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PART 1

**LATE ORDOVICIAN CONODONTS FROM THE VAURÉAL
FORMATION, ANTICOSTI ISLAND, QUEBEC**

GODFREY S. NOWLAN
CHRISTOPHER R. BARNES

PART 2

**CONODONT BIOSTRATIGRAPHY AND PALEOECOLOGY
OF THE ELLIS BAY FORMATION, ANTICOSTI ISLAND,
QUEBEC, WITH SPECIAL REFERENCE TO LATE
ORDOVICIAN - EARLY SILURIAN CHRONOSTRATIGRAPHY
AND THE SYSTEMATIC BOUNDARY**

ALEXANDER D. McCracken
CHRISTOPHER R. BARNES

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Preface

The two papers comprising this bulletin describe conodont faunas from the Vauréal and Ellis Bay formations exposed on Anticosti Island. The strata are of late Ordovician and earliest Silurian age and provide an apparently continuous sequence across the Ordovician-Silurian boundary. Abundant, well-preserved conodonts occur throughout the section providing a biostratigraphic framework for this poorly known boundary interval.

Computer-based clustering techniques have been used to aid in recognition of natural associations of conodont elements at the specific level. Further cluster analysis of the species has shown paleoecologic associations through time.

This work provides detailed biostratigraphic and paleoecologic information on a possibly unique complete sequence across the Ordovician-Silurian boundary. The results will aid greatly in correlation of strata of this age in other sedimentary basins in Canada and elsewhere. This framework is necessary for accurate dating of strata and the accompanying paleoecologic information defines clearly the environmental setting of these conodont faunas. Knowledge of both is important for economic assessment of sedimentary basins.

OTTAWA, June 1980

D.J. McLaren
Director General
Geological Survey of Canada

LATE ORDOVICIAN CONODONTS FROM THE VAURÉAL FORMATION, ANTICOSTI ISLAND, QUEBEC

Godfrey S. Nowlan and Christopher R. Barnes

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LATE ORDOVICIAN CONODONTS FROM THE VAURÉAL FORMATION ANTICOSTI ISLAND, QUEBEC

Godfrey S. Nowlan and Christopher R. Barnes¹

Abstract

During the Late Ordovician and Early Silurian, a considerable thickness of strata accumulated in the Anticosti Basin, Québec. At least 350 m of argillaceous limestone and shale of the Vauréal Formation is exposed and subsurface data indicate a total thickness of about 1 000 m. The Vauréal Formation is underlain by Upper Ordovician black shale (Macasty Formation), and overlain by argillaceous limestone and shale (Ellis Bay Formation). Graptolites from three wells indicate that the lower (subsurface) part lies within the *Dicellograptus complanatus* Zone and younger faunas suggest a post-Ashgillian, pre-Llandoveryan age. Shelly fossils indicate a Richmondian age.

Nearly 50 000 conodont elements have been recovered from 102 samples within a composite section of the Vauréal Formation. The data were analysed by R- and Q-mode cluster analysis using a P-LOG transformation to assist taxonomic and paleoecologic interpretations. The diverse fauna includes representatives of thirteen multielement genera and is dominated (50-60 per cent) by *Drepanoistodus suberectus* and *Panderodus gracilis*. Several well known Late Ordovician species are present throughout the sequence, including *Amorphognathus ordovicicus*, *Belodina profunda*, *Phragmodus undatus*, *Plectodina tenuis*, *Plegagnathus dartoni* and species of *Aphelognathus* and *Oulodus*. A key species, *Gamachignathus ensifer* is present in low abundance, first appearing about 50 m above the base of exposed Vauréal Formation. Only minor variations in faunal composition are present throughout the exposed formation, but distinct mutual and antipathetic relationships between certain taxa are evident. Three conodont ecozones are recognized: *Phragmodus*, *Amorphognathus-Plectodina*, and *Oulodus-Aphelognathus*, that appear to reflect deep subtidal to shallow subtidal environments. The fauna represents a mixture of elements that characterized eastern and western Midcontinent subprovinces earlier in the Cincinnati together with a few North Atlantic Province representatives.

Résumé

Vers la fin de l'Ordovicien et au début du Silurien, bon nombre de couches se sont accumulées dans le bassin Anticosti, au Québec. Une couche d'au moins 350 m de calcaire argileux et d'argile schisteuse est exposée et des données des terrains sous-jacents indiquent une épaisseur totale d'environ 1 000 m. La formation repose sur une couche d'argile schisteuse noire de l'Ordovicien supérieur (formation de Macasty) et est recouverte par une couche de calcaire argileux et d'argile schisteuse (formation d'Ellis Bay). Des graptolites de trois carottes de forage indiquent que la partie inférieure (terrains sous-jacents) repose dans la zone *Dicellograptus complanatus* et la présence de faunules plus jeunes indique qu'il pourrait s'agir d'une couche post-ashgil-lienne ou pre-Llandoveryenne. Les fossiles de coquillages indiquent également qu'il pourrait s'agir d'une couche du Richmondien.

Près de 50 000 éléments de conodontes ont été récupérés de 102 échantillons extraits d'une coupe composite de la formation de Vauréal. Les données ont fait l'objet d'une analyse par bloc selon le mode R- et Q- à l'aide d'une transformation P-LOG pour faciliter les interprétations taxonomiques et paléo-écologiques. Parmi les faunules figuraient des représentants de 13 genres à éléments multiples où dominaient (dans une proportion de 50 à 60 per cent) les *Drepanoistodus suberectus* et les *Panderodus gracilis*. D'autres espèces bien connues vers la fin de l'Ordovicien étaient présentes dans la séquence, notamment les *Amorphognathus ordovicicus*, *Belodina profunda*, *Phragmodus undatus*, *Plectodina tenuis*, *Plegagnathus dartoni*, ainsi que des *Aphelognathus* et *Oulodus*. Une espèce dominante, les *Gamachignathus ensifer*, étaient présente en faible quantité; les premiers spécimens observés apparaissent à environ 50 m au-dessus de la base de la formation de Vauréal exposé. Seules quelques variations mineures dans la composition fossilifère pouvaient s'observer dans cette formation; néanmoins, il existait des relations d'opposition distinctes entre certains taxa. Trois écozones de conodontes ont été détectées, soit les *Phragmodus*, les *Amorphognathus-Plectodina*, et les *Oulodus-Aphelognathus*, qui laissaient supposer la présence d'environnements submergés profonds à peu profonds. Les faunules représentent un amalgame d'éléments qui caractérisaient les sous-provinces de l'Est et de l'Ouest du *Mid-continent au début du Cincinnati* et de quelques représentants de la province de l'Atlantique Nord.

Introduction

Anticosti Island, in the Gulf of St. Lawrence (Fig. 1), is underlain by Upper Ordovician and Lower Silurian strata. These dip gently to the southwest at less than two degrees. Older strata underlie the Jacques Cartier Passage and basal Ordovician strata are exposed on the north shore of the St. Lawrence and on the Mingan Islands as the Romaine (Canadian) and Mingan (Chazyan) formations. The oldest strata exposed on the island belong to the Vauréal Formation, the conodonts from which form the basis of this report.

Early geological investigations of the stratigraphy and paleontology of the island were undertaken by Richardson (1857), Schuchert and Twenhofel (1910) and Twenhofel (1921, 1926, 1928). Roliff (1968) reviewed the subsurface stratigraphy and structure of the island and the petroleum potential. In particular, he

demonstrated that late Middle Ordovician or early Late Ordovician faulting affected the island and consequently the thickness of the Vauréal Formation that covered the fault scarp terrain. Bolton (1972) reviewed much of the earlier studies, prepared a new geological map of the island, revised some of the stratigraphy, and documented the main aspects of the biostratigraphy. The island is presently being remapped by A. A. Petryk for the Ministère des Richesses Naturelles, Québec.

Bolton (1972) also reviewed the earlier paleontological work. The main recent studies on the Vauréal faunas have been by Riva (1969, 1974) on graptolites, Bolton (1970) on brachiopods, trilobites and echinoderms, Copeland (1970) on ostracodes, and Jansonius (1967) and Achab (1977a, b) on chitinozoans.

Apart from a brief note in Sweet et al. (1971, p. 182), no previous conodont studies of Anticosti Island have been published.

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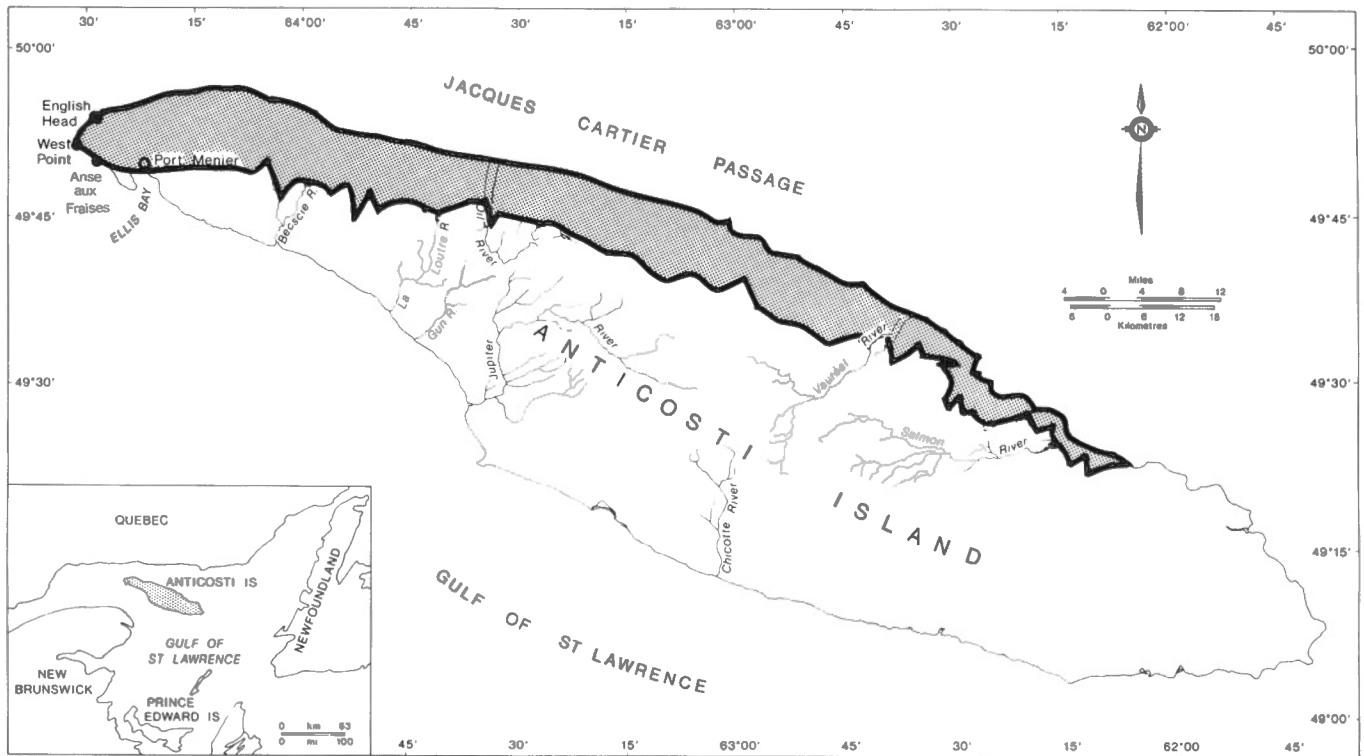


Figure 1. Location map of Anticosti Island showing the outcrop belt (shaded) of the Vauréal Formation. The formation was sampled at Salmon River, Oil River and at the western end of the island between English Head and Anse aux Fraises.

A program to study all the conodont faunas of the island was begun in 1975, co-ordinated by C. R. Barnes. The authors collected all exposed Ordovician and Silurian formations with samples taken at approximately 2 m intervals. A. D. McCracken and C. R. Barnes revisited the island in 1976 and made further collections, mainly from the Ellis Bay Formation. In the present study, the Vauréal Formation was sampled on Oil River and the western shoreline from English Head to Anse aux Fraises (Fig. 1). These two main sections provide a composite section through the exposed 310 m of the Vauréal. One sample from the upper Vauréal was also collected near the mouth of the Salmon River (Fig. 1). One hundred and two samples, each about 2-4 kg, yielded nearly 50 000 disjunct conodont elements. The specimens are well preserved and their colour indicates a position of 1 on the Conodont Alteration Index (Epstein et al. 1977) reflecting burial temperatures of less than 50-80°C.

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The SEM photographs were taken by David Walker, Geological Survey of Canada, Ottawa, using an Etec Autoscan and Polaroid type 55 P/N film.

Dr. R.L. Ethington (University of Missouri), Dr. L.E. Fahraeus (Memorial University of Newfoundland) and Dr. A.

Harris (U.S. Geological Survey) critically read the manuscript, and their comments are gratefully acknowledged. Additional comments and discussion on taxonomy with A.D. McCracken (University of Western Ontario) were of great assistance. D.M. Carson (University of Waterloo) aided greatly in the running of the computer programme.

Stratigraphy

Twenhofel (1921) erected the term Vauréal for a unit earlier called Charleton by Schuchert and Twenhofel (1910) and Twenhofel (1914). In his 1928 monograph, Twenhofel estimated the thickness to be 730 ft., overlying 228 ft. of the English Head Formation. He recognized certain key beds, or groups of beds, characterized by brachiopod assemblages, tracks, and the stromatoporoid *Beatricea*. Bolton (1961) established that the strata of the type English Head actually occur in the middle part of Twenhofel's (1921, 1928) Vauréal Formation. This problem was resolved by Bolton (1972) who referred all the strata of Twenhofel's two formations to the revised Vauréal Formation which included two members. The lower member, composed of grey shale with interbedded blue-grey to reddish grey or brown, micritic limestone and common intraformational limestone conglomerate, is at least 130 m thick. The upper member includes the type English Head at or near its base and is composed of grey micritic limestone with grey shale partings and intraformational limestone conglomerate with abundant slump structures. Inland, small coral-stromatoporoid biostromes are present near the top; some beds have concentrations of *Beatricea*, one specimen observed on the western wave-cut platform was 3 m in length. The thickness of the upper member is about 200 m to give a total thickness of the exposed Vauréal Formation of about 330-400 m. The difference with our measured sections that totalled 310 m is

probably in the estimation of covered intervals and in the problem of the very low and variable dip of the strata.

Several wells have been drilled on Anticosti Island in the search for hydrocarbons and they have provided valuable subsurface stratigraphic data (Roliff, 1968). In the New Associated Consolidated Paper Anticosti No. 1 well that was located near the centre of the island, the thickness of the Vauréal is about 1 100 m. Thus, the exposed Vauréal represents only the upper third of the total thickness.

The age of the Vauréal Formation was regarded as Richmondian by Twenhofel (1928) and by most later workers. Riva (1969) provided a more precise age from graptolites found in the well cores. Specifically, the zonal graptolites *Dicellograptus complanatus* and *D. anceps* (transient forms) occur in the upper part of the lower member of the Vauréal Formation. The overlying zone of *Climacograptus prominens-elongatus* occurs in the lower part of the upper member. Riva considered this fauna in the upper member (= his Vauréal) and that of the overlying Ellis Bay Formation to be hitherto unknown and of post-Ashgillian but pre-Llandoverly age.

Achab (1977a, b) examined chitinozoans from the same wells studied by Riva (1969). The fauna from the *D. complanatus* Zone was correlated with the upper Caradocian to lower Ashgillian of Europe. That from the overlying *C. prominens-elongatus* Zone contained some species from the underlying zone but also several new ones unknown elsewhere.

Twenhofel (1928) considered the exposed Vauréal Formation to be Richmondian whereas Sinclair (1956) regarded it as in part Maysvillian. Copeland (1970, p. 16) reported that the "Stony Mountain, Maquoketa, and Vauréal ostracod faunas are very possibly equivalent, but their reputed Richmondian age needs verification. There is little similarity between these ostracod faunas and that reported from the type Richmond strata of Indiana".

The data reported above, particularly the graptolite data, confirm a Richmondian age for the Vauréal Formation, especially the subsurface part. As discussed in the paper by McCracken and Barnes (this volume) dealing with conodonts from the overlying Ellis Bay Formation, evidence exists that most of the Ellis Bay may be post-Richmondian, i.e. Gamachian of Schuchert and Twenhofel (1910). It is uncertain whether all of the exposed Vauréal Formation should be assigned to the Richmondian or whether an upper part may be also Gamachian.

In order to ensure a relatively complete composite section, the authors followed the earlier work of Bolton (1961, 1972) and made collections along the lower part of the Oil River and on the western end of the island from English Head to Anse aux Fraises. The Oil River section (Figure 1) was sampled at 2 m intervals with a lithologic description being made of the sampled beds. The sampled section extended from the mouth of Oil River upstream to the last exposures below the main highway bridge. Bolton (1961, appendix) provided a general description and A. A. Petryk (Ministère des Richesses Naturelles, Québec) is currently preparing a more detailed description of this section and that of the western end of the island. There is almost complete exposure through 105 m of strata representing the lower six units of Bolton (1972, appendix, p. 18) from which samples 1-41 were collected. Above this point is a 27 m covered interval with a few poor outcrops near the bridge that were not sampled. The total unsampled interval from sample 41 to the bridge is about 75 m. It is estimated (Bolton, personal communication, 1978) that the base of the English Head section on the western coast is at approximately the same stratigraphic position in the Vauréal Formation as the beds exposed at the Oil River bridge.

On the western coast, cliff exposures are rare and poorly accessible north of English Head. One sample (42) was taken from shore outcrops at Pointe Jolliet, 1 km northeast of English Head, and approximately 17 m below the base of the English Head sec-

tion. A virtually complete section was collected at 2 m intervals from the base of English Head (27 m, samples 43-56), south along the wave-cut platform (34 m, samples 57 - 73), and at the Pointe à la Goélette cliff section (11 m samples 74 - 78), and south along the wave-cut platform past the West Point lighthouse (49 m, samples 79 - 98). The final collections on the west coast were made at Anse aux Fraises (5 m, samples 99 - 101). A gap of about 12 m exists between the last sample (98) taken at West Point and the lowest one (99) taken at Anse aux Fraises. Samples taken between Anse aux Fraises and Junction Cliff (Member 1, Ellis Bay Formation) are regarded as being from the Ellis Bay Formation and are part of the study by McCracken and Barnes (this volume).

A single sample (sample 102) was taken near the top of the Vauréal Formation on Salmon River in a small limestone ledge outcropping on the west bank, 3 km upstream from the lodge. This occurs about 10 m below the basal shales of the Ellis Bay Formation.

Thus, the exposed Vauréal Formation studied herein is considered to be about 310 m thick. Lower strata could possibly be collected out on the exposed wave-cut platform on parts of the north shore. In terms of depositional environment, the Vauréal Formation accumulated in a rapidly subsiding Anticosti Basin (Sanford, 1970). If the upper Macasty Shale is regarded as of late Maysvillian age from graptolite data (Riva, 1969) then 1 100-1 200 m of strata (Vauréal and lower Ellis Bay formations) were deposited to the end of the Ordovician. The clastic facies of the Ellis Bay Formation in the eastern end of the island suggests that the shoreline lay to the east or northeast. The predominantly shale facies of the lower member of the Vauréal probably represents relatively unstable, deep subtidal conditions. The gradual reduction in abundance of slump structures, increase in limestone content and presence of small coral-stromatoporoid biostromes inland in the upper member of the Vauréal Formation, all suggest progressively shallower subtidal environment. An upward shallowing in the Vauréal from a deep to shallow shelf environment was also interpreted by Erdtmann (1976, Tables 9, 10) in his discussion of graptolite ecostratigraphy.

Conodont biostratigraphy

A diverse fauna of almost 50 000 conodont specimens has been recovered from 102 samples of Vauréal Formation. Sample by sample numerical distribution of the fauna is shown in Table 1. Thirty-five species (of which seven are treated as form taxa) representing seventeen genera (of which three are form taxa) have been recognized. Species of the simple cone genera *Panderodus* Ethington and *Drepanoistodus* Lindström numerically dominate the fauna, constituting between 40 per cent and 60 per cent of the elements in most samples. The most abundant ramiform genera are *Amorphognathus* Branson and Mehl, *Oulodus* Branson and Mehl, and *Phragmodus* Branson and Mehl.

Four new species are proposed: *Panderodus gibber*, *P. liratus*, *Plectodina bidentata* and *Staufferella brevispinata*. A number of new, informal species are also recognized: one in *Aphelognathus* and three in *Panderodus*.

The fauna is typical of the Midcontinent Province (Barnes, Rexroad and Miller, 1973) with a few exceptions. The most notable genus is *Amorphognathus* which is common in the lower part of the exposed portion of the formation. *Paroistodus*? Lindström has a similar distribution to *Amorphognathus* and both are characteristic of the North Atlantic Province (Barnes et al., *ibid.*, 1973). Together, these two genera characterize faunas of Late Ordovician (Ashgillian) age in the Carnic Alps (Serpagli, 1967) and northern England (Rhodes, 1955). *Walliserodus* Serpagli which is best known from the Silurian, may also be characteristic of North Atlantic Province faunas in the Late Ordovician (Serpagli, 1967).

Subprovincial distinctions within the Midcontinent Province during the Upper Ordovician have been discussed by Sweet et al. (1959), Kohut and Sweet (1968) and Barnes, Rexroad and Miller (1973). The latter authors recognized an eastern subprovince and a western and northern subprovince (Barnes et al. *ibid.*, 1973, p. 172; fig. 11). The eastern subprovince was regarded as being characterized by *Plectodina* Stauffer and *Phragmodus* Branson and Mehl, and the western subprovince by *Panderodus* Ethington, *Belodina* Ethington, *Oulodus* Branson and Mehl, *Plegagnathus* Ethington and Furnish and *Pristognathus* Stone and Furnish. Elements typical of both subprovinces are common in the Vauréal Formation.

A number of long-ranging species are common in the Vauréal Formation, including *Belodina compressa* (Branson and Mehl), *Phragmodus undatus* Branson and Mehl and *Plectodina tenuis* (Branson and Mehl), which range upward from Fauna 7 (Blackriveran), Fauna 8 (Rocklandian) and Fauna 9 (Kirkfieldian) respectively. In addition, *Panderodus gracilis* (Branson and Mehl) and *Drepanostodus suberectus* (Branson and Mehl) have very long stratigraphic ranges. The remainder of the fauna is characteristic of the Late Ordovician.

Amorphognathus ordovicicus Branson and Mehl, the main component of the *A. ordovicicus* Zone of Ashgillian age (Bergström, 1971), is also characteristic of the upper part of Fauna 11 and Fauna 12 (late Maysvillian to Richmondian age). This taxon provides the only correlation with strata of the North Atlantic Province, but biogeographical differences make the correlation imprecise (see e.g. Sweet et al. 1971). *A. ordovicicus* is known from both eastern and western areas of the Midcontinent. The distribution of *A. ordovicicus* in the Vauréal Formation is discussed below.

Aphelognathus grandis Branson, Mehl and Branson and *A. pyramidalis* (Branson, Mehl and Branson) are characteristic of Richmondian strata in Kentucky and Indiana (Branson et al. 1951) and the type Richmond in Ohio (Kohut and Sweet, 1968). They are also listed in an unpublished report from the upper Georgian Bay Formation of southwestern Ontario (Tarrant, 1977). The same report records *A. grandis* from marine units in the younger Queenston Formation. The restricted distribution of these taxa suggests a Richmondian age, although *A. grandis* occurs together with *Belodina* sp. A of Sweet et al. (1971) in the Ely Springs and Hanson Creek formations of the Great Basin and these occurrences are considered as Maysvillian or older Late Ordovician age (A. Harris, personal communication, 1978).

Plegagnathus dartoni (Stone and Furnish) is known from Upper Ordovician carbonates in Wyoming, Hudson Bay and the Canadian Arctic Archipelago, including the upper Bighorn Formation (Stone and Furnish, 1959), the "Shamattawa Limestone" (Ethington and Furnish, 1959), the Stony Mountain Formation (Ethington and Furnish, 1960), the Caution Creek Formation of the Churchill River Group (Le Fevre et al., 1976) and the upper Thumb Mountain, Irene Bay and Allen Bay formations (Weyant, 1968; Barnes, 1974). The form described from the Richmond Group by Kohut and Sweet (1968) probably belongs within *Belodina profunda* (Branson and Mehl). Sweet et al. (1971) suggested that *P. dartoni* is diagnostic of their Fauna 12. In several of its occurrences, it is associated with *Oulodus ulrichi* (Stone and Furnish) and *A. ordovicicus*.

Oulodus rohneri Ethington and Furnish is known only from the "Shamattawa Limestone" (Ethington and Furnish, 1959). The fauna with which it is associated suggests Fauna 12. The closely related *O. ulrichi* has a wider distribution which includes the Richmond Group (Kohut and Sweet, 1968), the Stony Mountain Formation (Ethington and Furnish, 1960) and possibly the Bighorn Formation (Stone and Furnish, 1959). It is also known from the upper Georgian Bay Formation of southwestern Ontario (Tarrant, 1977). Sweet and Bergström (1976) consider *O. ulrichi* as a component of Fauna 12.

Belodina profunda is present throughout the exposed Vauréal Formation, and has a regional distribution similar to that of *Plegagnathus dartoni*, although it is also known from older strata such as the Bad Cache Rapids Formation of Melville Peninsula, District of Franklin (Barnes, 1977). It is often associated with a proliferation of species of *Belodina* and New Genus A of Barnes (1977); these latter taxa are conspicuously absent from the Vauréal Formation.

The new species of *Plectodina*, *P. bidentata*, is also known from unpublished reports elsewhere. Munro (1975) has indicated its presence in the Farr Formation of the Lake Timiskaming outlier. It has also been found by the authors in topotype material collected from the Clarkesville section of the Girardeau Limestone of Thompson and Satterfield (1975). These occurrences indicate a probable maximum stratigraphic range from Edenian to late Richmondian for the taxon.

The proliferation of new species of *Panderodus* in the Vauréal Formation may prove biostratigraphically useful. *Panderodus angularis* Branson, Mehl and Branson s.f. is considered indicative of Fauna 12 (Sweet et al., 1971; Sweet and Bergström, 1976). It is known from the Richmond Group (Branson, Mehl and Branson, 1951; Kohut and Sweet, 1968) and is listed as being present in the Stony Mountain Formation by Ethington and Furnish (1959). Unfortunately it is rare in the Vauréal Formation. Other forms of *Panderodus* recognized in this study may be equivalent to forms illustrated from the Richmond Group by Branson et al. (1951) (see discussion under *P. sp. aff. P. gracilis* and *P. n. sp. A*).

P. liratus n. sp. is known previously from the Bad Cache Rapids Formation, Melville Peninsula, District of Franklin (Barnes, 1977). That formation is older than the Vauréal Formation, thus the range of this new species is probably Edenian through Richmondian. *P. gibber* n. sp. has not been reported elsewhere but is similar to, and a possible descendant of, *P. brevisculus* Barnes which is known from older strata (Barnes, 1977).

Walliserodus sp. cf. *W. curvatus* Branson and Branson is similar to Silurian forms of the genus as reconstructed by Cooper (1975, 1976) from the Brassfield Limestone of southern Ohio and the St. Clair Limestone of southern Illinois. Serpagli (1967) has reported similar elements from Ashgillian strata of the Carnic Alps, and Flajs and Schönlaub (1976) have possible elements of *Walliserodus* from the Late Ordovician Cystoideenkalk of Austria. *W. cf. W. curvatus* is also known from strata of an outlier north of Aberdeen Lake, District of Keewatin, where it is associated with elements of Fauna 12 (Bolton and Nowlan, 1979). The biostratigraphic significance of its occurrence in the Vauréal Formation is uncertain, although it may indicate a Richmondian age. The genus is probably of North Atlantic Province affinity in the Ordovician, becoming widespread in the Silurian.

Another species which is similar to forms reported from the Silurian is *Panderodus* sp. cf. *P. serratus* Rexroad. This has not been reported previously from strata of Ordovician age. Its distribution in the Vauréal Formation parallels that of *Amorphognathus ordovicicus*, possibly indicating that it is of North Atlantic Province affinity.

The occurrence of species of *Gamachignathus* McCracken, Nowlan and Barnes is of particular biostratigraphic interest. This genus contains elements similar to those reported as *Prioniodus ferrarius* Knüpfner and *Exochognathus breviaalata* (Walliser) by Satterfield (1971) from the Girardeau Limestone of southeast Missouri and southwest Illinois. Thompson and Satterfield (1975) have also reported such elements from the Girardeau and Leemon formations of southeast Missouri and the Noix Limestone and Cyrene Formation of the Edgewood Group of northeast Missouri. It is doubtful that the elements illustrated in those reports are, in fact, *P. ferrarius*, the holotype of which is apparently from Llanvirnian strata (Knüpfner, 1967). The elements of *Gamachignathus* from the Vauréal are specifically different

from those of the *Prioniodus ferrarius* fauna of Thompson and Satterfield (1975), (McCracken, Nowlan and Barnes, 1980). Elements of *Gamachignathus* are present 50 m above the base of the exposed Vauréal Formation and extend sparsely through the remainder of the formation. If the presence of this genus indicates a very late Ordovician age (Gamachian), at least 255 m of the Vauréal Formation can be considered as such. The genus could be used to indicate the presence of a "Fauna 13", above the Faunas 1-12 outlined by Sweet et al. (1971). *Gamachignathus* becomes very abundant in the overlying Ellis Bay Formation. Indeed many of the taxa from the Vauréal Formation carry upwards into the Ellis Bay Formation, but with the exception of *Gamachignathus* and species of *Panderodus*, they are sparsely represented (McCracken and Barnes, this volume).

In summary, the exposed portion of the Vauréal Formation is characterized largely by species characteristic of Fauna 12 (Sweet et al., 1971) although some range down into Fauna 11. The graptolite evidence of Riva (1969) indicates that the lower, subsurface part of the Vauréal Formation (his English Head Formation) lies in the *Dicellograptus complanatus* Zone of the Ashgillian and that the upper part of the Vauréal Formation is characterized by a *Climacograptus prominens-elongatus* fauna of post-Ashgillian, pre-Llandovery age. The presence of *Gamachignathus* may support this evidence and indicate that the uppermost part of the Vauréal Formation and part of the overlying Ellis Bay Formation represent deposition in latest Ordovician.

Conodont paleoecology

As noted above, the conodont fauna from the Vauréal Formation is assignable to Fauna 12. Most of the species present range throughout most of the formation (Table 1) and allow no precise internal zonation. However, the distribution and faunal association of many species can be seen from Table 1 to follow definite patterns. Of particular interest is the relationship between the distribution of key compound and cone genera and whether any repetitive ecological associations can be recognized.

The distribution of *Oulodus*, *Phragmodus* and *Amorphognathus* as a percentage of the total fauna in samples yielding over 100 conodonts is shown in Figure 2. In the Oil River section, *Phragmodus* is seen to reach three major separate peaks. The peaks are not the product of single samples but are spread over several samples, each 2 m apart. Examination of thin sections of these samples (Fig. 3) indicates a change from biosparudites and biointramicrites to finely laminated micrites. This change is interpreted as representing a transition from a shallow subtidal to a deeper subtidal environment, followed by a return to the former. It would appear that the *Phragmodus* peaks correlate with phases of deeper water. From Figure 2 it can be seen that first *Amorphognathus* and then *Oulodus* also exhibit peak abundances before and after the *Phragmodus* peaks. Both genera are proportionally less abundant during the *Phragmodus* peak.

In the English Head section (Figs. 1,2), *Phragmodus* is a dominant form with two peak phases between which *Oulodus* exceeds *Phragmodus* in abundance. In the overlying strata *Oulodus* is the dominant form with *Amorphognathus* rarely present and *Phragmodus* rapidly diminishing. As indicated earlier, lithologic and faunal evidence suggests a progressive shallowing in this upper part of the Vauréal Formation.

The cones are a major component of the Vauréal fauna and a study was made of the proportions of *Panderodus* and *Drepanoistodus* of the total fauna (Fig. 4). At the generic level there appear to be many periods when an increase of one form is noted by a decrease in the other, as shown by arrows on Figure 4. This pattern has been observed to occur by the authors in other collections. In the Anticosti fauna, *Drepanoistodus* occurs as a single species whereas there are eight multielement and three additional form species representing *Panderodus*. Examination of Table 1, shows that some species of *Panderodus* are restricted to certain parts of the Vauréal section (e.g. *P. cf. P. serratus*, *P. n. sp. B.*, *P. n. sp. C*) whereas others range throughout (e.g. *P. gracilis*, *P. n. sp. A*).

The large amount of data allows a statistical analysis of conodont distribution. The NT-SYS program used to test the proposed multielement taxonomy (Fig. 5, element by element com-

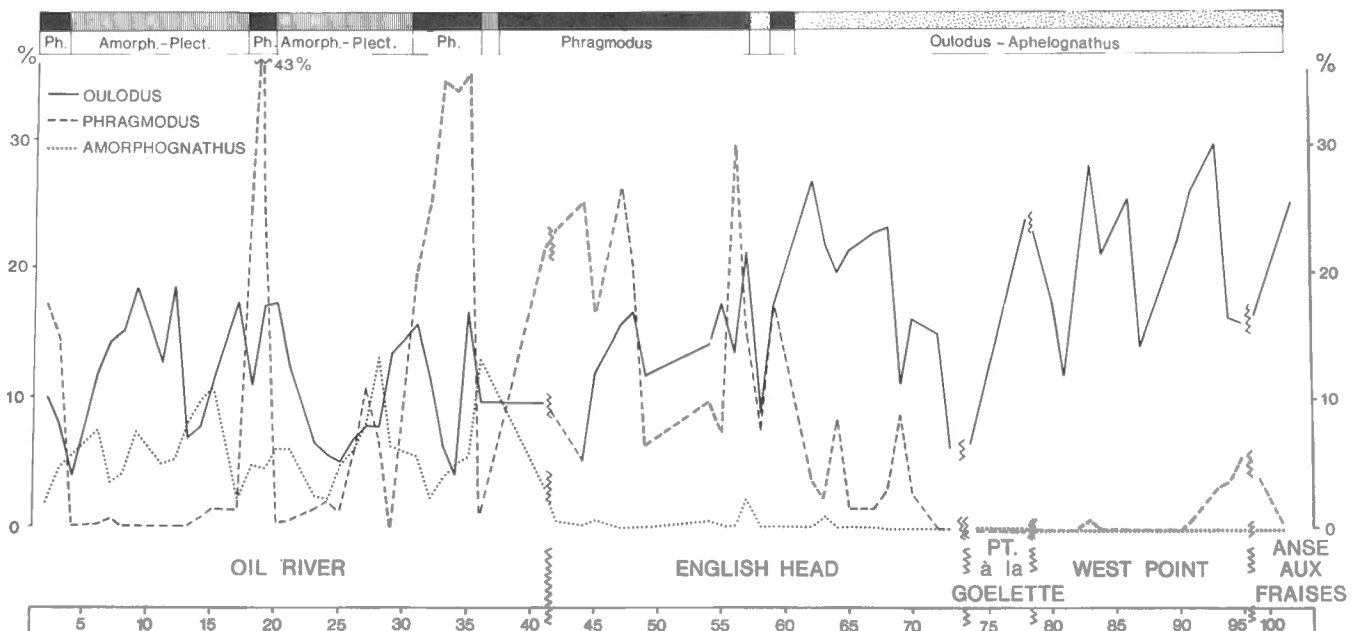
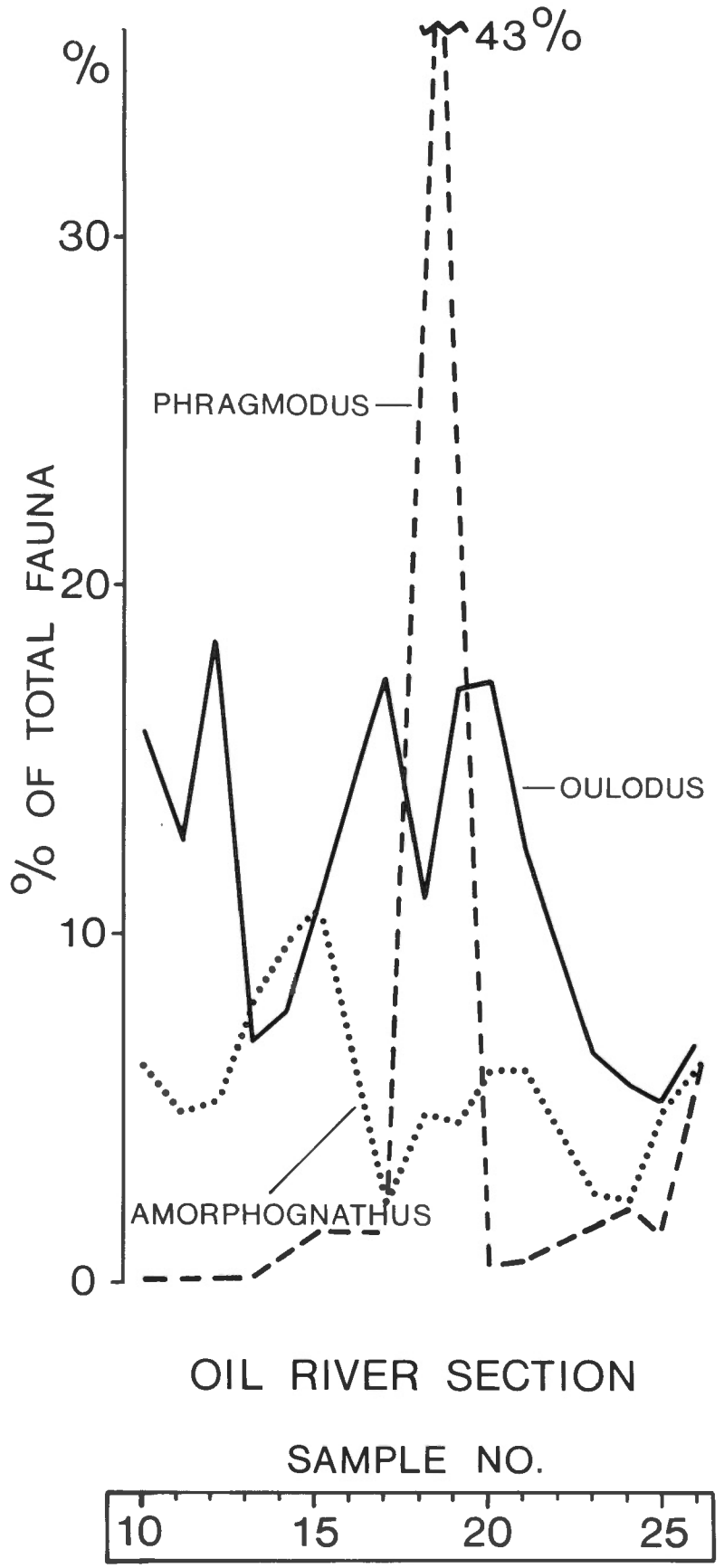
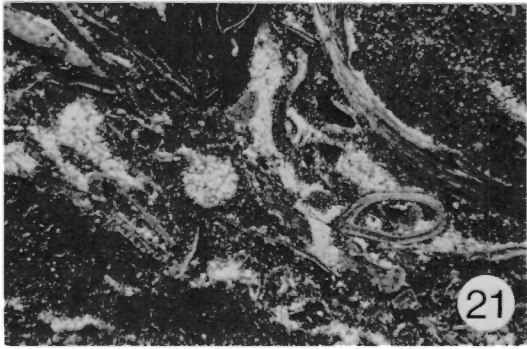
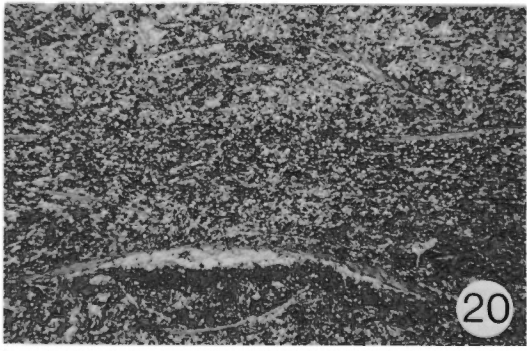
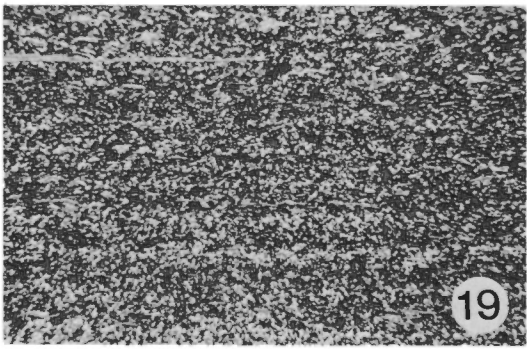
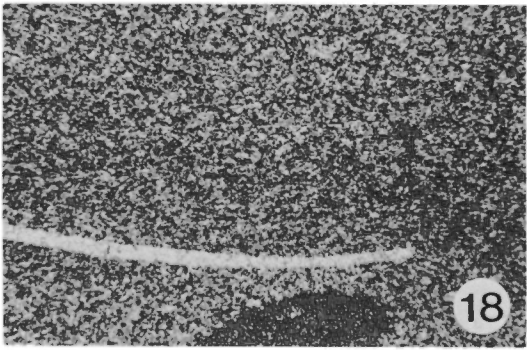
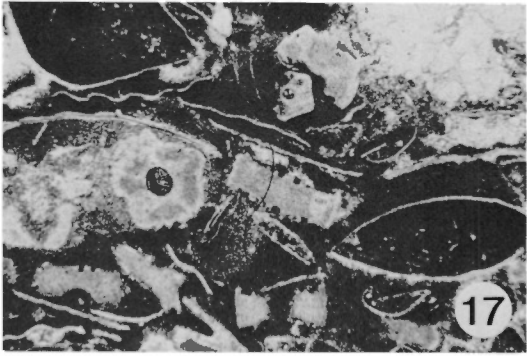


Figure 2. Variation in the relative abundance (per cent of the total fauna) of the genera *Amorphognathus*, *Oulodus* and *Phragmodus* through the composite section of the Vauréal Formation (horizontal axis). Sample numbers are shown at the bottom. Distribution of the three ecozones identified by cluster analysis is shown at the top. Compare with Fig. 6 that reveals the presence of three main ecozones from a cluster analysis of the samples.



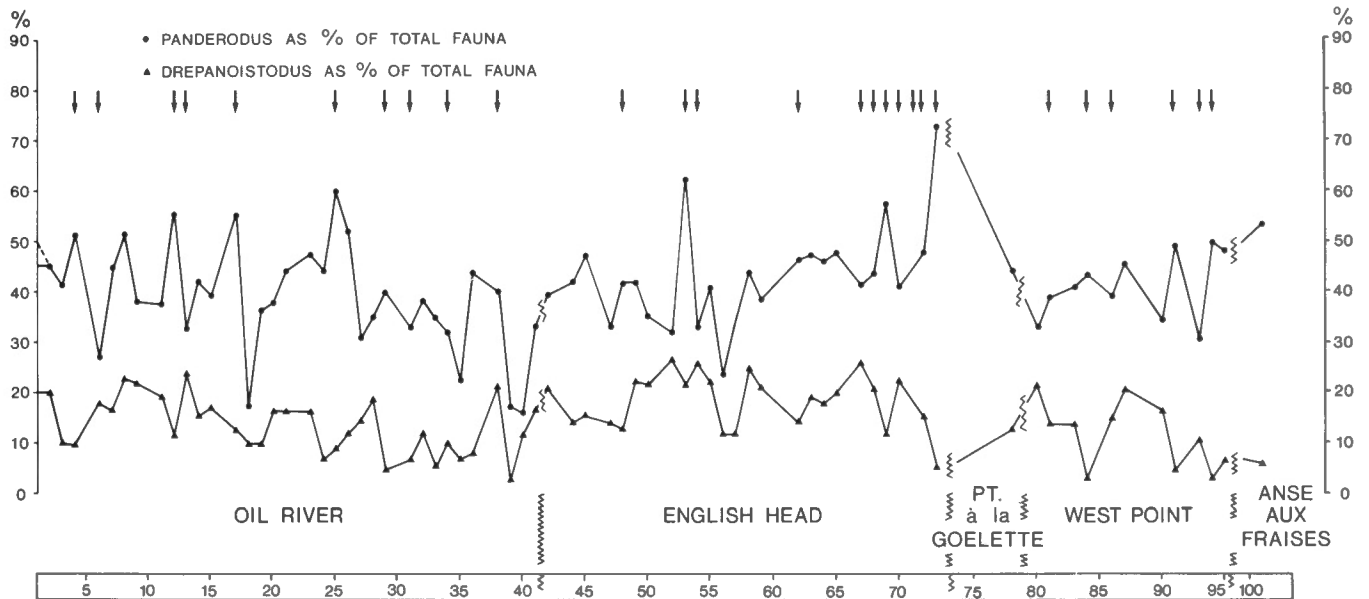


Figure 4. Variation in the relative abundance (per cent of the total fauna) of the genera *Drepanoistodus* and *Panderodus* through the composite section of the Vauréal Formation (horizontal axis). Sample numbers are shown at the bottom. Points of antipathetic abundance of the two genera are marked by arrows at the top.

parison) can also be employed to examine the faunas in a sample by sample comparison. Figure 6 shows the results of the computation. The clusters represent samples (ROW00001, etc.) that contain closely similar faunal associations. The level of similarity is also recorded on the figure. The associations reflect ecologic controls but using a single composite section it is inappropriate to attempt to regard these as communities or biofacies. Rather, the more general term ecozone (Hedberg, 1971, p. 34; Le Fevre et al. 1976) is employed to refer to a stratigraphic interval characterized by a particular conodont association. The program was run first using the form element data (used in Fig. 5) and also using the numerical data of Table 1 converted into multielement taxa. As expected, the two sets of results were similar. The print-out data of Figure 6 is simplified in terms of ecozones through the stratigraphic sequence on Figure 2. It should be emphasized that the ecozones are defined using ramiform conodonts; the simple cone genera are abundant, representing approximately 40-60 per cent of most samples. Three main ecozones are recognized: *Phragmodus*, *Amorphognathus-Plectodina* and *Oulodus-Aphelognathus*.

The *Phragmodus* ecozone (Fig. 6) contains *Phragmodus undatus* as the dominant ramiform taxon. It is present as two brief intervals (samples 2, 3 and 18, 19) in the lower part of the Oil River section and then occurs in the upper part of this section (samples 31-42) as well as the English Head section (samples 44-57) (Fig. 2).

Between the brief peaks of the *Phragmodus* ecozone in the Oil River section are intervals characterized by the *Amorphognathus-Plectodina* ecozone (Figs. 2,6). In the interval represented by samples 4-17, the main ramiform species are *Amorphognathus ordovicicus*, *Oulodus ulrichi* and *Plectodina tenuis*. In the next interval (samples 20-30), *A. ordovicicus* is joined by different species of *Oulodus* (*O. rohneri*) and *Plectodina* (*P. bidentata* n. sp.) as well as *Aphelognathus grandis* as a minor component.

In the stratigraphic interval above the English Head section (Fig. 2), there is a replacement of the *Phragmodus* ecozone by the *Oulodus-Aphelognathus* ecozone. In the latter, *Oulodus rohneri* and *Aphelognathus* n. sp. A. are characteristic forms with *Aphelognathus pyramidalis* as a minor component.

With the 102 samples of the Vauréal Formation being taken through a single composite section, it is not certain that the ecozones are laterally extensive. We believe that they reflect significant environmental changes that are represented by considerable thicknesses of strata and so should be regional features. They could be useful in subsurface correlations or, if they reflect regional eustatic or temperature changes, be applicable to long range correlations similar to the relative-abundance logs used by Bergström and Sweet (1966).

Figure 3. Photomicrographs of samples 17-21, that include a major peak in the relative abundance of *Phragmodus*. High values for *Phragmodus* are present in the laminated, locally bioturbated micrites and biomicrites (18-20) interpreted as deeper water carbonates than the flanking biointramicrites and biosparudites (17, 21). This peak is the second major *Phragmodus* peak above the base of the Oil River section illustrated in Figure 2.

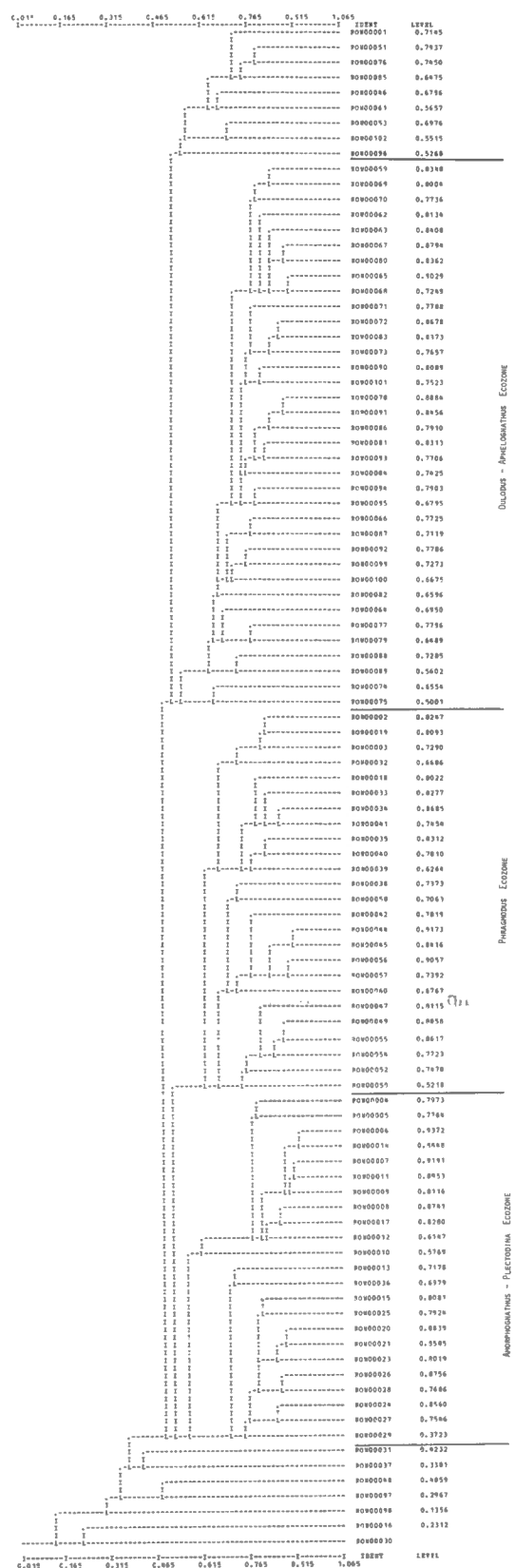
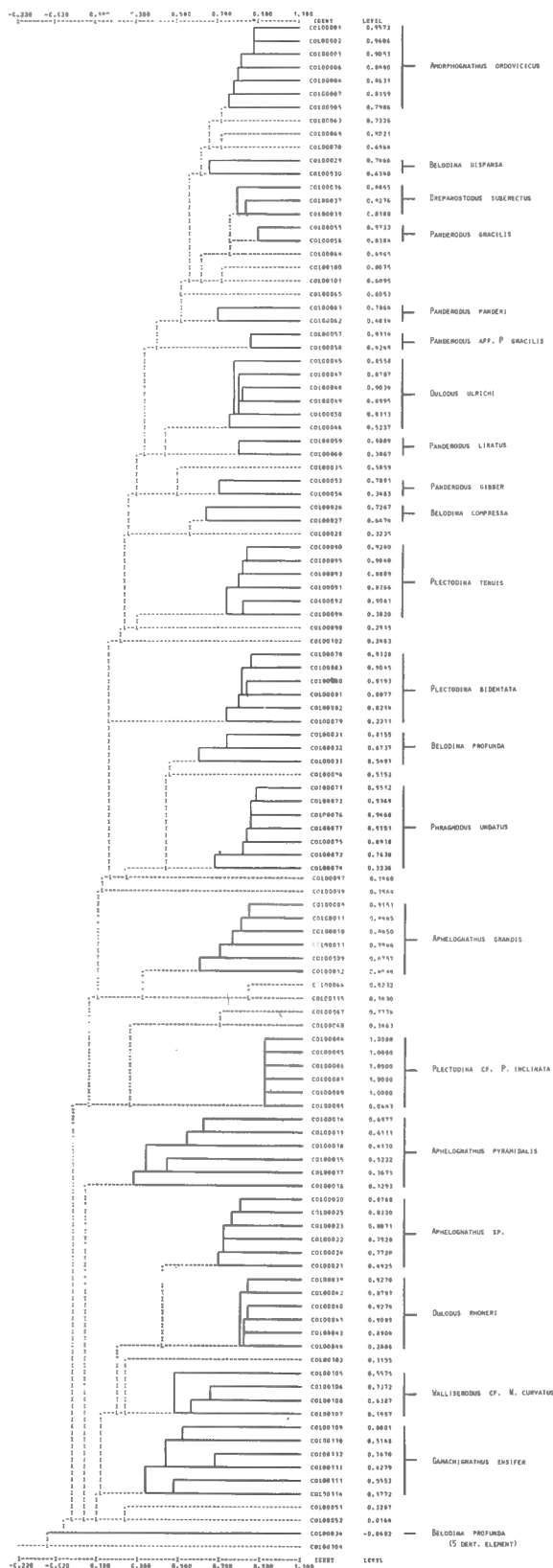


Figure 5. R-mode cluster analysis of 115 conodont form elements from the Vauréal Formation. The phenogram shows the clustering of elements. 'IDENT' refers to the variables used in the analysis *i.e.* conodont from elements identified by 'COL' and a number. 'LEVEL' is the level of correlation between the variables. Clusters of multielement apparatuses are marked and named where good correlation exists.

Figure 6. Q-mode cluster analysis of 102 conodont samples from the Vauréal Formation. 'IDENT' refers to the variables (*i.e.* samples) used in the study 'ROW' and the number refers to specific samples. 'LEVEL' refers to the level of correlation between the variables. The three clustered groups are interpreted as representing three conodont ecozones: *Amorphognathus-Plectodina*, *Phragmodus*, and *Oulodus-Aphelognathus* as shown. Compare with Fig. 2, which plots the relative distribution of some of these key genera.

Cluster analysis of conodont elements

With the large amount of available data involving over 30 multielement species from 102 samples and nearly 50 000 specimens, it is feasible to test the subjective multielement taxonomic assignments by means of cluster analysis. The data used are a matrix of the distribution of 115 form elements in the 102 samples as plotted in Table 1. The computer program adopted is NT-SYS which employs standardization of the data and clustering using a P-LOG transformation to establish a symmetrical matrix of cophenetic values. This programme was developed by R.J. Rolf, J. Kishpaugh (The State University of New York at Stony Brook, New York, 11790) and D. Kirk (Quantra Development Corporation).

Because some species have different average abundances, i.e. some are rare and some are abundant, the similarity in samples will appear less than it really is. Standardization is then used to transform rows (i.e. samples) or columns (i.e. species) of a rectangular matrix so that they will have a mean of zero and a standard deviation of unity, thus making rarity or extreme abundance less important.

The P-LOG transformation in NT-SYS is used where the data to be handled is in a quantitative form, rather than simple presence or absence (in which case Jaccard co-efficient or Simple Matching techniques are used). It is employed because abundance data derived from natural situations are usually log-normally distributed; that is, there are generally a few samples with many specimens and many samples with few specimens such that a histogram of the data produces a skewed distribution.

A log transformation of the data will normalize the curve. This is preferred because higher correlations are attained where the data show a linear relationship. The P-LOG transformation computes the log (base 10) of the sum of an input element and the floating point number for each input element. The floating point number is included so that the log of zero will not be taken in the case of absent elements. It is set to one in this program; this is totally arbitrary and has no effect on the overall cluster.

The dendrogram produced (Fig. 5) clusters elements of similar distribution within the samples. In this R-mode technique, attributes (species) are related to each other on the basis of the objects (samples) in which they occur. The degree of similarity, as indicated on the figure, depends partly on the abundance of the elements. Thus, rare forms such as species of *Pseudooneotodus* have a low similarity coefficient compared to abundant forms (e.g. *Phragmodus undatus*) and those with limited distribution (e.g. *Plectodina? inclinata* where all elements occur in a single sample). Within an apparatus the rarer elements likewise have the poorest correlation coefficients such as the trichonodelliform and zygognathiform elements of species of *Plectodina*, *Oulodus* and *Aphelognathus*.

The results of the cluster analysis (Fig. 5) confirm nearly all of the multielement assignments made in the Systematic Paleontology section. The differences reflect the failure to group elements into the proposed multielement assignments in cases of elements which occur in low abundance. Thus, the two asymmetrical elements of *Staufferella brevispinata* n. sp. are clustered but not with the rare symmetrical element (COL00102); *Cordylodus robustus* s.f. (COL00035) and the two elements of *Plegagnathus dartoni* (COL00096, COL00097) are not clustered; the rare five denticle form of *Belodina profunda* (COL00034) is not grouped with the other elements; the elements assigned to *Paroistodus? mutatus* (COL00067-COL00070) are clustered into two separate groups. Apart from these expected exceptions, the dendrogram provides support for the proposed multielement species.

Other conodont workers (e.g. von Bitter, 1972) have used cluster analysis to treat their data. Most have used Jaccard or Simple Matching coefficients which consider distribution on a presence-absence basis. The P-LOG transformation employed herein allows consideration of relative abundance rather than just presence-absence relationships.

Systematic paleontology

Genus *Amorphognathus* Branson and Mehl, 1933

Type species. *A. ordovicica* Branson and Mehl, 1933

Amorphognathus ordovicicus Branson and Mehl

Plate 1, figs. 1-14

- Amorphognathus ordovicica* Branson and Mehl, 1933, p. 127, Pl. 10, fig. 38; Stone and Furnish, 1959, p. 220, Pl. 32, fig. 12; Weyant, 1968, p. 33, Pl. 1, figs. 1-4.
- Amorphognathus ordovicicus* Branson and Mehl. Bergström, 1971, p. 134, 135, Pl. 2, figs. 6, 7 (includes most of synonymy to 1970); Sweet, Ethington and Barnes, 1971, p. 179, Pl. 2, fig. 19; Barnes, 1974, Pl. 1, fig. 26; Sweet, Thompson and Satterfield, 1975, Pl. 3, figs. 8-15; ?Dzik, 1976, fig. 28K.
- Ambalodus triangularis* Branson and Mehl, 1933, p. 128, Pl. 10, figs. 35-37; Stone and Furnish, 1959, p. 219, Pl. 32, fig. 3; Serpagli and Greco, 1964, p. 198, 199, Pl. 34, figs. 3a, b, 4, 5; Weyant, 1968, p. 30, Pl. 1, figs. 7-9; Satterfield, 1971, p. 270, Pl. 34, fig. 17.
- Amorphognathus* sp. Serpagli and Greco, 1964, p. 199, Pl. 34, figs. 6-10.
- Eoligonodina delicata* (Branson and Mehl). Weyant, 1968, p. 50, Pl. 3, figs. 10-13.
- Goniodontus superbus* Ethington. Weyant, 1968, p. 51, Pl. 3, fig. 9, Pl. 6, figs. 10a, b.
- Keislognathus gracilis* Rhodes. Serpagli and Greco, 1964, p. 201, Pl. 35, fig. 3; Weyant, 1968, p. 52, Pl. 3, figs. 7, 8.
- Keislognathus simplex* Ethington. Serpagli and Greco, 1964, p. 201, 202, Pl. 35, figs. 4a, b.
- Keislognathus* sp. Stone and Furnish, 1959, p. 223, Pl. 32, fig. 6.
- Ligonodina delicata* (Branson and Mehl). Serpagli and Greco, 1964, p. 202, 203, Pl. 35, figs. 6a, b.
- Roundya diminuta* Rhodes. Serpagli and Greco, 1964, p. 207, 208, Pl. 36, figs. 1a-c.
- Tetraprioniodus superbus* (Rhodes). Stone and Furnish, 1959, p. 227, Pl. 32, fig. 13; Serpagli and Greco, 1964, p. 208, 209, Pl. 36, figs. 2a, b; Weyant, 1968, p. 61, Pl. 3, figs. 1-6.

Remarks. Bergström (1971, p. 131-135) discussed *Amorphognathus* and its type species in considerable detail, and his reconstruction is followed herein. Serpagli and Greco (1964) reported several elements of an *Amorphognathus* apparatus which, in view of their stratigraphic position and the subsequent report of Serpagli (1967), are considered as representing *A. ordovicicus*.

Well preserved material has been recovered from the Vauréal Formation which permits some discussion of the apparatus of this species. The ramiform complex is characterized by an eoligonodiniform element (*Phragmodus delicatus* Branson and Mehl), a cladognathiform element (*Keislognathus gracilis* Rhodes), a trichonodelliform element (*Roundya diminuta* Rhodes) and a tetraprioniodiform element (*Rosagnathus superbus* Rhodes). All these morphotypes are readily distinguished, even in rather fragmentary material. Calculations indicate that the approximate ratio of these elements in *A. ordovicicus* was 6:6:3:2. Webers (1966), on the basis of restricted material suggested a ratio of 2:2:2:1 for a ramiform complex which is probably part of *A. superbus* (see Bergström, 1971, p. 135).

The distinction of *A. ordovicicus* from the older *A. superbus* (Rhodes) is based mainly on the holodontiform element. Sweet and Bergström (1971) viewed the change from *A. superbus* to *A. ordovicicus* as a gradual evolution of the holodontiform element from *Holodontus superbus* Rhodes s.f. to *Goniodontus*

superbus Ethington s.f. Unfortunately, holodontiform elements are rare in most collections (Winder, 1974) making distinctions difficult.

In this study, holodontiform elements are about as abundant as tetraprioniodiform elements. They differ from some reports of the element in important ways. Both Serpagli (1967) and Weyant (1968) noted denticles on the posterior process of elements they ascribed to *Goniodontus superbus*. Whereas Serpagli's form has only a small single denticle, Weyant's specimen (ibid., Pl. 6, fig. 10) has hindeodellid denticulation. In almost all Vauréal specimens the posterior process bears a single obvious denticle. It is possible that the specimen illustrated by Ethington (1959) as the holotype is slightly broken posteriorly, although a few specimens in the Vauréal collections appear complete and lack a denticle on the posterior process. In addition, the cusp of Vauréal specimens bears a faint groove above the point at which the posterior process begins. The cusp is also flattened antero-posteriorly above this point. Glenister (1957, Pl. 88, fig. 25) illustrated a similar holodontiform specimen as *Ligonodina* sp. In contrast, the holotype of Ethington (1959) has a sharply convex posterior face. A further variable in the Vauréal specimens is the nature of the outer lateral process. It may have hindeodellid denticulation with a single larger denticle or up to three large denticles without intervening small ones. Serpagli (1967, Pl. 16, fig. 6) has illustrated the former type. The inner lateral process is simply an adenticulate costa which extends aborally as illustrated by Ethington (1959).

This variation in the holodontiform element may represent different species, but the general rarity of this element and the co-occurrence of a variety of forms in the Vauréal collections does not readily allow identification of separate species. In summary, we conclude that the typical holodontiform element of *A. ordovicicus* has a denticulate posterior process and a cusp that is antero-posteriorly compressed distally. Hindeodellid denticulation is most common, but discrete peg-like denticles may occur on the outer lateral process.

A number of complete amorphognathiform elements have been recovered from the Vauréal Formation. In samples where all elements are unbroken, specimens are few, but the ratio of blade and non-blade elements present is 1:1, as is the ratio of ambalodiform to amorphognathiform elements in such samples. Numerical separation of the two kinds of amorphognathiform elements is impossible in samples with fragmentary representatives and their abundance is conservatively estimated. As a result, most samples appear to have a ratio of ambalodiform to amorphognathiform elements of 2:1.

Non-blade (sinistral) elements are more commonly complete than blade (dextral) elements, the latter tending to lose the postero-lateral process. Despite differences in morphology, the processes of each type are arranged so as to be mirror images of each other, suggesting that one or more pairs were present in the apparatus.

Types. Hypotypes, GSC 59244-59254; unfigured hypotype, GSC 59255.

Genus *Aphelognathus* Branson, Mehl and Branson, 1951

Type species. *A. grandis* Branson, Mehl and Branson, 1951 Sweet et al. (1975) discussed in detail the validity and multi element nature of this genus. They erected a new species, *A. kimmswickensis* bearing a dichognathiform element. The homologous element is prioniodiniform in the species recognized here, as suggested for the evolution of *Aphelognathus* by Sweet et al. (1975, p. 31). The skeletal apparatuses of the species reported from the Vauréal are otherwise similar to that of *A. kimmswickensis*. *Aphelognathus* is similar to *Plectodina* and distinction

between small (?juvenile) aphelognathiform elements and the ozarkodiniform elements of *Plectodina* may pose problems in some species.

A. grandis and *A. pyramidalis* are present in small quantities in this study. Both are abundant in Upper Ordovician strata in Southern Ontario (Tarrant, 1977), and detailed description and discussion of them is deferred to Tarrant and Barnes (in preparation). The material from the Vauréal Formation has been compared with Tarrant's (1977) specimens and his specific reconstructions are followed herein.

Aphelognathus grandis Branson, Mehl and Branson

Plate 5, figs. 5-10

Cordylodiform element

Eoligonodina richmondensis Branson, Mehl and Branson, 1951, p. 15, Pl. 4, figs. 24-27, non Pl. 4, fig. 23.

Zygognathiform element

Zygognathus sp. Branson, Mehl and Branson, 1951, p. 13, Pl. 4, figs. 13, 18, 20, 21, non Pl. 4, fig. 19.

Trichonodelliform element

Trichonodella nitida Branson, Mehl and Branson, 1951, p. 14, Pl. 4, figs. 15, 16.

Cyrtioniodiform element

Cordylodus sp.? Branson, Mehl and Branson, 1951, p. 13, Pl. 4, fig. 17.

Prioniodiniform element

?*Prioniodina oregonia* Branson, Mehl and Branson, 1951, p. 15, 16, Pl. 4, fig. 30 only.

Aphelognathiform element

Aphelognathus grandis Branson, Mehl and Branson, 1951, p. 9, Pl. 2, figs. 11-14.

Aphelognathus acutidentata Branson, Mehl and Branson, 1951, p. 9, 10, Pl. 2, figs. 15, 16.

Diagnosis. A species characterized by aphelognathiform elements that are slightly arched and laterally bowed; broad basal flares are present at about mid-length. All elements bear compressed cusp and denticles which are closely spaced but discrete. Cordylodiform and cyrtioniodiform elements have a distinctive anterobasal flange which may be weakly denticulated. Trichonodelliform elements have slightly bowed lateral processes that produce a distinctive arcuate aboral outline. Prioniodiniform elements have a high anterior process in the cusp plane. Posterior process is slightly flexed outwards and down.

Remarks. Most of these elements were described by Branson, Mehl and Branson (1951) and detailed description and discussion of the apparatus is deferred to Tarrant and Barnes (in prep.) (see remarks under genus).

Types. Hypotypes, GSC 59336-59341.

Aphelognathus pyramidalis (Branson, Mehl and Branson)

Plate 5, figs. 1-4

Cordylodiform element

Zygognathus pyramidalis Branson, Mehl and Branson, Kohut and Sweet, 1968 (*partim*), p. 1475, 1476, Pl. 186, fig. 12 only.

Zygognathiform element

?*Zygognathus plebia* Branson, Mehl and Branson, 1951 (*partim*), p. 12, 13, Pl. 3, figs. 22, 23 only.

Trichonodelliform element

Trichonodella undulata? Branson, Mehl and Branson, 1951, Pl. 3, fig. 26.

Cyrtioniodiform (prioniodiniform) element

Microcoelodus panderi Branson, Mehl and Branson, 1951, p. 16, Pl. 4, fig. 12.

Prioniodiniform element

Zygognathus pyramidalis Branson, Mehl and Branson, 1951, p. 12, Pl. 3, figs. 10-16, 21; Kohut and Sweet, 1968 (*partim*), p. 1475, 1476, Pl. 186, fig. 17 only.

Remarks. Identification of fragments of this multielement species is based upon the species reconstruction of Tarrant (1977) and detailed description is deferred to Tarrant and Barnes (in preparation). All elements except the cyrtioniodiform have been recovered, but most are highly fragmentary and no sample contains a complete apparatus. The aphelognathiform element of this species is distinguished from that of *A. grandis* by shorter denticles on the posterior process and broader lateral flares.

Types. Hypotypes, GSC 59330-59333; unfigured hypotypes GSC 59334, 59335.

Aphelognathus n. sp. A

Plate 5, figs. 11-17

Description. Cordylodiform element has a long straight posterior process with up to seven erect to posteriorly reclined denticles. Cusp is compressed and slightly twisted so that anterior edge is inner and posterior edge is outer. Anterior edge of base is deflected laterally as a weak flange. Basal cavity deep and conical with apex directed upward and anteriorly; it extends beneath the process as a groove.

Zygnathiform element has a cusp with flat anterior margin and sharp antero-lateral edges. Posterior face is sharply rounded. Antero-lateral edges give rise to lateral processes. One is straight and downwardly directed with three broad antero-posteriorly compressed denticles that are parallel and confluent. Other process is flexed posteriorly with four, more discrete denticles. Proximal denticles are vertical whereas distal ones are laterally directed. Basal cavity deepest beneath cusp and shallowing gradually beneath processes.

Trichonodelliform and zygnathiform elements are similar except that both processes are straight and symmetrically situated. Three antero-posteriorly compressed denticles are present on each process. Postero-oral surface is narrowly rounded and extends a short distance posteriorly.

Cyrtioniodiform element has a broad, long cusp with a medially situated weak inner carina. Anterior margin curves evenly and the antero-basal edge may be short or extended downward. Base flares to inner side. Posterior process is short and low with up to five laterally compressed, posteriorly reclined denticles; it may be inclined slightly to the outer side. Basal cavity deepest beneath flare slightly posterior of main cusp, shallowing anteriorly and posteriorly, and extending to the antero-basal angle.

Prioniodiniform element has a long, laterally compressed cusp with sharp edges. Posterior process is straight and short with up to four denticles that are laterally compressed and posteriorly reclined. It originates on the outer side of the base. Anterior process is downwardly directed with up to three vertical, subparallel, laterally compressed denticles. It is deflected slightly inward. Basal cavity deep and conical beneath cusp with apex upwardly and anteriorly directed, shallowing beneath the processes.

Aphelognathiform element is only weakly arched. Cusp is broad and laterally compressed. A weak, rounded ridge is present

on the outer side and restricted to upper portion. Anterior process is long, typically with five, but up to seven, high, laterally compressed denticles that decrease in size anteriorly. Denticle adjacent to cusp reaches about half cusp height. Posterior process shorter with lower, more discrete denticles, two to six in number; it is flexed to inner side, the flexure being more prominent in larger specimens. Base is flared asymmetrically, being more pronounced on inner side, and slightly offset. Basal cavity is deepest just anterior of main cusp and shallows gradually to distal ends of element. Upper margin of basal cavity may undulate slightly in lateral view.

White matter is developed in cusp and denticles of all elements, but rare to absent in distal denticles.

Remarks. Elements assigned to this species are generally small and somewhat variable. In particular there are two distinct forms of cyrtioniodiform and aphelognathiform elements. The antero-basal corner of the cyrtioniodiform element may be short or extended anteriorly. The latter type dominates in earlier representatives.

In small elements, edges of denticles and cusp are sharper. Small aphelognathiform elements have a short posterior process, however, in large specimens it is longer. The larger the size the more the element becomes typically aphelognathiform.

This species bears some resemblance to *A. pyramidalis*, particularly in the distinctive morphology of the prioniodiniform element, but the rather generalized cordylodiform element of this species is unlike the eoligonodiform element of *A. pyramidalis*.

It is not certain whether the variable nature of the elements represents one or two species, and so the species is unnamed.

Types. Figured specimens, GSC 59342-59348.

Genus *Belodina* Ethington, 1959

Type species. *Belodus compressus* Branson and Mehl, 1933 (emend. Bergström and Sweet, 1966).

Ethington (1959) erected *Belodina* as a form genus to include elements with crowded, blade-like denticles on the posterior margin, a deep basal cavity and an expanded basal portion termed the 'heel'. As a multielement taxon, the genus includes a number of different apparatus types, which may be divided into three groups.

Group I includes the type species, *B. compressa* (Branson and Mehl). This apparatus bears three distinctive element types: elongate, broadly curved elements (grandiform), more tightly recurved elements (compressiform) and elements lacking denticles between cusp and heel (eobelodiform). *B. compressa* is the only species of *Belodina* described as having all three such morphotypes, however, a new eobelodiform element of unknown multielement affinity has been reported by Barnes (1977), and this may belong in an apparatus similar to that of the type species.

Group II is characterized by apparatuses that contain only elements homologous with grandiform and compressiform elements of *B. compressa*. Species with an apparatus of this type are: *B. dispansa* (Glenister) as described by Barnes (1977) and in this paper, and *B. leithi* Ethington and Furnish as described by Barnes (1977).

A representative of Group III is the more complex apparatus of *B. profunda* (Branson and Mehl) as reconstructed herein. This type includes both broad and recurved elements, but in addition the number of denticles vary in each type from one to three or more (see Pl. 7, figs. 1-9, 12).

Subsequent studies on the nature of the apparatus in species of *Belodina* may show the need for subdivision of the genus into two or three genera.

Belodina compressa (Branson and Mehl)

Plate 8, figs. 1-4

Belodus compressus Branson and Mehl, 1933, p. 114, Pl. 9, figs. 15, 16.*Belodina compressa* (Branson and Mehl). Bergström and Sweet, 1966, p. 312-315, Pl. 31, figs. 12-19 (includes synonymy through 1966); Weyant, 1968, p. 36, Pl. 2, fig. 6; Atkinson, 1971, p. 82, Pl. 5, figs. 13, 15, 16; Sweet, Ethington and Barnes, 1971, Pl. 2, figs. 27, 28; Moskalenko, 1973, p. 56, 57, Pl. 5, figs. 3-6; Uyeno, 1974, p. 15, Pl. 1, figs. 10-13; ?Miller, 1975, fig. 2, no. 9; Sweet, Thompson and Satterfield, 1975, Pl. 1, figs. 4-6; Miller, 1976, fig. 8, nos. 62, 63; Dzik, 1976, fig. 14g, h; Barnes, 1977, p. 105, Pl. 4, figs. 16-18.*Belodina grandis* (Stauffer). Winder, 1966, Pl. 10, fig. 1; Weyant, 1968, p. 38, Pl. 2, fig. 1.*Belodina inclinata* (Branson and Mehl). Winder, 1966, Pl. 10, fig. 2.*Eobelodina fornicata* (Stauffer). Winder, 1966, Pl. 10, fig. 3; Weyant, 1968, p. 49, 50, Pl. 2, fig. 7; Moskalenko, 1973, p. 34, 35, Pl. 1, figs. 5a, 6.

Remarks. The multielement apparatus reconstruction for this species proposed by Bergström and Sweet (1966) is accepted. Moskalenko (1972) discussed the composition of this species based upon Siberian material, and included the form species *Culumbodina mangazeica* Moskalenko and *Belodina diminutiva* (Branson and Mehl). It seems probable that these two forms belong to some other multielement species, considering the repeated co-occurrence of grandiform, compressiform and eobelodiform elements in other studies. Moskalenko's (1973) illustrations include all three morphotypes.

Types. Hypotypes, GSC 59405-59407; unfigured hypotype, GSC 59408.

Belodina dispansa (Glenister)

Plate 8, figs. 6,7,10,11

Belodus dispansus Glenister, 1957, p. 729, 730, Pl. 88, figs. 14, 15.*Belodina dispansa* (Glenister). Barnes, 1977, p. 105, Pl. 4, figs. 8-10 (includes synonymy through 1976).

Remarks. The multielement reconstruction of this species proposed by Barnes (1977) is followed herein. A few slender forms are strongly bowed laterally.

Types. Hypotypes, GSC 59409-59412.

Belodina profunda (Branson and Mehl)

Plate 7, figs. 1-9, 12

Belodus profundus Branson and Mehl, 1933, p. 125, Pl. 10, fig. 25.*Belodina profunda* (Branson and Mehl). Barnes, 1977, p. 105, Pl. 4, fig. 11 (includes synonymy through 1976).*?Plegagnathus dartoni* (Stone and Furnish). Kohut and Sweet, 1968, p. 1472, Pl. 186, figs. 9-11.

Remarks. A number of different morphotypes can be recognized within this species. Previous authors (e.g. Kohut and Sweet, 1968)

have noted the presence of elements with two or three denticles. In the present study elements with from one to five denticles have been recovered. An increase in the number of denticles leads to a decrease in the size of the heel. A further distinction between the morphotypes, besides the number of denticles, is the curvature of the anterior margin. In forms with two or three denticles, two distinct variants can be recognized: those with a tightly curved anterior margin (Pl. 7, figs. 7-9) and those with a broadly curved anterior margin (Pl. 7, figs. 2-5). Forms with four or five denticles are relatively rare and first appear about halfway through the section of exposed Vauréal Formation. These morphotypes have longer cusps that project above the plane of the denticles. It is not certain whether this is of evolutionary and therefore biostratigraphic significance. It may be noted, however, that relatively abundant samples from the lower part of the section contain no elements with four or five denticles whereas those forms are present in a few sparse samples in the upper part of the section.

The specimen illustrated by Kohut and Sweet (1968, Pl. 186, figs. 9-11) as *Plegagnathus dartoni* (Stone and Furnish) is similar to Vauréal specimens of *B. profunda* bearing five denticles.

Types. Hypotypes, GSC 59390-59399.

Genus *Cordylodus* Pander, 1856 s.f.Type species. *C. angulatus* Pander, 1856

In a multielement sense, this genus should be restricted to a plexus of Early Ordovician *Cordylodus* species of Faunas A, B and C (Ethington and Clark, 1971) which includes *C. angulatus*, the type species. It is retained here in form taxonomy for elements described as form species of the genus for which the apparatus is unknown.

"Cordylodus" robustus Ethington and Furnish s.f.

Plate 7, figs. 16-19

Cordylodus robustus Ethington and Furnish, 1959, p. 543, Pl. 73, fig. 11; Ethington and Furnish, 1960, p. 270; Barnes, 1974, Pl. 1, fig. 23.

Remarks. The general morphology of this species suggests that it may best be placed within *Plegagnathus* Ethington and Furnish. It may even belong within the apparatus of the type species, *P. nelsoni*, but occurrence data are inconclusive. The abundance of *C. robustus* increases with an increase in *P. nelsoni*, but they do not always co-occur. Unfortunately, both of these species are rare.

Types. Hypotypes, GSC 59403, 59404.

Genus *Drepanoistodus* Lindström, 1971Type species. *Oistodus forceps* Lindström, 1955*Drepanoistodus suberectus* (Branson and Mehl)

Plate 4, figs. 17-19

Oistodus suberectus Branson and Mehl, 1933, p. 111, Pl. 9, fig. 7.*Drepanoistodus suberectus* (Branson and Mehl). Uyeno, 1974, p. 14, Pl. 1, figs. 5-9; Barnes, 1977, p. 106, Pl. 3, figs. 18-20 (contains synonymy through 1976).

Remarks. This widespread species is notoriously variable in its development of white matter. In the Vauréal collections three types of white matter development can be recognized: (a) white matter well developed in the cusp and extending from basal cavity to tip; (b) white matter developed as a cloudy appearance in the cusp, beginning somewhat above apex of basal cavity and with a growth axis of solid white matter sometimes visible; and (c) a total absence of white matter or simply a fine growth axis of solid white matter. Elements with well developed white matter are most common, but all three types co-occur in several samples. Forms without any white matter tend to be very large and rather variable in form, whereas edges are sharp and the elements are more compact on those forms that have well-developed white matter. The significance of this variation is an enigma, although details of white matter development have been documented (Barnes, Sass and Monroe, 1973; Barnes, Nord and Sass, 1975). As white matter is viewed as a secondary development, it is puzzling that very large forms tend to be hyaline. The significance of white matter in species differentiation is uncertain.

Recently, Dzik (1976, p. 402) suggested that it is impossible to differentiate clearly between species of *Drepanoistodus*. However, no oistodiform elements similar to those of *D. forceps* (Lindström) or *D. basiovalis* (Sergeyeva) were found in this study and this seems to be an adequate specific distinction (see Dzik, 1976, fig. 3).

Types. Hypotypes, GSC 59325-59327; unfigured hypotypes GSC 59328, 59329.

Genus *Gamachignathus* McCracken, Nowlan and Barnes, 1980

Type species. *G. ensifer* McCracken, Nowlan and Barnes, 1980

Gamachignathus ensifer McCracken, Nowlan and Barnes

Plate 3, figs. 13, 14, 17-21

Gamachignathus ensifer McCracken, Nowlan and Barnes, 1980, p. 105 - 110, Pl. 1, figs. 1-17; McCracken and Barnes (this volume), p. 77, Pl. 5, figs. 1-27 (include synonymy through 1979).

Remarks. McCracken and Barnes (this volume) recovered abundant material of *Gamachignathus* from the Ellis Bay Formation which immediately overlies the Vauréal Formation. Representatives of this genus occur in several samples from the Vauréal Formation but always in low abundance. McCracken et al. (1980) reported more fully on the genus *Gamachignathus* and its occurrence in the Vauréal and Ellis Bay formations.

Types. Hypotypes, GSC 59302-59308.

Genus *Oulodus* Branson and Mehl, 1933

Type species. *Cordylodus serratus* Stauffer, 1930
Sweet and Schönlaub (1975) have discussed this genus in detail and their reconstruction is followed herein. They designated *Cordylodus serratus* as the type species, regarding it as a senior subjective synonym of *Oulodus mediocris* Branson and Mehl.

Some morphotypes in species of *Oulodus* have a tendency to show dimorphism, particularly the cordylodiform and cyrtionodiform elements. The development of a lateral process within the cordylodiform element is a variable feature of both species

reported herein. Similarly, the anterior denticles of the cyrtionodiform element of *O. ulrichi* are rather variably developed. This flexibility is also reflected in the close morphologic gradation recognized between zygognathiform and trichonodelliform elements and also between prioniodiniform and oulodiform elements. This degree of flexibility and morphologic plasticity is quite uncharacteristic of the related genus *Plectodina* and may be a significant feature of the apparatus structure of *Oulodus*.

Oulodus rohneri Ethington and Furnish

Plate 2, figs. 8-16

Cordylodiform (eoligonodiniform) element

?*Plectodina dilata* Stauffer. Ethington and Furnish, 1959, p. 544, Pl. 73, fig. 10.

Trichonodelliform element

Trichonodella sp. Ethington and Furnish, 1959, Pl. 73, figs. 19, 20.

Oulodiform element

Oulodus rohneri Ethington and Furnish, 1959, p. 544, Pl. 73, figs. 17, 18.

Diagnosis. A species of *Oulodus* characterized by strongly compressed elements with broad, sharp-edged denticles. Oulodiform element has a narrow, small posterior flare and unequal, downwardly directed processes.

Description. Cordylodiform (eoligonodiniform) element has a straight posterior process with up to six laterally compressed, posteriorly inclined denticles that tend to increase in size at mid-length and decrease distally. Cusp is long, laterally compressed and twisted distally. Posterior face is narrowly rounded near the base with a median costa that is confluent with posterior process; median costa becomes sharp posterior edge distally. Anterior edge is sharp on cusp becoming laterally deflected on base. It gives rise to a short process that is adenticulate or bears up to three antero-posteriorly compressed denticles. Denticles are at right angles to posterior process. A shallow groove is developed posteriorly of lateral process on base. Basal cavity is conical beneath cusp with anterior margin and apex close to anterior edge. Posterior (upper) margin of basal cavity is straight in lateral view. White matter is present in cusp and denticles, extending farther downward anteriorly than posteriorly in cusp and distal denticles, resulting in a diagonal pattern.

Zygognathiform element has a laterally compressed cusp with lenticular cross section. Posterior edge is sharp to sharply rounded and extends posteriorly. Lateral processes join base near the anterior margin; both are downwardly directed. One process is at right angles to cusp and bears one to three antero-posteriorly compressed, subparallel denticles. Other lateral process is arched, longer and bowed posteriorly with up to six denticles which are crowded near cusp and more widely spaced distally. Basal cavity is conical beneath cusp and extends beneath processes as a groove.

Trichonodelliform element is similar to zygognathiform element but more nearly symmetrical. Both lateral processes are at right angles to cusp and denticles are subparallel. Posterior edge may be developed as a short posterior process with one or two laterally compressed denticles.

Cyrtionodiform element has a broad laterally compressed cusp with sharp edges. It is flexed to the inner side. Anterior edge is evenly convex in lateral view. Posterior process is slightly bowed inwards, with up to six laterally compressed, sharp-edged posteriorly inclined denticles. Base is flared on inner side with maximum convexity beneath proximal process denticles. Flare narrows abruptly to antero-basal angle. Basal cavity is deepest at flare and shallows markedly anteriorly and posteriorly.

Prioniodiniform element is laterally compressed with a long cusp. Anterior and posterior processes are of about equal length; they may be parallel; alternatively the posterior process is inwardly directed. In the former case the cusp is biconvex and parallel to processes. In the latter case, the inner side of cusp is flat to concave with its edges parallel to adjacent processes. Anterior process bears up to four laterally compressed denticles which are discrete. Spaces between denticles are asymmetrical curves. Up to four denticles are present on posterior process; they are posteriorly inclined and subparallel, but deflected outwards.

Oulodiform element is strongly antero-posteriorly compressed. Cusp is broad and triangular in posterior view. Lateral processes are of unequal length and both downwardly directed. Cusp may be parallel to longer process, but is more commonly at a shallow angle to both processes. The longer process joins the cusp anteriorly; it bears up to five subparallel, blade-like denticles that are crowded near cusp and more discrete distally. Unit is flexed posteriorly at cusp so that shorter process is in a more posterior position. Short process is downwardly and anteriorly directed and bears from two to four denticles. Base is high and compressed with a small posterior flare beneath side of cusp adjacent to shorter process. Basal cavity is shallow, deepest beneath cusp at basal flare, without apparent apex and very shallow beneath processes. White matter is present in cusp and denticles, but restricted to tips in more distal denticles.

Remarks. This species is readily distinguished from *O. ulrichi* in several ways, but mainly on the basis of the compressed nature of the elements. In oulodiform elements, the downwardly directed processes and narrow posterior flare are characteristic. Asymmetry is much more marked in the prioniodiniform element of *O. ulrichi* than in that of this species. Confusion can occur when distinguishing small or broken eoligonodiniform or cyrtoniodiform elements. The eoligonodiniform element of *O. rohneri* has a more laterally directed process than that of *O. ulrichi*, which runs close to the posterior process. However, in broken or adenticulate specimens this distinction is difficult to recognize. Similarly, small cyrtoniodiform elements of *O. ulrichi* that lack anterior denticles can be confused with the cyrtoniodiform element of *O. rohneri*. In such cases, the specimens of uncertain affinity are grouped with the more abundant species for tabulation purposes.

Types. Hypotypes, GSC 59271-59279; unfigured hypotype, 59280.

Oulodus ulrichi (Stone and Furnish, 1959)

Plate 2, figs. 1-7

Cordylodiform (eoligonodiniform) element

Eoligonodina ulrichi Stone and Furnish, 1959, p. 222, Pl. 32, figs. 16-18; Ethington and Furnish, 1960, p. 271, Pl. 38, figs. 2, 3.

?*Plectodina dilata* Stauffer. Ethington and Furnish, 1960, p. 272, Pl. 38, fig. 7.

Zygognathiform element

Erismodus tantus Stauffer. Stone and Furnish, 1959, p. 223, Pl. 32, fig. 11.

?*Trichonodella* spp. Ethington and Furnish, 1960, p. 273, Pl. 38, fig. 6 only.

Trichonodelliform element

Trichonodella barbara (Stauffer). Stone and Furnish, 1959, p. 227, Pl. 32, fig. 15.

Trichonodella recurva (Branson and Mehl). Stone and Furnish, 1959, p. 227, Pl. 32, fig. 14. *Trichonodella* spp. Ethington and Furnish, 1960, p. 273, Pl. 38, fig. 5 only.

Cyrtoniodiform element

?*Cyrtoniodus complicatus* Stauffer. Stone and Furnish, 1959, p. 221, 222, Pl. 31, fig. 9.

Cyrtoniodus sinclairi Ethington and Furnish, 1960, p. 270, 271, Pl. 38, fig. 16; Kohut and Sweet, 1968, p. 1468, Pl. 185, fig. 28; Sweet, Ethington and Barnes, 1971, p. 173, Pl. 2, fig. 33.

Prioniodiniform element

Microcoelodus sweeti Stone and Furnish, 1959, p. 224, Pl. 31, fig. 18.

Prioniodina? sp. Ethington and Furnish, 1960, p. 272, Pl. 38, fig. 14.

?*Prioniodina? oregonia* Branson, Mehl and Branson. Ethington and Furnish, 1959, p. 545, Pl. 73, fig. 15.

Zygognathus abnormis (Branson, Mehl and Branson). Kohut and Sweet, 1968, p. 1474, 1475, Pl. 186, figs. 13, 15.

Oulodiform element

Oulodus mediocris Branson and Mehl. Stone and Furnish, 1959, p. 224, 225, Pl. 32, figs. 4, 5.

Oulodus? sp. Ethington and Furnish, 1960, p. 271, Pl. 38, fig. 15.

Multielement synonyms

Oulodus oregonia ulrichi (Stone and Furnish). Kohut and Sweet, 1968, p. 1469, Pl. 185, figs. 7, 11; Sweet, Ethington and Barnes, 1971, p. 173, Pl. 2, fig. 18.

Description. Cyrtoniodiform and prioniodiniform elements have been adequately described by Ethington and Furnish (1960) and Stone and Furnish (1959) respectively. Additional comments are restricted to Remarks.

Cordylodiform (eoligonodiniform) element has a long slender recurved cusp which is subrounded basally and laterally compressed and twisted distally. Inner postero-lateral face is broadly rounded near base at origin of posterior process. Posterior process is straight and slightly laterally compressed, with up to eight rounded to laterally compressed, posteriorly reclined, discrete denticles. Anterior part of base is rounded, terminating on inner side in a sharp costa, which develops aborally into a postero-laterally directed process. Process is short in smaller specimens to long in larger specimens (reaching the length of the posterior process). It bears up to eight rounded to slightly compressed denticles that are inclined towards the posterior process. A narrow groove is developed on base posterior to the postero-lateral process. Basal cavity is deep and conical beneath cusp with apex directed anteriorly and lying near anterior margin. It extends beneath posterior process as a broad groove.

In zygognathiform elements, cusp is long, posteriorly recurved and has a subrounded to oval cross section. It extends postero-basally as a subrounded to sharp posterior extension that rarely may bear one or two denticles. Lateral processes are unequally developed. One process is about normal to cusp and bears up to four subrounded denticles. The other is posteriorly directed and bears up to five more compressed denticles, proximally nearly parallel to cusp and distally at right angles to it. Basal cavity is conical beneath cusp and reduced to shallow groove beneath processes.

Trichonodelliform element is similar to zygognathiform element in most respects but processes are more equally developed, denticles are antero-posteriorly compressed, and both processes are posteriorly recurved. Anterior margin of the unit is broadly curved.

Oulodiform element has a long, straight cusp which is subrounded to antero-posteriorly compressed. Lateral faces of cusp are costate and costae extend to processes. Cusp is set at a slight angle to processes. Shorter lateral process is straight and horizontal with up to four antero-posteriorly compressed denticles which are directed anteriorly. Longer lateral process is arched and

downwardly directed at an angle up to 90° from horizontal. It is also deflected anteriorly and bears up to six antero-posteriorly compressed denticles which are near vertical adjacent to main cusp, but become progressively more anteriorly and laterally directed distally. Posterior oral margin is broadly flared, narrowing gently along processes. Basal cavity is deepest and widest beneath cusp becoming a shallow groove beneath processes distally. Anterior face of unit is concave following configuration of processes.

Remarks. Several differences can be noted between large and small forms of this species. In general, smaller forms have more compressed denticles and narrower processes. The characteristic anterior denticulation of the cyrtionodiform element may be reduced to an angularity in the anterior margin. The postero-lateral process of eoligonodiform elements is often rudimentary and adenticulate in smaller forms. In oulodiform element, the distinctive posterior basal flare tends to be subdued in smaller forms. Despite this apparent dimorphism, both large and small elements are believed to belong in a single species because they are always admixed.

This species is distinctive from all other species of *Oulodus* in the nature of the cyrtionodiform and eoligonodiform elements. Closest similarity is recognized with *O. serratus* (Stauffer) as illustrated by Sweet and Schönlaub (1975), particularly in the nature of the oulodiform element. It is readily distinguished from *O. rohneri* (see remarks under that species).

Types. Hypotypes, GSC 59264-59270.

Genus *Ozarkodina* Branson and Mehl, 1933 s.f.

Type species. *O. typica* Branson and Mehl, 1933

Ozarkodina sp. s.f.

Plate 8, fig. 25

Description. Small, laterally compressed element with subequal anterior and posterior processes. Aboral outline slightly arched. Basal cavity shallow, deepest beneath cusp with very shallow extensions beneath the processes. Basal flares are present beneath main cusp. Anterior process bears five laterally compressed erect to slightly reclined denticles; they are fused along most of their length with discrete sharp pointed apices, and increase in size posteriorly. Laterally compressed main cusp only slightly higher than adjacent denticles and is posteriorly reclined. Posterior process bears six denticles identical to those on anterior process, which decrease in size away from main cusp. White matter is present in the cusp and denticles, emphasizing the degree of fusion.

Remarks. This form bears some resemblance to the elements of *Bryantodina? staufferi* Bergström and Sweet, but the prionodiform element in that species (Bergström and Sweet, 1966, Pl. 34, figs. 1, 2) has a more prominent main cusp and is more strongly arched. The ozarkodiform element (Bergström and Sweet, 1966, Pl. 34, figs. 3, 4) has short denticles posterior of the main cusp which reach their greatest height at mid-length of the process.

Type. Figured specimen, GSC 59979.

Genus *Panderodus* Ethington, 1959

Type species. *Paltodus unicastatus* Branson and Mehl, 1933 Ethington (1959, p. 284) erected this genus for: "simple asymmetrical curved cones which have a deep, tapered, basal cavity generally extending at least to mid-height. Lateral faces are orna-

mented by costae or grooves..." He added that species can be erected on the basis of cross sectional shape. This diagnosis is appropriate when considering *Panderodus* as a form taxon.

As a multielement genus, *Panderodus* can be shown to possess a number of different apparatus styles. These include three groups based on the Vauréal material. Group I apparatuses are those similar to that of the type species, *P. unicastatus*. This group has a broad, laterally compressed, asymmetrical element (compressiform, simplexiform) together with a variable group of slender asymmetrical to subsymmetrical cones (graciliform, unicastiform). Typical species with this type of apparatus are *P. gracilis* (Branson and Mehl), *P. unicastatus sensu* Cooper (1976) and *P. serratus* Rexroad *sensu* Cooper (1975).

Group II apparatuses are bi-elemental consisting of generally similar asymmetrical and symmetrical elements, between which there is little or no gradation. A representative of this type is *P. gibber* n.sp.

Group III apparatuses are also bi-elemental with broad, laterally compressed, low-based elements and long, slender elements with high base and long, laterally compressed cusps. Both elements vary greatly in symmetry. Examples of this group are *P. panderi* (Stauffer) and *P. liratus* n.sp.

These three different apparatus styles may provide the basis for subdivision of *Panderodus* into three separate genera, but this would be premature at this point in our understanding of the genus.

Panderodus angularis Branson, Mehl and Branson s.f.

Plate 5, figs. 23, 24

Paltodus angularis Branson, Mehl and Branson, 1951, p. 8, Pl. 1, figs. 34-39.

Panderodus angularis (Branson, Mehl and Branson). Kohut and Sweet, 1968, p. 1469, Pl. 185, figs. 20,23,27; non Bradshaw, 1969, p. 1159, Pl. 134, fig. 15.

Remarks. All previous reports of this species, including a listing from the Stony Mountain Formation of Manitoba (Ethington and Furnish, 1960) are from strata of Richmondian age. Only a few specimens have been recovered from the Vauréal Formation.

Being rare, the multielement apparatus cannot be established. One element does approach the symmetry of *P. staufferi* Branson, Mehl and Branson, s.f., and this is considered as the probable symmetrical variant. In addition *P. staufferi* s.f. is similar to *P. angularis* s.f. in terms of general morphology and reported co-occurrence.

Types. Hypotypes, GSC 59355-59356.

Panderodus cf. *P. compressus* (Branson and Mehl) s.f.

Plate 6, figs. 25, 26

cf. *Paltodus compressus* Branson and Mehl, 1933, p. 109, Pl. 8, fig. 19.

Remarks. The elements assigned to this taxon are closely similar to *P. compressus* s.f. in terms of symmetry. The major difference is the ratio between height of base relative to cusp length. Typically, *P. compressus* s.f. has a high base and a relatively short cusp. *P. cf. P. compressus*, however, has a much lower base and a much longer cusp. The multielement associates of this form have not been recognized, but they probably lie within the plexus of graciliform elements of *P. gracilis*. The variation of such apparatuses is reviewed under *P. gracilis* and *P. aff. P. gracilis*.

Type. Figured specimen, GSC 59385.

Panderodus gibber n.sp.

Plate 6, figs. 15-19; Text-figs. 7H,J

Diagnosis. A bielement apparatus of *Panderodus* with symmetrical and asymmetrical components. Symmetrical element has a rounded anterior margin, a lateral groove on each face and a sharply rounded to costate posterior margin. Asymmetrical element has a smooth inner lateral face, a pronounced antero-lateral ridge and a grooved outer lateral face. Both elements have a short rapidly tapering cusp.

Description. Symmetrical element has a broadly rounded anterior margin, meeting the lateral faces at sharp antero-lateral edges. Each edge bears a fine ridge which is most pronounced at mid-length and does not reach basal margin. A groove is present posterior to each ridge. Each lateral face bears a broad furrow at the base which tapers distally. A median groove is developed in the furrow and this extends to cusp tip. Groove is flanked by costae which are most evident at mid-length. Posterior edge is sharply rounded at the base with a sharp costa developed at mid-height of base, extending to cusp tip. Cusp is slightly longer than that of asymmetrical element and is weakly compressed antero-posteriorly.

Asymmetrical element has a rounded anterior margin that meets the inner lateral face at a sharp ridge. Ridge does not extend to aboral margin or distal end of cusp, being most prominent at mid-length. Inner lateral face is smooth and broadly convex. Outer, antero-lateral margin is broadly rounded. A broad furrow is developed on the outer side which tapers markedly from aboral margin to point of curvature. It bears a median groove which extends to tip of cusp. A faint posteriorly directed costa bounds anterior margin of groove. Posterior portion of base is laterally compressed and may be twisted toward outer side. Posterior edge is sharp except close to basal margin where it is sharply rounded. Cusp is short and laterally compressed with a relatively blunt tip; it is abruptly recurved at point of curvature.

Basal cavity of both elements is deep and conical with tip near anterior margin. White matter is developed in cusp of both elements with a cloudy transition from hyaline to white matter above tip of basal cavity.

Remarks. The two elements of this species are quite distinctive and transitional forms do not seem to occur. Of previously described species, it is most similar to *P. brevisculus* Barnes, but that form has a much shorter cusp and a more rounded antero-lateral face.

Large-scale striations are restricted to a band around the base, just above the basal margin. Below the band of striations, elements may appear thickened and develop a convex rim around the basal opening.

Type. Holotype, GSC 59371; paratypes, GSC 59372, 59373; unfigured paratypes, GSC 59374, 59375.

Panderodus gracilis (Branson and Mehl)

Plate 6, figs. 20, 23, 27

Paltodus gracilis Branson and Mehl, 1933, p. 108, Pl. 8, figs. 20,21.

Panderodus gracilis (Branson and Mehl). Bergström and Sweet, 1966, p. 355-359, Pl. 35, figs. 1-6 (contains synonymy through 1966); Uyeno, 1974, p. 15, Pl. 3, figs. 7-14 (contains synonymy through 1974); Viira, 1974, p. 101, Pl. 12, figs. 1, 10-12, Pl. 13, figs. 1,3; Sweet, Thompson and Satterfield, 1975, Pl. 1, figs. 7,8; ?Flajs and Schönlaub, 1976, Pl. 2, fig. 30; Barnes, 1977, p. 107, Pl. 3, figs. 6,7.

Paltodus arcuatus Stauffer, 1935b, p. 612, Pl. 74, figs. 6,8,9; Mehl and Strothmann, in Branson, 1944, p. 81, Pl. 12, figs. 27,28; Branson and Mehl, 1944, p.240, Pl. 93, fig. 26.

Panderodus arcuatus (Stauffer). Carlson, 1960, Pl. 2, figs. 8,17; Schopf, 1966, p.65, Pl. 5, figs. 26,28; Webers, 1966, p. 38, Pl. 2, figs. 8a,b,9a,b; Winder, 1966, p. 58, Pl. 9, fig. 23, Text-fig. 3-23; Weyant, 1968, p. 55, Pl. 5, fig. 7; non Barnes, 1977, p. 106, Pl. 3, figs. 23-25 (= *P. liratus* n.sp.).

Paltodus compressus Branson and Mehl, 1933, p. 109, Pl. 8, fig. 19.

Panderodus compressus (Branson and Mehl). Viira, 1974, p. 101, Pl. 12, fig. 2, Pl. 13, fig. 2; Lee, 1975, p. 177, 178, Pl. 1, fig. 13; ?Flajs and Schönlaub, 1976, Pl. 2, figs. 24,25.

Remarks. Bergström and Sweet (1966) discussed this species in detail, and their reconstruction is followed herein except that *P. arcuatus* s.f. is added to the apparatus as a broad, flattened extreme variant of the graciliform element.

P. gracilis may be an ancestor of *P. unicosatus* (Branson and Mehl) of Silurian age. The simplexiform and costate elements as described by Cooper (1976) are probably homologous to the compressiform and graciliform of *P. gracilis*. Cooper (1975) described an apparatus similar to *P. unicosatus* as *P. serratus* and the problem of serrated elements is discussed under *P. cf. P. serratus* herein.

The ratio of graciliform to compressiform is about 2:1 but may be as high as 3:1.

A number of elements in the Vauréal collections are characterized by very broad bases and these are described and discussed under *P. aff. P. gracilis*.

Types. Hypotypes, GSC 59376-59378.

Panderodus aff. *P. gracilis* (Branson and Mehl)

Plate 6, figs. 30-33

aff. *Paltodus gracilis* Branson and Mehl, 1933, p. 108, Pl. 8, figs. 20,21.

aff. *Panderodus gracilis* (Branson and Mehl). See synonymy under *P. gracilis* above.

?*Panderodus gracilis* (Branson and Mehl). Kohut and Sweet, 1968, p. 1469, 1470, Pl. 185, figs. 1,6,9 only.

?*Paltodus intermedius* Branson, Mehl and Branson, 1951, p. 7, Pl. 1, figs. 9-15.

?*Paltodus gracilis* Branson and Mehl. Branson, Mehl and Branson, 1951, p. 6,7, Pl. 1, fig. 8 only.

?*Paltodus compressus* Branson and Mehl. Branson, Mehl and Branson, 1951, p. 7, Pl. 1, figs. 16-22.

Remarks. A number of broad-based, posteriorly extended elements similar to graciliform and compressiform elements of *P. gracilis* have been recovered. They differ from *P. gracilis* in the following ways: a) the base is posteriorly extended, which is reflected in the sharper curve of the posterior margin; b) they are generally much larger in size; and c) the grooves and furrows are much more pronounced throughout the length of the elements.

Kohut and Sweet (1968) expressed difficulty in distinguishing between *P. gracilis* s.f. and *P. intermedius* s.f. and regarded them as end members of a completely gradational series. Furthermore they noted that specimens of *P. intermedius* tended to be larger than those of *P. gracilis* and they regarded this to be a function of growth.

Both the specimens illustrated by Kohut and Sweet (1968, Pl. 185, figs. 1,6,9) and the specimens herein referred to *P. aff. P. gracilis* resemble those specimens described as *P. compressus*, *P. intermedius* and *P. gracilis* by Branson, Mehl and Branson (1951). Whether or not *P. aff. P. gracilis* should be named *P. intermedius* is an unresolved problem.

A similar difficulty has been presented by specimens of *P. feulneri* (Glenister) which are generally large and resemble the compressiform element of *P. gracilis*. Some authors have chosen to place *P. feulneri* in *P. gracilis* as a gerontic growth form (e.g. Bergström and Sweet, 1966) whereas others have retained it as a separate species (e.g. Barnes, 1977). As *P. feulneri* may be associated with graciliform elements indistinguishable from those of *P. gracilis*, the matter remains open to question.

The recognition of *P. intermedius* as a species distinct from *P. gracilis* will depend upon further discoveries of posteriorly expanded elements, preferably in samples from which *P. gracilis* is absent. For the present, it is referred to *P. aff. P. gracilis* because of its great overall similarity to that species.

The occurrence of these unusual forms may be of stratigraphic significance, as similar elements are known only from Late Ordovician (Richmondian) strata.

Additional associates of this species, may be the graciliform elements identified as *Panderodus* sp.A (see Remarks under that species).

Types. Figured specimens, GSC 59386-59389.

Panderodus liratus n. sp.

Plate 6, figs. 21,22,24,28,29; Text-figs. 7C,D

Panderodus arcuatus (Stauffer). Barnes, 1977, p. 106, Pl. 3, figs. 23-25.

Panderodus panderi (Stauffer). Barnes, 1977, p. 107, Pl. 3, fig. 22 only.

Panderodus n. sp. C s.f. Nowlan, in Bolton and Nowlan 1979, Pl. 7, figs. 17, 18.

Diagnosis. A bi-element apparatus of *Panderodus* with broad, laterally compressed, short-based elements and more rounded, long, slender elements. Both elements are asymmetrical and bear grooves and costae on both sides, but the broader element shows a wider range of asymmetry.

Description. Broad element is laterally compressed and asymmetrical. Anterior edge is sharp and deflected to inner side, forming an antero-lateral ridge. Inner lateral face bears a sharp, posteriorly directed costa that extends from cusp onto upper half of base. A weak fold in the basal margin is situated posterior to the line of the costa and extends as a shallow groove enclosed by the costa. Posterior portion of inner lateral face is more steeply inclined posteriorly. Posterior edge is sharp, except at basal margin where it is acutely rounded. Anterior half of outer lateral face is broadly convex. Posterior portion of outer lateral face is furrowed. The deep, narrow furrow is broader at the base and produces a notch in aboral outline. Margins of furrow are rounded basally and sharp from mid-length of base to cusp tip, being bounded by posteriorly directed costae. A narrow groove is situated medially in furrow. Posterior portion of outer lateral face is sharply inclined to meet posterior edge. Base is broad, tapering rapidly to point of curvature. Cusp is broad, laterally compressed and straight; it may be twisted to inner side. Basal cavity is deep and conical with tip situated near anterior margin.

Slender element is exceptionally long and narrow. Base is very high with a deep, slender, conical basal cavity extending to point of curvature. Anterior margin is rounded at the base, becoming progressively sharper distally. Anterior edge of cusp is sharp. Each lateral face bears a sharp, posteriorly directed costa at mid-line or more posteriorly. A groove is present posteriorly to each costa and is reflected as a faint furrow and basal notch on the basal edge. A secondary posteriorly directed costa, situated halfway

between main costa and posterior edge, is present on outer side. Main groove is generally deeper on outer side also. Lateral costae and enclosed posterior grooves become more posteriorly situated on cusp. Posterior edge is sharp except at basal margin where it is narrowly rounded. Cusp is laterally compressed and may be slightly twisted to inner side. It is slender proximally, broadening towards mid-length and tapering to tip. It typically is acutely recurved, but may be quite proclined, and is of about equal length with the base.

Both elements contain white matter in tip of cusp with a cloudy transition zone from hyaline material above basal cavity apex.

Remarks. The apparatus style of this species is similar to that of *P. panderi* in the development of broad and slender elements. The broad element is similar to the homologous element in *P. panderi* but may be distinguished by the less posteriorly expanded base and less prominent anterior flange. The slender element is highly distinctive, particularly in its long, slender base and centrally broadening flat cusp.

The forms described as *P. arcuatus* Stauffer by Barnes (1977) belong within this species and it is possible that one of his figured specimens of *P. panderi* may be the compressed, broad form (see synonymy).

The form illustrated by Nowlan as *P. n. sp. C s.f.* (Bolton and Nowlan, 1979) is a slender element of *P. liratus*.

The ratio of slender elements to broad elements is about 3:1, but varies from 2:1 to 4:1.

Types. Holotype, GSC 59380, paratypes, GSC 59379, 59381-59383; unfigured paratype, GSC 59384.

Panderodus panderi (Stauffer)

Plate 6, figs. 3,4,14

Paltodus panderi Stauffer, 1940, p. 427, Pl. 60, figs. 8,9.

Panderodus panderi (Stauffer). Stone and Furnish, 1959, p. 226, Pl. 31, fig. 4; Sweet, Thompson and Satterfield, 1975, p. 33,34, Pl. 1, fig. 12 (includes synonymy to 1975); Barnes, 1977, p. 107, Pl. 3, fig. 21 only.

Panderodus sp. aff. *P. panderi* (Stauffer). Sweet, Thompson and Satterfield, 1975, p. 34, 35, Pl. 1, fig. 13 (includes synonymy through 1975).

Remarks. Sweet, Thompson and Satterfield (1975) indicated that recent work has suggested that two forms of *P. panderi* occur as an evolutionary series with slender forms preceding the more reclined, shorter-based, typical *P. panderi*. The Vauréal material suggests that both long and short-based forms co-occur, forming an apparatus similar to that of *P. liratus* n.sp. Those elements with longer bases appear to have a lesser range of symmetry variants than those with short bases.

Types. Hypotypes, GSC 59362-59364.

Panderodus cf. *P. serratus* Rexroad s.f.

Plate 6, figs. 9,11; Text-Fig. 7A

cf. *Panderodus unicastatus serratus* Rexroad, 1967, p. 47, Pl. 4, figs. 3,4.

cf. *Panderodus serratus* Rexroad. Aldridge, 1972, p. 204, Pl. 9, fig. 7; Cooper, 1975, p. 993, 994, Pl. 1, figs. 5,7 only.

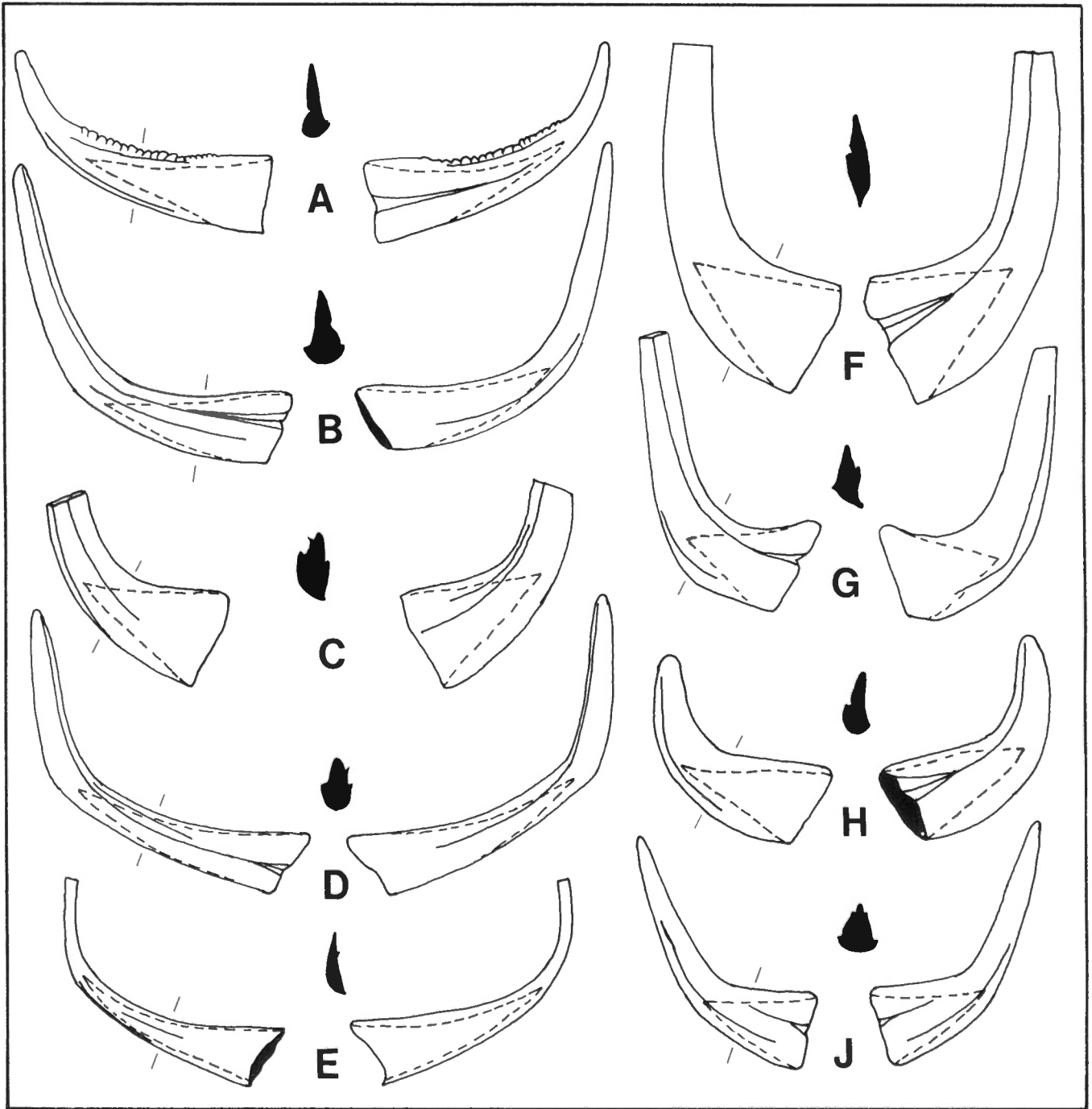


Figure 7. Sketches of selected species of *Panderoodus* showing inner view, cross section shape and outer view respectively (except B and G where inner and outer are reversed). A, *P. cf. P. serratus* s.f.; B, *P. n. sp.* A; C, D, broad and slender elements of *P. liratus* n. sp.; E, *P. n. sp.* B; F, G, compressiform and graciliform elements, *P. n. sp.* C; H, J, asymmetrical and symmetrical elements, *P. gibber* n. sp.

Description. Long, slender, laterally compressed, asymmetrical cone. Inner lateral face is smooth and inclined posteriorly. A faint furrow may be developed at the base. Anterior margin is narrowly rounded, meeting inner lateral face at a sharp costa that is most pronounced from about mid-length to near distal end. Proximal, inner antero-lateral face is rounded. Posterior margin is sharp basally and distally. Intervening portion is serrated by numerous, small, blunt denticles, which are weakly inclined towards the cusp. At the base, outer lateral face bears a narrow furrow that tapers rapidly distally. It has a median groove that extends to tip of cusp, running slightly posterior to mid-line. Basal cavity is deep and conical, extending to point of curvature. Cusp is proclined and very short. It is filled with white matter and may be inclined to inner side.

Remarks. This species is similar to serrated elements described as *P. unicostatus serratus* by Rexroad (1967), which Cooper (1975) included in a multielement species, *P. serratus*. It differs in having a shorter cusp than those elements described as *P. serratus* by Cooper (1975) and Aldridge (1972). The cusp of the holotype of *P. serratus* is broken (Rexroad, 1967, Pl. 4, figs. 3,4). Furthermore, the ridge of the inner, lateral face is less pronounced than that of the holotype.

Cooper (1975) placed serrated elements in *P. serratus* and grouped them with *P. unicostatus* Branson and Mehl s.f. If *P. gracilis* is considered as the ancestor of *P. serratus sensu* Cooper (1975), then it might be expected that *P. cf. P. serratus* belongs in the *P. gracilis* apparatus. However, the distribution of these two forms is quite different in the Vauréal Formation, *P. cf. P. serratus* being virtually restricted to the lower part (Table 1). It is possible that serrated elements were locally developed in response to environmental factors, but the rather invariable morphology of this species is in contrast to the variability of elements described as *P. arcuatus* Stauffer s.f. and *P. gracilis* Branson and Mehl s.f. which are the similar components of *P. gracilis*. *P. cf. P. serratus* is most similar to *P. arcuatus* s.f. which is the more flattened graciliform element of *P. gracilis*. Similarly, Aldridge (1972, p. 204) notes that his specimens of *P. serratus* resembled "only the broader, flatter specimens of *P. unicostatus*, which represent one extreme of the variant range of that species".

A serrate form of *Panderodus* has been reported from the Middle Ordovician Pratt Ferry and Copenhagen formations (Sweet and Bergström, 1962; Ethington and Schumacher, 1969). This form is rather different to *P. cf. P. serratus*, but it indicates that *Panderodus* has developed serrated forms at several times in its history.

This species is retained in form taxonomy pending further discoveries elsewhere. It seems unlikely that this form constituted a single element-type apparatus, in view of the variability of other species of *Panderodus*.

Types. Figured specimens, GSC 59369, 59370.

Panderodus n.sp. A

Plate 6, figs. 1,2,5-7,10; Text-fig. 7B

?*Paltodus gracilis* Branson and Mehl. Branson, Mehl and Branson, 1951, p. 6,7, Pl. 1, figs. 1-7.

Description. Asymmetrical to subsymmetrical slender simple cone. Inner lateral face is smooth and posteriorly inclined. A weak fold is present on lower part of base, situated at mid-line or more posteriorly. Oral edge is sharp and slightly convex in lateral view. Anterior margin is rounded, meeting inner lateral face at a sharp ridge, which extends from just above basal margin onto cusp, becoming less distinct distally. A similar, less prominent, ridge

occurs at junction of anterior and outer lateral faces. Outer lateral face bears a deep furrow situated at mid-line or more posteriorly. It extends from a basal notch, narrowing to top of base. An axial groove is present in furrow, extending from base to distal end. Anterior of furrow, base is convex, becoming flattened posteriorly. Posterior edge is sharp. Cusp is laterally compressed and of about equal length with base. It is sharply recurved above base and distally straight. Basal cavity is deep and conical extending to point of curvature. White matter is developed in cusp and may form a cloudy region in the base, surrounding basal cavity.

Remarks. Considerable variation occurs in the symmetry of these elements. The position and depth of the grooves varies such that a few elements are almost symmetrical. In some forms the cusp is shorter and more proclined (e.g. Pl. 6, figs. 1, 2).

Specimens assigned to this species resemble the graciliform elements of *Panderodus gracilis* in symmetry but differ in the cusp-to-base ratio and the abrupt recurvature. The absence of associated compressiform elements is puzzling. A number of possibilities exist to explain this anomaly. Firstly, the compressiform elements might be those assigned to *P. cf. P. compressus* s.f., but these are so rare that it is considered unlikely. Secondly, the compressiform element of *P. n.sp.* C may be associated, but these have distinctive lateral carinae and are also rare. Thirdly, and most likely, this species may be associated with those elements assigned to *Panderodus* aff. *P. gracilis*. Although less abundant than *P. sp. A*, it is the most similar morphologically. In addition, it may be that only extreme forms of the compressiform element of *P. sp. aff. P. gracilis* have been distinguished from *P. gracilis*. Furthermore, *P. n.sp. A* is similar to those elements described and illustrated as *P. gracilis* by Branson, Mehl and Branson (1951). It differs from those elements in having less pronounced grooves and ridges. Similarly, elements of *P. aff. P. gracilis* are similar to *P. intermedius* and *P. compressus* as illustrated by Branson, Mehl and Branson (1951) (see remarks under that species).

This problem of separation of elements of similar species of *Panderodus* is one of the profound difficulties in the treatment of the genus. It will be necessary to recover samples containing only one species to resolve these difficulties.

Types. Figured specimens, GSC 59357-59360; unfigured specimens, GSC 59361.

Panderodus n.sp. B

Plate 6, figs. 8,12,13; Text-fig. 7E

Description. Slender, laterally compressed cone with a high base and a long slender recurved cusp. Aboral outline is straight to concave. Inner lateral face is smooth or faintly costate. A weak costa is situated anteriorly, extending from base to cusp tip. Outer lateral face bears a shallow furrow posterior to mid-line; the side is convex anterior to furrow and flattened posteriorly. A shallow axial groove in the furrow extends to point of curvature where it merges with posterior edge. Anterior and posterior edges are sharp. Cusp is sharply recurved at point of curvature and distally straight. It is extremely slender and laterally compressed, and it is twisted slightly to inner side. White matter is restricted to cusp and may be cloudy or dense.

Remarks. This distinctive slender cone most resembles *P. cf. P. serratus*, but the cusp is much longer and the outer furrow is far less pronounced. Cusp curvature and the degree of expansion of the base are variable morphologic features. No multielement associates are known for this relatively scarce simple cone.

Types. Figured specimens, GSC 59365-59367; unfigured specimen, GSC 59368.

Panderodus n.sp. C

Plate 5, figs. 18-22; Text-figs. 7F,G

Description. A bi-element apparatus of two asymmetrical elements: one is broader and more laterally compressed (referred to as compressiform element) and the other acutely recurved, laterally compressed and more slender (referred to as graciliform element).

Compressiform element has a low base and weakly expanded posterior margin. Inner face is broadly convex with a median carina extending length of element. Anterior and posterior edges are sharp. Outer face has a narrow median carina which is most prominent at point of curvature. Posterior to carina is a deep groove which runs from a pronounced basal notch to tip of cusp. Anterior to carina, base is flattened, producing a thin anterior edge. Cusp is broad and long.

Graciliform element is acutely recurved with a posteriorly extended base. Oral margin is slightly convex in lateral view. Inner lateral face is broadly convex and ornamented by a ridge situated anteriorly to mid-line. Ridge is sharply rounded on base, becoming more broadly rounded distally, disappearing on convex surface of cusp. Anterior edge is sharp and abruptly recurved at top of base. Outer lateral face bears a deep groove situated posteriorly to mid-line and extending length of element, from a broad basal notch, narrowing to tip of cusp. Anterior to groove, the side is convex with a slight flattening at anterior margin. Posteriorly, the face is flat and inclined toward posterior edge. Cusp is slender, laterally compressed and slightly twisted relative to base so that anterior edge is more outwardly directed.

Basal cavity in both elements is generally obscured by heavy development of white matter throughout element. Where visible, it is a concave-sided triangle in lateral view with apex close to anterior margin. Posterior margin of cavity diverges anteriorly from oral margin. A thickened rim is present around basal opening.

Remarks. The compressiform element differs from that of *P. gracilis* in having a much lower base, and in the development of lateral carinae. The heavy development of white matter is unusual for a species of *Panderodus* and may serve as a distinguishing feature. Considerable variation is present in the situation of the inner ridge and outer groove of the graciliform element.

Types. Figured specimens, GSC 59349-59353; unfigured specimen, GSC 59354.

Genus *Paroistodus* Lindström, 1971

Type species. *Oistodus parallelus* Pander, 1856
Lindström (1971, p. 46) erected this genus to include "drepanodid conodonts with drepanodiform and oistodiform elements. The basal cavity tends to become inverted anteriorly. Drepanodiform elements tend to develop a sharp low costa on each side. Base of oistodiform elements is roughly square in side view and does not extend very far anteriorly". The species tentatively referred to *Paroistodus* herein differs in some respects from this definition. Barnes and Poplawski (1973, p. 779) first suggested that elements referred to *Acodus mutatus* (Branson and Mehl) and *Oistodus venustus* Stauffer might belong in *Paroistodus* and they discussed these differences. In addition, the presence of at least two morphotypes of 'drepanodiform' elements is not consistent with described species of this genus. Lindström (1971) also suggested that the ratio of drepanodiform to oistodiform elements was about 2:1. In contrast, *Paroistodus? mutatus* seems to have a rather variable ratio which does not exceed 1:1.

Van Wamel (1974, p. 78) added "slightly asymmetrical forms with a basal cavity opening to one side (=scandodiform elements)" to the description of this genus. In this study, a number of the drepanodiform elements are scandodiform in appearance because of a flexure of the cusp with respect to the base.

Cooper (1976) has placed similar simple cones into a new genus termed *Dapsilodus*, however he indicated that no oistodiform elements are present in the genus. Certainly the acodiform and distacodiform elements of *P.? mutatus* are similar to some of those included in *Dapsilodus*, but the probable presence of an oistodiform element (*O. venustus* s.f.) in *P.? mutatus* precludes assignment to *Dapsilodus*. A new genus may eventually be established to accommodate these Late Ordovician forms that resemble Early Ordovician *Paroistodus* and Silurian *Dapsilodus*.

Paroistodus? mutatus (Branson and Mehl)

Plate 1, figs. 15-24

Belodus? mutatus Branson and Mehl, 1933, p. 126, Pl. 10, fig. 17.

Acodus mutatus (Branson and Mehl). Bergström and Sweet, 1966, p. 303-305, Pl. 35, figs. 7-9 (includes synonymy through 1966); ?Serpagli, 1967, p. 41, Pl. 6, figs. 1a, b, 6a, b; Uyeno, 1974, p. 16, 17, Pl. 1, fig. 23; Barnes, 1977, p. 104, 105, Pl. 3, figs. 4,5.

Distacodus procerus Ethington. Weyant, 1968, p. 45, Pl. 5, fig. 12.

?*Distacodus* sp. Weyant, 1968, p. 46, Pl. 5, figs. 9, 11.

Acodus sp. Weyant, 1968, p. 28, Pl. 5, fig. 8.

Oistodus venustus Stauffer, 1935a, p. 147, Pl. 12, fig. 12; Bergström and Sweet, 1966, p. 341, Pl. 35, figs. 20, 21 (includes synonymy through 1966); Weyant, 1968, p. 53, Pl. 2, fig. 9; ?Sweet, Thompson and Satterfield, 1975, Pl. 1, fig. 9.

Remarks. In this species there are three basic morphotypes. The first is represented by elements referable to *Acodus mutatus* (Branson and Mehl) s.f. or *Acodus inornatus* Ethington s.f. which have a low base and a costa on the inner side. Under this group are included elements with a low base, but with a costa on both sides (distacodiform). Weyant (1968) illustrated a similar form as *Distacodus* sp., which he recognized as being very similar to *Acodus inornatus* Ethington s.f., however his specimen has a shallow basal cavity. About half of the low-based elements have a costa on each side, rather than a single lateral costa.

The second morphotype is represented by elements referable to *Distacodus procerus* Ethington s.f. and these are characterized by a high base and a costa on each side. Some of these forms are laterally flexed to resemble scandodiform elements.

The third morphotype is the oistodiform element which is referable to *Oistodus venustus* Stauffer s.f. Each of these three morphotypes is well described in the literature and no further comments are required.

These elements consistently co-occur and are present in thirty-two of the samples. The numerical ratio between the elements are not at all consistent, except that the other elements combined seldom exceed the number of oistodiform elements. This lack of consistency may be a result of the low abundance of this species in most samples. In samples with more than twenty specimens, the ratio of 'drepanodiform' to oistodiform elements ranges from 1:1 to 1:1.5. Overall the ratio is 1:1.

Types. Hypotypes, GSC 59256-59261; unfigured hypotypes, GSC 59262, 59263.

Genus *Phragmodus* Branson and Mehl, 1933

Type species. *P. primus* Branson and Mehl, 1933

Phragmodus undatus Branson and Mehl

Plate 4, figs. 1-11, 13

Phragmodus undatus Branson and Mehl, 1933, p. 115, 116, Pl. 8, figs. 22-26; Bergström and Sweet, 1966, p. 369-372, Pl. 28, figs. 13-20 (includes synonymy through 1966); Globensky and Jauffred, 1971, p. 57, Pl. 4, figs. 7-13 (includes synonymy through 1970); Sweet and Bergström, 1970, figs. 5A-D; Atkinson, 1971, p. 85, Pl. 4, fig. 6, Pl. 5, fig. 8, Pl. 6, fig. 6; Sweet, Ethington and Barnes, 1971, p. 175, Pl. 2, figs. 7-10; Uyeno, 1974, p. 15, 16, Pl. 1, figs. 26-30; Sweet, Thompson and Satterfield, 1975, Pl. 2, figs. 8, 12, 13; Barnes, 1977, p. 107, Pl. 4, figs. 2-5.

Remarks. Sweet et al. (1959) and Bergström and Sweet (1966) both recognized distinct groups of elements within the ramiform complex (phragmodiform elements) based upon cusp ornamentation. However, the groups in each study are not identical. Those recognized by Bergström and Sweet (1966) are most applicable to the specimens under study. Group 1 includes those elements with anterior and posterior edges and, in some specimens, a weak outer lateral costa. This group is considered as the cordylodiform to cladognathiform part of the transition series. Specimens belonging to Group 2 have anterior and posterior edges and a lateral costa on each side. The costae are variable in position but most commonly are posterior near the base, to median distally. This group is regarded as tetraprioniodiform. Group 3 specimens have a flattened to convex anterior margin with an antero-lateral costa on each side and are regarded as trichonodelliform. Group 1 and 2 elements each outnumber Group 3 elements by about six to one. This variation within the phragmodiform elements represents a typical transition series for ramiform complexes of many genera (Sweet and Bergström, 1972).

Both dichognathiform elements (*D. brevis* Branson and Mehl s.f. and *D. typica* Branson and Mehl s.f.) are about equally abundant and oistodiform elements outnumber each of them about three to two. The resulting ratio for elements in the *P. undatus* apparatus is 6:6:1:6:4:4 (phragmodiform 1, phragmodiform 2, phragmodiform 3, oistodiform, breviform and typicaform respectively). This suggests that at least 27 elements were present in a single animal.

Pulse and Sweet (1960, Text-fig. 2) reported robust forms of *P. undatus* and suggested that these were the end products of a growth series. In this study, specimens can be recognized which have a reduced number of denticles between the cusp and main denticle on the posterior process. These are generally rather robust and seem to represent overgrowth by the main denticle which becomes very broad. However, in the form illustrated by Pulse and Sweet (1960, Text-fig. 2E) as the most robust element, the proximal denticles parallel the cusp, whereas in all other forms these denticles are reclined posteriorly, parallel to the main denticle. The latter is the case for Vauréal specimens and it may be that the specimen illustrated by Pulse and Sweet (1960, Text-fig. 2E) represents a separate species. 'Robust' specimens from the Vauréal Formation are of only modest size; the angle between the posterior process and downward extension of the base is reduced, and all phragmodiform groups are represented by such elements.

Types. Hypotypes, GSC 59309-59316; unfigured hypotypes, GSC 59317, 59318.

Genus *Plectodina* Stauffer, 1935a

Type species. *Prioniodus aculeatus* Stauffer, 1930

Sweet et al. (1975) have reviewed the history of the taxonomic concept of this genus and their conclusion that the apparatus consists of six elements is followed herein.

Plectodina bidentata n. sp.

Plate 3, figs. 1-8

Diagnosis. A *Plectodina* apparatus characterized by the presence of an enlarged denticle adjacent to the main cusp. This denticle is anterior in cordylodiform, cyrtoniodiform, prioniodiniform and ozarkodiniform elements, lateral in zygnathiform elements and absent in trichonodelliform elements. Denticles are broad, closely spaced and sharp-edged with keels developed.

Description. Cordylodiform element is laterally compressed with a long posterior process. Denticles are erect to slightly posteriorly reclined. Cusp is broad and sharp-edged with lenticular cross section. A denticle is present anteriorly which may reach two-thirds of cusp height. It forms a sharp anterior edge which is flexed slightly inwards so that the denticle is out of the cusp plane. Unit is bowed gently and a very weak median ridge is present on inner side of cusp. Basal cavity is deep beneath main cusp, with apex anteriorly directed. It extends shallowly beneath the posterior process, but does not reach antero-basal angle beneath secondary denticle. White matter is present in cusp and denticles and extends downwards at anterior margin.

Zygnathiform element is asymmetrical with a strongly laterally compressed main cusp which extends posteriorly as a sharp postero-oral edge. Processes are strongly antero-posteriorly compressed and one bears a large, broad denticle adjacent and perpendicular to the cusp and extending almost to cusp height. An additional small denticle may be present distally. The other process bears two or three low blade-like denticles, and is bowed posteriorly. Basal cavity is deep and narrow beneath cusp extending as a groove to ends of process. Trichonodelliform element is similar to zygnathiform element but it lacks an enlarged process denticle and bears straight, subequal, lateral processes.

A large anterior denticle characterizes the cyrtoniodiform element. It is situated anteriorly and strongly laterally compressed. Denticle is both flexed and slightly recurved inward displaced from plane of the main cusp. Cusp is broad, sharp-edged and posteriorly inclined. Basal cavity is broadly flared on inner side; it is deepest beneath cusp but does not extend into cusp. It reaches antero-basal angle and extends beneath posterior process. Posterior process is long and slightly twisted inwards or outwards so that denticles lie out of the plane of the main cusp.

Cusp of prioniodiniform element is offset so that posterior edge is slightly inwardly directed. Anterior process is high with two or three broad denticles. Posterior process is longer and lower with three to four denticles diminishing in size distally. Unit is bowed inward and posterior process is twisted slightly outward. Base is flared beneath main cusp. Basal cavity deepest beneath cusp and shallows to grooves distally. Apex is anteriorly directed. Anterior denticle adjacent to cusp is not markedly enlarged but is situated very close to, and partly confluent with anterior edge of cusp.

Ozarkodiniform element is a uniformly arched blade with subequal anterior and posterior processes. Anterior process is high with up to eight broad denticles which are even in size except for one or two small ones distally. Posterior process is lower with smaller, more discrete denticles up to seven in number. Basal cavity is slightly expanded beneath the cusp and extends shallowly to

process tips. Angle between processes tends to be smaller than that of prioniodiniform elements. Anterior denticle adjacent to main cusp is parallel to main cusp and may be basally fused with it.

Remarks. This species commonly is preserved with denticles broken away except for their confluent bases, particularly in prioniodiniform and ozarkodiniform elements.

It is known from the Farr Formation in an outlier at Lake Timiskaming along the Ontario-Québec border (Munro, 1975) and also from undescribed collections of the Upper Ordovician of Hudson Bay and Manitoba. In addition, elements of this species have been recognized in topotype material collected from the Clarkesville section of Satterfield (1971). It is also reported from the Ely Springs Dolomite and Hansen Creek Formation (Upper Ordovician) of the Great Basin (Harris, 1978, pers. comm.).

Types. Holotype, GSC59290; paratypes, GSC 59286-59289, 59291-59293; unfigured paratypes, GSC 59294, 59295.

Plectodina cf. *P. inclinata* (Glenister) 1957

Plate 3, figs. 9-12, 15, 16

cf. *Ozarkodina inclinata* Glenister, 1957, p. 735, Pl. 88, figs. 3, 7.

cf. *Ozarkodina concinna* Stauffer. Ethington, 1959, p. 282, Pl. 41, figs. 15, 16.

cf. *Plectodina furcata inclinata* (Glenister). Sweet et al., 1975, p. 41, 42, Pl. 2, figs. 1-7.

Remarks. Sparse and fragmentary material at hand does not permit definitive identification of *P. inclinata*, but several features serve to distinguish this grouping from *P. tenuis*. Firstly, the ozarkodiniform element has a longer anterior than posterior process, a feature characteristic of *P. inclinata* (Sweet et al., 1975). Secondly, all elements of the transition series have slightly broader and more crowded denticles on the processes, and the basal cavity is broader and deeper, filling almost the whole base.

The trichonodelliform element characteristic of *P. inclinata*, which has a long posterior process, has not been identified in the Vauréal material. This is probably due to the fragmentary nature of preservation. A characteristic cyrtioniodiform element occurs within *P. cf. P. inclinata*. It differs from that of *P. tenuis* in that the denticles are broader, shorter and more posteriorly inclined. In addition, the antero-basal corner is more extended than that in *P. tenuis*, resulting in a straighter anterior outline. This distinctive element was not reported for *P. furcata inclinata* by Sweet et al. (1975). See remarks under *P. tenuis*.

Types. Figured specimens, GSC 59296-59301.

Plectodina tenuis (Branson and Mehl)

Plate 4, figs. 12, 14-16, 20, 21

Cordylodiform element

Cordylodus? delicatus Branson and Mehl, 1933, p. 129, Pl. 10, figs. 14, 15.

Cordylodus delicatus Branson and Mehl. Sweet et al., 1959, p. 1044, 1045, Pl. 132, figs. 12, 14, 17; Pulse and Sweet, 1960, p. 251, Pl. 36, figs. 4, 7.

Zygonathiform element

?*Phragmodus mirus* Branson and Mehl, 1933, p. 123, Pl. 10, fig. 12.

Zygonathus deformis (Stauffer). Sweet et al., 1959, p. 1066, 1067, Pl. 132, figs. 1-5; Pulse and Sweet, 1960, p. 261, Pl. 37, figs. 1, 5.

Trichonodelliform element

Trichognathus tenuis Branson and Mehl, 1933, p. 131, Pl. 10, fig. 18.

Trichonodella tenuis (Branson and Mehl). Sweet et al., 1959, p. 1065, Pl. 132, figs. 10, 15; Pulse and Sweet, 1960, p. 260, Pl. 37, figs. 3, 8.

Trichonodella angulata Sweet et al., 1959, p. 1064, Pl. 131, figs. 9, 13; Pulse and Sweet, 1960, p. 260, Pl. 37, figs. 2, 7.

Cyrtioniodiform element

Prioniodus? flexuosus Branson and Mehl, 1933, p. 130, Pl. 10, fig. 16.

Cordylodus flexuosus (Branson and Mehl). ?Sweet et al., 1959, p. 1045, Pl. 132, fig. 13; Pulse and Sweet, 1960, p. 251, 252, Pl. 36, figs. 6, 9.

Cyrtioniodus flexuosus (Branson and Mehl). Bergström and Sweet, 1966, p. 324-327, Pl. 32, figs. 9, 10, non Pl. 32, fig. 11.

Prioniodiniform element

Prioniodina delecta (Stauffer). ?Sweet et al., 1959, p. 1060, 1061, Pl. 131, fig. 11; Pulse and Sweet, 1960, p. 251, 252, Pl. 36, figs. 6, 9.

Ozarkodiniform element

Ozarkodina tenuis Branson and Mehl, 1933, p. 128, Pl. 10, figs. 19-21, 23; Bergström and Sweet, 1966, p. 353-355, Pl. 31, figs. 1-5.

Ozarkodina robusta Stauffer. Sweet et al., 1959, p. 1055, 1056, Pl. 132, figs. 19, 20, Pl. 133, fig. 14; Pulse and Sweet, 1960, p. 256, Pl. 35, figs. 18, 19.

Multielement synonyms

Plectodina furcata (Hinde). Bergström and Sweet, 1966, p. 377-382, Pl. 32, figs. 17, 18, Pl. 33, figs. 1, 2, 16-19, Pl. 34, figs. 9-12, ?Pl. 32, fig. 19, ?Pl. 33, figs. 3, 4, 14, 15, 20, 21; Sweet and Bergström, 1970, fig. 5E-5I; Sweet, Ethington and Barnes, 1971, p. 170, Pl. 1, figs. 7-11.

Plectodina furcata tenuis (Branson and Mehl). Sweet, Thompson and Satterfield, 1975, p. 42, 43, Pl. 2, figs. 9-11, 14-17.

Remarks. Tarrant (1977) has shown that *Prioniodus furcata* Hinde s.f. is associated with *Prioniodus? politus* Hinde s.f. in material collected from the Don Valley Brickyard, Toronto. This locality is stratigraphically equivalent to, and only one-half mile away from Hinde's (1879) Garrison Common section. Tarrant (1977) has regarded these two elements as part of a multielement species *Aphelognathus politus* (Hinde). *Prioniodus furcatus* has formerly been regarded as part of *Plectodina furcata* (Hinde) by Bergström and Sweet (1966) and later authors. This requires revision of *Plectodina furcata*, and *Ozarkodina tenuis* Branson and Mehl is chosen as the junior subjective synonym, resulting in *Plectodina tenuis* (Branson and Mehl).

Sweet et al. (1975) distinguished two subspecies of *Plectodina furcata*: *P. f. tenuis* (Branson and Mehl) and *P. f. inclinata* (Glenister) based primarily upon the distinction of two types of ozarkodiniform and trichonodelliform elements. The skeletal components of *P. tenuis* as reported herein are based upon the concept of *P. furcata tenuis* as outlined by Sweet et al. (1975). They have been thoroughly described in the literature.

Types. Hypotypes, GSC 59319-59324.

Genus *Plegagnathus* Ethington and Furnish, 1959

Type species. *Belodina dartoni* Stone and Furnish, 1959

Only two species of this genus have been reported: *P. dartoni* (Stone and Furnish) s.f. and *P. nelsoni* Ethington and Furnish s.f. Specimens of these two form species are morphologically similar and commonly co-occur, usually in low numbers.

Plegagnathus is herein raised to multielement status. The apparatus is diagnosed as consisting of two plegagnathiform morphotypes, one of which is suberect and the other is reclined. In the single multielement species known to date, these morphotypes are represented by *P. dartoni* s.f. and *P. nelsoni* s.f. respectively.

The apparatus is similar to that of many species of *Belodina* Ethington but no heel is developed at the base. The lack of a heel appears to allow the denticulation to extend posteriorly with growth, so the number of denticles is far more variable than in species of *Belodina*. Two or three morphotypes are present in species of *Belodina* and it is possible that the apparatus of *Plegagnathus* may contain another element, namely "*Cordylodus*" *robustus* Ethington and Furnish s.f. as noted in the remarks on that species.

In erecting this genus, Ethington and Furnish (1959) chose *P. nelsoni* as the type species. With the inclusion of *P. dartoni* and *P. nelsoni* in a single taxon, *P. dartoni* is a senior subjective synonym and becomes the type species, giving its name to the multielement species.

Plegagnathus dartoni (Stone and Furnish)

Plate 7, figs. 10,11,13-15

Belodina dartoni Stone and Furnish, 1959, p. 220, Pl. 31, fig. 15.

Plegagnathus dartoni (Stone and Furnish). Ethington and Furnish, 1959, p. 545, Pl. 73, figs. 6, 7; ?Kohut and Sweet, 1968, p. 1472, Pl. 186, figs. 9-11; Weyant, 1968, p. 59, Pl. 4, figs. 6, 7; Barnes, 1974, Pl. 7, fig. 27.

Plegagnathus nelsoni Ethington and Furnish, 1959, p. 544, 545, Pl. 73, figs. 2, 3; Ethington and Furnish, 1960, p. 272, Pl. 38, fig. 1; Weyant, 1968, p. 59, 60, Pl. 4, fig. 8.

Remarks. The constituents of this multielement species have been well described in the literature and only a few additional comments are necessary. Two variants of each morphotype can be recognized. Weyant (1968, p. 59) observed that his material had fewer denticles than those specimens illustrated by Ethington and Furnish (1959). This is the case for the majority of specimens in this study, and the same situation has been observed in material from an outlier north of Aberdeen Lake, District of Keewatin. The two variants are distinguished on the basis of size and number of denticles and they are particularly distinct within the suberect (*P. dartoni* s.f.) morphotype. The large variant has up to twelve narrow denticles that are fused along most of their length. In addition, it is more robust with a stout cusp that is grooved near the posterior margin on the inner side. The groove continues onto the base. The small variant has three to six denticles which are broader and fused for only half their length. The lateral groove is less pronounced. The significance of this dimorphism is not understood, and the erection of separate species may become warranted with further discoveries, but is not desirable at present.

P. dartoni s.f. and *P. nelsoni* s.f. are known to occur in the Shamattawa Limestone of Manitoba (Ethington and Furnish, 1959) and the Irene Bay Formation of the Arctic Islands (Weyant, 1968; Barnes, 1974).

The element reported as *P. dartoni* s.f. by Kohut and Sweet (1968) is believed possibly part of *Belodina profunda* (Branson and Mehl); see discussion under that species.

Types. Hypotypes, GSC 59400-59402.

Genus *Pseudooneotodus* Drygant, 1974

Type species. *Oneotodus? beckmanni* Bischoff and Sannemann, 1958 Drygant (1974, p. 66) erected this genus for short, conical

elements with a broad base, deep basal cavity and an apex consisting of one or more tips. Cooper (1977) has discussed the genus and illustrated a number of species from the Silurian.

Pseudooneotodus beckmanni (Bischoff and Sannemann)

Plate 2, figs. 20,21

Oneotodus? beckmanni Bischoff and Sannemann, 1958, p. 98, Pl. 15, figs. 22-25.

Pseudooneotodus beckmanni (Bischoff and Sannemann). Drygant, 1974, p. 67, Pl. 2, figs. 34-39; Cooper, 1977, p. 1068, 1069, Pl. 2, figs. 14, 17 (includes comprehensive synonymy through 1976).

Indeterminate element - Form C. Weyant, 1968, p. 64, Pl. 6, figs. 13, 15 only.

Remarks. Cooper (1977) included all of Form C (Weyant, 1968) in *P. beckmanni*, but some of these forms belong within *Pseudooneotodus mitratus* (Moskalenko) (see below). All the specimens included in this species from the Vauréal Formation have a laterally compressed, oval, basal outline. One of the specimens illustrated by Winder (1976, Pl. 2, fig. 13) as 'elf caps' may belong in this species.

Types. Hypotypes, GSC 59284, 59285.

Pseudooneotodus mitratus (Moskalenko)

Plate 2, figs. 17-19

Ambalodus mitratus mitratus Moskalenko, 1973, p. 86, Pl. 17, figs. 9-11.

Ambalodus mitratus nostras Moskalenko, 1973, p. 87, Pl. 17, figs. 12-14, ?15.

Oistodus? sp. Branson and Mehl, 1933, Pl. 9, fig. 3.

Lepodus sp. Webers, 1966, p. 71, 72, Pl. 14, fig. 4.

Indeterminate element - Form C. Weyant, 1968, p. 64, Pl. 6, figs. 11, 12 only.

Description. Low conical elements with a deep basal excavation and trilobate basal outline. Apex is small and slightly directed posteriorly; it is commonly broken leaving an elongate scar. Each lateral face is folded inwards producing broad antero-lateral lobes and a posterior lobe. Antero-lateral lobes may be subequally developed, resulting in a more or less symmetrical element or they may be markedly asymmetrically developed on either side. Anterior face is smoothly convex; lateral folds are broadly concave. Posterior margin is rounded and slightly laterally compressed. Upper surface is smooth in weakly folded elements, but in more sharply folded elements a ridge runs down one side from apex to aboral margin. A pair of unequally developed ridges is present in some elements. The more pronounced ridge is on same side as the more developed antero-lateral lobe in asymmetrical elements.

Basal cavity fills most of element, not quite extending to apex or upper part of anterior margin. Outer surface is smooth, except for a few horizontal striations near aboral margin.

Remarks. This species shows a crude transition from asymmetrical to symmetrical elements. It is readily placed in *Pseudooneotodus* because of its low conical form and distinguished from the other species by its trilobate basal outline.

Sharply folded elements such as that illustrated by Moskalenko (1973, Pl. 17, fig. 15) have not been recovered from the Vauréal Formation.

Types. Hypotypes, GSC 59281-59283.

Genus *Staufferella* Sweet, Thompson and Satterfield, 1975

Type species. *Distacodus falcatus* Stauffer, 1935a

Staufferella brevispinata n. sp.

Plate 8, figs. 5,8,9,12-16

Diagnosis. Apparatus consists of laterally compressed asymmetrical elements, weakly compressed, and variably asymmetrical elements and symmetrical elements. Symmetrical element has short denticles on lateral edges.

Description. Laterally compressed asymmetrical elements have a low base and erect to proclined cusp. Cusp is at least twice as long as base is high. Oral edge is sharp and curves smoothly into sharp posterior edge. Aboral outline is straight. Basal cavity is conical and deep, extending to point of curvature with apex slightly anterior of mid-line. Basal portion of cavity broadens anteriorly and posteriorly to fill base. Base is flared on inner side. Outer face is smooth and gently convex. Anterior edge is flexed to inner side, and a shallow groove is formed between anterior margin of the cavity and the flexure. Cusp is laterally compressed and slightly offset with respect to base.

Weakly compressed asymmetrical elements have a high base and an abruptly proclined to erect cusp. Aboral outline is straight. Basal cross section is oval to circular. Oral edge is sharply rounded to sharp and is rarely costate. Anterior margin of base is rounded. Basal cavity is a deep slender cone which broadens near base to fill the entire element; it extends to point of curvature or slightly beyond and apex is situated anterior of mid-line. Cusp is abruptly curved into a proclined or erect position and is of about equal length to base height. Weak lateral costae are developed which are most prominent near point of curvature. A single costa may be developed on one or both lateral faces. Costae are twisted longitudinally from an anterior position on base to a mid-lateral position distally. Cusp is more laterally compressed than base.

Symmetrical elements are antero-posteriorly compressed with erect to proclined, slightly recurved cusp. Anterior margin is smoothly convex and continues laterally into sharp and denticulate lateral edges. Edges are broad costae at mid-cusp, contract near tip of basal cavity and expand into denticulate edges on base. Denticles are discrete, distally directed, antero-posteriorly compressed and number between four and six on each side. They produce slight thickening of lateral edges near their bases. Posterior margin is more convex and marked by median costa which extends from the aboral margin to tip of cusp.

All elements are faintly striated longitudinally and are characteristically cloudy white in colour. No clear distinction between hyaline and white matter can be discerned and white matter seems to be unevenly developed throughout elements. Basal portion of many elements is darker in colour.

Remarks. Sweet et. al. (1975) erected this genus to include simple cones previously assigned to *Distacodus* Hinde and *Acontiodus* Pander. They described three morphotypes (symmetrical, slightly asymmetrical and markedly asymmetrical) for *S. falcata* (Stauffer). The laterally compressed element of *S. brevispinata* n. sp. seems to have no homologue in the *S. falcata* apparatus. The weakly compressed asymmetrical element of the new species is equivalent to the markedly asymmetrical element of *S. falcata*.

Slightly asymmetrical elements of Sweet et al. (1975) are not recognized for *S. brevispinata*. The symmetrical elements of both species are homologous.

The symmetrical element is most similar to that of *S. lindstroemi* (Ethington and Schumacher) but that species lacks lateral denticulation. Asymmetrical elements differ from those of *S. falcata* in that the costae are less prominent, but otherwise are quite similar.

Types. Holotype, GSC 59413; paratypes, GSC 59414-59420.

Genus *Trichonodella* Branson and Mehl, 1948

Type species. *Trichognathus primus* Branson and Mehl, 1933

Trichonodella sp. s.f.

Plate 8, fig. 26

Description. Diminutive, strongly antero-posteriorly compressed element. Lateral processes symmetrical, intersecting cusp plane at about 45°. Each bears five slender, parallel, antero-posteriorly compressed denticles; those adjacent to the cusp are fused to it along most of their length. Cusp is erect, anteroposteriorly compressed with faintly carinate posterior face. Base is compressed with no flaring. Basal cavity is a shallow groove which shallows toward distal end of processes. White matter is present in cusp and denticles.

Remarks. This isolated specimen may belong in an apparatus with *Ozarkodina* sp. s.f. but they do not co-occur. It is somewhat similar to the trichonodelliform element considered as a possible part of *Bryantodina? staufferi* (Bergström and Sweet, 1966, Pl. 33, figs. 10, 11).

Type. Figured specimen, GSC 59980.

Genus *Walliserodus* Serpagli, 1967

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

Remarks. Serpagli (1967) erected this genus as a form genus including a variety of costate cones and gave *Paltodus debolti* Rexroad (1967) as the type species. Cooper (1975) in a comprehensive discussion of this genus, described it in multielement taxonomy and included *Acodus curvatus* Branson and Branson, together with *Paltodus debolti* and other form species in *Walliserodus curvatus*, thus requiring a change in the type species.

Walliserodus cf. *W. curvatus* (Branson and Branson)

Plate 8, figs. 17-24

cf. *Acodus curvatus* Branson and Branson, 1947, p. 554, Pl. 81, fig. 20.

cf. *Walliserodus curvatus* (Branson and Branson). Cooper, 1975, p. 995, 996, Pl. 1, fig. 10, 11, 16-21 (includes synonymy to 1975).

- Walliserodus debolti* (Rexroad). Serpagli, 1967, p. 104-106, Pl. 31, figs. 1, 6, 9, 11, ?Pl. 31, figs. 2-5, 7, 8, 10, 12, 13.
- Drepanodus amplissimus* Serpagli, 1967, p. 66, Pl. 15, figs. 1a-5b.
- ?*Acodus similis* Rhodes. Serpagli, 1967, p. 42-44, Pl. 7, figs. 1a-10d.
- ?*Scandodus zermulaensis* Serpagli, 1967, p. 96, 97, Pl. 27, figs. 4a-6d.
- ?*Paltodus dyscritus* Rexroad. Thompson and Satterfield, 1975, p. 70, fig. 5D.

Description. A multielement species consisting of an element that lacks lateral costae (carinate element) and a costate group including asymmetrical acodiform, distacodiform (paltodiform) and acontiodiform elements.

Carinate element. Oral edge is straight and sharp, curving evenly into sharp posterior edge. Basal cavity is deep and conical with apex near anterior margin at point of curvature. Anterior edge is keeled. Keel is most prominent on upper part of base and rarely reaches the aboral margin; it may be slightly flexed to inner side. Lateral faces are smooth and convex, having greatest convexity near anterior margin where they may form broad carinae. These lateral carinae may be equally or unequally developed; in the latter case, outer carina is more convex, and inner face may be almost flat. Cusp is broad, laterally compressed and suberect to proclined.

Costate elements. Three basic groups of costate elements can be recognized: acodiform (cf. *Acodus curvatus* Branson and Branson), distacodiform-paltodiform (cf. *Paltodus migratus* Rexroad) and acontiodiform (cf. *Paltodus dyscritus* Rexroad). All elements are slightly to markedly asymmetrical. Base is posteriorly expanded and basal cavity is deep and conical, extending to point of curvature, with apex near anterior margin. Cusp erect to proclined.

Acodiform elements have sharp anterior and posterior edges. Anterior edge is inwardly flexed. Base is slightly flared to inner side. Oral edge is highly keeled. An inner lateral costa extends from cusp onto upper part of base well posterior to midline. It is posteriorly directed and may be weakly to strongly developed. Base may be broad and low or more slender and higher. Cusp is twisted to inner side, such that elements with only a weak lateral costa appear scandodiform.

Distacodiform-paltodiform elements are subsymmetrical to asymmetrical. Anterior and posterior edges are sharp and keeled. A prominent posteriorly directed, lateral costa is present on each side, extending from cusp to a point just above aboral margin. These may be situated symmetrically or one may be posterior and the other anterior. A single secondary costa may be present posteriorly or on one side, restricted to cusp and uppermost part of base. Cusp is slender.

Acontiodiform elements are nearly symmetrical. Posterior edge is sharp and keeled. Aboral outline is straight to slightly undulatory. Anterior face is flat to concave with a shallow linear depression medially. A prominent antero-lateral costa is developed on each side. Element is narrowly triangular in posterior view. Asymmetry is produced by a single lateral costa on one side, close to posterior margin and restricted to cusp and upper portion of base.

All elements may be finely striated, and striations are most prominent on carinate element. White matter is variably developed in cusp and posterior portion of base. It may be well developed or cloudy, and is sometimes absent in apical portions of cusp.

Remarks. The elements described are very similar to those described by Branson and Branson (1947) and Rexroad (1967) from the Brassfield Formation which were grouped into *W. curvatus* by Cooper (1975). The acodontiform element of Cooper (1975) (*Acodus unicostatus* Branson and Branson) is homologous to the carinate element of this study. The range of symmetry variants in the costate elements recognized by Cooper (1975) for *W. curvatus* can also be demonstrated in this material. There are, however, some differences between the Brassfield and Vauréal specimens. The number of secondary costae illustrated by Rexroad (1967, fig. 4) for several of the constituent form species of *W. curvatus* are not present in this material. The carinate element, although similar to the acodontiform element of Cooper (1975) is more variable and lacks a lateral costa as illustrated by Rexroad (1967, fig. 4). Furthermore, the anterior face of the acontiodiform element in the present study is flat to concave rather than convex as illustrated for *Paltodus dyscritus* Rexroad s.f.

Some of the forms illustrated and described as *W. debolti* by Serpagli (1967) are probably conspecific with this material, but the great variability shown by his illustrations is not present in the Vauréal specimens. Cooper (1975) concluded that Serpagli's (1967) *W. debolti* might represent an earlier more variable species of *Walliserodus*. The elements described as *Drepanodus amplissimus* by Serpagli (1967) are considered conspecific with the carinate element of the present study and his *Scandodus zermulaensis* may be equivalent to narrow-based acodiform elements. Some of the elements Serpagli (1967) referred to *Acodus similis* Rhodes are also similar to the acodiform element of this study and may be conspecific.

Thompson and Satterfield (1975) illustrate but do not describe a specimen referred to *Paltodus dyscritus* from the Bowling Green Dolomite of northeastern Missouri. They reported the occurrence of a '*Paltodus dyscritus* fauna' (including *Acodus curvatus* and *A. unicostatus*) from Upper Ordovician and Lower Silurian strata, but considered the co-occurring Late Ordovician material to be reworked. These elements may be conspecific with the Ordovician material described herein.

This species has also been described from Upper Ordovician strata in an outlier north of Aberdeen Lake, District of Keewatin, by Nowlan in Bolton and Nowlan (1979).

The height of the base in carinate and acodiform elements appears to decrease in younger forms of this species, otherwise it remains unchanged through its range in the Vauréal Formation. Further study is required to determine whether or not the forms reported here are sufficiently different from *W. curvatus* to warrant erection of a separate species.

The presence of striations visible under the SEM is variable on all elements.

Types. Figured specimens, GSC 59421-59423, 59967-59971; unfigured specimens, GSC 59972-59978.

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Addendum

Since this bulletin was submitted for publication, Sweet (1979) has published a revision of several Late Ordovician conodont taxa. As a result there are cases of synonymy between taxa in the two studies that should be pointed out.

Sweet (1979) revised the group of cones previously referred to *Belodina* Ethington. Our paper contains some comments on the variety of belodinan apparatuses and suggests that a division of the genus is possible. Sweet (1979) has proceeded with such a subdivision and therefore elements described herein as *Belodina dispansa* (Glenister) are synonymous with *Pseudobelodina dispansa* (Glenister) of Sweet (1979). In addition elements referred to herein as *Belodina profunda* (Branson and Mehl) are synonymous with *Pseudobelodina vulgaris* Sweet, 1979.

Plectodina bidentata n. sp. Nowlan and Barnes is probably a junior synonym of *Plectodina florida* Sweet, although the cyrtionidiform elements are apparently different. In *P. bidentata* there is a prominent denticle anterior of the main cusp, whereas in *P. florida* the anterobasal corner is pick-shaped. This may be sufficiently significant to retain them as separate species, but otherwise they are very similar.

Staufferella n. sp. of Sweet (1979) belongs to *S. brevispinata* n. sp. Nowlan and Barnes.

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Plates 1 to 8

All specimens photographed with an ETEC 'Autoscan' scanning electron microscope, using Polaroid Type 55 positive/negative film.

Plate 1

Figures 1 - 14. *Amorphognathus ordovicicus* Branson and Mehl. Hypotypes. (1) Inner lateral view, eoligonodiform element, X115, GSC 59244. (2) Outer lateral view, cladognathiform element, X100, GSC 59245. (3,4) Inner lateral and posterior views, holodontiform element, X115, GSC 59246. (5) Lateral view, trichonodelliform element, X170, GSC 59247. (6) Lateral view, tetraprioniodiform element, X170, GSC 59248. (7,8) Inner lateral and posterior views, holodontiform element, X115, GSC 59249. (9,10) Outer lateral and upper views, ambalodiform element, X110, GSC 59250. (11) Outer lateral view, ambalodiform element, X100, GSC 59251. (12) Lateral view, holodontiform element, X170, GSC 59252. (13) Upper view, non-blade platform elements, X57, GSC 59253. (14) Upper view, blade platform elements, X51, GSC 59254. All specimens (including unfigured hypotype, GSC 59255) from sample 9, except GSC 59245 which is from sample 29, and GSC 59249, 59251 and 59252 which are from sample 3.

Figures 15 - 24. *Paroistodus? mutatus* (Branson and Mehl). Hypotypes. (15) Lateral view, oistodiform element, X150, GSC 59256. (16,17) Lateral views, low-based 'acodiform' element, X125, GSC 59257. (18,19) Lateral views, distacodiform element, X135, GSC 59258. (20,21) Lateral views low-based distacodiform element, X140, GSC 59259. (22,23) Lateral views of high-based distacodiform element, X170, GSC 59260. (24) Lateral view, oistodiform element, X125, GSC 59261. All specimens (including unfigured hypotypes, GSC 59262, 59263) from sample 13.

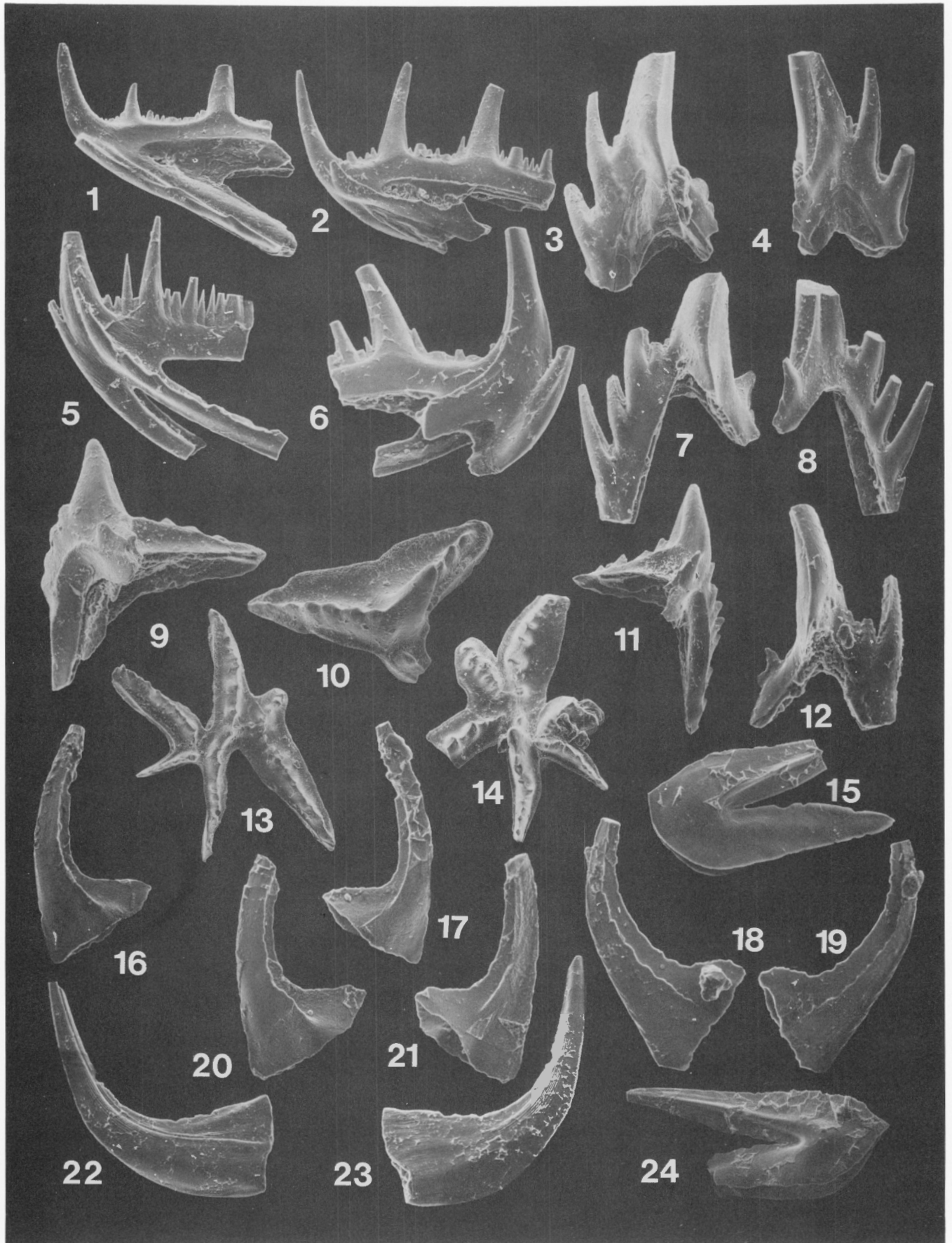


Plate 2

Figures 1 - 7. *Oulodus ulrichi* (Stone and Furnish). Hypotypes. (1) Inner lateral view, eoligonodiform element, X63, GSC 59264. (2) Posterior view, zygognathiform element, X70, GSC 59265. (3) Posterior view, trichonodelliform element, X68, GSC 59266. (4) Inner lateral view, cyrtionodiform element, X55, GSC 59267. (5) Inner lateral view, prioniodiniform element, X55, GSC 59268. (6) Inner lateral view, prioniodiniform element, X75, GSC 59269. (7) Posterior view, oulodiform element, X50, GSC 59270. All specimens from sample 3, except GSC 59264 and 59269 which are from sample 12.

Figures 8 - 16. *Oulodus rohneri* Ethington and Furnish. Hypotypes. (8) Inner lateral view, cyrtionodiform element, X90, GSC 59271. (9) Inner lateral view, eoligonodiform element, X70, GSC 59272. (10) Posterior view, zygognathiform element, X90, GSC 59273. (11) Posterior view, trichonodelliform element, X100, GSC 59274. (12) Inner lateral view, cyrtionodiform element, X90, GSC 59275. (13) Inner lateral view, prioniodiniform element, X100, GSC 59276. (14) Inner lateral view, prioniodiniform element, X115, GSC 59277. (15) Posterior view, oulodiform element, typically preserved, X110, GSC 59278. (16) Posterior view, oulodiform element, X62, GSC 59279. All specimens (including unfigured hypotype, GSC 59280) from sample 67.

Figures 17 - 19. *Pseudooneotodus mitratus* (Moskalenko). Hypotypes; upper views. (17) Sinistrally asymmetrical element, X115, GSC 59281. (18) Subsymmetrical element, X90, GSC 59282. (19) Dextrally asymmetrical element, X115, GSC 59283. All specimens from sample 28.

Figures 20, 21. *Pseudooneotodus beckmanni* (Bischoff and Sannemann). Hypotypes. (20) Lateral view, X170, GSC 59284. (21) Upper view, X170, GSC 59285. Both specimens from sample 36.

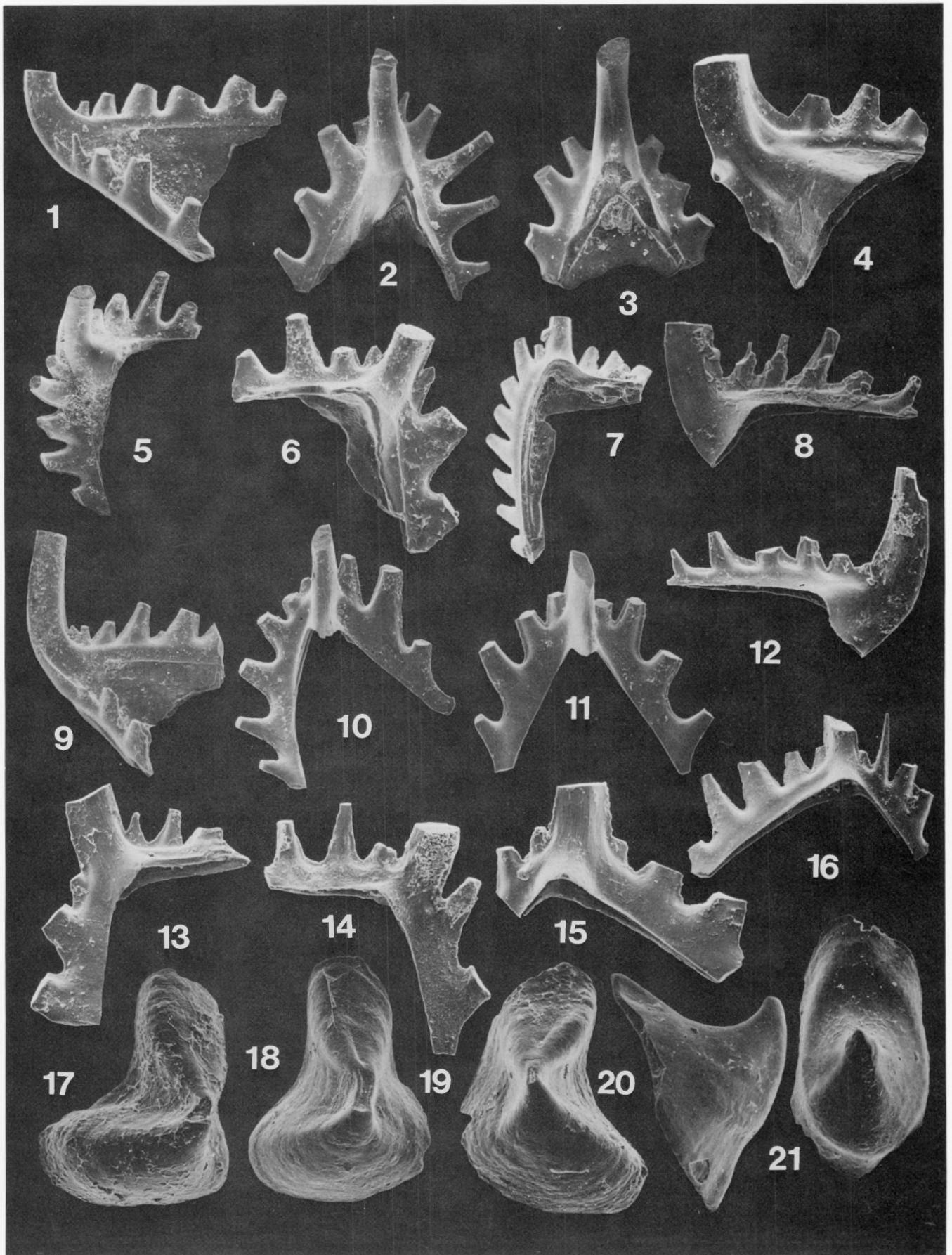


Plate 3

Figures 1 - 8. *Plectodina bidentata* n. sp. (1) Lateral view, cordylodiform element, paratype, X80, GSC 59286; sample 21. (2) Posterior view, zygognathiform element, paratype, X90, GSC 59287; sample 24. (3) Posterior view, trichonodelliform element, paratype, X170, GSC 59288; sample 24. (4) Lateral view, cyrtoniodiform element, paratype, X130, GSC 59289; sample 27. (5) Lateral view, cordylodiform element, holotype, X75, GSC 59290; sample 27. (6) Lateral view, ozarkodiniform element, paratype, X90, GSC 59291; sample 27. (7) Inner lateral view, cyrtoniodiform element, paratype, X65, GSC 59292; sample 21. (8) Inner lateral view, prioniodiniform element, paratype, X95, GSC 59293; sample 27. (Unfigured paratypes, GSC 59294, 59295 from sample 27).

Figures 9 - 12, 15, 16. *Plectodina* cf. *P. inclinata* (Glenister). Figured specimens. (9) Lateral view, cordylodiform element, X148, GSC 59296. (10) Posterior view, zygognathiform element, X220, GSC 59297. (11) Lateral view, trichonodelliform element, X150, GSC 59298. (12) Lateral view, cyrtoniodiform element, X135, GSC 59299. (15) Lateral view, ozarkodiniform element, X108, GSC 59300. (16) Lateral view, prioniodiniform element, X130, GSC 59301. All specimens from sample 13.

Figures 13, 14, 17 - 21. *Gamachignathus ensifer* McCracken, Nowlan and Barnes. Hypotypes. (13) Outer lateral view, gothodiform element, X115, GSC 59302; sample 89. (14) Posterior view, zygognathiform element, X115, GSC 59303; sample 89. (17) Posterior view, trichonodelliform element, X115, GSC 59304; sample 90. (18) Inner lateral view, cyrtoniodiform element, X65, GSC 59305; sample 89. (19) Outer lateral view, dichognathiform element with antero-lateral and posterior processes at a divergent angle, X170, GSC 59306; sample 89. (20) Outer lateral view, blade-like dichognathiform element, X115, GSC 59307; sample 101. (21) Outer lateral view, blade-like dichognathiform element, X125, GSC 59308; sample 29.

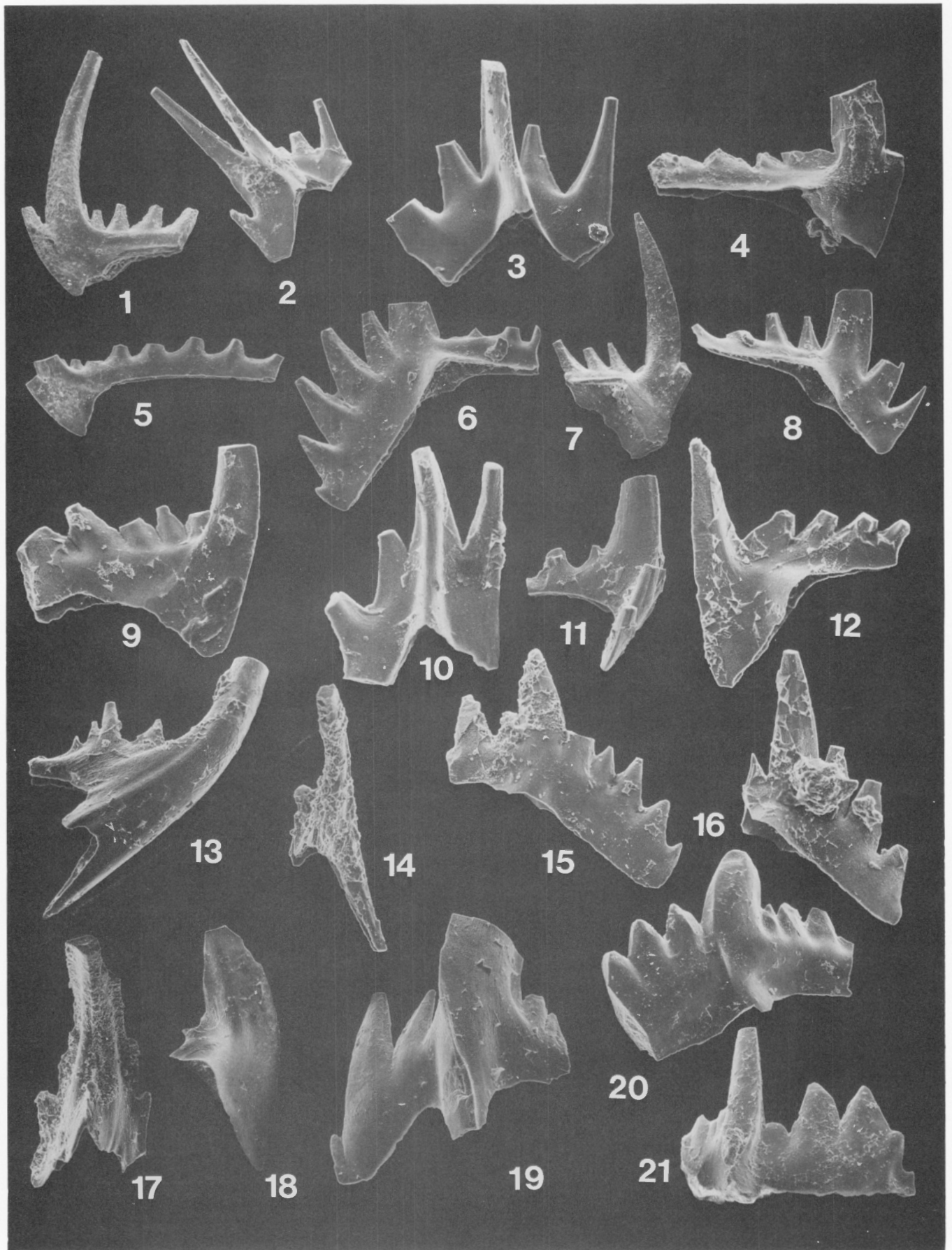


Plate 4

Figures 1 - 11, 13. *Phragmodus undatus* Branson and Mehl. Hypotypes. (1,2) Lateral views, cordylodiform - cladognathiform element (Group 1, see remarks under *P. undatus*), X75, GSC 59309. (3) Outer lateral view of cordylodiform - cladognathiform (Group 1) element with costa, X62, GSC 59310. (4) Inner lateral view, oistodiform element, X75, GSC 59311. (5) Inner lateral view, oistodiform element, X62, GSC 59312. (6,7) Lateral views, tetraprioniodiform element (Group 2), X100, GSC 59313. (8,9) Inner and outer lateral views, breviform element, X85, GSC 59314. (10) Lateral view, trichonodelliform element (Group 3), X120, GSC 59315. (11) Outer lateral view, typicaform element, X85, GSC 59316. (13) View of broken cusp tip, trichonodelliform element (Group 3), X1400, GSC 59315. All specimens (including unfigured hypotypes, GSC 59317, 59318) from sample 3.

Figures 12, 14 - 16, 20, 21. *Plectodina tenuis* (Branson and Mehl). Hypotypes. (12) Lateral view, cordylodiform element, X70, GSC 59319. (14) Posterior view, trichonodelliform element, X170, GSC 59320. (15) Inner lateral view, cyrtoniodiform element, X115, GSC 59321. (16) Posterior view, zygnognathiform element, X115, GSC 59322. (20) Inner lateral view, prioniodiniform element, X90, GSC 59323. (21) Lateral view, ozarkodiniform element, X95, GSC 59324. All specimens from sample 3.

Figures 17 - 19. *Drepanoistodus suberectus* (Branson and Mehl). Hypotypes. (17) Lateral view, suberectiform element, X40, GSC 59325. (18) Lateral view, homocurvatiform element, X40, GSC 59326. (19) Inner lateral view, oistodiform element, X55, GSC 59327. All specimens (including unfigured hypotypes, GSC 59328, 59329) from sample 6.

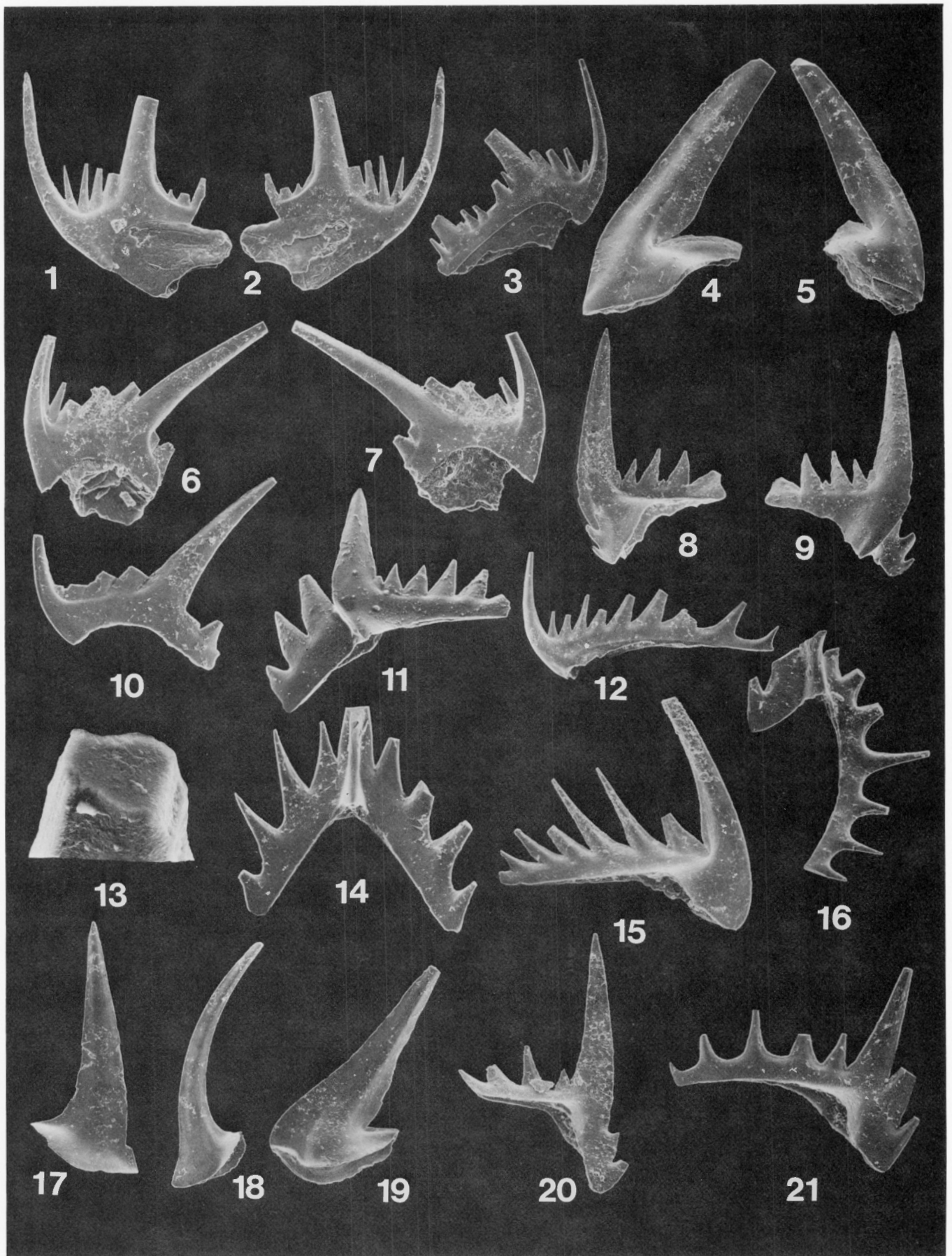


Plate 5

Figures 1 - 4. *Aphelognathus pyramidalis* (Branson, Mehl and Branson). Hypotypes. (1) Inner lateral view, oligonodiform element, X110, GSC 59330; sample 101. (2) Posterior view, zygognathiform element, X85, GSC 59331; sample 101. (3) Inner lateral view, prioniodiniform element, X75, GSC 59332; sample 86. (4) Lateral view, aphelognathiform element, X45, GSC 59333; sample 70. Trichonodelliform and cyrtioniodiform elements too poorly preserved to be photographed. (Unfigured hypotypes, GSC 59334, 59335 from sample 86).

Figures 5 - 10. *Aphelognathus grandis* Branson, Mehl and Branson. Hypotypes. (5) Inner lateral view, cordylodiform element, X68, GSC 59336. (6) Posterior view, zygognathiform element, X90, GSC 59337. (7) Posterior view, trichonodelliform element, X60, GSC 59338. (8) Lateral view, aphelognathiform element, X50, GSC 59339. (9) Inner lateral view, cyrtioniodiform element, X90, GSC 59340. (10) Lateral view, prioniodiniform element, X90, GSC 59341. All specimens from sample 36.

Figures 11 - 17. *Aphelognathus* n. sp. A. Figured specimens. (11) Lateral view, cordylodiform element, X75, GSC 59342. (12) Posterior view, zygognathiform element, X170, GSC 59343. (13) Posterior view, trichonodelliform element, X125, GSC 59344. (14) Lateral view, aphelognathiform element, X60, GSC 59345. (15) Lateral view, typical aphelognathiform (?ozarkodiniform) element, X125, GSC 59346. (16) Lateral view, prioniodiniform element, X125, GSC 59347. (17) Lateral view, cyrtioniodiform element, X125, GSC 59348. All specimens from sample 78.

Figures 18 - 22. *Panderodus* n. sp. C. Figured specimens. (18) Inner lateral view, graciliform element, X55, GSC 59349. (19) Outer lateral view, graciliform element, X65, GSC 59350. (20) Outer lateral view, graciliform element, X65, GSC 59351. (21) Outer lateral view, compressiform element, X55, GSC 59352. (22) Inner lateral view, arcuatiform-like, graciliform element, X75, GSC 59353. All specimens (including unfigured specimen, GSC 59354) from sample 36.

Figures 23, 24. *Panderodus argularis* Branson, Mehl and Branson s.f. Hypotypes. (23) Outer lateral view, X75, GSC 59355. (24) Inner lateral view, X70, GSC 59356. Both specimens from sample 87.

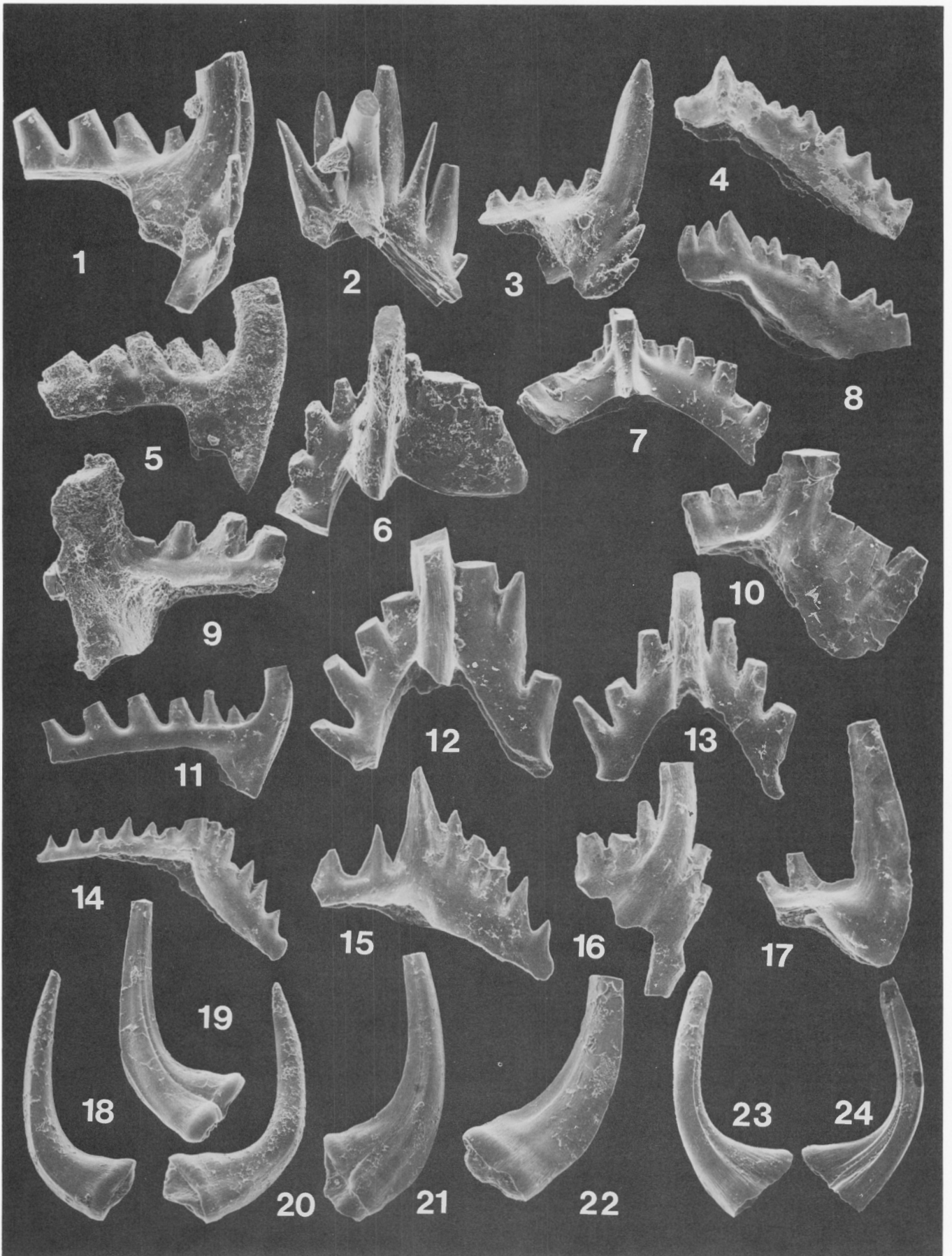


Plate 6

Figures 1, 2, 5 - 7, 10. *Panderodus* n. sp. A. Figured specimens. (1,2) Outer and inner lateral views, sharply recurved specimen, X95, GSC 59357; sample 18. (5,6) Inner and outer external views, asymmetrical element, X60, GSC 59358; sample 12. (7) Posterior views, subsymmetrical element, X60, GSC 59359; sample 12. (10) Outer lateral view, subsymmetrical element, X65, GSC 59360; sample 18. (Unfigured specimen, GSC 59361 from sample 12).

Figures 3, 4, 14. *Panderodus panderi* (Stauffer). Hypotypes. (3) Lateral view of slender, high-based element, X75, GSC 59362. (4) Lateral view of broad, low-based element, X75, GSC 59363. (14) Lateral view, broad, low-based element, X75, GSC 59364. All specimens from sample 54.

Figures 8, 12, 13. *Panderodus* n. sp. B. Figured specimens. (8) Inner lateral view, X85, GSC 59365; sample 24. (12) Inner lateral view, specimen with inner lateral costa, X108, GSC 59366; sample 29. (13) Outer lateral view, X95, GSC 59367; sample 24. (Unfigured specimen, GSC 59368 from sample 24).

Figures 9, 11. *Panderodus* cf. *P. serratus* Rexroad s.f. Figured specimens. (9) Inner lateral view, X85, GSC 59369. (11) Outer lateral view, X100, GSC 59370. Both specimens from sample 3.

Figures 15 - 19. *Panderodus gibber* n. sp. (15, 16) Inner and outer lateral views, asymmetrical element, holotype, X115, GSC 59371; sample 6. (17,18) Posterior view, X75, and lateral view, symmetrical elements, X95, paratype, GSC 59372; sample 14. (19) Lateral view, symmetrical element, X85, paratype, GSC 59373; sample 6. (Unfigured paratypes, GSC 59374, 59375 from samples 14 and 16 respectively).

Figures 20, 23, 27. *Panderodus gracilis* (Branson and Mehl). Hypotypes. (20) Lateral view, compressiform element, X75, GSC 59376. (23) Inner lateral view, asymmetrical graciliform element (arcuatiform element), X80, GSC 59377. (27) Lateral view, symmetrical graciliform element, X80, GSC 59378. All specimens from sample 24.

Figures 21, 22, 24, 28, 29. *Panderodus liratus* n. sp. (21) Posterior view, slender element, paratype, X55, GSC 59379. (22) Inner lateral view, slender element, holotype, X55, GSC 59380. (24) Inner lateral view, broad element, paratype, X55, GSC 59381. (28) Inner lateral view, slender element, paratype, X55, GSC 59382. (29) Outer lateral view, broad element, paratype, X55, GSC 59383. All specimens (including unfigured paratype, GSC 59384) from sample 36.

Figures 25, 26. *Panderodus* cf. *P. compressus* (Branson and Mehl) s.f. Figured specimen. (25,26) Inner and outer lateral views, X55, GSC 59385; sample 65.

Figures 30 - 33. *Panderodus* aff. *P. gracilis* (Branson and Mehl). Figured specimens. (30) Outer lateral view, compressiform element, X55, GSC 59386. (31) Inner lateral view, graciliform element, X55, GSC 59387. (32) Outer lateral view, graciliform element, X55, GSC 59388. (33) Inner lateral view, compressiform element, X55, GSC 59389. All specimens from sample 36.

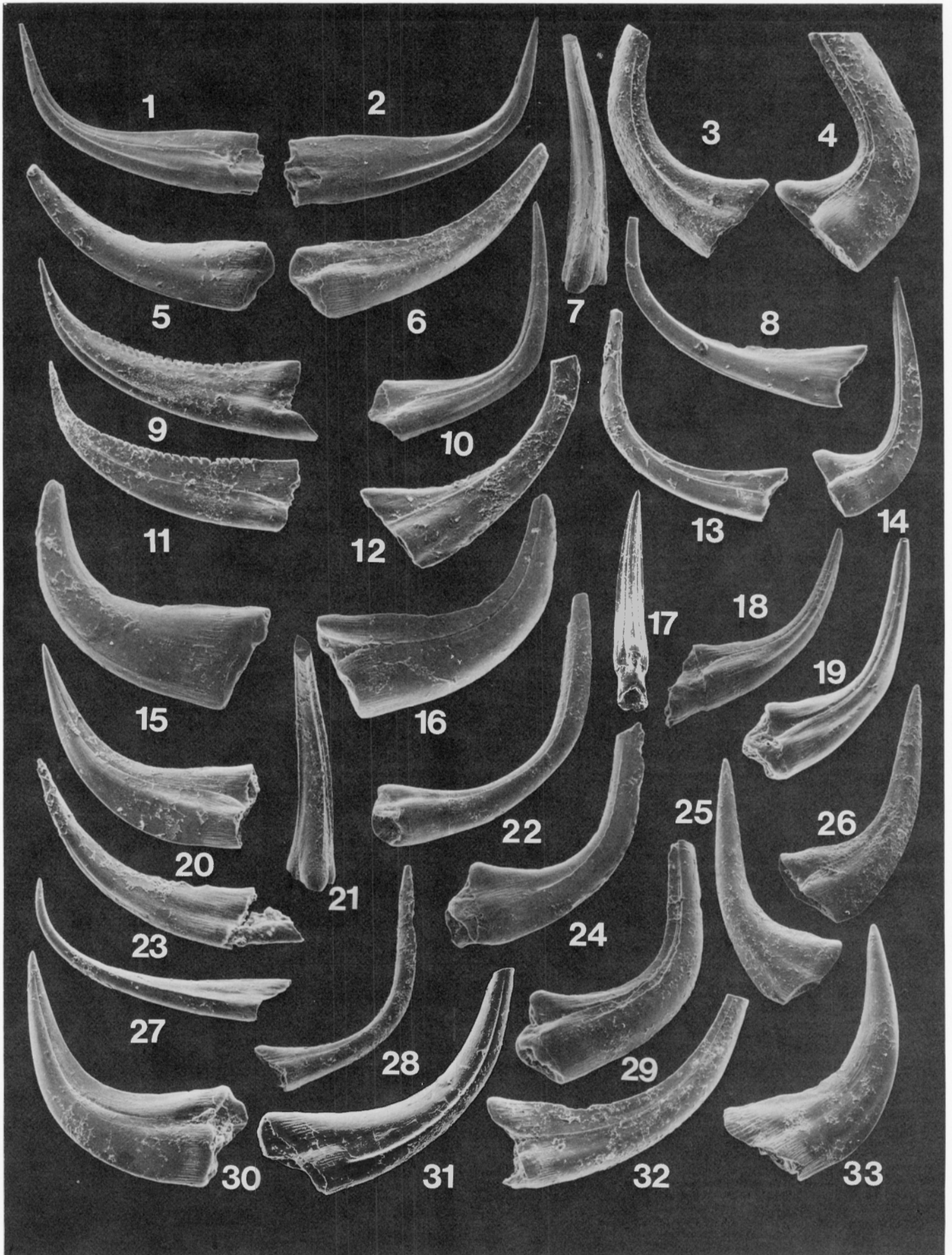


Plate 7

Figures 1 - 9, 12. *Belodina profunda* (Branson and Mehl). Hypotypes. (1) Inner lateral view, one-denticled, broadly curved element, X115, GSC 59390; sample 8. (2) Outer lateral view, two-denticled, broadly curved element, X115, GSC 59391; sample 54. (3) Inner lateral view, two-denticled, broadly curved element, X115, GSC 59392; sample 54. (4) Outer lateral view, three-denticled, broadly curved element, X170, GSC 59393; sample 56. (5) Outer lateral view, three-denticled, broadly curved element, X170, GSC 59394; sample 62. (6) Inner lateral view, four-denticled, broadly curved element, X115, GSC 59395; sample 36. (7) Outer lateral view, three-denticled, tightly curved element, X170, GSC 59396; sample 62. (8) Inner lateral view, three-denticled, tightly curved element, X170, GSC 59397; sample 56. (9) Inner lateral view, two-denticled, tightly curved element, X115, GSC 59398; sample 36. (12) Outer lateral view, four-denticled, tightly curved element, X115, GSC 59399; sample 55.

Figures 10, 11, 13 - 15. *Plegagnathus dartoni* (Stone and Furnish). Hypotypes. (10,11) Inner and outer lateral views, recurved element (*P. nelsoni* s.f.), X170, GSC 59400; sample 44. (13,14) Outer and inner lateral views, proclined element (*P. dartoni* s.f.), X170, GSC 59401; sample 44. (15) Inner lateral view, large, proclined element, X65, GSC 59402; sample 34.

Figures 16 - 19. "*Cordylodus*" *robustus* Ethington and Furnish s.f. Hypotypes. (16,17) Outer and inner lateral views, X115, GSC 59403. (18,19) Posterior and outer lateral views, X115, GSC 59404. Both specimens from sample 45.

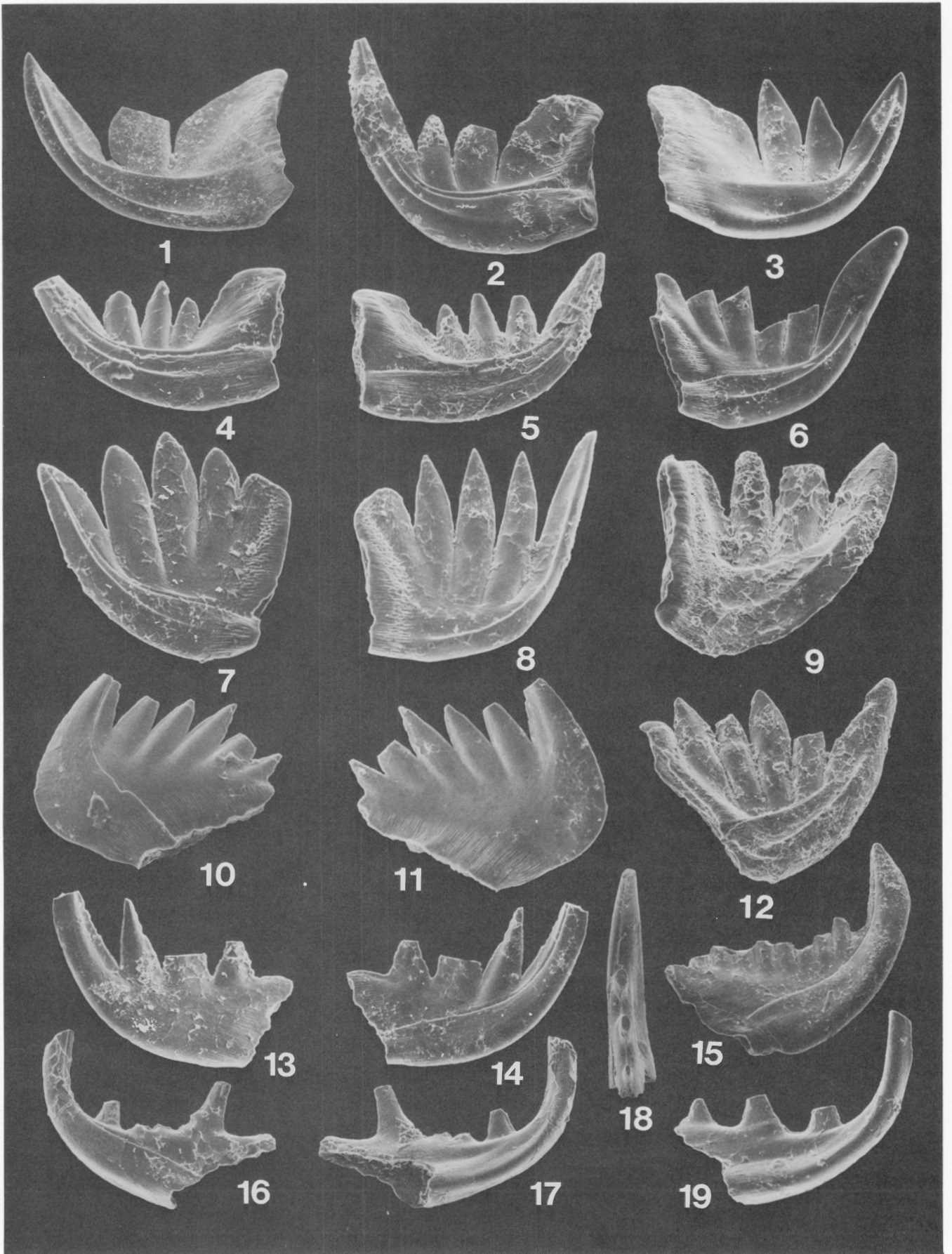


Plate 8

Figures 1 - 4. *Belodina compressa* (Branson and Mehl). Hypotypes. (1,2) Inner and outer lateral views, eobelodiniiform element, X115, GSC 59405. (3) Inner lateral view, compressiform element, X150, GSC 59406. (4) Inner lateral view, grandiform element, X55, GSC 59407. All specimens (including unfigured hypotype, GSC 59408) from sample 42.

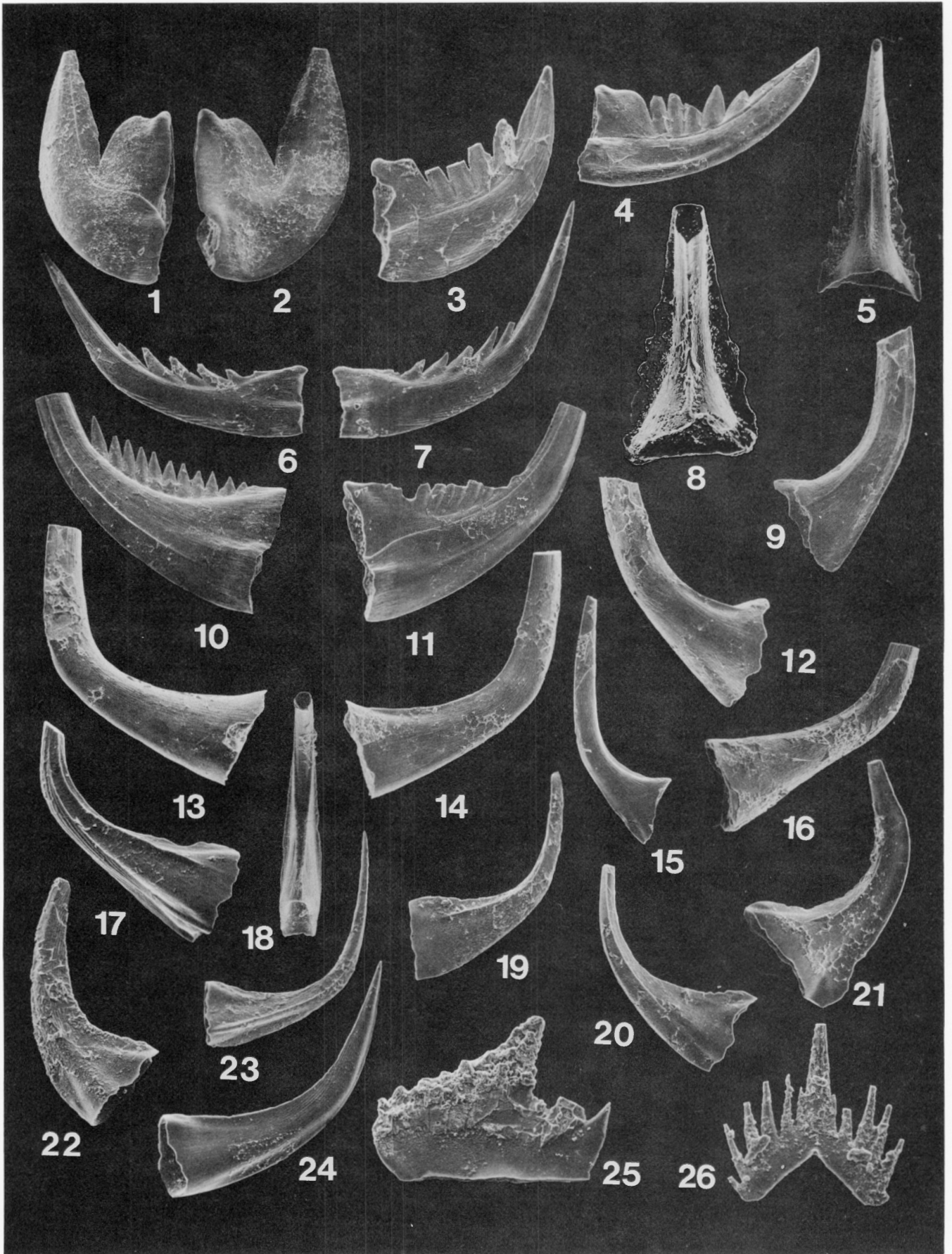
Figures 6, 7, 10, 11. *Belodina dispansa* (Glenister). Hypotypes. (6) Lateral view, slender element, X125, GSC 59409; sample 42. (7) Lateral view, slender element, X110, GSC 59410; sample 91. (10) Lateral view, broad element, X80, GSC 59411; sample 4. (11) Lateral view, broad element, X100, GSC 59412; sample 24.

Figures 5, 8, 9, 12 - 16. *Staufferella brevispinata* n. sp. (5) Posterior view, symmetrical element, holotype, X115, GSC 59413; sample 78. (8) Posterior view, symmetrical element, paratype, X115, GSC 59414; sample 13. (9,12) Inner and outer lateral views, laterally compressed asymmetrical element, paratype, X115, GSC 59415; sample 13. (13,14) Lateral views, asymmetrical element, paratype, X115, GSC 59416; sample 78. (15) Inner lateral view, laterally compressed asymmetrical element, paratype, X115, GSC 59417; sample 78. (16) Lateral view, asymmetrical element, paratype, GSC 59418; sample 13.

Figures 17 - 24. *Walliserodus* cf. *W. curvatus* (Branson and Branson). Figured specimens. (17) Lateral view, acontiodiform element with prominent anterior striations, X150, GSC 59421; sample 44. (18) Posterior view, acontiodiform element, X135, GSC 59422; sample 44. (19) Lateral view, distacodiform element, X130, GSC 59423; sample 54. (20) Lateral view, distacodiform element, X115, GSC 59967; sample 23. (21) Inner lateral view, acodiform element, X115, GSC 59968; sample 24. (22) Lateral view, carinate element, X125, GSC 59969; sample 84. (23) Lateral view, acontiodiform element lacking anterior striations, X115, GSC 59970; sample 44. (24) Lateral view, carinate element, X115, GSC 59971; sample 44. (Unfigured specimens, GSC 59972, 59974 from sample 84; GSC 59973, 59975-59978 from sample 44).

Figure 25. *Ozarkodina* sp. s.f. Figured specimen. Lateral view, X170, GSC 59979; sample 62.

Figure 26. *Trichonodella* sp. s.f. Figured specimen. Posterior view, X170, GSC 59980; sample 16.



CONODONT BIOSTRATIGRAPHY AND PALEOECOLOGY OF THE ELLIS BAY FORMATION, ANTICOSTI ISLAND, QUEBEC, WITH SPECIAL REFERENCE TO LATE ORDOVICIAN — EARLY SILURIAN CHRONOSTRATIGRAPHY AND THE SYSTEMIC BOUNDARY

Alexander D. McCracken¹ and Christopher R. Barnes

Abstract

The Ellis Bay Formation on Anticosti Island, Québec, is subdivided into six members and is composed of calcareous shale and argillaceous limestone and varies in thickness from 53 m in the west to about 96 m in the east. Member 6 accounts for about half the total thickness of the formation and near its base small bioherms are developed widely across the island. Lateral variation in lithology represents a gradual transition from a near-shore facies (east) to an offshore, shallow subtidal facies (west). The members may reflect eustatic changes produced by the Ashgillian glaciation in North Africa.

Conodont samples were collected from three composite stratigraphic sections, at Ellis Bay, and the Vauréal and Salmon Rivers, over a distance of about 140 km. Thirty-five multielement species representing 18 multielement genera are recognized in the fauna of 14 665 conodont elements from 183 samples. New species are *Oulodus? nathani*, *Panderodus clinatus* and *Staufferella inaligera*. Eighteen form species, ten of which are new and unnamed, are also present, as is one new, unnamed form genus. *Panderodus* is the major component of the Ordovician fauna and is represented by seven multielement and four form species. Two species of *Gamachignathus* comprise about 45 per cent of the Ordovician conodont fauna of the Ellis Bay section. An almost complete faunal replacement occurs in the Silurian with only three species of *Panderodus* and one species each of *Decoriconus* and *Pseudooneotodus* continuing across the systemic boundary. Other than these taxa, the Silurian fauna contains 5 multielement genera and 8 multielement species. *Panderodus gracilis* (Branson and Mehl) dominates the Silurian fauna; *Ozarkodina* and *Oulodus?* are the most abundant ramiform conodont genera.

The Ordovician fauna, although including many taxa from the underlying Richmondian Vauréal Formation, is characterized by *Gamachignathus*. The strata containing this fauna are regarded as representing a latest Ordovician time interval bearing a fauna referred to as Fauna 13 and for which the re-introduction of the Gamachian Stage is advocated. An Ordovician-Silurian transition zone, about 1.5 m thick, is present with species from both periods co-occurring. The Silurian fauna is similar to that of the *Distomodus kentuckyensis* Zone, the oldest conodont zone of the North American Llandoveryan. However, the new species appear to represent an earlier, new, Llandoveryan zone, the *Oulodus? nathani* Zone. The Ordovician-Silurian boundary is herein drawn at the first appearance of species of *Ozarkodina* and this occurs about 2 - 3 m above the base of Member 6 of the Ellis Bay Formation.

The distribution of the Ordovician conodonts indicates the presence of three laterally segregated communities corresponding to the offshore subtidal, intermediate and nearshore environments. The offshore community (Community A) is dominated by *Gamachignathus* and *Panderodus*. The intermediate community (Community B) includes several species of *Panderodus*, *Oulodus*, *Amorphognathus* and *Aphelognathus*. Community C, the nearshore community, is characterized by large and robust elements belonging to *Aphelognathus* and *Panderodus*. In Silurian strata, Community D is characterized by the presence of *Ozarkodina oldhamensis* (Rexroad) and *Oulodus? nathani* n.sp. and is developed in an intermediate subtidal facies. *Ozarkodina hassi* (Pollock, Rexroad and Nicoll) and *Oulodus? kentuckyensis* (Branson and Branson) dominate within Community E and reflect a shallow subtidal environment.

Résumé

La formation d'Ellis Bay de l'île d'Anticosti (Québec) est composée de schistes argileux calcaires et de calcaires argileux; son épaisseur varie entre 53 m à l'ouest et 96 m à l'est. Ces deux lithologies alternées définissent six niveaux qui sont le mieux exposés dans la coupe de la baie Ellis. On retrouve de nombreux petits biohermes partout dans l'île à la base du niveau 6; ce dernier représente presque la moitié de l'épaisseur totale de la formation. Vers l'est, les niveaux inférieurs sont indistincts (niveaux 1? à 3?) et sont formés surtout de sédiments clastiques terrigènes. La variation lithologique latérale représente une transition progressive d'un faciès littoral à l'est à un faciès subtidal marin peu profond à l'ouest. Les niveaux reflètent peut-être des changements eustatiques provoqués par la glaciation ashgillienne en Afrique du Nord.

Des échantillons ont été recueillis dans 3 coupes stratigraphiques, à la baie Ellis, à la rivière Vauréal et à la rivière aux Saumons, soit sur une distance d'environ 140 km. Les 183 échantillons, pesant en moyenne 1 kg chacun, ont donné 14 665 conodontes identifiables. Des études taxonomiques ont permis de reconnaître 35 espèces multiélementaires représentant 18 genres multiélementaires. *Oulodus? nathani*, *Panderodus clinatus* et *Staufferella inaligera* sont de nouvelles espèces. Dix huit espèces de forme, dont 10 nouvelles et innommées, sont présentes, ainsi qu'un nouveau genre de forme innomé. Le genre *Panderodus* forme la majeure partie de la faune ordovicienne et est représenté par 7 espèces multiélementaires et 4 espèces de forme. Deux espèces de *Gamachignathus* représentent environ 45 % des conodontes ordoviciens dans la coupe de la baie Ellis. Trois espèces *d'Oulodus* sont présentes, ainsi que les genres ordoviciens suivants, en ordre décroissant d'abondance: *Drepanoistodus*, *Phragmodus*, *Aphelognathus* et *Amorphognathus*. La faune est presque complètement différente au Silurien, 3 espèces de *Panderodus* et une espèce chacune de *Decoriconus* et de *Pseudooneotodus* étant les seuls à traverser la limite du système. Outre ces taxa, la faune silurienne est composée de 5 genres multiélementaires et de 8 espèces multiélementaires. *Panderodus gracilis* (Branson et Mehl) domine la faune silurienne. *Ozarkodina* et *Oulodus?* sont les genres les plus abondants de conodontes ramiformes. *Walliserodus*, *Distomodus* et *Icriodella* sont également présents.

Bien qu'elle contienne de nombreux taxa de la formation de Vauréal sous-jacente du Richmondien, la faune ordovicienne est caractérisée par le genre *Gamachignathus*. Les couches qui referment ces fossiles représentent le dernier intervalle ordovicien à contenir une faune dite Faune 13 et pour lequel on préconise le rétablissement du sous-étage gamachien. Une zone de transition ordovicienne-silurienne, dont l'épaisseur est environ 1,5 m, est présente et referme des espèces qui proviennent des deux périodes. La Faune silurienne ressemble à celle de la zone de *Distomodus kentuckyensis*, la plus ancienne zone de conodontes du Valentin de l'Amérique du Nord. Toutefois, les nouvelles espèces semblent représenter une nouvelle zone valentienne, plus ancienne, la zone *d'Oulodus? nathani*. Dans le présent rapport, la limite ordovicienne-silurienne se situe là où apparaissent les premières espèces *d'Ozarkodina* et *Oulodus?* environ 2 ou 3 mètres au-dessus de la base du niveau 6 de la formation d'Ellis Bay.

La répartition des conodontes ordoviciens indique la présence de 3 communautés, séparées latéralement, qui correspondent à des environnements subtidal marin, intermédiaire et littoral. *Gamachignathus* et *Panderodus* dominent la communauté marine (communauté A). La communauté intermédiaire (communauté B) est caractérisée par plusieurs espèces de *Panderodus*, *d'Oulodus*, *d'Amorphognathus* et *d'Aphelognathus*. La communauté C, littorale, est caractérisée par la présence de gros fossiles solides *d'Aphelognathus* et de *Panderodus*. Dans les couches siluriennes, la communauté D, qui représente un faciès subtidal intermédiaire, est composée *d'Ozarkodina oldhamensis* (Rexroad) et *d'Oulodus? nathani* nou. esp. *Ozarkodina hassi* (Pollock, Rexroad et Nicoll) et *Oulodus? kentuckyensis* (Branson et Branson) dominent la communauté E et reflètent un environnement subtidal peu profond.

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Introduction

Conodonts of Late Ordovician-Early Silurian age were collected from three measured sections of the Ellis Bay Formation on Anticosti Island (Fig. 1). Anticosti Island, situated in the Gulf of the St. Lawrence, is underlain by Ordovician and Silurian limestone and shale that unconformably overlies Precambrian gneiss. The total subsurface thickness varies from 900 m to 3 300 m from north to south across the island (Roliff, 1968). The strata dip at less than two degrees to the southwest and major structural folds and faults are absent (Bolton, 1972). Exploratory drilling has also indicated a south or southwest thickening of the Vauréal Formation (*sensu* Bolton, 1972) which suggests deposition in a basin that was subsiding in this direction. The island has a major northeast-southwest drainage system that cuts through and exposes the Upper Ordovician and Lower Silurian formations. These units are also exposed along the coast as both cliff exposures and a wave-cut platform.

Previous studies of the paleontology and stratigraphy of Anticosti Island have been reviewed by Nowlan and Barnes (this volume). Major studies that involve the Ellis Bay Formation include those by Schuchert and Twenhofel (1910), Twenhofel (1914, 1921, 1926, 1928), Bolton (1961, 1965, 1972), Roliff (1968), Dixon (1970), and Copeland and Bolton (1975). Studies of the paleontology of this formation include those by Riva (1969, 1974), Bolton (1970), Copeland (1970b, 1973, 1974), Dixon (1974) and Copper (1976). Bolton (1972) summarized most of these and other paleontological studies in his introduction. The only previous brief report of conodonts from the Ellis Bay Formation is by Le Fevre et al. (1976) in their study of conodont paleoecology from the Hudson Bay Basin.

Field work for this present study was undertaken by C. R. Barnes and G. S. Nowlan during the summer of 1975. They collected the exposed sequence of strata on Anticosti Island at approximately 2 m intervals. From this collection, 122 samples of the

Ellis Bay Formation and lowermost part of the Becscie Formation were examined. Initial investigation indicated that the Ordovician-Silurian boundary based on conodonts was within the lowermost part of Member 6 of the Ellis Bay Formation. The writers returned to Anticosti the following year and collected an additional 61 samples. Of these, 18 samples were the result of detailed collecting at intervals of 0.5 m or less across the Ordovician-Silurian boundary at the Ellis Bay and Salmon River sections (Section I and III, respectively) and 20 samples were from the Vauréal River section (Section II). The remaining 23 samples were taken from within the Ellis Bay Formation and across the boundary of the Ellis Bay and Becscie formations. In total, 183 samples, averaging about 1 kg each, were used in this study.

Acknowledgements

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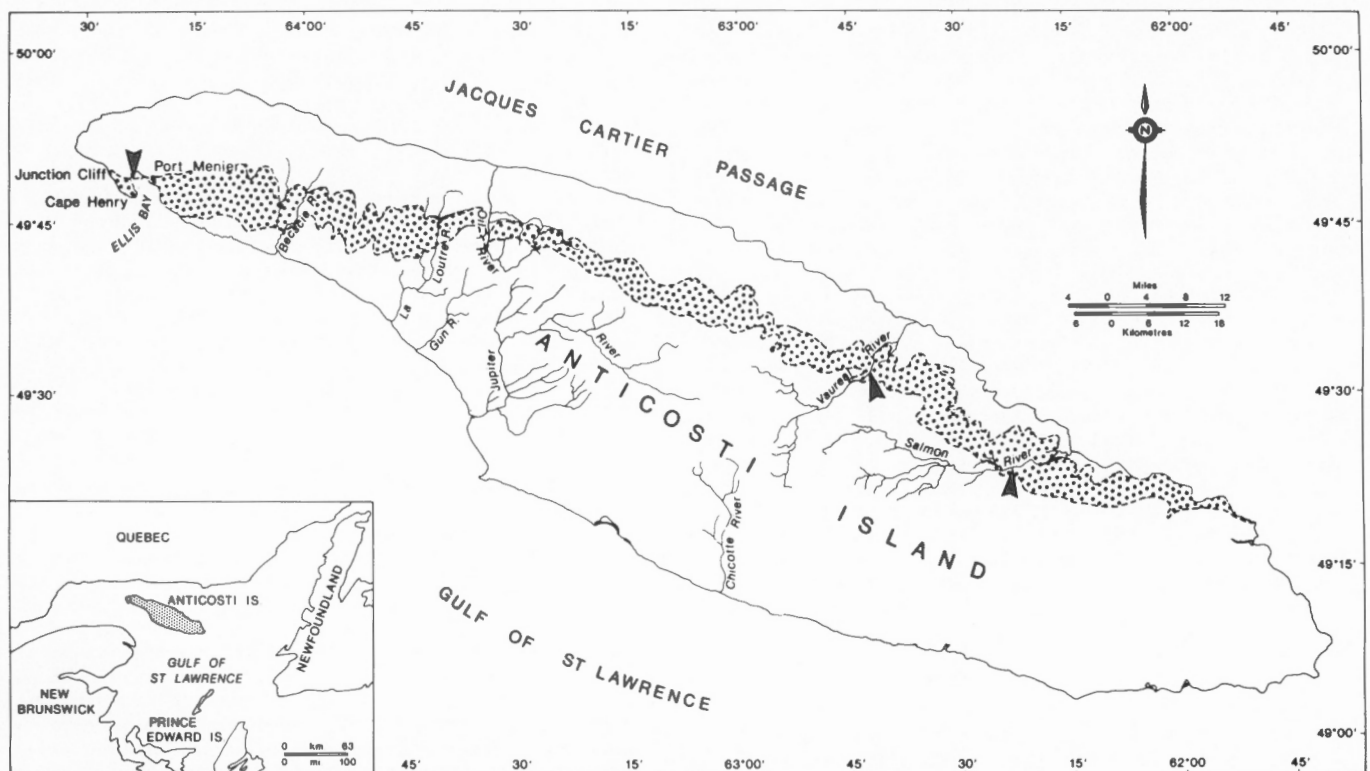


Figure 1. Index map of Anticosti Island showing the distribution of the Ellis Bay Formation (stippled) and locations of sections studied (arrows). Section I includes strata on the west and east sides of Cape Henry, and the east side of Ellis Bay. Sections II and III are along the Vauréal and Salmon Rivers, respectively.

Stratigraphy

Anticosti Island lies in the part of the St. Lawrence Platform that is referred to as the Anticosti Basin. This basin also includes strata of the Mingan Islands, the coastal plain of western Newfoundland, and the southeastern coast of Labrador. Paleozoic rocks of the Anticosti Basin range from Cambrian to Early Devonian in age and are more than 3 300 m thick in the central part (Sanford, *in* Poole et al., 1968, p. 228-229). The basin is bordered by the strata of the Canadian Shield to the north and the Appalachian Orogen to the south and east. The late phase of the Taconic Orogeny resulted in the uplift, folding, and erosion of the rocks of the Appalachian Orogen and some faulting in the Anticosti Basin. During the late Caradocian and Ashgillian, the continental glaciation in north Africa probably resulted in a maximum regression of epeiric seas in North America. This is indicated by the transition of marine carbonate and shale to the red shale and siltstone facies of the Queenston delta complex in the midcontinent (Dennison, 1976).

In the Anticosti Basin, the Upper Ordovician is represented by a thick sequence of shale and limestone of the Macasty, Vauréal and lower Ellis Bay formations. A land area to the east or northeast is suggested by arenaceous limestone in the eastern part of the Ellis Bay Formation (Twenhofel, 1928, Sanford, *in* Poole et al., 1968) and to a lesser extent, probable Silurian clastics in western Newfoundland (Rodgers, 1965). Sedimentation in the Anticosti Basin was apparently continuous from the Late Ordovician into the Early Silurian as represented by limestone and shale of the upper Ellis Bay, Becscie and Gun River formations. Lithologic evidence in these units indicates a continuation of a shallow water depositional environment. The youngest Silurian strata present on Anticosti are the Jupiter and Chicotte formations, the latter being late Llandoveryan or early Wenlockian (Bolton 1972).

Lithostratigraphy

The Upper Ordovician succession on Anticosti Island is divided into two apparently conformable formations, the Macasty and Vauréal, plus the lower Ellis Bay which is overlain by an apparently conformable Lower Silurian sequence of the upper Ellis Bay, Becscie, Gun River, Jupiter and Chicotte formations.

The Macasty Formation is a unit of black limestone and shale. Riva (1969) reported that the subsurface thickness varies from 25 m to 85 m; the thickness of pre-Macasty strata is more than 490 m. Overlying the Macasty Formation, in subsurface, is a distinctive grey shale unit of the lower member of the Vauréal Formation (Bolton, 1972). The lower member (> 120 m) consists of grey shale with interbedded limestone with the shale content increasing with depth. This member includes what has been described as the English Head Formation by Roliff (1968) and others. The upper member (> 180 m) consists of limestone with shale interbeds and partings. The shale content increases and limestone becomes more argillaceous upwards. Clastic content of the upper part of the Vauréal Formation is generally higher in the eastern exposures than in those to the west (Bolton, 1972).

The Ellis Bay Formation (Figs. 1, 2), 53 m to 96 m in thickness (Bolton, 1972), has been divided by Bolton into six members based on argillaceous content. Members 1, 3 and 5 consist of shale with interbeds of argillaceous limestone, whereas Members 2, 4 and 6 consist predominantly of limestone with shale interbeds or partings. This lithologic variation is best exhibited in the western half of the island. In the eastern half, the lower members are often difficult to recognize and thus are queried in both this discussion and in the illustrations. The contacts between members, or their equivalents, appear to be gradational and conformable. There is some lateral variation in lithology, strata to the east being more arenaceous. The lithology of the Ellis Bay Formation suggests that the eastern part of the island was closer to a terrigenous clastic source. Twenhofel (1928) noted that along the

north shore of the island, the strata contain cross-beds, ripple marks, and in one bed, channel infilling. The contacts with the over- and underlying formations (Becscie and Vauréal formations, respectively) are conformable and gradational. The following discussion of the Ellis Bay Formation lithostratigraphy is compiled from previous reports, in particular Bolton (1965, 1972), and study of Sections I, II and III (Ellis Bay, Vauréal River, and Salmon River, respectively; Fig. 2).

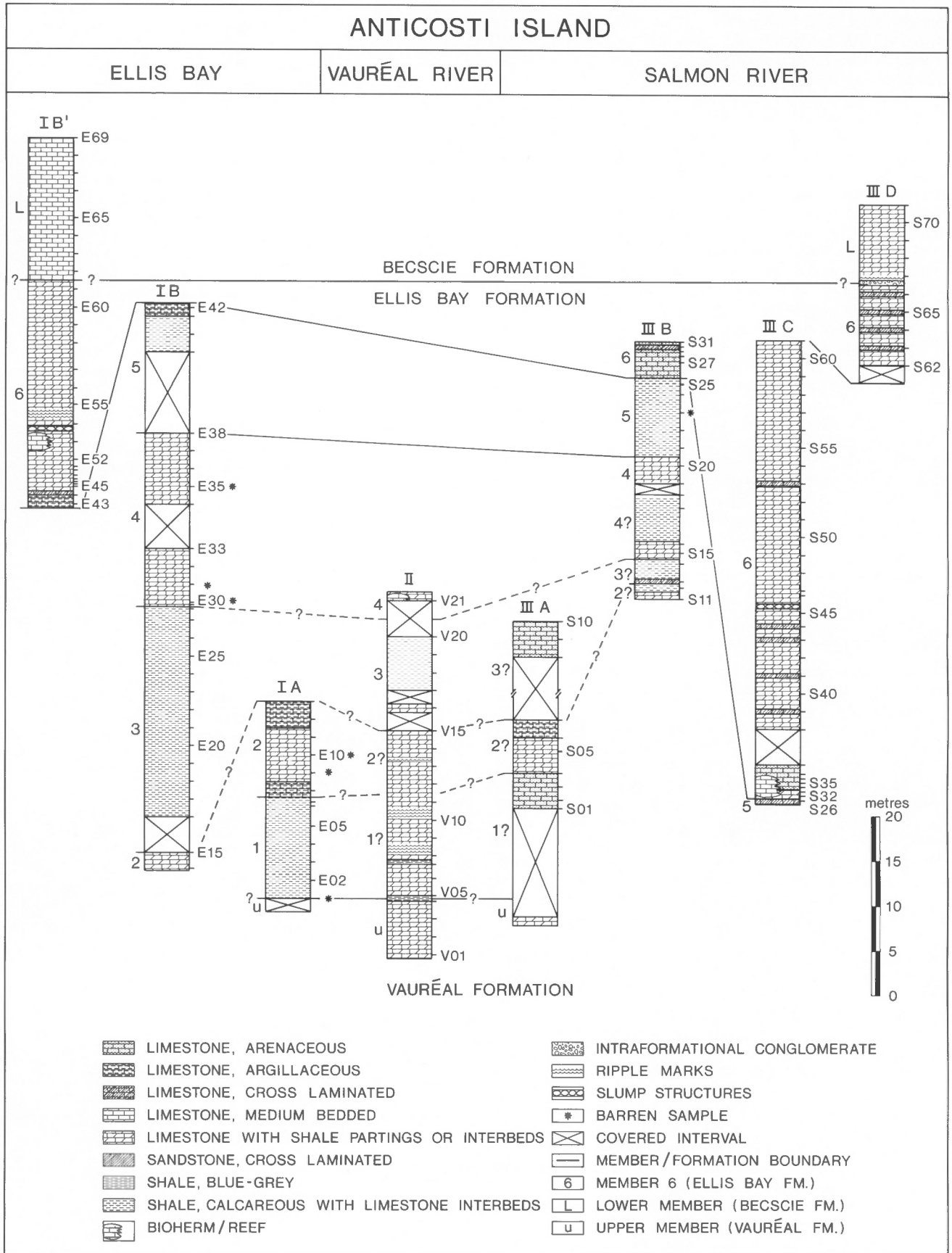
Member 1, as exposed at Ellis Bay (Section IA; Fig. 3) is comprised predominantly of blue and grey shale with interbedded nodular and argillaceous biomicrite. In places, the shale is highly fossiliferous, and the limestone is a medium to coarse, poorly washed biosparite. The lower contact of the member is placed above the argillaceous limestone of the Vauréal Formation; the change in lithology is gradational. At Section II (Vauréal River; Fig. 4), the formational contact is herein arbitrarily considered to be a thin recessive shale interval near the upper ledge of Vauréal Falls. Below this, the strata are predominantly thin bedded, nodular, grey biomicrite with argillaceous partings alternating with grey-brown, brachiopod biosparite. Strata of the lowest Ellis Bay member consist of thin bedded grey biomicrite with argillaceous partings and some beds of intraformational conglomerate. Pararipples trending NNE occur about 8-10 m above the base of Member 1. The contact with Member 2? at Section II is difficult to recognize. At Salmon River (Section III), Member 1? is composed of shale interbedded with biosparite. The biosparite contains silt or fine quartz sand.

Carbonates of Member 2 at Ellis Bay are argillaceous at the base and grade upward into thin bedded biomicrite with argillaceous partings. In places, these have a considerable amount of mud-supported fossil debris. Bolton (1972, p.8) noted that the beds of Member 2 grade upward into thin to thick bedded limestone with intraformational conglomerate and argillaceous partings. Member 2 cannot be clearly distinguished on Vauréal River, except for the decrease in argillaceous content. Member 2? at Section III also has a lower argillaceous content; the limestone is generally biosparite.

At Section I (Fig. 5), Member 3 is comprised of grey shale with interbeds of biomicrite and, in places near the top of the member, brachiopod and trilobite-bearing biosparite. Section II, Member 3 is more argillaceous than the underlying member. Large specimens of *Beatricea* occur on bedding planes. The contact with the strata equivalent to Member 2 is unrecognizable. However, the upper part of Member 3 weathers recessively and underlies a bioherm or small reef considered by Bolton (1972) to be within Member 4. Member 3? at Section III consists of shale with biosparite interbeds.

Member 4 at Ellis Bay (Fig. 5) is composed of thin to thick bedded biomicrite and fossils are less common than in Member 3. The limestone has minor interbeds of grey shale. Member 4 on Vauréal River has a small coral and stromatoporoid bioherm with abundant *Solenopora*. This is overlain by biomicrite and is flanked by thin beds of bioclastic debris. At Section III, Member 4 consists of thin to medium bedded, somewhat nodular, biosparite and biomicrite with shale partings.

Member 5 at Section I (Fig. 6) is comprised of shale and interbeds of argillaceous biomicrite. The lower part of this member has few megafossils except for large specimens of *Beatricea*, isolated tabulate corals, gastropods and brachiopods. With respect to the underlying strata, the beds of the uppermost part of Member 5 become more compact with abundant but isolated corals. The contact with Member 6 is gradational over about 20 cm (Fig. 7). Many *Beatricea* specimens found on the east side of Ellis Bay appear to be in growth position. Bolton (1972) reported that Member 5 on Vauréal River is capped by a 15 cm thick grey sandstone band. At Section III, the limestone interbeds within the shale are biomicrite or biosparite, rarely brachiopod-bearing intrasparite.



(GSC 203707-B)



Figure 3. Members 1 and 2, Ellis Bay formation (Section IA) (arrow marks boundary); Junction Cliff (west side of Cape Henry, looking west), Anticosti Island.

(GSC 203707-E)

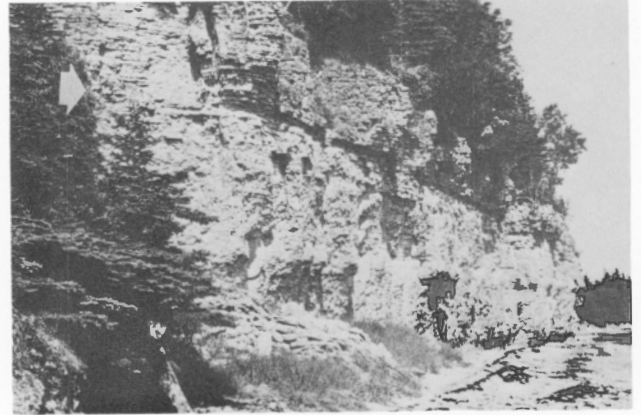


Figure 5. Members 3 and 4, Ellis Bay Formation (Section IB) (arrow marks boundary); West Cliff, west side of Ellis Bay, Anticosti Island.

(GSC 203707-C)

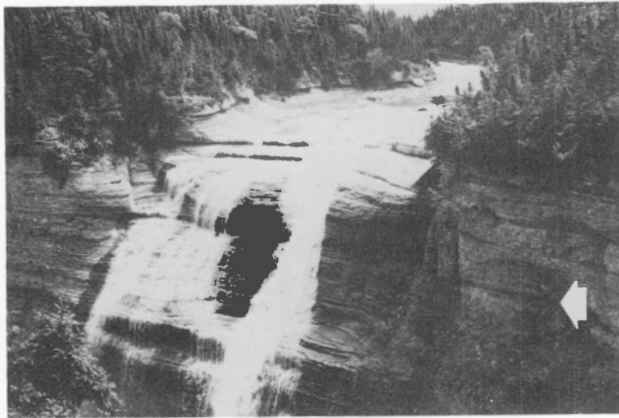


Figure 4. Boundary of upper member, Vauréal Formation and Member 1? (arrow) Ellis Bay Formation (Section II; Vauréal Falls, Anticosti Island).

(GSC 203707-D)



Figure 6. Member 5, Ellis Bay Formation (Section IB); west side of Ellis Bay, north of Cape Henry (looking north), Anticosti Island. Basal beds of Member 6 outcrop below trees.



Figure 2. Lithologic logs of composite sections studied on Anticosti Island. Member subdivisions are indicated on the left side of the logs and sample positions are indicated on the right side. Details of sampling and conodont distributions for all these samples are contained in Appendices B and A, respectively. Interpreted boundaries are queried. The lower members of Sections II and III are not as distinct as those of Section I, hence the identification and correlation of the members and their equivalents are queried.

(GSC 203707)

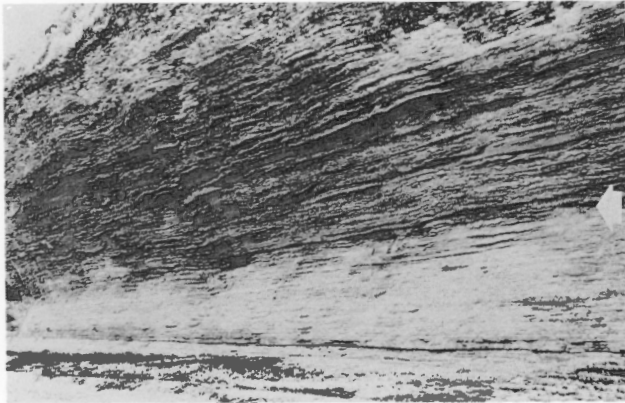


Figure 7. Members 5 and 6, Ellis Bay Formation (Section IC) (arrow marks approximate boundary); near Anse aux Navets (east side of Ellis Bay, looking north), Anticosti Island.

(GSC 203707-F)

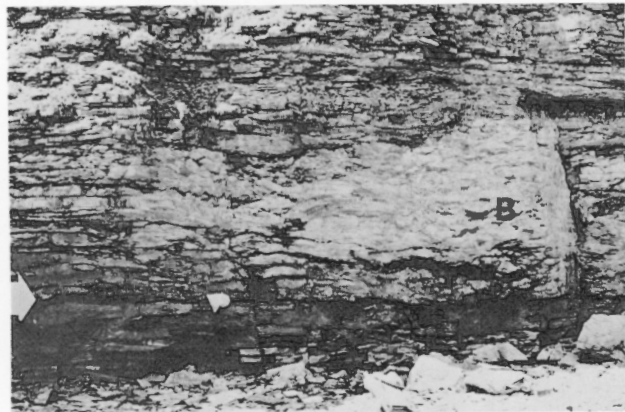


Figure 8. Basal part of Member 6, Ellis Bay Formation (Section IB); east side of Cape Henry, Anticosti Island. Sample bag (sample E45 (A-7640)) lies on top of bed containing uppermost Ordovician fauna. Transition zone bearing both Ordovician and Silurian forms extends for 2 m before a sample (E51 (A-7645)) yields only Silurian forms (see Fig. 13C, Ellis Bay section). Small bioherm (B) occurs to right of sample bag.

At the base of Member 6, on the west side of Ellis Bay, is a 70 cm bed of finely laminated micrite; the cross-laminations producing irregular, platy beds. Above this, the biosparite contains abundant fossils including small rugose corals and isolated coral heads that are about 4 to 20 cm in diameter. Small patch reefs or bioherms are present a few metres above the base of Member 6 (Figs. 8, 9). These are exposed in both vertical and horizontal cross-section and are particularly evident on the extensive wave-cut platform. The beds underlying the structures are depressed. The reef core itself consists of a framework of halysitids, heliolitids, favositids and *Palaeophyllum* sp. (Bolton, 1972). Flanking the core is highly fossiliferous (brachiopods, crinoids, trilobite fragments) biosparite, in places showing minor slumping. The bioherms are generally about 2-3 m wide and about 2 m high. On the west side of Ellis Bay, the bioherms are about 5-10 m apart. Approximately 2 m above the reefs pararipples are widespread and they trend ESE. Dixon (1970) studied both the pararipples and orthoconic nautiloids as paleocurrent indicators and considered their orientation to be the result of currents, probably of a small scale. Above this, the bedding changes from even, regular thin beds to beds that are lensoid, more nodular and massive.

Bolton (1972) considered the contact between the Ellis Bay and Becscie formations to be gradational and to lie between beds containing intraformational conglomerate. He reported that in the interior of the island, small biohermal complexes are exposed in

(GSC 203707-G)

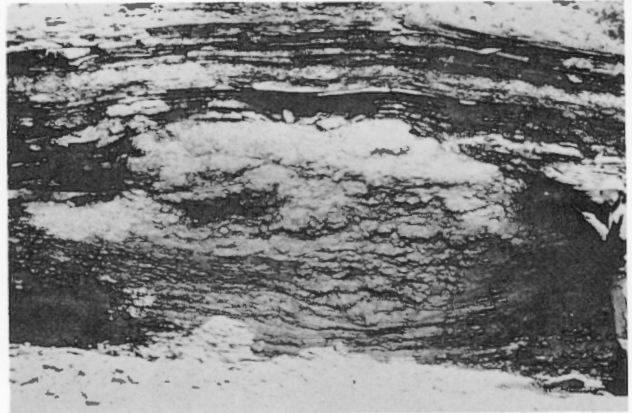


Figure 9. Member 6 bioherm, Ellis Bay Formation (Section I); at Pointe Laframboise, Anticosti Island.

(GSC 203707-A)



Figure 10. Member 6, Ellis Bay Formation (Section IIIC, foreground; IIID, background); Salmon River (looking southwest), Anticosti Island.

several road cuts; these are probably equivalent to those of Member 6. The lowest part of Member 6 on Salmon River is an arenaceous biomicrite with a few solitary corals. Reefs similar to those at Ellis Bay are present on the Vauréal and Salmon rivers. Above the base of Member 6, biomicrite and biosparite beds are more arenaceous than at Ellis Bay. In one place, a bed (S30(A7607); Appendix B) contains about 60 per cent detrital material including abundant garnets. The arenaceous beds are commonly cross-laminated; slump structures occur rarely. The uppermost beds of Member 6 at Salmon River (Fig. 10) also contain abundant slump structures, ripple marks and intraformational conglomerates. The first occurrence of the brachiopod *Virgiana* occurs a few metres above this level and is considered to indicate a mid-Llandoveryan age. Bolton (1972) regarded this occurrence as indicating definite Silurian age.

Two members are distinguished within the 80 m of the overlying Becscie Formation (Bolton, 1972). The lower member consists of limestone which becomes more fossiliferous and argillaceous upwards. The upper member, approximately 7 m thick, is a fossiliferous shale with limestone nodules. Bolton (1972) noted that there is no evidence of a major structural or depositional break with the overlying Gun River Formation. The Jupiter and Chicotte formations complete the apparently conformable Llandoveryan sequence.

Biostratigraphy

Twenhofel (1928), in his extensive paleontological monograph on Anticosti Island, noted changes in faunal composition through the Vauréal, Ellis Bay and Becscie formations. Twenhofel (*ibid.*, p. 32) stated "The Ellis Bay fauna is somewhat distinct from that which preceded it and markedly so from that which follows". The fauna he described consists of 172 species, of which 59 species extended from the underlying formations: "Eighty-six species are confined to the formation and 142 species - over 70 per cent of the fauna - become extinct therein" (Twenhofel, *ibid.*, p. 32). Twenhofel (*ibid.*, p. 35-36) also gave his arguments for the establishment of a new Upper Ordovician series (i.e. stage in present terminology) to be represented by the strata of the Ellis Bay Formation. With regard to the fauna of this formation, he (*ibid.*, p. 35-36) noted that it:

"is largely composed of species derived from the two lower formations, or indigenous species belonging to genera usually considered of Ordovician age. In view of these facts it is not considered possible on faunal grounds to refer this formation to the Silurian, and it is included in the Ordovician. As, however, equivalent beds do not appear to have been recognized in other localities where rocks of Richmondian age have been studied, it is hardly possible to refer the Ellis Bay beds to the Richmondian series without amending the term and giving to it a significance which it may not possess in any North American region other than Anticosti. For this reason it has been considered best to separate the Ellis Bay formation - a formation intended to include all strata higher than the Richmondian of the Mississippian sea and below that which can be clearly recognized as of Silurian age - from those preceding and place it in a series coordinate with the Richmondian. For this series the name Gamachian has been proposed, the name being derived from a former name of Ellis Bay, borne at a time when it was the home of the smuggler chieftain Gamache."

Twenhofel (1928, p. 69) believed that during this time every path permitting migration to the interior was closed to this area, or that the interior region was free from marine waters.

The Becscie Formation is distinguished from the underlying Ellis Bay Formation on both faunal and lithologic characteristics. Twenhofel (1928) considered that the Becscie fauna had little similarity with faunas from strata at other localities. He regarded Billings' (1857) term Anticostian (in amended form) to be appropriate for defining the interval between the youngest Ordovician (Gamachian) and oldest previously known Silurian in North America (Alexandrian). One of the genera present in the lower part of the Becscie Formation is the brachiopod *Virgiana*. Twenhofel (1928, p. 72-73) realized that this genus is indicative of the Lower Silurian of the Midcontinent area, but thought the most tenable explanation for its distribution was that *Virgiana* occurred first in the Anticosti area and slowly migrated southwest.

Thus, Twenhofel (1928) recognized a post-Richmondian, pre-Alexandrian time interval and placed the Ordovician-Silurian boundary at the contact of the Ellis Bay and Becscie formations, but there has been a continuing dispute over his conclusions.

Ayrton et al. (1969) and Berry and Boucot (1970) considered the Ellis Bay Formation to be early Llandoveryan. This was based on the occurrence of the brachiopod *Spirigerina* (*Eospirigerina*) *praemarginalis* (Savage) *Atrypa marginalis* (Dalman) of Twenhofel, (1928). This species is otherwise known only from the Silurian (Boucot and Johnson, 1967, p.91). *A. mar-*

ginalis first occurs in Twenhofel's (1928) Zone 2 at Junction Cliff (Member 2) and ranges to the Chicotte Formation. Ayrton et al. (1969, p. 462) stated that "Twenhofel's (1928) assignment of the Ellis Bay Formation to the Ordovician rather than to the Silurian was made for physical rather than for faunal reasons", quoting from his discussion on the lithologic characteristics of the formations. Taken as a whole, they believed that the fauna of the Ellis Bay Formation, as described by Twenhofel (1928) could be as easily assigned to the early Llandoveryan as to the Ordovician. The presence of *Virgiana* was considered to indicate a probable Middle Llandoveryan age. Ayrton et al. (1969, p. 463) concluded that the Ellis Bay Formation "should be assigned, at least in part, to the early Llandoveryan".

Bolton (1972) considered the fauna of the Ellis Bay Formation to be of Richmondian aspect. He retained the Ordovician age for the formation because many genera characteristic of the Ellis Bay Formation are found elsewhere only in Ordovician strata.

Lespérance (1968) did not recognize Hirnantian equivalents in the Upper Ordovician of Anticosti. The shelly fauna of the uppermost Ordovician and lowermost Silurian has few elements in common with the strata of the Percé area (Lespérance, 1974). He considered almost all of the Ellis Bay Formation to be Ordovician due to the presence of *Chasmops anticostiensis* Twenhofel, found near the level of the bioherms of Member 6. He regarded the strata between this occurrence and the *Virgiana* beds of the Becscie Formation to represent the Hirnantian and the Lower Llandoveryan (Rhuddanian), an interval of about 15 m to 40 m.

Riva (1969) proposed a new graptolite zonal scheme for the St. Lawrence Lowlands. He believed that this area lay in a separate faunal province and that the Marathon zonal succession of Texas (Berry, 1960) was incomplete. The succession on Anticosti included the *Dicellograptus complanatus* Zone, which extended to about the English Head-Vauréal formational boundary (=lower-upper Vauréal Formation of Bolton, 1972). Forms in this zone are diagnostic, being the common Ashgillian graptolites of Britain. The climacograptids and glyptograptids that follow this fauna belong to an assemblage (*Climacograptus prominens-elongatus* Zone) which has not been identified elsewhere in the Upper Ordovician (Riva, 1969). He considered this graptolite fauna to be post-Ashgillian but pre-Llandoveryan. Also present in this zone is *Orthograptus truncatus* var. *abbreviatus*, a form which, in the British succession, ranges from the upper Ordovician to the lower Silurian. Graptolite occurrences in the Ellis Bay Formation are generally rare, but the dendroid *Medusaegraptus* covers many bedding planes (Riva, 1969). Illustrated on figure 12 of Riva (1969) is the occurrence of *Climacograptus* sp. slightly below the lower boundary of the Becscie Formation.

Erdtmann (1976) regarded the *D. complanatus* Zone of the upper English Head (=lower Vauréal) Formation as representing a carbonate-shale (deep shelf) environment and the *C. prominens-elongatus* Zone of the (upper) Vauréal Formation as being a limestone-mudstone (shallow shelf) belt. He did not report on the faunas of either the Ellis Bay or Becscie formations.

Jansonius (1964) and Achab (1977a, 1977b) studied the chitinozoan fauna from the Vauréal Formation. Achab (1977a) correlated the chitinozoans from the *D. complanatus* Zone with the Upper Caradocian-Lower Ashgillian of Europe. The chitinozoans of the overlying graptolite zone (*C. prominens-elongatus*) were considered by Achab (1977b) to be distinctive and unlike those reported elsewhere. The Ellis Bay Formation chitinozoan fauna is presently being examined by A. Achab using part of the same samples as in the present study.

Copeland (1973) erected six ostracode subzones, each equivalent to a member of the Ellis Bay Formation. He (1970a, 1970b) considered the Vauréal-Ellis Bay Formation ostracode assemblage to be late Maysvillian-Richmondian. Some elements

of the Ellis Bay Formation fauna were reported by Copeland (1973) to bear resemblance to those of the Porkuni Stage of Estonia (Sarv, 1962). Species of several genera are common to both areas but are unknown from Silurian strata. Copeland (1973) also thought the relative absence of forms of the Beyrichiacea (characteristic of the Silurian) from the above two areas seemed to support an Ordovician age. He traced the Vauréal-Ellis Bay ostracode fauna to about 11 m below the base of the Becscie Formation and, therefore, within approximately 15 m of the lowest occurring, undoubted Silurian brachiopods (*Virgiana barrandei* (Billings)). He concluded that because there is no stratigraphic hiatus between the Ellis Bay and Becscie formations, the Ordovician-Silurian boundary should lie within this 11 m to 15 m interval. Since the upper limit of the Cincinnati Series is marked by the highest occurrence of tetradellid ostracodes (Copeland, 1973) and the lower limit of the Niagaran Series is marked by the occurrence of zygobolbine ostracodes and *Virgiana*, Copeland (1974) believed that a stratigraphic interval of between 61 m to 69 m should bracket the Alexandrian Series. He found that the Alexandrian had a poorly developed ostracode fauna but, beginning in the Niagaran and throughout the remaining interval, numerous new species and several new genera were present. Copeland (1974) stated that no composite fauna stratigraphically or morphologically similar to this is known from elsewhere in North America.

Flower (1976) mentioned that several Ordovician genera found in Anticosti strata represented a migration of cephalopods from sub-boreal realms to this area as a result of warming in Richmondian time. These forms then underwent further evolution. Flower (1976) considered genera such as *Billingsites* and *Schuchertoceras* to be of Richmondian age.

Conodont Paleontology

A total of 183 samples was collected from the Ellis Bay Formation and the lowermost part of the Becscie Formation. An average of one kilogram of rock per sample was processed for conodonts using standard techniques. The interpretation of conodont paleoecology is based on 163 stratigraphically controlled samples (see Appendix A for distribution tables; Appendix B for section and sample descriptions). The remaining 20 samples (see Appendix D for distribution table, section and sample descriptions) consist of a few samples whose exact stratigraphic position cannot be determined and 16 samples collected on the east side of Ellis Bay (Section IC). The conodonts from all samples (as well as 10 samples from which additional rock was processed) were used in the taxonomic and biostratigraphic studies. The conodont distribution of these latter 10 samples is also listed in the table of Appendix D. Of the samples used in this study, approximately 90 per cent were productive, yielding 14 665 identifiable conodonts (Table 1). Yields varied from zero to about 1 000 conodonts per kilogram.

The conodont elements are generally amber in colour although some variation is noted. Some small compound specimens are almost completely white or translucent whereas larger specimens of the same species have a more typical amber colour. There is commonly a difference in colour in medium sized elements of different species. For example, elements of *Oulodus robustus* (Branson, Mehl and Branson) are generally a darker amber colour compared to other species in the same samples. Elements of *Gamachignathus* tend to have a more pearly lustre than do elements of other genera. Since these colour variations are not restricted to any one section, it is unlikely that they are due strictly to depth of burial (*sensu* Epstein et al., 1977). With reference to the conodont colour alteration index, the Anticosti elements have a CAI of about 1-1.5, reflecting burial temperatures of less than 90 degrees C.

Cluster analysis was conducted on the 159 conodont form elements listed in Table 1. This type of analysis groups elements that commonly occur together. Thus, elements that belong to the same multielement species should cluster together. The dendrograms provided in Appendix C illustrate some of these apparatus clusters. The information derived from the cluster analysis is used to support the reconstructions based on element morphology and familiarity of apparatus plans. Other criteria such as colour, pattern of denticulation, distribution of white matter, and other common morphologic features were also considered. Clustering techniques are discussed further in Appendix C.

Multielement Apparatuses

A total of 35 multielement species representing 18 multielement genera is present in the Ellis Bay Formation conodont fauna, as shown by Table 1 and Figure 12. The Ordovician fauna consists of 27 multielement species representing 14 genera, respectively, of which 4 species and 4 genera are common to the Silurian. Of the taxa, the genus *Gamachignathus* is the most significant. Other new multielement species belong to *Aphelognathus*, *Distomodus*, *Oulodus*?, *Panderodus*, and *Staufferella*. A significant new form genus, N.gen.A, is represented by two species, but by only three specimens, and is regarded as a possible platform element of the Silurian *Distomodus* aff. *D. kentuckyensis* Branson and Branson.

The apparatuses of the conodontophorids are described herein as consisting of a certain number of element-positions. Each position is represented by a distinct, stable, morphologic form, referred to as an element-type. Each position may have contained one or rarely two element-types, and an unknown number of elements.

Many ramiform apparatuses contain what is referred to as a symmetry transition series (Sweet and Schönlaub, 1975) or a first transition series (Barnes et al., 1979). This series is usually represented by elements in the cordylodiform, zygognathiform, trichonodelliform (and in some genera, tetraprioniodiform) positions. Some variation within this series is noted. In some genera (e.g. *Oulodus*) the series can contain both cordylodiform and eoliogonodiform elements. It is suggested that this represents a "splitting" of the cordylodiform position resulting in two element-types. A further example is the cordylodiform and gothodiform element-types of *Gamachignathus*.

A symmetry transition series is also present in the apparatuses of most simple cones. Some of these can be equated with the first transition series ramiform apparatuses (cf. *Walliserodus*, this study; Cooper, 1975; Barrick, 1977). Apparatuses of *Panderodus* appear to contain a symmetry transition series but, at present, they are not equated with other genera. Barrick (1977), however, regarded this genus as having an apparatus that contains elements homologous to those of ramiform apparatuses. Most *Panderodus* species reported herein have an apparatus with two element-positions. These are the arcuatiform (asymmetrical elements = Sc element of Barrick, 1977) and compressiform (biconvex, symmetrical elements = M element of Barrick) positions. *P. gracilis* (Branson and Mehl) has a variation of this apparatus in that it contains either an additional position, the graciliform (narrow; symmetrical and asymmetrical element-types = Sa and Sb of Barrick) or a more complex arcuatiform position. Other genera of simple cones (e.g. *Drepanoistodus*, *Belodina*) have apparatuses that cannot at present be equated with those of ramiform conodonts, or the above two simple cone genera.

The remaining elements of the ramiform conodont apparatuses found in this material usually represent three positions (referred to as the second transition series by Barnes et al., 1979). Unlike the positions of the first transition series, the positions are occupied by one of a variety of element-types. In most cases, the

Table 1. Conodont fauna of the Ellis Bay Formation, Anticosti Island. Element totals are given for each section and for all sections combined. The computer element numbers are those which are used in Appendix A and in the cluster diagrams showing multielement reconstructions. The computer apparatus numbers are the numbers that were used in producing the cluster diagrams showing the conodont community reconstructions. Species and their elements that are found in strata of both systems are denoted by '#'. Species that have elements common with other species are followed by the symbol '@'. Species of Silurian age are preceded by an asterisk (*).

SPECIES	CONSTITUENT ELEMENTS	COMPUTER NUMBER Apparatus/Element	SECTION I TOTAL	SECTION II TOTAL	SECTION III TOTAL	TOTAL FORM ELEMENTS	TOTAL APPARATUS ELEMENTS	
Amorphognathus cf. A. ordovicicus	eoligonodini form	3	14	1	8	9	116	
	keislognathi form		15	1	4	5		
	hibbardelli form		16	2	5	7		
	tetraprioniodi form		17	2	9	11		
	holodonti form		18	2	9	11		
	ambalodi form		19	4	33	37		
	platform		20	11	25	36		
Apheognathus aff. A. grandis	eoligonodini form	1	1	3	2	14	177	
	zygognathi form		2	3	1	25		
	trichonodelli form		3		1	9		
	cyrtioniodi form		4	1	2	5		
	prioniodini form		5	21	1	21		
	apheognathi form		6	8	21	51		
Apheognathus pyramidalis	cordylodi form	2	7			2	49	
	eoligonodini form		8	1		8		
	zygognathi form		9		1	3		
	trichonodelli form		10			4		
	prioniodini form		11		2	3		
	pyramidalis form		12			6		
	apheognathi form		13	1	12	6		
Belodina compressa	grandi form	4	21		7	7	18	
	compressi form		22	1	8	9		
	eobelodini form		23		2	2		
Belodina dispansa	grandi form	5	24		2	2	8	
	compressi form		25		6	6		
Belodina profunda	three-denticled	6	26		2	5	24	
	two-denticled		27		15	4		
Belodina? n.sp. A. s.f.	belodini form	7	28		1	1	1	
"Codylodus" robustus	robusti form	8	29		3	3	3	
#Decoriconus costulatus	acantiodi form	9	30	7#		23#	30#	94#
	paltodi form		31	6#		47#	53#	
	drepanodi form		32	1#		10#	11#	
#Drepanoistodus suberectus	suberecti form	10	33	5	11	7	23	258
	homocurvati form		34	24	131	50	205	
	oistodi form		35	10	12	8	30	
Eobelodina n.sp. A s.f.	eobelodini form	11	36			1	1	
Eobelodina n.sp. A s.f.	eobelodini form	12	37			1	1	
Gamachignathus ensifer n.sp.	cordylodi form	13	38	215	12	51	278	1894
	gothodi form		39	62	7	20	89	
	keislognathi form		40	300	39	65	404	
	hibbardelli form		41	28	7	11	46	
	cyrtioniodi form		42	259	28	38	325	
	falodi form		43	70	11	28	109	
	prioniodini form		44	153	28	36	217	
	modified prioniodi form		45	359	13	54	426	
	Gamachignathus hastatus	cordylodi form	14	46	46		6	
gothodi form			47		1		1	
keislognathi form			48	126	3	20	149	
hibbardelli form			49	17	1	1	19	
cyrtioniodi form			50	45			45	
falodi form			51	24		2	26	
prioniodi form			52	82	3	6	91	
modified prioniodi form			53	40	2	3	45	
Oulodus robustus		cordylodi form	15	54	4			4
	eoligonodini form		55	8			8	
	zygognathi form		56	12			12	
	trichonodelli form		57	6			6	
	oregoni form		58	4			4	
	prioniodini form		59	8			8	
	oulodi form		60	3			3	
Oulodus rohneri	cordylodi form	16	61	1	20	2	23	161
	eoligonodini form		62	5	19		24	
	zygognathi form		63	2	13	2	17	
	trichonodelli form		64	5	20	2	27	
	cyrtioniodi form		65	3	13		16	
	prioniodini form		66	3	16		19	
	oulodi form		67	3	30	2	35	

Table 1. (continued)

SPECIES	CONSTITUENT ELEMENTS	COMPUTER NUMBER Apparatus/Element	SECTION I TOTAL	SECTION II TOTAL	SECTION III TOTAL	TOTAL FORM ELEMENTS	TOTAL APPARATUS ELEMENTS		
<i>Oulodus ulrichi</i>	codylodiiform	17	68		4	2	6	66	
	eoligonodiniiform		69		8		8		
	zygognathiiform		70		10		10		
	trichonodelliiform		71		7		7		
	cyrtionodiiform		72		14		16		
	prioniodiniiform		73		8	2	3		11
	oulodiiform		74		8				8
<i>Panderodus clinatus</i>	arcuatiiform	18	75	19	66	5	90	266	
	compressiiform		76	29	132	15	176		
<i>Panderodus feulneri</i>	graciliiform	19	77		67	14	81	239	
	arcuatiiform		78		103	4	107		
	compressiiform		79		43	8	51		
# <i>Panderodus gibber</i>	arcuatiiform	20	80	8#	28	56#	92#	157#	
	compressiiform		81	19#	16	30#	65#		
# <i>Panderodus gracilis</i>	graciliiform	21	82	784#	384	2426#	3594#	7017#	
	arcuatiiform		83	491#	211	934#	1636#		
	compressiiform		84	487#	198	1102#	1787#		
<i>Panderodus liratus</i>	arcuatiiform	22	85		31	9	40	103	
	compressiiform		86		48	15	63		
<i>Panderodus panderi</i>	arcuatiiform	23	87	79			79	126	
	compressiiform		88	42	5		47		
# <i>Panderodus serratus</i> s.f.	arcuatiiform	24	89	28#		12#	40#	40#	
<i>Panderodus</i> cf. <i>P. staufferi</i>	arcuatiiform	25	90	34	63	9	106	197	
	compressiiform		91	23	58	10	91		
<i>Panderodus</i> n.sp.A s.f.	arcuatiiform	26	92		6	6	12	12	
<i>Panderodus</i> n.sp.B s.f.	compressiiform	27	93		4	6	10	10	
<i>Panderodus</i> n.sp.C s.f.		28	94		1	1	2	2	
<i>Paroistodus mutatus</i>	acodiiform	29	95	1	2	1	4	22	
	distacodiiform		96		4		4		
	oistodiiform		97	2	11	1	14		
<i>Phragmodus undatus</i>	phragmodiiform	30	98	70	23	1	94	241	
	oistodiiform		99	44	13	1	58		
	breviiform		100	26	13	1	40		
	typiciiform		101	25	24		49		
<i>Plegagnathus dartoni</i> s.f.		31	102		4	1	5	5	
<i>Plegagnathus nelsoni</i> s.f.		32	103		4	2	6	6	
# <i>Pseudooneotodus beckmanni</i>		33	104	84#	1	21#	106#	106#	
<i>Pseudooneotodus mitratus</i> mitratus		34	105	2		2	4	4	
<i>Ptiloncodus harrisi</i> s.f.		35	106		4		4	4	
<i>Rhipidognathus symmetricus</i> <i>symmetricus</i>	trichonodelliiform	36	107		2	1	3	4	
	bryantodiniiform		108			1	1		
<i>Staufferella inaligerae</i>	symmetrical	37	109	2		5	7	46	
	markedly asymmetrical		110	15		24	39		
<i>Walliserodus</i> cf. <i>W. curvatus</i>	curvatiiform	38	111	1			1	33	
	deboltiiform		112		2	2	4		
	dyscritiiform		113		3	1	6		
	unicostatiiform		114	13	6	5	22		
* <i>Belodella?</i> n.sp.A s.f.		39	115			1	1	1	

Table 1. (continued)

SPECIES	CONSTITUENT ELEMENTS	COMPUTER NUMBER Apparatus/Element	SECTION I TOTAL	SECTION II TOTAL	SECTION III TOTAL	TOTAL FORM ELEMENTS	TOTAL APPARATUS ELEMENTS
*Distomodus aff. <i>D. kentuckyensis</i>	eoligonodini form	40	116	5	10	15	53
	zygognathi form		117	1	8	9	
	trichonodelli form		118	1	11	12	
	distomodiform		119		11	11	
	modified ambalodi form		120		6	6	
	platform		121				
*"Drepanodus suberectus" s.f.		41	122		11	11	11
*Icriodella deflecta @	platform	42	123	3		3	3
*Icriodella dyscrita @	eoligonodini form	43	124	1	9	10	59
	zygognathi form		125	2		2	
	trichonodelli form		126	2	6	8	
	sagittodontiform		127	4	9	13	
	ambalodi form		128	4	1	5	
	platform		129	16	5	21	
*Oulodus? kentuckyensis	ligonodini form	44	130		107	107	378
	zygognathi form		131	8	91	99	
	trichonodelli form		132	1	44	45	
	euprioniodini form		133	3	39	42	
	lonchodini form		134	3	43	46	
	modified oulodi form		135	2	37	39	
*Oulodus? nathani	ligonodini form	45	136	5	34	39	163
	zygognathi form		137	8	17	25	
	trichonodelli form		138	2	27	26	
	euprioniodini form		139		11	11	
	lonchodini form		140	6	15	21	
	blade		141	4	34	38	
*Ozarkodina hassi @	ozarkodini form	46	142	13	42	55	149
	spathognathodi form		143	22	72	94	
*Ozarkodina oldhamensis @	ozarkodini form	47	144	45	156	201	536
	spathognathodi form		145	69	266	335	
*Ozarkodina sp. @	ligonodini form	48	146	26	181	207	578
	zygognathi form		147	33	172	205	
	trichonodelli form		148	10	43	53	
	synprioniodini form		149	15	98	113	
*Ozarkodina n.sp.A s.f.	ozarkodini form	49	150		5	5	5
*Spathognathodus elibatus s.f.	spathognathodi form	50	151		1	1	1
*Spathognathodus manitoulinensis s.f.	spathognathodi form	51	152		5	5	5
*Walliserodus curvatus	curvati form	52	153	12	68	80	735
	deboliti form		154	38	136	174	
	dyscriti form		155	27	178	205	
	multicostati form		156	11	62	73	
	unicostati form		157	32	171	203	
*N.gen.A n.sp.A s.f.	platform	53	158	1		1	1
*N.gen.A n.sp.B s.f.	platform	54	159	1	1	2	2
TOTAL ELEMENTS			4771	2262	7632	14665	14665

second transition series lacks elements that are intermediate in form between element-types, which can occur in the first transition series. The presence of a falodiform as well as a cyrtioniodiform element-type within the apparatus of *Gamachignathus*, and two forms of cyrtioniodiform elements in some species of *Oulodus* again suggests "splitting" or dual element-position (as found with some cordylodiform positions). Of the two other positions in the second transition series, one is generally represented by a prioniodiform or prioniodiniform element-type; the other is represented by elements of a more varied morphology. The latter includes aphelognathiform, oulodiform, platform, spathognathodiform, and other blade-like elements.

Formal suprageneric classification of conodonts has been attempted previously (e.g. Lindström, 1970; Cooper, 1977). Rather than using such taxonomic terms, two informal groups are proposed herein for conodonts with ramiform apparatuses. Both are considered to be part of, but of a lower taxonomic hierarchical group than that defined by the prioniodid plan of Sweet and Bergström (1970). These are the *Amorphognathus-Prioniodus* and the *Aphelognathus-Oulodus* informal suprageneric groups. The groups generally represent apparatuses from the North Atlantic and Midcontinent Provinces, respectively.

Elements of the first transition series in taxa of the *Amorphognathus-Prioniodus* group have narrowly divergent lateral processes and an elongated posterior process, the latter with hindeodellid-type denticulation. These differ from the homologous elements of the *Aphelognathus-Oulodus* group, which generally have a short, undenticulated posterior process and widely divergent lateral processes. The genus *Gamachignathus* has more in common with genera such as *Prioniodus* than those of the other informal group and it is suggested that it may have been derived from a North Atlantic Province stock.

Nine multielement species in the Anticosti material are recognized from the *Aphelognathus-Oulodus* informal group. All species of the above two genera are restricted to the Ordovician; two species questionably assigned to *Oulodus* are found only in the Silurian. These latter species have similarities to younger species of *Oulodus* but they differ in that they contain a modified oulodiform or blade-like (aphelognathiform?) element rather than a true oulodiform element. Their generic affinity is questioned because of the uncertainty of the evolutionary lineages of *Aphelognathus* and of Ordovician and younger Silurian species of *Oulodus*. *Ozarkodina* is also considered to be part of the *Aphelognathus-Oulodus* informal group.

Conodont Biostratigraphy

Ordovician conodontophorids exhibited a high degree of provincialism; conodont faunas from the Baltic area generally have little in common with those from the North American Midcontinent. Strata from the eastern margins of the North American craton bearing the Midcontinent Province fauna also locally contain representatives from the North Atlantic Province. At times, conodontophorids from the North Atlantic Province migrated towards the interior of the craton (Sweet et al., 1971, fig. 3). Evidence concerning provincialism in the Silurian is more tenuous, especially during the Llandoveryan. This is due in part to the limited number and distribution of studies. Barnes et al. (1973) thought that the provincialism exhibited by Ordovician conodontophorids also affected those of the Llandoveryan and early Wenlockian. As a result of provincialism, two conodont successional schemes have been devised, one for each Ordovician province (Fig. 11). Both must be considered in any biostratigraphic study that involves an admixture of these provinces. The Silurian biostratigraphy used herein (Fig. 11) is based on the North American succession with references to the scheme for Europe.

The Middle and Upper Ordovician North Atlantic Province zonation of Bergström (1971) is based in part on the evolution of *Amorphognathus*. The succession includes the zones *A. tvaerensis* Bergström, *A. superbus* (Rhodes) and *A. ordovicicus* Branson and Mehl. Sweet et al. (1971) provided a succession of twelve conodont faunas based on assemblages of stratigraphically important species. Sweet and Bergström (1976) noted that direct correlation of these two schemes is possible at only three points. These are: the boundaries between Faunas 5/6 and 7, and *Prioniodus variabilis* and *P. gerdæ* Subzones (*A. tvaerensis* Zone) of the Midcontinent and North Atlantic Provinces, respectively; the top of Fauna 9 and the top of the *A. tvaerensis* Zone; and the boundary of the *A. superbus* and *A. ordovicicus* Zones, which is approximately midway through the range of Fauna 11.

Walliser (1962, 1964) recognized a succession of Silurian conodont zones from the Carnic Alps. This scheme was further refined by Walliser (1971) (Fig. 11) with reference to the Silurian graptolite zonation. The lowermost interval, the Bereich I, has an undefined base. Walliser (1971) and Schönlaub (1971) questionably assigned the lowest part of the zone to the Ordovician. Aldridge (1972) established four conodont assemblage zones from strata of the Welsh Borderland. The lowest zone is the *Icriodella discreta-I. deflecta* Assemblage Zone. The lower limit is unknown, but was thought to be defined on the earliest occurrence of the above species. It was recognized that the oldest part of the Llandoveryan was not represented by this scheme. The zonation used in the Silurian of North America was developed by Rexroad (1967) and Nicoll and Rexroad (1969) and later redefined by others. The *Icriodina irregularis* Assemblage Zone of the North American midwest (Nicoll and Rexroad, 1969) is approximately equivalent to the *I. discreta-I. deflecta* Assemblage Zone and the upper part of the Bereich I interval. Pollock et al. (1970) recognized an interval that they believed corresponded with the pre-*Icriodina* Zone of Rexroad (1967) and the lower part of the Bereich I interval. They referred to this interval as the *Panderodus simplex* Assemblage Zone. This zone was based on the presence of this form species, and the absence of *Icriodella*. We agree with Cooper (1975) that the above zone should be excluded because it was based on a long ranging species and because it probably reflected specific environmental conditions. Cooper (1975) used multielement taxonomy with the result that the *Icriodina irregularis* Zone was re-named the *Distomodus kentuckyensis* Zone.

Upper Ordovician faunas that contain Fauna 12, and thus pertinent to this study, and components from the *A. ordovicicus* Zone have been studied from several areas of the North American midcontinent. Branson, Mehl and Branson (1951) and Kohut and Sweet (1968) studied conodonts from the Richmond Group of the Cincinnati region in Indiana, Kentucky and Ohio. Sweet et al. (1975) investigated the conodont fauna of the Upper Ordovician of Missouri.

Sweet and Bergström (1976) reported that Fauna 12 is distinguished by *A. ordovicicus*, *Belodina inclinata* (Branson and Mehl), *Oulodus ulrichi* (Stone and Furnish), *Panderodus angularis* (Branson, Mehl and Branson) s.f., *P. staufferi* (Branson, Mehl and Branson) s.f. and several unnamed species. They noted that *A. ordovicicus* had not yet been definitely recognized in the Richmondian of the Cincinnati region. However, the presence of advanced forms of *A. superbus*, its evolutionary predecessor, within Maysvillian strata suggested to Sweet and Bergström (1971, 1976) that Fauna 12 first appeared in the type area somewhat before the middle of the Maysvillian. As defined above, Fauna 12 does not appear in the Cincinnati region until the base of the Richmondian.

In Missouri, the lower range of *B. inclinata* overlaps the upper range of *B. compressa* (Branson and Mehl) (Sweet et al., 1975). In sections west of the Cincinnati region, *B. compressa* occurs with a short-ranging, unnamed species of *Belodina* (*B.*

sp.A s.f. of Sweet et al., 1971). This association characterizes the part of the Fauna 12 range that is of mid-Maysvillian age. Barnes (1977) found this form of *Belodina* in mid-Edenian to mid-Maysvillian strata of northern Canada.

Kohut and Sweet (1968) in their restudy of the type Richmond conodonts found the following species restricted to the Richmondian: *Belodina profunda* (Branson and Mehl), *Panderodus angularis* s.f., *P. staufferi* s.f., *Plegagnathus dartoni* (Stone and Furnish) s.f. and *Zygognathus pyramidalis* Branson, Mehl and Branson s.f. The Richmondian strata also contained form species or incomplete multielement species that Tarrant (1977) has recently placed in new apparatuses. These new reconstructions include *Aphelognathus grandis* Branson, Mehl and Branson, *A. pyramidalis* (Branson, Mehl and Branson), *Oulodus robustus* (Branson, Mehl and Branson), *O. ulrichi*, *O. undulatus* (Branson, Mehl and Branson), and *Panderodus staufferi*. Barnes (1974) found *B. profunda*

and *P. dartoni* s.f. in strata of the Canadian Arctic Islands thought to be late Maysvillian to Richmondian.

The fauna from the Georgian Bay Formation, Ontario, described by Tarrant (1977) differs from that of the Cincinnati region in that it has several new species of *Belodina*, form species of *Plegagnathus* are absent, and two species of *Plectodina* are present. The latter, *P. inclinata* (Glenister) and *P. tenuis* (Branson and Mehl), were found by Sweet et al. (1975) in Richmondian and older strata of Missouri.

The fauna of the Vauréal Formation of Anticosti Island has a Richmondian aspect but also contains several new taxa (Nowlan and Barnes, this volume). Present are *Aphelognathus pyramidalis*, *Amorphognathus ordovicicus*, *Belodina profunda*, *Oulodus rohneri* Ethington and Furnish, *O. ulrichi*, and *Plegagnathus dartoni*. *O. rohneri* is a newly reconstructed apparatus containing elements originally found in the Upper Ordovician of Manitoba by Ethington and Furnish (1959). The new taxa include species

PERIOD	EPOCH	SERIES/ STAGES	CARNIC ALPS WALLISER, 1971	GREAT BRITAIN	U.S. MIDCONTINENT	ANTICOSTI (THIS STUDY)	SERIES/ STAGES (THIS STUDY)		
				ALDRIDGE, 1975 BERGSTRÖM, 1971	COOPER, 1975 SWEET et al., 1971				
SILURIAN	MIDDLE	WENLOCKIAN	patula		---	? --- P.amorpho- gnathoides O.ranuliformis ? ---	WENLOCKIAN		
			amorpho- gnathoides	---	P.amorpho- gnathoides				
	LOWER	LLANDOVERIAN	celloni		I. inconstans	L. celloni	---	LLANDOVERIAN	
			Bereich I	H. stauro- gnathoides		D. kentucky- ensis			D. kentucky- ensis
				I. discreta- I. deflecta		---			O. ? nathani
				---		---			---
ORDOVICIAN	UPPER	RICHMONDIAN	---	A. ordovicicus	Fauna 12	Fauna 13	GAMACHIAN		
		MAYSVILLIAN			Fauna 11	Fauna 12	RICHMONDIAN		
		EDENIAN		A. superbus	Fauna 10	Fauna 11	MAYSVILLIAN		
	MIDDLE	SHERMANIAN				Fauna 10	Fauna 10	EDENIAN	
		KIRKFIELDIAN		A. tvaerensis	Fauna 9	Fauna 9	Fauna 9	SHERMANIAN	
								KIRKFIELDIAN	

Figure 11. Correlation of Anticosti Island conodont Faunas and zones with North American and western European Faunas and zones. A queried broken line indicates that the exact age of a boundary is unknown.

of *Aphelognathus*, *Panderodus*, *Plectodina* and *Staufferella*. All multielement species of *Panderodus* range throughout the Ordovician of the Ellis Bay Formation. Also present in low numbers in the upper Vauréal Formation are elements of *Gamachignathus*.

The conodont fauna of the lowest Llandoveryian zone in North America (*D. kentuckyensis*) as recognized herein was described by Cooper (1975) from the Brassfield Limestone of Ohio. It contains in addition to this species, *Decoriconus costulatus* (Rexroad), *Icriodella deflecta* Aldridge, *I. discreta* Pollock, Rexroad and Nicoll, *Oulodus* sp. A Cooper, *O.* sp. B Cooper, *Ozarkodina hassi* (Pollock, Rexroad and Nicoll), *O. oldhamensis* (Rexroad), *O. protexcavata* Cooper, *Panderodus serratus* Rexroad and *Walliserodus curvatus* (Branson and Branson). Cooper (1975) also described species that had affinities to *D. kentuckyensis* (Branson and Branson) and *P. serratus*. The fauna described by Cooper (1975) contained elements in common with faunas from North American strata studied by Rexroad (1967), Nicoll and Rexroad (1969), and Pollock et al. (1970), and faunas from Britain (Aldridge, 1972, 1975). Cooper's two new species of *Oulodus* are herein considered to be conspecific with *Oulodus? kentuckyensis* (Branson and Branson). Rexroad (1967), Pollock et al. (1970), Aldridge (1972, 1975), and Cooper (1975) all recognized that the *D. kentuckyensis* Assemblage Zone (or its equivalents) may not represent the oldest part of the Llandoveryian.

The Ordovician conodont fauna of the Ellis Bay Formation, Anticosti Island, contains some elements that are indicative of Fauna 12 and the *Amorphognathus ordovicicus* Zone of the Midcontinent and North Atlantic Provinces, respectively. Other forms are present which show affinities to Upper Ordovician conodont species. In addition, several new species of simple cone conodonts and the genus *Gamachignathus* are present. Several species present are long ranging elsewhere and thus of little biostratigraphic value. These include *Belodina compressa* (Branson and Mehl), *Drepanoistodus suberectus* (Branson and Mehl), *Panderodus gracilis* (Branson and Mehl), *Phragmodus undatus* Branson and Mehl, *Pseudooneotodus beckmanni* (Bischoff and Sannemann) and *Rhipidognathus symmetricus* Branson, Mehl and Branson.

The conodont species present in the Ellis Bay Formation that are characteristic of Fauna 12 or the Richmondian include *Aphelognathus pyramidalis*, "*Cordylodus*" *robustus* Ethington and Furnish s.f., *Oulodus robustus*, *O. rohneri*, *O. ulrichi*, *Plegagnathus dartoni* s.f., *P. nelsoni* Ethington and Furnish s.f., *Amorphognathus* cf. *A. ordovicicus* and *Panderodus* cf. *P. staufferi*. *Aphelognathus* aff. *A. grandis* has some affinities to *A. grandis*, a Richmondian species. Representatives of the North Atlantic Province are *A.* cf. *A. ordovicicus* and *Paroistodus? mutatus* (Branson and Mehl). Notably absent from the Ordovician fauna are species of *Plectodina*.

New taxa of Ordovician conodonts in the fauna from the Ellis Bay Formation include three species of *Panderodus* (two are described and named by Nowlan and Barnes, this volume) and a new species of *Staufferella*. *Panderodus gibber* Nowlan and Barnes and *P. liratus* Nowlan and Barnes are present in other localities. Tarrant (1977) found the former species in Richmondian strata of southwestern Ontario. Barnes (1977) illustrated two forms of *P. brevisculus* Barnes that are similar to *P. gibber*. These were from mid-Edenian to mid-Maysvillian strata of northern Canada. *P. liratus* is also present in the above study (identified by Barnes (1977) as *P. arcuatus* (Stauffer)). As mentioned above, all multielement species of *Panderodus* have been found in the underlying Vauréal Formation. The genus *Gamachignathus* has characteristics of the *Amorphognathus-Prioniodus* informal suprageneric group and thus may have North Atlantic Province affinities. This genus first appears high in the Vauréal Formation

but its abundance is low. *Gamachignathus* does not flourish until the lowest part of the Ellis Bay Formation, where it dominates the fauna at Section I (Ellis Bay area).

In terms of the conodont faunas proposed by Sweet et al. (1971) and reconsidered by Sweet and Bergström (1976), the Ellis Bay fauna shows some significant differences to Fauna 12 as found in the underlying Vauréal Formation. These differences are considered to be more than simply ecologically controlled. It is therefore proposed that a Fauna 13 be recognized in latest Ordovician strata. Fauna 13 is characterized by the presence of *Gamachignathus ensifer* and *G. hastatus*. Most of the other species present range upward from Fauna 12, although some seem to show significant differences (e.g. *Aphelognathus* aff. *A. grandis*). It is uncertain whether the absence of species of *Plectodina* within the Ellis Bay fauna is also diagnostic of Fauna 13 elsewhere. Although *Gamachignathus* first appears in the upper Vauréal Formation, the base of Fauna 13 is taken at the level where this genus becomes a dominant component of the fauna. This level is at the base of the Ellis Bay Formation and Fauna 13 ranges into the base of Member 6 of this formation.

Elements of Fauna 13 are known from largely unpublished collections elsewhere. Similar or closely related forms occur in late Ordovician strata of the Matapedia Group, Gaspé, Québec (McCracken et al., 1980), and the Hanson Creek Formation, Ely Springs Dolomite, and Unnamed Limestone at Ikes Canyon, Toquima Range, Central Nevada and southeast California (A. G. Harris, pers. comm., 1978). The "*Prioniodus ferrarius*" fauna from the Edgewood Group and its equivalents of Missouri described by Thompson and Satterfield (1975) is also probably assignable to Fauna 13. In recent collections from the Road River Formation of the Ogilvie Mountains, Yukon Territory, made by A. D. McCracken, elements of Fauna 13 *Gamachignathus* were present 3 m below beds containing graptolites indicative of the *Glyptograptus persculptus* Zone of early Silurian age. It is likely that Fauna 13 will have limited geographical extent in North America and be largely restricted to near the Ordovician continental margins (McCracken et al., 1980).

Thus, the conodont data suggest the presence of strata, bearing Fauna 13, that are probably younger than the type Richmondian strata that contain Fauna 12. As indicated earlier in this paper, Twenhofel (1928) in his major study of the Ellis Bay Mega fossils demonstrated that half of the rich fauna was restricted to the Ellis Bay Formation. Twenhofel (*ibid.*) defined the Gamachian Stage to accommodate these strata, interpreted as post-Richmondian and pre-Llandoveryian. Most later workers have tended to ignore or reject this stage, but few have examined correlative strata of latest Ordovician age. The present writers advocate the re-establishment of the Gamachian Stage to comprise strata from the base of Member 1 to a few metres above the base of Member 6 of the type Ellis Bay Formation. Precise correlation of the base of this stage with the type Richmondian of the Cincinnati region is difficult and the available conodont data are discussed above. The sharp conodont faunal change near the base of Member 6 and the appearance of Silurian faunas provide a clear boundary. Precise correlation with the type Llandoveryian is also difficult, particularly since conodonts are unknown from the earliest Llandoveryian strata in Britain.

Further research on the fossil groups within the Ellis Bay Formation is required to determine the full nature of faunal change at the Ordovician-Silurian boundary. In terms of conodont faunas, the Ellis Bay Formation of Anticosti Island appears to represent latest Ordovician and earliest Silurian time. Mitchell and Bergström (1977) have also noted that the upper Ordovician-lower Silurian succession in the Cincinnati region is incomplete. They suggested that the latest Ordovician succession on Anticosti would be a prime candidate for the stratotype of post-Richmondian Ordovician rocks with the stage name Gamachian already being

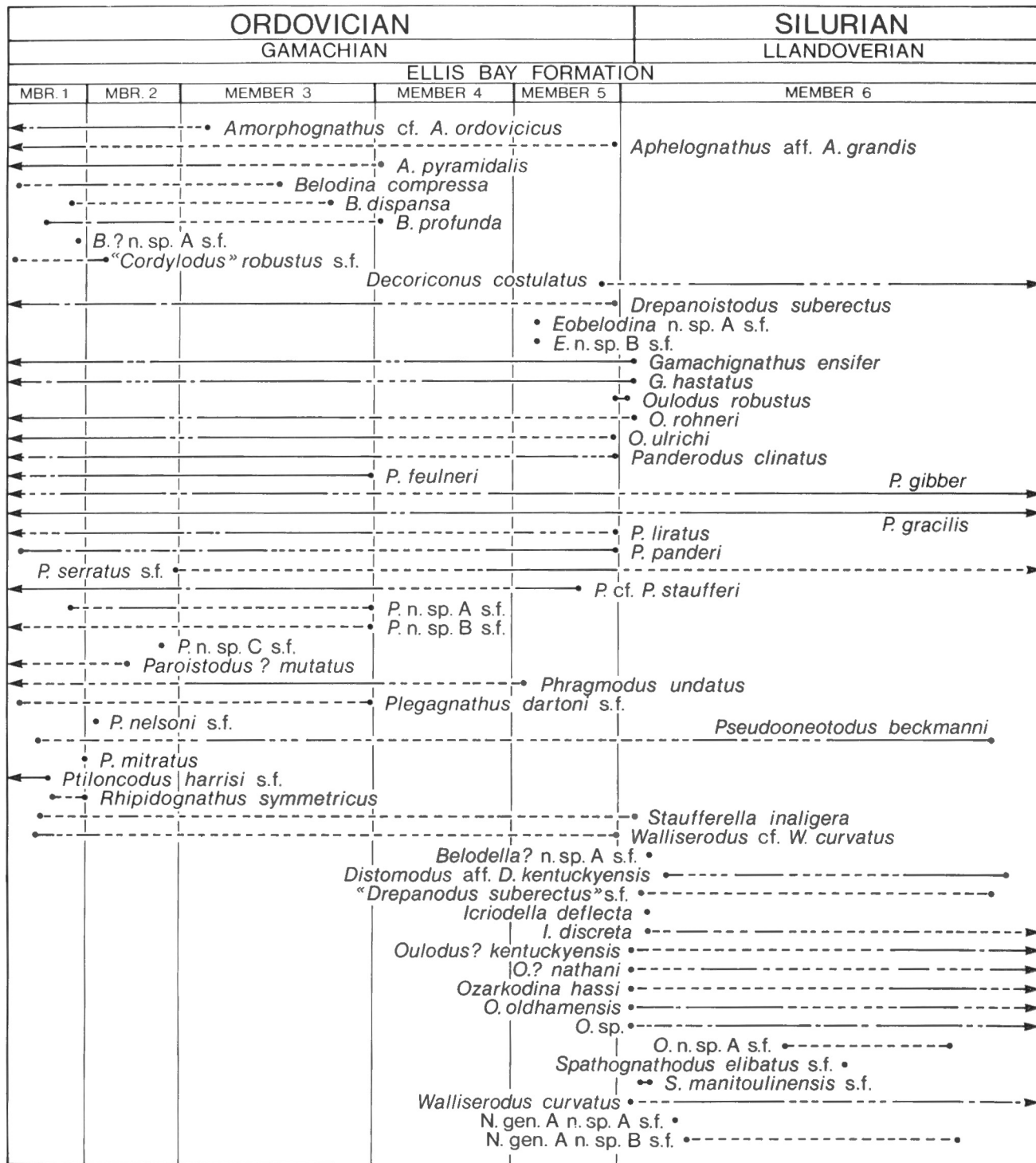


Figure 12. Stratigraphic range of conodont taxa from the Ellis Bay Formation, Anticosti Island. Figure is composite of all three sections, showing relative thicknesses of members from Section I (Member 1 - 5) and Section III (Member 6) (see Figure 2). Upper and lower boundaries of ranges are shown by solid circles, arrows indicate ranges that extend beyond boundary of Ellis Bay Formation (as shown by this study). Broken lines indicate either discontinuous occurrences or absence of taxa. Actual distribution of conodont taxa for each section are recorded in Appendices A and D. *Ozarkodina* sp. represents those elements belonging to either *O. hassi* or *O. oldhamensis* but which cannot be readily assigned to one of these species (see under *O. oldhamensis* in Systematic Paleontology).

available. Lespérance and Sheehan (1976) noted that if the faunas from the Ellis Bay Formation are proved to be partly the same age as the Hirnantian Stage, then the term Gamachian has priority in the standard stratigraphic scale over the term Hirnantian. The Ordovician and Silurian conodont faunas are distinguishable at both the generic and specific levels. The Ordovician forms *Decoriconus costulatus*, *Panderodus gibber*, *P. gracilis*, *P. serratus* s.f., and *Pseudooneotodus beckmanni* cross the boundary and are present throughout most of the Silurian strata (Fig. 12). *Walliserodus* is present in both the Ordovician and Silurian strata, although the species may not be the same. The remainder of the Anticosti conodont taxa are restricted to either the Ordovician or the Silurian. However, the change is not entirely abrupt. At sections containing the Ordovician-Silurian boundary (i.e. Sections I and III) there are intervals that contain a mixture of the two faunas, referred to herein as transitional zones (Figs. 13, 14). The recognition of these zones is the result of detailed sampling across the Ordovician-Silurian boundary at intervals of 0.5 m or less. In all transitional zones there is no apparent lithologic break that separates non-mixed Ordovician and Silurian faunas although it is recognized that water depths were probably shallow. At Section I (Fig. 14), *Oulodus robustus* and *Panderodus gracilis* are present until the first occurrence of the Silurian *Ozarkodina* species. *Gamachignathus* is present with *Ozarkodina* until the appearance of *Icriodella*. This transitional zone is about 1.5 m. At Section IIIB (Fig. 14), the strata containing Ordovician forms is 0.5 m below strata containing only *Ozarkodina*. Above this is a calcareous sandstone unit that contains abraded or possibly reworked conodonts ("R" on Fig. 14). The sample above this, however, contains a mixture of both Ordovician and Silurian forms that are not abraded. At section IIIC (Fig. 14), *Aphelognathus* and *Gamachignathus* disappear before the first occurrence of Silurian conodonts but *Oulodus rohneri* co-occurs with species of *Ozarkodina* although in very low numbers. Above this, only the Silurian fauna is present. The transitional zone at Section IIIC has a maximum thickness of about 1 m. Because of the transitional zones, the placement of the Ordovician-Silurian boundary as a single level in a stratigraphic section is difficult and somewhat arbitrary. If based on the last appearance of Ordovician forms then it would involve *Gamachignathus* at Section I and *Oulodus* at Section IIIC. At Section IIIB, the boundary would be somewhere above the last sample collected. It may be appropriate to establish the boundary at the point of first appearance of recognized Silurian forms. This would place it at the first occurrence of either *Ozarkodina hassi* or *O. oldhamensis* in all transitional zones (Fig. 14). This is still arbitrary but it may be more consistently recognizable in strata of the Ellis Bay Formation.

The Silurian conodont fauna of the Ellis Bay Formation contains species found within the *Distomodus kentuckyensis* Assemblage Zone at other localities. These include *Decoriconus costulatus*, *Icriodella deflecta*, *I. discreta*, *Ozarkodina hassi*, *O. oldhamensis* and its associated form species (*Spathognathodus manitoulinensis* Pollock, Rexroad and Nicoll s.f.), *Oulodus? kentuckyensis* (Branson and Branson), *S. elibatus* Pollock, Rexroad, and Nicoll s.f., and *Walliserodus curvatus*. As mentioned previously, this zone is generally correlated with the *I. discreta-I. deflecta* Assemblage Zone and the upper part of the Bereich I interval of the Welsh Borderlands and the Carnic Alps, respectively. The dominant form species of *Panderodus* in the Llandoveryan of North America are *P. simplex* (Branson and Mehl) and *P. uncostatus* (Branson and Mehl). Species of *Panderodus* (*P. gibber* and *P. gracilis*) in the Silurian part of the Ellis Bay Formation are indistinguishable from their equivalents in the Ordovician strata. The Silurian forms of *P. gracilis* are generally more slender, but similar forms do occur in the Ordovician. Hence, these two species of *Panderodus* are not con-

sidered diagnostic of this particular time interval. The relationship of these Silurian *Panderodus* species and the above mentioned form species is unclear.

Certain species that are present in the Ellis Bay fauna differ from those described elsewhere from the *D. kentuckyensis* Zone. *Oulodus? nathani* n.sp. has a similar apparatus and element morphology as *O.? kentuckyensis* but differs in a number of important features (see Systematic Paleontology). *O.? nathani* is more abundant in the oldest Silurian strata on Anticosti and is partly replaced in younger strata by *O.? kentuckyensis*. *Distomodus* aff. *D. kentuckyensis* differs somewhat from *D. kentuckyensis* especially in the form of the cordylodiform element. If the elements referred to the form genus N.gen.A are part of the apparatus, then the platform element differs as well. Other writers have suggested that there is a close relationship between older species of *Distomodus* and younger conodonts. Cooper (1975, 1977) considered that the younger multielement genus *Hadrognathus* is closely related to *Distomodus*, the differences being in the platform and ambalodiform elements. Thus, there may be an evolutionary change in *Distomodus* similar to that of the Ordovician genus *Amorphognathus*. Unfortunately, the material from Anticosti contains relatively few elements of *D. aff. D. kentuckyensis* and N.gen.A s.f. and, therefore, these taxa remain separate. In view of the possible evolutionary and biostratigraphic importance of an apparatus consisting of the above, *D. aff. D. kentuckyensis* is neither formally equated with N.gen.A s.f. nor *D. kentuckyensis*.

On the basis of this evidence, it appears that the Silurian fauna in Member 6 of the Ellis Bay Formation represents a pre-*D. kentuckyensis* Zone interval. The fauna is herein referred to a new zone, the *Oulodus? nathani* Zone. The base of this zone is defined by the first appearance of *O.? nathani* and the zone extends up to the base of the *D. kentuckyensis* Zone. Characteristic species of this zone include *O.? nathani* and *D. kentuckyensis*; other species range up into the *D. kentuckyensis* Zone. The age of this fauna is probably earliest Llandoveryan. At Salmon River (Section III), the base of the zone occurs 3.5 m above the base of Member 6 (Table 6, Fig. 2, Appendix B). Further sampling may show the first appearance of *O.? nathani* to be associated with the *Ozarkodina* species in the two samples below, that is from 2.7 m above the base of Member 6.

Conodont Paleocology

Introduction

There are no apparent extinctions of conodont taxa in the Ellis Bay Formation until the Ordovician-Silurian boundary. Most of the Ordovician and Silurian taxa present range throughout one or more sections. Because of this, and since the sections represent different depositional environments, most changes in conodont distribution can be related to ecologic factors.

The depositional environments are represented by three main lithofacies: a) nearshore, arenaceous and calcareous deposits (Section III); b) offshore, alternating argillaceous and calcareous deposits (Section I); and c) intermediate, argillaceous and calcareous deposits (Section II) that are geographically closer to Section III (Fig. 2). In the following interpretation of conodont paleoecology it is noted that distributional changes due to environment may not only involve depth of water but also other factors such as salinity, nutrient supply, patterns of water circulation, etc., that may in turn be related to proximity to shore or variations in substrate relief (e.g. bioherms).

ELLIS BAY FORMATION (MEMBERS 1-5) CONODONT DISTRIBUTION

KEY FOR RELATIVE ABUNDANCE

- | | |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> APHELOGNATHUS GAMACHIGNATHUS OULODUS PANDERODUS PHRAGMODUS RESIDUAL TAXA | <ul style="list-style-type: none"> barren sample covered interval section overlap approximate thickness |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|

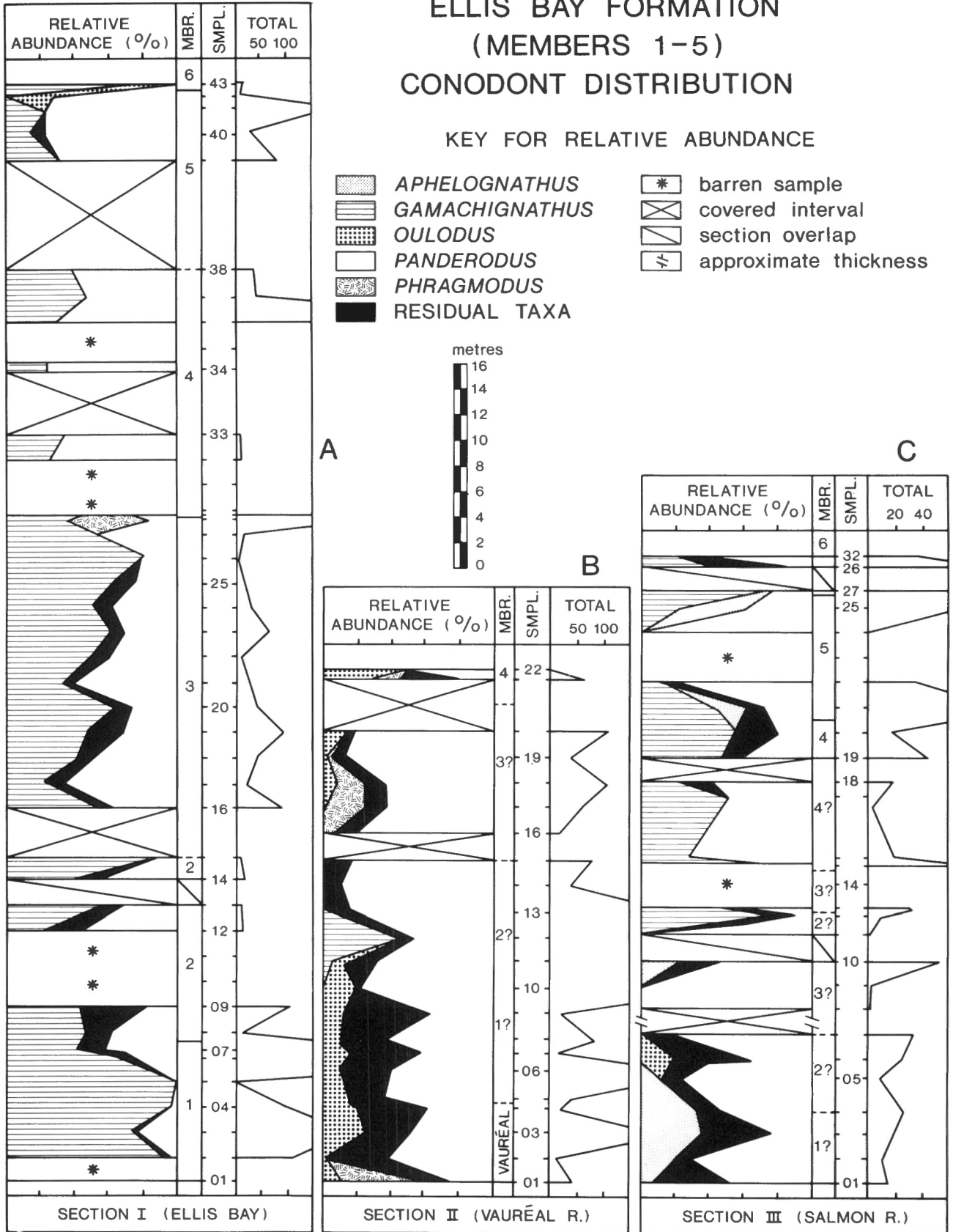


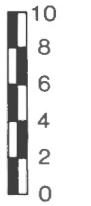
Figure 13. Relative abundance logs for major conodont taxa of Members 1-5, Ellis Bay Formation, Anticosti Island at Sections I, II and III (columns A, B and C respectively). The total conodont yield per sample is given on the right side of each column. The samples correspond to those of Figure 2 and Appendices A and B.

ELLIS BAY FORMATION (MEMBER 6) CONODONT DISTRIBUTION

KEY FOR RELATIVE ABUNDANCE

- APHELOGNATHUS
- GAMACHIGNATHUS
- ICRIODELLA
- OULODUS / OULODUS ?
- OZARKODINA
- PANDERODUS
- RESIDUAL TAXA
- barren sample
- covered interval
- reworked sample

metres (column A and B)



metres (column C)

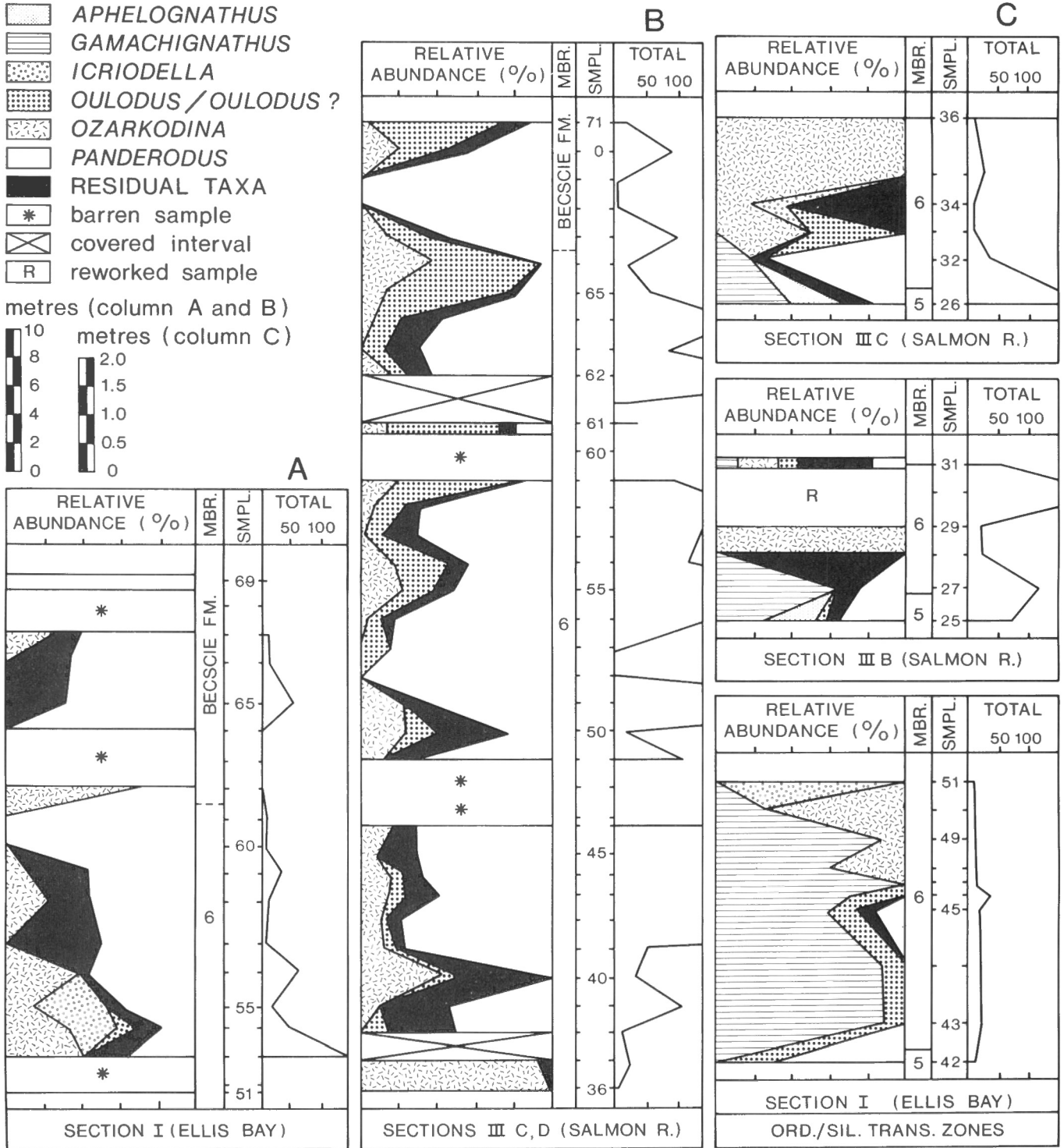
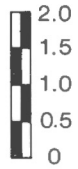


Figure 14. Relative abundance logs for major conodont taxa of Member 6, Ellis Bay Formation, Anticosti Island. The total yield per sample is given on the right side of each column. The sample numbers correspond to those of Figure 2 and Appendices A and B. Column C is an enlargement of the Ordovician-Silurian boundary at Sections I and III. The location of this boundary is placed at the first occurrence of *Ozarkodina* (see Conodont Biostratigraphy for explanation). The scale for Columns A and B differs from that of Column C (see Key). In the log of Section III C (Ordovician/Silurian transition zones), *Gamachignathus* and *Ozarkodina* do not co-occur in sample S33 since *Gamachignathus* is absent above sample S32.

Total numbers of conodonts vary considerably from sample to sample (Appendix A). In general, the Ordovician part of Section III has a low conodont yield in contrast to the other two Ordovician sections. Conversely, in Silurian strata, Section III yielded an order of magnitude more elements than Section I. At Section I, samples from the argillaceous strata of Member 1 contain a higher average number of elements than those from the overlying members. This member also has more abundant macrofossils than the other members. This may indicate a period of relatively slow deposition with a resultant higher concentration of fossil material.

Variation in element size of some apparatuses is evident. The elements of *Panderodus feulneri* (Glenister) and *Aphelognathus pyramidalis* (Branson, Mehl and Branson) are large and robust whereas those of *P. gracilis* (Branson and Mehl) and *A. aff. A. grandis* Branson, Mehl and Branson are smaller and more delicate. The former two species are found in the nearshore, arenaceous limestones of Section III; the latter are from the more offshore, argillaceous limestones of Sections I and II. The elements of *A. pyramidalis* also have a greater basal excavation beneath the processes than do elements of *A. aff. A. grandis*. These differences may suggest that nearshore conodontophorids had apparatuses with elements that were stronger and with larger areas of attachment to cope with a higher energy environment. Moskalenko (1976) and Le Fèvre et al. (1976) found a similar relationship between element size and environment. Comparisons of element size of the same species from different environments are inconclusive.

Two methods of paleoecologic examination were followed in this study. These consider the relative abundance of the conodont taxa (using relative abundance logs) and computer clustering of samples on the basis of similarity of conodont faunas. Interpretation of these methods follows below. An account of the clustering method used in this study is given in Appendix C.

Paleoecology

Relative abundance logs were constructed for the major conodont genera (Figs. 13,14). These, as well as the distribution tables (Appendix A) and sample by sample cluster dendrograms (Appendix C) were used to interpret the conodont paleoecology and to establish conodont communities. Sample yields are commonly low and interpretation of information illustrated by the above genera is necessarily general. However, there are some noteworthy trends.

Figure 13 shows that *Gamachignathus*, along with *Panderodus*, is a major component of the Ordovician fauna at Section I. The lithologic alternation of members does not appear to have a profound effect on the fauna: there are few corresponding changes or migrations into this area of other taxa. *Gamachignathus* does appear to fluctuate in relative abundance near all the member boundaries. The genus decreases in relative abundance at the boundaries of Members 1-2 and 3-4; and increases in relative abundance across the Members 2-3 and Members 5-6 boundaries. At Salmon River (Section III), *Gamachignathus* increases in relative abundance across the boundaries of Members 4-5 and 5-6. Whether this fluctuation is ecologically controlled or coincidental is uncertain.

The relative abundance logs (Fig. 13) illustrate a marked increase of *Gamachignathus* in the lower parts of Sections II and III. The bioherms at Section II are considered to be part of Member 4 (Bolton, 1972) and are underlain by a recessive, argillaceous unit herein considered to be equivalent to the upper part of Member 3. Hence, the point of major influx of *Gamachignathus* at Section II is probably in strata equivalent to Member 2 or the lower part of Member 3. This relatively sudden increase may reflect a

major migration into this area from the west. At Section I (Fig. 13A) there is a noticeable increase in the relative abundance of *Gamachignathus* at the boundary of Members 2-3. The genus at Section III (Fig. 13C) first appears with high relative abundance in samples that may be stratigraphically equivalent to the Member 2-3 boundary. Thus, the major increase of *Gamachignathus* may be correlative with the Member 2-3 boundary.

Panderodus is a major component of the faunas at all three sections, in both Ordovician and Silurian strata. At Sections I and II (Fig. 13A,B) there is an increase in its relative abundance in younger strata. In the Silurian part of Section III (Fig. 14B) *Panderodus* is more abundant in the lower part than in the upper part of the section.

Phragmodus is uncommon in all sections. At Section I (Fig. 13A) the genus is not present until the Member 3-4 boundary where it exhibits a marked increase. This increase corresponds to the drastic reduction in the relative abundance of *Gamachignathus*. At Section II (Fig. 13B) *Phragmodus* occurs in a sample from shale within the Member 4 bioherm, and in the underlying argillaceous unit (upper part of Member 3). This distribution appears to indicate a flourish or influx of *Phragmodus* at the time of deposition of the Member 3-4 strata.

The occurrence of *Phragmodus undatus* in the Ellis Bay Formation is interesting because of its paleoecologic implications suggested by other writers. Other taxa from the bioclastic bed near the Member 4 bioherm (Section II) include *Aphelognathus pyramidalis*, *Drepanoistodus suberectus*, *Oulodus rohneri*, *O. ulrichi* as well as several species of *Panderodus*. The depositional environment of this part of Section II was shallow and relatively nearshore. *A. pyramidalis* and both species of *Oulodus* are suggested herein as being inhabitants of relatively nearshore environments. Tarrant (1977) concluded the same for *A. pyramidalis* and *O. ulrichi*. *P. undatus*, as suggested by other writers, is usually a relatively deep water inhabitant (Seddon and Sweet, 1971; Tarrant, 1977) or lived in more offshore waters (Barnes and Fahraeus, 1975). Thus, the occurrence of *P. undatus* near this bioherm is somewhat anomalous but it is noted that in other study areas it is not excluded from more shallow environments.

At Section I (Fig. 13A), bioherms of the lower part of Member 6 contain primarily *Gamachignathus* species and *Oulodus robustus*. This latter species was shown by Tarrant (1977) to inhabit deeper water than did *O. ulrichi* for the Upper Ordovician of southern Ontario. As with *Phragmodus*, the distribution of *O. robustus* in the Ellis Bay Formation suggests a somewhat different pattern. The member 6 bioherms appear to have been common and widespread at this horizon, and may have significantly influenced local environments. At Section III, Member 6 strata close to the bioherms (Section IIIC) and strata without exposed bioherms (Section IIIB) were sampled. *Gamachignathus* was a major component only at the latter section and this may reflect a preference for the more off-reef, lower energy environments. *Panderodus* was uncommon near the bioherms.

Also present, but in low abundance are genera whose paleoecology has been considered by other writers (e.g. Seddon and Sweet, 1971; Barnes and Fahraeus, 1975; Aldridge, 1976; Le Fèvre et al., 1976). These genera include *Amorphognathus*, *Belodina*, *Distomodus*, *Drepanoistodus*, *Icriodella*, *Paroistodus?* and *Rhipidognathus*. The paleoecological significance of representatives of these genera cannot be elaborated further because of their low abundance.

The Ordovician conodont fauna discussed herein displays a marked geographic and, in places, vertical segregation of taxa. The Silurian fauna is sparse in Section I, hence geographic differences cannot be studied. At Section III, however, this fauna changes vertically. The different faunal associations between and within the sections are considered to represent conodontophorid

communities. As with many other such studies, the term 'community' is used in a restricted sense: it refers only to the conodontophorids. The major associations of conodonts are referred to as communities. It may be assumed that communities based on genera are more broadly defined than those based on species. Species of *Panderodus* have been included with ramiform conodonts within the various communities. As they have a lateral differentiation similar to the ramiform species, we prefer to consider both simple cone and ramiform conodonts as part of the same community, regardless of any proposed pelagic or nektobenthic habit. Five conodont communities are described, three of which are from Ordovician strata.

Community A (Fig. 15) corresponds with the Ordovician part of Section I (offshore environment). Although there is a regular alternation of lithologies into six distinctive members, there is no corresponding alternation of communities in this area. It is thought that if transgressive-regressive phases were involved, the magnitude was not great. The persistence of this community may be the result of expansion and contraction of a relatively stable and widespread offshore community. The community is dominated by the two species of *Gamachignathus* and by *Panderodus gracilis*. These two genera represent about 90 per cent of the fauna, both being approximately equal in abundance. The following species of *Panderodus* are also present (in decreasing abundance): *P. panderi*, *P. aff. P. staufferi* and *P. clinatus*, each being less than 3 per cent of the fauna. *P. gibber* and *P. serratus* s.f. are rare. Rare genera include *Amorphognathus*, *Aphelognathus*, *Drepanoistodus*, *Oulodus*, *Phragmodus*, *Pseudooneotodus* and *Walliserodus*. This community is unlike any previously described.

The Ordovician *Community B* (Fig. 15) is found in the more nearshore environments of Section II. The fauna is dominated by *Panderodus* species (about 65 per cent of total) with the ramiform conodonts representing about 25 per cent of the total fauna. *Oulodus rohneri*, *O. ulrichi*, *Amorphognathus* cf. *A. ordovicicus* and *Aphelognathus* aff. *A. grandis* are the common ramiform conodonts. *Gamachignathus* is abundant in one sample in this section, otherwise it occurs in low numbers. The *Panderodus* component of this community is the most diverse of all three sections. *P. gracilis* is the most abundant species, but it does not dominate the *Panderodus* fauna as it does at Section I. The major species present (in decreasing abundance) are: *P. feulneri*, *P. clinatus*, *P. aff. P. staufferi*, *P. liratus* and *P. gibber*. The three new form species of *Panderodus* and *P. serratus* s.f. are also present, but rare. *Drepanoistodus* and three species of *Belodina* are also found in this community in moderate abundance. Tarrant (1977) found *A. grandis* and *O. ulrichi* in relatively nearshore, shallow water deposits of the Upper Ordovician of southern Ontario.

The conodont fauna of *Community C* (Fig. 15) is found in the lower part (Members 1? and 2?) of Section III. This section is considered the most nearshore of all three sections. Conodonts in these strata are few but are characterized by the robust species *Aphelognathus pyramidalis* and *Panderodus feulneri* which occur along with *P. gracilis* and *P. clinatus*. *P. gibber*, *P. liratus* and *P. aff. P. staufferi* are also present. Other compound conodonts found in the other sections are essentially absent. *Drepanoistodus* and *Belodina* are present in low numbers. *A. pyramidalis* was found by Tarrant (1977) to be an inhabitant of more nearshore environments than *A. grandis*.

Communities D and *E* (Fig. 16) are present in Silurian strata in Section III. The lithology of these strata suggests that the environment was relatively shallow and nearshore. There is no indication of a marked increase in water depth after the maximum regression at the Ordovician-Silurian boundary. These communities are dominated by the same four genera: *Panderodus*, *Ozarkodina*, *Walliserodus* and *Oulodus*?. The remaining taxa represent less than 5 per cent of the total. *P. gracilis* is the most common species of *Panderodus*; *P. gibber* and *P. serratus* are numeri-

cally minor and rare components, respectively. All three species are present in both communities, as are both species of *Ozarkodina* and *Oulodus*?. The distinction between these two communities is based on replacement of one dominant species of both *Ozarkodina* and *Oulodus*?. *Walliserodus* is a consistent component of both communities.

Community D corresponds to the lower part of the Silurian of Section III with *Ozarkodina oldhamensis* and *Oulodus? nathani* being the dominant ramiform species. Those of *Community E* are *Oulodus? kentuckyensis* and *Ozarkodina hassi*. *Oulodus?* and *Ozarkodina* represent a larger component of this fauna than they do in *Community D*. This increase appears to be at the expense of *Panderodus*. Other genera in both of these Silurian communities include *Decoriconus*, *Distomodus* and *Icriodella*.

Discussion of Community Patterns

The three Ordovician communities can be related to proximity of the ancient shoreline. Whether the environmental control was depth or other factors such as temperature, salinity or energy (or a combination of factors) cannot be demonstrated. Although it is suggested that the offshore environments were likely deeper, cooler and of lower energy than the nearshore, these differences were probably not great.

The major influx of *Gamachignathus* in the lower parts of Sections II and III is likely due to a migration from offshore areas. The sudden flourish of *Phragmodus* near the boundary of Members 3-4 at Sections I and II may represent expansion of a community in which it was a major component. Barnes and Fähræus (1975) suggested that a Midcontinent Province community dominated by *Phragmodus* existed in an environment offshore to a community characterized by *Oulodus*, *Plectodina* and *Belodina* (similar to *Community B*). The occurrence of the *Gamachignathus*-dominated community offshore to *Community B* may suggest that it replaced the *Phragmodus* community in the latest Ordovician (Gamachian) or restricted the latter community to a narrow area between *Communities A* and *B*.

The relative abundance of *Panderodus* species and the ramiform species appears to be inversely related. Aldridge (1976) found that *Panderodus* was more abundant in samples from deeper water environments and believed that the genus was controlled by a parameter that was significantly depth dependent. This observation cannot be supported herein. In the Ordovician, *Panderodus* represents approximately 40, 60 and 43 per cent of the faunas from Sections III, II and I. The depth gradient of the environment of the Ellis Bay Formation may have been less than that in Aldridge's (1976) study area. The increase in the *Panderodus* component at Section II is in part due to an increase in the relative abundance of *P. gracilis*, a species of *Panderodus* that is more dominant in the offshore environment of Section I.

Comparison of the Ordovician conodont communities can be made with those of other writers. Barnes and Fähræus (1975) found that in the Cincinnati of the Midcontinent Province at least three communities were present away from the shore. The littoral community characterized by *Rhipidognathus* is not recognized in the Ellis Bay Formation. Its absence may be due to a replacement in the latest Ordovician by *Community C*, or it may have been located even more nearshore. The rare occurrence of this genus in Sections II and III suggests only that extinction was not a factor. The *Rhipidognathus* community on the Hudson Bay Platform was found by Le Fèvre et al. (1976) to be associated with evaporites, and when compared with other occurrences it was concluded that *Rhipidognathus* was euryhaline and stenographic. Barnes and Fähræus (1975) and Le Fèvre et al. (1976) noted that the more nearshore communities were of low diversity and had conodonts with elements that were large and robust. This is generally true of *Community C*.

Offshore to the *Rhipidognathus* community of both Barnes and Fähræus (1975) and Le Fèvre et al. (1976) was a shallow subtidal community characterized by *Oulodus*, *Plectodina* and *Belodina*. Le Fèvre et al. also found species of *Amorphognathus*, *Paroistodus* and *Plegagnathus*. Community B of this study is equated with the shallow subtidal community of the above writers. It is recognized that the interpretation of some of the communities of this study may be of a lower taxonomic level than those of other studies: Communities B and C may be subdivisions of the shallow subtidal community of the above studies.

The offshore community of the Midcontinent Province (*Phragmodus* community) is not present in the strata studied on Anticosti. The new offshore community (Community A) cannot at present be equated to the offshore communities of Barnes and Fähræus (1975). The domination of this community by a low number of taxa (*Gamachignathus* and *Panderodus gracilis*) is similar to that of offshore communities of Barnes and Fähræus (1975). *Gamachignathus* probably has its closest affinity to *Prioniodus* (= *Baltoniodus*), a conodont of the North Atlantic Province shallow sublittoral environment (Barnes and Fähræus, 1975). If it is a member of the North Atlantic Province, its occurrence in the offshore environment could indicate a mixing of the two provinces at this time. Bergström and Carnes (1976) studied a North Atlantic Province fauna from the Middle Ordovician Holston Formation of Tennessee and noted that *Prioniodus* (*sensu stricto*) occurred in carbonate bank environments.

Interpretation of the Silurian conodont paleoecology of the Ellis Bay Formation is restricted due to limited data from Section I. Communities D and E differ at the specific rather than generic level; there is a change in relative abundance of certain taxa. It cannot be shown conclusively that the replacement of faunas is due to environmental changes. Study of the Becscie Formation and younger faunas may show that this change is evolutionary. If the changes in fauna were environmentally controlled, the low level of taxonomic difference may suggest that the environmental changes were minimal.

Ozarkodina and *Oulodus* are considered herein to indicate a shallow sublittoral environment. Aldridge (1976) compared Llandoveryan to Ludlovian conodont faunas from the Welsh Borderland with known brachiopod-dominated macrofossil communities of Ziegler (1965) and others. *Ozarkodina hassi* was reported from nearshore, shallow water deposits. Other Llandoveryan species of *Ozarkodina* and *Oulodus* (or their constituent form species) are found in shallow water environments or are widely distributed. Le Fèvre et al. (1976) found that the generalized early Middle Llandoveryan fauna consisted of *Ozarkodina* and *Llandoverygnathus* with *Panderodus* being ubiquitous. They found that in the Late Llandoveryan community differentiation occurred. The more offshore community contained *Ozarkodina*, but since a major component of these Late Llandoveryan communities were platform-bearing taxa, no further comparison can be made. Sweet and Schönlaub (1975) thought that *Oulodus* in the Llandoveryan was adapted to relatively shallow water environments, as were Ordovician species of *Oulodus*. Shallow water, high energy environments in the Llandoveryan were found by Aldridge (1976) to contain *Icriodella* and *Distomodus*. Le Fèvre et al. (1976) included these genera (along with "*Drepanodus*" and *Pelekysgnathus*?) in the littoral community. The above genera display many of the characteristics found in Ordovician littoral faunas, that is, robust elements with crude denticulation, expansive basal excavations and little white matter. These characteristics are found in *Icriodella* and its Ordovician distribution (Seddon and Sweet, 1971; Barnes and Fähræus, 1975) suggests that it was a shallow water, littoral inhabitant. Further study may confirm that *Distomodus* and *Icriodella* are relatively nearshore genera. The Silurian communities of this study can be compared with the fauna from the Brassfield Formation of Cooper (1975). He

found *Ozarkodina hassi* along with elements referable herein to *Oulodus? kentuckyensis*; *O. oldhamensis* was rare. This is an association similar to that of Community E. Cooper's (1975) fauna differed in that *Distomodus* and *Icriodella* were more abundant. If these two genera do indeed represent nearshore environments, then their associated species, *O. hassi* and *O.? kentuckyensis* may be more nearshore inhabitants than *Ozarkodina oldhamensis* and *O.? nathani* n.sp. Community E first occurs in the upper part of the Silurian Section III and may indicate a progressive shallowing due to progradation or regression towards the Ellis Bay-Becscie Formation boundary.

To summarize the conodont paleoecology, the three Ordovician communities are related to shoreline proximity. The upward replacement of faunal associations of the intermediate and nearshore environments by one more characteristic of the offshore environment indicates a corresponding change in environment. The cause of this change in environment is unknown: it is empirically noted that this was a time of continental glaciation in North Africa and this may have had an effect on the environment, such as lowering of sea level, cooling, etc. The latest Ordovician fauna of the Ellis Bay Formation is one of low diversity and is characterized by offshore taxa that may have had a preference for cooler waters.

Aldridge (1976) also found a marked decrease in diversity in post-Llandoveryan faunas and thought that this was the result of some major environmental crisis. The almost complete replacement of the Ordovician fauna by Silurian conodontophorids suggests a severe ecologic crisis, considered herein to be due to a maximum regression caused by the Ordovician-Silurian glaciation. The surviving taxa on Anticosti are all simple cones, the major species being *Panderodus gracilis*, a species shown by its distribution in the Ordovician communities to be eurygraphic and possibly euryhaline. The oldest nearshore Silurian community has a large number of simple cones (especially *P. gracilis*), suggesting an occupation of the area by a generalized, opportunistic species. The replacement of this fauna in younger strata could be evolutionary, or it could represent a replacement of a nearshore community by one that inhabited even more nearshore waters. This change in fauna includes a reduction of the *Panderodus* component. The occurrence of many species of conodonts in distinct lateral associations in the Ordovician suggests a nektobenthic mode of habit rather than a depth stratified habit.

Ordovician-Silurian Boundary

A major continental glaciation occurred in North Africa near the time boundary between Ordovician and Silurian and has been studied by many writers (Beuf and Biju-Duval, 1966; Crowell and Frakes, 1970; Beuf et al., 1971; Harland, 1972; Allen, 1975, among others). A glaciation of continental proportions has profound worldwide influence on environments. Thus in more recent geological time waxing and waning of the Pleistocene glaciation caused oscillations in sea level (Mörner, 1971), an estimated 100 m or more (Newell and Bloom, 1970).

Evidence of Ordovician-Silurian glaciation has been obtained from an extensive area. Glacial and related deposits have been found not only in North Africa but also in South Africa (Cocks et al., 1970; Daily and Cooper, 1976), France (Doré and LeGall, 1972), and South America (Berry and Boucot, 1972). The age of this glaciation is generally considered to be from Late Caradocian or Ashgillian to middle Llandoveryan (Beuf et al., 1971; Destombes, 1968, 1971; Havlicek, 1971; Cocks et al., 1970). Berry and Boucot (1973) summarized the offlap-onlap evidence for the late Ordovician-early Silurian strata at widely located areas. Dennison (1976) and Thompson (1970) suggested that much of the Queenston delta complex was the result of glacio-eustatic lowering of the sea level in late Ordovician times.

Stratigraphic evidence includes hiatuses and lithologic changes. Sheehan (1975) suggested that fluctuations in ice mass may have triggered community migrations during the Lower and Middle Llandoveryan. Following glaciation, a rapid transgression resulted in shale overlying glacial and periglacial deposits in North Africa (Bennacef et al., 1971).

One of the most noticeable effects of the Ordovician-Silurian glaciation in the lower latitudes is the faunal changeover. Boucot (1968), Boucot and Johnson (1972) and Sheehan (1973) noted an almost complete replacement of North American brachiopods during this interval. A phyletic changeover is also seen in graptolites (Berry and Boucot, 1973), ostracodes (Copeland, 1973, 1974), corals (Kaljo and Klaamann, 1973) and trilobites (Lespérance, 1974). This event also affected at least some faunas at a community (Sheehan, 1973) and provincial (Sheehan, 1975) level. The causes for this rapid turnover of marine faunas are complex, involving biologic, climatic and paleogeographic factors. Presently, explanations offered by some writers are inadequate for all faunal groups. Part of the problem is a relatively poor knowledge of the faunal distribution at that time and an inadequate understanding of the above mentioned factors. The various models and hypotheses will not be delved into here; the reader is referred to other studies (Valentine, 1967, 1968, 1973 for a model of climatic regulation of species diversity and extinction; Moore, 1954, Newell, 1967, and Kauffman, 1977 for biologic effects of regression; Bretsky and Lorenz, 1970a, 1970b for causes of extinction; and Sheehan, 1975 for causes of a faunal changeover).

The faunal changeover across the Ordovician-Silurian boundary in known stratigraphic sequences is significant and has prompted the search for sections that represent a more complete interval of time. To properly define the boundary on paleontologic evidence, several major fossil groups need to be represented, and in a variety of paleoenvironments. However, many potential sections either lack more than one or two diagnostic groups or have not been fully studied. To illustrate a complete stratigraphic sequence across this interval a section also needs to have evidence of continuous deposition.

The following comments concern previously studied strata that are or have been considered to represent the uppermost Ordovician and lowermost Silurian interval. These comments are restricted to those sections where conodont studies have been undertaken.

Three conodont faunas of the Edgewood Group in Missouri and Illinois were described by Satterfield (1971) and Thompson and Satterfield (1975). The Late Ordovician *Amorphognathus ordovicicus* fauna was found to be mixed locally with the "*Prioniodus ferrarius*" fauna. The co-occurrence of these two faunas with the Silurian *Paltodus dyscritus* (*Distomodus kentuckyensis* Zone) fauna was thought to represent lithologic reworking. The "*P. ferrarius*" fauna has not been previously reported (but may be present in northern Yukon, see below).

Study of topotype material (Clarksville Section of Thompson and Satterfield, 1975) by the authors confirms a Late Ordovician-Early Silurian age for the conodont fauna. The occurrence of "*P. ferrarius*" Knüpfers s.f. with other elements (*P. girardeauensis* Satterfield s.f., "*Trichonodella asymmetrica*" (Knüpfers) s.f., cordylodiform elements, tetraprioniodiform elements) is thought to represent a new multielement species of *Prioniodus*. Most of the other components of the Ordovician fauna are typical of the Midcontinent Province. An unnamed species of *Plectodina* is also present; specimens similar to this have been found in the Vauréal Formation, Anticosti Island (Nowlan and Barnes, this volume) and in samples from Hudson Bay and Manitoba (Barnes and Munro, 1973). This fauna suggests a Richmondian or younger age but cannot be equated with the fauna from the Ellis Bay

Formation. The Silurian fauna from the topotype material contains *Ozarkodina oldhamensis* (Rexroad), *Spathognathodus elibatus* Pollock, Rexroad and Nicoll s.f. and *Walliserodus curvatus* (Branson and Branson), species indicative of the *Distomodus kentuckyensis* Zone. Thompson and Satterfield (1975) reported elements of the *Llandoverygnathus celloni* Zone immediately overlying the above Silurian fauna. There is lithologic evidence of an unconformity (intraclastic beds, irregular erosional surfaces) at the Ordovician-Silurian boundary in the sections studied by Thompson and Satterfield (1975).

The Silurian conodont fauna of the Carnic Alps in Western Europe provided Walliser (1962, 1964, 1971) with the basis for the European conodont faunal succession. Serpagli (1967) studied an Ashgillian fauna from the Carnic Alps that included an element which is similar to *W. cf. W. curvatus* (Branson and Branson) of the Ordovician fauna of this study. Graptolite evidence suggests that there was continuous deposition across the Ordovician-Silurian boundary in sections from the Austrian-Italian Carnic Alps. However, his recent studies (Schönlaub, 1971, 1977) have led to the recognition of an unconformity (hardgrounds, lithologic reworking, microconglomerates, erosional surfaces). He believed that a short stratigraphic gap was present between the two systems at those localities.

The Road River Formation in northern Yukon Territory is a sequence of basinal shale, mudstone and chert. The graptolite zones and lithostratigraphy from the upper canyon of the Peel River have been described by Lenz and Pedder (1972). A. D. McCracken collected samples from rare limestone beds (debris flows?) in Ashgillian and Llandoveryan strata from both the above section and one nearby (Blackstone River). The youngest Ordovician fauna from the Peel River section contains *Amorphognathus ordovicicus* Branson and Mehl and elements similar to those from the Upper Ordovician Girardeau Limestone in Missouri and Illinois (Satterfield, 1971). Samples above this (and across the graptolite-based Ordovician-Silurian boundary) were unproductive. Samples from the Blackstone River section yielded abundant and well preserved conodonts from the *Llandoverygnathus celloni* Zone. Samples from older strata at this section were barren of conodonts. The Ordovician-Silurian boundary cannot be delineated by conodonts, as chert samples collected have not yet been processed.

The Ordovician-Silurian boundary on Anticosti is considered to be in the lower part of Member 6 of the Ellis Bay Formation, about 2-3 m above the base of Member 6. There is no evidence for a lithologic break although there is evidence of shallowing towards the east. The conodont transitional zones, which contain elements from both periods, probably represent co-occurrence of faunas or lithologic reworking but there is no clear evidence of the latter. The Ordovician-Silurian boundary is herein placed at the first occurrence of species of *Ozarkodina* in the transitional zones (i.e. *O. hassi* and/or *O. oldhamensis*).

It has previously been suggested herein that the conodont fauna may represent an undefined time interval of the latest Ordovician and possibly earliest Silurian. Other fossil groups appear to represent a previously undefined time interval (e.g. graptolites, chitinozoans) or are noted by the absence of diagnostic forms near the boundary (e.g. ostracodes). Macrofossils (e.g. brachiopods, trilobites) compare with those from strata of the midcontinent. These groups, however, have been studied in less detail.

It is suggested herein that the Ellis Bay Formation contains one of the most complete latest Ordovician and earliest Silurian sequences known. The reintroduction of the Gamachian Stage (Schuchert and Twenhofel, 1910; Twenhofel, 1928) is advocated and a Fauna 13 and a new early Silurian conodont Zone are proposed. Anticosti Island has considerable potential as a stratotype or parastratotype for the base of the Silurian System.

Systematic Paleontology

The systematic paleontology of this paper has been co-ordinated with that of Nowlan and Barnes (this volume) to avoid duplication of generic discussions and details of those taxa present in both the Vauréal and Ellis Bay formations. Elements that cannot be placed within multielement apparatuses are treated as form species and are assigned the abbreviation s.f. (*sensu formo*) after the binomen, as used by Barnes and Poplawski (1973). Quotation marks are placed around the names of previously identified taxa that are considered to be incorrectly named and in need of later revision. Elements within an apparatus are referred to using the suffix -iform with the form generic name. If two form genera are present in the same apparatus, then the same suffix is used as above for one element-type, and with the form species name for the other.

Some individual element totals are followed by '#'; this indicates that the totals are for both Ordovician and Silurian forms. Elements that are shared by more than one species have the symbol '@' following the element totals.

Genus *Amorphognathus* Branson and Mehl, 1933

Type species. *Amorphognathus ordovicica* Branson and Mehl, 1933.

Amorphognathus cf. *A. ordovicicus* Branson and Mehl

Plate 4, figs. 34-43

Amorphognathiform element

cf. *Amorphognathus ordovicica* Branson and Mehl, 1933, p. 127, Pl. 10, fig. 38.

Multielement synonymy

cf. *Amorphognathus ordovicicus* Branson and Mehl. Palmieri, 1978, p. 7-8, Pl. 11, figs. 1-12; fig. 7 (2a-4d); Nowlan and Barnes, 1980, p. 9, Pl. 1, figs. 1-14 (includes synonymy to 1978).

Remarks. The elements of the ramiform complex and the ambalodiform element are indistinguishable from those of *A. ordovicicus*. However, the holodontiform element differs from that of *A. ordovicicus* in that it has an inner lateral process that is undenticulated and aborally extended. This distinction in holodontiform elements may be important in determining the evolutionary lineage of *Amorphognathus*. The platform elements are small, fragmentary and as a result cannot be readily compared to platforms of *A. ordovicicus*. The one complete platform element is a small, six processed element.

Material. Elements: eoligonodiniform - 9; keislognathiform - 5; hibbardelliform - 7; tetraprioniodiform - 11; holodontiform - 11; ambalodiform - 37; platform - 36.

Types. Hypotypes, GSC 59983-59992.

Genus *Aphelognathus* Branson, Mehl and Branson, 1951

Type species. *Aphelognathus grandis* Branson, Mehl and Branson, 1951.

Aphelognathus aff. *A. grandis* Branson, Mehl and Branson

Plate 3, figs. 34-43

Aphelognathiform element

aff. *Aphelognathus grandis* Branson, Mehl and Branson, 1951, p. 9, Pl. 2, figs. 11-14.

Multielement synonymy

aff. *Aphelognathus grandis* Branson, Mehl and Branson. Nowlan and Barnes, 1980, p. 10, Pl. 5, figs. 5-10 (includes synonymy to 1978).

Description. For all elements: Cusp and denticles are laterally compressed with sharp edges. Denticles are long and discrete except on blade element. Basal cavity is shallow, extending under processes. Deep base occurs under cusp. White matter occurs in cusp and denticles; in small distal denticles white matter occurs only in tips.

Eoligonodiniform element: Anterior margin has short antero-lateral process that is perpendicular to posterior process and has one, rarely two long denticles. Basal cavity is flared to greater degree on outer lateral face.

Zygonathiform element: Cusp is flexed to side of long process. Short process generally has only one denticle. Cusp has faint costa on both lateral faces. Anterior face of base is concave. Posterior face has high, narrow basal flare.

Trichonodelliform element: Cusp has faint costa on both antero-lateral margins. Lateral processes are straight to slightly arched and bowed. Processes diverge at about 80 degrees. Posterior process is short; undenticulated in small specimens, larger specimens have one or two small denticles. Basal cavity extends for at least part of process length. Anterior face of element is concave.

Cyrtioniodiform element: Cusp is sharply reclined at base and flexed in postero-lateral direction. Anterior margin or anticusp develops short process bearing one slender denticle. Posterior process not preserved after first denticle. Outer lateral face of base is concave, opposite face has high, narrow half cone shaped flare posterior to cusp.

Prioniodiniform element: Processes are subequal in length. Base has high, narrow flare on both faces beneath cusp.

Aphelognathiform element: Element is blade-like and slightly arched and bowed. Cusp is broader, higher than denticles. Denticles are short. Anterior process denticles are slightly reclined, basally confluent. In large specimens, proximal denticles are confluent for most of length. Posterior process denticles are discrete, suberect. Anterior process is slightly shorter but higher than posterior process. Small, narrow half cone flares occur on both faces beneath cusp.

Remarks. Most elements of *A. aff. A. grandis* are small and delicate making direct comparison with other species difficult. The zygonathiform, prioniodiniform and aphelognathiform elements are similar to small forms of *A. grandis* available from collections of the Georgian Bay Formation in southern Ontario and the Vauréal Formation, Anticosti Island. Larger eoligonodiniform and trichonodelliform elements are similar to specimens of *A. grandis* from the former area in that they have two antero-lateral peg-like denticles and a weakly denticulated posterior process, respectively. The cyrtioniodiform element differs from that of *A. grandis* in that the anterior margin is extended into a short process with one denticle. The aphelognathiform element is distinguished from small blade elements of *Plectodina inclinata* (Glenister) in that the processes are more equal in length and are less arched. The process length also distinguishes the blade element from small elements of *A. pyramidalis* (Branson, Mehl and Branson) which have a relatively short posterior process.

Material. Elements: eoligonodiniform - 14; zygonathiform - 25; trichonodelliform - 10; cyrtioniodiform - 5; prioniodiniform - 43; aphelognathiform - 80.

Types. Hypotypes, GSC 59993-60002.

Aphelognathus pyramidalis (Branson, Mehl and Branson)

Plate 3, figs. 44-53

Pyramidaliform element

Zygonathus pyramidalis Branson, Mehl and Branson, 1951, p. 12, Pl. 3, figs. 10-16, 21.

Multielement synonymy

Aphelognathus pyramidalis (Branson, Mehl and Branson). Nowlan and Barnes, 1980, p. 10, Pl. 5, figs. 1-4 (includes synonymy to 1978).

Description. For all elements: Cusp has costae or sharp edges that extend for its full length, merging with processes. Denticles are generally closely packed or confluent at bases. Cusp and denticle cross-sections are subcircular. Basal cavity is deep and extends beneath processes. Base is flared beneath cusp. Some specimens have well developed basal sheath. White matter is present in cusp and denticles. Distal denticles commonly lack white matter.

Zygonathiform element: Processes are asymmetrical and arched such that aboral margin of lateral and antero-lateral processes are convex and concave, respectively. Cusp is directed out of plane of processes. Denticles are long, and in large specimens distal denticles are slightly compressed. Lobate basal flare is aborally directed. Flare on posterior face is more pronounced than on anterior.

Prioniodiniform element (= cyrtioniodiform (prioniodiniform) element of Nowlan and Barnes, 1980): Cusp is laterally compressed and directed out of plane of processes. Processes are subequal in length. Denticles are short. Basal flare on inner face is larger than on outer face.

Aphelognathiform element: Element is slightly arched and bowed. Posterior process is shorter than anterior, becoming proportionally shorter on larger specimens. Cusp is short, broader than denticles, incorporating up to three proximal denticles in large specimens. Denticles are peg-like and confluent proximally, becoming triangular and laterally compressed distally. Base is high relative to denticles. Base of anterior process is higher than that of posterior process. Basal cavity is widely excavated. Basal flare is developed more on outer face than on inner face.

Remarks. The pyramidaliform (= prioniodiniform of Nowlan and Barnes, this volume) and trichonodelliform elements have been thoroughly described by Branson, Mehl and Branson (1951) and Kohut and Sweet (1968), respectively. Kohut and Sweet (1968) regarded *Z. pyramidalis* as a bielement species with eoligonodiform and zygonathiform elements. Tarrant (1977) reconstructed the apparatus of *A. pyramidalis* to include the elements of *Z. pyramidalis*. His interpretation is followed herein. The apparatus of *A. pyramidalis* contains six element-types, the zygonathiform element being represented by an asymmetrical trichonodelliform element rather than *Z. pyramidalis* s.f. (*sensu* Kohut and Sweet, 1968). *Z. pyramidalis* s.f. is one of two prioniodiniform elements in the second transition series. The other, (*Microcoelodus panderi* Branson, Mehl and Branson s.f.) belongs in the cyrtioniodiform position.

The prioniodiniform element of *A. pyramidalis* is similar to the equivalent element of *Oulodus robustus* (Branson, Mehl and Branson). However, the cusp and denticles of the former are wider and more laterally compressed. The aphelognathiform element of *A. pyramidalis* differs from the same element of *A. aff. A. grandis* (Branson, Mehl and Branson) in that the former is more arched and the posterior process is shorter than the anterior. The denticulation of the remaining elements and the wide short cusp of the prioniodiniform and pyramidaliform elements distinguish *A. pyramidalis* from other species of *Aphelognathus* and *Oulodus*.

Oberg (1966) described *Z. pyramidalis* s.f. and other form species from the Winnipeg Formation of Manitoba. Uyeno (1974) illustrated elements of the multielement species *Plectodina aculeata* (Stauffer) from the Hull Formation in Ontario and Québec. Some of the elements in the above strata are comparable to elements of *A. pyramidalis*. Both of these formations are considered to be Middle Ordovician and since the stratigraphic range of *A. pyramidalis* is unclear, they are not included in the synonymy.

The cordylodiform elements listed in Appendix A may be broken eoligonodiform elements.

Material. Elements: cordylodiform - 2?; eoligonodiform - 9; zygonathiform - 4; trichonodelliform - 4; prioniodiniform - 5; pyramidaliform - 6; aphelognathiform - 19.

Types. Hypotypes, GSC 60003-60012.

Genus *Belodella* Ethington, 1959Type species. *Belodus devonicus* Stauffer, 1940.*Belodella?* n.sp.A s.f.

Plate 3, fig. 26

Description. Element has reclined cusp with denticulate posterior margin and is slightly bowed. Anterior margin is sharp. Cusp has medial costa on inner face that extends for full length of element. Costa is developed at junction of concave antero- and postero-lateral faces. Postero-lateral face merges with denticles. Denticles are long, basally confluent, numbering at least nine and are inclined towards tip of cusp. Outer face of element is similar to inner face but costa is more subdued and face is less concave. Base is expanded posteriorly. Basal cavity extends for about two-thirds height of cusp. White matter occurs in tip of cusp above basal cavity and in denticles.

Remarks. The generic assignment of this single Silurian specimen is questioned because of the lack of preservation of the basal part of the posterior margin, hence it may be a form species of *Belodella* or *Belodina*. However, unlike species of *Belodina*, this specimen lacks an offset costa that extends across the base of the denticles. All previously described species of *Belodella* have lateral costae that are more anteriorly situated. Elements of *B. cf. B. devonica* (Stauffer) as described by Cooper (1976) are longer, more narrow and more finely denticulated than *B. n.sp.A* s.f. Other species (e.g. *B. anomalis* Cooper, 1974, *B. n.sp. Rexroad and Craig* s.f., 1971) differ in that the cusp is more erect proximally and recurved distally.

Material. 1 element.

Type. Figured specimen, GSC 60013.

Genus *Belodina* Ethington, 1959

Type species. *Belodus compressus* Branson and Mehl, 1933 (= *Belodus grandis* Stauffer 1935b, designated as type species of *Belodina* by Ethington, 1959); emend. Bergström and Sweet, 1966.

Belodina compressa (Branson and Mehl)

Plate 3, figs. 10-12, 16-18

Compressiform element

Belodus compressus Branson and Mehl, 1933, p. 114, Pl. 9, figs. 15, 16.

Multielement synonymy

Belodina compressa (Branson and Mehl). Palmieri, 1978, p. 13, Pl. 3, figs. 11-15, 20-21, 23-25; Pl. 4, figs. 1-17; fig. 5 (6-10, 16-19); Nowlan and Barnes, this volume, p. 12, Pl. 8, figs. 1-4 (includes synonymy to 1978).

Remarks. The grandiform elements differ from typical forms of *B. grandis* (Branson and Mehl) s.f. in that the distal end of the cusp is usually wide with a rounded apex, rather than being sharply pointed. In this respect, they are more similar to grandiform elements of *B. compressa* and *B. leithi* Ethington and Furnish from the Melville Peninsula, Canadian Arctic (Barnes, 1977). The grandiform elements are also bowed inwards, a characteristic of *B. leithi* (Barnes, 1977, p. 105). The grandiform element of *B. leithi* differs in that the heel is long, narrow, and more aborally directed, and the denticles are longer and more numerous.

Material. Elements: grandiform - 7; compressiform - 9; eobelodiform - 2.

Types. Hypotypes, GSC 60014-60019.

Belodina dispansa (Glenister)

Plate 3, figs. 19-21

Grandiform element

Belodus dispansus Glenister, 1957, p. 729-730, Pl. 88, figs. 14, 15.

Multielement synonymy

Belodina dispansa (Glenister). Nowlan and Barnes, this volume, p. 12, Pl. 8, figs. 6, 7, 10, 11.

Material. Elements: grandiform - 2; compressiform - 6.

Types. Hypotypes, GSC 60020-60022.

Belodina profunda (Branson and Mehl)

Plate 3, figs. 13-15

Belodus profundus Branson and Mehl, 1933, p. 125, Pl. 10, fig. 25.

Multielement synonymy

Belodina profunda (Branson and Mehl). Nowlan and Barnes, this volume, p. 12, Pl. 7, figs. 1-9, 12 (includes synonymy to 1978).

Material. Elements: three-denticled - 5; two-denticled - 19.

Types. Hypotypes, GSC 60023-60025.

Belodina? n.sp.A s.f.

Plate 3, fig. 25

Description. Element is long, recurved above mid-height with

denticulated posterior edge. Anterior margin is convex, posterior margin tapers to sharp edge. Inner lateral face is concave; outer lateral face is plano-convex. Posterior margin has three short denticles at mid-height; denticles are inclined towards apex of element. A fourth denticle may be fused to cusp, extending from other denticles to tip of cusp. Basal cavity is relatively shallow with tip close to anterior margin. White matter occurs above one-third height.

Remarks. The generic identity of this element is questioned because of its unusual morphology and lack of a posterior heel. There is no evidence of denticles in the proximal area of the posterior margin.

Material. Elements: belodiform - 1.

Type. Figured specimen, GSC 60026.

Genus *Cordylodus* Pander, 1856 s.f.

Type species. *Cordylodus angulatus* Pander, 1856.

"Cordylodus" robustus Ethington and Furnish s.f.

Plate 3, fig. 22

Cordylodus robustus Ethington and Furnish, 1959, p. 543, Pl. 73, fig. 11; Ethington and Furnish, 1960, p. 270; Barnes, 1974, Pl. 1, fig. 23; Nowlan and Barnes, this volume, p. 12, Pl. 7, figs. 16-19.

Material. 3 elements.

Type. Hypotype, GSC 60027.

Genus *Decoriconus* Cooper, 1975

Type species. *Paltodus costulatus* Rexroad, 1967.

Cooper (1975) established *Decoriconus* to include small, twisted, and striated simple cones. He regarded the apparatus as consisting of paltodiform and acontiodiform elements, with a drepanodiform element in some species. Elements of *Decoriconus* were previously assigned to the form species of *Drepanodus* and *Paltodus* in the Silurian and *Acontiodus* in the Upper Ordovician. The apparatuses of the above genera have either been redefined or are still vague, hence, Cooper (1975) included these striated elements in a new genus. A critical feature of *Decoriconus* is the degree of element curvature. *Decoriconus* ranges from the Upper Ordovician to Upper Silurina.

Decoriconus costulatus (Rexroad)

Plate 2, figs. 24-27

Acontiodiform element

?Acontiodus minutus Serpagli, 1967 (in part), p. 45-46, Pl. 9, figs. 1a-3c (only). *Paltodus costulatus* Rexroad, 1967 (in part), p. 40-41, Pl. 4, figs. 26, 29 (only).

Paltodiform element

?Acontiodus minutus Serpagli, 1967 (in part), p. 45-46, Pl. 9, figs. 4a-5c (only). *Paltodus costulatus* Rexroad, 1967 (in part), p. 40-41, Pl. 4, figs. 27, 28 (only).

Drepanodiform element

?*Paltodus costulatus* Rexroad. Pollock, Rexroad and Nicoll, 1967 (in part), p. 757-758, Pl. 114, fig. 30 (only).

Multielement synonymy

Decoriconus costulatus (Rexroad). Cooper, 1975, p. 992-993, Pl. 1, figs. 1, 12, 15, 22.

Description. Elements have basal outline that is suboval. Cusp has sharp or narrowly compressed anterior margin that is flanked by offset ridges on postero-lateral face. Elements are twisted laterally and have fine striations on cusp. Some elements have serrated posterior keels. White matter occurs in cusp above tip of basal cavity.

Acontiodiform and paltodiform elements: Acontiodiform elements are erect basally and slightly reclined and curved above this point, tapering rapidly to apex. They differ from the paltodiform elements which are smoothly recurved above a short base.

Drepanodiform element: Element is greatly reclined immediately above base. Below this point, anterior and posterior margins are reclined and erect, respectively. Posterior keel and offset ridges are less prominent distally than in other elements. Anterior extension of cusp may be short or long and laterally flexed.

Remarks. Cooper (1975) did not describe or identify a drepanodiform element in *D. costulatus* even though he had an abundance of specimens and was aware that in younger species this element was present. However, if the element described by Pollock et al. (1970, p. 114, fig. 30) and considered by Cooper (1975) to be an acontiodiform element is actually drepanodiform, then the two interpretations do not differ. If *D. costulatus* does have a drepanodiform element then it may be conspecific with, and thus a junior subjective synonym of, *D. fragilis* (Branson and Mehl), a younger species described by Cooper (1976).

Material. Elements: acontiodiform - 30#; paltodiform - 53#; drepanodiform - 11#.

Types. Hypotypes, GSC 60028-60031.

Genus *Distomodus* Branson and Branson, 1947;

emend. Cooper, 1975

Type species. *Distomodus kentuckyensis* Branson and Branson, 1947.

Cooper (1975) considered the genus *Distomodus* to be closely related to the younger multielement genus *Hadrognathus*. Barrick and Klapper (1976) regarded the type species of *Hadrognathus* as part of a *Distomodus* apparatus on the basis of common apparatus style and several common elements. The reconstruction by Klapper and Murphy (1975) of *D. kentuckyensis* Branson and Branson differs from that of the above authors.

Distomodus aff. *D. kentuckyensis* Branson and Branson

Plate 7, figs. 22-27

Multielement synonymy

aff. *Distomodus kentuckyensis* Branson and Branson. Cooper, 1975, p. 998-1000, Pl. 2, figs. 6,8,10,11,13,14 (includes synonymy to 1975).

Description. Eoligonodiniform element: Element is markedly asymmetrical. One face of cusp has denticulated lateral process that is directed aborally and posteriorly; opposite face is planar.

Anticusp and posterior process are in same plane. Cusp has costae on anterior and antero-lateral margins that extend along anticusp and lateral process, respectively. Anterior cusp costa is high and sharp.

Remarks. This multielement species bears some resemblance to *D. kentuckyensis* as defined by Cooper (1975) but most elements show minor differences and the eoligonodiniform element is markedly different. The eoligonodiniform element differs from *Ligonodina egregia* Walliser s.f., the equivalent element of *D. kentuckyensis*. This form species lacks the denticulated lateral process that is present on the element of this species. The modified ambalodiform element can be compared to *Drepanodus? arrectus* Rexroad s.f. A few of these elements have an atypical anterior process denticle that is large and laterally compressed. An element equivalent to the platform element of *D. kentuckyensis*, represented by *Icriodina irregularis* Branson and Branson s.f. is absent. However, a rare platform element (described herein as N.gen.A s.f.) may be the equivalent element of this species.

Cooper (1975) described a species (*D. sp. cf. D. kentuckyensis*) that was similar to *D. kentuckyensis* but it differs in that the elements are smaller than those of the other species. He also suggested that the element equivalent to the platform element of *D. kentuckyensis* was made up of a fused series of simple cones. This reconstruction cannot be followed herein, the recovery of elements of *Distomodus* species are too low to support Cooper's (1975) conclusions. These cones are regarded herein as "*Drepanodus suberectus*" (Branson and Mehl) s.f.

Material. Elements: eoligonodiniform - 15; zygognathiform - 9; trichonodelliform - 12; distomodiform - 11; modified ambalodiform - 6.

Types. Hypotypes, GSC 60032-60037.

Genus *Drepanodus* Pander, 1856 s.f.

Type species. *Drepanodus arcuatus* Pander, 1856.

"*Drepanodus suberectus*" (Branson and Mehl) (*sensu* Rexroad, 1967) s.f.

Plate 7, fig. 43

Drepanodus suberectus (Branson and Mehl). Rexroad, 1967, p. 30-31, Pl. 2, fig. 4; Pollock, Rexroad and Nicoll, 1970, p. 751, Pl. 114, fig. 21; Aldridge, 1972, p. 174-175, Pl. 9, fig. 16.

Distomodus sp. cf. D. kentuckyensis Branson and Branson. Cooper, 1975 (in part, p. 1000-1003, Pl. 2, fig. 9 (only).

Remarks. Simple cone elements from Silurian strata have been incorrectly referred to as *D. suberectus* s.f. They are suberect but differ from the Ordovician form species. In particular, these elements are antero-posteriorly compressed rather than being laterally compressed. Cooper (1975) found these elements as fused series and the latter author believed that this fused series represented a reduced platform element that, with other small elements, formed the apparatus of *D. sp.cf. D. kentuckyensis*. This interpretation cannot be followed herein. Fused series of these elements were not found, and the distinction of *D. sp.cf. D. kentuckyensis* on the basis of small elements is considered tenuous.

Material. 11 elements.

Types. Hypotype, GSC 60038.

Genus *Drepanoistodus* Lindström, 1971

Type species. *Oistodus forceps* Lindström, 1955.

Drepanoistodus suberectus (Branson and Mehl)

Plate 3, figs. 1-6

Suberectiform element

Oistodus suberectus Branson and Mehl, 1933, p. 111, Pl. 9, fig. 7.

Multielement synonymy

Drepanoistodus suberectus (Branson and Mehl). Sweet, Thompson and Satterfield, 1975, Pl. 1, figs. 15-17; Palmieri, 1978, p. 20, Pl. 5, figs. 14-31; fig. 6 (1a-6b); Nowlan and Barnes, this volume, p. 12, Pl. 4, figs. 17-19 (includes synonymy to 1978).

Material. Elements: suberectiform - 23; homocurviform - 205; oistodiform - 30.

Types. Hypotypes, GSC 60039-60044.

Genus *Eobelodina* Sweet, Turco, Warner and Wilkie, 1959 s.f.

Type species. *Oistodus forniculus* Stauffer, 1935b.

Eobelodina n.sp.A s.f.

Plate 3, fig. 27

Description. Element has long recurved cusp with heel about one-third height of element. Element is slightly bowed. Cusp has two faint antero-lateral costae and is laterally compressed with sharp anterior and posterior edges. Posterior edge is offset to inner side. Base is laterally compressed; inner face has shallow groove. Basal cavity is conical, extending to height of heel. Cavity is subcircular in cross-section anterior to basal groove, from here it narrows posteriorly and extends full length of heel. White matter occurs throughout cusp, boundary is cloudy.

Remarks. The single specimen differs from *E. fornicula* (Stauffer) s.f. found in the Anticosti Island material in that the cusp is longer and less recurved and the base is shorter.

E. n.sp.A s.f. has a different basal cavity cross-section compared to *E. n.sp.B* s.f. and also has a lower heel and shorter base. *E. n.sp.B* s.f. has a prominent groove on the outer lateral face and lacks any noticeable antero-lateral costae.

Material. Element: eobelodiniform - 1.

Type. Figured specimen, GSC 60045.

Eobelodina n.sp.B s.f.

Plate 3, fig. 28

Description. Element has long recurved cusp with high heel. Abrupt recurvature occurs at height of heel. Element is moderately bowed. Cusp is laterally compressed with sharp anterior margin; posterior margin is sharp and offset to inner face. Cusp has faint groove on outer lateral face extending from aboral margin of base to tip of cusp. Heel is about one-half height of element. Inner face of base is nearly flat; outer face is convex on both sides of groove.

Basal cavity is conical, extending to height of heel. Anterior margin of cavity is nearly perpendicular to base. Cavity is suboval in outline, extended under heel; anterior and posterior ends of cavity are narrowed to point. White matter occurs in cusp, boundary is cloudy.

Remarks. The specimen of *E. n.sp.B* s.f. bears more resemblance to *E. n.sp.A* s.f. than to the type species. A form similar to this specimen was described by Barnes (1977) as *E. n.sp. s.f.* but differs in that it has a smaller length-height ratio, longer heel and lacks the groove on the outer lateral face.

Material. Element: eobelodiniform - 1.

Type. Figured specimen, GSC 60046.

Genus *Gamachignathus* McCracken, Nowlan and Barnes, 1980

Type species. *Gamachignathus ensifer* McCracken, Nowlan and Barnes, 1980. Two new species, *Gamachignathus ensifer* and *G. hastatus*, were described from Anticosti Island (McCracken et al., 1980). A full account of their occurrence was provided by these authors.

The genus is represented in both the Vauréal and Ellis Bay formations, but is abundant only in the latter. McCracken et al. (1980) believed that *Gamachignathus* is most similar to *Prioniodus*, with respect to apparatus plan. *Gamachignathus* is one of the key components in the latest Ordovician Ellis Bay fauna that is used to establish herein a new conodont fauna (Fauna 13) and to support the re-establishment of the Gamachian Stage to represent post-Richmondian, pre-Silurian time.

Gamachignathus ensifer McCracken, Nowlan and Barnes

Plate 5, figs. 1-27

Gamachignathus ensifer McCracken, Nowlan and Barnes, 1980, p. 105-110, Pl. 10.1, figs. 1-17.

Material. Elements: cordylodiform - 278; gothodiform - 89; keislognathiform - 404; hibbardelliform - 46; cyrtioniodiform - 325; falodiform - 109; prioniodiform - 217; modified prioniodiform - 426.

Types. Paratypes GSC 60047-60062, 60064-60072; holotype GSC 60063 (McCracken et al. (1980) illustrated the holotype and some of the paratypes; the remaining paratypes were listed as unfigured).

Gamachignathus hastatus McCracken, Nowlan and Barnes

Plate 5, figs. 28-45

Gamachignathus hastatus McCracken, Nowlan and Barnes, 1980, p. 110, 111, Pl. 10.2, figs. 1-16.

Material. Elements: cordylodiform - 52; gothodiform - 1; keislognathiform - 149; hibbardelliform - 19; cyrtioniodiform - 45; falodiform - 26; prioniodiform - 91; modified prioniodiform - 45.

Types. Paratypes GSC 60073-60083; 60085-60087; 60801; holotype GSC 60084 (the holotype and some paratypes were illustrated in McCracken et al. (1980); the remaining paratypes were listed as unfigured).

Genus *Icriodella* Rhodes, 1953, emend. Bergström and Sweet,

1966

Type species. *Icriodella superba* Rhodes, 1953.

Icriodella deflecta Aldridge

Plate 7, figs. 40-42

Platform element

Icriodella deflecta Aldridge, 1972, p. 183-184, Pl. 1, figs. 4-7.

Multielement synonymy

Icriodella deflecta Aldridge, Aldridge, 1975, Pl. 1, fig. 16; Cooper, 1975, p. 1003-1004, Pl. 2, fig. 7 (includes synonymy to 1975).

Remarks. The platform element of *Icriodella deflecta* is distinguished from that of *I. discreta* Pollock, Rexroad and Nicoll by its blade-like process being laterally deflected rather than offset. Cooper (1975) regarded the other elements of *I. deflecta* as indistinguishable from those of *I. discreta*. In this study, the platform element is rare and occurs with elements (including platforms) of *I. discreta*.

Material. 3 platform elements.

Types. Hypotypes, GSC 60088-60090.

Icriodella discreta Pollock, Rexroad and Nicoll

Plate 7, figs. 30-39

Trichonodelliform element

Exochognathus brevialatus (Walliser). Aldridge, 1972, p. 177, Pl. 7, figs. 8,9; Rexroad and Nicoll, 1972, Pl. 2, figs. 21,22.

Sagittodontiform element

Trichonodella? edentata Branson and Branson, 1947, p. 552, Pl. 81, fig. 28, Pl. 82, figs. 40,44,48.

Ambalodiform element

Distomodus triangularis triangularis (Walliser). Pollock, Rexroad and Nicoll, 1970, p. 750-751, Pl. 112, figs. 2-6; Aldridge, 1972, p. 174, Pl. 6, fig. 12.

Platform element

Icriodella discreta Pollock, Rexroad and Nicoll, 1970, p. 754-755, Pl. 111, figs. 27-30; Aldridge, 1972, p. 184, Pl. 1, figs. 1-3.

Multielement synonymy

Icriodella discreta Pollock, Rexroad and Nicoll, Aldridge, 1975, Pl. 1, fig. 15; Cooper, 1975, p. 1004, Pl. 2, figs. 1-4 (includes synonymy to 1975).

Description. Ambalodiform element: Element has laterally compressed cusp. Anterior process is long with short triangular denticles that are posteriorly reclined. Lateral processes are variable in morphology, and may be reduced to undenticulated flares, one of which is narrower than the other. Posterior face of base is flat. Other specimens have denticulated outer lateral process and undenticulated postero-lateral process. One specimen has only one small lateral process and sharp posterior margin with small, fused denticles. All elements have basal sheath or well developed basal filling.

Remarks. The eoligonodiniform element of *I. discreta* differs from the comparable element of *Distomodus* aff. *D. kentuckyensis* Branson and Branson in that the cusp is shorter and the lateral processes are less aborally directed. The zygognathiform and trichonodelliform elements differ from small homologous elements of the above species in that the cusp is shorter, more subtriangular in cross-section, and with flatter lateral faces on the base. The sagittodontiform element is referable to the form species *Sagittodontus edentatus* (Branson and Branson). The ambalodiform element is similar to that illustrated by Cooper (1975, Pl. 2, fig. 4) but both Cooper's and this form differ from the form species he (1975) considered synonymous with the ambalodiform element. *D. triangularis triangularis* s.f. has an undenticulated anticusp (or anterior process) and a denticulated posterior process. The anterior process on the specimens of this study is long and denticulated.

The platform element is assignable to the form species *I. discreta*. There is some morphological variation within these elements. Some have up to seven denticles on the blade and have a narrow, poorly developed platform. These specimens are similar to those described by Cooper (1975) and have minor lateral deflection or offset of the blade. Other specimens have a shorter more offset blade and a well developed platform. One large element of the former variety has denticles on the blade that are laterally offset and some are paired. Small platform elements have a conspicuous cusp.

The apparatuses of *I. discreta* and *I. superba* Rhodes (as described by Bergström and Sweet, 1966) are comparable. As noted by Cooper (1975), each element of *I. discreta* has a readily discernible counterpart in *I. superba*. However, he recognized only one element in the ramiform complex of *I. discreta*, probably a trichonodelliform element. Both zygognathiform and trichonodelliform elements, and possibly eoligonodiniform elements of *I. discreta* are identifiable. Specimens of *I. superba* available from the Georgian Bay formation in southern Ontario indicate that all three elements are present within the ramiform complex of this apparatus. The zygognathiform and trichonodelliform elements are asymmetrical and symmetrical forms, respectively, of *Rhynchognathus divaricatus* (Rhodes) s.f. The eoligonodiniform element is represented by *R. typicus* (Ethington) s.f. The other elements of *I. superba* are sagittodontiform, ambalodiform and platform. Thus, the apparatuses of these two species of *Icriodella* are closely similar. The oldest available trivial name for this species from Anticosti is derived from *T. ? edentata* s.f. Since this form species is a component of both *I. discreta* and *I. deflecta* Aldridge, Cooper (1975) regarded it as a *nomem dubium* and consequently used the names *I. discreta* and *I. deflecta*.

Material. Elements: eoligonodiniform - 10@; zygognathiform - 2@; trichonodelliform - 8@; sagittodontiform - 13@; ambalodiform - 5@; platform - 21.

Types. Hypotypes, GSC 60091-60100.

Genus *Oulodus* Branson and Mehl, 1933

Type species. *Cordylodus serratus* Stauffer, 1930 (=senior subjective synonym of *Oulodus mediocris* Branson and Mehl, 1933). Five species that are either referable to or questionably assigned to the genus *Oulodus* are present in the Anticosti Island fauna. Three Ordovician species, *O. robustus* (Branson, Mehl and Branson) *O. ulrichi* (Stone and Furnish) and *O. rohneri* (Ethington and Furnish) have been reported from elsewhere.

The generic assignment of the two Silurian species of *Oulodus* is questionable, especially when considering their relationships with other apparatuses. They clearly belong to the informal suprageneric group that includes the genera *Aphelognathus*,

Plectodina, *Oulodus*, and possibly *Ozarkodina*. The only truly diagnostic element of the first three genera is the blade element (i.e. apheleognathiform, ozarkodiniform) or its equivalent (i.e. oulodiform element). The form of all other elements within the apparatuses is variable and depends on the species. Apparatuses of species of *Plectodina* have not yet been identified from the Silurian. The only possible Silurian record of *Apheleognathus* is *A. siluricus* Pollock, Rexroad and Nicoll s.f. (Pollock et al., 1970). Silurian species of *Oulodus* differ from Ordovician species in that the cordylodiform/eoligonodiniform, cyrtionodiform/prioniodiniform, and prioniodiniform elements are replaced by ligonodiniform, neoprioniodiniform/euprioniodiniform, and lonchodiniform elements, respectively. Llandoveryan and younger species of *Oulodus* (e.g. *O. jeanae* Schönlaub, *O. elegans* (Walliser)) also have a typical oulodiform element. The early Llandoveryan species described herein as *O. ? kentuckyensis* Branson and Branson and *O. ? nathani* n.sp. have atypical oulodiform elements. This element of the former species is referred to as a modified oulodiform element, although it is morphologically similar to that of *O. ? nathani*. For this reason, and the similarity of the other elements, these two new species are considered to be closely related. The equivalent element of *O. ? nathani* is difficult to classify using form taxonomy and is therefore referred to as a blade element. The morphology of the denticles and cusp are similar to the form genus *Ozarkodina* but the straight or nearly straight aboral margin is more typical of the form genus *Spathognathodus*. It differs from most form species of *Spathognathodus* in denticulation. The generic assignment of these Silurian species from Anticosti Island is questioned because it cannot be shown that they were derived from Ordovician species of *Oulodus*. If Ordovician species were ancestral to younger species referred to *Oulodus*, then possibly there should be a distinction made between these Ordovician and Silurian species. The apparatuses of Silurian species of *Oulodus* and *Oulodus ?* may be defined as containing distinctive ligonodiniform, neoprioniodiniform/ euprioniodiniform, lonchodiniform, and blade/oulodiform elements as well as zygognathiform and trichonodelliform elements.

Oulodus robustus (Branson, Mehl and Branson)

Plate 4, figs. 1-6

Eoligonodiniform element

Eoligonodina robusta Branson, Mehl and Branson, 1951, p. 15, Pl. 4, figs. 33, 35-37.

Zygognathiform element

Zygognathus sp. Branson, Mehl and Branson, 1951 (in part), p. 13, Pl. 4, fig. 19 (only).

Trichonodelliform element

Trichonodella ? sp. Branson, Mehl and Branson, 1951, p. 12, Pl. 3, fig. 27.

Oregoniform element

Prionidina oregonia Branson, Mehl and Branson, 1951 (in part), p. 15-16, Pl. 3, fig. 18, Pl. 4, figs. 29, 31, 32 (only). *Oulodus oregonia oregonia* (Branson, Mehl and Branson). Kohut and Sweet, 1968 (in part), p. 1469, Pl. 186, fig. 6 (only).

Oulodiform element

Oulodus sp. Branson, Mehl and Branson, 1951, Pl. 3, fig. 19.

Multielement synonymy

Plectodina robusta (Branson, Mehl and Branson). Kohut and Sweet, 1968 (in part), p. 1471, Pl. 185, figs. 12, 15, 17, 24 (only).

Oulodus robustus (Branson, Mehl and Branson). Sweet and Schönlaub, 1975, p. 48-49, Pl. 2, figs. 7-12.

Description. Prioniodiniform element: Element has laterally compressed cusp, and denticulated anterior and posterior processes intersecting at 90 degrees. Cusp is nearly in same plane as processes. It has sharp antero- and postero-lateral edges. Denticles are subcircular in cross-section, discrete, and peg-like. Basal cavity is shallow, extends under processes. Base flares beneath cusp as narrow half cones on both faces. White matter occurs in cusp and in denticles.

Remarks. All other elements of *Oulodus robustus* have been previously described in detail, more recently by Kohut and Sweet (1968) as *Plectodina robusta* and by Sweet and Schönlaub (1975) as *O. robustus*. Tarrant (1977) considered the oregoniform element of *O. subundulatus* (Sweet, Turco, Warner and Wilkie) as described by Sweet and Schönlaub (1975; = cyrtionodiform) and the prioniodiniform element of *O. oregonia oregonia* as conspecific with *Prionidina oregonia* s.f. and thus occupying the oregoniform element position of *O. robustus*. This element is represented by few specimens in the Anticosti material; however, they are similar to those illustrated by the above authors. The eoligonodiniform position includes both eoligonodiniform and cordylodiform elements; both forms can co-occur.

Elements of *O. robustus* can be distinguished from other species of *Oulodus* by the stout discrete denticles that have a sub-circular cross-section and the more widely divergent processes. Comparison of *O. robustus* and *O. rohneri* is included in the remarks on the latter.

Material. Elements: cordylodiform - 4; eoligonodiniform - 8; zygognathiform - 12; trichonodelliform - 6; oregoniform - 4; prioniodiniform - 8; oulodiform 3.

Types. Hypotypes, GSC 60101-60106.

Oulodus rohneri Ethington and Furnish

Plate 4, figs. 7-22

Oulodiform element

Oulodus rohneri Ethington and Furnish, 1959, p. 544, Pl. 73, figs. 17, 18.

Multielement synonymy

Oulodus rohneri Ethington and Furnish. Nowlan and Barnes, this volume, p. 13, 14, Pl. 2, figs. 8-16.

Remarks. Some of the elements of *O. rohneri* have been identified by Ethington and Furnish (1959, 1960) from the Upper Ordovician of Manitoba. The cordylodiform, eoligonodiniform and cyrtionodiform elements have not been illustrated or described previous to this study or that of Nowlan and Barnes (this volume). The latter authors provided a detailed description of the elements in the apparatus.

Elements of *O. rohneri* can be differentiated from both *O. robustus* (Branson, Mehl and Branson) and *O. ulrichi* (Stone and Furnish). The most distinguishing characteristic of *O. rohneri* is the broad, lateral compression of the cusp and denticles. This characteristic is most evident in all elements but the cordylodiform, eoligonodiniform and cyrtionodiform elements and can be used to differentiate *O. rohneri* from other species, regardless of size. The cordylodiform element of *O. rohneri* is similar to that of *O. robustus*. However, this element of *O. rohneri* has an anterior margin that is more flange-like, in addition to having laterally compressed cusp and denticles. The cordylodiform elements of both *O. robustus* and *O. ulrichi* have subcircular cross-sections of the cusp and denticles. The eoligonodiniform elements of all three

species can be distinguished from each other. The cyrtionodiform elements of *O. rohneri* and *O. ulrichi* are difficult to separate. The curvature and flexure of the margin of these elements are used to distinguish between these species, but it is thought that this may be somewhat artificial, considering the variations of morphology in other elements. Crytonodiform elements with and without an anterior denticle have been assigned to both species.

In this collection, the occurrence of *O. rohneri* (along with *O. ulrichi*) and *O. robustus* appears to be mutually exclusive (although the latter occurs in low numbers and over a restricted range).

Material. Elements: cordylodiform -23; eoligonodiform - 24; zygognathiform - 17; trichonodelliform - 27; cyrtionodiform - 16; prioniodiniform - 19; oulodiform - 35.

Types. Hypotypes, GSC 60107-60122.

Oulodus ulrichi (Stone and Furnish)

Plate 4, figs. 23-33

Eoligonodiform element

Eoligonodina ulrichi Stone and Furnish, 1959, p. 222-223, Pl. 32, figs. 16-18.

Multielement synonymy

Oulodus ulrichi (Stone and Furnish). Nowlan and Barnes, this volume, p. 14,15, Pl. 2, figs. 1-7 (includes synonymy to 1978).

Remarks. The apparatus of *O. ulrichi* is considered by Nowlan and Barnes (this volume). Elements of *O. ulrichi* can be differentiated from those of *O. robustus* (Branson, Mehl and Branson). The lower part of the cordylodiform element is subequally biconvex, whereas the same element of *O. robustus* has a well developed antero-lateral edge. The antero-lateral process of the eoligonodiform element of *O. ulrichi* diverges at a smaller angle and the element lacks the conspicuous inner basal flare that characterizes these elements of *O. robustus*. The cyrtionodiform element of *O. ulrichi* lacks the antero-lateral process present on the equivalent element (prioniodiniform) of *O. robustus*. The cyrtionodiform element rarely develops a peg-like denticle on the antero-lateral margin. It co-occurs with an adenticulated form of equivalent size. The oulodiform element has an antero-lateral process that is approximately normal to the posterior process; the angle between processes is greater than that of *O. robustus*. In addition all elements differ from *O. robustus* and *O. rohneri* in their denticle cross-section and spacing. The differences between *O. ulrichi* and *O. rohneri* are discussed under the latter species.

Material. Elements: cordylodiform - 6; eoligonodiform - 8; zygognathiform - 10; trichonodelliform - 7; cyrtionodiform - 16; prioniodiniform - 11; oulodiform - 8.

Types. Hypotypes, GSC 60123-60133.

Oulodus? kentuckyensis (Branson and Branson)

Plate 6, figs. 1-20

Ligonodiform element

Ligonodina kentuckyensis Branson and Branson, 1947, p. 555, Pl. 82, figs. 28,35; Rexroad, 1967, p. 35, Pl. 2, fig. 5; Pollock, Rexroad and Nicoll, 1970, p. 755, Pl. 114, figs. 9,10; Aldridge, 1972, p. 188, Pl. 8, figs. 15,16; Liebe and Rexroad, 1977, Pl. 2, fig. 39.

Zygognathiform element

Plectospathodus irregularis (Branson and Branson). Rexroad, 1967, p. 48-49, Pl. 3, fig. 15.

Prioniodina irregularis Branson and Branson, 1947, p. 555, Pl. 82, figs. 30,31.

Trichonodelliform element

Trichonodella cf. *T. inconstans* Walliser. Rexroad, 1967, Pl. 3, fig. 19.

Trichonodella n.sp.A Rexroad, 1967, Pl. 3, fig. 18.

Euprioniodiniform element

Euprioniodina cf. *Prioniodus excavatus* Branson and Mehl. Rexroad, 1967, p. 31-32, Pl. 3, figs. 7,8.

Neoprioniodus aff. *N. excavatus* (Branson and Mehl). Liebe and Rexroad, 1977, Pl. 2, figs. 36,37.

Neoprioniodus cf. *N. excavatus* (Branson and Mehl). Pollock, Rexroad and Nicoll, 1970 (in part), p. 756, Pl. 114, figs. 18,19 (only).

Lonchodiform element

?*Lonchodina detorta* Walliser. Pollock, Rexroad and Nicoll, 1970, p. 755-756, Pl. 113, fig. 29.

Lonchodina walliseri Ziegler. Rexroad, 1967, p. 37-38, Pl. 3, fig. 6; Pollock, Rexroad and Nicoll, 1970, p. 755-756, Pl. 113, fig. 30; Aldridge, 1972, p. 191-192, Pl. 8, fig. 5.

Modified oulodiform element

?*Lonchodina* aff. *L. walliseri* Ziegler. Liebe and Rexroad, 1977, Pl. 2, fig. 40.

?*Lonchodina* sp. Rexroad, 1967, p. 38, Pl. 3, fig. 5.

?*Lonchodina* sp. B Aldridge, 1972, p. 192, Pl. 8, fig. 8.

Multielement synonymy

cf. *Oulodus* n.sp.A Cooper, 1975 (in part), p. 997, Pl. 2, figs. 16,18,19,21 (only).

cf.

Oulodus n.sp.B Cooper, 1975 (in part), p. 997-998, Pl. 2, figs. 15,17,20 (only).

Diagnosis. Apparatus consists of ligonodiform, zygognathiform, trichonodelliform, euprioniodiniform, lonchodiform, and modified oulodiform elements. Elements have cusp and denticles that are only slightly compressed. Denticles are discrete with U-shaped interspaces. Basal cavity is widely flared, aboral surfaces of processes are widely excavated or inverted. Zygognathiform and trichonodelliform elements have short undenticulated posterior process. Modified oulodiform element has partially fused denticles on straight anterior process. Posterior process has discrete denticles and is slightly directed laterally and aborally.

Description. Elements are similar to those of *O. ? nathani* n.sp. but differ in a number of respects, as described below. Cusp is long and slender and less compressed. Denticles are long, peg-like and only slightly compressed laterally. Denticles are discrete with U-shaped interdenticular spaces (except anterior process of modified oulodiform element). Central denticles on processes of all except modified oulodiform element are longer than those on either side. Basal cavity is large and flared. Cavity extends under processes as shallow furrow. Aboral surface of processes is widely excavated to flat or inverted in larger specimens. White matter occurs in cusp, denticles and oral region of processes.

Ligonodiform element: Cusp has subcircular basal cross-section but is laterally compressed distally with sharp edges. Lateral process is directed less towards anterior and is more aborally directed. Aboral angle of process divergence is greater than 90

degrees. Denticles of lateral and posterior processes are more inclined to cusp and to posterior, respectively.

Zygonathiform element: Element is similar to trichonodelliform element. Cusp is erect on large specimens, proclined on others. Cusp is twisted so that costae are offset to antero- and postero-lateral directions. Lateral processes diverge at angle generally less than 80 degrees; are aborally arched and commonly bowed differentially to posterior. One lateral process is generally shorter than other. On small specimens, posterior face of base is not as flared as on large specimens.

Trichonodelliform element: Cusp is erect to slightly proclined, subcircular in cross-section with lateral costae extending to processes. Processes diverge from each other at about 90 degrees or less. Processes are posteriorly bowed and slightly arched. Denticles of large elements are recurved so that tips are subparallel to cusp. Base on all but smallest specimens is flared at posterior beneath cusp producing short, undenticulated oral margin that is approximately normal to cusp axis. Flare is high, narrow, producing greatly expanded basal cavity. Anterior face of base is gently flared.

Euprioniodiniform element: Denticles of postero-lateral process are more discrete; antero-lateral process is shorter, generally with one or two denticles. Basal cavity is greatly flared on posterior side only.

Lonchodiniform element: Cusp is reclined, slightly compressed laterally with sharp anterior edge. Processes are subequal in length with five or six denticles each. Processes are slightly out of antero-posterior plane of cusp. Basal flare is greater on posterior side.

Modified oulodiform element: Posterior process is longer than anterior process. Anterior process is high for most of length, narrowing sharply towards distal end. Posterior process is low for entire length. Anterior process and aboral margin are straight. Posterior process is laterally bowed and aborally arched. Process is laterally flexed so that denticles are inclined in direction opposite to that of bowing. Denticles of processes are short. Denticles on anterior process are confluent for part of length and have triangular tips, increasing progressively in size towards cusp. Cusp is not prominent; similar in size and width to flanking denticles. Denticles and cusp are slightly reclined and laterally compressed. Denticles on posterior process are suberect, discrete. Those nearer to cusp are more closely packed. They number about six or less on each process. Basal flare is larger, broader on side to which posterior process is bowed.

Remarks. The holotype, selected as the form species *Ligonodina kentuckyensis* is from Llandoveryan strata of Kentucky and is found associated with other elements that form this apparatus. Some of these are unnamed form species with questionable affinities, whereas others are long-ranging with their holotype from younger strata. In the latter case, *L. walliseri* s.f. was considered by Ziegler (1972) to be part of a Lower Devonian apparatus, one which is different than that of *O. ? kentuckyensis*. The reasons for questioning the generic assignment are given in the discussion of the genus *Oulodus*.

The ligonodiniform and euprioniodiniform elements are referable to the form species *L. kentuckyensis* and *Euprioniodina* cf. *Prioniodus excavatus*, respectively. The descriptive terminology of the latter element differs from that used by Rexroad (1967) in that the processes are herein considered as lateral rather than anterior and posterior. The zygonathiform and trichonodelliform elements have an expanded basal cavity comparable to *T. cf. T. inconstans* as described by Rexroad (1967). The lonchodiniform element has characteristics of *L. walliseri* s.f., a long ranging form species. The modified oulodiform element is similar to *L. ? sp. s.f.* described by Rexroad (1967), especially in the sigmoidal aspect of the element. Unlike this form species, the Anticosti elements have a discernible cusp and the anterior process denticles are confluent for part of their length.

Cooper (1975) described two new species of *Oulodus* from the Brassfield Limestone of Ohio that have some similarities to *O. ? kentuckyensis*. These species are listed in the synonymy but the affinities to *O. ? kentuckyensis* are questioned partly because of the incomplete nature of their reconstruction. He distinguished the two species primarily on the basis of the zygonathiform, trichonodelliform and neoprioniodiform (or its equivalent) elements; the other elements were considered either indistinguishable or similar. The ligonodiniform and modified oulodiform elements of *O. ? kentuckyensis* are comparable with the same elements of *O. n.sp.A* Cooper (these two elements of *O. n.sp.B* Cooper were indistinguishable and absent, respectively). The lonchodiniform element of *O. ? kentuckyensis* and *O. n.sp.B* are referable to the same form species. Cooper (1975) included a neoprioniodiform element in the apparatus of *O. n.sp.B*, the equivalent element of *O. n.sp.A* was not definitely recognized but was thought to be of the sort referable to *E. cf. P. excavatus* s.f. by Rexroad (1967). This form species is included in the reconstruction of *O. ? kentuckyensis*. The zygonathiform and trichonodelliform elements of *O. n.sp.B* differ from those of *O. n.sp.A* in that they are robust, have expanded basal cavities, and the former element has a sharply curved "apical denticle" (Cooper, 1975, p. 998). It is also noted that the illustrated elements of both species all have inverted aboral margins. The above features are found in the elements of *O. ? kentuckyensis*. That is, the aboral margin is inverted, and large specimens have basal cavities that are more excavated and the cusp and denticles are more recurved than in small specimens.

The absence or similarity of corresponding elements of *O. n.sp.A* and *O. n.sp.B* may suggest that these two species are conspecific. This suggestion may be further supported if it can be shown that the differences in other elements are due to growth. It is believed that *O. ? kentuckyensis* has some elements in common with those in the species described by Cooper (1975) and hence has closer affinities to these species than does *O. ? nathani* n.sp. A direct comparison cannot be made because of the questionable reconstruction of *O. n.sp.A* and *O. n.sp.B*.

Sweet and Schönlaub (1975) discussed a Llandoveryan species of *Oulodus*, *O. jeannae* Schönlaub, that has a lonchodiniform element similar to that of *O. ? kentuckyensis*. The apparatus of *O. jeannae* differs in that the elements of the ramiform complex lack the characteristic basal flare, and it has a more typical oulodiform element. A specimen from the Anticosti Silurian fauna has a more typical oulodiform shape but is considered a variant of either the euprioniodiniform or lonchodiniform element (Pl. 6, fig. 14).

Material. Elements: ligonodiniform - 107; zygonathiform - 99; trichonodelliform - 45; euprioniodiniform - 42; lonchodiniform - 46; modified oulodiform - 39.

Types. Hypotypes, GSC 60134-60153.

Oulodus ? nathani n.sp.

Plate 6, figs. 21-32

Derivation of name. In honour of Nathan J. McCracken.

Diagnosis. Apparatus consists of ligonodiniform, zygonathiform, trichonodelliform, euprioniodiniform, lonchodiniform and blade elements. Cusp and denticles are long, slender and compressed. Denticles are closely spaced so that interspaces are V-shaped. Basal cavity is small and extends under process as shallow or nearly flat excavation. Blade element has denticles of anterior process fused into high, straight blade; posterior process has denticles that are more discrete and is only slightly deflected laterally and aborally.

Description. Cusp and denticles are long and slender with sharp margins. Cusp is laterally compressed in ligonodiniform, lonchodiniform, and blade elements, antero-posteriorly compressed in other elements. Denticles are laterally compressed and closely spaced so that interdenticular spaces are roughly V-shaped. Central denticles on processes are longer than those on either side. Basal cavity is small, conical and extends under processes as shallow furrow. Aboral surface of processes is narrow and is slightly excavated in small elements, nearly flat in larger elements. White matter occurs in cusp, denticles and oral region of processes.

Ligonodiniform element: Cusp is reclined and directed slightly out of plane of posterior process. Processes are straight; posterior process is rarely sinuous. Antero-lateral process is aborally directed. Processes diverge at about 135 degrees. Degree of lateral and aboral deflection of antero-lateral process is somewhat variable. Denticles are slightly reclined, commonly number about six and four on posterior and antero-lateral processes, respectively. Apex of basal cavity extends to a level immediately below oral margin of posterior process.

Zygnathiform element: Element is similar to trichonodelliform element in most respects. Cusp is twisted so that sharp lateral edges become antero- and postero-lateral. Processes are arched; one process is more posteriorly bowed than other.

Trichonodelliform element: Cusp is proclined with sharp edges that extend its full length and merge with lateral processes. Lateral processes diverge at high angle, generally about 105 degrees. Processes are aborally arched, posteriorly bowed. Denticles are recurved towards cusp. Angle between oral margin of base and cusp is greater than 90 degrees. Anterior face of base is smoothly convex, merges with processes and is not flared. Posterior face of base is slightly flared, narrowly pinched. Basal cavity is not expanded beneath cusp.

Euprioniodiniform element: Cusp is recurved with gently convex anterior face and strongly convex posterior face. Processes are slightly directed aborally. Antero-lateral process is short and bears two or three denticles. Postero-lateral process is bowed inward near cusp so that distal end is posteriorly oriented. Process is long, generally with seven or eight denticles. Denticles of both processes are inclined slightly towards cusp. Those of antero-lateral process are shorter than most denticles of posterior process. Base is slightly flared on posterior face beneath cusp. Aboral area beneath processes is generally excavated, rarely flat.

Lonchodiniform element: Cusp is reclined and slightly out of plane of processes. Processes are subequal in length, diverge at high angle, and are bowed slightly in opposite directions. Aboral margin of processes is nearly straight; in some elements, process has slight aboral flexure distally. Number of denticles on each process is generally five to seven. Denticles of anterior process are inclined towards cusp and are larger, more closely spaced and confluent than those of posterior process. Those of posterior process are suberect proximal to cusp, slightly reclined distally. Base is flared slightly beneath cusp; flares are unequal in size.

Blade element: Element has denticulate processes that are subequal in length. On large specimens, posterior process is slightly longer than the anterior. Anterior process height is approximately equal for entire length whereas height of posterior process diminishes distally. Anterior process is nearly straight with distal end slightly flexed laterally and is aborally directed. Aboral margin is straight from this point of flexure to proximal part of posterior process where it is laterally bowed and aborally directed. Small specimens have slightly arched aboral margin and are less bowed laterally. Bowing of posterior process is in same lateral direction as that of distal end of anterior process; distal end is slightly flexed in opposite direction. Denticles number about seven on anterior process; number is generally less on posterior process. Denticles of anterior process are confluent for most of length and have triangular apices. They increase unevenly in length towards

cusp. Cusp is slightly wider and longer than denticles of anterior process. Posterior process has denticles that are confluent only at bases. Base is slightly flared beneath cusp.

Remarks. *O. ? nathani* n.sp. and *O. ? kentuckyensis* (Branson and Branson) are distinguishable on the basis of differences noted below but particularly by the presence of a distinctive blade in *O. ? nathani*. The elements of *O. ? nathani* differ from the equivalent elements of *O. ? kentuckyensis* in that the denticles of the former are more closely spaced and are nearly confluent basally, and the basal cavity and the aboral margin of the processes are not as well excavated. Although these species do co-occur, their relative abundance changes throughout the section. The same element associations are constant.

The ligonodiniform element differs from forms referred to *Ligonodina kentuckyensis* Branson and Branson s.f. (assigned to *O. ? kentuckyensis*) in that the antero-lateral process is directed more to the anterior, and the denticles are more closely spaced, almost basally confluent. The zygnathiform element has similarities to the same element of *O. n.sp.A* (Cooper 1975, Pl. 2, fig. 19), in that the base is not well excavated and the processes are widely divergent. However, in the zygnathiform element of *O. ? nathani* the style of denticulation is different, and both processes are subequal in length. The trichonodelliform element has a small basal excavation and widely divergent processes as does *Trichonodella* sp.B Rexroad s.f. (Rexroad, 1967, Pl. 3, fig. 17) but comparisons cannot be made because of the lack of preserved denticles on the illustrated specimen. Rexroad (1967) did note that the denticles of *T. sp.B* s.f. were partially fused. The Anticosti elements have denticles that are more closely spaced, laterally compressed and with more widely divergent processes than the trichonodelliform elements of *O. n.sp.A* Cooper. The euprioniodiniform element has a longer, more denticulated antero-lateral process than *Euprioniodus* cf. *Prioniodus excavatus* Branson and Mehl s.f., described by Rexroad (1967). The lonchodiniform element differs from previously described form species in the style of denticulation and the process orientation. These processes are oriented in the antero-posterior plane. The blade element has an anterior and posterior process, hence it differs from typical oulodiform elements. Also, the flexed posterior process is not normal to the other process and the denticles of the latter are fused to form a blade. These three characteristics are found on the equivalent element (referred to as a modified oulodiform element) of *O. ? kentuckyensis*. The questioned generic assignment of *O. ? nathani* and *O. ? kentuckyensis* is discussed within the generic remarks of *Oulodus*.

Material. Elements: ligonodiniform - 39; zygnathiform - 25; trichonodelliform - 26; euprioniodiniform - 11; lonchodiniform - 21; blade - 38.

Types. Paratypes, GSC 60154-60164; holotype, GSC 60165.

Genus *Ozarkodina* Branson and Mehl, 1933;

emend. Lindström, 1970

Type species. *Ozarkodina confluens* (Branson and Mehl, 1933) (= *O. typica* Branson and Mehl, 1933).

Studies of the Llandoveryan conodonts of North America and Britain (e.g. Pollock et al., 1970; Aldridge, 1972) listed elements that were probably part of one or more multielement species of *Ozarkodina*. Aldridge (1975) and Cooper (1975) placed ozarkodiniform and spathognathodiform elements from these study areas into two and three species of *Ozarkodina*, respectively.

Cooper was not able to establish the differences between the ramiform complex and synprioniodiniform elements of *O. hassi* (Pollock, Rexroad and Nicoll) and *O. oldhamensis* (Rexroad) because of the rare occurrence of the latter species. In the Anticosti Island fauna, *O. oldhamensis* is more abundant than *O. hassi*. The elements of these species cannot at present be separated with confidence. Thus, the two species *O. hassi* and *O. oldhamensis* are considered to have similar apparatus elements and are distinguished only on the basis of their ozarkodiniform and spathognathodiform elements. The ramiform complex and synprioniodiniform elements of these species are presently included in the synonymy of *O. hassi*. The similarity of these elements of the two species suggests close affinity between them. These elements are illustrated separately on the stratigraphic range diagram (Fig. 12) as *O. sp.* so that differences in the ranges of *O. hassi* and *O. oldhamensis* can be seen.

Ozarkodina hassi (Pollock, Rexroad and Nicoll)

Plate 7, figs. 1,2,4,6-13

Ligonodiniform element

Ligonodina variabilis Nicoll and Rexroad. Liebe and Rexroad, 1977, Pl. 1, fig. 14.

Zygognathiform element

Plectospathodus flexuosus Branson and Mehl. Liebe and Rexroad, 1977, Pl. 2, fig. 34.

Synprioniodiniform element

Synprioniodina bicurvata (Branson and Mehl). Liebe and Rexroad, 1977, Pl. 1, fig. 6.

Ozarkodiniform element

Ozarkodina aff. *O. edithae* Walliser. Liebe and Rexroad, 1977, Pl. 1, fig. 22.

Ozarkodina cf. *O. edithae* Walliser. Aldridge, 1972, p. 199-200, Pl. 4, fig. 17.

Spathognathodiform element

Spathognathodus hassi Pollock, Rexroad and Nicoll, 1970, p. 760-761, Pl. 111, figs. 8-12; Liebe and Rexroad, 1977, Pl. 1, figs. 20,21.

Spathognathodus cf. *S. oldhamensis* Rexroad. Rexroad and Nicoll, 1971, Pl. 1, fig. 13.

Multielement synonymy

Ozarkodina hassi (Pollock, Rexroad and Nicoll). Aldridge, 1975, Pl. 2, fig. 22 (spathognathodiform element); Cooper, 1975, p. 1005, Pl. 3, figs. 7-12 (includes synonymy to 1975).

Description. Cusp and denticles are long and compressed with sharp edges. Denticles are basally confluent, with white matter occurring in denticle bases and forming a continuous straight line along length of process. Basal cavity is small, conical, and extends under processes as shallow groove. White matter occurs in cusp and denticles. Ozarkodiniform and spathognathodiform elements are diagnostic of the *O. hassi* apparatus and are described below, together with the variation observed in the trichonodelliform element.

Trichonodelliform element: Cusp is proclined. Cusp and denticles are long. Processes diverge at about 130 degrees in small forms. In large forms, they are more arched distally, hence divergence angle is about 90 degrees. Denticles are slightly recurved towards cusp. Two forms of large elements are present. First form has cusp that is lanceolate in cross-section with sharp lateral edges. Denticles flanking cusp are short and partially to entirely fused to sharp edges of cusp (Pl. 7, fig. 6). Second form has cusp with gen-

tly convex or planar anterior face and strongly convex posterior face. Cusp has sharp antero-lateral edges that are fused with proximal denticles. Denticles are confluent for most of length (Pl. 7, fig. 5). Zygognathiform elements also exhibit two variants in large specimens (Pl. 7, figs. 3,4).

Ozarkodiniform element: Element is short with high, wide cusp. Anterior process is slightly longer than posterior process. In larger specimens, cusp width increases by overgrowth of short proximal denticles, usually of posterior process. Cusp has nearly straight free margins; anterior margin is more reclined than posterior. Processes are slightly arched with aboral margin nearly straight or slightly arched at distal end of anterior process. Denticles on anterior and posterior process number about eight and five, respectively. They are laterally compressed and fused for most of length with triangular apices. Those on anterior and posterior processes are reclined and erect, respectively. Denticles are higher on anterior process than on posterior process. On both processes they increase uniformly in height towards cusp. Tips of cusp and anterior process denticles form straight line, viewed laterally. Basal cavity is slightly flared. Processes are shallowly excavated near cavity, excavation diminishes abruptly distally. Processes and cusp may be slightly bowed laterally.

Spathognathodiform element: Large specimens have a cusp that increases in width by overgrowth of short proximal denticles, and by fusion and overgrowth of longer flanking denticles.

Remarks. Two forms of zygognathiform, trichonodelliform and possibly synprioniodiniform elements are presently based on the cusp cross-section but they are distinguishable only in large specimens. The forms with a lanceolate and plano-convex cusp cross-section generally occur with *O. hassi* and *O. oldhamensis* (Rexroad) respectively, but since this feature is indistinguishable in most specimens, it is preferable not to equate these with either species. These forms are differentiated, however, in the plate illustrations.

The ozarkodiniform elements of *O. hassi* differ somewhat from the type material of *O. edithae* s.f. in that the processes are shorter and slightly arched. Other Llandoveryan elements assigned or compared to this form species differ in the same manner (Pollock, et al., 1970; Aldridge, 1972). Helfrich (1975) erected the subspecies *O. edithae mariae* s.f., which has similar characteristics to the ozarkodiniform element of *O. hassi*. This subspecies is not included in the synonymy of *O. hassi* since it is probably part of a different multielement species of *Ozarkodina*. The ozarkodiniform elements of *O. hassi* and *O. oldhamensis* differ in that the element of the former has shorter processes, a wider cusp, and an aboral margin that is less bowed or is nearly straight. Large specimens of the ozarkodiniform element of *O. oldhamensis* may have a wide cusp, but this occurs through gradual widening and fusion of the long flanking denticles. The cusp of this element of *O. hassi* is wide even in early growth stages. The cusp height and width is similar in both ozarkodiniform and spathognathodiform elements and is one of the features that supports the reconstruction of the apparatus.

The spathognathodiform element of *O. hassi* has a longer, wider cusp and larger, more discrete denticles than the equivalent element of *O. oldhamensis*. The denticles are also less uniform in height than those of the spathognathodiform element of *O. oldhamensis*.

The reconstruction of *O. hassi* used herein is similar to that of Aldridge (1975) and Cooper (1975).

Material. Elements: ligonodiniform - 207@; zygognathiform - 205@, trichonodelliform - 53@; synprioniodiniform - 113@, ozarkodiniform - 55; spathognathodiform - 94.

Types. Hypotypes, GSC 60166-60176.

Ozarkodina oldhamensis (Rexroad)

Plate 7, figs. 3,5,14-18

Ozarkodiniform element

Ozarkodina aff. *O. typica* Branson and Mehl. Liebe and Rexroad, 1977, Pl. 1, fig. 15.

Spathognathodiform element

Spathognathodus oldhamensis Rexroad, 1967, p. 49-50, Pl. 3, figs. 1,2; Rexroad and Nicoll, 1971, Pl. 1, fig. 12.

Multielement synonymy

Ozarkodina oldhamensis (Rexroad). Aldridge, 1975, Pl. 2, figs. 16,17; Cooper, 1975, p. 1005-1006, Pl. 3, figs. 13,14 (includes synonymy to 1975).

Description. Ozarkodiniform and spathognathodiform elements are diagnostic of the *O. oldhamensis* apparatus.

Ozarkodiniform element: Element has anterior process that is longer than posterior. Cusp is high, laterally compressed with sharp edges. In small forms it is narrow, increasing in width by overgrowth of proximal denticles, and by fusion and overgrowth of long flanking denticles in larger specimens. Cusp is much higher than flanking denticles in small elements; in large forms, difference is not as great. In large specimens, free anterior margin of cusp is straight, posterior margin may be slightly concave. Processes are aborally arched, aboral margin is gently concave. Denticles number about ten and six on anterior and posterior processes, respectively. They are laterally compressed, fused for most of length and have triangular apices. Denticles of anterior and posterior processes are long and reclined, short and erect, respectively. They increase evenly in height towards cusp, tips form straight or slightly convex line. Basal cavity is short, conical with flared margins beneath cusp. Cavity is widely excavated beneath cusp only, continuing distally under processes as shallow furrow. Tip of cavity may be directed anteriorly. Cusp and processes may be slightly bowed laterally.

Spathognathodiform element: Central three or four denticles are rarely completely fused; denticles usually have discrete apices. Cusp is slightly larger than denticles to anterior and is followed posteriorly by short denticle. Rare elements have a posterior process that is slightly bowed laterally. These forms have the same type of denticulation and basal cavity flare as other elements.

Remarks. Many ozarkodiniform elements of *O. oldhamensis*, as noted by Pollock et al. (1970) and Aldridge (1972) are shorter than those from younger strata. Other specimens tend to have longer process that are more typical of the type material of *O. typica*. Younger occurrences of *O. typica* s.f. are not included in the synonymy since they appear to be part of a multielement species that has a different spathognathodiform element. Comparisons of the ozarkodiniform element of *O. oldhamensis* and *O. hassi* (Pollock, Rexroad and Nicoll) are discussed in the remarks of the latter species.

The basal flare, denticulation and the lack of a prominent cusp distinguish the spathognathodiform element of *O. oldhamensis* from the equivalent element of *O. hassi*. It is noted that large specimens of the ozarkodiniform element may also have a prominent basal flare; this lends support to the reconstruction of this species. Forms of the spathognathodiform elements that have a fused central oral area are identical to the type material of Rexroad (1967). A fragment of an element similar to *S. comptus* Pollock, Rexroad and Nicoll s.f. was found in one sample. This form species differs from *S. oldhamensis* s.f. in that the basal flare has a small denticle but in other respects (e.g. basal flare shape, denticulation) it is similar. This may again represent element variation, but the single occurrence does not warrant inclusion of *S. comptus* s.f. within the synonymy of *O. oldhamensis*. The form species *S.*

manitoulinensis Pollock, Rexroad and Nicoll occurs infrequently in the Anticosti material. It is considered as a separate form species although rare elements of *O. oldhamensis* have a slightly bowed posterior process like that of *S. manitoulinensis* s.f. These elements may be transitional between *S. oldhamensis* s.f. and *S. manitoulinensis* s.f. and if so, the latter could be included as part of *O. oldhamensis*.

Aldridge (1975) and Cooper (1975) both recognized the association of ozarkodiniform and spathognathodiform elements as being part of the *O. oldhamensis* apparatus. This association is supported by the distribution and taxonomic data of the present study. The other elements of *O. oldhamensis* are indistinguishable from those of *O. hassi* (see description and remarks for *O. hassi*).

Material. Elements: ozarkodiniform - 201; spathognathodiform - 335.

Types. Hypotypes, GSC 60177-60183.

Ozarkodina n.sp.A s.f.

Plate 7, fig. 21

Ozarkodina n.sp.A Pollock, Rexroad and Nicoll, 1970, p. 757, Pl. 113, figs. 5-8.

Remarks. Cooper (1975) included this form species and *O. n.sp.B* Pollock, Rexroad and Nicoll s.f. in his new multielement species *O. protexcavata* Cooper. His figured specimen of the ozarkodiniform(?) element is poorly preserved and thus a direct comparison is difficult. The other elements of *O. protexcavata* are not present in the Anticosti Island material.

Material. Element: ozarkodiniform - 5.

Type. Figured specimen, GSC 60184.

Genus *Panderodus* Ethington, 1959

Type species. *Paltodus unicastatus* Branson and Mehl, 1933.

Panderodus clinatus n.sp.

Plate 2, figs. 1-6

Panderodus n.sp.C Nowlan and Barnes, this volume, p. 20, Pl. 5, figs. 18-22, text-fig. 7 F,G.

Derivation of name. From the Latin "clinatus" meaning "bent", in reference to the strong recurvature of the cusp.

Diagnosis. A bielement apparatus with elements that are sharply recurved at less than mid-height. Above point of recurvature, cusp tapers abruptly to point. Cusp is laterally compressed with sharp edges and has offset shoulder and furrow on one lateral face. Arcuatiform element has cusp with convex inner face inclined to posterior. Outer postero-lateral face is nearly flat and ornamented. Compressiform element is nearly symmetrical. Outer lateral face has sharp medial ridge, inner-postero-lateral face is ornamented.

Description. Elements are recurved and have sharp anterior and posterior edges that extend from immediately above base to tip of cusp. Point of recurvature is below mid-height. Cusp tapers

abruptly above this point with nearly straight margins to tip of cusp. Proximal part of anterior margin is proclined. Cusp is laterally compressed. Offset shoulder and furrow are present on one face of cusp. Furrow extends along length of cusp and as deep groove in base. Opposite face of base has weak groove. Base is short and striated with anterior and posterior margins narrowly convex. Anterior basal outline is subcircular; outline narrows posterior to grooves. Basal cavity extends to point of recurvature as abruptly tapered cone. White matter occurs in cusp above base and is cloudy to point of recurvature.

Arcuatiform element: Element is slightly bowed laterally. Cusp has smooth, gently convex inner face that is inclined posteriorly. Outer antero-lateral face is broadly convex and merges with nearly flat postero-lateral face. Ornamentation is at mid-width of outer postero-lateral face. Inner face of cusp is unornamented and inclined towards posterior.

Compressiform element: Element is nearly symmetrical, recurved at about one-third height. Slightly convex outer antero-lateral face meets concave postero-lateral face at sharp, pre-medial ridge. Inner lateral faces are slightly concave with medial offset shoulder and furrow on postero-lateral face. Some elements are slightly twisted laterally; ornamentation is on inner face. Point of recurvature is variable.

Remarks. The elements of *P. clinatus* n.sp. have a rather sharp recurvature and straight distal cusp margins, similar to elements of *P. cf. P. staufferi* (Branson, Mehl and Branson). The elements of *P. clinatus* however, are recurved at a lower point on the cusp with the proximal part of the anterior margin being proclined rather than erect. Elements of *P. cf. P. staufferi* lack the sharp anterior margin and thus are not as laterally compressed. The two elements of this new species were referred to *P. n.sp.C* by Nowlan and Barnes (this volume) and were described as compressiform and graciliform elements.

Material. Elements: arcuatiform - 90; compressiform - 176.

Types. Paratypes, GSC 60185-60187, 60189, 60190, holotype, GSC 60188.

Panderodus feulneri (Glenister)

Plate 1, figs. 16-21

Compressiform element

Paltodus feulneri Glenister, 1957, p. 728, Pl. 85, fig. 11.

Panderodus feulneri (Glenister). Ethington, 1959, p. 284-285, Pl. 39, fig. 2; Stone and Furnish, 1959, p. 225, Pl. 31, fig. 3; Schopf, 1966, p. 66, Pl. 5, fig. 30; Webers, 1966, p. 38, Pl. 3, figs. 1a,b,2a,b; Winder, 1966, p. 48, Pl. 9, fig. 9, text-fig. 3, no. 19; Weyant, 1968, p. 56, Pl. 5, fig. 4.

Arcuatiform element

Paltodus intermedius Branson, Mehl and Branson. Glenister, 1957, p. 728, Pl. 85, fig. 10.

Panderodus robustus (Branson, Mehl and Branson). Weyant, 1968 (in part), p. 57, Pl. 5, fig. 6 (only).

Multielement synonymy

Panderodus feulneri (Glenister). Barnes, 1977, p. 107, Pl. 3, figs. 11, 12.

Remarks. Bergström and Sweet (1966) considered *P. feulneri* s.f. to be a robust gerontic variant of *P. compressus* (Branson and Mehl) s.f., but the distribution of these forms differs in the

Anticosti sections. In the Ellis Bay area, *P. compressus* s.f. occurs without *P. feulneri* s.f., both co-occur in the Vauréal River section, whereas *P. feulneri* s.f. is dominant in the lower part of the Salmon River section. *P. feulneri* has an apparatus similar to *P. gracilis* (Branson and Mehl). It includes graciliform, arcuatiform and compressiform elements. The elements of *P. feulneri* are larger than those of *P. gracilis* but are short and robust compared to the more delicately proportioned elements of *P. gracilis*. The ornamentation is usually well developed in these elements with the compressiform element usually having prominent antero-lateral offset shoulders. Small compressiform elements are also assigned to this species since they are short and wide compared to similar sized elements of *P. gracilis*. The ornamentation on these small elements is not as well developed as on larger forms. Barnes (1977) was able to distinguish these above two form species in collections from northern Canada. He considered that *P. feulneri* was a separate multielement species that included elements of *P. gracilis* s.f.

Material. Elements: graciliform - 81; arcuatiform - 107; compressiform - 51.

Types. Hypotypes, GSC 60191-60196.

Panderodus gibber Nowlan and Barnes

Plate 2, figs. 7-10

Multielement synonymy

?*Panderodus brevisculus* Barnes, 1977 (in part), p. 106, Pl. 3, figs. 13, 14 (only).

Panderodus gibber Nowlan and Barnes, this volume, p. p. 16, Pl. 6, figs. 15-19; text-fig. 7 H,J.

?*Panderodus cf. P. serratus* Rexroad. Cooper, 1975, p. 994-995, Pl. 1, figs. 2, 6.

Remarks. The diminutive size, relative robustness and curvature are characteristic of *P. gibber* as described by Nowlan and Barnes (this volume). In the arcuatiform element the cusp is more recurved distally than that in the compressiform element but is suberect for a greater part of its length. The compressiform element is similar to that of *P. cf. P. staufferi* (Branson, Mehl and Branson), particularly in the symmetry and ornamentation. The compressiform element of *P. gibber* differs in that it is smaller and is not as abruptly recurved as the element of *P. cf. P. staufferi*.

Two elements illustrated by Barnes (1977, Pl. 3, figs. 13, 14) of *P. brevisculus* are similar in overall morphology and size to *P. gibber*. They differ from the holotype of *P. brevisculus* which is more robust. Cooper (1975) illustrated two elements of *P. sp.cf. P. serratus* from the Silurian of Ohio, considered herein to be possibly conspecific with *P. gibber*, although they are considerably more slender. *P. gibber* occurs in both Ordovician and Silurian strata of Ellis Bay Formation.

Material. Elements: arcuatiform - 92#; compressiform - 65#.

Types. Hypotypes, GSC 60197-60200.

Panderodus gracilis (Branson and Mehl)

Plate 1, figs. 1-12, 15

Graciliform element

Paltodus gracilis Branson and Mehl, 1933, p. 108, Pl. 8, figs. 20, 21.

Multielement synonymy

Panderodus gracilis (Branson and Mehl). Kohut and Sweet, 1968, p. 1469-1470, Pl. 185, figs. 1,6,9,10,13,16; Uyeno, 1974 (in part), p. 15, Pl. 3, figs. 7-9, 11-14 (only) (includes synonymy through 1973); Dzik, 1976, p. 435, fig. 15a,b,e,f; Palmieri, 1978, p. 21-22, Pl. 1, figs. 1-3, 17-23; fig. 3(1a-2d); Nowlan and Barnes, this volume, p. 16, Pl. 6, figs. 20,23,27 (includes synonymy to 1978).

Remarks. In the Anticosti Island collections, *P. gracilis* s.f. is also found associated with *P. arcuatus* s.f. These asymmetrical elements are characterized by a sharp antero-lateral edge on the inner face. The postero-lateral face is flat and is variably inclined towards the posterior. There appears to be a transition from forms that are highly inclined and, thus, narrow, to forms that are less inclined and, hence, relatively wide. The common association and appearance of these forms with *P. gracilis* suggests that they should be included within this multielement species. A variation of the arcuatiform element is present. It has a sharp anterior margin rather than a costate antero-lateral edge. It is similar to the arcuatiform element of *P. clinatus* n.sp. but the cusp recurvature is less and is not as close to the base. The element is comparable to *P.* n.sp. illustrated by Rexroad and Craig (1971, Pl. 80, figs. 26,27) except that the distal part of the cusp is not as long. Nowlan and Barnes (this volume) noted that *P. gracilis* may be ancestral to *P. unicostatus* (Branson and Mehl). No specimens that could be unequivocally assigned to *P. unicostatus* were recognized in the Ellis Bay collection. Ordovician and Silurian elements from the Ellis Bay Formation are included within *P. gracilis* for several reasons. The apparatuses of both the Ordovician and Silurian species are identical. They consist of graciliform (symmetrical bicostate, asymmetrical and narrow unicostate), arcuatiform (asymmetrical and wide unicostate with a variable costa position) and compressiform (nearly symmetrical and laterally compressed) elements. Silurian graciliform elements are commonly more recurved and the arcuatiform and compressiform elements are generally more slender than the equivalent elements in the Ordovician. Ordovician elements are more variable in morphology possibly reflecting the more variable environmental conditions, both vertically and laterally.

Material. Elements: graciliform - 3594#; arcuatiform - 1636#; compressiform - 1787#.

Types. Hypotypes, GSC 60201-60213.

Panderodus liratus Nowlan and Barnes

Plate 2, figs. 19-21

Multielement synonymy

Panderodus liratus Nowlan and Barnes, this volume, p. 17, Pl. 6, figs. 21,22,24,28,29; text fig. 7 C,D (includes synonymy to 1978).

Material. Elements: arcuatiform - 40; compressiform - 63.

Types. Hypotypes, GSC 60214-60216.

Panderodus panderi (Stauffer)

Plate 2, figs. 11-13

Compressiform element

Paltodus panderi Stauffer, 1940, p. 427, Pl. 60, figs. 8,9.

Multielement synonymy

Panderodus panderi (Stauffer). Nowlan and Barnes, this volume, p. 17, Pl. 6, figs. 3,4,14 (includes synonymy to 1978).

Description. Arcuatiform element: Element is long with proximal part high and erect. Cusp curves abruptly at about two-thirds height so that distal part is subparallel to aboral margin of base. Cusp is laterally compressed with sharp anterior and posterior margins and is laterally twisted so that inner face is inclined to posterior. Anterior face is continuous with outer lateral face to post-medial offset shoulder and furrow. Furrow extends from shallow groove in base to tip of cusp. Base is expanded posteriorly and is low, striated. Base has nearly flat inner face and nearly flat outer posterior face. Basal cavity is deep, extending to about mid-height; cavity tapers abruptly to point. White matter occurs in cusp from tip to above base. White matter boundary is cloudy.

Remarks. *P. panderi* is expanded herein to include both arcuatiform and compressiform elements. The compressiform element has previously been described as *P. panderi* s.f. Both elements have a characteristic abrupt cusp curvature, a short, posteriorly expanded base, ornamentation, basal cavity and white matter distribution. The former element is longer, narrower and more laterally bowed than the compressiform. The arcuatiform element also has a posteriorly inclined inner lateral face and ornamentation on the outer lateral face similar to *P. arcuatus* (Stauffer) s.f.

The compressiform elements of *P. panderi* have a sharp anterior edge and hence differ from those described by Glenister (1957) and Bergström and Sweet (1966). The specimens also differ from those of Glenister (1957) in that there is only a faint basal groove on one side and they lack an offset shoulder on each lateral face.

Sweet et al. (1975) discussed *P. panderi* and noted that typical representatives have a characteristic ungrooved face that is flat and inclined slightly to the posterior. The specimen they illustrated as *P. panderi* is similar to the compressiform element in shape. The latter differs from that discussed by Sweet et al. (1975) in that the ungrooved face is convex. Also, some elements that are slightly bowed laterally have the grooved face inclined to the posterior. *P. sp.aff. P. panderi*, described by Sweet et al. (1975) as being more slender than *P. panderi*, differs from the arcuatiform element in that both lateral faces are convex.

P. panderi has a strong cusp curvature that is similar to that of some specimens of *P. liratus* Nowlan and Barnes but the latter species is longer, more slender and more costate.

Material. Elements: arcuatiform - 79; compressiform - 47.

Types. Hypotypes, GSC 60217-60219.

Panderodus serratus Rexroad s.f.

Plate 2, fig. 28

Panderodus unicostatus serratus Rexroad, 1967, p. 47, Pl. 4, figs. 3,4.

Panderodus serratus Rexroad. Aldridge, 1972, p. 204, Pl. 9, fig. 7; Cooper, 1975 (in part), p. 993-994, Pl. 1, figs. 5,7 (only).

Remarks. *P. serratus* s.f. from the Ellis Bay Formation is indistinguishable from specimens described by Rexroad (1967) and

Aldridge (1972). Cooper (1975) considered this form species to be part of a Silurian multielement apparatus that also included *P. simplex* (Branson and Mehl) s.f. and *P. unicosatus* (Branson and Mehl) s.f. In this study *P. serratus* s.f. is a rare element but is found sporadically throughout the Ordovician and Silurian strata. The form species is similar to the arcuatiform elements of *P. gracilis* (Branson and Mehl) except that the posterior edge has short fused denticles that are inclined slightly towards the apex of the cusp. *P. serratus* s.f. may be a variant of the arcuatiform element of *P. gracilis* but is not included within that species because of its rarity. Similar elements, generally having a shorter cusp, were described as *P. cf. P. serratus* by Nowlan and Barnes (this volume).

In one large element, white matter is present in the denticles as well as the tip of the cusp.

Material. Element: arcuatiform - 40#.

Type. Hypotype, GSC 60220.

Panderodus cf. P. staufferi (Branson, Mehl and Branson)

Plate 2, figs. 14-18

Compressiform element

cf. *Panderodus staufferi* (Branson, Mehl and Branson). Kohut and Sweet, 1968, p. 1470, Pl. 186, figs. 4,5; Palmieri, 1978, p. 22-23, Pl. 2, figs. 7-8, fig. 3 (6a-6d).

Arcuatiform element

cf. *Panderodus angularis* (Branson, Mehl and Branson). Kohut and Sweet, 1968, p. 1469, Pl. 185, figs. 20,23,27; Nowlan and Barnes, this volume, p. 15, Pl. 5, figs. 23,24.

Multielement synonymy

Panderodus staufferi (Branson, Mehl and Branson). Barnes, 1977, p. 107, Pl. 3, figs. 8,10.

Remarks. Barnes (1977) established the multielement species *P. staufferi* which consists of the form species *P. staufferi* and *P. angularis*. Elements are characterized by a sharp, abrupt change of curvature at or below mid-height and by a posteriorly expanded base. The multielement apparatus is comparable in part to that of *P. gracilis* (Branson and Mehl) but the arcuatiform element is more narrow, asymmetrical and erect whereas the compressiform element is wider and more symmetrical and recurved. The point of curvature of the compressiform element is quite variable. On some specimens, the point of curvature occurs just above the base.

These elements differ in some respects from the type material of Branson, Mehl and Branson (1951). Both elements are narrower than the typical forms and have a less expanded base. The point of abrupt curvature of the arcuatiform element occurs at about mid-height rather than about one-third the height. In this respect, the arcuatiform element is more similar to forms illustrated by Kohut and Sweet (1968) and Barnes (1977). This element lacks any discernible ornamentation on the inner lateral face. The inner lateral face of the compressiform element is slightly concave with a postero-lateral groove; the outer postero-lateral face is slightly convex and unornamented.

The arcuatiform element of *P. cf. P. staufferi* is similar to the same element of *P. feulneri* (Glenister) in that both have a wide base. But, the latter element is shorter, more robust and lacks the abrupt change in curvature. These elements also do not taper as abruptly as do the arcuatiform elements of *P. staufferi*. Slender arcuatiform elements are similar in some respects to the arcuatiform elements of *P. liratus* Nowlan and Barnes but lack the distinctive type of ornamentation found on elements of the latter species.

Material. Elements: arcuatiform - 106; compressiform - 91.

Types. Hypotypes, GSC 60221-60225.

Panderodus n.sp.A s.f.

Plate 1, fig. 13

Description. Recurved, laterally compressed element has sharp posterior edge and a faint, inner, antero-lateral offset shoulder. Sharp edge and shoulder extend for length of cusp, the latter diminishes above base of cusp. Element is proclined basally, becoming reclined distally with a broad, evenly convex anterior margin. Point of recurvature is at about one-third height. Element is bowed inwards. Anterior face of cusp is narrowly convex and continues to broadly convex outer antero-lateral face which meets nearly flat postero-lateral face at rounded shoulder. Postero-lateral face has shallow furrow extending length of cusp, deepening to aboral margin. Inner face of element is unornamented, inclined towards posterior. Face is slightly concave distally, slightly convex on either side of faint longitudinal depression. Posterior margin is more narrowly curved than anterior. Margin has slight aboral inflection at about one-third height and is nearly straight, or slightly convex to aboral margin of base. Proximal one-third of element is slightly expanded posteriorly. Base is short and striated with narrowly convex anterior and posterior margins. Outline of base is nearly flat on inner side; outer side is convex anterior to groove, nearly flat posterior to groove. Basal cavity extends for two-thirds length and is conical, tapering gradually to point. White matter occurs in tip of cusp immediately above apex of cavity and boundary is slightly oblique to cusp axis.

Remarks. *P. n.sp.A. s.f.* is an arcuatiform element characterized by its cusp recurvature, expanded base and almost heel-like posterior margin. This form species shares many of the characteristics of *P. n.sp.B s.f.* which is a compressiform element and both may be constituents of a new multielement species. *P. n.sp.A s.f.* and *P. n.sp.B s.f.* bear some resemblance to elements illustrated as *P. aff. P. gracilis* (Branson and Mehl) by Nowlan and Barnes (this volume).

Material. 12 elements.

Type. Figured specimen, GSC 60226.

Panderodus n.sp.B s.f.

Plate 1, fig. 14

Description. Recurved, laterally compressed element has sharp posterior edge and offset shoulder on inner antero-lateral margin. Element is proclined basally becoming reclined distally with point of recurvature at about mid-height. Anterior margin is broadly convex. Posterior margin is more narrowly convex than anterior margin and is nearly straight from below mid-height. Element is bowed inward slightly. Anterior face is narrowly convex with faint costa and continues to slightly convex unornamented outer lateral face. Inner postero-lateral face is inclined towards posterior and has deep groove in base that narrows to tip of cusp. Groove is located toward the posterior margin. Inner antero-lateral face is concave and postero-lateral face is nearly flat distally, slightly convex on either side of groove proximally. Base is short and striated with broadly and narrowly convex anterior and posterior margins, respectively. Outer face of base has slight depression opposite groove on inner face. Basal outline is subcircular anterior to

groove with flat outer side and convex inner side posterior to groove. Basal cavity is deep and extends to about two-thirds height. Cavity is conical, tapers gradually to point. White matter occurs in tip of cusp immediately above cavity apex and boundary is slightly oblique to cusp axis.

Remarks. *P. n.sp.B* s.f. is a compressiform element. It is similar to *P. compressus* (Branson and Mehl) s.f. but is shorter, wider and more recurved. In addition, this compressiform element has a nearly flat inner face, and is slightly bowed. This form species has characteristics similar to *P. n.sp.A* s.f. and they may represent the compressiform and arcuatiform element, respectively, of a new multielement species.

Material. 10 elements.

Type. Figured specimens, GSC 60227.

Panderodus n.sp.C s.f.

Plate 2, fig. 29

Description. Element has reclined cusp with anterior margin gently convex from base to tip. Posterior margin of cusp is narrowly concave with slight inflection immediately above base resulting in short basal heel. Anterior and posterior margins are narrowly convex, distally sharp. Base has medial groove on both lateral faces. Groove on one face continues for length of cusp as prominent shoulder. Basal outline is subcircular anteriorly with nearly flat lateral margins posterior to groove. Element is slightly twisted laterally. Cavity is short, conical. White matter occurs in cusp above tip of cavity.

Remarks. *Panderodus n.sp.C* s.f. is rare but differs significantly from other species of *Panderodus*. The base is posteriorly expanded as in elements of *P. panderi* (Stauffer) but is developed into a short heel, a feature that is not present in *P. panderi*. The element is less recurved than elements of *P. panderi*.

Material. 2 elements.

Type. Figured specimen, GSC 60228.

Genus *Paroistodus* Lindström, 1971

Type species. *Oistodus parallelus* Pander, 1856.

Paroistodus? mutatus (Branson and Mehl)

Plate 3, figs. 7-9

Acodiform element

Belodus? mutatus Branson and Mehl, 1933, p. 126, Pl. 10, fig. 17.

Multielement synonymy

Acodus mutatus (Branson and Mehl). Serpagli, 1970, Pl. 23, figs. 11-14; Palmieri, 1978, p. 6-7, Pl. 2, figs. 17-19, Fig. 4 (4a-5c).

Paroistodus? mutatus (Branson and Mehl). Nowlan and Barnes, this volume, p. 20, Pl. 1, figs. 15-24 (includes synonymy to 1978).

Remarks. Nowlan and Barnes (this volume) discussed the nature of the apparatus and the questionable assignment to the genus *Paroistodus*.

Cooper (1976) noted a close relationship between the acodiform and distacodiform elements of *P. mutatus* and the Silurian species *Dapsilodus obliquicostatus* (Branson and Mehl). Serpagli (1967) also noted this relationship but pointed out that *Acontiodus obliquicostatus* has oblique striae on the anterior edge. This close similarity may indicate that *D. obliquicostatus* evolved from *P.? mutatus*. Cooper (1976) did not recognize an oistodiform element in the apparatus of *D. obliquicostatus*.

Löfgren (1978) thought that *Oistodus venustus* Stauffer s.f. was not part of the same apparatus as *A. mutatus* s.f. The numerical relations of these forms were found to vary randomly, suggesting that they do not belong to the same natural species. Löfgren (1978) considered *O. venustus* s.f. as part of *Drepanoistodus? venustus* and *A. mutatus* s.f. as belonging to a species of *Paroistodus*.

Material. Elements: acodiform - 4; distacodiform - 4; oistodiform - 14.

Types. Hypotypes, GSC 60229-60231.

Genus *Phragmodus* Branson and Mehl, 1933

Type species. *P. primus* Branson and Mehl, 1933.

Phragmodus undatus Branson and Mehl

Plate 3, figs. 29-33

Phragmodiform element

Phragmodus undatus Branson and Mehl, 1933, p. 115-116, Pl. 8, figs. 22-26.

Multielement synonymy

Phragmodus undatus Branson and Mehl. Palmieri, 1978, p. 24, Pl. 4, figs. 18-23, Pl. 6, figs. 2-5, 7-12, 15-16, Pl. 7, figs. 1-8, 11-12; Nowlan and Barnes, this volume, p. 21, Pl. 4, figs. 1-11, 13 (includes synonymy to 1978).

Material. Elements: phragmodiform - 94; oistodiform - 58; breviform - 40; typiciform - 49.

Types. Hypotypes, GSC 60232, 60772-60775.

Genus *Plegagnathus* Ethington and Furnish, 1959 s.f.

Type species. *Plegagnathus nelsoni* Ethington and Furnish, 1959. Nowlan and Barnes (this volume) redefined the genus *Plegagnathus* as a multielement taxon. The elements are retained herein as form taxa since specimens from the Ellis Bay Formation are rare.

Plegagnathus dartoni (Stone and Furnish) s.f.

Plate 3, fig. 23

Belodina dartoni Stone and Furnish, 1959, p. 220, Pl. 31, fig. 15.

Plegagnathus dartoni (Stone and Furnish). Ethington and Furnish, 1959, p. 545, Pl. 73, figs. 6,7; Kohut and Sweet, 1968, p. 1482, Pl. 186, figs. 9-11; Weyant, 1968, p. 59, Pl. 4, figs. 6,7; Barnes, 1974, Pl. 1, fig. 27; Nowlan and Barnes, this volume, p. 23, Pl. 7, figs. 13-15 (only).

Material. 5 elements.

Type. Hypotype, GSC 60776.

Plegagnathus nelsoni Ethington and Furnish s.f.

Plate 3, fig. 24

Plegagnathus nelsoni Ethington and Furnish, 1959, p. 541, Pl. 73, figs. 2,3; Ethington and Furnish, 1960, p. 272, Pl. 38, fig. 1; Weyant, 1968, p. 59, Pl. 4, fig. 8.

Plegagnathus dartoni Ethington and Furnish. Nowlan and Barnes, this volume, p. 23, Pl. 7, figs. 10, 11 (only).

Material. 6 elements.

Type. Hypotype, GSC 60777.

Genus *Pseudooneotodus* Drygant, 1974

Type species. *Oneotodus? beckmanni* Bischoff and Sannemann, 1958.

Pseudooneotodus beckmanni (Bischoff and Sannemann)

Plate 2, figs. 30, 31.

Oneotodus? beckmanni Bischoff and Sannemann, 1958, p. 98, Pl. 15, figs. 22-25.

Oneotodus mitratus (Moskalenko). Dzik, 1976, p. 435, figs. 12e,f.

Pseudooneotodus beckmanni (Bischoff and Sannemann). Nowlan and Barnes, this volume, p. 23, Pl. 2, figs. 20, 21 (includes synonymy to 1978).

Remarks. Cooper (1977) noted that *P. beckmanni* showed greater variation in basal outline than originally described. He included specimens that had bases with circular, oval and other outlines within this species. The specimens in this study have a slightly flattened posterior face. The apex is often broad and blunt with white matter present in some specimens, and it may be either centrally or posteriorly located. We concur with Cooper (1977) in considering the apparatus of *P. beckmanni* to be monoelemental, consisting of elements that have a variable basal outline.

Material. 106# elements.

Types. Hypotypes, GSC 60778, 60779.

Pseudooneotodus mitratus (Moskalenko)

Plate 2, fig. 32

Ambalodus mitratus mitratus Moskalenko, 1973, p. 86, Pl. 17, figs. 9-11.

Pseudooneotodus mitratus (Moskalenko). Nowlan and Barnes, this volume, p. 23, Pl. 2, figs. 17-19 (includes synonymy to 1978).

Material. 4 elements.

Type. Hypotype, GSC 60780.

Genus *Ptiloncodus* Harris, 1962 s.f.

Type species. *Ptiloncodus simplex* Harris, 1962.

Several writers have questioned the assignment of *Ptiloncodus* to the Conodontophorida (Sweet, 1963; Lindström, 1964; Barnes and Poplawski, 1973). Mound (1965, p. 33) noted a similarity in microstructure and substance between *P. simplex* and conodonts as well as the lack of a basal cavity or any signs of attachment. Bordeau (1972) thought that the rounded basal knobs on *P. harrisi* Bordeau s.f. represented attachment scars. Bordeau (1972, p. 119) further noted that his specimens "display the characteristic amber and white appearance of conodonts". However, it is important to note that the hyaline and white matter of *Ptiloncodus* is found in the cusp and base respectively, the reverse distribution of that in conodonts. Based on the lack of basal cavity and the location of white matter, the assignment of *Ptiloncodus* to the Conodontophorida is probably unwarranted, but its presence in the Anticosti Island material is recorded herein.

Ptiloncodus harrisi Bordeau s.f.

Plate 4, fig. 44

Ptiloncodus harrisi Bourdeau, 1972, p. 119, figs. 1-7.

Material. 4 elements.

Type. Hypotype, GSC 60781.

Genus *Rhipidognathus* Branson, Mehl and Branson, 1951

Type species. *Rhipidognathus symmetrica* Branson, Mehl and Branson, 1951.

Rhipidognathus symmetricus Branson, Mehl and Branson

Plate 4, fig. 45,46

Trichonodelliform element

Rhipidognathus symmetrica Branson, Mehl and Branson, 1951, p. 10, Pl. 2, figs. 29-37, Pl. 3, fig. 31.

Bryantodiniform element

Rhipidognathus paucidentata Branson, Mehl and Branson. Schopf, 1966, p. 72-73, Pl. 2, fig. 21.

Multielement synonymy

Rhipidognathus symmetrica symmetrica Branson, Mehl and Branson. Kohut and Sweet, 1968, p. 1474, Pl. 185, figs. 21,22,25,26,29-31 (includes synonymy to 1968).

Rhipidognathus symmetricus Branson, Mehl and Branson. Sweet, Ethington and Barnes, 1971, Pl. 1, fig. 42.

Remarks. This species is rare in the Anticosti Island material. However, the trichonodelliform elements are referable to *R. symmetricus* s.f. The specimen of the bryantodiniform element is fragmentary but it does show similarities to *R. paucidentatus* s.f.

Material. Elements: trichonodelliform - 3; bryantodiniform - 1.

Types. Hypotypes, GSC 60782, 60783.

Genus *Spathognathodus* Branson and Mehl, 1941 s.f.

Type species. *Spathodus primus* Branson and Mehl, 1933.

Spathognathodus elibatus Pollock, Rexroad and Nicoll s.f.

Plate 7, fig. 20

Spathognathodus elibatus Pollock, Rexroad and Nicoll, 1970,
p. 759-760, Pl. 111, figs. 22-26.

Material. Element: spathognathodiform - 1.

Type. Hypotype, GSC 60784.

Spathognathodus manitoulinensis Pollock, Rexroad and Nicoll
s.f.

Plate 7, fig. 19

Spathognathodus manitoulinensis Pollock, Rexroad and
Nicoll, 1970, p. 761-762, Pl. 111, figs. 17-19; Liebe and
Rexroad, 1977, Pl. 1, fig. 26.

Spathognathodus abruptus Aldridge, 1972, p. 211-212, Pl. 4,
figs. 6,7.

Remarks. The form species listed in the synonymy are characterized by an inwardly deflected posterior process; the angle of deflection is between 30 and 60 degrees. Aldridge (1972) established *S. abruptus* s.f., a species that differs from *S. manitoulinensis* s.f. in the angle of posterior process deflection and in having a shorter, more denticulated posterior process. Aldridge noted that the basal flare of *S. manitoulinensis* s.f. is almost restricted to the outer side whereas *S. abruptus* s.f. has a more expanded inner posterior part of basal cavity. The elements of this study have a denticulation similar to that of both form species. The basal cavity is flared as described by Aldridge for *S. abruptus* s.f. However, Pollock, Rexroad and Nicoll (1970) also recorded this in their description and figured specimen (Pl. 111, figs. 17-19).

S. manitoulinensis s.f. similar to *S. oldhamensis* s.f. The anterior process denticles are long and almost completely fused whereas the posterior process denticles are short and more discrete. Both form species have a similar cusp and wide basal flare (on outer face of *S. manitoulinensis* s.f.). The cusp of *S. oldhamensis* s.f. is flanked by an anterior space and small denticles of posterior process. The denticulation pattern of *S. manitoulinensis* s.f. is similar. Forms which appear to be transitional between *S. oldhamensis* s.f. (*sensu stricto*) and *S. manitoulinensis* s.f. are assigned herein to the multielement species *Ozarkodina oldhamensis*. *S. manitoulinensis* s.f. is retained herein as a separate form species because of its distinctive form.

Material. Element: spathognathodiform - 5.

Type. Hypotype, GSC 60785.

Genus *Staufferella* Sweet, Thompson and Satterfield, 1975

Type species. *Distacodus falcatus* Stauffer, 1935a.

Staufferella inaligera n.sp.

Plate 2, figs. 22,23

Derivation of name. From the Latin "aligerae" meaning "winged", prefix from the Latin "in", meaning "not". This is in reference to the absence of the alae found on the symmetrical element of *S. falcatus* (Stauffer).

Diagnosis. Symmetrical element is acontiodiform with short base and cusp that has weakly developed lateral alae or offset costae and sharp posterior edge. Base is inornate and slightly compressed laterally. Markedly asymmetrical element is laterally compressed and has cusp that is variably recurved distally. Cusp has cross-section that is subcircular proximally, lanceolate distally and is twisted so that distal inner face is posteriorly inclined.

Description. Symmetrical element: Cusp is reclined proximal to base; distal portion is straight. Element is basally compressed antero-posteriorly. Broadly convex anterior face is continuous to mid-point of lateral faces where it meets concave postero-lateral faces as sharp offset shoulder. Laterally offset shoulders begin immediately above base where they attain maximum width; their width diminishes distally. Posterior edge of cusp is sharp, extending from base to near tip of cusp. Base is inornate and slightly compressed laterally. Basal cavity is low, conical and extends to about point of recurvature. White matter occurs throughout most of cusp, and in the costae and posterior edge.

Markedly asymmetrical element: Element is laterally compressed, symmetrical with long, narrow cusp. Cusp is slightly proclined proximally and variably recurved distally, so that in some elements tip of cusp is subparallel to aboral margin of base. Anterior and posterior margins are narrowly rounded. Postero-lateral faces of element are slightly compressed. Posterior face has faint costa offset towards more compressed side of element. Distal portion of antero-lateral margin has faint costa. Antero-lateral costa extends from base of cusp to tip. Cusp is twisted distally so that one lateral face is inclined towards posterior. Cusp cross-section is lanceolate distally. Basal cavity is low, conical. White matter in cusp occurs from above cavity apex to tip of cusp. Some elements have cloudy white matter that extends to near base.

Remarks. The symmetrical element of *S. inaligerae* n.sp. is acontiodiform but differs from the same element in *S. falcatus* (Stauffer) and *S. lindstroemi* (Ethington and Schumacher) in lacking prominent baso-lateral alae. The symmetrical element of *S. falcatus* differs from that in both *S. inaligerae* and *S. lindstroemi* in that it is posteriorly bicarinate rather than unicastate. The markedly asymmetrical element is similar to that in *S. falcatus* except that it lacks a lateral costa. Slightly asymmetrical elements of *S. inaligerae* were not recognized, although one small element differs from the symmetrical elements in that the basal outline is circular and the lateral and posterior costae are not developed into short alae.

Material. Elements: symmetrical - 7; markedly asymmetrical - 39.

Types. Holotype, GSC 60786; paratype GSC 60787.

Genus *Walliserodus* Serpagli, 1967

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

Walliserodus curvatus (Branson and Branson)

Plate 1, figs. 26-30

Unicostatiform element

Acodus unicostatus Branson and Branson. Pollock, Rexroad and Nicoll, 1970, p. 749, Pl. 114, figs. 36,37; Liebe and Rexroad, 1977, Pl. 2, figs. 20,21.

Costate elements

Curvatiform element

Acodus curvatus Branson and Branson, 1947, p. 554, Pl. 81, fig. 20; Liebe and Rexroad, 1977, Pl. 2, figs. 16,17.

Deboltiform element

Paltodus debolti Rexroad. Liebe and Rexroad, 1977, Pl. 2, figs. 2,3.

Dyscritiform element

Paltodus dyscritus Rexroad, 1967, p. 42-43, Pl. 4, figs. 30-34; Nicoll and Rexroad, 1969, p. 52, Pl. 7, figs. 31-33; Pollock, Rexroad and Nicoll, 1970, p. 758, Pl. 114, fig. 31; Thompson and Satterfield, 1975, fig. 5D; Liebe and Rexroad, 1977, Pl. 2, fig. 1.

Multicostatiform element

Paltodus migratus Rexroad. Pollock, Rexroad and Nicoll, 1970, p. 758, Pl. 114, fig. 34.

Paltodus multicostatus Branson and Mehl. Liebe and Rexroad, 1977, Pl. 2, fig. 4.

Multielement synonymy

Walliserodus curvatus (Branson and Branson). Cooper, 1975, p. 995-996, Pl. 1, figs. 10,11,16-21.

Remarks. Cooper (1975) reconstructed the apparatus of *W. curvatus* noting a possible morphologic series within his "costate elements". He separated these elements from *A. unicostatus* s.f. A similar apparatus plan is followed herein. All costate elements bear characteristic costae and transitional forms with additional or bifurcating costae occur. *A. unicostatus* s.f. differs from the others in that it has a cusp that narrows gradually rather than sharply to the apex, and it is smoothly recurved rather than having an abrupt change in curvature. Cooper (1975) compared the elements of this apparatus to the prioniodid plan of Sweet and Bergström (1970). He placed *P. debolti* s.f., *P. multicostatus* s.f. and *P. dyscritus* in the cordylodiform, zygognathiform and trichonodelliform positions, respectively. Barrick (1977) had an alternative interpretation with which we concur. In this, *P. debolti* s.f. is considered to be an asymmetrical form of the trichonodelliform element and, hence, is the zygognathiform element. *P. multicostatus* s.f. differs from the trichonodelliform element in that it has an anterior costa. In this respect, it is regarded as homologous to tetraprioniodiform elements of certain prioniodid genera (e.g. *Amorphognathus*). The curvatiform element is considered to be homologous to the cordylodiform element of other apparatuses.

Cooper (1975) noted that only the acodiform element of *W. curvatus* has extensive fine longitudinal striations. In this study, this ornamentation is visible on some specimens of *A. curvatus* s.f. and *P. debolti* s.f. as well. In the latter case, the striations cover the entire element. In other respects, the elements are similar to those of Cooper.

Some of these form species have been identified from the Upper Silurian Bainbridge Formation of Missouri (Rexroad and Craig, 1971). These elements belong to a different species of *Walliserodus* and thus are not included in the synonymy.

Material. curvatiform - 80; deboltiform - 174; dyscritiform - 205; multicostatiform - 73; unicostatiform - 203.

Types. Hypotypes, GSC 60788-60792.

Walliserodus cf. *W. curvatus* (Branson and Branson)

Plate 1, figs. 22-25

Curvatiform element

cf. *Acodus curvatus* Branson and Branson. Serpagli, 1967, p. 13, Pl. 6, figs. 3a-c.

Multielement synonymy

Walliserodus cf. *W. curvatus* (Branson and Branson). Nowlan and Barnes, this volume, p. 24, 25, Pl. 8, figs. 17-24 (includes synonymy to 1978).

Remarks. The elements of *W. cf. W. curvatus* occur rarely in the Anticosti Ordovician samples but are similar to the Silurian multielement species described herein as *W. curvatus*. Both species have curvatiform, deboltiform, dyscritiform and unicostatiform elements. An element equivalent to *Paltodus multicostatus* Branson and Mehl s.f. was not found. The ornamentation of the Ordovician species is not as well developed as in the Silurian species. A description and discussion of *W. cf. W. curvatus* is given by Nowlan and Barnes (this volume).

Material. Elements: curvatiform - 1; deboltiform - 4; dyscritiform - 6; unicostatiform - 22.

Types. Hypotypes, GSC 60793-60796.

New Genus A s.f.

New Genus A is proposed herein for platform elements with short anterior and posterior processes and longer lateral processes. The processes intersect at right angles immediately posterior to the cusp. The lateral processes have short discrete denticles in small specimens, fused denticle ridge in large specimens.

These elements bear minor resemblance to the four-processed form species *Icriodina irregularis* Branson and Branson, the platform element of *Distomodus kentuckyensis* Branson and Branson. *I. irregularis* s.f. differs in that the lateral processes are shorter than the anterior and posterior, and the platform denticulation is well developed and paired. A species with close affinities to *D. kentuckyensis* is present in this material but lacks a platform element. The forms herein referred to N. gen. A may be part of this apparatus. The large specimen has the same colour and robust nature as that found in the large ramiform elements of *D. aff. D. kentuckyensis*. These elements are not assigned to this species because of their rare occurrence but it is noted that *Distomodus* species are characterized by different elements in the platform position (cf. *D. kentuckyensis*, *D. staurognathoides* (Walliser)). N.gen.A s.f. is similar in form to *Astrognathus* but lacks the type of denticulation found on the processes of the latter genus.

N.gen.A n.sp.A s.f.

Plate 7, fig. 29

Description. Element has four processes that originate at posterior face of cusp. Process with short cusp is designated as anterior. Element is high at cusp with oral margins of processes inclined downward. Aboral margin of element is nearly flat. Anterior process is short, narrow. Posterior process is longer and wider than

anterior process. Both processes have sharp ridge that is proximally irregular. Preserved lateral process is longer than anterior and posterior processes and is directed slightly towards posterior with the distal end posteriorly twisted. Process has fused denticles that form sharp irregular ridge. All processes are slightly tapered distally. Base is completely excavated with tip of cavity beneath cusp, and is more expanded between lateral and posterior processes. White matter is present in cusp and ridges.

Remarks. The single element of N.gen.A n.sp.A s.f. has a broken lateral process. A comparison of this element and N.gen.A n.sp.B s.f. is in the remarks of the latter form species.

Material. 1 element.

Types. Figured specimen, GSC 60797.

N.gen.A n.sp.B s.f.

Plate 7, fig. 28

Description. Platform element has short anterior and posterior processes and two long lateral processes. All processes except anterior have a denticulated ridge. Anterior process is short and has sharp oral margin or, is slightly expanded anteriorly with sharp irregular ridge. Anterior and lateral processes join immediately posterior to cusp; posterior process is laterally offset from anterior process. Cusp is straight and, on larger specimen, slightly reclined to posterior. Cusp is laterally compressed, higher than denticles. Lateral processes have three to four discrete, erect and laterally compressed denticles. Denticles on posterior process are short, fused. Bases of processes are flared; flare is greater between lateral and posterior processes. Base is completely excavated; cavity tip extends into cusp. White matter occurs in cusp, denticles and ridges.

Remarks. Two specimens of N.gen.A n.sp.B s.f. are present. Both are small, thin walled and probably represent an early growth stage. These elements bear minor resemblance to small forms of the platform element of *Icriodella* that lack well developed denticulation. *I. discreta* Pollock, Rexroad and Nicoll s.f. lacks the long denticulated processes and short anterior process found on these new elements. The affinities of this form species and *Distomodus* aff. *D. kentuckyensis* Branson and Branson are discussed within the generic remarks.

N.gen.A. n.sp.B s.f. can be compared to N.gen.A n.sp.A s.f. The only specimen of this latter form species is very large and robust and this may account for most of the differences. The lateral processes of N.gen.A n.sp.A s.f. have a fused denticle ridge and the posterior process is not laterally offset.

Material. 2 elements.

Type. Figured specimen, GSC 60798.

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Plates 1 to 7

All specimens photographed with light microscopy and are hypotypes except where noted. Type numbers are followed by sample numbers in parentheses.

Plate 1

Figures 1 - 21 are X60; figures 22 - 30 are X85.

Figures 1 - 12, 15. *Panderodus gracilis* (Branson and Mehl). Figures 1,2,5,6,9,10 are Silurian, others are Ordovician. (1,4) Inner lateral views of asymmetrical graciliform elements; GSC 60201 (S42), GSC 60204 (E36). (10,15) Lateral views of symmetrical graciliform elements; GSC 60210 (S42), GSC 60213 (E36). (2,3,5,8) Inner lateral views of arcuatiform elements; GSC 60202 (S42), GSC 60203 (E36), GSC 60205 (S42), GSC 60208 (E36). (6,7,9,11,12) Lateral views of compressiform elements; GSC 60206 (S42), GSC 60207 (E36), GSC 60209 (S42), GSC 60211 (E42), GSC 60212 (E42).

Figure 13. *Panderodus* n.sp. A s.f. Inner lateral view of arcuatiform element; figured specimen, GSC 60226 (S07).

Figure 14. *Panderodus* n.sp. B s.f. Lateral view of compressiform element; figured specimen, GSC 60227 (S04).

Figures 16 - 21. *Panderodus feulneri* (Glenister). (16,19) Lateral views of graciliform elements; GSC 60191 (V12), GSC 60192 (S01). (17,20) Inner lateral views of arcuatiform elements; GSC 60193 (V11), GSC 60194 (S01). (18,21) Lateral views of compressiform elements; GSC 60195 (V11), GSC 60196 (S01).

Figures 22 - 25. *Walliserodus* cf. *W. curvatus* (Branson and Branson). (22) Inner lateral view of curvatiform element; GSC 60793 (E07). (23) Inner lateral view of deboltiform element; GSC 60794 (S26). (24) Lateral view of dyscritiform element, GSC 60795 (S26). (25) Lateral view of unicostatiform element, GSC 60796 (E12).

Figures 26 - 30. *Walliserodus curvatus* (Branson and Branson). (26) Inner lateral view of curvatiform element; GSC 60788 (S44). (27) Outer lateral view of deboltiform element; GSC 60789 (S46). (28) Lateral view of dyscritiform element; GSC 60790 (S43). (29) Lateral view of multicostatiform element; GSC 60791 (S43). (30) Lateral view of unicostatiform element; GSC 60792 (S43).

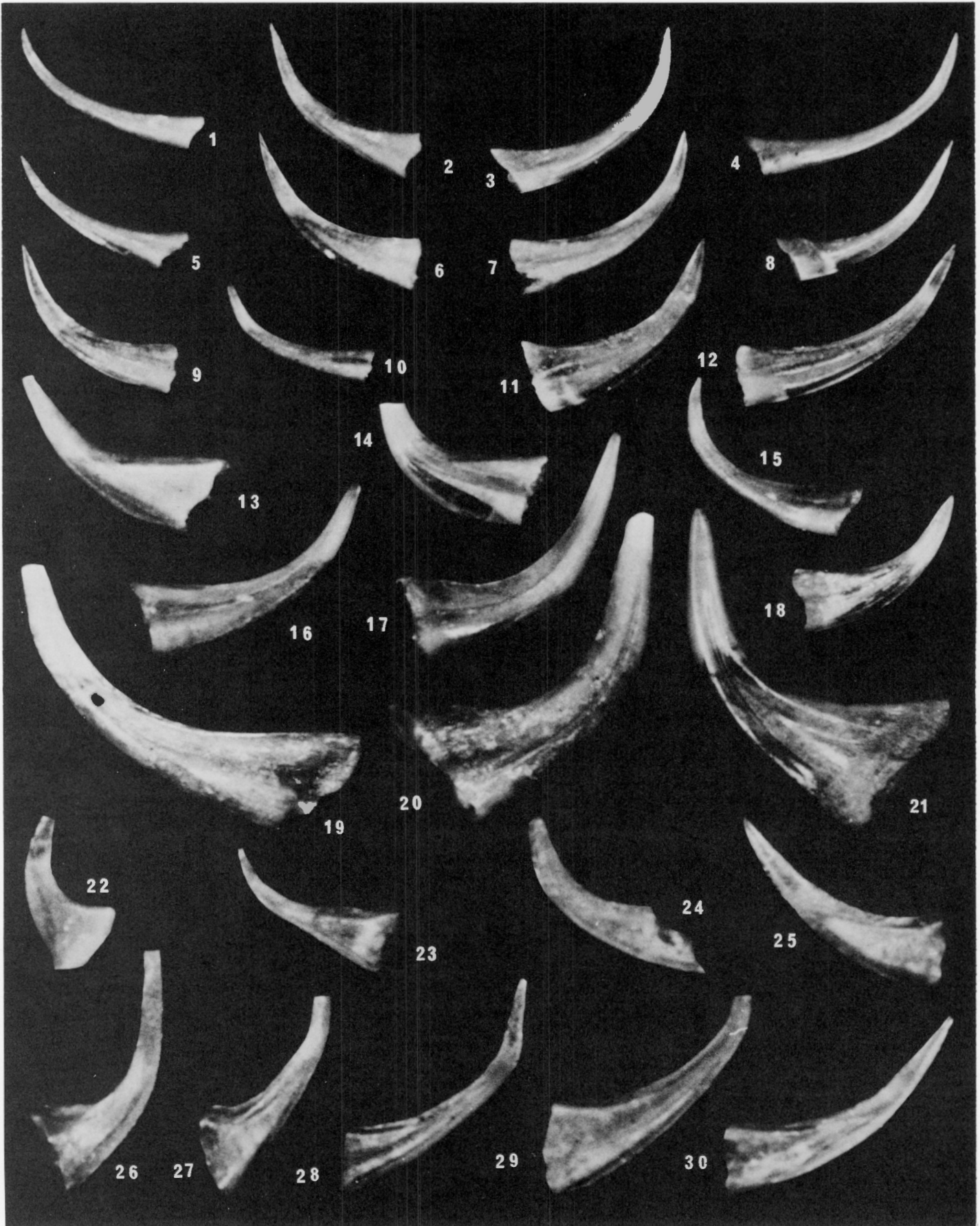


Plate 2

All figures are X60 except figures 7-10, 24-28 X85; figures 30, 31 X50; figure 32 X15.

Figures 1 - 6. *Panderodus clinatus* n.sp. (1,4-6) Lateral views of compressiform elements; paratype GSC 60185 (E07), holotype, GSC 60188 (V13), paratypes, GSC 60189 (E36), GSC 60190 (E07). (2,3) Outer and inner lateral views of arcuatiform elements; paratypes, GSC 60186 (E36), GSC 60187 (E07).

Figures 7 - 10. *Panderodus gibber* Nowlan and Barnes. (7) Inner lateral view of arcuatiform element (Silurian); GSC 60197 (S42). (8) Lateral view of compressiform element (Silurian); GSC 60198 (S42). (9) Inner lateral view of arcuatiform element (Ordovician); GSC 60199 (V12). (10) Lateral view of compressiform element (Ordovician); GSC 60200 (V12).

Figures 11 - 13. *Panderodus panderi* (Stauffer). (11,12) Lateral views of compressiform elements; GSC 60217 (E07), GSC 60218 (E07). (13) Inner lateral view of arcuatiform element; GSC 60219 (E07).

Figures 14 - 18. *Panderodus* cf. *P. staufferi* (Branson, Mehl and Branson). (14,16-18) Lateral views of compressiform elements; GSC 60221 (V10), GSC 60222 (E07), GSC 60223 (V10), GSC 60224 (E07). (15) Outer lateral view of arcuatiform element; GSC 60225 (E07).

Figures 19 - 21. *Panderodus liratus* Nowlan and Barnes. (19) Inner lateral view of arcuatiform element; GSC 60214 (V10). (20,21) Lateral views of compressiform elements; GSC 60215 (V10), GSC 60216 (V10).

Figures 22, 23. *Staufferella inaligera* n.sp. (22) Posterior view of acontiodiform element; holotype, GSC 60786 (E03). (23) Outer lateral view of markedly asymmetrical element; paratype, GSC 60787 (E06).

Figures 24 - 27. *Decoriconus costulatus* (Rexroad). (24) Lateral view of distacodiform element with serrated posterior edge; GSC 60028 (S58). (25) Lateral view of distacodiform element; GSC 60029 (S57). (26) Lateral view of acontiodiform element; GSC 60030 (S57). (27) Lateral view of drepanodiform element; GSC 60031 (S42).

Figure 28. *Panderodus serratus* Rexroad s.f. Inner lateral view of arcuatiform element; GSC 60220 (E39).

Figure 29: *Panderodus* n.sp. C. s.f. Lateral view; figured specimen, GSC 60228 (S03).

Figures 30, 31. *Pseudooneotodus beckmanni* (Bischoff and Sannemann). (30) Anterior view of element; GSC 60778 (E06). (31) Posterior view of element; GSC 60779 (E06).

Figure 32. *Pseudooneotodus mitratus* (Moskalenko). Oral view of element; GSC 60780 (E07).

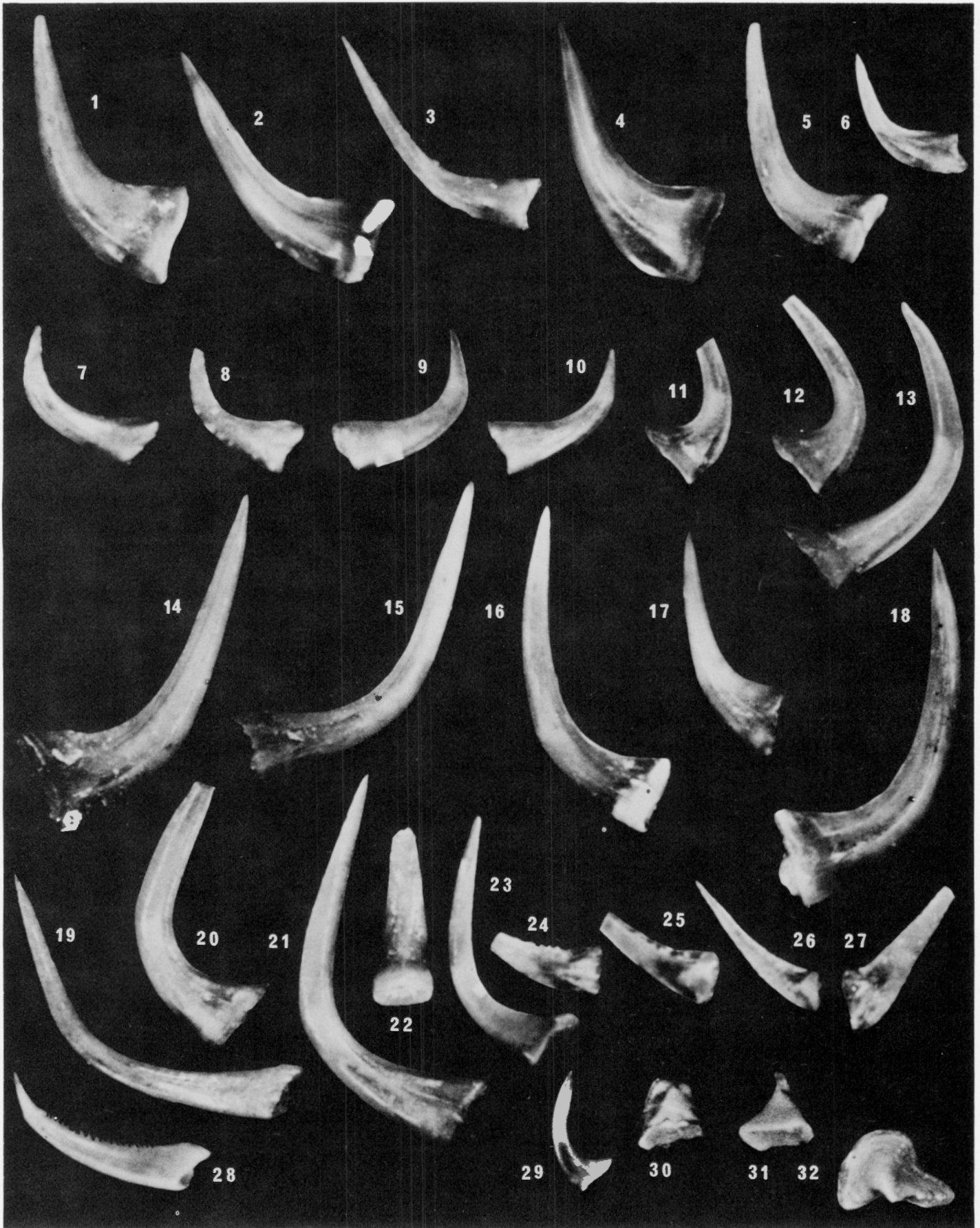


Plate 3

All figures are X35 except figures 1-4,12,17,19-21,26,46 X50; figures 7-9,27,28, 40 X60.

Figures 1 - 6. *Drepanoistodus suberectus* (Branson and Mehl). (1) Lateral view of suberectiform element; GSC 60039 (V06). (2,3,5) Lateral views of homocurvatifiform elements; GSC 60040 (V06), GSC 60041 (V06), GSC 60042 (E07). (4) Lateral view of oistodiform element; GSC 60043 (V06). (6) Lateral view of aberrant homocurvatifiform element; GSC 60044 (V08).

Figures 7 - 9. *Paroistodus? mutatus* (Branson and Mehl). Lateral views of acodiform, distacodiform, oistodiform elements; GSC 60229 (V06), GSC 60230 (V06), GSC 60231 (V06).

Figures 10 - 12, 16 - 18. *Belodina compressa* (Branson and Mehl). (10-12) Lateral views of grandiform elements; GSC 60014 (V08), GSC 60015 (V06), GSC 60016 (V06). (16,17) Lateral views of compressiform elements; GSC 60017 (V06), GSC 60018 (V06). (18) Lateral view of eobelodiniform element; GSC 60019 (V10).

Figures 13 - 15. *Belodina profunda* (Branson and Mehl). (13) Outer lateral view of strongly recurved two-denticle element; GSC 60023 (S04). (14) Lateral view of two-denticle element; GSC 60024 (V13). (15) Lateral view of three-denticle element; GSC 60025 (S04).

Figures 19 - 21. *Belodina dispansa* (Glenister). (19) Outer lateral view of grandiform element; GSC 60020 (V18). (20-21) Lateral views of compressiform elements; GSC 60021 (V18), GSC 60022 (V10).

Figure 22. "*Cordylodus*" *robustus* Ethington and Furnish s.f. Lateral view; GSC 60027 (V13).

Figure 23. *Plegagnathus dartoni* (Stone and Furnish) s.f. Lateral view; GSC 60776 (V10).

Figure 24. *Plegagnathus nelsoni* Ethington and Furnish s.f. Lateral view; GSC 60777 (V12).

Figure 25. *Belodina?* n.sp. A s.f. Lateral view; figured specimen, GSC 60026 (V10).

Figure 26. *Belodella?* n.sp. A s.f. Lateral view; figured specimen, GSC 60013 (S37).

Figure 27. *Eobelodina* n.sp. A s.f. Lateral view; figured specimen, GSC 60045 (S22).

Figure 28. *Eobelodina* n.sp. B s.f. Lateral view; figured specimen, GSC 60046 (S22).

Figures 29 - 33. *Phragmodus undatus* Branson and Mehl. (29,30) Lateral views of phragmodiform elements; GSC 60232 (V21), GSC 60772 (V21). (31) Lateral view of oistodiform element; GSC 60773 (V18). (32) Outer lateral view of breviform element; GSC 60774 (V21). (33) Outer lateral view of typiciform element; GSC 60775 (V17).

Figures 34 - 43. *Aphelognathus* aff. *A. grandis* Branson, Mehl and Branson. (34,35) Lateral views of eoligonodiniform elements; GSC 59993 (S26), GSC 59994 (S26). (36) Postero-lateral view of zygognathiform element; GSC 59995 (S25). (37) Posterior view of trichonodelliform element; GSC 59996 (S25). (38) Lateral view of cyrtionodiform element; GSC 59997 (S26). (39) Outer lateral view of prioniodiniform element; GSC 59998 (S21). (40-43) Lateral views of aphelognathiform elements; GSC 59999 (S21), GSC 60000 (S26), GSC 60001 (S26), GSC 60002 (S26).

Figures 44 - 53. *Aphelognathus pyramidalis* (Branson, Mehl and Branson). (44-46) Lateral views of eoligonodiniform elements; GSC 60003 (S04), GSC 60004 (S21), GSC 60005 (S04). (47) Posterior view of zygognathiform element; GSC 60006 (S03). (48) Posterior view of trichonodelliform element; GSC 60007 (S03). (49) Lateral view of prioniodiniform element; GSC 60008 (S10). (50) Lateral view of pyramidaliform element; GSC 60009 (S10). (51-53) Lateral views of aphelognathiform elements; GSC 60010 (S04), GSC 60011 (V21), GSC 60012 (V21).

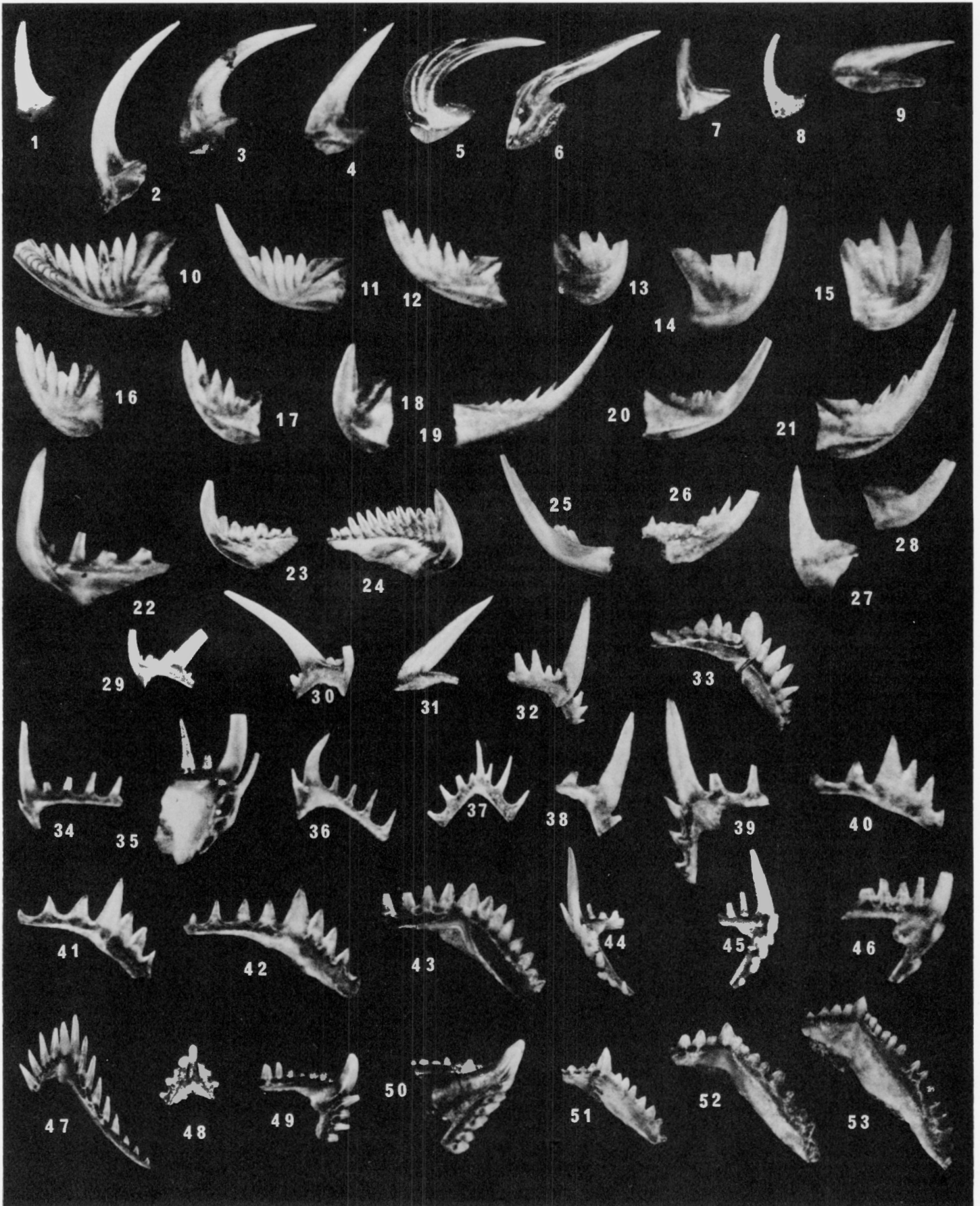


Plate 4

All figures are X30 except figures 4,17,19,21,31-34,38,40,43,44,46 X40; figure 6 X25; figures 8,13,35,39 X60.

Figures 1 - 6. *Oulodus robustus* (Branson, Mehl and Branson). (1) Lateral view of eoligonodiniform element; GSC 60101 (E43). (2) Lateral view of cordylodiform element; GSC 60102 (E44). (3) Posterior view of zygognathiform element; GSC 60103 (E74). (4) Posterior view of trichonodelliform element; GSC 60104 (E71). (5) Lateral view of oregoniform element; GSC 60105 (E45). (6) Lateral view of prioniodiniform element; GSC 60106 (E70).

Figures 7 - 22. *Oulodus rohneri* Ethington and Furnish. (7,10) Lateral views of eoligonodiniform elements; GSC 60107 (V20), GSC 60108 (E19). (8,9) Lateral views of cordylodiform elements; GSC 60109 (V06), GSC 60110 (V14). (11,12) Posterior views of zygognathiform elements; GSC 60111 (V06), GSC 60112 (V03). (13-15) Posterior, lateral, and posterior views of trichonodelliform elements; GSC 60113 (V09), GSC 60114 (V03), GSC 60115 (V03). (16) Lateral view of cyrtioniodiform element with denticulated anterior margin; GSC 60116 (V06). (17,18) Lateral views of cyrtioniodiform elements; GSC 60117 (V03), GSC 60118 (V21). (19,20) Posterior views of prioniodiniform elements; GSC 60119 (V18), GSC 60120 (E19). (21,22) Posterior views of oulodiform elements, GSC 60121 (E19), GSC 60122 (E19).

Figures 23 - 33. *Oulodus ulrichi* (Stone and Furnish). (23) Lateral view of eoligonodiniform element; GSC 60123 (V11). (24) Lateral view of cordylodiform element; GSC 60124 (V08). (25) Posterior view of zygognathiform element; GSC 60125 (V03). (26,27) Posterior and oral views of trichonodelliform elements; GSC 60126 (V06), GSC 60127 (V21). (28) Lateral view of cyrtioniodiform element with denticulated anterior margin; GSC 60128 (V06). (29) Lateral view of cyrtioniodiform element; GSC 60129 (V21). (30) Lateral view of prioniodiniform element; GSC 60130 (V20). (31-33) Posterior views of oulodiform elements; GSC 60131 (V06), GSC 60132 (V13), GSC 60133 (V21).

Figures 34 - 43. *Amorphognathus* cf. *A. ordovicicus* Branson and Mehl. (34) Lateral view of ligonodiniform element; GSC 59983 (V03). (35) Lateral view of keislognathiform element; GSC 59984 (V03). (36) Lateral view of hibbardelliform element; GSC 59985 (V03). (37) Lateral view of tetraprioniodiform element; GSC 59986 (V06). (38,39) Posterior and anterior views of holodontiform elements; GSC 59987 (E06), GSC 59988 (V03). (40,41) Lateral views of ambalodiform elements; GSC 59989 (V03), GSC 59990 (V03). (42,43) Oral views of fragmentary platform elements; GSC 59991 (V06), GSC 59992 (V09).

Figure 44. *Ptiloncodus harrisi* Bordeau s.f. Lateral view; GSC 60781 (V03).

Figures 45,46. *Rhipidognathus symmetricus* Branson, Mehl and Branson. (45) Posterior view of trichonodelliform element; GSC 60782 (V11). (46) Lateral view of bryantodiniform element; GSC 60783 (S01).

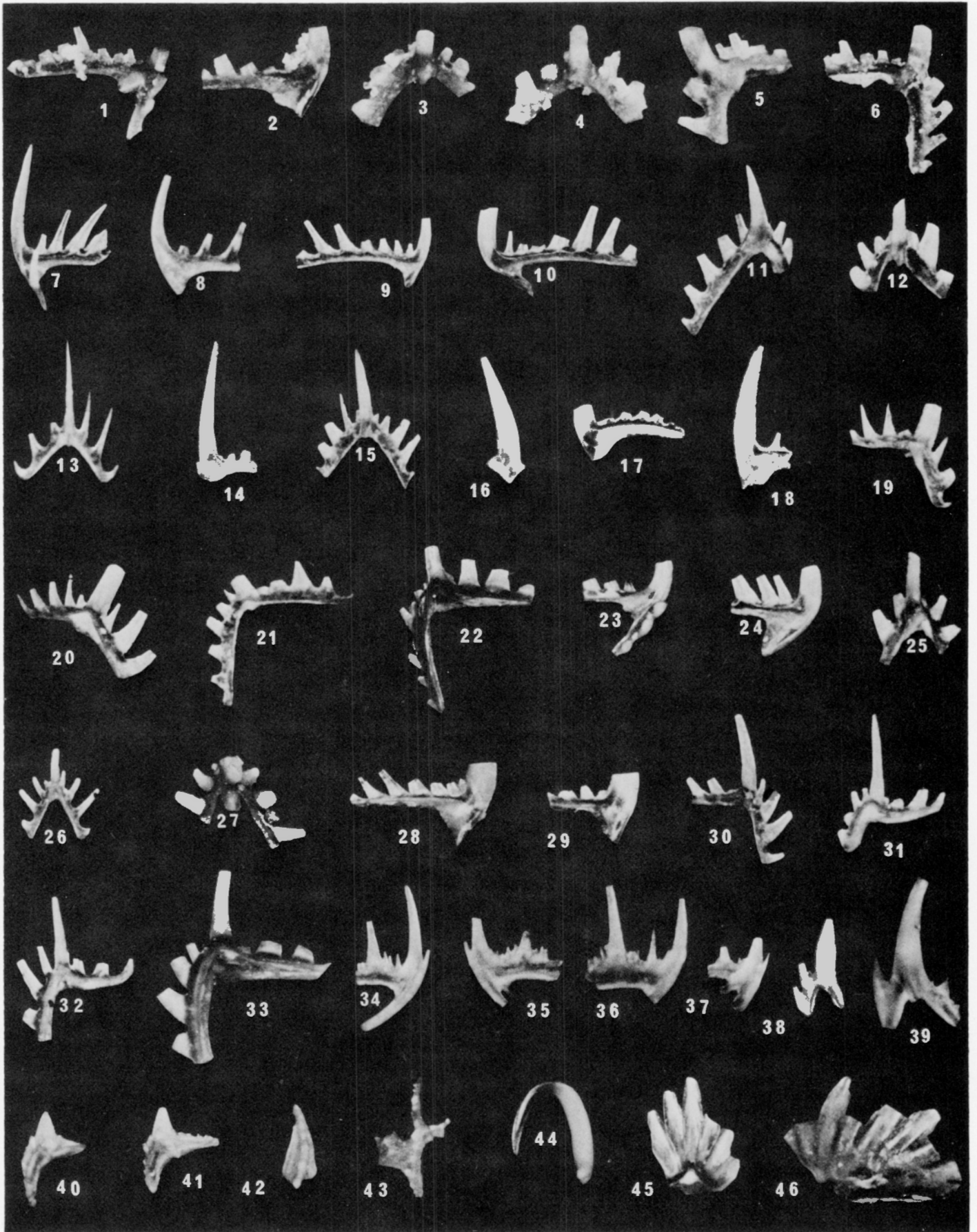


Plate 5

All figures are X35 except figure 2 X40; figures 21,31,39 X50; figure 38 X25. Specimens 17,18,41,42 are holotypes, others are paratypes.

Figures 1 - 27. *Gamachignathus ensifer* McCracken, Nowlan and Barnes. (1,2) Outer lateral views of cordylodiform elements; GSC 60047 (E36), GSC 60048 (E07). (3,4) Outer lateral views of gothodiform elements; GSC 60049 (S25), GSC 60050 (S25). (5-7) Posterior views of keislognathiform elements; GSC 60051 (V12), GSC 60052 (E06), GSC 60053 (E36). (8,9) Posterior views of hibbardelliform elements; GSC 60054 (E36), GSC 60055 (E07). (10) Lateral view of hibbardelliform element; GSC 60056 (V12). (11-13) Inner lateral views of cyrtoniodiform elements; GSC 60057 (E36), GSC 60058 (E36), GSC 60059 (S25). (14,16) Inner lateral views of falodiform elements; GSC 60060 (E36), GSC 60062 (E36). (15) Outer lateral view of falodiform element; GSC 60061 (E36). (17,18) Outer and inner views of prioniodiform element; holotype, GSC 60063 (E36). (19,20) Anterior views of prioniodiform element; GSC 60064 (E07), GSC 60065 (E36). (21-26) Outer lateral views of modified prioniodiform elements; GSC 60066 (E34), GSC 60067 (E32), GSC 60068 (E36), GSC 60069 (E36), GSC 60070 (E36), GSC 60071 (E36). (27) Oral view of modified prioniodiform element; GSC 60072 (E44).

Figures 28 - 45. *Gamachignathus hastatus* McCracken, Nowlan and Barnes. (28,29) Outer lateral views of cordylodiform elements; GSC 60073 (S21), GSC 60074 (E36). (30) Outer lateral view of gothodiform element; GSC 60075 (V12). (31,32) Posterior views of keislognathiform elements; GSC 60076 (E36), GSC 60077 (E06). (33,34) Posterior and antero-lateral views of keislognathiform element; GSC 60078 (E36). (35) Posterior view of hibbardelliform elements; GSC 60079 (E36). (36,37) Inner lateral view of cyrtoniodiform elements; GSC 60080 (E02), GSC 60081 (E09). (38) Outer lateral view of falodiform element; GSC 60082 (E16). (39,40) Anterior and oblique anterior views of prioniodiform element; GSC 60083 (E36). (41,42) Anterior and posterior views of prioniodiform element; holotype, GSC 60084 (S21). (43-45) Outer lateral views of modified prioniodiform elements; GSC 60085 (E36), GSC 60086 (E02), GSC 60087 (E26).

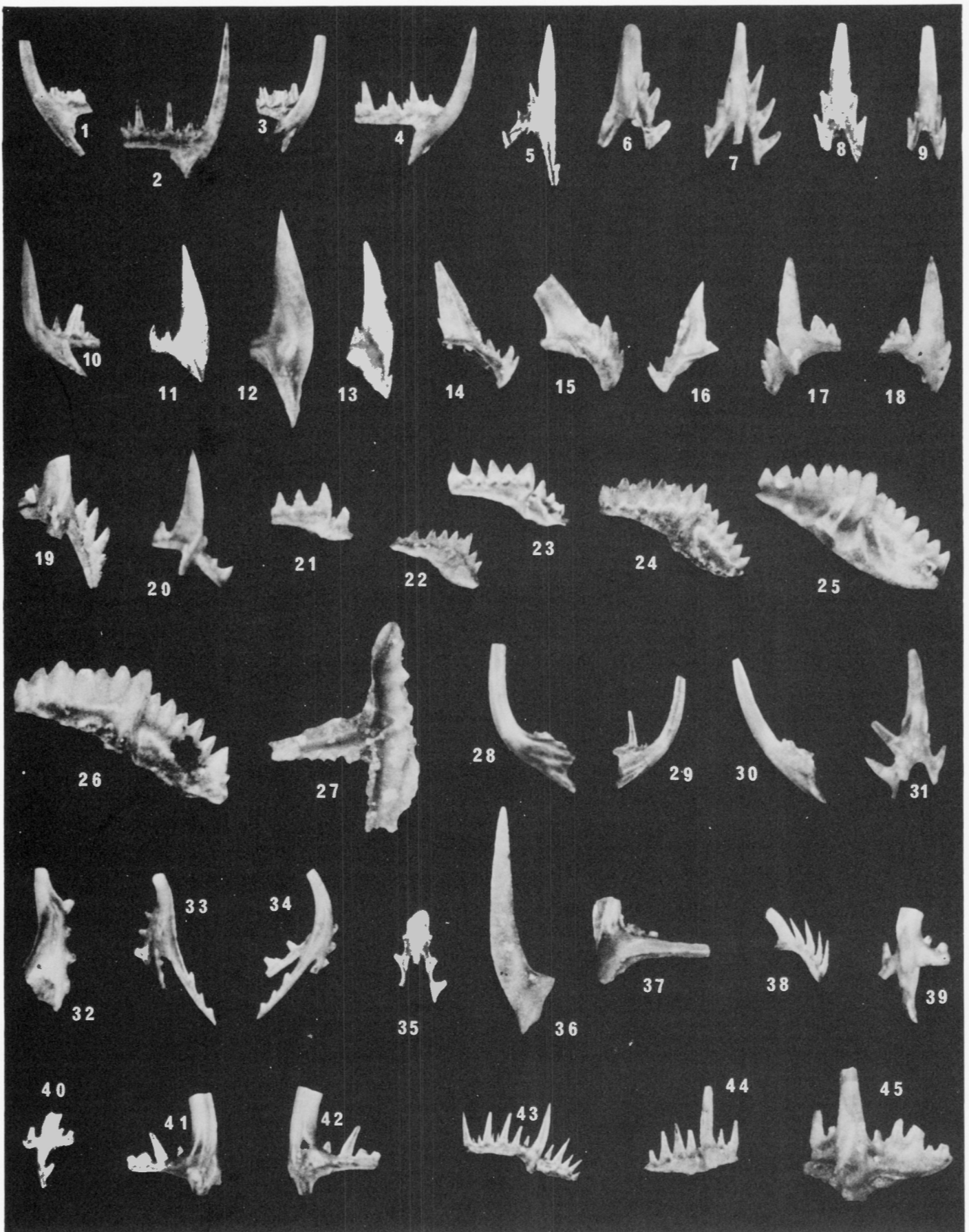


Plate 6

All figures are X30 except figure 31 X100.

Figures 1 - 20. *Oulodus? kentuckyensis* (Branson and Branson). (1-3) Lateral views of ligonodiniiform elements; GSC 60134 (S54), GSC 60135 (S59), GSC 60136 (S55). (4-7) Posterior views of zygognathiform elements; GSC 60137 (S55), GSC 60138 (S67), GSC 60139 (S59), GSC 60140 (S59). (8) Postero-aboral view of zygognathiform element; GSC 60141 (S67). (9) Posterior view of ?zygognathiform element; GSC 60142 (S59). (10,11) Posterior views of trichondelliiform elements; GSC 60143 (S67), GSC 60144 (S62). (12,13) Posterior views of euprioniodiniiform elements; GSC 60145 (S59), GSC 60146 (S62). (14) Posterior view of ?euprioniodiniiform element; GSC 60147 (S59). (15-18) Inner posterior views of lonchodiniiform elements; GSC 60148 (S59), GSC 60149 (S59), GSC 60150 (S59), GSC 60151 (S67). (19,20) Outer and inner lateral views of modified oulodiform elements; GSC 60152 (S43), GSC 60153 (S62).

Figures 21 - 32. *Oulodus? nathani* n.sp. (21,22) Lateral views of ligonodiniiform elements; paratypes, GSC 60154 (S43), GSC 60155 (S43). (23,24) Posterior views of zygognathiform elements; paratypes, GSC 60156 (S43), GSC 60157 (S43). (25,26) Posterior views of trichonodelliiform elements; paratypes, GSC 60158 (S43), GSC 60159 (S67). (27) Posterior view of euprioniodiniiform element; GSC 60160 (S43). (28-30) Inner lateral views of lonchodiniiform elements; paratypes, GSC 60161 (S43), GSC 60162 (S43), GSC 60163 (S44). (31,32) Inner lateral views of blade elements; paratype GSC 60164 (S43), holotype, GSC 60165 (S43).

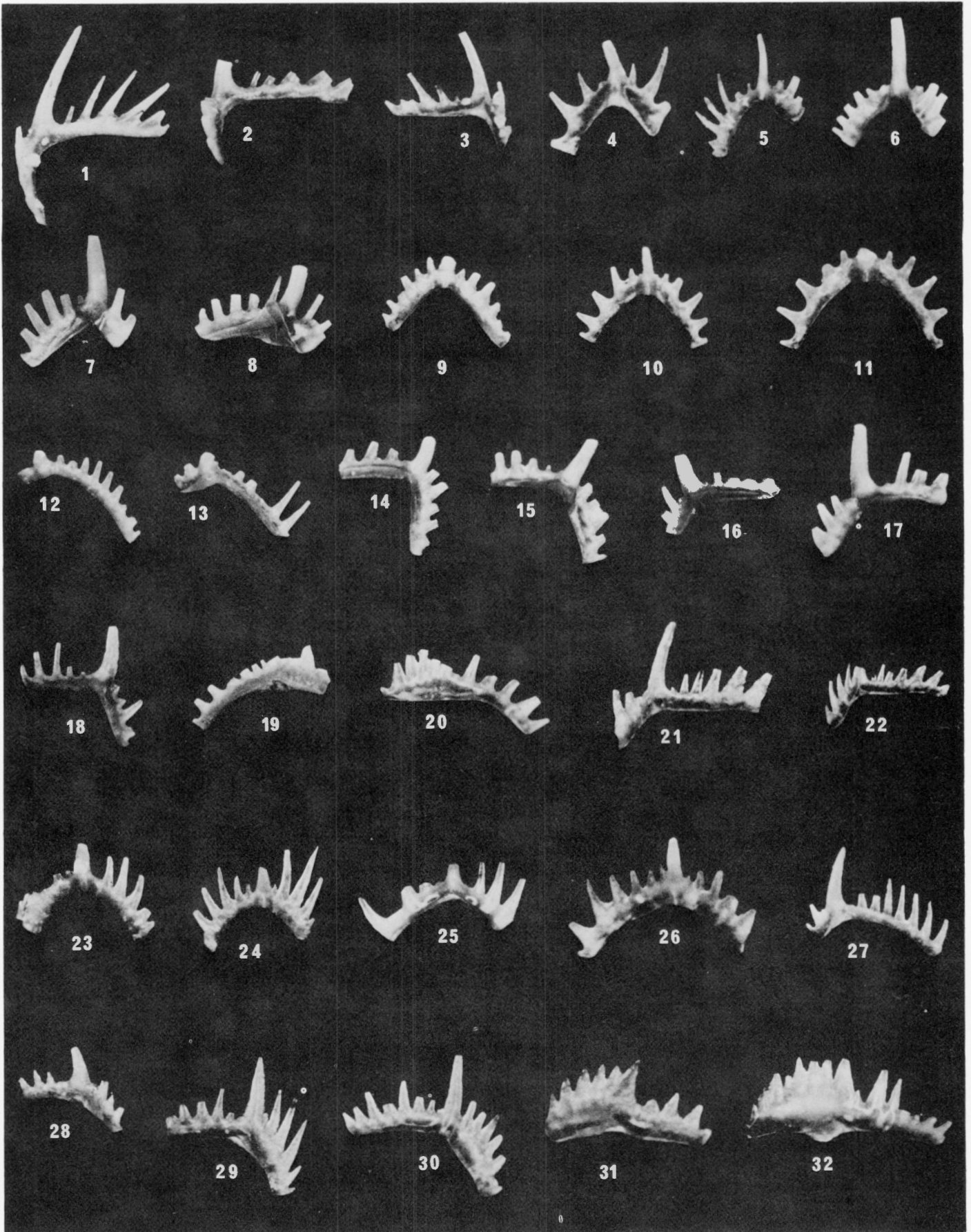


Plate 7

All figures are X30 except figures 1-9,15,26 X46; figures 10,20,22,25,27,30,31 X40; figures 23,24 X25; fig. 29 X30.

Figures 1, 2, 4, 6 - 13. *Ozarkodina hassi* (Pollock, Rexroad and Nicoll). (1,2) Lateral views of ligonodiniform elements; GSC 60166 (S51), GSC 60167 (S43). (4) Posterior view of zygognathiform element; GSC 60168 (S55). (6) Posterior view of trichonodelliform element; GSC 60169 (S44). (7,8) Lateral views of synprioniodiniform elements; GSC 60170 (S51), GSC 60171 (S55). (9,10) Lateral views of ozarkodiniform elements; GSC 60172 (S62), GSC 60173 (S59). (11-13) Lateral views of spathognathodiform elements; GSC 60174 (S59), GSC 60175 (S55), GSC 60176 (S55).

Figures 3, 5, 14 - 18. *Ozarkodina oldhamensis* (Rexroad). (3) Posterior view of zygognathiform element (*O. oldhamensis?*); GSC 60177 (S51). (5) Posterior view of trichonodelliform element (*O. oldhamensis?*) GSC 60178 (S55). (14,15) Lateral views of ozarkodiniform elements; GSC 60179 (S42), GSC 60180 (S59). (16-18) Lateral views of spathognathodiform elements; GSC 60181 (S42), GSC 60182 (S43), GSC 60183 (S44).

Figure 19. *Spathognathodus Manitoulinensis* Pollock, Rexroad and Nicoll s.f. Inner lateral view of spathognathodiform element; GSC 60785 (S31).

Figure 20. *Spathognathodus elibatus* Pollock, Rexroad and Nicoll s.f. Lateral view of spathognathodiform element; GSC 60784 (S51).

Figure 21. *Ozarkodina* n.sp.A s.f. Lateral view of ?ozarkodiniform element; figured specimen, GSC 60184 (S46).

Figures 22 - 27. *Distomodus* aff. *D. kentuckyensis* Branson and Branson. (22,23) Lateral views of eoligonodiniform elements; GSC 60032 (S55), GSC 60033 (S59). (24) Lateral view of zygognathiform element; GSC 60034 (A7651). (25) Posterior view of trichonodelliform element; GSC 60035 (S45). (26) Lateral view of distomodiform element; GSC 60036 (S62). (27) Lateral view of modified ambalodiform element; GSC 60037 (S55).

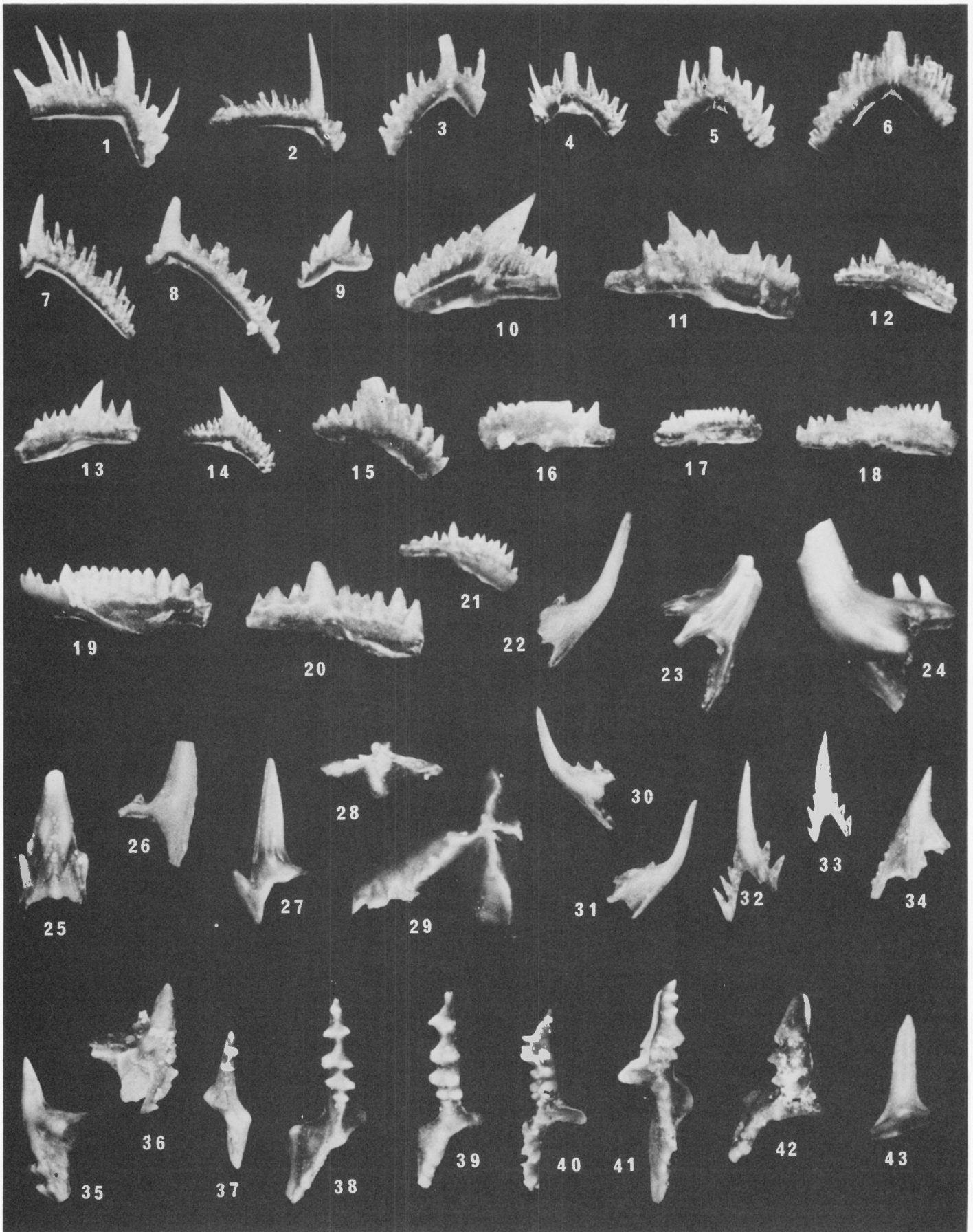
Figure 28. N.gen.A n.sp.B s.f. Oral view of platform element; figured specimen, GSC 60798 (E85).

Figure 29. N.gen.A n.sp.A s.f. Oral view of platform element; figured specimen, GSC 60797 (E81).

Figures 30 - 39. *Icriodella discreta* Pollock, Rexroad and Nicoll. (30,31) Lateral views of eoligonodiniform elements; GSC 60091 (S49), GSC 60092 (S40). (32) Posterior view of zygognathiform element; GSC 60093 (S49). (33) Posterior view of trichonodelliform element; GSC 60094 (S67). (34) Anterior view of sagittodontiform element; GSC 60095 (E54). (35,36) Lateral views of ambalodiform elements; GSC 60096 (E55), GSC 60097 (E53). (37-39) Oral views of platform elements; GSC 60098 (E55), GSC 60099 (E54), GSC 60100 (E54).

Figures 40 - 42. *Icriodella deflecta* Aldridge. Oral views of platform elements; GSC 60088 (E53), *I. deflecta?*, GSC 60089 (E54), GSC 60090 (E54).

Figure 43. "*Drepanodus suberectus*" (Branson and Mehl) (*sensu* Rexroad, 1967) s.f. Posterior view; GSC 60038 (S55).



APPENDIX A

Conodont Distribution Charts

Distribution of conodont elements in each sample for each section (Tables 2-6). See Figure 2 for sample location. 'Taxa' numbers refer to the conodont element numbers found in Table 1. The horizontal lines along both side of the chart represent multielement species.

Table 2. Anticosti Island conodont distribution : Section I (Ellis Bay); Ellis Bay Formation Members 1-5.

TOTAL TAXA		ANTICOSTI ISLAND CONODONT DISTRIBUTION: SECTION I (ELLIS BAY)																			
		E01	E02	E03	E04	E05	E06	E07	E08	E09	E10	E11	E12	E13	E14	E15	E16	E17	E18	E19	E20
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	3	6	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	2	3	6	1	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
4	4	4	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	5	21	23	2	19	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
8	6	8	4	1	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	16	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2	17	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2	18	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
4	19	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
4	19	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
10	20	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
1	22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	33	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
24	34	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
10	35	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
188	38	188	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
58	39	58	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39
269	40	269	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
22	41	22	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
237	42	237	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
65	43	65	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43
143	44	143	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
293	45	293	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
40	46	40	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
116	48	116	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48
16	49	16	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49
43	50	43	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
23	51	23	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
73	52	73	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
39	53	39	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53
1	55	1	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
1	60	1	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
1	61	1	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
5	62	5	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
2	63	2	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63
5	64	5	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
3	65	3	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65
3	66	3	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66
3	67	3	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67
19	75	19	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
29	76	29	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76
6	80	6	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
17	81	17	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81
552	82	552	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
380	83	380	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83
321	84	321	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84
74	87	74	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87
41	88	41	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88
24	89	24	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89	89
34	90	34	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
21	91	21	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91	91
1	95	1	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95
2	97	2	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
70	98	70	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98
44	99	44	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99
26	100	26	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
25	101	25	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101
56	104	56	104	104	104	104	104	104	104	104	104	104	104	104	104	104	104	104	104	104	104
2	105	2	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105
2	109	2	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109
12	110	12	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
12	114	12	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114
3519	TOTAL	0	112	245	104	1	472	369	13	105	0	0	16	12	21	8	94	18	38	94	38

Table 3. Anticosti Island conodont distribution : Section I (Ellis Bay) continued; Ellis Bay Formation Member 6.

ANTICOSTI ISLAND CONODONT DISTRIBUTION: SECTION I (ELLIS BAY) continued

TAXA	E43	E44	E45	E46	E47	E48	E49	E50	E51	E52	E53	E54	E55	E56	E57	E58	E59	E60	E61	E62	E63	E64	E65	E66	E67	E68	E69	TOTAL	
30										0	2	1			2						0							0	
31										1																			1
32																													1
38																													1
39																													1
40																													2
41																													16
42																													3
43																													11
44																													2
45																													24
46																													1
50																													1
51																													3
55																													2
56																													5
58																													2
59																													2
60																													2
81																													1
82																													2
83																													108
84																													44
104																													47
110																													21
116																													1
118																													3
123																													1
124																													1
125																													1
126																													2
127																													4
128																													4
129																													14
131																													1
134																													1
142																													1
143																													3
145																													8
146																													27
147																													39
148																													20
149																													15
153																													7
154																													3
155																													10
157																													12
TOTAL	17	16	12	31	5	5	9	11	2	0	153	44	21	63	2	9	30	1	8	3	0	4	53	9	8	0	8	524	

Table 4. Anticosti Island conodont distribution : Section II (Vauréal River); Ellis Bay Formation Members 1-4.

ANTICOSTI ISLAND CONODONT DISTRIBUTION: SECTION II (VAURÉAL R.)

TAXA	V01	V02	V03	V04	V05	V06	V07	V08	V09	V10	V11	V12	V13	V14	V15	V16	V17	V18	V19	V20	V21	V22	V23	TOTAL	
2						1	1			1														2	
3											1														1
4																									1
5				2																					2
6																									1
8																									1
9																									1
11																									1
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105																									1
107																									1
112																									1
113																									1
114																									1
TOTAL	41	8	236	16	35	284	12	85	16	345	181	258	251	36	77	15	54	105	32	103	69	2	1	2262	

APPENDIX B

Appendix B contains the field logs of the sections studied (Figs. 1,2). Sections were measured from the oldest to the youngest strata. The lithologic descriptions generally refer to the beds from which the conodont samples were taken.

Ellis Bay Section (Section I)

The Ellis Bay Formation, Section I, is located at the southwest end of Anticosti Island on both west and east sides of Cape Henry. The strata are exposed along the shore in cliff faces and on the wave cut platform. The formation is similarly exposed on the east side of Ellis Bay. Section IA (Members 1 and 2) and IB (Members 2 to 6) were collected on the west and east side of Cape Henry, respectively (Fig. 2).

Section IA (Members 1 and 2)

Section IA begins at platform exposures by a creek and midway between Anse aux Fraises and Junction Cliff. Sample E01 was taken on ledge just east of creek (west of building at Anse aux Fraises). Sample E02 was collected by creek midway between Anse aux Fraises and Junction Cliff. E02 was taken from ridge of rock between creek and "road" to beach. Samples E03 and E04 were collected at one-third and two-thirds the distance between E02 and Junction Cliff.

Conodont sample (Field no.)	Sample interval(m)	Height(m) above base	Description
E01(A-048)		0	Calcsiltite to calcarenite: medium dark grey; finely crystalline; fossils not visible; beds are slumped.
E02(A-045)	2	2	Calcsiltite to fine calcarenite: medium grey-brown; finely crystalline; fossils are matrix supported; upper surfaces are burrowed.
E03(A-046)	2	4	Same as E02.
E04(A-047)	2	6	Coarse calcarenite: medium dark grey; coarsely crystalline; mud-supported fossil debris.

Section continues at Junction Cliff, near Anse aux Fraises (west side of Cape Henry). Member 1 consists of one unit that is predominantly shale with interbedded limestone. The shale is medium grey, weathering grey-green and friable. It is highly fossiliferous with abundant brachiopods (orthid, rhynchonellid, sowerbyellid), small tabulate corals, gastropods, cephalopods, crinoid ossicles, criocarids (= "tentaculitids"), tiny bryozoans, pelecypods, and rare trilobites.

E05(A-037)	2	8	Calcsiltite to fine calcarenite: medium grey; finely crystalline; largely micritic but with patches of fossil debris.
E06(A-038)	2.3	10.3	Medium to coarse calcarenite: medium grey; medium crystalline; persistent marker bed 1 m below Member 2; 5 cm thick, thickening to 10 cm where intersects beach, weathered white at this point.
E07(A-03876)	0.3	10.6	Same as E06.

Member 2 at Junction Cliff (Fig. 3) consists of three units. The basal unit is more thinly bedded and argillaceous than the rest of Member 2. It includes:

1) thin (1-2 cm) beds of medium grey, finely crystalline calcilitite and calcsiltite with burrowed lower surfaces; 2) shale, grey and friable; 3) shale with medium grey, finely crystalline calcarenite with scattered fossil debris; 4) a few impersistent crinoidal calcirudite beds that are less than 2 cm thick.

E08(A-039)	1.4	12	Calcsiltite: argillaceous; some crinoidal calcirudite (over 10 cm thick); from 0.7 m above base of Member 2.
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The second unit is about 6 m thick with thin bedded (5-10 cm thick) compact, medium grey-grown calcilitite interbedded with shale partings (up to 3 cm, usually 0.5-1 cm thick). The beds have smooth upper and lower surfaces (burrows are rare) with some beds being impersistent and lenticular. The limestone weathers light grey, paler than that of Member 1. Bedding surfaces rarely have brachiopods, crinoid ossicles, tiny bryozoans but shales have numerous orthid brachiopods and small solitary corals. Samples E09 and E11 were taken from the bottom and top of this unit, respectively.

E09(A-040)	2	14	As above.
E10(A-041)	2	16	as above.
E11(A-042)	2	18	as above.

The upper unit comprises the top part of the overhand of Junction Cliff. It consists of medium grey-brown, finely crystalline calcilitite to calcsiltite similar to underlying unit but the beds are thinner with more shale partings. Beds are mottled, weathering to buff and grey colour. Sample E13 was taken from the top of the cliff.

E12(A-043)	2	20	As above.
E13(A-044)	2	22	as above.

Section IB (Members 2 - 6)

Section IB begins nears Ruisseau Barbarin on the east side of Cape Henry. The first exposure is on the north side of the small bay by West Cliff. The section starts in Member 2 (resistant limestones).

Conodont sample (Field no.)	Sample interval(m)	Height(m) above base	Description
E14(A-083)		0.3	Calcsiltite: medium brown-grey; finely crystalline; considerable mud-supported fossil debris; thin bedded, beds lenticular in places, and separated by grey shal partings, shale/limestone ratio is about 30:70.
E15(A-084)	1.7	2.0	Same as E14 but only sparse fossil debris; weathered grey-green; surfaces often covered with moderately well preserved brachiopods.

This unit is overlain by a covered interval that is about 4 m thick. The next exposure is nearly continuous to the center of the cove. This is a shaly, argillaceous unit, probably Member 3 (limestone:shale = 60:40). The first sample was taken from the base of the exposure.

E16(A-085)	4	6	Medium calcarenite: medium grey; medium crystalline; many mud-supported brachiopod, trilobite and gastropod fragments.
E17(A-086)	2	8	Calcsiltite to calcilitite: medium grey; finely crystalline; few brachiopods on bedding plane but not within bed.

The above lithology is typical of the limestone beds in this member.

E18(A-087)	2	10	Same as E17 but with small, pale grey anastomosing burrows.
E19(A-088)	2	12	Same as E16 but upper surface is covered with strong-ribbed, convex, orthid brachiopods.
E10(A-089)	2	14	Same as E18 with large brachiopods.
E21(A-090)	2	16	Same as E20.
E22(A-091)	2	18	Same as E20.
E23(A-092)	2	20	Calcilitite: medium grey; finely crystalline; argillaceous; has scattered fossil debris in places.

The above sample outcrops at beach level in the corner of the bay, 1 m below the base of West Cliff. Two thin pale weathering marker beds occur at base of West Cliff and 1 m above the base in central part of the cliff. Sample E24 was taken just above this second marker bed.

E24(A-093)	2	22	Calcsiltite: medium dark grey; finely crystalline; highly argillaceous, basal metre weathers blue-grey due to high tide level being at this point; beds above weather light buff-grey; cliff is highly jointed.
E25(A-094)	2	24	Same as E24, but slightly less argillaceous.

The next sample (E26) was taken near the base of the south end of West Cliff (Fig. 5).

E26(A-095)	2	26	Calcsiltite: medium brown-grey; extremely coarsely crystalline; dark weathering; well washed coquina of brachiopod and trilobite fragments; bed is lenticular (0-10 cm thick), compact.
E27(A-096)	2	28	Same as E25.
E28(A-7633)	1.4	29.4	Calcsiltite: light blue-grey; finely crystalline; numerous fossils (brachiopods, corals, trilobites); beds nodular with shale partings.

Member 3 is about 23.5 m \pm 4 m. Sample E28 is the top sample in Member 3 and was taken from immediately below Member 4.

E29(A-7634)	0.2	29.6	Calcsiltite: light grey; finely crystalline.
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Sample E29 was taken from bed (10-15 cm thick) immediately above Member 3-Member 4 boundary. Member 4 is a unit of thin bedded limestone with minor interbedded grey shale. The limestone is predominantly a medium grey, finely crystalline calcilitite with few fossils.

E30(A-097)	0.4	30	As above with some brachiopods.
E31(A-098)	2	32	Same as E30 but fossils are rare.

Sample E31 was taken from within 1 m of the top of West Cliff. Further samples were taken from beach exposures.

E32(A-099)	2	34	Same as E30.
E33(A-100)	2	36	Same as E30.

This exposure is followed by a covered interval (about 5 m thick). Part of the area is water filled even at low tide and is likely to be a shaly interval. Above this is a small bluff exposing about 4 m (3 samples were taken). Section continues past bluff.

E34(A-101)	5	41	Same as E30.
E35(A-102)	2	43	Same as E30.
E36(A-103)	2	45	Same as E30.
E37(A-104)	2	47	Same as E30.
E38(A-105)	2	49	Same as E30.

Fossils are rare in samples E34 to E38; *Beatricea* rare. Beds are thin bedded but with irregular boundaries and many lens out laterally. Sample E38 is probably the top sample of Member 4. This is overlain by a covered interval that is approximately 9 m (\pm 1 m) thick, probably a shaly interval (marsh on land side, no beach exposure to seaward). It is likely to be the lower part of Member 5. The upper part of Member 5 is present, seen in cliffs and is capped by Member 6 (Fig. 6). Sample E39 was taken from the base of the cliff.

E39(A-106)	9	58	Calcsiltite to calcilitite: medium grey; finely crystalline; very argillaceous; beds are not distinct, rubbly to nodular in appearance; few fossils are visible except for rare large <i>Beatricea</i> , isolated tabulate corals, gastropods, brachiopods.
E40(A-107)	2	60	Same as E39.
E41(A-108)	2	62	Medium calcarenite: medium grey; medium crystalline; scattered rugose corals, gastropods, brachiopods.
E42(A7636)	1.25	63.25	Calcsiltite: medium blue-grey; finely crystalline.

The top 1.5 m of Member 5 become more calcarenitic with more isolated coral colonies. Contact with Member 6 is not sharp but gradational over about 20 cm. Beds become medium grey, finely crystalline calcilitite and are less argillaceous; they weather blue-grey rather than grey. Samples E42-E51 were part of a detailed sampling across the conodont-based Ordovician-Silurian boundary. These samples are included herein with samples A109 and A110 excluded (see Appendix D).

E43(A7637)	0.75	64.0	Calcarenite to calcilitite: medium grey; weathers buff-brown; fossiliferous (brachiopods, ?ostracodes).
E44(A7638)	1	65.0	Fine calcilitite: medium grey-brown; finely crystalline; finely laminated.
E45(A7639)	1	66.0	Calcsiltite: light blue-grey; finely crystalline; some fossiliferous patches (brachiopods).

The above sample (E45) is at the top of this exposure; this level was traced to the next good exposure near a small bioherm. A 0.5 m thick laminated unit is at the base overlain by a 40 cm bed of calcarenite. Sample E46 was taken from the upper most 10 cm of this bed.

E46(A7640) 0.25 66.25 Calcarenite: blue-grey; finely crystalline; fossiliferous (brachiopods, gastropods, crinoids).

This bed is overlain by a thin (generally less than 5 cm thick) shale marker horizon. The shale is blue-grey, friable, and recessively weathered. Sample E47 was taken immediately above this shale marker and to norther of bioherm mentioned above (Fig. 8).

E47(A7641) 0.25 66.5 Calcarenite: blue-grey.
E48(A7642) 0.25 66.75 Calcisiltite: medium blue-grey; slightly arenaceous in places.

E49(A7643) 0.5 67.25 Same as E47.
E50(A7644) 0.5 67.75 Same as E48.
E51(A7645) 0.5 68.25 Same as E47.
E52(A-111) 0.75 69.0 Fine calcarenite: medium grey; medium crystalline; few fossils (brachiopods), thin bedded, more argillaceous than the above samples.

E53(A-112) 2 71 Coarse calcarenite: medium grey-brown; medium to coarsely crystalline; much brachiopod debris; well washed.

Sample E53 is laterally equivalent to a small bioherm. The bioherm is rather structureless but corals (*Halysites?*) are common throughout and seem to be the only frame-builder. Above 30 cm above the bioherms, and extending laterally, is a slumped bed (20 cm thick) of laminated and contorted calcisiltites to fine calcarenite.

E54(A-13) 2 73 Same as E53.
E55(A-114) 1.7 74.7 Fine calcilutite: medium grey; coarsely crystalline; much brachiopod debris; bed is compact, lenticular.

The next sample, E56, is from beach exposures between the above outcrop and the main cliff at Cape Henry.

E56(A-115) 2.3 77 Calcilutite: medium brown-grey; finely crystalline; small pale anastomosing burrows within bed, larger burrows on upper surface.

The following samples were taken from the main Cape Henry cliff exposure and southward to tip of Cape Henry.

E57(A-116) 2 79 Same as E56.
E58(A-117) 3 81 Calcilutite: medium brown-grey; finely crystalline.

E59(A-118) 2 83 Same as E58 but includes thin (1 cm) bioclastic lens with brachiopods and rugose corals.

E60(A-119) 2 85 Same as E58.
E61(A-120) 2 87 Same as E58.

Above sample E61 the lithology changes from even, regular thin bedded limestone with irregular burrowed surfaces to similar beds of more resistant fine calcarenite. These are internally laminated, some of which are lenticular and medium bedded. Sample E62 was taken 0.5 m above the first lenticular resistant bed. This is probably close to the top of the Ellis Bay Formation, or may be the lowermost part of the Becscie Formation (Fig. 2).

E62(A-121) 2 89 Calcilutite to calcisiltite: medium grey-brown; finely crystalline.

E63(A-122) 2 91 Same as E62: irregular upper surfaces are burrowed; pale anastomosing burrows are within bed.

E64(A-123) 2 93 Same as E63 but from 10 cm thick resistant, lenticular bed.

E65(A-124) 2 95 Same as E64.

Sample E65 was taken from the top of the bluff. The following samples are from beach exposure near the south tip of Cape Henry.

E66(A-125) 2-3 98 Same as E63.
E67(A-126) 2 100 Calcirudite: medium brown; finely crystalline; weathers buff; thin bedded with thicker resistant lenticular beds (fine calcarenites) and grey shaly partings.

E68(A-127) 2 102 Same as E64.
E69(A-128) 2 104 Same as E67.

Vauréal River Section (Section II)

Section II is exposed along the upper part of the Vauréal River on Anticosti Island. The section begins at Vauréal Falls (Fig. 4) and extends upstream to just west of the intersection of the main road and the river. The section is accessible by way of the road to the river mouth.

The base of the Ellis Bay Formation is herein considered to lie at the major recessive notch near the top of the Vauréal Falls (Fig. 4). This is the lower of two prominent recessive notches visible in the walls of the lower Vauréal River gorge. A third, less prominent, notch occurs about 50 cm below the base of the Ellis Bay Formation (about half way down to the final lip of the falls). Notches are composed of soft brown shale that weathers quite readily. They are thin continuous units (5-10 cm). Sampling started at final lip of the falls (reached by descending on north side of the river) to include the top of the Vauréal Formation. In general, little difference between the Vauréal and Ellis Bay Formations can be seen in the gorge walls. No obvious differences are evident to distinguish the members of the Ellis Bay Formation, although some parts are slightly more argillaceous (Fig. 2).

The upper part of the Vauréal Formation is considered as one unit. It consists primarily of thin bedded limestone with shaly partings. Many beds are irregular to nodular, giving a wavy-bedded appearance to the unit.

Conodont sample	Sample interval(m)	Height(m) above base	Description
V01(A-7613)		0.5	Coarse calcarenite to coarse calcirudite: reddish grey-brown; coarsely to very coarsely crystalline; composed primarily of brachiopod debris, especially sowerbyellid, which is present on bedding planes.
V02(A-7614)	2	2.5	Calcilutite to calcisiltite: medium grey to medium brown-grey; finely crystalline, unfossiliferous but with extensive burrowing, primarily on upper surfaces; burrows are mainly horizontal, sinuous tubes or groves (approximately 1-3 cm in width).
V03(A-7615)	2	4.5	Same as V02.
V04(A-7616)	2	6.5	Same as V02 but with fine calcarenite patches (fossil debris).

The overlying Ellis Bay Formation is slightly thinner bedded at its base than the Vauréal Formation. The surface of beds up to and including those of the second falls commonly display sinuous burrows, and more rarely, *Beatricea*.

V05(A-7617)	0.5	7	Calclutite: medium grey to medium brown-grey; finely crystalline; similar to V02 but lacks sowerbyellid brachiopods.
V06(A-7618)	2	9	Same as V05.
V07(A-7619)	1.5	10.5	Calclutite coquina: medium grey-brown; coarsely crystalline.

Sample V07 is from prominent ledge with forms broad flat area on north side of river, just below and around corner from second falls.

V08(A-7620)	1	11.5	Fine calcarenite with patches of calcisiltite: medium grey-brown; slightly mottled; thin bedded (2-4 cm thick) with irregular wavy surfaces.
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Sample V08 is from 1 m above prominent notch that occurs at the base of the second falls. Pararipples that trend NNE occur just above V08 and V10. These are rather irregular with crests about 4-6 cm and amplitudes of 50-100 cm. The strata at the second falls are composed of the following lithologies: 1) medium grey-brown, finely crystalline calcilutite to calcisiltite; beds are thin (2-4 cm), rubbly with shale partings and some mottling (burrowing); approximately 75 per cent of unit; 2) medium grey-brown to medium grey, coarsely crystalline, intraclastic calcirudite; intraclasts are up to 1.5 cm in diameter; approximately 20 per cent of unit; 3) medium brown-grey, medium to coarsely crystalline, medium to coarse calcarenite within fossil spreads found in even, or laterally discontinuous beds.

V09(A-7621)	2	13.5	Calclutite: medium brown-grey; finely crystalline.
V10(A-7622)	2	15.5	Medium calcarenite with patches of calcilutite (burrowed?): medium brown-grey; medium crystalline; cephalopods present on bedding surface.

Sample V10 is from near top of second falls just below pararipples.

V11(A-7623)	2	17.5	Coarse calcarenite: medium grey; coarsely crystalline; upper surface has <i>Beatricea</i> and cephalopods.
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Sample V11 is from ledge where sideroad meets Vauréal River. Next sample (V12) is taken from bluff on west side of river (before long curve of river and next outcrop). Curver in river exposes about 4 m of strata on east side.

V12(A-7624)	2	19.5	Same as V11.
V13(A-7625)	2	21.5	Medium calcarenite: medium to light grey; medium crystalline.

Section continues on west side of river, just above the level of V13 is a bed with pararipples trending ENE. Ripples have crests that are 5-10 cm high, and have amplitudes of about 50 cm.

V14(A-7626)	2	23.5	Calclutite with fine calcarenite patches: medium grey; finely crystalline; mottled and burrowed on upper surfaces.
V15(A-7627)	2	25.5	Medium calcarenite: medium grey; medium crystalline; about 20 per cent intraclastic; intraclasts are calcilutite and small (average length is about 0.5 cm).

Sample V15 is about 1 m below top of exposure. Upstream about 100 m is the last ledge of limestone extending into river. This is past the old road that goes down to the river and is in view of bridge. The ledge is about 2 m (possibly 3 m) above V15.

V16(A-7628)	2.5	28	Coarse calcarenite to fine calcirudite: medium grey, coarsely to very coarsely crystalline; large <i>Beatricea</i> are present on upper surface (one is 1.25 M in length).
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Interval between V16 and V17 is covered. Immediately west of the bridge is the last exposure before the Member 4 bioherm. Little lithologic change is seen in this exposure. Beds are thin and wavy, rather rubbly. Upper part is poorly exposed.

V17(A-7629)	2	30	Fine calcarenite: medium to light grey; finely crystalline.
V18(A-7630)	2	32	Same as V17.
V19(A-7631)	2	34	Same as V17.
V20(A-7632)	2	36	Calclutite: medium grey; coarsely crystalline; intraclastic.

The next three samples are taken from bioherm within Member 4 (Members 5 and 6 are poorly exposed upstream but were not sampled). The exposure of the reef (bioherm) is about 30 m by 10 m in area. The reef has abundant corals and rarer stromatoporoids similar to those on Salmon River (Member 6). This bioherm differs in that it has abundant *Solenopora* within some depressions. On top of the reef are areas of calcilutite (V23) and on the east side area thin beds of calcirudite (bioclastic debris from reef).

V21(A-362)	4	40	Medium calcirudite: medium blue-grey, weathers sandy-buff; very coarsely crystalline; abundant fossil debris including <i>Solenopora</i> and small corals.
V2(A-363)	0	40	Fine calcarenite: medium grey; finely crystalline; argillaceous; a veneer of limestone from depression in reef that includes pelecypods, trilobites, trepostome bryozoans; <i>Solenopora</i> absent but common on edge of reef.
V23(A-361)	0	40	Calclutite: medium brown; finely crystalline; unfossiliferous, 5-10 cm veneer over coral heads.

Salmon River (Section III)

Section III is located on Salmon River with exposures in the bluffs adjacent to the river. The section is accessible from the road, leading to the mouth of the river. The section is in four parts. Section IIIA is the northernmost section; Section IIIB is near what is referred to as the Natural Bridge; Section IIIC begins near the fishing site, "8 Mile Pool" and Section IIID continues upstream from IIIC at the main falls (Fig. 2).

Section IIIA (Members 1? - 3?)

The section begins about 10 m above the base of the Ellis Bay Formation, on the east side of the river. The sequence is about 10-12 m of interbedded shale and limestone. Both weather brown in contrast to the darker grey in the overlying outcrop. This part of the section is probably equivalent to Members 1 and 2 of Section I; the upper part has much limestone and thus is probably equivalent to Member 2. Sample S01 is taken from the lowest exposed bed.

Conodont sample	Sample interval(m)	Height(m) above base	Description
S01(A-300)	-	0	Coarse calcarenite: medium blue-grey; coarsely crystalline.
S02(A-301)	1	1	Fine calcarenite: medium blue-grey; finely crystalline; weathers brown; silty with about 10-20 per cent quartz silt or fine sand.
S03(A-302)	1.5	2.5	Fine calcarenite: medium brown-grey; finely crystalline; silty as S02; laminated; some bryozoans.
S04(A-303)	1.5	4	Same as S03.

These samples are from a 4 m thick sequence of about 75 per cent shale, 25 per cent limestone but above this the figures are reversed and thus the lower samples could be from strata equivalent to Member 1 at Ellis Bay.

S05(A-304)	2.5	6.5	Coarse calcarenite to coarse calcirudite: medium grey-brown with blue patches; coarsely crystalline; well washed; trepostome bryozoans are abundant; shale partings.
S06(A-306)	1.5	8	Same as S05 but shale-limestone ratio of strata is about 60:40; shales are interbedded with limestone.
S07(A-306)	2	10	Same as S06.

The overlying section is about 4-5 km from the lodge at the mouth of the Salmon River, and 300 m north of underlying section (probably about 5-10 m above S07). These strata include about 4 m of shale and limestone that may be equivalent to Member 3 Section I. The section has dark grey, silty shale that is friable and flaky with some limestone interbeds (1-3 cm thick) especially in the upper part. Samples were taken at 2 m intervals in limestone beds. Sample S08 is from the lowermost bed.

S08(A-307)	7	17	Calcarenite: medium blue-grey; medium crystalline; crinoid ossicles, brachiopods.
S09(A-308)	2	19	Medium calcarenite: medium blue-grey with patches of blue-green shale, crinoid ossicles, brachiopods, rare trilobite fragments.
S10(A-309)	2	21	Same as S09; trilobite fragments are more abundant; blue-green shale is silty.

Section IIIB (Members 2? - 6)

Samples were taken from the exposures along the river near what is called Natural Bridge. The member designations of Bolton (1972) are difficult to recognize except for Members 5 and 6 which can be equated with the same members at Ellis Bay. Member 2? is a unit of thin bedded blue-grey and grey limestones separated by thin shale partings and beds. This unit resembles Members 2 or 4 at Ellis Bay. Member 3? is relatively uniform; it consists of grey shale with interbeds of limestone. It appears to grade into Member 4? with at least one bed with Member 4? lithology occurring in the upper part. Member 4? is not uniform. A unit at the top and bottom have a distinctly nodular bedding type (thin to medium bedded) separated by a grey shale unit with interbedded limestone (similar to Member 3?). Member 5 is thin bedded, platy, with thicker shale partings and beds. The limestone beds are calcilitites with some calcarenite coquinas present. This unit is poorly fossiliferous. There is a sharp lithologic change into Member 6. In other places the lower part of Member 6 is reefal or inter-reefal; here it is more arenaceous but does have scattered corals and other fossils.

Conodont sample	Sample interval(m)	Height(m) above base	Description
S11(A-310)	-	0	Calcilitite: medium grey; finely crystalline; 4 cm bed with even surfaces; weathers grey to blue-green grey.
S12(A-7063)	1.25	1.25	Calcisiltite: medium grey; in places calcarenite with brachiopods, crinoid ossicles; bryozoans.

The next sample (S13) is from the base of the overlying unit of shale and minor limestone interbeds. This unit is Member 3?.

S13(A-311)	0.75	2	Medium calcarenite: medium grey; medium crystalline; laminated 6 cm bed.
S14(A-312)	2	4	Same as S13 but not laminated.

The next unit (Member 4?) is about 12 m thick. S15(A-7604) 1.25 5.25 Calcisiltite: medium grey; finely crystalline; isolated rugose corals; bed 10-15 cm thick; overlain by about 50 cm of grey, friable shale and thin bedded, nodular limestone.

S15(A-313)	1	6.25	Coarse calcarenite: medium grey; coarsely crystalline; partly washed; some cephalopods, gastropods; 25 cm bed.
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Above this is a 6 m interval in a small dry creek bed that exposes mostly grey shale with a few limestone interbeds. Two samples were taken from the latter lithology.

S17(A-314)	4	10.25	Calcisiltite to calcilitite: medium grey; finely crystalline; argillaceous; thin (3 cm) bed.
S18(A-315)	1.6	11.85	Fine to medium calcarenite: medium grey; finely crystalline; somewhat argillaceous.

About 50 m upstream, past a covered interval, is next bluff exposing Member 5. Sample S19 is from base of rubbly, nodular bedded unit.

S19(A-316)	1.15	13	Fine calcarenite: medium grey; finely crystalline; argillaceous; nodules surrounded by shale films and separated by shale partings.
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S20(A-317)	2	15	Same as S19.
S21(A-318)	2	17	Coarse calcarenite to calcirudite: medium grey; coarsely crystalline; brachiopod coquina, rare

About 50 m upstream, past a covered interval, is next bluff exposing Member 5. Sample S19 is from base of rubbly, nodular bedded unit.

S19(A-316)	1.15	13	Fine calcarenite: medium grey; finely crystalline; argillaceous; nodules surrounded by shale films and separated by shale partings.
S20(A-317)	2	15	Same as S19.
S21(A-318)	2	17	Coarse calcarenite to calcirudite: medium grey; coarsely crystalline; brachiopod coquina, rare intraclasts.

Sample S21 was taken 1 m above the base of Member 5; samples S25 was taken from 0.6 m below the base of Member 6.

S22(A-319)	2	19	Coarse calcarenite: medium grey; coarsely crystalline.
S23(A-320)	2	21	Calcilutite: medium to light grey; finely crystalline.
S24(A-321)	2	23	Same as S23.
S25(A-322)	2	25	Calcilutite to calcisiltite: medium to light grey; finely crystalline; burrows.

Sample S27 was taken from about 10-15 cm above the base of Member 6. The lower 25 cm is one bed. Above this are sandy limestone beds followed by about 20 cm of fine quartz sandstone that is partly calcareous.

S27(A-323)	1.5	26.5	Calcisiltite: light brown; finely crystalline; arenaceous; few corals present.
S28(A-7605)	0.65	27.15	Calcisiltite: light brown; finely crystalline.

Samples S29-S31 were studied by thin section and the results are included in the descriptions. The matrix may include clays as well as micrite.

S29(A-7606)	0.5	27.65	Calcarenite: light brown; medium crystalline; modal composition: carbonate allochems (55-65 per cent) of abundant pellets, brachiopod, coral, trilobite, crinoid, and mollusc debris; quartz and feldspar (1-2 per cent), very fine grained; fine grained matrix (10-15 per cent); sparry calcite (20-25 per cent), very fine grained; conodonts well preserved.
S30(A-7607)	0.6	28.25	Quartz arenite: light buff-brown, slightly reddish; finely laminated upon weathering; modal composition: carbonate allochems (10-15 per cent) of fossil debris; quartz and feldspar (plagioclase and orthoclase)

S31(A-7608)	0.5	28.75	(55-60 per cent), sub-rounded to rounded; fine grained matrix (30-35 per cent); other (<5 per cent) includes rock fragments, pink garnets, abraded conodonts, rounded blue-grey phosphate? nodules. Slightly arenaceous calcilutite: light grey-brown; modal composition: carbonate allochems (30-40 per cent), similar to S29; quartz and feldspar (15-25 per cent), subangular to round; fine grained matrix (45-55 per cent).
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Section IIIC (Members 5 and 6)

At 8 Mile Pool, the base of Member 6 is exposed, overlying a few metres (1-3 m) of Member 5. The sandy limestone seen in the top of Section IIIB (sample S27) is present and can be traced directly into the reef. On both east and west bank, small reefs or bioherms are present. The reefs are up to 3 m in height and usually 5-10 m wide but the size varies. They contain abundant corals (*Paleofavosites*, *Heleolites*, *Catenipora*, *Cyathophylloides*, *Paleophyllum*, *Favistina*) and a few stromatoporoids. Inter-reef beds dip at angle up to about 30 degrees and are largely bioclastic, partly arenaceous. Te inter-reef beds were sampled.

Conodont sample	Sample interval(m)	Height(m) above base	Description
S26(A-7609)	-	0.5	Calcisiltite: medium blue-grey; thin bedded (10-15 cm); crinoid ossicles; burrows.
S32(A-7610)	0.5	1.0	Calcisiltite: brown; finely crystalline; weathers brown.
S33(A-7611)	0.5	1.5	Calcarenite: medium grey-brown; weathers brown; from same beds as S32.
S34(A-7612)	0.5	2.0	Calcarenite: buff-brown; finely crystalline.
S35(A-324)	0.5	2.5	Fine to medium calcarenite; medium brown; finely crystalline; about 10-15 per cent quartz sand; some brachiopods.

Samples S26, S32-34 were taken from the west bank, samples S35-37 were taken from the east bank of Salmon River.

S36(A-325)	1.0	3.5	Same as S35.
S37(A-326)	1.0	4.5	Same as S35.

Above this is a covered interval about 200 m in length, thus representing about 4 m of strata. The next bluff (at next "pool") was sampled in 2 m intervals (Fig. 10).

S38(A-327)	4	8.5	Calcisiltite: medium grey; finely crystalline; top surface has many leptaeid and orthid brachiopods, some trilobite fragments, but fossils are generally restricted to upper surface only.
S39(A-328)	2	10.5	Fine calcarenite: medium grey; finely crystalline; laminated; some leptaeid brachiopods on bedding planes.

S40(A-329)	1.5	12	Calcirudite to calcisiltite: medium grey; finely crystalline; small brachiopods; upper part barren except for anastomosing burrows; both parts poorly washed.	S56(A-345)	2	41.5	Same as S53, but grey-brown.
				S57(A-346)	2	43.5	Same as S56.
				S58(A-347)	2	45.5	Medium calcarenite: medium blue-grey; finely crystalline; bioclastic lens (1-2 cm thick); some argillaceous partings.
S41(A-330)	2	14	Fine calcarenite to calcisiltite: medium grey; finely crystalline; laminated; flat base, irregular top.	S59(A-348)	2	47.5	Fine calcarenite: medium blue-grey; finely crystalline; laminated with some intraclasts, brachiopods.
S42(A-331)	2	16	Calclutite to burrowed calcisiltite and calcarenite: medium grey; finely crystalline; diverse microfacies in 7 cm bed; argillaceous partings.	S60(A-349)	2	49.5	Calclutite: medium-brown; finely crystalline.
S43(A-332)	2	18	Medium to coarse calcarenite: medium grey; medium crystalline; partially laminated; some brachiopod debris; bed has flat base, irregular top.	S61(A-350)	2	51.5	Calcirudite: medium brown; finely crystalline; brachiopods; few intraclasts.
S44(A-333)	1.5	19.5	Medium to fine calcirudite: medium grey; very coarsely crystalline; bed is conchoidal with brachiopods and a few gastropods; laminated.	<i>Section IIID (Member 6; and lower Becscie Formation)</i>			
Sample S44 is from a calcirudite bed (20 cm) that grades upwards into a fine calcarenite (5 cm) at the top. This sample is 2 m below a thick bed with slump structures (1 m across, about 20 cm high). Above this, a cliff on south side of the entrance of a road was sampled starting at the base and working up the side. This is probably at, or just below the level of the last sample.				Section IIID is located near the major falls on Salmon River, starting at the lower falls. The base of the rapids ends in a 0.5 m waterfall and the first sample was taken here. This is probably about the same level as S61 at last section. Sampling continued upwards in 2 m intervals to <i>Virgiana</i> beds. The lithologies include 1) thin calcarenite with brachiopods; 2) thicker, laminated calcarenites with few fossils visible; 3) argillaceous, nodular limestone; 4) limestone with conglomerate, ripple marks, and slump structures.			
				Conodont sample	Sample interval(m)	Height(m) above base	Description
				S62(A-351)	2	53.5	Calcarenite: medium-grey, reddish; medium crystalline; sparse brachiopods.
				S63(A-352)	2	55.5	Medium calcarenite: medium-grey; medium crystalline; laminated; no fossils visible; smooth upper and lower surfaces.
S45(A-334)	1.5	21	Fine calcilutite to calcarenite: medium grey; finely crystalline; 1 cm bed; argillaceous; brachiopod debris.	S64(A-353)	2	57.5	Same as S63, but with sparse brachiopods.
S46(A-335)	2.0	2.3	Fine to medium calcarenite: medium grey; medium crystalline; cross-bedded; lenticular pinching out into argillaceous (shaly) limestone.	S65(A-354)	2	59.5	Same as S64, bed varies in thickness (5-10 cm).
				S66(A-355)	2	61.5	Same as S65, but with some intraclasts, silicified brachiopods.
S47(A-336)	0.5	23.5	Calclutite to calcarenite: medium grey-brown; finely crystalline; argillaceous with many shale partings producing nodular appearance.	S67(A-356)	2	63.5	Calcisiltite: medium-brown; finely crystalline; partly siliceous; has brachiopods on upper surface.
S48(A-337)	2	25.5	Medium calcarenite: medium to dark blue-grey; medium crystalline; few small intraclasts; thin (3 cm) platy bed.	Sample S67 is located 15 cm above a conglomerate bed that includes intraclasts up to 1 m in length plus many blocks of intraclastic conglomerate. This conglomerate unit is only about 25 cm thick and is overlain in places by rippled calcarenite. The unit is about 1 m below the top of the major falls.			
S49(A-338)	2	27.5	Fine calcarenite: medium grey; finely crystalline; intraclastic bed.	S68(A-357)	2	65.5	Calclutite: medium-brown; finally crystalline; burrows produce faint mottling upon weathering.
S50(A-339)	2	29.5	Fine calcarenite: medium grey; finely crystalline.	S69(A-358)	2	67.5	Same as S68.
S51(A-340)	2	31.5	Same as S50.	S70(A-359)	2	69.5	Calclutite: medium brown; finely crystalline.
S52(A-341)	2	33.5	Calclutite: medium brown-grey; finely crystalline.	S71(A-360)	2	71.5	Coarse calcarenite: medium brown; coarsely crystalline; brachiopods, corals; <i>Virgiana</i> occurs in these beds.
S53(A-342)	2	35.5	Calcisiltite: medium to light grey; finely crystalline; finely laminated.	Samples S70 and S71 are in a unit of rubby calcilutite and lensoidal calcarenite with rare conglomerate and lacking slump structures. Bolton (1972) placed the boundary between the Ellis Bay and Becscie formations at the conglomeratic beds mentioned above (below Sample S67; Fig. 2).			
S54(A-343)	2	37.5	Same as S53.				
S55(A-344)	2	39.5	Same as S53.				

APPENDIX C

Introduction

The study of conodont distribution with regard to apparatus reconstruction and paleoecology included the use of a computer program for cluster analysis (NT-SYS : Numerical Taxonomy System of Multivariate Statistical Programs, by F. J. Rohlf, J. Kishpaugh and D. Kirk, 1974) (made available by F. J. Rohlf, The State University of New York at Stony Brook, Stony Brook, New York, U.S.A. 11790). A brief discussion is included herein to explain the cluster analysis of this study. The same procedures were followed by Nowlan and Barnes (this volume).

Cluster analysis groups variables (such as elements or species) and samples (associations of elements or species) together according to the magnitudes and interrelationships of their similarity coefficients (Sokal and Rohlf, 1969). Rohlf (1970, p. 59) summarized the computational steps performed in a 'typical' numerical taxonomy study. These are: 1) data are gathered (usually quantitative measurements forming an array or matrix); 2) data are standardized (to place measurements in equivalent units); 3) using one of many similarity coefficients, a matrix of coefficients is computed (which measures the relative degree of similarity between all pairs of categories). The matrices generated by the above step are usually large, therefore a method of summarizing the information is necessary (such as the tree-like cluster diagram, or dendrogram that is used herein).

The data matrices used in this study contain the absolute numbers of conodonts for each sample (i.e. conodont distribution data) with computer numbers assigned to each element and species (Table 1). Two types of data were utilized. For multielement analysis the absolute numbers are those for each form element, while for paleoecologic analysis the absolute numbers are those for each multielement species. Either the form or multielement type of data can be used for the second analysis; the latter data type were used solely to simplify the information to be processed.

The data matrices can be used with two different modes of analysis. In the Q-mode technique, samples are related on the basis of their attributes (elements or species) whereas in the R-mode technique, the attributes are related to each other on the basis of the samples in which they occur (Hazel, 1970). Both techniques were used in this study, the former to interpret the conodont paleoecology, the latter to study the apparatus reconstructions.

There are a number of correlation coefficients that can be used in cluster analysis. Cheetham and Hazel (1969) listed a great number of coefficients for ecologic studies. Von Bitter (1972) discussed in detail the use of several similarity coefficients. The simple matching coefficient (Kaesler, 1966) and the Jaccard coefficient (Kaesler, 1966; Sneath and Sokal, 1973) were experimented with but the writers finally selected a product-moment correlation coefficient because it was regarded as the one that best expressed the distributional data. In addition, a P-LOG transformation was employed to ensure a log-normal distribution of the data. In this study, the data were standardized (mean of zero and standard deviation of unity) to place all the variables on an equally weighted basis before the computation of correlation coefficients.

Two clustering techniques are commonly used. These are the weighted and unweighted pair group methods (WPGMA and UPGMA, respectively). Von Bitter (1972) and Tarrant (1977) both found that analyses using the UPGMA clustering method consistently resulted in a better degree of fit between the original correlation coefficient matrix and the resulting cluster diagram (as shown by the cophenetic correlation coefficient). The UPGMA clustering method was used herein.

Results of Cluster Analysis

While the methods of multielement reconstruction used in this study are those commonly accepted and used by other conodont specialists, other methods exist that will permit a check on the validity of the reconstructed apparatuses. These include recurrent group analysis (Kohut, 1969) and cluster analysis (von Bitter, 1972, among others). The latter method, using the R-mode technique, was used with form element data from the Ellis Bay Formation. This method was used to produce resulting cluster diagrams that would suggest or test possible multielement associations. In the interpretation of these patterns (which express the distributional associations), it is necessary also to consider other characteristics of the elements (such as morphology) and to make comparisons with homologous apparatuses.

The resulting cluster diagrams (Figs. 17-19) do not suggest any associations that had not been determined previously by the more traditional methods of multielement reconstruction. The analyses did, however, lend support to many reconstructions while being in conflict with others.

Some groupings of elements include all of the elements described herein as being part of a multielement species (e.g. *Drepanostodus suberectus* (Branson and Mehl), *Panderodus panderi* (Stauffer), *Phragmodus undatus* Branson and Mehl, Fig. 17; *Panderodus clinatus* n.sp., *P. gracilis* (Branson and Mehl), Fig. 18; *Oulodus? kentuckyensis* (Branson and Branson), *O.? nathani* n.sp., *Walliserodus curvatus* (Branson and Branson), Fig. 19).

Many species have element groupings that are incomplete (e.g. *Amorphognathus* cf. *A. ordovicicus* Branson and Mehl, Fig. 17; *Aphelognathus pyramidalis* (Branson, Mehl and Branson), Fig. 18). In many cases, the apparatuses of species grouped in this manner have been well documented elsewhere, the lack of clustering of all elements of these species is thought to be the result of insufficient material.

Other examples can be given where some elements of two species were grouped together (e.g. *Gamachignathus ensifer* McCracken, Nowlan and Barnes and *G. hastatus* McCracken, Nowlan and Barnes, Fig. 17; *Oulodus rohneri* Ethington and Furnish and *O. ulrichi* (Stone and Furnish), Fig. 18). This type of clustering shows the close similarity of occurrence of these respective species and may suggest that they are not separate species. However, it does support the generic grouping of these elements. In the above examples, it was thought that other methods of species reconstruction were more reliable.

In the analysis of data from the Ellis Bay section (Section I), elements of *Panderodus* species (*P. gracilis*, *P. panderi*) are clustered with elements of the two species of *Gamachignathus* (Fig. 17). In this case, it is clear that they do not represent the same multielement taxon but are probably clustered together because they are ecologic associates. In fact, these four species comprise over 90 per cent of the taxa from this section.

The elements of other new species or suggested apparatuses not mentioned above were not grouped by cluster analysis. These taxa include *Aphelognathus* aff. *A. grandis* Branson, Mehl and Branson, *Staufferella inaligerae* n.sp., and the suggested association of taxa of the following: *Distomodus* and N.gen. A.; *Panderodus* n.sp. A.s.f. and *P.* n.sp. B.s.f. Again, the lack of clustering is not surprising since the total number of these taxa is small.

An interesting grouping is that of the elements identified in Figure 19 as *Ozarkodina oldhamensis* (Rexroad) and *O. hassi* (Pollock, Rexroad and Nicoll). The former (reported herein as incomplete) consists only of ozarkodiniform and spathognathodiform elements, the latter includes the elements that are shared between *O. oldhamensis* and *O. hassi* (and arbitrarily assigned to *O. hassi*). This grouping suggests that these shared elements occur more regularly with *O. hassi* than with the remaining elements of *O. oldhamensis* (cf. Tables 1,6).

The study of the conodont paleoecology involved the interpretation of cluster diagrams (Figs. 15,16) as well as distributional charts (Appendices A,D) and relative abundance logs (Figs. 13,14). All of the above represent different methods of diagrammatically summarizing the basic conodont distribution data. Cluster analysis was performed in the Q-mode for paleoecologic reconstruction, using multielement species distribution data. Data of Members 1 through 5 from all three sections were used (Fig. 15), as well as data from Member 6 of Section III (Fig. 16).

Figures 15 and 16 illustrate the conodont communities. These communities are discussed in detail in the section on paleoecology. In most cases, the association of samples that are clustered are the same as those used to define the communities. Communities A through E contain samples which have a diagnostic association of conodont species and are found in a characteristic section or part of a section. In Figure 19, Community A? is queried because although the samples contain an association of species that is similar to that of Community A the samples are from the upper parts of Members 1-5 of all three sections. Other community designations are queried because the samples have characteristics of both Communities A and B. Other sample clusters are not given community designations because the conodont yields for these samples are poor and hence may not be considered valid for this type of analysis.

Figure 15. Conodont apparatus cluster (Q-mode: community reconstruction), Ellis Bay Formation Members 1-5 (Sections, I, II, III). 'IDENT' refers to the variables used in this analysis. 'ROW' refers to the samples. 'LEVEL' refers to the level of correlation. Location of samples is given in Figure 2 and Appendix B. The cluster diagram has been abbreviated (at left margin) for reproduction.

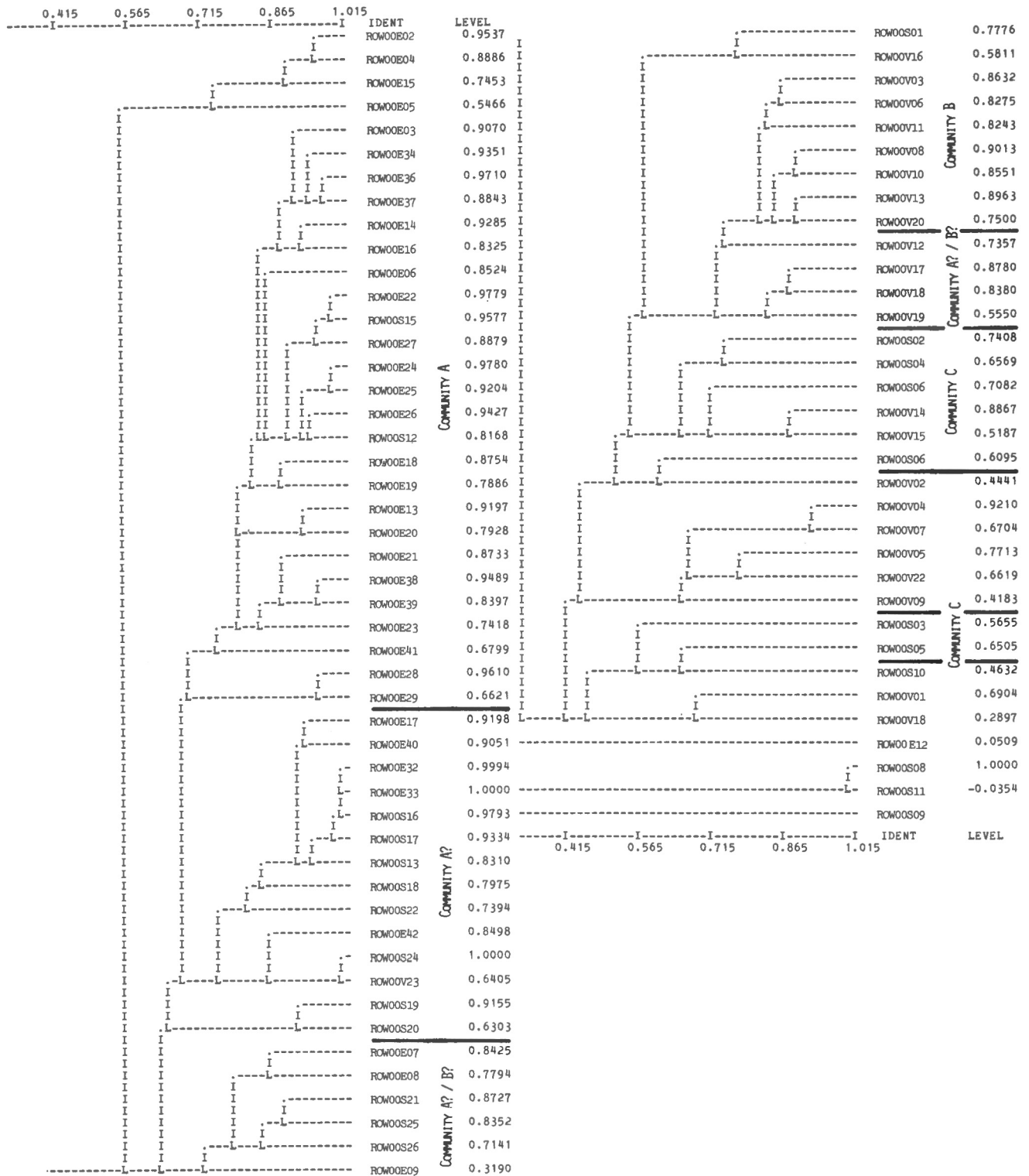


Figure 16. Conodont apparatus cluster (Q-mode: community reconstruction), Ellis Bay Formation Member 6 (Section III). 'IDENT' refers to the variables used in this analysis. 'ROW' refers to the samples. 'LEVEL' refers to the level of correlation. Location of samples is given in Figure 2 and Appendix B.

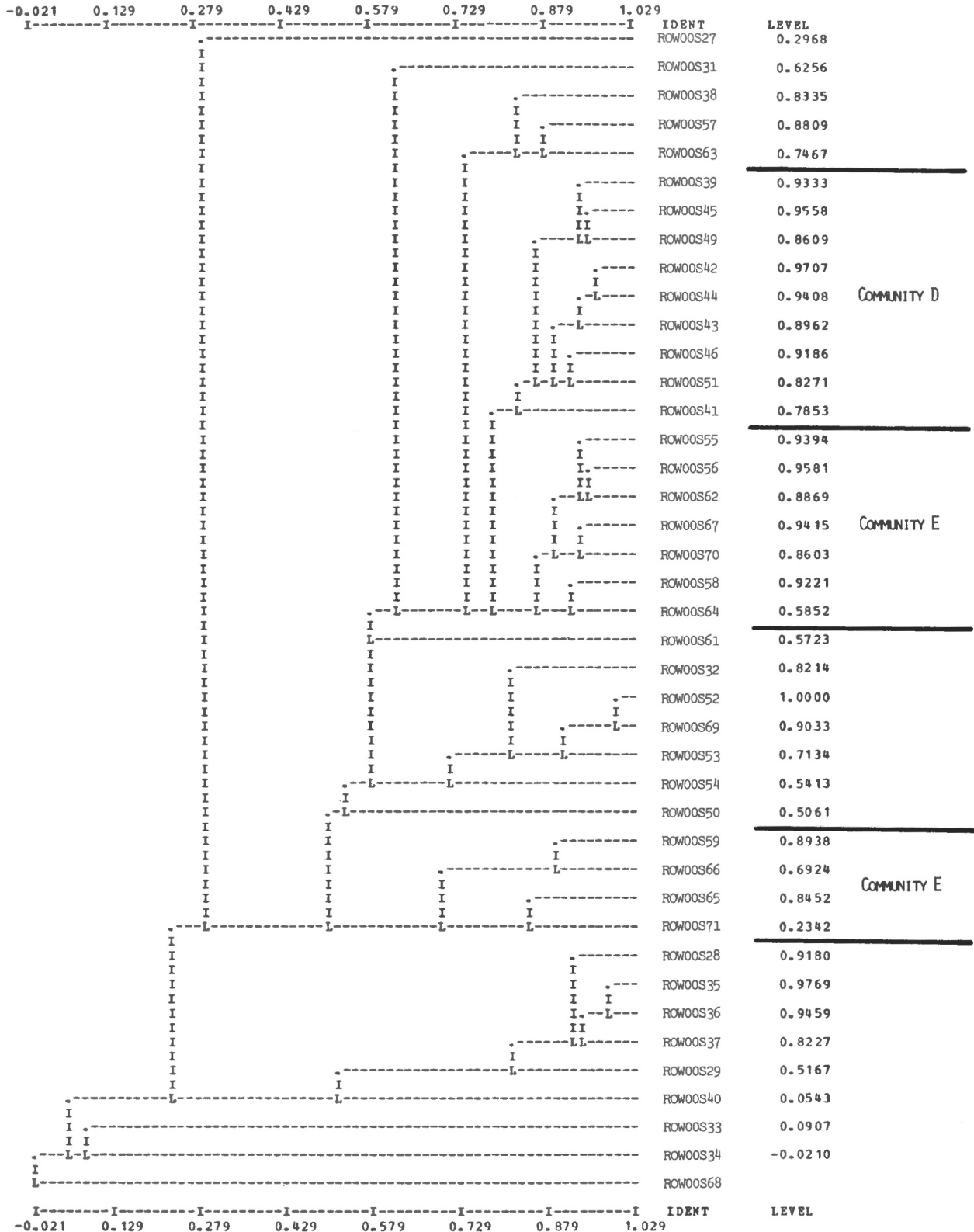


Figure 17. Conodont element cluster (R-mode: multielement assemblage reconstruction), Ellis Bay Formation Members 1-5 (Section I). The cluster diagram shows the clustering of elements into multielement species. Some of these species are outlined. 'IDENT' refers to the variables used in the analysis. 'COL' refers to the conodont element numbers. Table 1 gives the key to the conodont element numbers. The diagram has been abbreviated for reproduction by deleting a few elements with low correlation levels from the bottom.

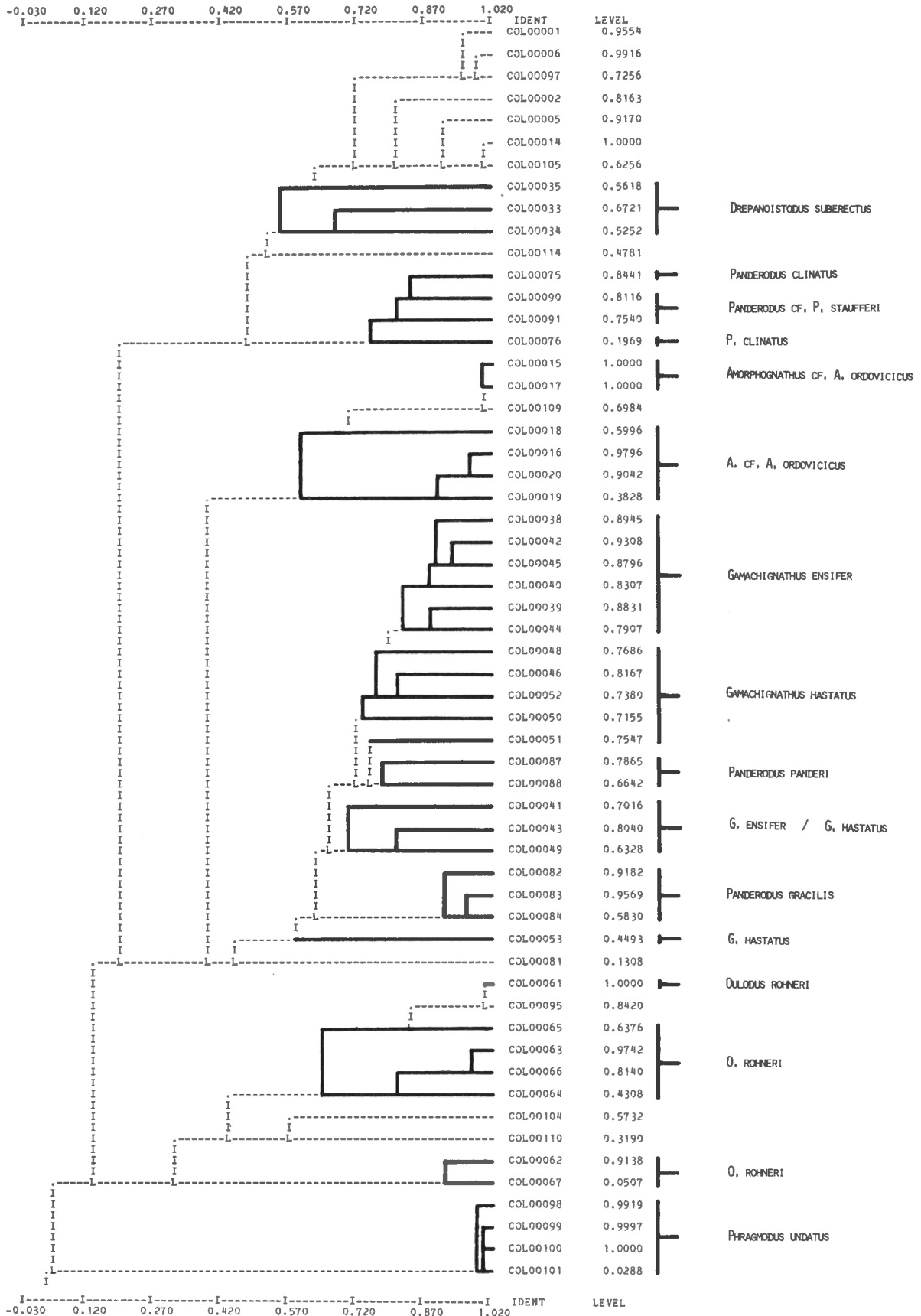


Figure 18. Conodont element cluster (R-mode: multielement apparatus reconstruction), Ellis Bay Formation Members 1-4 (Section II). The cluster diagram shows the clustering of elements into multielement species. Some of these species are outlined. 'IDENT' refers to the variables used in the analysis. 'COL' refers to the conodont elements. 'LEVEL' is the level of correlation. Table 1 gives the key to the conodont element numbers. The diagram has been abbreviated for reproduction by deleting a few elements with low correlation levels from the bottom.

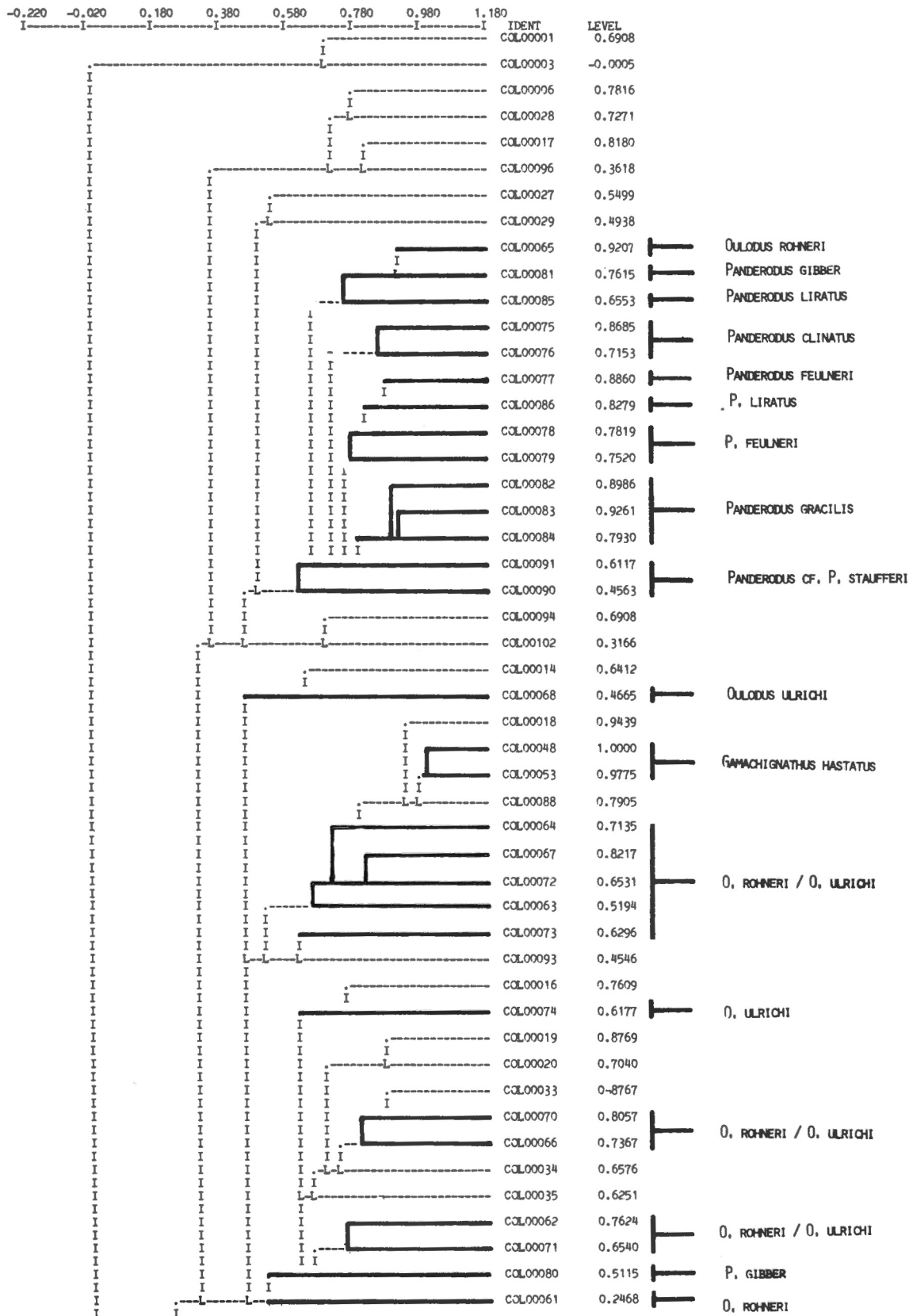


Figure 18. (continued)

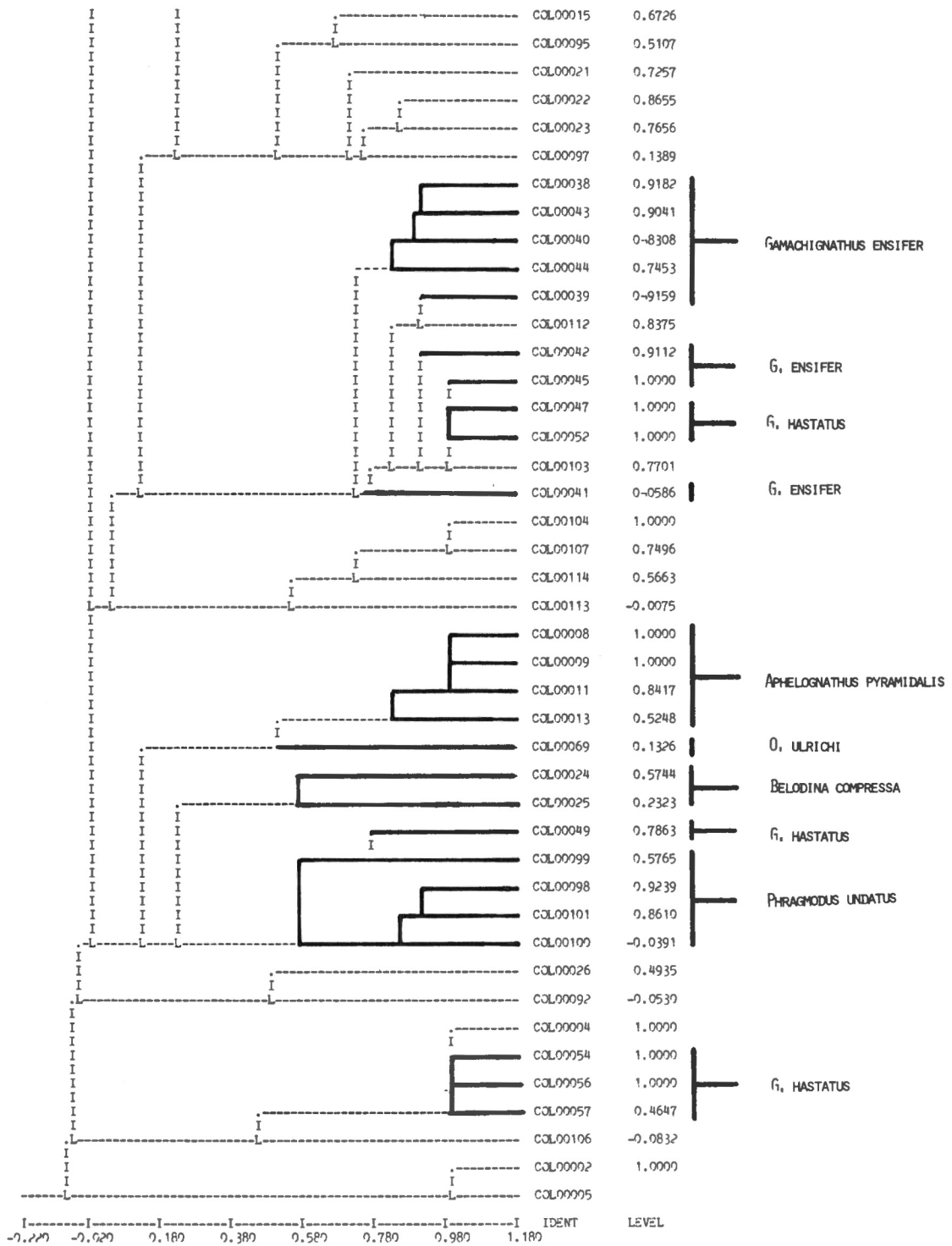
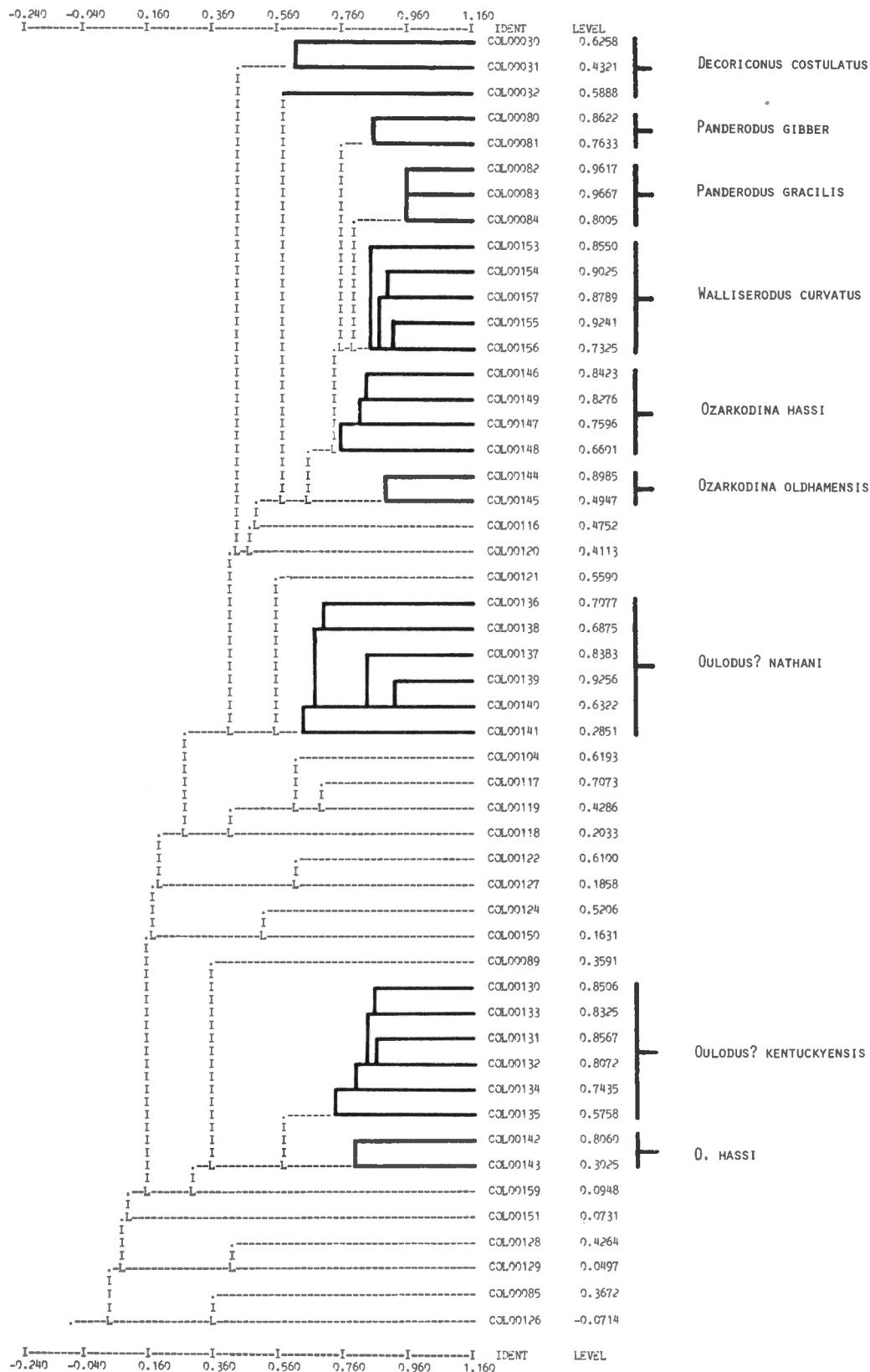


Figure 19. Conodont element cluster (R-mode: multielement apparatus reconstruction), Ellis Bay Formation Member 6 (Section III). The cluster diagram shows the clustering of elements into multielement species. Some of these species are outlined. 'IDENT' refers to the variables used in the analysis. 'COL' refers to the conodont element numbers. 'LEVEL' is the level of correlation. The diagram has been abbreviated for reproduction by deleting a few elements with low correlation levels from the bottom.



APPENDIX D

This appendix contains the distribution chart and lithologic descriptions for the samples excluded from Appendices A and B.

Residual Samples: Lithologic Descriptions

The following samples were not included in Appendix A and B and the text section on Paleoecology.

Samples E70 and E71 were collected in 1975 and may have been duplicated by the detailed collecting of 1976. The first sample, E70, was taken from just about the base of Member 6 at the Ellis Bay Section (Section IB).

Conodont sample (Field no.)	Sample interval(m)	Height(m) above base	Description
E70(A-109)	0	64	Calcsiltite: medium grey, weathers blue-grey; finely crystalline; less argillaceous than underlying strata.
E71(A-110)	3	67	Calcarenite: light grey; coarsely crystalline; abundant gastropods, cephalopods, some brachiopods.

Samples S72 and S73 were taken from Section IIIA in 1976.

S72(A7601)	-	-	Calcsiltite: grey-brown; very argillaceous; probably equivalent to Member 1.
S73(A7602)	-	-	Calcsiltite: dark grey, highly argillaceous; possibly below bed from where sample S09 was taken.

Ellis Bay Section (Section IIIC)

Section IC was collected in 1976 from the east side of Ellis Bay. The section includes samples from the Member 5 and 6 boundary to about the Ellis Bay - Becscie formational boundary at 0.5 km intervals along the shore.

Samples E72 to E74 were taken from about 0.5 km north of sample E75 location. These include the strata of the Member 5 and 6 boundary. Samples E72 and E73 were taken at 1 m and 0.25 m below the boundary, respectively; E74 was from the base of Member 6.

Conodont Sample (Field no.)	Sample interval(m)	Height(m) above base	Description
E72(A7659)	-	-	Calcsiltite: brown-grey; finely crystalline; weathers light grey.
E73(A7661)	-	-	Same as E72.
E74(A7660)	-	-	Calcarenite; brown-grey; weathers medium brown; fine to medium crystalline; some intraclastic material.

The small reefs or bioherms exposed at this locality are similar to those from the equivalent strata on both sides of Cape Henry. Samples E75 to E77 were collected from strata between above locality and that of E78. Location of sample E75 was 0.5 km south of Member 5 and 6 boundary. Samples E76 and E77 were from strata 1.1 km and 1.6 km south of same locality.

E75(A7658)	-	-	Calcsiltite: brown-grey; finely crystalline.
E76(A7657)	-	-	Same as E77.
E77(A7656)	-	-	Calcsiltite: blue-grey; finely crystalline; no fossils visible; upper surface burrowed.

Samples E78 to E87 were collected from a site 2.1 km south of Member 5-6 boundary.

E78(A7646)	-	0	Calcsiltite: blue-grey; finely crystalline; upper surface burrowed.
E79(A7647)	2	2	Calcsiltite: grey-brown weathers light blue-grey; finely crystalline.

The next sample (E80) is from a large cliff exposure.

E80(A7648)	2	4	Calcsiltite: blue-grey; finely crystalline; upper surface is possibly burrowed; strata are thin bedded, somewhat lenticular and irregular.
E81(A7649)	0.5	4.5	Calcsiltite: blue-grey; finely crystalline; bedding as above; blue-grey shale covers most bedding plane surfaces.
E82(A7650)	0.5	5	Calcarenite: brown-grey; medium crystalline; small brachiopods present; 25 cm below thin (less than 5 cm thick) recessive blue-grey shale bed.
E83(A7651)	0.5	5.5	Same as E82; thin bedded, lensoidal and irregular with a few trough-shaped beds; lower surfaces burrowed.

Above this is a covered interval; recessive shale unit can be traced to next exposure.

E84(A7652)	1.0	6.5	Calcsiltite: blue-grey; finely crystalline; bedding thin, irregular, nodular.
E85(A7653)	2.0	8.5	Calcsiltite to calcarenite: blue-grey; no fossils visible; bedding similar to above (E84).
E86(A7654)	2.0	10.5	Same as E85 but bedding becomes more uniform in maximum thickness; fewer large lenticular beds; appears to be more nodular than lower part of exposure.
E87(A7655)	2.0	12.5	Calcsiltite: blue-grey; finely crystalline; no fossils visible; thick bedded.

Samples E78 to E85 are probably from the uppermost part of Member 6 of the Ellis Bay Formation. Samples from the overlying strata are possibly from the lower most part of the Becscie Formation.

