clasts were collected from a conglomerate bed in the Lower Head Formation (James and Stevens, in press) at Martin Point (Figure 3, p. 17). Each sample weighed an average of five kilograms. A total of 219 samples were collected at both sections, with 129 coming from St. Pauls Inlet.

1.4.2 Processing

Limestone samples were processed in 10-15% acetic acid. The average processing weight for each sample was three and a half kilograms. Shale and siltstone samples were processed mostly by gentle boiling with detergent. Residue weights are given in Tables 1-3 (p. 225-231).

Sieved residues were separated with tetrabromomethane at S.G. 2.84 and the heavy residues were then picked for conodonts. Photography was by light microscopy (Wild M400) or by the Hitachi S570 scanning electron microscope.

2. GEOLOGIC SETTING

2.1 Tectonic elements

The Cow Head Group lies within the Humber Zone (Williams, 1975, 1979) which consists of Lower Cambrian to Middle Ordovician platformal rocks overthrust by allochthonous rocks of equivalent age (Figure 1, p. 2). These transported rocks have been recently named the Humber Arm Terrane (Williams and Hatcher, 1983). This terrane comprises sedimentary, volcanic, and igneous rocks deposited at a continental margin and in the adjacent ocean basin. Both the platformal and deep water strata of the Humber Zone are underlain by Precambrian Grenville basement (Williams, 1975; 1979).

To the east and north of the Cow Head Group are outcrops of platformal rocks of Early Cambrian to Middle Ordovician age. The Early Cambrian rocks (Labrador Group of James and Stevens, 1982) are predominantly siliciclastic in nature, with some volcanics near their base. These are interpreted as being related to an episode of rifting which marked the initial opening of the Iapetus Ocean. Rocks higher in the sequence record siliciclastic and carbonate deposition on a shallow shelf, followed by a quartzitic sequence indicating a possible regressive event at the Lower-Middle Cambrian boundary (Palmer and James, 1979).

The rest of the sequence is comprised mostly of carbonates which range in age from Middle Cambrian to Middle Ordovician. Of particular importance are the carbonates of the St. George Group (Schuchert and Dunbar, 1934; Knight, 1977; Knight and Boyce, 1984; Knight and James, in press). These rocks are equivalent in age to those of the Cow Head Group and represent intertidal to subtidal shelf carbonates. The intertidal carbonates are cyclic in nature, with cycles consisting of shallowing-upward sequences. Within the St. George are several horizons which indicate regressive events ("pebble beds", see Knight and Boyce, 1984; Haywick and James, 1984). These horizons have been correlated with major limestone breccia beds in the Cow Head Group (Barnes, 1984). Four formations have been recognized in the St. George Group. These are, in ascending order, the Watt's Bight, Boat Harbour, Catoche, and Aguathuna formations (Haywick and James, 1984; Knight and Boyce, 1984;

Stouge, 1982; Knight and James, in press). Beds of the lower two formations record subtidal to intertidal carbonate deposition. The Catoche Formation consists of subtidal limestone, marking a major transgression across the shelf. The Aguathuna Formation reflects a major shallowing, culminating in the formation of a karst surface near the top, close to the contact with the overlying Table Head Group. This formation may also represent discontinuous deposition across a periodically subaerially exposed topographic surface controlled by block faulting (Knight and Boyce, 1984).

The Table Head Group is of Middle Ordovician age, and records the transition from shelf to basinal deposition (Stevens, 1970; Fåhraeus, 1970, 1977a, b; Stouge, 1984; Klappa *et al.*, 1980). This sequence documents the final destruction of the continental margin. It has been divided into several formations. The Table Point Formation represents supratidal to subtidal shelf carbonates. The Table Cove Formation reflects deposition on the upper slope, The overlying formations, the Black Cove and the Cape Cormorant, reflect basinal deposition and the influx of debris flows derived from the platformal and upper slope strata. Capping the Table Head Group is flysch derived from the approaching allochthons (Stevens, 1970; Klappa *et al.*, 1980).

Transported rocks in western Newfoundland are included in the Humber Arm Allochthon in the south, and in the Hare Bay Allochthon in the north (Figure 1). The Humber Arm Allochthon is comprised of a series of tectonic slices. The lowest slices are sedimentary rocks deposited at the continental margin while those towards the top are volcanic and igneous rocks, with minor sedimentary sequences, formed in the adjoining ocean basin. This entire sequence is equivalent in age to the platform strata (Williams, 1975). Rocks comprising the Curling Group are deep water siliciclastics and carbonates which are equivalent in part to the Cow Head Group (Williams, 1975). The provenance of the sediments in the lower part of the sequence was the craton. At the top of the sequence, their provenance is the approaching allochthons (Williams, 1975; Stevens, 1970).

The higher volcanic and igneous slices are interpreted to represent island arc volcanism, plus a section of oceanic crust and mantle. The Skinner Cove Formation or tectonic slice consists of alkalic volcanics and associated sediments. This sequence has been interpreted to represent "off-axis" ocean ridge volcanism (Strong, 1974), although it may be associated with rifting at or near the continental margin associated with tensional stress caused by closure of the Iapetus Ocean (Williams, 1975). The Little Port Complex consists of gabbroic and granitic rocks intruded by mafic dikes with associated mafic volcanics. This entire sequence is interpreted to be associated with island-arc development (Strong and Payne, 1973; Williams and Payne, 1975). The Bay of Islands ophiolite complex consists of ultramafic rocks, with gabbros, sheeted dikes, and pillow lavas overlying them in sequence. These rocks, of probable Early Ordovician age, are interpreted to represent oceanic crust and mantle. A metamorphic aureole is developed at the bottom of the ophiolite pile (Stevens, 1970; Williams, 1975).

2.2 Nature of emplacement

The structural slices of the Humber Arm Allochthon were assembled from the east (Stevens, 1970; Williams, 1975). The highest slices are the farthest travelled (Stevens, 1970; Williams, 1975). Transport of the allochthons first began near the end of the Early Ordovician with the obduction of oceanic crust and mantle over continental crust. Associated with this early phase of deformation is the metamorphic aureole. This aureole marks the contact between hot ocean lithosphere and sediments of the continental margin (Stevens, 1970; Williams, 1975, 1979). With further movement the volcanic and igneous sequences associated with "off-axis" and island arc volcanism were incorporated into the allochthon. In the final stages of emplacement, the lower structural slices comprising the rocks of the Curling Group were incorporated into the entire assemblage (Stevens, 1970; Williams, 1975, 1979). Melanges started to form during the later stages of movement as a result of mass movement and tectonic mixing in the flysch basin and the décollement zones. (Stevens, 1970; Williams, 1975). They are confined to the lower structural slices, and are comprised of material from both lower and higher slices (Williams, 1979). Flysch was deposited ahead of the structural stack into the foreland basin formed as a result of downwarping of the continental margin.

The flysch covers both the autochthonous platformal and proximal continental margin strata. Cessation of movement was prior to the deposition of the Long Point Group atop the allochthons in early Caradoc time (Fåhraeus, 1973; Bergström *et al.*, 1974).

The presumed source of the allochthonous strata is to the east of White Bay (Rodgers and Neale, 1963, Stevens, 1970). Metamorphosed equivalents of autochthonous strata to the west are found on the Baie Verte Peninsula and around White Bay. This and geophysical data suggest that the ancient edge of the continent lay along the Baie Verte-Brompton Line (Stevens, 1970; Williams, 1975, 1979). Ophiolites found along this boundary are presumed to be time equivalent to those in western Newfoundland. Strata comparable to the higher structural slices of the Humber Arm and Hare Bay allochthons are also found in central Newfoundland (Williams, 1979). Therefore, it is presumed that the Cow Head Group and other allochthonous sequences in western Newfoundland were transported at least 100 km to the west.

3. LITHOSTRATIGRAPHY

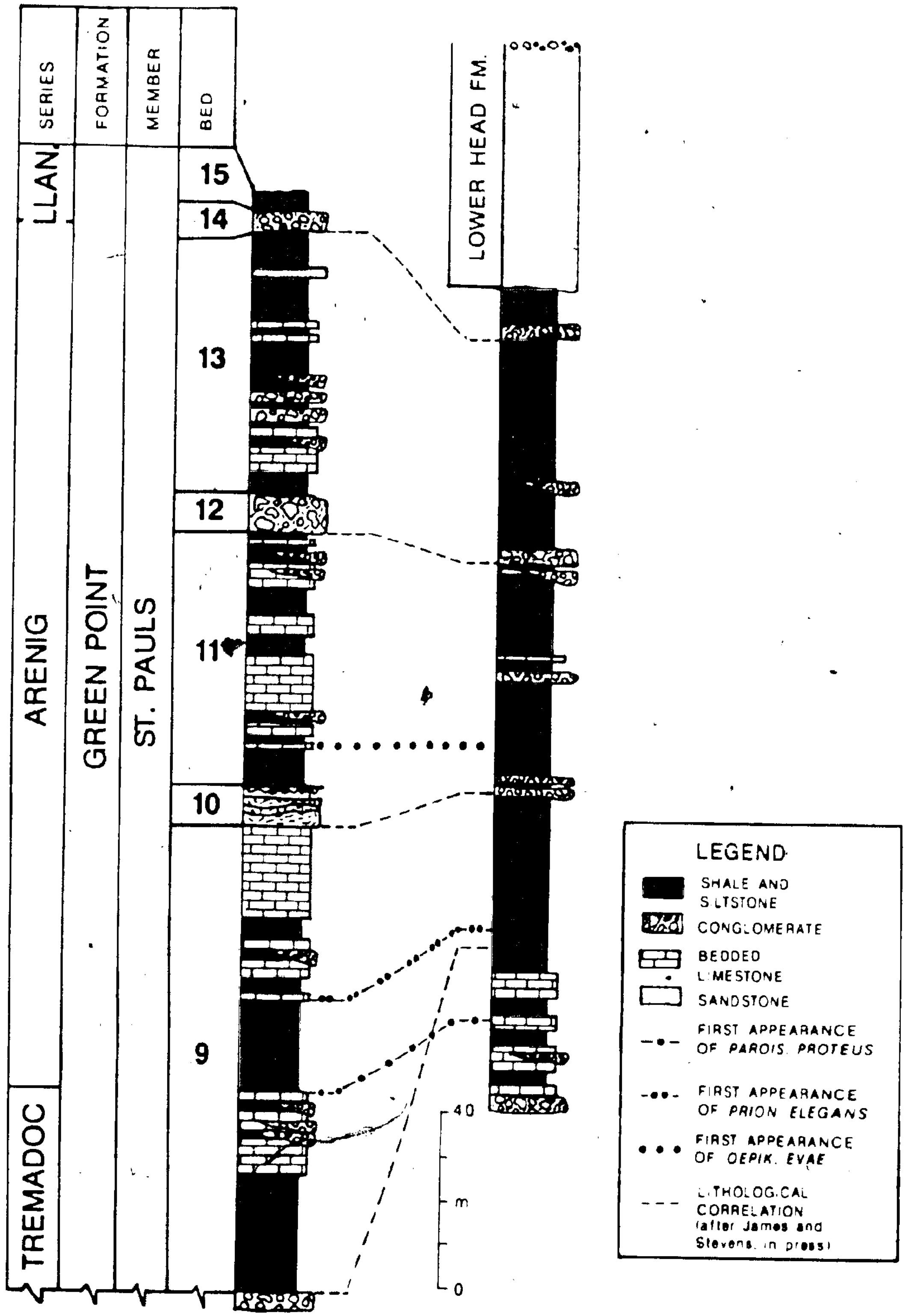
3.1 Description of beds and lithological features

Kindle and Whittington (1958) subdivided the Cow Head Group into Beds numbered 1-14. In a recent revision of the stratigraphy of this sequence, James and Stevens (in press) recognized an additional Bed, Bed 15, and proposed new formational names for the proximal and distal facies of the Cow Head Group (James and Stevens, in press; Williams *et al.*, 1985) (in further discussion in this and subsequent chapters, "Bed" will refer to the entire unit (e.g. Bed 9; conodonts in this Bed) while "bed" will refer to just a single horizon (e.g. conglomerate bed)). The St. Pauls Inlet and Martin Point sections are included with other distal Cow Head sections in the Green Point Formation (James and Stevens, in press). Arenig strata are represented by the St. Pauls Member (James and Stevens, in press; Figure 3). This member encompasses Beds 8-15. Beds 8, 9, 11, 13 and 15 are bedded limestones and siliciclastics, interbedded with minor conglomerate horizons. Megaconglomerates are represented by Beds 10, 12, and 14. These same beds are represented in proximal facies by the Factory Cove Member of the Shallow Bay Formation (James and Stevens, in press) on the Cow Head Peninsula, at Broom Point, and at Lower Head (Figure 2, p. 9).

Figure 3 depicts the stratigraphic columns (after James and Stevens, in press) for both the Martin Point and St. Pauls Inlet sections and the biostratigraphic and lithologic correlations between them. The total measured thickness for these sections is 214 m and 226 m, respectively. Measuring commenced from the tops of conglomerate beds in strata dated as Tremadoc (James and Stevens, in press) in both sections. Part of the measured thickness of the Martin Point section includes the overlying green sandstone of the Lower Head Formation (James and Stevens, in press) up to a 1 m thick conglomerate bed with carbonate clasts yielding late Arenig-early Llanvirn conodont faunas. Of the thicknesses given above, only 154 m at Martin Point and 180 m at St. Pauls Inlet are considered Arenig.

The base of the Arenig at St. Pauls Inlet begins in Bed 9 at the top of a 15 m thick bedded limestone and conglomerate unit approximately 35 m above the base of the measured

FIGURE 3--Stratigraphic columns (after James and Stevens, in press) showing biostratigraphic and lithological correlations between St. Pauls Inlet section on left and Martin Point section on right. Datum is first appearance of *Oepikodus evae* Lindström. Bed numbers, stratigraphic units and series to left of columns and above Martin Point section. Stratigraphic nomenclature after James and Stevens (in press) and Williams *et al.* (1985).


SERIES
FORMATION
MEMBER
BED
LLAN.
ARENIG
TREMADOC
GREEN POINT
ST. PAULS
15
14
13
12
11
10
9
LOWER HEAD FM.
40
m
0
LEGEND
SHALE AND SILTSTONE
CONGLOMERATE
BEDDED LIMESTONE
SANDSTONE
FIRST APPEARANCE OF PAROIS PROTEUS
FIRST APPEARANCE OF PRION ELEGANS
FIRST APPEARANCE OF OEPIK. EVAE
LITHOLOGICAL CORRELATION (after James and Stevens, in press)

section. The overlying unit consists of beds of dolomitized siltstone interbedded with red and green shale and rare limestone conglomerate overlain by red shale and minor siltstone. This unit is about 20 m thick. The next unit is a 29 m thick bedded limestone unit consisting mostly of ribbon and parted limestone in the lower part and parted limestone in the upper part (for definition of these terms, see Wilson, 1969, and James and Stevens, 1982).

Bed 10 at St. Pauls Inlet consists of a series of conglomerate beds, some of which downcut into each other and also exhibit graded bedding. (James and Stevens, in press).

Bed 11 strata at this section begin with a 10 m thick red and green shale unit with bedded chert near the base. The remaining 45 m of this Bed consists of mainly green and black shale, rare dolostone, bedded limestone, and conglomerate. Conglomerates are more common towards the top of this Bed, as are phosphorite pebbles within the conglomerates.

Bed 12 at St. Pauls Inlet consists of a single megaconglomerate containing some boulders exceeding 1 m in diameter. This Bed is the thickest megaconglomerate of the two sections.

Bed 13 strata at St. Pauls Inlet begin with a 4 m thick unit of green shale followed by 6 m of grainstone. Bedded limestone and conglomerate interbedded with green and black shale occur in the next 14 m above the grainstone, with conglomerates thickening toward the top of this interval. The uppermost 30 m of Bed 13 consists mainly of red shale and dolomitized siltstone, with minor grainstone beds. A 1 m thick bed of green sandstone of the Lower Head Formation (James and Stevens, in press) occurs 8 m below the top of this Bed (Figure 3).

Bed 14 at St. Pauls Inlet is a single megaconglomerate. Bed 15 consists red shale and dolomitized siltstone in this section.

Arenig strata at Martin Point begin approximately 16 m above the base of measured section within a unit of parted and ribbon limestone and nodules interbedded with black and green shale. This unit occurs in the uppermost part of Bed 8. Bed 9 in this section is a 25 m thick unit of red and green shale near the base and top and massive red shale in the middle (Appendix A, p. 206, 207). Bed 10 at Martin Point consists of several conglomerate beds separated by thin beds of shale.

Bed 11 at Martin Point is predominantly argillaceous. A prominent conglomerate bed occurs in the middle of this Bed (Figure 3) and minor limestone and conglomerate occur sporadically throughout. The upper 3 m of this Bed consists of ribbon limestone and conglomerate. The overall thickness of Bed 11 at Martin Point is 40 m (Figure 3). Bed 12 is a single megaeonglomerate, but with only half the thickness of the same Bed at St. Pauls Inlet.

Green shale comprises the lower 14 m of Bed 13 at Martin Point. Rare limestone nodules occur with the green shale. These lithologies are capped by a minor conglomerate bed (Figure 3) which is overlain by 20 m of dolomitized siltstone interbedded with red and green shale. The uppermost 10 m of Bed 13 at Martin Point consists of red shale and dolomitized siltstone. Bed 14 in this section is a single megaconglomerate bed with a grainstone cap and Bed 15 comprises of red shale and dolomitized siltstone.

The shale, siltstone, and bedded limestone in the two sections are interpreted as hemipelagic and turbiditic in origin (Coniglio, 1985; James and Stevens, in press). The turbiditic origin of some beds (Coniglio, 1985) is suggested by both cross bedding and graded bedding which was observed in both limestone and siltstone in both sections. Some of these lithologies may have undergone winnowing by bottom currents to produce contourites (McIlreath and James, 1984). Most lime mudstones in both sections exhibit fine laminations characteristic of hemipelagic limestones (McIlreath and James, 1984).

Bioturbation is evident with U-shaped *Arenicolites* burrows in the bedded limestones. Red shale and siltstone in both sections commonly have vertical burrows filled with red mud penetrating several silt layers. Intervals of red shale lacking siltstone also observed in both sections are interpreted to have undergone intense bioturbation (Coniglio, 1985; James and Stevens, in press). Bedded carbonates in both sections appear to have been affected by solution, as many of them have a wavy texture (Coniglio, 1985). Syndepositional slumping was observed in bedded carbonates at St. Pauls Inlet.

Clasts in the conglomerates in both sections range from large boulder to pebble size. The matrix is mostly argillaceous in the thicker and younger megaconglomerates (James and Stevens, 1982, in press). Clast shape ranges from flattened and elongate to rounded. The thickness of the conglomerates ranges from several centimeters to several meters. Some are lenticular and commonly pinch out over short distances. One conglomerate in Bed 13 at St. Pauls Inlet pinches out over a short distance, but the chert layer capping it continues as a discrete bed along strike for several tens of meters. Younger conglomerates in both sections also contain clasts and grains of phosphorite. A common feature in both sections is reddish-brown chert capping many conglomerate beds. These cherts commonly truncate individual boulders in the proximal localities signifying possible erosion due to solution (James and Stevens, in press).

The green sandstone of the Lower Head Formation (James and Stevens, in press) overlying Cow Head strata is generally massive, with bedding obscure. Crude bedding was observed in this formation at Martin Point south of the contact between Lower Head and Cow Head strata above the conglomerate bed.

3.2 Interpretation

The Cow Head Group is currently interpreted to represent deposition on a continental slope adjacent to a carbonate bank from Middle Cambrian to Middle Ordovician time (Hiscott and James, 1985; James and Stevens, in press; Williams and Stevens, in press). This slope is considered to have been relatively steep in Arenig time (Hiscott and James, 1985). This is suggested by the occurrence of large blocks of shallow water limestone in megaconglomerates interbedded with deep water limestone, shale and siltstone (Hiscott and James, 1985; James and Mountjoy, 1983; McIlreath and James, 1978, 1984). These deposits accumulate on the toe of the slope and the continental rise according to the by-pass margin model first proposed by McIlreath and James (1978). In this model the platform margin is a steep rampart, with an apron of peri-platform talus on its seaward side. The upper slope is composed of hemipelagic ooze and lime turbidites, and is dissected by infraformational truncation surfaces (James and Mountjoy, 1983; McIlreath and James, 1984). The occurrence of rafts of bedded hemipelagic carbonates in megaconglomerates is one line of evidence suggesting the Arenig margin in western Newfoundland was a by-pass type margin (James and Stevens, in press).

The Martin Point and St. Pauls Inlet sections are interpreted to occupy a more distal position on the continental rise than equivalent strata outcropping at Broom Point, on the Cow Head Peninsula and at Lower Head occupying the toe-of-slope (James and Stevens, in press). Bedded carbonates and siliciclastics are more abundant volumetrically than the lime conglomerates in these two sections, with siliciclastics being the dominant lithology in the Arenig portion of the section at Martin Point. Minimal undercutting of bedded strata by conglomerates was observed at these localities. In more proximal localities, undercutting by conglomerates can be quite pronounced. For instance, at Lower Head Bed 14 appears to have cut out Beds 12 and 13 completely (James and Stevens, 1982).

The predominance of argillites in the Arenig portion of the Martin Point section, plus the red shales indicating well-oxygenated bottom waters (Williams and Stevens, in press), suggests that the Martin Point section was deposited more distally on the continental rise than the St. Pauls Inlet section. The latter section is interpreted to be deposited in the most proximal part of the Green Point Formation because it contains volumetrically more bedded limestone and conglomerate than the other distal sections (James and Stevens, in press).

The preceeding was only a brief discussion of the lithostratigraphy and interpreted depositional environments of the Cow Head Group at Martin Point and St. Pauls Inlet. For a more detailed description and discussion of the lithologies of these sections, the reader is referred to Appendices A and B (p. 203-223), and to Coniglio (1985), Hiscott and James (1985), and James and Stevens (in press).

4. BIOSTRATIGRAPHY

4.1 Preservation and characteristics of conodont faunas

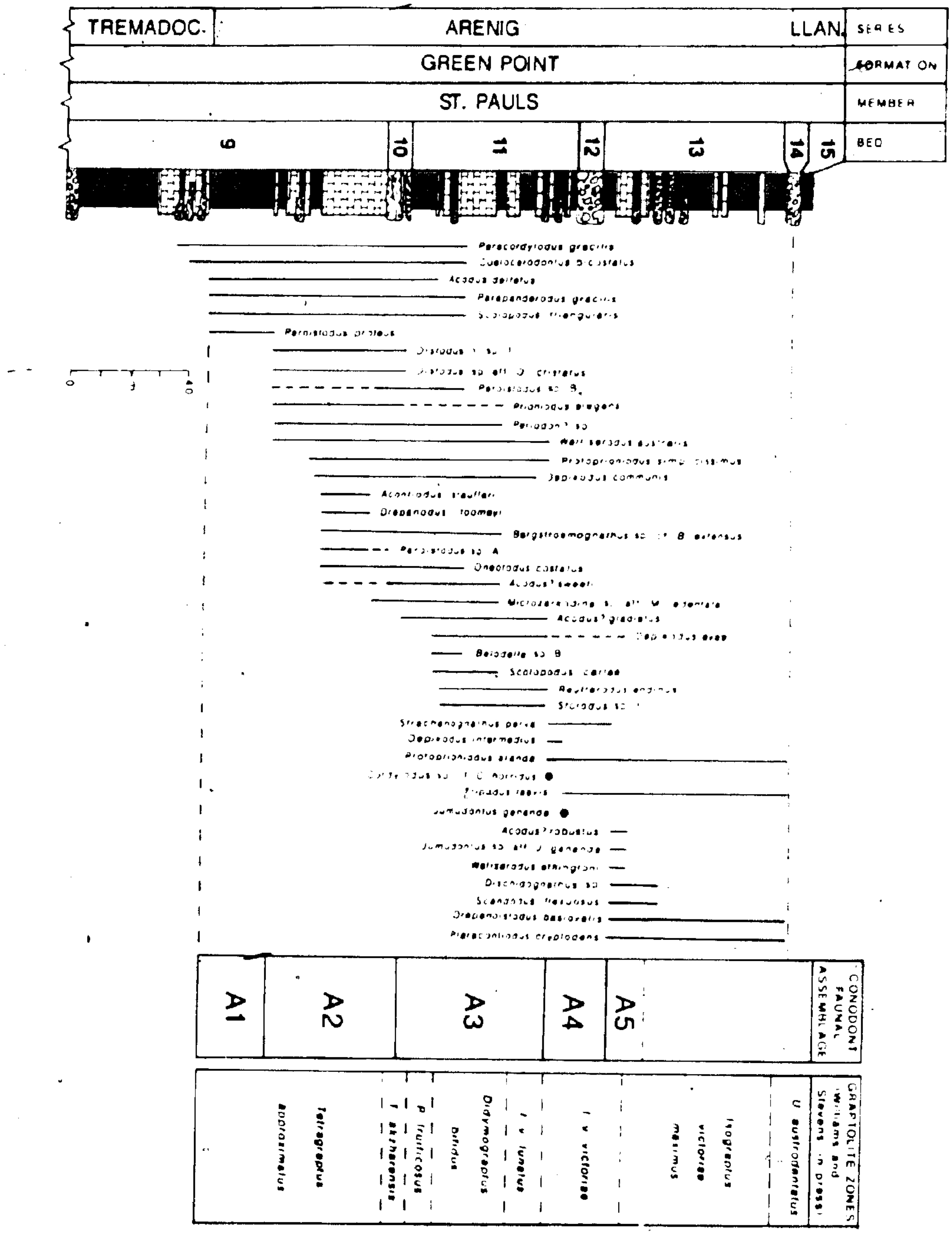
Nearly all the conodonts recovered from the Martin Point and St. Pauls Inlet sections are well preserved, with the majority of specimens lacking any crystal overgrowth. The colour alteration index (CAI) for these conodonts is low (1.5-2). This indicates low burial temperatures in the order of 50 - 140° C for the enclosing rocks (Epstein *et al.*, 1977). Most conodont samples were productive, although the number of elements varied from less than ten to a few thousand per sample (see Tables 1-3, p. 225-231). A total of 35,659 conodont elements (Tables 1-3) were recovered from 64 samples from the two sections. Elements recovered from bedded limestones and conglomerates were commonly unbroken. Those recovered from shales are fragmentary, although still identifiable.

4.2 Faunal assemblages

Most of the discussion in this and the following sections centers on conodont data from the St. Pauls Inlet section. Conodont data from the Martin Point section are sparse, and come mostly from conglomerate beds. Many taxa from these conglomerates are probably reworked, which diminishes their biostratigraphic value in this section. However, a few fragmentary conodont elements have been recovered from shales. These conodonts and those from bedded limestones are the basis for the limited correlation proposed between this and the St. Pauls Inlet section in Section 4.5.

Figure 4 shows the stratigraphic ranges of key conodont taxa at St. Pauls Inlet. Most species appear as part of major influxes of taxa occurring in step-wise fashion up the section (Figure 4). Some major gaps between major influxes are accounted for by lack of data. These intervals were either not collected or samples from them remain unprocessed. The other gaps may be due to paleoecological factors. The latter hypothesis will be discussed more fully in the next chapter.

FIGURE 4--Range chart showing stratigraphic ranges of key conodont taxa in St. Pauls Inlet section. Conodont faunal assemblages and equivalent Arenig graptolite zonation (Williams and Stevens, in press) also shown. Possible extensions of ranges are shown by dashed lines. Llan. = Llanvirn. Bed numbers, stratigraphic units, and lithologies as in Figure 3.


TREMADOC.
ARENIG
LLAN.
SERIES
GREEN POINT
FORMATION
ST. PAULS
MEMBER
9
10
11
12
13
14
15
BED
Paracordylodus gracilis
Acodus deltatus
Paroistodus proteus
Prioniodus elegans
Protoprioniodus simplicissimus
Drepanodus toomeyi
Paroistodus sp. A
Oneotodus costatus
Belodella sp. B
Scolopodus carlae
Dapsilodus intermedius
Jumudontus gananda
Acodus? robustus
Scandodus flexuosus
Drepanoistodus basiovalis
A1
A2
A3
A4
A5
CONODONT FAUNAL ASSEMBLAGE
GRAPTOLITE ZONES

Five major faunal assemblages (A1-A5) were recognized at St. Pauls Inlet. The assemblages are defined by the first appearance of specific taxa.

Assemblage A1.--This assemblage is characterized by the first appearance of *Paroistodus proteus* (Lindström) which occurs 50 m and 70 m above the base of the measured section in Bed 9. This interval is characterized by red shale and buff-weathering dolomitized siltstone. These lithologies overlie the lowermost bedded limestone and conglomerate unit straddling the Arenig-Tremadoc boundary (Figure 4). It is not known if *P. proteus* occurs in the shale and siltstone unit as processed samples from this unit yielded only a few unidentifiable conodont fragments. These samples are not shown in Table 1 (p. 225).

Assemblage A2.--The base of this assemblage is defined by the first appearance of *Oistodus* n. sp. 1 Serpagli and "*Oistodus*" sp. aff. "*O.*" *cristatus* Ethington and Clark s.f.. These taxa co-occur with *Prioniodus elegans* Pander and *Paracordylodus gracilis* Lindström which are both abundant (Table 1 and Figure 6, p. 43). This assemblage occurs in the uppermost 25 m of Bed 9 and in Bed 10 (Figure 4).

Several important taxa are introduced in this assemblage. These are *Bergstroemognathus* sp. cf. *B. extensus* Serpagli, "*Microzarkodina*" sp. aff. "*M.*" *adentata* McTavish, *Oneotodus costatus* Ethington and Brand, *Protoprioniodus simplicissimus* McTavish, *Semiacontiodus cornuformis* (Sergeeva) and *Walliserodus australis* Serpagli. Taxa appearing briefly in this assemblage are "*Acontiodus*" *staufferi* Furnish s.f. and "*Drepanodus*" *toomeyi* Ethington and Clark s.f..

Assemblage A3.--The base of this assemblage is defined by the first appearance of *Acodus*? *gladiatus* Lindström. It is accompanied throughout its range by *Acodus*? *sweeti* (Serpagli), "*Belodella*" sp. B Serpagli, *Reutterodus andinus* Serpagli, "*Scolopodus*" *carlae* Repetski s.f., and *Stolodus* n. sp. 1 Serpagli (Figure 4). *Oepikodus evae* (Lindström) is very abundant in this assemblage (Figure 6). This assemblage occurs in the lower 46 m of Bed 11. Important taxa appearing for the first time in this assemblage include species of *Juanognathus*, *Periodon flabellum* (Lindström), and *Protopanderodus rectus* (Lindström).

Assemblage A4.--The base of this assemblage is defined by the first appearance of *Oepikodus intermedius* Serpagli. This species is associated with *Cordylodus* sp. cf. *C. horridus* Barnes and Poplawski, *Jumudontus gananda* Cooper, and *Strachanognathus parvus* Rhodes. All these taxa but *S. parvus* have single occurrences in this interval (Figure 4). *J. gananda* has a longer stratigraphic range reported from elsewhere (Ethington and Clark, 1982). Early forms of *Periodon aculeatus* are abundant in this assemblage. This assemblage occurs between 158 m and 174 m above the base of the measured section in the upper part of Bed 11, Bed 12 and the lower part of Bed 13. Two important species that first appear in this interval are *Protoprioniodus aranda* Cooper and *Tripodus laevis* (Bradshaw).

Assemblage A5.--The base of this assemblage is defined by the first appearance of *Acodus*? *robustus* (Serpagli), *Drepanoistodus basiovalis* (Sergeeva), "*Scandodus*" *flexuosus* Barnes and Poplawski s.f. and *Walliserodus ethingtoni* (Fåhraeus). These forms are accompanied by *Dischidognathus* sp., *Jumudontus* sp. aff *J. gananda*, species of *Parapanderodus*, and *Pteracontiodus cryptodens* (Mound). Intermediate forms of *P. aculeatus* are very abundant. This assemblage occurs between 174 m and 180 m above the base of the section in lower Bed 13 strata.

Late forms of *P. aculeatus* and *Spinodus* sp. cf. *S. spinatus* Hadding appear in the middle of Bed 13. They could be considered part of another assemblage, except that they are intermixed with forms from older strata in conglomerates, so that a discrete association is not recognized. This intermixing is also the reason for these taxa not being included in Assemblage A5.

An additional fauna occurs in a limestone clast collected from a conglomerate bed in the Lower Head Formation overlying Cow Head strata at Martin Point. The age of this fauna is considered late Arenig (see Section 4.3). This fauna is characterized by *Erraticodon* sp. c.f. *E. balticus* Dzik, *Histiodella holodentata* Ethington and Clark, *Lenodus falodiformis* Sergeeva, *Oistodella* sp. cf. *O. pulchra* Bradshaw and *Polonodus*? *peavyi* n. sp. Late forms of *P. aculeatus* are abundant in this fauna. This fauna has many taxa in common with those in uppermost Bed 13 and Bed 14 strata in both sections. Some of these taxa include *Ansella* *jemtlandica* (Löfgren), *Drepanoistodus*? sp. cf. *D.*? *venustus* (Stauffer), *P. aculeatus* (late form), *Protopanderodus cooperi* (Sweet and Bergström), and *S.* sp. cf. *S. spinatus*.

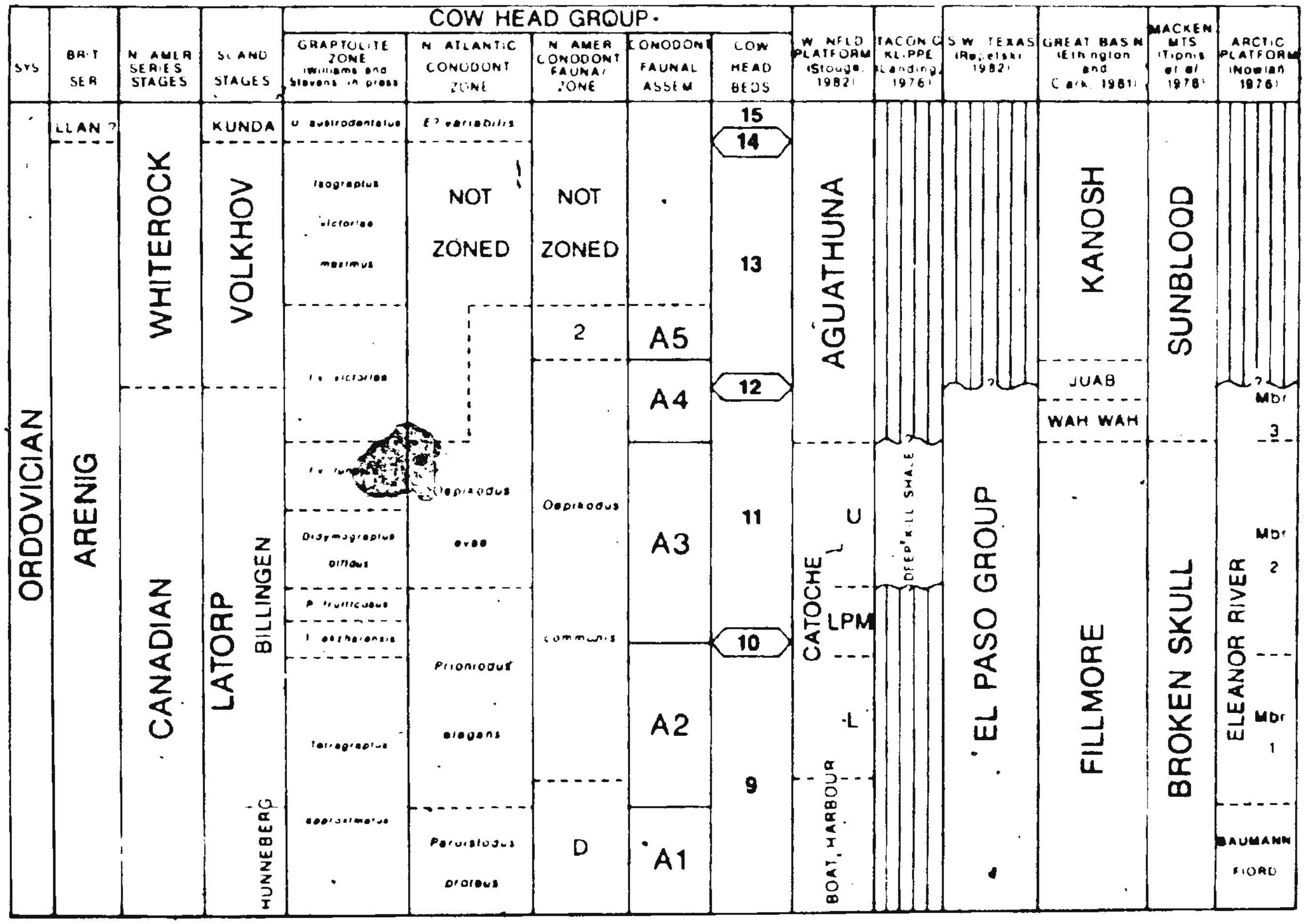
4.3 Comparison with North Atlantic zonation

Only the *Paroistodus proteus*, *Prioniodus elegans*, and *Oepikodus evae* zones are recognized in Cow Head strata at St. Pauls Inlet. This assigns a Latorpian age to the upper half of Bed 9, and Beds 10 and 11 in this section (Figure 5). This same age is tentatively assigned to Bed 12 on the Cow Head Peninsula as suggested by the occurrence of *O. evae* in this unit (Fåhraeus, 1970; Fåhraeus and Nowlan, 1978; Pohler *et al.*, in press), although a younger age for this Bed is possible. The base of the Arenig is recognized in both sections by the first occurrence of *P. proteus* (Lindström, 1971; Löfgren, 1978, 1985). The *O. evae* Zone may extend into the lower part of Bed 13 at St. Pauls Inlet (Figure 5), however, the few elements of this species in this Bed may be reworked.

The stratigraphic thickness of these zones far exceeds that of equivalent zones in Balto-Scandia. There the thickness of the *P. elegans* Zone is about 0.5 m while the *O. evae* and *P. proteus* zones are approximately 1.0 m (e.g. Lindström, 1955; Löfgren, 1978, 1985; van Wamel, 1974). In Cow Head strata at St. Pauls Inlet the former zone is about 46 m in thickness while the latter two are approximately 60 m and 20 m in thickness, respectively. The greater thickness of North Atlantic zones in Cow Head strata allows a more exact assessment of the stratigraphic ranges of the conodont taxa of each zone.

The *Baltoniodus navis/triangularis* and *Microzarkodina flabellum parva* zones (Löfgren, 1978) are not recognized. Several hypotheses may explain the absence of these taxa. One is that strata containing these taxa are missing because of erosion. This hypothesis is discounted by graptolite data assembled by Williams and Stevens (in press) which show that Cow Head strata are complete in having all the Australian graptolite zones represented equivalent to the upper Arenig. It is more likely that their absence is due to endemism of these taxa. Previously reported Early Ordovician occurrences of *Baltoniodus* have been from platformal facies in Balto-Scandia (Lindström, 1955, 1971, 1984; van Wamel, 1974; Dzik,

FIGURE 5--Correlation chart showing conodont-based correlations of Arenig Cow Head beds and conodont faunal assemblages at St. Pauls Inlet with standard British, North American, and Scandinavian series and stages, North American and North Atlantic conodont faunas and zones, and Cow Head graptolite zones. Correlations with other North American Early Ordovician (Arenig) sequences mentioned in text also shown. Sources of conodont and graptolite-based correlations from the Cow Head Group and other sequences given at top of chart. Megaconglomerates are drawn in manner shown to indicate they are geologically instantaneous depositional events. LPM=Laignet Point Member.


COW HEAD GROUP
SYS
BRIT SER
N. AMER SERIES STAGES
SCAND STAGES
GRAPTOLITE ZONE (Williams and Stevens, in press)
N. ATLANTIC CONODONT ZONE
N. AMER CONODONT FAUNA/ZONE
CONODONT FAUNAL ASSEM
COW HEAD BEDS
W. NFLD PLATFORM (Stouge, 1982)
TACONIC KLIPPE (Landing, 1976)
S.W. TEXAS (Repetski, 1982)
GREAT BASIN (Ethington and Clark, 1981)
MACKEN MTS (Tipnis et al. 1978)
ARCTIC PLATFORM (Nowlan, 1976)
ORDOVICIAN
LLAN ?
ARENIG
WHITEROCK
CANADIAN
KUNDA
VOLKHOV
LATORP
BILLINGEN
HUNNEBERG
Isograptus victoriae maximus
I. v. victoriae
Didymograptus bifidus
P. fruticosus
T. akzharensis
Tetragraptus approximatus
E? variabilis
NOT ZONED
Oepikodus evae
Prioniodus elegans
Paroistodus proteus
NOT ZONED
2
Oepikodus communis
D
A5
A4
A3
A2
A1
15
14
13
12
11
10
9
AGUATHUNA
CATOCHE
U
LPM
L
BOAT HARBOUR
DEEPKILL SHALE
EL PASO GROUP
KANOSH
JUAB
WAH WAH
FILLMORE
SUNBLOOD
BROKEN SKULL
ELEANOR RIVER
Mbr 3
Mbr 2
Mbr 1
BAUMANN FIORD

1976, 1978; Löfgren, 1978, 1985). No species of *Baltoniodus* have been reported from Early Ordovician platformal strata in North America. It is probable that this genus was restricted to Balto-Scandia in the Arenig (Lindström, 1984). *Microzarkodina* was probably also restricted to this area, although elements of *M. flabellum* Lindström have been reported from the Pogonip Group (Ethington, 1979, Ethington and Clark, 1982) and from the Tetagouche Group in New Brunswick (Nowlan, 1981). Neither genus has been recovered from boulders representing shelfbreak and upper slope facies in the megaconglomerates (S.L. Pohler, pers. comm., 1985).

An acodontiform element tentatively assigned to *Scandodus* sp. cf. *S. brevibasis* Sergeeva, occurring in one sample (StPI 90) near the base of Bed 13 at St. Pauls Inlet together with *Drepanoistodus basiovalis* and *Paroistodus parallelus* (=*originalis*) suggests that the *P. originalis* Zone of Lindström (1971) may be represented. The base of this zone is usually recognized by the first appearance of *S. brevibasis* with *D. basiovalis* outnumbering *D. forceps*, and with *P. originalis* occurring in abundance. Neither of the two latter species occur in large numbers in the Cow Head Group, although the presence of *D. basiovalis* does suggest the lower part of Bed 13 is Volkhovian in age (e.g. Lindström, 1971, Löfgren, 1978, 1985) (Figure 5).

The occurrence of *Ansella jemtlandica* in Bed 14 at St. Pauls Inlet may suggest that the *Eoplacognathus*? *variabilis* Zone is present. This species is first found in the uppermost part of the *E.*? *variabilis-M. flabellum* Subzone and above (Löfgren, 1978). Few species of this zone from the Baltic area occur in the Cow Head Group. Bed 14 is dated as late early to early middle Kundan in Scandinavian terms. In British terms this is equivalent to the latest Arenig or earliest Llanvirn (Löfgren, 1978). This age assignment appears to be in agreement with graptolite data of Williams and Stevens (in press) (Section 4.7).

The occurrence of *Ansella jemtlandiea* and *Erraticodon* sp. cf. *E. balticus* suggests that the fauna from the limestone clast in the Lower Head Formation is latest Arenig-earliest Llanvirn in age (Löfgren, 1978, 1985). For the purposes of this study, this fauna is considered late Arenig.

4.4 Comparison with North American Midcontinent Faunas

Fauna D is sparsely represented in lowermost Arenig strata at St. Pauls Inlet. It is represented by *Parapanderodus gracilis* (Ethington and Clark) at the base of the Arenig. *Eucharodus parallelus* (Branson and Mehl) and *Glyptoconus quadraplicatus* (Branson and Mehl) appear higher in this interval. Fauna D is represented by *Macerodus dianae* Fåhraeus and Nowlan s.f. in underlying Tremadoc strata.

The *Oepikodus communis* Zone (Ethington and Repetski, 1984) is recognized, with the zone species first appearing 78 m above the base of the measured section in the upper part of Bed 9. It ranges near the top of Bed 11, where it is replaced by its descendant, *O. intermedius* (see Remarks for *Oepikodus* under taxonomy). The occurrence of *O. communis* and associated forms in Beds 9-11 assigns a late Canadian age to these strata (Figure 5).

The *O. communis* Zone is generally considered to be coeval with the *O. evae* Zone (Ethington and Repetski, 1984). In Cow Head strata it is equivalent to both the *P. elegans* and *O. evae* zones (Figure 5). The *O. communis* Zone in this sequence is apparently of greater temporal extent than that suggested by previous studies. The occurrence of *O. communis* with both these North Atlantic zone fossils enables more precise correlations to be made between faunas of the Midcontinent and North Atlantic provinces.

Species of Fauna 2 of Sweet *et al.* (1971) (= *Histiodella altifrons* Chronozone of Sweet, 1984) first appear near the base of Bed 13. These are *Pteracontiodus cryptodens* (Mound) and *Scandodus sinuosus* (Mound). They are associated with *Histiodella altifrons* Harris and *Multioistodus auritus* (Harris and Harris) in the Whiterockian Kanosh Shale, Pogonip Group, Utah (Ethington and Clark, 1982). The occurrence of *P. cryptodens* and *S. sinuosus* in Bed 13 suggests that this Bed is Whiterockian in age (Figure 5).

Fortey (1980) proposed the Valhallan Stage which equates to the interval between the last occurrence of trilobite Zone J and the first occurrence of Zone L in the Pogonip Group. This interval in Spitsbergen is characterized by new species of *Oepikodus* and *Periodon* (Fortey and Barnes, 1977) and graptolites of the *Isograptus* group, which occur in the Castlemanian Stage (Ca2-3) of Australia (Fortey, 1980). The occurrence of Whiterockian conodonts with

Castlemanian graptolites (Williams and Stevens, in press) in Bed 13 in the Cow Head Group would suggest that equivalent strata of the Valhallfonna Formation should equate to the lower Whiterock. This correlation is also supported by the occurrence of *Endymionia clavata* Fortey in Bed 13 (James and Stevens, in press). This species is one of the trilobite taxa characteristic of the Valhallan Stage (Fortey, 1980).

The occurrence of *Histiodella holodentata* Ethington and Clark in the fauna recovered from the limestone clast in the Lower Head Formation would equate this fauna with Fauna 4 of Sweet *et al.* (1971) (= *Histiodella holodentata* Chronozone of Sweet, 1984).

An alternative conodont zonation to the Faunas proposed by Ethington and Clark (1971) and Sweet *et al.* (1971) for the North American Midcontinent has been proposed recently by Ethington and Clark (1982) for the Early and early Middle Ordovician. Thirteen conodont intervals were erected spanning the entire Pogonip Group. Each interval is defined by the occurrence of conodonts that belong to both North Atlantic and Midcontinent faunal provinces, as well as by forms described from Argentina by Serpagli (1974). These taxa include *Acodus deltatus*, species of *Drepanodus*, *Drepanoistodus*, *Juanognathus*, *Macerodus dianae*, and *Oepikodus communis*. This new scheme has the advantages of being based on conodont distributions in measured sections and in which the distribution of other fossil groups is well known. However, since this scheme was first proposed, it has been little used.

4.5 Correlation of St. Pauls Inlet with Martin Point section

A limited biostratigraphic correlation is proposed between the two sections based on the first occurrences of *Paroistodus proteus*, *Prioniodus elegans*, and *Oepikodus evae*. These correlations are depicted in Figure 3 (p. 17). The correlation between the bases of both sections differs from that proposed by James and Stevens (in press). The conodont evidence suggests that the base of the Martin Point section correlates with the first bedded limestone and conglomerate unit at St. Pauls Inlet (Figure 3). The former unit is considered older than the latter by James and Stevens (in press). No correlations are attempted between the upper part of the Martin Point section and equivalent strata at St. Pauls Inlet. Taxa from bedded limestones at this level in the Martin Point section have only single occurrences or are undiagnostic. James and Stevens' (in press) lithological correlations in Beds 10-15 are tentatively accepted pending further data.

4.6 Correlation with other sequences

Figure 5 shows the suggested correlations between Cow Head Beds 9-15 at St. Pauls Inlet and the coeval St. George Group and other Early Ordovician sequences representative of different parts of the North American craton.

The occurrence of *Macerodus dianae* Fåhraeus and Nowlan in Bed 9 just below the Arenig-Tremadoc boundary and immediately below the "pebble bed" in the upper part of the Boat Harbour Formation of the St. George Group (Stouge, 1982) suggests that Boat Harbour strata above the "pebble bed" are perhaps correlative with earliest Arenig strata in Bed 9. The correlation of the lower part of the Catoche Formation with the upper part of Bed 9 (Figure 5) is based on the occurrence of *Oepikodus communis* at the base of the former unit (Stouge, 1982) and in the latter unit (Figure 4). The occurrence of *Acodus*? *sweeti*, *Bergstroemognathus extensus*, *Oistodus* n. sp. 1 and *Semiacontiodus cornuformis* in the Laignet Point Member suggests the correlation depicted in Figure 5 between this unit and Cow Head strata. The upper Catoche Formation is probably correlative with most of Bed 11, except the uppermost part, which is probably equivalent to basal Aguathuna Formation strata (Figure 5). The latter correlation is based on the occurrence of species characteristic of Fauna E-1 near the base of the Aguathuna Formation (James and Stevens, in press; Kenna, 1985; Stouge, 1982) and in uppermost Bed 11 strata in the Cow Head Group (Figure 4). Beds 12-15 are probably equivalent to the rest of the Aguathuna Formation.

The occurrence of *Oepikodus evae* and associated taxa such as *Acodus*? *gladiatus*, *Bergstroemognathus* sp. cf. *B. extensus*, *Paroistodus parallelus*, *Periodon flabellum*, *Stolodus* aff. *S. stola* (=?*Stolodus* n. sp. 1) and *Walliserodus australis* in the lower Deep Kill Shale and in Bed 11 suggests the correlation of the former unit with the latter (Figure 5).

The correlation of Arenig strata in Cow Head Beds 9-11 with the El Paso Group shown in Figure 5 is suggested by the occurrence in both sequences of *Macerodus dianae* and *Oepikodus communis* stratigraphically above this species and then by the appearance of *Reutterodus andinus* and *Semiacontiodus cornuformis* above these first two taxa. *Protoprioniodus aranda* occurs near the top of the El Paso Group (Repetski, 1982). As suggested by the previous correlation of Cow Head with St. George strata, El Paso strata between the last occurrence of *M. dianae* and first appearance of *O. communis* can perhaps be considered earliest Arenig.

Macerodus dianae, Oepikodus communis and *Reutterodus andinus* also appear in the same order in the Fillmore Formation. Their occurrence in this formation suggests that the Fillmore is correlative with Beds 9-11 (Figure 5). The overlying Wah Wah Formation is correlated with the upper part of Bed 11 (Figure 5). This correlation is based on the occurrence of *Protoprioniodus aranda* in both units. (Ethington and Clark, 1982; Figure 4). The Juab Formation is possibly correlative with Bed 12 and the lowermost strata of Bed 13 (Figure 5) as suggested by the occurrence of *Tripodus laevis* 1.0 m below the base of Bed 12 (Figure 4). The correlation of the Kanosh Shale and Bed 13 is suggested by the occurrence of *Pteracontiodus cryptodens* and *Scandodus sinuosus* in both units (see also Section 4.4). The lack of diagnostic conodont taxa in the upper part of Bed 13 prevents the correlation of Cow Head strata at this level with higher Pogonip Group formations.

The occurrence of *Histiodella holodentata* in the fauna in the Lower Head Formation suggests that this fauna is correlative with that in the Lehman Formation (Ethington and Clark, 1982).

The correlation between the Broken Skull and Sunblood formations (Tipnis *et al.*, 1978) and the Cow Head Group depicted in Figure 5 is based on the occurrence of "*Microzarkodina*" sp. aff. "*M.*" *adentata, O. communis*, *Oistodus lanceolatus*, and *Walliserodus australis* in the lower part of the Broken Skull Formation and *Jumudontus gananda* and *Protoprioniodus aranda* in uppermost Broken Skull and in lowermost Sunblood strata. The occurrence of *Scandodus sinuosus* slightly higher in the Sunblood suggests that this part of the formation is correlative with the lower part of Bed 13.

The occurrence of *O. evae* between 20 and 95 m above the base of the Road River Formation (Tipnis *et al.*, 1978) suggests that this interval is possibly correlative with Bed 11.

The correlation of the uppermost part of the Baumann Fiord and Eleanor River formations with Beds 9-11 is suggested by the occurrence of *Macerodus dianae* slightly lower in the Baumann Fiord Formation than shown in Figure 5 and also by the occurrence of *Semiacontiodus cornuformis* in Member 2 and *Protoprioniodus aranda* in Member 3 of the Eleanor River Formation (Nowlan, 1976). A hiatus perhaps exists between topmost Eleanor River strata and overlying Bay Fiord, because conodonts of Fauna 4 appear in the next productive horizons above this presumed hiatus (Nowlan, 1976).

In Argentina the lower 120 m of the San Juan Formation (Serpagli, 1974) is perhaps correlative with uppermost Bed 9, Bed 10 and Bed 11 strata. This interval is typified by the occurrence of *Oepikodus evae*, *O. intermedius*, and *Periodon flabellum* plus other North Atlantic taxa. The upper 80 m of the San Juan is possibly correlative with lower Bed 13 strata, as suggested by the occurrence of *Scandodus brevibasis* in the former unit and *Scandodus* sp. cf. *S. brevibasis* in the latter.

In Australia the uppermost part of Zone OCB and all of OCC of the Australian conodont zonation (McTavish and Legg, 1976) is probably equivalent to uppermost Bed 9 strata. Zone OCD is possibly correlative with Bed 11.

4.7 Comparison of conodont faunas to graptolite and shelly fossil zonations in the Cow Head Group

Williams and Stevens (in press) have recently erected a graptolite biozonation for the Arenig in the Cow Head Group for which eight zones were recognized. Many of the graptolites in this zonation also occur in Australia, so that the Australasian standard is partly applicable to the Cow Head Group. This scheme is used for zoning Cow Head strata, but in a modified form (Williams and Stevens, in press).

The bases of the *Paroistodus proteus* and *Tetragraptus approximatus* zones are shown to be equivalent in Figure 5. The first appearance of *P. proteus* is within a meter or two of the first appearance of *T. approximatus* in both sections. Thus the base of the Arenig occurs at roughly the same level in both sections as defined by either conodonts or graptolites. The occurrence of *P. proteus* and *T. approximatus* together in Cow Head strata demonstrates the equivalence of the zones named for these taxa. Their equivalence is implied by indirect correlation of the British graptolite sequence with the Scandinavian conodont succession (e.g. Lindström, 1971; Löfgren, 1978).

The base of the *Didymograptus bifidus* Zone appears to coincide with the base of the *Oepikodus evae* Zone (Figure 5). The equivalence of these two zones was first established by Bergström and Cooper (1973) from conodont and graptolite faunas from the upper part of the Marathon limestone in Texas. The occurrence of these taxa together reaffirms that the *D. bifidus* Zone is middle Arenig in age.

The base of the *Isograptus victoriae lunatus* Zone appears to correspond to the simultaneous disappearance of several conodont taxa in the middle of Bed 11 (Figure 4). At this level *Acodus sweeti, Bergstroemognathus* sp. cf. *B. extensus*, "*Microzarkodina*" sp. aff. "*M.*" *adentata, Prioniodus elegans*, and "*Scolopodus*" *carlae* disappear from the sequence. The base of this graptolite zone also coincides with the first appearance of early forms of *Periodon aculeatus* (Table 1). The base of the *I. v. victoriae* Zone coincides with first appearances of *Oepikodus intermedius, Protoprioniodus aranda*, and *Strachanognathus parvus*. The base of the *I. v. maximus* zone coincides with the disappearances of *Acodus*? *robustus, Jumudontus* sp. aff. *J. gananda, Scandodus sinuosus*, and *Walliserodus ethingtoni* (Figure 4). The *I. v. victoriae* Zone straddles the Canadian-Whiterock boundary as defined by conodonts in this study and by shelly fossils. No major changes in the graptolite fauna occurs across this boundary while conodonts show a marked change.

Graptolite evidence suggests that the Arenig-Llanvirn boundary may possibly be found at Bed 14 or above. Some graptolites with the first thecae having a metasicular origin occur in Bed 15 (*Udulograptus austrodentatus* Zone) (Williams and Stevens, in press). This morphology may represent an evolutionary event which could be the basis for establishing a biostratigraphic boundary at this level. The occurrence of *Ansella jemtlandica* in Bed 14 at St. Pauls Inlet is evidence that the Arenig-Llanvirn boundary may be placed at the base of this Bed or above (see Section 4.3).

Data based on shelly fossils from Bed 10 (Kindle and Whittington, 1958; James and Stevens, in press) are generally consistent with conodont data from immediately over- and underlying beds. Zone H and possibly Zone I trilobites occur in boulders of this bed (James and Stevens, in press). Conodonts occurring in these zones in the Pogonip Group occur in beds above and below Bed 10 in Cow Head strata. Trilobites of zones H and I occur in Bed 12, as well as those of Zone J (James and Stevens, in press). The occurrence of Zone J trilobites in this bed support the correlation of underlying strata with the Wah Wah Formation. These trilobites co-occur with *Protoprioniodus aranda* in this formation. *P. aranda* first appears near the top of Bed 11 in Cow Head strata (Figure 4).

The occurrence of brachiopods of the genus *Orthidiella* in Beds 12-14 in Cow Head strata supports the Whiterockian age assignment suggested by the conodonts. This genus defines the base of the Whiterock stage in the Antelope Valley Limestone in Nevada (Ross *et al.*, 1982).

4.8 Conclusions

Five faunal assemblages are recognized in Arenig Cow Head strata at St. Pauls Inlet (Figure 5). Each assemblage can be considered a distinct fauna occurring within a certain stratigraphic interval in each bed. The distribution of these faunas is paleoecologically significant. This will be discussed in greater detail in the next chapter.

Only the three lower North Atlantic conodont zones were recognized (Figure 5). The base of the Arenig is recognized by the first appearance of *Paroistodus proteus*. The stratigraphic thickness of these zones far exceeds the thickness of equivalent strata in Balto-Scandia, which allows a more exact assessment of the ranges of taxa of each zone. Only two of the upper five North Atlantic zones are tentatively recognized (Figure 5). The probable endemism of *Baltoniodus* in the Early Ordovician and the rare occurrence of *Microzarkodina* in North America (e.g. Ethington, 1979; Ethington and Clark, 1982; Nowlan, 1981) limits the applicability of the North Atlantic conodont zonation schemes outside the Balto-Scandian craton. Perhaps the use of species of other genera in this interval might prove to be more suitable for subdividing middle to late Arenig strata. The possible occurrence of the Arenig-Llanvirn boundary in uppermost Cow Head strata at St. Pauls Inlet is suggested by the occurrence of *Ansella jemtlandica* at this level. This species occurs in latest Arenig-early Llanvirn strata in Balto-Scandia (Löfgren, 1978).

Midcontinent Fauna D, the *Oepikodus communis* Zone, and Fauna 2 are recognized in Cow Head strata at St. Pauls Inlet. The *O. communis* Zone equates with both the *O. evae* and *Prioniodus elegans* zones. Previous studies have equated the *O. communis* Zone with the *O. evae* Zone. This study shows that the *O. communis* Zone is more extensive than previously thought. The occurrence of this zone fossil with both the *O. evae* and *P. elegans* provides an important tie point for correlating North Atlantic and Midcontinent faunas.

The occurrence of Fauna 2 conodonts in lower Bed 13 strata assigns a Whiterockian age to this and overlying Cow Head units. The occurrence of graptolites and shelly fossils characteristic of the Valhallfonna Formation of Spitsbergen with Whiterockian conodonts in Bed 13 suggest that the Valhallan Stage of Fortey (1980) is equivalent to the lower Whiterock.

Correlations with the St. George Group suggest that Arenig Cow Head strata are equivalent to the uppermost Boat Harbour, Catoche, and Aguathuna formations. The same Cow Head strata are correlative with rocks from the lower part of the Fillmore Formation to at least the base of the Kanosh Shale in the Pogonip Group. Arenig Cow Head strata are also equivalent to the upper part of the El Paso Group, the lower Deep Kill Shale, the Broken Skull, Road River and lower Sunblood formations, and uppermost Baumann Fiord and Eleanor River strata. Most of these sequences can only be correlated to the top of Bed 11. Strata equivalent to Beds 12-15 are either absent or barren of conodonts. This probably reflects the hiatus resulting from the regressive event that occurs around the North American craton in lower Whiterockian strata (Fortey, 1980).

The bases of the *Paroistodus proteus* and *Tetragraptus approximatus* zones nearly coincide in both sections. The occurrence of these fossils together demonstrates the equivalence of these zones, which has only been implied in previous correlations. The *Didymograptus bifidus* and *O. evae* zones are equivalent in Cow Head strata, which reaffirms the age of the former zone as middle Arenig. The possible occurrence of the Arenig-Llanvirn boundary is uppermost Cow Head strata is suggested by graptolite as well as conodont data.

Correlations based on shelly fossil data from megaconglomerates in Cow Head strata are generally supported by conodont data. The occurrence of *Orthidiella* in conglomerates in Beds 12-15 supports the Whiterockian age assigned to these beds (James and Stevens, in press).

5. PALEOECOLOGY

5.1 Review of conodont paleoecology

Several models have been proposed for conodont paleoecology. Conodonts were first considered pelagic organisms because they occur in various lithofacies (Müller, 1962; Lindström, 1964). Seddon and Sweet (1971) proposed a depth stratification model where conodont species were vertically zoned in the water column. In an alternative model proposed by Barnes *et al.* (1973), Barnes and Fåhraeus (1975), and Fåhraeus and Barnes (1975), conodont taxa were laterally segregated, which implies that most were benthic or nektobenthic with relatively few pelagic taxa. Both models have been utilized, often together, for interpreting the distribution of conodont taxa in Paleozoic and early Mesozoic rocks (e.g. papers in volumes on conodont paleoecology edited by Barnes (1976) and Clark (1984)). Pelagic and nektobenthic habits for conodonts were probably both common, given the large diversity of the group (Lindström, 1976b, 1984). Klapper and Barrick (1977) caution that both models may be too simplistic and that more complex ones are perhaps necessary.

Several factors are considered to have controlled conodont distribution. Many workers consider temperature and salinity to be the primary controlling factors (e.g. Barnes and Fåhraeus, 1975; Le Fèvre *et al.*, 1976, Lindström, 1984, Ethington and Repetski, 1984). Substrate may have also have controlled their distribution (e.g. Barnes and Fåhraeus, 1975) as well as seawater chemistry (e.g. Merrill and von Bitter, 1976; Jeppsson, 1984) and oxygen levels (Fortey and Barnes, 1977).

5.2 Paleoecology of Arenig conodonts at St. Pauls Inlet and Martin Point sections

5.2.1 Relationship of conodonts to lithology

The size of conodont elements appears to be related to grain size in the bedded carbonates. Lime mudstones usually contain small and delicate conodont elements while grainstones usually contain large and robust elements. The largest and most robust elements occur in coarse sand-sized grainstones while smaller and less robust elements occur in fine sand-sized grainstones. The size and robustness of elements generally increases from Bed 9 to Bed 13. Faunas are less diverse in mudstones than in grainstones. For example, faunas from both bedded and nodular mudstones in Beds 11 and 13 in both sections generally contain only species of *Coelocerodontus*, *Diaphorodus*, *Drepanodus*, *Paroistodus*, *Periodon*, *Protopanderodus*, and *Protoprioniodus* (Tables 2 and 3, p. 227, 229).

Conodonts were recovered from processed samples of red shale. They were also observed on the surfaces of hand specimens of red and green shales from both sections, being generally large and robust. In these shales, cone taxa occur most frequently, although ramiform taxa such as *Oepikodus*, *Paracordylodus*, *Periodon*, and *Prioniodus* also occur.

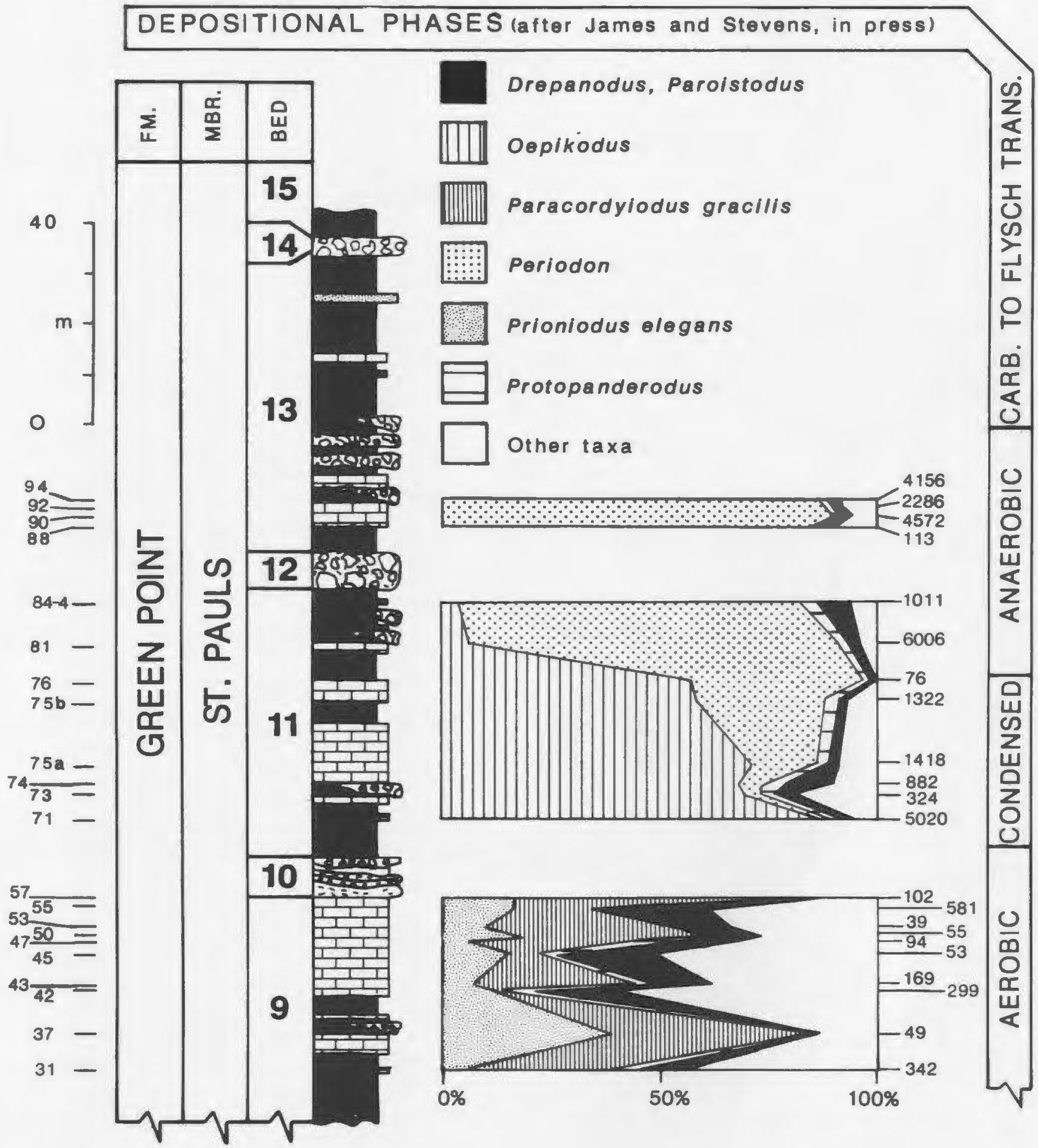
Almost all Cow Head bedded carbonates, shales and siltstones are interpreted as turbiditic or hemipelagic in origin (Coniglio, 1985). This means that many conodont elements may be transported. Transported elements do not necessarily need to show signs of wear (Ethington and Repetski, 1984; Lindström, 1984). Therefore, abrasion cannot be used as an unambiguous criterion for distinguishing between *in situ* and "exotic" taxa. Some conodont taxa may then occur together because of post-mortem transport.

5.2.2 Paleoecological patterns of conodont taxa in the St. Pauls Inlet section

Figure 6 shows the relative abundances of selected conodont taxa in certain samples from bedded limestones from all Beds plus the number of elements per sample. In each Bed the most abundant taxa are plotted together with the coniform genera *Drepanodus*, *Paroistodus*, and *Protopanderodus* and "other taxa". The coniform genera are singled out for comparison with other studies (e.g. Fortey and Barnes, 1977). "Other taxa" include other Midcontinent and North Atlantic species. The relative abundances of *Oepikodus communis*, *O. evae* and *O. intermedius* are depicted in Bed 11.

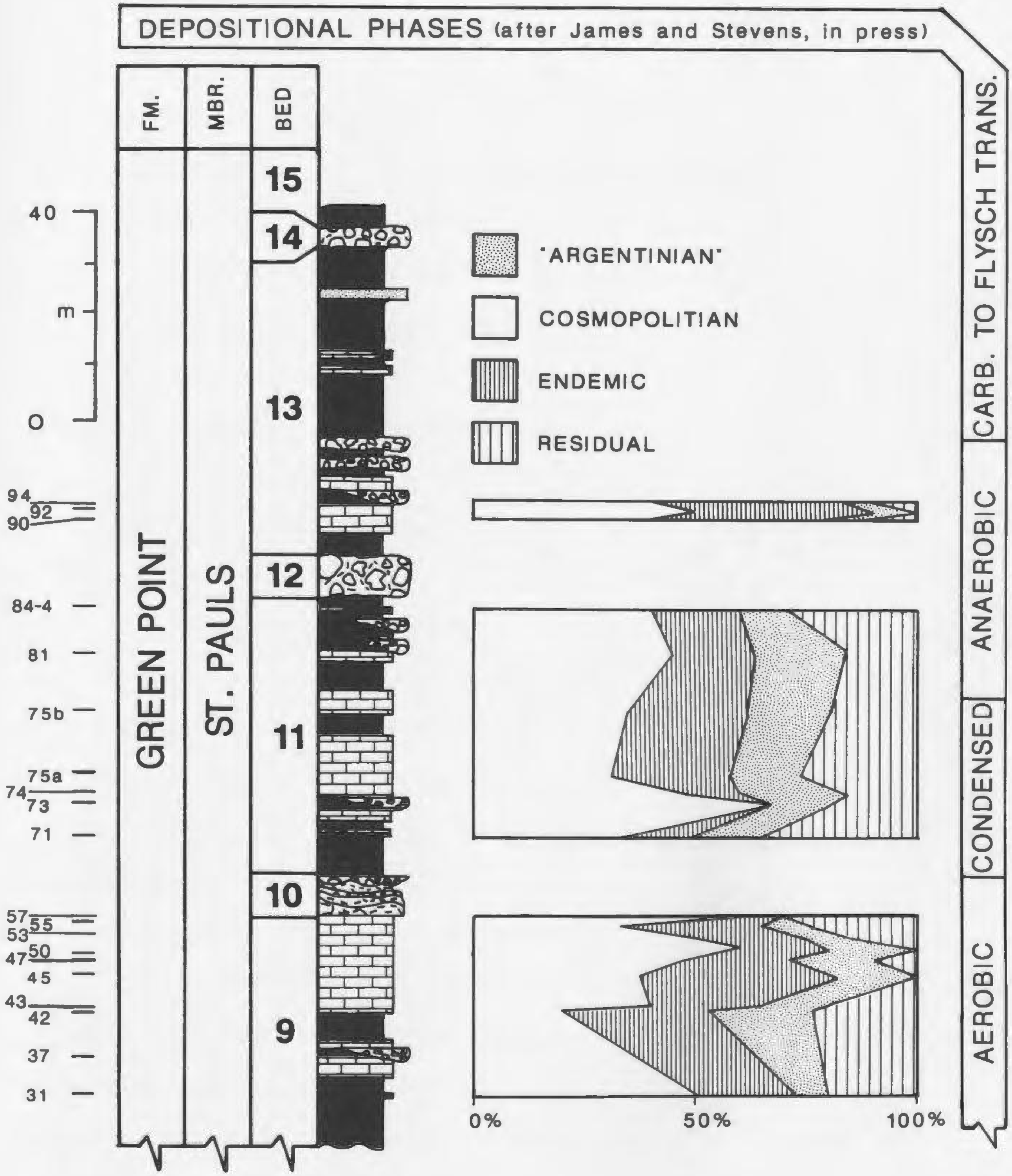
Figure 7 illustrates the relative proportions of endemic to cosmopolitan to "Argentinian" to residual taxa for the same samples. Endemic forms are Midcontinent taxa that occur in warm shallow shelf environments (e.g. *Eucharodus parallelus*, *Glyptoconus*

FIGURE 6--Relative abundances of key conodont taxa in upper part of Bed 9, and Beds 11 and 13 in St. Pauls Inlet section. Sample size is indicated to right of relative abundance curves. Sample size is total number of elements per sample. Sample numbers are given on the left for referral to sample descriptions in Appendix B and to conodont distributions in Tables 1 and 2. Depositional phases after James and Stevens (in press) (see text). Beds, stratigraphic columns and units as in Figures 3 and 4.



DEPOSITIONAL PHASES (after James and Stevens, in press)
FM.
MBR.
BED
GREEN POINT
ST. PAULS
15
14
13
12
11
10
9
40
m
0
Drepanodus, Paroistodus
Oepikodus
Paracordylodus gracilis
Periodon
Prioniodus elegans
Protopanderodus
Other taxa
94
92
90
88
84-4
81
76
75b
75a
74
73
71
57
55
53
50
47
45
43
42
37
31
4156
2286
4572
113
1011
6006
76
1322
1418
882
324
5020
102
581
39
55
94
53
169
299
49
342
0%
50%
100%
CARB. TO FLYSCH TRANS.
ANAEROBIC
CONDENSED
AEROBIC

FIGURE 7--Relative proportions of "Argentinian" versus cosmopolitan versus endemic and residual taxa in Beds 9, 11, and 13 in the St. Pauls Inlet section. Beds, stratigraphic columns and units as in Figure 6.


DEPOSITIONAL PHASES (after James and Stevens, in press)
FM.
MBR.
BED
GREEN POINT
ST. PAULS
15
14
13
12
11
10
9
40
m
0
94
92
90
84-4
81
75b
75a
74
73
71
57
55
53
50
47
45
43
42
37
31
"ARGENTINIAN"
COSMOPOLITIAN
ENDEMIC
RESIDUAL
0%
50%
100%
CARB. TO FLYSCH TRANS.
ANAEROBIC
CONDENSED
AEROBIC

quadraplicatus and species of *Ulrichodina*) (Ethington and Repetski, 1984). North Atlantic taxa that occur in outer shelf to basinal settings are considered cosmopolitan (e.g. *Oepikodus evae, Paracordylodus gracilis*, species of *Periodon*, *Prioniodus elegans*) (Lindström, 1976b, 1984). "Argentinian" taxa described by Serpagli (1974) are considered by some authors to partly comprise a shelf-edge biofacies together with North Atlantic taxa (Ethington, 1979; Fortey and Barnes, 1977; Landing and Ludvigsen, 1984; Lindström, 1976a). These include *Bergstroemognathus extensus*, species of *Juanognathus* and *Walliserodus australis*. Residual taxa are forms that cannot be classified in the previous three catagories (e.g. *Paroistodus?* sp. A, Drepanodontiform element A, New Genus A sp., etc). Certain paleoecological patterns are observed to occur in each Bed (Figures 6 and 7). These patterns are described Bed by Bed in the following account in greater detail.

Bed 9.-- *Paracordylodus gracilis* and *Prioniodus elegans* comprise about 40% and 12%, respectively, of the faunas in this Bed. (Figure 6). *Drepanodus* and *Paroistodus* are more abundant in this Bed than in the others. Together they comprise 15-20% of the faunas while in the beds above they comprise less than 5% (Figure 6). *Protopanderodus* (represented by *P. elongatus* and *P. leonardii*) comprises about 1-2% of the faunas. Other taxa (predominantly hyaline species) are more abundant in Bed 9 than in Beds 11 and 13. Cosmopolitan species comprise about 40% of the faunas in this and in overlying beds (Figure 7).

In one sample (StPl 42) *P. gracilis* comprises only 2% of the fauna. (Figure 6). The proportion of cosmopolitan taxa declines sharply to 20% (Figure 7). These changes also coincide with the second major influx of taxa in Bed 9 (Figure 4, p. 24). Conodonts in this sample are generally large and robust, with Midcontinent hyaline taxa dominating the fauna. Hyaline taxa also occur in larger numbers than usual in one other sample (StPl 55). These do not dominate the fauna since the relative abundance of *P. gracilis* to *P. elegans* as well as cosmopolitan to endemic taxa remains the same as other samples in Bed 9. In StPl 55 and samples above the relative percentages of endemic and "Argentinian" taxa begins to drop (Figure 7). This decrease coincides with the first occurrence of *Acodus sweeti* and "*Micozarkodina*" sp. aff. "*M.*" *adentata* and the disappearance of "*Acontiodus*" *staufferi*.

"*Drepanodus*" *toomeyi*, and *Paroistodus*? sp. A (Figure 4).

Bed 11.--The changeover from *Oepikodus evae*-dominated to *Periodon*-dominated faunas is the most dramatic faunal event recorded in this bed (Figure 6). This has been documented previously in sections on the Cow Head Peninsula by Fåhraeus and Barnes (1975) and Fåhraeus and Nowlan (1978). *O. evae* dominated faunas occur between 10 and 32 m above the base of Bed 11 (Figure 6). This interval is also marked by an influx of new taxa (Figure 4). In the lower 8 m of this interval, *Periodon* comprises only 2% of the faunas. The percentage of endemic and "Argentinian" taxa is also low and in one sample (StPI 73) endemic taxa are absent (Figure 7). The relative abundance of *Periodon* increases to 20% in the upper 14 m of this interval (Figure 6) and the percentages of endemic and "Argentinian" taxa increase to previous levels (Figure 7). The increased relative abundance of *Periodon* is accompanied by the simultaneous disappearance of several taxa each at 18 and at 32 m above the base of Bed 11 (Figure 4). Some are carry-over taxa from Bed 9 (e.g. *Bergstroemognathus* sp. cf. *B. extensus*, *Paracordylodus gracilis*, *Prioniodus elegans*) while others are short-ranging taxa of Bed 11 (e.g. "*Bellodella*" sp. B and "*Scolopodus*" *carlae*) (Figure 4).

Periodon comprises 80-90% of the faunas in the upper 20 m of Bed 11 (Figure 6). A major faunal turnover occurs 46 m above the base of Bed 11 with the disappearance of taxa that originate in Beds 9 and 11 (e.g. *Acodus*? *gladiatus*, *Protoprioniodus simplicissimus*, and *Walliserodus australis*) and the appearance of several new taxa (e.g. *Oepikodus intermedius* and *Protoprioniodus aranda*) (Figure 4). The abundance of *Drepanodus*, *Paroistodus*, and *Protopanderodus* does not change significantly throughout Bed 11 although the abundance of "other taxa" is reduced dramatically (Figure 6).

Bed 13.--*Periodon* comprises about ninety percent of the faunas in the lower 10 m of this bed (Figure 6). The relative abundance of coniform genera does not change from Bed 11, with only *Protopanderodus* absent from one sample (StPI 68, Figure 6). The abundance of other taxa is small (Figure 6). The proportion of endemic taxa doubles from that of previous Beds (Figure 7) at the expense of "Argentinian" and other taxa. The larger percentage of endemics coincides with the influx of forms such as *Pteracontiodus cryptodens* and *Scandodus sinuosus* (Figure 4).

Most of the paleoecological patterns depicted in Figures 6 and 7 and the major influxes of taxa in Figure 4 can also be correlated with major, and in some cases, minor changes in lithology at St. Pauls Inlet. For example, a change from mudstone to grainstone deposition occurs between the first and second major influx of taxa in Bed 9 (Figure 4). Red and green shale and chert deposition occurs in the interval of *Oepikodus evae* dominated faunas in Bed 11. These lithologies also coincide with the low representation by endemics (Figure 7) and a major influx of new taxa (Figure 4). The domination of faunas by *Periodon*, plus the major influxes and extinctions of taxa in the upper part of Bed 11 and in lower Bed 13 strata (Figure 4), coincides with black and green shale deposition and an increase in the frequency of phosphorite pebbles in conglomerates.

Each of the above lithological units represents a depositional phase in Arenig Cow Head strata (James and Stevens, in press). The first phase, the aerobic phase, is represented by rocks of Bed 9. The sea bottom at this time is interpreted to be oxygenated in distal sections of the Cow Head Group. This interval is marked by deposition of red shales with extensive bioturbation occurring in both carbonates and siliciclastics. Transgressive conditions occur on the shelf (lower Catoche Formation) (James and Stevens, in press). The next phase, represented by lower Bed 11 strata, is interpreted as a condensed phase. It represents a time of maximum transgression on the shelf (Laignet Point Member and upper Catoche) and starved sedimentation on the slope and rise (James and Stevens, in press). The anaerobic phase is represented by upper Bed 11 and lower Bed 13 strata. The sea floor is interpreted as commonly anoxic at this time, due to expansion of the oxygen mimimum layer. Conditions on the shelf are regressive (Aquathuna Formation), with subaerial exposure and karsting (Knight and James, in press). The final phase, represented by rocks in the upper half of Bed 13, marks a transition from carbonate to flysch deposition. Red and green shales are again deposited and beds of green sandstone of the Lower Head Formation (James and Stevens, in press) occur in the shales, marking the onset of flysch deposition (Figures 3 (p. 17) and 4) within an aerobic environment.

Red and green shales in Cow Head strata are generally interpreted to indicate the presence of well oxygenated bottom waters (Coniglio, 1985). Such conditons in the deep ocean are well developed during periods of glaciation (Fischer and Arthur, 1977). It has been suggested by Barnes (1984) and Fortey (1984), on the basis of eustatic curves, that glaciation may have occurred in the Arenig. Black and green shales in the Cow Head Group are interpreted to be deposited under anoxic or dysaerobic conditions (Coniglio, 1985). Deposition of black shale commonly occurs under anoxic bottom conditions (e.g. Rhodes and Morse, 1971; Schlanger and Jenkyns, 1976; Hallam, 1980; Williams and Rickards, 1984). The occurrence of phosphorites in slope environments generally indicates strong coastal upwelling (Schopf, 1980). The oxygen minimum layer is usually expanded under zones of upwelling due to increased oxygen consumption by bacteria decomposing large amounts of organic matter produced by increased productivity (Rowe and Haedrich, 1979). The occurrence of phosphorites in conglomerates and extensive black and green shale deposition in upper Bed 11 and lower Bed 13 strata suggests that strong upwelling was occurring and anoxic conditions existed on the slope and most of the rise (James and Stevens, in press). The large robust conodont elements in this interval suggests that ample phosphate was available for mineralization.

Conodont data from St. Pauls Inlet appear to support James and Stevens' (in press) interpretations. The occurrence of *Oepikodus evae*, *Paracordylodus gracilis*, and *Prioniodus elegans* in great abundances in Beds 9 and 11 supports the interpretation that conditions were transgressive. These taxa are commonly considered deep water forms according to Barnes and Fåhraeus (1975) community segregation model. The occurrence of taxa such as *Bergstroemognathus extensus*, *Oepikodus communis*, *Oistodus* n. sp. 1, and *Walliserodus australis* in both the lower Catoche Formation (Stouge, 1984; Kenna, 1985) and Beds 9-11 (Figure 4) suggests that there was free and open exchange between shelf and oceanic conodont faunas. This also would be expected during times of transgression (Stouge, 1982; Fortey, 1984). The low percentage or absence of endemic taxa in lower Bed 11 strata also suggests that this interval represents maximum transgression. Few endemic species would be expected to occur in the slope-rise environment since most were presumably adapted to warmer and shallower waters far shoreward of the shelf-edge (Barnes and Fåhraeus, 1975).

The occurrence of *Periodon*-dominated faunas in the upper part of Bed 11 and the lower part of Bed 13, plus the large number of endemic taxa present (Figures 6 and 7) supports the interpretation that conditions were regressive. The change from *Oepikodus*-dominated to *Periodon*-dominated faunas has been interpreted to represent shifting biofacies in response to a sea level drop (e.g. Fåhraeus and Barnes (1975), Fortey and Barnes (1977)). This drop is also indicated by the appearance of more endemic forms which have previously been reported to occur in outer shelf sequences (e.g. Mound, 1965a, b; Ethington and Clark, 1982; Repetski, 1982). The increase of these endemic taxa in Bed 13 may reflect a greater degree of ecological overlap with deep water forms than in underlying beds or transport of elements into deep water by periodic collapse of an oversteepened margin (James and Stevens, in press; Pohler *et al.*, in press).

The relatively constant abundances of individual taxa and consistent percentages of cosmopolitan, endemic and "Argentinian" species, except for StPI 42, in Bed 9 suggests enviromental conditions were relatively stable throughout the deposition of the mudstone-grainstone facies of Bed 9. The general increase in size of conodont elements and frequency of burrowing towards the top of this unit may indicate a progressive oxygenation, although the increase in element size may just mirror the increase in overall grain size observed in this interval by James and Stevens (in press). The low percentages of *P. gracilis* and cosmopolitan taxa, plus the large abundance of hyaline taxa in StPI 42, perhaps reflects a local change in ecological conditions, although the coarse grain size of the sample lithology suggests that elements were transported some distance.

The distribution patterns of *Oepikodus evae* and *Periodon* in Bed 11 at St. Pauls Inlet are unlike the distribution patterns of these taxa reported by Fortey and Barnes (1977) in the Valhallfonna Formation in Spitsbergen. In this formation *Oepikodus* occurs with olenid trilobites which are interpreted to have lived on the lower slope under near anoxic conditions.

Species of *Periodon* co-occur with nileid trilobites which lived on the upper slope under aerobic conditions (Fortey and Barnes, 1977). This same general pattern is observed in the Table Head Group where *P. aculeatus* co-occurs with nileid-type trilobites (Stouge, 1984).

O. evae appears to thrive under aerobic conditions in lower Bed 11 strata. Higher up in this bed and in Bed 13 *Periodon* predominates under anoxic conditions (Figure 6). Because the distribution patterns of these taxa were observed in a slope setting by Fortey and Barnes (1977), their distribution in the St. Pauls Inlet section and in sections on the Cow Head Peninsula (Fåhraeus and Barnes, 1975; Fåhraeus and Nowlan, 1978) might reflect post-mortem distributions due to the transport of elements of these and associated taxa onto the lower slope and rise. Alternatively, if these taxa and associated forms were living in this environment, then their distributions may suggest that depth was a more significant controlling factor than oxygen levels.

The previous observations and interpretations are based on conodont data from a single section of the Cow Head Group. Future work will determine if the paleoecological patterns of conodont taxa discussed here are applicable only to the one locality (St. Pauls Inlet) or throughout all the Cow Head Group.

5.3 Conclusions

The size and robustness of conodont elements in bedded carbonates generally correlates with grain size while large and robust elements occur in red and green shales. Lime mudstone and shale faunas are less diverse than faunas in grainstones. Future work should involve systematic collecting of mudstones, grainstones, shales and siltstones to test whether the relationships of conodonts to lithological characteristics noted above are consistent in other sections of the Cow Head Group.

There appears to be a general correlation between the paleoecological patterns depicted in Figures 6 and 7 and the major influxes and disappearances of taxa in Figure 4. Faunas in Beds 9-11 are dominated by deep water taxa, while those in the upper part of Bed 11 and lower part of Bed 13 are dominated by shallower water forms as suggested by Barnes and

Fåhraeus (1975) community segregation model. These patterns can also be tied to major changes in lithologies. The distribution patterns of conodont taxa in the St. Pauls Inlet section generally support James and Stevens' (in press) interpretation that the lower part of the Arenig sequence in the Cow Head Group is transgressive and the upper part is regressive. The transgressive-regressive cycles that occur on the shelf (James and Stevens, in press) appear also to be reflected by changes in the composition and abundance patterns of conodont faunas on the slope and/or rise in addition to the lithological changes. These patterns may reflect major changes in the oceanic environment during the transition from transgressive to regressive conditions.

6. CONCLUSIONS

The Arenig stratigraphy of the Cow Head Group first established by Schuchert and Dunbar (1934) has recently been revised by James and Stevens (in press). The taxonomy and biostratigraphy of both Arenig shelly fossils and graptolites is currently being revised (e.g. James and Stevens, in press; Williams and Stevens, in press). Prior investigations of Arenig conodont faunas by Fåhraeus (1970), Nowlan (1974), Fåhraeus and Barnes (1975), and Fåhraeus and Nowlan (1978) focused on small faunas collected from proximal Cow Head sections on the Cow Head Peninsula.

This study is an investigation of the taxonomy, biostratigraphy, and paleoecology of Arenig conodont faunas from both intermediate and distal sections of the Cow Head Group. It is undertaken in conjunction with other studies currently investigating Arenig conodonts in other Cow Head sections and from boulders derived from shelf-break and upper slope facies in the megaconglomerates (e.g. Pohler *et al.*, in press).

Arenig section is represented at St. Pauls Inlet and Martin Point by 180 m and 154 m respectively of deep-water limestone, shale, siltstone, and conglomerate belonging to the St. Pauls Member of the Green Point Formation (James and Stevens, in press; Williams *et al.*, 1985). The Green Point Formation represents distal shale-dominated Cow Head strata which was deposited on the continental rise at the Early Ordovician (Arenig) margin. The St. Pauls Inlet and Martin Point sections are interpreted as proximal and distal facies of this formation respectively with the former section containing significantly more carbonate than the latter section.

Each section was intensively sampled with 3.5 kg. limestone and shale samples taken at approximately 1 m intervals. The majority of processed samples were limestones collected at St. Pauls Inlet. Limestones were dissolved in 10-15% acetic acid while shales were gently boiled in water and detergent. Residues were sieved and separated with tetrabromomethane at S.G. 2.84. Heavy residues were picked for conodonts. A total of 35,659 conodont elements were recovered from 64 limestone and shale samples from both sections (Tables 1-3, p. 225-231). Elements were well preserved with low colour alteration indicies (CAI=1.5-2).

The apparatus of *Lenodus* Sergeeva is revised to include falodontiform and a multiramiform series consisting of cordylodontiform, trichonodelliform, and tetraprioniodontiform elements in addition to previously known prioniodiniform elements. These elements are characterized by small albid denticles which form serrated edges on the processes. *Oepikodus communis* (Ethington and Clark) appears in section before the first occurrences of either *O. evae* (Lindström) or *O. intermedius* (Serpagli). The first occurrence of *O. communis* below the first appearances of both the latter taxa supports McTavish's (1973) hypothesis that *O. communis* and *O. evae* belong to separate lineages. The occurrence of *O. communis* below *O. intermedius* (Figure 4, p. 24) suggests the former species is ancestral to the latter.

The apparatus of *Oistodella* Bradshaw consists of cyrtoniodontiform, oistodontiform, and a multiramiform series comprising of cordylodontiform, cladognathiform, and trichonodelliform elements. These elements are hyaline with albid oral denticles that commonly continue partly onto the cusp. The cusp of each element has a prominent growth axis which is flanked first by hyaline and then by white matter.

Species of *Parapanderodus* Stouge with elements resembling "*Scolopodus*" *gracilis* s.f. Ethington and Clark (e.g. *P. arcuatus* Stouge, *P.* sp. cf. *P. arcuatus*) are perhaps monoelemental taxa. A recent apparatus reconstruction has grouped "*S.*" *gracilis* s.f. with *Protopanderodus asymmetricus* Barnes and Poplawski s.f., and "*S.*" *cornuformis* Sergeeva s.f. (Bergström, 1979; Löfgren, 1985). However, elements of *P. arcuatus* Stouge and *P.* sp. cf. *P. arcuatus* are mostly albid and have triangular cross sections in contrast to hyaline and antero-posteriorly compressed elements of *Semiacontiodus cornuformis* Sergeeva. "*S.*" gracilis s.f. cannot be associated with "*S.*" *triangularis* s.f. in an apparatus since the latter form taxon occurs sporadically in lower and is absent in upper strata of the Cow Head Group.

Early, intermediate and late forms of *Periodon aculeatus* Hadding are recognized in middle and late Arenig Cow Head strata. Early forms are characterized by falodontiform, prioniodiniform, and oulodontiform elements that resemble those in younger beds while multiramiform elements strongly resemble those of *P. flabellum* (Lindström). Intermediate forms have multiramiform elements which resemble those of late forms of *P. aculeatus* which have an acute antero-basal angle and the aboral margins of the base and posterior process meeting at right angles. Prioniodiniform and oulodontiform elements have shorter, less twisted posterior processes than late forms of these elements.

Elements of this species appear to undergo mosaic evolution with falodontiform, oulodontiform, and prioniodiniform elements evolving faster than multiramiform elements (Figure 10, p. 111). In some samples the majority of prioniodontiform elements have a long anterior process while in others the anterior process is short in the majority of these elements. Strongly denticulate falodontiform elements are usually associated with the first type of prioniodiniform element while weakly denticulated falodontiform elements are associated with the latter type. *P. flabellum* is distinguished from *P. aculeatus* by having an adenticulate oistodontiform element, prioniodontiform and oulodontiform elements with inflated basal cavities, and multiramiform elements with several large denticles behind the "big" denticle on the posterior process and an open antero-basal angle.

A new species tentatively assigned to *Polonodus* Dzik comprises asymmetrical and subsymmetrical elements characterized by medially denticulated anterior and posterior lobes that meet at a right angle at the apex. The occurrence of deltaform and oistodontiform elements of *Protoprioniodus papiliosus* van Wamel with triangulariform elements of this species suggests that this latter element is not an aberrant form of the oistodontiform element of *P. aranda* Cooper as suggested by Ethington and Clark (1982).

Elements of "*Scolopodus*" *peselephantis* Lindström representing an intermediate stage in the evolution of this species occur in one sample (dMP 16) at Martin Point. These elements have laterally compressed cusps which are constricted near the base. The cross section of the element is circular below this constriction.

Spinodus Dzik is revised to include falodontiform and prioniodiniform elements in its apparatus in addition to ramiform elements. Cusps and denticles of *S.* sp. cf. *S. spinatus* Hadding are albid in contrast to other occurrences of *Spinodus* where the cusps and denticles are entirely hyaline.

Five faunal assemblages (A1-A5) are recognized from the above taxa at St. Pauls Inlet. The first assemblage (A1) is characterized by the first appearance of *Paroistodus proteus* (Lindström), the second (A2) by the first appearances of *Oistodus* n. sp. 1 Serpagli and "*Oistodus*" sp. aff. "*O.*" *cristatus* Ethington and Clark. The third assemblage (A3) is characterized by the first appearance of *Acodus*? *gladiatus* Lindström while the fourth (A4) is characterized by the first occurrence of *Oepikodus intermedius* Serpagli. The fifth assemblage (A5) is defined by the first appearances of *Acodus*? *robustus* (Serpagli), *Drepanoistodus basiovalis* (Sergeeva), "*Scandodus*" *flexuosus* Barnes and Poplawski s.f. and *Walliserodus ethingtoni* (Fåhraeus).

Only the three lowermost Arenig North Atlantic conodont zones are recognized at St. Pauls Inlet. Some late Arenig North Atlantic zones are tentatively recognized while others are missing. Zonal taxa are absent probably due to endemism. The absence of species of *Baltoniodus* Lindström and *Microzarkodina* Lindström in Cow Head strata underscores the limited applicability of the North Atlantic Province conodont zonation outside the Balto-Scandian craton for the late Arenig. The greater thickness of the *Paroistodus proteus*, *Prioniodus elegans*, and *Oepikodus evae* zones in Cow Head strata suggests that rates of sedimentation were much higher in this sequence than in Balto-Scandia in the Early Ordovician. The occurrence of *Ansella jemtlandica* (Löfgren) in Bed 14 at St. Pauls Inlet suggests that the Arenig-Llanvirn boundary is close to this level. This species occurs in uppermost Arenig and Llanvirn strata in Balto-Scandia (Löfgren, 1978).

Components of Midcontinent Fauna D, the *Oepikodus communis* Zone (Ethington and Repetski, 1984) and Fauna 2 (= *Histiodella altifrons* Chronozone, Sweet, 1984) were recognized in Arenig Cow Head strata at St. Pauls Inlet. The *O. communis* Zone is coeval with both the *P. elegans* and *O. evae* zones (Figure 5, p. 40), which suggests that this zone is of greater duration than previously thought. The occurrence of *Pteracontiodus cryptodens* (Mound) and *Scandodus sinuosus* (Mound) in Bed 13 at St. Pauls Inlet suggests that this Bed is Whiterockian in age. The Valhallan Stage (Fortey, 1980) is shown to be equivalent to the Lower Whiterockian, as suggested by the occurrence of Valhallan trilobites and graptolites with Whiterockian conodonts in Bed 13 at St. Pauls Inlet.

The first appearance of the zone taxa *Tetragraptus approximatus* and *Paroistodus proteus* occurs at about the same level in both sections; their zonal equivalence was only implied in previous correlations. Graptolite data also suggests that the Arenig-Llanvirn boundary may lie in uppermost Bed 13, Bed 14, and Bed 15 strata. Shelly fossils evidence corroborates with conodont evidence suggesting that Beds 12-15 are Whiterockian in age.

The Arenig conodont biostratigraphy of the Cow Head Group suggests that the St. Pauls Inlet section can be correlated with the uppermost Boat Harbour, Catoche and Aguathuna formations of the platformal St. George Group.

The size and robustness of conodont elements in bedded carbonates was found to generally correlate with grain size. Elements in shale, however, tend to be large and robust. The abrupt turnover from *Oepikodus*-dominated to *Periodon*-dominated faunas observed in proximal sections of the Cow Head Group (Fåhraeus and Barnes, 1975; Fåhraeus and Nowlan, 1978) was also observed in the intermediate facies of this group at St. Pauls Inlet (Figure 6, p. 43). Significant changes in paleoecological patterns (Figures 6 and 7, p. 43 and 45) generally coincide with major influxes and extinctions of conodont taxa (Figure 4, p. 24) at particular horizons in Beds 9, 11, and 13 at St. Pauls Inlet. Significant changes in paleoecological patterns and faunal influxes and/or extinctions occur in each of the aerobic, condensed, and anaerobic phases in this section (Figures 6 and 7). The predominance of deep-water taxa in lower to middle Arenig Cow Head strata and shallow-water taxa in middle to upper Arenig strata support the interpretation that Beds 9, 10, and the lower part of 11 represent overall transgressive and the upper part of Bed 11 and Beds 12-15 represent regressive conditions (James and Stevens, in press).

7. SYSTEMATIC PALEONTOLOGY

7.1 Preamble

Because the suprageneric classification of conodonts proposed in Robison (1981) is in dispute (e.g. Fåhraeus, 1983, 1984), conodont taxa herein are only classified to genus. Conodont genera and species are listed in the following sections in alphabetical order. The questionable assignment of conodont elements to some genera is indicated by a question mark (e.g. *Baltoniodus*? sp., *Polonodus*? *peavyi*). Quotes indicate the traditional generic assignment of form and multielement species in the literature, although such taxa should be assigned to other genera (e.g. "*Drepanodus*" *toomeyi* s.f., "*Microzarkodina*" *marathonensis*). Form taxa are designated by the suffix s.f. (*sensu formo*) (Barnes and Poplawski, 1973).

Element terminology generally follows that used in Löfgren (1978) and Ethington and Clark (1982). Most element types are named after the form genera or species they most resemble (e.g. drepanodontiform, concaviform). Some elements in some apparatuses do not closely resemble the form taxa they are named after, but these terms are still used for convenience (e.g. prioniodiniform elements of *Spinodus* sp. cf. *S. spinatus*). Elements are also named on the basis of their shape, symmetry or ornamentation (e.g. platform, coniform; symmetrical, asymmetrical; costate, acostate). Letter designations with descriptive terms are used as well (e.g. symmetrical A, B, etc.) The letter designations and terms proposed by Sweet and Schönlaub (1975), Barnes *et al.* (1979) and in Robison (1981) have not been used because of the incompleteness of many apparatuses, and the uncertainty about the homologies of elements in several taxa. However, reference is made to these schemes in some taxonomic descriptions.

All types, figured and unfigured, are deposited in the National Type Fossil Collection, Geological Survey of Canada (GSC), Ottawa.

7.2 Conodont taxonomy

7.2.1 Conodont taxa to be illustrated

The following taxa, because they are few or because nothing new can be stated about them taxonomically, are only illustrated.

Acodus deltatus Lindström Figures 15.2-15.4, 15.6-15.9.

A.? russoi Serpagli Figures 15.18, 15.22, 15.23, 15.27.

A.? sweeti (Serpagli) Figures 15.15, 15.19.

"*Acontiodus*" *staufferi* Furnish s.f. Figure 26.34.

Ansella jemtlandica (Löfgren) Figures 19.10-19.12, 19.17.

Coelocerodontus bicostatus van Wamel s.f. Figure 20.9.

C. latus van Wamel s.f. Figure 20.10.

"*Drepanodus*" *toomeyi* Ethington and Clark s.f. Figure 26.1.

"*D.*" n. sp. C Barnes and Poplawski s.f. Figures 25.28, 25.29.

Drepanoistodus basiovalis (Sergeeva) Figure 25.11.

D. tableheadensis Stouge Figures 25.7-25.9, 25.12, 25.13.

Ecplacognathus? sp. Figure 28.20.

Eucharodus parallelus (Branson and Mehl) Figures 26.2, 26.3.

Glyptoconus quadraplicatus (Branson and Mehl) Figures 26.4, 26.5.

Histiodella altifrons Harris Figure 29.2.

H. holodentata Ethington and Clark Figure 29.7.

H. serrata Harris s.f. Figure 29.6.

Juanognathus variabilis Serpagli Figure 27.6.

Jumudontus gananda Cooper Figure 18.22.

Oepikodus communis (Ethington and Clark) Figures 16.14-16.16.

O. evae (Lindström) Figures 16.24-16.26.

Oistodus n. sp. 1 Serpagli Figures 19.15, 19.20, 19.25, 19.29.

Oneotodus costatus Ethington and Brand Figure 29.10.

Parapanderodus arcuatus Stouge Figures 26.22-26.27.

Paroistodus proteus (Lindström) Figures 23.20, 23.21, 23.24, 23.25.

Periodon flabellum (Lindström) Figures 27.7-27.10; 27.14-27.16, 27.19.

Pteracontiodus cryptodens (Mound) Figures 21.12, 21.15, 21.16, 21.19-21.21.

Reutterodus andinus Serpagli Figures 27.4, 27.5.

Scandodus sinuosus (Mound) Figures 21.26-21.29.

"*Scolopodus*" *carlae* Repetski s.f. Figure 26.16.

"*S.*" *emarginatus* Barnes and Tuke s.f. Figure 26.35.

S. quadratus Pander Figures 26.6, 26.7.

"*S.*" *triangularis* Ethington and Clark s.f. Figure 26.12.

Semiacontiodus cornuformis (Sergeeva) Figures 26.17-26.19.

Stolodus sp. 1 Serpagli Figure 29.5.

Strachanognathus parvus Rhodes Figures 20.13, 20.14.

Tripodus laevis Bradshaw Figures 19.1-19.4, 19.7, 19.13, 19.14.

Ulrichodina sp. aff. *U. wisconsinensis* Furnish s.f. Figure 26.30.

U. cristata Harris and Harris s.f. Figures 26.31, 26.32.

U. n. sp. Barnes 1977 s.f. Figure 26.29.

U. sp. Stouge 1982 s.f. Figure 26.33.

Walliserodus ethingtoni Fåhraeus Figures 19.18, 19.19, 19.21-19.24.

7.2.2 Taxonomic descriptions

Genus ACODUS Pander, 1856

Type species.--Acodus erectus Pander, 1856

Remarks.--The apparatus of *Acodus* is considered here to comprise of acodontiform, oistodontiform, and a ramiform series of drepanodontiform, gothodontiform, trichonodelliform, and distacodontiform elements. This apparatus composition is in accord with recent reconstructions in the literature (e.g. Ethington and Clark, 1982; Dzik, 1983).

with the exception of Löfgren (1985) who recognized only three morphotypes of the ramiform series.

Acodus has an apparatus composition very similar to that of *Diaphorodus* Kennedy. However, the apparatus of *Acodus* includes a gothodontiform element (e.g. Ethington and Clark, 1982). *Diaphorodus* lacks this element (Kennedy, 1980; see also Remarks for *D. delicatus* Kennedy). In addition, acodontiform elements of *Acodus* have larger bases and deeper basal cavities than corresponding elements of *Diaphorodus* (Lindström, 1977). The angle between the oral margin and the posterior edge of the cusp is much more acute in oistodontiform elements of *Acodus*. Drepanodontiform and trichonodelliform elements in both genera are generally the same in overall morphology.

Both genera are represented in Cow Head strata by the occurrence of both *A. deltatus* Lindström and *D. delicatus* (Table 1, p. 225). These species also co-occur in the El Paso Group (Repetski, 1982). The distribution of *Diaphorodus* appears to be restricted to cratonal sequences (Kennedy, 1980; Ethington and Repetski, 1984), while *Acodus*' distribution appears to have been more widespread (e.g. Lindström, 1955; Viira, 1974; Ethington and Repetski, 1984). Some doubt exists as to whether adenticulate prioniodids described by McTavish (1973) from the Canning Basin should be assigned to *Acodus* or *Diaphorodus* (e.g. McTavish, 1973; Lindström, 1977; Kennedy, 1980; Ethington and Clark, 1982).

The taxonomic status of *Acodus* is presently disputed because the apparatus of the type species remains undescribed. Kennedy (1980) considers *Acodus* to be a *nomen dubium*. However, due to the scarcity of material, the writer chooses to retain the forms described herein and illustrated on Figure 15 (p. 169) in *Acodus*, following Stouge (1982, 1984) as no opportunity for revision of this genus is possible at this time.

Only *A. deltatus* Lindström and *A.* sp. aff. *A. deltatus* are definitely assigned to *Acodus*, as both have complete apparatuses. The other taxa are assigned tentatively to this genus. Most lack complete apparatuses (e.g. *A.? gladiatus*, *A.? robustus*, and *A.? sweeti*), making their relationship to *Acodus* uncertain.

The writer agrees with Cooper (1981) that *A.? russoi* Serpagli may belong to *Protoprioniodus* McTavish because of its similar colouration and surface ornamentation to species of this genus.

ACODUS? GLADIATUS Lindström s.f.

Figures 15.1, 15.5

Acodus gladiatus LINDSTRÖM, 1955, p. 544, 545, Pl. 3, figs. 10-12; SERPAGLI, 1974, p. 18-19, Pl. 7, figs. 5a-10c, Pl. 20, figs. 4, 5, Pl. 30, fig. 6, LANDING, 1976, p. 629, Pl. 1, fig. 7.

Remarks.--Only acodontiform elements occur in the writer's collection. No other elements like those described by Serpagli (1974) and by Löfgren (1978) were found in association with these elements. In general they show little variation, although in one sample (StPl 75b) some had short broad cusps and bases with a medially situated lateral carina.

Occurrence.--Bed 11 at St. Pauls Inlet and Martin Point.

Material.--48 specimens.

Types.--Hypotypes, GSC 82419, 82481.

ACODUS? ROBUSTUS (Serpagli)

Figures 15.10, 15.11-15.14.

"*Scandodus*" *robustus* SERPAGLI, 1974, p. 69, Pl. 18, figs. 3a-4d, Pl. 28, figs. 12, 13; ETHINGTON and CLARK, 1982, p. 94, Pl. 10, figs. 25-27.

Remarks.--Both morphotypes of *A.? robustus* described by Ethington and Clark (1982) are recognized in the Cow Head collections. Included with these elements are those with basal cavities asymmetrically flared to one side and lacking the "anticusp" of the other morphotypes. All these elements may comprise a symmetry transition series. This series is made up of acostate asymmetrical, unicostate and bicostate elements with an "anticusp". This series is partly analogous to the drepanodontiform-gothodontiform-prioniodontiform transition series of *Acodus*. It is for this reason that these elements are tentatively assigned to this genus.

Elements of the form species "*S.*" *flexuosus* in Cow Head collections should perhaps also be included in this apparatus. Their stratigraphic range and those discussed above are concurrent. They are similar in robustness and development of white matter. "*S.*" *flexousus* s.f. has previously been matched with "*S.*" *mysticus* s.f. in an apparatus (Löfgren, 1978). The latter species does not occur in the Cow Head collections. However, with relatively few numbers and slight morphological differences, "*S.*" *flexuosus* s.f. and *A.*? *robustus* are retained as separate taxa.

Occurrence.--Bed 13 at St. Pauls Inlet.

Material.--32 costate, 14 acostate asymmetrical elements.

Types.--Hypotypes, GSC 82420-82422.

ACODUS? sp.

Figures 15.16, 15.17, 15.20, 15.21

Description.--Elements in an incomplete transition series are assigned to *Acodus*? sp. Elongate elements with deep basal cavity and sharp lanceolate cusp. Base elongate with cavity extending to point of curvature between cusp and base. Apex situated near anterior margin. Cross section of base plano-convex to triangular in outline. Oral margin concave, sharply keeled, continues as smooth curve onto cusp. Aboral margin deeply concave (may be artifact of broken basal sheath). Anterior margin of base straight, undergoes abrupt change in curvature at junction of base and cusp. Cusp albid, proclined, and short relative to base. Anterior and posterior margins sharp, tapering rapidly to point distally; cross section lanceolate.

Acodontiform element characterized by strong costa or carina developed medially on outer side of basal cavity. Gothodontiform element has just strong carina. Drepanodontiform element laterally compressed, symmetrically biconvex. Trichonodelliform element triangular in cross section at base. Oral and antero-lateral margin may be keeled.

Remarks.--The elements described above, although rare, appear to follow the apparatus pattern of *Acodus* Pander. It is for this reason that they are tentatively assigned to this genus. No distacodontiform or oistodontiform elements were found.

Occurrence.--Bed 11 at St. Pauls Inlet.

Material.--1 drepanodontiform, 1 acodontiform, 3 gothodontiform, and 4 trichonodelliform elements.

Types.--Figured specimens, GSC 82427-82430.

ACODUS? sp. aff. A. SWEETI (Serpagli)

Figures 29.14, 29.15.

aff. "*Paltodus*?" *sweeti* SERPAGLI, 1974, p. 42, 43, Pl. 14, figs. 13a-14b, Pl. 24, figs. 8-10, text-fig. 12; STOUGE, 1982, Pl. 6, fig. 16; REPETSKI, 1982, p. 38, Pl. 15, fig. 8.

Remarks.--Cow Head specimens have antero-lateral processes that are weakly developed and are situated more anteriorly than the type specimen. No oistodontiform elements were found.

Occurrence.--Bed 10 at St. Pauls Inlet.

Material.--20 specimens.

Type.--Figured specimen, GSC 82440.

ACODUS sp. aff. A. DELTATUS Lindström

Figures 16.6-16.8; 16.10-16.13, 16.17, 16.21

aff. *Acodus deltatus* LINDSTRÖM, 1955, p. 544, Pl. 3, fig. 30; ETHINGTON and CLARK, 1982, p. 18, 19, Pl. 1, figs. 1-6, text-fig. 4; REPETSKI, 1982, p. 12, Pl. 2, figs. 1-6; LÖFGREN, 1985, p. 124, figs. 4Z, AA, AB.

Remarks.--The bases of acodontiform elements appear to be shallower than those of *A. deltatus*. The posterior process is longer than the anterior process in several specimens, and the latter process is often turned inward. Oistodontiform elements have longer, more arched posterior processes, and the antero-basal angle is sharper. A slight concavity is developed on the anterior margin of the base in some specimens.

The elements discussed above and others making up this apparatus were recovered from a limestone boulder in Bed 12 at St. Pauls Inlet. Collections of S. Pohler (pers. comm., 1985) may suggest that these forms are a new species of *Acodus*, with some distacodontiform elements developing incipient denticulation on the posterior process.

Occurrence.--Bed 12 at St. Pauls Inlet.

Material.--19 acodontiform, 9 drepanodontiform, 4 trichonodelliform, 8 distacodontiform, 4 gothodontiform and 9 oistodontiform elements.

Types.--Figured specimens, GSC 82431-82439.

Genus BALTONIODUS Lindström, 1971

Type species.--*Prioniodus navis* Lindström, 1971.

BALTONIODUS? sp.

Figure 17.12

?*Prioniodus* aff. *Dichognathus* sp. VIIRA, 1967, text-fig. 1:6.

Remarks.--Several prioniodontiform(?) elements with elongate posterior and lateral processes and a short posteriorly directed, denticulated anterior process are tentatively referred to this genus. They lack the flared basal cavity of *Baltoniodus* Lindström. The illustration of ?*P.* aff. *Dichognathus* sp. in Viira (1967) appears to lack the posteriorly directed denticulated process of the Cow Head material.

Occurrence.--Bed 13 at St. Pauls Inlet and Martin Point.

Material.--5 specimens.

Type.--Figured specimen, GSC 82448.

Genus BELODELLA Ethington, 1959

Type species.--*Belodus devonicus* Stauffer, 1935.

"BELODELLA" sp. B Serpagli

Figures 16.20, 16.23

"*Belodella*" sp. B SERPAGLI, 1974, p. 23, Pl. 7, figs. 1a-c, Pl. 20, fig. 11.

Description.--Laterally compressed, asymmetric simple cones with elongate bases and denticulated oral and anterior margins. Laterally directed keel runs entire length of element on anterior margin. Base elongate, laterally compressed. Oral margin keeled, with numerous small denticles that are confluent basally. Oral keel continuous with posterior keel of cusp. Aboral margin concave towards apex of basal cavity. Basal cavity elongate cone, with apex extending past point of curvature between base and cusp. Anterior margin of base keeled.

with denticles forming serrated edge. Apices of denticles anteriorly directed. Anterior keel inwardly directed and continuous with anterior keel of cusp. Both oral and anterior keels extend beyond aboral margin as short processes. Base subtriangular in cross section with outer side forming one non-keeled, undenticulated corner anteriorly. Inner side slightly to moderately convex. Sides of base thin, translucent.

Cusp albid, proclined to erect, with anterior and posterior keels. Outer side of cusp convex, with bulge more anteriorly directed. Inner side is flat. Anterior keel sharp, inwardly directed, continuous with oral keel. Cusp twisted inward with respect to base, so that anterior and posterior edges are oriented postero-laterally, and antero-laterally, respectively.

Remarks.--"*Belodella*" sp. B superficially resembles plano-convex elements of *Ansella* Fåhraeus and Hunter except that the oral and anterior margins of "*B.*" sp. B are both denticulated. This denticulation is not developed as extensively as that in *Ansella*. The cusp of "*B.*" sp. B is also less proclined and the base is narrower and more elongate than in elements of the latter genus. With these differences "*B.*" sp. B is probably not assignable to *Ansella*, unlike other Ordovician belodelliform elements (Fåhraeus and Hunter, 1985). However, because of scarcity of material, the present generic assignment will be retained.

The illustration of "*B.*" sp. B in Serpagli (1974) lacks denticles on the anterior margin of the base, but otherwise is similar to Cow Head material.

Occurrence.--Bed 11 at St. Pauls Inlet.

Material.--6 specimens.

Types.--Hypotypes, GSC 82449, 82450.

Genus BERGSTROEMOGNATHUS Serpagli 1974

Type species.--*Oistodus extensus* Graves & Ellison, 1941.

BERGSTROEMOGNATHUS sp. cf. B. EXTENSUS (Graves & Ellison)

Figures 18.10, 18.12, 18.15-18.17, 18.19

Oistodus extensus GRAVES & ELLISON, 1941, p. 13, Pl. 1, figs. 16, 28.

Berstroemognathus cf. *B. extensus* (Graves and Ellison) LANDING, 1976, p. 630, Pl. 1, figs. 1-6, 9, 10, (contains synononmy to 1976).

cf. *Bergstroemognathus extensus* (Graves and Ellison). COOPER, 1981, p. 161, Pl. 31, fig. 12, Pl. 32, figs. 7, 9-11.

cf. *Bergstroemognathus extensus* Serpagli. ETHINGTON, 1979, p. 5, Figs. 6E, F; STOUGE, 1982, Pl. 6, figs. 1-4; STOUGE and BOYCE, 1983, Pl. 4, figs. 15, 16.

Remarks.--Most trichonodelliform elements in Cow Head collections are highly symmetrical, with broad denticles on the lateral processes rising evenly towards the cusp. The posterior faces of these denticles are costate. The lateral process can be extremely long in relation to the cusp. These elements most closely resemble trichonodelliform elements of Landing (1976) which are less strongly arched, and do not show the same denticulation pattern as specimens illustrated by Serpagli (1974). Trichonodelliform and other elements of *B.* sp. cf. *B. extensus* occur in different facies from that of *B. extensus*. Those of Serpagli (1974) and Stouge (1982) occur in shelf carbonates whereas those of Landing's (1976) and the Cow Head specimens occur in lower slope-continental rise strata. These latter trichonodelliform elements may belong to a different species of *Bergstroemognathus*.

Three types of prioniodiniform elements are recognized. The first type is narrow in width and generally keeled (Figure 18.10). It occurs with *Prioniodus elegans* Pander in Bed 9 at St. Pauls Inlet as well as in a limestone boulder in Bed 14 at Martin Point. The second type is broadly arched with the cusp and denticles lacking keels (Figures 18.16, 18.17). This type occurs with *Oepikodus evae* in lower Bed 11 strata at St. Pauls Inlet. The third type has narrow denticles that are usually long and discrete basally. It was recovered from a limestone boulder in a conglomerate in the middle of Bed 11 at Martin Point. The first and second type may represent evolutionary change in this element, although keeled forms do occur with unkeeled forms in Bed 11 at St. Pauls Inlet. The third type may belong to another species of *Bergstroemognathus*. These observations and interpretations need confirmation through larger collections.

White matter appears to be developed more extensively in younger prioniodiniform elements of *B.* sp. cf. *B. extensus*. In older elements white matter is restricted to the growth axis while in younger elements it is spread throughout the cusp. This trend is also seen in falodontiform elements, but to a lesser degree.

Occurrence.--Beds 9, 10,and 11 at St. Pauls Inlet; Beds 10, 11, and 14 at Martin Point.

Material.--23 falodontiform, 10 trichonodelliform, and 33 prioniodiniform elements.

Types.--Figured specimens, GSC 82451-82455.

Genus COELOCERODONTUS Ethington, 1959

Type species.--*Coelocerodontus trigonius* Ethington, 1959.

COELOCERODONTUS sp.

Figures 20.11, 20.12, 20.16

Remarks.--Simple cone elements with triangular cross section and basal cavity extending to the tip are asigned to *Coelocerodontus*. Two types of elements occur: those with sharply keeled oral and antero-lateral margins and those with the oral margin sharply keeled and with rounded antero-lateral margins. Both have flattened or slightly concave lateral sides and rounded anterior faces. Several of both types of elements are twisted asymmetrically.

Occurrence.--Beds 9-11 and 13 at St. Pauls Inlet.

Material.--30 specimens.

Types.--Figured specimens, GSC 82458, 82459.

Genus CORDYLODUS Pander, 1856

Type species.--*Cordylodus angulatus* Pander, 1856.

CORDYLODUS sp. cf. C. HORRIDUS Barnes and Poplawski

Figure 20.15

cf. *Cordylodus horridus* BARNES and POPLAWSKI, 1973, p. 771, 772, Pl. 2, figs. 16-18; LANDING, 1976, p. 631, Pl. 1, fig. 11; BERGSTRÖM, 1979, p. 305, Fig. 4J.

cf. *Cordylodus*? *horridus* Barnes and Poplawski, STOUGE, 1984, p. 45, 46, Pl. 1, figs. 1-11.

Remarks.--Specimens of *C.* sp. cf. *C. horridus* differ from *C. horridus* in the following ways: there appears to be less than four denticles developed on the posterior process; there is no enlarged third or fourth denticle; the basal cavity is largely restricted to below the first denticle and the posterior process is shorter.

Occurrence.--Bed 11 at St. Pauls Inlet and Martin Point.

Material.--18 specimens.

Types.--Figured specimen, GSC 82460.

Genus CORNUODUS Fåhraeus, 1966

Type species.--*Cornuodus erectus* Fåhraeus, 1966.

CORNUODUS LONGIBASIS (Lindström)

Figures 21.3, 21.4, 21.8, 21.9

Drepanodus longibasis LINDSTRÖM, 1955, p. 564, Pl. 3, fig. 31.

Cornuodus bergstroemi Serpagli, LOFGREN, 1978, p. 51, Pl. 4, fig. 37, text-fig. 25D.

Cornuodus longibasis (Lindström) LÖFGREN, 1978, p. 49-51, Pl. 4, figs. 36, 38-42, text-figs. 25A-C (contains synonymy to 1978); BEDNARCZYK, 1979, p. 423-424, Pl. 6, fig. 2; AN, 1981, Pl. 2, figs. 24, 25; COOPER, 1981, p. 161, 162, Pl. 26, figs. 10, 11; LANDING and BARNES, 1981, p. 1614, Pl. 2, fig. 6; LANDING and LUDVIGSEN, 1984, p. 1484, Pl. 1, fig. 4; STOUGE, 1984, p. 62, Pl. 8, figs. 1-8.

Protopanderodus longibasis (Lindström), REPETSKI, 1982, p. 40, Pl. 17, figs. 11, 12.

Description.--Elements occur which resemble the illustrations of *C. bergstroemi* of Löfgren (1978), which are hereafter referred to as bergstroemiforn elements: Albid, laterally compressed elements with hyaline basal cavity flaring abruptly posteriorly, and with costae of different heights running entire length of cusp. Base short, laterally compressed, with aboral portion flared widely posteriorly. Oral margin keeled with curved posterior portion meeting rest of margin at high angle. Basal cavity hyaline, with anterior margins of cavity concave posteriorly; intersects anterior and oral margins of base so that cavity forms posterior part of base. Apex of cavity sharply pointed, situated anteriorly in base and cusp. Aboral margin highly convex. Antero-basal angle of basal cavity acute, with anterior margin of basal cavity meeting same margin of base at aproximately 120 degrees. Anterior margin of base and cusp form continuous curve. Basal outline elongate oval; lateral sides of basal cavity may be slightly concave.

Cusp albid, proclined to semi-erect, triangular proximally in cross section and lanceolate distally. Medial keel developed on posterior margin, flanked by pair of costae that are of different heights with respect to each other. Anterior margin of cusp sharp, almost keel-like. Cusp and base are in same plane.

Remarks.--The same symmetry transition series in *C. longibasis* as Löfgren's (1978) was recognized in the Cow Head collections. However, some major morphological differences were observed on the elements comprising this series. Elements comparable to Löfgren's (1978) symmetrical element A were noted to have slight keels developed on the oral margin on older horizons. Specimens comparable to symmetrical element B have one side that is flattened and the anterior keel is directed laterally on that side. This configuration of the anterior keel makes these elements slightly asymmetrical. In a younger sample (StPI 92), one such element was observed to be almost asymmetrical. Stouge (1984) reported elements of *C. longibasis* intermediate in morphology between symmetrical A and B elements from the Table Head Group.

The symmetrical element B occurs throughout the stratigraphic range of *C. longibasis*, unlike in Löfgren's Swedish material (1978, p. 50). Asymmetrical elements fit Löfgren's (1978) description, except that there is an oral keel in older specimens.

Bergstroemiform elements described under the previous heading occur with the elements discussed above in larger samples from the writer's collections. Their concordant range with the symmetrical and asymmetrical forms may suggest that they may belong in the apparatus of *C. longibasis*. This was also suggested by Stouge (1984). The apparent absence of bergstroemiform elements in younger Cow Head samples might be explained by their relatively few numbers with respect to the other elements.

Occurrence.--Beds 9-11, 13 at St. Pauls Inlet; Beds 9, 11, and 13 and limestone clast in Lower Head Formation at Martin Point.

Material.--68 symmetrical A, 34 symmetrical B, 15 asymmetrical and 15 bergstroemiform elements.

Types.--Hypotypes, GSC 82461-82464.

Genus DIAPHORODUS Kennedy, 1980

Type species.--*Acodus delicatus* Branson and Mehl, 1933.

DIAPHORODUS DELICATUS (Branson and Mehl)

Figure 16.1-16.5, 16.9

Acodus delicatus BRANSON and MEHL, 1933, p. 56, Pl. 4, fig. 10; REPETSKI, 1982, p. 12, Pl. 2, figs. 1-6.

Acodus? sp. cf. *A. delicatus* Branson and Mehl, STOUGE, 1982, p. 33, Pl. 4, figs. 1, 2, 5.

Diaphorodus delicatus (Branson and Mehl), KENNEDY, 1980, p. 52-54, Pl. 1, figs. 3-25 (contains symonymy to 1980).

Remarks.--The lack of gothodontiform elements, the pronounced asymmetrical twisting of the distacodontiform elements, and the small base in acodontiform elements were the reasons for assigning these elements to this species. Several elements near the base of Bed 13 at St. Pauls Inlet are assigned tentatively to *D. delicatus*. Acodontiform elements at this level have nearly hyaline bases, with a wide, flange-like costa developed laterally on one side. The cusps of stratigraphically older oistodontiform elements of *D. delicatus* are inclined more strongly than those in younger samples. These oistodontiform elements are like those belonging to *D. delicatus vulgaris*, a subspecies of *D. delicatus* (Kennedy, 1980). Kennedy reports that mainly oistodontiform elements of the subspecies *D. delicatus delicatus* were recovered from the Jefferson City Formation.

Occurrence.--Beds 9-11, 13, 14 at St. Pauls Inlet; Bed 11 and 13 at Martin Point.

Material.--96 acodontiform, 82 drepanodontiform, 47 trichonodelliform, 46 distacodontiform and 80 oistodontiform elements.

Types.--Hypotypes, GSC 82465-82469.

Genus DISCHIDOGNATHUS Ethington and Clark, 1982

Type species.--*Dischidognathus primus* Ethington and Clark, 1982.

DISCHIDOGNATHUS sp.

Figures 21.5, 21.16

Description.--Palmate, bilaterally symmetrical element with medial cusp and short lateral denticles. Base is small, with basal opening directed posteriorly. Oral margin short and nearly straight in lateral view. Oral and aboral margins meet at near right angle. Aboral margin straight, with opening to basal cavity quadrate to oval in posterior view. A notch extends anteriorly from the edge of the aboral margin orally. Antero-basal margin nearly perpendicular; anterior margin short, meets anterior edge of central cusp at aproximately 120 degrees. Base and proximal parts of cusp and denticles hyaline.

Central cusp albid, nearly triangular in cross section, with broad V-shaped groove extending from tip to proximal end. Thin posterior slit situated in middle of groove, extends to proximal end of cusp. Lateral edges sharp, and directed posteriorly. Anterior margin sharp, almost keel-like. Lateral denticles symmetrically disposed about central cusp, making an angle of aproximately 30 degrees with it. Denticles triangular in cross section, with posterior groove and slit like central cusp, and almost keel-like anterior margin. Inner edges are fused with central cusp, outer edges extend nearly to aboral margin, becoming more medially directed. Tips and inner sides of denticles are albid.

Remarks.--This species lacks the posterior recess and groove which runs the entire length of the posterior side of *D. primus*. *Dischidognathus* sp. differs from elements described by Nowlan (1976) by having a posteriorly directed base, with a symmetrical basal cavity.

Occurrence.--Bed 13 at St. Pauls Inlet.

Material.--7 specimens.

Types.--Figured specimens, GSC 82470, 82471.

Genus DREPANODUS Pander, 1856

Type species.--*Drepanodus arcuatus* Pander, 1856.

DREPANODUS ARCUATUS Pander

Figures 24.1-24.9, 24.12, 24.13

Drepanodus arcuatus PANDER, 1856, p. 20, Pl. 1, figs. 2, 4, 17, *non* figs. 30, 31; LÖFGREN, 1978, p. 51-53, Pl. 2, figs. 1-8 (contains synonymy to 1978); FÅHRAEUS and NOWLAN, 1978, p. 458, Pl. 2, figs. 1, 2, 8; TIPNIS, CHATTERTON and

LUDVIGSEN, 1978, Pl. 2, figs. 1-3; ETHINGTON, 1979, text-fig. 3B; AN, 1981, Pl. 3, fig. 22; ETHINGTON and CLARK, 1982, p. 36, 37, Pl. 3, figs. 4-6, 12; REPETSKI, 1982, p. 19, Pl. 6, fig. 1; STÓUGE, 1982, Pl. 5, figs. 18, 19; DZIK, 1983, p. 336, 337, Pl. 3, figs. 5-7, text-fig. 3; LANDING and LUDVIGSEN, 1984, p. 1484, Pl. 1, figs. 2, 3, 5, 6, 10, 11, table 1.

Drepanodus sculponea Lindström s.f., REPETSKI, 1982, p. 22, Pl. 7, fig. 9.

Scandodus cf. *S. pipa* Lindström s.f., REPETSKI, 1982, p. 44, Pl. 20, fig. 5.

Remarks.--The occurrence of costate and acostate versions of elements of *D. arcuatus* suggests that two species of *Drepanodus* may be present (Fåhraeus and Nowlan, 1978). Costate drepanodontiform (=acontiodontiform) and pipaform elements occur in approximately even proportion to their acostate counterparts. Costate sculponeaform elements out-number their acostate counterparts by a ratio of about 4:1. The small number of acostate sculponeaform elements, plus the inability to distinguish between these and their costate counterparts in some samples, causes both acostate and costate elements to be included in *D. arcuatus*.

Costate drepanodontiform elements of *D. arcuatus* are distinguished from symmetrical acontiodontiform elements of *Protopanderodus* Lindström by having bases with a constricted antero-basal margin that almost forms a keel. The base near the oral margin is usually flared laterally. Symmetrical acontiodontiform elements of *Protopanderodus* have aboral margins which are open up to and including the antero-basal margin, which usually forms a characteristic "notch" (e.g. Löfgren, 1978). Elements resembling *Acontiodus robustus* (Hadding) s.f. have usually been assigned to *Protopanderodus* (e.g. Löfgren, 1978; Stouge, 1984). They are assigned to *Drepanodus* here (see Remarks for *P. cooperi*).

In addition to the elements discussed above, drepanodontiform elements with a proclined cusp with sharp anterior and posterior keels and carinate sides (Figure 24.3) are included in this species.

Occurrence.--Beds 9-11, 13 and 14 at St. Pauls Inlet; Beds 8-11, 13 and 14 and limestone clast in Lower Head Formation at Martin Point.

Material.--217 drepanodontiform, 187 acontiodontiform, 134 costate, 47 acostate sculponeaform, and 163 costate, 122 acostate pipaform elements.

Types.--Hypotypes, GSC 82472-82480, 82482.

Genus DREPANOISTODUS Lindström, 1971

Type species.--*Oistodus forceps* Lindström, 1955.

Remarks.--*D.*? *concavus* (Branson and Mehl) and *D.*? sp. cf. *D.? venustus* (Stauffer) are both tentatively assigned to *Drepanoistodus*, although both species probably belong in other genera. Early forms of the former species are predominantly hyaline, whereas later forms are mostly albid (see Remarks for *D.*? *concavus*). Elements of the latter species are costate. *D.*? sp. A has the same apparatus plan as other species of *Drepanoistodus*, but its oistodontiform element is different from typical oistodontiform elements of this genus. This species should perhaps be assigned to a separate genus, but it will be retained in *Drepanoistodus* because of limited material.

DREPANOISTODUS? CONCAVUS (Branson and Mehl)

Figures 25.14, 25.17, 25.20, 25.21

Oistodus concavus BRANSON and MEHL, 1933, p. 59, Pl. 4, fig. 6.

Drepanodus concavus (Branson and Mehl), KENNEDY, 1980, p. 55-57, Pl. 1, figs. 26-34 (contains synonymy to 1980); REPETSKI, 1982, p. 20, Pl. 6, fig. 11.

Drepanodus? *gracilis* (Branson and Mehl) s.f., REPETSKI, 1982, p. 34, Pl. 3, figs. 2, 3.

Drepanodus pandus (Branson and Mehl) s.f., REPETSKI, 1982, p. 20, Pl. 6, fig. 7.

Oistodus gracilis Branson and Mehl s.f., REPETSKI, 1982, p. 32, Pl. 9, fig. 10.

Remarks.--Nowlan (1976) included suberectiform elements in this species, thereby assigning it to *Drepanoistodus*. Suberectiform elements exhibiting the same general robustness and coloration as elements assigned to *D.*? *concavus* in the Cow Head Group are also assigned to this species. The assignment of this species to *Drepanoistodus* is tentative because older representives of this species are hyaline.

The cusps of elements of *D. concavus* become albid in younger strata. Elements of this species in older strata show varying amounts of white matter. The occurrence of white matter in the cusps of *D. concavus* was noted by Stouge (1982) in specimens recovered from the St. George Group.

Occurrence.--Beds 9-11 and 13 at St. Pauls Inlet; Beds 8-11, 13 and limestone clast in Lower Head Formation at Martin Point.

Material.--149 homocurvatiform, 9 suberectiform, and 28 oistodontiform elements.

Types.--Hypotypes, GSC 82489-82492.

DREPANOISTODUS sp.

Figures 25.15, 25.16

Remarks.--Oistodontiform elements of *Drepanoistodus* do not occur with drepanodontiform elements of this genus in lower and middle Arenig strata in both sections. The former elements characterize species of this genus. With the absence of these elements drepanodontiform elements in this interval are assigned to *Drepanoistodus*.

Occurrence.--Beds 9-12 at St. Pauls Inlet; Beds 8, 11, 13 and limestone clast in Lower Head Formation at Martin Point.

Material.--194 homocurvatiform and 17 suberectiform elements.

Types.--Figured specimens, GSC 82497, 82498.

DREPANOISTODUS? sp. A

Figures 25.18, 25.19, 25.22, 25.23, 25.26, 25.27

Drepanoistodus forceps (Lindström), SERPAGLI, 1974, p. 30, Pl. 10, figs. 9a-12c, *non* figs. 8a-c, Pl. 21, figs. 9-11, 13, 14; *non* fig. 12.

"*Oistodus*" *inequalis* Pander s.f., ETHINGTON and CLARK, 1982, p. 67, 68, Pl. 7, fig. 7, text-fig. 15 (contains synonymy to 1981).

Remarks.--Oistodontiform elements with a prominent carina and basal swelling on the inside and sharp anterior and posterior keels occur in association with robust homocurvatiform elements with a thickened rim around the basal cavity. Also included are homocurvatiform elements with sharp anterior and posterior keels and suberect cusps. The oistodontiform elements become less angular in younger strata. Only one suberectiform element which might be associated with the other elements discussed above was found.

Occurrence.--Beds 9-13 at St. Pauls Inlet; Beds 10, 11, 14, and limestone clast in Lower Head Formation at Martin Point.

Material.--73 homocurvatiform, 1 suberectiform, and 28 oistodontiform elements.

Types.--Figured specimens, GSC 82499-82502.

DREPANOISTODUS? sp. cf. D. VENUSTUS (Stauffer)

Figures 25.1-25.6, 25.10

cf. *Oistodus venustus* STAUFFER, 1935, p. 146, 159, Pl. 12, fig. 12.

Drepanoistodus? cf. *venustus* (Stauffer), STOUGE, 1984, p. 55, Pl. 4, figs. 18-25 (contains synonymy to 1984).

Description.--Apparatus consisting of homocurvatiform, concaviform, and oistodontiform elements. The homocurvatiform element has asymmetrically arranged costae and torsion of cusp. The concaviform element (named so because of its resemblance to *Drepanodus concavus* s.f.) has a rounded, posteriorly flared base and suberect albid cusp. The oistodontiform element was described by Stauffer (1935), and recently by Löfgren (1978) and Stouge (1984).

Base of homocurvatiform element roughly triangular in outline, with keeled convex oral margin continuing as smooth curve onto posterior margin of cusp. Aboral margin semicircular in outline. Basal cavity shallow, with apex situated medially and pointed anteriorly. Anterior region of base flange-like, with antero-basal angle acute. Base hyaline; anterior margin of base forms smooth curve with anterior margin of recurved albid cusp. Outer side of elements convex, inner side concave. Costae variable in number and arrangement, begining on base and continuing onto cusp. Concave side may have single medially placed simple or double costa with opposite side acostate or with postero-lateral costa. In other elements costae on concave and convex sides are placed postero-laterally and directed posteriorly. Highly asymmetrical elements have anterior margins keeled and directed laterally, with cusp twisted. Inner costa laterally directed; outer costa directed posteriorly.

Base of concaviform element triangular with keeled oral margin. Aboral margin straight; basal cavity shallow, rounded in outline, flared laterally, and restricted to posterior portion of base. Anterior margin of base has small triangular flange. Outer side of element convex, inner side concave. Cusp albid, slightly proclined to suberect. Costa developed on inner and outer surface of cusp, antero-lateral in position. Faint costa may be developed between outer postero-lateral costa and posterior margin near base.

Remarks.--Drepanodontiform elements were desribed only briefly by Stouge (1984). Above is a more complete description. The concaviform element was not reported previously. The inner costa on the cusp of the oistodontiform element is weakly developed in specimens from Bed 14. A carina may also occur in place of this costa. No costate suberectiform elements of *D.* sp. cf. *D. venustus* occur in Cow Head strata.

Occurrence.--Bed 14 at Martin Point and St. Pauls Inlet; limestone clast in Lower Head Formation at Martin Point.

Material.--23 drepanodontiform and 21 oistodontiform elements.

Types.--Figured specimens, GSC 82503-82508.

Genus ERRATICODON Dzik, 1978

Type species.--*Erraticodon balticus* Dzik, 1978.

ERRATICODON sp. cf. E. BALTICUS Dzik

Figures 18.18, 18.20, 18.23, 18.24, 18.29

cf. *Erraticodon balticus* DZIK, 1978, p. 66, Pl. 15, figs. 1-3, 5, 6, text-fig. 6a-e.

Erraticodon aff. *E. balticus* Dzik, ETHINGTON and CLARK, 1982, p. 45, Pl. 45, figs. 15, 17, 23, 24.

Erraticodon sp. HARRIS, BERGSTRÖM, ETHINGTON, and ROSS, 1979, Pl. 3, figs. 1-5.

"Fibrous" conodont-elements, SWEET and BERGSTRÖM, 1962, p. 1249, 1250, Pl. 169, figs. 5, ?13, 15, 16, *non* figs. 1, 2, 10.

Remarks.--Ligonodiniform, cyrtoniodontiform, and plectospathodontiform elements agree with the descriptions of these elements in Dzik (1978). Prioniodiniform and trichonodelliform elements lack the "big denticle" on the posterior process. White matter occurs in the growth axes of the cusps of most elements in small amounts.

Occurrence.--Limestone clast in Lower Head Formation at Martin Point.

Material.--25 cyrtoniodontiform, 5 prioniodiniform, 5 plectospathodontiform, 3 trichonodelliform, and 7 ligonodiniform elements.

Types.--Figured specimens, GSC 82510-82514.

Genus FRYXELLODONTUS Miller, 1969

Type species.--*Fryxellodontus inornatus* Miller, 1969.

Remarks.--The presence of albid nodes in *F.*? sp. cf. *F.*? *reudemanni* suggests that this species, and perhaps *F.*? sp. aff. *F.*? *corbatoi*, are euconodonts and hence do not belong in *Fryxellodontus*. This genus has usually little white matter developed (Miller, 1981).

FRYXELLODONTUS? sp. aff. F.? CORBATOI Serpagli

Figures 28.17, 28.18, 28.21

aff. *Fryxellodontus*? *corbatoi* SERPAGLI, 1974, p. 31, 32, Pl. 10, figs. 1a-6c, Pl. 22, figs. 1-5.

Description.--Elements trangular in lateral view, with a lateral costa to one side or situated medially. Edges are sharp, serrated, with sides of element biconvex in cross section. Lateral costa also sharp and serrate; directed outward and to one side. Surface of element undulating, with series of transverse ridges and grooves developed on each lateral face. Aboral margins broadly concave, with costate side convex underneath costa, then again concave. Costae may be situated more to one side than the other.

Remarks.--This rare element has a few features in common with *F.*? *corbatoi*. These are the transverse ridges connecting the edges of the elements and the (?)posteriorly situated costa. *F.*? sp. aff. *F.*? *corbatoi* lacks the strong nodes developed along the lateral and posterior edges of *F.*? *corbatoi* and there is little variance in the angles between the lateral edges, as there is in the latter species.

Occurrence.--Beds 9 and 13 at St. Pauls Inlet; Bed 8 at Martin Point.

Material.--7 specimens.

Types.--Figured specimens, GSC 82517, 82518.

FRYXELLODONTUS? sp. cf. F.? REUDEMANNI Landing

Figure 28.8

cf. *Fryxellodontus*? *reudemanni* LANDING, 1976, p. 632, 633, Pl. 2, figs. 1-10.

Remarks.--Serratus elements of *F*.? sp. cf. *F*.? *reudemanni* generally agree with the descriptions given in Landing (1976), although some may be transitional between the serratus and symmetricus elements. Intermedius elements of this taxon differ from those of *F*.? *reudemanni* by having only two carinae which are both nodose. A single antero-posteriorly flattened element with antero-lateral and posterior nodose carinae will be assigned to this species, although it could belong to *F*.? *corbatoi* Serpagli.

Occurrence.--Beds 9-11 at St. Pauls Inlet.

Material.--12 specimens

Types.--Figured specimens, GSC 82519.

Genus JUANOGNATHUS Serpagli, 1974

Type species.--*Juanognathus variabilis* Serpagli, 1974.

JUANOGNATHUS JAANUSSONI Serpagli

Figure 27.11

Juanognathus jaanussoni SERPAGLI, 1974, p. 34, Pl. 11, figs. 8a-12c, Pl. 23, figs. 1a-5b, text-fig. 9; ETHINGTON and CLARK, 1982, p. 50, Pl. 5, figs. 12, 13 (contains synonymy to 1982); REPETSKI, 1982, p. 26, Pl. 8, fig. 8.

Remarks.--Repetski (1982) reported the co-occurrence of *J. variabilis* and *J. jaanussoni* in the El Paso Group. Serpagli (1974) suggested that these species might comprise a lineage, with *J. variabilis* being ancestral to *J. jaanussoni*. He also noted that many specimens of *J. variabilis* approach *J. jaanussoni* in appearance. The two species have concordant stratigraphic ranges in the Cow Head Group. These data may suggest that these two taxa may possibly belong to the same species. They are retained as separate taxa because they are rare.

Occurrence.--Beds 11 and 13 at St. Pauls Inlet; limestone clast in Lower Head Formation at Martin Point.

Material.--22 specimens.

Type.--Hypotype, GSC 82525.

Genus JUMUDONTUS Cooper, 1981

Type species.--*Jumudontus gananda* Cooper, 1981.

JUMUDONTUS sp. aff. J. GANANDA Cooper

Figures 18.21, 18.25-18.28

aff. *Jumudontus gananda* COOPER, 1981, p. 170, 172, Pl. 31, fig. 13; ETHINGTON and CLARK, 1982, p. 51, 52, Pl. 2, figs. 9, 10 (contains synonymy to 1981).

Description.--High, laterally compressed blade element with broad, triangular posterior albid cusp and erect anterior denticles. Aboral part of element twisted inward posteriorly; hyaline base flared to outside beneath cusp. Base hyaline, extending entire length of element becoming twisted inward posteriorly. Base broadens rapidly on outer side to maximum width beneath main posterior cusp, then narrows rapidly posteriorly. Shallow groove or sulcus developed above aboral margin with slight ridge or shoulder developed just below denticle row and cusp. Basal cavity shallow, with deepest part beneath cusp. Basal filling present in several specimens. Posterior cusp albid, broad, lanceolate in cross section and triangular in lateral view. Anterior margin of cusp vertical with respect to aboral margin and posterior margin slopes posteriorly reaching its widest extent above base. Basal portion of cusp twisted inwardly along with base. Anterior denticles erect, laterally compressed and discrete distally. Denticles albid distally, hyaline basally. Number of anterior denticles variable. Indistinct accessory denticles may be developed on the posterior margin of the cusp.

Remarks.--Elements assigned to this taxon are more laterally compressed, and have a broader cusp than *J. gananda*. The basally twisted posterior process bearing denticles is not evident in most specimens (Figures 18.21, 18.25). These taxonomic features warrant assigning elements of this type to a separate species, unnamed because of limited material.

Short, sharply carinate coniform elements with sharp anterior and posterior edges and convex outer and concave inner sides are included with the blade elements (Figures 18.27, 18.28). These elements exhibit the same colouration pattern as the blades, suggesting that both elements may belong together in an apparatus.

Occurrence.--Bed 13 at St. Pauls Inlet; Bed 11 at Martin Point.

Material.--20 blade and 13 coniform elements.

Types.--Figured specimens, GSC 82527-82530.

Genus LENODUS Sergeeva, 1963

Type species.--*Lenodus clarus* Sergeeva, 1963.

Emended diagnosis.--Multielement apparatus consisting of mostly hyaline prioniodiniform, falodontiform, cordylodontiform, trichonodelliform, and tetraprioniodontiform elements. Prioniodiniform elements have broad, laterally expanded triangular bases and serrated anterior and oral margins. Multiramiform elements have serrate processes continuous with sharp costae. Falodontiform elements have short bases with flat, blade-like cusp, and serrate anterior processes.

Remarks.--This genus was previously defined on the basis of the prioniodiniform element of *L. falodiformis* (emended herein) and *L. clarus* s.f.. *Lenodus* is considered a junior synonym of *Amorphognathus* Branson and Mehl by Lindström (1977). It is shown here to have a prioniodid-like apparatus similar to *Acodus* Pander and *Prioniodus* Pander. No specimens of *L. clarus* occur in Cow Head material, so that the apparatus of this species remains unknown.

Lenodus has a similar apparatus to that of *Prioniodus* Pander, except that the former genus lacks a costate belodontiform (Sb) element. Basal cavities of elements of *Lenodus* are more excavated than corresponding elements of *Prioniodus*, with the exception of tetraprioniodontiform elements of both genera. Denticulation on processes is less well developed in *Lenodus*. P elements in *Lenodus* are prioniodiniform; corresponding elements of *Prioniodus* are prioniodontiform. Falodontiform (M) elements of *Lenodus* have short anterior and posterior processes, with the latter process lacking denticles. Ramiform elements of *Lenodus* are broadly similar to those of *Prioniodus* except that trichonodelliform (Sa) elements are wider in anterior view, and tetraprioniodontiform (Sd) elements have asymmetrically disposed processes.

Lenodus is also close to *Hamarodus* Viira in elemental morphology and apparatus composition. These two genera share prioniodiniform (P), cordylodontiform (Sc), and trichonodelliform (Sa) elements in common. As noted above, *Lenodus* lacks a costate belodontiform (Sb) element. *Hamarodus* retains this element in its apparatus (Orchard, 1980). No tetraprioniodontiform (Sd) element has been associated with the apparatus of *Hamarodus*. The M element in *Lenodus* is falodontiform; the corresponding element in *Hamarodus* is oistodontiform. Elements of the latter genus appear to have more open basal cavities, while those in *Lenodus* are more enclosed. Denticulation on ramiform elements of *Hamarodus* appears more pronounced (e.g. Dzik, 1976, figs. 36a-g) than on corresponding elements of *Lenodus*.

LENODUS FALODIFORMIS Sergeeva

Figure 8A-L, 17.16-17.31

Lenodus falodiformis SERGEEVA, 1963b, p. 140, Fig. 1:A-D.

Amorphognathus falodiformis (Sergeeva), LINDSTRÖM, 1977, p. 29, 30, Pl. 1, figs. 4, 5.

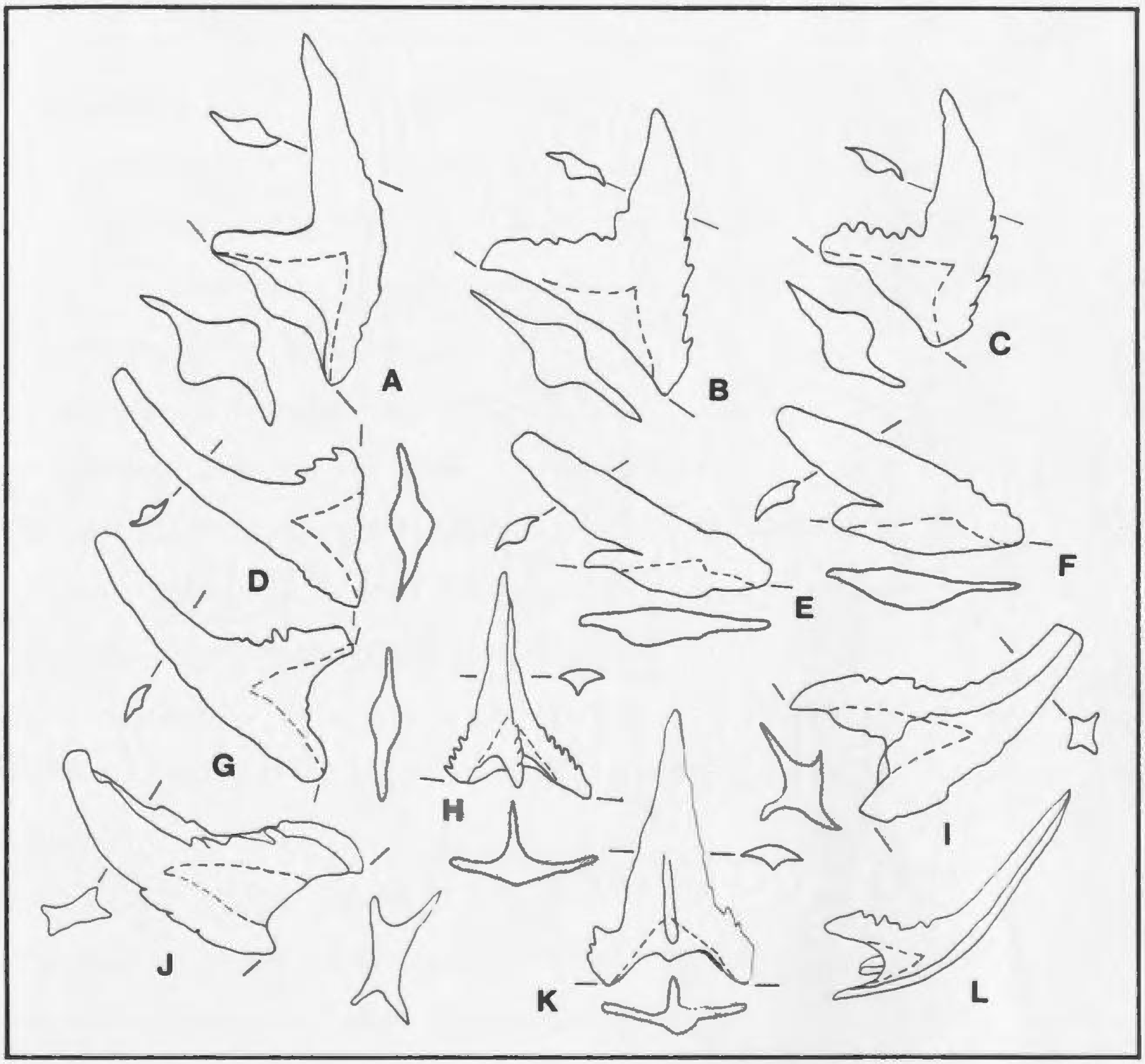
?*Reutterodus borealis* REPETSKI, 1982, p. 41, 42, Pl. 19, fig. 4, *non* figs. 5-7.

?*Reutterodus* sp. ETHINGTON and CLARK, 1982, p. 91, 92, Pl. 10, figs. 14, 15, 19, *non* fig. 16.

Diagnosis.--As for genus.

Description.--Multielement apparatus consisting of mainly hyaline prioniodiniform, falodontiform, and multiramiform elements. Processes and oral margins denticulate, with small, albid, sharp denticles commonly fused together to form serrate edges. Processes continuous with sharp costae or edges on cusp. Base and basal cavity triangular in prioniodiniform and cordylodontiform elements. Apex of basal cavity anteriorly pointed, with growth axis orginating at apex and extending to tip through middle of cusp. Cusp in prioniodiniform, cordylodontiform and falodontioform elements laterally compressed, with slightly convex outer side and medially situated carina on inner side. Some white material may be present in body of elements in addition to white matter in denticles.

FIGURE 8--Apparatus of *Lenodus falodiformis* Sergeeva showing outline of basal cavity and cross-section of cusp of each element; A-C, lateral views, prioniodiniform elements, GSC 82538, GSC 82542, GSC 82539, X 83, X 95, and X 71; D, G, lateral views, cordylodontiform elements, GSC 82531, GSC 82537, X 83 and X 98; E, F, lateral views, oistodontiform elements, GSC 82536, GSC 82535, X 95 and X 83; H, L, posterior and lateral views, trichonodelliform element, GSC 82533, X 65 and X 117; I, lateral view, tetraprioniodontiform element, GSC 82541, X 95; J, lateral view, tetraprioniodontiform element, GSC 82540, X 103; K, anterior view, trichonodelliform element, GSC 82532, X 83.


A
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Prioniodiniform elements roughly triangular in lateral view, with outer side convex and inner side concave. Base flared outwards anteriorly and inwards posteriorly. Carina usually developed on inner side of base. Anterior and posterior ends of basal cavity connected by broad sheath. Antero-basal process turned inwards and pointed aborally. Oral margin straight, forming about 30 degree angle with aboral margin. Aboral margin sinuous, with most convex portion at point of maximum flexure on both sides. Cusp reclined to slightly proclined. Anterior margin of base and cusp denticulated nearly to tip.

Cordylodontiform elements have laterally compressed base and slightly arched oral margin and aborally directed anterior process. Aboral margin concave; base restricted to medial portion of element, with slight flare to outside. Element may be concavo-convex or straight. Cusp proclined, elongate and slender.

Trichonodelliform element triangular in antero-posterior profile with tetrahedral base. Lateral processes extend posteriorly and laterally, meeting aboral margin at angle of 120 degrees. Medially situated posterior costa continuous with straight posterior process. Processes connected by basal sheath; anterior sheath has medial carina. Cusp proclined, convex anteriorly and concave posteriorly, with sharp tip.

Tetraprioniodontiform element quadriramate, with posteriorly expanded base and pyramidal basal cavity extending into processes with apex of cavity nearly touching anterior margin. Oral process highly arched, and extends the farthest posteriorly of the processes beyond the aboral margin. Oral-lateral and antero-lateral processes extend the next farthest. Oral-lateral process runs parallel to oral process and is continuous with oral-lateral costa merging with posterior costa on proclined cusp. Antero-lateral costa forms outer edge of antero-lateral plate on cusp with anterior costa forming other edge. Anterior process extends just beyond aboral margin, with several anteriorly directed denticles on cusp. Areas between processes and costae concave.

Falodontiform element has short, laterally compressed, rectangular base with proximally straight oral keel becoming curved posteriorly. Aboral margin convex anteriorly for three quarters of its length, the other quarter is straight. Basal cavity extends for entire length of base, flared slightly at midlength. Apex of cavity situated beneath median carina, usually just behind posterior-most denticle on anterior process.

Remarks.--Cow Head prioniodiniform elements of *L. falodiformis* have bases strongly flared outwards unlike similar elements described by Sergeeva (1963b) with straight sides. The anterior margin of the cusp meets with the anterior margin of the base at about 30 degrees in large specimens of this element. In small elements the anterior margins of the base and cusp are in line with each other. Those elements identified in the synonymy as belonging to *Reutterodus borealis* (Repetski, 1982) and ?*Reutterodus* sp. (Ethington and Clark, 1982) are similar to *L. falodiformis* in morphology, but are probably not conspecific with the latter species. These forms also occur in much older strata.

Occurrence.--Bed 13 at St. Pauls Inlet; limestone clast in Lower Head Formation at Martin Point.

Material.--39 prioniodiniform, 14 falodontiform, 7 cordylodontiform, 12 trichonodelliform, and 4 tetraprioniodontiform elements.

Types.--Hypotypes, GSC 82531-82533, 82535-82542.

Genus MICROZARKODINA Lindström, 1971

Type species.--*Prioniodina flabellum* Lindström, 1955.

Remarks.--Both "*M.*" *marathonensis* (Bradshaw) and "*M.*" sp. aff. "*M.*" *adentata* McTavish should be assigned to a different genus. As pointed out by Ethington and Clark (1982, p. 56), species of *Microzarkodina* described by Lindström (1971) and more recently by Löfgren (1978) lack the ledges occurring on both "*M.*" *marathonensis* and "*M.*" sp. aff. "*M.*" *adentata*. They also point out that these species, although denticulated, may be more closely related to *Protoprioniodus* McTavish. *Microzarkodina*? sp. has been tentatively assigned to this genus, because of its similar ozarkodiniform elements.

"MICROZARKODINA" MARATHONENSIS (Bradshaw)

Figures 20.1, 20.2, 20.5, 20.6

—*Gothodus marathonensis* BRADSHAW, 1969, p. 1151, Pl. 137, figs. 13-15, text-figs. 3S, T, U.

"*Microzarkodina*" *marathonensis* (Bradshaw), ETHINGTON and CLARK, 1982, p. 55, 56, Pl. 5, figs. 14, 19, 24, 27, *non* figs. 20, 23 (contains synonymy to 1982); REPETSKI, 1982, p. 28, Pl. 10, figs. 1, 2, 3, 4, 5, 6.

Description.--Apparatus consists of ozarkodiniform, ramiform and oistodontiform elements. The latter two elements are described adequately in the literature. Triangular ozarkodiniform elements bladelike, strongly flexed, and arched in lateral view with denticulated oral margin. Base hyaline near aboral margin for entire length of element. Basal cavity ~~low, slit-like,~~ flaring slightly beneath posterior margin of cusp. Prominent ledge developed along base of cusp and denticles. Ledge slightly sinuous, follows bends in aboral margin becoming sub-parallel to anterior margin in antero-basal region. Aboral margin slightly to strongly arched, with anterior and posterior portions meeting at aproximately 150 degrees. Basal part ~~of anterior margin~~ rectangular in lateral view and upper part continuous with anterior margin of cusp. Reclined cusp bladelike, with sharp anterior and posterior edges and costae on either side. Cusp followed by posterior denticle row, with denticles becoming smaller and narrower posteriorly. Denticles sharp, costate on both sides, and fused for most of their length. Cusp, denticles, and upper portion of basal region albid. Posterior portion of element strongly flexed with respect to anterior portion.

Remarks.--Small ozarkodiniform and multiramiform elements of "*M.*" *marathonensis* occurring in uppermost Bed 11 and in Bed 13 strata probably belong to a new genus (S.L. Pohler, pers. comm., 1985). Because these elements are few, they are included in "*M.*" *marathonensis*. A new description of the ozarkodiniform element was thought necessary because Ethington and Clark's (1982) description of this element covers both early and late forms, herein recognized as separate taxa (see Remarks under "*M.*" sp. aff. "*M.*" *adentata*).

Occurrence.--Beds 11 and 13 at St. Pauls Inlet and limestone clast in Lower Head Formation at Martin Point.

Material.--49 ozarkodiniform, 50 multiramiform, and 8 oistodontiform elements.

Types.--Hypotypes, GSC 82543-82546.

MICROZARKODINA? sp.

Figures 20.3, 20.7

Description.--Robust, denticulate blade-like elements with row of large, compressed, anterior denticles that are flexed inward. Base elongate, constricted in middle, and flared aborally. Aboral margin straight. Basal cavity restricted beneath cusp, continues as groove anteriorly and posteriorly. Base beneath cusp expands outward. Prominent ledge developed at base of denticle row, most strongly in central portion of element. Albid cusp is reclined, robust, lanceolate in cross section, originating at basal expansion. Denticles on posterior process reclined, confluent and laterally compressed. Posterior denticles about half height of cusp. Anterior process flexed inward with respect to rest of element. Denticles on anterior process tightly compressed, and decreasing in height anteriorly.

Occurrence.--Bed 9 at St. Pauls Inlet.

Material.--4 specimens.

Type.--Figured specimen, GSC 82547.

"MICROZARKODINA" sp. aff. "M." ADENTATA McTavish

Figures 20.4, 20.8

aff. ?*Microzarkodina adentata* McTAVISH, 1973, p. 49, 50, figs. 28, 33-35, 38-40, 42-44.

Cordylodiform? element A TIPNIS, CHATTERTON and LUDVIGSEN, 1978, Pl. 3, fig. 8.

Microzarkodina marathonensis (Bradshaw), ETHINGTON and CLARK, 1982, p. 55, 56, Pl. 5, figs. 20, 23, *non* figs. 14, 19, 24, 27; REPETSKI, 1982, p. 28, Pl. 10, figs. 7, ?9, *non* figs. 1, 2, 3, 5, 6.

Prioniodus cf. *P*. sp. C. m.s. McTavish, TIPNIS, CHATTERTON, and LUDVIGSEN, 1978, Pl. 3, fig. 6.

Remarks.--Specimens included in this species are considered to have significant differences in morphology from corresponding elements of "*M.*" *marathonensis*, as reflected in the synonymy. Ozarkodiniform elements are nearly bilaterally symmetrical, with robust denticles of equal size. Multiramiform elements resemble the illustrations of the same elements of *M. adentata* (McTavish, 1973). They exhibit the same general arching of the posterior process which has confluent denticles. However, like Ethington and Clark's (1982) Pogonip specimens, the Cow Head multiramiform elements do not exhibit the same transition series as those of McTavish (1973).

Occurrence.--Beds 9-11 and 13 at St. Pauls Inlet.

Material.--8 ozarkodiniform elements, 23 multiramiform elements.

Types.--Figured specimens, GSC 82548, 82549.

Genus OEPIKODUS Lindström, 1955

Type species.--*Oepikodus smithensis* Lindström, 1955.

Remarks.--The apparatus of species of *Oepikodus* consists of denticulated prioniodontiform elements with free processes, oepikodontiform elements with a subdued symmetry transition series, and non-denticuated oistodontform elements (Fåhraeus and Nowlan, 1978). As Landing (1976) pointed out for *O. evae*, the prioniodontiform element is extremely variable in the number of denticles on and the amount of twisting of the posterior process. This variation is evident in prioniodontiform elements of both *O. evae* and *O. intermedius*, and to a lesser extent, *O. communis*. The only difference is that the number of denticles on the posterior process of *O. evae* has a greater range than that reported by Landing (1976). The number of denticles varies from as few as two to as many as fifteen. Correspondingly, the amount of twisting of the posterior process is greater.

Great difficulty is encountered in distinguishing between ramiform and oistodontiform elements of *O. evae* and *O. intermedius*. Ramiform elements of *O. evae* and *O. intermedius* are identical, except for their size. It was also difficult to distinguish between the same element of *O. communis* and the belodontiform element of *Prioniodus elegans* Pander. Only tetraprioniodontiform elements could be associated with elements of *O. communis* with certainty. The angle between the cusp and posterior process of oistodontiform elements of both *O. evae* and *O. intermedius* is variable with no clear distinction between them. Oistodontiform elements of these two species are distinguished by this angle (Serpagli, 1974). Because of this difficulty, the Cow Head ramiform and oistodontiform elements of *Oepikodus* are assigned to particular species of this genus arbitrarily. The number of these elements may therefore be over- or under-represented. Their lack of distinctiveness suggests that they evolved slowly in constrast to the prioniodontiform elements.

The occurrence of *O. communis* below the first appearance of *O. evae* supports McTavish's (1973) hypothesis that these species belong to separate lineages. Serpagli (1974) suggests that *O. communis* and *O. intermedius* both evolved from *O. evae* with *O. communis* evolving from *O. intermedius*. The occurrence of the *O. intermedius* above *O. communis* (Figure 4, p. 24) suggests that the latter species is ancestral to the former.

OEPIKODUS INTERMEDIUS Serpagli

Figures 16.18, 16.19, 16.22

Prioniodus (*Oepikodus*) *intermedius* SERPAGLI, 1974, p. 53-57, Pl. 15, figs. 1a-4b, Pl. 27, figs. 1-7, text-figs. 15D-F (contains synonymy to 1974); DZIK, 1983, p. 71, text-fig. 6:16.

Remarks.--Both Ethington and Clark (1982) and Repetski (1982) considered this species a junior synonym of *O. communis*. The writer considers *O. intermedius* to be a distinct species. It occurs in the upper part of Bed 11 at both St. Pauls Inlet and Martin Point. In lateral view, the anterior process of the prioniodontiform element is twisted posteriorly so that it is nearly occluded by the lateral process. The distal part of the lateral process is also directed anteriorly. No intermediates between these elements and those of *O. communis*, which have the anterior process directed forward, were found in samples containing *O. intermedius*. Oepikodontiform and ramiform elements appear indistinguishable from the same elements of *O. evae*.

Specimens illustrated by Stouge (1982, Pl. 6, figs. 17-20) were considered to be probably conspecific with *O. intermedius*. However, the anterior process of the figured prioniodontiform element is directed forward, unlike those of *O. intermedius* which are directed posteriorly.

Occurrence.--Beds 11 at St. Pauls Inlet and Martin Point.

Material.--201 prioniodontiform, 80 oistodontiform, and 121 ramiform elements.

Types.--Hypotypes, GSC 82556-82558.

Genus OISTODELLA Bradshaw, 1969

Type species.--*Oistodella pulchra* Bradshaw, 1969.

Description.--Apparatus is comprised of hyaline cyrtoniodontiform, oistodontiform, and ramiform elements. Oral margin of base arched and denticulated on cyrtoniodontiform and ramiform elements. Oral denticle row begins on posterior margin of cusp just above junction of base and cusp in oistodontiform and ramiform elements. Posterior margin of cusp denticulated in oistodontiform elements. Sharp antero-lateral costae developed on base and cusp of cladognathiform and trichonodelliform elements.

Remarks.--Bradshaw's (1969) original description of this genus was based on an oistodontiform element. This element occurs with cyrtoniodontiform and ramiform elements with denticulation beginning on the posterior margin of the cusp and continuing along the oral margin. These elements may all belong in the same apparatus. The cusps of the cyrtoniodontiform and oistodontiform exhibit the same colouration, with anterior and posterior portions partly albid, and hyaline material flanking the growth axis.

The ramiform symmetry transition series of this genus is *Oistodus*-like, especially the cladognathiform and trichonodelliform elements which have sharp costae developed on their antero-lateral margins. The apparatus of *Oistodus* Pander differs from *Oistodella* by lacking P elements (e.g. Lindström, 1964; Barnes *et al.*, 1979). Elements of *Oistodus* also differ from those of *Oistodella* by lacking denticulation. The cladognathiform element of *Oistodella* has a more open and curved aboral margin (Figure 17.3, 17.4) than the corresponding element of *Oistodus*.

Oistodella is broadly similar in apparatus plan to *Periodon* Hadding, except that the former genus has one type of P element, which is neoprioniodontiform. The M element of *Oistodella* is oistodontiform; the corresponding element of *Periodon* is oistodontiform and falodontiform. Both genera have similar ramiform transition series (Sa-Sc), except that both ligonodiniform and cladognathiform elements occupy the Sb position in the ramiform series of *Periodon*. Ramiform elements of *Oistodella* have wider bases and deeper basal cavities than corresponding elements of *Periodon*, as well as shorter denticulated posterior processes.

OISTODELLA sp. cf. O. PULCHRA Bradshaw

Figures 9A-H, 17.3, 17.4, 17.8-17.10; 17.13-17.15

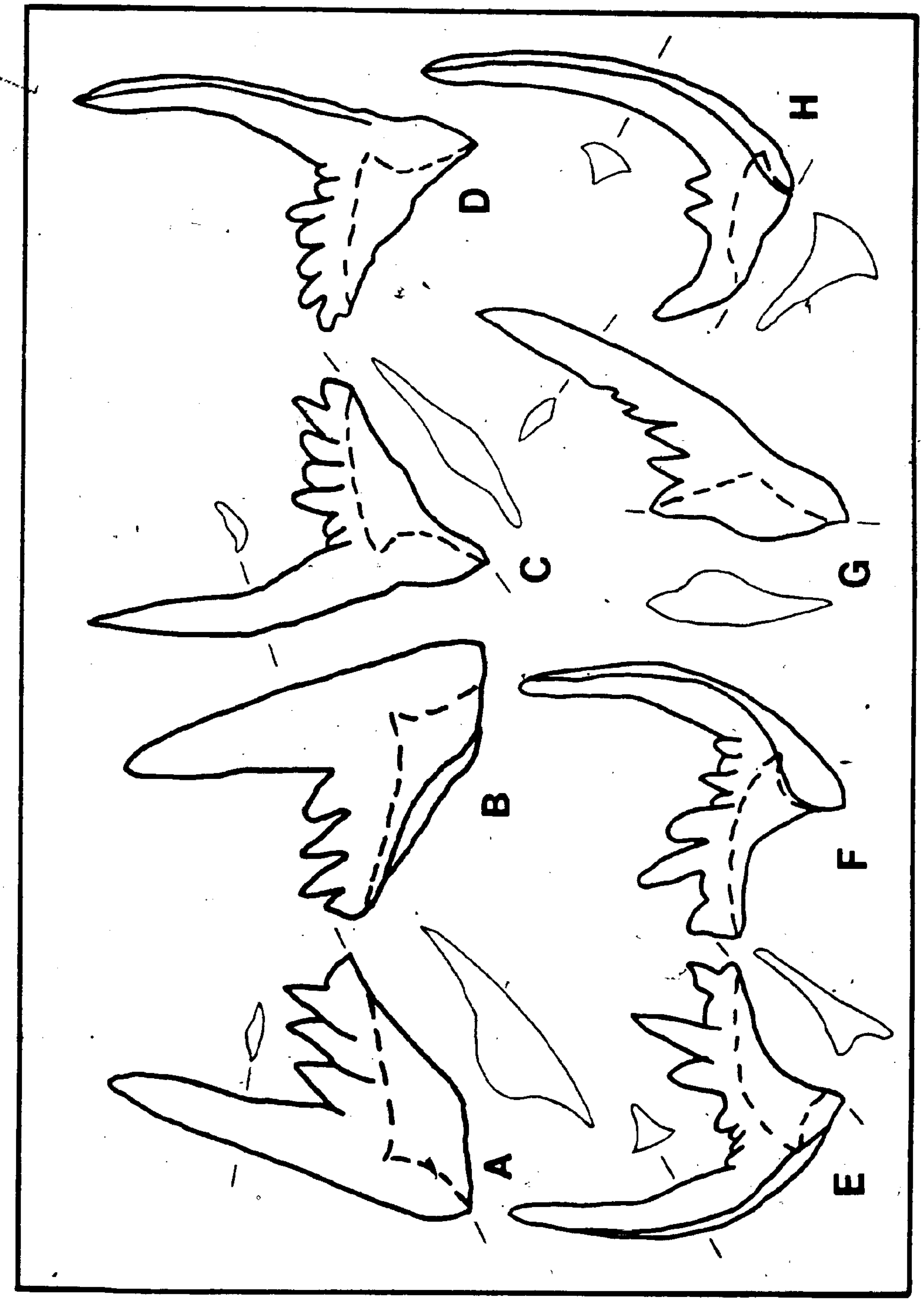
cf. *Oistodella pulchra* BRADSHAW, 1969, p. 1155, Pl. 136, figs. 10, 11, text-figs. 3L, M, Q.

Description.--Multielement apparatus of hyaline cyrtoniodontiform, cordylodontiform, cladognathiform, trichonodelliform and oistodontiform elements. Elements have denticulated oral margins with albid denticles becoming more inclined posteriorly, commonly originating above the junction of oral and posterior margins of the base and cusp. Denticles commonly laterally compressed, and blade-like. Anterior and posterior portions of cusp in cyrtoniodontiform and oistodontiform elements albid, with white matter extending down to antero-basal corner in former element. Growth axis flanked by hyaline material.

Elements of ramiform series laterally compressed with highest part of triangular base situated anteriorly. Oral margin straight in cordylodontiform, and arched in cladognathiform and trichonodelliform elements. Oral margin meets aboral margin at about 30 degrees. Basal cavity also triangular in outline, with arched oral margin, and posteriorly curved anterior margin. Apex of cavity anteriorly directed. Aboral margin broadly concave, with anterior and posterior ends of base joined by broad sheath. Cusp hyaline, recurved, with sharp posterior keels in all ramiform and sharp anterior keels in cordylodontiform and cladognathiform elements. Cross section flat on inside and convex on outside in cordylodontiform and cladognathiform, triangular with convex anterior margin in trichonodelliform elements. Growth axis originates anteriorly at apex proximally, becoming medially situated in distal portion of cusp. Oistodontiform element described by Bradshaw (1969) with differences noted under Remarks.

Cyrtonjodontiform element has base aproximately equal in length to cusp with outer side broadly convex. Oral margin with three to four broad, triangular denticles directed outwardly and fused basally and discrete apically. Aboral margin convex with greatest curvature beneath cusp. Basal cavity elongate cone, with apex pointed slightly anteriorly and situated beneath mid-point of cusp. Cavity flared to inner side anteriorly. Cusp reclined, triangular, lanceolate in cross section, and inwardly directed at tip. Anterior and posterior edges of cusp sharp. Antero-basal margin may be turned outward slightly. Growth axis

FIGURE 9--Apparatus of *Oistodella* sp. cf. *O. pulchra* Bradshaw showing outline of basal cavity and cross-section of cusp of each element. A, B, lateral views, cyrtoniodontiform element, GSC 82573, both X 42; C, D, lateral views, cordylodontiform element, GSC 82571, both X 21; E, F, lateral views, cladognathiform element, GSC 82570, both X 21; G, lateral view, oistodontiform element, GSC 82572, X 21; H, lateral view, trichonodelliform element, GSC 82574, X 42.


A
B
C
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E
F
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H

extends medially from apex of basal cavity to tip.

Cordylodontiform elements have elongate oral margin meeting posterior margin of cusp at about 120 degrees. Oral denticles sub-rounded in cross section, fused basally, becoming discrete at aproximately half length orally. Antero-basal angle aproximately 45 degrees. Anterior portion of base flange like, narrowing rapidly and becoming inwardly directed anterior costa on cusp. Cladognathiform element has sharp antero-lateral costa on cusp becoming medially situated and posteriorly directed basally. Anterior basal flange separated from antero-lateral costa by sharp indentation. Trichonodelliform element has sharp antero-lateral costae directed laterally on cusp and anteriorly on base. Anterior margin of base indented aborally, with low keel developed proximally on cusp.

Remarks.--The oistodontiform elments differ from those described by Bradshaw (1969) by having up to four denticles posteriorly. The white matter occurring in both anterior and posterior portions of the cusp and the hyaline material around the growth axis are features not noted by Bradshaw.

Occurrence.--limestone clast in Lower Head Formation at Martin Point.

Material.--3 cyrtoniodontiform, 7 oistodontiform, 4 cordylodontiform, 2 cladognathiform, and 6 trichonodelliform elements.

Types.--Figured specimens, GSC 82570-82574.

Genus OISTODUS Pander, 1856

Type species.--*Oistodus lanceolatus* Pander, 1856.

OISTODUS LANCEOLATUS Pander

Figures 19.26-19.28; 19.30-19.33

Oistodus lanceolatus PANDER, 1856, p. 27, Pl. 2, figs. 17, 18, 19; LÖFGREN, 1978, p. 63, 64, Pl. 1, figs. 26-28 (contains synonymy to 1978); FÅHRAEUS and NOWLAN, 1978, p. 467, Pl. 2, figs. 15, 16; LANDING and LUDVIGSEN, 1984, p. 1484, 1485, Pl. 1, figs. 18, 19, table 1.

Oistodus cf. *O. lanceolatus* Pander, REPETSKI, 1982, p. 33, Pl. 11, fig. 13, Pl. 12, figs. 2, 4, 6-8.

?*Oistodus*? cf. *O.*? *striolatus* Serpagli, REPETSKI, 1982, p. 35, Pl. 13, fig. 10.

?*Oistodus*? *striolatus* SERPAGLI, 1974, p. 41, Pl. 12, figs. 5a-9b, Pl. 24, figs. 5-7, Pl. 30, figs. 7a, 8.

Remarks.--Elements in Bed 13 have sharp, posteriorly directed, single and multiple costae on the inner and outer surfaces of cordylodontiform and cladognathiform elements. These elements are similar to those of *O.*? *striolatus* illustrated by Serpagli (1974) from Argentina. The similarity is such that the two forms could be considered conspecific. Other elements that occur with these look like *O. lanceolatus*. Several elements transitional between these latter forms and the costate forms also occur. They are all assigned to *O. lanceolatus*. Variable amounts of white matter are developed in this species throughout its stratigraphic range.

Occurrence.--Beds 9, 11, 13, and 14 at St. Pauls Inlet; Beds 11 and limestone clast in Lower Head Formation at Martin Point.

Material.--35 oistodontiform, 45 cordylodontiform, 50 cladognathiform and 5 deltiform elements.

Types.--Hypotypes, GSC 82559-82564.

"OISTODUS" sp. aff. "O." CRISTATUS Ethington and Clark s.f.

Figure 29.1

aff. *Oistodus cristatus* ETHINGTON and CLARK, 1982, p. 66, 67, Pl. 7, fig. 4.

Description.--Broad, spatulate or leaf-shaped element with blunt anterior end and cusp strongly reclined with sharp tapered tip. Base elongate, narrow, extends three-quarters length of cusp and comprises approximately one-quarter of the lateral area of the element. Oral margin short, slightly curved orally, meets posterior margin of cusp at sharp angle. Aboral and oral margins meet at sharp angle. Aboral margin gently convex downwards. Basal cavity elongate, occupies mostly aboral portion of base. Basal outline lanceolate, with greatest width at midlength. Antero-basal angle aproximately 60 degrees.

Cusp strongly reclined, spatulate or leaf shaped in lateral view. Anterior margin of cusp forms continuous smooth curve towards distal end. A slight concavity may be developed near the distal end of the cusp. Sharp tip formed at distal end. Posterior margin of cusp moderately concave and then strongly convex towards oral margin of base. Faint medial carina may be developed on one side of cusp.

Remarks.--Elements of this type are comparable in outline to those of "*O.*" *cristatus* s.f.. There is a considerable gap in the stratigraphic occurrences of these elements and "*O.*" *cristatus* s.f.. "*O.*" sp. aff. "*O.*" *cristatus* s.f. occurs in lower Arenig strata in the Cow Head Group whereas "*O.*" *cristatus* s.f. occurs elsewhere in Whiterock strata. They also differ in several morphologcal features. "*O.*" sp. aff. "*O.*" *cristatus* s.f. lacks the inner bulge on the distal portion of the cusp. The outline of the posterior margins and antero-basal angle of the cusp differ as well. The anterior margin is considerably more sloped in "*O.*" sp. aff. "*O.*" *cristatus* s.f.. The same margin is straight in "*O.*" *cristatus* s.f.. The posterior margin is highly convex in "*O.*" sp. aff. "*O.*" *cristatus* s.f..

Occurrence.--Beds 9 and 10 at St. Pauls Inlet; Bed 10 at Martin Point.

Material.--7 specimens.

Type.--Figured specimen, GSC 82568.

"OISTODUS" sp. aff. "O." HUNICKENI Serpagli s.f.

Figure 29.11

aff. *Oistodus hunickeni* SERPAGLI, 1974, p. 38, Pl. 13, figs. 1a-3b, Pl. 23, figs. 6, 7; ETHINGTON and CLARK, 1982, p. 67, Pl. 7, fig. 8.

Remarks.--These elements differ from *O. hunickeni* by lacking a basal ledge. This ledge was said to be evident in most specimens described by Serpagli (1974). The anterior margin also appears shorter.

Occurrence.--Bed 10 at St. Pauls Inlet.

Material.--4 specimens.

Types.--Figured specimen, GSC 82569.

Genus PARACORDYLODUS Lindström, 1955

Type species.--*Paracordylodus gracilis* Lindström, 1955.

PARACORDYLODUS GRACILIS Lindström

Figures 18.3, 18.4, 18.8, 18.9

Paracordylodus gracilis LINDSTRÖM, 1955, p. 584, 585, Pl. 6, figs. 11, 12; LÖFGREN, 1978, p. 67, 68, Pl. 9, figs. 15, 16 (contains synonymy to 1978); FÅHRAEUS and NOWLAN, 1978, p. 466, Pl. 3, fig. 26; BARNES, KENNEDY, McCRACKEN, NOWLAN and TARRANT, 1979, p. 136, text-fig. 7, Type IVE a-c, e, f; ETHINGTON, 1979, p. 5, text-fig. 6H, I; REPETSKI, 1982, p. 38, Pl. 15, figs. 3, 5, 7.

Remarks.--Two distinctive paracordylodontiform elements were recognized. One type has a narrow elongate "anticusp" in lateral view, with a costa running from the tip of the cusp to the distal end of the anticusp on each side. These costae are exactly or nearly opposite each other, and are disposed more posteriorly on the anticusp. In the other form, the anticusp is broad, and in some cases, lobate in lateral view. A prominent costa is usually developed on the outer side. A weakly developed costa may occur on the inner side extending only half as far as the outside costa. The outer side is generally convex while the inner side is concave. The distal end sometimes curves outward. Striations usually run acutely onto the costa in both types of elements.

Sorting these elements in large samples has shown that the two types of paracordylodontiform elements described above form a symmetry transition series. This series consists of asymmetrical-unicostate, asymmetrical-bicostate, and symmetrical to nearly symmetrical bicostate elements. Paracordylodontiforms with broad anticusps with concave-convex sides comprise the former elements of the series while those with elongate anticusps and symmetrical to nearly symmetrical costae comprise the latter elements. This arrangement is similar in configuration to the apparatus of *P. gracilis* illustrated in Barnes *et al.* (1979). This apparatus (Type IVE) is characterized by a first transition series (in this case, the paracordylodontiform elements) which is weakly developed. The elements in this series are distinguished only by the number and arrangement of costae (Barnes *et al.*, 1979). However, some samples are dominated by paracordylodontiform elements with elongate anticusps and nearly symmetrical costae which are commonly larger than the other type.

Occurrence.--Beds 9-11 at St. Pauls Inlet and Martin Point.

Material.--281 paracordylodontiform, 122 cordylodontiform, and 214 oistodontiform elements.

Types.--Hypotypes, GSC 82576-82579.

Genus PARAPANDERODUS Stouge, 1984

Type species.--*Scolopodus* sp. cf. *S. quadraplicatus* Branson and Mehl, 1933.

Remarks.--Stouge (1984) erected the genus *Parapanderodus* for laterally compressed, striated, and costate drepanodontiforms with a posterior groove. Several species belonging to this genus are present in the Cow Head collections. These forms have been previously identified as "*Scolopodus*" *gracilis* Ethington and Clark s.f. (for the most recent synonymy, see Stouge, 1984). The "*S.*" *gracilis* s.f. element has been placed in an apparatus with "*S.*" *triangularis* by several authors (e.g. Barnes and Poplawski, 1973; Ethington and Clark, 1982; Repetski, 1982). More recently, this element has been grouped with *Semiacontiodus cornuformis* (Sergeeva) (Bergström, 1979; Löfgren, 1985). Evidence from the Cow Head collections indicates that "*S.*" *gracilis* s.f. may not belong with any of these elements, but to a monoelemental apparatus. This conclusion is based upon a comparison of the younger species of *Parapanderodus* with the form taxa mentioned above.

Forms such as *P. arcuatus* Stouge and *P.* sp. cf. *P. arcuatus* are mostly triangular to laterally compressed in cross section. This is in contrast to the antero-posterior flattening seen in elements of *Semiacontiodus cornuformis*. In addition, this latter species is mostly hyaline, while *P. arcuatus* and *P.* cf. *P. arcuatus* are predominantly albid. *P. striatus* (Graves and Ellison), *P. elegans* Stouge and *P.* sp. cf. *P. striatus*, although hyaline, have circular to triangular cross sections. "*S.*" *triangularis* does not appear to belong with "*S.*" *gracilis* s.f. in an apparatus because they do not co-occur in younger strata (see remarks for *P. gracilis*).

Several species assigned to *Parapanderodus* herein may belong to a different genus. The hyaline nature of *P. striatus*, *P. elegans*, and *P.* sp. cf. *P. striatus* and their similar external morphology may be reason to group them together in a single genus. However, the present state of knowledge of these taxa, plus limited material, does not permit their being given a separate taxonomic assignment at this time.

PARAPANDERODUS ELEGANS Stouge

Figures 26.9, 26.10

Parapanderodus elegans STOUGE, 1984, p. 66, 67, Pl. 9, figs. 20-27 (contains synonymy to 1984).

Scolopodus gracilis Ethington and Clark, STOUGE, 1982, p. 43, Pl. 5, figs. 10, 11.

Remarks.--This species is distinguished from *P.* sp. cf. *P. striatus* by having a straight oral margin and a long base. *P. elegans* Stouge differs from *P. striatus* (Graves and Ellison) by having a sharply proclined cusp, and not having a thickened rim around the basal margin. *P. elegans* tends to be smaller in size than these other two species.

This species first appears in the top half of Bed 11 at St. Pauls Inlet. Its range may extend down farther, but possible older forms are indistinguishable from *P. gracilis* (Ethington and Clark) (see remarks for this species).

Occurrence.--Beds 11, 13 and 14 at St. Pauls Inlet

Material.--14 specimens

Types.--Hypotypes, GSC 82583, 82584.

PARAPANDERODUS GRACILIS (Ethington and Clark)

Figure 26.11

Scolopodus gracilis ETHINGTON and CLARK, 1964, p. 699, Pl. 115, figs. 2-4, 8, 9, text-fig. 2D, G; ETHINGTON and CLARK, 1965, p. 200; MOUND, 1968, p. 418, Pl. 5, figs. 29-31, 34-38, 40, 42-49, 52-53; BARNES and TUKE, 1970, p. 92, Pl. 18, figs. 11, 12; ETHINGTON and CLARK, 1971, p. 76, Pl. 2, figs. 3, 9; BARNES, 1974, p. 227, Pl. 1, fig. 2; BARNES and SLACK, 1975, figs. 3A-D; FÅHRAEUS and NOWLAN, 1978, p. 468, Pl. 1, figs. 10, 11; ETHINGTON and CLARK, 1982, p. 100, 101, Pl. 11, fig. 28, *non* fig. 27; REPETSKI, 1982, p. 48, Pl. 22, fig. 8, *non* figs. 5, 10-11; STOUGE, 1982, P. 43, 44, Pl. 2, figs. 12, 13.

Scolopodus? sp. A STOUGE, 1982, p. 43, 44, Pl. 2, figs. 3, 11, *non* figs. 1, 2, 4-6, 10.

Remarks.--Elements of the form taxa "*Scolopodus*" *gracilis* Ethington and Clark s.f. and "*Scolopodus*" *triangularis* Ethington and Clark s.f. are commonly assigned to the same apparatus. This is because of their usually concurrent stratigraphic range and the occurrence of transitional forms (e.g. Barnes and Poplawski, 1973; Ethington and Clark, 1982; Stouge, 1982). In the Cow Head material elements identified as "*S.*" *trangularis* s.f. occur sporadically and not with other species of *Parapanderodus* Stouge in younger strata. In this work "*S.*" *triangularis* is treated as a separate form taxon, although it may belong with *Glyptoconus quadraplicatus* (Branson and Mehl).

Small elements with a posteriorly expanded base and an erect cusp which are commonly asymmetrical occur in lowest samples of both sections. These elements, which have a posterior groove, may possibly be ancestral to *P. gracilis* and other species of *Parapanderodus*.

Many of the elements of *P. gracilis* studied show morphological features similar to both *P. elegans* Stouge and and *P. arcuatus* Stouge. These elements have bases which are either rounded or laterally compressed, and their cusps are roughly triangular in cross section. These features occur especially in younger specimens. It is possible that *P. gracilis* may be an ancestor to both *P. elegans* and *P. arcuatus*.

The synonymy excludes those elements herein assigned to other species of *Parapanderodus*. These forms occur in younger strata of Middle Ordovician (Whiterockian) age (e.g. Uyeno and Barnes, 1970; Barnes and Poplawski, 1973; Bergström, 1977; Stouge, 1980)

Occurrence.--Beds 9-12 at St. Pauls Inlet; Beds 8, 11, and 14 at Martin Point.

Material.--89 specimens.

Types.--Hypotype, GSC 82585.

PARAPANDERODUS sp. cf. P. ARCUATUS Stouge

Figures 26.20, 26.21, 26.28

cf. *Parapanderodus arcuatus* STOUGE, 1984, p. 65, 66, Pl. 9, figs. 10-15.

Remarks.--Most elements agree well with the description of the second element type of *P. arcuatus* (Stouge, 1984) which lacks the slightly asymmetrical posterior costa. The first element type with the costa does not occur. However, in the youngest sample containing this species, some elements approach the costate forms in appearance. *P.* sp. cf. *P. arcuatus* Stouge may represent an intermediate stage of evolution between *P. gracilis* (Ethington and Clark) and *P. arcuatus*.

Occurrence.--Beds 11, 13 and 14 at St. Pauls Inlet; Bed 13 at Martin Point.

Material.--84 specimens.

Types.--Figured specimens, GSC 82589-82591.

PARAPANDERODUS sp. cf. P. STRIATUS (Graves and Ellison)

Figure 26.8

cf. *Drepanodus striatus* GRAVES AND ELLISON, 1941, p. 11, Pl. 1, figs. 3, 12.

Parapanderodus striatus (Graves and Ellison), STOUGE, 1984, p. 67, Pl. 10, figs. 1-3 (contains synonymy to 1984).

Description.--Curved, robust, hyaline elements with surface striations and a deep posterior groove and base broadening towards the aboral margin. Elongate basal cavity extends to anterior margin. Base expanded posteriorly, and subtriangular in lateral view. Oral margin concave, continues onto posterior margin of cusp in smooth curve. Oral and aboral margin meet at approximately 60 degrees. Aboral margin straight; basal cavity elongate cone with tip pointed downward, nearly touching anterior margin at point of greatest curvature. Antero-basal margin perpendicular; anterior margin of base straight, joining anterior margin of cusp in smooth curve. Base subcircular to quadrate in cross section.

Cusp proclined, triangular in cross section. Lateral surfaces smooth, anterior keel faintly developed. Deep medial posterior groove extends from near tip of cusp to aboral margin. Groove deepest near aboral margin. Surface of element striated, with strongest development on base, and fading distally on cusp. Striations form acute angle with posterior groove. Growth axis situated anteriorly, near margin, being medial in position distally, filling tip with white matter.

Remarks.--*P.* sp. cf. *P. striatus* differs from *P. striatus* in Cow Head strata by having a proclined cusp that is shorter relative to the base. These elements are completely hyaline, unlike *P. striatus* which is partly albid in the base. *P.* sp. cf. *P. striatus* (Graves and Ellison) has several features in common with *P. elegans* Stouge. These features are the proclined cusp, elongate basal cavity, and the concave oral margin meeting the aboral margin at an acute angle. The stratigraphic occurrence of this species is younger than the oldest occurrence of either *P. striatus* or *P. elegans*. Therefore, it is improbable that this species gave rise to either taxon.

Occurrence.--Limestone clast in Lower Head Formation at Martin Point.

Material.--15 specimens.

Types.--Figured specimen, GSC 82592.

PARAPANDERODUS STRIATUS (Graves and Ellison)

Figures 26.13-26.15

Drepanodus striatus GRAVES and ELLISON, 1941, p. 11, Pl. 1, figs. 3, 12.

?"*Scolopodus*" sp. BERGSTRÖM, 1979, p. 302, 303, Fig. 4B, D, text-fig. 2K.

Description.--Hyaline, suberect, slightly asymmetrical elements with short or moderately long bases with a thickened rim around the aboral margin. Base expanded posteriorly and short to moderately elongate. Oral margin concave to straight, with oral and aboral margins meeting at slightly acute angle. Aboral margin straight; basal cavity conical, with tip extending nearly to anterior margin. Antero-basal angle acute, showing no break in curvature between anterior margin of base and cusp. Base thickened and darker in colour around rim of aboral margin. Base partly albid.

Cusp hyaline, slightly proclined to nearly erect, and triangular to lanceolate in cross section. Some specimens are asymmetrical, with the cusp twisted with respect to the base. Lateral faces are smooth to slightly grooved, with some having a slight anterior keel. Posterior faces of cusp and oral margin marked by posterior groove extending from just below tip to aboral margin. Surface of base weakly striated, with striations fading distally on the cusp. Growth axis begins near anterior margin above tip of the basal cavity and occupies the medial portion the cusp distally.

Remarks.--One feature of this species not noted by Graves and Ellison (1941) is white matter in the base. Forms which may be ancestral to *P. striatus* are found in Beds 9-11 at St. Pauls Inlet. These elements are characterized by having an erect cusp with a posteriorly expanded base, and a posterior groove. These specimens are herein included in *P. gracilis* (Ethington and Clark).

In younger specimens of this species, the cusp tends to become laterally compressed distally, becoming almost spatulate, with sharp anterior and posterior keels. Symmetrical and asymmetrical elements with short and elongate bases may form a symmetry transition series.

Specimens illustrated as "*Scolopodus*" sp. by Bergström (1979) may belong to this species. One element(Figure 4B) exhibits a concave oral margin, while the other (Figure 4D) has a straight oral margin. Both appear to have nearly erect to slightly proclined cusps.

Occurrence.--Beds 13 and 14 at St. Pauls Inlet; Bed 11 and limestone clast in Lower Head Formation at Martin Point.

Material.--35 specimens.

Types.--Hypotypes, GSC 82586-82588.

Genus PAROISTODUS Lindström, 1971

Type species.--*Oistodus parallelus* Pander, 1856.

Remarks.--Lindström (1971) defined *Paroistodus* as comprised of two elements: drepanodontiform and oistodontiform. This concept is followed by Barnes *et al.* (1979), although they suggested that a more subtle transition may occur in the q elements. Viira (1974, fig. 15) illustrated several curvature transition series for the drepanodontiform elements of each species of *Paroistodus*. Each element within a series exhibits a different degree of curvature of the cusp, as well as a different morphology, with respect to other elements of the series. Several morphotypes of the drepanodontiform element of *P. parallelus* in the Cow Head Group are recognized, most correspond to the types illustrated by Viira (1974). One other type was also recognized. All types are given letter designations A-E and described briefly under *P. parallelus*.

Only two types of drepanodontiform elements can be recognized in *P. proteus*. The one type has a roughly rectangular base, while in the other the base is aborally rounded. The cusp is reclined in the latter type. The aboral margins of some elements of the first type are rounded. The other morphotypes of this element are absent.

PAROISTODUS PARALLELUS (Pander)

Figures 24.10, 24.11, 24.15-24.17, 24.20

Oistodus parallelus PANDER, 1856, p. 27, Pl. 2, fig. 20.

Oistodus originalis SERGEEVA, 1963a, p. 98, Pl. 7, figs. 8, 9, text-fig. 4.

Paroistodus originalis (Sergeeva), LÖFGREN, 1978, p. 69-71, Pl. 1, figs. 22-25, text-fig. 28 (contains synonymy to 1978); DZIK, 1983, p. 69, text-figs. 4:15, 4.17?

Paroistodus parallelus (Lindström), ETHINGTON and CLARK, 1982, p. 79, Pl. 9, fig. 1 (contains synonymy to 1982); STOUGE, 1982, Pl. 6, figs. 6-8, *non* fig. 5; DZIK, 1984, text-fig. 4:16.

Description.--Several morphotypes of the drepanodontiform element are recognized. They will be designated Types A-E in the following descriptions:

Type A.--Element has elongate base with posterior end pointed. Basal cavity flared; antero-basal corner in line with aboral margin, forming right angle. Small flange formed on anterior margin.

Type B.--Base short or elongate and rounded posteriorly. Element weakly or strongly flexed outwards; oral margin forms continuous curve with posterior margin of cusp. Anterior part of base rounded, with triangular keel that may be flexed inwards.

Type C.--Base broad, with basal cavity low, oblong, usually restricted to posterior portion of base. Oral and posterior margins of base and cusp form continuous line with no break in curvature. Narrow keel formed along anterior margin of element.

Type D.--Element laterally compressed, with strongly reclined cusp. Triangular anterior keel developed with apex situated opposite bend between base and cusp.

Type E.--Element with strongly reclined cusp, carinate on inside. Basal cavity flared to the inside and opens posteriorly. Strong anterior keel developed.

Remarks.--Morphotypes A and B occur in varying proportions throughout the range of *P. parallelus*. Type A occurs most frequently in lower strata; it then becomes rare higher up in section. Type B becomes more frequent in younger strata, being dominant in the youngest sample. Types C-E occur uniformly throughout. All these elements represent a curvature transition series like that depicted in Fig. 15 of Viira (1974) (see Remarks for this genus).

The writer follows van Wamel (1974), Serpagli (1974), and Landing (1976) in assigning elements of both *P. originalis* and *P. parallelus* to the latter species. Costate drepanodontiform elements resembling homologous elements of *P. orginalis* co-occur with non-costate or strongly carinate forms throughout the lower part of the range of *P. parallelus*. It is uncertain whether these costate forms are a separate species, since some weakly costate forms also occur. The writer concurs with van Wamel (1974) who suggested that the presence of costae is not a strong criterion for distinguishing *P. parallelus* from *P. originalis*. van Wamel also reported that non-costate drepanodontiform elements predominate and then occur solely in samples from younger strata at Oland, Sweden. The same pattern is evident in the Cow Head Group.

Barnes and Poplawski (1973) reported the occurrence of large oistodontiform elements without corresponding large drepanodontiform elements in their collections. Large oistodontiform elements occur in collections from younger strata of the Cow Head Group. In older material the drepanodontiform and oistodontiform elements are approximately of the same size.

Occurrence.--Beds 9-11, 13 and 14 at St. Pauls Inlet; Beds 8-11, 13, 14, and limestone clast in Lower Head Formation at Martin Point.

Material.--555 drepanodontiform and 588 oistodontiform elements.

Types.--Hypotypes, GSC 82593, 82594, 82596-82599, unfigured specimen, GSC 82595.

PAROISTODUS? sp. A

Figures 24.14, 24.18, 24.19, 24.21-24.24

Paroistodus parallelus (Pander), SERPAGLI, 1974, p. 45, 46, Pl. 14, figs. 8-12b, Pl. 25, figs. 1-6, Pl. 30, fig. 5.

Description.--Robust drepanodontiform element with triangular, inwardly directed anterior keel and sharp, high oral keel. Base offset posteriorly from cusp, may be flexed sigmoidally in lateral plane. High, sharp oral keel developed on base, with rounded posterior portion. Oral keel forms continuous curve with posterior margin of cusp. Oral and aboral margins meet at approximately 45 degrees. Aboral margin mostly straight, with some specimens developing strong central undulations on outer side. Undulation concave with respect to rest of margin. Anterior portion of aboral margin meets posterior portion at 45 degrees. Basal cavity shaped broadly like phrygian cap, with apex directed anteriorly. Sides of cavity strongly or moderately inflated. Inwardly directed anterior keel triangular in lateral view. Outer side convex and continuous with outer side of base. Cusp albid, suberect, lanceolate in cross section, with sharp anterior and posterior keels.

Remarks.--The elements differ from others of *Paroistodus* by the apparent absence of an inverted basal cavity, and hence are tentatively referred to *Paroistodus*. These elements may be related to *Drepanodus* Pander, except that the aboral margins of non-costate arcuatiform elements of that genus are straight and the anterior flange is not developed as extensively.

Oistodontiform elements with inverted basal cavities of equal size and robustness to and co-occurring with the drepanodontiform elements described above in some samples are in included in *Paroistodus*? sp. A.

Occurrence.--Bed 9 at St. Pauls Inlet, Beds 10 and 14 at Martin Point.

Material.--19 drepanodontiform and 7 oistodontiform elements.

Types.--Figured specimens, GSC 82604-82607.

PAROISTODUS? sp. B

Figure 23.29

Description.--Highly laterally compressed, recurved drepanodontiform element with strong anterior keel developed basally and rounded antero-basal margins. Base strongly laterally compressed. Oral margin forms continuous unbroken curve with posterior margin of cusp, and meets aboral margin at near right angle. Aboral margin short and straight. Basal cavity shallow, rounded, with deepest part situated posteriorly and anterior portion restricted to a groove. Apex directed anteriorly. Anteriorly directed keel begins at rounded antero-basal corner; widens then narrows distally. Basal portion of keel may be nearly equal in width to base. Cusp albid, recurved, laterally compressed, lanceolate in cross section.

Remarks.--These elements generally tend to be small and delicate. They occur sporadically throughout the sequence.

Occurrence.--Beds 9-11 at St. Pauls Inlet.

Material.--45 specimens.

Types.--Figured specimen, GSC 82608.

Genus PERIODON Hadding, 1913

Type species.--*Periodon aculeatus* Hadding, 1913.

PERIODON ACULEATUS Hadding

Figures 10.8-10.28, 11A-D, 27.12, 27.13, 27.17, 27.18, 27.20-27.31; 28.1-28.7

Periodon aculeatus HADDING, 1913, p. 33, Pl. 1, fig. 14; REPETSKI and ETHINGTON, 1977, p. 98, Pl. 1, figs. 16-18, 20, 22, 24, Table 2; LÖFGREN, 1978, p. 74, 75, Pl. 10, figs. 1A,B, Pl. 11, figs. 12-26, fig. 29 (in part) (contains synonymy to 1976); FÅHRAEUS and NOWLAN, 1978, p. 462, Pl. 3, figs. 1, 7-13, text-figs. 5G-C; TIPNIS, 1978, p. 77, Pl. 31.1, figs. 1-5; LINDSTRÖM, 1981, p. 237, 238, Pl. 1, figs. 12-14, 17, 18; NOWLAN, 1981, p. 12, Pl. 2, figs. 7-10, Pl. 4, figs. 1-9; NOWLAN and THURLOW, 1984, p. 293, Pl. 1, figs. 12-14, 17, 18.

Periodon aculeatus aculeatus Hadding, NICOLL, 1980, p. 150, 151, Fig. 3A-G.

Periodon aculeatus zgierzensis Dzik, STOUGE and BOYCE, 1983, Pl. 9-14; STOUGE, 1984, p. 82, 83, Pl. 16, figs. 1-15.

Periodon cf. *P. aculeatus* Hadding, KENNEDY, BARNES and UYENO, 1979, p. 544, 546, Pl. 1, figs. 1-7, 8?, 35.

Periodon flabellum (Lindström), FÅHRAEUS and NOWLAN, 1978, p. 462, 463, Pl. 3, figs.

2-6, text-fig. 5A-F.

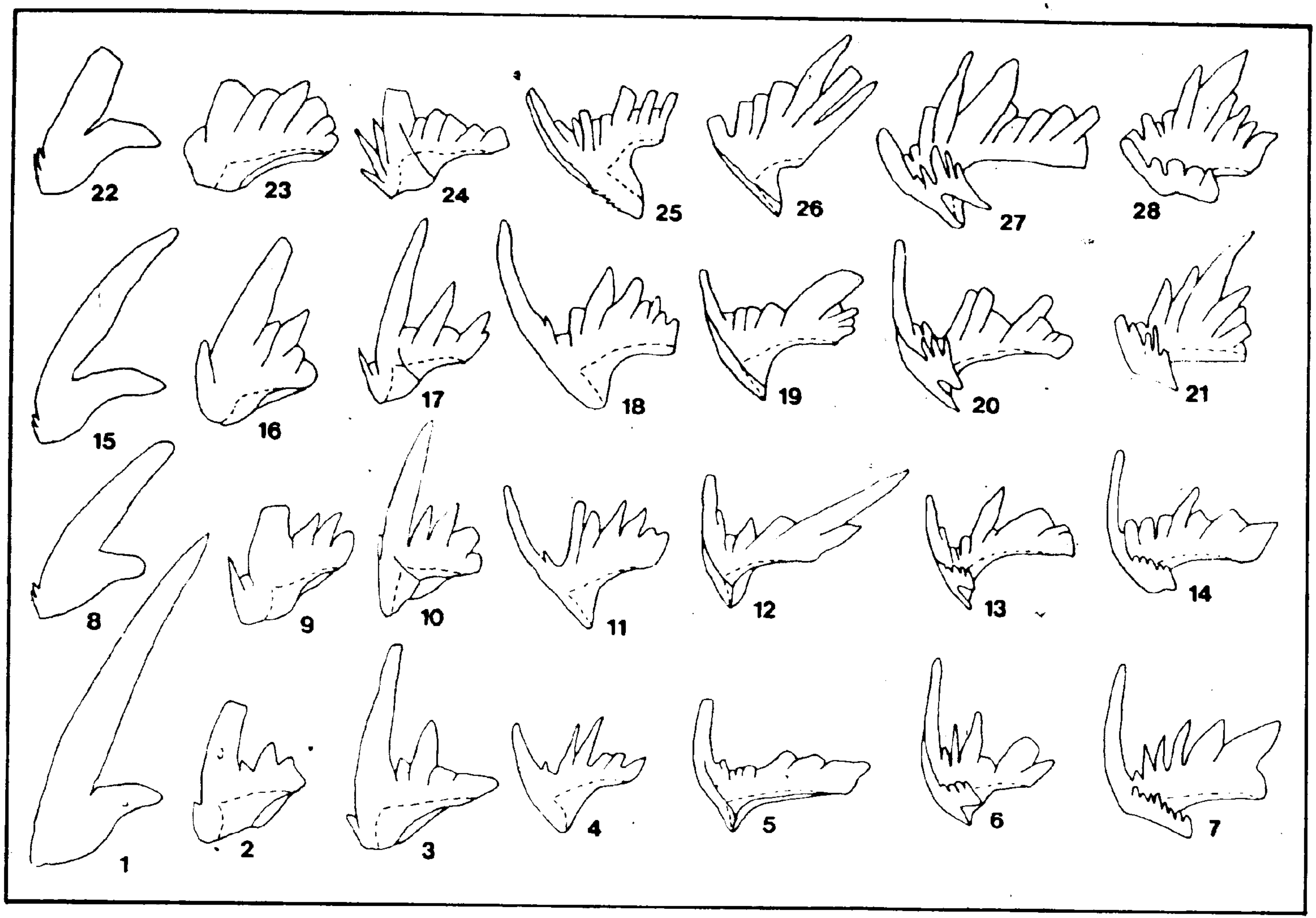
Periodon sp. cf. *aculeatus* Hadding, SIMES, 1980, p. 530, Fig. 5.

Remarks.--Early, intermediate and late forms of *P. aculeatus* are recognized at St. Pauls Inlet. Early forms occur in upper Bed 11 strata while intermediate and late forms are found in Bed 13. Apparatuses representative of each form of *P. aculeatus* and of *P. flabellum* Lindström are illustrated in Figure 10.

Early forms retain several primitive features characteristic of *P. flabellum*, their immediate ancestor (see below), while showing more advanced traits. Oistodontiform (=falodontiform) elements (Figures 10:8, 15) usually have from one to three denticles anteriorly. The anterior process of the prioniodiniform element carries one to several denticles. Both single and multidenticulated forms have restricted basal cavities. Those with several denticles on the anterior process have a strong carina on the inner surface of the basal cavity. When these elements are abundant in a sample (see below), they are commonly associated with strongly denticulated falodontiform elements. Weakly denticulated falodontiform elements usually occur with abundant prioniodiniform elements with a single anterior denticle. Oulodontiform elements have a sharp carina developed on the inner side. This feature is retained in younger oulodontiform elements of *P. aculeatus*. Multiramiform elements have an aboral margin which is still openly curved like the same elements of *P. flabellum* (Figures 10:11-14, 18-21). The earliest multiramiform elements of *P. aculeatus* still retain the primitive denticulation on the posterior process (Figures 10:11-14) while younger early forms have several elongate, narrow, denticles developed behind the "big" denticle. The antero-basal angle is the same as that in multiramiform elements of *P. flabellum*.

Elements of the intermediate stage exhibit more advanced features, especially the multiramiform elements. Falodontiform elements are strongly denticulated anteriorly (Figure 10:22). Prioniodiniform elements have resticted basal cavities, and the majority have only a single anterior denticle. The sides of the cusp and denticles are strongly carinate, and their edges are strongly keeled. Oulodontiform elements are also strongly carinate and keeled and the posterior process is longer and more twisted (Figure 10:24). Multiramiform elements have

FIGURE 10--Apparatuses of *Periodon flabellum* Lindström and *P. aculeatus* Hadding demonstrating the gradual evolution of the former species into the latter by mosaic evolution. Sample numbers given in parenthesis. 1-7, *P. flabellum*, GSC 82653-GSC 82659, (StPl 71); 8-14, early form, *P. aculeatus*, GSC 82609-GSC 82615, (StPl 75b); 15-21, early form of *P. aculeatus* showing more advanced falodontiform, prioniodontiform, and oulodontiform elements while multiramiform elements retain more primitive features, GSC 82643, GSC 82644, GSC 82638, GSC 82641, GSC 82639, GSC 82640, GSC 82642, (StPl 81); 22-28, intermediate forms, *P. aculeatus*, GSC 82616-GSC 82622, (StPl 90); 1, oistodontiform element; 2, 9, 16, 23, prioniodiniform elements; 3, 10, 17, 24, oulodontiform elements; 4, 11, 18, 25, cordylodontiform elements; 5, 12, 19, 26, ligonodiniform elements; 6, 13, 20, 27, cladognathiform elements; 8, 15, 22, falodontiform elements; all figures X 40.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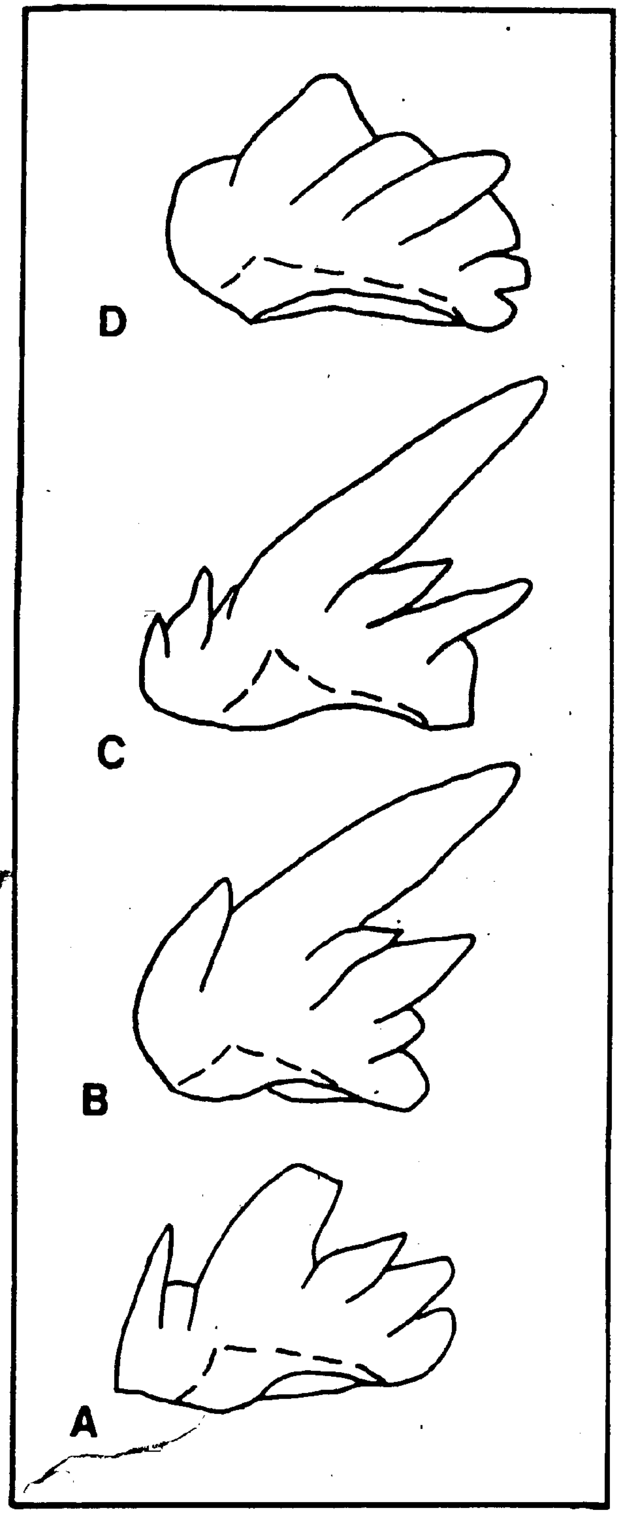
elongate, commonly twisted, posterior processes with many narrow, delicate denticles situated behind the "big" denticle as well as in front of it. The aboral margin of this process meets the aboral margin of the basal cavity at right angles. The antero-basal angle is more acute, like in younger multiramiforms of *P. aculeatus* (Figures 10:25-28). The late forms of *P. aculeatus* are typified by elements which first appear in the upper half of Bed 13 and are reported in late Arenig-Llanvirn strata elsewhere (e.g. Löfgren, 1978; Stouge, 1984).

Prioniodiniform elements of *P. aculeatus* with only a single anterior denticle dominate over those with several denticles in some samples containing large numbers of this species. In other samples with large numbers of *P. aculeatus*, elements of this type with several anterior denticles are predominant. These changes in dominance patterns happen over a short stratigraphic interval. This is illustrated in Figure 11. The prioniodiniform elements illustrated in this figure represent the length of the anterior process on the majority of these elements in each sample. Most prioniodiniform elements in samples StPI 75b and SPI84-4 have a long anterior process, with typically three denticles. Some elements carry up to four or five denticles on the anterior process. Typical prioniodiniform elements of *P. aculeatus* in the Cow Head Group have usually long anterior processes that carry up to five denticles. In samples StPI 81 and 90, the majority of prioniodiniform elements have a short anterior process, with just a single denticle. A few elements have long anterior denticulate processes. These patterns are interpreted to represent phenotypic variation in this element. The other elements in the apparatus appear to undergo very little change, except the falodontiform elements, as noted above.

Löfgren (1978, fig. 29) attempted to demonstrate graphically that the number of anterior denticles on the prioniodiniform elements increases over time. Figure 11 shows that this is apparently not the case. Prioniodiniform elements with long anterior processes occur more frequently in younger Cow Head horizons above those indicated in Figure 11. It seems that this particular character state becomes stable in younger populations of *P. aculeatus*.

The gradual evolution of *P. flabellum* into *P. aculeatus* has been noted in the literature (e.g. Löfgren, 1978; Serpagli, 1974). In Cow Head collections elements of these species

FIGURE 11--A-D. Prioniodiniform elements of *Periodon aculeatus* Hadding from StPI 75b, 81, 90 and SPI84-4 showing the variation of length of the anterior process and the number of corresponding denticles in the majority of these elements from sample to sample; A, StPI 75b, GSC 82610; B, StPI 81, GSC 82644; C, SPI84-4, GSC 82623; D, StPI 90, GSC 82617; all X 80.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undergo mosaic evolution with certain elements in the apparatus evolving faster than others. Figure 10 shows that the prioniodiniform elements appear to evolve the fastest, with the basal cavity rapidly becoming shallower proceeding from StPl 71-81. The next fastest evolving elements are the oistodontiform and oulodontiform elements, with the former element acquiring persistent denticulation (and thus becoming a falodontiform element) and the latter acquiring an outer postero-lateral costa on the base and the lower part of the cusp. The slowest evolving elements are the multiramiforms, which only lose the large denticles posterior to the middle "big" denticle in the last step between StPl 75b and StPl 81, but still retain the primitive smoothly curved aboral margin and steep antero-basal angle (Figures 10:11-14, 18-21).

P. aculeatus and *P. flabellum* co-occur in the upper part of Bed 11 and Bed 13. The latter species is distinguished from the former by the following characteristics: The oistodontiform element remains adenticulate throughout the range of *P. flabellum*, although younger elements show incipient denticulation anteriorly. The prioniodiniform and oulodontiform of *P. flabellum* have weakly carinate cusps and expanded basal cavities. The latter elements do not have a sharp outer carina on the outer side. Multiramiform elements of *P. flabellum* have smoothly curved aboral margins, with antero-basal angle more open. A few large, broad denticles occur behind the "big" denticle on the posterior process.

Occurrence.--Beds 11, 13, and 14 at St. Pauls Inlet; Beds 11, 13, and 14 and limestone clast in Lower Head Formation at Martin Point.

Material.--5259 prioniodiniform, 2749 oulodontiform, 6042 multiramiform, and 4236 falodontiform elements.

Types.--Hypotypes, GSC 82609-82623; 82630-82652, unfigured specimens, GSC 82624-82629.

PERIODON? sp.

Figures 27.1-27.3

Periodon flabellum (Lindström), VAN WAMEL, 1974, p. 80, 81, Pl. 4, fig. 18, *non* figs. 14-17, 19, 20.

Periodon? oistodontiform element LÖFGREN, 1978, p. 71, Pl. 10, fig. 7.

?*Periodon* prioniodontiform element A LÖFGREN, 1978, p. 71, Pl. 10, figs. 4, 6.

Remarks.--No multiramiform elements were found associated with prioniodiniform and oistodontiform elements of this taxon. Prioniodiniform elements with low bases and short oral margins have been included in this species. These elements may be a separate taxon.

Occurrence.--Beds 9, 11, and 13 at St. Pauls Inlet.

Material.--77 prioniodiniform and 31 oistodontiform elements.

Types.--Figured specimens, GSC 82668-82670.

Genus POLONODUS Dzik, 1976

Type species.--*Ambalodus clivosus* Viira, 1974.

POLONODUS? PEAVYI n. sp.

Figures 28.9, 28.10, 28.12, 28.13, 28.15, 28.16

Derivation of name.--This species is named for Samuel Thomas Peavy, recent graduate student in the Department of Earth Sciences, Memorial University of Newfoundland.

Diagnosis.--Multielement apparatus consisting of highly arched lobate platform elements with medially situated denticle row extending along each lobe. Plane of anterior and posterior lobes intersect each other at 90 degrees. Subsymmetrical element highly arched with four lobes, with anterior lobes paddle shaped. Asymmetrical element has three lobes with broad, oval posterior lobe and elongate and narrow anterior lobes.

Description.--Multielement platform apparatus comprising subsymmetrical and asymmetrical elements. Elements highly arched, with three or four lobes with a thick rim and narrow ledge developed around each lobe. Plane of anterior and posterior lobes intersect each other at nearly 90 degrees. Ornamentation of oral surface honeycomb texture. Strongly to weakly developed transverse ridges occur on oral surface of each lobe. Denticles stout, pointed, and developed most strongly near cusp. Cusp short, broad, blade-like, with sharp anterior and posterior edge commonly continous with denticle rows extending away from cusp in middle of each lobe.

Subsymmetrical element with four lobes converging and constricted at apex with sides of each lobe sloping away from denticle row. Anterior and antero-lateral lobes elongate, roughly paddle shaped in oral view. Lobes meet at aproximately 30 degrees at apex of element, with distal end of antero-lateral lobe curving outward with respect to its proximal end. Lobes confluent for half their length, becoming discrete distally. Posterior portion of element bilobed with each lobe sub-circular in outline. Incipient ridge may be developed on one posterior lobe, extending obliquely from the posterior denticle row. Denticles on posterior denticle row fused for most of their length, and are discrete distally.

Asymmetrical element trilobed, with anterior and antero-lateral lobes narrower and shorter than posterior lobe. Anterior lobe begins at anterior keel of apical cusp, then flexes inward. Antero-lateral lobe in line with posterior denticle row. Posterior lobe broad, oval in oral view, with outer side gently convex, and inner side strongly convex. Width of posterior lobe variable, with some elements appearing elongate in oral view. Denticle row of posterior lobe may be situated medially or to one side with denticles sometimes occurring sporadically.

Remarks.--This species is only tentatively referred to *Polonodus* Dzik, because strong tuberculated transverse ridges appear to be lacking on most elements, and the asymmetrical element is trilobed unlike other species of this genus. The subsymmetrical element of *P.*? *peavyi* may have some affinities with *Polonodus*? sp. A (Löfgren, 1978), which has four lobes, though it lacks the turberculated ridges of the latter species.

Occurrence.--limestone clast in Lower Head Formation at Martin Point.

Material.--25 subsymmetrical and 24 asymmetrical elements.

Types.--Holotype, GSC 82671, paratypes, GSC 82672- 82674.

Genus PRIONIODUS Pander, 1856

Type species.--*Prioniodus elegans* Pander, 1856.

PRIONIODUS ELEGANS Pander

Figures 17.1, 17.2, 17.5-17.7, 17.11

Prioniodus elegans PANDER, 1856, p. 29, Pl. 2, figs. 22, 23; LÖFGREN, 1978, p. 78, 79, Pl. 9, figs. 1-6 (contains synonymy to 1978); FÅHRAEUS and NOWLAN, 1978, p. 464-466, Pl. 3, figs. 19, 20, 22-25, text-fig. 6; DZIK, 1983, p. 71, text-fig. 6:6; LANDING and LUDVIGSEN, 1984, p. 1485, Pl. 1, figs. 8, 9.

?*Falodus* sp. A s.f. FÅHRAEUS and NOWLAN, 1978, p. 466, 467, Pl. 3, fig. 18.

Remarks.--Younger tetraprioniodontiform and trichonodelliform elements of *P. elegans* develop denticulation on their lateral processes. The latter element is denticulated at the first appearance of this species. The lateral processes of most these elements in Bed 9 are adenticulate. ?*Falodus* sp. A. s.f. of Fåhraeus and Nowlan (1978) is included in *P. elegans*. In most falodontiform elements, the posterior process is broken near the base of the cusp. The posterior process with denticles developed on the distal end is a delicate feature and not readily preserved. ?*Falodus* sp. A, which retains this process, appears to be similar in morphological detail to to other falodontiform elements which just retain the anterior portion. The number of belodontiform elements listed under Material may be over representative for *P. elegans*. Those in one sample (StPI 67) may also include ramiform elements of *Oepikodus communis* (see Remarks for that genus).

Occurrence.--Beds 9-11 and 13 at St. Pauls Inlet; Beds 9-11, 13, 14, and limestone clast in Lower Head Formation at Martin Point.

Material.--206 prioniodontiform, 246 belodontiform, 16 trichonodelliform, 135 tetraprioniodontiform, and 94 falodontiform elements.

Types.--Hypotypes, GSC 82676-82681.

Genus PROTOPANDERODUS Lindström, 1971

Type species.--*Acontiodus rectus* Lindström, 1955.

Remarks.--The writer concurs with Löfgren (1978) that *Protopanderodus* should be restricted to taxa resembling the type species. Some of the forms described by Serpagli (1974) (e.g. *P. elongatus* and *P. leonardii*) should be assigned to other genera because the apparent apparatus plan of these taxa differ from typical *Protopanderodus*, and the elements themselves do not resemble the type species.

PROTOPANDERODUS COOPERI (Sweet and Bergström)

Figures 13.12-13.14; 13.17-13.19; 22.24-22.26; 22.30-22.32

FIGURE 12--Line drawings of species of *Protopanderodus* discussed in text; 1-6, 12-15, 22-26, *P.* sp. cf. *P. varicostatus*, lateral views; 1, 2, scandodontiform element, GSC 82717, X 18; 3, 4, asymmetrical drepanodontiform element, GSC 82715, X 18; 5, 6, scandodontiform element, GSC 82716, X 18; 12, 13, asymmetrical drepanodontiform element, GSC 82714, X 47; 14, 15, asymmetrical drepanodontiform element, GSC 82713, X 18; 22, 23, asymmetrical drepanodontiform element, GSC 82710, X 47; 24, 26, asymmetrical drepanodontiform element, GSC 82712, X 18; 25, symmetrical drepanodontiform element, GSC 82711, X 18; 7-11, *P. gradatus*; 7, symmetrical acontiodontiform element, GSC 82690, X 29; 8, 9, scandodontiform element, GSC 82689, both X 48; 10, 11, sulcatiform element, GSC 82691, X 29; 16, 17, 27-30, *P.* sp. aff. *P. gradatus*; 16, symmetrical acontiodontiform element, GSC 82703, X 31; 17, asymmetrical acontiodontiform element, GSC 82702, X 31; 27, 28, sulcatiform element, GSC 82704, both X 31; 30, scandodontiform element, GSC 82705, both X 64; 18-21, 31, 32, *P. rectus*; 18, 19, asymmetrical acontiodontiform element, GSC 82695; 20, acontiodontiform element, GSC 82696; 21, sulcatiform element, GSC 82697; 31, 32, scandodontiform element, GSC 82698; all X 48.

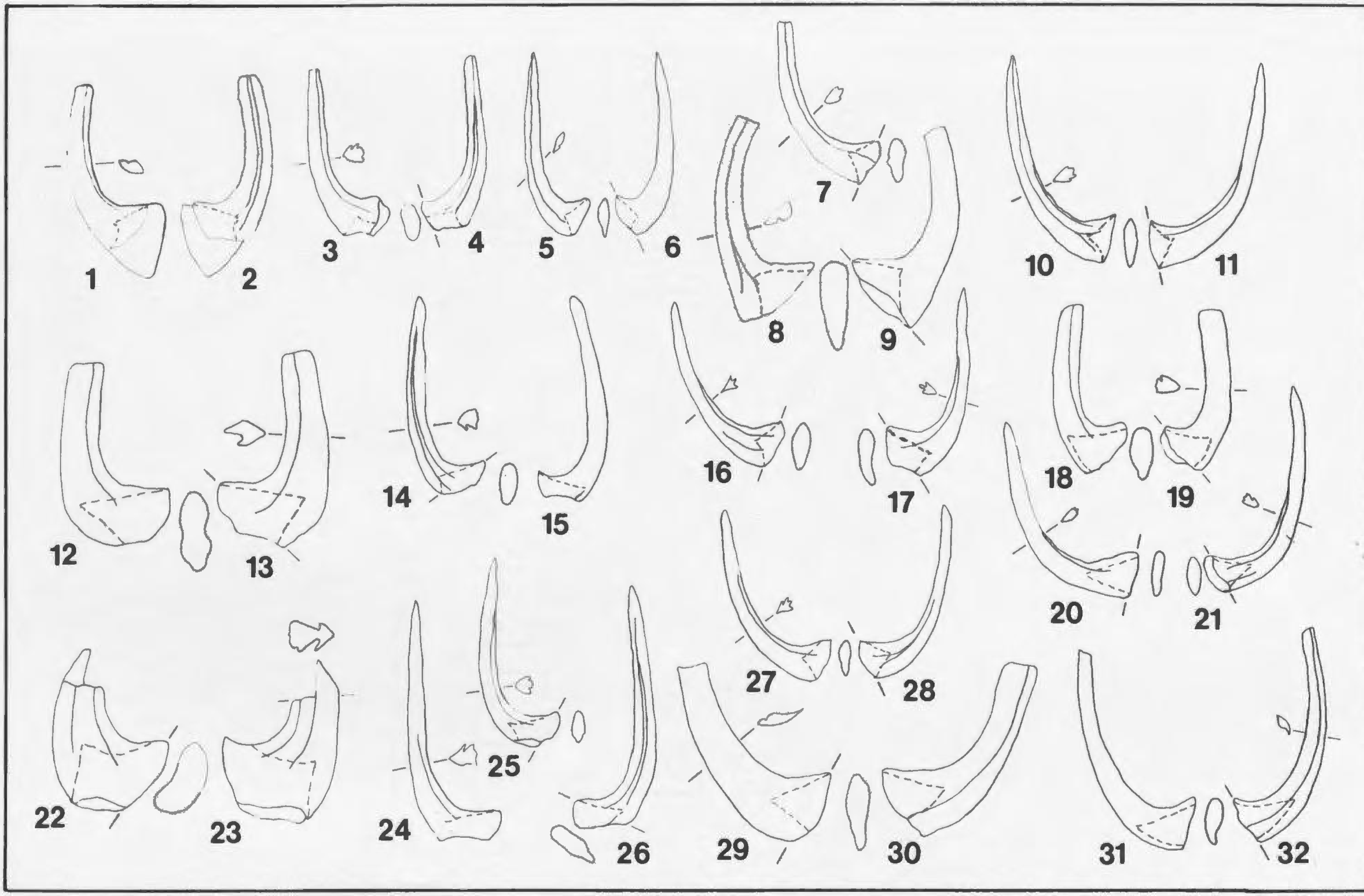
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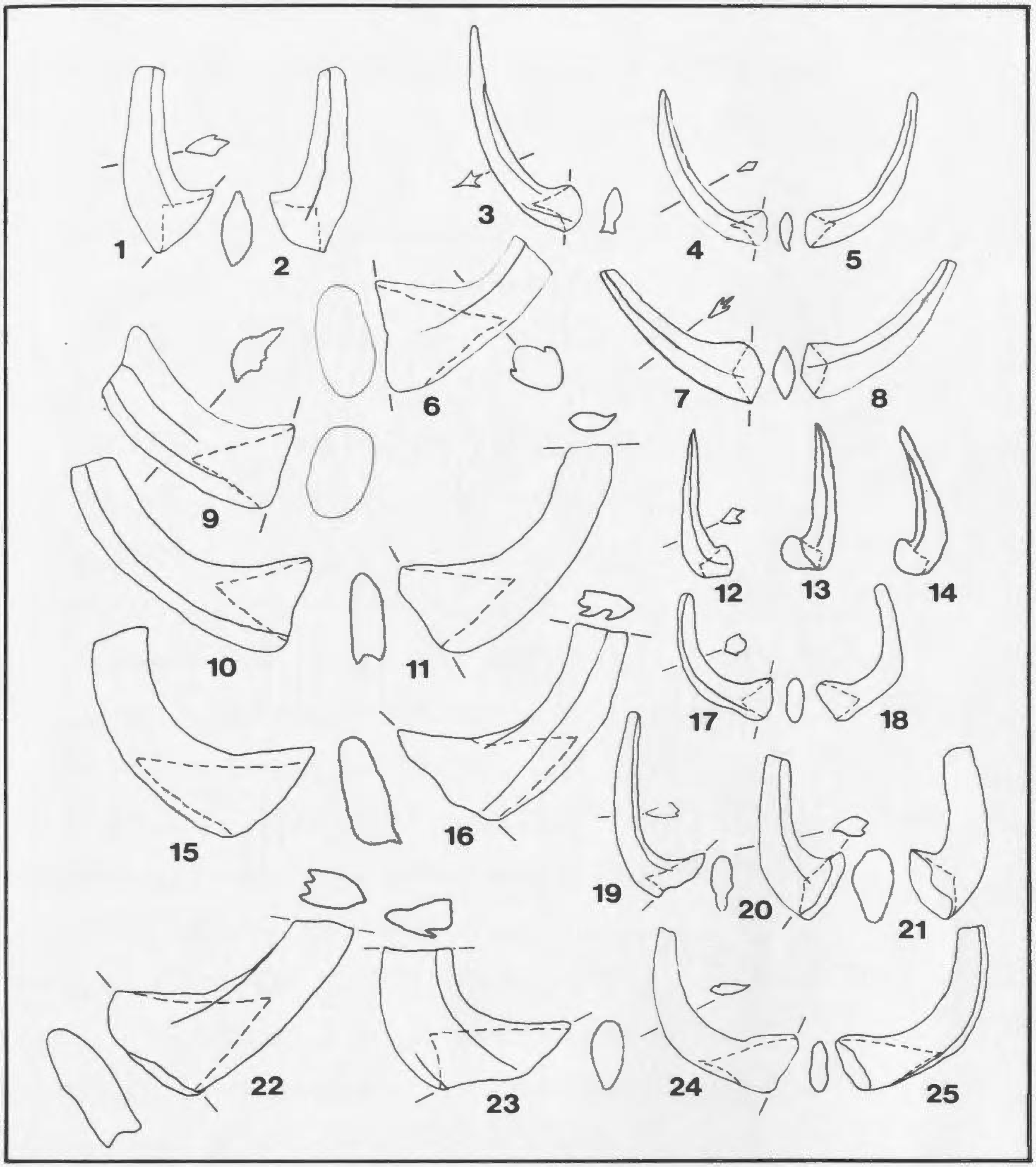
FIGURE 13--Line drawings of species of *Protopanderodus* discussed in text; 1, 2, 6, 9, *P. leonardii*; 1, 2, asymmetrical element, GSC 82694, X 48; 6, symmetrical element, GSC 82693, X 64; 9, scandodontiform element, GSC 82692, X 64; 3-5, 7, 8, *P. elongatus*; 3, symmetrical element, GSC 82685, X 48; 4, 5, slightly asymmetrical element, GSC 82686, X 48; 7, 8, asymmetrical element, GSC 82688, X 64; 10, 11, 15, 16, 22, *P. strigatus*; 10, 11, asymmetrical acontiodontiform element, GSC 82700; 15, 16, asymmetrical acontiodontiform element, GSC 82699; 22, symmetrical element, GSC 82701; all X 64. 12-14, 17-19, *P. cooperi*; 12-14, asymmetrical acontiodontiform element, GSC 82682; 17, 18, scandodontiform element, GSC 82684; 19, symmetrical acontiodontiform element, GSC 82683; all X 29. 20, 21, 23-25, *P.* sp. aff. *P. rectus*; 20, 21, asymmetrical acontiodontiform element, GSC 82708, X 78 and X 47; 23, symmetrical acontiodontiform element, GSC 82707, X 78; 24, 25, scandodontiform element, GSC 82706, both X 48.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Acontiodus cooperi SWEET and BERGSTRÖM, 1962, p. 1221, 1222, Pl. 168, figs. 2, 3, text-fig. 1G; BRADSHAW, 1969, p. 1147, Pl. 131, fig. 5.

Acontiodus rectus Lindström. LINDSTRÖM, 1960, text-figs. 6:10, 3:7?, *non* text-fig. 2:8.

Acontiodus robustus (Hadding). FÅHRAEUS, 1966, p. 16, Pl. 2, figs. 5a-b.

Acontiodus unciformis FÅHRAEUS, 1966, p. 17, Pl. 2, figs. 7a-b.

Distacodus n. sp. HAMAR, 1964, p. 263, Pl. 1, figs. 19, 20.

Protopanderodus cooperi Sweet and Bergström. BARNES and POPLAWSKI, 1973, p. 782, Pl. 4, fig. 15, *non* Pl. 3, figs. 1, 4, 5, Pl. 4, fig. 8.

Protopanderodus rectus (Lindström) LÖFGREN, 1978, p. 90, 91, Pl. 3, fig. 1, *non* figs. 2-7, 36A, B.

Protopanderodus robustus (Hadding). LÖFGREN, 1978, p. 94, 95, Pl. 3, figs. 32-35, text-figs. 31G-J; NOWLAN and THURLOW, 1984, p. 293, Pl. 2, figs. 7, 13, 14; STOUGE, 1984, p. 49, Pl. 2, figs. 5-8, *non* figs. 3, 4.

Scandodus dubius BRADSHAW, 1969, p. 1161, Pl. 134, figs. 19, 20.

Scandodus formosus FÅHRAEUS, 1966, p. 30, Pl. 3, fig. 11, text-fig. 3K.

?*Scandodus rectus* Lindström, HAMAR, 1964, p. 282, Pl. 2, figs. 6, 7, text-figs. 6:9, 6:11.

?*Scandodus* sp. SWEET and BERGSTRÖM, 1962, p. 1246, Pl. 168, figs. 13, 16.

Remarks.--*Acontiodus robustus* (Hadding) s.f. is assigned herein to *Drepanodus* Pander following Lindström (1971, p. 41). However, symmetrical acontiodontiform elements are assigned to *A. cooperi* Sweet and Bergström s.f..

Barnes and Poplawski's (1973) definition of *P. cooperi* included asymmetrical drepanodontiform and scandodontiform elements resembling *S. rectus* s.f. in an apparatus with symmetrical acontiodontiform elements. In the present work the first two elements have been assigned to *P.* sp. cf. *P. varicostatus* and *P. rectus*, respectively. Löfgren's (1978) concept of the species is followed in which the apparatus consists of symmetrical and asymmetrical acontiodontiform, and scandodontiform elements.

Some asymmetrical acontiodontiform elements appear to differ from *Distacodus* n. sp. s.f. by having a more quadrate cross section in the proximal part of the cusp. The symmetrical acontiodiform elements form a weak symmetry transition series. This series consists of elements with a postero-lateral furrow on one side of the cusp to those with a medially placed posterior costa flanked by postero-lateral ridges. The same transition series appears to be developed in *P.* sp. aff. *P. rectus* (see remarks for that species).

Occurrence.--Beds 13 and 14 at St. Pauls Inlet; Beds 13 and 14 and limestone clast in Lower Head Formation at Martin Point.

Material.--40 symmetrical, 16 asymmetrical acontiodontiform and 9 scandodontiform elements.

Types.--Hypotypes, GSC 82682-82684.

PROTOPANDERODUS ELONGATUS Serpagli

Figures 13.3-13.5, 13.7, 13.8, 22.17-22.21

Protopanderodus elongatus SERPAGLI, 1974, p. 57, Pl. 16, figs. 8a-11c, Pl 25, figs. 13-16, Pl. 30, fig. 4, text- fig. 16; ETHINGTON and CLARK, 1982, p. 84, Pl. 9, fig. 15; REPETSKI, 1982, p. 39, Pl. 16, figs. 4, 5, 7, 9, 11, 12, text-fig. 6T.

Remarks.--No scandodontiform elements of *P. elongatus*, described by Serpagli (1974), were found in the Cow Head collections. The absence of this element was also reported by Ethington and Clark (1982) in their Pogonip material. Younger specimens of this species exhibit a greater degree of curvature, and are more asymmetrical. The costae are sharper, and the basal cavity is much more flared on younger material.

Occurrence.--Beds 9-11, 13 and 14 at St. Pauls Inlet; limestone clast in Lower Head Formation at Martin Point.

Material.--31 symmetrical, 10 slightly symmetrical, and 9 asymmetrical elements.

Types.--Hypotypes, GSC 82685, 82686, 82688.

PROTOPANDERODUS GRADATUS Serpagli

Figures 12.7-12.11; 22.7-22.9, 22.11

Protopanderodus gradatus SERPAGLI, 1974, p. 59-61, Pl. 15, figs. 5a-8b, Pl. 26, figs. 11-15, Pl. 30, figs. 1a, b, text-fig. 17; LANDING, 1976, p. 639, Pl. 4, figs. 8, 9, 11, 12; ?ETHINGTON and CLARK, 1982, p. 84, 85, Pl. 9, figs. 16, 17, 20, 21; ?REPETSKI, 1982, p. 39, Pl. 17, figs. 1-5.

Remarks.--Symmetrical and sulcatiform elements belonging to *P. gradatus* are close to homologous elements of *P.* sp. aff. *P. gradatus* and *P. strigatus*. They differ from these other species in the degree of lateral compression of the basal cavity and the spacing and robustness of the lateral costae. Elements assigned to this species by Ethington and Clark (1982) and Repetski (1982) appear to have a more rounded to oval basal cross section and wider spaced lateral costae. These elements may belong to *P. strigatus*. The apparatus of *P. gradatus* seems to lack asymmetrical acontiodiform elements.

Occurrence.--Beds 11 and 14 at St. Pauls Inlet; Beds 11 and limestone clast in Lower Head Formation at Martin Point.

Material.--23 symmetrical, 30 asymmetrical acontiodontiform and 8 scandodontiform elements.

Types.--Hypotypes, GSC 82689-82691.

PROTOPANDERODUS LEONARDII Serpagli

Figures 13.1, 13.2, 13.6, 13.9, 23.22, 23.26-23.28

Protopanderodus leonardii SERPAGLI, 1974, p. 61-63, Pl. 16, figs. 1a-4c, Pl. 27, figs. 12-16, text-fig. 18; ETHINGTON and CLARK, 1982, p. 85, Pl. 9, figs. 18, 22, 23; REPETSKI, 1982, p. 40, Pl. 17, figs. 8, 10, text-fig. 6X.

Remarks.--Sulcatiform and scandodontiform elements are included in *P. leonardii*. These elements have not been previously reported for this species (e.g. Serpagli, 1974; Ethington and Clark, 1982). Sulcatiform elements have a short base and erect cusp, with an antero-lateral groove on one side. Scandodontiform elements are costate, with two major costae developed on the outer-lateral and inner-anterior edges of the base. Several minor costae may occur on the inner lateral surface of the base between the major costae. Slightly asymmetrical elements are included in this species. They have twisted cusps with respect to the base. In younger specimens, the cusps tend to become more concavo-convex in cross section.

Occurrence.--Beds 9-11 and 13 at St. Pauls Inlet; Beds 11 and 19 at Martin Point.

Material.--15 asymmetrical, 12 symmetrical, 2 sulcatiform and 13 scandodontiform elements.

Types.--Hypotypes, GSC 82692-82694.

PROTOPANDERODUS RECTUS (Lindström)

Figures 12.18-12.21, 12.31, 12.32, 22.1-22.4, 22.5, 22.6

Acontiodus rectus LINDSTRÖM, 1955, p. 549, Pl. 2, figs. 7- 11, text-figs. 2K-M, 3B.

?*Protopanderodus graeai* (Hamar), LÖFGREN, 1978, p. 93, 94, Pl. 3, figs. 19-25, text-fig. 31K-M; NOWLAN, 1981, p. 14, Pl. 3, figs. 9, 11, 13.

?*Protopanderodus parvibasis* LÖFGREN, 1978, p. 93, Pl. 3, figs. 11-18, text-figs. 31D-F.

Protopanderodus rectus (Lindström), LÖFGREN, 1978, p. 90, 91, Pl. 3, figs. 2-7, 36A, B, *non* fig. 1, text-figs. 31A-C (contains synonymy to 1978 (in part)); NOWLAN, 1981, p. 15, Pl. 1, figs. 6, 7.

?*Protopanderodus rectus*? (Lindström), NOWLAN, 1981, p. 15, Pl. 1, figs. 8, 11, Pl. 3, figs. 8, 10.

Protopanderodus sp. LÖFGREN, 1978, p. 95, Pl. 3, figs. 8-10.

Protopanderodus sp. cf. *P. rectus* (Lindström), REPETSKI, 1982, p. 40, Pl. 17, fig. 9, Pl. 18, figs. 2-3.

Remarks.--The majority of symmetrical and sulcatiform elements resemble homologous elements of *P. graeai* in basal outline (Löfgren, 1978, Pl. 3, figs. 19, 20). These latter elements occur in late middle Kundan and younger strata in Balto-Scandia (Löfgren, 1978). The oldest occurrence of symmetrical acontiodontiform and sulcatiform elements with long and short laterally compressed bases in the Cow Head Group is near the base of the *Oepikodus evae* Zone. Asymmetrical acontiodiform elements at this level and higher up appear to agree with the description of the same element of *P. graeai* in Löfgren (1978). However, only a few scandodontiform elements carry an inner costa.

The sulcatiform element is apparently absent in *P. graeai*. This species may be conspecific with *P. rectus*, having similar symmetrical acontiodiform elements. The sulcatiform element may have been lost during the evolution of the apparatus.

Elements like *Protopanderodus* sp. (Löfgren, 1978) are included in *P. rectus*. These forms occur in younger horizons with the latter species. They may reflect a trend towards asymmetry in non-sulcate acontiodontiform elements. Scandodontiform elements appear to show a great deal of variation in their morphology, especially near the base of Bed 13 at St. Pauls Inlet. However, this variation is not systematic, so it does not seem to have any taxonomic significance.

Occurrence.--Beds 10, 11, 13 and 14 at St. Pauls Inlet; Beds 11 and 13 and limestone clast in Lower Head Formation at Martin Point.

Material.--117 symmetrical and 48 asymmetrical acontiodontiform, 81 sulcatiform, and 110 scandodontiform elements.

Types.--Hypotypes, GSC 82695-82698.

PROTOPANDERODUS STRIGATUS Barnes and Poplawski

Figures 13.10, 13.11, 13.15, 13.16, 13.22, 23.14, 23.15, 23.18, 23.19, 23.23

Protopanderodus strigatus BARNES and POPLAWSKI, 1973, p. 784, Pl. 3, figs. 14, 17, text-fig. 2E; STOUGE, 1984, p. 50, 51, Pl. 2, figs. 15-16, 18-24.

?*Walliserodus iniquus* (Viira), LÖFGREN, 1978, p. 116, 117, Pl. 4, figs. 15-26.

Remarks.--Several strongly costate asymmetrical elements of this species seem to be indistinguishable from homologous elements of *P. gradatus*. This element has a rounded anterior margin, and is much less laterally compressed in cross section basally. It is also distinguished from the same element of *P. gradatus* by having a antero-lateral goove on the side opposite the strongly costate face.

Elements of *W. iniquus* appear to show the same general shape and arrangement of costae as those identified herein as *P. strigatus*. The former species seems close to if not conspecific with the latter.

Occurrence.--Beds 13 and 14 at St. Pauls Inlet; Bed 11 and limestone clast in Lower Head Formation at Martin Point.

Material.--26 symmetrical and 5 asymmetrical acontiodontiform elements.

Types.--Hypotypes, GSC 82699-82701.

PROTOPANDERODUS sp. aff. P. GRADATUS Serpagli

Figures 12.16, 12.17, 12.27-12.30, 22.10, 22.12-22.16

aff. *Protopanderodus gradatus* SERPAGLI, 1974, p. 59-61, Pl. 15, figs. 5a-8b, Pl. 26, figs. 11-15.

Description.--Simple cone apparatus consisting of symmetrical and asymmetrical acontiodontiform, sulcatiform, and scandodontiform elements. Shallow grooves are commonly developed on antero-lateral faces of first three forms. Elements laterally compressed, with bases expanded posteriorly. Oral margins keeled in acontiodontiform and sulcatiform elements, straight to strongly concave. Oral margin forms continuous curve with posterior margin of cusp; meets aboral margin at acute or right angle. Aboral margin gently convex. Basal cavity laterally compressed cone, extending a third to half the length of the base, with the apex situated close to the mid line. Antero-basal angle slightly obtuse with anterior margin of base and cusp form continuous smooth curve. Cusp albid, proclined to semi-erect, with posterior keel flanked by a postero-lateral costa in acontiodontiform and sulcatiform elements. Cusp may exhibit varying degrees of torsion with respect to base; anterior margin may form keel.

Symmetrical acontiodontiform elements laterally compressed with posterior keel on the cusp and base flanked by a pair of postero-lateral costae. Antero-lateral groove on these elements most strongly developed below the postero-lateral costae on the base. Asymmetrical acontiodontiform have one postero-lateral costa whch is more strongly developed than the other, and directed posteriorly.

Sulcatiform element has narrow lateral groove on one side opening proximally on base to produce recess. Edges of grooves may be costate or carinate in some specimens. Slight symmetry transition series developed in this element with sides opposite lateral groove having strong or weak poster-lateral costa.

Scandodontiform elements lanceolate in cross section, with lateral groove situated about one-third the width of cusp away from anterior margin. Flat flange developed between groove and anterior margin on base, broadening aborally.

Remarks.--As noted under *P. gradatus*, this species is close to *P. gradatus* and *P. strigatus*. However, the composition of the apparatus differs. *P.* sp. aff. *P. gradatus* has asymmetrical acontiodiform elements. These elements are lacking in *P. gradatus*. *P. strigatus* appears to lack both asymmetrical acontiodontiform and scandodontiform elements. The apparatus of *P.* sp. aff. *P. gradatus* is close to that of *P. rectus*.

Elements found in the highest sample (dMP 56C) resemble the symmetrical acontiodontiform, sulcatiform, and scandodontiform elements from older strata but are less compressed and have more rounded margins.

Occurrence.--Bed 11 at St. Pauls Inlet; Bed 11 and limestone clast in Lower Head Formation at Martin Point.

Material.--23 symmetrical, 9 asymmetrical acontiodontiform, 17 sulcatiform, and 7 scandodontiform elements.

Types.--Figured specimens, GSC 82702-82705.

PROTOPANDERODUS sp. aff. P. RECTUS (Lindström)

Figures 13.20, 13.21, 13.23-13.25, 22.22, 22.23, 22.27-22.29

aff. *Acontiodus rectus* LINDSTRÖM, 1955, p. 549, Pl. 2, figs. 7-11, text-figs. 2k-m, 3B.

aff. *Protopanderodus rectus* (Lindström), LÖFGREN, 1978, p. 90, 91, Pl. 3, figs. 2, 3, 36A, B, *non* figs. 1, 4-7 (contains synonymy to 1978).

Remarks.--Symmetrical, slightly asymmetrical, and asymmetrical acontiodontiform elements are assigned to this species. Most elements have a slightly to moderately sinuous aboral margin similar to those in the apparatus of *P. rectus*. In younger samples, the aboral margin is more angular, comparable to that of *A. rectus* s.f. (Lindström, 1955, Pl. 2, fig. 10, text-fig. 2l and Löfgren, 1978, Pl. 3, figs. 2, 3 and 36A, B). Asymmetrical acontiodiform elements are virtually identical to those of *P. cooperi*. Only a few scandodontiform elements were found. Their appearance is strongly suggestive of *Juanognathus jaanussoni*.

P. sp. aff. *P. rectus* may be an ancestor to *P. cooperi*, with probable change in symmetrical acontiodontiform element with the aboral margin of this element becoming more sinuous, and finally developing the antero-basal "notch" of *P. cooperi*. Younger specimens of this element have an aboral margin that is either slightly or moderately sinuous. These elements also appear to exhibit the same arrangement of posterior costae on the cusp as seen in *P. cooperi*. Hence they may have the same symmetry transition series. This feature in both *P. cooperi* and *P.* sp. aff. *P. rectus* suggests the apparatuses of these species are related.

Occurrence.--Bed 13 at St. Pauls Inlet; Bed 11 at Martin Point.

Material.--12 symmetrical, 9 asymmetrical acontiodontiform and 3 ?scandodontiform elements.

Types.--Figured specimens, GSC 82706-82708.

PROTOPANDERODUS sp. cf. P. VARICOSTATUS Sweet and Bergström

Figures 12.1-12.6; 12.12-12.15; 12.22-12.26; 23.1-23.13, 23.16, 23.17

cf. *Scolopodus varicostatus* SWEET and BERGSTRÖM, 1962, p. 1247, 1248, Pl. 168, figs. 4-9, text-figs. 1A, C, K.

Protopanderodus cooperi (Sweet and Bergström), BARNES and POPLAWSKI, 1973, p. 783, Pl. 4, fig. 8, *non* Pl. 3, figs. 1, 4, 5, Pl. 4, fig. 15.

Protopanderodus cf. *varicostatus* (Sweet and Bergström), LÖFGREN, 1978, p. 91-93, Pl. 3, figs. 26-31 (contains synonymy to 1978); STOUGE, 1984, p. 51, 52, Pl. 3, figs. 11-15, 17A, B, *non* fig. 16.

Protopanderodus gradatus Serpagli, LANDING and LUDVIGSEN, 1984, p. 1487, Pl. 1, fig. 7.

Protopanderodus rectus (Lindström), MERRILL, 1980, Fig. 6:17.

Protopanderodus varicostatus (Sweet and Bergström), BERGSTRÖM, 1978, Table 1, Pl. 79, figs. 6, 7; SIMES, 1980, p. 530, Fig. 6; GASTIL and MILLER, 1981, Table 1, Figs. 2j, k; NOWLAN and THURLOW, 1984, p. 293, 294, Pl. 2, figs. 1-3, 8.

Scolopodus n. sp. 2 UYENO and BARNES, 1970, p. 116, 117, Pl. 21, figs. 3-5, text-fig. 7A.

Remarks.--Most elements assigned to *P.* sp. cf. *P. varicostatus* lack the prominent antero-basal "notch" characteristic of *P. varicostatus* (Sweet and Bergström, 1962) as also noted by Löfgren (1978). Some scandodontiform elements in the youngest Cow Head sample (dMP 56C) are close to *S. unistriatus* Sweet and Bergström s.f., the presumed scandodontiform element of *P. varicostatus* (Löfgren, 1978). The occurrence of these elements may imply that *P. varicostatus* is present, but the writer follows Löfgren (1978) in assigning elements of this type to a possibly separate taxon.

Early representatives of this species occur near the base of the *Oepikodus evae* Zone in Bed 11 at St. Pauls Inlet. At this level the angle between the anterior and posterior portions of the basal margin is slightly obtuse in most asymmetrical drepanodontiform elements. This angle becomes a right angle in younger specimens. This transition appears to be gradual, so that assigning these older elements to a separate taxon may be difficult.

Fine to coarse to striations occur on the posterior and postero-lateral surfaces of asymmetrical drepanodontiform and scandodontiform elements. There appears to be no regular pattern of occurrence of this feature. Scandodontiform elements also have variable cross sections with some lanceolate like *S. unistriatus* s.f. while others are triangular with the inner lateral and posterior faces of the element meeting at right angles. There are also elements intermediate between these character states.

Occurrence.--Beds 11, 13, and 14 at St. Pauls Inlet; Beds 11, 13, and 14 and limestone clast in Lower Head Formation at Martin Point.

Material.--15 symmetrical acontiodontiform, 128 asymmetrical drepanodontiform, and 51 scandodontiform elements.

Types.--Figured specimens, GSC 82710-82717.

Genus PROTOPRIONIODUS McTavish, 1973

Type species.--*Protoprioniodus simplicissimus* McTavish, 1973.

PROTOPRIONIODUS ARANDA Cooper

Figures 20.17, 20.22-20.24, 20.26, 20.30

Protoprioniodus aranda COOPER, 1981, p. 175, 176, Pl. 30, figs. 1, 6, 7, 10, 12; ETHINGTON and CLARK, 1982, p. 86, 87, Pl. 9, figs. 24-30 (contains synonymy to 1981).

New Genus A (Sweet, Ethington and Barnes), REPETSKI, 1982, p. 56, Pl. 27, figs. 1-6.

Protoprioniodus sp. A STOUGE, 1982, p. 42, Pl. 5, figs. 5-7.

?*Protoprioniodus* sp. B STOUGE, 1982, p. 42, Pl. 6, figs. 9-11.

Protoprioniodus yapu COOPER, 1981, p. 178, Pl. 30, figs. 3-5, 8, 9, 11, 13.

Remarks.--Elements of *P. yapu* described by Cooper (1981) are included in *P. aranda*. These elements have sharp, reclined, carinate cusps with an arched and keeled posterior process. Two types are distinguished: those with and those lacking an extended anterior process. Those with the anterior process resemble oistodontiform elements of *Microzarkodina marathonensis* of Ethington and Clark (1981) and always occur with other elements of *P. aranda* in the Cow Head collections. They are similar in both external morphology and development of white matter. They may occupy the "Pa" and "Pb" (f and g) positions in the apparatus of *P. aranda*.

P. arandu and *P. simplicissimus* overlap in range near the top of Bed 11 at St. Pauls Inlet. Some juvenile oistodontiform elements of *P. aranda* resemble some adult specimens of *P. simplicissimus*. This may suggest that the evolution of the one species into the other is gradual, with *P. simplicissimus* evolving into *P. aranda* by progressive elongation and arching of the anterior and posterior processes of the elements.

Occurrence.--Beds 11, 13, and 14 at St. Pauls Inlet; Beds 11 and 13 at Martin Point.

Material.--121 prioniodiniform, 51 ramiform, and 121 oistodontiform elements.

Types.--Hypotypes, GSC 82718-82722.

PROTOPRIONIODUS PAPILIOSUS (van Wamel)

Figures 20.18-20.21

Oistodus papiliosus VAN WAMEL, 1974, p. 76, 77, Pl. 1, figs. 18-20.

Gen. Nov. B n. sp. 1 SERPAGLI, 1974, p. 77, Pl 19, figs. 4a, b, Pl. 29, figs. 4, 5, text-fig. 26.

Protoprioniodus papiliosus (van Wamel), ETHINGTON and CLARK, 1982, p. 87, 88, Pl. 10, fig. 5.

Remarks.--Ethington and Clark (1982) suggested that the triangulariform element might be an aberrant ramiform element of *P. aranda* Cooper. Oistodontiform and deltiform elements of *P. papillosus* like those illustrated by van Wamel (1974) were recovered in small numbers in the Cow Head Group with this element. The occurrence of these elements together is evidence that the triangulariform element does not belong in the apparatus of *P. aranda*.

Occurrence.--Beds 9-11 and 13 at St. Pauls Inlet; Bed 11 at Martin Point.

Material.--31 triangulariform, 4 deltiform, and 24 oistodontiform elements.

Types.--Hypotypes, GSC 82723-82725.

PROTOPRIONIODUS SIMPLICISSIMUS McTavish

Figures 20.25, 20.27-20.29, 20.32, 20.33

Protoprioniodus simplicissimus McTAVISH, 1973, p. 48, 49, Pl. 2, figs. 6, 8, 9.

Remarks.--Oistodontiform elements with elongate anterior and posterior processes and weakly develped carinae on the cusp are included in this species. Most oistodontiform elements included in *P. simplicissimus* have strongly carinate cusps with prominent anterior and posterior flanges developed on the cusp and base. Elements similar to *P. yapu* are included in this species, although these have posterior processes which are shorter and more arched.

Occurrence.--Beds 9-11 at St. Pauls Inlet.

Material.--44 prioniodiniform, 25 ramiform, and 85 oistodontiform elements.

Types.--Hypotypes, GSC 82726-82730.

PROTOPRIONIODUS? sp.

Figure 20.31

Description.--Blade-like element with sharp, triangular cusp and narrow base with medial constriction. Base separated from cusp by sharp ridge or ledge. Base hyaline, rectangular in lateral view, with square antero- and postero-basal corners. Base constricted in middle portion, flares orally and aborally. Aboral margin nearly straight, with basal cavity forming narrow slit. Cusp albid, reclined, triangular in lateral view, with anterior edge straight or slightly convex. Posterior margin straight or slightly concave; forms notch with short oral margin. Anterior and posterior edges sharp, forming keels. Inner side of cusp carinate anteriorly, with flange proximal to base. Outer side cusp broadly convex; tip flexed inward. Sharp ledge formed of junction of base and cusp on inner side, same ledge subdued on outer side.

Remarks.--These elements are tentatively assigned to *Protoprioniodus*, although a full apparatus cannot be reconstructed. In the youngest sample (dMP 56C) containing *Protoprioniodus*? sp., oistodontiform elements associated with "*Microzarkodina*" *marathonensis* (Bradshaw) may possibly be associated with this form. However,. *Protoprioniodus*? sp. is more albid and robust than these elements.

Occurrence.--Beds 11 at St. Pauls Inlet; limestone clast in Lower Head Formation at Martin Point.

Material.--72 specimens.

Types.--Figured specimen, GSC 82731.

Genus SCANDODUS Lindström, 1971

Type species.--*Scandodus furnishi* Lindström, 1971.

"SCANDODUS" FLEXUOSUS Barnes and Poplawski s.f.

Figures 25.24, 25.25

Scandodus flexuosus BARNES and POPLAWSKI, 1973, p. 785, Pl. figs. 1, 4, text-fig. 2L.

Remarks.--White matter is much more extensively developed in elements of this form species in the Cow Head collections than in those described by Barnes and Poplawski (1973). This element may belong in the apparatus of *Acodus*? *robustus* (Serpagli) (see Remarks for that species).

Occurrence.--Beds 11 and 13 at St. Pauls Inlet.

Material.--17 specimens.

Types.--Hypotype, GSC 82738.

SCANDODUS FURNISHI Lindström

Figures 21.17, 21.18, 21.22-21.25

Scandodus furnishi LINDSTRÖM, 1955, p. 592, Pl. 5, fig. 3; REPETSKI, 1982, p. 42, Pl. 20, figs. 3, 4 (contains synonymy to 1982).

?*Drepanodus* cf. *D. conulatus* Lindström s.f.; REPETSKI, 1982, p. 20, Pl. 6, fig. 6.

?*Drepanodus subarcuatus* Furnish, MOUND, 1965a, p. 19, Pl. 2, fig. 19, *non* figs. 14, 18.

Drepanoistodus conulatus (Lindström), VAN WAMEL, 1974, p. 63, 64, Pl. 3, figs. 1-4.

?*Scandodus sinuosus* Mound, ETHINGTON and CLARK, 1982, p. 94-96, Pl. 11, fig. 4, *non* figs. 1-3, 5.

?*Trigonodus larapintinensis* (Crespin), COOPER, 1981, p. 180, Pl. 27, fig. 12, *non* figs. 5, 6, 11, 16, 17.

Remarks.--Several elements have been assigned to this species. Of special interest are erect drepanodontiform elements with the basal portion of their anterior keels directed laterally and posteriorly (Figure 21.24). These elements occur in middle Arenig strata together with other forms assigned to this species. Other possible occurrences are noted in the synonymy list. These elements may occupy a "scandodontiform" position in the apparatus. Alternatively, they could be scandodontiform elements in the apparatus of *S. sinuosus* (Mound). However, in Ethington and Clark's (1982) description of the scandodontiform element of this latter species, the anterior and posterior keels are basally pointed antero-posteriorly. The Cow Head specimens do not exhibit this feature, instead, the anterior keel has the configuration noted above. They have the same colouration pattern as other elements assigned to *S. furnishi* at this level, with a distinct albid growth axis developed in the cusp.

Specimens of *S. furnishi* occurring in late Arenig strata in the Cow Head Group are generally larger and more robust than those occuring in the early Arenig. The bases are shorter in drepanodontiform elements, and the oral margins appear more concave. These elements may belong to a separate species but being few in number, they are retained in *S. furnishi*.

Occurrence--Beds 9, 10, and 13 at St. Pauls Inlet; Beds 8, 11, 14 and limestone clast in Lower Head Formation at Martin Point.

Material.--33 drepanodontiform, 9 oistodontiform, 5 scandodontiform, and 3 suberectiform elements.

Types.--Hypotypes, GSC 82740-82743.

SCANDODUS sp. cf. S. BREVIBASIS (Sergeeva)

Figures 21.1, 21.2, 21.7, 21.10-21.14

Oistodus brevibasis SERGEEVA, 1963a, p. 95, Pl. 7, figs. 4, 5, text-fig. 2.

Scandodus brevibasis (Sergeeva), LÖFGREN, 1978, p. 104, Pl. 1, figs. 30-35 (contains synonymy to 1978).

Remarks.--White matter is extensively developed in the cusps of elements fitting the description of *S. brevibasis*. This species is normally considered to be hyaline (Lindström, 1971). The proximal end of the growth axis is visible in most specimens. The distal portion of the growth axis of Cow Head specimens of *S. brevibasis* is diffuse. Ethington (1972) noted the presence of white matter in elements he called *S. brevibasis* in the Nilemile Formation It was his opinion that these elements should be assigned to a separate genus and species (Ethington, 1972).

No oistodontiform elements of *S.* sp. cf. *S. brevibasis* were recognized in the Cow Head collections.

Occurrence.--Bed 13 at St. Pauls Inlet and limestone clast in Lower Head Formation at Martin Point.

Material.--6 acodontiform, 6 drepanodontiform, and 3 distacodontiform elements.

Types.--Figured specimens, GSC 82748-82751.

Genus SCOLOPODUS Pander, 1856

Type species.--*Scolopodus sublaevis* Pander, 1856.

"SCOLOPODUS" PESELEPHANTIS Lindström

Figure 29.3

Scolopodus? *peselephantis* LINDSTRÖM, 1955, p. 595, Pl. 2, figs. 19, 20, text-fig. 3Q; LÖFGREN, 1978, p. 108, 109, Pl. 4, figs. 43-47 (contains synonymy to 1978); ETHINGTON and CLARK, 1982, p. 102, 103, Pl. 11, fig. 26.

Scolopodus peselephantis Lindström, BEDNARCZYK, 1979, p. 434, 435, Pl. 4, fig. 9; ?SZANIAWSKI, 1980, p. 116, 117, Pl. 18, figs. 3, 4.

"*Scolopodus*" *peselephantis* Lindström, NOWLAN, 1981, p. 13, Pl. 5, figs. 10, 11.

Remarks.--Specimens of "*S.*" *peselephantis* in the Cow Head Group appear to show the same evolutionary trends as those found in Lower to Middle Ordovician strata in Jämtland, Sweden (Löfgren, 1978). Asymmetrical and symmetrical forms intermediate between early and later forms of this species occur in one sample (dMP 16) in lower strata sampled at Martin Point. These forms have laterally compressed, striated cusps that are straight or twisted laterally. A sharp keel is developed posteriorly. A slight groove or indentation may be detected on the inner side of the cusp of asymmetrical elements. Symmetrical forms may have a slight ridge developed on both sides, followed by a constriction at the point of greatest curvature. Distally from this constriction, the cusp is laterally compressed and keeled, but rounded in cross section proximally.

Occurrence.--Beds 9-11 and 13 at St. Pauls Inlet; Beds 8-10, and 13 at Martin Point.

Material.--151 specimens.

Types.--Hypotype, GSC 82754.

Genus SPINODUS Dzik, 1976

Type species.--*Cordylodus spinatus* Hadding, 1913.

Emended diagnosis.--Multielement apparatus comprising of prioniodiniform, oulodontiform, falodontiform and multiramiform elements. Elements have hyaline, elongate and narrow denticulated processes. Cusp and denticles are elongate, reclined, and laterally compressed with denticles commonly alternating from side to side on the posterior process. Basal cavity commonly inverted on posterior process of multiramiform elements. Angle between anterior and posterior processes commonly approaches 90 degrees. Distal ends of anterior and posterior processes commonly connected by broad and thin basal sheath.

Remarks.--In previous discussions of *Spinodus* only the multiramiform elements were considered. They were shown to comprise a symmetry transition series of cordylodiform-ligonodiniform- cladognathiform-trichonodelliform elements (Lindström, 1964; Uyeno and Barnes, 1970; Barnes and Poplawski, 1973; Dzik, 1976). The occurrence of falodontiform, prioniodiniform, and oulodontiform elements similar in gross morphology to multiramiform elements of *Spinodus* in Cow Head strata suggests that the apparatus of this genus (Figure 14) is similar to that of *Periodon* Hadding. Uyeno and Barnes (1970) have already noted that the multiramiform elements of *Spinodus* have nearly the same symmetry transition series as the latter genus.

The apparent absence of these elements in other reported occurrences of *Spinodus* might be explained by the relatively few numbers of these elements recovered per sample. However, Repetski and Ethington (1977) reported the occurrence of 16 specimens of *C. spinatus* s.f. in one sample from the Womble Shale of Arkansas. They did not comment on variation among these elements.

SPINODUS sp. cf. S. SPINATUS (Hadding)

Figures 14A-K, 18.1, 18.2, 18.5-18.7, 18.11, 18.13, 18.14

cf. *Polygnathus spinatus* HADDING s.f., 1913, p. 32, Pl. 1, fig. 8.

cf. *Cordylodus spinatus* (Hadding), NASSEDKINA, 1975, p. 123, Pl. 4, fig. 11; REPETSKI and ETHINGTON, 1977, Pl. 2, fig. 20; TIPNIS, CHATTERTON and LUDVIGSEN, 1978, Pl. 8, fig. 16.

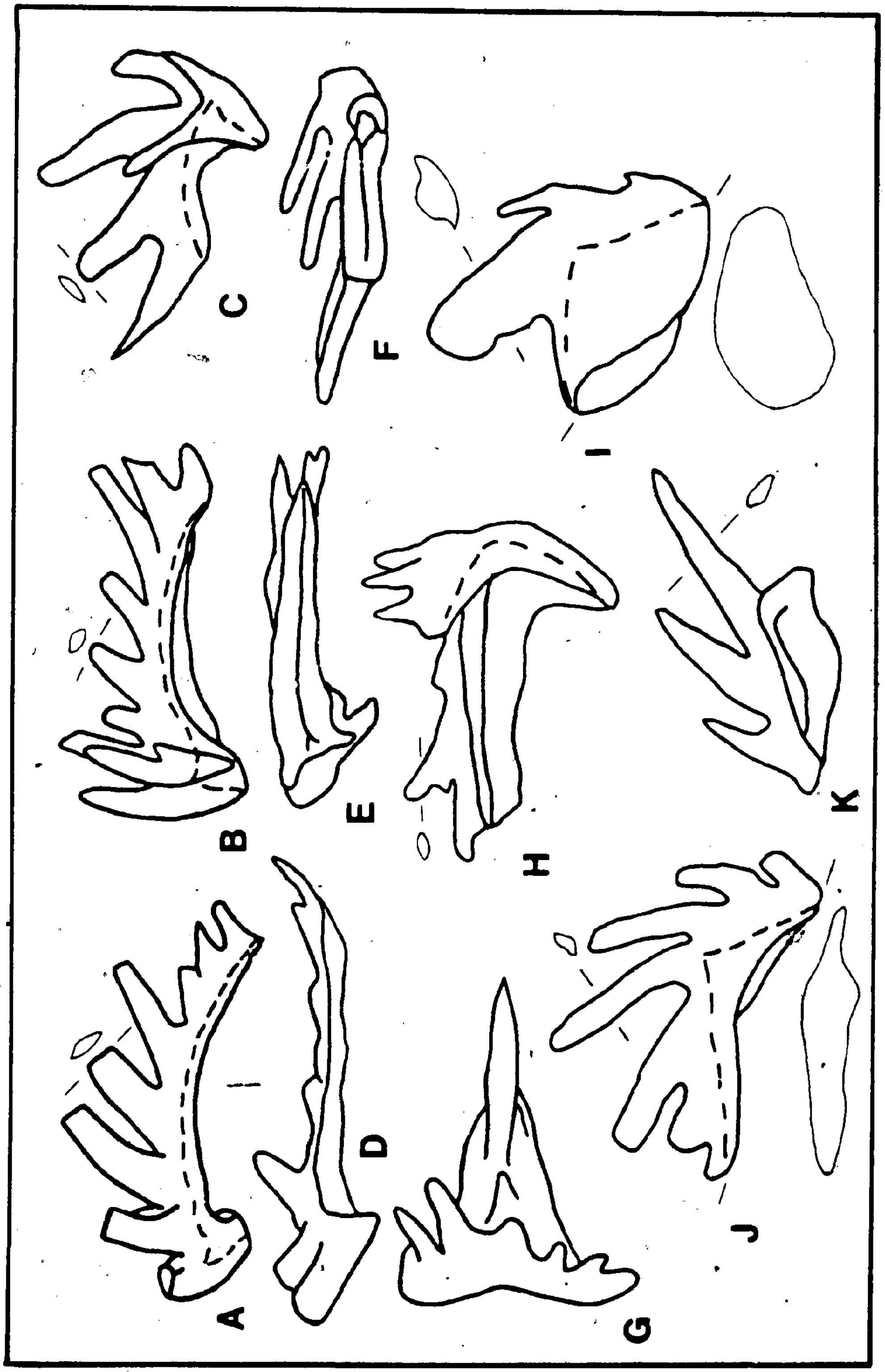
?*Cordylodus* sp. aff. *C. spinatus* (Hadding), LANDING, 1976, p. 631, Pl. 1, fig. 14 (contains synonymy to 1976).

cf. *Spinodus spinatus* (Hadding), DZIK, 1976, text-fig. 21c.

Description.--Multielement ramiform apparatus consisting of prioniodiniform, oulodiform, falodontiform, and multiramiform elements. The multiramiform series has been described extensively in the literature and is not described herein.

Prioniodiniform elements blade-like, with basal cavity situated medially. Aboral margin almost straight or curved; commonly sinuous. Apex of basal cavity situated beneath third or fourth denticle. Basal cavity extends to tips of both anterior and posterior processes. Cavity flares laterally near apex. Denticles mostly albid, lanceolate in cross section; anterior denticles may be hyaline. Denticles small, recurved anteriorly, become larger and more reclined posteriorly, pointing alternately from side to side.

FIGURE 14--Apparatus of *Spinodus* sp. cf. *S. spinatus* (Hadding) showing outline of basal cavities and cross-sections of cusps of all elements and basal cavities of falodontiform and prioniodiniform elements; A, D, lateral and aboral views, cordylodontiform element, GSC 82761, X 107 and X 110; B, E, lateral and aboral view, cladognathiform element, GSC 82760, X 107 and X 116; C, F, lateral and aboral view, ligonodiniform element, GSC 82763, X 120 and X 160; G, oral view, trichonodelliform element, GSC 82687, X 143; H, aboral-lateral view, trichonodelliform element, GSC 82762, X 143; I, lateral view, falodontiform element, GSC 82765, X 200; J, lateral view, prioniodiniform element, GSC 82766, X 133; K, aboral-lateral view, falodontiform element, GSC 82764, X 185.


A
B
C
D
E
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G
H
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K

Oulodontiform elements asymmetrical, with broad expanded base with posterior and anterior processes meeting at oblique angle in oral view and nearly right angle in lateral view. Base broad, expansive, with basal sheath connecting tips of posterior and anterior processes. Outer side of base broadly convex. Posterior process denticulate, with denticles albid, reclined, and lanceolate in cross section, with sharp posterior and anterior keels. Denticles appear to point alternately inwards and outwards slightly. Anterior process also denticulate, with denticles pointing inwards laterally and slightly posteriorly.

Falodontiform elements inwardly bowed, with posteriorly expanded short base and anterior process carrying commonly several inwardly directed denticles. Base mostly hyaline, asymmetrically to symmetrically triangular in lateral view. Oral margin short, slightly curved, meets posterior margin of cusp at near right angle. Aboral and oral margins meet at nearly forty-five degrees. Aboral margin sinuous, with posterior portion convex downward. Base roughly wedge-shaped in aboral view, with inner side expanded posteriorly. Anterior margin of element flange-like, commonly carrying several denticles. Denticles albid, sub-rounded in cross section, keeled anteriorly and posteriorly. Cusp reclined, albid, lanceolate in cross section, sharply keeled anteriorly and posteriorly. Prominent carina developed on inner side of cusp, extends onto base as slight bulge. Outer sides of denticles and cusp highly convex; outer side of base slightly convex.

Remarks.--Multiramiform elements of *S.* sp. cf. *S. spinatus* differ from those of *Cordylodus spinatus* s.f. by having denticles on the posterior process spaced closely together. These denticles are albid. In other occurrences of *Spinodus* they are hyaline (e.g. Uyeno and Barnes, 1970; Barnes and Poplawski, 1973). No elements of *C. ramosus* Hadding s.f. occur in Cow Head strata. However, Nowlan (1981) reported that these elements were outnumbered by *C. spinatus* s.f. by a ratio of 7:1 in material from the Tetagouche Group of New Brunswick.

Prioniodiniform and oulodontiform elements are described and listed separately. It is possible that the oulodontiform elements are extreme variants of the prioniodiniform elements. This is suggested by the far greater number of prioniodiniform elements in comparison to oulodontiform elements. There are several prioniodiniform elements that are transitional between the two types.

Occurrence.--Beds 13 and 14 at St. Pauls Inlet; Bed 13 and limestone clast in Lower Head Formation at Martin Point.

Material.--15 prioniodiniform, 4 oulodontiform, 6 falodontiform, and 14 multiramiform elements.

Types.--Figured specimens, GSC 82687, 82760-82766.

Genus TRIANGULODUS van Wamel, 1974

Type species.--*Oistodus brevibasis* Sergeeva, 1963.

TRIANGULODUS sp. cf. T. SUBTILIS van Wamel

Figures 15.24-15.26

cf. *Triangulodus subtilis* VAN WAMEL, 1974, p. 97-99, Pl. 5, figs. 8-13.

Remarks.--The oral margins of acodontiform elements are straight, in contrast ot those of *T. subtilis* described by van Wamel (1974), which are concave. Aboral margins of drepanodontiform and acodontiform elements are straight or slightly convex. No erect scandodontiform and oulodontiform elements were found to occur with the elements discussed above.

Occurrence.--Beds 9-11 at St. Pauls Inlet; Bed 10 at Martin Point.

Material.--6 acodontiform, 22 drepanodontiform, and 11 trichonodelliform elements.

Types.--Figured specimens, GSC 82776-82778.

Genus ULRICHODINA Furnish, 1938

Type species.--*Acontiodus abnormalis* Branson and Mehl, 1933.

ULRICHODINA? sp. s.f.

Figures 29.4, 29.9

Remarks.--This specimen is tentatively placed in *Ulrichodina* Furnish although it probably belongs in some other genus. The single specimen recovered differs from other species of *Ulrichodina* by having white matter in the cusp. This specimen has low, sharp costae which are developed on the antero-lateral portion of the base. A single costa on each side extends onto the cusp.

The presence of sharp costae on this element may suggest that it may belong in an apparatus with elements assigned to New Genus A sp. (see Remarks for that species).

Occurrence.--Bed 11 at Martin Point

Material.--1 specimen

Types.--Figured specimen, GSC 82783.

Genus WALLISERODUS Serpagli, 1967

Type species.--*Acodus curvatus* Branson and Mehl, 1933.

WALLISERODUS AUSTRALIS Serpagli

Figures 19.5, 19.6, 19.8, 19.9, 19.16

Walliserodus australis SERPAGLI, 1974, p. 73-75, Pl. 19, figs. 5a-10c, Pl. 29, figs. 8-15, text-figs. 23, 24; LANDING, 1976, p. 641, 642, Pl. 4, figs. 16, 19, 22, 23; ETHINGTON, 1979, p. 5, text-fig. 4D; LANDING and LUDVIGSEN, 1984, p. 1485, 1487, Pl. 1, fig. 16.

Remarks.--Several multicostate specimens from a sample (StPI 42) in Bed 9 at St. Pauls Inlet appear to match descriptions of comptiform and pseudoquadratiform elements of *Tropodus comptus* (Branson and Mehl) (Kennedy, 1980). These same elements were included in an apparatus with asymmetrical multicostate, tricostate, and quadricostate forms in *W. comptus* by Ethington and Clark (1982). The latter type of elements occur in the Cow Head collections. Some small quadricostate forms may be juvenile multicostate elements, since a faint medial costa on the outer side was observed on some specimens. The similarity of the multicostate elements mentioned above to those of *W. comptus* and the occurrence of quadricostate elements with those normally associated with *W. australis* may suggest that both species are present. A recent work, however, has suggested that these species may be conspecific (Landing and Ludvigsen, 1984). As abundant material is not available, it is not possible to confirm this possibility, hence elements discussed above will be included in *W. australis*.

Occurrence.--Beds 9-10 at St. Pauls Inlet; Beds 11 and 14 at Martin Point.

Material.--22 three-costate, 16 four-costate, 15 five-costate, 28 multicostate elements.

Types.--Hypotypes, GSC 82784-82787.

7.2.3 Residual taxa

DREPANODONTIFORM ELEMENT A

Figure 29.16

Description.--Drepanodontiform (=homocurvatiform) element with suberect to proclined cusp. Outer side of element broadly convex while inner side nearly flat. Base small, with shallow, rounded basal cavity, and short straight oral margin. Anterior flange on base nearly forms process. Flange continuous with inwardly directed keel on cusp. Basal outline roughly oval.

Occurrence.--Beds 9-11, and 13 at St. Pauls Inlet; Bed 14 at Martin Point.

Material.--27 specimens

Type.--Figured specimen, GSC 82791.

DREPANODONTIFORM ELEMENT B

Figure 29.8

Description.--Laterally compressed drepanodontiform element with sharp, keeled anterior and posterior edges and basal cavity extending into cusp. Outer side of element convex, inner side concave. Base triangular, laterally compressed, with straight keeled oral margin. Oral and aboral margin meet at about 45 degrees. Aboral margin slightly sinuous. Basal cavity triangular with apex at junction of base and cusp and pointed anteriorly. Anterior portion of base flange-like, continuous with anterior margin of cusp. Albid cusp proclined, lanceolate in cross section. Posterior margin forms nearly right angle with oral margin.

Occurrence.--Bed 10 at St. Pauls Inlet.

Material.--6 specimens

Types.--Figured specimen, GSC 82792.

DREPANODONTIFORM ELEMENT C

Figures 29.12, 29.13

Description.--Drepanodontiform element with blade-like cusp and basal cavity with sides nearly equidimensional. Base triangular, with straight keeled oral margin meeting posterior margin of cusp at slightly obtuse angle. Oral and aboral margin meet at nearly 45 degrees, with aboral margin straight. Basal cavity conical, with sides nearly equidimensional in length. Sides of basal cavity flared laterally. Anterior portion of base flange or keel-like, continuous with cusp. Antero-basal angle approximately 45 degrees. Albid cusp slightly proclined, lanceolate in cross section with sharp anterior and posterior keels.

Remarks.--This element is distinguished from drepanodontiform element B by its equidimensional basal cavity, and the flared base. It differs from "*Oistodus*" sp. aff. "*O.*" *hunickeni* by the base being flared on both sides, rather than on one side in the latter species.

Occurrence.--Beds 10 and 11 at St. Pauls Inlet.

Material.--5 specimens.

Types.--Figured specimen, GSC 82793.

NEW GENUS A sp.

Figures 29.17-29.19

?*Protopanderodus varicostatus*? (Sweet and Bergström), NOWLAN, 1981, p. 15, Pl. 3, fig. 15, *non* Pl. 1, fig. 5.

?"*Scolopodus*" *giganteus* Sweet and Bergström s.f., NOWLAN, 1981, p. 13, Pl. 3, fig. 14; LANDING, 1976, p. 639, 640, Pl. 4, fig. 13 (contains synonymy to 1976).

Description.--Symmetrical and asymmetrical albid drepanodontiform elements with strong, posteriorly directed multiple costae developed on base. Base laterally compressed to moderately expanded with major portion situated posteriorly of the cusp. Lower part of base hyaline, upper part albid. Oral margin straight to slightly curved in symmetrical elements, somewhat concave in asymmetrical elements. Oral and aboral margins meet at approximately 45 degrees. Aboral margin mostly straight in lateral view. Basal cavity placed posteriorly with basal outline indistinct but appearing to be semicircular. Antero-basal angle slightly to moderately acute. Anterior margin of base forms either continuous curve with anterior margin of cusp or shows abrupt break in curvature at junction of base and cusp. Anterior margin of base may be keeled. Strong posteriorly directed costae developed on both sides of base, extending part way up the cusp. Costae become successively longer posteriorly. Most postero-oral set developed between postero-lateral ridges and posterior ridge proximally on cusp. Proximal ends of some costae may bifurcate towards aboral margin. Accessory costae may be developed in between major costae. Costae terminate short of aboral margin.

Cusp albid, recurved, *Acontiodus*-like in cross section proximally, lanceolate distally. Central posterior ridge flanked by postero-lateral ridges with faces between ridges concave. Postero-lateral ridges placed more anteriorly on cusp. Posterior ridge situated to one side in asymmetrical element. Antero-lateral faces straight or slightly concave or convex. Anterior margin sharp, may be keel-like.

Remarks.--The occurrence of strong posteriorly directed costae suggests that these elements should be assigned to a new genus. The presence of strong costae on *Ulrichodina*? sp. may suggest it may belong in the same apparatus as the elements described above. Both this form and elements of New Genus A sp. are retained as separate taxa because of the scarcity of material.

Occurrence.--Bed 11 at Martin Point.

Material.--3 symmetrical, 2 asymmetrical elements.

Types.--Figured specimens, GSC 82795, 82534.

NEW GENUS B sp.

Figures 28.11, 28.14

Description.--Broad elongate platform element with oral ridge ornamented with albid nodes, intersected by lateral ridge also with nodes near its anterior end. Element broad, flaring laterally and aborally from oral ridge, with undulating aboral margin. Outer side broadly convex, and inner side gently convex. Oral margin straight posteriorly in lateral view for three-quarters length of element. Anterior quarter rises up to and slopes down from apex, continuing straight anteriorly. Slight lobe developed opposite apex. Oral ridge also straight in oral view, twists inward past apex then straightens anteriorly. Several antero-oral and postero-aboral ridges developed; most anterior of these the strongest with nodes closely spaced and intersects oral ridge at apex of platform. Posterior ridges with nodes spaced widely apart, weakly developed. Slight recess developed behind anterior lateral ridge and oral ridge.

Remarks.--This single element in the Cow Head collections may have affinities to New Genus E sp., although it lacks the apical pit and ridges converging on it and the extensively developed ornamented outer oral surface.

Occurrence.--Bed 9 at St. Pauls Inlet.

Material.--1 specimen.

Type.--Figured specimen, GSC 82796.

NEW GENUS C sp.

Figures 28.22, 28.24, 28.25, 28.28

Description.--Triangular platform element with posterior process and node. Small denticles occur on posterior edge of main cusp and gently sloping posterior edge of posterior node. Main cusp high, triangular in cross section basally, laterally compressed distally, with sharp antero-lateral edges. Apex of cusp directed inwards, so that outer surface slopes away from aboral margin. Anterior face between antero-lateral edges flat or sightly arched. Slight postero-lateral ridge developed at junction of cusp and posterior process on outer side. Posterior process elongate, deflected inwardly from main axis of element at aproximately 30 degrees. Distal end rounded in oral view. Node developed in anterior portion of oral surface of process. Anterior edge of node steep, posterior edge sloped gently. Node separated from main cusp by gap. Aboral outline of cusp biconcave laterally, slightly convex anteriorly, same outline of posterior process straight laterally, rounded distally. Basal cavity deep, extends to apex of both cusp and node. Posterior margin of cusp and node denticulate; denticles small, discrete. Denticles developed on antero-lateral and postero-lateral edges. Surface ornamentation consists of low transverse carina and grooves.

Remarks.--These elements appear to be a very primitive platform, unlike those illustrated by Lindström (1955). They resemble in a superficial way elements of Gen. et. sp. nov. illustrated by Löfgren (1978, fig. 34A-F). These forms are subpyramidal, but lack the posterior process and denticulation of New Genus C sp.. One element is included with those described above with three processes basally. It may represent an early growth stage, or correspond to the "haddingodontiform" element in an apparatus analogous to that of *Pygodus* Lamont and Lindström.

Occurrence.--Bed 8 at Martin Point.

Material.--4 specimens.

Types.--Figured specimens, GSC 82797, 82798.

NEW GENUS D sp. s.f.

Figure 29.20, 29.21, 29.24, 29.25

Description.--Triangular coniform element with deep basal cavity extending to tip. Element triangular in lateral view with sharp edges tapering rapidly to tip. Sides of element biconvex, with some elements more strongly so than others. Tips may curve away from the plane of the element or are recurved.

Remarks.--These elements have a generalized form, and could be associated with many of the taxa described in this report. Their range appears to be restricted to the lower Arenig. One specimen was found in Bed 13 at St. Pauls Inlet, but being from a limestone conglomerate it may have been reworked from older strata.

Occurrence.--Bed 9 and 13 at St. Pauls Inlet; Bed 8 at Martin Point.

Material.--15 specimens.

Types.--Figured specimens, GSC 82799, 82800.

NEW GENUS E sp.

Figures 28.19, 28.23, 28.26, 28.27

Description.--Apparatus consists of platform and coniform elements. Platform element broad platform with strong, outwardly directed, undulating lateral flange. Inner side aborally directed, concave plate. Two sets of paired ridges developed on inner edge of element on either side and converging on central apical pit. Ridges consist of rows of short, stout, and albid nodes. One pair directed orally and inwards with ridges meeting at aproximately 30 degrees at pit. Apical end of ridges directed aborally and inwardly. Area between ridges concave, generally smooth with concentric growth lamellae commonly observed. Second pair of ridges directed inwardly. Innermost ridge with nodes generally smaller, more widely spaced across transverse ridges. Oral ridge runs along inner edge and nearly around outer edge of apical pit. Apical pit separates ridge pairs; pit deep, with depth one-third width of inner side. Outer flange undulating, broadly convex in oral outline on outside. Nodes developed radially and concentrically around apical area, situated on low transverse carina. Medial row of nodes opposite apical area flanked by auxiliary rows of nodes directed towards apical pit. Outer flange and inner side of element meet at aproximately 90 degrees. Basal cavity occupies entire underside; inner surface smooth with junctions of inner and outer sides and interareas between ridges meeting at central knob.

Coniform elements triangular in lateral view having either sharp, serrate or smooth, broadly rounded edges. Element may have either lateral process posteriorly directed with notch between lateral edge and main body of element, or sides that are smoothly rounded. Basal cavity extends to apex; basal outline elongate oval continuous with lateral process.

Remarks.--The elements described above are suggestive of *Pygodus* Lamont and Lindström in terms of general form but the platform element differs significantly from those normally assigned to this genus. The sides of ~~the platform~~ elements of *Pygodus* meet at a low angle of the anterior end. The oral surface of these elements have strong nodes arranged antero-posteriorly in rows. In New Genus E sp., the sides of the outer flange meet at oblique angles, and most nodes are weakly developed. The phylogenetic relationships of this species to other platform species is uncertain because of its sporadic occurrence. Complete specimens of platform elements occur only in one sample (StPl 71).

Occurrence.--Beds 9-11 at St. Pauls Inlet.

Material.--16 platform and 4 coniform elements.

Types.--Figured specimens, GSC 82801-82803.

SCANDODONTIFORM ELEMENT

Figures 29.22, 29.23

?"*Scandodus*" sp. 4, ETHINGTON and CLARK, 1982, p. 98, Pl. 11, fig. 11.

Description.--Sharply keeled element with base expanded to the inside. Base triangular in outline with straight oral keel. Aboral margin straight, basal cavity conical with apex situated near anterior margin. Inner side of base expanded while outer side is flat or slightly concave. Anterior portion of element forms keel that continues onto cusp. Albid cusp proclined, sharply keeled anteriorly and posteriorly with carinae developed on inner face. Outer side of cusp gently convex. Anterior keel turned outward and slightly downward basally.

Remark.--Forms described as "*Scandodus*" sp. 4 by Ethington and Clark (1982) might be conspecific, although they occur in much younger strata.

Occurrence.--Bed 9 at St. Pauls Inlet.

Material.--4 specimens.

Types.--Figured specimens, GSC 82794.

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PLATES AND PLATE DESCRIPTIONS

Sample numbers from which specimens were recovered are given in parentheses after type numbers.

FIGURE 15

1, 5, *Acodus*? *gladiatus* Lindström s.f., hypotypes; 1, postero-lateral view, GSC 82481 (StPl 71), X 116, specimen lost; 5, lateral view, GSC 82419(StPl 71), X 68.

2-4, 6-9, *Acodus deltatus* Lindström, hypotypes; 2, lateral view, drepanodontiform element, GSC 82413 (StPl 67), specimen lost; 3, lateral view, distacodontiform element, GSC 82414 (StPl 67), X 43; 4, lateral view, oistodontiform element, GSC 82515 (StPl 67), X 77; 6, lateral view, gothodontiform element, GSC 82416 (StPl 67); 7, lateral view, acodontiform element, GSC 82417 (StPl 67); 8, 9, lateral and posterior view, trichonodelliform element, GSC 82418 (StPl 67); 2, 4, 6, all X 77; 7-9 all X 68.

10, 11-14, *Acodus*? *robustus* Serpagli, lateral views, hypotypes; 10, acostate asymmetrical element, GSC 82420 (StPl 94); 11, 12, costate acodontiform element, GSC 82421 (StPl 94), X 43 and X 66; 13, 14, costate acodontiform element with "anticusp", GSC 82422 (StPl 94); 10, 13, and 14 all X 41.

15, 19, *Acodus*? *sweeti* (Serpagli), lateral views, hypotypes; 15, oistodontiform element, GSC 82441 (StPl 71), X 68; 19, acodontiform element, GSC 82442 (StPl 71), X 145.

16, 17, 20, 21, *Acodus*? sp., lateral views; 16, acodontiform element, GSC 82427 (StPl 75a); 17, trichonodelliform element, GSC 82428 (StPl 74); 20, gothodontiform element, GSC 82429 (StPl 71); 21, drepanodontiform element, GSC 82430 (StPl 71); 16 and 17 both X 43; 20 and 21 X 68.

18, 22, 23, 27, *Acodus*? *russoi* Serpagli, lateral views, hypotypes; 18, distacodontiform element, GSC 82423 (StPl 31), X 125, specimen lost; 22, trichonodelliform element, GSC 82424 (StPl 31), X 191; 23, oistodontiform element, GSC 82425 (StPl 31), X 133; 27, belodontiform element, GSC 82426 (StPl 31), X 383.

24-26, *Triangulodus* sp. cf. *T. subtilis* van Wamel; 24, lateral view, acodontiform element, GSC 82776 (StPl 71), X 166; 25, posterior view, trichonodelliform element, GSC 82777 (StPl 71), specimen lost; 26, lateral view, drepanodontiform element, GSC 82778 (StPl 71); 25 and 26 X 116.

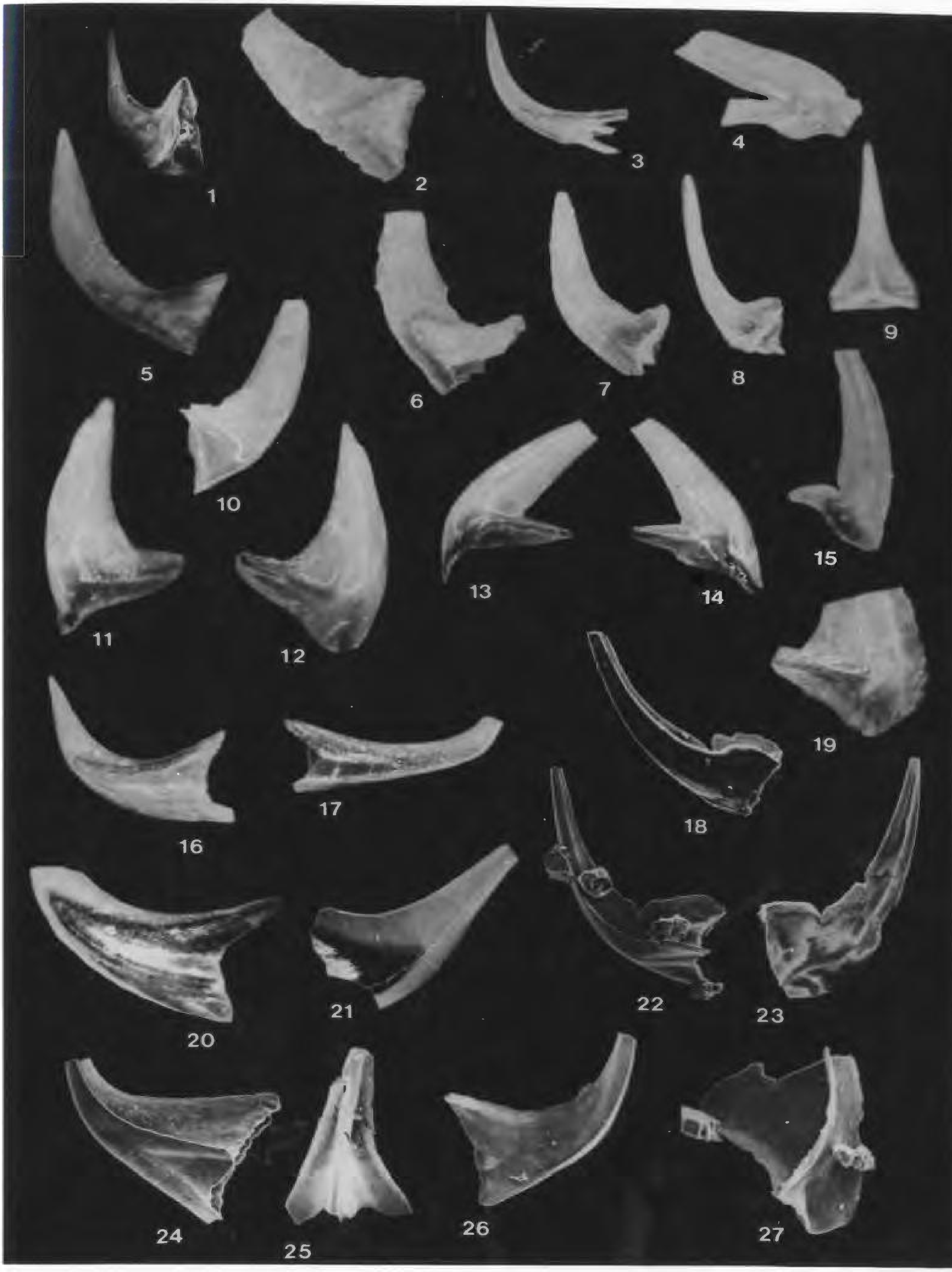
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FIGURE 16

1-5, 9, *Diaphorodus delicatus* (Branson and Mehl), hypotypes; 1, lateral view, oistodontiform element, GSC 82465 (StPI 73); 2, lateral view, drepanodontiform element, GSC 82466 (StPI 73); 3, 4, lateral and posterior views, trichonodelliform element, GSC 84467 (StPI 73); 5, lateral view, distacodontiform element, GSC 82468(StPI 73); 9, lateral view, acodontiform element, GSC 82469 (StPI 73), GSC (StPI 73), X 204; 1, 2, and 5 X 187; 3 and 4 X 217.

6-8, 10-13, 17, 21, *Acodus* sp. aff. *A. deltatus* Lindström; 6, 7, lateral views, acodontiform elements, GSC 82431 (StPI 86), GSC 82432 (StPI 86), latter specimen lost, both X 116; 8, lateral view, oistodontiform element, GSC 82433 (StPI 86), X 68; 10, lateral view, drepanodontiform element, GSC 82434 (StPI 86), X 68; 11, 12, lateral and posterior views, trichonodelliform elements, GSC 82435 (StPI 86), GSC 82436 (StPI 86), X 170 and X 116; 13, lateral view, gothodontiform element, GSC 82437 (StPI 86), X 68; 17, 21, lateral views, distacodontiform elements, GSC 82438 (StPI 86), GSC 82439 (StPI 86), both X 116.

14-16, *Oepikodus communis* (Ethington and Clark), lateral views, hypotypes; 14, prioniodontiform element, GSC 82550 (StPI 67); 15, ramiform element, GSC 82551 (StPI 67); 16, oistodontiform element, GSC 82552 (StPI 67); all specimens X 68.

18, 19, 22, *Oepikodus intermedius* (Serpagli), lateral views, hypotypes; 18, prioniodontiform element, GSC 82556 (StPI 81); 19, oistodontiform element, GSC 82557 (StPI 81); 22, ramiform element, GSC 82558 (StPI 81), X 68; 18 and 19 X 77.

20, 23, "*Belodella*" sp. B Serpagli, lateral views, hypotypes, GSC 82449 (StPI 71), GSC 82450 (StPI 71), both X 41.

24-26, *Oepikodus evae* (Lindström), lateral views, hypotypes; 24, oistodontiform element, GSC 82553 (StPI 71); 25, ramiform element, GSC 82554 (StPI 71); 26, prioniodontiform element, GSC 82555 (StPI 71), X 77; 24 and 25 X 34.

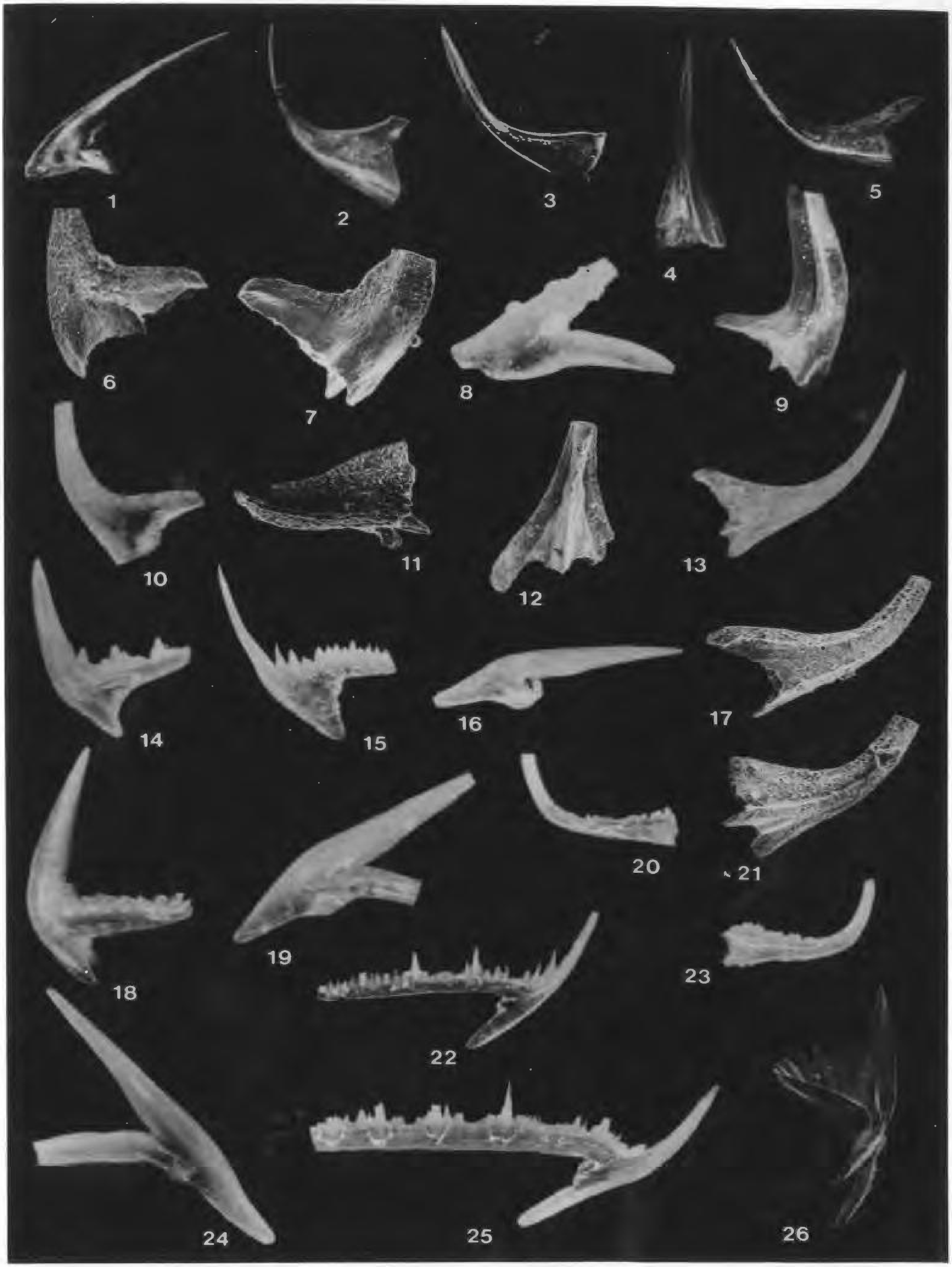
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FIGURE 17

1, 2, 5-7, 11, *Prioniodus elegans* Pander, hypotypes; 1, lateral view, prioniodontiform element, GSC 82676 (StPI 67); 2, lateral view, falodontiform element, GSC 82677 (StPI 67); 5, posterior view, trichonodelliform element, GSC 82678 (StPI 67), X 128; 6, lateral view, costate belodontiform element, GSC 82679 (StPI 67); 7, lateral view, acostate belodontiform element, GSC 82680 (StPI 67), X 77; 11, lateral view, tetraprioniodontiform element, GSC 82681 (StPI 67); 1, 2, 6, and 11 all X 88.

3, 4, 8-10, 13-15, *Oistodella* sp. cf. *O. pulchra* Bradshaw, lateral views; 3, 4, cladognathiform element, GSC 82570 (dMP 56C); 8, 10, cordylodontiform element, GSC 82571 (dMP 56C); 9, oistodontiform element, GSC 82572 (dMP 56C); 13, 14, cyrtoniodontiform element, GSC 82573 (dMP 56C); 15, trichonodelliform element, GSC 82574 (dMP 56C); 3, 4, 8-10 all X 26; 13-15 all X 43.

12, *Baltoniodus*? sp., lateral view, GSC 82448 (dMP 76), X 170.

16-31, *Lenodus falodiformis* Sergeeva, hypotypes; 16, 23, aboral and lateral views, cordylodontiform element, GSC 82531 (dMP 56C), X 116 and X 101; 17, anterior view, trichonodelliform element, GSC 82532 (dMP 56C), X 101; 18, 19, posterior and lateral views, trichonodelliform element, GSC 82533 (dMP 56C), X 116 and X 145; 20, 21, aboral view showing basal cavity and lateral view, falodontiform element, GSC 82535 (dMP 56C), X 101; 22, lateral view, falodontiform element, GSC 82536, (dMP 56C), X 101; 24, lateral view, cordylodontiform element, GSC 82537 (dMP 56C), X 134; 25, lateral view, prioniodiniform element, GSC 82538 (dMP 56C), X 101; 26, 27, aboral and lateral views, prioniodiniform element, GSC 82539 (dMP 56C), X 116 and X 87; 28, 29, lateral and aboral views, tetraprioniodontiform element, GSC 82540 (dMP 56C), X 116 and X 243, specimen lost; 30, lateral view, tetraprioniodontiform element, GSC 82541 (dMP 56C), X 177; 31, lateral view, prioniodiniform element, GSC 82542 (dMP 56C), X 116.


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FIGURE 18

1, 2, 5-7, 11, 13, 14, *Spinodus* sp. cf. *S. spinatus* (Hadding); 1, lateral view, cladognathiform element, GSC 82760 (dMP 56C), X 77, specimen broken; 2, lateral view, cordylodontiform element, GSC 82761 (dMP 56C), X 77; 5, 11, oral and aboral views, trichonodelliform elements, GSC 82687 (dMP 56C), GSC 82762 (dMP 56C), X 89 and X 87, specimens broken; 6, lateral view, ligonodontiform element, GSC 82763 (dMP 56C), X 87; 7, aboral-lateral view, falodontiform element, GSC 82764 (dMP 56C), X 87; 13, lateral view, falodontiform element, GSC 82765 (dMP 56C), X 116; 14, lateral view, prioniodiniform element, GSC 82766 (dMP 56C), X 89;

3, 4, 8, 9, *Paracordylodus gracilis* Lindström, lateral views, hypotypes; 3, 9, paracordylodontiform elements, note difference in anticusp outline in both specimens, GSC 82576 (dMP 45a), GSC 82579 (dMP 45a), both X 68; 4, cordylodontiform element, GSC 82577 (dMP 45a), X 243; 8, oistodontiform element, GSC 82578 (dMP 45a), X 77.

10, 12, 15-17, 19, *Bergstroemognathus* sp. cf. *B. extensus* Serpagli; 10, lateral view, prioniodiniform element (keeled form), GSC 82451 (StPI 55), X 77; 12, lateral view, falodontiform element, GSC 82452 (StPI 71), X 26; 15, anterior view, trichonodelliform element, GSC 82453 (StPI 71), X 77; 16, 17, lateral views, prioniodiniform element (non-keeled form), GSC 82454 (StPI 71), both X 34; 19, posterior view, trichonodelliform element, GSC 82455 (StPI 71), X 66.

18, 20, 23, 24, 29, *Erraticodon* sp. cf. *E. balticus* Dzik; 18, lateral view, trichonodelliform element, GSC 82510 (dMP 56C), X 168; 20, posterior view, plectospathodontiform element, GSC 82511 (dMP 56C), X 168; 23, lateral view, cyrtoniodontiform element, GSC 82512 (dMP 56C), X 88; 24, lateral view, prioniodiniform element, GSC 82513 (dMP 56C), X 133; 29, lateral view, ligonodiniform element, GSC 82514 (dMP 56C), X 77.

21, 25-28, *Jumudontus* sp. aff. *J. gananda* Cooper, lateral views; 21, blade element, note slightly denticulate posterior of cusp, GSC 82527 (StPI 94), X 44; 25, 26, blade elements, GSC 82528, (StPI 94), GSC 82529 (StPI 94); 27, 28, lateral views, coniform element, GSC 82530 (StPI 90); 25-28 all X 68.

22. *Jumudontus gananda* Cooper, lateral view, hypotype, blade element, GSC 82526 (SPI84-4), X 88.


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FIGURE 19

1-4, 7, 13, 14, *Tripodus laevis* Bradshaw, hypotypes; 1, anterior view, trichonodelliform element, GSC 82770 (StPI 94), specimen broken; 2, 14, posterior and lateral views, trichonodelliform element, GSC 82771 (StPI 94), specimen broken; 3, anterior view, paltodontiform element, GSC 82772 (StPI 94), specimen broken; 4, 7, lateral views, distacodontiform element, GSC 82773 (StPI 94), specimen broken; 13, lateral view, drepanodontiform element, GSC 82774 (StPI 94); 1-3, 7, 13, 14, all X 77, except 4 which is X 87.

5, 6, 8, 9, 16, *Walliserodus australis* Serpagli, 5, 8, lateral and postero-lateral views, 5-cosate element, GSC 82784 (StPI 71), X 165 and X 190, specimen broken; 6, oral-lateral view, 3-costate element, GSC 82785 (StPI 71), X 133; 9, postero-lateral view, 4-costate element, GSC 82786 (StPI 71), X 88, specimen broken; 16, multicostate element, GSC 82787 (StPI 71), X 88.

10-12, 17, *Ansella jemtlandica* (Löfgren), lateral views, hypotypes; 10, oistodontiform element, GSC 82443 (dMP 56C); 11, triangular element, GSC 82444 (StPI 120); 12, plano-convex element, GSC 82445 (dMP 56C); 17, biconvex element, GSC 82446 (dMP 56C), X 68; 10-12 all X 43.

15, 20, 25, 29, *Oistodus* n. sp. 1 Serpagli, lateral views, hypotypes; 15, 20, GSC 82565 (StPI 55); 25, GSC 82566 (StPI 55); 29, GSC 82567 (StPI 55); all specimens X 43.

18, 19, 21-24, *Walliserodus ethingtoni* Fåhraeus, hypotypes; 18, 19, lateral views, subsymmetrical elements, GSC 82788 (StPI 94), specimen lost; 21, 22, posterior and lateral views, symmetrical element, GSC 82789 (StPI 94), both X 54; 23, 24, lateral views, asymmetrical element, 82790 GSC (StPI 94); 18, 19, 23, 24, all X 66.

26-28, 30-33, *Oistodus lanceolatus* Pander, hypotypes; 26, lateral view, oistodontiform element, GSC 82559 (StPI 71), X 34; 27, 28, posterior and antero-lateral views, deltiform element, GSC 82560 (dMP 59), both X 41; 30, lateral view, cladognathiform element, GSC 82561 (StPI 71), X 54; 31, lateral view, trichonodelliform element, GSC 82562 (StPI 71), X 54; 32, lateral view, cladognathiform (=ligonodiniform) element, GSC 82563 (StPI

71). X 43; 33, lateral view, cordylodontiform element, GSC 82564 (StPI 71), X 34.


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FIGURE 20

1, 2, 5, 6, "*Microzarkodina*" *marathonensis* (Bradshaw), lateral views, hypotypes; 1, ozarkodiniform element, GSC 82543 (dMP 56C), X 46; 2, multiramiform element, GSC 82544 (dMP 56C), X 46; 5, oistodontiform element, GSC 82545 (dMP 56C), X 77; 6, multiramiform element, GSC 82546 (dMP 56C), X 68.

3, 7, *Microzarkodina*? sp., lateral views; GSC 82547 (StPI 42), X 41.

4, 8, "*Microzarkodina*" sp. aff. "*M.*" *adentata* McTavish, lateral views; 4, ozarkodiniform element, GSC 82548 (StPI 71), X 68; 8, multiramiform element, GSC 82549, (StPI 71), X 41.

9, *Coelocerodontus bicostatus* van Wamel s.f., lateral view, hypotype, GSC 82456 (dMP 16), X 68.

10, *Coelocerodontus latus* van Wamel s.f., lateral view, hypotype, GSC 82457 (dMP 16), X 68.

11, 12, 16, *Coelocerodontus* sp.; 11, 16, lateral and oral view of tri-keeled element, GSC 82458 (StPI 71), both X 68. 12, lateral view, single-keeled element, GSC 82459 (StPI 71), X 68;

13, 14, *Strachanognathus parvus* Rhodes, lateral views, hypotypes, GSC 82768 (StPI 81), GSC 82769 (StPI 81), X 66 and X 54.

15, *Cordylodus* sp. cf. *C. horridus* Barnes and Poplawski, lateral view, GSC 82460 (StPI 81), X 43.

17, 22-24, 26, 30, *Protoprioniodus aranda* Cooper, hypotypes; 17, lateral view, prioniodiniform element with long anterior process, GSC 82718 (StPI 94), X 68; 22, lateral view, prioniodiniform with short anterior process, GSC 82719 (StPI 94), X 68; 23, 24, aboral and lateral views of oistodontiform element, GSC 82720 (StPI 94), both X 133; 26, lateral view, ramiform element, GSC 82721 (StPI 94), X 126; 30, lateral view, oistodontiform element, GSC 82722 (StPI 94), X 126.

18-21, *Protoprioniodus papiliosus* van Wamel, hypotypes; 18, lateral view, triangulariform element, GSC 82723 (StPI 81), X 166; 19, lateral view, oistodontiform element, GSC 82724 (StPI 81), X 166; 20, 21, lateral and posterior view, deltiform element, GSC 82725 (StPI 81), X 243 and X 170.

25, 27-29, 32, 33, ***Protoprioniodus simplicissimus*** McTavish, lateral views, hypotypes; 25, prioniodiniform element, GSC 82726 (StPI 67), X 128; 27, ramiform element, GSC 82727 (StPI 71), X 168; 28, prioniodiniform element, GSC 82728 (StPI 67), X 128; 29, ramiform element, GSC 82729 (StPI 67), X 29; 32, 33, lateral views, oistodontiform element, GSC 82730 (StPI 67), both X 77.

31, *Protoprioniodus*? sp., lateral view, GSC 82731 (dMP 56C), X 68.


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FIGURE 21

1, 2, 7, 10-14, *Scandodus* sp. cf. *S. brevibasis* (Sergeeva); 1, 2, oral and anterior view, distacodontiform element, GSC 82748 (dMP 56C), X 85 and X 88; 7, lateral view, drepanodontiform element, GSC 82749 (dMP 56C), X 100; 10, 14, lateral and posterior view, acodontiform element, GSC 82750 (dMP 56C), X 85 and X 115. 11, 13, lateral and posterior view, distacodontiform element, GSC 82751 (dMP 56C), both X 85;

3, 4, 8, 9, *Cornuodus longibasis* (Lindström), lateral views, hypotypes; 3, asymmetrical element, GSC 82461 (StPI 81); 4, bergstroemiform element, GSC 82462 (StPI 81); 8, symmetrical A element, GSC 82463 (StPI 81); 9, symmetrical B element, GSC 82464 (StPI 81), X 68; 3, 4, and 8 all X 77.

5, 6, *Dischidognathus* sp., postero-lateral and anterior views, GSC 82470 (StPI 77), 82471 GSC (StPI 77), both X 170.

12, 15, 16, 19-21, *Pteracontiodus cryptodens* (Mound), hypotypes; 12, lateral view, cordylodontiform element, GSC 82732 (StPI 92), X 88; 15, 20, lateral and posterior views, distacodontiform element, GSC 82733 (StPI 92), X 77 and X 88, specimen broken; 16, lateral view, acodontiform element, GSC 82734 (StPI 90), X 66; 19, anterior view, trichonodelliform element, GSC 82735 (StPI 90), X 116; 21, posterior view, trichonodelliform element, GSC 82736 (StPI 90), X 88, specimen lost.

17, 18, 22-25, *Scandodus furnishi* Lindström, hypotypes; 17, 18, lateral views, oistodontiform element, GSC 82740 (StPI 94); 22, lateral view, suberectiform element, GSC 82741 (StPI 94); 23, lateral view, drepanodontiform element, GSC 82742 (StPI 94); 24, 25, inner view with antero-lateral costa and outer view, scandodontiform element, GSC 82743 (StPI 77); all specimens X 34.

26-29, *Scandodus sinuosus* Mound, lateral views, hypotypes; 26, acodontiform element, GSC 82744 (StPI 92), X 133; 27, scandodontiform element, GSC 82745 (StPI 92); 28, oistodontiform element, GSC 82746 (StPI 92); 29, distacodontiform element, GSC 82747 (StPI 92); 27, 28, and 29 all X 88.

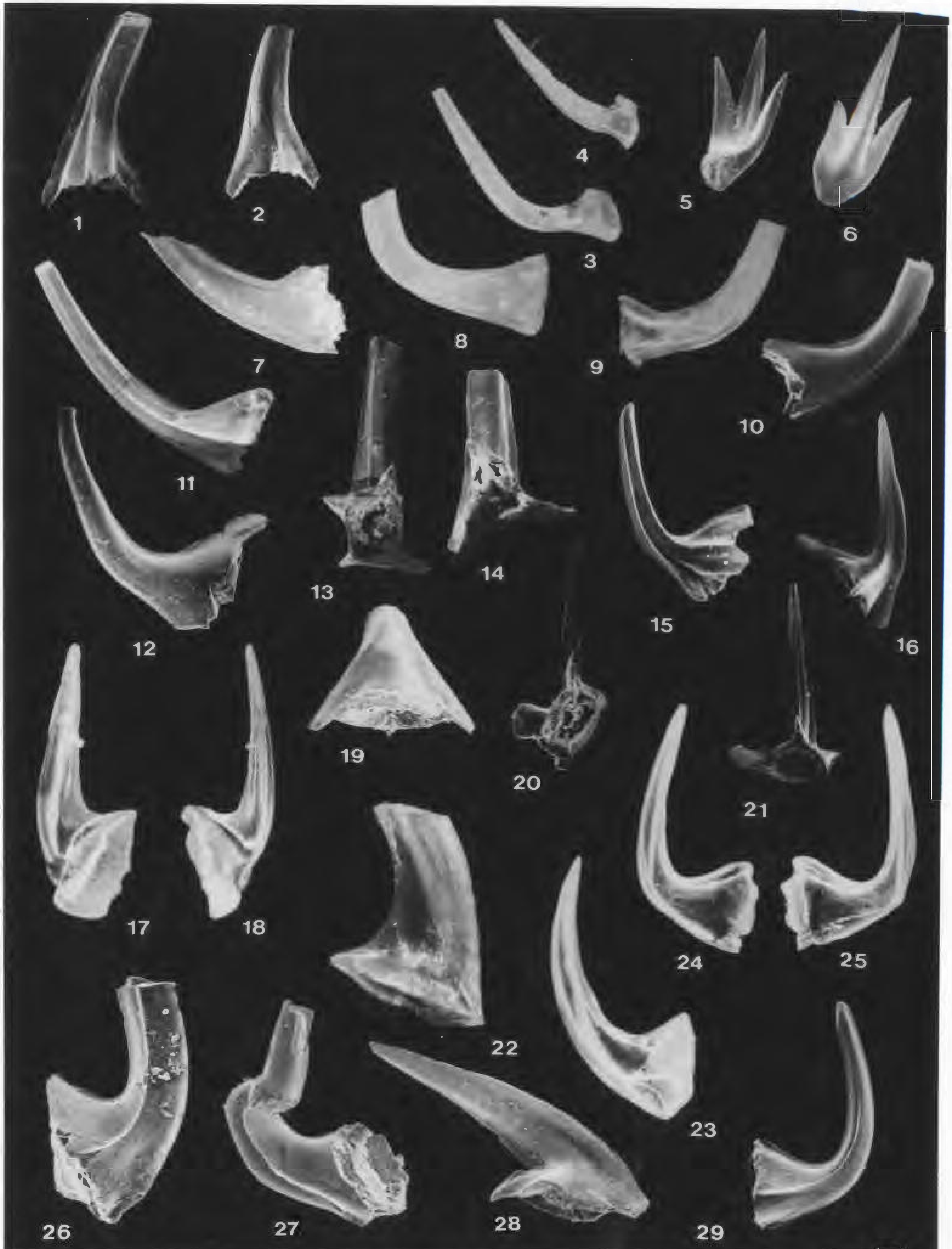
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FIGURE 22

1-4, 5, 6, *Protopanderodus rectus* (Lindström), lateral views, hypotypes; 1, 2, asymmetrical acontiodontiform element, 82695 GSC (StPI 75b); 3, symmetrical acontiodontiform element, GSC 82696 (StPI 75b); 4, sulcatiform element, GSC 82697 (StPI 75b); 5, 6, scandodontiform element, GSC 82698 (StPI 75b); all specimens X 68.

7-9, 11, *Protopanderodus gradatus* Serpagli, lateral views, hypotypes; 7, 11, scandodontiform element, GSC 82689 (SPI84-4), both X 68; 8, acontiodontiform element, GSC 82690 (SPI84-4), X 41; 9, asymmetrical acontiodontiform element, GSC 82691 (SPI84-4), X 41.

10, 12-16, *Protopanderodus* sp. aff. *P. gradatus* Serpagli, lateral views; 10, asymmetrical acontiodontiform element, GSC 82702 (StPI 81), specimen lost; 12, symmetrical acontiodontiform element, GSC 82703 (StPI 81); 13, 14, sulcatiform element, GSC 82704 (StPI 81); 15, 16, scandodontiform element, GSC 82705 (StPI 81), both X 77; 10, 12-14 all X 44.

17-21, *Protopanderodus elongatus* Serpagli, lateral views, hypotypes; 17, symmetrical element, GSC 82685 (StPI 71); 18, 19, slightly asymmetrical element, GSC 82686 (StPI 71); 20, 21, asymmetrical element, GSC 82688 (StPI 71), both X 77; 17-19 all X 68.

22, 23, 27-29, *Protopanderodus* sp. aff. *P. rectus* (Lindström), lateral views; 22, 23, scandodontiform element, GSC 82706 (StPI 92); 27, symmetrical acontiodontiform element, GSC 82707 (StPI 94), X 126; 28, 29, asymmetrical acontiodontiform element, GSC 82708 (StPI 94), X 126 and X 66.

24-26, 30-32, *Protopanderodus cooperi* (Sweet and Bergström), hypotypes; 24, 26, lateral views, 25, postero-lateral view, asymmetrical acontiodontiform element, GSC 82682 (dMP 56C); 30, lateral view, symmetrical acontiodontiform element, GSC 82683 (StPI 56C); 31, 32, lateral views, scandodontiform element, GSC 82684 (dMP 56C), specimen lost; specimens all X 41.


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FIGURE 23

1-13, 16, 17, *Protopanderodus* sp. cf. *P. varicostatus* (Sweet and Bergström), lateral views; 1, 2, asymmetrical drepanodontiform element, GSC 82710 (dMP 56C); 3, symmetrical drepanodontiform element, GSC 82711 (dMP 56C); 4, 5, asymmetrical drepanodontiform element, GSC 82712 (dMP 56C); 6, 7, asymmetrical drepanodontiform element, GSC 82713 (dMP 56C); 8, 9, asymmetrical drepanodontiform element, GSC 82714 (dMP 56C); 10, 11, asymmetrical drepanodontiform element, GSC 82715 (dMP 56C); 12, 13, scandodontiform element, GSC 82716 (dMP 56C); 16, 17, scandodontiform element, GSC 82717 (dMP 56C); 1, 2, 8, 9, all X 66, 11-14 all X 26.

14, 15, 18, 19, 23, *Protopanderodus strigatus* Barnes and Poplawski, lateral views, hypotypes; 14, 15, asymmetrical acontiodontiform element, GSC 82699 (dMP 56C); 18, 19, asymmetrical acontiodontiform element, GSC 82700 (dMP 56C); 23, symmetrical acontiodontiform element, GSC 82701 (dMP 56C); specimens all X 77.

20, 21, 24, 25, *Paroistodus proteus* (Lindström), lateral views, hypotypes; 20, 21, 24, drepanodontiform elements, GSC 82600 (dMP 16), GSC 82601 (dMP 16), GSC 82602 (dMP 16), all X 68; 25, oistodontiform element, GSC 82603 (dMP 16), X 77.

22, 26-28, *Protopanderodus leonardii* Serpagli, lateral views, hypotypes; 22, scandodontiform element, note major antero-lateral costa and minor costae on inner-lateral surface, GSC 82692 (StPI 71), X 77; 26, symmetrical element, GSC 82693 (StPI 71), X 77; 27, 28, asymmetrical element, GSC 82694 (StPI 71), both X 68.

29, *Paroistodus* sp. A., lateral view, GSC 82608 (StPI 74), X 77.


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FIGURE 24

1-9, 12, 13, *Drepanodus arcuatus* Pander, lateral views, hypotypes; 1, 2, acontiodontiform element, GSC 82472 (StPI 71); 3, aberrant drepanodontiform element, GSC 82473 (StPI 71); 4, costate pipiform element, GSC 82474 (StPI 71); 5, asymmetrical drepanodontiform element, GSC 82475 (StPI 71); 6, asymmetrical acontiodontiform element, GSC 82476 (StPI 71); 7, sculponeiform element, GSC 82477 (StPI 71); 8, pipiform element, GSC 82478 (StPI 71); 9, symmetrical drepanodontiform element, GSC 82479 (StPI 71); 12, costate sculponeiform element, GSC 82480 (StPI 71); 13, acontiodontiform element, GSC 82482 (StPI 71); 1, 2, 4, 5, 8, all X 54; 3, 6, 7, 9, 12, 15, all X 41.

10, 11, 15-17, 20, *Paroistodus parallelus* (Pander), lateral views, hypotypes; 10, Type A drepanodontiform element, GSC 82593 (StPI 81), X 77; 11, costate drepanodontiform element, GSC 82594 (StPI 71), X 116; 15, oistodontiform element, GSC 82596 (StPI 81); 16, Type C drepanodontiform element, GSC 82597 (StPI 81); 17, Type D drepanodontiform element, GSC 82598 (StPI 81); 18, Type E drepanodontiform element, GSC 82599 (StPI 81), X 77; 15-17 all X 68.

14, 18, 19, 21-24, *Paroistodus*? sp. A., lateral views; 14, 18, drepanodontiform element, GSC 82604 (StPI 42), both X 66; 19, oistodontiform element, GSC 82605 (StPI 42), X 43; 21, 22, drepanodontiform element, GSC 82606 (StPI 42), both X 54; 23, 24, drepanodontiform element, GSC 82607 (StPI 42), both X 34.

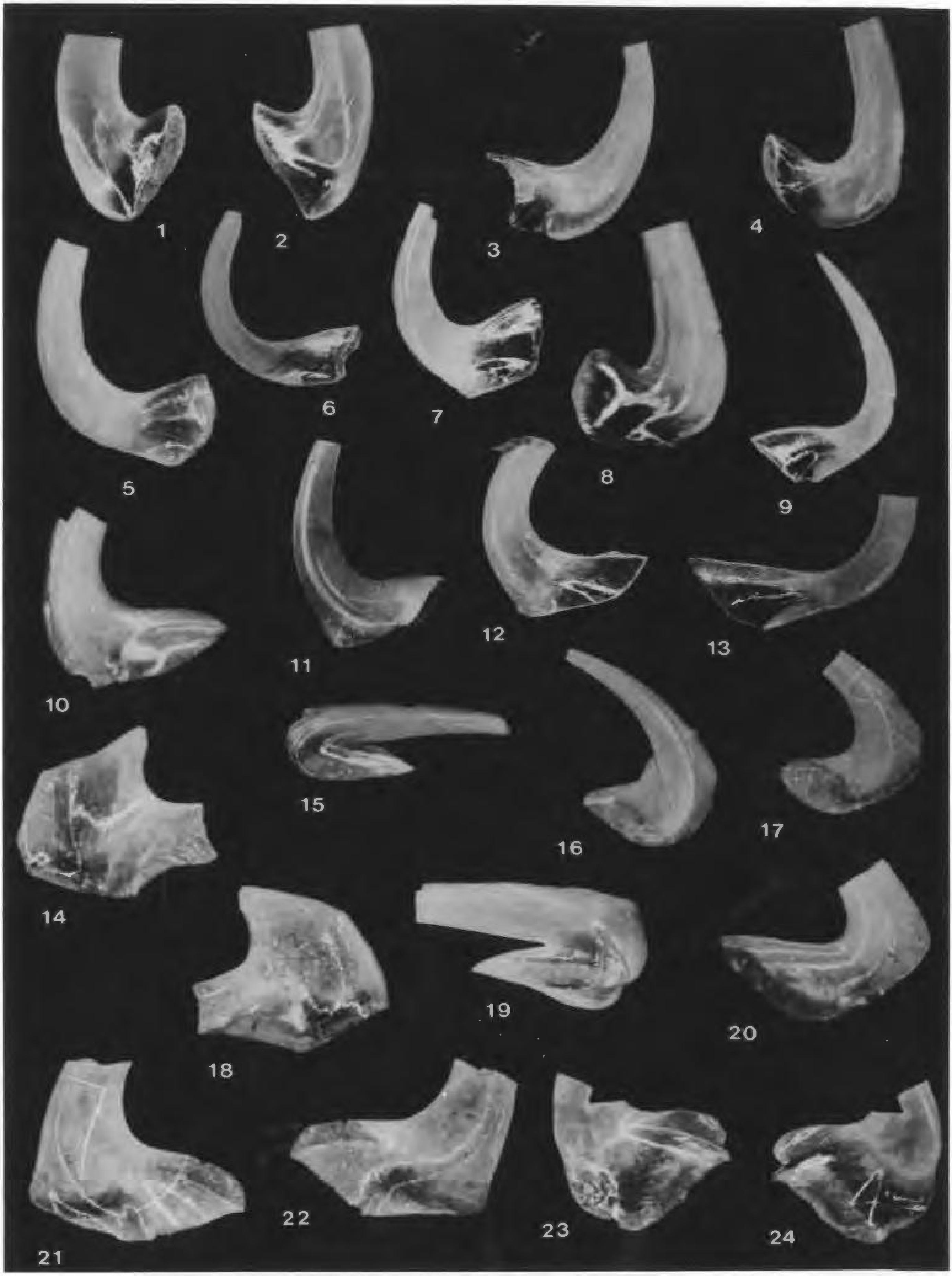
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FIGURE 25

1-6, 10, *Drepanoistodus*? sp. cf. *D.*? *venustus* (Stauffer); 1, lateral view, drepanodontiform (=concaviform) element, GSC 82503 (dMP 56C), X 87; 2, 3, lateral views, drepanodontiform (=homocurvatiform) elements, GSC 82504 (dMP 56C), GSC 82505 (dMP 56C), X 88 and X 126; 4, 5, lateral and posterior views, strongly costate drepanodontiform element, GSC 82506 (dMP 56C), X 126 and X 122; 6, lateral view, drepanodontiform (=concaviform) element, GSC 82507 (dMP 56C), X 126; 10, lateral view, oistodontiform element, GSC 82508 (dMP 56C), X 43.

7-9, 12, 13, *Drepanoistodus tableheadensis* Stouge, lateral views, hypotypes; 7, suberectiform element, GSC 82493 (dMP 56C); 8, drepanodontiform element, GSC 82494 (dMP 56C); 9, oistodontiform element, GSC 82495 (dMP 56C); 12, 13, drepanodontiform element, GSC 82496 (dMP 56C); specimens all X 68.

11, *Drepanoistodus basiovalis* (Sergeeva), lateral view, hypotype, oistodontiform element, GSC 82486 (StPI 94), X 90.

14, 17, 20, 21, *Drepanoistodus*? *concavus* (Branson and Mehl), lateral views, hypotypes; 14, 17, drepanodontiform elements, GSC 82489 (StPI 42), GSC 82490 (StPI 42); 20, suberectiform element, GSC 82491 (StPI 42), X 54; 21, oistodontiform element, GSC 82492 (StPI 42); 14, 17, and 21 all X 41.

15, 16, *Drepanoistodus* sp., lateral views, 15, homocurvatiform element, GSC 82497 (StPI 81); 16, suberectiform element, GSC 82498 (StPI 81); both X 68.

18, 19, 22, 23, 26, 27, *Drepanoistodus*? sp. A., lateral views; 18, 19, drepanodontiform element, GSC 82499 (StPI 42); 22, oistodontiform element, GSC 82500 (StPI 42); 23, suberectiform element, GSC 82501 (StPI 42); 26, 27, drepanodontiform element, GSC 82502 (StPI 42); specimens all X 43.

24, 25, "*Scandodus*" *flexuosus* Barnes and Poplawski s.f., lateral views, hypotype; GSC 82738 (StPI 94), X 77 and X 26.

28, 29, "*Drepanodus*" n. sp. C Barnes and Poplawski s.f., lateral views, hypotype, GSC 82483 (StPI 94), both X 68.

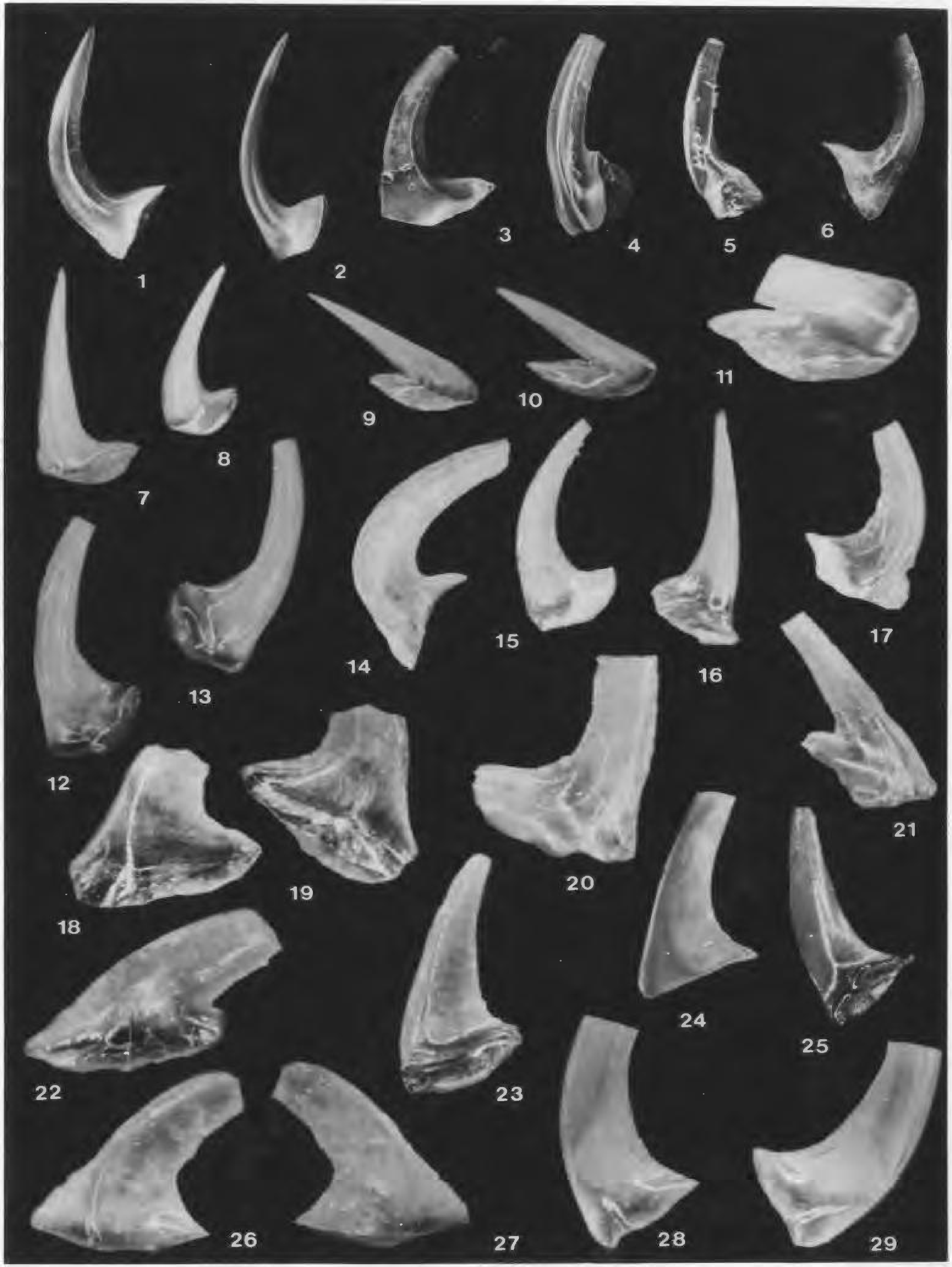
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FIGURE 26

1. "*Drepanodus*" *toomeyi* Ethington and Clark s.f., lateral views, hypotype, GSC 82485 (StPI 42), X 41.

2, 3. *Eucharodus parallelus* (Branson and Mehl), lateral views, hypotypes, GSC 82515 (StPI 42), GSC 82516 (StPI 42), X 41 and X 26.

4, 5. *Glyptoconus quadraplicatus* (Branson and Mehl), hypotypes, lateral and posterior views, GSC 82520 (StPI 42), both X 41.

6, 7. *Scolopodus quadratus* Pander, hypotype, posterior and lateral views, GSC 82755 (dMP 68), both X 66, specimen broken.

8. *Parapanderodus* sp. cf. *P. striatus* (Graves and Ellison), lateral view, GSC 82592 (dMP 56C), X 44.

9, 10. *Parapanderodus elegans* Stouge, lateral views, hypotypes, GSC 82583 (dMP 56C), GSC 82584 (StPI 77), both X 68.

11. *Parapanderodus gracilis* (Ethington and Clark), lateral view, hypotype, GSC 82585 (StPI 67), X 68.

12. "*Scolopodus*" *triangularis* Ethington and Clark s.f., postero-lateral view, hypotype, GSC 82756 (StPI 75b), X 170.

13-15. *Parapanderodus striatus* (Graves and Ellison), hypotypes; 13, 14, lateral views, symmetrical elements, GSC 82586 (StPI 90), GSC 82587 (StPI 90), X 43 and X 41; 15, postero-lateral view, asymmetrical element, GSC 82588 (StPI 87), X 68.

16. "*Scolopodus*" *carlae* Repetski s.f., posterior view, hypotype, GSC 82752 (StPI 75b), X 44.

17-19. *Semiacontiodus cornuformis* (Sergeeva), hypotypes; 17, posterior view, asymmetrical element, GSC 82757 (StPI 90), X 68; 18, 19, lateral and posterior views, symmetrical elements, GSC 82758 (StPI 94), GSC 82759 (StPI 94), X 87 and X 89.

20, 21, 28. *Parapanderodus* sp. cf. *P. arcuatus* Stouge, lateral views; 20, 21, Type 2 elements, GSC 82589 (StPI 90), GSC 82590 (StPI 90), X 87 and X 68; 28, laterally compressed element, GSC 82591 (StPI 90), X 68.

22-27. *Parapanderodus arcuatus* Stouge, hypotypes; 22, 23, lateral and oral-lateral views with latter view showing costa adjacent to posterior groove, Type 1 element, GSC 82580 (dMP 56C), X 88 and X 87; 24, 25, lateral and oral views, Type 2 element, GSC 82581 (dMP 56C), X 88 and X 87; 26, 27, oral and lateral views, laterally compressed element, GSC 82582 (dMP 56C), X 116 and X 126.

29, *Ulrichodina* n. sp. Barnes 1977 s.f., lateral view, hypotype, GSC 82781 (dMP 59), X 41.

30, *Ulrichodina* sp. aff. *U. wisconsinensis* Furnish s.f., lateral view, GSC 82779 (dMP 54A), X 41.

31, 32, *Ulrichodina cristata* Harris and Harris s.f., lateral and antero-lateral views, hypotype, GSC 82780 (dMP 59), both X 41.

33, *Ulrichodina* sp. Stouge 1982 s.f., lateral view, hypotype, GSC 82782 (StPI 92), X 41.

34, "*Acontiodus*" *staufferi* Furnish s.f., posterior view, hypotype, GSC 82447 (StPI 42), X 68.

35, "*Scolopodus*" *emarginatus* Barnes and Tuke s.f. postero-lateral view, hypotype, GSC 82753 (StPI 42), X 54.


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FIGURE 27

1-3, *Periodon*? sp., lateral views; 1, 3, prioniodiniform elements, GSC 82668, GSC 82670 (StPI 55), both X 87; 2, oistodontiform element, GSC 82669 (StPI 55), X 105.

4, 5, *Reutterodus andinus* Serpagli, lateral views, hypotype, GSC 82737 (StPI 81), both X 26.

6, *Juanognathus variabilis* Serpagli, oral view, hypotype, GSC 82524 (StPI 81), X 126.

7-10, 14-16, 19, *Periodon flabellum* (Lindström), hypotypes; 7, posterior view, trichonodelliform element, GSC 82660 (StPI 81), X 88; 8, lateral view, cladognathiform element, GSC 82661 (StPI 81), X 88; 9, lateral view, ligonodiniform element, GSC 82[illegible] (StPI 81), X 87, specimen broken; 10, lateral view, cordylodontiform element, GSC 82663 (StPI 81), X 88, specimen lost; 14, 15, lateral views, oulodontiform elements, GSC 82664 (StPI 81), GSC 82665 (StPI 81), X 88 and X 87; 16, lateral view, prioniodiniform element, GSC 82666, (StPI 81), X 116; 19, lateral view, oistodontiform element, GSC 82667 (StPI 81), X 77.

11, *Juanognathus jaanussoni* Serpagli, oral lateral view, hypotype, GSC 82525 (StPI 81), X 146.

12, 13, 17, 18, 20-31, *Periodon aculeatus* Hadding, lateral views, hypotypes; 12, 13, oulodontiform elements, GSC 82630 (StPI 94), GSC 82638 (StPI 81), both X 88; 17, 18, ligonodiniform elements, GSC 82631 (StPI 94), GSC 82639 (StPI 81), X 88 and X 87; 20, 21, cladognathiform elements, GSC 82632 (StPI 94), GSC 82640 (StPI 81), X 77 and X 88; 22, 23, falodontiform elements, GSC 82643 (StPI 81), GSC 82635 (StPI 94), X 88 and X 77; 24, 25, cordylodontiform elements, GSC 82633 (StPI 94), GSC 82641 (StPI 81), X 87 and X 88. 26, 27, prioniodiniform elements with single anterior denticle, GSC 82644 (StPI 81), GSC 82636 (StPI 94), X 87 and X 88; 28, 29, trichonodelliform elements, GSC 82634 (StPI 94), GSC 82642 (StPI 81), both X 87. 30, 31, prioniodiniform elements with several anterior denticles, GSC 82645 (StPI 81), GSC 82637 (StPI 94), X 87 and X 77; 12, 17, 20, 23, 24, 28, 27, and 31 intermediate forms, 13, 18, 21, 22, 25, 26, 29, and 30 early forms.


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FIGURE 28

1-7, *Periodon aculeatus* Hadding, (late form), lateral views, hypotypes; 1, cordylodontiform element, GSC 82646 (dMP 56C); 2, ligonodiniform element, GSC 82647 (dMP 56C); 3, cladognathiform element, GSC 82648 (dMP 56C); 4, trichonodelliform element, GSC 82649 (dMP 56C), X 45; 5, prioniodiniform element, GSC 82650 (dMP 56C); 6, oulodontiform element, GSC 82651 (dMP 56C); 7, falodontiform element, GSC 82652 (dMP 56C), X 77; 1-3, 5, and 6, all X 66.

8, *Fryxellodontus*? sp. cf. *F.*? *reudemanni* Landing, postero-lateral view, GSC 82519 (StPI 67), X 170.

9, 10, 12, 13, 15, 16, *Polonodus*? *peavyi* n. sp., 9, 15, holotype, lateral and oral views, subsymmetrical element, GSC 82671 (dMP 56C), X 116 and X 136. 10, 13, paratype, lateral and oral view, asymmetrical element with narrow posterior platform, GSC 82672 (dMP 56C), both X 116; 12, paratype, aboral view, asymmetrical element, GSC 82673 (dMP 56C), X 101; 16, paratype, oral view, asymmetrical element with broad posterior platform, GSC 82674 (dMP 56C), X 101.

11, 14, New Genus B sp., oral and lateral views, GSC 82796 (StPI 55), both X 42.

17, 18, 21, *Fryxellodontus*? sp. aff. *F.*? *corbatoi* Serpagli; 17, 18, posterior and lateral views, GSC 82517 (dMP 16), X 101 and X 134; 21, anterior view, GSC 82518 (dMP 16), X 116.

19, 23, 26, 27, New Genus E sp.; 19, 23, oral and lateral view, platform element, GSC 82801 (StPI 71), X 43 and X 51; 26, aboral view, platform element, GSC 82802 (StPI 71), X 34; 27, lateral view, coniform element, note serrations on each edge, GSC 82803 (StPI 71), X 43.

20, *Eoplacognathus*? sp., oral view, ambalodontiform? element, GSC 82509 (dMP 56C), X 88.

22, 24, 25, 28, New Genus C sp.; 22, 25, aboral and lateral views, platform element with three processes, GSC 82797 (dMP 16), both X 116; 24, 28, lateral and aboral views, platform element, GSC 82798 (dMP 16), X 116 and X 101.

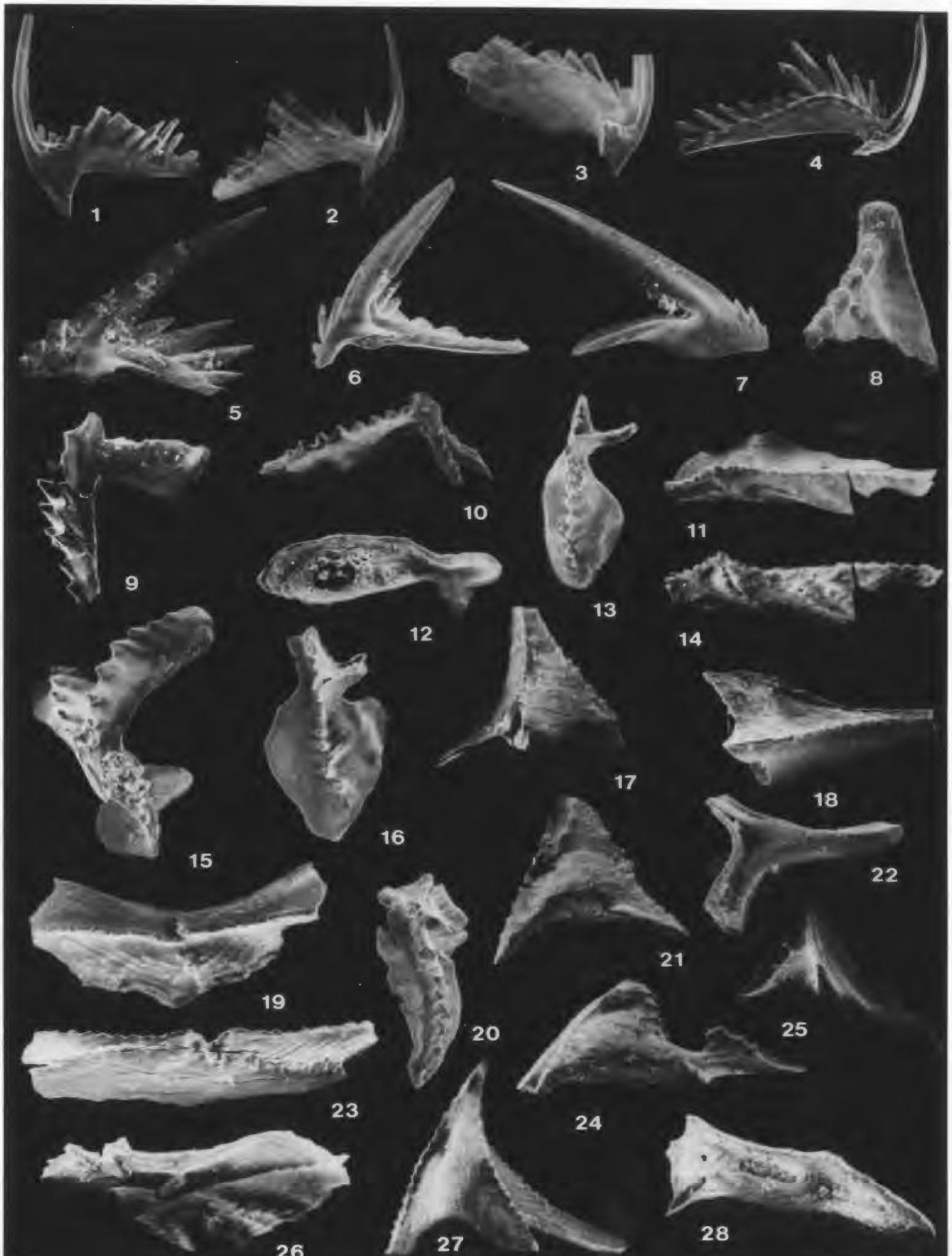
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FIGURE 29.

1, *"Oistodus"* sp. aff. *"O." cristatus* Ethington and Clark s.f., lateral view, GSC 82568 (StPI 67), X 77.

2, *Histiodella altifrons* Harris, lateral view, bryantodontiform element, GSC 82521(dMP 56C), X 126.

3, *"Scolopodus" peselephantis* Lindström, lateral view, GSC 82754 (StPI 90), X 68.

4, *?. Ulrichodina*? sp. s.f., oral and lateral views, GSC 82783 (dMP 59), both X 41.

5, *Stolodus* sp. 1 Serpagli, lateral view, hypotype, GSC 82767 (StPI 71), X 41.

6, *Histiodella serrata* Harris s.f., lateral view, hypotype, GSC 82523 (dMP 56C), X 68.

7, *Histiodella holodentata* Ethington and Clark, lateral view, hypotype, GSC 82522 (dMP 56C), X 77.

8, Drepanodontiform element B, lateral view, GSC 82792 (StPI 67), X 43.

10, *Oneotodus costatus* Ethington and Brand, lateral view, hypotype, GSC 82575 (StPI 42), X 116.

11, *"Oistodus"* sp. aff. *"O." hunickeni* Serpagli, lateral view, GSC 82569 (StPI 67), X 68.

12, 13, Drepanodontiform element C, lateral view, GSC 82793 (StPI 67), X 41.

14, 15, *Acodus*? sp. aff. *A. sweeti* Serpagli, lateral views, GSC 82440 (StPI 67), both X 68.

16, Drepanodontiform element A, lateral view, GSC 82791 (StPI 67), X 68.

17-19, New Genus A sp.; 17, 18, aboral and lateral views, symmetrical element, GSC 82795 (dMP 59), both X 116; 19, lateral view, asymmetrical element, GSC 82534 (dMP 59), X 68.

20, 21, 24, 25, New Genus D sp.; 20, 24, 25, lateral, aboral and oral views, GSC 82799 (dMP 16), X 88, X 100 and X 88; 21, oral view, GSC 82800 (dMP 16), X 87.

22, 23, Scandodontiform element, lateral view, GSC 82794 (StPI 42), both X 54.


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APPENDIX A

Lithologic descriptions of conodont samples from the Martin Point (South) section. The number of each sample is given along with its height above the base in meters. Due to sampling methods, the numbering is not consecutive, but the samples are placed in stratigraphic order, from oldest to youngest. A more detailed description of the lithologic units comprising this and the St. Pauls Inlet (North Tickle) section is given in James and Stevens (in press).

Martin Point (South) section.--Measuring commenced from the top of an approximately 2 m thick limestone conglomerate unit. The section continues southward from this unit along the cliff top and the shoreline, terminating at the top of the 1 m thick conglomerate bed in the Lower Head Formation. Each sample is prefixed by "dMP", "dMP84", or "dMP85".

m above base	Sample no.	Description
0	dMP 1	Limestone conglomerate, clasts sub-angular to sub-rounded, with diameters less than 5 cm. Matrix sparry calcite.
1	dMP 2	Lime mudstone, medium brown, thinly bedded, wavy, low crystallinity.
2	dMP 2a	Grainstone, light grey, intraclasts sub-rounded to angular, moderately to poorly sorted, bed thickness 2 cm, possible cross-bedding, moderate crystallinity.
2.8	dMP 3	Lime mudstone, medium brown, weathers light brown, bed wavy, 1 cm thick, cross bedded, low crystallinity. Graptolites on bedding plane.
3.6	dMP 4	Shale, green, weathers red, bed thickness 0.5 cm.
4.8	dMP 5	Grainstone, grey with some green intraclasts, nodular. Intraclasts coarse sand-sized, sub-rounded, poorly sorted.
5.8	dMP 6	Lime mudstone, medium brown, bed thickness 3 cm.
6.8	dMP 7	Lime mudstone, medium grey, weathers light grey, bed thickness 3-4 cm, loadcasts(?) on upper bedding plane. Low crystallinity.
7.8	dMP 8	Lime mudstone, medium grey, bed 2 cm thick. Low crystallinity.

8.3	dMP 9	Lime mudstone, medium grey, weathers light grey, bed thickness 10 cm. Chert nodules in bed as well as *Arenicolites* burrows filled in with calcite. Low crystallinity.
10.2	dMP 10	Lime mudstone, light brown to green. Cross-bedded.
11.3	dMP 11	Lime mudstone, light brown to olive green, wavy bedding with bed thickness about 2 cm.
12.5	dMP 12	Shale, black, laminated, graptolitic.
13.4	dMP 13	Lime mudstone, medium grey, weathers light grey, nodular. Low crystallinity.
14.4	dMP 14	Same as above.
15.4	dMP 15	Lime mudstone, medium grey, weathers light grey. Bed wavy, about 3 cm thick. Low crystallinity.
16.4	dMP 16	Lime mudstone, medium grey, weathers light grey, chert cap on upper bedding plane. Low crystallinity. Graptolites occur on upper and lower bedding planes.
17.4	dMP 17	Lime mudstone, light brown, bed thickness 2-3 cm. Low crystallinity.
18.3	dMP 18	Shale, black, weathers light grey, calcareous, laminated. Graptolites and inarticulate brachiopods on upper and lower bedding planes.
19.5	dMP 19	Shale, black, laminated, interbedded with chert lenses approximately 5 cm in diameter.
21.3	dMP 20	Limestone conglomerate, clasts pebble to coarse sand-sized, sub-rounded to sub-angular. Bed lenticular, about 4-5 cm thick. Pyrite grains.
23.2	dMP 21	Lime mudstone, medium grey, weathers light grey, bed thickness 2.5 cm. Low crystallinity.

24.0	dMP 22	Shale, green, fissile, non-fossiliferous.
25.1	dMP 23	Shale, green and black, laminated, with green and black laminations up to 2 mm in thickness. Non-calcareous.
26.0	dMP 24	Limestone conglomerate, with mudstone clasts 0.25-2.0 in diameter. Bed thickness 1-3 cm. Clasts rounded to sub-rounded, very poorly sorted, comprising several lithologies. Pyrite grains.
32.8	dMP 25	Shaly siltstone, green, weathers same, thinly to thickly laminated. Shale and siltstone interbedded, non-calcareous.
33.8	dMP 26	Shale and siltstone, red and green, laminated, with minor siltstone laminations alternately light and dark. Non-calcareous.
34.4	dMP 27	Shale, red, weathers same, with thin green siltstone laminations.
35.4	dMP 28	Shale and siltstone, green, weathers same, thinly bedded to thickly laminated, with wavy bedding. Traces of red shale visible.
36.4	dMP 29	Shale, red, weathers same, with minor green siltstone laminations.
37.6	dMP 30	Same as dMP 28.
38.6	dMP 31	Shale, red, weathers same, non-calcareous.
39.6	dMP 32	Same as previous sample.
40.6	dMP 33	Green shale and siltstone, other features same as dMP 28 and 30.
41.6	dMP 34	Shale, red, weathers same.
43.1	dMP 35	Same as previous sample.

44.5	dMP 36	Shale, red, interbedded with green shale and siltstone weathering light green. Siltstone laminated.
46.3	dMP 37	Shale, red, weathers same, non-calcareous.
47.6	dMP 38	Shale, red, interbedded with green shale and siltstone. Siltstone exhibits alternating light and dark bands. Lighter bands contain coarser grains.
50.4	dMP 39	Shale, red and green, with silty laminations in red shale, thinly bedded, non-calcareous.
51.3	dMP 40	Shale and siltstone, green, weathers same, laminated, with lighter-coloured laminations consisting of coarse-grained particles, and darker laminations fine-grained material.
52.6	dMP 41	Same as dMP 40.
53.8	dMP 42	Shale and siltstone, green, laminated, non-calcareous.
54.6	dMP 43	Shale, green and red. Black shale with lenses of green shale within. Non-calcareous.
55.5	dMP 49	Shale, green, weathers same, non-calcareous.
56.0	dMP 45	Limestone conglomerate, medium grey, weathers light grey, matrix grainstone. Clasts and intraclast rounded, poorly sorted.
56.0	dMP 45a	Lime mudstone, medium to dark grey, bedding lenticular, with light coloured mudstone interbedded with dark mudstone.
58.5	dMP 46	Shale, green, weathers same, non-calcareous.
59.7	dMP 48	Shale, red and green, laminated. Green shale occurs as lenses within red shale.
60.0	dMP 47	Lime mudstone, light grey, weathers buff, nodular.
62.0	dMP 49	Shale, red, weathers same, non-calcareous.

63.1	dMP 50	Shale, red, weathers same, with thin laminations or lenses, non-calcareous.
64.0	dMP 51	Shale, green, weathers same, non-calcareous.
65.0	dMP 52	Shale, red, weathers same, with thin bands of green shale interbedded with red shale.
65.8	dMP 53	Shale, green, weathers same, non-calcareous.
66.8	dMP 60	Shale, red and green, with green shale thinly banded.
67.8	dMP 61	Siltstone, red and green, forms resistant bed immediately above and below shale.
68.3	dMP 62	Shale, red and green, weathers same, with interbedded red and green bands. Vertical burrows filled with red shale perpendicular to bedding.
74.0	dMP85-2	Lime mudstone, medium brown, weathers grey, bed thickness 2 cm. Pyrite grains, possible occurrence of burrows infilled with green shale on underside of bed.
76.0	dMP 63	Shale, red and green, siliceous, laminated, with red shale predominant lithology, and green shale occurring in minor amounts. Vertical burrows perpendicular to bedding.
79.5	dMP 59	Limestone conglomerate, limestone clasts set in argillaceous matrix.
83.0	dMP 64	Lime mudstone, medium grey, weathers light grey, wavy bedding.
83.0	dMP85-1	Shale and siltstone, medium brown to black, weathers grey, laminated, with black shale bands alternating with brown siltstone bands.
84.2	dMP 65	Shale, green-black, weathers light green, non-calcareous. Shell fragments of inarticulate brachiopods.

85.2	dMP 66	Siltstone, green, weathers reddish brown.
94.0	dMP84-1	Siltstone, shaley, black and grey, laminated, with clasts of black shale in grey siltstone.
94.8	dMP 67	Lime mudstone, medium grey, weathers light grey, wavy bedding, bioturbated, pyrite grains.
95.2	dMP 68	Limestone conglomerate, clasts boulder to pebble size, rounded. Matrix argillaceous.
96.0	dMP 70	Lime mudstone, medium to dark grey, bed thickness 2-3 cm.
96.8	dMP 69	Lime mudstone, medium to dark grey, weathers light grey, thinly bedded, with light grey mudstone interbedded with dark grey mudstone.
97.4	dMP 58	Lime mudstone.
98.0	dMP 57	Lime mudstone boulder at base of conglomerate bed along shore.
104.0	dMP 74	Lime mudstone, medium grey, weathers buff, nodular, with weathering "halo" on outside.
105.8	dMP 75	Shale, green, weathers light green, bedding undulating.
113.3	dMP 76	Limestone conglomerate, clasts pebble size, rounded, poorly sorted, matrix argillaceous.
115.8	dMP 77	Dolomitic siltstone, green, weathers reddish brown.
118.2	dMP 78	Siltstone, red, with laminations of dark grey siltstone.
121.0	dMP 84	Siltstone, green and grey, interbedded with bioturbated red shale.
122.0	dMP 79	Shale, red, and green siltstone, shale weathers red, siltstone light brown. Siltstone laminated with vertical burrows filled with red shale perpendicular to laminations.

124.2	dMP 80	Dolomitic siltstone, green, weathers buff-yellow.
125.0	dMP 81	Siltstone, green, weathers red, thinly laminated.
127.6	dMP 83	Siltstone, green and grey, weathers same, massive.
133.0	dMP 82	Dolomitic siltstone, light grey, weathers same, laminated, non-calcareous.
137.0	dMP 71	Siltstone, red, weathers same. Laminations possibly present.
141.0	dMP 72	Siltstone and shale, red and grey, weathers rust-brown, bed thickness 1 cm. Red and grey laminations in siltstone.
139.0	dMP 73	Lime mudstone and red-green siltstone. Laminated, shows some traces of burrowing. Lime mudstone light brown, weathers same, cross-bedding possibly present.
145.6	dMP 54A	Lime mudstone boulder in limestone conglomerate, diameter about 30 cm.
145.6	dMP 54B	Lime mudstone boulder in limestone conglomerate.
147.0	dMP 55	Limestone conglomerate grading into grainstone. Overlain by chert cap.
214.0	dMP 56C	Lime mudstone clast collected from conglomerate bed in green sandstone.
215.0	dMP 56A	Lime mudstone with abundant sponge spicules.
215.0	dMP 56A	Lime mudstone clast in green sandstone.

APPENDIX B

Lithologic descriptions of conodont samples from the St. Pauls Inlet North Tickle section. All samples are numbered in ascending stratigraphic order except those designated "SPI84". Sample numbers and height above the base are given as in Appendix A.

St. Pauls Inlet North Tickle.--Measuring commenced from the top of the conglomerate bed immediately below the abutment on the north side of the bridge spanning the inlet and then east to the end of the peninsula (Figure 2, p. 9). Measuring continued along strike on the northeast shore of the peninsula for about 1 km.

m above base	Sample no.	Description
1.0	StPI 1	Dolomitic siltstone, light grey, weathers buff, bed thickness 5 cm, cross-bedded.
34.0	StPI 2	Shale, black, weathers medium grey, laminated.
34.8	StPI 3	Lime mudstone, black, weathers light grey, pyrite grains.
35.8	StPI 3a	Lime mudstone, dark grey, bed thickness 2-3 cm, low crystallinity.
37.1	StPI 3b	Lime mudstone, medium grey, weathers buff. Bed thickness 2-3 cm.
38.0	StPI 4	Lime mudstone, medium brown. Bed thickness 4 cm, calcite infills small veins.
39.4	StPI 5	Grainstone, medium brown, intraclasts sub-rounded to rounded, poorly sorted, cross-bedded. Bed thickness 10 cm. Light coloured grains interbedded with dark coloured grains, lenticular.
40.5	StPI 6	Shale, black, bed thickness 2-3 cm thick, laminated, calcareous, pyrite grains.
42.7	StPI 7	Grainstone, light brown-grey intraclasts sub-rounded to angular, poorly sorted. Bed thickness 2-3 cm, high crystallinity.
43.6	StPI 8	Lime mudstone, light brown.
44.6	StPI 9	Lime mudstone, light grey, bed thickness 1-1.5 cm, with laminations alternately light and dark grey.

45.6	StPl 10	Shale, dark green, weathers rust colour in fracture planes. Bed thickness 0.25 cm, non-calcareous.
46.8	StPl 11	Lime mudstone, light to dark grey, bands of light grey limestone vary from 1.5 to less than 0.5 cm in thickness, interbedded with dark grey limestone, for total bed thickness of 5 cm.
48.0	StPl 12	Lime mudstone, medium grey, weathers light grey, nodular. Small amounts of green and red mineral present.
49.0	StPl 13	Lime mudstone, light to dark brown, weathers light yellowish-grey. Bed thickness 10 cm. Light brown lenses occur within dark matrix, solution features possibly present.
50.0	StPl 14	Dolomitized siltstone, weathers light brown, grains sub-angular to sub-rounded, poorly sorted. Bed thickness variable with truncated cross- and graded bedding.
51.1	StPl 15	Shale, green, weathers red, laminated.
52.0	StPl 16	Dolomitized siltstone, medium grey, weathers light brown to buff. Grains of chert and/or quartz more than 1 mm but less than 0.5 cm at bottom of bed fining upwards. Cross-bedded, best displayed on weathered surface.
53.2	StPl 17	Dolomitized siltstone, grey-green, graded bedding, chert pebbles at bottom of bed. Alternately light and dark banded.
54.3	StPl 18	Shale, red, and siltstone, green shale non-calcareous, siltstone laminated with light and dark bands.

55.3	StPI 19	Shale, red, with green siltstone bands, shale siliceous, hard. Siltstone with fine laminations faintly visible, some bands possibly lenticular.
56.7	StPI 20	Shale, red, bed thickness 10 cm, non-calcareous.
57.7	StPI 21	Shale, red, with very thin laminations.
58.7	StPI 22	Same as previous sample.
61.2	StPI 23	Same as previous sample.
62.3	StPI 24	Same as previous sample.
63.3	StPI 25	Shale, red, no bedding observed, non-calcareous.
64.3	StPI 26	Shale, red, and siltstone, green. Shale much like previously described lithologies; siltstone thinly bedded, consisting of two bands about 2 cm apart.
65.4	StPI 27	Shale, red, with dark siltly laminations.
67.0	StPI 28	Shale and siltstone, green, weathers dull brown, laminated, with upper part of bed containing coarse grains, lower half fine-grained. Laminations interbedded with shale.
68.0	StPI 29	Shale, red, and siltstone, dark grey, both weather same. Shale non-calcareous, siltstone finely laminated.
69.2	StPI 30	Shale, red, and siltstone, dark grey-green, shale contains 1 cm long siltstone lenses; barely visible laminations in siltstone.
70.8	StPI 31	Lime mudstone, light grey, contains *Tetragraptus approximatus*.
71.6	StPI 32	Dolomitized siltstone, light to dark grey, laminated, interbedded light and dark beds 1 1 mm-2 cm thick, non-calcareous.

72.8	StPl 33	Lime mudstone, light brown to dark grey, lighter material nodular, surrounded by dark, highly siltly mudstone.
73.6	StPl 34	Same as previous sample.
75.0	StPl 35	Same as in previous sample, except that matrix greenish.
76.0	StPl 36	Lime mudstone, medium grey, weathers light grey, bed thickness 1-3 cm. Wavy bedding, occasionally lenticular, burrows visible on bedding surface.
76.8	StPl 37	Lime mudstone, medium to dark-grey, bed thickness 10 cm. Light coloured lenses occur in dark-coloured matrix towards top of bed, see evidence of cross-bedding(?) on weathered surface.
77.8	StPl 38	Shale, green, laminated, non-calcareous.
78.8	StPl 39	Grainstone(?), lime mudstone, shale, green, mudstone associated with grainstone, commonly thin-bedded, above lithologies lenticular or thinly bedded, shale calcareous, laminated.
79.8	StPl 40	Shale, green, laminated or thinly bedded.
80.8	StPl 41	Shale, green, laminated. Laminations about 1 mm, green bands interbedded with brownish-red bands. Non-calcareous.
82.3	StPl 42	Grainstone and lime mudstone, intraclasts sub-rounded to rounded, poorly sorted, high crystallinity. Mudstone dark grey, overlies grainstone.
83.2	StPl 43	Lime mudstone, medium brown, bed thickness 2-5 cm, nodular, low crystallinity.

85.8	StPl 44	Lime mudstone, medium grey, bed thickness 5-10 cm, nodular. Graptolites on lower bedding surface, rare chert nodules.
86.8	StPl 45	Lime mudstone, medium grey, bed thickness 12 cm. Lithology may be very fine grainstone.
87.8	StPl 46	Lime mudstone, medium grey, bed thickness 5 cm, mottled.
88.4	StPl 47	Grainstone, medium grey, intraclasts fine-grained, sorting indeterminate, bed thickness 10 cm, laminated.
88.8	StPl 48	Lime mudstone, medium grey, weathers light grey, dark laminations near top of bed, graptolites on top bedding plane.
89.9	StPl 49	Lime mudstone, medium grey, thinly bedded, burrows on upper bedding plane.
91.0	StPl 50	Lime mudstone, bed thickness generally 1 cm, although variable. Wavy bedding, burrows.
92.0	StPl 51	Lime mudstone, medium grey, bed thickness 3 cm, thinly bedded to thickly laminated with laminations alternately light and dark.
92.9	StPl 52	Grainstone, medium grey, intraclasts sub-rounded, poorly sorted, bedding lenticular, pyrite grains.
93.9	StPl 53	Grainstone or lime mudstone, medium grey, medium bedding to thick laminations, chert nodules. *Arenicolites* burrows filled with calcite, graptolites on upper bedding plane.
94.9	StPl 54	Grainstone or mudstone, light grey, bedded, pyrite present in small amounts. *Arenicolites* burrows. *Tetragraptus*.

96.0	StPI 55	Grainstone, medium grey, weathers light grey, intraclasts sub-rounded, moderately to poorly sorted with chert nodules 10-15 cm in diameter.
96.8	StPI 56	Grainstone, medium grey, bed thickness 3-4 cm, thin bedding to thick laminations. *Arenicolites* burrows filled with calcite.
97.9	StPI 57	Lime mudstone, medium grey, weathers light grey, laminated, pyrite grains. *Arenicolites* burrows filled with calcite.
99.0	StPI 58	Grainstone, medium to dark grey, weathers light grey to buff, intraclasts sub-rounded, lenticular light-coloured material surrounded by darker matrix, graptolites on lower bedding plane.
100.0	StPI 59	Grainstone, medium to light grey, intraclasts sub-rounded, chert present, forms nodules and encrusts around limestone.
100.6	StPI 61	Limestone conglomerate, clasts coarse sand-size to large flat pebbles to boulders. Clasts mostly mudstone.
102.5	StPI 62	Limestone conglomerate, clasts coarse sand-size to large pebbles, clasts generally smaller than those of last two samples. Sparry calcite matrix.
103.5	StPI 63	Limestone conglomerate, clasts angular, although flat, range from coarse-sand to boulder size. Bed thickness 0.5 m, argillaceous matrix.
104.0	StPI 64	Limestone conglomerate, clasts coarse-grain to pebble size, sub-rounded to rounded, matrix sparry.

106.5	StPI 65	Limestone conglomerate, grains very coarse-grain sized, about 3 mm, grain supported, some clasts up to 3 cm in diameter.
107.4	StPI 66	Grainstone, dark grey, weathers buff, texture indeterminate, contains three dimensional graptolite material.
107.6	StPI 67	Limestone conglomerate, clasts medium grey to dark brown to black, mostly mudstone, pebble to small boulder size, argillaceous matrix. Layer of black chert weathering reddish-brown caps entire bed.
108.8	StPI 68	Shale, black, non-calcareous, graptolitic.
109.7	StPI 69	Shale, green, laminated, pyrite grains.
114.3	SPI84-2	Shale, red, calcareous(?).
116.2	SPI84-3	Shale, green, laminated.
117.2	StPI 70	Dolomitic siltstone, green, weathers yellow to buff, bed thickness 25 cm, non-calcareous, burrows in bedding planes.
118.2	StPI 71	Lime mudstone and grainstone, light brown, exhibits graded bedding, chert within bed and on bedding surfaces.
121.5	StPI 72	Lime mudstone, medium brown, weathers light grey, bed thickness 3-4 cm.
122.5	StPI 73	Lime mudstone, medium brown, bed thickness 4 cm.
125.0	StPI 74	Limestone conglomerate, clasts small boulder to pebble size, argillaceous matrix, conglomerate overlain by chert layer.

126.6	StPI 75	Lime mudstone, medium brown, weathers blue-grey. Entire bed grades from light-coloured at base to dark-coloured at top.
127.0	StPI 75a	Lime mudstone, medium brown, weathers light grey, bed thickness 10 cm.
139.8	StPI 75b	Same as previous sample.
141.0	StPI 76	Same as previous sample.
142.0	StPI 77	Lime mudstone, medium brown, weathers light grey, *Arenicolites* burrows.
143.3	StPI 78	Same as previous sample.
151.0	StPI 79	Lime mudstone, medium brown, weathers light grey, bed thickness 1-2.5 cm.
152.8	SPI84-1	Lime mudstone, brownish-grey, thinly bedded, laminated, high crystallinity.
154.7	StPI 81	Lime mudstone and grainstone, medium brown, weathers grey, graded bedding, coarse-grained particles at bottom of bed graded into finer-grained particles towards top. Cross-bedding, *Arenicolites* burrows.
155.5	StPI 82	Shale, black and green, weathers same except for oxidation of surface. Black and green shale interbedded, laminations and lenses of green shale occur within black shale.
156.5	StPI 83	Lime mudstone, medium brown, weathers light grey, thick bedding, wavy. *Arenicolites* burrows filled with calcite.
157.3	StPI 84	Lime mudstone, medium brown, weathers light grey, truncated cross-bedding.

158.4	StPI 85	Limestone conglomerate, clasts sub-rounded to sub-angular, matrix argillaceous, phosphorite pebbles.
161.2	SPI84-4	Lime mudstone, light brown, weathers grey, wavy bedding, high crystallinity.
162.0	SPI84-5	Chert, green, light bands with coarse sand-sized grains.
166.0	StPI 86	Limestone boulder in megaconglomerate (Bed 12), grey, prominent banding throughout, matrix weathers brown.
169.2	StPI 87	Shale, green, hard, pyrite present.
170.9	StPI 88	Lime mudstone, medium to dark brown, weathers light grey to buff, bed thickness 3-4 cm, laminated at top.
171.8	StPI 89	Lime mudstone, medium brown, weathers light grey, bed thickness 10 cm, chert nodules dark grey to black, with light brown "halo" on rim.
172.7	StPI 90	Grainstone, medium to dark brown, weathers light grey, clasts sub-rounded, poorly sorted.
173.4	StPI 91	Lime mudstone, medium brown, weathers light grey, with chert nodules.
174.7	StPI 92	Grainstone and mudstone, medium brown, weathers light grey, with thin bands of chert, black, weathering reddish-brown.
175.5	StPI 93	Lime mudstone, medium brown, weathers light grey, with chert nodules.
176.4	StPI 94	Grainstone, medium brown, weathers buff, intraclasts sub-angular to sub-rounded, poorly sorted, bed thickness 15 cm. Bed capped by dark grey chert layer, 1 cm thick.

177.6	StPI 95	Limestone conglomerate, clasts very coarse-grained size to long, angular flat pebbles, phosphorite pebbles up to 3 cm.
178.5	StPI 96	Shale, green, non-calcareous.
179.3	StPI 97	Lime mudstone, medium brown, weathers light grey, bed thickness 7 cm, wavy bedding.
180.1	StPI 98	Lime mudstone, light brown, weathers grey, wavy bedding, almost nodular. Calcite infillings, pyrite grains.
181.2	StPI 99	Lime mudstone, light brown, weathers medium grey, cross-bedded.
182.3	StPI 100	Shale and siltstone, black to green to light grey, weathers greenish-yellow, laminated, non-calcareous.
183.2	StPI 101	Limestone conglomerate, clasts rounded to flat, large granule to small pebble size, argillaceous matrix.
185.4	StPI 102	Shale, green, non-calcareous.
186.0	StPI 103	Limestone conglomerate, clasts small pebbles and large flat clasts, includes bed of dolostone, green, weathering yellow.
187.6	StPI 104	Limestone conglomerate, clasts commonly large boulders, rounded to sub-angular, clast supported.
188.6	StPI 105a	Grainstone, light grey, weathers same, intraclasts sub-rounded to rounded, very poorly sorted. Top dolomitic, weathering green-yellow.
189.7	StPI 105b	Silty shale, black and green, laminated, non-calcareous.
190.0	StPI 105	Limestone conglomerate with phosphorite pebbles.
190.0	StPI 105c	Chert, blue-black, weathers reddish-brown, brittle, includes other minerals with colours ranging from buff to green.

192.0	StPI 106	Shale, red, dolomitic siltstone lenses 5 cm wide, weather yellow, interbedded with red shale, non-calcareous.
193.3	StPI 107	Shale, red, with lenses of siltstone, weathering yellow, non-calcareous.
194.2	StPI 108	Same as previous sample.
195.6	StPI 109	Shaly siltstone, green, thinly bedded, with lenses of light-coloured material.
196.6	StPI 110	Dolostone, medium grey, weathers buff, bed thickness 10 cm.
197.1	StPI 111	Grainstone, medium grey, weathers yellowish-brown, intraclasts rounded, very poorly sorted, slight graded bedding.
198.0	StPI 112	Shale and siltstone, green, weathers buff-yellow, light-coloured banding.
205.8	StPI 113	Silty shale, grey-black, weathers buff, laminated. Notable feature is 1 cm thick horizon of coarse-grain sized particles.
206.6	StPI 114	Shale, red, and siltstone, black, dolomitic, laminated with siltstone lenses and bands about 1 cm thick.
207.6	StPI 115	Same as previous sample.
208.3	StPI 116	Limestone conglomerate, large clasts supported by coarse sand-sized particles.
209.8	StPI 117	Grainstone, medium brown, weathers same, texture indeterminate.
210.4	StPI 118	Shale, green, dolomitic(?), thick bedded, beds of light and dark material interbedded, non-calcareous.
220.8	StPI 119	Shale, red, thick bedded, lenses of green shale, non-calcareous.

221.4	StPI 120	Limestone conglomerate, clasts small pebble to small boulder size, argillaceous matrix.
224.2	StPI 121	Shale, red, with siltstone bands and lenses, other features much like previous samples of red shale.

APPENDIX C

Distribution tables for productive samples from Martin Point and St. Pauls Inlet sections. Diss. Res. Wt. = Dissolved Residue Weight for all tables. L.H. = Lower Head Formation for Table 3. The following is a key to the abbreviations used for the element types listed in Tables 1-3.

acod. = acodontiform
acont. = acontiodontiform
acos. = acostate
asym. = asymmetrical
ambal. = ambalodontiform
belod. = belodontiform
bergstro. = bergstroemiform
bicon. = biconvex
bryanto. = bryantodontiform
clad. = cladognathiform
coni. = coniform
cordy. = cordylodontiform
cos. = costate
cyrt. = cyrtoniodontiform
delt. = deltiform
dist. = distacodontiform
drep. = drepanodontiform
falod. = falodontiform
goth. = gothodontiform
homo. = homocurvatiform
ligono. = ligonodiniform
multi. = multicostate
multiram. = multiramiform
oist. = oistodontiform
oulod. = oulodontiform
ozark. = ozarkodiniform
palt. = paltodontiform
paracordy. = paracordylodontiform
pip. = pipiform
plano-con. = plano-convex.
plat. = platform
plect. = plectospathodontiform
prion. = prioniodiniform; prioniodontiform
ramif. = ramiform
scand. = scandodontiform
sculp. = sculponeiform
sl. sym. = slightly symmetrical
suberect. = suberectiform
subsym. = subsymmetrical
sul. = sulcatiform
sym. = symmetrical
tetra. = tetraprioniodontiform
triang. = triangulariform; triangular
trich. = trichonodelliform

TABLE 1-Distribution of conodonts in lower part of St. Pauls Inlet section.

BED		9															10			11				
SAMPLE NO.		13	31	36	37	39	42	43	45	46	47	50	53	55	57	59	61	63	67	71	73	74	75a	
SPECIES	DISS. RES. WT. (kg.)	2.0	1.1	2.7	3.2	1.2	3.2	3.5	3.4	2.7	3.4	3.3	3.1	3.3	3.2	3.1	3.1	3.4	3.3	2.7	3.3	2.1	3.3	Total
Acodus deltatus	acod.										3			2					11	1				17
	oist.	2																	4					6
	drep.	3	5								3		1						4					16
	goth.	1	11	1									1						8					22
	trich.	1																						1
	dist.	3	3																2					8
***A.*? *gladiatus* s.f.**																			1	21	1	3	1	27
A.*? *russoi	oist.		2								2			1							2	1		8
	belod		1				1																	2
	trich.		2																			1		3
	dist.		4																			2		6
***A.*? sp.**	acod.																						1	1
	drep.																			1				1
	goth.																			3				3
	trich.																			1	1	1	1	4
A.*? sp. aff. *A. sweeti																			20					20
A.*? *sweeti	acod.						1												1	8				10
	oist.																			6		1	1	8
"Acontiodus" staufferi s.f.							8		2					1										11
"Belodella" sp. B																				5			1	6
Bergstroemognathus sp. cf. ***B. extensus***	falod.						2							2					3	9				16
	prion.						4							3					2	12		1		22
	trich.						2						1							4				7
Coelocerodontus bicostatus s.f.		1													2					1	1			5
C. latus s.f.			2												1									3
C. sp.		1	1														1		1	12	2	3	8	29
Cornuodus longibasis	asym.																		6	5		1		12
	bergstro.																		3	4		3		10
	sym. A							1				1		4					5	11		6		28
	sym. B																		5	2		2	1	10
Diaphorodus delicatus	acod.		10		1		1					1		2	1		7	1	3	5	13	5	8	58
	oist.		17											1			4		22	2	7	2	8	63
	drep.		12											1			1		17	4	13	9	5	62
	trich.		4		1		1								1		1		7	3	6	4	3	31
	dist.		9									1			1		1			9	6	4	3	33
Drepanodus arcuatus	acont.						8	8						5				2	1	25		8	4	61
	cos. pip.		3				9		2					22			1		5	10	4	12	3	71
	cos. sculp.		2				10	2	1								2	1	6	24		3	4	55
	pip.		3				19	2			1			7					8	10			5	55
	sculp.						9		2					9					1	8				29
	sym. drep.		10				1	2	4		6	4	1	35		1	4	2	6	21	4	6	13	120
"D." n. sp. C s.f.							3													7			1	11
"D." toomeyi s.f.							6	2						1										9
Drepanoistodus*? *concavus	homo.		2				11	3	9		1	2	2	17					3	3			1	54
	oist.						9		2					2				3	1	1				18
	suberect.						1	1						3					1					6
D. sp.	homo.	2	16					7		1				8	2				26	12	4		7	85
	suberect.																		4	1			2	7
***D.*?** sp. A	homo.						19							6				2		8			1	36
	oist.						9							2					4	1				16
	suberect.						1																	1
Eucharodus parallelus			10				19		3	1			1	6			1		4				8	53
Fryxellodontus*?** sp. aff. ***F.*? *corbatoi				1																				1
F.*?** sp. cf. ***F.*? *reudemanni								1						3					3	4			1	12
Glyptoconus quadraplicatus			5				31	2	3		2			21	1		1		1				2	69
Juanognathus jaanussoni																				4			1	5
J. variabilis																				6		1	2	9
***Microzarkodina*?** sp.							4																	4
"M." sp. aff. ***"M." adentata***	ozark.																			2		1	1	4
	multram.													1					1	4		9	4	19
Oepikodus communis	prion.					2													39				9	50
	oist.																		15				1	16
	ramif.																		25				1	26
O. evae	prion.																			2551	67	232	487	3337
	oist.																			454	37	105	145	741
	ramif.																			1346	119	266	364	2095
Oistodus lanceolatus	oist.																			11				11
	cordy.																			13				13
	clad.																			17				17
	trich.																			6			1	7
	delt.										1													1
O. n. sp. 1			1		1		1	11	3		7	5	2	19		2	1		9					62
"O." sp. aff. ***"O." cristatus*** s.f.								2		1	1				1				1					6
"O." sp. aff. ***"O." hunickeni*** s.f.																			4					4
Oneotodus costatus							6		1					6									4	17

Paracordylodus gracilis	cordy.		47				2	13			6	5	3	22	11		2		2			1		114
	oist.		50		10		1	37			15	9	7	39	12	2	12		4	2				200
	paracordy		20	3	13		4	15	4		17	9	7	43	42	2	4		4		1	1	1	190
Parapanderodus gracilis		2	4				1				1			4				1	43	1		2	11	70
Paroistodus parallelus	drep.		6					7	3		7	1	2	33	3	2	4	1	33	24	5	32	9	172
	oist.		13					3			4	2	2	39			2	3	41	14	2	7	4	136
P. proteus	drep.	3	5																					8
	oist.	1																						1
***P.*? sp. A**	drep.						8	1						6										15
	oist.						7																	7
***P.* sp. B**			4											1	2		2	1	1	2		30	2	45
Periodon flabellum	prion.																			15	1	5	40	61
	oulod.																			13	4	3	26	46
	oist.																			35		13	36	84
	multiram.																			57	9	33	112	211
***P.*? sp.**	prion.		17				2	8	2		1		1	32						8		4		75
	oist.		8		1			6					3	12		1								31
Prioniodus elegans	prion.		6	1	5		15		1			4	1	37	2		6	21	69	1			1	170
	falod.		4	1			10	4			1	3		13	3		3	11	22	3			1	79
	belod.		4	1	10		6	7			2	3	2	20	10	2	4	9	150					230
	trich.		1		1									6	1		2	1	7					19
	tetra.		3		3		5	1	7		3		1	19	3		10	6	54	1				116
Protopanderodus elongatus	asym.						1												1	5				7
	sl. sym.																		2	3				5
	sym.		6														1		7	12			2	28
P. gradatus	asym. acont.																						2	2
	scand.																						1	1
P. leonardii	asym.								1										5	3		1	2	14
	scand.																		2	5		1	2	10
	sul.																		2					2
	sym.						2	2			3							1	2	2				12
P. rectus	asym. acont.																		4	5	1	1	4	15
	sym. acont.																		2	10	1	11	3	27
	scand.																		9	15	2	7	5	38
	sul.																		2	21	5	16	5	49
P.* sp. cf. *P. varicostatus	asym. drep.																			3		4	6	13
	sym. drep.																			2				2
	scand.																			3		1		4
Protoprioniodus papillosus	triang.														2				10	3	3	3	1	22
	oist.																		1		2	1	2	6
P. simplicissimus	prion.				1						2			5					27			1		36
	oist.							14			2			4	2				54			4		81
	ramif.				1			4			2	5		5					6	2				25
***P.*? sp.**																				2				2
Reutterodus andinus																				1				1
Scandodus furnishi	drep.						1	1											1					3
"Scolopodus" cariae s.f.																				2			1	3
"S." emarginatus s.f.							12	1	2				1	5			1		1				1	24
"S." peselephantis														3					3	1			1	8
"S." triangularis s.f.		2	1											1									1	5
Semiacontiodus cornuformis	asym.																		19				2	21
	sym.		1											4					12				4	21
***Stolodus* sp. 1**																				9		5	6	21
Triangulodus* sp. cf. *T. subtilis	acod.																			6				6
	drep.													14			1			7				22
	trich.													8						2				10
***Ulrichodina* sp.**							2							1										3
Walliserodus australis	3-cos.				1				1											13			1	16
	4-cos.																1		1	11			1	14
	5-cos.							1						2					2	3			3	11
	multi.						17				1			1					10	3		3	1	36
Drepanodontiform element A							1							7				1	11	1				21
Drepanodontiform element B																			6					6
Drepanodontiform element C																			1				4	5
New Genus B sp.														1										1
New Genus D sp.			7				1																	8
New Genus E sp.	con.																		1	3				4
	plat.						1							4					1	8			1	15
Scandodontiform element							4																	4
Total		22	342	8	49	2	299	169	53	3	94	55	39	581	102	12	80	68	928	[illegible]	324	882	[illegible]	10 550

TABLE 2-Distribution of conodonts in upper part of St. Pauls Inlet section.

SPECIES	BED	11								12	13												14	
	SAMPLE NO.	75b	76	78	79	81	83	85	84-4	86	88	90	92	94	99	101	103	104	105	105a	116	117	120	
	DISS. RES. WT. (kg.)	3.0	3.0	3.0	2.4	2.4	3.2	2.9	—	2.6	1.9	2.6	3.1	3.2	3.0	2.1	1.9	3.3	3.0	.03	2.8	0.2	1.0	Total
***Acodus*? *gladiatus* s.f.**		13				7																		20
A.*? *robustus	acos. acod.											4	5	5										14
	cos. acod.											9	4	19										32
A.*? *russoi	oist.		1																					1
A.* sp. aff. *A. deltatus	acod.									19														19
	oist.									9														9
	drep.									9														9
	goth.									4														4
	trich.									4														4
	dist.									8														8
A.*? *sweeti	acod.	3																						3
	oist.	1																						1
Ansella jemtlandica	plano-con.																						1	1
	trich.																						2	2
***Baltoniodus*? sp.**														1										1
Bergstroemognathus* sp. cf. *B. extensus	prion.	2				1																		3
	falod.	2																						2
	trich.	2																						2
***Coelocerodontus latus* s.f.**							1				3													4
***C.* sp.**											1													1
Cordylodus* sp. cf. *C. horridus						16																		16
Cornuodus longibasis	asym.					2																		2
	bergstro.					5																		5
	sym. A	1				24			2			2	1	1										31
	sym. B					20						2	2											24
Diaphorodus delicatus	acod.	1			1	14						3	2		5									26
	oist.				2	1						1												6
	drep.					12						1			3									16
	trich.	1				7						1			2		1						1	13
	dist.					6							1		2									9
***Dischidognathus* sp.**												3		2	1			1						7
Drepanodus arcuatus	acont.					7			14			10	10	20								2	4	67
	cos. pip.	4				13			19			2	3	21									1	63
	cos. sculp.	2				4			12			5	7	6				1	1			3	3	44
	pip.					3		1	2			11	11	19			2							49
	sculp.				1	4						1		1			1							8
	sym. drep.	7	1		1	10	1		6	2	3	8	19	19				1						78
"*D.*" n. sp. C s.f.		1				2			2			3	6	20									3	37
Drepanoistodus basiovalis	homo.	1										8	4	6		1								19
	oist.											2	2	1		1		2						8
	suberect.											4	3	1										8
D.*? *concavus	homo.	1				8			11			3	5	7			3	1						39
	oist.	2						1	4					1										8
	suberect.													2									3	5
***D.* sp.**	homo.	7				15			5	3														30
	suberect.	2				3																		5
***D.*? sp. A**	homo.	1							5	1		2												9
	oist.								3															3
D.*? sp. cf. *D. venustus	drep.																						6	6
	oist.																						7	7
Eucharodus parallelus		4										2	3	5										14
Fryxellodontus*? sp. aff. *F.*? *corbatoi														1										1
Glyptoconus quadraplicatus		1								3				1										5
Juanognathus jaanussoni		1				5			6				1											13
J. variabilis						8							1											9
Jumudontus gananda	blade								4															4
J.* sp. aff *J. gananda	blade											5	1	13										19
	coni.											9		3			1							13
Lenodus falodiformis	prion.																					5		5
"*Microzarkodina*" *marathonensis*	ozark.					5												1						6
	multram.					7									1			1						9
"*M.*" sp. aff. "*M.*" *adentata*	ozark.	3														1								4
	multiram.	4																						4
Oepikodus communis	prion.		4		1										1?									6
	oist.		2																					2
	ramif.	1	1																					2
O. evae	prion.	392	5		1	27		2	1			1	5	1										435
	oist.	167	5		1	8						2	2											185
	ramif.	211	26	1	2	13		2				2	1											258
O. intermedius	prion.					162	5		19															186
	oist.					68	2		6															76
	ramif.					91	6		13															110
Oistodus lanceolatus	oist.								1			7	1	10				1	1?				1	22
	cordy.					4			1			7	4	10									3	29
	clad.											7	7	10			2	2					3	31
	trich.											2		1										3
	delt.											3												3
Parapanderodus elegans		4										2	1										1	8
P. gracilis										4														4
P.* sp. cf. *P. arcuatus		4				3			1			26	21	18				1					9	83
P. striatus												11	4	12									3	30
Paroistodus parallelus	drep.	7				64	2		16		2	33	18	18	3		3		1	1		1	39	208
	oist.	9				68			16		2	63	27	28	2		3	8	1			2	40	269

Periodon aculeatus	pnon	91	3		1	[illegible]			257		10	[illegible]	557	[illegible]	1	3	4	19	2	4	5	25	76	4812
	oulod.	30				872			93		5	675	274	514	1	4	5	12					25	2510
	falod	115	2		3	917	3	1	221	1	9	828	364	957	1	3	9	23	1		5	40	82	3585
	multiram	157	25		6	[illegible]	2	1	198		70	[illegible]	745	667	2	10	22	33	1	2	10	11	100	5322
P. flabellum	pnon			1	1	54			1			33	20	31		1				1	2			145
	oulod.					25						7	13	21										66
	oist				1	23			8			36	20	78		1								167
	multiram					49			5			44	19	61		1				1				180
***P.*? sp.**	pnon.	1														1								2
Prioniodus elegans	falod.	1																						1
	tetra.																	2						2
Protopanderodus cooperi	asym acont																						2	2
	sym acont.																						3	3
	scand.																					1	2	3
P. elongatus	asym.					2																		2
	sl. sym					1						1	1										2?	5
	sym.					1																		1
P. gradatus	acont.	1							7															8
	asym acont.	2				7			7														2	18
	scand.	2							4															6
P. leonardii	asym	2										1												3
	scand.													1										1
P. rectus	asym. acont.	5				7			2			4		2				1		1			1	23
	sym. acont	8				28			3			11	3	11				3						67
	scand	6				16			2			9	5	3				2					6	49
	sul.	3	1			10						5								1			2	22
P. strigatus	asym. acont.												1											1
	sym. acont.											3					1						1	5
P. sp. aff. *P. gradatus*	asym acont.	2				2			1															5
	sym. acont.	1				2			1															4
	scand.	2				1																		3
	sul.					16																		16
P. sp. aff *P. rectus*	asym. acont.											1		8										9
	sym. acont.											2	1	5				2						10
	?scand.												2					1						3
P. sp. cf. *P. varicostatus*	asym. drep.	9				7			6			3	4	10				1				4	4	48
	sym. drep.													2									1	3
	scand.					3			4			1	1	3								1	2	15
Protoprioniodus aranda	pnon.					1			3		2	37	14	31	3	2	1	1					15	110
	oist.					3			4		2	19	21	31	4		8	4					17	113
	ramif					1			2		4	13	8	10			3	1		3	1		4	50
P. papiliosus	delt.					2			1															3
	triang.					4			1			1		1										7
	oist.	3				3			4			2	1					4						17
P. simplicissimus	pnon.					8																		8
	oist.	1				3																		4
***P.*? sp.**		2				10			4															16
Pteracontiodus cryptodens	acod											1	2	3									3	9
	cordy											1	1	1										3
	trich											4		1									1	6
	dist.											1	1											2
Reutterodus andinus						4																		4
"Scandodus" *flexuosus* s.f.						1						6	4	8				1						20
S. furnishi	drep.											2		9										11
	oist.													3										3
	scand.											2		1										3
	suberect													1										1
S. sinuosus	acod.												1	1										2
	dist.												1											1
	oist.											2	2	3										7
	scand.												1											1
S. sp. cf. *S. brevibasis*	acod.											1												1
"Scolopodus" *cariae* s.f		2																						2
"S." *emarginatus* s.f									2			1		2										5
"S." *peselephantis*						4						4											1	9
S. quadratus													1											1
"S." *triangularis* s.f		1																						1
Semiacontiodus cornuformis	asym.	1										8	1	5									4	19
	sym	3										8	4	12									5	32
Spinodus* sp cf *S. spinatus	pnon																						2	2
	cordy																1					1		2
	ligono																					1		1
***Stolodus* sp 1**		3				7																		10
Strachanognathus parvus						14						1												15
Tripodus laevis	oist								1			5	3	7									1	17
	drep											1		2										3
	dist.											5	1	5										11
	trich.													4				1						5
	palt											7	2	13									1	23
Ulrichodina cristata s.f		2												2										4
***U.* n sp. s.f**														2										2
Walliserodus australis	3-cos	3				1																		4
	4-cos	1																						1
W. ethingtoni												5	5	9										19
Drepanodontiform element A												1		1										2
New Genus D sp																		1						1
New Genus E sp	plat	1																						1
Total		[illegible]	76	2	22	[illegible]	22	8	[illegible]	67	113	[illegible]	[illegible]	[illegible]	32	29	70	133	8	14	23	97	497	20 566

TABLE 3-Distribution of conodonts in Martin Point section.

SPECIES		8			9				10		11						13		14		L.H.	
SAMPLE NO.		16	20	24	27	29	34	39	45	45a	47	49	52	59	64	68	74	76	54A	55	56C	
DISS. RES. WT. (kg.)		2.9	3.1	3.1	1.5	2.0	2.0	1.9	3.3	2.5	2.9	2.0	2.0	2.0	2.4	1.2	2.2	2.9	3.1	0.5	1.1	Total
Acodus*? *gladiatus s.f															1							1
A.*? *sweeti	acod													1								1
Ansella jemtlandica	bicon																				28	28
	oist.																				11	11
	plano-con.																				10	10
***Baltoniodus*?** sp.																		4				4
Bergstroemognathus sp. cf. ***B. extensus***	falod.													3					2			5
	prion.								1					4					3			8
	trich.																		1			1
Coelocerodontus bicostatus s.f		23								1	1						5					30
C. latus s.f		8								2												10
Cordylodus sp. cf. ***C. horridus***														1	1							2
Cornuodus longibasis	asym.																1					1
	sym. A				1		1								1		4		1		1	9
Diaphorodus delicatus	acod.										1			1	10							12
	oist.										2				9							11
	drep.														4							4
	trich.										1				1			1				3
	dist.										1				3							4
Drepanodus arcuatus	acont.							1	1					3	1			1	2	2	48	59
	cos. pip.										1				1			2		2	23	29
	cos. sculp.	1							1		1			2	2	1		4		1	22	35
	pip.					1		2	1	1				4		2		3	3		1	18
	sculp.			3															7			10
	sym. drep.	2		3				1			2			2	1	2		1	5			19
"D." n. sp. C s.f																2					4	6
Drepanoistodus*? *concavus	homo.	1				1			4					8				3	18		21	56
	oist.								1												1	2
	suberect.																		1			1
D. sp.	homo	62												2				3			12	79
	suberect.	4												1								5
D. tableheadensis	drep.																				32	32
	oist																				5	5
***D.*?** sp. A	homo								4					1					11		12	28
	oist.																		8		1	9
D.*?** sp. cf. ***D. venustus	drep.																			2	15	17
	oist.																			1	13	14
***Eoplacognathus*?** sp.	ambal.																				1	1
Erraticodon sp. cf. ***E. balticus***	cyrt.																				25	25
	ligono.																				7	7
	plect.																				5	5
	prion.																				5	5
	trich.																				3	3
Eucharodus parallelus											1			8					1	1		11
Fryxellodontus*?** sp. aff. ***F.*? *corbatoi		5																				5
Glyptoconus quadraplicatus		1	1	1												1						4
Histiodella altifrons	bryanto.																				1	1
H. holodentata																					73	73
H. serrata s.f																					1	1
Juanognathus jaanussoni																					4	4
J. variabilis														2								2
Jumudontus sp. aff. ***J. gananda***	blade.													1								1
Lenodus falodiformis	prion																				34	34
	falod																				14	14
	cordy																				7	7
	trich																				12	12
	tetra																				4	4
"*Microzarkodina*" *marathonensis*	ozark																				43	43
	oist																				8	8
	multiram.																				41	41
Oepikodus evae	prion.												4	4				3		1	1	13
	oist.												17	1				1				19
	ramif												16	4		1		7				28
O. intermedius	prion														15							15
	oist														4							4
	ramif														11							11
Oistodella sp. cf. ***O. pulchra***	cyrt.																				3	3
	oist																				7	7
	cordy																				4	4
	clad																				2	2
	trich.																				6	6

Oistodus lanceolatus	oist											1							1	2
	cordy																		3	3
	clad.																		2	2
	delt											1								1
O. n sp. 1								1	11								10			22
"O." sp. aff ***"O." cristatus*** s.f									1											1
Paracordylodus gracilis	cordy						2	1	5											8
	oist						1	4	9											14
	paracordy.						1	2	86	2										91
Parapanderodus arcuatus																			31	31
P. elegans																2			4	6
P. gracilis		10								1		1					3			15
P. sp cf. ***P. arcuatus***																1				1
P. sp. cf ***P. striatus***																			15	15
P. striatus													1						7	8
Paroistodus parallelus	drep.						2	3			2	1	5	3	7	6		3	143	175
	oist.			1	1	1	3	3			2	1	2	3	5	7		12	142	183
P. proteus	drep	42						1												43
	oist.	14	1																	15
P.? sp. A	drep.							2									2			4
Periodon aculeatus	prion											4	15	18	43	12		25	330	447
	oulod.											9	3	13	26	7		3	178	239
	falod											31	25	32	29	15		18	501	651
	multiram.											19	17	27	133	27		14	483	720
P. flabellum	prion.														8					8
	oulod.														4					4
	oist														24					24
	multiram														21					21
Polonodus? peavyi	subsym.																		25	25
	asym.																		24	24
Prioniodus elegans	prion.							2		8	2	2					21		1	36
	falod.							1	1	3	2					2	5			14
	belod.				2			2		7	3					1			1	16
	trich.									2							2			4
	tetra.							3		4						4	6			17
Protopanderodus cooperi	asym. acont.																	1	13	14
	sym. acont.															1		1	35	37
	scand.																		6	6
P. elongatus	asym																		1	1
	sym																		1	1
P. gradatus	acont.																		15	15
	asym acont.												1						9	10
	scand.																		1	1
P. leonardii	scand.											1					1			2
P. rectus	asym. acont.												1						9	10
	sym. acont									1			1	1		1			19	23
	scand.												2	1	3	1			16	23
	sul.												2	1					7	10
P. strigatus	asym acont.																		4	4
	sym acont.													1					20	21
P. sp. aff. ***P. gradatus***	asym acont																		4	4
	sym. acont.												1						18	19
	scand.																		4	4
	sul.												1							1
P. sp. aff ***P. rectus***	sym. acont.												1	1						2
P. sp cf ***P. varicostatus***	asym drep.															4		1	62	67
	sym. drep.																		10	10
	scand.												1					1	30	32
Protoprioniodus aranda	prion.													3	3	5				11
	oist											1	2		4	1				8
	ramif.															1				1
P. papillosus	delt													1						1
	triang.									1			1							2
	oist.													1						1
P.? sp.															2				52	54
Pteracontiodus cryptodens	acod											2?							1	3
	trich															1?				1
Scandodus furnishi	drep	17										1					1			19
	oist	6																		6
	scand.													1					1	2
	suberect	2																		2
S. sinuosus	acod																	1?		1
S. sp cf ***S. brevibasis***	acod																		5	5
	dist																		3	3
	drep																		6	6

"Scolopodus" peselephantis		109			1	1					1							1				113
S. quadratus																1						1
Semiacontiodus cornuformis	asym.																				6	6
	sym													1				1			7	9
Spinodus sp. cf. ***S. spinatus***	pnon.																				13	13
	oulod.																				4	4
	falod.																				6	6
	cordy																	1?			4	5
	ligono.																				1	1
	clad.																				5	5
	trich.																				5	5
Strachanognathus parvus																1						1
Tripodus laevis	drep.													1								1
	dist.													1								1
	oist.																	1				1
Triangulodus sp. cf. ***T. subtilis***	trich.								1													1
Ulrichodina sp. aff. ***U. wisconsinensis*** s.f.																			1			1
U. cristata s.f.														1								1
U. n. sp. s.f.														2								2
U.? sp. s.f.														1								1
Walliserodus australis	3-cos.													1					1			2
	4-cos.										1											1
	5-cos.													4								4
W. ethingtoni															1						3	4
Drepanodontiform element A																			4			4
New Genus A sp.	asym.												1	2								3
	sym													2								2
New Genus C sp.		4																				4
New Genus D sp.		6																				6
Total		317	2	8	5	3	2	13	39	117	42	11	38	144	146	120	322	136	120	90	[illegible]	4543