EARLY ORDOVICIAN CONODONTS FROM THE HORN VALLEY SILTSTONE, CENTRAL AUSTRALIA

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ABSTRACT. Conodonts from the early Ordovician Horn Valley Siltstone in the Amadeus Basin, Northern Territory, Australia, are described and illustrated. Samples were collected from limestone beds within the unit at two easily accessible localities. Twenty-two multi-element species belonging to seventeen genera are described. One new genus (*Jumudontus*) and eight new species (*Acodus buetefueri*, *Drepanoistodus pitjanti*, *Erraticodon patu*, *Jumudontus gananda*, *Prioniodus amadeus*, *Protoprioniodus aranda*, *Protoprioniodus nyinti*, and *Protoprioniodus vapu*) are proposed. The report also constitutes a revision of a small conodont collection described by Crespin (1943).

The Horn Valley conodonts are mid Arenig in age. They correlate with conodont zones OCD and OCE of the Canning Basin, north-west Australia, and relate to faunas from the *Oepikodus evae* and *Baltoniodus triangularis*/*Baltoniodus navis* Zones on the Baltic Platform. In North America the Horn Valley conodonts are equivalent to late Fauna E, Fauna 1, and early Fauna 2 of the Midcontinent succession, thus indicating an uppermost Canadian and early Whiterock age.

THIS investigation comprises a taxonomic and biostratigraphic study of abundant and superbly preserved conodonts from the Horn Valley Siltstone, Central Australia. The first record of conodonts in Australia was made from the Horn Valley Siltstone by Crespin (1943), who proposed two new species in her brief paper. Crespin's material was collected by petroleum geologists in the Waterhouse Range, about 65 km south-west of Alice Springs. Widespread use of acid disaggregation to free conodonts soon led to the realization that the Horn Valley Siltstone was one of the world's most prolific conodont producers. Philip (1965) was undoubtedly referring to Horn Valley conodonts when he recorded abundances of 30 000 elements per kg from certain Ordovician limestones in central Australia. Bergström (1971, p. 130) also referred to Horn Valley conodonts and suggested that this fauna may belong to a previously unrecorded, major conodont faunal province. Müller (1978, p. 278) illustrated a skeletal element of a Horn Valley conodontophorid.

This paper is the first systematic treatment of Horn Valley conodonts since that of Crespin (1943). However Nieper (1970) included a description of several Horn Valley form-species in her Ph.D. thesis at the University of Queensland.

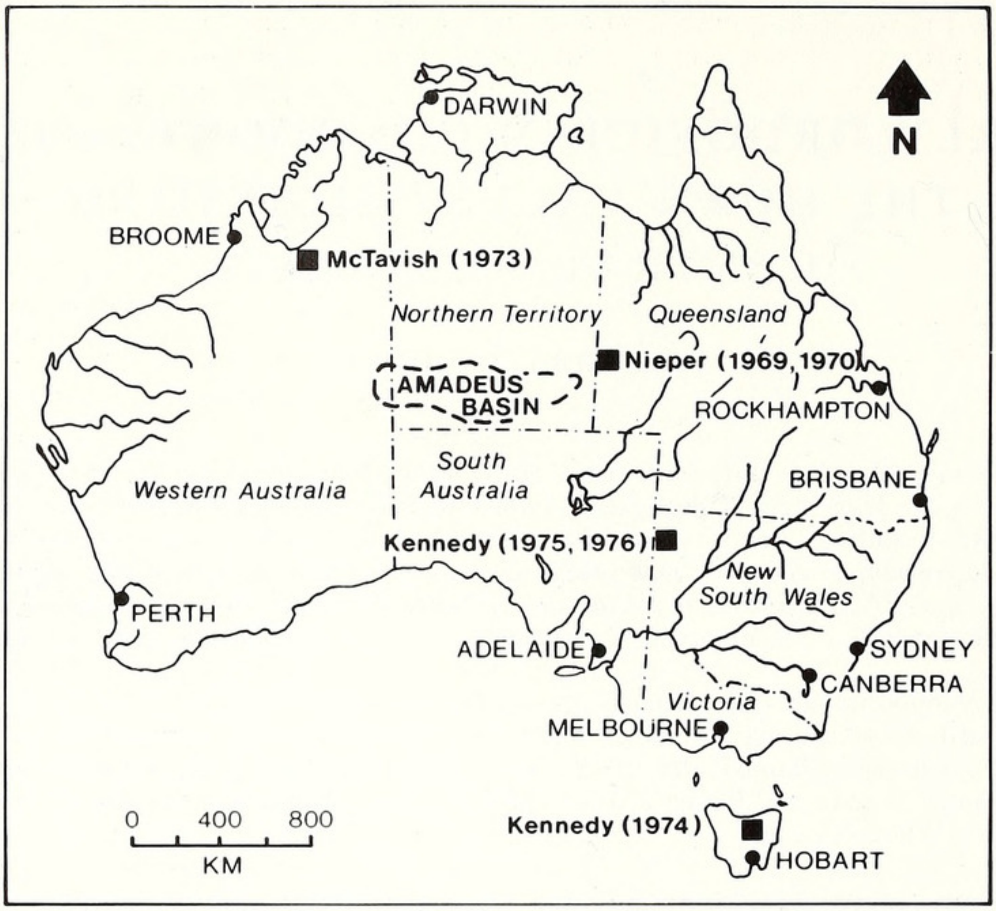
REGIONAL SETTING

The Horn Valley Siltstone is a unit within the 800-km-long intracratonic depression called the Amadeus Basin, which occupies the southern part of the Northern Territory in central Australia (text-fig. 1). Proterozoic and Palaeozoic sediments constitute most of the 10 000 m of sedimentary deposits within the basin (Wells, Forman, Ranford, and Cook 1970).

Late Cambrian and Ordovician sediments within the basin form the Larapinta Group, which has been subdivided into formations, from youngest to oldest, as follows:

Carmichael Sandstone
Stokes Siltstone
Stairway Sandstone
Horn Valley Siltstone
Pacoota Sandstone

[Palaeontology, Vol. 24, Part 1, 1981, pp. 147–183, pls. 26–32.]



TEXT-FIG. 1. Location of the Amadeus Basin and of previously recorded Arenig conodont collections in Australia.

The Larapinta Group is regarded by most workers to have been deposited in a shallow east-west seaway that extended across Australia during the Ordovician (Webby 1978).

The Horn Valley Siltstone has been recognized over a wide area of the Amadeus Basin and outcrops have been mapped over a distance of 550 km within the basin. The unit varies in thickness from 0 to 300 m. As suggested by its name, the unit is predominantly a siltstone, coloured green-grey in outcrop; however, varying proportions of bioclastic limestone occur within the formation. These limestone intervals yielded the conodonts examined here. In addition to conodonts, the Horn Valley Siltstone contains a rich and well-preserved fauna of trilobites, brachiopods, pelecypods, nautiloids, ostracods, and graptolites.

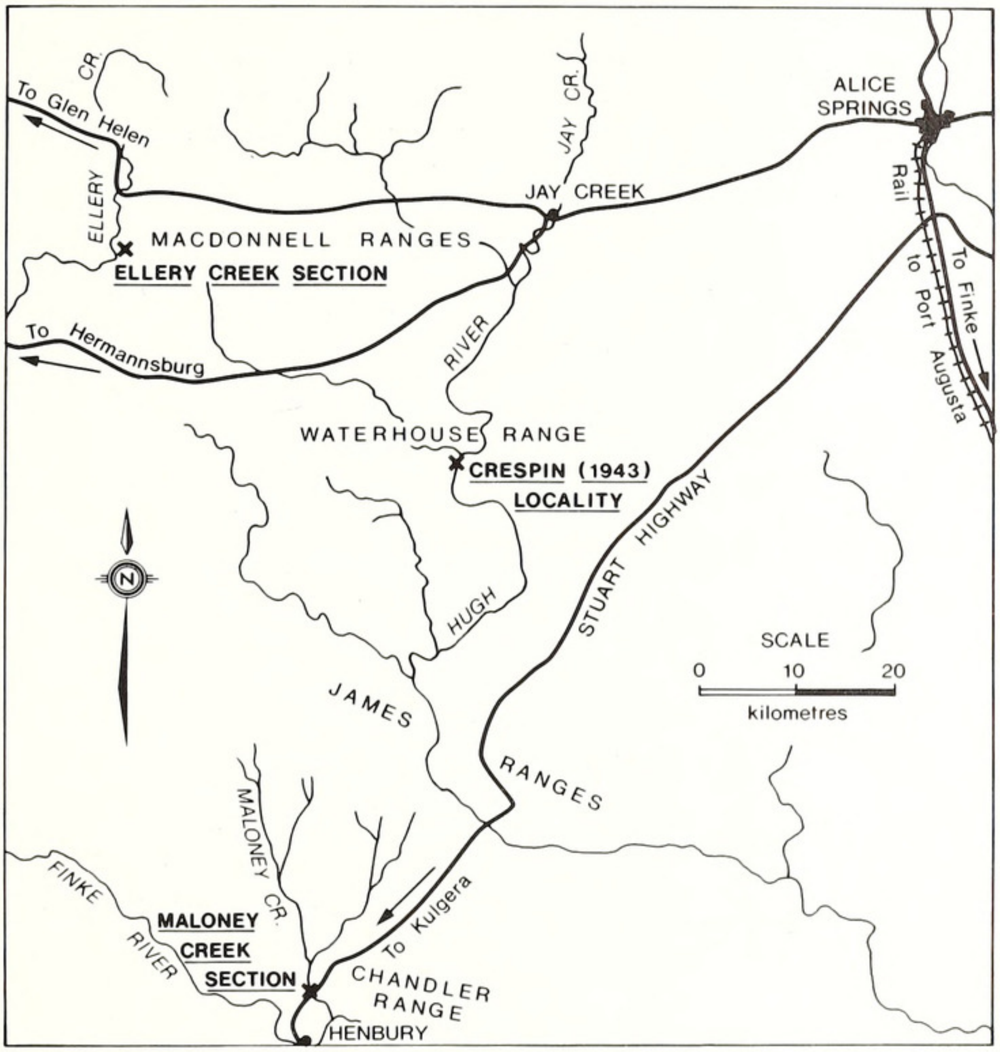
MEASURED SECTIONS

The conodonts described here were collected from two measured sections of the Horn Valley Siltstone about 75 km apart and close to Alice Springs (text-fig. 2). Detailed locality information for each section is as follows:

1. Ellery Creek section. Hermannsburg 1:250 000 map sheet, Lat. 27° 49′ S, Long. 133° 04′ E (deduced from Geologic Map enclosed in Quinlan and Forman 1968). The section occurs adjacent to the east bank of Ellery Creek, about 3 km due south of the main Alice Springs-Glen Helen road.
2. Maloney Creek section. Henbury 1:250 000 map sheet, Lat. 24° 30′ S, Long. 133° 16′ E (deduced from Geologic Map enclosed in Cook 1968). The section occurs immediately west of the Stuart Highway, where it crosses Maloney Creek, about 120 km south of Alice Springs.

The Ellery Creek section is the type locality for the Horn Valley Siltstone. The local geology of this area is well known (Pritchard and Quinlan 1962) and the location of the collected samples within the section is shown on text-fig. 3.

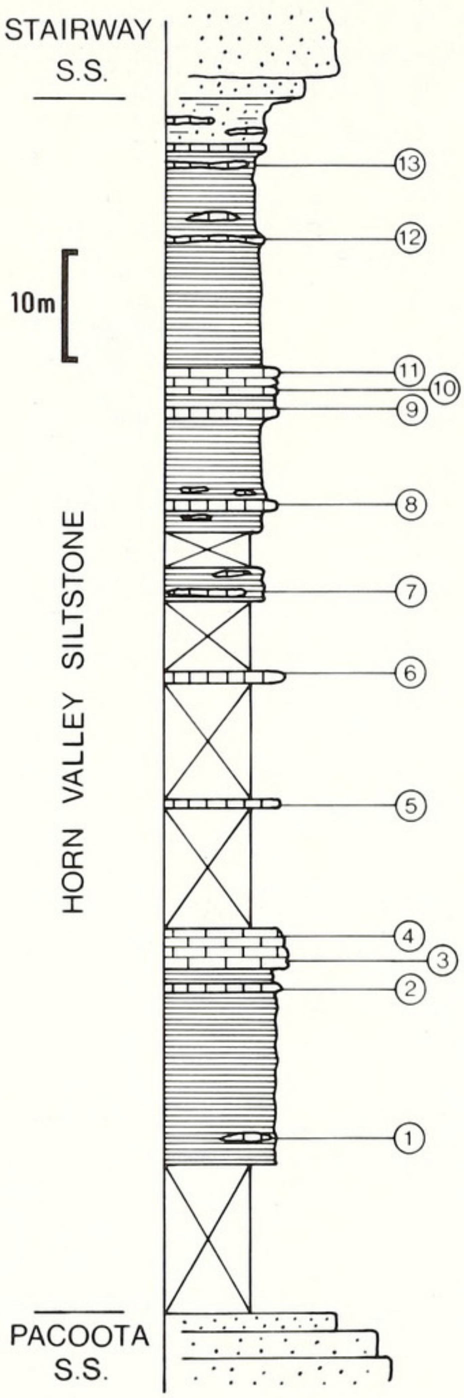
The Maloney Creek section (text-fig. 4) was collected because of ease of access and because grab samples taken by field geologists, when the area was mapped, had produced prolific conodonts. The outcrop of Horn Valley is poor at Maloney Creek, and the boundaries of adjacent formations can only be delineated approximately. Outcrop is limited to resistant limestone beds projecting through soil cover.



TEXT-FIG. 2. Locality map showing the two measured sections of the Horn Valley Siltstone and the Crespin (1943) locality.

NATURE OF THE CONODONTS

Thirteen 1-kg limestone samples from each of the Ellery Creek and Maloney Creek sections were processed using standard acetic-acid techniques followed by electromagnetic separation of the residue. Heavy-liquid separation was also carried out if a large residue persisted after use of the electromagnetic separator. All samples except one contained conodonts; however, abundances varied from low to prolific (tables 1 and 2). Most samples were such good producers that it was possible to reconstruct multi-element apparatuses of most species within a single sample. Preservation was generally excellent although several samples from the Ellery Creek section yielded abundant worn and indeterminable elements. This poor preservation is attributed to primary conditions of sedimentation rather than secondary alteration. The samples probably originated from carbonate beds deposited under high-energy conditions.

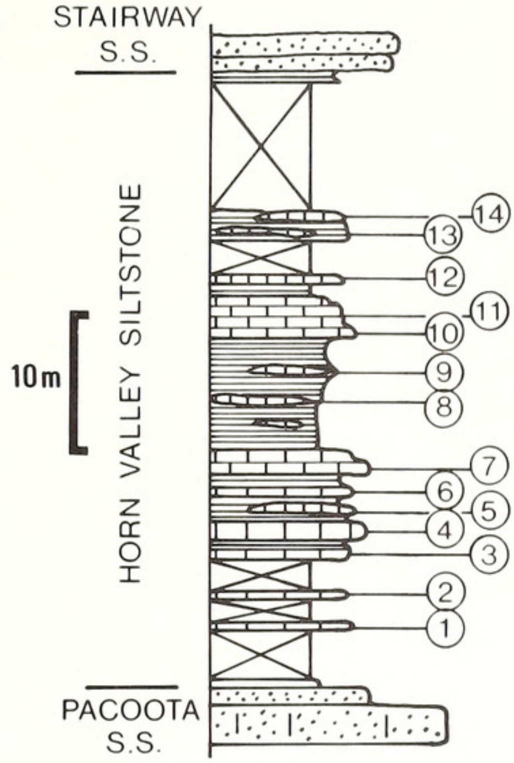


TEXT-FIG. 3. Simplified columnar section of the Horn Valley Siltstone along Ellery Creek (EC section), measured August 1976; average dip of strata 67 °S.

All Horn Valley conodonts are coloured pale yellow or very pale brown indicating a Colour Alteration Index of 1·0–1·5 (Epstein, Epstein and Harris 1977). This suggests that the Horn Valley Siltstone at both sections has not experienced burial temperatures exceeding about 90 °C. Consequently, the temperature effects of regional metamorphism resulting from the Devonian-Carboniferous Alice Springs Orogeny (Wells *et al.* 1970) are negligible at the sections under consideration. However, Epstein *et al.* (1977) found that a low Colour Alteration Index was also possible at temperatures higher than 90 °C with water saturation and high pressure.

The faunal succession of conodonts through both sections of the Horn Valley does not exhibit sufficient variation to warrant zonation. The stratigraphic interval embraced by both sections appears to be small and the faunal variation through the succession is principally ecological in nature, a fact exhibited by changes in the abundance of species.

TEXT-FIG. 4. Simplified columnar section of the Horn Valley Siltstone along Maloney Creek (MC section), measured August 1976; average dip of strata 30 °N.



Horn Valley conodont collections are dominated by *Trigonodus larapintinensis* (Crespin), *Acodus emanuelensis* McTavish *Drepanoistodus pitjanti* n. sp., and *Erraticodon patu* sp. nov. Specific intervals also contain prolific representatives of *Protoprioniodus* and *Prioniodus amadeus* sp. nov. *Bergstroemognathus* is a significant faunal component from limestones deposited under high-energy conditions. Less common simple cone bearing conodontophorids in the Horn Valley include *Scalpellodus latus* (van Wamel) and *Drepanoistodus suberectus* (Branson and Mehl). Rare, but stratigraphically useful species are *Baltoniodus navis* (Lindström), *Oepikodus evae* (Lindström), *Jumudontus gananda* sp. nov., and *Microzarkodina flabellum* (Lindström).

TABLE 1. Distribution of Conodonts, Horn Valley Siltstone, Ellery Creek Section. All identifiable elements in each 1-kg sample were picked and counted.

SPECIES \ SAMPLE E.C.	2	3	4	5	6	7	8	9	10	11	12	13
Acodus emanuelensis	82	41	103	336	67	45	284	1402	526	157	30	18
Baltoniodus navis								1				
Bergstroemognathus extensus	120	42	5									?
Cornuodus longibasis							2					
Drepanoistodus pitjanti	26	12		30		4	64	317	42	31	2	13
D. suberectus	16	3	9	16	1	1	8	23	21	4		
Erraticodon patu				16		1	143	545	11	60	3	2
Jumudontus gananda			1				1	3				
Oepikodus evae		2	185									
Oistodus scalenocarinatus		1		8		1	14	56	3	9	3	
Oneotodus sp.	28	5										
Prioniodus amadeus				1046			48	87	901	22		
Protoprioniodus aranda				78								
P. nyinti		2	55	229	2	2	3	7	3			
P. yapu				155			4	1				
Scalpellodus latus			4	1			1	13	11	1		
Trigonodus larapintinensis	457	104	2	6	3	8	89	314	809	332	49	80

TABLE 2. Distribution of Conodonts, Horn Valley Siltstone, Maloney Creek Section. Several samples were not picked exhaustively.

SPECIES \ SAMPLE M.C.	1	2	3	4	6	7	8	9	10	11	12	13	14
Acodus buetefueri							132						
A. emanuelensis	226	96	199	307	336	618	264	166	115	321	377	289	203
Baltoniodus navis					2		28			6			6
Belodella jemtlandica									4				
Cornuodus longibasis	2		4		2		3	2	1	50		10	3
Drepanoistodus pitjanti	61	47	72	90	141	72	217	44	22	174	37	40	57
D. suberectus	14			6	7	66	67	28	44	50	13	48	46
Erraticodon patu	13	18	47	36	89	56	149	62	41	206	153	69	255
Jumudontus gananda								1	2	4	5	2	7
Microzarkodina flabellum							10					3	
Oistodus scalenocarinatus	15	2		16	24	9	55	18	22	63	16	68	3
Prioniodus amadeus	441		21	160	401	438	450	133	142	84	39	126	134
Protopanderodus primitus												50	1
Protoprioniodus aranda					16	99	33		5			5	
P. nyinti	28	16	14	4	75	311	48	11	47	10		33	13
P. yapu	32	1	1	1	15	82	17	7	21	1		30	10
Scalpellodus latus	4	6	19	8	35	50	57	26	64	207	45	66	38
Trigonodus larapintinensis	91	89	159	253	398	293	145	310	266	313	646	152	262

AGE AND CORRELATION

The Horn Valley Siltstone is the best datable unit within the Larapinta Group. With the discovery of this richly fossiliferous horizon its Ordovician age was established. Later discovery of the graptolites *Didymograptus nitidus* and *D. patulus* within the formation suggested a late Lower Ordovician (Arenig) age (Öpik 1956; Thomas 1960; Pojeta and Gilbert-Tomlinson 1977). Rocks of similar age in Australia occur in carbonate facies in the Canning Basin (Western Australia), north-west New South Wales, in the Georgina Basin (Queensland), and on the Tasmanian Shelf. Graptolitic facies of equivalent age are found in the Tasman geosyncline (Webby 1978).

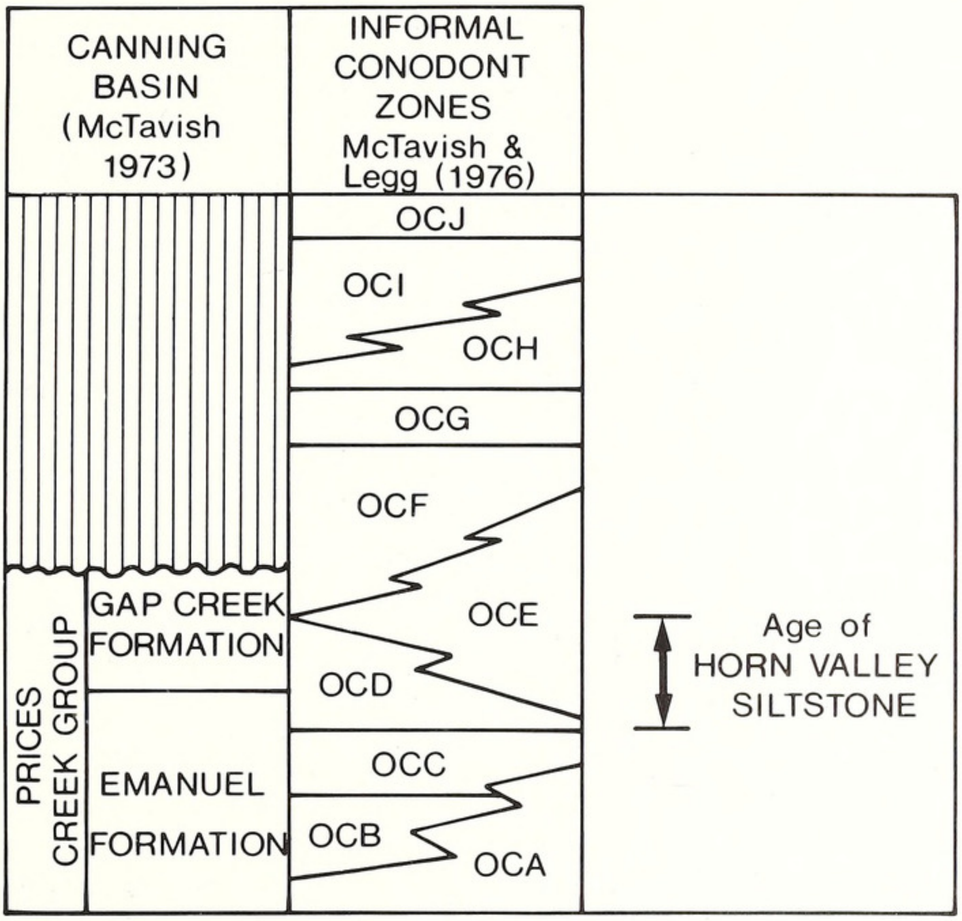
Local conodont correlation

Conodonts have been reported from all areas of late Lower Ordovician carbonate sedimentation in Australia referred to above. Text-fig. 1 shows the location and author of these records.

The best-documented area is the Canning Basin in north-west Australia. McTavish (1973) partly described the conodonts and later he (McTavish and Legg 1976) established ten informal conodont zones (OCA, OCB, . . . OCJ) for Ordovician strata in the basin. Horn Valley conodonts correlate best with zones OCD and OCE in this scheme. *Oepikodus evae* occurs only in top OCD close to the youngest horizon containing *Protoprioniodus* in the Canning (McTavish and Legg 1976; text-fig. 5). Also *Baltoniodus navis* ranges through OCE to basal OCF, while *Microzarkodina flabellum* is limited to top OCE. A tentative correlation of the Horn Valley to conodont zones OCD and OCE in the Canning Basin is thus suggested. McTavish and Legg (1976, text-fig. 3) regarded the boundaries between their conodont zones OCD, OCE, and OCF as being diachronous.

McTavish (1973) is the only comprehensive study of a specific Ordovician conodont fauna in the Canning, and it deals only with a selected part of collections from two outcrop sections of the Emanuel Formation. McTavish and Legg (1976) assigned this fauna to their zones OCA–OCD, thus suggesting an age older than most, if not all of the Horn Valley. This is confirmed by considering the species in both collections. The Horn Valley contains three species of *Protoprioniodus* (*P. aranda* sp. nov., *P. nyinti* sp. nov., and *P. yapu* sp. nov.) whereas the Emanuel yields only *P. simplicissimus*. *P. aranda* and *P. nyinti* appear to be phylogenetically more advanced than *P. simplicissimus*, thus suggesting a younger age for the Horn Valley. Both faunas include important occurrences of *Acodus* and *Prioniodus*. The Emanuel contains *A. deltatus s.l.*, *A. emanuelensis*, *P. minutus*, and *P. oepiki*, whereas the Horn Valley contains *A. emanuelensis*, *A. buetefueri* sp. nov., and *P. amadeus* sp. nov. Over-all, the Horn Valley association again appears to be phylogenetically more advanced than the Emanuel counterparts.

The conodonts from the Tabila Formation, north-west New South Wales, described by Kennedy (1975) appear to be of similar age to the Horn Valley. Both faunas contain *Protoprioniodus aranda* and *P. nyinti*.



TEXT-FIG. 5. Correlation of the Horn Valley Siltstone with the Canning Basin succession.

The Nora Formation (Georgina Basin) contains conodonts that were described using form taxonomy by Nieper (1969, 1970). It contains several new species which, from phylogenetic evidence, should be younger than the Horn Valley. Nieper (1970) concluded that the Nora was of Middle Ordovician age. The Nora also has several species in common with the Horn Valley so that these parts of the Amadeus and Georgina Basin succession may be in part stratigraphically equivalent. Druce (pers. comm. 1979) agrees that the Horn Valley is equivalent to the Coolibah Formation and the lower part of the Nora Formation in the Georgina Basin.

The conodonts reported from the Cabbage Tree Formation, northern Tasmania (Kennedy 1974), are probably in part older than, and of similar age to, the Horn Valley. Older conodonts than the Horn Valley were extracted from the Ordovician succession at Mt. Patriarch, north-west Nelson, New Zealand, by Cooper and Druce (1975). This New Zealand succession ranges from latest Tremadoc to early Arenig in age.

International conodont correlation: Europe

The best-known Lower Ordovician conodont successions are in Europe where zonations have been established for the thin deposits overlying the Baltic Shield (Sergeeva 1966; Viira 1966, 1974; Bergström 1968; Lindström 1971; van Wamel 1974; Löfgren 1978). Individual zonations of the Baltic succession vary considerably in their definition, nomenclature, and utility. In considering the Horn Valley conodonts, I use the zonal scheme of Löfgren (1978), which not only has widespread utility but also refines previous zonations. Several of the early Ordovician conodont zones in the Baltic region are not well defined according to the recommendations of Hedberg (1976), especially with regard to their utility, limits, and discussion as to the kind of biozone under consideration.

The critical species in the Horn Valley for correlating with the European successions are *Bergstroemognathus extensus*, *Baltoniodus navis*, *Oepikodus evae*, and *Microzarkodina flabellum*. *Bergstroemognathus extensus* and *O. evae* commonly occur together in strata assigned to the *O. evae* Zone (Serpagli 1974; Landing 1976). Consequently the basal third of the Ellery Creek section correlates with this zone.

Baltoniodus navis appears within the overlying *B. triangularis* and *B. navis* Zones on the Baltic platform. *B. navis* first occurs in the middle of the Horn Valley in both sections and extends to the top of the formation, thus suggesting a correlation of this interval with the *B. triangularis*/*B. navis* Zones in Europe. It is noteworthy that Lindström (1971) recognized separate *B. triangularis* and *B. navis* Zones on the Baltic Platform; however, this subdivision was not confirmed in the conodont collections described by Löfgren (1978). *M. flabellum*, which co-occurs with *B. navis* in the Horn Valley, first appears in Europe in the *B. triangularis*/*B. navis* Zones.

In conclusion, the Horn Valley is correlated with the *O. evae* and *B. triangularis*/*B. navis* Zones of the Baltic Platform. The occurrence of *Trigonodus larapintinensis* throughout the Horn Valley is of considerable interest for international Ordovician conodont correlation. A close relative, *T. brevibasis*, defines the base of the *Paroistodus originalis* Zone, the conodont zone overlying the *B. triangularis*/*B. navis* Zones in Europe. Utilizing the conodont correlation with Europe, it is concluded that the Horn Valley Siltstone is of latest Latorp or early Volkhov age using the Baltic stages, or middle Arenig applying the standard British series (text-fig. 6).

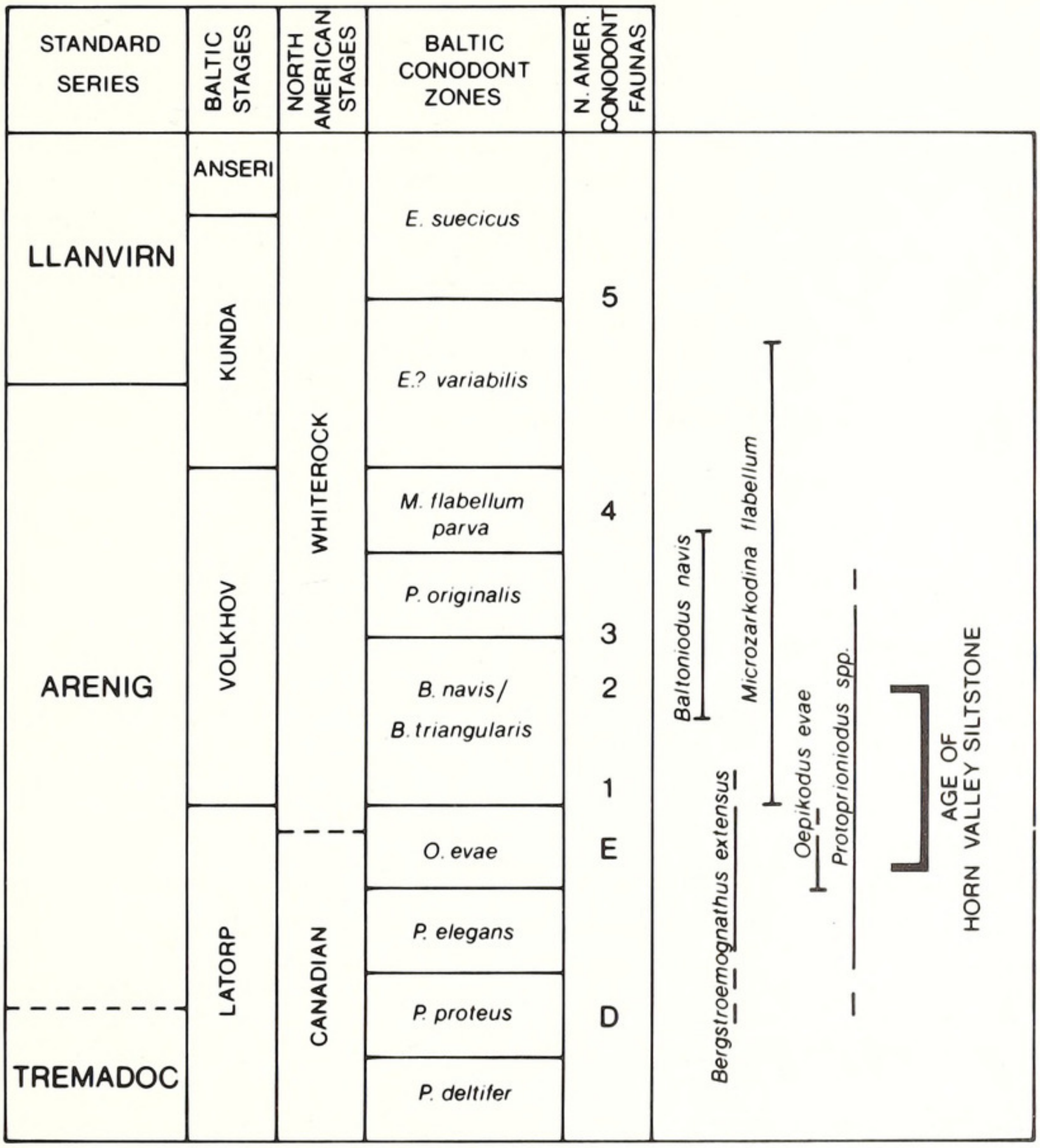
International conodont correlation: North America

The stratigraphy of Ordovician conodonts in North America is incompletely documented. Important published works are Ethington and Clark (1971), Sweet, Ethington, and Barnes (1971), and Sweet and Bergström (1976). Ethington and Clark (1971) recognized a series of five faunas within the Lower Ordovician, which were annotated, from oldest to youngest, A, B, C, D, E respectively. The Middle and Upper Ordovician was considered by Sweet *et al.* (1971), who recognized twelve faunas annotated numerically from oldest to youngest.

Important Horn Valley species for correlating with North American sections are *Protoprioniodus nyinti* and *O. evae*. *P. nyinti* (referred to as New Genus A by Sweet *et al.* 1971) is an important faunal component of Fauna 1 of Sweet *et al.* (1971) and extends into the base of their Fauna 2. *O. evae* is closely related to *O.* (described as *Gothodus*) *communis* which is also common in Fauna 1 and basal Fauna 2 but ranges downwards into Fauna E of Ethington and Clark (1971). As *P. nyinti* was not recognized at the base of Horn Valley at Ellery Creek, I conclude that the Horn Valley correlates within an interval including top Fauna E, Fauna 1, and basal Fauna 2 of the North American Ordovician conodont succession. Relating this determination to the standard North American Ordovician series indicates that the Horn Valley is uppermost Canadian and early Whiterock in age.

BIOGEOGRAPHICAL SIGNIFICANCE

Ordovician conodontophorids were affected by a notable degree of provincialism (Sweet, Turco, Warner, and Wilkie 1959; Bergström 1971, 1973; Barnes, Rexroad, and Miller 1973; Serpagli 1974; Sweet and Bergström 1974; Barnes and Fåhraeus 1975; Lindström 1976). According to Sweet and



TEXT-FIG. 6. Correlation of the Horn Valley Siltstone with the European and the North American succession.

Bergström (1974), a North American Midcontinent Province can be recognized in collections from central North America, the Siberian Platform, and eastern Australia, whereas a North Atlantic Province can be discerned in collections from Europe, the Appalachian region of North America, and from a locality in Argentina. A questionable North Atlantic collection was noted from north-west Australia. Bergström (1971, p. 130) suggested, after examining a collection from the Horn Valley Siltstone, that a third major Ordovician conodont province may exist in Australia.

The Horn Valley conodonts described here do not have clear affinities with any of the Ordovician conodontophorid provinces. The Horn Valley collection may be regarded as containing four faunal components:

1. Conodonts characteristic of the North American Midcontinent Province.
2. Conodonts characteristic of the North Atlantic Province.
3. Endemic conodonts.
4. Possible cosmopolitan conodonts.

Conodontophorids common to the North American Midcontinent province which occur in the Horn Valley include: *Jumudontus gananda*, *Oistodus scalenocarinatus*, *Protoprioniodus aranda*, and *P. nyinti*.

North Atlantic conodontophorids found in the Horn Valley include: *Baltoniodus navis*, *Belodella jemtlandica*, *Bergstroemognathus extensus*, *Cornuodus longibasis*, *Microzarkodina flabellum*, *Oepikodus evae*, and *Scalpellodus latus*.

Endemic Australia elements are: *Acodus buetefueri*, *A. emanuelensis*, *Drepanoistodus pitjanti*, *Erraticodon patu*, and *Prioniodus amadeus*.

Possible cosmopolitan species are: *Drepanoistodus suberectus* and *Trigonodus larapintinensis*.

From this faunal analysis it can be concluded that biogeographically the Horn Valley contains a mixed conodontophorid fauna with elements of both the Midcontinent and North Atlantic Provinces being recognized. The endemic faunal component, specifically *E. patu* and *D. pitjanti* is very abundant in some samples and this probably led to Bergström's (1971) proposal of a separate Australian Ordovician conodont province. The reality of an Australian province cannot be affirmed by this study. The endemic faunal component probably results from longitudinal and latitudinal separation from areas where conodont collections are well documented (refer to palaeogeographic map in Serpagli 1974).

Lindström (1976) considered the regional variations of Ordovician conodontophorids in a slightly different way. Instead of emphasizing distinct provinces, he recognized ten evolving faunas within the system, five of which broadly corresponded to the North Atlantic Province, with the remainder related to the Midcontinent Province. Using Lindström's scheme, the Horn Valley conodonts generally relate to his *Paroistodus* and *Periodon* faunas together with a minor component from his *Juanognathus* fauna. Consequently, the Horn Valley conodonts have best affinities with the North Atlantic Province. However, Lindström (1976, p. 522) regards Australia as being close to the shifting boundary between both provinces and this is a reasonable conclusion.

SYSTEMATIC PALAEONTOLOGY

The importance of White Matter

The occurrence of white matter has been widely used by conodont researchers in systematics. Much evidence is now available from late Ordovician and younger collections to suggest that white matter is of taxonomic value (e.g. see Jeppsson 1969). When dealing with early Ordovician conodonts, the occurrence and nature of white matter may be a difficult and confusing morphologic criterion. Three examples from the Horn Valley Siltstone are discussed.

Skeletal elements of *Oistodus scalenocarinatus* may be totally hyaline or contain abundant dense white matter. There is a gradation between hyaline and albid elements. Albid elements in this case appear to be of smaller size than hyaline units.

Protopioniodus nyinti in the Horn Valley generally has skeletal elements containing abundant white matter; however, one of the Ellery Creek samples contains identical but tiny skeletal elements of *P. nyinti* that are almost totally hyaline. This species seems to contradict the trend observed in *O. scalenocarinatus* where tiny skeletal elements contain more white matter.

Skeletal elements of *Trigonodus* in the Horn Valley contain variable amounts of white matter. It may be restricted to the growth axis of elements or it may be present abundantly as a slightly transparent, diffuse cloud throughout elements. *Acodus* is morphologically similar to *Trigonodus* but may be distinguished by the nature of its white matter. Skeletal elements of *Acodus* are invariably albid, with dense white matter unlike the cloudiness in units of *Trigonodus*. The white matter common to elements of *Acodus* appears to concentrate in costae and processes.

I conclude from this study that the presence or absence of white matter appears to be controlled by different factors in different conodontophorids. White matter is a useful morphologic character but in the early Ordovician it should be used for the definition of taxa only with extreme caution.

Gain and loss of skeletal elements

An important characteristic of the skeletal apparatuses of conodontophorids appears to be their ability to gain or lose skeletal elements (Carls 1977). In the descriptions below it is stated that *Drepanoistodus* and *Scandodus* are best differentiated by the absence of an oistodontiform (M) skeletal element. I am aware of further possible examples of this phenomenom in Ordovician and Silurian collections. Consequently, it is recognized that the differing numbers of elements in a skeletal apparatus is no longer a barrier to postulating a close relationship between taxa. The gain or loss concept must become part of our refined concept of the conodont apparatus, its systematics, and evolution.

Crespin's (1943) type collection

In this paper I describe conodonts from the same formation as Crespin (1943). The Crespin types were examined as part of this study and *O. larapintinensis* Crespin has been revised in multi-element nomenclature. It is interesting to note that Crespin's concept of *O. larapintinensis* was a multi-element concept as she included ?P, ?M, Sc, and Sd skeletal elements in her type collection. The holotype of *Paltodus madigani*, which was also described by Crespin, was lost as a consequence of the fire that destroyed much of the Commonwealth Palaeontological Collection in 1953. Consequently, *P. madigani* is regarded as a *nomen dubium* in this study. A paratype of *P. madigani* is probably an Sa element of a species of *Acodus*.

Elemental notation

The elemental notation of Sweet and Schönlaub (1975) is used here in preference to that of Barnes, Kennedy, McCracken, Nowlan, and Tarrant (1979). I understand that the Sweet and Schonlaub scheme will be used in the forthcoming revision of vol. W of the *Treatise on Invertebrate Paleontology*. This notation is also applied to simple-cone bearing apparatuses following the lead of Barrick (1977).

Description of taxa

Multi-element taxonomy is used throughout this paper. All specimens are housed in the palaeontological collections of the Geological Survey of South Australia. Illustrated elements have been assigned specific catalogue numbers (GSSA Co). Bulk collections from each sample are stored with the catalogued specimens, each being labelled with an EC or MC prefix for the Ellery Creek or Maloney Creek sections respectively. Topotype material of new species are also housed with the Commonwealth Palaeontological Collection, Canberra.

Only illustrations of *Belodella jemtlandica* Löfgren, 1978, *Microzarkodina flabellum* (Lindström, 1955), and *Oepikodus evae* (Lindström, 1955) are given here as no new descriptive information was forthcoming from Horn Valley collections of these species.

Genus ACODUS Pander, 1856 emended Lindström, 1977

1856 *Acodus* Pander, p. 21.
1956 *Acontiodus* Pander, p. 28.
1977 *Acodus* Pander; Lindström, p. 1.
1978 *Acodus* Pander; Fåhraeus and Nowlan, p. 463.

Type species. *Acodus erectus* Pander.

Diagnosis. A conodontophorid with a skeletal apparatus containing acodontiform or prioniodontiform (P) elements, an oistodontiform (M) element, and a symmetry transition series of trichonodelliform (Sa), tetraprioniodontiform (Sb), and belodontiform (Sd) units. All elements albid. Denticulation or incipient denticulation evident in many species.

Remarks. Separation of *Prioniodus* and *Acodus* is difficult and van Wamel (1974) apparently regarded the genera as synonymous. Typical *Acodus* has a skeletal apparatus composed entirely of simple cones, whereas *Prioniodus* bears mainly denticulated elements. However, *Prioniodus* evolved from *Acodus* via a plexus of intermediate species (McTavish 1973) with numerous closely related lineages. My concept of *Acodus* is essentially that of Lindström (1977, p. 1) and Fåhraeus and Nowlan (1978, p. 463), except that here a new denticulated species (*A. buetefueri*) that is closely related to *A. emanuelensis* McTavish, 1973 is included.

Acodus buetefueri sp. nov.

Plate 28, figs. 7, 8, 11, 13

Origin of name. After Mr. Hans Buetefuer, former Laboratory Technician, S.A. Department of Mines and Energy, who picked most of the Horn Valley conodont collection.

Material. Holotype (GSSA Co 3); Paratypes (GSSA Co 1, 2); total collection studied, 132 elements.

Type locality and strata. Maloney Creek, adjacent to Stuart Highway Bridge, south of Alice Springs, Northern Territory, Australia. Horn Valley Siltstone, limestone beds about 19 m above base of formation (Sample MC-8).

Diagnosis. A species of *Acodus* similar to *A. emanuelensis* but with skeletal elements developing conspicuous, fused, compressed auxiliary denticles. Denticulation best developed on the P and M units but no denticles form on lateral processes.

Description. P element is ozarkodiniform. Unit flat, arched, excavated, and possessing a straight basal profile. Cusp large and bears a costa on one lateral face. Four to six denticles on anterior process. Each is compressed, fused, and has a width of about one-quarter that of cusp. Posterior process may bear up to six denticles of a similar nature. Both cusp and denticles filled with dense white matter, which overlies a thin line of hyaline material.

M element is falodontiform or modified oistodontiform, with prominent cusp. Anterior margin or process bears four or more fused, rudimentary denticles. Unit has a prominent posterior process that is adentate in most specimens with a conspicuous niche between the cusp and the posterior process. A narrow groove excavates the element, which broadens to form a constricted basal cavity under cusp. White-matter distribution is like that of P element.

Sc skeletal element resembles counterpart in *A. emanuelensis* except that posterior margin bears three or four small fused denticles.

No characteristic Sa and Sb skeletal units were recognized.

Remarks. A. buetefueri is closely related to *A. emanuelensis* from which it probably evolved. The denticulation found in this species is unlike that in species of *Acodus* described by McTavish (1973). In *A. buetefueri* the denticles develop on distinct processes. Further, as no denticulation occurs on lateral processes the P element is ozarkodiniform rather than prioniodontiform. Future workers may prefer to assign this species to a new genus because of its denticulation.

Acodus emanuelensis McTavish, 1973

Plate 28, figs. 1, 5, 6, 9, 10, 12

1973 *Acodus emanuelensis* McTavish, p. 40, pl. 2, figs. 16–21.
1975 *Acodus emanuelensis* McTavish; Lindström p. 7, Protoprioniodus pl. 1, figs. 4–8.

Material. Approximately 6600 elements.

EXPLANATION OF PLATE 26

Figs. 1, 2, 6. *Drepanoistodus suberectus* (Branson and Mehl). 1, lateral view of Sa (suberectiform) element, GSSA Co 26, ×140. 2, lateral view of ?S element, GSSA Co 23, ×140. 6, lateral view of asymmetrical S element, GSSA Co 24, ×150. All specimens from MC-11.

Figs. 3–5, 7, 8. *Drepanoistodus pitjanti* sp. nov. 3, lateral view of Sa (suberectiform) element, GSSA Co 18, ×60 (Holotype). 4, lateral view of Sc (acodontiform) element, GSSA Co 21, ×60. 5, lateral view of Sb (paltodontiform) element, GSSA Co 19, ×55. 7, lateral view of Sd (drepanodontiform) element, GSSA Co 20, ×65. 8, lateral view of M (oistodontiform) element, GSSA Co 22, ×75. All specimens from MC-8.

Figs. 9, 12, 13, 15. *Oistodus scalenocarinatus* Mound. 9, lateral view of Sb element, GSSA Co 57, ×100. 13, posterior view of Sa element, GSSA Co 58, ×120. 15, lateral view of Sc element, GSSA Co 55, ×69. All specimens from MC-8.

Figs. 10, 11. *Cornuodus longibasis* (Lindström). Lateral and oblique lateral views of GSSA Co 120, ×100, MC-14.

Fig. 14. *Belodella jemtlandica* Löfgren. Lateral view of asymmetrical S element, GSSA Co 42, ×150, MC-11.

COOPER, Ordovician conodonts

Remarks. The skeletal apparatus of *A. emanuelensis* has been adequately described by McTavish (1973). Well-preserved representatives of the five constituent elements (P, M, Sa, Sb, Sc) are abundant in the collections considered here. *A. emanuelensis* is closely related to *A. brevis* Branson and Mehl, 1933 emended Lindström, 1977.

Genus BALTONIODUS Lindström, 1971

1955 *Trapezognathus* Lindström, p. 597.
1971 *Baltoniodus* Lindström, p. 55.
1974 *Prioniodus* (*Baltoniodus*) Lindström; Serpagli, p. 51.
1974 *Volchodina* Sergeeva, p. 82.

Type species. Prioniodus navis Lindström.

Remarks. Löfgren (1978) and Fåhraeus and Nowlan (1978) have referred to all literature concerning use of *Baltoniodus* and *Prioniodus*. I prefer to use *Baltoniodus*. The skeletal apparatus of *Baltoniodus* contains amorphognathodontiform (Pa), ambalodontiform (Pb), oistodontiform (M), and a symmetry transition series of trichonodelliform (Sa), tetraprioniodontiform (Sb), and oepikodontiform (Sc) elements.

The work of Lindström (1971, 1974) and Löfgren (1978) implies that *Trapezognathus* is a senior synonym of *Baltoniodus*. All studies show the type species of *Trapezognathus* as a S element in *B. triangularis*. However, both have used *Baltoniodus* in preference to *Trapezognathus* so it must be assumed that either they doubt whether the type of *Trapezognathus* is synonymous with *B. triangularis* or they are uncertain about assigning *B. triangularis* and *B. navis* to the same genus.

Baltoniodus navis (Lindström, 1955)

Plate 29, figs. 9, 10; Plate 30, fig. 2

Pa element
1955 *Prioniodus navis* Lindström, p. 590, pl. 5, fig. 33.

S elements
1974 *Volchodina densa* (Lindström); Sergeeva, p. 82, pl. 1, figs. 2-4.
1974 *Volchodina costulata* Sergeeva, p. 83, pl. 1, figs. 1, 5.

Multi-element
1971 *Baltoniodus navis* (Lindström); Lindström, p. 56, pl. 1, figs. 13, 18-23.
1974 *Prioniodus navis* Lindström; van Wamel, p. 89, pl. 8, figs. 11, 12, 16-18 only.
1977 *Baltoniodus navis* (Lindström); Lindström, p. 73, Baltoniodus pl. 1, figs. 8, 9.
1978 *Prioniodus* (*Baltoniodus*) *navis* Lindström; Löfgren, p. 83, pl. 12, figs. 8-16, pl. 14, figs. 1A-B, 3A-D. [With comprehensive synonymy]

Material. 43 elements.

Remarks. The small number of skeletal elements of this species in the Horn Valley are identical to illustrated material from the Baltic Shield. Probable oistodontiform (M) elements lack denticulation along the anterior edge, a feature common to early apparatuses of *B. navis* (van Wamel 1974).

Genus BERGSTROEMOGNATHUS Serpagli, 1974

1974 *Bergstroemognathus* Serpagli p. 39.

Type species. Oistodus extensus Graves and Ellison.

Remarks. Bergstroemognathus is the only conodont genus in the Horn Valley to contain totally hyaline skeletal elements. Applying the Sweet and Schönlaub (1975) elemental notation here, the 'trichonodelliform', and 'prioniodiform' elements of Serpagli (1974) form a symmetry transition series of S elements. The 'falodiform' element of Serpagli occupies the M position in the apparatus.

Bergstroemognathus extensus (Graves and Ellison, 1941)

Plate 31, fig. 12; Plate 32, figs. 7, 9–11

M element
1941 *Oistodus extensus* Graves and Ellison, p. 13, pl. 13, figs. 16, 28.
?1969 *Falodus* cf. *F. extensus* (Graves and Ellison); Bradshaw, p. 1151, pl. 135, fig. 15.

S element
1941 Indeterminable specimen; Graves and Ellison, p. 7, pl. 1, fig. 20.

Multi-element
1974 *Bergstroemognathus extensus* (Graves and Ellison); Serpagli, p. 40, pl. 9, figs. 1*a*–8*c*; pl. 21, figs. 1–7; text-fig. 7.
1976 *Bergstroemognathus* cf. *B. extensus* (Graves and Ellison); Landing, p. 40, pl. 1, figs. 1–6, 9, 10.

Material. 167 elements.

Remarks. Horn Valley collections of *B. extensus* are poorly preserved. Both Serpagli (1974) and I have probably included more than one species here. Both collections include elements with many closely spaced, fused denticles, as well as robust elements bearing a small number of discrete denticles.

S elements of three types are recognized in the Horn Valley. Sa components are symmetrical trichonodelliform units and are identical to the corresponding element of Serpagli (1974) except that fewer than six denticles are generally present on each process. Sb elements are asymmetrical units similar to Sa elements. Sc elements may be similar to the 'prioniodiform' element of Serpagli or may be belodontiform with up to five posterior denticles and no anterior process.

The M element is identical to the 'falodiform' element of Serpagli.

Genus CORNUODUS Fåhraeus, 1966

1966 *Cornuodus* Fåhraeus p. 20.

Type species. *Drepanodus longibasis* Lindström (= *Cornuodus erectus* Fåhraeus).

Diagnosis. Multi-element *Cornuodus* has a skeletal apparatus comprising a symmetry transition series (S elements) of albid simple cones. The cones are characterized by a long base, subcircular basal outline, and the lack of conspicuous costae. Costae may occur near the posterior margin accompanied by fine striation.

Remarks. Skeletal elements of *Cornuodus* show such little morphologic variability that redefinition of the genus has been unnecessary for use as a multi-element genus. *Cornuodus* is closely related to *Scalpellodus* Dzik, 1976 and *Protopanderodus* Lindström, 1971. My concept of *Cornuodus* follows that of Löfgren (1978).

Cornuodus longibasis (Lindström, 1955)

Plate 26, figs. 10–11

1955 *Drepanodus longibasis* Lindström, p. 564, pl. 3, fig. 31.
1966 *Cornuodus erectus* Fåhraeus, p. 20, pl. 2, fig. 8*a*–*b*; text-fig. 2B.
1967 *Cornuodus erectus* Fåhraeus; Serpagli, p. 57, pl. 12, figs. 5–8.
1967 *Scandodus lanzaensis* Serpagli, p. 95, pl. 26, figs. 4–7.
1970 *Cornuodus erectus* Fåhraeus; Lee, p. 315, pl. 7, fig. 9.
1974 *Cornuodus longibasis* (Lindström); Serpagli, p. 43, pl. 7, fig. 2; pl. 20, fig. 12.
1974 *Protopanderodus longibasis* (Lindström); van Wamel, p. 92, pl. 4, figs. 4–6.
1976 *Cornuodus longibasis* (Lindström); Landing, p. 631, pl. 1, figs. 12, 13, 15.
1976 *Scalpellodus* (?*Cornuodus*) *laevis* Dzik, p. 421, pl. 41, fig. 1; text-fig. 13*a*–*c*.
1978 *Cornuodus longibasis* (Lindström); Löfgren, p. 49, pl. 4, figs. 36, 38–42; text-fig. 25A–C [with additional synonymy].

Material. 79 elements.

Remarks. Löfgren (1978) has provided a full description of this species. Most Horn Valley elements are symmetrical or slightly asymmetrical elements of the type Löfgren called 'Symmetrical Element A'.

Genus DREPANOISTODUS Lindström, 1971 emended van Wamel, 1974

1971 *Drepanoistodus* Lindström, p. 42.
1973 *Drepanoistodus* Lindström; Lindström, p. 71.
1974 *Drepanoistodus* Lindström; van Wamel, p. 62.

Type species. Oistodus forceps Lindström, 1955.

Revised diagnosis. Skeletal apparatuses of *Drepanoistodus* are characterized by an oistodontiform (M) element and a symmetry transition series (S elements) including suberectiform, paltodontiform, drepanodontiform, scandodontiform, or acodontiform elements. All elements may carry costae.

Remarks. My concept of *Drepanoistodus* is close to that of van Wamel (1974). *Paltodus* Pander, 1856 emended Lindström 1971, 1977 may be a senior synonym of *Drepanoistodus* as conceived here. However, the skeletal apparatus of the type species of *Paltodus* (*P. subaequalis*) is not adequately known.

Conodontophorids close to *Drepanoistodus* but lacking an oistodontiform (M) unit have been recognized by Nowlan (1976) and Druce (pers. comm. 1979). Such skeletal apparatuses are assigned here to *Scandodus*. *Drepanoistodus* may be an ancestor to *Trigonodus* Nieper, 1969 as emended herein. The latter genus is differentiated from *Drepanoistodus* by the addition of P units to its skeletal apparatus.

Drepanoistodus pitjanti sp. nov.

Plate 26, figs. 3–5, 7, 8

Origin of name. An abbreviated form of 'Pitjantjatjara', the name given to one of the native aboriginal tribes of Central Australia.

Material. Holotype (GSSA Co 18); Paratypes (GSSA Co 19–22); total collection studied 1615 elements.

Type locality and strata. Maloney Creek, adjacent to Stuart Highway Bridge, south of Alice Springs, Northern Territory, Australia. Horn Valley Siltstone, limestone beds about 19 m above base of formation (Sample MC-8).

Diagnosis. A *Drepanoistodus* with a skeletal apparatus composed of robust, keeled, dominantly hyaline elements with one to five prominent lateral costae near the posterior margin. A basal cavity of moderate size is present.

EXPLANATION OF PLATE 27

Figs. 1, 2. *Oneotodus* sp. Lateral and oblique lateral views of GSSA Co 59, both ×125, EC-2.
Figs. 3, 4. *Protopanderodus primitus* Druce. 3, lateral view of S element, GSSA Co 71, ×92. 4, lateral view of S element, GSSA Co 72, ×85. Both specimens from MC-13.
Figs. 5, 6, 11, 12, 16, 17. *Trigonodus larapintinensis* (Crespin). 5, lateral view of Sc (acodontiform) element GSSA Co 108, ×77, MC-7. 6, lateral view of M (oistodontiform) element, GSSA Co 106, ×86, MC-11. 11, lateral view of P (modified scandodontiform) element, GSSA Co 105, ×77, MC-11. 12, lateral view of Sd (drepanodontiform) element, GSSA Co 101, ×110, MC-11. 16, lateral view of Sa (symmetrical) element, GSSA Co 107, ×60, MC-7. 17, lateral view of P (scandodontiform) element, GSSA Co 104, ×87, MC-11.
Figs. 7–10, 13–15. *Scalpellodus latus* (van Wamel). 7, lateral view of Sa (symmetrical) element GSSA Co 111, ×100. 8, lateral view of Sb (scandodontiform) element, GSSA Co 109, ×120. 9, posterior view of Sa (symmetrical) element, GSSA Co 111, ×106. 10, lateral view of Sb (scandodontiform) element, GSSA Co 114, ×125. 13, lateral view of Sb element, GSSA Co 114, ×900, showing microsculpture. 14, lateral view of Sb (scandodontiform) element, GSSA Co 110, ×117. 15, lateral view of Sc (drepanodontiform) element, GSSA Co 116, ×110. All specimens from MC-11 except GSSA Co 116 from MC-14.

COOPER, Ordovician conodonts

Description. M element is oistodontiform. Cusp is keeled, reclined, and twisted. Inner side bears one prominent longitudinal costa, which extends along most of the unit. Secondary costae may also be present. Outer side has a gently curved surface. There is only a short posterior prolongation of base.

S elements are all modified drepanodontiform units. All bear prominent costae. They vary in morphology from symmetrical, costate, suberectiform (Sa) elements through asymmetric paltodontiform (Sb) elements, acodontiform (Sc) elements, and drepanodontiform (Sd) elements. Elements also vary progressively in curvature from suberect (Sa) to highly recurved (Sd). Sa elements bear two to four prominent longitudinal costae on each face. Unit is strongly keeled and has a flaring base. Sb components are gently recurved and twisted with three or four costae on each lateral face. Anterior keel is bent inwards. There is posterior prolongation of the base. Sb and Sc components are similar in morphology. However, the cusp on Sc units bears fewer costae and has greater curvature than Sb elements. Sd element is drepanodontiform, showing little twisting and approaching bilateral symmetry. One or two short costae are placed adjacent to the posterior margin on each face.

All elements of *D. pitjanti* are predominantly hyaline; however, a narrow longitudinal band of white matter is consistently present. In some elements white matter may become diffuse throughout.

Remarks. A close relative of *D. pitjanti* has been recognized in the Lena River Basin, Siberia, U.S.S.R., by Abaimova (1975, pl. 3, figs. 6–8, 14; pl. 5, fig. 10; pl. 6, fig. 6). However, Druce (pers. comm. 1979) has reconstructed this apparatus as *Scandodus costatus* (Abaimova, 1971) from samples collected in western Queensland and has found no oistodontiform (M) unit in his material.

Drepanoistodus suberectus (Branson and Mehl, 1933) emended Bergström and Sweet, 1966

Plate 26, figs. 1, 2, 6

1933 *Oistodus suberectus* Branson and Mehl, p. 111, pl. 8, fig. 7.
1966 *Drepanodus suberectus* (Branson and Mehl); Bergström and Sweet p. 330, pl. 35, figs. 22–27 [with further synonymy to 1966].
1977 *Drepanoistodus suberectus* (Branson and Mehl); Barnes, p. 196, pl. 3, figs. 18–20 [with synonymy 1966–1977].

Material. 491 elements.

Remarks. Lindström (1971, p. 43) assigned this species to *Drepanoistodus*. *D. suberectus* evolves gradationally from *D. basiovalis* (Sergeeva) emended Lindström. Much of the Horn Valley collection of these conodonts consists of minute elements. As a consequence it is impossible to discern whether *D. suberectus* or *D. basiovalis* is present or even to differentiate oistodontiform (M) elements from drepanodontiform (S) elements.

Genus ERRATICODON Dzik, 1978

1978 *Erraticodon* Dzik, p. 64.

Type species. *Erraticodon balticus* Dzik, 1978.

EXPLANATION OF PLATE 28

Figs. 1, 5, 6, 9, 10, 12. *Acodus emanuelensis* McTavish. 1, lateral view of Sc (cordylodontiform) element, GSSA Co 9, ×93. 5, lateral view of Sb (tetraprioniodontiform) element, GSSA Co 4, ×83. 6, lateral view of P (scandodontiform) element, GSSA Co 7, ×70. 9, lateral view of Sa (trichonodelliform) element, GSSA Co 5, ×85. 10, lateral view of M (oistodontiform) element, GSSA Co 6, ×90. 12, lateral view of P element, GSSA Co 7, ×1050 showing microsculpture. All specimens from MC-7 except GSSA Co 9 from MC-8.

Figs. 2–4. *Microzarkodina flabellum* (Lindström). 2, lateral view of P (ozarkodiniform) element, GSSA Co 45, ×100. 3, lateral view of Sc (cordylodontiform) element, GSSA Co 44, ×78. 4, posterior view of Sa (trichonodelliform) element, GSSA Co 43, ×80. All specimens from MC-8.

Figs. 7, 8, 11, 13. *Acodus buetefueri* sp. nov. 7, lateral view of P (ozarkodiniform) element, GSSA Co 3, ×105 (Holotype). 8, lateral view of P (ozarkodiniform) element, GSSA Co 1, ×95. 11, lateral view of M (oistodontiform) element, GSSA Co 2, ×95. 13, lateral view of M element GSSA Co 2, ×220, showing microsculpture. All specimens from MC-8.

COOPER, Ordovician conodonts

Diagnosis. A conodontophorid having a fully differentiated skeletal apparatus with components recognizable in the Pa, Pb, M, Sa, Sb, Sc positions. In the P positions are oulodontiform or modified oulodontiform components. The M element is neoprioniodontiform. The symmetry transition series consists of three branched trichonodelliform (Sa) and plectospathodontiform (Sb) elements, and a hindeodelliform or cordylodontiform (Sc) element. All elements are hyaline and the processes bear discrete peg-like denticles.

Remarks. *Erraticodon* was proposed by Dzik (1978) for conodontophorids with a skeletal apparatus regarded as being transitional between *Periodon* and *Oulodus*. The only species found by Dzik, *E. balticus*, was recorded from Llanvirn and Llandeilo strata (fig. 2 of Dzik). The new species of *Erraticodon* proposed here shows strong similarities to Ordovician species of *Oulodus* (Sweet and Schönlaub, 1975). Indeed it is tempting to synonymize *Erraticodon* with *Oulodus*. However, *Erraticodon* can be distinguished from its predecessor by Sa and Sb elements that bear three denticulated processes. The relationship postulated by Dzik between *Periodon* and *Erraticodon* is not confirmed here. The Horn Valley species of *Erraticodon* is older than *E. balticus* and the morphology of its Pa element is significantly different from counterparts in *Periodon*.

In addition to the occurrences of *Erraticodon* noted by Dzik (1978) from the Baltic and Siberian platforms, skeletal elements referable to the genus also occur in Utah (Sweet *et al.* 1971, pl. 1, figs. 28, 30), Arctic Canada (Barnes 1974, pl. 1, figs. 13, 14), and Australia.

Erraticodon patu sp. nov.

Plate 32, figs. 1–6, 8

1978 Prioniodid conodont element. Müller, p. 276.

Origin of name. From 'patu' an Australian aboriginal (Pitjantjatjara) word meaning 'some distance from'. The name alludes to the discrete nature of denticles in the genus.

Material. Holotype (GSSA Co 28); Paratypes (GSSA Co 27, 29–40); total collection studied 1975 elements.

Type locality and strata. Ellery Creek Gorge, west of Alice Springs, Northern Territory, Australia. Horn Valley Siltstone, limestone beds about 84 m above base of formation (Sample EC-9).

Diagnosis. A species of *Erraticodon* with a Pa skeletal component having three denticulated processes.

Description. Pa element is a modified oulodontiform or lonchodiniform unit. It is arched with three processes, anterior, posterior, and lateral, extending outwards from a prominent cusp. Anterior and posterior processes almost form a single plane with cusp forming an apex. However, both processes are slightly bent inwards and away from cusp. Lateral process is directed outwards at about 60 degrees to anterior process. All three processes are of similar length and bear three or four discrete compressed denticles. Entire element is broadly excavated. Costae are discernible on cusp, which extend on to each process.

EXPLANATION OF PLATE 29

Figs. 1–8, 11, 12. *Protoprioniodus nyinti* sp. nov. 1, outer lateral view of P element, GSSA Co 82, × 140. 2, outer lateral view of M (oistodontiform) element, GSSA Co 87, × 142. 3, outer lateral view of P element, GSSA Co 81, × 142. 4, inner lateral view of P element, GSSA Co 80, × 145. 5, inner lateral view of M (oistodontiform) element, GSSA Co 85, × 150. 6, lateral view of Sa element, GSSA Co 88, × 95. 7, lateral view of asymmetrical S element, GSSA Co 90, × 74. 8, lateral view of asymmetrical S element, GSSA Co 89, × 100 (Holotype). 11, lateral view of Sa element, GSSA Co 88, × 510, showing microsculpture. 12, lateral view of M element, GSSA Co 87, × 1500, showing reticulate ornament. All specimens from MC-7.

Figs. 9, 10. '*Baltoniodus navis* (Lindström). 9, lateral view of Pb (ambalodontiform) element, GSSA Co 12, × 109. 10, lateral view of M (oistodontiform) element, GSSA Co 10, × 103. All specimens from MC-8.

COOPER, Ordovician conodonts

Pb element is oulodontiform. It consists of a twisted bar, bearing discrete flattened denticles. Cusp may not be conspicuous amongst surrounding denticles. Entire unit is excavated, basal cavity being widest near cusp.

M element is neoprioniodontiform and is similar to its counterpart in *E. balticus*. It is a denticulated bar with a conspicuous, wide, flattened cusp at anterior end. Posterior process bears three or four compressed denticles. In some specimens denticles can be observed anterior to cusp. Basal cavity is excavated under the entire unit and is expanded on one side of element.

Sa element is trichonodelliform with a well-developed anterior arch and posterior process. All three processes may bear one to four denticles. Sb element is plectospathodontiform and indistinguishable from its counterpart in *E. balticus*. Unit is entirely excavated and bears several denticles on each of its three processes. Lateral process is the shortest in most specimens. Sc element is cordylodontiform or hindeodelliform. Lateral or anterior process may be directed at various angles from large cusp. Both lateral and posterior processes bear two or four discrete denticles.

Remarks. E. patu differs from *E. balticus* in the possession of a Pa skeletal component having three processes. In addition, the Sa element of *E. patu* has denticulated processes of approximately equal length and bearing a similar number of denticles.

E. patu also occurs in early Ordovician limestones at Mt. Arrowsmith, New South Wales, Australia (Kennedy 1975, 1976), and in the Bay Fiord Formation, Arctic Canada (Nowlan 1976). *E. patu* possibly occurs in collections recently described using form taxonomy, from the Siberian platform (Kanigin, Moskalenko, Yadrenkind, and Semenova 1977, pl. 9, figs. 8–12). However, the diagnostic Pa component of *E. patu* was not described in that paper. If this Russian collection includes *E. patu*, then one of Moskalenko's names should be chosen to have priority over the trivial name *patu*.

Genus JUMUDONTUS gen. nov.

Type species. Jumudontus gananda sp. nov.

Derivation of name. From 'Jumu' an Australian aboriginal language group in central Australia.

Diagnosis. Jumudontus has a skeletal apparatus that comprises straight or slightly arched, denticulated, bar elements. No conspicuous cusp is present. A shallow groove underlies the units, which expands towards the posterior end to form the basal cavity. Most elements contain clearly discernible albid and hyaline regions.

Remarks. Jumudontus has either a monoelemental apparatus or an apparatus composed of morphologically similar units. It is a rare representative in many early Ordovician conodont collections, especially in North America. The genus is probably related to *Loxodus* Furnish, 1938. Skeletal elements of *Jumudontus* also resemble units referred to *Histiodella* Harris, 1962; however, early species of this genus, common to the stratigraphic level of the Horn Valley Siltstone, generally contain adentate elements (Sweet *et al.* 1971).

EXPLANATION OF PLATE 30

Figs. 1, 6, 7, 10, 12. *Protoprioniodus aranda* sp. nov. 1, lateral view of Sa element, GSSA Co 76, ×73, EC-5 (Holotype). 6, lateral view of asymmetrical S element, GSSA Co 73, ×110, MC-8. 7, oblique lateral view of S element, GSSA Co 73, ×150, MC-8. 10, outer lateral view of M (oistodontiform) element, GSSA Co 74, ×100, MC-8. 12, lateral view of M element, GSSA Co 74, ×525, MC-8.

Fig. 2. *Baltoniodus navis* (Lindström). Lateral view of Pa (amorphognathodontiform) element, GSSA Co 11, ×80, MC-8.

Figs. 3–5, 8, 9, 11, 13. *Protoprioniodus yapu* sp. nov. 3, lateral view of M element, GSSA Co 98, ×102. 4, basal view of S element, GSSA Co 94, ×87. 5, lateral view of S element, GSSA Co 97, ×100. 8, lateral view of S element, GSSA Co 94, ×87. 9, outer lateral view of P element, GSSA Co 95, ×90 (Holotype). 11, outer lateral view of P element, GSSA Co 96, ×110. 13, outer lateral view of P element, GSSA Co 95, ×310 (Holotype). All specimens from EC-5.

COOPER, Ordovician conodonts

Elements of *Jumudontus* also resemble those of *Ozarkodina*; however, no equivalent symmetry transition series or M components can be recognized in *Jumudontus*, and *Ozarkodina* has not been positively recognized below the late Ordovician. *Loxodus asiaticus* Abaimova, 1975 may belong to *Jumudontus*.

Jumudontus gananda sp. nov.

Plate 31, fig. 13

?1964 ?*Spathognathodus* sp. Ethington and Clark, p. 201, pl. 2, fig. 5.
?1970 *Spathognathodus* n. sp. Fåhraeus, fig. 3I.
1971 New Genus B, Sweet *et al.*, pl. 1, fig. 34.
1974 New Genus B Barnes, pl. 1, fig. 9.
?1974 *Spathognathodus* sp. Serpagli, p. 87, pl. 19, fig. 11*a–b*; pl. 29, fig. 16.
1976 *Spathognathodus* sp. Landing, p. 640, pl. 4, fig. 15.
1977 New Genus B n. sp. s.f. Barnes, p. 104, pl. 1, figs. 16–18.
?1978 *Histiodella* n. sp. s.f. Fåhraeus and Nowlan, p. 460, pl. 3, fig. 14.

Origin of name. From the Australian Aboriginal (Djingili) word 'gananda' meaning jaw.

Material. Holotype (GSSA Co 41); total collection examined twenty-six elements.

Type locality and strata. Maloney Creek, adjacent to Stuart Highway Bridge, south of Alice Springs, Northern Territory, Australia. Horn Valley Siltstone, limestone beds about 72 m above base of formation (Sample MC-11).

Diagnosis. A species of *Jumudontus* bearing a robust bar element with up to a dozen erect and inclined denticles and a short, blunt, adentate lateral process. This element contains a distinctive wedge of white matter with an apex at the tip of the basal cavity.

Description. Skeletal elements of *J. gananda* are straight or slightly arched spathognathodontiform units. Up to a dozen predominantly fused denticles of uniform height constitute this element. Denticles erect posteriorly but progressively incline along unit towards the anterior. White matter developed in most denticles. Contact between hyaline and albid material generally passes in an oblique line from tips of extreme anterior and posterior denticles to the tip of the basal cavity.

Basal cavity is shallow and is located towards posterior of unit. It constricts to a groove under most of element. Basal cavity is bounded by lateral flanges, one of which forms a sharp spur-like lateral process. Posterior denticles also may be completely fused or unrecognizable and contain variable concentrations of white matter.

Remarks. In Australia, *J. gananda* also occurs in the early Ordovician of the Georgina Basin, Queensland (Druce pers. comm. 1979) and at Mt. Arrowsmith, New South Wales (Kennedy 1976). In the Canadian Arctic it occurs in the Ship Point Formation (Barnes 1974, 1977) and in the Eleanor River Formation (Nowlan 1976). It is also found in New York (Landing 1976), in the upper West

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EXPLANATION OF PLATE 31

Figs. 1–3, 5, 6, 8, 9. *Prioniodus amadeus* sp. nov. 1, upper view of P (prioniodontiform) element, GSSA Co 67, ×153, MC-7 (Holotype). 2, lateral view of Sa (trichonodelliform) element, GSSA Co 61, ×70, MC-8. 3, lateral view of Sb (tetraprioniodontiform) element, GSSA Co 62, ×70, MC-8. 5, lateral view of Sc (belodontiform) element, GSSA Co 65, ×95, MC-8. 8, upper view of P (prioniodontiform) element, GSSA Co 70, ×150, MC-7. 9, lateral view of M (oistodontiform) element, GSSA Co 66, ×95, MC-8.

Figs. 4, 7, 10, 11, 14. *Oepikodus evae* (Lindström). 4, lateral view of P (prioniodontiform) element, GSSA Co 53, ×195. 7, lateral view of M (oistodontiform) element, GSSA Co 46, ×155. 10, upper view of P (prioniodontiform) element, GSSA Co 53, ×210. 11, lateral view of S (oepikodontiform) element, GSSA Co 53, ×210. 14, lateral view of S (oepikodontiform) element, GSSA Co 47, ×187. All specimens from EC-4.

Fig. 12. *Bergstroemognathus extensus* (Graves and Ellison). Lateral view of M (falodontiform) element, GSSA Co 16, ×115, EC-2.

Fig. 13. *Jumudontus gananda* gen. et sp. nov. Lateral view of Holotype, GSSA Co 41, ×80, MC-11.

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Spring Creek Formation in Oklahoma (Potter 1975), in the Juab Formation, Utah (Sweet *et al.* 1971), and in western Alberta (Ethington and Clark 1964). It probably occurs in the Cow Head Group in Newfoundland (Fåhraeus 1970; Fåhraeus and Nowlan 1978), the San Juan Formation, Argentina (Serpagli 1974), and in Sweden (Bergström *in* Serpagli 1974, p. 88) and New York (Landing 1976, p. 640).

Genus OISTODUS Pander, 1856 emended van Wamel, 1974

1856 *Oistodus* Pander, p. 27.
1955 *Oistodus* Pander; Lindström, p. 572.
1971 *Oistodus* Pander; Lindström, p. 35.
1974 *Oistodus* Pander; van Wamel, p. 75.

Type species. Oistodus lanceolatus Pander, 1956.

Remarks. Oistodus is one of the best-known Ordovician multi-element conodont genera. Its skeletal apparatus consists of a symmetry transition series of S elements.

Oistodus scalenocarinatus Mound, 1965 emended Barnes, 1977

Plate 26, figs. 9, 12, 13, 15

1965 *Oistodus scalenocarinatus* Mound, p. 30, pl. 4, figs. 6, 7, 10–12.
1970 *Oistodus lanceolatus* Pander; Uyeno and Barnes, p. 119, pl. 24, figs. 23, 24.
1974 *Oistodus multicorrugatus* Harris; Barnes, pl. 1, fig. 7.
1977 *Oistodus scalenocarinatus* Mound; Barnes, p. 103, pl. 1, figs. 11–13.

Material. 406 elements.

Remarks. Horn Valley representatives are transitional with *Oistodus lanceolatus* Pander, 1856 emended van Wamel, 1974.

Genus ONEOTODUS Lindström, 1955

1955 *Oneotodus* Lindström, p. 581.
1973 *Oneotodus* Lindström; Lindström, p. 203.

Type species. Distacodus? simplex Furnish, 1938.

Oneotodus sp.

Plate 27, figs. 1–2

Material. 33 elements.

Description. Oneotodus sp. has a skeletal apparatus of proclined simple cones. Elements are circular in cross-section and a flaring base encloses a shallow basal cavity. Cones are symmetrical or slightly asymmetrical but no costae were recognized. Dense white matter occurs in varying quantities in cusp.

Remarks. The small number of elements in the Horn Valley referable to this species preclude a complete description.

Genus PRIONIODUS Pander, 1956 emended Fåhraeus and Nowlan, 1978

1856 *Belodus* Pander, p. 30.
1856 *Prioniodus* Pander, p. 29.
1955 *Gothodus* Lindström, p. 569.
1955 *Prioniodus* Pander; Lindström, p. 588.
1955 *Tetraprioniodus* Lindström, p. 596.
1971 *Prioniodus* Pander; Bergström, p. 144.

1974 *Prioniodus* (*Prioniodus*) Pander; Serpagli, p. 67.
1974 *Prioniodus* Pander; van Wamel, p. 82.
1975 *Prioniodus* Pander; Lindström, p. 329.
1978 *Prioniodus* Pander; Fåhraeus and Nowlan, p. 463.

Type species. Prioniodus elegans Pander.

Diagnosis. Prioniodus has a skeletal apparatus with denticulated prioniodontiform (P) elements, adentate or anteriorly denticulate oistodontiform (M) elements, and a fully developed symmetry transition series of ramiform (S) elements.

Remarks. My concept of *Prioniodus* is essentially that of Fåhraeus and Nowlan (1978) except that an adentate M skeletal element may also occur in the apparatus. The views of Serpagli (1974) and van Wamel (1974) differ substantially from this definition.

Four species of *Prioniodus* are currently known: *P. amadeus* sp. nov., *P. elegans* Pander, *P. minutus* (McTavish), and *P. oepiki* (McTavish). *Prioniodus* evolved from *Acodus* (McTavish, 1973) and gave rise to *Baltoniodus* and *Oepikodus*.

Prioniodus amadeus sp. nov.

Plate 31, figs. 1–3, 5, 6, 8, 9

Origin of name. From the 'Amadeus Basin', the sedimentary basin in which the Horn Valley Siltstone is developed.

Material. Holotype (GSSA Co 67); Paratypes (GSSA Co 60–66, 68–70); total collection examined approximately 4700 elements.

Type locality and strata. Maloney Creek, adjacent to the Stuart Highway Bridge, south of Alice Springs, Northern Territory, Australia. Horn Valley Siltstone, limestone beds about 14 m above the base of the formation (Sample MC-7).

Diagnosis. The P element is suberect and has a blade-like cusp with short denticulate processes. The M element is adentate. The processes of the S element are generally denticulate and posterior processes are the longest.

Description. P element is prioniodontiform. It has a suberect, blade-like cusp with three conspicuous costae that are drawn out into anterior, posterior, and lateral processes. Small rudimentary flattened denticles occur on processes, which decrease in size away from cusp. Lateral and posterior processes are longest with three or four denticles commonly present. Anterior process is shortest and denticles cannot be discerned on many specimens. Anterior edge is straight along distal two-thirds of its length but is redirected inwards along plane of cusp at base. Basal cavity is deep and extends under processes, which are joined by a basal sheath. Basal cavity terminates distally in a tip under cusp. Base is triangular in profile and cross-section. Cusp is filled with white matter from a point immediately distal to tip of basal cavity.

M element is oistodontiform. It has a prominent reclined cusp filled with white matter. Cusp is flattened and sharp-edged, and broad longitudinal costae may be discerned. Posterior edge of cusp is straight or with a slight inward curvature near base. It makes an acute angle with base. Anterior edge of unit is gently curved around basal margin. Posterior prolongation of the base is generally short and does not exceed length of cusp. Basal cavity fills most of base and tip can be discerned under cusp. Basal outline is an asymmetrical ellipse having greater curvature around anterior margin. Cusp has a slight inward and lateral twist resulting in a depressed region on inner lateral side, where posterior edge of cusp meets base.

Sa element is trichonodelliform. It is a symmetrical skeletal component, having a slender, proclined or erect cusp. Cusp has three prominent costae, which extend into two lateral processes and one posterior process. Anterior margin is flat and gently curved. Posterior process may be twice length of cusp, and is bent downwards away from it. Up to eighteen compressed, partly fused denticles have been counted on this process. Denticles have sharp edges, are similar in size, and are erect or slightly directed posteriorly. Lateral processes are extremely short in contrast to cusp and posterior process. They are divergent with respect to one another and are posteriorly as well as laterally directed. Denticles have not been recognized on lateral processes. A narrow basal sheath connects all processes and encloses basal cavity. Basal cavity extends as a narrow and shallow groove under processes. Its tip is directed anteriorly and located near anterior margin of element. Basal outline is triangular. White matter has formed in cusp distal to basal cavity and fills ancillary denticles. Hyaline matter occupies basal region of cusp and posterior process as well as forming a distinctive fine wedge between adjacent denticles on process. Lateral processes appear to be hyaline material.

Sb element is tetraprioniodontiform. It has a slender, proclined to erect cusp. Cusp has four costae, which extend into two lateral processes, an anterior process and a posterior process. Twisting of cusp and the disposition of processes with respect to one another impart a recognizable asymmetry to element. Posterior process is slightly twisted laterally, consequently it is possible to discern inner and outer sides of the unit. The size of posterior process and the nature of its denticulation are similar to Sa element. Lateral processes of the Sb component are also short as in Sa unit. However, one or two denticles are commonly present on longer inner lateral process. Short anterior process forms as a prolongation of cusp. No denticles have been noted on it. Basal cavity is large and has sharp apex, under cusp, adjacent to anterior margin. It extends as a groove under each process. Basal outline is quadrangular. White-matter distribution in cusp and ancillary denticles is same as in Sa component.

Sc element is belodontiform. Unit has a slender, proclined to erect cusp. Two conspicuous costae are present on cusp, which extend as anterior and posterior processes. A faint lateral costa occurs on a few specimens, which are transitional in morphology to Sb skeletal component. Cusp and processes are compressed and directed in different planes so that unit is asymmetrical. Posterior process is identical in morphology to its counterpart in Sb position. Anterior process may develop rudimentary denticle(s). Basal outline is biconvex.

Scanning Electron Microscope studies of skeletal components of *P. amadeus* reveal that longitudinal striation may ornament any or all elements, especially on the cusp.

Remarks. P. amadeus resembles *P. minutus* (McTavish, 1973). The latter differs in the possession of ramiform elements having long denticulated lateral processes. In the Horn Valley collections, some samples contain adentate P elements that resemble the denticulate P element of *P. amadeus*. These elements lack a lateral process but are similar in size, colour, lateral profile, and white-matter distribution.

Genus PROTOPANDERODUS Lindström, 1971

1971 *Protopanderodus* Lindström, p. 50.

Type species. Acontiodus rectus Lindström, 1955.

Remarks. I agree with Barnes and Poplawski (1973) that the definition of *Protopanderodus* is broad and in need of revision. Adequate material is not yet available to achieve this. In this paper I assign to *Protopanderodus* a species that appears to be transitional to *Panderodus*.

Protopanderodus primitus Druce

Plate 27, figs. 3, 4

1967 *Scolopodus* cf. *bassleri* Furnish; Igo and Koike, p. 23, pl. 3, figs. 7, 8; text-fig. 6B.
1969 *Scolopodus* sp. nov. A, Hill, Playford, and Woods, p. O14, pl. OVII, fig. 13.
1969 *Scolopodus* sp. nov. C, Hill *et al.*, p. O14, pl. OVII, fig. 15.
1974 '*Panderodus*' sp. Serpagli, p. 43, pl. 23, figs. 12, 13; pl. 30, figs. 12, 13.

Material. 51 elements.

Remarks. This species will be fully described by Druce (in preparation). It has an apparatus composed of a symmetry transition series of albid simple cones (S elements). Each constituent element has a conspicuous deep groove on each side.

Genus PROTOPRIONIODUS McTavish, 1973

1973 *Protoprioniodus* McTavish, p. 47.
1974 *Oelandodus* van Wamel, p. 71.

Type species. Protoprioniodus simplicissimus McTavish, 1973.

Remarks. The diagnostic features of skeletal elements of *Protoprioniodus* are the adentate processes. The genus undoubtedly evolved from *Acodus*. A P element, an M element, and a symmetry transition series of S skeletal components are all recognizable in species of the genus. In addition to species of *Oelandodus* van Wamel, 1974, *Acodus*? *russoi* Serpagli, 1974 probably also belongs in *Protoprioniodus*. However, Lindström (1978, p. 3) refers *A*? *russoi* to *Oistodus*.

Protoprioniodus has been recorded from many parts of the world. In Scandinavia, it has been recorded by van Wamel (1974) (= *Oelandodus*) and Löfgren (1978). In North America, skeletal elements have been found by Ethington and Clark (1965, pl. 2, figs. 11, 17), Sweet *et al.* (1971, pl. 1, figs. 19, 22), Barnes (1974, pl. 1, fig. 5), Repetski (1975), and Nowlan (1976). Reports from Australia were made by McTavish (1973), Kennedy (1974, 1976), and this paper.

Morphologic changes between the skeletal apparatuses of species of *Protoprioniodus* is considerable, and consequently the genus shows great biostratigraphic potential. *Protoprioniodus* appears to evolve from the *Acodus deltatus* group (McTavish, 1973, p. 48). Slight elongation of the posterior processes of skeletal elements referred to the *A. deltatus* plexus results in *P. elongatus* (Lindström, 1955, emended van Wamel, 1973).

Further elongation of the posterior process in the ramiform (S) elements produces *Protoprioniodus yapu* sp. nov. and *P. simplicissimus* McTavish, 1973. The former can be differentiated by a virtual absence of lateral processes. It may also provide an evolutionary link to *Paracordylodus* Lindström, 1955. *P. simplicissimus* is differentiated by an anterior extension on the oistodontiform (M) unit.

Thickening of the P and M skeletal elements, and the presence of long, straight adentate processes on units within the symmetry transition are common to *P. costatus* (van Wamel, 1974) and *P. nyinti* sp. nov. *P. nyinti* is distinguished from *P. costatus* as no cusp is developed on the P element of the former. Also, skeletal elements of *P. nyinti* have a pronounced groove near the aboral margin. Ramiform (S) skeletal elements of *P. aranda* sp. nov. have curved adentate processes with a discernible niche between the cusp and posterior process. Like *P. nyinti*, all units of *P. aranda* possess a pronounced groove adjacent to the aboral margin.

Further work is required to clarify the phylogeny of *Protoprioniodus* and the stratigraphic range of constituent species. Van Wamel (1974) shows *P. elongatus* with a range that entirely overlaps that of *P. costatus*. The P element of *P. simplicissimus* remains undescribed as the specimen illustrated by McTavish (1973, pl. 2, fig. 6) is a ramiform (S) element rather than a prioniodontiform (P) unit.

Protoprioniodus aranda sp. nov.

Plate 29, figs. 1, 6, 7, 10, 12

M element

1965 *Oistodus* sp. B, Ethington and Clark, p. 196, pl. 2, fig. 11.

S elements

1965 New Genus and species, Ethington and Clark, p. 203, pl. 2, fig. 17.

Origin of name. From 'Aranda' or 'Arunta', a general name given to the Australian aboriginal languages spoken in central Australia.

Material. Holotype (GSSA Co 76); Paratypes (GSSA Co 73–75, 77–79); total collection examined 236 elements.

Type locality and strata. Ellery Creek Gorge, west of Alice Springs, Northern Territory, Australia. Horn Valley Siltstone, limestone beds, about 47 m above base of formation (Sample EC-5).

Diagnosis. A species of *Protoprioniodus* with a skeletal apparatus having a flattened M element with spear-like cusp and anterior process, and ramiform (S) elements bearing gently curved posterior processes with a discernible niche between cusp and posterior process. All elements possess a distinctive longitudinal groove adjacent to the aboral or lower margin.

Description. P element of *P. aranda* is probably very similar to its counterpart in *P. nyinti*. Some arched bar elements are different from P elements of *P. nyinti* solely in size, degree of thickening, and robustness. These elements are most likely P units of *P. aranda*.

M element is a delicate oistodontiform. Unit has a sharp-edged, sharp-pointed, reclined cusp, which is laterally thickened on one side to produce a broad carina. Posterior process has a distinctive arched upper margin. An anterior process, with straight edges can be discerned, which tapers to a sharp point. The distinctive lateral groove is prominent near aboral margin on one side. A small basal cavity with short lateral flanges is present under cusp, constricting to a narrow groove under remainder of element. Unit is slightly twisted.

Ramiform (S) elements have long, curved posterior processes with a conspicuous niche between cusp and posterior processes. Lateral and anterior processes are short. In other respects these elements are similar morphologically to their counterparts in *P. nyinti*.

Remarks. *P. aranda* also occurs in the El Paso Group, West Texas (Repetski 1975), in the upper West Spring Creek Formation, Oklahoma (Potter 1975), and in the Eleanor River Formation, Canadian Arctic (Nowlan 1976).

Protoprioniodus nyinti sp. nov.

Plate 29, figs. 1–8, 11, 12

1971 New Genus A, Sweet *et al.*, pl. 1, figs. 19, 22.

Origin of name. A corruption of the Australian aboriginal (Pitjantjatjara) word 'nyintji', meaning spear. This alludes to the sharp spear-like processes belonging to the ramiform elements of this species.

Material. Holotype (GSSA Co 89); Paratypes (GSSA Co 80–88, 90–91); total collection examined 913 elements.

Type locality and strata. Maloney Creek, adjacent to Stuart Highway Bridge, south of Alice Springs, Northern Territory, Australia. Horn Valley Siltstone, limestone beds about 14 m above base of formation (Sample MC-7).

Diagnosis. A species of *Protoprioniodus* with a skeletal apparatus having a thickened arched bar in the P position, a robust, strongly recurved oistodontiform (M) element, and ramiform (S) elements bearing long, straight, delicate, blade-like processes, which markedly increase in height adjacent to the cusp. All elements possess a longitudinal groove near the aboral margin.

Description. P element is a robust arched bar with a swollen and depressed face. On swollen side, a very short process projects at an angle perpendicular to rest of unit. Longitudinal groove is present near aboral margin on this face. Element tapers on either side of apex of arch. Basal cavity is tiny but extends as a second, very narrow groove under unit. Element is a highly modified prioniodontiform skeletal component.

M element is oistodontiform. Cusp is strongly recurved or reclined and fused to base through much of its length. Unit is robust and twisted with the longitudinal groove being very prominent on one side. Element may be slightly arched. It is also excavated by a narrow groove, which extends under cusp to form a small basal cavity.

All elements of the symmetry transition series (S elements) have a long, straight, delicate, gently tapering, sharp-ended posterior process. Basal cavity is very small and underlies a large cusp, the length of which is about two-thirds that of posterior process. Basal cavity tapers to a narrow groove under processes.

Sa element has bilateral symmetry. Cusp possesses two, short, compressed lateral flanges, which are directed downwards, outwards, and posteriorly to form anterior arch. The characteristic aboral groove of this species is repeated on both sides of posterior process so that bilateral symmetry is retained. Sb element is similar to Sa element. However, Sb unit loses the symmetry of Sa skeletal components through twisting of its posterior

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EXPLANATION OF PLATE 32

Figs. 1–6, 8. *Erraticodon patu* sp. nov. 1, lateral view of Pb (oulodontiform) element, GSSA Co 37, ×80. 2, lateral view of Sc (cordylodontiform) element, GSSA Co 40, ×85. 3, lateral view of M (neoprioniodontiform) element, GSSA Co 39, ×80. 4, outer lateral view of Pa (lonchodiniform) element, GSSA Co 27, ×75. 5, posterior view of Sa (trichonodelliform) element, GSSA Co 36, ×50. 6, inner lateral view of Pa (lonchodiniform) element, GSSA Co 28, ×75 (Holotype). 8, lateral view of Sb (plectospathodontiform) element, GSSA Co 33, ×80. All specimens from EC-9.

Figs. 7, 9–11. *Bergstroemognathus extensus* (Graves and Ellison). 7, lateral view of Sc (belodontiform) element, GSSA Co 13, ×175. 9, lateral view of Sb element, GSSA Co 15, ×105. 10, lateral view of Sb element, GSSA Co 14, ×185. 11, posterior view of Sa (symmetrical) element, GSSA Co 17, ×160.

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process and a variation in length of its lateral processes. The groove adjacent to aboral margin also forms only on one face.

An Sc element is difficult to discern in *P. nyinti*. Ramiform elements, in which one lateral process is reduced to a costa and the other extends as an anteriorly directed process, appear to fill this position in the skeletal apparatus.

Remarks. *P. nyinti* also occurs in the Juab Formation, western Utah (Sweet *et al.* 1971), the El Paso Group, west Texas (Repetski 1975), the Eleanor River Formation, Arctic Canada (Nowlan 1976), at Mt. Arrowsmith, New South Wales (Kennedy 1976), and in the Nora Formation and upper part of the Coolibah Formation, western Queensland (Druce pers. comm. 1979).

Protoprioniodus yapu sp. nov.

Plate 30, figs. 3–5, 8, 9, 11, 13

M element

1975 *Oistodus longiramis* Lindström; Cooper and Druce, p. 575, fig. 28.

Origin of name. From the Australian aboriginal (Pitjantjatjara) word, 'yapu', meaning rock.

Material. Holotype (GSSA Co 95); Paratypes (GSSA Co 92–94, 96–98); total collection examined 378 elements.

Type locality and strata. Ellery Creek Gorge, west of Alice Springs, Northern Territory, Australia. Horn Valley Siltstone, limestone beds about 47 m above base of the formation (Sample EC-5).

Diagnosis. A *Protoprioniodus* with ramiform (S) skeletal elements having no lateral processes and an M element lacking an anterior process.

Description. P element is a highly modified prioniodontiform unit. It consists of a large reclined or erect cusp with anterior and posterior processes of similar length and width. Anterior process is bent downwards so that it forms angle of 120–150 degrees to posterior process. Element is compressed and twisted. A longitudinal carina is evident on outer side of cusp. A faint longitudinal ridge and groove is also evident on posterior process. A basal cavity of moderate size occurs under cusp.

M element is oistodontiform. It has a large reclined cusp and an anterior process or base of similar size. Basal margin is straight and it meets the anterior edge of cusp at an acute angle. Unit is compressed, slightly twisted, and broadly excavated.

Individual elements of the symmetry transition series are difficult to differentiate. All are compressed and consist of a reclined cusp and long, gently curved posterior process. A small basal cavity underlies the unit, which extends as a narrow groove along posterior process. A costa is evident on side of cusp. S elements may be symmetrical or asymmetrical depending on the placement of costa on cusp and the degree, if any, of twisting in these units.

Remarks. Without a cusp, the P skeletal element of *P. yapu* would be very similar to its counterpart in *P. nyinti*. Elemental morphology of *P. yapu* suggests a relationship between *Protoprioniodus* and *Paracordylodus* (see also Löfgren 1978, p. 67). Nowlan (1976) described a conodontophorid called ?*Paracordylodus* sp. from the Eleanor River Formation of Arctic Canada, which may be identical with *P. yapu*.

Genus SCALPELLODUS Dzik, 1976 emended Löfgren, 1978

1976 *Scalpellodus* Dzik, p. 421.
1978 *Scalpellodus* Dzik; Löfgren, p. 98.

Type species. *Protopanderodus latus* van Wamel, 1974.

Remarks. The skeletal apparatus of *Scalpellodus* comprises a symmetry transition series (S elements) of striated, albid, simple cones including drepanodontiform and scandodontiform units. The genus is most closely related to *Cornuodus* and *Protopanderodus*.

Scalpellodus latus (van Wamel)

Plate 27, figs. 7–10, 13–15

1974 *Protopanderodus latus* van Wamel, p. 91, pl. 4, figs. 1–3.
1978 *Scalpellodus latus* (van Wamel); Löfgren, p. 99, pl. 5, figs. 10, 14; pl. 6, figs. 1–4, 7, 21.

Material. 691 elements.

Remarks. The Sa or symmetrical element in the Horn Valley collection is identical to the 'long-based drepanodontiform element' of Löfgren (1978) and the symmetrical, narrow, proclined to erect elements of van Wamel (1974). Sb components are the scandodontiform units of van Wamel. Sc elements are the short-based drepanodontiform elements of Löfgren and the symmetrical, recurved, wide-based, wide-cusped element of van Wamel. Horn Valley collections contain elements intermediate in morphology between the principal element types.

I am not convinced that a clear-cut separation can be made between *S. latus* and *S. gracilis* (Sergeeva) emended Löfgren.

Genus TRIGONODUS Nieper, 1969 emended herein

1969 *Trigonodus* Nieper, p. O2.
1974 *Triangulodus* van Wamel, p. 96.

Type species. *Trigonodus larapintinensis* (Crespin, 1943) (= *T. triangularius* Nieper, 1969).

Revised diagnosis. A conodontophorid with a skeletal apparatus containing scandodontiform (P) elements, an oistodontiform (M) element, and a symmetry transition series of trichonodelliform or roundyaform (Sa) elements, paltodontiform (Sb) elements, acodontiform (Sc) elements, and drepanodontiform (Sd) elements. Skeletal elements of *Trigonodus* are predominantly hyaline.

Remarks. *Trigonodus* was proposed as a form genus by Nieper (1969) from the Nora Formation, Toko Range, western Queensland. Here the holotype is regarded as an Sa element in *T. larapintinensis* (Crespin). The type species of *Triangulodus* van Wamel, 1974 is here assigned to *Trigonodus*, so consequently the two genera are synonymous.

Acodus can be distinguished from *Trigonodus* principally by its possession of milky-white albid elements. Elements of *Trigonodus* are predominantly hyaline. White matter may occur along the growth axis or as a dispersed cloud throughout elements. *Trigonodus* includes species that were assigned to *Scandodus* by Löfgren (1978, p. 104). In the present study, *Scandodus* is reserved for conodontophorids whose skeletal apparatuses lack typical P and M units and are constructed entirely of S elements in a symmetry transition.

Lindström (1977, p. 417) places the type of *Triangulodus* (= *Trigonodus*) in *Pteracontiodus* Harris and Harris, 1965. However, I believe that *Pteracontiodus* is a related denticulated descendant of *Trigonodus*. Sweet and Bergström (1972, p. 42) have suggested that *Pteracontiodus* is a junior synonym of *Multioistodus* Cullison, 1938 and this has been supported by McHargue (1974).

Eoneoprioniodus Mound, 1965 emended Barnes, 1977 is a closely related descendant of *Trigonodus*. *Trigonodus* is differentiated from *Eoneoprioniodus* here as ramiform (S) elements of the latter develop adentate or weakly denticulate processes. Processes, if developed in the symmetry transition series of *Trigonodus*, are not prominent and never bear denticles. *Multioistodus* Cullison, 1938 emended McHargue, 1974 (= *Pteracontiodus*) is closely related to *Eoneoprioniodus*.

Multi-element *Oistodella* Bradshaw, 1969 is also closely related to *Trigonodus*. *Oistodella* is readily distinguished by the possession of denticulated M elements. Multi-element *Tokognathus* Nieper, 1969 is regarded here as a junior synonym of *Oistodella*. Multi-element *Tripodus* Bradshaw, 1969 may also be closely related to, or synonymous with, *Trigonodus*. I assign the following species to *Trigonodus*: *T. brevibasis* (Sergeeva, 1963) emended van Wamel, 1974; *T. akpatokensis* (Barnes, 1976) emended Barnes, 1977; *T. larapintinensis* (Crespin, 1943) emended herein. *Triangulodus*(?) *alatus* Dzik, 1976 probably belongs in *Eoneoprioniodus*. *Triangulodus subtilis* van Wamel, 1974 was assigned to *Acodus* by Lindström (1977, p. 14).

Trigonodus larapintinensis (Crespin, 1943)

Plate 27, figs. 5, 6, 11, 12, 16, 17

1943 *Oistodus larapintinensis* Crespin, p. 231, pl. 31, figs. 1-6, 9, 12, 13 (only).
1969 *Trigonodus triangularius* Nieper, p. O14, pl. OVII fig. 22.

Material. Approximately 5600 elements.

Type locality and strata. South Gorge, Waterhouse Range, south-west of Alice Springs, Northern Territory, Australia. Horn Valley Siltstone. According to Crespin (1943) the type collection was recovered from 'hard brownish to yellowish calcareous strata'.

Diagnosis. A *Trigonodus* bearing skeletal elements containing a thin conspicuous band of white matter along the growth axis. Elements within the symmetry transition series are commonly strongly recurved. A recurved, laterally twisted, modified scandodontiform (P) component is also characteristic.

Description. P elements are scandodontiform and modified scandodontiform. Elements in this position(s) are variable in morphology between both forms.

Scandodontiform components are proclined to erect, slightly twisted and laterally flattened near anterior and posterior margins, producing sharp keels. Base is variably expanded to accommodate a basal cavity of moderate size. Modified scandodontiform elements are erect to recurved and are markedly twisted. Flattening is not very apparent but anterior and posterior costae are prominent. As a consequence of lateral twisting, the anterior costa has a pronounced lateral component. In addition, a further faint costa may appear on inner lateral face.

M element is a gently recurved oistodontiform unit. Negligible posterior prolongation of base occurs; however, element has keeled anterior and posterior margins as well as slight lateral twisting.

Elements of symmetry transition series show considerable morphologic variation especially with regard to curvature and placement of costae. These simple cones may be proclined, erect, sharply recurved, or an intermediate variant. Width of base is also variable and all these elements have a basal cavity that extends to a tip at point of sharp curvature.

Sa element is a symmetrical cone with triangular cross-section. Unit bears three conspicuous costae which are symmetrically disposed. Sb element is paltodontiform. It is slightly twisted with anterior, posterior, and two lateral costae. Costae are not symmetrically arranged. Sc element is acodontiform with anterior, posterior, and one lateral costae. Sd element is drepanodontiform. Unit is flattened and slightly twisted with sharp anterior and posterior keels. No lateral costae were recognized. Degree of compression, twisting, and width of base is sufficiently variable that some specimens are cordylodontiform.

Remarks. Crespin's holotype of this species has been re-examined and found to be a recurved drepanodontiform (Sd) element. Crespin's concept of *Oistodus larapintinensis* included several different skeletal elements of the multi-element species conceived here. The synonymy herein includes only determinable and existing elements in the Crespin collection.

T. larapintinensis is closely related to *T. brevibasis* (Sergeeva, 1963) emended van Wamel, 1974 and may be found synonymous when abundant Baltic collections are examined. *T. larapintinensis* is differentiated here on the basis of its modified scandodontiform (P) component and sharply recurved S skeletal elements.

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