GEOLOGICAL SURVEY OF CANADA
BULLETIN 459

CONODONT BIOFACIES OF LOWER TO LOWER MIDDLE ORDOVICIAN MEGACONGLOMERATES, COW HEAD GROUP, WESTERN NEWFOUNDLAND

S.M.L. Pohler

1994

Natural Resources Canada
Ressources naturelles Canada

Canada

GEOLOGICAL SURVEY OF CANADA
BULLETIN 459

CONODONT BIOFACIES OF LOWER TO LOWER MIDDLE ORDOVICIAN MEGACONGLOMERATES, COW HEAD GROUP, WESTERN NEWFOUNDLAND

S.M.L. Pohler

1994

Available in Canada through authorized
bookstore agents and other bookstores

or by mail from

Canada Communication Group-Publishing
Ottawa, Ontario Canada K1A 0S9

and from

Geological Survey of Canada offices:

601 Booth Street
Ottawa, Ontario K1A 0E8

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

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

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

Cat. No. M42-459E
ISBN 0-660-15163-4

Price subject to change without notice

Illustrations

Author's own submissions

Critical readers

R.L. Ethington
P. Smith

Author's address

School of Earth Sciences
Maquarie University
Sydney, N.S.W. 2109
Australia

Manuscript submitted: 92.10.15
Approved for publication: 92.10.15

PREFACE

The Cow Head Group of western Newfoundland represents part of the early Paleozoic Iapetus continental slope. Study of strata from the shelf break/upper slope environment provided an opportunity to investigate this rarely preserved segment of ancient margins.

Conodonts retrieved from clasts and boulders in the megaconglomerates of this group allowed the paleoecology of the inner marginal environment to be determined. Five biofacies were recognized and linked to changes in the ancient environment.

Studies such as these aid in the precise dating and correlation of strata in the North American craton and are an essential part of the foundation for mineral and hydrocarbon exploration.

Elkanah A. Babcock
Assistant Deputy Minister
Geological Survey of Canada

PRÉFACE

Le Groupe de Cow Head, dans l'ouest de Terre-Neuve, représente une partie du talus continental de l'Océan Iapetus du Paléozoïque précoce. L'étude de strates de l'accore et du talus supérieur a fourni l'occasion d'examiner ce segment rarement conservé des marges anciennes.

L'examen de conodontes extraits de clastes et de blocs provenant de mégaconglomérats de ce groupe a permis de reconstituer la paléoécologie de la marge interne. Cinq biofaciès ont été identifiés et associés à des changements survenus dans l'ancien milieu.

Les travaux de ce genre aident à établir la datation précise des strates du craton nord-américain et de les corréler. Elles sont essentielles à la prospection des minéraux et des hydrocarbures.

Elkanah A. Babcock
Sous-ministre
Commission géologique du Canada

CONTENTS

Figures

CONODONT BIOFACIES OF LOWER TO LOWER MIDDLE ORDOVICIAN MEGACONGLOMERATES, COW HEAD GROUP, WESTERN NEWFOUNDLAND

Abstract

Clasts from three conglomerate and megaconglomerate horizons in the Cow Head Group of western Newfoundland were sampled for conodonts to determine age and faunal composition. The Cow Head Group represents a fragment of the paleoslope of the Cambro-Ordovician Iapetus Ocean that was thrust upon age-equivalent shelf strata of the Port-au-Port and St. George groups. Although shelf and slope facies are preserved in sequence, the record of shelf break and upper slope facies is only retained in clasts of the conglomerate units of the Cow Head Group. The Arenig interval with the thickest conglomerate units was chosen for the study. Conodonts from the shelf edge and upper slope environment were compared and correlated with slope and shelf faunas.

*The 300 samples collected from limestone clasts yielded 12 492 well preserved conodonts with a low colour alteration index of 1.5 to 2.0. Altogether 132 form- and multielement species were determined, and one new genus (**Texania**) and several new species (**Texania heligma, T. teras, Prioniodus marginalis** and **P. serratus**) were established.*

*Conodont faunas from the shelf edge and upper slope derived clasts contain elements of North Atlantic and Midcontinent aspect as well as endemic and cosmopolitan species. They range in age from late Canadian (Fauna D) to basal Whiterock (Fauna 1) of the North American Series and through the British Arenig Series (**Paroistodus proteus** Zone to earliest ?**Eoplacognathus suecicus** Zone of Baltoscandia).*

*Five different biofacies were found, beginning with the oldest **Paroistodus-Drepanoistodus** Biofacies, followed by the slightly younger **Prioniodus-Texania** Biofacies; both were found in clasts from Bed 10. Bed 12 yielded clasts with the older **Oepikodus-Periodon** Biofacies and the younger **Periodon-Texania** Biofacies. Bed 14 clasts contained the **Periodon-Parapanderodus** Biofacies. The shelf break and upper slope environment was characterized by a distinct faunal realm whose composition was controlled by changes in the adjacent habitats of shelf and lower slope.*

Résumé

On a recueilli des clastes dans trois horizons de conglomérats et de mégaconglomérats du Groupe de Cow Head, dans l'ouest de Terre-Neuve, afin d'analyser les conodontes pour déterminer l'âge et la composition faunique de ces strates. Le Groupe de Cow Head représente un fragment du paléotalus de l'Océan Iapetus cambro-ordovicien, lequel fragment a été chevauché sur les strates de plate-forme continentale du même âge des groupes de Port-au-Prince et de St. George. Bien que les faciès de plate-forme continentale et de talus soient conservés sous la forme d'une séquence, seuls les clastes des unités conglomératiques du Groupe de Cow Head témoignent des faciès de l'accore et du talus supérieur. On a choisi d'étudier l'intervalle arénigien, ses unités conglomératiques étant les plus épaisses. On a établi une comparaison et une corrélation entre, d'une part, des conodontes provenant du rebord de la plate-forme continentale et du talus supérieur et, d'autre part, des faunes de talus et de plate-forme continentale.

*On a recueilli 300 échantillons de clastes calcaires qui contenaient 12 492 conodontes bien conservés ayant un indice d'altération de la couleur peu élevé (de 1,5 à 2,0). On a reconnu 132 espèces de forme et espèces à éléments multiples, de même qu'un nouveau genre (**Texania**) et plusieurs nouvelles espèces (**Texania heligma, T. teras, Prioniodus marginalis** et **P. serratus**).*

Les faunes à conodontes provenant de clastes dérivés du rebord de la plate-forme et du talus supérieur contiennent des éléments dont l'aspect s'apparente à ceux de l'Atlantique Nord et du *milieu du continent ainsi que des espèces endémiques et cosmopolites. Elles varient en âge du Canadien tardif (Faune D) au Whiterockien basal (Faune 1) de la Série nord-américaine et couvrent toute la Série arénigienne britannique (de la zone à **Paroistodus proteus** au tout début de la zone à (?) **Eoplacognathus suecicus** de la Baltoscandie).*

*On reconnaît cinq biofaciès différents dans ces strates. Le biofaciès à **Paroistodus–Drepanoistodus**, le plus vieux, et le biofaciès à **Prioniodus–Texania**, légèrement plus jeune, se rencontrent dans des clastes extraits de la couche 10. Les clastes de la couche 12 contiennent un biofaciès ancien à **Oepikodus–Periodon** et un biofaciès plus jeune à **Periodon–Texania**. Quant au biofaciès à **Periodon–Parapanderodus**, il est associé aux clastes de la couche 14. L'accore et le talus supérieur étaient donc représentés par un royaume faunique caractéristique, dont la composition variait selon les changements qui survenaient dans les habitats contigus de la plate-forme continentale et du talus inférieur.*

Summary

In the Lower Ordovician (Arenig) strata in the Humber Zone of the northern Appalachians, the transition from a tectonically passive (Atlantic-type) margin to an active margin is recorded. The margin deposits were thrust onto coeval platform carbonates during the Middle Ordovician. The Cow Head Group represents a well preserved fragment of the continental slope of the early Paleozoic Iapetus Ocean. Cow Head Group strata are characterized by conglomerate beds intercalated with deep water carbonates and minor siliciclastic units. Three megaconglomerate units (Beds 10, 12 and 14) on Cow Head Peninsula with lateral and distal equivalents exposed at Lower Head, on Stearing Island, at St. Pauls Inlet, Western Brook Pond and Martin Point yielded clasts and boulders from the shelf edge and upper slope of the Iapetus Ocean. The clasts represent the remains of this segment of the continental margin—a rarely preserved facies around the North American craton.

This study contains a documentation of conodont biofacies deduced from fragments of the shelf margin facies for the purpose of establishing a biostratigraphic zonation and determining conodont paleoecology of the inner marginal environment through the Arenig interval. Among clasts in the megaconglomerates, local (lower slope derived), foreign (shelf, shelf break and upper slope derived), and older clasts were distinguished. About 300 conodont samples were collected and processed, principally from clasts of the three conglomerate horizons. The 12 492 conodont specimens recovered represent 132 different form and multielement species.

The new genus *Texania* is established. Several new species are described and four new species are named: *Texania heligma, T. teras, Prioniodus marginalis*, and *P. serratus*.

Faunal assemblages from clasts contained conodonts of North Atlantic and North American Midcontinent aspect as well as endemic and cosmopolitan species. Bed 10 clasts yielded conodonts of the *Paroistodus proteus* and *Prioniodus elegans* zones of Baltoscandia, together with faunal elements of Faunas D and basal E of the Midcontinent zonal scheme. Bed 12 yielded older clasts with conodonts of the *Oepikodus evae* Zone and younger clasts with dominantly *Periodon aculeatus* together with faunal elements typically found in Fauna E-1 (e.g., *Protoprioniodus aranda*) of the Midcontinent faunal scheme. Boulders from Bed 14 also contained abundant *P. aculeatus*, and the occurrence of *Tripodus laevis* and *Pteracontiodus cryptodens* suggests basal Whiterock age.

Correlation to Scandinavia is problematic and upper Bed 11 to Bed 14 probably span the *Baltoniodus triangularis, B. navis, Paroistodus originalis, Microzarkodina flabellum parva* and lower (?)*Eoplacognathus suecicus* zones. Conodonts from the matrix of Beds 10–14 are of mixed ages; most are age equivalent to, and none are younger than, the clasts. The oldest clast faunas are of late Cambrian age. With regard to the dominant species, clast faunas show a generally closer affinity to faunas found in the bedded lower slope sediments than to faunas from the shelf.

Five different biofacies were recognized in the three conglomerate beds. In Bed 10, the foreign lithotypes derived from the upper slope and shelf break yielded an older *Paroistodus–Drepanoistodus* Biofacies and a younger *Prioniodus–Texania* Biofacies. Bed 12 margin-derived, older clasts yielded a distinct *Oepikodus–Periodon* Biofacies with a mixed North Altantic and Argentinian fauna; younger clasts in Bed 12 contained conodonts of a *Periodon–Texania* Biofacies with species of Australian and Midcontinent affinity. In Bed 14, clasts of a *Periodon–Parapanderodus* Biofacies occurred. The shelf break and upper slope environment represents an independent faunal realm with distinct conodont assemblages. The composition of the various biofacies was controlled by environmental changes on the shelf such as sea level fluctuations that induced on- or offshelf migrations of the faunas.

Sommaire

Les strates de l'Ordovicien inférieur (Arénigien) de la zone de Humber, dans la partie nord des Appalaches, attestent le passage d'une marge passive (de type atlantique) à une marge active. Les dépôts de marge ont été poussés sur des roches carbonatées contemporaines de plate-forme à l'Ordovicien moyen. Le Groupe de Cow Head représente un fragment bien conservé du talus continental de l'Océan Iapetus (Protérozoïque précoce). Les strates du Groupe de Cow Head se caractérisent par la présence de lits conglomératiques, intercalés au sein de roches carbonatées d'eau profonde et d'unités silicoclastiques mineures. Trois unités de mégaconglomérats (couches 10, 12 et 14) de la péninsule Cow Head, de même que des sédiments équivalents latéraux et distaux qui affleurent au cap Lower, sur l'île Stearing, à l'inlet St. Pauls, à l'étang Western Brook et à la pointe Martin, contenaient des clastes et des blocs dérivés du rebord de la plate-forme continentale et du talus supérieur de l'Océan Iapetus. Les clastes sont des vestiges de ce segment de marge continentale, un faciès rarement conservé autour du craton nord-américain.

Le présent bulletin traite des biofaciès à conodontes identifiés à partir des fragments de faciès de la marge de la plate-forme continentale; il vise à établir une zonation biostratigraphique et à déterminer la paléoécologie des conodontes de la marge interne tout au long de l'Arénigien. Parmi les clastes contenus dans les mégaconglomérats, il y en a d'origine autochtone (dérivés du talus inférieur) et d'origine allochtone (dérivés de la plate-forme continentale, de l'accore et du talus supérieur), mais aussi de plus anciens. On a recueilli et traité environ 300 échantillons de conodontes, principalement extraits des clastes provenant des trois horizons de conglomérats. Les 12 492 spécimens de conodontes récupérés ont été attribués à 132 espèces de forme et espèces à éléments multiples.

De plus, le nouveau genre *Texania* a été établi et plusieurs nouvelles espèces décrites, dont les quatre suivantes : *Texania heligma*, *T. teras*, *Prioniodus marginalis* et *P. serratus*.

Les clastes contiennent des associations fauniques qui comportent des conodontes dont l'aspect s'apparente à ceux de l'Atlantique Nord et du milieu du continent nord-américain, de même que des espèces endémiques et cosmopolites. Les clastes de la couche 10 contiennent des conodontes des zones à *Paroistodus proteus* et à *Prioniodus elegans* de la Baltoscandie, ainsi que des éléments de la Faune D et de la base de la Faune E (zonation du milieu du continent). Dans la couche 12, on obtient des clastes plus anciens dans lesquels il y a des conodontes de la zone à *Oepikodus evae* et des clastes plus jeunes où prédomine *Periodon aculeatus*; on observe également des éléments typiques de la Faune E-1 (zonation du milieu du continent), comme par exemple *Protoprioniodus aranda*. Dans les blocs provenant de la couche 14, les spécimens de *P. aculeatus* sont nombreux; en outre, la présence de *Tripodus laevis* et de *Pteracontiodus cryptodens* semble indiquer un âge qui se situe à la base du Whiterockien.

La corrélation avec la Scandinavie est problématique; l'intervalle s'échelonnant de la partie supérieure de la couche 11 jusqu'à la couche 14 couvre probablement les zones à *Baltoniodus triangularis oblique navis*, à *Paroistodus originalis* et à *Microzarkodina flabellum parva*, de même que la partie inférieure de la zone à (?) *Eoplacognathus suecicus*. Les conodontes extraits de la

matrice des couches 10 à 14 ont livré divers âges; la plupart d'entre eux ont le même âge que les clastes, mais aucun n'est plus jeune. Les faunes les plus anciennes identifiées dans les clastes remontent au Cambrien tardif. En matière d'espèces dominantes, les faunes associées aux clastes se rapprochent généralement plus des faunes dans les sédiments lités de talus inférieur que de celles qui sont rattachées à des unités de plate-forme continentale.

On reconnaît cinq biofaciès différents dans les trois couches conglomératiques. Dans la couche 10, les lithotypes allochtones dérivés du talus supérieur et de l'accore représentent deux biofaciès, l'un plus vieux à *Paroistodus–Drepanoistodus* et l'autre plus récent à *Prioniodus–Texania.* Aux clastes plus anciens dérivés de la marge provenant de la couche 12, on associe un biofaciès à *Oepikodus–Periodon* distinct avec une faune aux caractéristiques mixtes de l'Atlantique Nord et de l'Argentine; les clastes plus jeunes de la couche 12 contiennent des conodontes qui correspondent à un biofaciès à *Periodon–Texania* avec des espèces présentant des affinités avec les faunes de l'Australie et du milieu du continent. Les clastes de la couche 14 présentent un biofaciès à *Periodon–Parapanderodus.* Le milieu constitué de l'accore et du talus supérieur représente un royaume faunique indépendant que caractérisent des associations distinctes de conodontes. Les changements environnementaux survenus sur la plate-forme continentale, tels que les fluctuations du niveau marin qui ont provoqué la migration des faunes tant vers le continent que vers le large, sont les facteurs qui ont contrôlé la composition des divers biofaciès.

INTRODUCTION

The Cow Head Group (Kindle and Whittington, 1958) located in western Newfoundland is part of the Humber Zone, a major tectonostratigraphic element of the northern Appalachians (Williams, 1975, 1979). It comprises a sequence of bedded limestone, conglomerate and fine grained siliciclastics, and extends along the west coast of Newfoundland from Portland Creek Pond in the north to Rocky Harbour in the south (Fig. 1).

Grenvillian rocks of the Long Range Mountains to the east and the Gulf of St. Lawrence to the south represent geographical boundaries. Much of the Cow Head Group lies within Gros Morne National Park, which has been established to ensure preservation of the unique rocks. Excellent coastal exposures can be found over a distance of approximately 60 km. The type sections and an informal stratigraphic nomenclature of the Cow Head Group were established on Cow Head Peninsula by Kindle and Whittington (1958). A new nomenclature was recently proposed by James and Stevens (1986), and their scheme is followed herein. These authors also provided a thorough review of the previous nomenclature to which the reader is referred.

The Cow Head Group is generally accepted to represent a well preserved, though tectonically complicated, fragment of the northwestern continental slope of the early Paleozoic Iapetus Ocean. Adjacent rocks are the remains of the coeval continental shelf (Port-au-Port, St. George, and Table Head groups) and of the basin floor (Bay of Islands Complex).

In this study, Arenigian conglomerate horizons of the Cow Head Group were investigated at several localities along the coast and inland. From north to south these are: Lower Head, Stearing Island, Cow Head Peninsula, St. Pauls Inlet, Martin Point and Western Brook Pond (Fig. 1).

The clasts and boulders within three megaconglomerate horizons (Beds 10, 12, and 14 of Kindle and Whittington, 1958) are the focus of this investigation. These deposits are interpreted as debris flows (Hiscott and James, 1985) involving unstable coeval shelf and slope sediments and eroding locally into stratigraphically older strata. The debris flows came to rest at the foot of the ancient slope (James and Stevens, 1986), having collected pebble- to boulder-sized clasts from the various facies belts across the shelf break down through the upper and lower slope (Fig. 2). The depositional setting of the Cow Head Group on the lower slope, or farther from the shelf edge, is indicated by the nature of the stratified sequences between the debris sheets (i.e., shale and thin bedded hemipelagic limestone). Large rafts of bedded, fine grained periplatform sediments within the conglomerates are different from underlying lithotypes and must have been acquired upslope. Other "foreign" boulders are of shallow water origin (James, 1981). Many of the clasts in the debris flows are fragments of a carbonate platform margin facies that was obliterated by later tectonism.

The shelf carbonates represented by the Port-au-Port, St. George and Table Head groups received attention recently from several authors (Stouge, 1984; Chow, 1986; Knight and James, 1987). The lower slope deposits of the Cow Head Group have also been documented (Coniglio, 1985; Hiscott and James, 1985; James and Stevens, 1986). However, in contrast, the zone of the shelf break and upper slope is a rarely preserved and therefore poorly understood segment of ancient margins, which is usually obliterated during orogeny. It represents a hinge zone between two distinct conodont faunal realms, which enables study of distribution patterns and migrations and aids in correlating shelf and slope faunas. Furthermore, the nature of the upper slope and shelf break controls sedimentation on the lower slope and, to an extent, on the shelf platform. The nature of the sedimentary and faunal "missing link" is thus important for understanding shelf and slope sedimentation and biofacies. This study is an attempt to reconstruct the inner margin (i.e., shelf edge and upper slope) conodont biofacies of the northwestern edge of the Iapetus Ocean as it existed during the Arenig. Data from the different clast lithotypes of the megaconglomerates are used in carbonate lithofacies and conodont biofacies analysis. Carbonate lithofacies were discussed separately in a different publication (Pohler and James, 1989).

GENERAL GEOLOGICAL SETTING

The Middle Cambrian to Middle Ordovician Cow Head Group comprises a 300–500 m thick succession of sedimentary rocks that are interpreted as a carbonate slope apron, deposited on the flank of the upper Precambrian to lower Paleozoic Iapetus Ocean and subsequently transported westward (James and Steven, 1986). The rocks are coarse conglomerate, calcarenite, bedded limestone, shale, chert, dolomitic siltstone and quartz-rich calcarenite. The overlying green sandstone units (Lower Head Sandstone) are interpreted as flysch deposits.

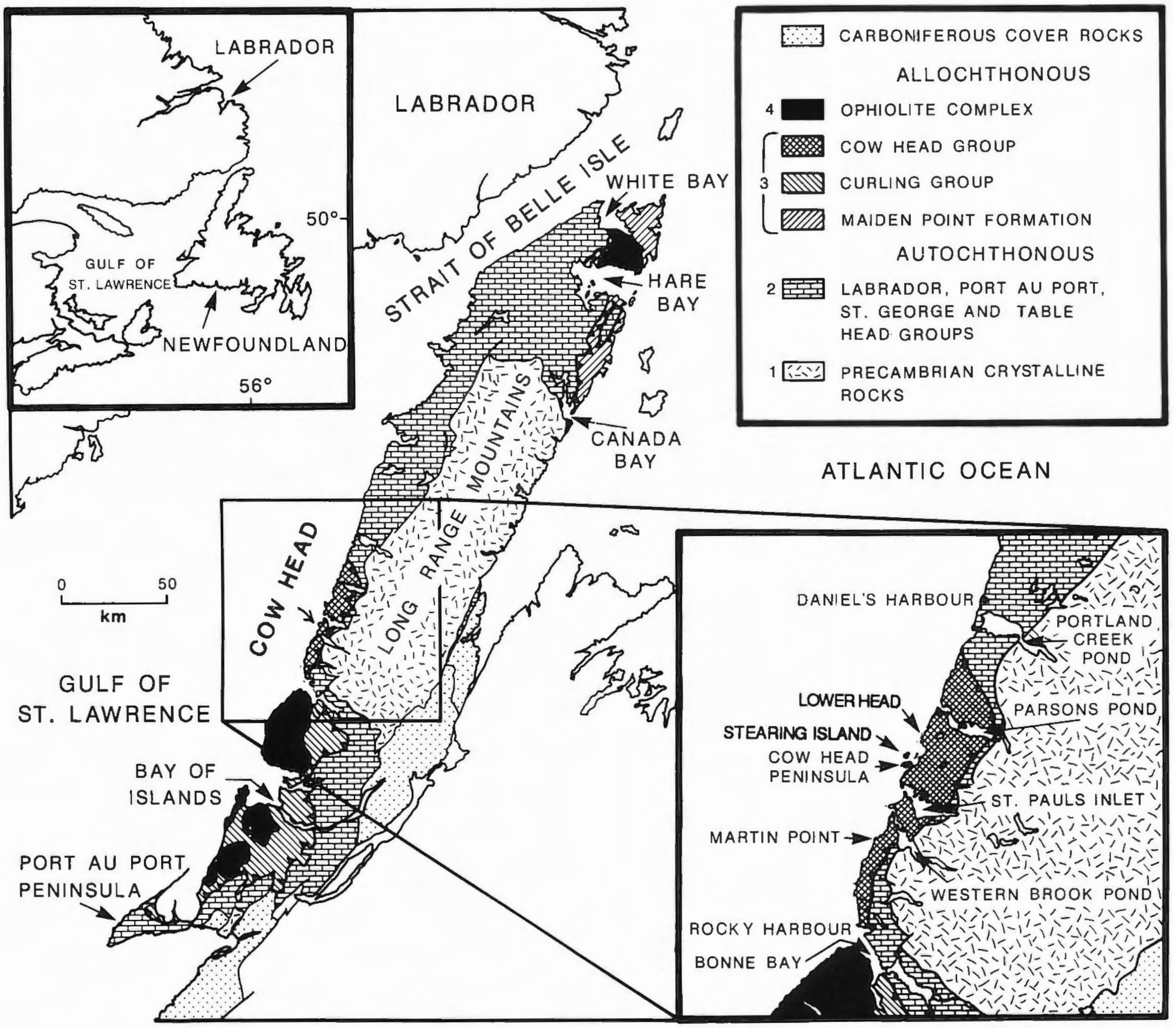


Figure 1. Study area showing localities (after James and Stevens, 1986).

The geological maps of Oxley (1953) and Williams et al. (1985) show northeast-southwest striking belts of Cow Head strata that dip to the southeast. These belts are interpreted as thrust slices (cf. Fleming, 1970) that show facies changes including a decrease in clast size in the conglomerates and an increase in the proportion of shale from northwest to southeast, reflecting proximal to distal slope deposition. Rocks of the proximal facies are found at Lower Head, on Stearing Island and on Cow Head Peninsula (Fig. 1), and rocks of the distal facies at St. Pauls Inlet, Martin Point, and Western Brook Pond (Fig. 1).

STRATIGRAPHY OF THE COW HEAD GROUP

Proximal and distal facies of the Cow Head Group were divided into two new coeval formations by James and Stevens (1986, following Williams et al., 1985). The coarse grained facies in the northwest is termed the Shallow Bay Formation, the finer grained shaly facies in the southeast the Green Point Formation. The Arenigian Factory Cove Member of the Shallow Bay Formation comprises a 100 m thick sequence of ribbon and parted limestone and minor shale. This is intercalated with beds of boulder and megaconglomerate, of Early to Middle Ordovician age and includes Beds 9–15 (Fig. 3) of Kindle and Whittington (1958). The age equivalent St. Pauls Member of the Green Point Formation is a 130–150 m thick sequence of red, green and black shale, limestone, limestone conglomerate, siltstone and dolomite. Rocks of the Cow Head Group are overlain by over 1700 m of green sandstone of the Lower Head Formation, which represents a Middle Ordovician flysch.

This report is based mainly on the boulders of Beds 10, 12, and 14 of the Factory Cove Member megaconglomerates, which are large enough to facilitate sampling and facies studies.

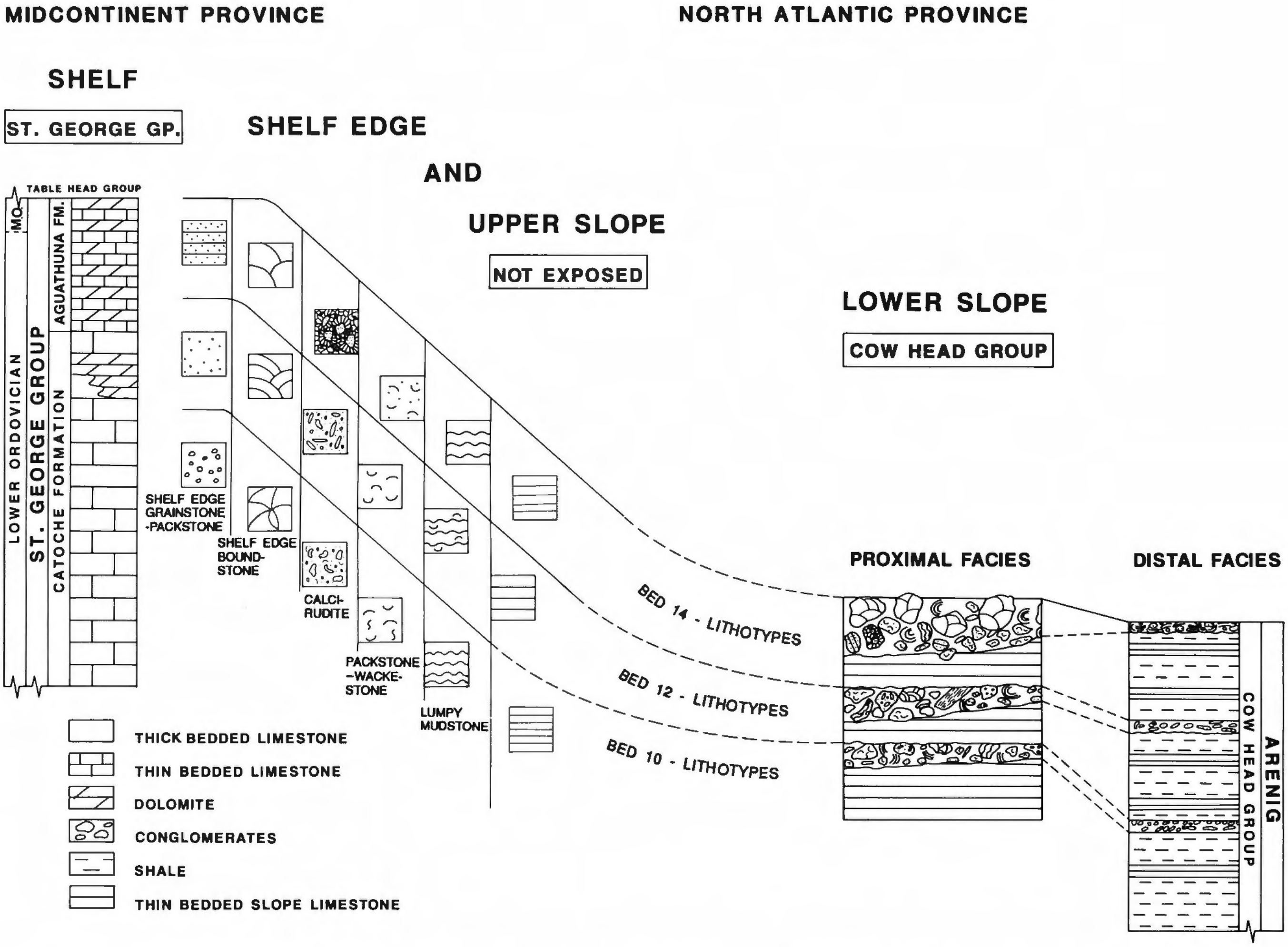


Figure 2. Schematic diagram illustrating the relationship between shelf and slope deposits.

Clast character

Conglomerates and megaconglomerates of the Cow Head Group are characterized by the presence of carbonate clasts of variable composition, origin, age and morphology.

Composition. The majority of the clasts are limestone; minor chert, shale, siltstone, marl, dolomite, phosphatic conglomerate and sandstone are also present, and these lithotypes can be found in the underlying bedded sequence. No basement-derived crystalline or volcanic clasts are present.

Origin. Massive or thinly bedded clasts of shallow water origin are mixed with thinly bedded or conglomeratic deep water limestone clasts. Conodont analysis indicates that most shallow water clasts came from the carbonate platform margin — very few came from the platform interior (St. George Group) (Pohler et al., 1987). Deep water clasts are similar to sediments of the underlying bedded sequence and are derived from the deep water, upper and the lower slope. These deep water clasts are herein termed *local clasts.* All penecontemporaneous lithotypes that cannot be assigned to this category are summarized as *foreign clasts.*

Age. Clasts older than the bed immediately underlying a conglomerate horizon are present in all three megaconglomerates, but in variable amounts. Like penecontemporaneous clasts they came from shelf, shelf margin, upper and lower slope environments.

Morphology. Conglomerates are poorly sorted; the poorest sorting occurred in the coarsest (proximal) facies in which clast size range from boulders hundreds of metres across to pebbles less than one centimetre in diameter. Clasts are angular to rounded. In general, foreign clasts are more rounded than local clasts. Induration is also variable; thin bedded local clasts

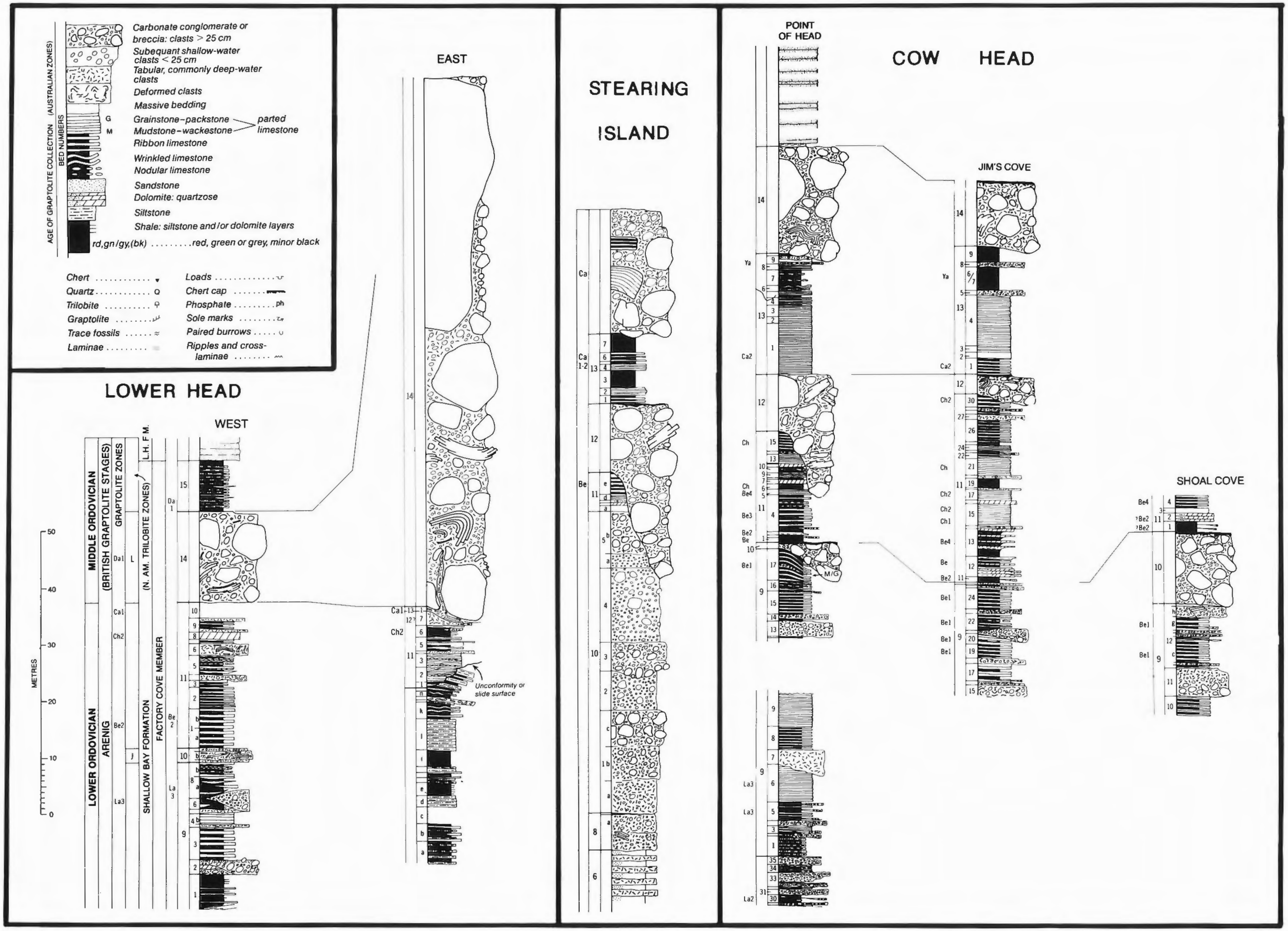


Figure 3. Proximal sections of Arenig age of the Cow Head Group (after James and Stevens, 1986).

commonly show soft sediment deformation, and some clasts have an exterior studded with small pebbles ("armored mudballs" of Breakey, 1974).

Method of study

Three hundred samples were collected for conodont processing, mainly from conglomerate clasts but 30 from the bedded sequence and conglomerate matrices were included. Average sample weight was 3 kg. Samples were processed in 10–15% acetic acid or in 10% formic acid in the case of dolomite-rich lithotypes. Acid residues were separated with tetrabromoethane at specific gravity 2.83.

Sample numbers, yield and faunal composition lists are summarized in Appendices 1 to 4. The largest number of samples was taken from the proximal facies containing the largest boulders and highest proportion of foreign clasts (i.e., clasts derived from outside the depositional environment). The foreign clasts were the most thoroughly sampled, as they represent fragments of the upper slope and the marginal build-up facies, which are the main concern of this study. Bed 14 yielded the largest variety of different lithotypes and was sampled most extensively. Collecting concentrated on boulders at Lower Head and on Cow Head Peninsula.

At Lower Head, Bed 14 contains clasts eroded from strata as old as Late Cambrian (James and Stevens, 1986). The number of different lithotypes is so high that, despite 147 samples being collected, probably not all lithofacies were recognized. Commonly, a lithofacies type is represented by only one clast that could not be duplicated elsewhere in the outcrop. The sampling of these rare lithotypes was therefore random. The samples taken from the conglomerate horizons yielded 12 492 condont elements representing 132 multielement and form species. The colour alteration index (CAI) of all conodonts recovered is 1.5 to 2, indicating low burial temperatures betwen 50° and 140°C (Epstein et al., 1977). This agrees with the regional values reported by Nowlan and Barnes (1987). Most conodonts are well preserved and complete. Worn and abraded conodonts occur in a few samples from clasts of bedded fine grained lime mudstone. Conodonts derived from upper slope and shelf platform usually have a sucrose surface, indicating diagenetic alteration, in contrast to specimens from the bedded sequence, which are shiny and unaltered. Backscatter and scanning electron microscope (SEM) analyses show a crystalline overgrowth composed of calcite-enriched apatite.

BIOSTRATIGRAPHY

Introduction

The boulders from the shelf edge that are incorporated in the Cow Head megaconglomerates come from the "hinge zone" between the shallow and deep water realms and commonly contain mixed faunas that allow correlation between different settings. A biostratigraphic framework is well established for the Cow Head Group; graptolites and conodonts from the bedded sediments have been studied from most sections, and shelly fossils mainly from the conglomerates. Because fossils from the adjacent shelf deposits of the St. George Group have been documented in detail, (e.g., Stouge, 1982; Stouge and Boyce, 1983) the composition of shelf, shelf edge and slope faunas can readily be compared. The biostratigraphy of shelf and slope sequences and fossil data from the conglomeates are summarized herein, in order to reconstruct their original stratigraphic position in the fragmented slope and shelf break sequence.

Conodont provincialism

The pronounced difference in faunal composition at different localites is a problem in correlating conodont assemblages over great distances or, in the case of North America, from shelf to slope deposits. This provincialism of Ordovician conodonts was first noted by Sweet et al. (1959) and by Sweet and Bergström (1962). The two faunal provinces distinguished for the Lower Ordovician, namely the North American Midcontinent Province and the North Atlantic Province, have been further reviewed by Barnes et al. (1973), Sweet and Bergström (1974), Barnes and Fåhræus (1975), Lindström (1976), Bergström (1977) and Ethington and Repetski (1984). According to these authors conodont faunal provincialism was initiated in the Tremadoc and modified with regard to distinctiveness and areal extent over the course of the Ordovician (Fåhræus, 1976; Bergström, 1977). The Midcontinent Province is interpreted herein as a habitat of conodontophorids adapted to life in tropical shelf seas with elevated temperatures and salinities, whereas the North Atlantic Province was the habitat of faunas adapted to cooler temperatures in low latitudes or deeper water and to normal salinity (Barnes and Fåhræus, 1975).

Two zonal schemes were established for the Lower and Middle Ordovician by Ethington and Clark (1971, 1981), Ethington and Repetski (1984), and Sweet et al. (1971) for the Midcontinent and by Lindström (1971), van Wamel (1974) and Löfgren (1978) for the North Atlantic Province. Precise correlation between these two principal conodont zonations is difficult and correlation via other faunal successions has been more successful. For example, the standard graptolite zonation has been linked to the conodont zonal schemes (Lindström, 1971; Bergström, 1971, 1973; Sweet and Bergström, 1976; Barnes et al., 1976).

Biostratigraphy of the shelf sequence

The segment of the shelf sequence roughly equivalent in age to the Arenig part of the slope sequence includes the upper part of the Boat Harbour Formation and the Catoche and Aguathuna formations of the St. George Group. Trilobites (Whittington and Kindle, 1969; Fortey, 1979; Boyce, 1979, 1983, 1985, 1986; Williams et al., 1987), conodonts (Stouge, 1982; Kenna, 1986; Ji, 1989) and graptolites (Williams et al., 1987) have been reported from these formations. Their biostratigraphy will be briefly reviewed because of their importance to correlation between shelf and slope environments.

Shelly fossils

Reference areas for North American Lower and Middle Ordovician trilobite and brachiopod biostratigraphy are in Utah and Nevada. Based on the work of Ross (1951) and Hintze (1951, 1952), 12 trilobite-brachiopod zones were erected and designated by the letters A–O (Fig. 4). Shelly fossils from the upper part of the Boat Harbour Formation above the "pebble-bed", a major discontinuity surface, belong to Zone G2. The Catoche Formation contains trilobites indicative of zones G2 to I, and possibly J (Williams et al., 1987). Trilobites from the top of the Aguathuna Formation belong to Zone L and possibly Zone M. The basal part of the overlying Table Head Group (Table Point Formation) contains trilobites of Zone M.

Graptolites

Graptolites horizons are known from the Catoche and basal Aguathuna formations (Williams et al., 1987). They indicate that most of the Catoche Formation falls within the *Tetragraptus approximatus* Zone (Williams,

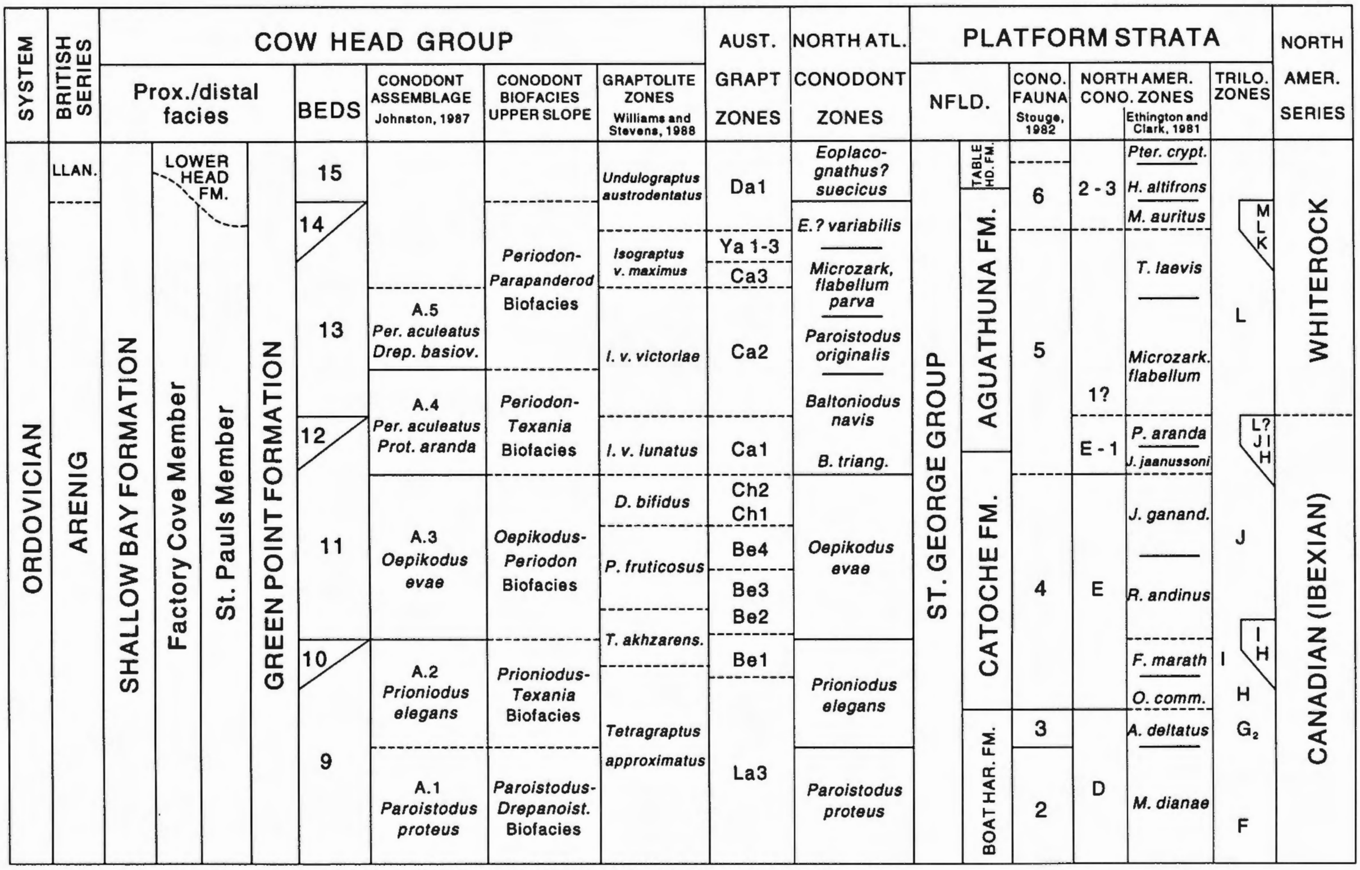


Figure 4. Correlation chart of Cow Head conodont assemblages with zones and fossil groups in other key areas.

1986; Williams and Stevens, 1988) and is thus equivalent to Bed 9 of the Cow Head Group. Near the top of the Catoche Formation a fauna occurs that is referable to the *Tetragraptus akzharensis* Zone and possibly the lowest part of the *Pendeograptus fruticosus* Zone, suggesting correlation with the upper part of Bed 9, Bed 10, and the lowest part of Bed 11. The lower Aguathuna Formation has yielded a large number of specimens of *Didymograptus* (*Expansograptus*) *nitidus* Hall, which is restricted to the *P. fruticosus* and *D. bifidus* zones of the Cow Head Group, indicating a lower to middle Bed 11 age.

Conodonts

Conodonts of the St. George Group were investigated by K. Stait (1989) and Ji (1989). Stouge (1982) proposed a preliminary conodont zonation for platform carbonates of the St. George Group on the Great Northern Peninsula. Beginning with the upper Boat Harbour Formation, he recognized six faunas (Faunas 1–6), which he subsequently correlated with the conodont successions of North America documented by Ethington and Clark (1971) and by Sweet et al. (1971). Faunas 1 and 2 of the Boat Harbour Formation below the unconformity ("pebble bed") were correlated with Fauna D and possibly Fauna C of Sweet et al. (1971). Fauna 3 recovered from horizons above the "pebble bed" also lies within Fauna D. Fauna 4 contains elements of Fauna E and appears at the base of the Catoche Formation, ranging upward to the Laignet Point Member. The diagenetic dolostones at the top of the Catoche Formation yielded a sparse fauna (Fauna 5) suggestive of Fauna E-1. The Aguathuna Formation contains only sparse fauna and barren intervals. Fauna 6, recovered from the top of the formation, yielded elements typical of Faunas 2 and 3 of the North American Midcontinent succession. This fauna ranges upward into the lowermost Table Head Group (Stouge, 1984; Fig. 4).

Biostratigraphy of the slope sequence

Graptolites

Graptolites from bedded sediments of the Cow Head Group were first collected by Richardson and described in Logan (1863) and by Billings (1865). Subsequent collections were made by Schuchert and Dunbar (1934) and Johnson (1941); descriptions are found in Ruedemann (1947). Kindle and Whittington (1958) also collected graptolites but focused on trilobites for biostratigraphic purposes. Erdtmann (1971) proposed a zonal scheme for the graptolite successions of the area. The most recent publications are by James and Stevens (1986), Williams (1986), and Williams and Stevens (1988). Most of the data summarized here are derived from Williams and Stevens (1988), who proposed a new local scheme based on the Cow Head faunas and subsequently correlated these with Australian graptolite zones (as defined by Webby, 1981). Graptolites from Beds 9–14 of the Cow Head Group can be correlated with Australian stages Lancefieldian 3 to Darriwillian 1 (Fig. 4).

Williams and Stevens distinguished eight different graptolite zones that can be correlated with the conodont succession determined by Fåhræus (1970), Nowlan (1974), Fåhræus and Nowlan (1978), and Johnston (1987).

1. The *Tetragraptus approximatus* Zone, defined near the base of Bed 9, is mostly equivalent to Lancefieldian 3 of the Australian scheme and is thought to define the base of the Arenig. The *T. approximatus* Zone spans the Baltoscandian conodont zones of *Paroistodus proteus* and *Prioniodus elegans*.

2. The *Tetragraptus akhzarensis* Zone is defined at Western Brook Pond North. This zone is equivalent to Bendigonian 1-2 and the upper part of the *P. elegans* Zone. Bed 10 and the upper part of Bed 9 fall in the range of this interval.

3. The *Pendeograptus fruticosus* Zone is equivalent to most of Be3 and Be4 and is defined at the base of Bed 11 on Cow Head Peninsula. It correlates with the lower part of the *Oepikodus evae* Zone.

4. The *Didymograptus bifidus* Zone is recognized in the middle of Bed 11 on Cow Head Peninsula (at Jim's Cove). It correlates with the Chewtonian Stage of Australia and with the upper part of the *O. evae* Zone.

5. The *Isograptus victoriae lunatus* Zone is recognized at Martin Point North and is equivalent to Castlemainian 1. It coincides with the change from faunas dominated by *O. evae* to faunas dominated by *Periodon aculeatus* Hadding in the upper part of Bed 11 (Johnston, 1987).

6. The *I. victoriae victoriae* Zone is defined at Martin Point North and correlates with Castlemainian 2. In distal sections this zone is found near the top of Bed 11; in proximal sections at the base of Bed 13. No change in conodont faunas coincides with the base of this interval. Fauna A.4 of Johnston (1987) is succeeded by Fauna A.5 somewhat higher in the sequence.

7. The *Isograptus victoriae maximus* Zone is defined on Cow Head Peninsula. It correlates with Ca3 and the Yapeenian stages 1-3 and falls within the range of Bed 13. No change in conodont faunas seems to coincide with the base of this graptolite zone, but conodonts of this interval are poorly known.

8. The *Undulograptus austrodentatus* Zone is recognized at Western Brook Pond South where it occurs below the highest conglomerate horizon considered to be Bed 14 and correlates with Darriwillian 1. The zone falls within the range of upper Bed 13, Beds 14 and 15. Conodont faunas from this interval are poorly known. An advanced form of *P. aculeatus* seems to be characteristic of this interval. The interval of the upper part of the *I. v. lunatus* Zone to the *U. austrodentatus* Zone is roughly equivalent to the British *Didymograptus hirundo* Zone, which Löfgren (1978) correlated with the upper *Paroistodus originalis* Zone, the *Microzarkodina flabellum parva* Zone and the *Eoplacognathus*?-*M. flabellum* Subzone in Jämtland. Williams (1986) proposed that the Arenig/Llanvirn boundary lies at the base of the *U. austrodentatus* Zone, equivalent to the boundary between the Australian Yapeenian and the Darriwillian stages. In terms of Baltoscandian conodonts, this would coincide either with the boundary between the *Microzarkodina parva* Zone and the *Eoplacogathus*? *variabilis-M. flabellum* Subzone or that between the *E.*? *variabilis-M. flabellum* and the *E.*? *variabilis-M. ozarkodella* subzones. In the Cow Head Group, the first platform conodonts appear in the *U. austrodentatus* Zone [Llanvirn?] at Western Brook Pond (C.R. Barnes, pers. comm., 1987) below a conglomerate horizon considered to be Bed 14. Conodont faunas from this conglomerate yield an advanced form of *Periodon aculeatus*. In the proximal sections, Bed 14 rests on sediments containing graptolites of the older *I. v. maximus* Zone.

Shelly fossils

Trilobites and brachiopds are well known from the boulders in the conglomerates. Brachiopods have been identified and described by Billings (1865), Cooper (1956) and Ross and James (1987). Ten genera and 17 species of brachiopods have been recognized in Beds 12, 13, and 14 by Ross and James (1987). Faunas from boulders in Bed 14 belong to trilobite zones K, L and lower M; those from clasts in Bed 12 to trilobite zones L, H, J and I.

Kindle and Whittington (1958) studied trilobites from the Cow Head Group and reached similar conclusions to those of Ross and James (1987). They assigned trilobites from Beds 9 and 10 to Ross/Hintze Zones G and H; Bed 12 trilobites were considered to be earliest Middle Ordovician, i.e., "Whiterock Stage"; Bed 14 trilobites were considered to show affinity to those of Zones M and N. In constrast to later workers, Kindle and Whittington concluded that the boulders were equivalent in age to the middle Table Head Group.

Conodont biostratigraphy of the Cow Head Group megaconglomerates and equivalent slope and shelf deposits

Arenig conodonts from the Cow Head Group have been studied from Cow Head Peninsula by Nowlan (1974), Fåhræus and Nowlan (1978) and Stouge and Bagnoli (1988) and from the Martin Point South and St. Pauls Inlet sections by Johnston (1987).

Five different biofacies are here recognized from the conglomerate clasts. They are coeval with the five faunal assemblages from the bedded slope sequence (Johnston, 1987). The shelf sequence is not yet well known and correlation is problematic. However, a preliminary version has been attempted.

Bed 10 and equivalents

Above a barren shale and siltstone unit in Bed 9 Assemblage A.1 of Johnston (1987) occurs (50–70 m above the base of the section) with *Paroistodus proteus* Lindström and *Acodus deltatus* Lindström. This interval is probably equivalent to the Boat Harbour Formation above the pebble bed and with Fauna 3 of Stouge (1982). This fauna is characterized by a species close to (if not identical with) *Acodus deltatus* accompanied by *Parapanderodus gracilis* (Ethington and Clark), *Eucharodus parallelus* (Branson and Mehl), *Glyptoconus quadraplicatus* (Branson and Mehl) and *Drepanoistodus*? sp. aff. *D. concavus* (Branson and Mehl). Two clasts in Bed 10 that yielded an assemblage with *Acodus deltatus* and *Paroistodus proteus* support this correlation.

The first appearance of *Oistodus*? *elongatus* Lindström (= *O.* n. sp. 1 Serpagli) and "*Oistodus*" sp. aff. "*O.*" *cristatus* Ethington and Clark s.f. defines the lower boundary of Assemblage A. 2 of Johnston (1987). It occurs in the uppermost 25 m of Bed 9. *Paracordylodus gracilis* Lindström and *Prioniodus elegans* Pander are the most abundant components, accompanied by *Bergstroemognathus* sp. cf. *B. extensus* (Graves and Ellison), *Protoprioniodus simplicissimus* McTavish and *Tropodus sweeti* (Serpagli). The *Prioniodus elegans* Zone coincides here with the first occurence of *Oepikodus communis* (Ethington and Clark), which in the Midcontinent zonal schemes defines the base of Fauna E (Ethington and Clark, 1971) or the *Oepikodus communis–Fahraeusodus marathonensis* interval (Ethington and Clark, 1981). In the St. George Group the base of the Catoche Formation coincides with the first appearance of *Oepikodus communis* (Fauna 4 of Stouge, 1982). The presence of the graptolite *Tetragraptus akhzarensis* below the dolomitized interval near the top of the Catoche Formation indicates that all of Bed 9 and Bed 10 correlate with most of the Catoche Formation (Williams et al., 1987), except the basal *Paroistodus proteus* interval.

Foreign lithotypes in Bed 10 are generally coeval with the upper part of Bed 9 and have many species in common such as *Oistodus*? *elongatus* Lindström, *Bergstroemognathus extensus* (Graves and Ellison), *Drepanoistodus* sp. aff. *D. concavus* (Branson and Mehl), *Paroistodus parallelus* (Pander), *Periodon*? *primus* Stouge and Bagnoli, *Protoprioniodus simplicissimus* McTavish and *Tropodus sweeti* (Serpagli). The assemblages from Bed 9 are distinct in their lack of *Paracordylodus gracilis* and scarcity of *Prioniodus elegans*. Instead, *Prioniodus marginalis* n. sp. dominates in all samples derived from the upper slope and shelf break. This species is rare in the lower slope sequence and absent from shelf-derived clasts of equivalent age. A possible precursor of this species is *Prioniodus serratus* n. sp., which occurs in a single sample from a conglomerate slightly older than Bed 10 at Lower Head West. Typically *P. marginalis* is accompanied by *Texania teras* n. gen. n. sp., *Protoprioniodus papiliosus* (van Wamel) and *Protoprioniodus simplicissimus*. Conodont samples collected from the matrix of Bed 10 also yielded *P. marginalis* and *P. elegans*.

Bed 12 and equivalents

Assemblage A.3 of Johnston (1987) occurs in the lower 46 m of Bed 11 at St. Pauls Inlet and is characterized by a high abundance of the Scandinavian zone fossil *Oepikodus evae* Lindström. Important species making their first appearance in this interval are *Acodus*? *gladiatus* Lindström, *Periodon flabellum* Lindström, *Protopanderodus rectus* Lindström, *Reutterodus andinus* Serpagli, "*Scolopodus*" *carlae* Repetski, and species of *Juanognathus*. Many of the Argentinian species that were first described by Serpagli (1974) persist from Beds 9 and 10 (i.e., *Acodus russoi, Tropodus sweeti, Bergstroemognathus extensus* and *Periodon*? *primus*).

Up section, Assemblage A.3 is gradually replaced by Assemblage A.4, which is dominated by *Periodon aculeatus* Hadding. Johnston (1987) defined the base of Assemblage A.4 by the first appearance of *Oepikodus intermedius* Serpagli, which is associated with *Cordylodus* sp. cf. *C. horridus* Barnes and Poplawski, *Jumudontus gananda* Cooper, *Protoprioniodus aranda* Cooper and *Strachanognathus parvus* Rhodes. This replacement probably correlates closely with the change from the *D. bifidus* Zone to the *I. v. lunatus* Zone of Williams and Stevens (1988). In the uppermost part of Bed 11, *Tripodus laevis* (Bradshaw) first appears. This faunal change coincides with a change in the graptolite fauna (the *I. v. lunatus* Zone is replaced by the *I. v. victoriae* Zone) (Williams and Stevens, 1988), and probably indicates the base of the Middle Ordovician.

The known conodont faunal record on the shelf is scanty for this interval. Based on graptolite data (Williams et al., 1987), it appears that the uppermost part of the Catoche Formation and an unknown proportion of the Aguathuna Formation are coeval with Beds 11 and 12. *Didymograptus* (*Extensograptus*) *extensus* is found in a shale horizon near the base of the Aguathuna Formation and suggests equivalence to the middle of Bed 11 (Williams et al., 1987). Conodonts of Canadian age are present in the lower part of the Aguathuna Formation (Ji, 1989) and those of Midcontinent Faunas 2–3 in the uppermost portion (Stouge, 1982). The exact position of the Lower–Middle Ordovician boundary is not yet known.

Clasts of Bed 12 reflect the faunal change from the *Oepikodus evae* dominated to *Periodon* dominated faunas found in the slope sequence (Fig. 4). The older assemblage is generally similar to that of the bedded strata and, in addition to the zone fossil *P. evae*, also contains *Periodon flabellum* and Argentinian species. The occurrence of *Paroistodus*? *mutatus* (Branson and Mehl) in some samples is of interest because these species are usually found in younger faunas (Löfgren, 1978). Younger clasts in Bed 12 contain faunas with abundant *Periodon aculeatus* accompanied by *Texania heligma* n. gen. n. sp., *Protoprioniodus papiliosus, P. aranda* and *Strachanognathus parvus. Tripodus laevis* is also present as well as a few specimens of *Pteracontiodus cryptodens* (Mound). Both species are generally considered to indicate Whiterockian age. *Oepikodus communis* is relatively rare and restricted to a few samples. The matrix of Bed 12 yielded a few broken elements of *O. evae* and *P. aculeatus* indicating that there is no significant age difference between clasts and matrix.

The recognition of coeval Scandinavian biofacies is hampered by the complete lack of baltoniodan zonal index fossils in North America. In Öland, Sweden the last occurrence of *O. evae* falls within the range of van Wamel's (1974) *Prioniodus navis–P. crassulus* Assemblage Zone. Van Wamel did not distinguish *P. navis* from the older *P. triangularis* as did Löfgren (1978), and the older part of the *P. navis–P. crassulus* Assemblage Zone of van Wamel may coincide with Löfgren's *P.* (*B.*) *triangularis* interval. The *P.* (*B.*) *navis* Zone and possibly the *Paroistodus originalis* Zone may correlate to the upper part of Bed 11. This interpretation is supported by the increased abundance of *P. originalis* in younger clasts of Bed 12.

Shelf derived clasts are scarce in Bed 12 and they are difficult to evaluate. They contain faunas similar to those described by Stouge (1982) from different levels of the Catoche Formation but yield, instead of *Oepikodus communis, O.* sp. aff. *O. minutus*, a species that is characterized by a denticulate lateral process in the prioniodontiform element. Similar elements occur in *Prioniodus* species from the Pogonip Group (Ethington and Clark, 1981) and the Antelope Valley Limestone (R.L. Ethington, pers. comm., 1986). Their biostratigraphic potential is unknown as yet.

Lower/Middle Ordovician boundary in North America

The conodont evidence from the Whiterock type section in Whiterock Canyon, Nevada suggests that the Lower/Middle Ordovician boundary lies between the older *Oepikodus evae* interval found near the top of the Ninemile Shale and the younger *Tripodus laevis* interval in the basal Antelope Valley Limestone (Ross and Ethington, 1991). Conodonts recovered from the Ibexian Ninemile Shale are similar to those found in the lower part of Bed 11 and older clasts in Bed 12. The type section in Nevada contains "Argentinian" species such as *Bergstroemognathus extensus, Tropodus sweeti*, and *Juanognathus variabilis*, together with *Oepikodus evae*. These forms range to almost the top of the Ninemile Shale and after a short, presumably barren interval are replaced by a new fauna at the base of the Antelope Valley Limestone that coincides with the base of Zone L (*Orthidiella* Zone of Cooper, 1956, 1976). This fauna contains, among others, *Ansella jemtlandica, Drepanoistodus venustus, D. basiovalis, Microozarkodina flabellum, Paltodus jemtlandicus, Parapanderodus asymmetricus, Periodon aculeatus*, and *Tripodus laevis*. At the section at Meiklejohn Peak, *Oepikodus* sp. aff. *O. minutus, Protoprioniodus aranda*, and *Protoprioniodus papiliosus* are also present in a short interval.

In the Cow Head Group, the base of the Whiterock could be correlated either with Johnston's Assemblage A.4 (upper Bed 11 or lowermost Bed 13) with *P. aranda*, or with the base or lower part of Assemblage A.5 (lower part of Bed 13) characterized by the appearance of *Acodus*? *robustus* (Serpagli) (="*S.*" *mysticus*) and *A. jemtlandica* (see below). Shelly fossils collected from the megaconglomerates of Bed 12 by Kindle and Whittington (1958) and Ross and James (1987) suggest that Whiterock faunas are present in the younger boulders of this horizon equivalent to the upper part of Bed 11. Finney and Ethington (1992), discussed graptolite faunas from the Whiterock sections in Nevada and contended that the Lower/Middle Ordovician boundary falls either within an interval correlated with Australian graptolite zone Ca2 (*I. v. victoriae* Zone) or at the boundary between Ca1 (*I. v. lunatus* Zone) and Ca2. This correlates very well with the placement of the boundary in the Cow Head Group discussed above.

Bed 13 and equivalents

Assemblage A.4 of Johnston (1987) persists from the top of Bed 11 into the basal part of Bed 13 where it is replaced by Assemblage A.5. The A.5 fauna is dominated by an intermediate form of *Periodon aculeatus* and is defined by the first appearance of *Acodus*? *robustus* (Serpagli), *Drepanoistodus basiovalis* (Sergeeva), "*Scandodus*" *flexuosus* Barnes and Poplawski, and *Walliserodus ethingtoni* (Fåhræus). *Drepanoistodus basiovalis* occurs earlier in foreign clasts in Bed 12, (i.e., is present earlier in the upper slope sequence).

In the middle of Bed 13, a mixed fauna with late forms of *Periodon aculeatus* and *Spinodus* sp. cf. *S. spinatus* (Hadding) occurs. Foreign clasts from Bed 14 typically contain *Ansella jemtlandica, Erraticodon balticus* Dzik, *Oistodus*? *tablepointensis* Stouge, *Parapanderodus* spp., and *Paroistodus*? *mutatus* (Branson and Mehl). It has many species in common with the lower and middle Table Head Formation as well as with faunas from uppermost Bed 13 and a conglomerate overlying Cow Head strata at Martin Point (basal Lower Head Formation). The occurrence of *Ansella jemtlandica* and *Erraticodon balticus* suggests latest Arenig to earliest Llanvirn age. Graptolite data support an assignment to the upper Arenig. Samples from the matrix of Bed 14 conglomerates contained poorly preserved and scarce specimens of the advanced form of *P. aculeatus* together with older species, suggesting that the matrix is as old as the penecontemporaneous clasts.

Most of the shelf-derived clasts in Bed 14 are age equivalent to the Catoche Formation and possibly the lower Aguathuna Formation. One large, synsedimentary deformed boulder at Lower Head yields species of Fauna C of the Midcontinent zonation with *Rossodus manitouensis* Repetski and Ethington and *Loxodus bransoni* Furnish. A single clast from Lower Head East contained *Paraprioniodus costatus* (Mound), and is the only representative of Stouge's Fauna 6 from the upper Aguathuna and basal Table Head formations. This fauna contained taxa characteristic of Midcontinent faunas 2–3, which are of lower Whiterock age. This rare shelf-derived clast fauna is considered to be age equivalent to the boundstone lithotypes usually found in Bed 14 that contain shelf edge faunas dominated by *Periodon* and *Parapanderodus*.

CONCLUSIONS

The *Paroistodus proteus, Prioniodus elegans* and *Oepikodus evae* zones of the Baltoscandian conodont zonation are recognized in bedded and conglomerate horizons ranging from the upper half of Bed 9 through Beds 10, 11, and 12. The younger *Baltoniodus navis/triangularis* and *Microzarkodina flabellum parva* zones (Löfgren, 1978) are not found in the Cow Head Group and are also rarely found elsewhere in North America. The upper part of Bed 11 and Bed 13 may correlate with this interval. The top of Bed 13 and Bed 14 probably correlate with the *Eoplacognathus*? *variabilis* Zone.

Of the North American Midcontinent zonation, Fauna E with *Oepikodus communis* is equivalent to the *P. elegans* and *O. evae* zones in the Cow Head Group, indicating a late Canadian age for Beds 9–11. The faunal change observed near the top of Bed 11 and in younger clasts of Bed 12 occurs at a level close to the Lower–Middle Ordovician boundary.

CONODONT PALEOECOLOGY

Introduction

Conodont paleoecology is a relatively new discipline in conodont research because in previous studies many conodont species were interpreted as global in distribution and of wide facies tolerance. Ideas about conodont ecology favoured a planktonic mode of life (Müller, 1962; Linström, 1964). With ongoing study, evidence accumulated that many conodonts were provincially restricted and that certain genera preferred distinct habitats within provinces (Merrill, 1966; Seddon and Sweet, 1971; Barnes et al., 1973; Lindström, 1976a). The faunal provinces that existed during the Ordovician became known as the North Atlantic and (North American) Midcontinent provinces (Sweet et al., 1959; Sweet and Bergström, 1974). Generally, Midcontinent Province faunas occur in carbonate platform environments of shallow, warm water and, possibly, of raised salinity. In contrast, faunas of the North Atlantic Province developed in deep and/or temperate to cold water environments (Barnes et al., 1973; Barnes and Fåhræus, 1975). In evaluating the terminology used in context with provincialism, Lindström (1976) pointed out that "provincialism" has a strong geographic connotation and that the Midcontinent Province *sensu strictu* is confined to North America. However, many conodont assemblages representing faunas of Midcontinent affinity are known from similar depositional settings, and referred to as subprovinces. Examples of Midcontinent subprovinces would be the Canadian Arctic (Nowlan, 1976), the Siberian Platform (Moskalenko, 1973) or parts of the Precordillera in Argentina (Serpagli, 1974).

The Appalachian faunas described by Barnes and Poplawski (1973), among others, could be regarded as a North Atlantic subprovince. For conodont assemblages showing strong endemicity, Lindström advocated the term "fauna" named after one or more genera or species (e.g., *Amorphognathus* Fauna) without geographic connotations. Faunas can be subdivided into communities as well as provinces (Lindström, 1976) or biofacies, as has been shown by several workers (Merrill, 1966; Druce, 1973). Barnes and Fåhræus (1975) in particular illustrated the composition and occurrence of conodont communities of the Ordovician. Fortey and Barnes (1977) observed four communities or biofacies in Lower Ordovician shelf, shelf edge, upper slope, and lower slope deposits of Spitsbergen. The different environments occur in vertical succession; that is, in a deepening upward cycle. The biofacies are therefore not time equivalent. This is the case in most studies conducted on this topic simply because laterally correlatable outcrops of shelf/slope successions are not common in the geological record. The recurrent species associations of Bergström and Carnes (1976) as well as Stouge's (1984) biofacies and subbiofacies are largely derived from vertical successions.

The Cow Head area, where slope and shelf deposits are found in close proximity, provides the opportunity to study the lateral distribution and composition of conodont communities. Correlation between shelf and slope successions has been outlined above. Conodont faunas from clasts that represent remains of the shelf edge lived in the boundary region where shelf (Midcontinent) and basin (North Atlantic) faunas met. This setting offers an opportunity to study the mechanisms of interaction between the two faunal provinces. The relationships can be demonstrated by comparing faunas reported in earlier studies from the lower slope sequence (Fåhræus, 1970; Fåhræus and Nowlan, 1978; Johnston, 1987) and from the shelf (Barnes and Tuke, 1970; Stouge, 1982, 1984) with those of the shelf edge. Ethington and Repetski (1984) as well as Stouge (1984) recognized inner shelf, outer shelf and shelf edge biofacies in Lower and Middle Ordovician rocks of the North American Midcontinent Province. Their terminology is adopted herein with the addition of a lower slope biofacies that has been recognized by Fortey and Barnes (1977). For a more detailed review of conodont paleoecology, the reader is referred to Pohler and Barnes (1990).

In order to establish the biofacies of the shelf edge-upper slope, environmental data regarding the sedimentology of clasts found in the three megaconglomerate horizons (Beds 10, 12 and 14) has been utilized. The clasts have been subdivided according to their origin and age into local, foreign and older lithotypes and assigned the letters A, B and C, respectively (cf. Pohler and James, 1989). Foreign clasts are interpreted as fragments of the shelf edge and upper slope (Fig. 2) and only conodont faunas from these lithotypes are used to establish the biofacies.

Paroistodus-Drepanoistodus biofacies

Two samples from clasts in Bed 10 (230 and 236) yielded a fauna characterized by *Paroistodus numarcuatus* (Lindström) and *Drepanoistodus inconstans* (Lindström). Accompanying species include *Scolopodus*? *peselephantis* Linström, "*Scandodus*" *pseudoramis* (Serpagli), *Paroistodus proteus* and *Drepanodus arcuatus*. Johnston (1987) reported a similar fauna from the base of Bed 9 and the assemblage obviously belongs to the *Paroistodus proteus* Zone of Baltoscandia. It is not further evaluated herein because of the small size of the collection.

Prioniodus-Texania biofacies

Of the 35 samples collected from Bed 10 (clasts and matrix), 22 are from foreign penecontemporaneous lithotypes and representative of the shelf edge and upper slope environments. These clasts yielded 2105 conodonts representing 56 multielement and form species (Appendix 1). Seven species are especially abundant and comprise 73.6 per cent of the fauna. These are: *Prioniodus marginalis* n. sp. (28%); *Prioniodus serratus* n. sp. (16%); *Prioniodus elegans* Pander (15.5%); *Oistodus*? *elongatus* Lindström (4%); *Drepanoistodus inconstans* (Lindström) (3.9%); *Drepanoistodus forceps* (Lindström) (3.4%); *Texania teras* n. gen. n. sp. (2.8%).

Also significant are *Paroistodus parallelus* Pander (2.3%); *Drepanoistodus* sp. aff. *D. concavus* (Branson and Mehl) (2.3%); and *Drepanodus arcuatus* Pander (2.2%). The assemblage is termed *Prioniodus-Texania* Biofacies after the most abundant and the most distinctive genera, respectively. The fauna is distinguished by the prioniodontids *Prionodus* and *Texania*, and the simple cone genera *Oistodus*? *Drepanoistodus*, *Drepanodus*, and *Paroistodus*. The prioniodids are, with the exception of *P. elegans*, restricted to the shelf edge and the upper slope. They show affinity with Australian species that have been described from the Emmanuel Formation by McTavish (1973). The dominant coniform species are mostly cosmopolitan or of North Atlantic aspect. *Drepanodus arcuatus* and *P. parallelus* are true cosmopolitan species and their worldwide distribution has been interpreted as being the result of their pelagic life style (Fortey and Barnes, 1977). *Oistodus*? *elongatus* is abundant in Argentinian and Baltoscandian faunas but is a rare component of Midcontinent faunas (cf. Ethington and Clark, 1981); it does, however, occur in the St. George Group (Stouge, 1982) and possibly the El Paso Group (Repetski, 1982). *Drepanoistodus inconstans* and *D. forceps* may also be cosmopolitan but their similarity to other species of *Drepanoistodus* makes evaluation difficult. A species close to, if not conspecific with, *D. forceps* has been reported from the Pogonip Group (Ethington and Clark, 1981).

Of the 56 species found in shelf edge-derived clasts, 20 are restricted to the Midcontinent Province with only sporadic occurrences reported from localities outside North America. They comprise about 8% of the fauna (Fig. 5). Four species (5.4%) are known from Argentina but also occur in North America in open shelf deposits. Thirteen of the species (31.1%) are largely restricted to the North Atlantic Province and seven species (9%) can be regarded as cosmopolitan.

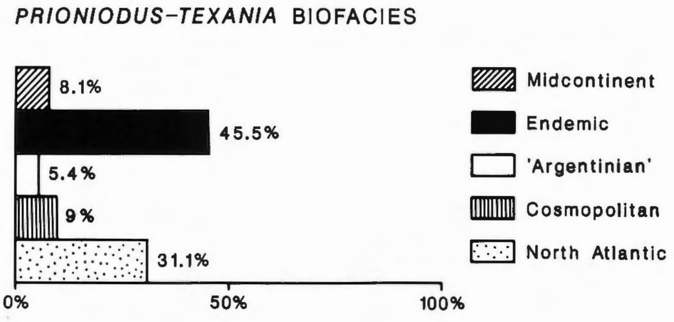


Figure 5. Composition of the Prioniodus-Texania Biofacies.

The remaining 12 species are endemic to the upper slope environment and are mostly of Australian affinity or single problematic elements. This endemic group accounts for 45.5 per cent of the biofacies.

Lower slope deposits (Bed 9) of the Cow Head Group

Johnston (1987) studied conodonts from the bedded Arenig sequence at St. Pauls Inlet and Martin Point. The Martin Point section, dominantly shale, produced only sparse faunas; in constrast, the St. Pauls Inlet section yielded large numbers of conodonts. Bed 9 here is equivalent in age to foreign clasts in Bed 10; 52 different species were recognized in Bed 9. In constrast to the prioniodontid dominated shelf edge biofacies, the lower slope fauna is dominated by *Paracordylodus gracilis* Lindström (25% of the total fauna) and *P. elegans* (13%). Johnston did not distinguish between *P. elegans, P. marginalis* and most of the prioniodontids described by Stouge and Bagnoli (1988). Study of his collections shows that the samples contain a mixture of both species with *P. elegans* (*sensu* Johnston, 1987) being the more abundant species. *Drepanodus arcuatus* comprises 10 per cent of the fauna, followed by *P. parallelus* (7%) and *Periodon*? *primus* Stouge and Bagnoli (5%). *Glyptoconus quadraplicatus* (Branson and Mehl), *D.* sp. aff. *D. concavus* and *Diaphorodus delicatus* (Branson and Mehl) each comprise 3.5 per cent of the fauna. Together these eight species represent 71 per cent of the fauna. North Atlantic (*P. elegans, Periodon*? *primus, Paracordylodus gracilis*) and cosmopolitan species (*D. arcuatus, P. parallelus*) dominate the lower slope biofacies. Of the shelf edge species, only *P. marginalis* is present in significant numbers. As with the upper slope biofacies, the fauna is highly diverse, but is not as strongly dominated by one species. These biofacies are quite distinct because of the different character of the dominant species.

Conclusions

Comparison of the upper slope/shelf break biofacies with age equivalent platformal and lower slope sequences shows that during deposition of Bed 9 and Bed 10, three strongly segregrated biofacies existed: 1) an *Oepikodus communis* biofacies characterized the open shelf environment; 2) a *Prioniodus-Texania* biofacies inhabited the shelf edge and upper slope; 3) a *Paracordylodus* biofacies was present on the lower slope. Figure 6 shows the distribution of the most abundant species of the three biofacies. Species are listed in order of decreasing abundance for shelf edge and lower slope. Each of these biofacies is dominated by a species that is largely restricted to its realm (i.e., *O. communis, P. marginalis, P. gracilis*). Accompanying species are either endemic or cosmopolitan. The strong faunal segregation impedes correlation among the three biofacies, and although an "interfingering" of the faunas can be observed, this seems to be controlled by environmental factors rather than biostratigraphic ranges. Consequently a species with a relatively short range in one environment may persist for a long time in another.

For the time interval of the *P. elegans* Zone, the boundaries between the biofacies are rather sharp and the upper slope/shelf break represents a distinct independant habitat rather than a "mixing zone" between two provinces. Some of the shelf edge species show kinship to Australian faunas (i.e., faunas described by McTavish, 1973; *P. marginalis* is close to *P. oepiki* McTavish; *P. serratus* is close to *Acodus longibasis* McTavish and *T. teras* is close to *F. adentata* (McTavish). Another Australian species (*Protoprioniodus simplicissimus* McTavis) is also present. An exchange of biostratigraphically important species is far more common between upper and lower slope biofacies than an exchange between shelf and upper slope. Also many of the dominant species of the upper and lower slope are of North Atlantic affinity allowing correlation with other North Atlantic Province faunas rather than with those from the Midcontinent. Short-ranging, abundant and distinct species are not yet known from the time equivalent Midcontinent Province and although many Midcontinent species are present as minor constituents in the shelf edge biofacies, they are not useful for detailed correlation.

Oepikodus-Periodon biofacies

Conodont samples of foreign lithotypes in Bed 12 yield conodonts of two different zones derived from older

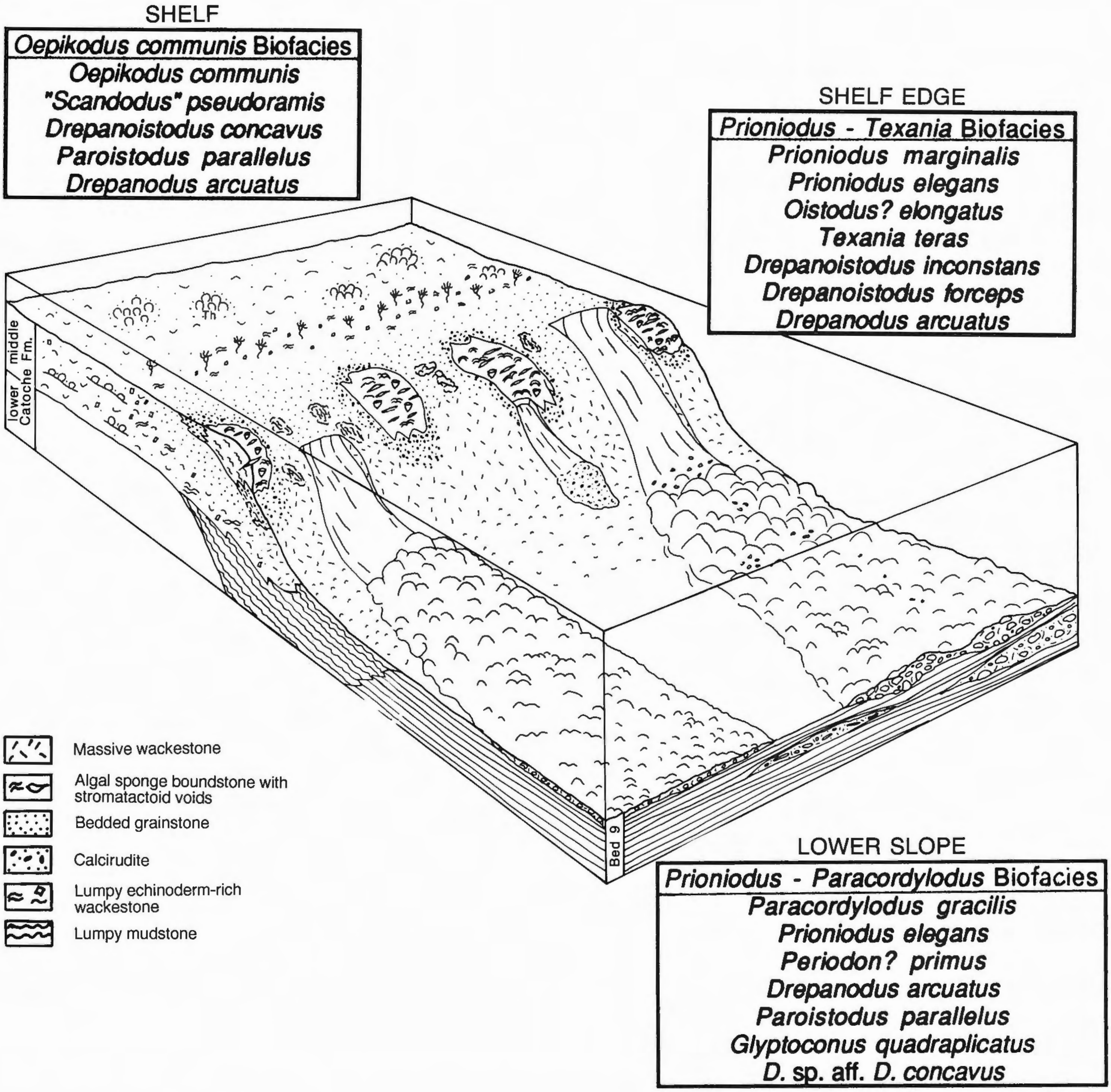


Figure 6. *Conodont biofacies distribution and composition during the time of deposition of Bed 9/10 on shelf, shelf edge and lower slope.*

(lower Bed 11 age) and younger (upper Bed 11 age) strata of the upper slope (Appendix 2). This is consistent with the biostratigraphic evidence reported from the bedded sequence of Bed 11 (Johnston, 1987) where *Oepikodus evae* occurs in the lower to middle part and *Periodon aculeatus* in the upper part of Bed 11. The middle part of the section produced faunas with about equal numbers of *O. evae* and *P. aculeatus*. Seventeen samples from Bed 12 can be recognized as older lithotypes. These are dominantly lumpy wackestones that yield large numbers of the Baltoscandian zonal index fossil *Oepikodus evae*. The fauna comprises 1238 elements representing 31 multielement and form species. Only four species comprise 85 per cent of the fauna: *O. evae* (76%); *Periodon flabellum* Linström (6%); *Protopanderodus rectus* and *Drepanoistodus forceps* (1.5% each). This association is termed the *Oepikodus–Periodon* Biofacies. Accompanying species are typically Argentinian faunal elements with *Bergstroemognathus extensus* (Graves and Ellison), *Tropodus sweeti* (Serpagli), and "*Scolopodus*" *quadratus* Pander. Samples of Bed 11 age from lower-slope-derived clasts found in Beds 12 and 14 are also dominanted by *O.*

evae, but the most abundant accompanying species, apart from *P. flabellum*, are *Bergstroemognathus extensus* and *Drepanodus arcuatus* (Johnston, 1987).

Plotting the percentages of the different species (Fig. 7) shows that almost 90 per cent of the shelf edge fauna is of North Atlantic affinity, followed by cosmopolitan species (5.6%). Argentinian species comprise 1.8 per cent of the fauna, and are more common in lower-slope-derived clasts. Species endemic to the margin and Midcontinent species are low in abundance (0.5 and 2.6%, respectively).

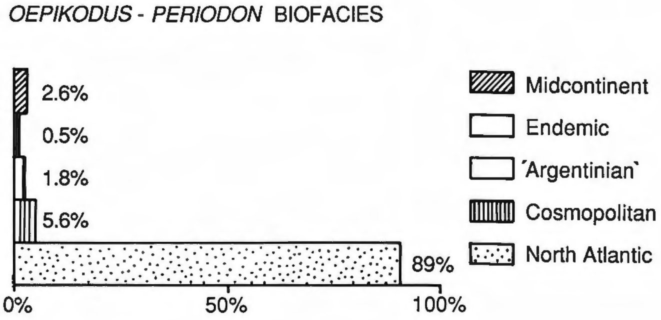


Figure 7. Composition of the ***Oepikodus-Periodon*** *Biofacies.*

Lower slope biofacies (lower Bed 11) of the Cow Head Group

Bedded lithotypes in the lower part of Bed 11 are similar in faunal composition to those of the upper slope, and the dominant species are *O. evae* and *P. flabellum*, together constituting about 80 per cent of the total fauna. Next in abundance are *D. arcuatus, Protopanderodus rectus* (Lindström) and *Paroistodus parallelus* (Pander). Argentinian faunal elements persist from Bed 9 into the *O. evae* Zone.

Conclusions

Compared to the *Prioniodus-Texania* Biofacies of Bed 10, endemism during lower Bed 11 time is low and North Atlantic, cosmopolitan and Argentinian species inhabited the shelf edge as well as the lower slope (Fig. 8). The shelf during this time interval was invaded by Argentinian faunal elements that are interpreted as deep shelf faunas (Ethington and Repetski, 1984). The almost worldwide spread of North Atlantic faunas with *O. evae* is interpreted as being the result of a eustatic sea level high (Vail et al., 1977; Barnes, 1984).

Periodon-Texania biofacies

Ten samples from Bed 12 can be identified as younger lithotypes based on lithological (lumpy wackestones are missing) and faunal (*O. evae* disappears) evidence. Thirty-eight species were identified (1542 elements) (Appendix 2). The fauna is composed of *Periodon aculeatus* Hadding (58.7%); *Texania heligma* n. gen. n. sp. (15.9%); *Protoprioniodus papiliosus* (van Wamel) (5.2%); *Strachanognathus parvus* Rhodes (3.8%); *Protoprioniodus aranda* Cooper (3.4%); and *O. communis* (2.6%).

Species of North Atlantic affinity decreased by almost 30 per cent in abundance in the assemblage compared to the *Oepikodus-Periodon* Biofacies (Fig. 9). Endemic and Midcontinent species are more abundant here (16.7% and 10%, respectively), whereas Argentinian faunas are minor components of the faunal assemblage.

Lower slope biofacies (Bed 11) of the Cow Head Group

The faunal shift is reflected in the bedded sequence of Bed 11 (Johnston, 1987) where the upper part also contains a *P. aculeatus* dominated fauna composed of 43 different species (7147 elements). Four species comprise 90 per cent of the fauna: *P. aculeatus* (80%), followed by *O. intermedius* (Serpagli), *P. flabellum* and *P. parallelus*. Characteristic accessory species introduced at this level are *Spinodus* sp. cf. *S. horridus* (Barnes and Poplawski), *P. aranda* and *S. parvus*. Many Argentinian elements (e.g., *Bergstroemognathus extensus, Tropodus sweeti*) disappear in this interval.

Conclusions

The faunal change during deposition of upper Bed 11 affected the graptolite as well as conodont faunas (Fig. 4) and probably occurred in response to a regression on the shelf platform that is reflected in the dolomitized shallow water carbonates of the lower Aguathuna Formation. The *Periodon-Texania* Biofacies, although still dominated by North Atlantic species, shows an increase of Midcontinent, endemic and cosmopolitan species at the expense of North Atlantic and Argentinian components (Fig. 10). The *Periodon-Texania* biofacies differs from the lower slope biofacies in yielding higher numbers of specimens of *P. originalis, P. aranda* and *S. parvus*. The endemic species *T. heligma*, a close relative of *Texania teras* from Bed 10, is rare in the bedded sequence, while *O. intermedius* is lacking in the upper slope facies. Most

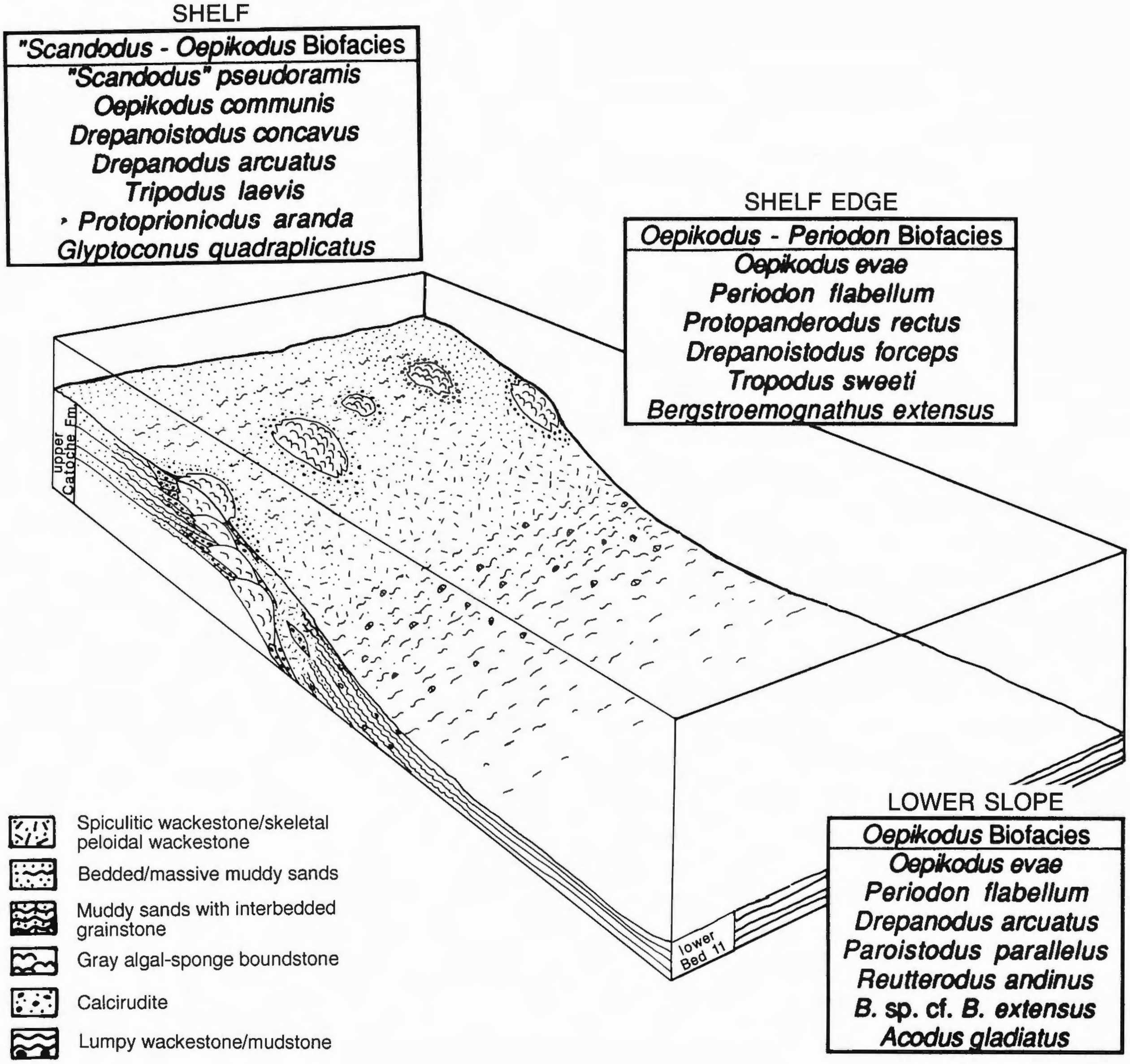


Figure 8. Conodont biofacies distribution and composition during the time of deposition of lower Bed 11 on shelf, shelf edge and lower slope.

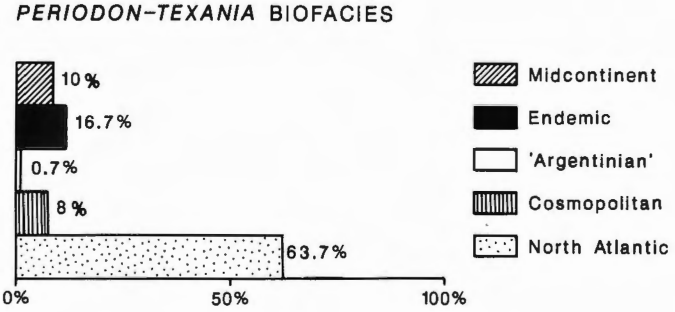


*Figure 9. Composition of the **Periodon–Texania** Biofacies.*

of the accessory species are present in low numbers in both biofacies.

Periodon–Parapanderodus biofacies

The 65 samples collected from foreign penecontemporaneous lithotypes in Bed 14 yielded 2250 conodonts representing 56 different multielement and form species (Appendix 3). Close to 90 per cent of the fauna consist of eight species: *Periodon aculeatus* (74.7%); *Parapanderodus arcuatus* Stouge (4.1%); *Protopanderodus rectus* (3.2%); *Paroistodus parallelus* (2.2%); *Oistodus lanceolatus* (1.7%); *Drepanoistodus basiovalis* (Sergeeva) (1.5%); *Paroistodus originalis* (1.5%); and *Parapanderodus* sp. 1 (1.5%).

In addition, small numbers of Table Head faunal elements such as *Parapaltodus simplicissimus* Stouge, Paltodus jemtlandicus Löfgren, *Scolopodus oldstockensis* Stouge, *Oistodus*? *tablepointensis* Stouge and *Erraticodon* (Stouge, 1984) occur. This faunal assemblage, found in shelf-margin-derived clasts, is termed the *Periodon–Parapanderodus* biofacies.

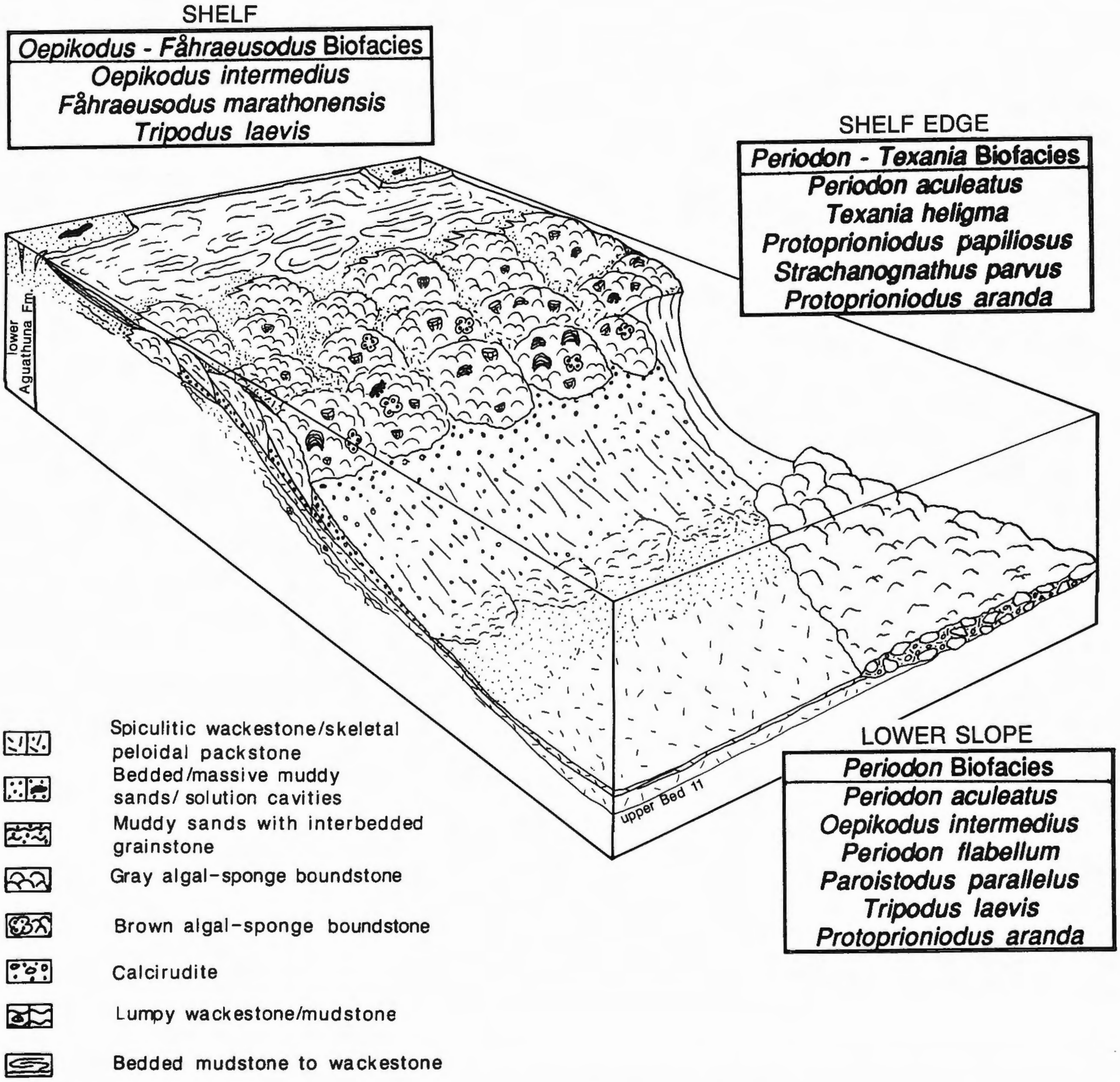


Figure 10. Conodont biofacies distribution and composition during the time of deposition of upper Bed 11 on shelf, shelf edge and lower slope.

Most of the species are of North Atlantic aspect (Fig. 11) but a high percentage (9%) are of Midcontinent affinity. Endemicity of the fauna is 3 per cent and Argentinian elements are rare (0.5%). Cosmopolitan species account for 7 per cent of the fauna.

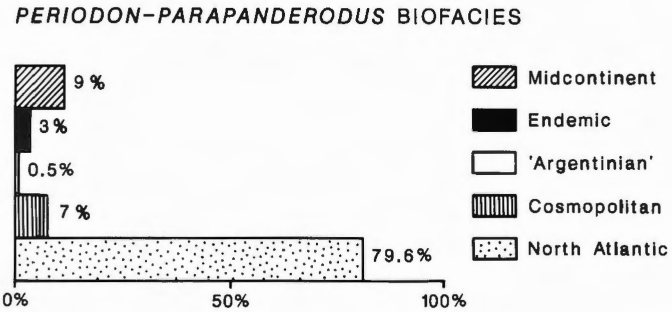


Figure 11. Composition of the Periodon-Parapanderodus Biofacies.

Lower slope biofacies

Age equivalent lower slope deposits of Bed 13 yielded rich faunas at the St. Pauls Inlet section (Johnston, 1987) with 11 533 elements representing 58 different multielement and form species. As in Bed 14, the fauna is dominated by *Periodon aculeatus*, which constitutes 84 per cent of the fauna. Also common are *P. flabellum, Protoprioniodus aranda, Paroistodus parallelus* and *Drepanodus arcuatus*. Comparison with the clast faunas in Bed 14 suggests that many species were restricted to the shelf edge environment at that time. These include *Ansella jemtlandica* (Löfgren), *Paroistodus*? *mutatus, P. originalis, Parapanderodus* sp. 1, and many of the rare Table Head species listed earlier. *Parapanderodus arcuatus* is almost absent in lower slope deposits; instead, a closely related form, *P.* sp. cf. *P. arcuatus*, is present.

Conclusions

The high proportion of *Periodon aculeatus* found in foreign penecontemporaneous clasts of Bed 13 age is characteristic of the shelf edge facies found in allochthonous sequences along the Appalachian Orogen. The shelf edge facies is strongly segregated from coeval platform faunas that are almost exclusively of Midcontinent affinity (Fig. 12). The *Periodon–Parapanderodus* biofacies has many species in common with the middle Table Head Group (*Cordylodus*?- *Periodon* Biofacies of Stouge [1984]). The similarity is probably the result of deepening of the water on the shelf during middle Table Head time as a result of foundering of the platform. This enabled the shelf edge faunas to migrate onto the platform (Pohler et al., 1987).

Summary and conclusions

Five different biofacies characterized the Arenig shelf break/upper slope environment. These are, from older to younger: 1) the *Paroistodus-Drepanoistodus* biofacies, 2) the *Prioniodus–Texania* biofacies, 3) the *Oepikodus–Periodon* biofacies, 4) the *Periodon–Texania* biofacies, and 5) the *Periodon–Parapanderodus* biofacies. The first two biofacies occur in boulders in Bed 10 and are thus contemporaneous with Bed 9 of the bedded sequence of the Cow Head Group; biofacies 3 and 4 are found in boulders in Bed 12, equivalent to Bed 11; biofacies 5 is restricted to Bed 14, equivalent to Bed 13 of the lower slope. Comparison of shelf break/upper-slope-derived faunas with those from the lower slope shows that both faunas are more closely related to the North Atlantic Province than to the Midcontinent Province and should be regarded as a subprovince of the North Atlantic Province. The lower Arenig faunas are representative of the older and younger *Paroistodus* Fauna (*sensu* Lindström, 1976); upper Arenig faunas can be referred to as *Periodon* faunas. Similar faunas can be found in deep water sediments around the North American craton. These faunas have been described from many localities, examples are: Levis (Uyeno and Barnes, 1970); the Mystic Conglomerate (Barnes and Poplawski, 1973); the Taconic Allochthon (Landing, 1976); the Hamburg Klippe (Bergström et al., 1972); the Ouachita Mountains (Repetski and Ethington, 1977); the Marathon Basin (Bradshaw, 1969), the Toquima Range (Ethington, 1972; Harris et al., 1979) and the Selwyn Basin (Tipnis et al., 1978; Pohler and Orchard, 1988; 1990).

Comparison of the shelf break/upper slope faunas with those reported from the lower slope (Johnston, 1987) of the Cow Head Group shows that the two environments were inhabited by different conodont assemblages. Except for the *Prioniodus–Texania* biofacies of Bed 10 the biofacies of shelf break/upper slope and lower slope are similar with regard to the dominating species but differ in the composition of accessory species. Shelf break and slope faunas are strongly segregated from those reported from the shelf platform (Stouge, 1982; Stouge and Boyce, 1983), which are of North American Midcontinent aspect and which can be correlated with sections on the North American craton. The shelf and slope faunas differ in the composition of the dominating species but have some of the accessory species in common. The shelf break apparently represents a sharp faunal boundary between shelf and slope with only minor interaction of the conodont faunas. The presence of boulders with shelf faunas indicates that the provincial boundary was not far from the site where the debris flows originated (i.e., shelf break/upper slope). There is no indication of the presence of a true "mixing zone" where the dominant species of both provinces occur together in large numbers.

Provincial boundaries are not well studied in other areas. The Lower to Middle Ordovician Pogonip Group probably represents a segment of an ancient shelf margin with the outer shelf environment preserved in the Ibex area of Utah and the upper slope in the Toquima ranges of Nevada. The faunas described from Utah (Ethington and Clark, 1981) are clearly of Midcontinent aspect with only few North Atlantic forms, while those of Nevada (Ethington, 1972; Harris et al., 1979; pers. obs., 1986, 1987) are mixed faunas with many North Atlantic as well as Midcontinent forms. Ocean currents or geographical barriers (e.g., reef barriers) may be responsible for the differences in migrational patterns.

A plot of biofacies composition of the shelf break/upper slope faunas of the Cow Head Group with respect to North Atlantic, Midcontinent, Argentinian, endemic and cosmopolitan species shows

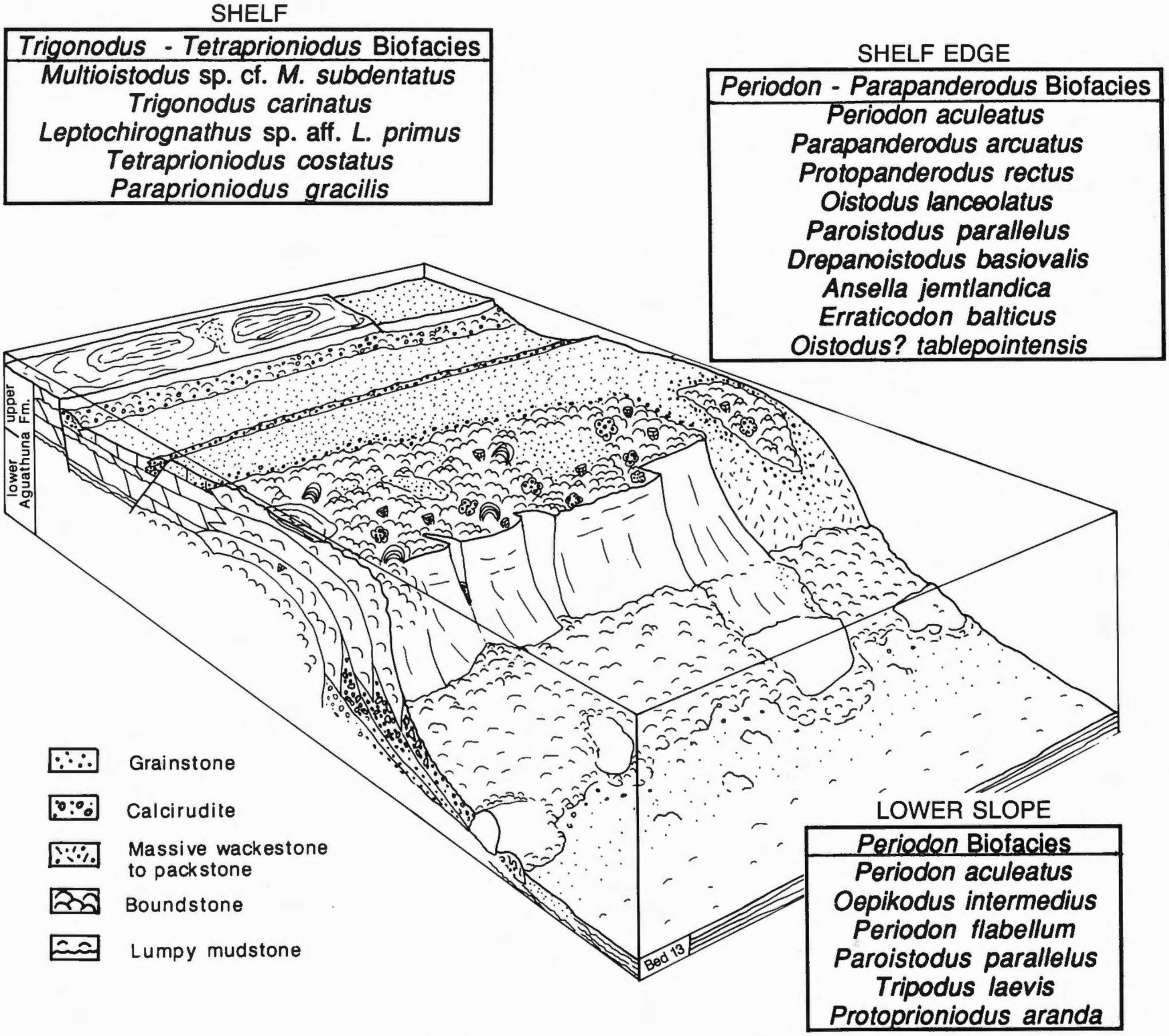


Figure 12. Conodont biofacies distribution and composition during the time of deposition of Bed 13/14 on shelf, shelf edge and lower slope.

fluctuations in composition which can be related to the sea level history of the platform (Fig. 13): the *Prioniodus–Texania* biofacies was established during a transgressive phase and persisted over a relatively long period of time. It yields the highest number of endemic species and is distinct from the lower slope as well as from the shelf. The succeeding, younger *Oepikodus–Periodon* biofacies was established during a period of high sea level on the shelf. It yields the lowest number of endemic and Midcontinent forms and the highest number of North Atlantic species. With the onset of regression on the shelf, a new fauna was established at the shelf edge, the *Periodon–Texania* biofacies with a higher number of Midcontinent and endemic species and a decreased number of North Atlantic forms. The youngest, *Periodon–Parapanderodus* biofacies corresponds with the lowest sea level on the shelf and records an increase of North Atlantic species, decrease of endemic forms and stable number of Midcontinent species. Argentinian and cosmopolitan species are rare.

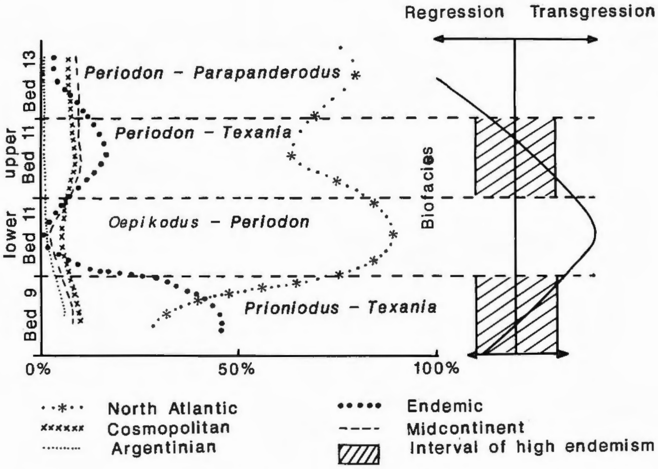


Figure 13. Relationship of biofacies composition and sea level history reflected in the Cow Head Group.

Migration of Midcontinent elements to the shelf edge are clearly related to shallowing of the water on the shelf; abundance of North Atlantic forms indicates relatively high sea level on the shelf recorded in the Catoche Formation (Knight and James, 1987).

Among the conodont faunas from other localities, those from the Mystic Conglomerate appear to be closely related to the *Periodon–Parapanderodus* biofacies (Barnes and Poplawski, 1973).

Comparison of conodont faunas from the Cow Head Group with those from other areas confirms a few consistent trends. Midcontinent faunas are present in shallow tropical or subtropical waters. In North America the interior shelf is inhabited by Midcontinent faunas, whereas the outer shelf with presumably deeper water is inhabitied by a mixture of Midcontinent, Australian and/or Argentinian faunas. The shelf break/upper slope is dominated either by endemic or by North Atlantic faunas, depending on locality. Incursions from North Atlantic faunas on the shelves are related to deepening (cooling?) of the water; excursions of Midcontinent faunas to the shelf edge or upper slope to shallowing (warming?) of water (Fig. 13).

The reasons for the strong segregation of provincial faunas are difficult to evaluate because a) few studies have dealt in detail with this problem, b) the lifestyle of the conodont animal is not clear, and c) the apparatus of many conodont species has not yet been established, which prevents a full understanding of species distribution. Study of recent oceans suggests that the shelf/slope break represents a fundamental boundary for marine life as demonstrated for isopod crustacean faunas in the northwestern Atlantic (Taylor, 1977). Cook and Taylor (1975) speculated on the role of the thermocline for the observed patterns of trilobite biofacies distribution. They suggested that water temperature was a leading factor in restricting universal spread of trilobites. This may apply for conodonts as well. Other causes for the faunal segregation may be bottom water aeration, different lifestyles and feeding styles of different genera and methods of larval dispersal. The contradictory evidence most likely results from a variety of factors.

SYSTEMATIC PALEONTOLOGY

Introduction

As this investigation concentrates on biostratigraphy and conodont biofacies, the systematics have been restricted to those species that add new information to the knowledge of Lower Ordovician conodonts.

Multielement taxonomy is employed where an apparatus has already been defined or the writer is confident that it can be reconstructed from the material at hand. Form taxa are distinguished by the abbreviaton s.f. (following Barnes and Poplawski, 1973). Tentative generic designations are enclosed in quotation marks.

The synonymy for species that are discussed only as "Remarks" is restricted to: the original author; authors who contributed significantly to the knowledge of the species; authors who provided a detailed synonymy; authors whose identification is questioned or revised. Species whose types were examined are marked with "**v**" in the synonymy; with "**vv**" if both types and type collection were seen; and with "**t**" if only the type collection were viewed. All species recovered are illustrated (Plates 1–8).

Figured specimens are deposited in the type collections of the Geological Survey of Canada. Many of the species illustrated here have also been found in the bedded sequence of the Cow Head Formation and the reader is referred to the reports of Fahræus and Nowlan (1978); Johnston (1987); and Stouge and Bagnoli (1988). Species recovered from conglomerate horizons are listed in alphabetical order in Table 1. Species described in the text are marked "*" in Table 1.

Phylum CONODONTA Pander, 1856

Class CONODONTATA Pander, 1856

Order CONODONTOPHORIDA
Eichenberg, 1930

Genus *Acodus* Pander, 1856

Type species. Acodus erectus. Ulrich and Bassler, 1926.

Acodontiform element 1

Plate 1, figure 10; Figure 14A, B

Description. A hyaline acodontiform element with a reclined cusp. Upper part of cusp is slightly twisted, with a lenticular cross-section. Both lateral faces are smooth. In lower part, cusp develops a triangular cross-section through gradual widening of the anterior margin to form a flat anterior face. Cross-section of base is triangular and lateral faces form long sides of triangle. Basal cavity is subtriangular in lateral view, apex is near anterior margin.

Occurrence. Bed 12.

Material. 4 specimens. Figured specimen, GSC 90312.

Acodontiform element 2

Plate 1, figure 7; Figure 14C, D

Description. Ramiform elements with a relatively large basal region compared to size of cusp. Basal region is triangular in lateral view and aboral margin forms longest side. Anterior and oral margin are both sharply keeled. Cusp is inclined at shallow angle (100-110°) to oral edge of base, flexed sideways and somewhat twisted. Posterior and anterior margins of cusp are sharp-edged and cross-section is lenticular. Inner side typically bears a sharp-edged carina that develops into a lateral bulge situated posteriorly from midline of lateral face. This inflation produces a sinuous outline of the aboral margin with largest downward extension marking highest point of bulge. Outer lateral face is convex and smooth. Below outer side, basal cavity is only weakly expanded and aboral margin is evenly curved. Basal cavity is triangular with its apex situated near anterior margin. Cusp is albid.

Remarks. The rather generalized kind of element described above is represented in several other genera (e.g., drepanodontiform element of *Tripodus*). As no accompanying elements of *Acodus*(?) sp. have been found, the generic assignment is tentative.

Occurrence. Bed 10, clast of Bed 10 age in Bed 14.

Material. 8 specimens. Figured specimen, GSC 90309.

Genus *Drepanodus* Pander, 1856

Type species. Drepanodus arcuatus Pander, 1856.

Drepanodus? sp. 1

Plate 2, figure 18; Figure 14I, J

Description. Recurved coniform elements with two costae dissecting both sides of the element or only the outer lateral face. Symmetrical element has shallow basal cavity with apex centrally situated. Aboral margin is convex, oral margin is short and sharp. Posterior and anterior margins are sharp-edged. One costa dissects lateral face medially, the other is more anteriorly situated. Asymmetrical element has laterally flexed cusp, and two costae are present only on outer lateral face. Aboral margin is straight; basal cavity flares to inner side. All elements have a hyaline base and an albid cusp.

Remarks. All elements are small. *Drepanodus*? sp. 1 may be closely related to *D. pitjanti* Cooper, but differs in being albid rather than hyaline.

Occurrence. Bed 10.

Material. 4 specimens. Figured specimen, GSC 90349.

TABLE 1

Faunal List

Species	Species ID	Plate, figure
Acodus deltatus Lindström	N	1, 1–4
A.? gladiatus Lindström s.f.	N	1, 5
*Acodontiform element 1	U	1, 10
*Acodontiform element 2	U	1, 7
Acontiodus iowensis Furnish	M	1, 18
A. latus Pander s.f.	U	1, 14
A. sp. 2 Uyeno and Barnes	M	1, 13
Ansella jemtlandica (Löfgren)	N	1, 15, 16
Bergstroemognathus extensus (Graves and Ellison)	A	1, 19–22
Cristodus loxoides Repetski	M	1, 23, 24
Coelocerodontus bicostatus van Wamel	N	1, 25
Cordylodus caboti Bagnoli et al.	C	1, 27
C. proavus Müller	C	1, 26
Cornuodus longibasis (Lindström)	N	1, 28, 29
Drepanodus arcuatus Pander	C	2, 1–6
D.? planus (Pander)	N	1, 11, 12; 2, 3, 7
D. sp. 2. Ethington and Clark	M	2, 10
D.? sp. 4 Repetski	M	2, 9
D. sp. 4 Serpagli	A	2, 11
**D.?* sp. 1 s.f.	U	2, 18
**D.* sp. 2 s.f.	U	2, 19
*Drepanodontiform element 1	U	2, 12
*Drepanodontiform element 2	U	2, 13
Drepanoistodus basiovalis (Sergeeva)	C	2, 16, 17
D. sp. aff. *D. basiovalis* (Sergeeva) *sensu* Ethington and Clark	M	2, 14, 15
**D.* sp. aff. *D. concavus* (Branson and Mehl)	M	2, 20–23
D. forceps (Lindström)	C	2, 24–26
D. inaequalis (Pander)	N	2, 27
D. inconstans (Lindström)	N	2, 28–31
Eoconodontus notchpeakensis (Miller)	C	3, 2
Erraticodon balticus Dzik	M	3, 3–5
Eucharodus parallelus (Branson and Mehl)	M	3, 6
E. toomeyi (Ethington and Clark)	M	2, 8
Fahraeusodus marathonensis (Bradshaw)	M	8, 16–20
F. mirus Stouge and Bagnoli	U	8, 21–25
Fryxellodontus? corbatoi Serpagli	A	3, 8–11
**F.?* sp.	U	3, 12
Glyptoconus quadraplicatus (Branson and Mehl)	M	3, 7
Juanognathus jaanussoni Serpagli	A	3, 13
J. variabilis Serpagli	A	3, 14
Jumudontus gananda Cooper	M	3, 15, 16
Loxodus bransoni Furnish	M	3, 17
Oepikodus communis (Ethington and Clark)	M	5, 4–6
O. evae (Lindström)	N	5, 7–9
**O.* sp. aff. *O. minutus* (McTavish)	E	5, 10–12
**Oistodus? elongatus* Lindström	A	3, 18–22
O. lanceolatus Pander	N	3, 23–26
"*O.*" *inaequalis* Pander *sensu* Ethington and Clark	M	3, 27
O.? tablepointensis Stouge	M	3, 28
O.? triangularis Furnish	M	3, 29
**O.* sp. 1 s.f.	U	3, 30
*Oistodontiform element 1	U	3, 32
*Oistodontiform element 2	U	3, 33
*Oistodontiform element 3	U	3, 34
Oneotodus costatus Ethington and Brand	M	4, 1
Paltodus jemtlandicus Löfgren	E	4, 2
**P.?* sp. s.f.	U	4, 3
Paracordylodus gracilis Lindström	N	4, 4–6
Parapaltodus simplicissimus Stouge	M	4, 7
**P.* sp.	U	4, 8, 9
Parapanderodus arcuatus Stouge	M	4, 10
P. asymmetricus (Barnes and Poplawski	M	7, 13
P. carlae (Repetski)	M	7, 12
P. emarginatus (Barnes and Tuke)	M	7, 2
P. gracilis (Ethington and Clark)	M	4, 11
P. paracornuformis (Ethington and Clark)	M	7, 6
**P.* sp. 1	E	4, 12
Paraprioniodus costatus (Mound)	M	4, 13–15
Paroistodus? mutatus (Branson and Mehl)	M	1, 6, 17; 3, 1, 31
P. numarcuatus (Lindström)	N	4, 16, 17
P. originalis (Sergeeva)	N	4, 18, 19
P. parallelus (Pander)	C	4, 20, 21
P. proteus (Lindström)	N	4, 22, 23
P.? sp. B Stouge	M	4, 24
**Periodon aculeatus* Hadding	N	4, 25–27, 30–32
P. flabellum (Lindström)	N	4, 28, 29, 33, 34
P.? primus Stouge and Bagnoli	N	5, 1–3
Prioniodus elegans Pander	N	5, 13–16
**P. marginalis* n. sp.	E	5, 17–20
**P. serratus* n. sp.	E	5, 21–25

Species	Species ID	Plate, figure
**P.* sp.	U	5, 26–30
*Prioniodontiform element	U	6, 1
Proconodontus muelleri Miller	C	6, 2
Protopanderodus elongatus Serpagli	A	6, 3, 4
P.? giganteus (Sweet and Bergström)	M	7, 3
P. gradatus Serpagli	A	6, 5
P. rectus (Lindström)	N	6, 6–8
P. sp. cf. *P. varicostatus* (Sweet and Bergström)	C	6, 9
Protoprioniodus aranda Cooper	M	6, 10–12
P. papiliosus (van Wamel)	C	6, 13, 14, 20
P. simplicissimus McTavish	M	6, 15, 16
**P.* sp. 1 s.f.	U	6, 17
Pteracontiodus cryptodens (Mound)	M	6, 18, 19, 21–23
Ptiloncodus simplex Harris	M	6, 24
Rossodus manitouensis Repetski and Ethington	M	6, 25
**Scalpellodus* sp. 1	E	6, 26–29
Scandodus furnishi Lindström	N	6, 30, 31
"*S.*" *mysticus* Barnes and Poplawski	M	6, 32–34
*"*S.*" *pseudoramis* (Serpagli)	M	6, 35–37
*Scandodontiform element 1	U	6, 38, 39
*Scandodontiform element 2	U	7, 1
S. multicostatus Barnes and Tuke	M	7, 4
S. oldstockensis Stouge	M	7, 5
S.? peselephantis Lindström	N	7, 8
"*S.*" *quadratus* Pander	N	7, 7
S. sp. aff. *S. filosus* Ethington and Clark	M	7, 9
?*Scolopodus* sp. Ethington and Clark	M	7, 10
*Scolopodontiform element 1	U	7, 11
**Serratognathus armadillodus* n. sp.	M	7, 14–16
Spinodus horridus (Barnes and Poplawski)	M	8, 1
S. ramosus Hadding	M	8, 2
Strachanognathus parvus Rhodes	M	8, 3
Stolodus sp. aff. *S. stola* Lindström	A	8, 4, 5
Teridontus nakamurai (Nogami)	M	8, 6
**Texania heligma* n. gen. n. sp.	E	8, 11–15
**T. teras* n. gen. n. sp.	E	8, 7, 8, 10
Tripodus laevis Bradshaw	M	8, 26
**T.* sp. aff. *T. laevis* Bradshaw	E	8, 27–31
T. subtilis (van Wamel)	N	8, 34, 35
**T.* sp.	U	8, 32, 33
Tropodus sweeti (Serpagli)	A	1, 8, 9; 7, 21, 24
?*Ulrichodina wisconsinensis* Furnish	M	7, 17
Variabiloconus bassleri (Furnish)	U	7, 18, 19
Walliserodus ethingtoni Fåhræus	N	7, 20
Westergaardodina sp.	U	7, 25
*N. gen. A n. sp. 1 s.f.	U	7, 29
*N. gen. A n. sp. 2 s.f.	U	7, 27, 28
*N. gen. B n. sp. 1 s.f.	U	7, 30
*N. gen. C n. sp. 1 s.f.	U	7, 26

*Species described in the text.

Species ID: A = Argentinian faunal elements, meaning species which were first described by Serpagli (1974) from Argentina; C = cosmopolitan species, refers to species which occur in both, Midcontinent and North Atlantic deposits; E = endemic species are those that have not been described from anywhere else up to now; M = Midcontinent species are described from the North American craton; N = North Atlantic species (described from Baltoscandia); and U = unidentified species. Plate and figure numbers where specimens are illustrated are given in the third column of the table.

Drepanodus sp. 2

Plate 2, figure 19

Remarks. Hyaline cones with recurved cusp. Lateral faces are smoothly convex and posterior and anterior margins are sharp. Base flares widely and has subcircular to subquadratic outline. Basal cavity is shallow with its apex situated slightly anterior of midline. White matter is confined to growth axis.

Occurrence. Clasts in Bed 12 and clasts of Bed 11 age in Bed 14.

Material. 5 specimens. Figured specimen, GSC 90350.

Drepanodontiform element 1

Plate 2, figure 12; Figure 14M

Description. Reclined to recurved element with small basal cavity and anteroposteriorly compressed cusp. Cusp is slightly twisted and develops lateral flange on inner side beginning shortly above base. Flange declines into merely a sharp edge in upper half of cusp and a broad median carina occurs from this point distally. Cross-section thus, changes from lanceolate with anterior extension in lower part to lenticular in upper part of cusp. Lateral faces of cusp are smoothly convex. Basal cavity is dark brown and of moderate depth. Its apex reaches point of greatest curvature of cusp. Cross-section of basal cavity resembles triangle with rounded edges; its longest side is anteriorly situated. Surface of cone is finely striated and element is albid.

Occurrence. Bed 10.

Material. 2 specimens. Figured specimen, GSC 90343.

Drepanodontiform element 2

Plate 2, figure 13; Figure 14K, L

Description. Coniform element with erect cusp and groove on inner side. Short base with oral edge forming about 80° angle with cusp. Basal cavity is shallow. Anterior and posterior margins are rounded. Groove reaches aboral margin and causes depression in otherwise oval cross-section of base. Elements are albid and have dark brown base.

Occurrence. Beds 14, 12 and 10.

Material. 6 elements. Figured specimen, GSC 90344.

Genus *Drepanoistodus* Lindström, 1971

Type species. Oistodus forceps Lindström, 1955.

Drepanoistodus sp. aff. *D. concavus* (Branson and Mehl)

Plate 2, figures 20–23

vv aff. *Oistodus concavus* Branson and Mehl, 1933, p. 59, Pl. 4, fig. 6.

vv aff. *Oistodus gracilis* Branson and Mehl, 1933, p. 60, Pl. 4, fig. 20.

vv aff. *Oistodus pandus* Branson and Mehl, 1933, p. 61, Pl. 4, figs. 21, 22.

vv aff. *Drepanodus concavus* (Branson and Mehl). Kennedy, 1980, p. 55, Pl. 1, figs. 26–34 (includes synonymy through 1979).

Remarks. The apparatus includes oistodontiform, suberectiform and homocurvatiform elements and is therefore assigned to the genus *Drepanoistodus*. The elements are usually large and have a hyaline base and an albid cusp. The amount of white matter in the cusp is variable and usually least in the oistodontiform elements. *Oistodus gracilis* s.f. is similar to *Oistodus parallelus* (Lindström, 1955, Pl. 4, figs. 27–29) in its morphology but differs by being more hyaline. The homocurvatiform elements are highly variable and the wide range of different morphologies led Kennedy (1980) to assign them to *Drepanodus*. His "sculponeaform" element (=*Oistodus pandus* Branson and Mehl) is part of a transition series. A gradual change occurs from the "sculponeaform" element, having a straight anterior part of the aboral margin and a low keel on the oral margin, to a more typical homocurvatiform element with a shorter curved aboral margin and a pronounced keel on the oral margin. This latter element has a more recurved cusp and resembles *Drepanodus amoenus* Lindström. Van Wamel (1974) included *Drepanodus amoenus* in *Drepanoistodus* and reported homocurvatiform elements with an open anterior stretch of a widely flaring base, similar to that occurring in *D. concavus*. Both *D. concavus sensu* Kennedy (1980) and the suberectiform elements are rare in the Cow Head material. The latter possess a thin keel on the oral margin that reaches the posterobasal corner. This keel is characteristic of the species and is important for distinguishing *D. concavus* from *D. basiovalis* (Sergeeva). *Drepanoistodus* sp. aff. *D. concavus* is abundant in Bed 10. Higher in the sequence, it decreases in both abundance and size. Inspection of the time-equivalent type material from the Jefferson City Formation in Missouri showed that *D. concavus* is more hyaline than the Cow Head species and the keels on the oral margins are somewht less pronounced. Therefore the latter is assigned only as showing affinity to *D. concavus*.

As in the Cow Head material, that type collection also contains suberectiform elements and the species is therefore assigned to *Drepanoistodus* rather than *Drepanodus*. Stouge and Bagnoli (1988) named a very similar species *D. lucidus*, which also differs from *D.* sp. aff. *D. concavus* in being more hyaline, and which is probably synonymous with *D. concavus*. The composition of the apparatus was recognized by Nowlan (1976) in collections from the Lower Ordovician Eleanor River Formation (Canadian Arctic Islands).

Occurrence. Beds 10 and 12, reworked clasts in Bed 14.

Material. 200 elements. Hypotypes, GSC 90351–90354.

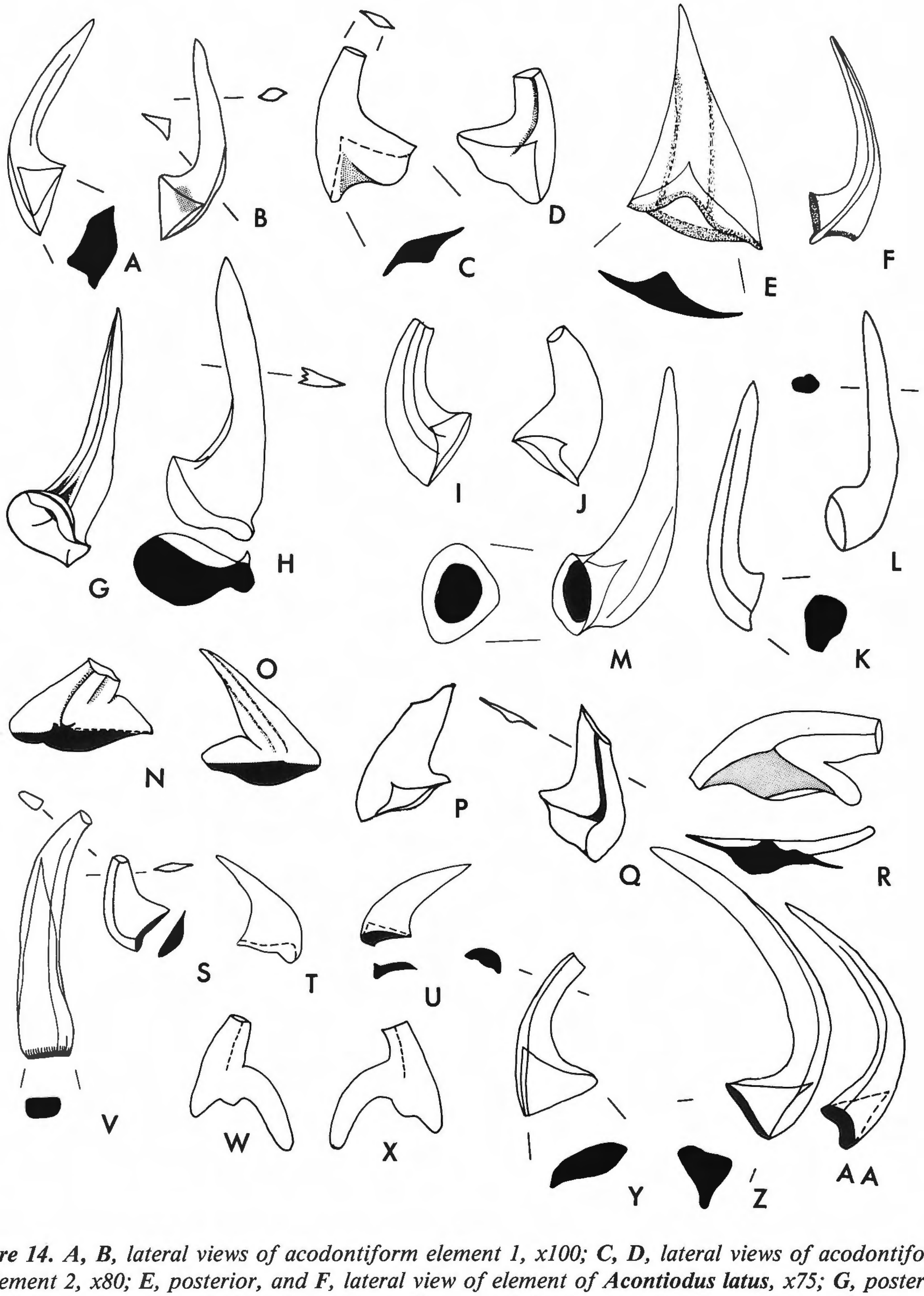


Figure 14. *A, B, lateral views of acodontiform element 1, x100; C, D, lateral views of acodontiform element 2, x80; E, posterior, and F, lateral view of element of* ***Acontiodus latus****, x75; G, posterior and H, lateral view of* ***Acontiodus*** *sp. 2 Uyeno and Barnes showing cross-section of cusp and outline of basal cavity, x45; I, J, lateral views of asymmetrical element of* ***Drepanodus****? sp. 1, x85; K, L, lateral views of drepanodontiform element 2, x80; M, lateral and aboral views of drepanodontiform element 1, x80; N, O, lateral views of two different specimens of* ***Oistodus*** *sp. 1 s.f., x85; P, Q, lateral views of oistodontiform element 2, x80; R, aboral and lateral views of oistodontiform element 3, x70; S, T, acostate and U, costate elements of* ***Paltodus****? sp. s.f., x60; V, lateral view of* ***Parapanderodus*** *sp. 1, illustrating deep basal cavity, cross-section of cusp and outline of basal cavity, x70; W, X, lateral views of* ***Protoprioniodus*** *sp. 1, x90; Y–AA, illustrations of Y, drepanodontiform, x70; Z, bicostate, x85; and AA, unicostate scandodontiform (x100) elements of* ***Scalpellodus*** *sp. 1. All lateral views.*

Genus *Fryxellodontus* Miller, 1969

Type species. Fryxellodontus inornatus Miller, 1969.

Fryxellodontus? sp.

Plate 3, figure 12

Remarks. Bilaterally symmetrical elements, triangular in posterior view with pointed tip of cusp. Surface is ornamented with "girdles" that traverse the element from side to side, terminating in nodes aligned along sharp lateral margins. Basal cavity is deep. Basal outline is lenticular, flaring slightly off-centre on posterior as well as anterior side.

Occurrence. Bed 10, clasts of Bed 9 age in Bed 12.

Material. 5 elements. Figured specimen, GSC 90374

Genus *Oepikodus* Lindström, 1955

Type species. Prioniodus evae Lindström, 1955.

Oepikodus sp. aff. *O. minutus* (McTavish)

Plate 5, figures 10–12

aff. *Baltoniodus minutus* McTavish, 1973, p. 42, Pl. 3, figs. 3, 14, 17 [*non* fig. 8(?) = *Prioniodus* sp. nov. B McTavish, 1973].

aff. *Oepikodus*(?) *minutus* (McTavish), Ethington and Clark, 1981, p. 62, Pl. 6, figs. 19, 23, 24, 26–28 (includes synonymy through 1973).

Remarks. The species from the Cow Head Group agrees in its overall morphology with the description of aff. *Oepikodus minutus* given by Ethington and Clark (1981). It differs from that form, however, in several respects. The oistodontiform element assigned to the species by Ethington and Clark is not present in the Cow Head material. Instead a form similar to the oistodontiform element of *Oepikodus communis* Ethington and Clark, but with a shorter anterior process, occurs associated with *Oepikodus* sp. aff. *O. minutus* in stratigraphically younger samples. This element is not present in assemblages from rocks lower in the sequence; here the prioniodontiform and oepikodontiform elements co-occur with a falodontiform element that has a laterally deflected, denticulated anterior process. The low number of specimens, however, does not allow further speculation on the elemental composition. The oepikodontiform elements show the lateral deflexion and the twisting of the posterior process described by Ethington and Clark (1981). A transition series from symmetrical costate, asymmetrical costate to acostate elements is developed. The trichonodelliform elements illustrated by Ethington and Clark have not been found. The denticles seem to be more slender and longer in the Cow Head specimens compared to the robust forms from the Pogonip Group. The prioniodontiform elements are characterized by always possessing two denticulated processess, a feature that sets them clearly apart from *O. communis*. Two types of prioniodontiform elements are developed: type I is a compact form with a deep basal cavity and a short posterior process. It corresponds to the specimens described by McTavish (1973) and Ethington and Clark (1981). Type II possesses a long posterior process and short lateral processes, one of which is denticulated. The posterior process commonly is laterally deflected and twisted. The basal cavity is shallow due to the lack of connecting basal sheaths.

The presence of two different prioniondontiform elements might justify an assignment of the species to *Baltoniodus* but the similarity to *O. communis* is a convincing argument for the inclusion in *Oepikodus*. Furthermore, the development of two types of prioniodontiform elements seems to be a characteristic of most prioniodontids. Cooper (1981) described a species, *Prioniodus amadeus*, from the Horn Valley Siltstone that is characterized by two denticulate processes. The specimens figured do not appear to be similar to those from the Cow Head Group, but the species may be closely related. Most specimens of *O.* sp. aff. *O. minutus* occur in shelf-derived clasts.

Occurrence. Beds 10 and 12, older clasts (Bed 9 age) in Bed 14.

Material. 90 elements. Hypotypes, GSC 90434–90436.

Genus *Oistodus* Pander, 1856

Type species. Oistodus lanceolatus Pander, 1856.

Oistodus? *elongatus* Lindström

Plate 3, figures 18–22

v *Oistodus elongatus* Lindström, 1955, p. 574, Pl. 4, figs. 32, 33.

v *Oistodus* cf. *elongatus* Lindström, 1955, p. 574, Textfig. 5b.

vv *Oelandodus elongatus* (Lindström) van Wamel, 1974, p. 71, Pl. 7, figs. 1, 2, 4, *non* fig. 3.

Oistodus n. sp. 1 Serpagli, 1974, p. 53, Pl. 12, figs. 1a–3c; Pl. 24, figs. 1–4; Textfig. 11.

Oelandodus cf. *O. elongatus* (Lindström). Repetski, 1982, p. 29, Pl. 10, fig. 11; Pl. 11, fig. 2, (?)fig. 1; Fig. 5, T, V, (?)U.

Oelandodus aff. *O. elongatus* (Lindström). Stouge and Bagnoli, 1988, p. 120, Pl. 4, figs. 1, 2, 5, 6.

Description. *Oistodus elongatus* has been described in detail by the authors listed in the synonymy list and does not need further description, with the exception of an additional laterally compressed element. This element is characterized by a large spatulate or leaf-shaped cusp and a smaller elongate base. Cusp is strongly reclined, anterior margin forms smooth curve with concavity at distal end. Faint median carina may be developed on inner side. Base extends three quarters of length of cusp. Basal outline is lanceolate, base widest at midlength. Oral margin is short and curved, aboral margin is convex downward. Elements are albid.

Remarks. Study of van Wamel's type collection showed that the triangulariform element figured in Plate 7, figure 3 (van Wamel, 1974) belongs to *Protoprioniodus* as do all the specimens of *Oelandodus costatus* van Wamel (cf. Cooper, 1981). Repetski (1982) included a different triangulariform element in his description of *Oelandodus* sp. cf. *O. elongatus*. This element has not been found in the Cow Head material, but may well be part of the apparatus of *O. elongatus*. One of the figured types of *Oistodus selene* Lindström (Pl. 4, fig. 20 only) may also be an element of *O. elongatus*. Cooper (1981) pointed out that the genus *Oelandodus* is based in part on the description of a species of *Protoprioniodus* and needs to be emended. It is therefore preferred herein to retain *O.*(?) *elongatus* in the genus *Oistodus* because the apparatus composition is similar to that of the hyaline type species *Oistodus lanceolatus*.

Occurrence. Bed 10.

Material. 114 elements. Hypotypes, GSC 90380–90384.

Oistodus sp. 1 s.f.

Plate 3, figure 30; Figure 14N, O

Description. Reclined element with carinate lateral faces. Anterior and posterior edges of cusp are sharp. Oral margin of base is keeled and curved, aboral margin is slightly sinuous or almost straight. Basal cavity is shallow. Basal region is dark brown; cusp is albid. This form resembles oistodontiform elements of *Acodus emmanuelensis* McTavish but lacks the flare of the basal cavity and is more reclined. Furthermore, no accompanying elements have been found.

Occurrence. Bed 12.

Material. 9 elements. Hypotype, GSC 90392.

Oistodontiform element 1

Plate 3, figure 32

Description. Oistodontiform element with broad reclined cusp. Cusp is deflected sideways; posterior and anterior margins are sharp. Lateral faces are swollen and cross-section of cusp is lenticular. Basal cavity is of moderate depth with its apex situated anterior of midline. Base flares slightly to inner side and is smoothly convex on outer side. Aboral margin is almost straight and outlined by a dark-coloured band. Cusp is albid. Oral margin is short and keeled.

Occurrence. Bed 14.

Material. 2 specimens. Figured specimen, GSC 90394.

Oistodontiform element 2

Plate 3, figure 33; Figure 14P, Q

Description. Entire element is extremely compressed laterally with broad, slightly reclined cusp. Inner face is smooth, outer side bears poorly defined median costa. Posterior and anterior margins are sharp. Cross-section of cusp is lenticular. Basal cavity is shallow and apex is situated centrally. Junction between oral margin and cusp is curved and forms an angle of about 90°.

Occurrence. Beds 12 and 14.

Material. 2 elements. Figured specimen, GSC 90395.

Oistodontiform element 3

Plate 3, figure 34; Figure 14R

Description. Compressed oistodontiform element with strongly reclined cusp and curved anterior margin. Cusp is flexed inward and possesses poorly developed costa on both lateral faces. Basal cavity is moderately deep with apex situated centrally. Outline of aboral margin is sinuous and base flares slightly to outer side. Aboral margin is long and curved with a shallow ledge running parallel to it. A short expansion of the base extends downward past the junction of keel and base on posterior and anterior sides. Elements are albid with dark-stained cavities. The morphology is similar to oistodontiform elements of *Protoprioniodus* but as accompanying elements are absent the oistodontiform elements are treated in open taxonomy.

Occurrence. Beds 10 and 14.

Material. 9 elements. Figured specimen, GSC 90396.

Paltodus? sp. s.f.

Plate 4, figure 3; Figure 14S–U

Description. A form species of *Paltodus* with a stout, acostate recurved cusp. Basal cavity is shallow, its apex is situated close to anterior margin. Inner side of cusp may be weakly carinate. Carina is situated at a variable distance from anterior margin and develops into a basal flare. Anterior margin is keeled; keel tapers out near base and anterior basal edge is rounded. Aboral margin is slightly arched. It may show undulation on outer side near anterobasal corner.

Remarks. The elements show some variation in the basal flaring, the basal outline and the curvature of the cusp. No oistodontiform elements have been found that could be part of the apparatus of *Paltodus*(?) sp. The forms described above are not typical drepanodontiform elements of *Paltodus* but have been assigned to that genus because of the superficial similarity to *Paltodus*(?) *sweeti* s.f. Serpagli. It is possible that they represent a new genus.

Occurrence. Bed 10 and reworked clasts in Bed 14.

Material. 24 elements. Figured specimen, GSC 90399.

Genus *Parapaltodus* Stouge, 1984

Type species. Parapaltodus simplicissimus Stouge, 1984.

Parapaltodus sp.

Plate 4, figures 8, 9

Remarks. A species of *Parapaltodus* with almost hyaline elements that show fine surface striations. Elements are laterally compressed with sharp anterior and posterior margins. Basal cavity is triangular and its tip almost reaches anterior margin. A faint groove extends from aboral margin laterally along the anterior margin but loses its definition in the lower third of the cusp. In scandodontiform elements cusp is flexed inward and inner side of base is slightly flared.

Occurrence. Beds 10, 12 and 14.

Material. 20 elements. Figured specimens, GSC 90404, 90405.

Genus *Parapanderodus* Stouge, 1984

Type species. Parapanderodus arcuatus Stouge, 1984.

Parapanderodus sp. 1

Plate 4, figure 12; Figure 14V

Description. Simple cones with a deep basal cavity that occupies the lower two thirds of the cusp. Lower part of cusp is straight. Curvature begins gradually in lower third of element or slightly higher. Apex of basal cavity lies near anterior margin at point of greatest curvature, which is usually in upper third of cone. Anterior margin of cusp has blunt edge, posterior margin bears a faint groove bordered by two weak posterolateral costae. Outline of basal cavity is a blunt-edged rectangle, whereas cross-section of cusp is more triangular due to distal sharpening of anterior margin. Aboral margin is either straight, or a short tongue-like extension of oral edge downward gives it a concave outline in lateral view. This extension together with a posterior groove is typical for *Parapanderodus*. Cusp is albid and entire element is striated, including basal rim.

Remarks. The elements display a weak curvature transition from forms with strongly curved cusps to those with slightly curved cusps. The species resembles *Parapanderodus elegans* Stouge in possessing a deep basal cavity, but lacks the nonstriated rim and is larger in size.

Occurrence. Bed 14.

Material. 11 specimens. Figured specimen, GSC 90408.

Genus *Periodon* Hadding, 1913

Type species. Periodon aculeatus Hadding, 1913.

Periodon aculeatus Hadding

Plate 4, figures 25-27, 30-32

Periodon aculeatus Hadding, 1913, p. 33, Pl. 1, fig. 14; Löfgren, 1978, p. 74, Pl. 10, figs. 1A, B, Pl. 11, figs. 12-26, Fig. 29 (includes synonymy through 1976).

Loxognathus flabellata Graves and Ellison, 1941, p. 12, Pl. 2, figs. 29, 32.

Oistodus prodentatus Graves and Ellison, 1941, p. 13, Pl. 2, figs. 6, 22, 23, 28.

Ozarkodina macrodentata Graves and Ellison, 1941, p. 14, Pl. 2, figs. 33, 35, 36.

Periodon aculeatus zgierzensis Dzik, 1976, p. 424, Pl. 44, figs. 5, 6, Fig. 34e-k; Stouge, 1984, p. 82, 83, Pl. 16, figs. 1-15.

Remarks. For the description of the different elements comprising the apparatus of *Periodon aculeatus*, the terminology of Lindström (1981, *in* Klapper et al., 1981) is adapted. The trend toward increasing denticulation in *Periodon* in general, and in *P. aculeatus* in particular, can be observed in the Cow Head material. The transition from *P. flabellum* to *P. aculeatus* is applied following Löfgren's (1978) numerical definition for ramiform elements (i.e., the number of small denticles between the cusp and the biggest denticle exceeds four in more than half of the elements). The rule cannot be employed for oistodontiform and prioniodiniform elements. The former are commonly represented by a higher mean number of denticulated forms (1-3 denticles) per sample than in the Scandinavian collections.

Prioniodiniform elements with only one denticle in front of the cusp commonly occur associated with otherwise fairly advanced forms of *P. aculeatus*. Stouge (1984) observed that the angle formed between anterior and posterior processes of oulodontiform elements is larger in *P. flabellum* (between 130 and 170°) than in *P. aculeatus* (between 130 and 90°). This relationship is not verified in the Cow Head material. The change in the ratio of cusp length to oral margin length (1:1 or 4:3 in *P. aculeatus*; 2:1 in *P. flabellum*) noted by Stouge (1984) seems to be a more valid criterion to distinguish between the two species. It is, however, difficult to employ because many cusps are broken. Two stages in the evolution of *P. aculeatus* can be distinguished in collections from clasts in Bed 14: the early forms possess a sparse denticulation and restricted basal cavities; advanced forms carry between three and five denticles on the basal anterior margin of oistodontiform and prioniodiniform elements (with a mean number of four). The ramiform elements bear between four and six denticles between the cusp and largest denticle. Also typical is the lack of trichonodelliform elements noted by Uyeno and Barnes (1970) and the return of large basal cavities. These advanced forms are consubspecific with *P. aculeatus zgierzensis* Dzik.

Occurrence. Youngest clasts in Bed 12; Bed 14.

Material. 3415 elements. Hypotypes, GSC 81354-81359.

Genus *Prioniodus* Pander, 1856

Type species. Prioniodus elegans Pander, 1856.

Prioniodus marginalis n. sp.

Plate 5, figures 17-20

?*Falodus* sp. A Fåhræus and Nowlan, 1978, p. 466, Pl. 3, fig. 18.

Prioniodus elegans Pander. Fåhræus and Nowlan, 1978, p. 464, Pl. 3, figs. 20, 25 only.

Etymology. From "margin", to indicate the environment in which this species apparently lived.

Diagnosis. A multielement species of *Prioniodus* Pander with prioniodontiform, tetraprioniodiform, trichonodelliform, belodontiform and oistodontiform elements. All elements are characterized by their relatively small size and slender appearance. All elements are albid.

Description. Prioniodontiform element has three denticulate processes and a relatively long stout cusp. No basal sheaths have been observed. Processes are rather short and straight or project downward. Basal cavity is shallow and continues along the processes.

Denticules are short and separate, and round to slightly flattened in cross-section. Cusp is suberect, thin with sharp margins. It may be weakly costate at the side where the lateral process branches off.

Tetraprioniodiform element possesses two to three denticulate processes and one to two undenticulate processes (always four processes). Denticulate processes are usually long and project downward; they are oriented posterolaterally. Angle between them is never larger than 50°. Denticles are thin and separate, round to slightly flattened in cross-section. Cusp is long, slender and curved. Costae arise from continuation of anterior processes to cusp. Shallow basal cavity continues into processes.

Belodontiform element possesses long slender cusp, and posterior process of similar length. Cusp is slightly curved and continues downward into a short, undenticulated anterior anticusp. Outer side of cusp may be costate and extension of costa projects downward as a short process. Posterior process points downward, forming angle between 90° and 130° with cusp. Denticles are isolated, short and thin, sometimes almost hyaline.

Trichonodelliform element is similar to tetraprioniodiform element in direction of processes but has three instead of four denticulated processes, and the posterior one is in line with cusp.

The oistodontiform element is the most distinct element in the apparatus. It is characterized by a posterior process longer than the cusp, with small denticles at the distal end. Small denticles also adorn the anterior process. This element has been described in detail by Fåhræus and Nowlan (1978).

Remarks. *Prioniodus marginalis* differs in several ways from *P. elegans* Pander. Generally all elements of *P. marginalis* are smaller and less robust. Their denticles are smaller and as a rule not fused. There are also fewer denticles present, particularly in the tetraprioniodiform and the belodontiform elements. The oistodontiform element is so obviously different, it needs no further comment. It is likely that the species has been found before but has been lumped together with *P. elegans* because in mixed faunas transitional elements occur that make distinction somewhat difficult (e.g., Fåhræus and Nowlan, 1978; Stouge and Bagnoli, 1988). Stouge and Bagnoli (1988) described a new species *Prioniodus hyalinus* from Bed 9, which also has an oistodontiform element with denticles on the distal part of the posterior process. The species differs, however, from *P. marginalis* in being hyaline and in possessing a distinctive ledge on most elements along with a robust denticulation. Stouge and Bagnoli (1988) tentatively included oistodontiform elements of *P. marginalis* in *Prioniodus elegans*.

Occurrence. Bed 10.

Material. 718 elements. Holotype, GSC 90441; paratypes, GSC 90442-90444.

Prioniodus serratus n. sp.

Plate 5, figures 21-25

Etymology. Referring to the serrated surface on the posterior process of the ramiform elements.

Diagnosis. A species of *Prioniodus* with oistodontiform, prioniodontiform, tetraprioniodontiform and belodontiform elements, in which the processes of the ramiform elements bear incipient denticulation or are adentate.

Description. Prioniodontiform element has broad, keeled cusp, which is weakly costate on the inner side. Basal sheath is widely flared and connects three adentate processes.

Ramiform elements of *P. serratus* are characterized by a posterior process that carries minute denticules in well preserved specimens. Denticles increase in size toward middle part of process and decrease again distally. Ratio between denticulated and undenticulated forms is difficult to determine because crystalline overgrowth easily obliterates delicate denticles, but the ratio is approximately 1:1.

In tetraprioniodontiform and trichonodelliform elements, lateral processes are prominent and always longer than anterior process but shorter than posterior process. In cordylodontiform elements curvature of cusp and angle of basal opening are variable. A large divergence of anterior and posterior processes usually coincides with a more strongly proclined cusp. The oistodontiform element has straight reclined cusp and a posterior process that reaches about three quarters of cusp length. Cusp and process show slight lateral deflection with opposed orientations. Short anterior process is slightly curved upward and bears three to four minute denticules that are visible only on well preserved specimens.

Remarks. *Prioniodus serratus* n. sp. probably represents an advanced form of *A. deltatus longibasis*. The denticulation and elemental composition imply an assignment to *Prioniodus*. *Prioniodus serratus* n. sp. is distinguished from *Acodus deltatus longibasis* McTavish by the presence of incipient denticulation, the different angles between cusp and processes and the shorter posterior process of the ramiform elements. This stage of development of *A. deltatus longibasis* is not known from the Emmanuel Formation, possibly due to a sampling or depositional gap or because of unfavourable environmental parameters.

Prioniodus serratus is distinguishable from *Prioniodus gilberti* Stouge and Bagnoli in possessing serrated or adentate processes rather than actual denticulation as seen in specimens of *P. gilberti.*

The oistodontiform element commonly carries incipient denticulation on the anterior process and has a longer posterior process than *P. gilberti.* The prominent carina described from elements of *P. gilberti* is not present in *P. serratus.*

This distribution of white matter is different in all elements (i.e., *P. serratus* is wholly albid). The two species also differ in their stratigraphic range, as *P. serratus* co-occurs with *P. elegans* and is probably younger than *P. gilberti.*

Occurrence. Bed 10.

Material. 345 elements. Holotype, GSC 90446; paratypes, GSC 90445, 90447-90449.

Prioniodus sp.

Plate 5, figures 26-30

Description. Oistodontiform and belodontiform elements with thin-walled deep basal cavities, short cusps and small denticules (on the belodontiform element only). Oistodontiform element is characterized by an extremely short blunt cusp and a large deep basal cavity. Virtually the entire element is hollow except for a short apical portion. Cusp is sharply reclined at about mid-length, creating a bend in the anterior margin of about 110-120°. Straight anterior margin of base is keeled and grades smoothly into lower part of cusp. Oral margin of base is keeled as well; portion proximal to cusp runs subparallel to aboral margin, and at about mid-length it bends down sharply and forms about 80° angle with anterobasal corner. Aboral margin of base is partly broken and its exact outline cannot be determined. Base flares to one side, with tip of basal cavity situated anteriorly. Belodontiform elements are acostate and flexed sideways with varying degrees of twisting of cusp with respect to base. Anterior and oral margins of base carry numerous small denticles. Denticles are short with blunt tips. They are laterally compressed and fused. Denticles on anterior side are smaller than posterior and decrease in size distally. Large basal cavity is thin walled and in some elements a lateral flare is developed that extends from base of cusp to middle of aboral margin. Cusp is reclined and short. The tip of the basal cavity is situated close to the anterior margin.

Remarks. Collections of Johnston (1987) from Bed 9 contained a tetraprioniodontiform element together with other specimens of *Prioniodus* sp. This evidence justifies the assignment of the form to *Prioniodus.*

Occurrence. Clast of Bed 9 age in Bed 12.

Material. 11 elements. Figured specimens, GSC 90450-90454.

Prioniodontiform element

Plate 6, figure 1

Description. A single fragmentary specimen with long cusp and three denticulated processes. Cusp is slender and reclined with lenticular cross-section. Costae may have been obliterated; the specimen is abraded. Two to three denticles on each process are curved and not fused but spaced apart. Basal sheaths connect the three processes, creating a large basal cavity. Specimen is hyaline.

Occurrence. Bed 14.

Material. 1 element. Figured specimen, GSC 90455.

Genus *Protoprioniodus* McTavish, 1973

Type species. Protoprioniodus simplicissimus McTavish, 1973.

Remarks. The genus *Protoprioniodus* McTavish is very similar to Fahraeusodus in its apparatus composition. It has one or two M elements, one or two P elements, plus a complete set of S elements and an additional modified symmetrical element (''blade'' element). Modification of the M and P elements seems to concentrate on extension of the anterobasal corner.

Protoprioniodus sp. 1 s.f.

Plate 6, figure 17, Figure 14W, X

Description. Cordylodontiform elements with slender continuously curved cusp, long posterior process and short anticusp. Lateral faces of cusp are somewhat swollen with a poorly defined median costa. Anterior and posterior margins are sharp. Posterior process is blade-like, long and curved; curvature increases from the proximal to distal portion and tip points downward. Process meets cusp in 90–100° angle. A short anticusp projects downward as extension of cusp. All processes are undenticulated. The element is albid and shows crystalline overgrowth. Designation to *Protoprioniodus* is based on the similarity to ramiform elements of *P. aranda*.

Occurrence. Bed 12, clast of Bed 11 age in Bed 14.

Material. 2 specimens. Figured specimen, GSC 90472.

Genus *Scalpellodus* Dzik, 1976

Type species. Protopanderodus latus van Wamel, 1974.

Scalpellodus sp. 1

Plate 6, figures 26–29; Figure 14Y–AA

Description. Scalpellodus sp. 1 includes a transition series of recurved symmetrical and asymmetrical drepanodontiform and scandodontiform elements. Scandodontiform elements are more or less recurved with shallow costae anterior of midline of lateral faces. Costae reach aboral margin. Basal cavity is of moderate depth with apex near anterior margin. Anterior side of cusp is gently convex, posterior margin is rounded. Cross-section of cusp is subtriangular. Asymmetrical acontiodontiform elements show transition from forms with two costae to those with only one costa. The former possess a weakly developed posteriorly directed costa on one side and a pronounced costa on the other, which resulted from displacement of anterior edge sideways. In unicostate forms only the anterolateral costa is strongly developed and extends downward below aboral margin; the other side is acostate and concave. Cross-section of cusp is roughly comma-shaped in forms with two weak costae, and triangular with round edges in forms with one costa. Acostate lateral face of the latter forms produces a concave short side of the triangle. Drepanodontiform element is more laterally compressed than the unicostate acontiodontiform element, and acostate lateral face is convex to flat. Posterior margin is bluntly rounded and posterobasal corner is extended, thus widening the basal cavity in posterior–anterior plane. All elements are albid and show curvature transition.

Remarks. The unicostate acontiodontiform elements resemble forms of *Juanognathus jaanussoni* Serpagli in possessing a basally extended costa. They lack, however, the characteristic twisting of the cusp. Furthermore, the accompanying scandodontiform elements suggest assignment of the species to *Scalpellodus*. Some of the asymmetrical scandodontiform elements resemble the scandodontiform element B of *Scolopodus cornuformis* Sergeeva described by Löfgren (1978, p. 106) but *Scalpellodus* sp. 1 lacks the flange-like extension of the cusp, the basal cavity is shallower and the costae are more pronounced. Stouge (1984) described several species of *Scalpellodus* from the Table Head Group, none of which seems to be conspecific with *Scalpellodus* sp. 1.

Occurrence. Bed 14.

Material. 40 elements. Figured specimens, GSC 90480–90483.

Genus *Scandodus* Lindström, 1955,
emend. 1971

Type species. Scandodus furnishi Lindström, 1971.

"*Scandodus*" *pseudoramis* (Serpagli)

Plate 6, figures 35–37; Figure 15A–C

Distomodus kentuckyensis Branson and Branson. Lee, 1970, p. 317, Pl. 7, figs. 11, 12.

Acodus deltatus Lindström. Viira, 1974, p. 41, Pl. 2, fig. 28.

?"*Drepanodus*" sp. 4 Serpagli, 1974, p. 45, Pl. 13, figs. 11a–c.

"*Oistodus*" *pseudoramis* Serpagli, 1974, p. 55, Pl. 13, figs. 7a–10b; Pl. 23, figs. 10–12.

"*Scandodus*" sp. 1 s.f. Ethington and Clark, 1981, p. 96, Pl. 11, figs. 6, 7; Fig. 22.

Triangulodus changshanensis An et al., 1983, p. 159, figs. 7–9, Textfigs. 18, 20.

Remarks. The scandodontiform element agrees with the description given by Ethington and Clark (1981) for "*Scandodus*" sp. 1. An oistodontiform element, which is herein interpreted as belonging in the apparatus of "*Scandodus*" sp. 1, is probably conspecific with "*Oistodus*" *pseudoramis* Serpagli, and was described in detail by Serpagli (1974).

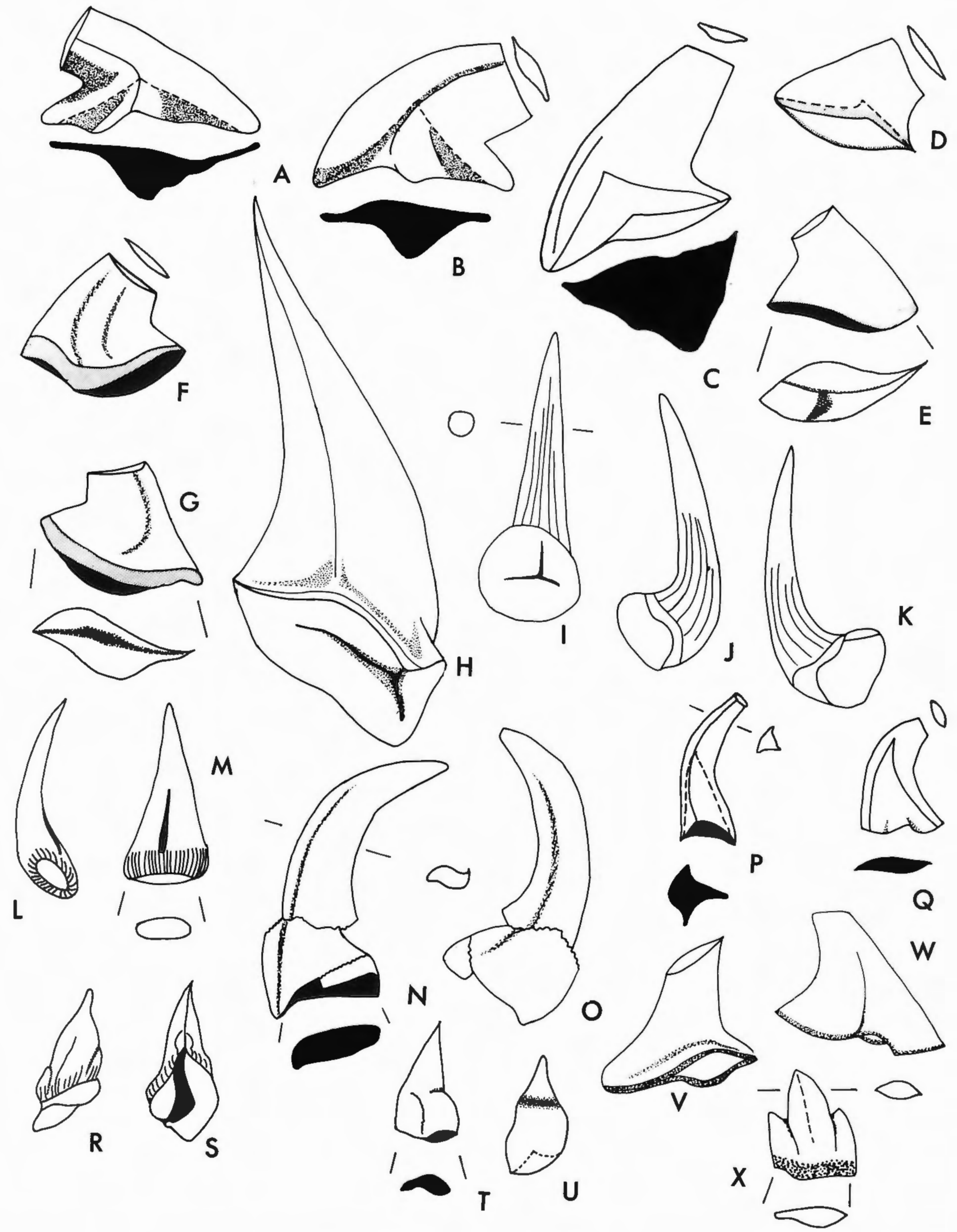


*Figure 15. A–C, elements of "**Scandodus**" **pseudoramis**; A, oistodontiform element, x85; **B**, costate acodontiform element, x100; C, acostate acodontiform element, x100; D–E, acostate and F–G, costate element types of scandodontiform element 1, x80 and x70, respectively; H, lateral view of scandodontiform element 2, x100; I, posterior and lateral (J, K) views of **Scolopodus multicostatus**, x60; M, posterior and L, aboral-lateral views of ?**Scolopodus** sp. Ethington and Clark, x45; N, postero- and O, anterolateral views of scolopodontiform element 1, x80; P, Q, lateral views of P, the trichonodelliform, and Q, the drepanodontiform element of **Tripodus** sp., x100; R, anterolateral and S, posterior view of new genus A new species 2, x90; T, posterior and U, anterior views of new genus A new species 1, x60; V, posterior and W, anterior views of new genus B new species 1, x65; X, lateral view of new genus C new species 1, x90.*

The acodiform element was previously described as *Acodus deltatus* Lindström by Viira (1974), as *Distomodus kentuckyensis* Branson and Branson by Lee (1970) and as the oistodontiform element of *Triangulodus changshanensis* by An et al. (1983). Ethington and Clark (1981) tentatively included the first two in their synonymy list of "*S.*" sp. 1. The acodiform element is reclined with the cusp forming an angle of 110° or larger with the oral margin. The cusp is straight with sharp edges; one lateral face is smoothly convex, the other has a broad median swelling that continues aborally to form a basal flare. The other side of the base is weakly inflated or flat. The lateral deflection of lower part of anterior margin is absent or weakly developed in typical acodiform elements but transitional forms to scandodontiform elements are present. All elements are albid and therefore cannot belong to *Scandodus* as defined by Lindström (1971); in addition, the acodiform element is not typical for *Scandodus*. Distacodiform elements which, for example, exist in *Scandodus brevibasis* have not been identified in "*S.*" *pseudoramis* so far but the similarity of the species to corresponding elements in *S. robustus* Serpagli, which was assigned to *Acodus* by Johnston (1987), suggests a relationship between the two taxa and also implies that not all elements have yet been recognized in either species.

Many Lower Ordovician conodont genera follow the basic plan of *Acodus* and its derivative *Prioniodus*, both of which have septimembrate apparatuses. It appears that many of the Midcontinent genera follow the same plan, but differ in having more elements for each position in the apparatus that show symmetry transition. The reason for this could be the lack of denticulated processes, which is typical for Arenigian Midcontinent species compared to their North Atlantic counterparts. For example, *Oepikodus evae* has more denticulated processes than does *O. communis* and the complexly denticulated genus *Periodon flabellum* does not seem to have a counterpart on the shelf until later when shallow water forms such as *Plectodina, Phragmodus*, and *Paraprioniodus* evolve. Examples of the undenticulated "*prioniodids*" are *Tripodus, Tropodus, Diaphorodus, Trigonodus, Pteracontiodus*, and *Protoprionidus*. It has been shown that *Protoprioniodus* possesses a complete transition series of S elements, possibly two P elements (similar to *Fahraeusodus* and *Baltoniodus*), two M elements and a symmetrical element that is probably a modified Sa element (suggesting presence of two different symmetrical elements).

Part of the apparatus of "*S.*" *pseudoramis* was assigned to *Tropodus comptus* (Branson and Mehl) by Stouge and Bagnoli (1988) (i.e., "*S.*" sp. 1 Ethington and Clark). In the Bed 10 material where elements of *Tropodus* co-occur with "*Scandodus*" *pseudoramis*, large differences in size and colour make derivation from the same species questionable. Ethington (pers. comm., 1986) reported having the same problem with *Scandodus* sp. 1. There appears to be a relationship to "*Scandodus*" *mysticus* that also occurs in the younger Cow Head fauna, but insufficient material has been studied to allow further speculation. This author prefers to retain "*Scandodus*" *pseudoramis* separate from *Tropodus* and other genera to which it could be assigned.

Occurrence. Bed 10, clasts of Bed 9 age in Beds 12 and 14.

Material. 34 elements. Hypotypes, GSC 90489–90491.

Scandodontiform element 1

Plate 6, figures 38, 39; Figure 15D–G

Description. Elements whose cusp is flexed and twisted so that base opens to one side. Both sides of cusp are regularly convex (Figs. 15D, E) or bear a faint costa (Figs. 15F, G). Cross-section of cusp is lanceolate. Anterior and posterior edges are sharp. Base flares strongly to one side and basal cavity is shallow with irregularly lanceolate outline in aboral view. Dark brown hyaline band is developed adjacent to basal margin, otherwise specimens are albid. Elements are fragmentary.

Occurrence. Older clast (Bed 9 age) in Bed 14.

Material. 2 elements. Figured specimens, GSC 90492, 90493.

Scandodontiform element 2

Plate 7, figure 1; Figure 15H

Description. Hyaline elements with weakly reclined and laterally flexed cusp. Long cusp is slightly twisted with respect to base and has sharp anterior and posterior edges. Basal cavity flares widely, especially on inner side. Basal margin extends from anterior to posterior edge in S-shape on inner side; on outer side it forms downward extension near rounded anterobasal corner.

Occurrence. Beds 10 and 12, older clasts in Bed 14.

Material. 4 specimens. Figured specimen, GSC 90494.

Genus *Scolopodus* Pander 1856

Type species. *Scolopodus sublaevis* Pander, 1856.

Scolopodontiform element 1

Plate 7, figure 11; Figure 15N, O

Remarks. A coniform element, recurved with greatest curvature in upper third of cusp. Form is laterally compressed with a deep groove adjacent to anterior margin on one lateral face and a shallower groove near posterior margin on other face. Cusp is albid and is slightly twisted with respect to base. Basal cavity extends one third of cusp length. The basal region of the element is broken and the shape of the basal cavity is obscured. The elements have some features in common with *Juanognathus* Serpagli but lack the characteristic short basal processes.

Occurrence. Beds 12 and 14.

Material. 3 specimens. Figured specimen, GSC 90504.

Genus *Serratognathus* Lee, 1970

Type species. Serratognathus bilobatus Lee, 1970.

Serratognathus armadillodus n. sp.

Plate 7, figures 14–16

Scolopodus? sp. C s.f. Stouge, 1982, p. 44, Pl. 3, figs. 16–18.

Etymology. After the animal, the armadillo, referring to the similarity in shape, and the latin *odus*, meaning tooth.

Description. Symmetrical elements: aberrant barrel-shaped coniform elements with a blunt or pointed tip. The basal cavity is shallow and lacks a tip. [In accordance with Sweet (1988) the concave margin of the basal cavity is taken as the posterior side.] A broad posterior groove dissects the element, producing a kidney-shaped cross-section. The anterior and lateral faces are ornamented with several serrated "girdles", which traverse the element, reaching from one side of the posterior groove to the other. Between six and seven "girdles" or ridges may be developed.

Remarks. Nowlan (1976) described the forms from the Canadian Arctic and suggested that they might be fish teeth. Undescribed material of Z. Ji from the St. George Group, however, yielded a species of *Clavohamulus* that resembles *S. armadillodus* in its shape but bears only faint ornaments. This suggests a relationship to the genus *Clavohamulus.* The species *S. bilobatus* Lee shows similar surface ornamentation to *S. armadillodus* and a somewhat similar shape. The new species is therefore assigned to *Serratognathus* rather than *Clavohamulus.*

Occurrence. Older clasts in Beds 12 and 14.

Material. 20 elements. Holotype, GSC 90508; paratypes, GSC 90507, 90509.

Genus *Texania* n. gen.

Figure 16

Type species. Texania heligma n. sp.

Etymology. Name derived from indianized version of spanish *tejas*, meaning allies, friends.

Description. Genus includes albid seximembrate conodont apparatuses with ozarkodiniform (Pa, Pb), oistodontiform (M) and ramiform (Sa, Sb, Sc) elements in the apparatus. Ozarkodiniform and ramiform elements possess a single denticulated (posterior) process. Cusp is reclined and may be costate. Oistodontiform elements display a reclined

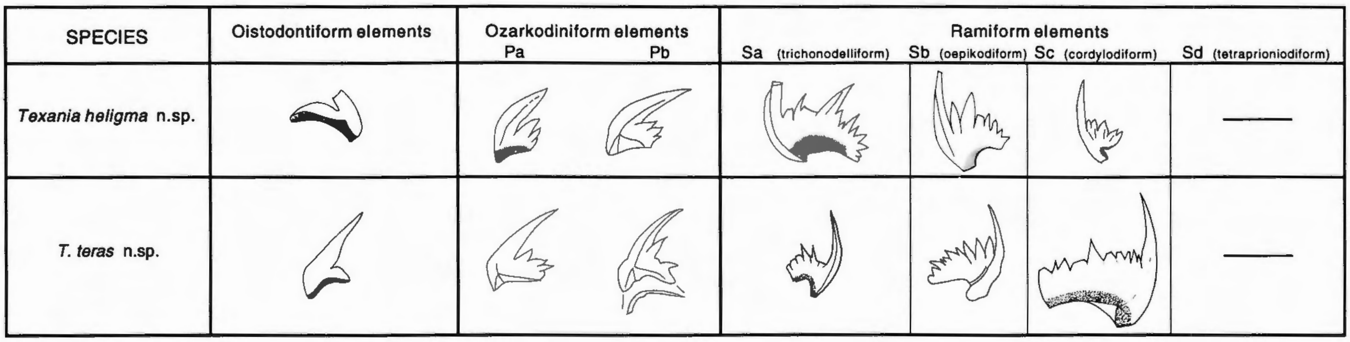


Figure 16. Comparison of elements in the apparatus of ***Texania heligma*** *n. sp. and* ***T. teras*** *n. sp. The figures are camera lucida drawings of specimens found in the Cow Head material. All x60.*

cusp that is longer than the posterior process, and sharp-edged. Base of most elements is dark brown; basal cavity is shallow.

Remarks. The characteristics of *Texania* imply relationships to *Periodon, Fahraeusodus, Protoprioniodus*, and *Microzarkodina*. *Texania* shares the elemental composition of the apparatus with *Periodon*, i.e., oistodontiform, ozarkodiniform and ramiform elements are present. In particular, some of the ramiform elements of *T. heligma* are difficult to distinguish from small (juvenile or stunted?) ramiform elements of *Periodon*. The ozarkodiniform elements of *Texania*, however, always lack a denticulated anterior process. *Texania* and *Fahraeusodus* are related in a similar way as *Oepikodus* and *Prioniodus* in that *Texania* lacks the tetraprioniodiform element that *Fahraeusodus* possesses. Furthermore, *Texania* contains Pa and Pb elements, which have not been described from *Fahraeusodus*.

In addition, the variability of all elements in *Fahraeusodus* and *Protoprioniodus* with regard to presence and absence of an anticusp and the rare blade-like element of *F. marathonensis*, which has its adentate counterpart in *P. aranda*, are not found in *Texania*.

Texania, as a rule, lacks the denticulate lateral processes that characterize ramiform elements of *Microzarkodina* but possesses a basically similar apparatus. The different elements of the two species of *Texania* found in the Cow Head material are illustrated in Figure 16.

Texania heligma n. sp.

Plate 8, figures 11–15; Figure 16

Etymology. From the Greek *helix*, meaning coiled, referring to the strong lateral flexion found in some elements.

Diagnosis. A species of *Texania* n. gen. with Pa, Pb, M, Sa, Sb, and Sc elements, all of which are albid with a dark base. Ramiform elements typically show strong lateral flexion. All elements are characteristically small and very fragile in appearance.

Description. A species of *Texania* in which the oistodontiform and ramiform elements are characterized by strong flexure of the posterior process. The upper part of all elements is filled with white matter, and the basal part is dark and translucent. Cusp of the oistodontiform elements is reclined, the curved posterior process is usually flexed sideways. Outer side of cusp is weakly carinate to costate. The anterobasal and posterobasal corners are subrounded. Oral and aboral margins are curved. The basal cavity is shallow and faintly sigmoidal. It runs parallel to the aboral margin along the entire length of the unit. The posterior process is straight or flexed sideways, in opposition to the orientation of the cusp. The P element has a straight aboral margin that meets the anterior margin of the cusp at a right or slightly obtuse angle. Three or four laterally compressed denticles on the posterior process decrease in size from anterior to posterior. The denticles are reclined to suberect, and the anterior process is rudimentary and adentate. The whole unit or only the denticles may be flexed inward with respect to the base. The ramiform elements are most abundant in this collection. They possess a long slender recurved cusp, which is laterally compressed and may be weakly costate on one side. Costate ramiform elements have one or two edges of the cusp developed as keels. The latter possess five to seven flat denticles, whereas the usually large acostate elements have up to 15 denticles of unequal length. The largest denticle is separated from the cusp by three to four shorter ones. The posterior process may be more or less strongly arched and the antero- and posterobasal corners are rounded. The flexure of the ramiform elements may be very complicated because the base of the denticles and the cusp can be deflected in three different directions. The acostate elements can be straight or flexed sideways, or the posterior process deviates in S-shape from the vertical plane with the cusp deflected with respect to the rest of the unit. In the costate ramiform elements a slightly different curvature transition is developed. Cusp and denticles may be flexed sideways with respect to the base or the strongest flexure may occur along a line that runs from the anterobasal corner to the second or third denticle.

Remarks. The unusual flexure of the elements sets this species apart from other forms. The oistodontiform element of *T. heligma* differs from *Fahraeusodus adentata* (McTavish) in lacking the upward curvature of the anterior part of the aboral margin. It can be distinguished from the corresponding element of *T. teras* whose cusp terminates with a smaller angle at the anterobasal corner. The "ozarkodiniform" element of *T. heligma* has fewer denticles compared to *T. teras* and cusp and denticules are more erect. The species is obviously closely related to *T. teras* and is probably its successor.

Occurrence. Bed 12.

Material. 263 elements. Holotype, GSC 90535; paratypes, GSC 90534, 90536–90538.

Texania teras n. sp.

Plate 8, figures 7-10; Figure 16

Etymology. From the Greek, *teras*, meaning wonder, monster.

Fahraeusodus adentatus (McTavish). Stouge and Bagnoli, 1988, p. 119, Pl. 4, figs. 12-14.

Diagnosis. A species of *Texania* in which the oistodontiform and ramiform elements are characterized by strong downward flexure of the posterior process. The upper part of all elements is filled with white matter, and the basal part is dark and translucent.

Description. Cusp of the oistodontiform elements is reclined, aboral margin is usually curved downward. Outer side of cusp is weakly carinate to costate. The anterobasal and posterobasal corners are subrounded. Anterior margin is straight and meets cusp at shallow angle. The posterior process is straight and short.

Two types of "ozarkodiniform" (P) elements are developed, one of which is common (Pa element in Fig. 16), the other rare (Pb element in Fig. 16). The Pa element has a straight aboral margin with a weak flare on the inner side. Anterior margin is straight until it meets the cusp at an angle similar to the oistodontiform element. Three to four laterally compressed denticles on the posterior process decrease in size from anterior to posterior. The denticles are reclined to suberect, and the anterior process is rudimentary and adentate. In the Pb element the outline of the aboral margin is flexed inward and the anterior margin is drawn out in the basal region.

Remarks. The ramiform elements are very similar to those of *Fahraeusodus adentatus* McTavish but lack the tetraprioniodiform (Sd) element. The aboral margin is strongly flexed downward. Denticles decrease in size away from cusp. The difference between the two species can be readily seen in the oistodontiform elements, which in *T. teras* have a straight anterobasal margin that meets the cusp at an angle of 90° or larger, whereas in *F. adentatus* the anterobasal margin continues upward without such change in direction. As in *T. heligma*, costae are weakly developed and all elements are very small.

Occurrence. Bed 10, clasts of Bed 9 age in Bed 14.

Material. 60 elements. Holotype, GSC 90530; paratypes, GSC 90531-90533.

Genus *Tripodus* Bradshaw, 1969

Type species. T. laevis Bradshaw, 1969.

Tripodus sp. aff. *T. laevis* Bradshaw

Plate 8, figures 27-31; Figure 17

aff. *Scolopodus alatus* Bradshaw, 1969, p. 1162, Pl. 132, fig. 4.

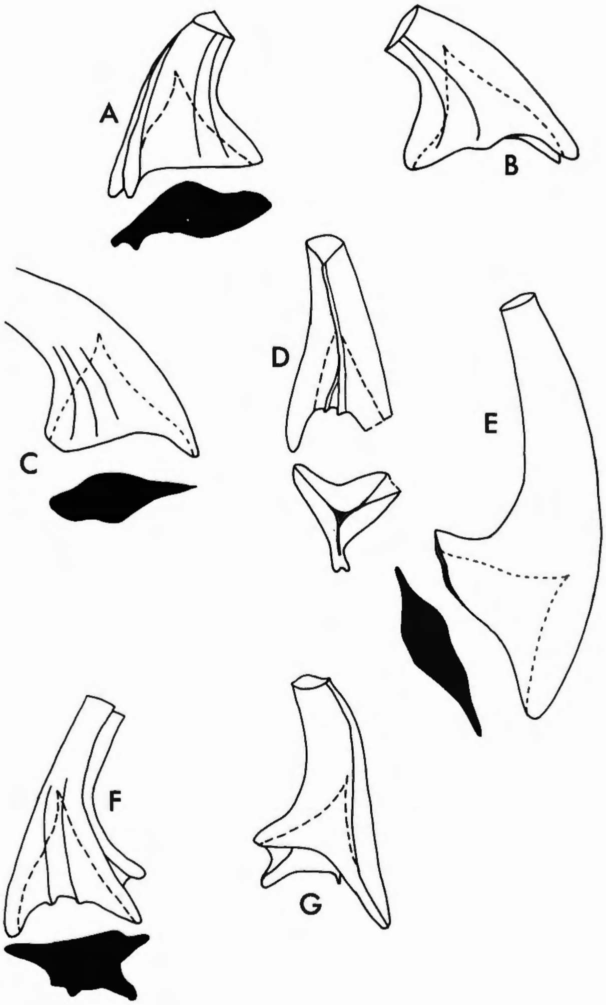


Figure 17. Elemental composition of the apparatus of ***Tripodus*** *sp. aff.* ***T. laevis.*** ***A****, anterolateral and* ***B****, posterolateral views of distacodontiform element, x100;* ***C****, lateral views of costate and* ***E****, acostate drepanodontiform elements, x100;* ***D****, posterior view of paltodontiform element, x100;* ***F****, anterior and* ***G****, posterolateral views of paltodontiform element, x100.*

aff. *Tripodus laevis* Bradshaw, 1969, p. 1164, Pl. 135, figs. 9, 10.

aff. *Tripodus laevis* Bradshaw. Ethington and Clark, 1981, p. 110, figs. 24, 25, 27–29, Textfig. 33.

Remarks. The composition of the apparatus of *Tripodus* sp. aff. *T. laevis* is similar to that reconstructed by Ethington and Clark (1981) for *T. laevis* Bradshaw, except that no oistodontiform element can be assigned. The Cow Head specimens differ in possessing distacodontiform elements with two costae on both lateral faces well in front of the midline. In addition, distacondontiform and paltodontiform elements commonly have one of the lateral or anterior edges with the keel bifurcated. This bifurcation is restricted to the basal area. Along the cusp, only one keel remains, fading distally into a sharp edge.

Occurrence. Bed 10.

Material. 35 elements. Hypotypes, GSC 90550–90554.

Tripodus sp.

Plate 8, figures 32, 33; Figure 15P, Q

Description. Drepanodontiform and trichonodelliform elements of *Tripodus* were found together in one sample. Similarities in shape of basal cavity, colour and general morphology suggest that they belong to the same apparatus. Drepanodontiform element has sharp anterior and posterior edges and swollen lateral faces. Both lateral faces are convex and unornamented. Basal cavity is deep and apex is near anterior margin at point of greatest curvature of cusp. Trichonodelliform element is recurved with convex anterior side and concave lateral faces. Basal cavity is deep and apex reaches anterior margin at point of greatest curvature. Base is not strongly expanded. Both elements are small with dark-stained cavities.

Occurrence. Bed 12, clasts of Bed 11 age in Bed 14.

Material. 8 elements. Figured specimens, GSC 90555, 90556.

New genus A s.f.

Remarks. Erect coniform elements, laterally compressed with bulging basal region and short suberect stout cusp. Basal cavity is shallow. Surfaces are finely striated. Cusp is albid, base may be hyaline.

New genus A n. sp. 1 s.f.

Plate 7, figure 29; Figure 15T, U

Description. Coniform elements, laterally compressed with sharp-edged anterior and posterior margins. In lateral view the basal region shows bulges on both sides, which give the element the shape of a bulbous spire. Cusp and base are of equal length. Element surface is covered with fine striations. Anterobasal corner is deflected to inner side, forming a groove that dissects inner face whereas outer face is smoothly curved.

Occurrence. Bed 14.

Material. 2 specimens. Figured specimen, GSC 90522.

New genus A n. sp. 2 s.f.

Plate 7, figures 27, 28; Figure 15R, S

Description. Proclined coniform element, laterally compressed with blunt-edged posterior and anterior margins. Depth and shape of basal cavity cannot be determined because the walls are opaque and basal filling is present. A few shallow protrusions are developed around base of element obscuring the overall bulbous outline. Base and cusp are of about equal length. Surface is covered with fine striae.

Occurrence. Bed 14.

Material. 1 specimen. Figured specimen, GSC 90520.

New genus B s.f.

Remarks. This new genus includes albid, laterally compressed, anteroposteriorly extended coniform elements with a shallow basal cavity. The anterior extension exceeds that of the posterior one in length.

New genus B n. sp. 1 s.f.

Plate 7, figure 30; Figure 15V, W

Description. Coniform albid elements with gently recurved inwardly flexed cusp and drawn out anterobasal and posterobasal corners. Both anterior and posterior margins have sharp edges. A weak costa is developed on outer face of cusp; inner face is smoothly curved. Cross-section of cusp is lanceolate. Basal cavity opens to inner side. Basal excavation begins at anterobasal corner as a shallow narrow trough, continues posteriorly to beneath cusp, where it flares prominently to inner side of element, then narrows to posterior extremity. Apex of shallow basal cavity is centrally situated. Basal outline forms gentle curve from distal end of anterior to tip of posterior extension. Thin dark brown band is developed adjacent to basal margin. Oral margin of anterior extension continues straight into cusp or forms obtuse angle (up to 150°) with it. Straight oral margin of posterior extension forms 130-150° angle with cusp. Elements are crudely triangular in lateral view.

Remarks. No additional elements that might belong in the apparatus were detected and the species is therefore described as a form taxon until larger collections are available.

Occurrence. Bed 14.

Material. 2 specimens. Figured specimen, GSC 90523.

New genus C s.f.

Remarks. New genus C is proposed herein for robust denticulate elements with crown-shaped morphology.

New genus C n. sp. 1 s.f.

Plate 7, figure 26; Figure 15X

Description. Crown-shaped element with one denticle fused to either side of cusp. Cross-section of cusp and denticles is lanceolate. Basal cavity is shallow with its apex situated under cusp. Dark band is developed adjacent to basal rim. The specimen shows crystalline overgrowth.

Occurrence. Clast of Bed 9 age in Bed 14.

Material. 1 specimen. Figured specimen, GSC 90519.

Acknowledgments

I wish to thank C.R. Barnes, H.P. Schönlaub and Graduate Studies who gave me the opportunity to study the Cow Head Group rocks at Memorial University. I greatly appreciated the ideas, discussions, knowledge and financial support provided by my supervisors C.R. Barnes, N.P. James, and R.K. Stevens. Much technical support was given by C. Emerson, W. Marsh, S. Neuland, F. O'Brien, A. Phillips, A. Pye, and the workshop staff at Memorial University. The cooperation of the administration and staff of Gros Morne National Park is also acknowledged. A two-year fellowship with the Geological Survey of Canada enabled further study of Ordovician conodonts and publication of the thesis material.

REFERENCES

An, T., Zhang, F., Xiang, W., Zhang, Y., et al.
1983: The Conodonts of North China and of the Adjacent Regions. Beijing, 233 p. (In Chinese with English abstract.)

Barnes, C.R.
1984: Early Ordovician eustatic events in Canada; *in* Aspects of the Ordovician System, D.L. Bruton (ed.); Paleontological Contributions from the University of Oslo. Universitetsforlaget, v. 295, p. 51-64.

Barnes, C.R. and Fåhræus, L.E.
1975: Provinces, communities, and the proposed nektobenthic habit of Ordovician conodontophorids. Lethaia, v. 8, p. 133-149.

Barnes, C.R., Jackson, D.E., and Norford, B.S.
1976: Correlation between Canadian Ordovician zonations based on graptolites, conodonts and benthic macrofossils from key successions; *in* The Ordovician System: Proceedings of a Palaeontological Association Symposium, Birmingham, September, 1974, M.G. Basset (ed.); p. 209-226.

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

Barnes, C.R., Rexroad, C.B., and Miller, J.F.
1973: Lower Paleozoic conodont provincialism; *in* Conodont Paleozoology, F.H.T. Rhodes (ed.); Geological Society of America, Special Paper, no. 141, p. 156-190.

Barnes, C.R. and Tuke, M.F.
1970: Conodonts from the St. George Formation (Ordovician), northern Newfoundland; *in* Contributions to Canadian Paleontology. Geological Survey of Canada, Bulletin 187, p. 79-97.

Bergström, S.M.
1971: Correlation of North Atlantic Middle and Upper Ordovician conodont zonation with the graptolite succession; *in* Colloque Ordovician-Silurian, Brest. Bureau de Recherches Géologiques et Minières, Mémoire, Minéraux, France, v. 73, p. 177-187.

1973: Biostratigraphy and facies relations in the lower Middle Ordovician of easternmost Tennessee. American Journal of Science, v. 273 A, p. 261-293.

1977: Early Paleozoic biostratigraphy in the Atlantic borderlands; *in* Stratigraphic Micropaleontology of Atlantic Basin and Borderlands, F.M. Swain (ed.); p. 85-100.

Bergström, S.M. and Carnes, J.B.
1976: Conodont biostratigraphy and paleoecology of the Holston Formation (Middle Ordovician) and associated strata in eastern Tennessee. Geological Association of Canada, Special Paper, no. 15, p. 27-57.

Bergström, S.M., Epstein, A.G., and Epstein, J.B.
1972: Early Ordovician Atlantic Province conodonts in eastern Pennsylvania. U.S. Geological Survey, Professional Paper 800-D, p. D37-D44.

Billings, E.
1865: Paleozoic Fossils, v. 1, Geological Survey of Canada, 326 p.

Boyce, W.D.
1979: Further developments in western Newfoundland Cambro-Ordovician biostratigraphy; *in* Report of Activities for 1978, R.U. Gibbons (ed.); Newfoundland Department of Mines and Energy, Mineral Development Division, Report 79-1, p. 7-10.

1983: Early Ordovician trilobite faunas of the Boat Harbour and Catoche formations (St. George Group) in the Boat Harbour-Cape Norman area, Great Northern Peninsula, western Newfoundland. Unpublished M.Sc. thesis, Memorial University of Newfoundland, St. John's, Newfoundland, 272 p.

1985: Cambrian-Ordovician biostratigraphic investigations, Great Northern Peninsula, western Newfoundland; *in* Current Research, K. Brewer, D. Walsh, and R.V. Gibbons (eds.); Newfoundland Department of Mines and Energy, Mineral Development Division, Report 85-1, p. 60-69.

1986: Ordovician biostratigraphic investigations, Great Northern Peninsula; *in* Current Research, R.F. Blackwood, D. Walsh, and R.V. Gibbons (eds.); Newfoundland Department of Mines and Energy, Mineral Development Division, Report 86-1, p. 161-168.

Bradshaw, L.E.
1969: Conodonts from the Fort Peña Formation (Middle Ordovician), Marathon Basin, Texas. Journal of Paleontology, v. 43, p. 1137-1168.

Branson, E.B. and Mehl, M.G.
1933: Conodonts from the Jefferson City (Lower Ordovician) of Missouri. The University of Missouri Studies, v. VIII, p. 53-64.

Breakey, E.C.
1974: Sedimentology of the Lower Paleozoic shelf-slope transition Levis, Quebec. M.Sc. thesis, McGill University, Montréal, 182 p.

Chow, N.
1986: Sedimentology and diagenesis of Middle and Upper Cambrian platform carbonates and siliciclastics, Port au Port Peninsula, western Newfoundland. Ph.D. thesis, Memorial University of Newfoundland, St. John's, Newfoundland, 458 p.

Coniglio, M.
1985: Origin and diagenesis of fine-grained slope sediments: Cow Head Group (Cambro-Ordovician), western Newfoundland. Ph.D. thesis, Memorial University of Newfoundland, St. John's, Newfoundland, 684 p.

Cook, H.E. and Taylor, M.E.
1975: Early Paleozoic continental margin sedimentation. Trilobite biofacies, and the thermocline, western U.S. Geology, v. 3, p. 559-562.

Cooper, B.J.
1981: Early Ordovician conodonts from the Horn Valley Siltstone, central Australia. Paleontology, v. 24, p. 147-183.

Cooper, G.A.
1956: Chazyan and related brachiopods. Smithsonian Miscellaneous Collections, v. 127, p. 1-1024.

1976: Early Middle Ordovician of the United States; *in* The Ordovician System, M.G. Basset (ed.); Proceedings of a Palaeontological Association Symposium, Birmingham, September, 1974, p. 171-194.

Druce, E.C.
1973: Upper Paleozoic and Triassic conodont distribution and the recognition of biofacies; *in* Conodont Paleozoology, F.H.T. Rhodes (ed.); Geological Society of America, Special Paper 141, p. 191-237.

Dzik, J.
1976: Remarks on the evolution of Ordovician conodonts. Acta Paleontologica Polonica, v. 21, p. 395-455.

Epstein, A.G., Epstein, J.B., and Harris, L.
1977: Conodont color alteration — an index to organic metamorphism. United States Geological Survey, Professional Paper 995, p. 1-27.

Erdtmann, B.-D.
1971: Ordovician graptolite zones of western Newfoundland in relation to paleogeography of the North Atlantic. Geological Society of America Bulletin, v. 82, p. 1509-1528.

Ethington, R.L.
1972: Lower Ordovician (Arenigian) conodonts from the Pogonip Group, Central Nevada; *in* Symposium on Conodont Taxonomy, M. Lindström and W. Ziegler (eds.); Geologica et Palaeontologica SB-1, p. 17-27.

Ethington, R.L. and Clark, D.L.
1971: Lower Ordovician conodonts in North America. Geological Society of America, Memoir 127, p. 63-82.

1981: Lower and Middle Ordovician conodonts from the Ibex area western Millard County, Utah. Brigham Young University Geology Studies, v. 28, pt. 2, 159 p.

Ethington, R.L. and Repetski, J.E.
1984: Paleobiogeographic distribution of Early Ordovician conodonts in central and western United States; *in* Conodont Biofacies and Provincialism, D.L. Clark (ed.);

Geological Society of America, Special Paper, v. 196, p. 89-102.

Fåhræus, L.E.
1970: Conodont-based correlations of Lower and Middle Ordovician strata in western Newfoundland. Geological Society of America, Bulletin 81, p. 2061-2076.

1976: Conodontophorid ecology and evolution related to global tectonics; *in* Paleoecology, C.R. Barnes (ed.); Geological Association of Canada, Special Paper 15, p. 12-26.

1977: Isocommunities and correlation of the North American *Didymograptus bifidus* Zone (Ordovician). Newsletters on Stratigraphy 6, p. 85-96.

Fåhræus, L. and Nowlan, G.S.
1978: Franconian (Late Cambrian) to Early Champlainian (Middle Ordovician) conodonts from the Cow Head Group, western Newfoundland. Journal of Paleontology, v. 52, p. 444-471.

Finney, S.C. and Ethington, R.L.
1992: Whiterockian graptolites and conodonts from the Vinini Formation, Nevada: Biostratigraphic implications; *in* 5th Symposium on the Ordovician System, B.D. Webby and J.R. Laurie (eds.); Global Perspectives on Ordovician Geology, p. 153-169.

Fleming, J.M.
1970: Petroleum exploration in Newfoundland and Labrador. Newfoundland Department of Mines, Agriculture and Resources, Mineral Resources Report No. 13, 118 p.

Fortey, R.A.
1979: Early Ordovician trilobites from the Catoche Formation (St. George Group), western Newfoundland. Geological Survey of Canada, Bulletin 321, p. 61-114.

Fortey, R.A. and Barnes, C.R.
1977: Early Ordovician conodont and trilobite communities of Spitsbergen: influence on biogeography. Alcheringa, v. 1, p. 297-340.

Graves, R.W. and Ellison, S.
1941: Ordovician conodonts of the Marathon Basin, Texas. Missouri University School of Mines and Metallurgy Bulletin, Technical Series, no. 14, 26 p.

Hadding, A.R.
1913: Undre dicellograptusskiffern i Skåne jämte några därmed equivalenta bildningar. Lunds Universitats Årsskrifter N.F. Avd. 2, bd. 9, no. 15, p. 1-90.

Harris, A.G., Bergström, S.M., Ethington, R.L., and Ross, R.J., Jr.
1979: Aspects of Middle and Upper Ordovician conodont biostratigraphy of carbonate facies in Nevada and southeast California and comparison with some Appalachian successions; *in* Conodont Biostratigraphy of the Great Basin and Rocky Mountains, C.A. Sandberg and D.L. Clark (eds.); Brigham Young University Geology Studies, v. 26, p. 7-43.

Hintze, L.F.
1951: Lower Ordovician detailed stratigraphic sections from western Utah. Utah Geological and Mineralogical Survey, Bulletin 39, 99 p.

1952: Lower Ordovician trilobites from western Utah and eastern Nevada. Utah Geological and Mineralogical Survey, Bulletin 48, 249 p.

Hiscott, R. and James, N.P.
1985: Carbonate debris flows, Cow Head Group, western Newfoundland. Journal of Sedimentary Petrology, v. 55, p. 735-745.

James, N.P.
1981: Megablocks of calcified algae in the Cow Head breccia, western Newfoundland: Vestiges of a Cambro-Ordovician platform margin. Geological Society of America Bulletin, v. 92, p. 799-811.

James, N.P. and Stevens, R.K.
1986: Stratigraphy and correlation of the Cambro-Ordovician Cow Head Group, western Newfoundland. Geological Survey of Canada, Bulletin 366, 143 p.

Ji, Z.
1989: Lower Ordovician conodonts from the St. George Group, Port au Port Peninsula, western Newfoundland. Ph.D. thesis, Memorial University, St. John's, Newfoundland, 576 p.

Johnson, H.
1941: Paleozoic lowlands of northwestern Newfoundland. The New York Academy of Sciences, Transactions, ser. II, v. 3, p. 141-145.

Johnston, D.I.,
1987: Early Ordovician (Arenig) conodonts from St. Pauls Inlet and Martin Point, Cow Head Group, western Newfoundland. M.Sc. thesis, Memorial University of Newfoundland, St. John's, Newfoundland, 226 p.

Kenna, K.
1986: Upper Canadian to Whiterock conodonts of the upper St. George Group, western Newfoundland. Canadian Paleontology and Biostratigraphy Seminar. Paleontology Division, Geological Association of Canada, Quebec City. Program with Abstracts, p. 11.

Kennedy, D.J.
1980: A restudy of conodonts described by Branson and Mehl, 1933, from the Jefferson City Formation, Lower Ordovician, Missouri. Geologica et Palaeontologica, v. 14, p. 45-76.

Kindle, C.H. and Whittington, H.B.
1958: Stratigraphy of the Cow Head region, western Newfoundland. Geological Society of America, Bulletin, v. 69, p. 315-342.

Klapper, G., Lindström, M., Sweet, W.C., and Ziegler, W.
1977: Catalogue of Conodonts, v. III. W. Ziegler (ed.); E. Schweitzerbart'sche Verlagsbuchhandlung, Stuttgart, 573 p.

1981: Catalogue of Conodonts, v. IV. W. Ziegler (ed.); E. Schweitzerbart'sche Verlagsbuchhandlung, Stuttgart, 445 p.

Knight, I. and James, N.P.
1987: Stratigraphy of the St. George Group (Lower-Middle Ordovician), western Newfoundland; the interaction between eustasy and tectonics. Canadian Journal of Earth Sciences, v. 24, p. 1927-1952.

Landing, E.
1976: Early Ordovician (Arenigian) conodont and graptolite biostratigraphy of the Taconic allochthon, eastern New York. Journal of Paleontology, v. 50, p. 614-646.

Lee, Ha-Young
1970: Conodonten aus der Choson Gruppe (Unteres Ordovizium) von Korea. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, v. 136, p. 303-344.

Lindström, M.
1955: Conodonts from the lowermost Ordovician strata of south central Sweden: Geologiska Föreningens i Stockholm Förhandlingar, v. 76, p. 517-604.

1964: Conodonts. Elsevier, New York, 196 p.

1971: Lower Ordovician conodonts of Europe. Geological Society of America, Memoir no. 127, p. 21-61.

1976: Conodont provincialism and paleoecology — a few concepts; *in* Paleoecology, C.R. Barnes (ed.); Geological Association of Canada, Special Paper 15, p. 3-9.

1976a: Conodont paleogeography of the Ordovician; *in* The Ordovician System: Proceedings of a Paleontological Assocation Symposium, M.G. Basset (ed.); Birmingham, September 1974, p. 501-522.

Lock, B.E.
1972: Lower Paleozoic history of a critical area; eastern margin of the St. Lawrence Platform in White Bay, Newfoundland, Canada. 24th IGC - Section 6, International Geological Congress Montreal, p. 310-324.

Löfgren, A.
1978: Arenigian and Llanvirnian conodonts from Jämtland, northern Sweden. Fossils and Strata, no. 13, 129 p.

Logan, W.E.
1863: Geology of Canada, Geological Survey of Canada, Report of Progress from its Commencement to 1863, 983 p.

McTavish, R.A.
1973: Prioniodontacean conodonts from the Emanuel Formation (Lower Ordovician) of Western Australia. Geologica et Palaeontologica, v. 7, p. 27-58.

Merrill, G.K.
1966: Pennsylvanian platform-type conodonts from the Appalachian Conemaugh. Geological Society of America, Special Paper 115, p. 147, 148. (Abstract.)

Moskalenko, T.A.
1973: Conodonts of the Middle and Upper Ordovician of the Siberian Platform. Akademiya Nauk SSSR, Sibirskoie Otdelenie, Instituta Geologii i Geofiziki Trudy, vyp. 137, 143 p.

Müller, K.J.
1962: Zur systematischen Einteilung der Conodontophorida. Paläontologische Zeitschrift, v. 36, p. 109-117.

Nowlan, G.S.
1974: Conodonts from the Cow Head Group, western Newfoundland. M.Sc. thesis, Memorial University of Newfoundland, St. John's, Newfoundland, 78 p.

1976: Late Cambrian to Late Ordovician conodont evolution and biostratigraphy of the Franklinian Miogeosyncline, eastern Canadian Arctic Islands. Ph.D. thesis, University of Waterloo, Waterloo, Ontario, 590 p.

Nowlan, G.S. and Barnes, C.R.
1987: Thermal maturation of Paleozoic strata in eastern Canada from conodont alteration index (CAI) with implications for burial history, tectonic evolution, hotspot tracks and mineral and hydrocarbon exploration. Geological Survey of Canada, Bulletin 367, 47 p.

Oxley, P.
1953: Geology of the Parsons Pond-St. Pauls area, west coast, Newfoundland. Geological Survey, Report no. 5, 53 p.

Pohler, S.L., Barnes, C.R., and James, N.P.
1987: Reconstructing a lost faunal realm: conodonts from the Ordovician Cow Head Group, western Newfoundland; *in* Conodonts: Investigative Techniques and Applications, R. Austin (ed.); Ellis Horwood, Chichester, p. 341-362.

Pohler, S.L. and Barnes, C.R.
1990: Conceptual models in conodont paleoecology. Courier des Forschungs-Instituts Senckenberg, v. 118, p. 409-440.

Pohler, S.L. and James, N.P.
1989: Reconstruction of a Lower/Middle Ordovician carbonate shelfmargin: Cow Head Group, western Newfoundland. Facies, v. 21, p. 189-262.

Pohler, S.M.L. and Orchard, M.J.
1990: Ordovician conodont biostratigraphy, western Canadian Cordillera. Geological Survey of Canada, Paper 90-15, 37 p.

Repetski, J.E.
1982: Conodonts from El Paso Group (Lower Ordovician) of westernmost Texas and southern New Mexico. New Mexico Bureau of Mines and Mineral Resources, Memoir 40, 121 p.

Repetski, J.E. and Ethington, R.L.
1977: Conodonts from graptolite facies in the Ouachita Mountains, Arkansas and Oklahoma. Arkansas Geological Commission Symposium on the Geology of the Ouachita Mountains, v. 1, p. 92-106.

Ross, R.J., Jr.

1951: Stratigraphy of the Garden City Formation in northeastern Utah, and its trilobite faunas. Yale University, Peabody Museum, Bulletin 6, 161 p.

1964: Relations of Middle Ordovician time and rock units in Basin Ranges, western United States. American Assocation of Petroleum Geologists, Bulletin, v. 48, p. 1526–1554.

Ross, R.J., Jr. and Ethington, R.L.

1991: Stratotype of Ordovician Whiterock Series. Palaios, v. 6, p. 156–173.

Ross, R.J., Jr., et al.

1982: The Ordovician System in the United States. International Union of Geological Sciences, Publication no. 12, 73 p.

Ross, J.R., Jr. and James, N.P.

1987: Brachiopod biostratigraphy of the middle Ordovician Cow Head and Table Head groups, western Newfoundland. Canadian Journal of Earth Sciences, v. 24, p. 70–95.

Ruedemann, R.

1947: Graptolites of North America. Geological Society of America, Memoir 19, 652 p.

Schuchert, C. and Dunbar, C.O.

1934: Stratigraphy of western Newfoundland. Geological Society of America, Memoir 1, 123 p.

Seddon, G. and Sweet, W.C.

1971: An ecologic model for conodonts. Journal of Paleontology, v. 45, p. 869–880.

Serpagli, E.

1974: Lower Ordovician conodonts from Precordilleran Argentina (Province of San Juan). Bolletino Società Paleontologica Italiana, 13, p. 17–93.

Stait, K.

1989: Upper Canadian to Whiterock conodonts of the upper St. George Group, western Newfoundland. Ph.D. thesis, Memorial University, Newfoundland, 356 p.

Stouge, S.S.

1982: Preliminary conodont biostratigraphy and correlation of Lower and Middle Ordovician carbonates of the St. George Group, Great Northern Peninsula, Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 82-3, p. 1–59.

1984: Conodonts of the Middle Ordovician Table Head Formation, western Newfoundland. Fossils and Strata, no. 16, 145 p.

Stouge, S.S. and Bagnoli, G.

1988: Early Ordovician conodonts from Cow Head Peninsula, Western Newfoundland. Palaeontographica Italica, v. 75, p. 89–179.

Stouge, S.S. and Boyce, W.D.

1983: Fossils of northwestern Newfoundland and southeastern Labrador: conodonts and trilobites. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 83-3, p. 1–55.

Sweet, W.C.

1981: Treatise on Invertebrate Paleontology Part W —Miscellanea. Supplement 2, Conodonta. R.A. Robison (ed.); p. W5–W20.

Sweet, W.C. and Bergström, S.M.

1962: Conodonts from the Pratt Ferry Formation (Middle Ordovician) of Alabama. Journal of Paleontology, v. 36, p. 1214–1252.

1974: Provincialism exhibited by Ordovician conodont faunas; *in* Paleogeographic Provinces and Provinciality, C.A. Ross (ed.); Society of Economic Paleontologists and Mineralogists Special Publication 21, p. 189–202.

1976: Conodont biostratigraphy of the Middle and Upper Ordovician of the United States; *in* The Ordovician System, M.G. Basset (ed.); Proceedings of a Paleontological Association Symposium, Birmingham, September, 1974, p. 121–151.

Sweet, W.C., Ethington, R.L., and Barnes, C.R.

1971: North American Middle and Upper Ordovician conodont faunas. Geological Society of America, Memoir 127, p. 163–193.

Sweet, W.C., Turco, C.A., Warner, E., and Wilkie, L.C.

1959: The American Upper Ordovician standard. I. Eden conodonts from the Cincinnati region of Ohio and Kentucky. Journal of Paleontology, v. 33, p. 1029–1068.

Taylor, M.E.

1977: Late Cambrian of western North America: trilobite biofacies, environmental significance, and biostratigraphic implications; *in* Concepts and Methods of Biostratigraphy, E.G. Kauffman and J.E. Hazel (eds.); Stroudsburg, p. 397–425.

Tipnis, R.S., Chatterton, B.D.E., and Ludvigsen, R.

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

Uyeno, T.T. and Barnes, C.R.

1970: Conodonts from the Levis Formation (zone Ordovician), Levis, Quebec; *in* Contributions to Canadian Paleontology, Geological Survey of Canada, Bulletin 187, p. 99–123.

Vail, P.R., Mitchum, R.M., and Thompson, S., III

1977: Global cycles of relative changes of sea level; *in* Seismic Stratigraphy — Applications to Hydrocarbon Exploration, C.E. Payton (ed.); American Association of Petroleum Geologists Memoir, v. 26, p. 83–92.

van Wamel, W.A.

1974: Conodont biostratigraphy of the Upper Cambrian and Lower Ordovician of northwestern Öland, southeastern Sweden. Utrecht Micropalaeontological Bulletins, v. 10, p. 1–125.

Viira, V.
1974: Ordovician conodonts of the east Baltic. Institut Geologii Akademii Nauk Estonskoi SSr, Tallin, 142 p.

Webby, B.D. (comp. and ed.)
1981: The Ordovician System in Australia, New Zealand and Antarctica: Correlation Chart and Explanatory Notes. International Union of Geological Sciences, Publication 6, 64 p.

Whittington, H.B. and Kindle, C.H.
1969: Cambrian and Ordovician stratigraphy of western Newfoundland; *in* North Atlantic Geology and Continental Drift, M. Kay (ed.); American Association of Petroleum Geologists Memoir 12, p. 655-664.

Williams, H.
1975: Structural succession, nomenclature, and interpretation of transported rocks in western Newfoundland. Canadian Journal of Earth Sciences, v. 12, p. 1874-1894.

1979: Appalachian Orogen in Canada. Canadian Journal of Earth Sciences, v. 16, p. 792-807.

Williams, H., James, N.P., and Stevens, R.K.
1985: Humber Arm Allochthon and nearby groups between Bonne Bay and Portland Creek, western Newfoundland; *in* Current Research, Part A; Geological Survey of Canada, Paper 85-1A, p. 399-409.

Williams, S.H.
1986: Lower Ordovician chronostratigraphy and graptolite biostratigraphy in eastern Canada; *in* Preprint of the Canadian Paleontology and Biostratigraphy Seminar, Albany, New York, p. 172-179.

Williams, S.H., Boyce, W.D., and James, N.P.
1987: Graptolites from the Lower-Middle Ordovician St. George and Table Head groups, western Newfoundland, and their correlation with trilobite, brachiopod, and conodont zones. Canadian Journal of Earth Sciences, v. 24, p. 456-470.

Williams, S.H. and Stevens, R.K.
1988: Lower Ordovician (Arenig) graptolites of the Cow Head Group, western Newfoundland. Palaeontographica Canadiana, v. 5, 167 p.

APPENDICES 1 to 4

APPENDIX 1

Conodonts from penecontemporaneous clasts in Bed 10 and from clasts of Bed 9 age in Beds 12 and 14.

Sample number	*Acodus deltatus*	Acodontiform element 2	*Acontiodus iowensis*	*Acontiodus* sp. 2 Uyeno and Barnes	*Acontiodus latus* s.f.	*Bergstroemognathus extensus*	*Coelocerodontus bicostatus*	*Cordylodus caboti*	*Cornuodus longibasis*	*Cristodus loxoides*	*Drepanodus arcuatus*	*Drepanodus* sp. 2 Ethington and Clark	*Drepanodus* sp. 4 Repetski	*Drepanodus* sp. 4 Serpagli	*Drepanodus*? sp. 1	Drepanodontiform element 2	Drepanodontiform element 1	*Drepanoistodus* sp. aff. *D. concavus*	*Drepanoistodus forceps*	*D. inaequalis*	*D. inconstans*	*D. pitjanti*	*D.* sp. aff. *D. basiovalis*	*Eucharodus parallelus*	*E. toomeyi*	*Fahraeusodus marathonensis*	*F. mirus*	*Fryxellodontus*? *corbatoi*	*F.*? sp.	*Glyptoconus quadraplicatus*	*Juanognathus variabilis*	*Oepikodus* sp. aff. *minutus*	*Oistodus*? *elongatus*	*O. lanceolatus*	Oistodontiform element 3	*Oneotodus costatus*	*Paltodus*? sp.	*Paracordylodus gracilis*	*Parapaltodus* sp.	*Parapanderodus asymmetricus*	*P. carlae*	*P. emarginatus*	*P. gracilis*	*Paroistodus numarcuatus*	*P. originalis*	*P. parallelus*
126	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
138	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
107	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
109	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
137	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
232	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
237	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
240	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	1
258	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
235	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	5	-	-	-	1	-	-	-	-	-	-	3	-	-	-	2	2	-	-	-	-	-	-	-	-	1	-	-	1
257	-	-	-	-	-	-	-	-	-	-	8	-	1	-	-	1	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	3	3	-	-	-	-	22	-	-	-	-	-	-	-	17
262	-	-	-	-	-	-	-	-	-	-	3	-	-	1	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	1	3	-	-	-	-	-	-	-	-
124	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
135	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	6	-	-	1	-	-	-	-	-	1	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
191	-	-	-	-	-	2	-	-	-	-	1	-	-	-	-	-	-	4	-	-	1	-	-	-	-	-	-	-	-	1	-	-	2	-	2	-	-	1	-	-	-	-	-	-	-	13
203	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
225	6	-	-	-	-	3	-	-	-	-	5	-	-	-	-	-	-	7	10	-	12	-	2	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	2	-	-	-	-	-	-	4
229	-	-	-	-	-	-	-	-	2	-	4	-	-	-	-	-	-	-	3	-	6	-	-	-	-	-	-	-	-	-	-	-	7	4	-	-	-	8	-	-	-	-	1	2	-	4
230-1	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	1	-	-	-	1	1	-	-
239	13	-	-	-	-	4	1	-	-	-	9	-	-	-	-	-	-	2	19	-	1	-	16	-	-	4	-	-	-	1	-	-	35	-	-	-	-	-	-	1	-	-	-	-	26	13
242	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	1
249	-	-	-	-	-	5	-	-	-	-	5	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	1	-	-	-	-	6	-	-	1
299	-	-	-	-	1	-	-	-	1	-	14	-	-	-	-	-	-	-	-	-	2	-	4	-	-	-	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	4
202	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	36	-	-	-	-	2	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	1
224	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
228-B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
241	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	4	-	-	1	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	2	-	4	2
226	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	7	-	-	10	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2
238	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
190	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	2
300	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	3	-	-	-	-	-	2	-	-	-	-	-	1	-	-	-	-
230-2	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	1	-	-	-	12	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	-	-
233	-	-	-	1	-	1	-	-	-	1	-	-	-	-	-	-	-	10	-	-	11	-	-	1	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	8	-	2
234	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
236	-	-	-	1	-	-	-	-	1	-	2	-	-	-	-	-	-	-	2	-	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-
108	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
243	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
231	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
275	-	-	2	-	-	-	-	10	-	-	1	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	3	2	1	-	-	5	-	-	-	-	18	-	-	-	2	2	-	-	9
223	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
75	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
265	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
110	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-	2	-	-	1	-	-	-	-	1	-	-	-	-	-	14	-	-	-	-	12	10	-	-	-	-	4	-	-	13
175	-	-	-	-	-	1	-	-	-	-	4	-	-	-	-	-	-	7	-	4	-	-	-	-	-	-	12	-	-	2	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	1
211	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
212	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
54	-	6	-	-	1	-	-	-	9	1	12	1	-	-	-	-	-	1	3	-	-	-	-	-	-	1	-	-	-	-	1	16	2	1	-	1	8	11	-	-	-	-	1	-	-	7
69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
244-B	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	6	-	-	1	-	-	-	-	-	-	-	-	-	-	-	3	-	1	-	1	1	-	-	-	-	-	-	-	2
264	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	1	-	-	1	-	-	-	-	-	1	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	1
289	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	3
282	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
163	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	-	-	4	-	-	1	-	-	-	-	-	-	-	-	1	9	-	-	-	-	-	-	-	-	-	-	3	15
14	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	3	-	-	-	-	-	-	-	-	-	-	8
268	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	21	6	5	2	2	24	1	11	15	3	100	1	1	1	4	1	2	189	76	4	95	1	22	13	1	9	14	3	5	15	2	38	114	27	8	3	24	79	3	1	1	4	30	35	35	131

P. proteus	*Periodon? primus*	*Prioniodus elegans*	*P. marginalis*	*P. serratus*	*P.* sp.	*Proconodontus muelleri*	*Protopanderodus elongatus*	*P. rectus*	*Protoprioniodus papiliosus*	*P. simplicissimus*	*"Scandodus" mysticus*	*"S." pseudoramis*	Scandodontiform element 1	Scandodontiform element 2	*Scandodus furnishi*	*Scolopodus multicostatus*	*"Scolopodus" quadratus*	*S.* sp. aff. *S. filosus* Ethington and Clark	*S.? peselephantis*	*S.?* sp. Ethington and Clark	*Serratognathus armadillodus*	*Strachanognathus parvus*	*Texania teras*	*Tripodus* sp. aff. *T. laevis*	*T. subtilis*	*Tropodus sweeti*	*?Ulrichodina wisconsinensis*	*Variabiloconus* sp. aff. *V. bassleri*	*Westergaardodina* sp.	New genus C new species 1	Total number of specimens	Sample number	Lithotype	Derivation of clasts
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	126	Matrix	Lower slope lithotypes
-	2	4	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	138		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	107	Parted limestone	
-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	109		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	137		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	232		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	237		
-	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	240		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	258		
-	-	60	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	8	235	Calcarenite	
5	-	15	2	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	87	257		
1	2	5	3	7	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	34	262		
-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	124	Conglomerate	
-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	22	135	Wackestone	Shelf edge lithotypes
-	-	-	26	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	2	-	-	-	-	62	191		
-	-	-	34	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41	203		
-	-	10	62	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	2	-	-	-	5	-	-	-	-	-	-	-	141	225		
-	4	69	16	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	2	-	-	-	-	-	-	134	229		
-	-	-	33	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	65	230-1		
-	7	-	117	-	-	-	-	2	8	6	-	-	-	1	-	-	-	-	4	-	-	-	46	-	-	-	-	-	-	-	336	239		
-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	3	-	-	-	-	-	17	242		
-	-	116	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	145	249		
21	6	-	117	-	-	2	-	-	-	2	-	-	-	-	-	-	-	-	14	-	-	7	5	4	-	-	-	-	-	-	221	299		
-	-	1	-	335	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	392	202	Boundstone	
-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	224		
-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	228-B		
-	-	2	114	-	-	-	-	-	2	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	146	241		
-	-	-	20	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	3	-	4	-	-	-	-	55	226	Grainstone	
-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	4	238		
-	-	-	34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	49	190	Calcirudite	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	11	300		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	230-2	Lumpy wackestone	
-	-	121	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	2	-	-	-	-	-	-	4	-	-	-	-	171	233		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	234		
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	39	236		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	108	*Epiphyton* boundstone	Older clasts in Beds 12 and 14
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	243		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	231	Oolitic grainstone	
7	3	-	-	1	11	2	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34	275	12 Wackestone	
-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	2	-	-	-	-	14	223	12 Calcirudite	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	75	14 Dolomitic wackestone–grainstone	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	265		
2	-	-	2	-	-	-	-	-	-	-	-	3	-	1	2	-	1	-	-	-	1	-	-	-	-	1	-	8	1	-	107	110	14 Lumpy echinoderm wackestone	
-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	4	-	-	-	8	-	-	5	175		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	211		
-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	12	212		
-	8	-	1	-	-	-	2	-	-	-	-	-	2	1	7	-	-	1	6	-	16	-	-	-	-	14	-	20	-	1	160	54	14 Bedded grainstone–rudstone	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	69	14 Wackestone	
-	-	-	82	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	102	244-B		
-	-	-	20	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32	264		
-	2	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-		2	-	-	24	289		
-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	282	14 Parted limestone	
-	-	14	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	1	-	-	-	-	21	15		
2	-	77	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	214	163		
-	-	28	4	-	-	-	-	-	1	-	-	1	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-		14	Calcarenite	
-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	268		
52	34	546	718	343	11	5	2	13	11	18	1	34	2	3	9	3	15	1	32	1	17	7	60	35	7	49	2	38	1	1	3253	Total		

APPENDIX 2

Conodonts from clasts of Bed 11 age in Beds 12 and 14

Sample number	*Acodus deltatus*	*A? gladiatus*	Acodontiform element 1	*Acontiodus* sp. 2 Uyeno & Barnes	*Bergstroemognathus extensus*	*Coelocerodontus bicostatus*	*Cornuodus longibasis*	*Drepanodus arcuatus*	*D.? planus*	*D.* sp. 2	Drepanodontiform element 2	*Drepanoistodus* sp. aff. *D. concavus*	*D. forceps*	*D. inaequalis*	*D. basiovalis*	*Eucharodus parallelus*	*Fahraeusodus marathonensis*	*Glyptoconus quadraplicatus*	*Juanognathus jaanussoni*	*J. variabilis*	*Jumudontus gananda*	*Oepikodus communis*	*O. evae*	*O.* sp. aff. *O. minutus*	*Oistodus lanceolatus*	*"O." inaequalis*	*O.* sp. 1	Oistodontiform element 2	*Parapaltodus* sp.	*Parapanderodus asymmetricus*	*P. carlae*	*P. gracilis*	*P. paracornuformis*	*Paraprioniodus costatus*	*Paroistodus mutatus*	*P. originalis*	*P. parallelus*	*P.?* sp. B Stouge	*Periodon aculeatus*
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
82	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12
96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
134	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
207	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
220	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
206	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
208	-	-	-	-	-	-	-	2	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21	-	49
218	-	-	-	-	-	-	-	3	2	-	-	-	2	-	4	-	-	-	-	-	-	-	2	-	-	-	5	-	-	-	-	4	-	-	-	73	-	-	-
86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
219	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
79	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
81	-	-	-	-	-	2	2	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
92	-	1	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	1	-	1	-	-	-	-	5	-	-	69
93	-	-	-	-	4	-	-	2	-	-	-	-	-	-	1	-	-	-	-	-	-	7	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	69
94-A	-	-	-	-	4	-	1	-	-	-	-	-	4	-	2	-	-	-	-	-	-	-	341	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-
94-B	-	-	-	-	-	-	5	-	-	-	-	-	1	-	8	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	4	1	-	300
98	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99	10	-	-	-	-	-	4	2	1	-	-	4	16	-	2	-	-	-	-	-	-	-	241	1	-	-	-	-	-	-	1	6	-	-	3	1	-	-	-
101	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
102	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	167
102-A	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	5	-	-	-	1	1	1	7	1	1	-	4	-	-	101
106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
177	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
178	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
198	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
216	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
217	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
222	-	-	-	-	-	-	1	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
252	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
256	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	38
260	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
292	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
293	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8
105	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
186	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
195	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
199	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	107
253	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
274	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
294	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
298	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
164	-	1	-	-	27	-	-	5	-	-	1	-	-	-	3	-	-	-	-	-	-	-	144	-	-	-	-	-	3	-	-	4	-	1	4	1	4	-	-
185	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
187	-	-	-	-	3	-	3	4	-	-	-	1	1	1	2	-	-	-	-	-	-	-	310	-	-	-	-	-	4	-	-	5	-	-	3	1	-	-	160
189	-	-	-	-	1	-	-	-	-	-	-	-	2	3	-	-	-	-	-	-	-	-	56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
189-A	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	13	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
131	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
132	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
133	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
197	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
221	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
227	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	17	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
228-A	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
254	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
254-A	-	-	-	2	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	66	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
273	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	29	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	6
MPN	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
91	-	-	-	-	-	-	3	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	2	-	-	1	6	-	-	28
295	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	2	-	10	-	-	15
83	-	-	-	-	18	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	2	-	-	24	-	-	-	-	-	-	1	-	-	-	-	4	-	-	-
297	-	-	-	-	2	-	-	1	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-
296	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	59	-	-	-	-	-	1	1	-	-	-	-	-	2	-	-	54
179	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
259	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
56	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
58	-	-	-	-	2	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
73	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
180	-	-	-	-	3	-	-	2	-	-	-	-	2	1	4	-	-	-	-	-	-	-	15	4	7	-	-	-	-	-	-	-	-	-	-	-	-	-	37
183	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
188	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
270	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
277	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
279	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
280	-	1	-	-	3	-	-	2	-	-	-	-	-	-	-	-	-	-	2	-	-	-	102	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
53	-	-	-	-	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	76	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-
66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
67	-	-	-	-	-	1	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	1	-	29	-	-	257
76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31	-	1	-	-	2	-	2	2	-	-	-	1	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38
172	-	-	-	-	19	-	5	-	1	-	-	-	-	6	-	-	-	-	-	-	-	-	190	3	1	-	-	-	-	-	1	1	-	-	-	1	-	-	-
210	-	-	-	-	2	-	5	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	63	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	14
244-A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
161	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
247	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
276	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	1	-	-	-	16	-	6	-	5	-	-	-	-	-	3	-	-	-	-	2	-	-	115	-	1	-	-	-	-	-	-	-	-	-	-	11	-	-	-
18	-	-	-	-	5	-	-	3	4	-	-	-	-	-	-	-	-	-	-	1	-	-	465	4	19	-	-	-	-	-	-	2	-	-	-	4	-	-	-
167	-	-	-	1	12	-	-	12	1	-	-	-	-	-	1	-	-	-	-	-	-	-	146	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
205	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
245	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	29	-	-	6	-	2	-	-	-	-	-	-	-	-	-	-	3	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
65	-	3	-	-	-	2	3	3	1	-	-	-	-	-	2	-	-	-	-	4	-	-	61	-	-	-	-	-	-	-	-	1	-	-	-	3	-	-	36
255	-	-	-	-	12	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
42	-	-	-	-	1	-	-	3	-	2	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	4	-	-	-	-	-	-
63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	14	10	1	3	170	7	43	64	16	5	1	12	53	13	53	2	1	6	5	26	6	41	2818	52	37	6	9	2	11	3	5	43	5	4	11	165	30	2	1607

P. flabellum	Prioniodus elegans	P. serratus	Protopanderodus? giganteus	P. gradatus	P. rectus	P. sp. aff. P. varicostatus	Protoprioniodus aranda	P. papilliosus	P.sp. 1	Pteracontiodus cryptodens	Ptiloncodus simplex	"Scandodus" mysticus	Scandodontiform element 2	"Scolopodus" quadratus	S.? peselephantis	"S." sp.	Scolopodontiform element 1	Serratognathus armadillodus	Spinodus horridus	Stolodus sp. aff. S. stola	Strachanognathus parvus	Texania heligma	Tripodus laevis	T.? sp.	Tropodus sweeti	Total number of specimens	Sample number	Lithotype	Derivation of clasts
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	100	Matrix	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	82	Parted limestone	Lower slope lithotypes
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	84		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	85		
-	-	-	-	-	1	-	2	3	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	20	95		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	96		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	134		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	207		
-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	220		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	206	Calcarenite	
-	-	-	-	-	6	-	11	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	93	208		
49	-	-	-	-	9	-	11	6	1	-	-	-	-	-	4	-	-	-	-	-	1	1	-	-	-	177	218		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	86	Dolomite	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	87		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	219	Chert	
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37	79	Wackestone	Shelf edge lithotypes
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	21	81		
-	-	-	-	-	-	-	-	2	-	-	1	-	-	-	-	1	-	-	-	1	-	3	-	-	-	119	92		
-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	89	93		
9	-	-	-	-	5	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	2	379	94-A		
-	-	-	-	-	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	1	-	333	94-B		
8	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	110	98		
50	-	-	-	-	7	4	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	2	370	99		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	101		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	1	-	176	102		
5	-	-	-	-	1	1	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	135	102-A		
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	106		
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	177		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	178		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	198		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	216		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	217		
3	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	222		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	252		
-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	43	256		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	260		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	292		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36	293		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	105	Boundstone	
-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	2	-	28	186		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	195		
-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	1	-	-	1	118	199		
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	253		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	274		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	294		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	298		
160	-	-	-	1	10	-	-	-	-	-	-	-	1	8	-	-	-	-	-	-	-	-	-	-	16	396	164	Calcirudite	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	185		
163	-	-	-	-	-	1	-	1	-	-	-	1	-	5	-	-	-	-	-	-	-	-	-	3	7	669	187		
-	-	-	-	-	4	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	3	73	189		
-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	189-A		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	131	Lumpy wackestone	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	132		
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	133		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	197		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	221		
6	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	227		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	228-A		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	18	254		
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	73	254-A		
-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	40	273		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	MPN		
-	-	-	-	-	-	-	24	77	-	1	-	-	-	-	3	-	-	-	-	-	53	234	-	-	-	441	91	Mudstone	
-	-	-	-	-	23	-	10	1	-	-	-	2	-	-	-	-	-	-	-	-	6	2	-	-	-	76	295		
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	5	59	83	Shelf-derived grainstone	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	10	297		
-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	128	296	Lumpy mudstone	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	179	Oolitic grainstone	Clasts of Bed 11 age from Bed 14
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	259		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	56	14 Lumpy wackestone	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	35	58		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	73		
-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	78	180		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	183		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	188		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	270		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	277		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	279		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	10	121	280		
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	99	53	14 Calcirudite	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	66		
-	-	-	-	-	2	-	24	13	-	-	-	3	-	12	-	-	-	-	-	-	2	14	-	-	1	369	67		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	76		
7	-	-	-	-	6	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	5	70	31	14 Wackestone–grainstone	
3	-	-	-	3	5	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	240	172		
-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	86	210		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	244-A		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	161		
5	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	247		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	276		
11	-	-	-	-	4	-	-	-	1	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	1	179	25	14 Parted limestone	
8	1	-	1	-	3	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2	524	18	14 Calcarenite	
2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	176	167		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	205		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	245		
-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	45	11	14 Conglomerate	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	39		
-	-	-	-	-	1	-	-	-	-	-	-	2	-	-	-	-	-	-	-	3	-	-	2	-	2	129	65		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	255		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	17	14 Dolomite	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	40	Bed 11	
21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	42		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	63		
566	1	2	2	11	102	11	90	106	2	2	2	13	1	29	24	1	1	3	1	9	62	263	3	8	65	6739	Total		

APPENDIX 3

Conodonts from penecontemporaneous clasts in Bed 14

Acodus deltatus	*Ansella jemtlandica*	Acodontiform element 1	Acodontiform element 2	*Bergstroemognathus extensus*	*Cornuodus longibasis*	*Drepanodus arcuatus*	*Drepanodus* sp. 4	Drepanodontiform element 2	*Drepanoistodus basiovalis*	*Erraticodon balticus*	*Eucharodus parallelus*	*E. toomeyi*	*Juanognathus jaanussoni*	*J. variabilis*	*Oepikodus evae*	*Oistodus lanceolatus*	"*O.*" *inaequalis*	*O.? tablepointensis*	Oistodontiform element 1	Oistodontiform element 3	*Paltodus jemtlandicus*	*Paracordylodus gracilis*	*Parapaltodus simplicissimus*	*P.* sp.	*Parapanderodus arcuatus*	*P. asymmetricus*	*P. emarginatus*	*P. gracilis*	*P. paracornuformis*	*P.* sp. 1	*Paraprioniodus costatus*	*Paroistodus? mutatus*	*Paroistodus originalis*	*P. parallelus*	*Periodon aculeatus*	Prioniodontiform element	*Protopanderodus gradatus*	*P. rectus*	P. sp. cf. *P. varicostatus*	*Protoprioniodus aranda*	*Pteracontiodus cryptodens*	*Ptiloncodus simplex*	*Scalpellodus* sp. 1	"*Scandodus*" *mysticus*	*Scolopodus oldstockensis*	*Spinodus ramosus*	*Strachanognathus parvus*	*Tripodus laevis*	*Tropodus sweeti*	*Walliserodus ethingtoni*	New genus A new species 1	New genus A new species 2	New genus B new species 1	Scolopodontiform element 1	Total number of specimens	Sample number	Lithotype	Derivation of clasts
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	12	Parted limestone	Lower slope lithotypes
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	55		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	61		
-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	74		
-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-	-	-	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	19	13	Calcarenite	
-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	204		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	215		
-	-	-	-	-	-	1	-	-	6	-	7	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	69	-	-	-	5	-	3	-	-	3	-	-	-	-	-	-	-	-	-	-	99	246		
-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	47	Conglomerate	
-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	8	64		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	71		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	291	Dolomite	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	263	Chert	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	268		
-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	3	1	-	5	-	-	-	-	-	-	19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	32	Matrix	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	281	Shelf-derived grainstone	Shelf edge lithotypes
-	-	-	-	-	-	1	-	-	4	-	-	-	1	-	-	2	-	-	-	-	-	5	-	-	-	-	-	-	-	2	-	-	-	11	96	-	-	-	3	-	-	-	1	1	-	-	-	-	-	1	1	-	-	-	129	45	Calcirudite	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	1	33	-	-	2	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	43	60		
-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	47	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	59	76-B		
-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	1	6	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	13	78-2		
-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	7	-	-	6	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	20	173		
1	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	4	-	-	1	-	1	-	4	-	3	1	-	1	-	1	-	-	8	5	426	-	-	6	-	1	-	-	-	1	1	-	-	-	-	-	-	1	-	-	469	181		
-	-	-	-	-	-	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	6	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	213		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	250		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-	2	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	251		
-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	3	-	115	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	127	290		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	19	Packstone–wackestone	
-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	30	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	35	20		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	48		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	51		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	33	-	-	2	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	43	59		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	63		
-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	2	1	-	-	-	-	5	-	-	3	-	-	-	4	-	-	2	6	21	-	-	-	2	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	50	70		
-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	5	-	17	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	26	76-1		
-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	10	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18	88		
-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	5	139		
-	-	1	-	-	-	1	-	-	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4	97	1	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	111	267		
-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	5	-	-	-	-	-	-	-	2	4	-	-	-	1	-	-	-	6	1	98	-	-	15	-	-	2	1	-	3	-	-	-	2	-	-	-	-	-	-	142	269		
-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	2	-	1	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33	271		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	2	-	3	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	11	278		
-	-	2	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	3	-	-	-	-	-	-	5	6	192	-	-	13	1	-	1	6	7	1	-	-	-	1	-	9	-	-	-	-	254	21	Grainstone–rudstone	
-	1	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	1	-	-	-	-	-	-	-	6	155	-	-	4	-	-	1	5	2	3	-	-	-	-	-	3	-	-	-	-	188	21-B		
-	2	-	-	-	-	-	-	1	2	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	10	-	-	-	-	-	1	-	2	2	65	-	-	9	-	-	-	-	2	-	-	1	-	1	-	-	-	-	2	1	104	24		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	5	26		
-	-	-	1	-	-	-	-	-	2	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	2	-	-	-	-	-	-	11	50		
-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	68		
-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	1	-	9	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	20	111		
-	-	-	-	-	-	-	-	-	1	3	-	-	-	-	-	-	-	1	1	-	-	-	-	-	8	1	-	-	-	-	-	-	1	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	1	24	112		
-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	3	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	113		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	214		
-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	1	3	-	-	-	-	-	6	-	-	-	6	1	-	1	-	1	-	-	-	-	-	-	34	276-1		
-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-	11	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	284		
-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	285		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	286		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	5	1	Boundstone	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26	2		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	3		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	4		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	1	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	18	5		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	3	6		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	7		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	8		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	9		
-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	29		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	34		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	30		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	35		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	36		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	14	52		
-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	5	57		
-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	62		
-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	4	193		
-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	45	-	2	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	52	194		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	1	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	287		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	288		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	7	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	10	Lumpy mudstone	
-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	49		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	72		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	89		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	182		
1	6	3	2	1	4	13	1	4	33	4	10	1	7	1	4	44	4	4	2	1	2	5	11	6	98	17	3	6	1	11	4	3	48	50	814	1	2	74	15	6	11	12	40	17	2	8	1	9	2	15	2	1	2	2	2451	Total		

APPENDIX 4

Conodonts from older clasts in Bed 14

Acontiodus iowensis	*Cordylodus caboti*	*Cordylodus proavus*	*Cordylodus* sp. (fragment)	*Drepanoistodus* sp. aff. *D. concavus*	*Eoconodontus notchpeakensis*	*Eucharodus parallelus*	*Loxodus bransoni*	*Oistodus? triangularis*	*Oneotodus costatus*	*Paroistodus proteus*	*Prioniodus?* sp.	*Proconodontus muelleri*	*Rossodus manitouensis*	*Teridontus nakamurai*	*Variabiliconus* sp. aff. *V. bassleri*	Total number of specimens	Sample number	Lithotype
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	44	Oolite
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	162	
-	-	-	-	-	1	-	1	1	-	-	-	-	13	-	6	22	16	Lumpy *Nula*–wackestone
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	142	Dolomitic wackestone–grainstone with well rounded quartz grains
1	-	-	-	2	-	1	-	-	1	2	-	-	-	-	2	9	166	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	283	
-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	1	3	164	*Epiphyton* boundstone
-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	192	
-	-	4	-	-	2	-	-	-	-	-	-	-	-	-	-	6	27	Old clasts of parted limestone
-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	2	29	
-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	33	
-	1	2	-	-	6	-	-	-	-	-	-	-	-	-	-	9	41	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	252	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	22	Conglomerate with flat mudstone pebbles
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	37	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	38	
1	3	6	1	2	9	1	1	1	1	2	2	1	13	1	9	54	Total	

PLATE 1

The specimens in figures 6, 7, 14, 25, 28, and 29 were photographed with a light microscope, the remainder with a scanning electron microscope.

In parenthesis, bed number and sample number are given for each occurrence.

Figures 1–4. *Acodus deltatus* Lindström. (Bed 10, 239.)

1. Drepanodontiform element, lateral view, hypotype GSC 90303, x40.
2. Prioniodontiform element, lateral view, hypotype GSC 90304, x50.
3. Tetraprioniodontiform element, lateral view, hypotype GSC 90305, x70.
4. Oistodontiform element, lateral view, GSC 90306, x100.

Figure 5. *Acodus*? *gladiatus* Lindström s.f.
Lateral view, hypotype GSC 90307, x50. (Bed 12; 184.)

Figure 6. *Paroistodus*? *mutatus* (Branson and Mehl)
Acodontiform element, lateral view, hypotype GSC 90308, x70. (Bed 12; 99.)

Figure 7. Acodontiform element 2
Lateral view, figured specimen, GSC 90309, x90. (Bed 14; 54.)

Figures 8, 9. *Tropodus sweeti* (Serpagli). (Bed 12; 184.)

8. Oistodontiform element, inner lateral view, hypotype GSC 90310, x40.
9. Prioniodontiform element, lateral view, hypotype GSC 90311, x40.

Figure 10. Acodontiform element 1.
Lateral view, figured specimen, GSC 90312, x40. (Bed 12; 198.)

Figures 11, 12. *Drepanodus*? *planus* (Pander). (Bed 12; 25.)

11. Sculponeaform element, outer lateral view, hypotype GSC 90313, x40.
12. Arcuatiform element, lateral view, hypotype GSC 90314, x40.

Figure 13. *Acontiodus* sp. 2 Uyeno and Barnes s.f.
Inner lateral view, hypotype GSC 90315, x35. (Bed 12; 167.)

Figure 14. *Acontiodus latus* Pander s.f.
Posterior view, hypotype GSC 90316, x75. (Bed 14; 54.)

Figures 15, 16. *Ansella jemtlandica* (Löfgren). (Bed 14; 24.)

15. Triangular element, anterolateral view, hypotype GSC 90317, x90.
16. Biconvex element, lateral view, hypotype GSC 90318, x80.

Figure 17. *Paroistodus*? *mutatus* (Branson and Mehl).
Oistodontiform element, lateral view, hypotype GSC 90319, x80. (Bed 14; 271.)

Figure 18. *Acontiodus iowensis* Furnish.
Hypotype GSC 90320, x90. (Bed 14; 166.)

Figure 19–22. *Bergstroemognathus extensus* (Graves and Ellison).

19. Prioniodiniform element, posterior view, hypotype GSC 90321, x35. (Bed 12; 167.)
20. Flat prioniodiniform element, posterior view, hypotype GSC 90322, x50. (Bed 12; 94-A.)
21. Trichonodelliform element, posterior view, hypotype GSC 90323, x50. (Bed 12; 94-A.)
22. Falodontiform element, lateral view, hypotype GSC 90324, x35. (Bed 12; 94-A.)

Figures 23, 24. *Cristodus loxoides* Repetski.

23. Multidenticulate element, inner lateral view, hypotype GSC 90325, x30. (Bed 10; 300.)
24. Monodenticulate element, outer lateral view, hypotype GSC 90326, x30. (Bed 14; 54.)

Figure 25. *Coelocerodontus bicostatus* van Wamel s.f.
Lateral view, hypotype GSC 90327, x75. (Bed 10; 239.)

Figure 26. *Cordylodus proavus* Müller.
Lateral view, hypotype GSC 90328, x60. (Bed 14; 27.)

Figure 27. *Cordylodus caboti* Bagnoli et al.
Lateral view, hypotype GSC 90329, x55. (Bed 12; 275.)

Figures 28, 29. *Cornuodus longibasis* (Lindström)

28. Lateral view, hypotype GSC 90330, x45. (Bed 14; 92.)
29. Lateral view, hypotype GSC 90331, x65. (Bed 12; 94-A.)

PLATE 1

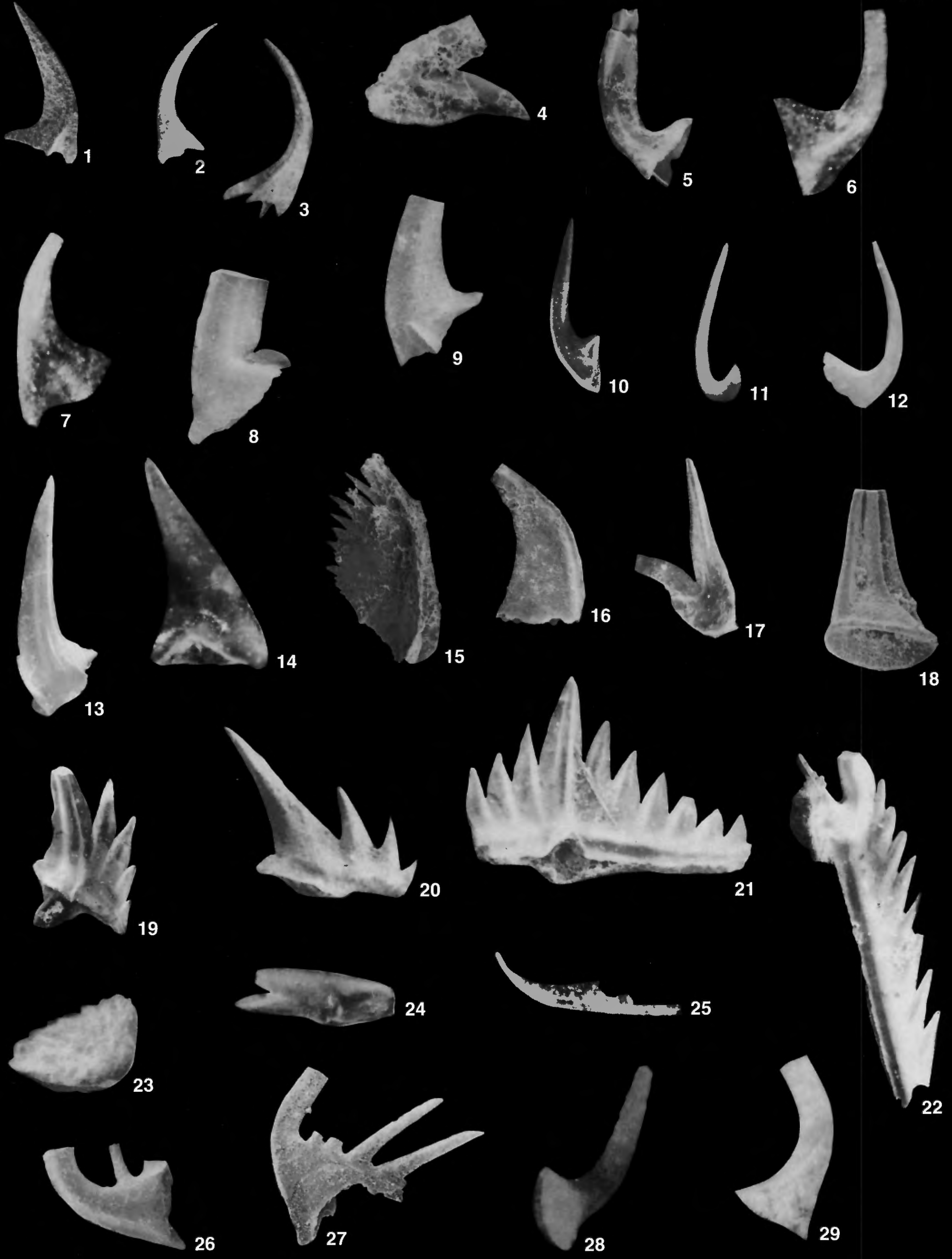


PLATE 2

Figures 1, 4, 6, 8, and 16–31 were photographed with a light microscope, the remainder with a scanning electron microscope.

Figures 1, 2, 4–6. *Drepanodus arcuatus* Pander.

1. Arcuatiform element, lateral view, hypotype GSC 90332, x35. (Bed 14; 18.)
2. Sculponeaform element, lateral view, holotype GSC 90333, x35. (Bed 14; 110.)
4. Pipaform element, lateral view, holotype GSC 90335, x50. (Bed 14; 167.)
5. Arcuatiform element, lateral view, hypotype GSC 90336, x40. (Bed 14; 184.)
6. Graciliform element, lateral view, hypotype GSC 90337, x40. (Bed 14; 11.)

Figures 3, 7. *Drepanodus*? *planus* (Pander).

3. Costate pipaform element, posterolateral view, hypotype GSC 90334, x40. (Bed 14; 25.)
7. Arcuatiform element, posterolateral view, hypotype GSC 90338, x35. (Bed 14; 25.)

Figure 8. *Eucharodus toomeyi* (Ethington and Clark).
Lateral view, hypotype GSC 90339, x65. (Bed 14; 246.)

Figure 9. *Drepanodus*? sp. 4 Repetski s.f.
Inner lateral view, hypotype GSC 90340, x70. (Bed 14; 70.)

Figure 10. *Drepanodus* sp. 2 Ethington and Clark s.f.
Lateral view, hypotype GSC 90341, x65. (Bed 14; 54.)

Figure 11. *Drepandous* sp. 4 Serpagli s.f.
Posterolateral view, hypotype GSC 90342, x50. (Bed 10; 262.)

Figure 12. Drepanodontiform element 1.
Posterolateral view, figured specimen GSC 90343, x35. (Bed 10; 230–2.)

Figure 13. Drepanodontiform element 2.
Lateral view, figured specimen GSC 90344, x40. (Bed 12; 184.)

Figures 14, 15. *Drepanoistodus* sp. aff. *D. basiovalis* (Sergeeva) *sensu* Ethington and Clark. (Bed 10; 225.)

14. Homocurvatiform element, outer lateral view, hypotype GSC 90345, x60.
15. Suberectiform element, outer lateral view, hypotype GSC 90346, x60.

Figures 16, 17. *Drepanoistodus basiovalis* (Sergeeva). (Bed 12; 91.)

16. Homocurvatiform element, lateral view, hypotype GSC 90347, x100.
17. Oistodontiform element, lateral view, hypotype GSC 90348, x100.

Figure 18. *Drepanodus*? sp. 1 s.f.
Outer lateral view, figured specimen GSC 90349, x75. (Bed 10; 138.)

Figure 19. *Drepanodus* sp. 2 s.f.
Posterolateral view, figured specimen GSC 90350, x65. (Bed 14; 11.)

Figures 20–23. *Drepanoistodus* sp. aff. *D. concavus* (Branson and Mehl). (Bed 14; 163.)

20. Homocurvatiform element, lateral view, hypotype GSC 90351, x60.
21. Oistodontiform element, lateral view, hypotype GSC 90352, x60.
22. Suberectiform element, lateral view, hypotype GSC 90353, x100.
23. Pipaform element, posterolateral view, hypotype GSC 90354, x90.

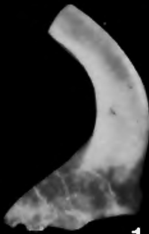
Figures 24–26. *Drepanoistodus forceps* (Lindström). (Bed 12; 94-A.)

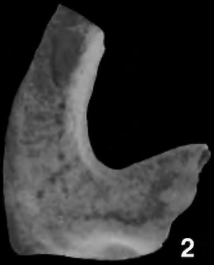
24. Oistodontiform element, lateral view, hypotype GSC 90355, x90.
25. Homocurvatiform element, lateral view, hypotype GSC 90356, x70.
26. Suberectiform element, lateral view, hypotype GSC 90357, x70.

Figure 27. *Drepanoistodus inaequalis* (Pander). Hypotype, GSC 90358, x75. (Bed 10; 175.)

Figures 28–31. *Drepanoistodus inconstans* (Lindström). (Bed 10; 236.)

28. Homocurvatiform element (note costa), lateral view, hypotype GSC 90359, x75.
29. Homocurvatiform element, lateral view, hypotype GSC 90360, x75.
30. Suberectiform element, lateral view, hypotype GSC 90361, x75.
31. Oistodontiform element, lateral view, hypotype GSC 90362, x75.

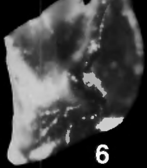

1

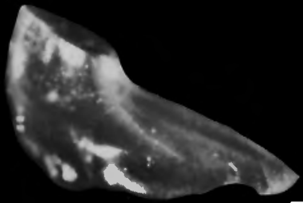

2


3


4

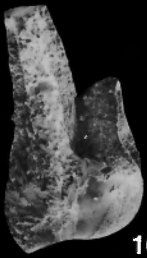

5


6


7


8


9


10


11

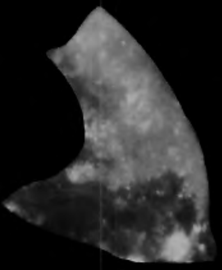

12


13

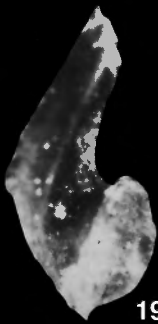

14


15


16


17


18


19


20


21

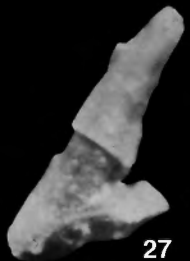

22

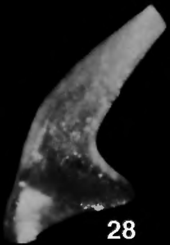

23


24


25


26


27


28


29


30

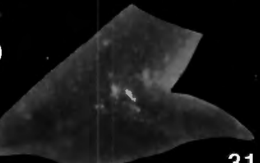

31

PLATE 3

Figures 11, 12, 18–21, and 30–33 were photographed with a light microscope, the remainder with a scanning electron microscope.

Figure 1. *Paroistodus*? *mutatus* (Branson and Mehl).
Costate drepanodontiform element, lateral view, hypotype GSC 90363, x55. (Bed 14; 271.)

Figure 2. *Eoconodontus notchpeakensis* (Miller).
Lateral view, hypotype GSC 90364, x65. (Bed 14; 41.)

Figure 3–5. *Erraticodon balticus* Dzik. (Bed 14; 112.)
3. Fragment of ozarkodiniform element, lateral view, hypotype GSC 90365, x70.
4. Fragment hindeodelliform element, lateral view, hypotype GSC 90366, x35.
5. Fragment of element, lateral view, hypotype GSC 90367, x30.

Figure 6. *Eucharodus parallelus* (Branson and Mehl).
Posterolateral view, hypotype GSC 90368, x35. (Bed 14; 163.)

Figure 7. *Glyptoconus quadraplicatus* (Branson and Mehl).
Posterolateral view, hypotype GSC 90369, x45. (Bed 10; 135.)

Figures 8–11. *Fryxellodontus*? *corbatoi* Serpagli. (Bed 12; 275.)
8. "Symmetricus" element, hypotype GSC 90370, x30.
9. "Intermedius" element, hypotype GSC 90371, x60.
10. "Intermedius" element, hypotype GSC 90372, x70.
11. "Intermedius" element, hypotype GSC 90373, x80. (Bed 14; 54.)

Figure 12. *Fryxellodontus*? sp. s.f.
Posterior view, figured specimen, GSC 90374, x80. (Bed 12; 275.)

Figure 13. *Juanognathus jaanussoni* Serpagli.
Posterior view, hypotype GSC 90375, x40. (Bed 12; 199.)

Figure 14. *Juanognathus variabilis* Serpagli.
Posterolateral view, hypotype GSC 90376, x40. (Bed 14; 65.)

Figures 15, 16. *Jumudontus gananda* Cooper
15. Lateral view, hypotype GSC 90377, x35. (Bed 12; 245.)
16. Aboral-lateral view, hypotype GSC 90378, x60. (Bed 12; 295.)

Figure 17. *Loxodus bransoni* Furnish.
Lateral view, hypotype GSC 90379, x100. (Bed 14; 16.)

Figures 18–22. *Oistodus*? *elongatus* Lindström. (Bed 10; 239.)
18. Lateral view, hypotype GSC 90380, x65.
19. Lateral view, hypotype GSC 90381, x65.
20. Lateral view, hypotype GSC 90382, x70.
21. Lateral view, hypotype GSC 90383, x70.
22. Lateral view, hypotype GSC 90384, x80.

Figures 23–26. *Oistodus lanceolatus* Pander. (Bed 14; 18.)
23. Cladognathodontiform element, outer lateral view, hypotype GSC 90385, x35.
24. Cordylodontiform element, outer lateral view, hypotype GSC 90386, x35.
25. Cordylodontiform element, lateral view, hypotype GSC 90387, x35.
26. Deltaform element, posterior view, hypotype GSC 90388, x70.

Figure 27. "*Oistodus*" *inaequalis* Pander *sensu* Ethington and Clark s.f.
Inner lateral view, hypotype GSC 90389, x70. (Bed 12; 254.)

Figure 28. *Oistodus*? *tablepointensis* Stouge.
Outer lateral view, hypotype GSC 90390, x40. (Bed 14; 112.)

Figure 29. *Oistodus*? *triangularis* Furnish.
Outer lateral view, hypotype GSC 90391, x115. (Bed 14; 16.)

Figure 30. *Oistodus* sp. 1 s.f.
Lateral view, hypotype GSC 90392, x95. (Bed 12; 218.)

Figure 31. *Paroistodus*? *mutatus* (Branson and Mehl).
Oistodontiform element, lateral view, hypotype GSC 90393, x100. (Bed 12; 91.)

Figure 32. Oistodontiform element 1 s.f.
Lateral view, figured specimen GSC 90394, x70. (Bed 14; 181.)

Figure 33. Oistodontiform element 2 s.f.
Lateral view, figured specimen GSC 90395, x80. (Bed 12; 199.)

Figure 34. Oistodontiform element 3 s.f.
Lateral view, figured specimen GSC 90396, x45. (Bed 14; 47.)

PLATE 3

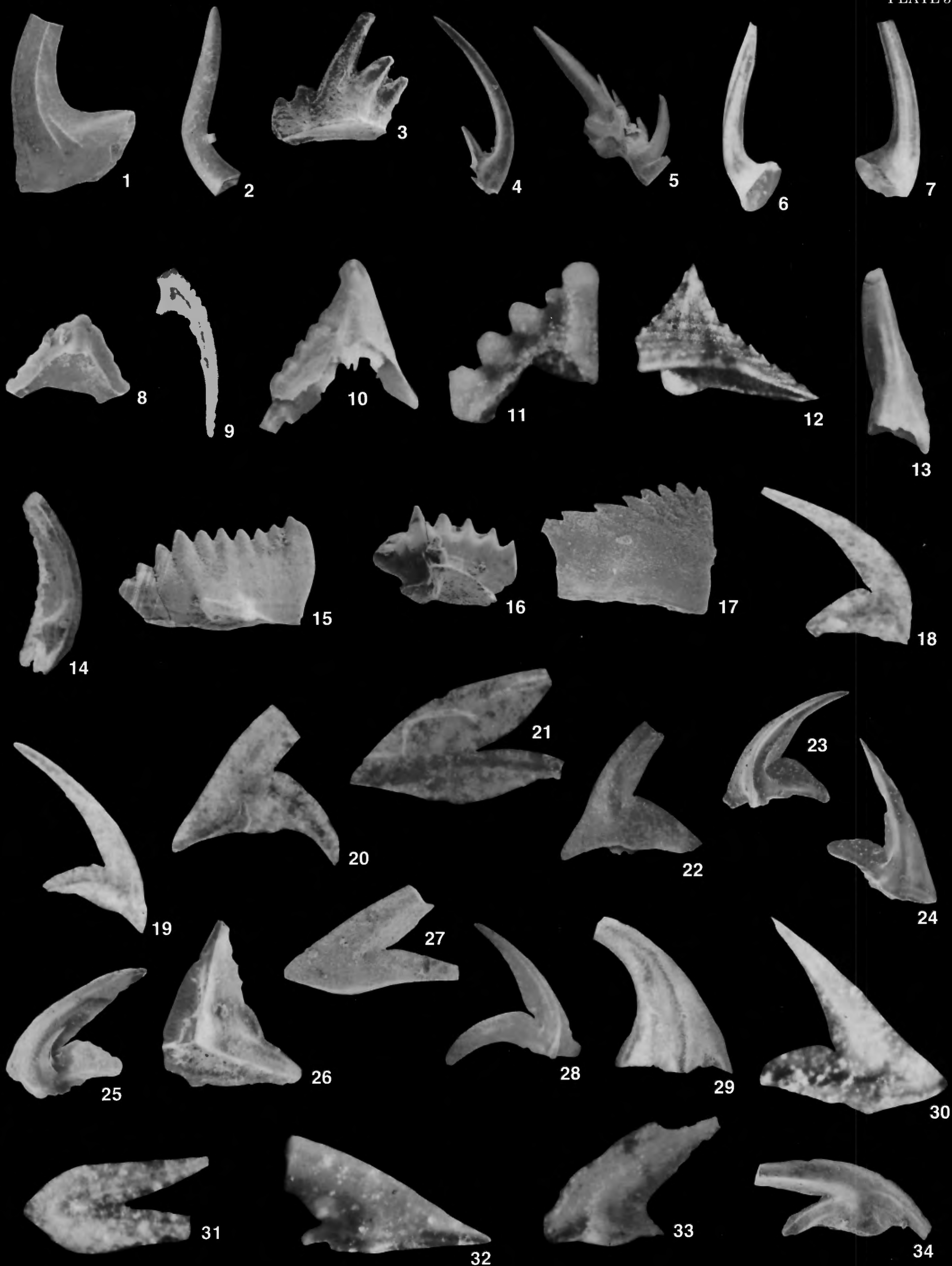

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34

PLATE 4

Figures 2, 3, 7-9, 11, 13-17, and 22-24 were photographed with a light microscope, the remainder with a scanning electron microscope.

Figure 1. *Oneotodus costatus* Ethington and Brand.
Lateral view, hypotype GSC 90397, x35. (Bed 14; 54.)

Figure 2. *Paltodus jemtlandicus* Löfgren.
Inner lateral view, hypotype GSC 90398, x100. (Bed 14; 181.)

Figure 3. *Paltodus*? sp. s.f.
Lateral view, figured specimen GSC 90399, x100. (Bed 10; 262.)

Figures 4-6. *Paracordylodus gracilis* Lindström. (Bed 12; 275.)
4. Oistodontiform element, lateral view, hypotype GSC 90400, x95.
5. Cordylodiform element, lateral view, hypotype GSC 90401, x60.
6. Paracordylodiform element, lateral view, hypotype GSC 90402, x60.

Figure 7. *Parapaltodus simplicissimus* Stouge.
Lateral view, hypotype GSC 90403, x85. (Bed 14; 213.)

Figures 8, 9. *Parapaltodus* sp. (Bed 10; 225.)
8. Lateral view, figured specimen GSC 90404, x50.
9. Lateral view, figured specimen GSC 90405, x90.

Figure 10. *Parapanderodus arcuatus* Stouge.
Lateral view, hypotype GSC 90406, x55. (Bed 14; 181.)

Figure 11. *Parapanderodus gracilis* (Ethington and Clark).
Lateral view, hypotype GSC 90407, x55. (Bed 12; 184.)

Figure 12. *Parapanderodus* sp. 1 s.f.
Lateral view, figured specimen GSC 90408, x40. (Bed 14; 45.)

Figures 13-15. *Paraprioniodus costatus* (Mound).
13. Broken cordylodiform element, lateral view, hypotype GSC 90409, x75. (Bed 14; 287.)
14, 15. Tetraprioniodiform elements, lateral views, hypotypes GSC 90410, 90411, x75. (Bed 14; 281.)

Figures 16, 17. *Paroistodus numarcuatus* (Lindström). (Bed 10; 236.)
16. Drepanodontiform element, lateral view, hypotype GSC 90412, x80.
17. Oistodontiform element, lateral view, hypotype GSC 90413, x80.

Figures 18, 19. *Paroistodus originalis* (Sergeeva). (Bed 12; 218.)
18. Oistodontiform element, lateral view, hypotype GSC 90414, x80.
19. Drepanodontiform element, lateral view, hypotype GSC 90415, x80.

Figures 20-21. *Paroistodus parallelus* (Pander). (Bed 10; 239.)
20. Drepanodontiform element, lateral view, hypotype GSC 90416, x70.
21. Oistodontiform element, lateral view, hypotype GSC 90417, x70.

Figures 22, 23. *Paroistodus proteus* (Lindström). (Bed 12; 275.)
22. Drepanodontiform element, lateral view, hypotype GSC 90418, x90.
23. Oistodontiform element, lateral view, hypotype GSC 90419, x90.

Figure 24. *Paroistodus* sp. B Stouge s.f.
Lateral view, hypotype GSC 90420, x75. (Bed 12; 189.)

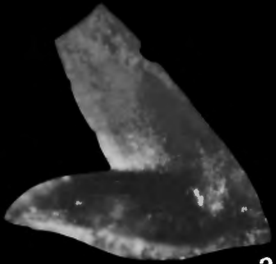
Figures 25-27. *Periodon aculeatus* Hadding. Intermediate form. (Bed 14; 181.)
25. Oistodontiform element, lateral view, hypotype GSC 81354, x70.
26. Multiramiform element, lateral view, hypotype GSC 81356, x70.
27. Ozarkodiniform element, lateral view, hypotype GSC 81355, x70.

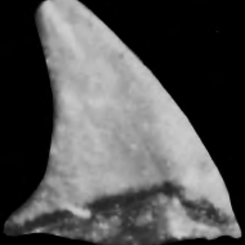
Figures 30-32. *Periodon aculeatus* Hadding. Advanced form, x75. (Bed 14; 45.)
30. Ozarkodiniform element, lateral view, hypotype GSC 81358.
31. Multiramiform element, lateral view, hypotype GSC 81359.
32. Oistodontiform element, lateral view, hypotype GSC 81357.

Figures 28, 29, 33, 34. *Periodon flabellum* (Lindström). (Bed 14; 25.)
28. Ozarkodiniform element, early form, lateral view, hypotype GSC 90421, x75.
29. Multiramiform element, lateral view, hypotype GSC 90422, x90.
33. Ozarkodiniform element, lateral view, hypotype GSC 90423, x90.
34. Oistodontiform element, lateral view, hypotype GSC 90424, x50.

PLATE 4


1


2


3

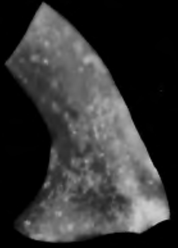

4


5


6


7

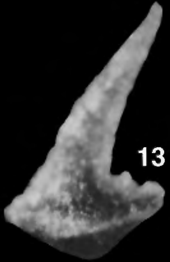

8


9


10


11


12


13


14


15

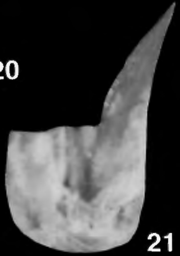

16


17


18


19


20

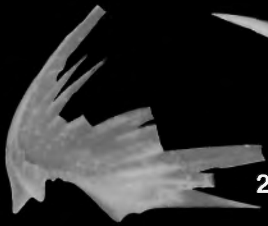

21


22


23


24

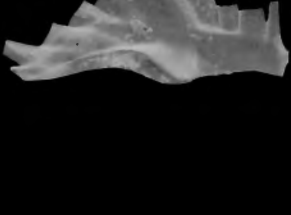

25


26


27

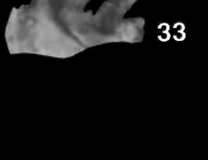

28


29


30


31


32


33

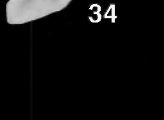

34

PLATE 5

Figures 24–30 were photographed with a light microscope, the remainder with a scanning electron microscope.

Figures 1-3. *Periodon*? *primus* Stouge and Bagnoli. (Bed 12; 275.)

1. Oistodontiform element, lateral view, hypotype GSC 90425, x90.
2. Ozarkodiniform element, lateral view, hypotype GSC 90426, x100.
3. Cordylodiform element, lateral view, hypotype GSC 90427, x100.

Figures 4-6. *Oepikodus communis* (Ethington and Clark). (Bed 12; 92.)

4. Oepikodiform element, lateral view, hypotype GSC 90428, x100.
5. Oistodontiform element, lateral view, hypotype GSC 90429, x65.
6. Prioniodontiform element, lateral view, hypotype GSC 90430, x80.

Figures 7-9. *Oepikodus evae* Lindström. (Bed 14; 18.)

7. Oistodontiform element, lateral view, hypotype GSC 90431, x90.
8. Oepikodiform element, lateral view, hypotype GSC 90432, x75.
9. Prioniodontiform element, posterior view, hypotype GSC 90433, x100.

Figures 10–12. *Oepikodus* sp. aff. *O. minutus* (McTavish). (Bed 12; 83.)

10. Oepikodiform element, lateral view, figured specimen GSC 90434, x75.
11. Prioniodontiform element, lateral view, note second denticulate process, figured specimen GSC 90435, x80.
12. Prioniodontiform element, lateral view, note second denticulate process, figured specimen GSC 90436, x80.

Figures 13–16. *Prioniodus elegans* Pander. (Bed 10; 233.)

13. Oistodontiform element, lateral view, hypotype GSC 90437, x40.
14. Belodontiform element, lateral view, hypotype GSC 90438, x80.
15. Prioniodontiform element, lateral view, hypotype GSC 90439, x80.
16. Tetraprioniodontiform element, anterolateral view, hypotype GSC 90440, x80.

Figures 17–20. *Prioniodus marginalis* n. sp. (Bed 10; 239.)

17. Oistodontiform element, lateral view, holotype GSC 90441, x75.
18. Belodontiform element, lateral view, paratype GSC 90442, x75.
19. Prioniodontiform element, lateral view, paratype GSC 90443, x75.
20. Tetraprioniodontiform element, lateral view, paratype GSC 90444, x75.

Figures 21–25. *Prioniodus serratus* n. sp. (Bed 10; 202.) All x90.

21. Oistodontiform element, lateral view, note incipient denticulation, paratype GSC 90445.
22. Belodontiform element, lateral view, holotype GSC 90446.
23. Prioniodontiform element, lateral view, paratype GSC 90447.

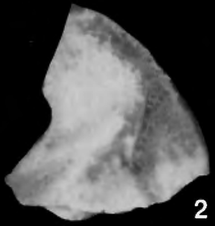
24, 25. Tetraprioniodontiform elements, lateral views, paratypes GSC 90448, 90449.

Figures 26–30. *Prioniodus* sp. (Bed 12; 275.) All x110.

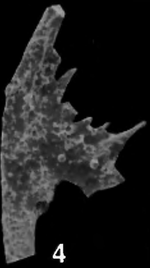
26. Oistodontiform element, lateral view, figured specimen GSC 90450.
27. Oepikodiform element, lateral view, figured specimen GSC 90551.
28. Prioniodontiform element, lateral view, figured specimen GSC 90452.
29. Oepikodontiform element, lateral view, figured specimen GSC 90453.
30. Costate oepikodiform element, lateral view, figured specimen GSC 90454.

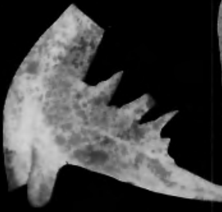
PLATE 5


1


2


3

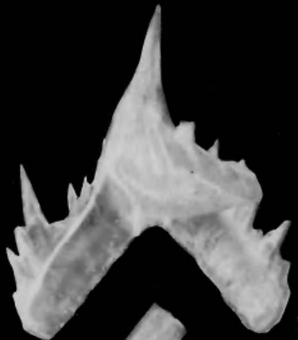

4


5

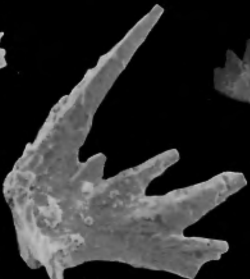

6

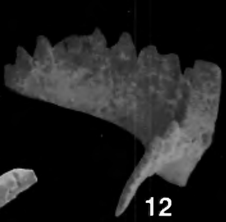

7


8


9

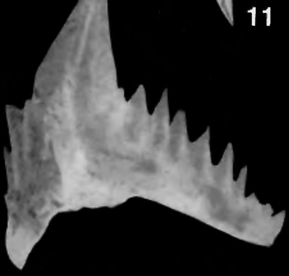

10

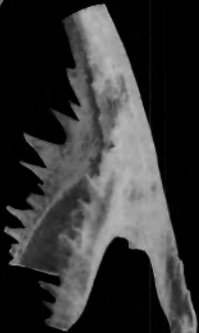

11


12


13

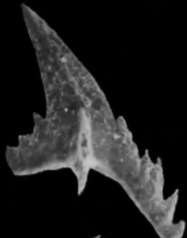

14


15

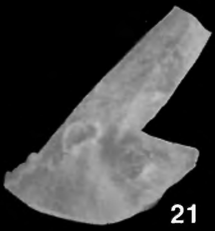

16

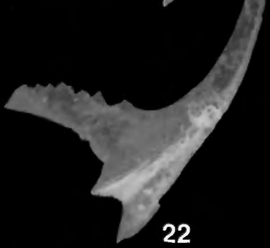

17

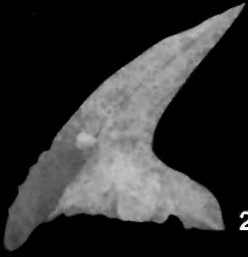

18

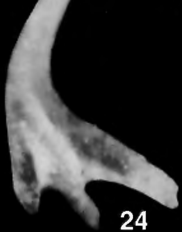

19

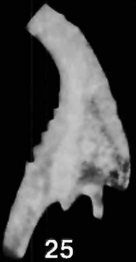

20


21

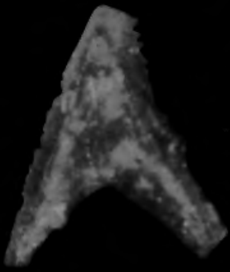

22

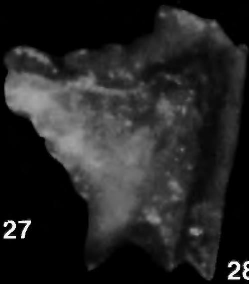

23

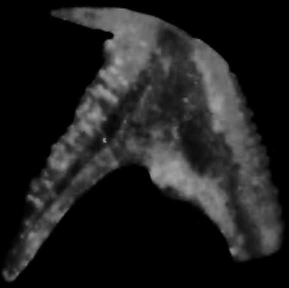

24


25


26


27


28


29

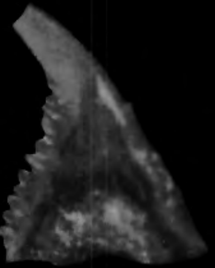

30

PLATE 6

Figures 5, 12, 17, and 30–37 were photographed with a light microscope, the remainder with a scanning electron microscope.

Figure 1. Prioniodontiform element.
Posterior view, figured specimen GSC 90455, x70. (Bed 14; 267.)

Figure 2. *Proconodontus muelleri* Miller.
Lateral view, hypotype GSC 90456, x50. (Bed 12; 275.)

Figures 3, 4. *Protopanderodus elongatus* Serpagli. (Bed 14; 54.)
3. Symmetrical acontiodontiform element, lateral view, hypotype GSC 90457, x85.
4. Scandodontiform element, lateral view, hypotype GSC 90458, x80.

Figure 5. *Protopanderodus gradatus* Serpagli.
Symmetrical acontiodontiform element, lateral view, hypotype GSC 90459, x95. (Bed 14; 194.)

Figures 6–8. *Protopanderodus rectus* (Lindström). (Bed 12; 184.)
6. Symmetrical acontiodontiform element, lateral view, hypotype GSC 90460, x35.
7. Asymmetrical acontiodontiform element, inner side, hypotype GSC 90461, x65.
8. Asymmetrical acontiodontiform element, posterolateral view, hypotype GSC 90462, x70.

Figure 9. *Protopanderodus* sp. cf. *P. varicostatus* (Sweet and Bergström).
Posterolateral view, hypotype GSC 90463, x50. (Bed 14; 246.)

Figures 10–12. *Protoprioniodus aranda* Cooper.
10. Oistodontiform element, lateral view, hypotype GSC 90464, x80. (Bed 12; 218.)
11. Ramiform element, lateral view, hypotype GSC 90465, x120. (Bed 12; 218.)
12. Costate oistodontiform element, lateral view, hypotype GSC 90466, x100. (Bed 12; 295.)

Figures 13, 14, 20. *Protoprioniodus papiliosus* (van Wamel). (Bed 12; 91.)
13. Ramiform element, lateral view, hypotype GSC 90467, x135.
14. Deltaform element, posterior view, hypotype GSC 90468, x150.
20. Oistodontiform element, lateral view, hypotype GSC 90469, x120.

Figures 15, 16. *Protoprioniodus simplicissimus* McTavish. (Bed 12; 275.)
15. Oistodontiform element, lateral view, hypotype GSC 90470, x80.
16. Ramiform element, lateral view, hypotype GSC 90471, x75.

Figure 17. *Protoprionidus* sp. 1 s.f. (Bed 12; 218.)
Lateral view, figured specimen GSC 90472, x90.

Figures 18, 19, 21–23. *Pteracontiodus cryptodens* (Mound).
18, 21. Distacodontiform elements, lateral views, hypotypes GSC 90473, 90474. (Bed 12; 199; Bed 14; 246.)
19. Trichonodelliform element, posterolateral view, hypotype GSC 90475, x45. (Bed 14; 57.)
22. Acodiform element, lateral view, hypotype GSC 90476, x45. (Bed 14; 194.)
23. Trichonodelliform element, anterolateral view, hypotype GSC 90477, x55. (Bed 14; 246.)

Figure 24. *Ptiloncodus simplex* Harris.
Lateral view, hypotype GSC 90478, x85. (Bed 14; 21.)

Figure 25. *Rossodus manitouensis* Repetski and Ethington.
Posterior view, hypotype GSC 90479, x55. (Bed 14; 16.)

Figures 26–29. *Scalpellodus* sp. 1
26. Costate asymmetrical specimen, lateral view, figured specimen GSC 90480, x55. (Bed 14; 5.)
27. Asymmetrical specimen, figured specimen GSC 90481, x60. (Bed 14; 24.)
28. Specimen with two costae, lateral view, figured specimen GSC 90482, x50. (Bed 14; 45.)
29. Acostate asymmetrical specimen, lateral view, figured specimen GSC 90483, x45. (Bed 14; 111.)

Figures 30, 31. *Scandodus furnishi* Lindström. (Bed 14; 54.)
30. Lateral view of drepanodontiform element, hypotype GSC 90484, x85.
31. Lateral view of drepanodontiform element, hypotype GSC 90485, x100.

Figures 32–34. ''*Scandodus*'' *mysticus* Barnes and Poplawski. (Bed 14; 269.)
32. Acostate acodiform element, lateral view, hypotype GSC 90486, x70.
33. Costate acodiform element, lateral view, hypotype GSC 90487, x70.
34. Costate acodiform element with ''anticusp'', lateral view, hypotype GSC 90488, x70.

Figures 35–37. ''*Scandodus*'' *pseudoramis* Serpagli. (Bed 10; 244-B.)
35. Acodiform element with ''anticusp'', lateral view, holotype GSC 90489, x80.
36. Oistodontiform element, lateral view, holotype GSC 90490, x75.
37. Costate acodiform element, lateral view, holotype GSC 90491, x75.

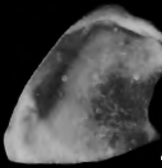
Figures 38, 39. Scandodontiform element 1. (Bed 14; 54.)
38. Lateral view of acostate specimen, figured specimen, GSC 90492, x70.
39. Lateral view of costate specimen, figured specimen GSC 90493, x80.

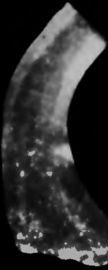
PLATE 6


1


2


3


4

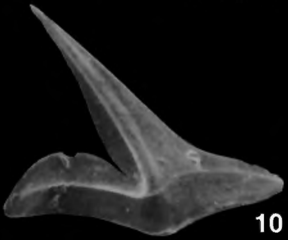

5

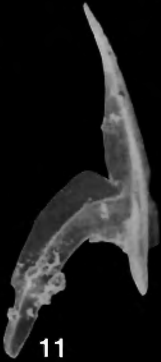

6


7

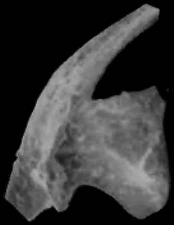

8

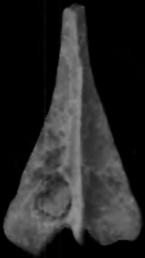

9

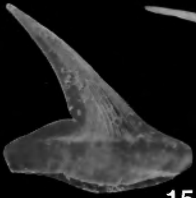

10


11

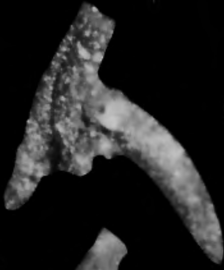

12

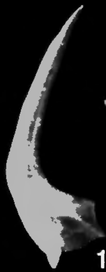

13


14

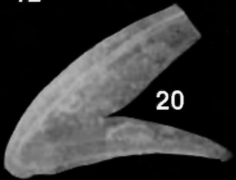

15


16


17

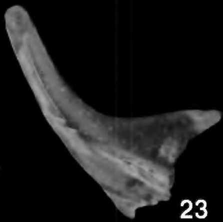

18


19

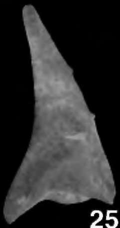

20


21


22


23


24


25

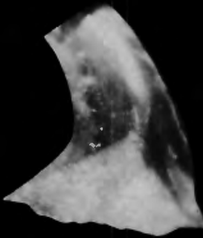

26

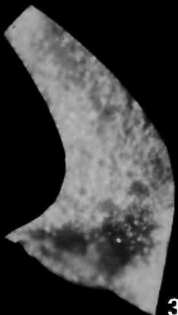

27

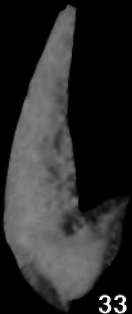

28

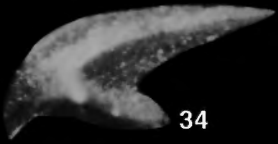

29

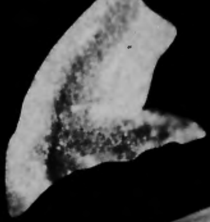

30

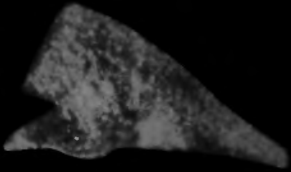

31

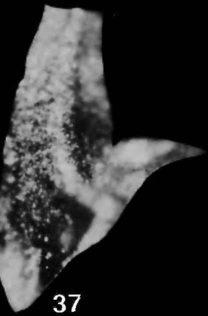

32

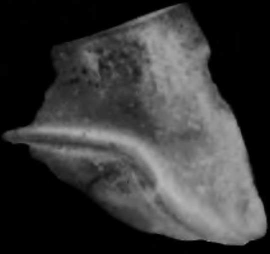

33


34


35


36


37


38

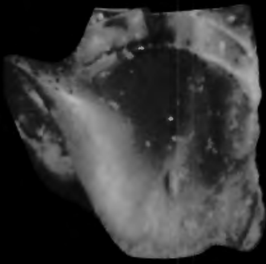

39

PLATE 7

Figures 3-8, 12, 23-26, and 29 were photographed with a light microscope, the remainder with a scanning electron microscope.

Figure 1. Scandodontiform element 2 s.f.
Posterior view, figured specimen GSC 90494, x15. (Bed 14; 110.)

Figure 2. *Parapanderodus emarginatus* (Barnes and Tuke).
Lateral view, hypotype GSC 90495, x35. (Bed 14; 246.)

Figure 3. *Protopanderodus*? *giganteus* (Sweet and Bergström) s.f.
Lateral view, hypotype GSC 90496, x50. (Bed 14; 18.)

Figure 4. *Scolopodus multicostatus* Barnes and Tuke.
Lateral view, holotype GSC 90497, x50. (Bed 14; 15.)

Figure 5. *Scolopodus oldstockensis* Stouge.
Lateral view, holotype GSC 90498, x50. (Bed 14; 181.)

Figure 6. *Parapanderodus paracornuformis* (Ethington and Clark).
Posterior view, hypotype GSC 90499, x50. (Bed 12; 102-A.)

Figure 7. "*Scolopodus*" *quadratus* Pander.
Lateral view, hypotype 90500, x45. (Bed 12; 184.)

Figure 8. *Scolopodus*? *peselephantis* Lindström.
Element with blade-like cusp, lateral view, holotype GSC 90501, x70. (Bed 12; 91.)

Figure 9. *Scolopodus* sp. aff. *S. filosus* Ethington and Clark s.f.
Lateral view, hypotype GSC 90502, x90. (Bed 14; 54.)

Figure 10. *Scolopodus* sp. Ethington and Clark.
Posterolateral view, hypotype GSC 90503, x50. (Bed 10; 202.)

Figure 11. Scolopodontiform element 1 s.f.
Lateral view, figured specimen GSC 90504, x35. (Bed 14; 24.)

Figure 12. *Parapanderodus carlae* (Repetski).
Posterior view, hypotype GSC 90505, x55. (Bed 12; 92.)

Figure 13. *Parapanderodus asymmetricus* (Barnes and Poplawski).
Posterior view, hypotype GSC 90506, x55. (Bed 12; 102-A.)

Figures 14-16. *Serratognathus armadillodus* n. sp. All x80. (Bed 14; 54.)

14. Anterior view, paratype GSC 90507.
15. Anterolateral view, holotype GSC 90508.
16. Aboral view, paratype GSC 90509.

Figure 17. ?*Ulrichodina wisconsinensis* Furnish.
Posterior view, hypotype GSC 90510, x50. (Bed 10, 135.)

Figures 18, 19. *Variabiloconus bassleri* (Furnish). (Bed 14; 16.)

18. Symmetrical costate element, posterior view, hypotype GSC 90511, x45.
19. Asymmetrical costate element, lateral view, hypotype GSC 90512, x40.

Figure 20. *Walliserodus ethingtoni* Fahræus.
Lateral view, hypotype GSC 90513, x50. (Bed 14; 21.)

Figures 21-24. *Tropodus sweeti* (Serpagli).

21. Multicostate element, posterolateral view, hypotype GSC 90514, x30. (Bed 14; 110.)
22. Tricostate element, lateral view, hypotype GSC 90515, x30. (Bed 14; 110.)
23. Advanced multicostate element, lateral view, hypotype GSC 90516, x30. (Bed 12; 83.)
24. Advanced tricostate element, lateral view, hypotype GSC 90517, x30. (Bed 12; 83.)

Figure 25. *Westergaardodina* sp.
Figured specimen GSC 90518, x70. (Bed 14; 110.)

Figure 26. New genus C n. sp. 1 s.f.
Lateral view, figured specimen GSC 90519, x90. (Bed 14; 54.)

Figures 27, 28. New genus A n. sp. 2 s.f. (Bed 14; 181.)

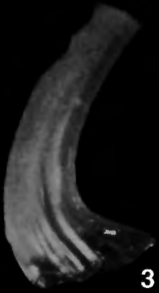
27. Aboral view, figured specimen GSC 90520, x75.
28. Anterolateral view, figured specimen GSC 90520, x90.

Figure 29. New genus A n. sp. 1 s.f.
Posterolateral view, figured specimen GSC 90522, x100. (Bed 14; 112.)

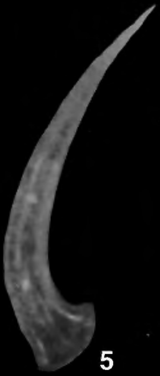
Figure 30. New genus B n. sp. 1 s.f.
Posterior view, figured specimen GSC 90523, x65. (Bed 14, 24.)


1


2


3


4


5


6


7


8


9


10


11


12


13


14


15


16


17


18


19


20

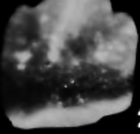

21

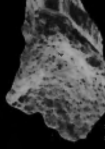

22

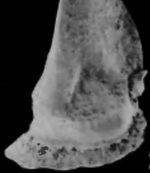

23

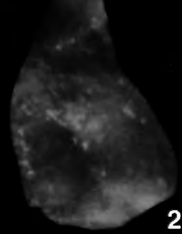

24


25


26


27


28


29

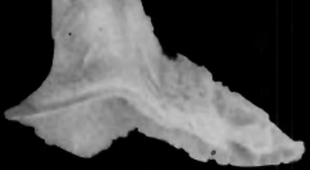

30

PLATE 8

Figures 4, 5, 9, 10, 14, 20, and 26-35 were photographed with a light microscope, the remainder with a scanning electron microscope.

Figure 1. *Spinodus horridus* (Barnes and Poplawski).
Lateral view, hypotype GSC 90524, x105. (Bed 12; 186.)

Figure 2. *Spinodus ramosus* Hadding.
Broken specimen, lateral view, hypotype GSC 90525, x50. (Bed 14; 60.)

Figure 3. *Strachanognathus parvus* Rhodes.
Lateral view, hypotype GSC 90526, x80. (Bed 12; 91.)

Figures 4, 5. *Stolodus* sp. aff. *S. stola* Lindström. All x70. (Bed 12; 102.)

4. Lateral view, hypotype GSC 90527.
5. Posterior view, hypotype GSC 90528.

Figure 6. *Teridontus nakamurai* (Nogami).
Lateral view, hypotype GSC 90529, x60. (Bed 14; 33.)

Figures 7-10. *Texania teras* n. gen. n. sp. (Bed 10; 239.)

7. Ramiform element, lateral view, paratype GSC 90530, x100.

8, 10. Ozarkodiniform elements, lateral views, paratypes GSC 90531, 90533, x110.

9. Oistodontiform element, lateral view, holotype GSC 90530, x100.

Figures 11-15. *Texania heligma* n. gen. n. sp. (Bed 12; 91.)

11. Ramiform element, lateral view, paratype GSC 90534, x100.
12. "Curled" ozarkodiniform element, inner lateral view, holotype GSC 90535, x110.
13. Oistodontiform element, lateral view, paratype GSC 90536, x105.

14, 15. Ozarkodiniform elements, lateral views, paratypes GSC 90537, 90538, x110.

Figures 16-20. *Fahraeusodus marathonensis* (Bradshaw).

16. Costate ramiform element, lateral view, hypotype GSC 90539, x50. (Bed 12; 83.)

17, 18. Ozarkodiniform elements, lateral views, hypotypes GSC 90540, 90541, x90. (Bed 10; 239.)

19. Oistodontiform element, lateral view, hypotype GSC 90542, x95. (Bed 10; 239.)
20. Blade-like denticulate element that is thought to belong in *Fahraeusodus* apparatus, hypotype GSC 90543, Ninemile Formation, Zone K of Ross/Hintze, sample N.1 of C.R. Barnes, Whiterock Canyon, Nevada, x100.

Figures 21-25. *Fahraeusodus mirus* Stouge and Bagnoli. (Bed 14; 175.)

21. Costate ozarkodiniform element, lateral view, hypotype GSC 90544, x80.
22. Slightly costate ozarkodiniform element, lateral view, hypotype GSC 90545, x75.
23. Acostate ozarkodiniform element, lateral view, hypotype GSC 90546, x80.
24. Oistodontiform element, lateral view, hypotype GSC 90547, x65.
25. Oistodontiform element with "anticusp", lateral view, hypotype GSC 90548, x45.

Figure 26. *Tripodus laevis* Bradshaw.
Lateral view, trichonodelliform element, hypotype GSC 90549, x85. (Bed 14; 269.)

Figures 27-31. *Tripodus* sp. aff. *T. laevis* Bradshaw.

27. Paltodiform element, lateral view, hypotype GSC 90550, x90. (Bed 10; 230-1.)
28. Paltodiform element, anterior view, hypotype GSC 90551, x80. (Bed 10; 230-1.)
29. Distacodontiform element, lateral view, note bifurcated costa, hypotype GSC 90552, x95. (Bed 10; 230-1.)
30. Drepanodontiform element, lateral view, hypotype GSC 90553, x90. (Bed 10; 226.)
31. Drepanodontiform element, lateral view, hypotype GSC 90554, x85. (Bed 10; 230-1.)

Figures 32, 33. *Tripodus* sp. (Bed 12; 186.)

32. Drepanodontiform element, lateral view, figured specimen GSC 90555, x110.
33. Trichonodelliform element, lateral view, figured specimen GSC 90556, x120.

Figures 34, 35. *Tripodus subtilis* (van Wamel). (Bed 12; 289.)

34. Trichonodelliform element, posterolateral view, hypotype GSC 90557, x90.
35. Paltodiform element, lateral view, hypotype GSC 90558, x90.


1


2


3


4


5


6


7


8


9


10


11

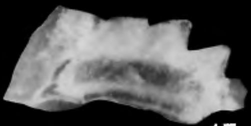

12

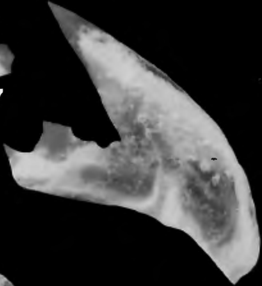

13

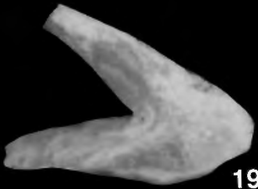

14

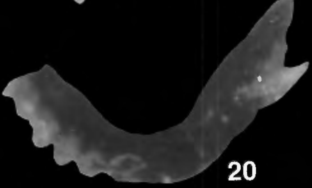

15

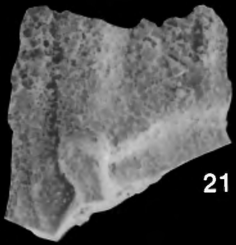

16

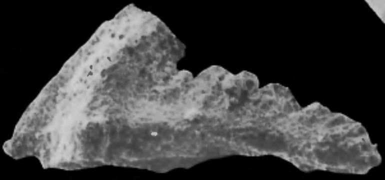

17

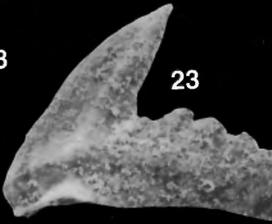

18

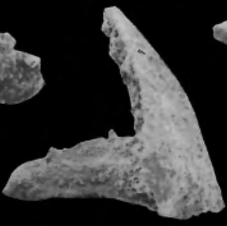

19


20


21

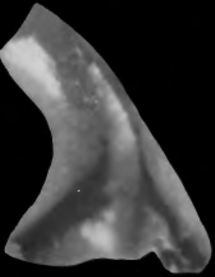

22


23

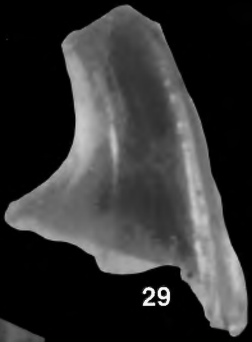

24

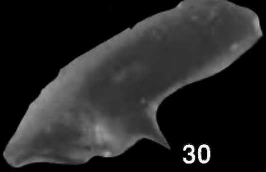

25


26

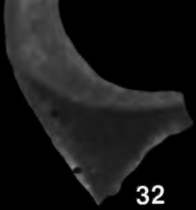

27


28


29


30


31


32


33


34


35