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OF
CANADA

DEPARTMENT OF ENERGY,
MINES AND RESOURCES

BULLETIN 222

CONTRIBUTIONS TO CANADIAN PALEONTOLOGY

(seven papers)

D. E. Jackson, B. S. Norford, D. S. Broad, D. L. Dineley, A. E. H Pedder,
Allen R. Ormiston, and L. Cameron Mosher

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PREFACE

From time to time it is appropriate to issue several short papers on paleontological topics as a single bulletin under the general title of *Contributions to Canadian Paleontology*. This Bulletin contains seven papers describing a number of different groups of fossils. Continuing study of new material by paleontologists enables them to up-date and refine the means at their disposal for precise paleontological determinations that are the basis of accurate stratigraphic interpretation which is so important in the scientific analysis of the sedimentary basins of northern and western Canada.

Y. O. FORTIER,
Director, Geological Survey of Canada

OTTAWA, June 13, 1972

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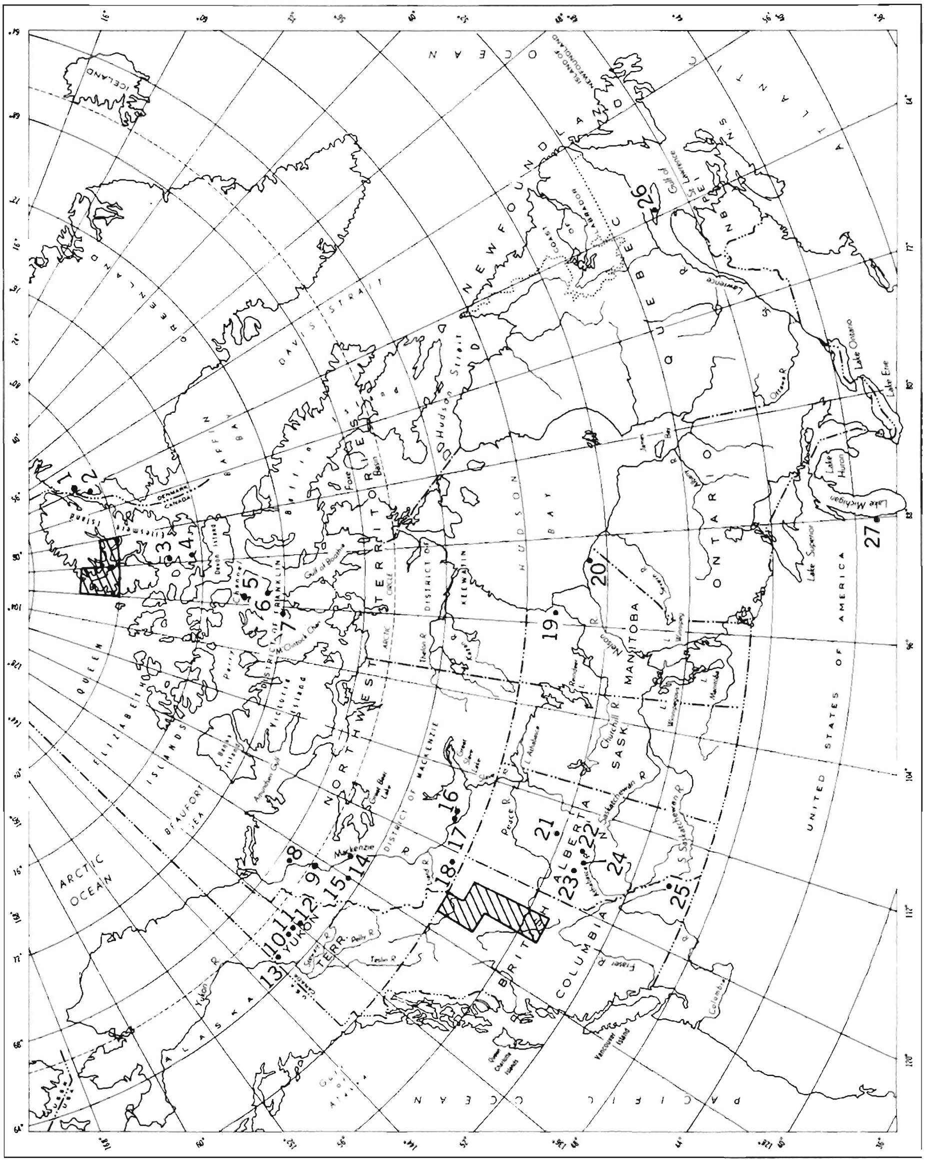

TEXTFIGURE 1. LOCALITY MAP FOR ALL PAPERS
Ruled areas indicate regions yielding Triassic conodonts (Mosher).

1. Kap Tyson, northwestern Greenland (Norford). 2. Kap Schuchert, northwestern Greenland (Norford). 3. Bjorne Peninsula, Ellesmere Island (Ormiston). 4. Southwestern Ellesmere Island (Broad). 5. Northwestern Somerset Island (Broad; Broad and Dineley). 6. Southeastern Somerset Island (Broad; Broad and Dineley). 7. Southeastern Prince of Wales Island (Broad; Broad and Dineley). 8. Near Little Chicago, District of Mackenzie (Pedder). 9. The Ramparts, Mackenzie River, District of Mackenzie (Pedder). 10. Near Ogilvie River, Yukon Territory (Ormiston). 11. Peel River, Yukon Territory (Ormiston). 12. Illtyd Range, Yukon Territory (Norford). 13. Tatonduk River, Yukon Territory (Ormiston). 14. Norman Wells; Imperial Norman Wells No. 37 x well; Imperial Mac No. 1 well; District of Mackenzie (Pedder). 15. Powell Creek, District of Mackenzie (Pedder). 16. Burnt Point, Great Slave Lake, District of Mackenzie (Pedder). 17. N.W.T. Deep Bay No. 2 well, District of Mackenzie (Pedder). 18. Union Pan Am Trainor L-59 well, District of Mackenzie (Pedder). 19. South Knife River, Manitoba (Jackson). 20. Sogpet-Aquitaine Kaskattama Province No. 1 well, Manitoba (Jackson). 21. Union Red Earth 2-22-88-8W5 well, Alberta (Pedder). 22. Canadian Kewanee A-30 Swan Hills 2-5-69-10W5 well, Alberta (Pedder). 23. Pan American A-1 Freeman 4-29-66-13W5 well; Phillips Kaybob 2-15-64-19W5 well; Alberta (Pedder). 24. Imperial Kinakin 4-13-63-9W5 well; Imperial Judy Creek 10-27-63-11W5 well; Alberta (Pedder). 25. Redstreak Creek, southeastern British Columbia (Norford). 26. Southwest Point, Anticosti Island, Quebec (Norford). 27. Milwaukee, Wisconsin, United States of America (Norford).

AMPLEXOGRAPTUS AND *GLYPTOGRAPTUS* ISOLATED FROM ORDOVICIAN LIMESTONES IN MANITOBA

by D. E. Jackson[1]

Abstract

New materials are described from surface and subsurface rocks in northern Manitoba and comprise *Amplexograptus* aff. *A. prominens* Barrass and *Amplexograptus* sp. indet. from the Bad Cache Rapids Group in the Kaskattama Province No. 1 Well, and *Glyptograptus* cf. *G. lorrainensis* (Ruedemann) and *G.* aff. *G. lorrainensis* (Ruedemann) from outcrops low in the Churchill River Group on South Knife River. ?*Amplexograptus inuiti* (Cox) is reported from the Bad Cache Rapid Group of the Kaskattama Well.

Résumé

L'auteur décrit de nouveaux matériaux provenant de roches en surface et souterraines du nord du Manitoba; il s'agit d'*Amplexograptus* aff. *A. prominens* Barrass et d'*Amplexograptus* (esp. indet.) du groupe de Bad Cache Rapids dans le puits n° 1 de la province de Kaskattama, ainsi que de *Glyptograptus* cf. G. *lorrainensis* (Ruedemann) et *G.* aff. *G. lorrainensis* (Ruedemann) tirés d'affleurements à la partie inférieure du groupe de Churchill River sur la rivière South Knife. Il mentionne également des *Amplexograptus inuiti*? (Cox) dans le groupe de Bad Cache Rapids du puits de Kaskattama.

Introduction

This paper describes *Glyptograptus* cf. *G. lorrainensis* (Ruedemann) and *G.* aff. *G. lorrainensis* isolated from outcrop samples of calcilutite from the Churchill River Group on South Knife River (Textfig. 1, loc. 19), an indeterminate form of *Amplexograptus*, and a new form of the genus that is probably subspecifically distinct from *A. prominens* Barrass, from limestone cores in the Bad Cache Rapids Group (*fide* Norford, 1970) in the Sogpet-Aquitaine Kaskattama Province No. 1 Well (Textfig. 1, loc. 20). These records augment our meagre knowledge of late Ordovician graptolite faunas over the craton of Canada which in general are characterized by biserial forms, especially *Amplexograptus*, *Climacograptus*, and *Glyptograptus*. Records of *Dicellograptus* are conspicuously lacking and the genus apparently was confined to the flanking Appalachian, Ouachita, Marathon, and Rocky Mountain fold belts. The genus seems to have failed to penetrate the epeiric seas of the craton except in the St. Lawrence Lowlands of Quebec. In most graptolitic sequences in the world species of *Dicellograptus* have been used as biostratigraphic indicators within the Upper Ordovician and their

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[1] The Open University, Bletchley, England.

absence in central Canada, together with capricious stratigraphic occurrences and local geographic distributions of many biserial species, renders most of the biserial species of little positive value for correlation.

The Kaskattama well also yielded dendroid graptolites at 2,519, 2,555, and 2,564 feet as well as Stolonoidea from 2,779 feet. These materials have not been described.

Acknowledgments

I wish to express my gratitude to L. M. Cumming, S. J. Nelson, and B. S. Norford for the opportunity to study these faunas and for providing necessary stratigraphic data, and to J. Riva for his observations on *G. lorrainensis* (Ruedemann). I am also grateful to Professor T. S. Westoll for his keen interest in this work during my stay at the University of Newcastle-upon-Tyne in 1969. The study was completed while the author was the recipient of a Nuffield Foundation Travel Grant.

Systematic Paleontology

Prefix GSC refers to specimens in the type collection of the Geological Survey of Canada, Ottawa.

Order GRAPTOLOIDEA Lapworth 1875

Family DIPLOGRAPTIDAE Lapworth 1873

Genus ***Amplexograptus*** Lapworth, Elles and Wood 1907

Amplexograptus aff. *A. prominens* Barrass 1954

Textfigures 2B, E, F

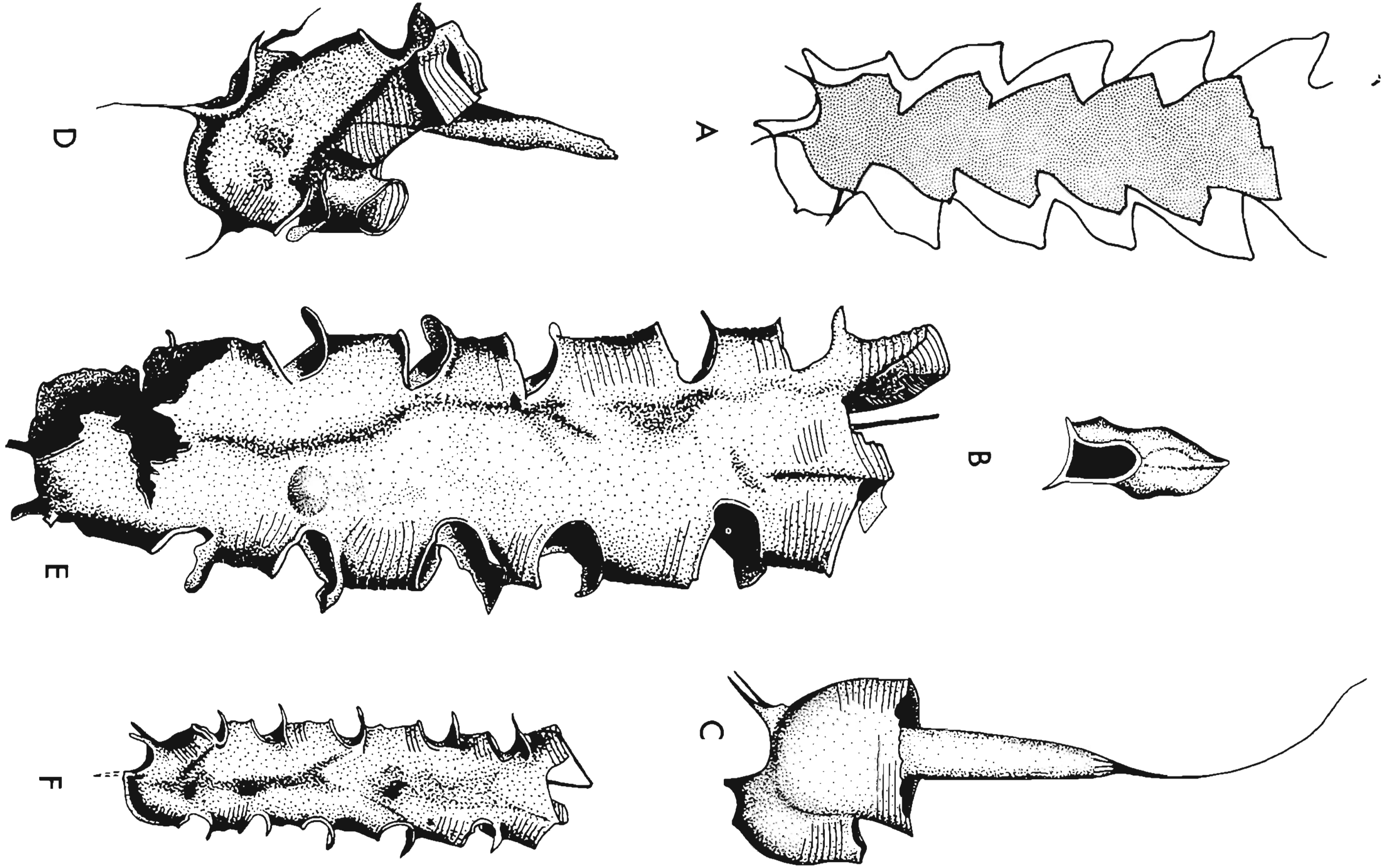
aff. *Amplexograptus prominens* Barrass 1954, p. 57–62, figs. 2–5, 6A.

Material and occurrence. Two partly compressed rhabdosomes, GSC hypotypes 26158 and 26160, isolated from limestone assigned to the Bad Cache Rapids Group from 2,862 feet (GSC loc. C-1698) in the Sogpet-Aquitaine Kaskattama Province No. 1 Well (Textfig. 1, loc. 20). Material collected by S. J. Nelson, 1966.

Description. Larger rhabdosome 3.3 mm long, widening from 0.6 to 0.7 mm immediately below apertures of th^{1^1} and th^{1^2} to a maximum width of 0.8 to 0.9 mm across fifth pair of thecae. No trace of a median septum. Aperture of sicula furnished with virgella 0.3 mm long and a shorter pair of antivirgellar spines; length of sicula unknown.

All thecae except th^{1^1} and th^{1^2} of climacograptid type, interthecal septa inclined to rhabdosomal axis at about 30 degrees (*see* Textfig. 2F). Supragenicular wall slightly concave, essentially parallel to rhabdosomal axis, nearly twice as long as infragenicular wall. Apertural excavation bordered by selvage on infragenicular wall and extended at geniculation into a flange or hood about 0.2 mm long. Apertural margins with thickened rims and occasional lappets. Excavation ratios (*sensu* Barrass, 1954) are: length 0.4 and width 0.24. In the larger specimen 6–7 thecae were measured in 3.3 mm.

Comparison. Amplexograptus aff. *A. prominens* resembles *A. prominens* Barrass in that th^{1^1} is non-spinose and also in having comparable thecal spacing, excavation ratios, and apertural lappets. A distinction exists in that it is about one half the width of *A. prominens*. *Amplexograptus inuiti* (Cox) and *A. elongatus* Barrass both differ from the form described here by the



TEXTFIGURE 2. A. Comparison of profiles of *Glyptograptus hudsoni* Jackson (outer profile) and *G.* cf. *G. lorrainensis* (Ruedemann) (stippled); both x19.

B, E, F. *Amplexograptus* aff. *A. prominens* Barrass from Sogpet-Aquitaine Kaskattama Province No. 1 Well at 2,862 feet. B, proximal end of GSC hypotype 26158 viewed parallel to rhabdosomal axis; x40. Note keel-shaped ventral wall of th^{11}. E, obverse view of GSC hypotype 26160; x40. F, reverse view of GSC hypotype 26158; x19.

C, *Amplexograptus* sp. indet. GSC hypotype 26166A; x40. Kaskattama Province No. 1 Well at 2,595 feet.

D, ?*Amplexograptus inuiti* (Cox: 1933), not described. GSC hypotype 26159; x40. Kaskattama Province No. 1 Well at 2,862 feet. Stunted nature of th^{21} is considered pathological.

possession of a subapertural spine of the first theca. *A. inuiti* is also distinctive on account of the relatively long excavation above th^{1^1} and in having a waist-like constriction above th^{1^1} and th^{1^2} as in certain late Ordovician glyptograptids.

Discussion. In the assignment of *Climacograptus inuiti* Cox to the genus *Amplexograptus*, the writer follows criteria used by Barrass (1954) and by Bulman (1962). The principal reasons for this assignment are the inclined interthecal septa, lappets on the apertural margin, and the greater length of the supragenicular wall compared to the infragenicular wall.

Concerning the age of this graptolite, one can assume that it is approximately the same age as *Amplexograptus inuiti* and *A. prominens.* The last species is now known to occur in the St. Lawrence Lowlands and on Anticosti Island where it forms a distinctive fauna (*see* Riva, 1969) which Riva considers to be post-*Dicellograptus complanatus* Zone but pre-Silurian.

Amplexograptus sp. indet.

Textfigures 2C, 4A, B

Material and occurrence. One early growth stage, GSC hypotype 26166A, and two fragments that probably represent the same rhabdosome, GSC hypotypes 26166B and C; all isolated from limestone of the Bad Cache Rapids Group at 2,595 feet (GSC loc. C-1601) in the Sogpet-Aquitaine Kaskattama Province No. 1 Well (Textfig. 1, loc. 20) collected by S. J. Nelson.

Description. The largest fragment GSC 26166C is 4.5 mm long, ovoid in cross-section and devoid of a median septum. In GSC 26166B, the width across th^{1^1} and th^{1^2} is 0.8 mm; a maximum width of 1.0 mm is seen in GSC 26166C. In GSC 26166A, the sicula is 1.2 mm long exclusive of nema and spines and the aperture of the metasicula is furnished with a virgella and paired antivirgellar spines about 0.2 mm long.

Th^{1^1} U-shaped and has no subapertural spine on the ventral wall; th^{1^2} and th^{2^1} erect with convexly curved free ventral wall; th^{2^2} and all subsequent thecae climacograptid, geniculation of ventral wall accentuated by a thickened ridge rather than a hood. Supragenicular ventral wall slightly concave, parallel to rhabdosomal axis; infragenicular wall concave and inclined at about 45 degrees. Positions of interthecal septa indicated by furrows on lateral walls of rhabdosome; they are parallel to axis of rhabdosome except for basal part, which is inclined inwards at about 45 degrees.

In GSC 26166C, there are 5½ thecae in 4 mm and all thecal apertures bear pointed lappets. Excavation ratios are: length 0.3–0.5; width 0.3.

Comparison. The narrow width of this form makes it distinct from *A. prominens* Barrass and the lack of a spine on th^{1^1} rules out an affinity with *A. elongatus* Barrass and *A. inuiti* (Cox).

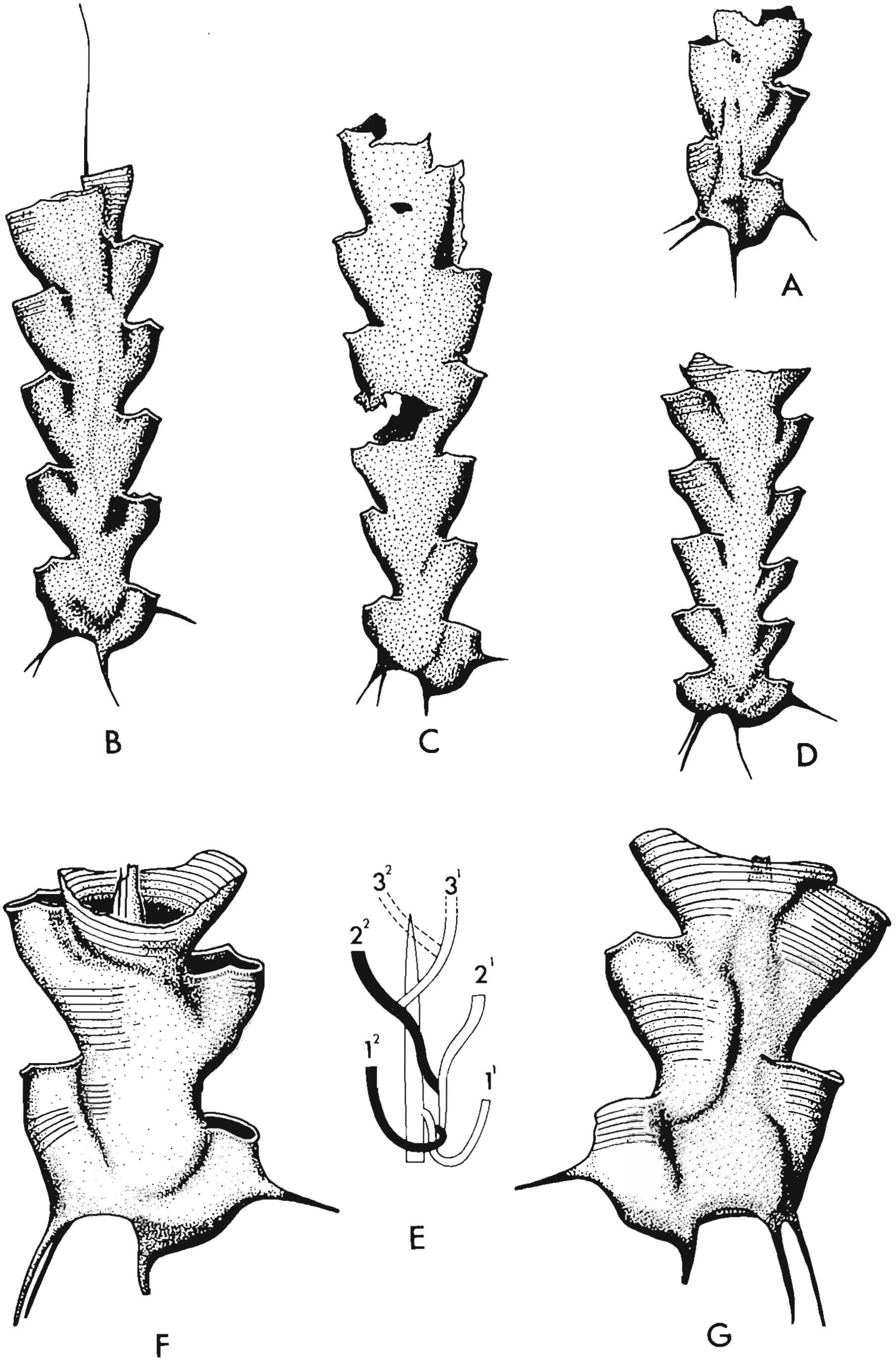
Genus ***Glyptograptus*** Lapworth 1873

Glyptograptus cf. *G. lorrainensis* (Ruedemann 1925)

Textfigures 2A, 3A, B, C, E, F, G

cf. *Climacograptus lorrainensis* Ruedemann 1925, p. 63, textfigs. 49–52, pl. 7, figs. 11–13.

Material and occurrence. Four partly compressed rhabdosomes, GSC hypotypes 26161–26164, lower part of Churchill River Group on South Knife River (GSC loc. 79806), 10 miles SSE of Nowell Lake, Manitoba (Textfig. 1, loc. 19); collected by L. M. Cumming, 1967.



TEXTFIGURE 3. A-C, E-G. *Glyptograptus* cf. *G. lorrainensis* (Ruedemann), from GSC loc. 79806, Churchill River Group, South Knife River, Manitoba. A, C. GSC hypotypes 26162, 26163 respectively; x19. B. GSC hypotype 26161; x19. F, G. Reverse and obverse views respectively of GSC hypotype 26164; x40. Note how wall of sicula is exposed on obverse side as far as theca3^1.
E. Diagram showing probable nature of thecal budding.
D. *Glyptograptus* aff. *G. lorrainensis* (Ruedemann). GSC hypotype 26165; x19; same locality as above.

Description. Rhabdosome small, up to 4 mm long exclusive of virgula, aseptate, ovate in cross-section. Width increases gradually from 0.65–0.85 mm immediately below apertures of th$^{1^1}$ and th$^{1^2}$ to 1.1 mm across th$^{5^1}$ and th$^{5^2}$. Interthecal widths immediately above these pairs of thecae are 0.40–0.45 mm and 0.65 mm respectively.

Sicula of diplograptid type, apex extending slightly beyond aperture of th$^{2^2}$, aperture furnished with virgellar spine 0.3–0.4 mm long and a pair of antivirgellar spines of similar length. An apertural notch between the paired spines is only faintly developed. Th$^{1^1}$ characteristically U-shaped and carries a prominent subapertural spine about 0.3 mm long. Subsequent thecae are erect tubes with one third overlap and glyptograptid profile. Two thecal series developed by alternate budding as in Textfigure 3E.

All apertural margins of thecae have thickened rims and pointed lappets with the exception of th$^{1^1}$ which usually does not have these features; there are 6 thecae in 4 mm.

Measurements in mm of *Glyptograptus* cf. *G. lorrainensis*

Types (GSC)	Rhabdosome						Thecal Spacing
		Width					
	Length	1^1–1^2	2^1–2^2	3^1–3^2	4^1–4^2	5^1–5^2	
26161	3.8	0.83	0.90	1.0	1.0	1.1	5 in 3.0 mm
26162	2.0	.64	.80	—	—	—	2 in 1.2 mm
26163	4.0	.83	.82	0.80	1.0	1.1	6 in 4.0 mm
26164	1.5	.80	.83	—	—	—	2 in 1.0 mm

Comparison. The three sicular spines and the subapertural spine of th$^{1^1}$, together with the narrowness of the rhabdosome above the first pair of thecae, and the lack of a median septum render this new species distinct from the few known Ordovician species of *Glyptograptus* except *G. hudsoni* Jackson (Jackson, 1971) from Upper Ordovician rocks of Southampton Island and *G. lorrainensis* (Ruedemann) from the high Middle to the low Upper Ordovician of eastern Canada. *G. hudsoni* differs from the specimens described herein in its greater width (*see* Textfig. 2A), lack of prominent pointed lappets on thecal apertures, by having a strongly developed notch between the antivirgellar spines on the aperture of the sicula, and by having slightly more widely spaced thecae. A comparison with Ruedemann's species shows that there is good agreement in the dimensions of the rhabdosome, thecal spacing, proximal spines, and lack of a median septum. The only difference that I can detect from the illustrations of his species is the apparent lack of lappets on the thecal apertures.

Discussion. According to Cumming (*in press*) the coral fauna from GSC loc. 79806 indicates a Stony Mountain equivalent and thus represents the lower part of the Churchill River Group at a horizon correlative with the *Pleurograptus linearis* Zone. Such an assignment agrees with the range of *G. lorrainensis* in eastern Canada which Riva (1969) has shown to be high Middle to low Upper Ordovician.

Glyptograptus aff. *G. lorrainensis* (Ruedemann 1925)

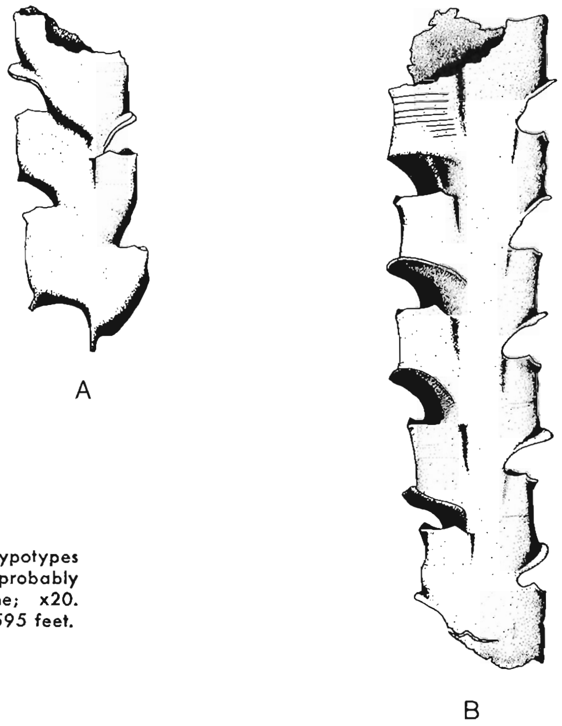
Textfigure 3D

aff. *Climacograptus lorrainensis* Ruedemann 1925, p. 63, textfigs. 49–52, pl. 7, figs. 11–13.

Material and occurrence. GSC hypotype 26165, lower part of Churchill River Group on South Knife River (GSC loc. 79806), Manitoba (Textfig. 1, loc. 19); collected by L. M. Cumming, 1967.

Description. Rhabdosome 2.9 mm long, widening from 0.8 mm across th^{1^1} and th^{1^2} to 1.0 mm across th^{5^1} and th^{5^2}. Details of spines on proximal end of rhabdosome as well as nature of apertural margins are similar to these features in *G.* cf. *G. lorrainensis.* There are 5 thecae in 2.0 mm.

Discussion. This form differs from *G.* cf. *G. lorrainensis* in the closer thecal spacing, i.e., 5 in 2 mm compared to 3 in 2 mm, in the shorter length of th^{1^1} and th^{2^2}, and in the tendency for the apertures of th^{1^1} and th^{1^2} to be nearly at the same level rather than alternating as in *G.* cf. *G. lorrainensis.* On this basis it is desirable to make a distinction pending acquisition of more data on intraspecific variability.



TEXTFIGURE 4

A, B. *Amplexograptus* sp. indet. GSC hypotypes 26166B and 26166C respectively, probably fragments of a single rhabdosome; x20. Kaskattama Province No. 1 Well at 2,595 feet.

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LOWER SILURIAN SPECIES OF THE TRILOBITE *SCOTOHARPES* FROM CANADA AND NORTHWESTERN GREENLAND

by B. S. Norford

Abstract

Five species are described from rocks of Late Llandovery age in Quebec, southeastern British Columbia, northern Yukon Territory, and northwestern Greenland. The Scottish type species *Scotoharpes domina* is redescribed as is the poorly preserved *Scotoharpes*? *telleri* from Wisconsin. A new species, *Scotoharpes raaschi*, is proposed for material from unnamed rocks of the Yukon.

Selenoharpes Whittington 1950 and *Aristoharpes* Whittington 1950 are junior subjective synonyms of *Scotoharpes* Lamont 1948.

Résumé

L'auteur décrit cinq espèces provenant de roches du Llandovérien supérieur du Québec, du sud-est de la Colombie-Britannique, du nord du Yukon, et du nord-ouest du Groenland. Il redécrit l'espèce de type écossais *Scotoharpes domina*, ainsi que le *Scotoharpes*? *telleri* mal préservé provenant du Wisconsin. Une nouvelle espèce est proposée: *S. raaschi* de roches sans nom du Yukon.

Selenoharpes Whittington 1950 et *Aristoharpes* Whittington 1950 sont des synonymes subjectifs plus récents de *Scotoharpes* Lamont 1948.

Introduction

Well-preserved material is required for comprehensive study of harpid trilobites. The present paper is based on such specimens collected by the author from the northern Yukon and from northwestern Greenland, supplemented by other material from Canada, Greenland, and Scotland.

The new species *Scotoharpes raaschi* is found in unnamed massive limestones deposited near the seaward edge of a carbonate bank in the northern Yukon (Textfig. 1, loc. 12; Norford, 1964, p. 4, 7–8, 34–37). The two Greenland species are described from a similar paleogeographic position (Textfig. 1, locs. 1 and 2; Norford, 1972, p. 17, 24). *S. loma* (Lane) is from the biostromal and biohermal Offley Island Formation very close to its lateral transition into the Cape Schuchert Formation that was deposited in somewhat deeper water. *S. latior* (Poulsen) was collected by Koch (1929) from either the Cape Schuchert Formation or the Cape Phillips Formation of graptolitic facies but which includes minor biohermal tongues and was deposited very close to the seaward edge of a carbonate platform that covered much of northern Greenland during Early Silurian time. In southeastern British Columbia, *Scotoharpes* sp. is known from the Tegart Formation of argillaceous limestones and minor graptolitic shales (Textfig. 1, loc. 25; Norford, 1969, p. 32–34). These four species are from rocks of late Early Silurian (Late Llandovery) age, as is the Scottish type species, *Scotoharpes domina* Lamont, the Welsh *S. willsi* (Whittington), a *Scotoharpes* sp. described by Whittington (1950a, p. 48) from Scotland, and perhaps also *S. judex* (Marr and Nicholson) from the Middle and Upper Llandovery of northern England. *Scotoharpes consuetus* (Billings) is probably also of Late Llandovery age and is from the dominantly biohermal Chicotte Formation of Anticosti Island, Quebec (Textfig. 1, loc. 26; Twenhofel, 1928, p. 26–27, 62).

A species was described from the Racine Dolomite of Wisconsin as *Harpes telleri* by Weller (Textfig. 1, loc. 27; 1907, p. 213–214). The Racine is a carbonate bank deposit and locally is biohermal, the available material of *telleri* is dolomitized and very poorly preserved but the species can be tentatively assigned to *Scotoharpes*. The Racine Dolomite is thought to be of Late Wenlock to Ludlow age (Berry and Boucot, 1971, p. 200–201).

A number of species of *Scotoharpes* have been described from Lower, Middle, and Upper Ordovician formations of Newfoundland, Ontario, Quebec, Scotland, Sweden, Poland, and England (Billings, 1862 and 1865, 1865; Whittington, 1950a, 1950b, 1963, 1965; Kielan, 1960; Ingham, 1970). The oldest of these is *S. excavatus* (Linnarsson) from the Zone of *Megistaspis planilimbata* (low Arenig) of Sweden.

Silurian harpid trilobites that perhaps could belong to *Scotoharpes* have been described from Nepal (*Aristoharpes* sp. of Pillet, *in* Bordet and others, 1960), from Bohemia (Prantl and Přibyl, 1954) and from the Alps (*Harpes bucco* Bather 1909) but none of this material has been examined by the author and most of the published descriptions are inadequate to allow assignment to the genus. *Harpes pansa* Maximova has been described from the Upper Silurian (Upper Ludlow) of the Soviet Union; Maximova's illustrations (1968a, p. 779, fig. 5; 1968b, Pl. 35) indicate a *Scotoharpes*. Some Devonian species described from Bohemia (Prantl and Přibyl, 1954) may also belong to the genus; if so, the range of the genus is Early Ordovician to Middle Devonian.

Acknowledgments

The manuscript has benefited greatly from critical reading by H. B. Whittington of Cambridge University and by W. T. Dean and A. E. H. Pedder of the Geological Survey of Canada. Archie Lamont kindly made available for study a plasticine cast of a specimen in his private collection, Christian Poulsen of the Universitets Mineralogisk-Geologiske Institute, Copenhagen, loaned type specimens in his care, as did Bernhard Kummel of the Museum of Comparative Zoology, Cambridge, Massachusetts, M. H. Nitecki of the Field Museum of Natural History, Chicago, and R.S. Boardman of the United States National Museum, Washington. D. G. Lawrence made the photographs.

Systematic Paleontology

Prefix GSC refers to specimens in the type collections of the Geological Survey of Canada, Ottawa; GGU to type specimens of the Grønlands Geologiske Undersøgelse, Copenhagen; MCZ to type specimens at the Museum of Comparative Zoology, Cambridge, Massachusetts; UC to the type specimens of the University of Chicago; USNM to type specimens at the United States National Museum; and MMH to type specimens at the Mineralogisk Museum in Copenhagen.

Phylum ARTHROPODA

Class TRILOBITA

Family HARPIDAE Hawle and Corda 1847

Genus ***Scotoharpes*** Lamont 1948

Scotoharpes Lamont 1948a, p. 534.
Selenoharpes Whittington 1950a, p. 10.
Aristoharpes Whittington 1950a, p. 11–12.
Selenoharpes Whittington, Whittington 1950b, p. 303.
Aristoharpes Whittington, Whittington *in* Harrington and others 1959, p. 0416.
Selenoharpes Whittington, Whittington *in* Harrington and others 1959, p. 0418.
Selenoharpes Whittington, Whittington 1963, p. 31–35.
Selenoharpes Whittington, Whittington 1965, p. 312–313.
Selenoharpes Whittington, Ingham 1970, p. 38–39.
Selenoharpes Whittington, Dean 1971, p. 10.
Selenoharpes Whittington, Lane 1972, p. 353.

Type species. *Scotoharpes domina* Lamont 1948 from the Upper Llandovery of Scotland. This species is poorly known and the genus is better characterized by *Scotoharpes willsi* (Whittington), the type species of *Aristoharpes.*

Diagnosis. Cephalic outline suboval to subcircular, central region of cephalon convex, prolongations almost straight or curving adaxially. Glabella (including occipital ring) longer than wide, moderately to strongly raised, transversely strongly convex, outline subquadrate to suboval; occipital, preglabellar, and axial furrows strong, last commonly with two or three pairs of very shallow pit-like areas between eye ridges and the one pair of short lateral glabellar furrows that delineate a pair of small triangular, lateral glabellar lobes. Preglabellar field short, flat with low axial mound; eye tubercles opposite front fourth of glabella. Adaxial edge of gena separated from rear three-fourths of axial furrow by two depressed triangular areas separated by low gently convex semicircular ala and alar furrow. Genal roll commonly with low axial mound, upper lamella strongly flexed at site of girder, brim very gently concave or flat, may be slightly convex locally. Girder meets lower internal rim some distance in front of tip of prolongation.

Gena and fringe with pits separated by smooth ramifying ridges (genal caeca) that appear to branch from region of axial furrow just behind eye ridge, genal caeca dominantly radial on outer part of gena and on fringe, cross inner margin of fringe, reach and match across smooth ridge of upper lamella that marks site of girder, in most species reach rim in parts of brim. In all, or almost all species, single rows of slightly coarser pits developed against girder and against upper and lower rims.

Thorax with at least seventeen segments, widest at fourth or fifth; axis narrow, strongly raised, pleurae flat and transverse but flexed abruptly ventrally and rearward just before bluntly rounded extremities.

Pygidium with strongly curved pleural furrows. Hypostome sagittally elongate.

Assigned North American species:

Harpes consuetus Billings 1866 from Lower to Middle Silurian (uppermost Llandovery to lower Wenlock) Chicotte Formation, Anticosti Island, Quebec.

Eoharpes fragilis Raymond 1925 from boulder in Lower and Middle Ordovician Cow Head Group, Newfoundland.

Harpes granti Billings 1865 from Lower(?) Ordovician "Quebec Group", Quebec.
Harpes latior Poulsen 1934 from Lower Silurian (Upper Llandovery) of northwestern Greenland.
Selenoharpes loma Lane 1972 from Silurian (Wenlock or older) Profilfjeldet, Drommebjerg and Centrum Formations, northeastern Greenland and from Lower Silurian (Upper Llandovery) Offley Island Formation, northwestern Greenland.
Scotoharpes raaschi new species from Lower Silurian (Upper Llandovery) of Yukon.
Selenoharpes singularis Whittington 1965 from Middle Ordovician Table Head Formation, Newfoundland.
Selenoharpes vitilis Whittington 1963 from Middle Ordovician at Lower Head, Newfoundland.
Selenoharpes sp. of Ross 1972 from Middle Ordovician Antelope Valley Limestone, Nevada.
Scotoharpes sp. of this paper from Lower Silurian (Upper Llandovery) Tegart Formation, British Columbia.

Species that may belong to the genus:
Harpes telleri Weller 1907 from Middle or Upper Silurian Racine Dolomite, Wisconsin.

Discussion. A short paper by Lamont (1948a) on Scottish trilobites included a photograph of a cephalon designated *Scotoharpes domina* and the following statement:

> In *Scotoharpes domina* (fig. 2) from the North Esk, where deposition was in deeper water, there is only a single row of larger pits around the margin of the fringe, and they do not grade into the complex of finer pits. The smallness and close-spacing of the pits may have helped to disguise the animal against its customary background of fine silt.

These two items are the sole mention of *Scotoharpes domina* in the paper and with such nominal description the question immediately arises of whether the species and the genus were validly proposed. The International Code of Zoological Nomenclature (Stoll *et al.*, 1961) has firm rules on validity of zoological names of the family, genus, and species levels. The phrases concerning the single row of larger pits and their relations to the finer pits can be construed as satisfying Article 13ai ("...name...must be...accompanied by a statement that purports to give characters differentiating the taxon; ....") and therefore both the genus and species can be accepted as valid.

The proposal of *Scotoharpes* by Lamont (1948a) was casual but valid and unfortunately was published while a comprehensive revision of the British harpid trilobites was being prepared by Whittington (1950a). Whittington erected *Aristoharpes* knowing that it closely resembled *Scotoharpes* and that both genera were of Late Llandovery age, but without any opportunity of examining Lamont's material on which *Scotoharpes* was based. He recognized differences in the characters of the fringe of *Scotoharpes* and *Aristoharpes* but was uncertain whether the two genera were distinct (1950a, p. 12). Lamont supplied the present author with a plasticine cast made from the single specimen on which *Scotoharpes* was based and the differences between this material and the specimens studied by Whittington are sufficient for discrimination of species but not of genera. *Aristoharpes* is a junior subjective synonym of *Scotoharpes*.

Whittington also proposed the Lower and Middle Ordovician genus *Selenoharpes* in 1950, noting its resemblance to *Aristoharpes* but stressing differences of subcircular as opposed to suboval cephalic outline, larger alae, and absence of radiating ridges (genal caeca) on the brim (1950a, p. 10). Later (1950b, 1963, 1965) he described several other Ordovician species of *Selenoharpes*, some of which have suboval cephalic outline, small alae and radiating ridges on the brim and therefore he recognized *Aristoharpes* as a synonym of *Selenoharpes*

Species	*S. domina*	*S. consuetus*	*S. latior*	*S. loma*	*S. loma*	*S. loma*	*S. loma*	*S. loma*	*S. loma*	*S. raaschi*	*S. sp.*	*S. ? telleri*	*S. ? telleri*	*S. ? telleri*
Type Number	GSC 27793	GSC 2550	MMH 3249	GGU 100801	GGU 100802	GGU 100814	GGU 100811	GGU 100812	GGU 100806	GSC 27794	GSC 27795	MCZ 1624	USNM 96656	MCZ 1625
Total length (*sag.*)	28.7•	23.2•	—	16.8•	16.2+	—	13.8	10.8+	7.0•	24.5+	—	21.5•	20.0+	26.7+
Axial cephalic length (*sag.*)	15.0•	11.8•	19.0•	10.7•	11.7•	—	8.5	7.3	4.7	14.5 †	—	10.5•	11.7•	13.7
Prolongation length (*exsag.*)	13.7•	11.5	—	6.2•	4.5+	—	4.7	3.5+	2.3•	10.0+	4.7•	11.0•	8.3•	13.0+
Cephalon width ^{1} (*tr.*)	24.8•	19.8	37.0•	16.0	16.7	14.3	11.8	10.5	7.2	24.3	—	17.8	18.8	22.2•
Glabella width ^{1} (*tr.*)	4.0•	4.5	6.0	3.0	3.0	2.7	2.3	2.0	1.4	4.7	—	3.2	3.8•	4.5•
Ala and alar furrow, width ^{1} (*tr.*)	1.3•	1.0	1.8	1.2	1.3	1.0	1.0	.8	.4	1.5	—	1.0•	1.2•	1.3•
Total genal region, width ^{1} (*tr.*)	10.3•	11.0•	23.0•	9.0	9.0	7.0•	7.5	5.7	4.0	12.7	—	8.5•	—	—
Gena width ^{1} (*tr.*)	2.3•	2.2•	5.3•	1.8	1.7	1.2	1.7	1.2	.8	2.5	—	—	—	—
Genal roll width ^{1} (*tr.*)	1.2•	1.2•	1.5•	.7	.8	.5	.7	.5	.3	1.0	—	—	—	—
Brim width ^{1} (*tr.*)	4.3•	3.5	5.0•	2.8	3.0	2.5	2.2	1.8	1.8	4.3	5.5	3.8•	3.7•	4.5•
Rim width ^{1} (*tr.*)	.5•	.7	—	.2	.2	.2	.2	.2	.2	.5	.7	.3•	.3•	.3•
Eye tubercle spacing from glabella (*sag.*)	.7•	.8	2.0	1.0	1.1	.9	.8	.7	.6	1.2	—	1.0•	1.2•	1.2•
Glabella ^{2} length (*sag.*)	6.5•	5.7	8.8•	5.0•	5.0•	4.5•	3.7	3.3	2.3•	7.0	—	4.5•	5.2•	5.2•
Occipital ring length (*sag.*)	1.2•	.8	1.3•	—	—	.8•	.5	.5	.3	1.3	—	.7•	.8•	1.0•
Preglabellar field length (*sag.*)	1.0	—	1.2•	.5	.7	.5	.5	.4	.2	.7	—	.4•	—	.5•
Genal roll length (*sag.*)	1.8•	—	2.5	1.7	1.8	1.2•	1.2	1.2	.6	1.3	—	—	—	1.5•
Brim length (*sag.*)	5.0•	4.0•	4.5•	3.7•	3.8		2.7	2.3	1.7	—	—	4.0•	4.3•	5.2•
Cephalon, maximum height	2.0•	3.2•	6.3•	4.0•	4.3•	3.8•	3.0•	3.0•	2.7•	3.5•	—	4.2•	4.3•	4.5•
Prolongation tip to junction of girder and rim	—	8.5	—	4.7	—	—	3.5	—	—	6.8+	10.8	6.0•	—	8.0+

GSC

Transverse measurement at saggittal position of lateral glabellar lobes . . . 1
Glabella includes occipital ring 2
Estimated figure . . . . 14.5†
Approximate figure . . . . 3.7•

Note: All measurements in millimetres

Textfigure 5. Dimensions of described species

(1963, p. 25, 35). *Scotoharpes* has priority over both *Aristoharpes* and *Selenoharpes*, and both these genera are junior subjective synonyms of *Scotoharpes*.

Scotoharpes has some similarities to *Australoharpes* Harrington and Leanza, *Hibbertia* Jones and Woodward, and *Paraharpes* Whittington, but in all these genera the girder extends to the tip of the prolongation whereas in *Scotoharpes* it joins the inner rim some distance in front of the tip. Other distinctive features of the genus are well-developed genal caeca that, in almost all species, extend on to the brim; and, also on the brim, against the girder and the rims, the presence of single rows of pits coarser than those elsewhere on the brim. *Dubhglasina* Lamont and *Metaharpes* Lamont as yet are too poorly known to be adequately compared with *Scotoharpes*.

Preservation. Cephala of harpid trilobites can be preserved in a variety of ways, each of which shows characters in different manners. The fringe that surrounds the genal region consists of two layers, the upper and lower lamellae, both with dorsal and ventral surfaces; the genal region has merely dorsal and ventral surfaces. Actual exoskeletons can be preserved or only natural moulds, either internal moulds of ventral surfaces or external moulds of dorsal surfaces, but both very commonly with pieces of exoskeleton sticking to the moulds and sometimes with scraps of secondary mineralization that was introduced into the cavity between the upper and lower lamellae. This cavity was left empty after ecdysis or after decay of the soft parts following death of the animal. Such fragments of exoskeleton attached to internal moulds show dorsal surfaces, but sometimes of the lower lamella; similarly for external moulds, such pieces show ventral surfaces of the genal region, of the upper lamella, and, rarely, of the lower lamella. Most external moulds and ventral surfaces are studied from silicone or rubber casts so that characters can be related readily to the dorsal surface. Moulds present negative impressions of exoskeletons and thus pits are represented as pustules and ridges as troughs. The characters of the dorsal surface of the upper lamella are virtually identical to those of the ventral surface of the lower lamella and similarly with their respective ventral and dorsal surfaces. These characters are very important in the study of *Scotoharpes* and their interpretation is complicated by the various styles of preservation of specimens or of different parts of the same specimen.

Many individuals of *Scotoharpes* are preserved as dorsal surfaces but holes may be present or layers may be partly or entirely missing (Pl. 2, fig. 1, *S. raaschi*: most of the brim is the internal mould of the ventral surface of the upper lamella; Pl. 3, figs. 1 and 3, *S. loma*: internal mould of genal roll locally is visible, most of brim is the dorsal surface of the upper lamella but parts show the internal mould of the ventral surface of the upper lamella). Other specimens are preserved as ventral surfaces (Pl. 4, fig. 3, *S.? telleri*, ventral surface of genal region and lower lamella except for anteriorly parts of ventral surface of upper lamella; Pl. 4, fig. 2, *S.? telleri*, ventral surface of genal region and upper lamella except for ventral surface of lower lamella of right-hand prolongation).

Scotoharpes domina Lamont 1948

Plate 1, figures 1–3

Scotoharpes domina Lamont 1948a, p. 532, fig. 2, p. 534.
Scotoharpes domina Lamont, Lamont 1948b, p. 376–377, fig. B.

Material and occurrence. Poorly preserved, slightly distorted, counterpart internal and external moulds of a cephalon in the private collection of Archie Lamont and collected

(Lamont, *written com.* 1964) from the Upper Llandovery *Plectodonta* aff. *canastonensis* beds at Wetherlaw Linn, North Esk Inlier, Midlothian, Scotland (Mitchell and Mykura, 1962; from horizon marked D of their Fig. 4). Description based on plasticine internal moulds (GSC 27793) representing the dorsal surface (including the upper lamella) made by Lamont from the external mould of the holotype and on Lamont's published illustration that appears to represent a natural internal mould of the ventral surface.

Description. Central parts of cephalon moderately convex, cephalic outline suboval; greatest width at about alae; prolongations in length subequal to axial length of cephalon, trending almost straight rearward.

Glabella strongly raised; sagittally rises abruptly from preglabellar furrow but shortly becomes evenly convex to highest point just in front of alae, next extremely gently convex to rear of occipital ring; outline almost subquadrate with abruptly truncated front; preglabellar furrow almost straight at front of glabella, strongly curved at anterolateral corners; axial furrows almost subparallel, no shallow pit-like areas detectable; lateral glabellar furrows trend diagonally back from axial furrow and swing subtransverse before fading at about a third of distance to axis; occipital furrow straight except for abaxial swing forward; occipital ring about same length sagittally as near axial furrows, probably without median node.

Preglabellar field grades laterally into evenly convex genae. Eye tubercles large, close to glabella; eye ridges faint, almost transverse but curve slightly rearward against axial furrow; genal ridges trending posterolaterally. Alae small; alar furrows indistinct, shallow, evenly convex. Posterior border strongly raised. Inner margin of fringe indistinctly preserved.

Ornament not detectable on glabella, preglabellar field, posterior border, border furrow, alae, and adjacent triangles. Genae with moderately coarse pits separated by genal caeca that become subradial on outer regions of genae.

Genal roll continues slopes of preglabellar field and genae, laterally dropping steeply to broad girder that bows slightly forward around axial mound, next curves evenly around genae to about sagittal position of alae, next trends almost straight rearward to join internal rim at about a third of distance from inner margin of fringe to tip of prolongation. Brim wider than glabella and slightly wider sagittally than laterally, apparently very slightly convex anteriorly, flat elsewhere.

Upper external rim narrow with strong relief above brim; lower rim and upper internal rim not seen. Upper lamella with fine pits locally separated by low smooth radial ridges that are strongest against girder but fade halfway across brim except anterolaterally where locally reach rim; no such ridges on prolongation; single row of coarser pits against rim, preservation too poor to show such a row against site of girder.

Thorax, pygidium, and hypostome unknown.

Dimensions. See Textfigure 5.

Discussion. Apparently only the one specimen of *Scotoharpes domina* is known and that is poorly preserved (as ascertained by study of the plasticine cast). *S. raaschi* new species seems to be the most similar species but the differences in quality of preservation make comparison difficult. However, the glabella of *raaschi* has a distinctive suboval outline and lacks the truncated front of the almost subquadrate glabella of *domina.*

Scotoharpes consuetus (Billings 1866)

Plate 2, figure 2

Harpes consuetus Billings 1866, p. 64.
Harpes consuetus Billings, Twenhofel 1928, p. 321, Pl. LIV, fig. 8.

Material and occurrence. One poorly preserved natural external mould of cephalon, including upper lamella (GSC holotype 2550); a scrap of anterolateral brim and a fragment of genal roll are attached. Cephalon collected by J. Richardson from his Division Four Beds at Southwest Point, Anticosti Island, Quebec (Textfig. 1, loc. 26; 49°23′N, 63°35′W); beds at the locality were later placed in the Chicotte Formation that is about 73 feet thick on the island but Twenhofel (1928, p. 62, 321) considered that the cephalon came from the basal 18 feet of the formation. Berry and Boucot (1971, p. 135), correlated the Chicotte as uppermost Llandovery and lower Wenlock and very likely the holotype is of latest Llandovery age.

Description. Central part of cephalon convex, cephalic outline suboval, greatest width at alae and considerably greater than axial cephalic length which is subequal to that of prolongations that curve evenly and strongly adaxially, ending in short spines that continue curve.

Glabella moderately raised; sagittally curves up from preglabella furrow with evenly diminishing convexity to high point opposite front of alae, next gently slopes down to occipital furrow, next moderately convex and high occipital ring; outline gently tapered forward, preglabellar furrow evenly rounds front of glabella and merges without inflexion to axial furrows, preservation of these insufficient to reveal presence or absence of any pit-like areas; lateral glabellar furrows trend diagonally back from axial furrows; axial part of occipital furrow slightly bowed forward; occipital ring just lower than high point of glabella, much longer sagittally than near axial furrows, preservation such that presence or absence of median node cannot be determined.

Preglabellar field grades laterally into evenly convex genae. Eye tubercles large, close to glabella; eye ridges poorly preserved, apparently transverse; genal ridges not preserved. Alae small; alar furrows poorly preserved. Posterior border raised; border furrow shallow, broad. Inner margin of fringe not shown.

A small area of gena behind left eye tubercle shows moderately coarse pits separated by low genal caeca.

Genal roll continues slopes of preglabellar field and genae, laterally dropping steeply to site of girder that is revealed only by strong inflexion of upper lamella, inflexion bows slightly forward around axial mound, next curves evenly around genae to opposite eye tubercles, next trends rearward with very slight curvature to meet internal rim slightly less than halfway between axial furrow and tip of prolongation. A scrap of genal roll shows its ventral surface with fine pits separated by genal caeca. Brim slightly narrower than maximum of glabella and wider anteriorly than laterally; laterally very slightly concave, axially convex near girder but slightly concave near rim; prolongation slightly concave except for slightly convex flexed part close to girder.

Upper external rim rather broad, strongly raised above brim, as is narrow internal rim that merges forward with posterior border. A scrap of upper lamella shows fine pits close to external rim and single row of slightly coarser pits against it, no radial ridges present in this fragment.

Thorax, pygidium, and hypostome unknown.

Dimensions. See Textfigure 5.

Discussion. The general shape of the holotype, the presence of a single row of slightly coarser pits against the external rim and the position of the girder's junction with the internal rim allow confident assignment to the genus.

Scotoharpes consuetus is similar to *S. raaschi* new species but has a higher occipital ring that medianly protrudes less rearward, a tapered glabellar outline rather than semioval, eye tubercles closer to the glabella and more incurved prolongations. Probably the two species are closely related but to determine whether they are conspecific requires better preserved material of *consuetus* and particularly more specimens of both taxa so that their variability can be assessed.

Scotoharpes latior (Poulsen 1934)

Plate 1, figures 4–9

Harpes latior Poulsen 1934, p. 20–21, pl. 2, fig. 23.

Material and occurrence. An incomplete dorsal surface of a cephalon, a dorsal surface of a glabella and adjacent regions, two internal moulds with scraps of exoskeleton attached, one fragment of an external mould. Holotype cephalon (MMH 3249) and four other specimens (paratypes MMH 12895–12898) collected by Lauge Koch, probably 1922, from unspecified beds at Kap Schuchert (Textfig. 1, loc. 2; 80°48′N, 65°10′W), northwestern Greenland, but assigned by Koch to the Cape Schuchert Formation. Norford (1972, p. 15–17, 33–37) has recognized the Cape Schuchert, Cape Phillips, and Offley Island Formations at Kap Schuchert but did not find any specimens of the species within his stratigraphic section just south of Kap Schuchert and thus was unable to stratigraphically position the type locality of the species. Essentially all of Norford's studied section is dated as Late Llandovery. Associated fauna; the piece of rock containing the holotype also bears fragments of other trilobite genera, fossils in other pieces of rock that contain paratypes include *Encrinurus princeps* Poulsen which, in the northern Yukon, is found in the Upper Llandovery *Monograptus turriculatus* Zone (Norford, 1964, p. 127; and unpublished).

Description (based almost entirely on holotype). Cephalon large, much wider than axial length; central region moderately convex; very little preserved of brim and prolongations.

Glabella moderately raised, sagittally curves evenly up from preglabellar furrow to high point opposite eye tubercles, next slopes very gently but with slight convexity to rear of occipital ring; outline slightly tapered with abruptly truncated front; axial furrows subparallel; lateral glabellar furrows trend almost straight rearward from axial furrows but curve transverse just before fading at about halfway to axis; two pairs of pit-shaped glabellar furrows described by Poulsen are not shown by the holotype but may be hidden by adventitious material covering parts of axial furrows, one small pit is discernible on glabella just about right hand axial furrow; only one of the three paratype cephala shows them, preserved as very small pits on the largely exfoliated dorsal surface of a glabella, just beside but isolated from axial furrow (Pl. 1, figs. 5, 6), a surface that was not exfoliated might show them to reach axial furrows and perhaps they correspond to pit-like areas in axial furrows of *loma* and *raaschi*; occipital furrow shallow, almost straight but with slight hook forward in outer third, against adaxial limit of lateral glabellar lobe; occipital ring slightly lower than rest of glabella, preservation insufficient to assess shape, or presence or absence of median node.

Preglabellar field grades laterally into evenly convex genae, axial mound diminishes forward; eye tubercles small, opposite and far from front fifth of glabella; eye ridges transverse, very faint, genal ridges discernible only for short distance posterolaterally from eye tubercles. Alae small; alar furrows barely detectable. Posterior border raised, border furrow broad, very shallow. Inner margin of fringe almost transverse in front of preglabellar field, next curves gently forward and evenly laterally around genae, meets internal rim close to latter's junction with girder.

Genal roll with very low axial rise, laterally its slopes are less than those of adjacent genae; site of girder marked by low smooth band and inflexion of upper lamella, bows very slightly forward and around axial rise, next curves gently laterally and joins internal rim apparently well in front of tip of prolongation. Brim poorly preserved, width about equal to maximum glabellar width, apparently very slightly concave laterally and anterolaterally; only front fraction of prolongation preserved; external rim narrow, internal rim not preserved.

Upper lamella of fringe with ornament of fine pits, very low radial caeca poorly developed but detectable on genal roll and on parts of brim close to site of girder; single rows of slightly coarser pits against external rim and both immediately inside and outside smooth band marking site of girder.

Thorax, pygidium, and hypostome unknown.

Dimensions. See Textfigure 5.

Discussion. The holotype is the most complete specimen collected by Koch, most of the others appear to be conspecific but are poorly preserved. The holotype is a smaller cephalon than those represented by paratypes MMH 12895 and 12896. Poulsen's photograph shows the holotype originally to have been more complete than the replica studied by and photographed for the present author; the present description relies on Poulsen's published photograph for some information about the holotype.

Although the species is poorly known, its large size, great width, relatively low profile, and truncate front of the glabella make it distinctive.

Scotoharpes loma (Lane 1972)

Plate 3, figures 1–13

Selenoharpes loma Lane 1972, p. 353–355, Pl. 62, figs. 1–9.

Material and occurrence. The description of the cephalon is based on seven dorsal surfaces (hypotypes GGU 100801–100807), seven natural external moulds of the dorsal surface and their latex casts (hypotypes GGU 100808–100814), one natural internal mould of the ventral surface (hypotype GGU 100815), and on fragments of the upper and lower lamellae adhering to some of these specimens. Four thoracic fragments (two dorsal surfaces, a ventral surface, and a natural internal mould of a ventral surface; hypotypes GGU 100816–100818, 100819) are associated with the cephala and almost certainly belong to the species. All material collected by B. S. Norford, 1966, from GSC locality 73921 from 30 feet of beds within the lower part of the Offley Island Formation in the Kap Tyson Section (Textfig. 1, loc. 1; 81°21′N, 61°45′W), northwestern Greenland (Norford, 1972, p. 29). A cephalon of the species is present at GSC locality 73920, about 70 feet lower in the same section. Both localities are of Late Llandovery age.

Description. Cephalon small, central part strongly convex, cephalic outline suboval, maximum width at eye tubercles and just less than total sagittal length of cephalon; prolongations slightly more than half axial cephalic length, bluntly terminated, curving very slightly adaxially behind posterior margin.

Glabella strongly raised above genae; front fifth with slight medial keel; sagittally curves strongly and evenly up from preglabellar furrow to about opposite eye tubercles, next rises in a slight incline to highest point at about opposite front of alae, next is very gently convex, curving down to rear of occipital ring; outline that of a blunt bullet, slightly tapering forward, axial furrows almost parallel, smoothly merging forward with evenly rounded preglabellar furrow, two pairs of broad very shallow pits in axial furrows, one just behind junctions with eye ridges, other at junctions with alar furrows; shallow crescentic lateral glabellar furrows diverge gently from axial furrows before curving evenly to trend just anterior of transverse where they fade about halfway to axis; occipital furrow shallow, almost straight but with a slight hook forward in outer thirds, behind very small lateral glabellar lobes; occipital ring slightly lower than rest of glabella, twice as long sagittally as at axial furrow, front half with a small median node.

Preglabellar field short, grades laterally into evenly convex genae. Eye tubercles small, opposite front fifth of glabella; eye ridges very faint, transverse; genal ridges just discernible, trending posterolaterally and reaching inner margin of fringe. Alae small, alar furrow shallow, starts near midlength of lateral glabellar furrows and curves strongly and evenly from axial furrow to occipital furrow; edge of gena trends anteromedianly from ala to axial furrow to delineate a small depressed triangle bounded by alar furrow, axial furrow, and edge of gena; edge trends posterolaterally from ala to posterior border furrow to delineate a very small and very depressed triangle bounded by alar furrow, genal edge, and posterior border furrow with which it merges. Posterior border strongly raised, border furrow a broad, deep trough. Inner margin of fringe has a slight re-entrant at preglabellar field, re-entrant modified by an axial bulge forward; inner margin curves evenly around genae and meets posterior border furrow at about a quarter of distance between axial furrow and tip of prolongation.

Glabella, posterior border, posterior border furrow, lateral parts of preglabellar field, triangles adjacent to alae, all with ornament of extremely fine pits; alae and median part of preglabellar field smooth; genae with fine pits separated by low genal caeca.

Genal roll laterally continues convex slopes of genae, dropping steeply to site of girder that is well marked on dorsal surface of upper lamella by a low smooth ridge that swings slightly forward around the axial mound, next curves evenly around genal roll to join internal rim at about a third of distance between inner margin of fringe and tip of prolongation. Girder broad, smooth; brim slightly concave laterally, slightly convex in front of anterior part of genal roll but almost flat anteriorly; prolongation very slightly concave except for flexed and slightly convex portion adjacent to anterior part of internal rim.

Upper and lower external rims narrow, with strong relief above and below levels of brim. Upper internal rim very narrow, strongly raised; lower internal rim unknown.

Upper and lower lamellae of fringe with ornament of fine pits, low smooth radial ridges separate pits on parts of the fringe, these ridges are strongest adjacent to site of girder and on genal roll, but are much reduced over most of brim, ridges seem to reach the rim laterally and anterolaterally but not anteriorly, ridges apparently absent in prolongations. Single rows of slightly coarser pits immediately against rim and, on upper lamella, against and outside site of girder; a single row of coarser pits against girder on lower lamella.

Largest thoracic fragment shows seventeen thoracic segments; maximum width of thorax at fourth segment. Axis about a quarter of width of thorax, tapering slightly rearward, transversely evenly convex; pleurae flat for most of length (*tr.*), abruptly flexed ventrally and rearward just before bluntly rounded extremities; both broad shallow pleural furrows and pleural margins transverse except on flexed portion where they run posterolaterally.

Pygidium unknown; *see* Lane (1972, p. 354, Pl. 62, fig. 5) for description of hypostome.

Dimensions. See Textfigure 5.

Discussion. This small species has a very strongly raised central part of the cephalon and a bullet-shaped glabella with very small lateral glabellar lobes. The present material is very similar to most of the specimens illustrated by Lane from northeastern Greenland but some of his larger individuals (Lane, 1972, Pl. 62, figs. 1a, 8) have proportionally wider cephalons and one (Pl. 62, fig. 6) seems to show a considerably less abrupt profile to the front of the glabella.

The holotype and several of the other illustrated specimens of *Scotoharpes loma* are from Lane's locality 1418 (one or more boulders within the basal Profilfjeldet Shales but thought to have been derived from the underlying Drommebjerg Limestone). The other illustrated specimens are from similar boulders and from the uppermost Drommebjerg Limestone but two specimens that are assigned to the species come from the Centrum Formation and from about 300 metres (about 1,000 feet) stratigraphically below the rest of the assigned material (Lane, 1972, p. 336, 337, 353). Lane thought *Scotoharpes loma* and associated trilobite species to be of Wenlock age, based on the occurrence of Late Wenlock species of graptolites 50 metres (about 165 feet) above the base of the Profilfjeldet Shales, and, in the same beds as some of the trilobites, the presence of brachiopods that he considered to indicate Wenlock age. No identifications or precise stratigraphic localities were given for these brachiopods, nor were data showing whether the brachiopods came from matrix of the beds or from contained boulders, nor were faunal assemblages for individual boulders. *Scotoharpes loma* and the other species of trilobites described by Lane cannot be younger than Wenlock but uncertainty remains whether they could be older.

The other described Greenland species, *Scotoharpes latior* (Poulsen), has a truncated front to the glabella and a much wider cephalon than *S. loma.* The lower Middle Ordovician *Scotoharpes singularis* (Whittington) is another small but high species. Its glabella has a more truncate front than *loma,* its girder meets the internal rim close to the tip of the prolongation and the maximum width of the cephalon is farther back (about at glabella lobes but at eye tubercles in *loma*).

Scotoharpes raaschi new species

Plate 2, figures 1, 3, 4, 5

Aristoharpes sp. Norford 1964, p. 125.

Material and occurrence. Single incomplete cephalon (holotype GSC 27794) showing dorsal surface of glabella, genae and strip of upper lamella near site of girder, rest of upper lamella is a natural internal mould; collected by B. S. Norford, 1962, from GSC locality 53109 from 1,400 to 1,403 feet above base of unnamed carbonate unit, South Illtyd Range Section (Textfig. 1, loc. 12; 65°14′N, 135°12′W), Yukon Territory. Associated fauna includes *Encrinurus* cf. *E. princeps* Poulsen, *Scutellum* sp., and cf. *Glassia* sp.; age, Late Llandovery.

Description. Central part of cephalon moderately convex; cephalic outline suboval, greatest width at, or just in front of alae, probably about equal to total sagittal length of cephalon; prolongations probably slightly less than axial cephalic length, curving very slightly adaxially near terminations.

Glabella strongly raised above genae; sagittally rises in steep plane from preglabellar furrow to opposite front of eye tubercles, next evenly convex to high point about opposite front of alae, next drops with gentle convexity to rear of occipital ring; outline semioval, preglabellar furrow evenly curved, merges without inflexion with axial furrows that bear three pairs of very shallow pits, one just behind eye ridges, one at alar furrows, one midway between alar furrow and fronts of glabellar lobes; lateral glabellar furrows trend diagonally back from axial furrows and curve to become subtransverse where they fade about halfway to axis; occipital furrow strong, straight except for abaxial swing forward; occipital ring lower than rest of glabella, twice as long sagittally as at close to axial furrow, apparently without median node.

Preglabellar field grades laterally into evenly convex genae. Eye tubercles large, opposite front fifth of glabella; eye ridges faint, trend slightly anterior of transverse from glabella; genal ridges trend posterolaterally to inner margin of fringe. Alae of moderate size; alar furrow very shallow, evenly convex from junction of lateral glabellar and axial furrows to occipital furrow. Posterior border strongly raised, border furrow deep, broad, merges with depressed triangular area between it and gena. Inner margin of fringe indistinctly preserved, transverse in front of preglabellar field, curving gently and evenly around genae to meet posterior border furrow.

Glabella, posterior border, posterior border furrows, alae and adjacent triangles, preglabellar field, all apparently smooth; genae with moderately coarse pits separated by genal caeca that branch from axial furrow behind eye ridge and become subradial in outer regions of genae and cross inner margin of fringe onto genal roll.

Genal roll with fairly strong axial mound, elsewhere continues convex slopes of genae, dropping steeply to site of girder that is marked by a very low smooth ridge on dorsal surface of upper lamella; ridge probably swings forward around axial mound, next curves evenly around gena to about opposite lateral glabellar lobes, next trends almost straight rearwards to join internal rim at about a third of distance from inner margin of fringe to tip of prolongation. Girder broad, smooth. Brim probably slightly wider anteriorly than laterally, concave anterolaterally and perhaps anteriorly, slightly concave laterally, prolongation flat except for flexed slightly convex portion adjacent to girder.

Internal and external rims narrow with strong relief relative to brim. Upper lamella of brim with ornament of pits which locally are separated by low smooth radial ridges that are strongest adjacent to girder, outer parts of brim poorly preserved but these ridges do not appear to reach the rim and are not present on prolongations. Single row of coarser pits against girder.

Thorax, pygidium, and hypostome unknown.

Dimensions. See Textfigure 5.

Discussion. The species is larger than *S. loma* (Lane), which has almost parallel axial glabellar furrows and proportionally smaller lateral glabellar lobes. The pits on the genae and on the fringe are much coarser than in *Scotoharpes latior* (Poulsen). The species is similar to the poorly known *S. domina* Lamont but has a glabella that is distinctively suboval instead of being almost subquadrate and truncated by the preglabella furrow. *S. consuetus* (Billings) is also poorly known and could be very closely related to *S. raaschi*, it has a tapered outline to its glabella and a higher occipital ring that medianly protrudes less rearward.

Scotoharpes willsi (Whittington) is about the same size and shape as *raaschi* and has a similar glabellar outline. The occipital ring is much higher in *willsi* than in *raaschi* and forms the high point of the glabella; some specimens of *willsi* show fine pits on the gena and ridges in the lateral parts (Whittington, 1950a, p. 44) but the gena of *raaschi* has coarser pits and well-developed genal caeca.

The species is named in honour of Dr. G. O. Raasch of Calgary.

Scotoharpes sp.

Plate 2, figure 6

Material and occurrence. A single specimen (hypotype GSC 27795) showing part of the ventral surface of the lower lamella of the fringe, primarily the prolongation, and the ventral surface of most of one gena, an eye tubercle and the edge of the glabella; collected by G. B. Leech, 1966, from GSC locality 70516, Tegart Formation at divide (Textfig. 1, loc. 25; 50°37'N, 115°58'W) between Redstreak and Stoddart Creeks, southeastern British Columbia. Associated fauna includes *Eophacops* sp., *?Glassia* sp. The Tegart Formation is latest Llandovery in age (Norford, 1969, p. 40).

Description. Prolongation trends almost straight rearward. Genal caeca present on gena, genal roll and, very indistinctly, close to girder on brim of prolongation. Ornament of moderately fine pits on lower lamella, with single rows of coarser pits against girder and against external and internal rims. Girder strong, joins internal margin well in front of tip of prolongation that bears a short spine. Internal and external rims rather wide, strongly raised.

Dimensions. See Textfigure 5.

Discussion. The fragment can be referred to *Scotoharpes* on the basis of the style of pitting on the brim and the position of the junction of the girder and the internal rim. Too little is known of the specimen to allow fruitful comparison with the described species of the genus.

Scotoharpes? *telleri* (Weller 1907)

Plate 4, figures 1–7

Harpes telleri Weller 1907, p. 213–214.
Harpes telleri Weller, Raymond 1925, p. 17–18, Pl. 6, fig. 6.
Harpes telleri Weller, Armstrong and Armstrong 1962, p. 2.
Harpes telleri Weller, Emielity 1963, p. 27–28.

Material and occurrence. Ventral surface of genal region and upper lamella of almost complete cephalon (holotype USNM 96656), with part of lower lamella adhering and showing ventral surface; collected by E. E. Teller from the Racine Dolomite at 26th Street, Milwaukee, Wisconsin (Textfig. 1, loc. 27; 43°02'N, 87°55'W). Ventral surface of genal region and upper lamella (hypotype UC 12318); also collected by E. E. Teller from Milwaukee. Ventral surface of genal region and lower lamella of virtually complete cephalon (hypotype MCZ 1624), parts of lower lamella missing from brim revealing ventral surface of upper lamella; ventral surface of genal region and upper lamella of virtually complete cephalon (hypotype MCZ 1625), with lower lamella adhering to one prolongation and showing ventral surface; thoracic fragment (hypotype MCZ 1823, that probably does not belong to the species) showing dorsal surface of parts of nine segments; all three collected by F. H. Day from the Racine Dolomite at Wauwatosa, Wisconsin (Textfig. 1, loc. 27; 43°03'N, 88°00'W); also reported from Racine, Wisconsin. Berry and Boucot (1971, p. 200–201) date the Racine as Late Wenlock to Ludlow. All the material (especially the holotype) is poorly preserved in dolomite with destruction of surface detail.

Description. Cephalic outline suboval, greatest width at alae and much greater than axial cephalic length which is subequal to that of prolongations which trend almost straight rearward. Glabella tapered forward with evenly rounded front and small lateral glabellar lobes, high point at front of occipital ring that bears a small median node in front half. Preglabellar field extremely short (*sag.*), axial mound very low; eye tubercles opposite front fifth of glabella; alae relatively large. Posterior border strongly raised; border furrow shallow, broad. Inner margin of fringe almost transverse in front of glabella, virtually undetectable elsewhere. Axial mound in genal roll very low, only developed in rear part. Girder strong, meets internal rim at about a third of distance from junction of inner margin and border to tip of prolongation. Brim wider anteriorly (*sag.*) than laterally (*tr.*), flat except anteriorly slightly convex close to girder and flexed near girder in prolongations. Rim narrow, with moderate relief relative to brim. No pits, genal caeca or ornament preserved on any part of cephalon. Pygidium and hypostome unknown; uncertain whether thorax known.

Dimensions. See Textfigure 5.

Discussion. Assignment of *telleri* to *Scotoharpes* is indicated by the general shape of the cephalon, the outlines of the glabella and of the prolongations and particularly the junction of the girder with the internal rim far forward of the tip of the prolongation. However, no ornament is preserved and thus the presence or absence of pits and genal caeca on the genae and fringe cannot be determined, nor can the presence or absence of single rows of coarse pits on the brim immediately adjacent to the rim and to the girder. The species can only be tentatively referred to *Scotoharpes.*

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PLATE 1

Scotoharpes domina Lamont (PAGE 14)

Figures 1–3. Plaster replica (GSC 27793) of plasticine dorsal surface made by Lamont from the holotype external mould; includes upper lamella; *Plectodonta* aff. *canastonensis* beds, Scotland; x3. Lamont's illustration (1948a, Fig. 2) seems to show the counterpart internal mould.

Scotoharpes latior (Poulsen) (PAGE 17)

Figures 4, 7, 9. Plaster replica of the holotype (MMH 3249), a dorsal surface; unspecified beds at Kap Schuchert, northwestern Greenland; x3.

Figures 5, 6. Paratype cranidial fragment (MMH 12895), a peeled dorsal surface; unspecified beds at Kap Schuchert, northwestern Greenland; x3. Showing two pairs of small pits on peeled dorsal surface of glabella next to axial furrows in front of lateral glabellar lobes.

Figure 8. Paratype cranidial fragment (MMH 12896), internal mould; unspecified beds at Kap Schuchert, northwestern Greenland; x4. Dorsal surface of exoskeleton of genal roll shown on fragment adhering to mould that adjacently shows negative impression of exoskeleton.

PLATE 1

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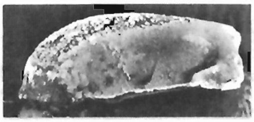

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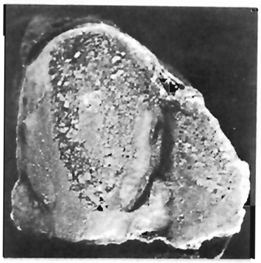

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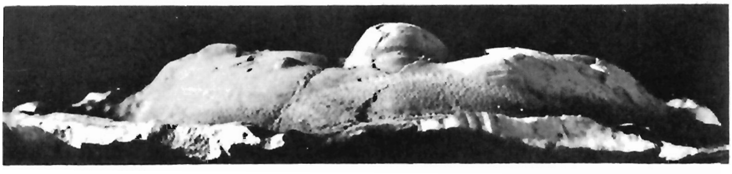

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PLATE 2

Scotoharpes raaschi new species (PAGE 20)

Figures 1, 3, 4, 5. Holotype cephalon (GSC 27794) showing dorsal surface of glabella, genae and a strip of upper lamella near site of girder, rest of upper lamella is a natural internal mould; GSC locality 53109, unnamed carbonate unit, Yukon Territory; figs. 1, 3, 4, x3; fig. 5, about x6.

Scotoharpes consuetus (Billings) (PAGE 16)

Figure 2. Replica of dorsal surface; a cast made from holotype cephalon (GSC 2550, natural external mould); Chicotte Formation, Anticosti Island, Quebec; x3.

Scotoharpes sp. (PAGE 22)

Figure 6. Ventral surface (hypotype GSC 27795) of lower lamella parts of fringe and gena; GSC locality 70516, Tegart Formation, southeastern British Columbia; x3. Rear part of girder is well shown and has strong relief against adjacent ventral surface of genal roll.

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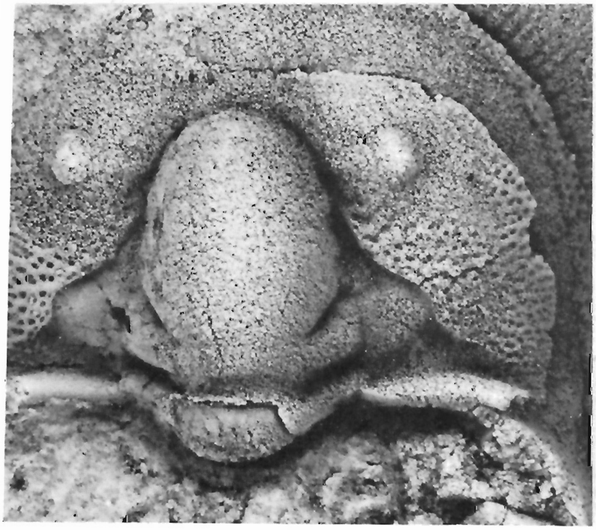

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PLATE 3

Scotoharpes loma (Lane) (PAGE 18)

Figures 1, 2, 4.	Hypotype cephalon (GGU 100801), a dorsal surface; GSC locality 73921, Offley Island Formation, northwestern Greenland; x3. Parts of the surface are missing and internal mould of genal roll and upper lamella shows through and bears pustules that are the negative representation of pits.
Figure 3.	Hypotype cephalon (GGU 100802), a dorsal surface; same locality as fig. 1; x3.
Figures 5, 6.	Small hypotype cephalon (GGU 100806), a dorsal surface showing node on occipital ring; same locality as fig. 1; fig. 5 x6; fig. 6 x3.
Figures 7, 8, 12, 13.	Hypotype thoracic fragments (GGU 100816, 100819), dorsal surfaces, partly peeled at axis; same locality as fig. 1; x3.
Figure 9.	Cast from hypotype cephalon (GGU 100812, fig. 11), a natural external mould of a dorsal surface; same locality as fig. 1; x3.
Figure 10.	Hypotype cephalon (GGU 100811), a natural external mould of a dorsal surface; same locality as fig. 1; x3. Fragment of genal roll is attached to mould.
Figure 11.	Three hypotype cephala (left GGU 100812, fig. 9; centre GGU 100809; right GGU 100814), all natural external moulds of dorsal surfaces; same locality as fig. 1; x3. Fragment of brim of upper lamella attached to left mould and shows ornament of its ventral surface; fragment of genal roll of upper lamella adheres to right mould and shows ornament of its ventral surface.


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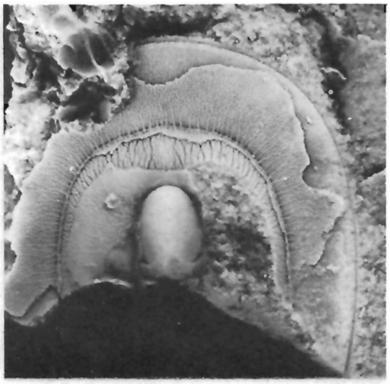
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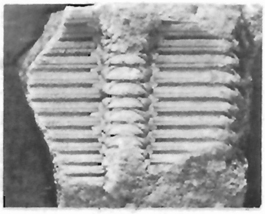
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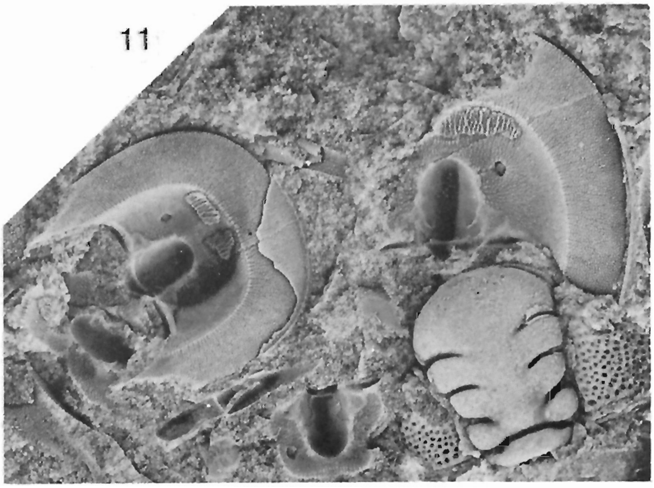
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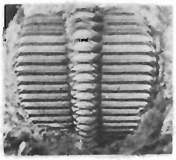
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PLATE 4

Scotoharpes? telleri (Weller) (PAGE 22)

Figure 1.	Cast made from holotype cephalon (USNM 96656), a ventral surface of upper lamella and genal region; Racine Dolomite, Wisconsin; x3. Top part of figure shows cast of ventral surface of a piece of lower lamella adhering to cephalon.
Figures 2, 4, 6, 7.	Fig. 2 shows ventral surface of hypotype cephalon (MCZ 1625), showing genal region and upper lamella and a fragment of lower lamella (prolongation of brim, girder and adjacent roll); Racine Dolomite, Wisconsin; x3. Figs. 4, 6, 7 show cast made from this ventral surface.
Figure 3.	Ventral surface of hypotype cephalon (MCZ 1624), showing genal region and lower lamella; Racine Dolomite, Wisconsin; x3. Strong girder is well shown as are flange-like posterior parts of genal roll of lower lamella.
Figure 5.	Ventral surface of hypotype cephalon (UC 12318), a ventral surface of upper lamella and genal region; ?Racine Dolomite, Wisconsin; x3.

PLATE 4


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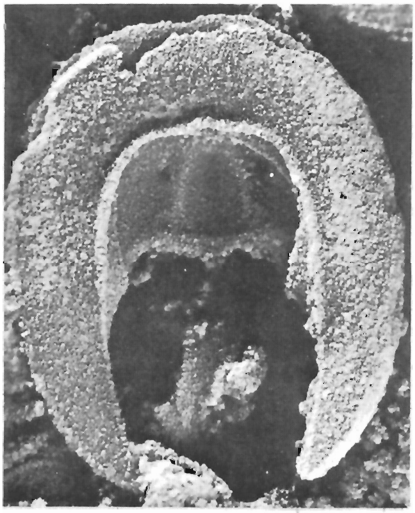
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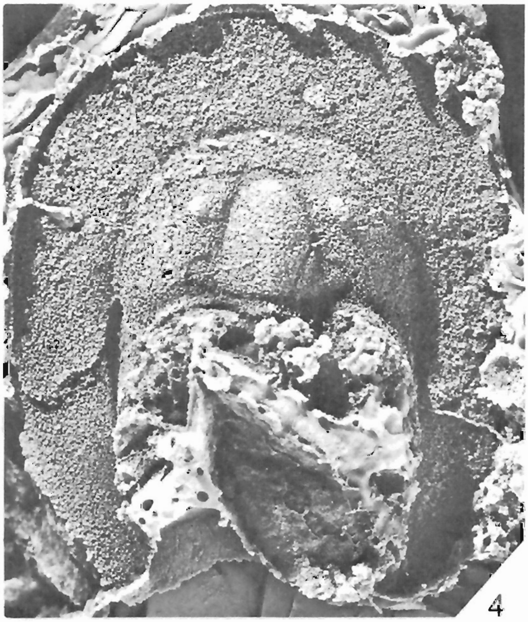
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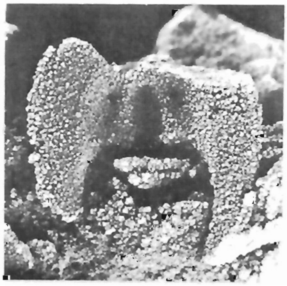
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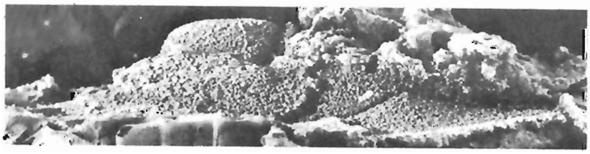
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AMPHIASPIDIFORMES (HETEROSTRACI) FROM THE SILURIAN OF THE CANADIAN ARCTIC ARCHIPELAGO

by D. S. Broad[1]

Abstract

Three new species of *Boothiaspis*, new genus, Order Amphiaspidiformes, are described from Pridolian or older horizons in the Devon Island, Read Bay, and Peel Sound Formations. Amphiaspids were previously recorded only from arctic Russia but are now known also from Ellesmere, Somerset, and Prince of Wales Islands. These new amphiaspids closely resemble the Russian forms in size, shape, and possession of a ventral shield more convex than the dorsal, but they are significantly different in their simpler ornament, well-developed lateral alae and a single lateral line sensory system. Their Pridolian, or older, age is supporting evidence for a heterostracan evolutionary centre in the Canadian Arctic Archipelago during late Silurian time.

Résumé

L'auteur décrit trois nouvelles espèces de *Boothiaspis*, nouveau genre, de l'ordre des Amphiaspidiformes, datant du Pridolien ou plus anciennes, et provenant des formations de l'île Devon, de la baie Read et du détroit de Peel. Antérieurement, on connaissait la présence d'Amphiaspidés dans l'Arctique russe seulement, mais on en a maintenant découvert dans les îles Ellesmere, Somerset et Prince-de-Galles. Ces nouveaux Amphiaspidés ressemblent beaucoup à ceux qui étaient connus en Russie en ce qui a trait à la forme et aux dimensions et au bouclier ventral qui est plus convexe que le bouclier dorsal, mais ils sont sensiblement différents par leurs ornements plus simples, leurs ailes latérales bien développées, et leur système sensoriel revêtant la forme d'une simple ligne latérale. Le fait qu'ils datent du Pridolien, ou qu'ils soient peut-être plus anciens démontre que l'archipel de l'Arctique canadien a été possiblement un centre d'évolution des hétérostracanidés lors du Silurien supérieur.

Introduction

This is the first reported occurrence of amphiaspids outside arctic Russia. The amphiaspids are a group of distinctive, and in some cases bizarre, Heterostraci and previously have been known only from the Lower Devonian of the northwestern Siberian Platform and southwestern Taimyr (Obruchev, 1938; Novitskaya, 1967, 1968, and 1971).

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The new forms from Canada are closely comparable with the Russian species but show significant differences, namely simpler ornament, wide lateral alae, and a single sensory canal system in contrast with the dual sensory system developed in some amphiaspids. A large number of shields are described from five localities in the Lower Member of the Peel Sound Formation of Somerset and Prince of Wales Islands, and in the upper part of the Read Bay Formation of Somerset Island. A single, moderately well preserved dorsal shield is described from a locality in the lower part of the Devon Island Formation of Ellesmere Island. All six faunules are thanatocoenose.

Acknowledgments

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Stratigraphy and Correlation

Read Bay Formation (Somerset and Prince of Wales Islands)

The formation consists of as much as 8,500 feet of limestone, argillaceous limestone, minor dolomite, calcareous shale, sandstone, siltstone and shale in the type area on Cornwallis Island (Thorsteinsson and Fortier, 1954; Thorsteinsson, 1958). The formation is lithologically similar on Somerset and Prince of Wales Islands but is considerably thinner.

Two different lithological criteria have been used for its contact with overlying formations. On Cornwallis Island, Thorsteinsson (1958, p. 75) drew the contact with the conformable Snowblind Bay Formation at the lowest persistent stratum of limestone–conglomerate. However, on Somerset Island Thorsteinsson and Tozer (*in* Fortier *et al.*, 1963, p. 122) drew the boundary between the Read Bay and Peel Sound Formations at the first appearance of red siltstone. The author follows Miall (1970, p. 126) in drawing the boundary between the Read Bay and Peel Sound Formations on Prince of Wales Island (Textfigure 1, loc. 7) at the base of the lowest pebble-conglomerate, but it is not possible to correlate this horizon accurately between Somerset and Prince of Wales Islands.

The age of the Read Bay Formation is best known from its development on Cornwallis Island where recent work by Thorsteinsson and Kerr (1968) indicates a range from Middle Silurian to Early Devonian. The formation has not been so well dated on Somerset and Prince of Wales Islands.

Heterostracan faunas, including Cyathaspididae and Pteraspididae, have been recorded from the Read Bay Formation on Cornwallis Island (Thorsteinsson, 1958; Fortier *et al.*, 1963). On Somerset Island Heterostraci and Acanthodii are known from a number of localities (Dineley, 1966; Broad and Dineley, *this volume*) including locality C-10049 where the amphiaspid *Boothiaspis ovata* new genus and new species occurs.

Peel Sound Formation (Somerset and Prince of Wales Islands)

This formation was described by Thorsteinsson and Tozer (*in* Fortier *et al.*, 1963) from Somerset and Prince of Wales Islands where it is a sequence of predominantly red beds comprising siltstone, sandstone, gneiss-dolomite-limestone pebble and boulder conglomerate, dolomite and dolomitic limestone. Miall (1970, p. 126) divided the formation on Prince of Wales Island into Lower and Upper Members. The Lower Member (and the lower part of the formation on Somerset Island) is predominantly clastic and consists of sandstone and conglomerate with rare siltstone and thin interbeds of limestone and dolomite. Vertebrates are abundant at certain localities and include Hemicyclaspididae, Cephalaspididae, Cyathaspididae, Corvaspididae, Traquairaspididae, Amphiaspidiformes, Acanthodii, and Arthrodira. The Upper Member is known only on Prince of Wales Island where it consists of three facies which are in part lateral equivalents. These facies were first recognized by Blackadar and Christie (1963). Miall later mapped them in sequence westwards as the Conglomerate Facies, the Sandstone Facies, the Carbonate Facies and two transitional facies (Broad, Dineley, and Miall, 1968; Miall, 1970). Vertebrates are locally abundant in the transition zone between the Sandstone and Carbonate Facies and are represented by Cephalaspididae, Ctenaspidinae, Pteraspididae, Acanthodii, Arthrodira, and Crossopterygii.

The age of the Upper Member has been discussed by Broad, Dineley, and Miall (1968). The age of the Lower Member also has been discussed by Broad and Dineley (*this volume*). The balance of vertebrate and invertebrate faunal evidence favours Pridolian and Gedinnian age.

Devon Island Formation (Ellesmere Island)

In the type area on Devon Island graptolite evidence indicates Ludlovian age (Thorsteinsson *in* Fortier *et al.*, 1963).

In southern Ellesmere Island the Devon Island Formation consists of dark grey to black shale, calcareous shale with graptolites, and thin beds of limestone. Vertebrate remains, mostly fragmentary, are known from a number of localities. In 1967 Kerr collected a single incomplete dorsal shield of *Boothiaspis alata* new species from Muskox Fiord, 200 feet above the base of the formation (GSC locality C-6462, *see* Appendix). According to Thorsteinsson (pers. com. 1968) other heterostracans from this locality include forms similar to *Corvaspis*, *Pionaspis*, and *Traquairaspis*. The heterostracans are directly associated with a monograptid that Thorsteinsson had dated as Pridolian on Cornwallis Island where it occurs below *Monograptus transgrediens* Perner. The Ludlovian graptolites *M. bohemicus* Barrande and *M. ultimus* Perner occur near the base of the formation and underlie the heterostracan bed.

Systematic Paleontology

Prefix NMC refers to specimens in the Vertebrate Paleontology collections of the National Museum of Canada, Ottawa.

Subclass HETEROSTRACI Lankester, 1868

Order AMPHIASPIDIFORMES Berg, 1940

Suborder SIBERIASPIDOIDEI Novitskaya, 1968

Family SIBERIASPIDIDAE Novitskaya, 1968

Genus **Boothiaspis** new genus

Type species. *Boothiaspis ovata* new species from the Peel Sound Formation, Prince of Wales Island.

Etymology. Referring to the occurrence of the genus in rocks flanking the Boothia Arch.

Diagnosis. Dorsal shields flat, oval to elongate, postbranchial lateral margins acuminate and expanded laterally to form alae. Posterior margin with or without median lobe. Orbits situated anterolaterally with overlying bony crest, mouth terminal.

Differs from other genera in the presence of well-developed lateral wings, simple ornament of fine dentine ridges, and in the absence of surface grooves of the sensory canal system and postorbital foramina.

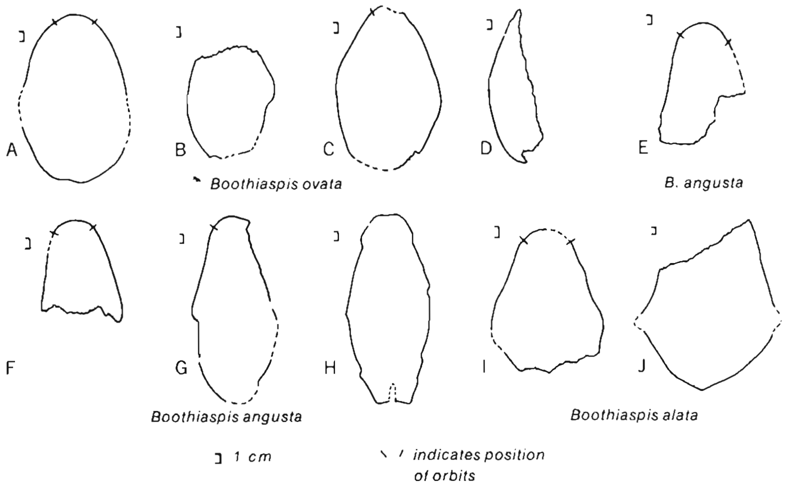
Known species. *Boothiaspis alata* new species
B. angusta new species
B. ovata new species

Boothiaspis ovata new species

Plate 5, figures 1, 2, 3; Textfigures 6A–D, 7A, B, 8A, 9A, B

Diagnosis. Dorsal shields generally flat and oval, with a width ratio of 0.57–0.74. Postbranchial margins acuminate and expanded laterally as continuous alae. Posterior margin without lobe.

Material and occurrence. One entire dorsal shield (holotype NMC 12778, Pl. 5, fig. 1; Textfigs. 6A, 7A, B, 8A); thirteen fragmentary dorsal shields (paratypes NMC 12766, 12773, 12775, 12779–12780, 12785, 12789, 12790, 12913); NMC 12773, from Read Bay Formation near locality C-10049, Somerset Island (*see* Appendix and Textfig. 1, loc. 5), NMC 12790 from locality C-10552 Somerset Island (Textfig. 1, loc. 6), all other specimens from locality C-10045, Lower Member of Peel Sound Formation, Prince of Wales Island (Textfig. 1, loc. 7).



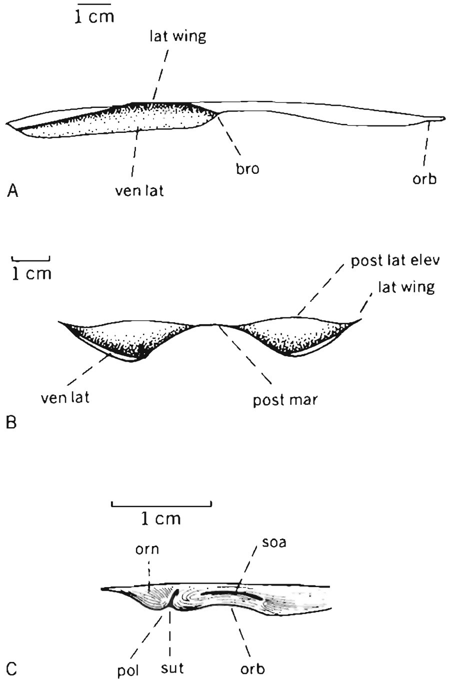
TEXTFIGURE 6

Outlines of dorsal (A-G, I, J) and ventral (H) shields of *Boothiaspis* new genus.
A, NMC 12778, holotype of *B. ovata* new species; B, NMC 12780; C, NMC 12789; D, NMC 12790; E, NMC 12783; F, NMC 12777; G, NMC 12760, holotype of *B. angusta* new species; H, NMC 12788; I, NMC 12767; J, NMC 12770, holotype of *B. alata* new species.

Etymology. Latin: *ovatus* (oval) referring to the outline of the dorsal shield.

Dimensions (cm)		No. of specimens
median length	13.2–15.0	5
maximum width	8.4– 9.7	6
orbital width	3.2– 4.1	4
orbital length	0.8– 1.0	3
pineal length	2.4	2
postbranchial length	6.3– 6.4	2
maximum width/median length	0.57–0.74	4
orbital width/median length	.24– .31	4
orbital length/median length	.05– .08	3
pineal length/median length	.17– .18	2
postbranchial length/median length	.45	2

Description. Holotype almost flat, maximum height 0.7 cm posteromedially, slightly arched longitudinally, paired gentle elevations in dorsal postbranchial region (Textfig. 7B). Prebranchial and rostral margins of shield form a continuous curve with little or no interruption of outline to indicate position of orbits (Pl. 5, fig. 1). Orbits sited anterolaterally, very shallow and elongate, overlain by a crest of bone so that orbit slightly underlies most lateral extent of dorsal shield (seen also in *B. angusta*, Textfig. 7C). Postbranchial margins of shield acuminate, ornamented on dorsal and ventral surfaces, continuous with underlying ventrolateral laminae which are inclined inwards (Textfig. 7A, B), extenuated laterally and slightly upwards



TEXTFIGURE 7

Dorsal shields of *Boothiaspis* new genus.
A, right lateral view, and B, posterior view, of dorsal shield of *B. ovata* new species (holotype, NMC 12778). C, left anterolateral view of dorsal shield of *B. angusta* new species (NMC 12783).
bro, branchial opening; lat wing, lateral wing; pol, preorbital lobe; post lat elev, posterolateral elevation; post mar, posterior margin; orn, general pattern of ornament; orb, orbit; soa, supraorbital arch; sut, preorbital suture; ven lat, ventrolateral lamina.

forming alae which extend to posterior margin (Pl. 5, figs. 1, 2). Branchial openings thought to lie at anterior end of wings. Posterior margin transverse, without median lobe. Posterior region sharply depressed laterally, broadly elevated centrally (Textfig. 7A, B), dorsal surface with small median elevation close to margin.

Ornament of long, thin discontinuous dentine ridges with flat crests and minutely sinuous narrow intercostal grooves (Pl. 5, fig. 3); 4 to 7 ridges per mm but more closely spaced on central epitegum. Lateral ornament parallel to margins, other ornament forms sinuous pattern across shield (Textfig. 8A). Lateral line sensory system consists of short canals with short side processes leading to surface pores (Textfig. 9A, B).

Boothiaspis angusta new species

Plate 5, figure 4; Plate 6, figures 1, 2, 3;
Textfigures 6E–H, 7C, 8B, 9C, D

Diagnosis. Dorsal shields flat and elongate with a width ratio of 0.40. Prebranchial margins straight, prebranchial outline of shield roughly triangular. Postbranchial margins acuminate and expanded laterally to form wings. Posterior margin without lobe. Ventral shield strongly convex, elongated, with posterior ventral spine.

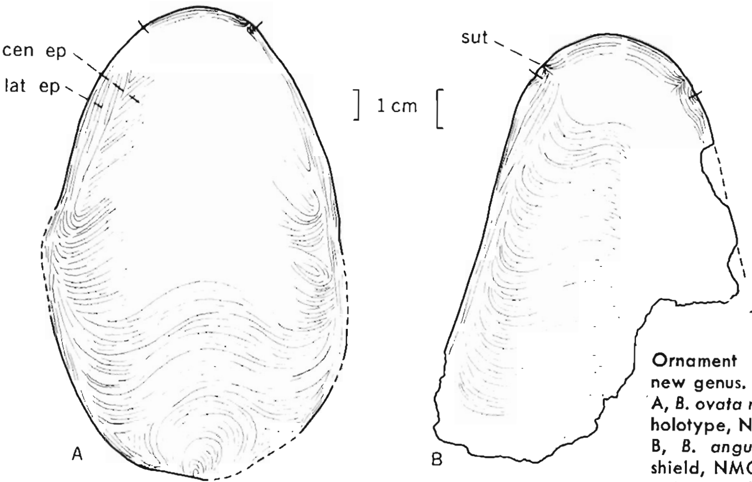
Material and occurrence. One almost entire dorsal shield (holotype NMC 12760, Pl. 6, fig. 1; Textfigs. 6G, 9C), three incomplete dorsal shields (paratypes NMC 12777, 12782, 12783) and one entire ventral shield (paratype NMC 12788), all from locality C-10045, Lower Member of Peel Sound Formation, Prince of Wales Island (Textfig. 1, loc. 7).

Etymology. Latin: *angustus* (narrow) referring to the slender proportions of the dorsal shield.

Dimensions (cm)	Dorsal shield	No. of specimens	Ventral shield	No. of specimens
median length	17.6	1	18.0	1
maximum width	7.5–7.9	2	7.2	1
orbital width	3.5–4.4	3	max. height 4.0	1
orbital length	1.1–1.5	3	—	
pineal length	2.8	1	—	
maximum width/median length	0.40	1	0.40	1
orbital width/median length	0.20	1	—	
orbital length/median length	0.06	1	—	

Description. Prebranchial margins long, straight, giving a roughly triangular outline to dorsal shield (Pl. 5, fig. 4; Pl. 6, fig. 1). Postbranchial margins acuminate, extend laterally as slightly upturned wings which extend to posterior margin. Preorbital lobe present, anterolateral orbits set inwards and slightly ventral, with an overlying arch of bone (Textfig. 7C). Ventral shield unusually convex compared with almost flat dorsal shield (Pl. 6, figs. 2, 3), maximum height in branchial and postbranchial regions, posterior margin concave, strongly arched, with broken median spine on ventral surface (spine originates 3.4 cm in front of margin), anterior part gently arched with concave anterior margin. Mouth is terminal.

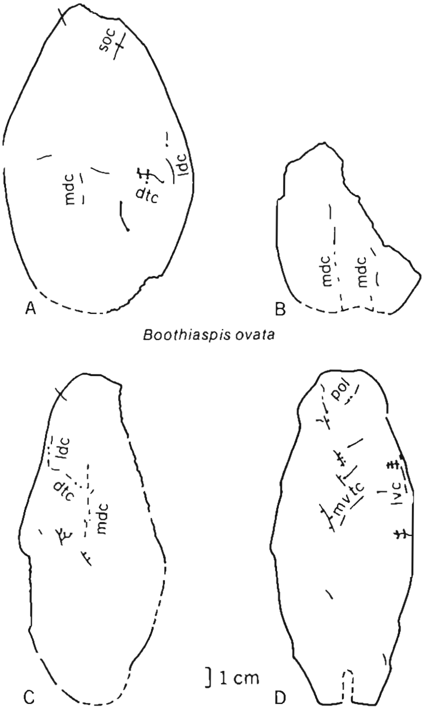
Ornament of long, discontinuous dentine ridges, 5 to 8 per mm centrally and flat-crested on dorsal shield and on ventral shield, but finer (8 to 12 per mm) and acutely crested on lateral epitega. Lateral ornament on dorsal shield parallel to margin, other dorsal ornament sinuous



\ / *indicates position of orbits*

TEXTFIGURE 8

Ornament patterns of *Boothiaspis* new genus.
A, *B. ovata new* species (dorsal shield, holotype, NMC 12778);
B, *B. angusta* new species (dorsal shield, NMC 12783). cen ep, central epitegum; lat ep, lateral epitegum; sut, suture line. Only the general pattern of dentine ridges is shown.



Boothiaspis ovata

Boothiaspis angusta

TEXTFIGURE 9

Lateral line sensory canal system in *Boothiaspis* new genus.
A, B, *B. ovata* new species, dorsal shields (NMC 12789, 12914).
C, *B. angusta* new species, dorsal shield (holotype NMC 12760).
D, *B. angusta* new species, ventral shield (NMC 12788).
dtc, dorsal transverse commissure; ldc, lateral dorsal canal; lvc, lateral ventral canal; mdc, median dorsal canal; mvtc, median ventral transverse canal; pol, postoral canal; soc, supra-orbital canal.

across shield (Textfig. 8B). Pattern on ventral shield transverse and broadly sinuous. Dorsal and ventral shields show short and separate lateral line canals with short side processes leading to small surface pores (Textfig. 9C, D).

Remarks. This new species differs from *Boothiaspis ovata* and *B. alata* in its almost straight prebranchial margins, triangular outline of the prebranchial part of the headshield, and its more slender proportions.

Boothiaspis alata new species

Plate 6, figure 5; Textfigures 6I, J

Diagnosis. Dorsal shield wide, flat, with width ratio approximately 0.70–0.73. Postbranchial margins acuminate, lateral wings very pronounced, present only in branchial region. Small posterior median lobe.

Etymology. Latin: *alatus* (winged) referring to the extreme development of lateral wings.

Material and occurrence. Three dorsal shields: holotype NMC 12770, (Pl. 6, fig. 5; Textfig. 6J) from locality C-10550, lower part of Peel Sound Formation, Somerset Island (Textfig. 1, loc. 5), paratype NMC 12767, from lower locality C-10045 Lower Member of Peel Sound Formation, Prince of Wales Island (Textfig. 1, loc. 7); paratype NMC 12738, from locality C-6462 Devon Island Formation, Ellesmere Island (Textfig. 1, loc. 4).

Dimensions (cm)

median length	15.0 –?20.0
maximum width	10.6 – 14.6
postbranchial length	8.0 – 9.9
maximum width/median length	0.70–?0.73
postbranchial length/median length	0.50

Description. Holotype slightly arched longitudinally and transversely, maximum height about 1.3 cm in prebranchial region. Lateral margin depressed at branchial opening, behind which shield broadens considerably and bears incomplete but prominent wings (Pl. 6, fig. 5; Textfig. 6J), which do not continue to posterior margin. A postbranchial inwardly inclined ventrolateral lamina present and continues to strongly depressed posterolateral corners. Posterior margin broadly arched, with prominent median lobe.

Ornament poorly preserved, consisting of flat-crested dentine ridges 9 to 10 per mm.

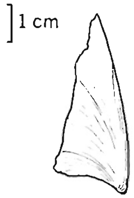
Remarks. This new species is closely related to *B. ovata* and *B. angusta* but differs in its larger size, possession of very wide wings in the branchial region which do not continue to the posterior margin, and the presence of a median lobe.

?Family OLBIASPIDIDAE Obruchev, 1964

Genus indet.

Plate 6, figure 4; Textfigure 10

Material and occurrence. One right cornuum (NMC 12787), from GSC loc. C-10052, lower part of Peel Sound Formation, Somerset Island (Textfig. 1, loc. 5).



TEXTFIGURE 10

Right cornual part of dorsal shield of ?olbiaspidid (NMC 12787).

Description. Cornuum 4 cm long, 2 cm wide, and is a broken lateral extremity of a dorsal shield. Surface gently inclined posteriorly, its tip points gently downwards. Lateral margin convex, posterior margin concave. Ornament of flat-crested dentine ridges, 8 per mm, which radiate from a growth centre near the cornual tip.

Remarks. This fragment is most likely part of an amphiaspid. In size and shape it is similar to a cornuum of *Angaraspis urvantzevi* Obruchev (1964, Fig. 67; Novitskaya 1971, Fig. 37).

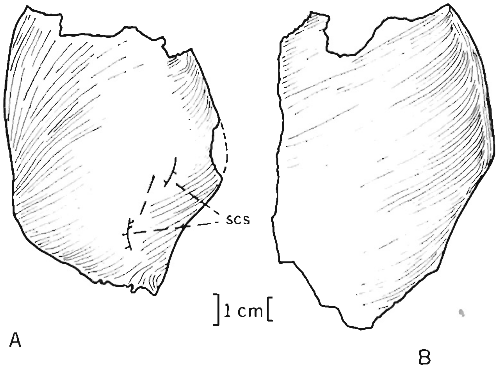
Heterostraci indet.

Plate 6, figure 6; Textfigure 11A, B

Material and occurrence. Three almost flat disarticulated plates (NMC 12763, 12768, 12769), from GSC loc. C-10045, Lower Member of Peel Sound Formation, Prince of Wales Island (Textfig. 1, loc. 7).

Description. Plates all about 12 cm long, 7 cm wide, slightly arched across width. Their orientation is uncertain. Outline and pattern of ornament indicate them to be asymmetric. Ornament similar to that of *Boothiaspis*, consisting of flat-crested dentine ridges (4 to 7 per mm). Short canals with side branches leading to small surface pores represent part of sensory canal system (Textfig. 11A).

Remarks. The affinity of these plates is uncertain. They are similar to the dorsal shields of *Boothiaspis* in size, ornament, and canal system, but their apparent asymmetry precludes association with the Amphiaspidiformes. They are possibly ventral plates of a large flat heterostracan.



TEXTFIGURE 11

?Ventral plates of heterostracan indet.

A, NMC 12768; B, NMC 12763.

scs, pores and canals of sensory canal system. Only the general pattern of dentine ridges is shown.

Discussion. As Dineley (1966, p. 12) has noted following a preliminary examination of some of the present material, the Canadian amphiaspids are closely comparable with the only other described amphiaspids which occur in the Siegenian Kureika Series of the northwest Siberian platform and in the Gedinnian Belokamensk Beds of southwest Taimyr (Obruchev *et al.*, 1968, p. 159; Krylova *et al.*, 1968, p. 475).

Novitskaya's work (1968, 1971) on the amphiaspids from these areas has considerably increased our understanding of the group and has divided the Amphiaspidiformes into three suborders, nine families, and twenty-one genera. *Boothiaspis* belongs in the family Siberiaspididae but does show certain differences from its two described genera *Siberiaspis* and *Argyriaspis*. *Boothiaspis* closely resembles *Siberiaspis plana* Obruchev as restored by Obruchev (1964, Fig. 66) in size, in the oval shape of the almost flat dorsal shield, in the acuminate lateral margins forming posterolateral planes, and in the position of the orbits. *B. ovata* differs in its ornament lacking dermal denticles. *B. angusta* resembles *S. plana* in possessing a strongly convex ventral shield. *B. ovata* is close to *Argyriaspis tcherkesovae* Novitskaya (1968, Figs. 73, 76B) in oval shape and pattern of sensory canals, but lacks tesserae, and has finer ornament and less prominent orbits.

Boothiaspis differs from all previously described amphiaspids in lacking the characteristic amphiaspid sensory canal system of open grooves (pit lines) on the surface of the shield. Some amphiaspids (*Siberiaspis*, *Argyriaspis*, *Olbiaspis*, *Angaraspis*, and *Gabreyaspis*) possess a second canal system which comprises canals in the cancellous layer connected with the surface by shorter canals and surface pores such as in the Cyathaspididae and *Boothiaspis*. Novitskaya (1971, p. 17, 18, 27) has discussed the homology of sensory canals in the Siberian amphiaspids and the Cyathaspididae. Compared with the Siberian amphiaspids, the sensory canal system of *Boothiaspis* is more closely related to that of the Cyathaspididae.

These comparisons with *Siberiaspis* and *Argyriaspis* indicate that *Boothiaspis* belongs to the evolutionary line of the suborder Siberiaspidoidei in the evolutionary scheme proposed by Novitskaya (1967, Fig. 1; 1968, Fig. 10; 1971, Fig. 12). *Boothiaspis* is not closely related to the two other suborders which are characterized by postorbital foramina. Novitskaya (1971) believes that the Russian amphiaspids are derived from a hypothetical member of the family Cyathaspididae, subfamily Ctenaspidinae. *Boothiaspis* would thus occupy a phylogenetic position between the Cyathaspididae and the Russian amphiaspids. Its older, Pridolian, age compared with the Gedinnian and Siegenian Russian amphiaspids would support this conclusion.

The presence in the faunules of an indeterminate heterostracan with amphiaspid affinities and a cornuum of an ?olbiaspidid indicate that other amphiaspids or related forms occur in the Peel Sound Formation.

The discovery of amphiaspids in the Canadian Arctic extends the geographical distribution of the group from Russian arctic regions. Tarlo (1964, p. 76) has pointed out, in general terms, the similarity between certain Siluro-Devonian vertebrate faunas in the Canadian Arctic and northern Siberia. Further study of Siluro-Devonian vertebrates from the Canadian Arctic Archipelago may confirm strong faunal links with arctic Russia. The Canadian amphiaspids are Pridolian or older whereas those in Russia are Gedinnian and Siegenian. If one accepts that considerable time is required for a taxonomic group to migrate from one area to another, such disparity supports speculation that certain vertebrate faunas originated in a centre in the Arctic from whence they colonized different and widely separated parts of the world (Tarlo, 1962, p. 153; 1964, p. 76). Such an evolutionary centre was probably in the Canadian Arctic Archipelago and was well established by Pridolian time.

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Appendix

List of localities and description of beds from which the Heterostraci were collected

Textfigure 1, loc. 7. *Prince of Wales Island*

GSC loc. C-10045: About 18 feet above the base of the Peel Sound Formation; unnamed gorge 9 miles north of Transition Bay, 72°10′N, 96°55′W; bed of a fissile grey-yellow, coarse-grained sandstone with well-rounded clasts of limestone and quartz of up to 1 inch (2.5 cm) maximum diameter. Heterostracans are abundant, aligned parallel to the bedding, and include *?Ariaspis*, *Boothiaspis alata* new genus and species, *B. angusta* new species, *B. ovata* new species, *Corvaspis*, *Poraspis* cf. *P. polaris* Kiaer, *Torpedaspis elongata* Broad and Dineley, and *Traquairaspis denisoni* Dineley.

Textfigure 1, loc. 5. *Somerset Island*

GSC loc. C-10049: About 140 feet below top of Read Bay Formation; cliff 400 yards east of Pressure Point, 73°58′N, 95°17′W. Heterostraci occur within 30 feet of massive, thinly bedded, bright yellow and green, micaceous sandstones and include *Boothiaspis ovata* new genus and species, *?Pionaspis*, *Torpedaspis elongata* Broad and Dineley, a traquairaspid, and acanthodian fragments.

GSC loc. C-10550: 50–103 feet above base of Peel Sound Formation; stream valley 1.2 miles east of Pressure Point, 73°59′N, 95°14′W (loc. A, Dineley, 1968, p. 51). Heterostraci occur in a grey, white, and buff, coarse- to fine-grained crossbedded sandstone and include *Boothiaspis alata* new genus and species, *Corvaspis*, *Pionaspis*, *Torpedaspis elongata* Broad and Dineley, a traquairaspid, *Hemicyclaspis murchisoni* (Egerton) and acanthodian fragments.

GSC loc. C-10052: J: Peel Sound Formation, lower part; crags on northeast side of stream 2.5 miles southeast of Pressure Point, 73°57′N, 95°14′W. Heterostraci occur in a slightly calcareous, white, crossbedded sandstone and include *Corvaspis*, *Pionaspis*, *Torpedaspis elongata* Broad and Dineley (1972, *this volume*), an olbiaspidid, a traquairaspid, and cyathaspidids indet.

Textfigure 1, loc. 6. *Somerset Island*

GSC loc. C-10552: N: Talus, thought to be from beds 250 to 300 feet above base of Peel Sound Formation; north bank of small river 4 miles north of Creswell Bay, 72°50′N, 93°42′W. Heterostraci occur in talus of yellow, green and red, medium- to coarse-grained sandstone, and include *Boothiaspis ovata* new genus and species.

Textfigure 1, loc. 4. *Ellesmere Island*

GSC loc. C-6462: 200 feet above base of Devon Island Formation; small island in Muskox Fiord, southwest Ellesmere Island, 76°34′N, 87°29′W, collected by J. W. Kerr, 1967. Heterostracans include *Boothiaspis alata* new genus and species and cyathaspidids similar to *Corvaspis*, *Pionaspis*, and *Traquairaspis*; monograptid graptolite.

PLATES 5 AND 6

PLATE 5

Boothiaspis ovata new genus, new species (PAGE 38)

Figure 1. Holotype dorsal shield (NMC 12778) from GSC loc. C-10045, Peel Sound Formation, Prince of Wales Island; x⅔.

Figure 2. Dorsal shield (NMC 12780) from the same locality; x⅔.

Figure 3. Detail of ornament of posterior part of dorsal shield (NMC 12785) from the same locality; x6.

Boothiaspis angusta new genus, new species (PAGE 40)

Figure 4. Dorsal shield (NMC 12777) from the same locality; x1.

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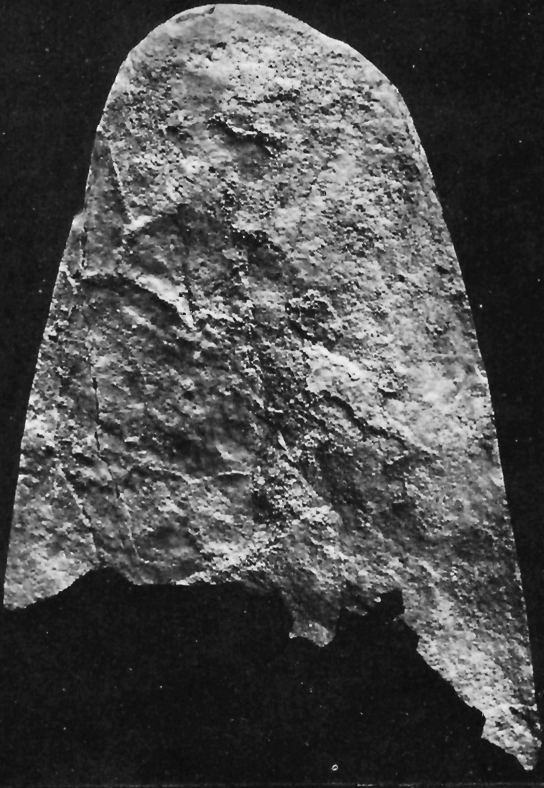

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PLATE 6

Boothiaspis angusta new genus, new species (PAGE 40)

Figure 1. Holotype dorsal shield (NMC 12760) from GSC loc. C-10045, Peel Sound Formation, Prince of Wales Island; x½.

Figure 2. Ventral shield (NMC 12788) from the same locality; x½.

Figure 3. Right lateral view of ventral shield (NMC 12788) from the same locality; x½.

?olbiaspidid indet. (PAGE 42)

Figure 4. Right cornual part of dorsal shield (NMC 12787) from GSC loc. C-10052, Peel Sound Formation, Somerset Island; approximately x1.

Boothiaspis alata new genus, new species (PAGE 42)

Figure 5. Holotype dorsal shield (NMC 12770) from GSC loc. C-10550, Peel Sound Formation, Somerset Island; x⅖.

heterostracan indet. (PAGE 43)

Figure 6. ?Ventral shield, orientation uncertain (NMC 12763), from GSC loc. C-10045, Peel Sound Formation, Prince of Wales Island; x⅔.

PLATE 6

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TORPEDASPIS, A NEW UPPER SILURIAN AND LOWER DEVONIAN GENUS OF CYATHASPIDIDAE (OSTRACODERMI) FROM ARCTIC CANADA

by D. S. Broad[1] and D. L. Dineley[2]

Abstract

Torpedaspis is common locally in the Peel Sound Formation of Somerset and Prince of Wales Islands and has been found also in the Read Bay Formation. The genus is unique in the family on account of its large size (the largest shield is 19.9 cm long), diphycercal caudal fin, median preoral process and nasal sinuses. The occurrence is the earliest in the fossil record of the Heterostraci with evidence of soft parts such as blood vascular system, axial structure, posterior body muscles, and possibly a buccal cavity. The rostral features indicate an advanced member of the Cyathaspididae and suggest a closer relationship of this family with the Pteraspididae than previously has been supposed. *Torpedaspis* was an intermittent swimmer, probably burrowed in soft sediment and was restricted to a succession of ephemeral fluvial to brackish or shallow nearshore marine environments flanking the Boothia Arch. Invertebrates indicate Silurian age for the lower part of the Peel Sound Formation which also can be correlated as Pridolian and Gedinnian by means of its vertebrate faunas. Vertebrates that are characteristic of the British Lower Devonian may have lived in the Canadian Arctic during Late Silurian time.

Résumé

Les *Torpedaspis* sont communs dans la formation du détroit de Peel des îles Somerset et Prince-de-Galles et on en trouve également dans la formation de la baie Read. C'est un spécimen bien particulier du genre en raison de sa grande dimension (le plus grand bouclier atteint 19.9 cm de longueur), d'une nageoire caudale diphycerque, d'un appareil prébuccal médian et de sinus nasaux. Ce sont les plus anciens fossiles maintenant connus dans les hétérostracanidés où il semble y avoir eu des parties moins dures comme un système sanguin vasculaire, une structure axiale, des muscles postérieurs, et peut-être une cavité buccale. Les caractéristiques rostrales indiquent qu'il s'agirait d'un membre avancé des Cyathaspidités et portent à croire qu'il y aurait un lien plus étroit entre cette famille et les Ptéraspidités qu'on ne le croyait. Les *Torpedaspis* étaient des nageurs intermittents qui s'enfouissaient probablement dans les couches molles de sédiments; ils étaient restreints à une succession de milieux éphémères fluviaux ou saumâtres, ou encore marins mais peu profonds et près des rives, qui retrouvaient le long de l'arc Boothia. Les invertébrés sont

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indicatifs du Silurien en ce qui a trait à la partie inférieure de la formation de Peel Sound qui peut aussi être rattachée au Pridolien et au Gédinnien en raison de ses faunes vertébrées. Les vertébrés caractéristiques du Dévonien inférieur britannique ont peut-être vécu dans l'Arctique canadien lors du Silurien supérieur.

Introduction

Recent collections of vertebrates from Somerset and Prince of Wales Islands include a new and distinctive large cyathaspidid with well-preserved internal features. At present this new genus is restricted to the upper part of the Read Bay Formation (Somerset Island) and to the Lower Member of the Peel Sound Formation (Somerset and Prince of Wales Islands). The best documented occurrences are in southeastern Prince of Wales Island (Textfig. 1, loc. 7) where the genus is found in the basal 368 feet (112 m) of the Peel Sound Formation.

The Peel Sound Formation (Thorsteinsson and Tozer *in* Fortier *et al.*, 1963, p. 121) is a fluviatile to shallow marine syntectonic and post-tectonic formation of which the most common lithologies are oligomict conglomerate, sandstone, and carbonate. The present authors have made detailed studies of the formation on the eastern (Somerset Island) and western (Prince of Wales Island) flanks of the Boothia Arch.

Acknowledgments

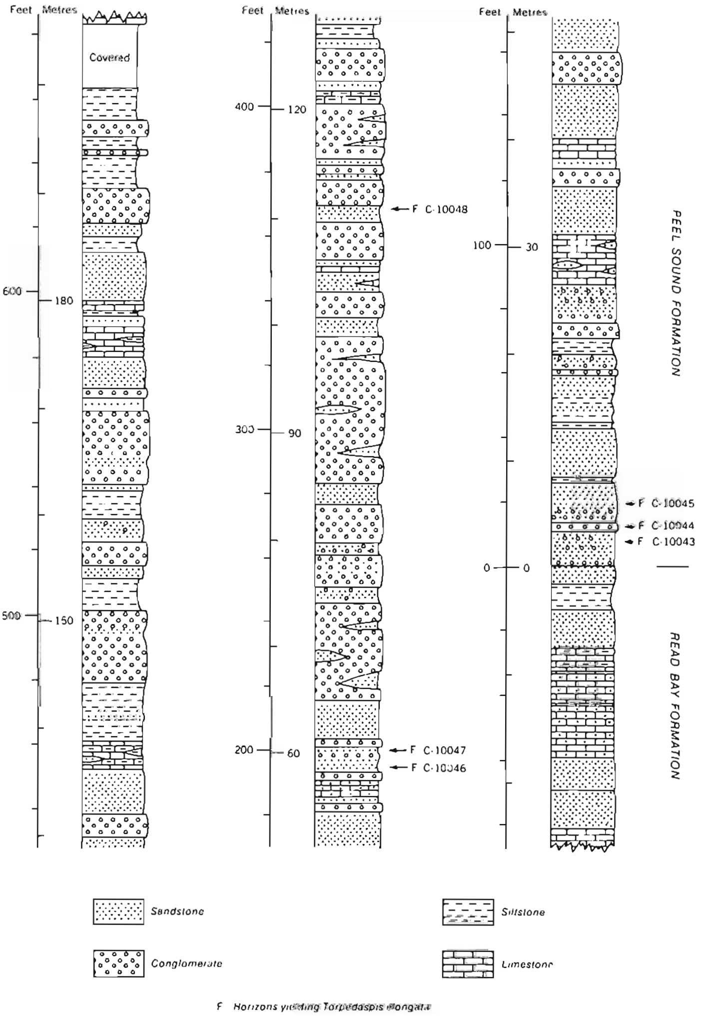
Field work was carried out in 1966 and 1967 as one of the projects of the University of Ottawa Arctic Program with the support of the Geological Survey of Canada. Additional financial support is acknowledged from the Department of Indian Affairs and Northern Development, the National Research Council of Canada, the National Museum of Canada, the Defence Research Board, the University of Ottawa, and the Natural Environment Research Council (Great Britain). T. E. Bolton and M. J. Copeland kindly identified the invertebrate faunas. The authors are grateful also for helpful comments and criticism from R. H. Denison, H. P. Whiting, and B. Thusu. Thanks are given for the field assistance of P. and S. Dodson, U. Mayr, A. D. Miall, M. Tuke, and J. Wilson.

Stratigraphy

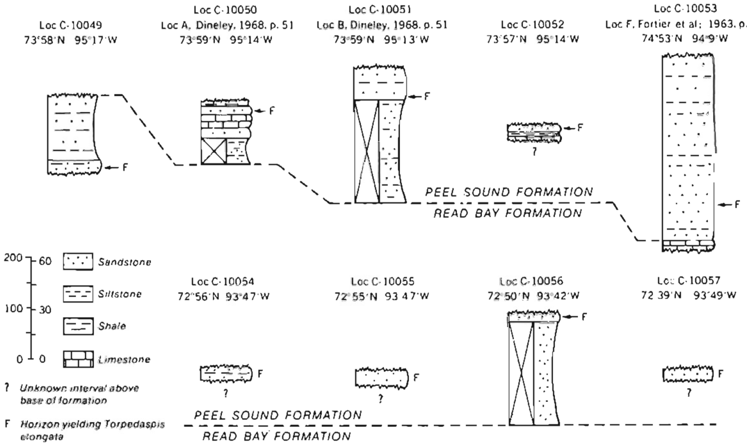
On Prince of Wales Island the Peel Sound Formation comprises five distinct facies outcropping as north–south bands. The easternmost facies, Conglomerate, is replaced laterally by Conglomerate–Sandstone, Sandstone, Sandstone–Carbonate, and Carbonate facies in sequence westwards (Broad, Dineley, and Miall, 1968; Miall, 1970a). Sedimentological features indicate fluviatile intertidal and shallow marine environments (Miall, 1970a, b).

Clastic sediment was derived from the rising axial part of the Boothia Arch and deposited in the shallow marginal seas flanking the arch. A transitional change upward from marine Read Bay Formation to predominantly supratidal Peel Sound Formation indicates that uplift was at times relatively rapid (*see* Brown, Dalziel, and Rust, 1969).

Miall (1970a, p. 126) divided the Peel Sound Formation into a lower and an upper member. The most complete documented succession of the Lower Member is on Prince of Wales Island in an unnamed gorge 9 miles north of Transition Bay (Textfig. 1, loc. 7; Textfig. 12). In this section over 674 feet of the Lower Member of the Peel Sound Formation conformably overlies several hundred feet of Read Bay Formation. The Upper Member of the Peel Sound Formation is not present and is not discussed in this paper. In the gorge the Lower Member is predominantly clastic: lithologies include interbedded sandstone, conglomerate, siltstone, and limestone in order of decreasing abundance. Sandstone units are coarse to fine grained, predominantly red, and are poorly sorted and often contain pebble-sized clasts. Conglomerate units are generally pebble or boulder oligomict conglomerates of which the constituent clasts are limestone, dolomite, reworked oligomict pebble-conglomerate, sandstone, siltstone, or igneous rocks. Siltstone and limestone quantitatively are relatively minor lithologies in the section but limestone is important for its contained invertebrate faunas.



TEXTFIGURE 12. Stratigraphic section of the Lower Member of the Peel Sound Formation and upper part of Read Bay Formation in the unnamed gorge, Prince of Wales Island. See Textfigure 1, loc. 7 and Appendix for location of section.



TEXTFIGURE 13. **Somerset Island: stratigraphic sections from which *Torpedaspis* was collected. See Textfigure 1, locs. 6 and 7, and Appendix for location of sections.**

Thorsteinsson and Tozer (*in* Fortier *et al.*, 1963, p. 121–126) designated the type area of the Peel Sound Formation in northwestern Somerset Island. They defined the base of the formation at the lowest red siltstone in the same section as locality C-10053 of this paper (Textfig. 1, loc. 5; Textfig. 13, and Appendix). Localities C-10049 to C-10052 and C-10054 to C-10057 were correlated by the same criterion and by field mapping (Textfig. 13). However, at the section containing localities C-10043 to C-10048 (Textfig. 1, loc. 7; Textfig. 12), Miall (1970a, p. 126) drew the base of the formation at the base of the lowest pebble-conglomerate which in this area is more readily mappable than red siltstone. Unfortunately, correlation between the red siltstone on Somerset Island and the pebble-conglomerate on Prince of Wales Island is uncertain, and the precise correspondence of the boundaries between the Read Bay Formation and the Peel Sound Formation in the two areas is not known.

Torpedaspis new genus occurs in both the Read Bay Formation and the Peel Sound Formation. On Prince of Wales Island it is restricted to the lower 368 feet of the Peel Sound Formation. On Somerset Island it is abundant in the lower part of the Peel Sound Formation but a lone specimen was recorded in the uppermost 180 feet of the Read Bay Formation. *Torpedaspis* has been collected from six horizons at one locality on Prince of Wales Island and from nine localities on Somerset Island.

Age of the Lower Member of the Peel Sound Formation

Invertebrate faunal evidence for the age of this member on Prince of Wales Island was summarized by Miall (1969, p. 217). Most of the invertebrates indicate a Silurian age. In particular, the following invertebrates from the lower 589 feet of the Peel Sound Formation and upper 43 feet of the Read Bay Formation in the unnamed section north of Transition Bay (Textfig. 1, loc. 7) were identified by Bolton and Copeland as being of Silurian age. In the following list of identifications of vertebrate and invertebrate fossils, the footages indicate the stratigraphic interval above or below (–) the arbitrarily defined boundary between the Read Bay and Peel Sound Formations.

GSC loc.	Footage above (below) base of Peel Sound Formation	Fauna
82473	589	*?Clorinda* sp. *Conocardium* sp. cephalopod (similar to *Amphicyrtoceras*)
82474	462	*Hormotoma* sp. *Primitia* sp.
—	426	*Anglaspis* cf. *A. expatriata* Denison *Traquairaspis* sp.
—	422	*Traquairaspis denisoni* Dineley *Traquairaspis* sp.
82762–82766	406	"*Beyrichia*" *plagosa* Jones *Bairdiocypris* sp. "*Bythocypris*" sp. *Leperditia gibbera* Jones *?Primitia* sp. cf. *Welleriopsis* sp. undetermined ostracodes
—	380	*Traquairaspis denisoni* Dineley
C-10048	368	*Corvaspis* cf. *C. kingi* Woodward *?Pionaspis* spp. *Pteraspis* (*Simopteraspis*) sp. *Torpedaspis elongata* new genus and species
—	265	*Corvaspis* cf. *C. kingi* Woodward *Listraspis* sp. traquairaspids indet.
C-10047	200	*Corvaspis* cf. *C. kingi* Woodward *Lingula* sp. *Poraspis* cf. *P. intermedia* Kiaer and Heintz *P.* cf. *P. polaris* Kiaer *Torpedaspis elongata* new genus and species *Traquairaspis* cf. *T. pococki* (White) traquairaspids indet.
C-10046	196–198	*Corvaspis* cf. *C. kingi* Woodward *Lingula* sp. *Poraspis* cf. *P. polaris* Kiaer *Torpedaspis elongata* new genus and species *Traquairaspis* cf. *T. pococki* (White) traquairaspids indet.
82490	180	arachnophyllid coral *Favosites* sp. *?Mesotrypa* sp. gastropods ostracodes
—	127	*Corvaspis* cf. *C. kingi* Woodward
82759	102	*Herrmanina* sp. *?Primitia* sp.
—	88	*Pionaspis* spp. traquairaspids indet.

GSC loc.	Footage above (below) base of Peel Sound Formation	Fauna
C-10045	18	*?Ariaspis* sp. *Boothiaspis alata* Broad *B. angusta* Broad *B. ovata* Broad *Corvaspis* cf. *C. kingi* Woodward *Poraspis* cf. *P. polaris* Kiaer *Torpedaspis elongata* new genus and species *Traquairaspis denisoni* Dineley *Traquairaspis* sp.
C-10044	15	*Corvaspis* cf. *C. kingi* Woodward *Torpedaspis elongata* new genus and species
C-10043	11	*Torpedaspis elongata* new genus and species
82470–82472	-6 to -43	*?Atrypella* sp. *Clorinda* sp. *?Harpidium* sp. *?Pentamifera* sp. cephalopod (similar to *Amphicyrtoceras*) gastropods *Leperditia gibbera* Jones undetermined ostracodes

On Somerset Island there is no stratigraphic section comparable in abundance of vertebrate faunas to that north of Transition Bay, Prince of Wales Island (Textfig. 1, loc. 7). Instead, vertebrate localities are more widely scattered and, therefore, are not easily correlated with each other (Textfig. 13). *Torpedaspis elongata* new genus and species is known from nine localities in the Read Bay and/or Peel Sound Formations and is associated with *Anglaspis*, *Cephalaspis*, *Corvaspis*, *Hemicyclaspis*, *Pionaspis*, *Poraspis*, acanthodian spines, and rare invertebrates.

Stratigraphic ranges of Siluro–Devonian vertebrates previously have been expressed, nearly always, relative to non-marine stages due to the inherent difficulty of correlating with a standard marine sequence. Table 1 is an attempt to provide such correlation and shows the Pridolian–Gedinnian (Siluro–Devonian) boundary as within the zone of *Traquairaspis pococki* (White). The lower part of the Peel Sound Formation on Somerset and Prince of Wales Islands contains *Anglaspis*, *Cephalaspis*, *Corvaspis*, *Hemicyclaspis murchisoni* (Egerton), *Poraspis*, *Pteraspis*, and *Traquairaspis*. These genera are characteristic of the Downtonian and Dittonian in the Welsh Borderland (Ball and Dineley, 1961; Dineley, 1968). In particular *Hemicyclaspis murchisoni* is an index fossil for the lowest Downtonian of Britain (White, 1950a), while *Cephalaspis* is virtually confined to the lower Dittonian. In the Welsh Borderland, White recognized replacement of *Traquairaspis* faunas by *Pteraspis* (*sensu lato*) faunas at the Downtonian–Dittonian boundary, and the importance of pteraspid species in the Dittonian. Subsequent work (White, 1956; Schmidt, 1959) demonstrated the *Traquairaspis–Pteraspis* faunal change in Western Europe and a similar sequence of younger pteraspid ranges. Both features also occur in Spitsbergen, eastern Europe, and in the Knoydart Formation, Nova Scotia (Dineley, 1967). In the Peel Sound Formation, Prince of Wales Island

(Textfig. 1, loc. 7) a single specimen of a new species of *Pteraspis* (*Simopteraspis*) occurs within a sequence of occurrences of *Traquairaspis*, but a *Traquairaspis–Pteraspis* faunal succession cannot be clearly demonstrated.

	MARINE STAGES	FISH ZONES	NON-MARINE STAGES
LOWER DEVONIAN	SIEGENIAN (part)	*Pteraspis* (*Rhinopteraspis*) *dunensis* (Roemer)	BRECONIAN (part)
		P. (*R.*) *leachi* White	DITTONIAN
	GEDINNIAN	*P.* (*Belgicaspis*) *crouchi* Lankester	
		P. rostrata (Agassiz)	
		P. (*Simopteraspis*) *leathensis* White	
		Traquairaspis symondsi (Lankester)	DOWNTONIAN
- - -	- - - - - - - - - - - ?	*Traquairaspis pococki* (White)	
UPPER SILURIAN	PRIDOLIAN	no zone fossil	
		Hemicyclaspis murchisoni (Egerton)	
	- - - - - - - - - - - ?		- - - - - ? - - - - -
	LUDLOVIAN (part)	no zone fossil	

TABLE 1. Tentative correlation of Upper Silurian and Lower Devonian fish zones of the United Kingdom with marine and non-marine stages. Sources of information (a) position of Gedinnian–Siegenian boundary and correlation of fish zones with non-marine stages, taken from White (1956, table 1), Dineley and Gossage (1959, table 2), and White and Dean (1964, table IV), (b) equivalence of Pridolian with Skala and lower part of the Downtonian... "including the zone of *Hemicyclaspis* and possibly part of the overlying zone of *Traquairaspis*" ... from Berry and Boucot (1971, p. 18, 19).

Agnathans probably appeared earlier in northern Canada than elsewhere in the world. The first three of the following four agnathan faunules are fairly reliably dated by associated graptolites.

(1) A Ludlovian heterostracan faunule with *Ariaspis* and the traquairaspid *Yukonaspis angusta* (Denison) has been described from the Beaver River area, Yukon Territory (Denison *et al.*, 1963). Although Denison (1964) subsequently refers it to the Early Devonian, his

original pre-Middle Ludlovian (i.e., pre-Pridolian) age seems more likely because the faunule apparently stratigraphically underlies *Monograptus dubius*, which ranges from the Upper Wenlockian to the Pridolian. The vertebrate fauna is underlain by beds containing Llandoverian or lowest Wenlockian graptolites.

(2) In the Devon Island Formation, Ellesmere Island, the amphiaspid *Boothiaspis alata* Broad is associated with Heterostraci similar to *Corvaspis*, *Pionaspis*, and *Traquairaspis*, and is dated by graptolites which indicate Pridolian age (Broad, *this volume*). *Boothiaspis alata* Broad also occurs at locality C-10045 near the base of the Peel Sound Formation, Prince of Wales Island (Textfig. 1, loc. 7) and is evidence for the Pridolian age of this part of the section. A Dittonian (Gedinnian) age can be suggested for the upper part of this section on the presence of a species of *Pteraspis*.

(3) The most reliably dated oldest known representatives of the anaspids, cyathaspidids, and thelodonts are in the Cape Phillips Formation, Cornwallis Island. Thorsteinsson (1967) reported five Silurian vertebrate faunas well dated by associated graptolites as Late Llandoverian to Early Ludlovian.

(4) Turner and Dixon (1971) recently reported thelodonts from Prince of Wales Island in the transition beds between the Allen Bay and Read Bay Formations. A comparison with thelodonts of the Baltic area indicates a possible Late Llandovery but probable Wenlockian to Middle Ludlovian age.

In conclusion, vertebrate evidence favours both Pridolian and Gedinnian ages for the Peel Sound Formation on Somerset and Prince of Wales Islands. One section on Prince of Wales Island (Textfig. 1, loc. 7) is Pridolian in its lower part, while the upper part is probably Gedinnian.

Systematic Paleontology

Prefix NMC refers to specimens deposited in the National Museum of Canada, Ottawa.

Class *AGNATHA*

Order HETEROSTRACI

Family CYATHASPIDIDAE

Subfamily PORASPIDINAE

Genus ***Torpedaspis*** new

Type species. *Torpedaspis elongata* new species.

Diagnosis. A large cyathaspidid with elongate shield with a width ratio of 0.22 to 0.39. Large ventral preorbital lobes and a pronounced median preoral rostral process; epitega poorly defined; sensory canal system similar to that of *Allocryptaspis* but pores much smaller. Ornament of fine, long, discontinuous dentine ridges.

Etymology. *Torpedo* (Latin) meaning sluggishness, referring to the apparent immobility of the animal due to its long inflexible shield.

Torpedaspis elongata new species

Plates 7–10; Textfigures 14–30

Material and occurrence. 54 dorsal shields, 36 ventral shields, 1 articulated specimen complete with trunk and caudal fin, 11 branchial plates, 47 lateral plates, 17 miscellaneous scales, and numerous fragments. NMC 12537 to 12744, 12746 to 12756 and holotype NMC 12745 (Pl. 7, fig. 1; Pl. 8, fig. 1; Textfig. 28) which is a natural internal cast of a dorsal shield preserved in fine-grained sandstone and bears considerable detail of the inner surface of the shield. The Appendix lists the locality for each specimen.

Etymology. Elongata (Latin) meaning protracted, and refers to the extreme length of the shield.

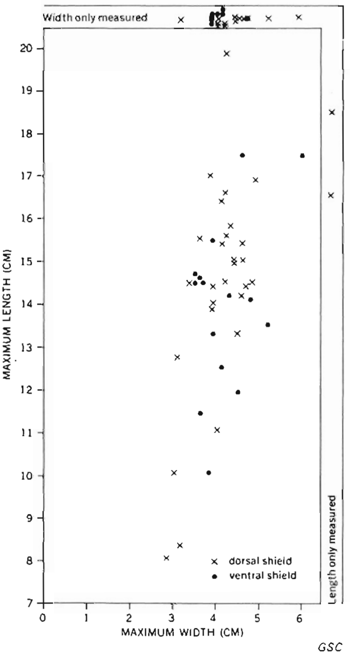
Description. Denison's plan (1964, fig. 93) is generally followed in the selection of measurements and ratios of dorsal and ventral shields except that measurements represent parameters of shields in plan view, and are not taken across the surface of concave or convex specimens.

Dimensions (cm) of dorsal shields:

median length	8.00–19.9	width ratio	0.22–0.39
maximum width	3.1 – 6.00	orbital width ratio	.14– .25
orbital width	2.3 – 3.8	orbital length ratio	.10– .16
orbital length	1.2 – 3.1	pineal ratio	.15– .20
pineal length	1.4 – 3.4	postbranchial ratio	.46– .63
postbranchial length	4.5 –10.4		

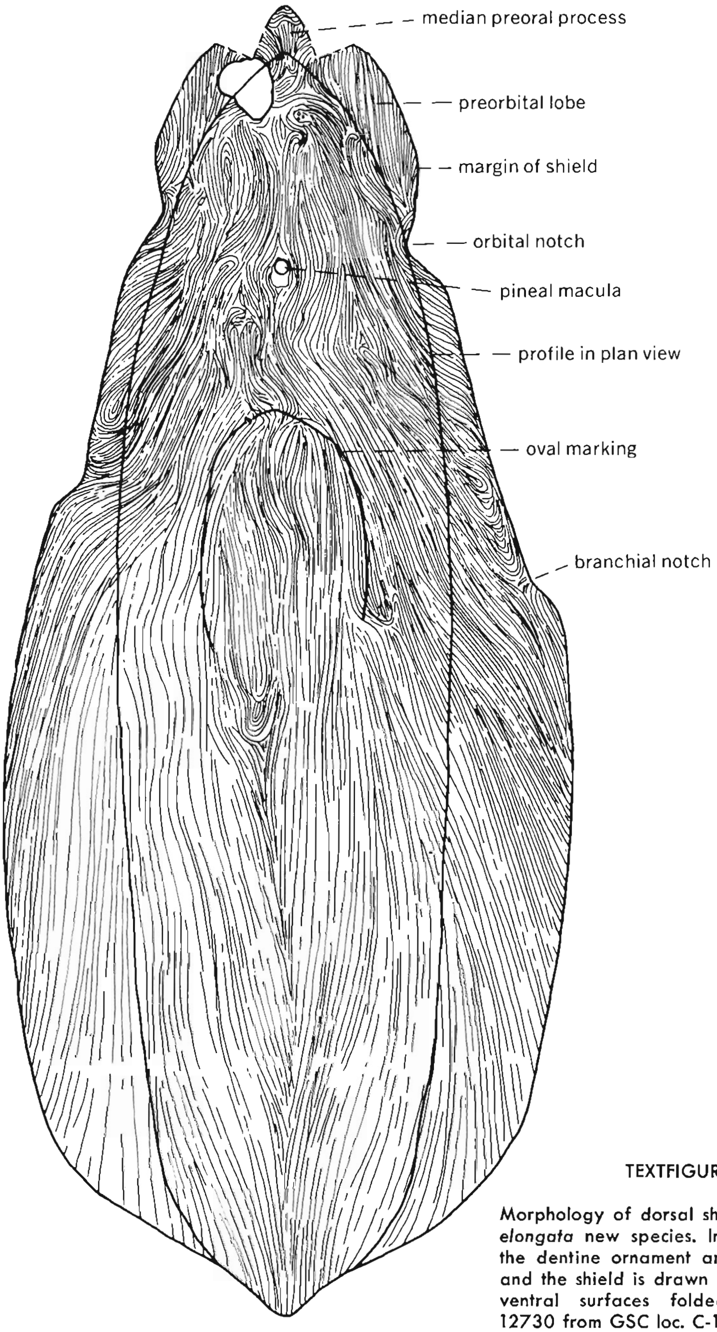
Total size range of the dorsal shield is shown in Textfig. 14 where width and length are plotted for all sufficiently well preserved dorsal shields.

Dorsal shield strongly arched, anteriorly depressed, streamlined in lateral and dorsal views (Pls. 7; 8; 10, fig. 3; Textfig. 15) narrowing rapidly anteriorly attaining maximum width in branchial region. Shape of anterior (rostral) margin varies from acutely pointed to bluntly rounded (Pl. 8, figs. 2 and 5; Pl. 9, fig. 3; Pl. 10, fig. 6; Textfigs. 16, 18, 25). A large median



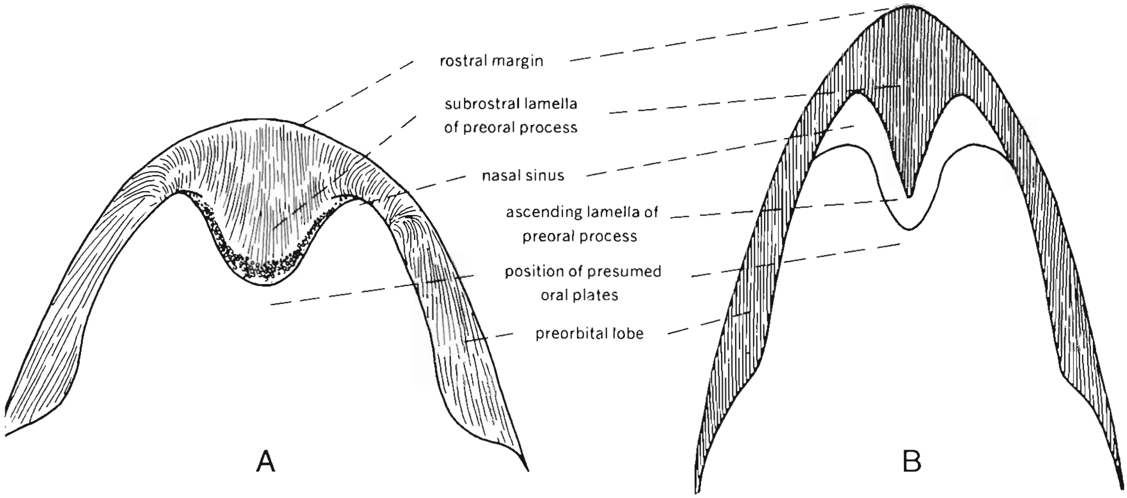
TEXTFIGURE 14

Dimensions of dorsal and ventral shields of *Torpedaspis elongata* new species.

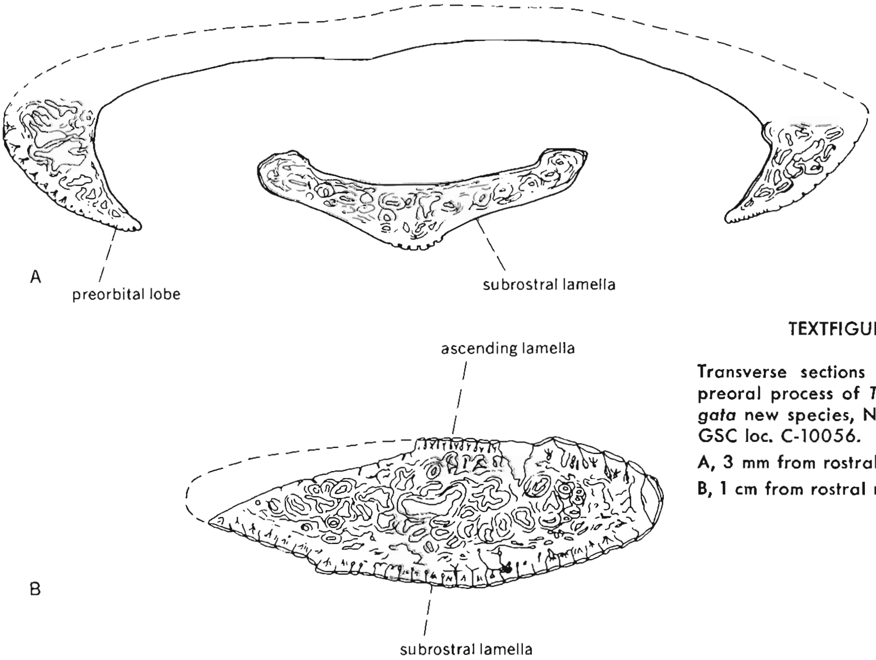


TEXTFIGURE 15

Morphology of dorsal shield of *Torpedaspis elongata* new species. Individual ridges of the dentine ornament are not represented, and the shield is drawn as if flattened with ventral surfaces folded dorsally. NMC 12730 from GSC loc. C-10056; x1.



TEXTFIGURE 16. **Rostral oral region of dorsal shields of *Torpedaspis elongata* new species.**
A, NMC 12556 from GSC loc. C-10046; x2.5.
B, NMC 12731 from GSC loc. C-10056; x2.

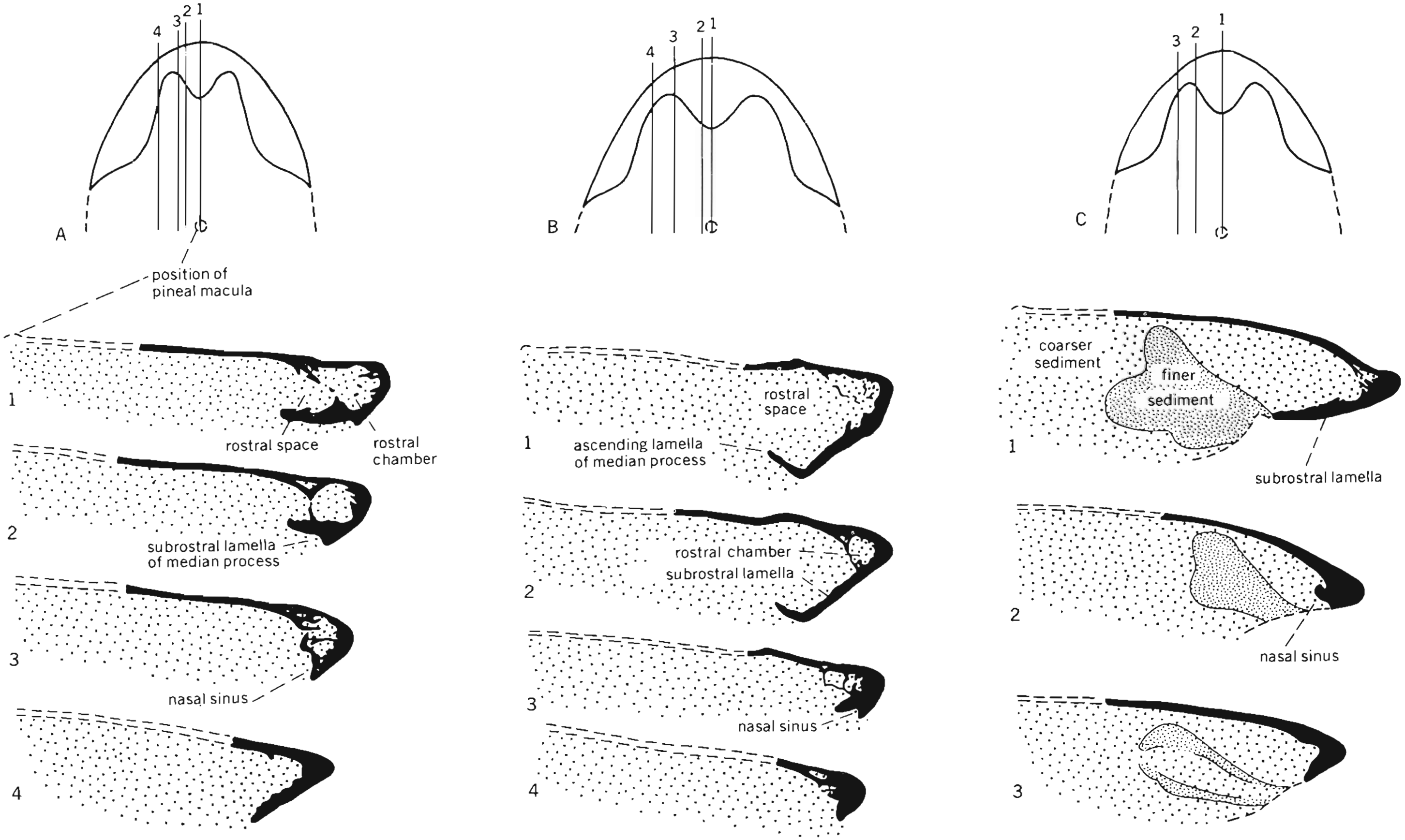


TEXTFIGURE 17

Transverse sections through median preoral process of *Torpedaspis elongata* new species, NMC 12727 from GSC loc. C-10056.

A, 3 mm from rostral margin; x6.

B, 1 cm from rostral margin; x8.5.



TEXTFIGURE 18. Structure of the rostral region of the dorsal shield of *Torpedaspis elongata* new species. A, B, C, ventral profiles of rostral regions of dorsal shields showing positions of longitudinal sections; x1. A 1-4, B 1-4, C 1-3, camera lucida drawings of ground longitudinal sections showing extent of median preoral process, and in C 1-3 possible outline of buccal cavity; x2. A, NMC 12562; B, NMC 12553; C, NMC 12564; all from GSC loc. C-10046.

preoral rostral process separates two posteriorly diverging deep channels interpreted as nasal sinuses (Pl. 9, fig. 3; Pl. 10, fig. 6; Textfig. 16) and is characteristic of *Torpedaspis*. This process is commonly gently rounded and triangular in outline but narrower and more elongate in some specimens and projecting posteriorly towards the mouth as a self-supporting process (Textfig. 16). Serial sections reveal an unpaired rostral space within process (Textfigs. 17 and 18) bounded ventrally by subrostral lamella and anteriorly by internal continuation of margin of preorbital lobes. An ascending lamella present in one specimen (Textfig. 18B). Anterior to rostral space, process consists of bone with large cancellous cells, most of the walls of which have collapsed forming an apparent rostral chamber.

Orbits consist of shallow notches on margin of shield less than 2 mm deep. Postorbital lobes vertical or inclined outwards. Branchial notches conspicuous and shallow but not acute. Postbranchial margin inclined inwards and shield narrows towards posterior margin, where it terminates in a rounded median lobe.

A conspicuous oval marking on branchial region of dorsal shield NMC 12730 (Textfig. 15) is considered pathological.

Dimensions (cm) of ventral shields:

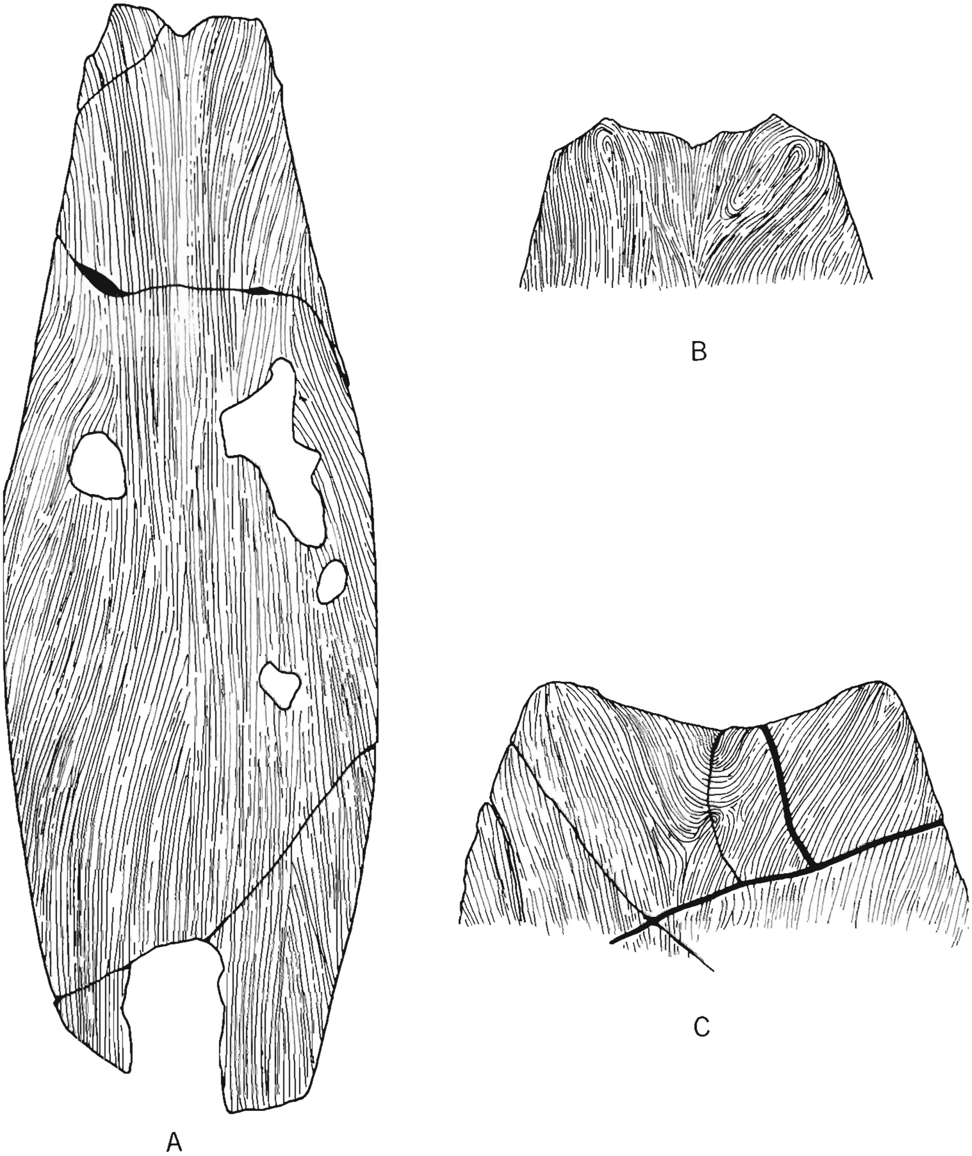
maximum length	10.0–17.5	width ratio	0.25–0.39
maximum width	3.6– 6.1	postbranchial width ratio	0.52–0.66
postbranchial length	5.9– 8.9		

Total size range of the ventral shield is shown in Textfigure 14, where width and length are plotted for all well-preserved specimens.

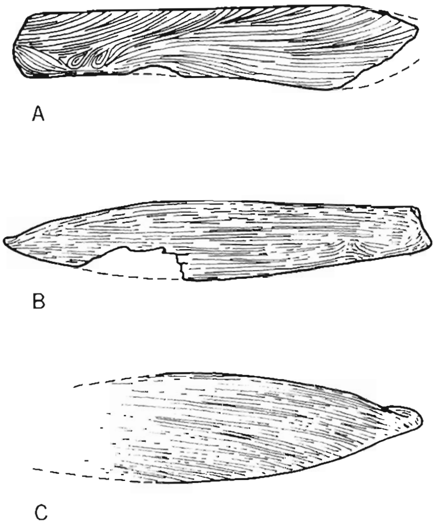
Ventral shield shorter and less strongly arched than dorsal shield (Pl. 8, figs. 2, 5) anteriorly almost flat; anterior margin, when preserved, bears a distinct shallow median sulcus (Textfig. 19). Lateral margins of shield converge in front of and behind branchial notches that are smaller and shallower than those of dorsal shield. Posterior margin bears a median lobe somewhat less pronounced than that of dorsal shield.

Branchial plate flat, narrow, elongate, 3.4 to 6.7 cm long and 0.6 to 1.6 cm wide (Pl. 8, fig. 6; Textfig. 20); dorsal and ventral margins gently curved, anterior margin transverse, convex, or slightly concave; posterior margin tapered, bearing conspicuous terminal notch that is margin of branchial opening (its function possibly was to help direct exhalant current away from branchial area).

Behind the headshield is a scale-clad trunk; a caudal fin or tail is posterior to trunk and bears smaller scales, or plates. Morphology of trunk and caudal fin known from one entire articulated but laterally compressed small specimen (Pl. 9, fig. 1; Textfig. 21) in which they attain a combined length of 9 cm; some scales are displaced. Scales of trunk and caudal fin overlapping those next behind and arranged in five longitudinal series; median dorsal (ridge), paired dorsolateral, paired lateral, paired ventrolateral, and median ventral. Twelve (possibly thirteen) median dorsal scales (Pl. 8, figs. 3, 4; Pl. 10, fig. 2; Textfig. 21, md; Textfig. 22) each strongly arched and overlapping its posterior neighbour by approximately half its length. Scales up to 1.9 cm long and 1.0 cm wide but smaller and flatter towards caudal fin. Dorsolateral scales small, paired, and probably rhomboidal in shape (Textfig. 21, dl); number and size uncertain, as is degree of overlap but each scale is inserted between adjacent median dorsal and lateral scales. Nine paired lateral scales about 2.1 cm long and 0.5 cm wide, but disarticulated scales are as large as 4.1 cm long and 1.1 cm wide (Pl. 10, fig. 1; Textfig. 21, l1–l9; Textfig. 23). Anterior seven scales are of normal shape (Textfig. 21); posterior two either incomplete or not attaining full lateral extent of others and give rise to irregular arrangement of anterior scales of caudal fin. Overlap between adjacent scales is 30 to 50 per

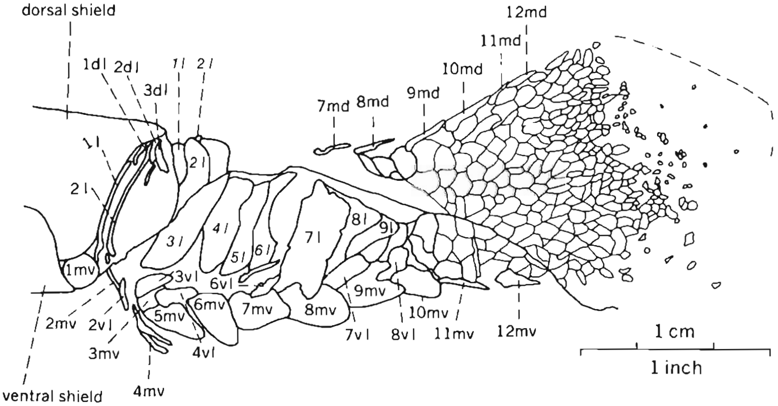


TEXTFIGURE 19. Ventral shields of *Torpedaspis elongata* new species, showing outlines, pattern of ornament, and anterior median notch. A, NMC 12732 from GSC loc. C-10056; x1. B, NMC 12575 from GSC loc. C-10046; x2. C, NMC 12614 from GSC loc. C-10045; x2.



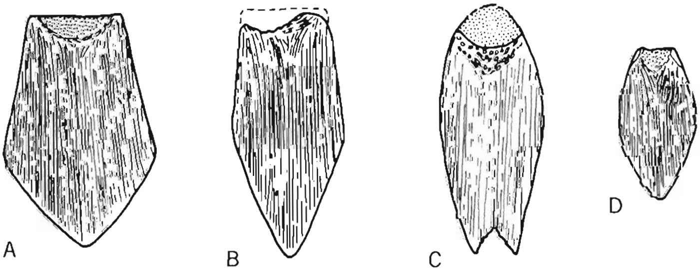
TEXTFIGURE 20

Branchial plates of *Torpedaspis elongata* new species. A, left branchial plate; x1.5, NMC 12577 from GSC loc. C-10046. B, right branchial plate; x1, NMC 12735 from GSC loc. C-10052. C, left branchial plate with prominent posterior notch; x1, NMC 12734 from GSC loc. C-10049.



TEXTFIGURE 21

Trunk and caudal fin; xl; of *Torpedaspis elongata* new species as seen in NMC 12554A from GSC loc. C-10046. Scales of the left side in lower case lettering, right side in italics; 1dl-3dl, dorsolateral scales; 1l-9l lateral scales; 7md-12md, median dorsal scales; 1mv-12mv, median ventral scales; 2vl-8vl, ventrolateral scales; broken line indicates extent of brown stain that underlies all scales.



TEXTFIGURE 22

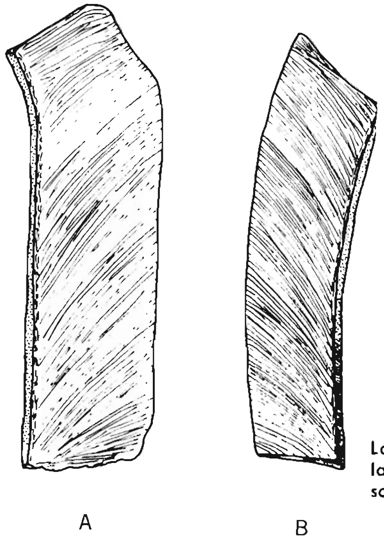
Median dorsal or median ventral (ridge) scales; x2; of *Torpedaspis elongata* new species. A, NMC 12714A from GSC loc. C-10056; B, 12733, from GSC loc. C-10051; C, 12739 from GSC loc. C-10056; D, 12738 from GSC loc. C-10051.

cent. Eight pairs of ventrolateral scales (Textfig. 21, vl), probably rhomboidal and intercalated between lateral and median ventral scales. Twelve median ventral scales, up to 0.8 cm long by 0.7 cm wide and arched along median line (Pl. 8, figs. 3, 4; Pl. 10, fig. 2; Textfig. 22), each inserted between adjacent lateral and ventrolateral plates (Textfig. 21, mv). Ventral scales not easily distinguished from ridge scales. Scales of caudal fin irregular in shape, not arranged in longitudinal rows except for most anterior dorsal and ventral scales. About four rows of irregular overlapping scales of varying size and shape behind last lateral scale of trunk; behind these rows, caudal fin consists of numerous irregular overlapping scales decreasing in size rearward, with posterior extremity devoid of scales but represented in specimen NMC 12554A by faint brown stain similar to dark brown stains underlying dorsal and ventral shields, trunk, and all scales of caudal fin. Caudal fin diphycercal, probably with a median lobe (Pl. 9, fig. 1; Textfig. 21); upturned dorsally in specimen NMC 12554A but would have been flexible in both vertical and lateral planes in living animal as shown in restoration (Textfig. 30).

Ornament consists of extremely fine, discontinuous ridges separated by narrow grooves not always open to surface. Most commonly number 6 to 8 ridges per millimetre, but overall range of 4 to 12. Ridge crests gently rounded when well preserved but commonly delimited only by their adjacent grooves owing to abrasion. Dentine ridges generally several centimetres long but in certain areas (posterior margin of median preoral process, Textfig. 24; and along anterior margins of median dorsal and ventral scales, Textfig. 22; and lateral scales, Pl. 10, fig. 1; Textfig. 23), shorter, wider and some replaced by flat tubercles. Dentine ridges generally orientated parallel to length of animal, which is parallel to length of each plate except lateral scales. Pattern variable on dorsal and ventral shields, may be irregularly swirled in the prebranchial and pineal regions, on prebranchial lobes a marginal reversal of direction of ornament is common (Textfigs. 15, 25A). Areas of swirled ornament seem to represent poorly defined epitega and thus, rostral, branchial, and central epitega are represented in dorsal shield. Swirled ornament less common on ventral shield, when present restricted to most anterior part. Ornament generally longitudinal but close to anterior margin either concave or anteriorly divergent, thus allowing for anterior median notch of shield (Textfig. 19).

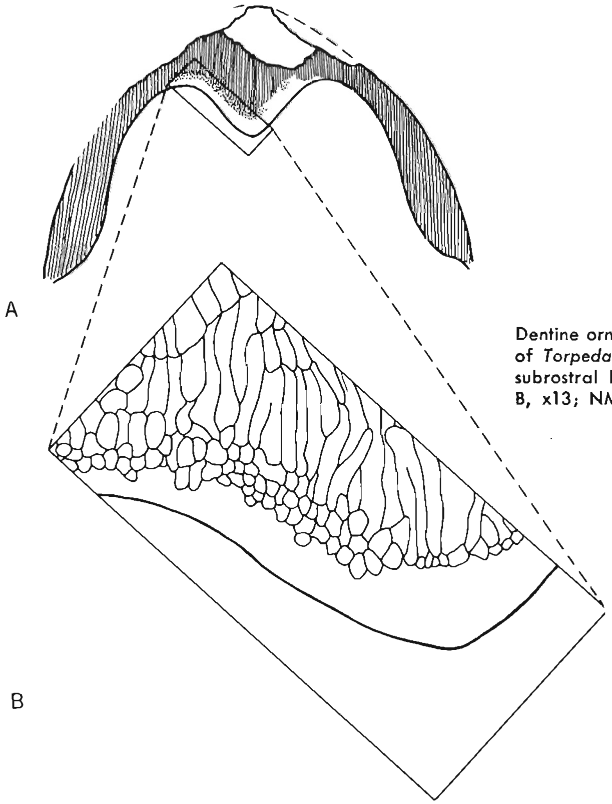
Pores and canals of lateral line system are very small and commonly visible only with immersion in ethyl alcohol or, more effectively, by etching surface dentine with dilute hydrochloric acid. Lateral line canals lie in upper part of cancellous layer and are connected to surface of shield by short, funnel-shaped side processes that narrow distally and terminate in extremely fine pores commonly situated within intercostal grooves. Pattern in dorsal shield consists of two pairs of longitudinal canals connected by transverse commissures (Textfig. 26A). At its anterior end, supraorbital canal reverses direction and is deflected outwards and posteroventrally on large preorbital lobes. Canals of ventral shield are less well known and pattern of paired lateral canals, short paired postoral canals and transverse commissures (Textfig. 26B) has been observed in only one specimen.

Microstructure and thickness of dermal shield of *Torpedaspis* conform to the established cyathaspidid pattern as summarized by Denison (1964, p. 330). Shield consists of four layers: superficial, reticular, cancellous, and basal (Pl. 10, figs. 4, 5; Textfig. 27). Most specimens are crushed and the cancellous layer is consequently poorly preserved and relatively thin. Uncrushed shield is generally 0.70 mm thick but is 2.67 mm thick in rostral region. Superficial layer continuous over, and tucked under, margins of shield; generally 0.075 mm thick, consisting of fine dentine ridges (6 to 8 per mm) of almost square cross-section, separated by tear-shaped intercostal grooves, most of which are closed but some open to surface by means of narrow discontinuous slits. Reticular layer generally 0.10 mm thick and containing three



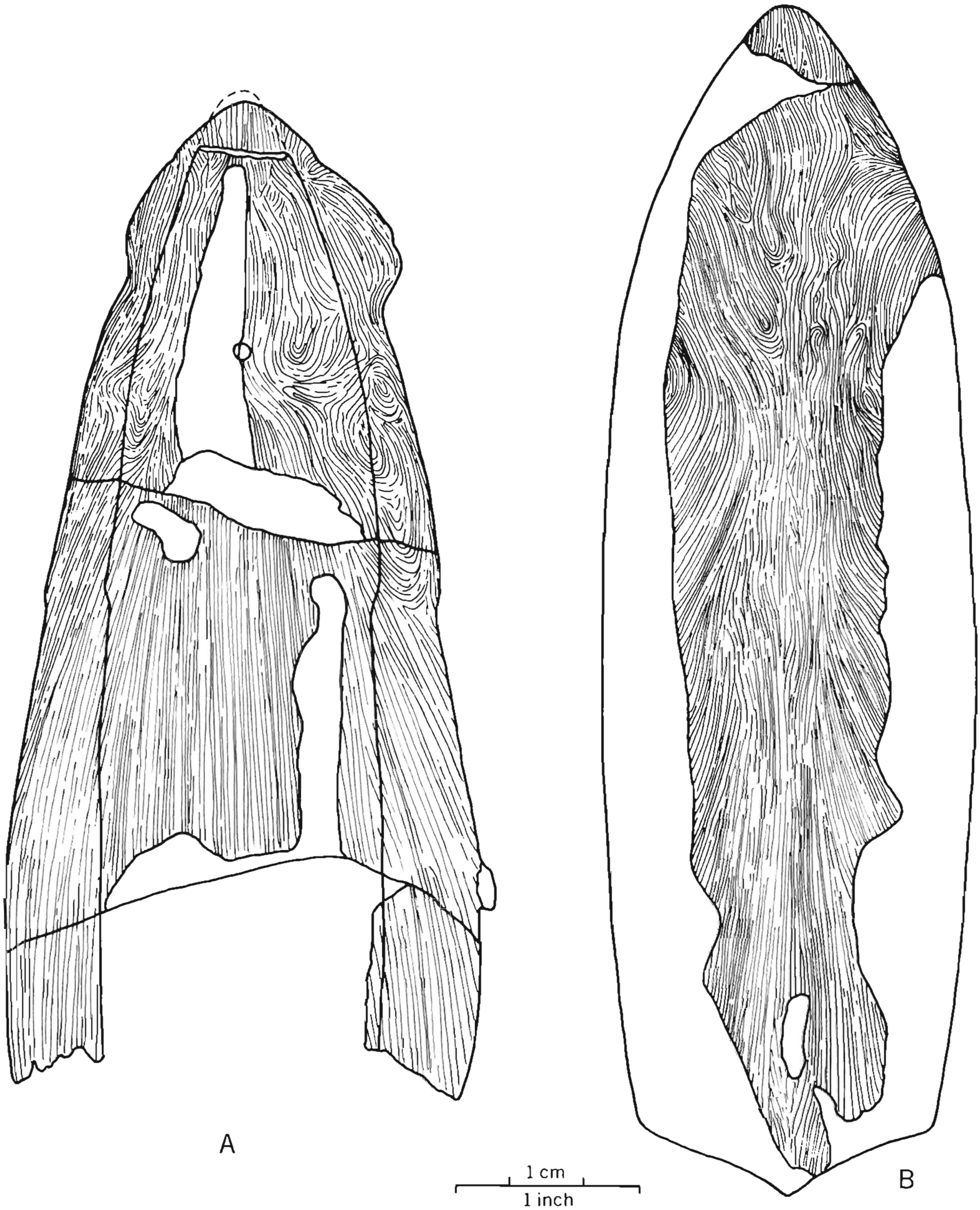
TEXTFIGURE 23

Lateral scales; x2; of *Torpedaspis elongata* new species. A, left lateral scale, NMC 12725 from GSC loc. C-10056. B, right lateral scale, NMC 12740 from GSC loc. C-10053.

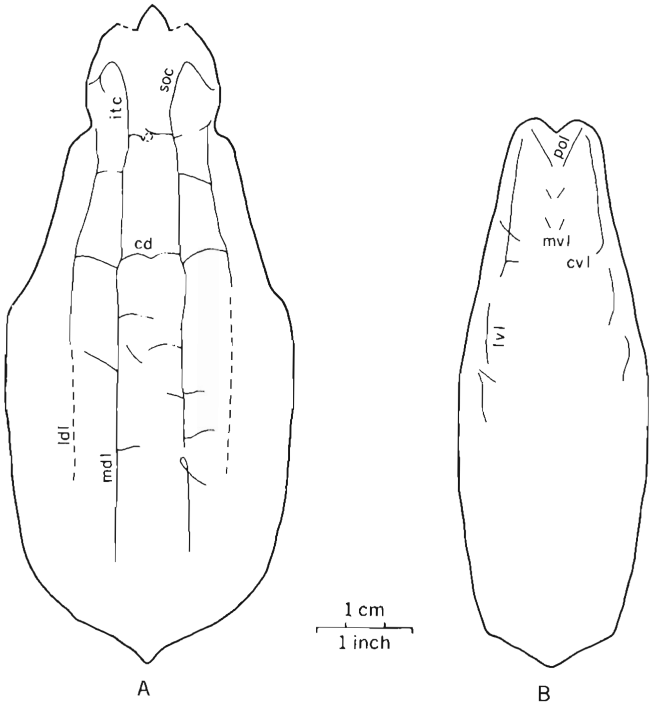


TEXTFIGURE 24

Dentine ornament of rostral oral region of dorsal shield of *Torpedaspis elongata* new species along margin of subrostral lamella of median preoral process. A, x2; B, x13; NMC 12557 from GSC loc. C-10046.

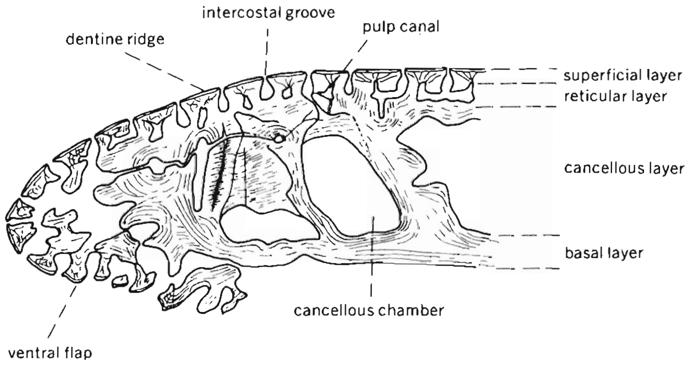


TEXTFIGURE 25. Pattern of ornament in dorsal shields of *Torpedaspis elongata* new species. Individual dentine ridges not represented. A, both plan view profile and outline of shield as if flattened are given, NMC 12537 from GSC loc. C-10046; x1. B, plan view only, NMC 12633 from GSC loc. C-10056; x1.



TEXTFIGURE 26

Lateral line sensory system in *Torpedaspis elongata* new species. A, dorsal shield shown as if completely flat (based mainly on NMC 12633 from GSC loc. C-10056 N; x½). B, ventral shield shown in natural profile (NMC 12657 from GSC loc. C-10050; x½). cd, cvl, dorsal, and lateral ventral, transverse commissures; ifc, infraorbital canal; ldl, mdl, lateral and median dorsal canals; mvl, median ventral canal; pol, postoral canal; soc, supraorbital canal.



TEXTFIGURE 27

Transverse marginal section of dorsal shield of *Torpedaspis elongata* new species to show microstructure and ventral flap of superficial layer; x80, NMC 12719 from GSC loc. C-10049.

types of canal (Textfig. 26): (i) single pulp canal underlies each dentine ridge, is wide and irregular in cross-section and gives rise to numerous dentine tubules that ramify throughout ridge; (ii) wide channels connect each pulp canal to expanded base of adjacent intercostal grooves; (iii) channels also connect pulp canals and intercostal grooves to chambers of cancellous layer, at margin of shield these channels are merely wide openings at the top of each chamber (Textfig. 27). Cancellous layer has a thickness of up to 0.34 mm, or 1.44 mm on rostral region, but is crushed in most specimens; chambers squarish in shape but some narrow distally and give rise to channels connecting to pulp canals and/or intercostal grooves. Basal layer varies from 0.07 mm to 0.22 mm thick; penetrated by channels connecting chambers of cancellous layer with inner surface of shield.

Internal organs. Natural sandstone casts of inner surfaces of several dorsal shields and one ventral shield reveal details of soft organs that formerly lay immediately inside the shield. Traces of gill sacs, pineal organ, semicircular canals, nasal sac, axial structure, myotomes, and a vascular system are preserved in fine-grained calcareous sandstone.

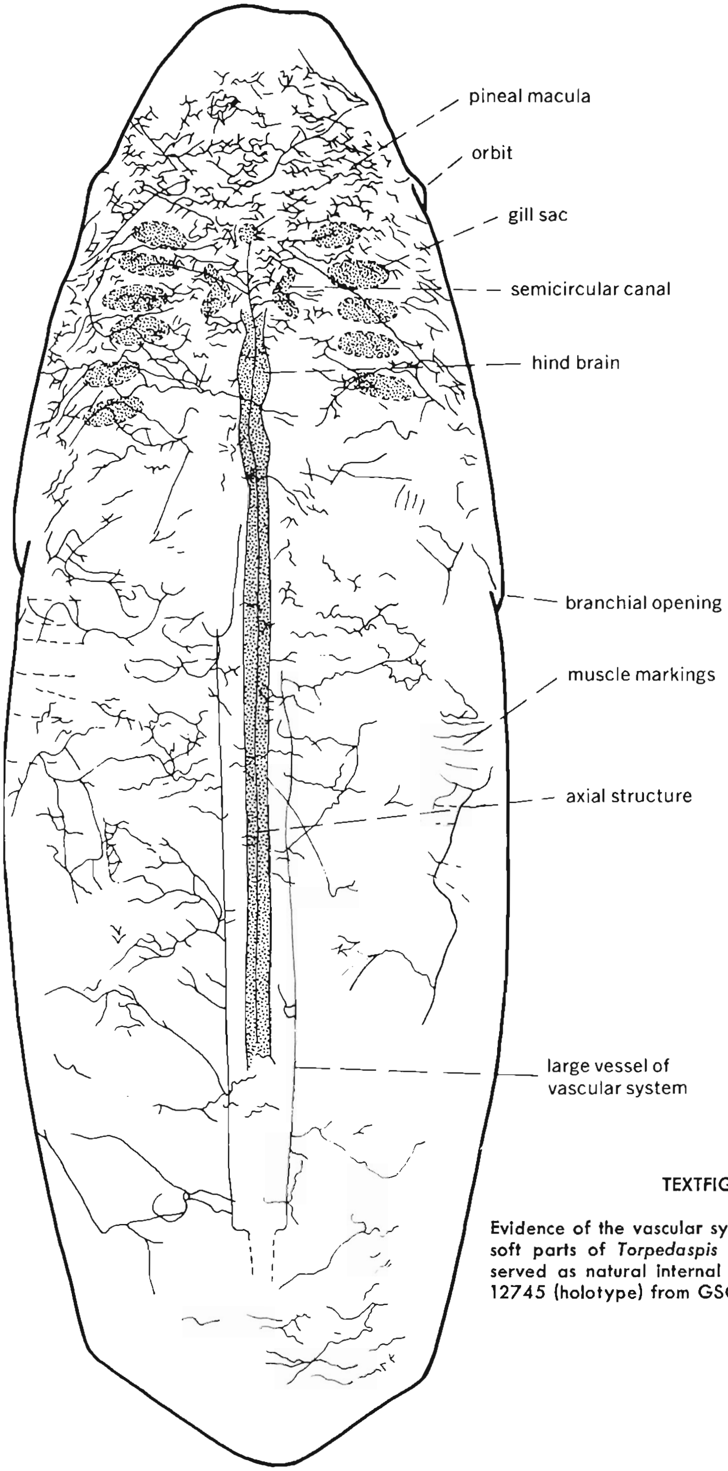
Paired elevations of up to seven gill sacs occur in both dorsal and ventral shields (Pls. 7, 8, figs. 1; Textfigs. 28, 29). Pineal organ lies just behind interorbital line between first pair of gill sacs. Semicircular canals lie between second and third pairs of gill chambers. Hind brain represented by a median elevation which begins between semicircular canals and passes posteriorly into conspicuous median axial structure (Pl. 7, fig. 1; Textfig. 28) that extends over two thirds of length of dorsal shield. Short transverse elevations lie on both sides of dorsal shield behind branchial openings and may represent transverse myotomes of postbranchial region (Pl. 7, fig. 1; Pl. 8, fig. 1; Textfig. 28).

Internal sandstone casts of dorsal and ventral shields covered with networks of fine elevations that represent ramifying blood vessels situated immediately within and impressed into basal layer of exoskeleton (Pl. 7, fig. 1; Pl. 8, fig. 1; Textfigs. 28, 29). Two large vessels lie parallel to posterior part of spinal cord and give rise to transverse subsidiary vessels that repeatedly divide and become finer. Fine blood vessels are most numerous and best preserved in branchial region.

Discussion

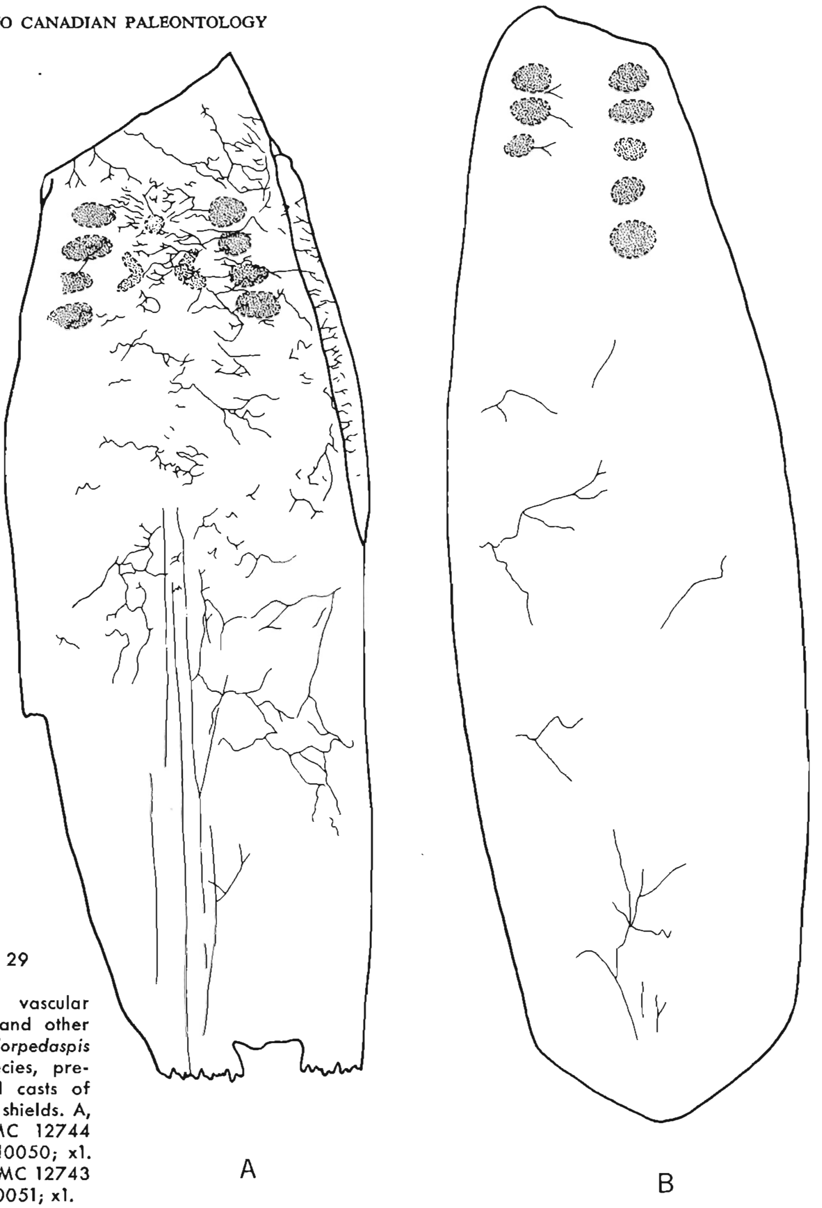
Rostral and oral region. The most intensive studies of the rostral and oral regions of the Heterostraci are those by Kiaer (1928) and, more recently, Stensiö (1958, 1964, 1968). Stensiö's terminology is not used in the present work although many features of *Torpedaspis* are homologous with those described by him in the cyathaspidids and pteraspids. In particular, the nasal sinuses and the median preoral process correspond respectively to the prenasal sinus and the median ridge as reconstructed by Stensiö (1964, fig. 92).

Although the rostral region of cyathaspidids has been shown by Denison (1964) to be of value in taxonomy, it is generally simple compared with that in the pteraspids. The modification of the rostral region of *Torpedaspis* is thus unusual in a cyathaspidid and is more similar to the arrangement common in most pteraspids (*see* Stensiö, 1964, figs. 46B, C, 91A–C). In particular it is similar to the structure of the rostral region in *Protaspis* (*Protaspis*) *brevispina* Denison which possesses a median preoral wall separating two rostral spaces interpreted as paired nasal sacs (Denison, 1970, p. 17, 18, figs. 9, 10). *Torpedaspis* differs in lacking a median preoral wall and hence its rostral space was not paired even though paired nasal sinuses are clearly visible in rostral view (Pl. 9, fig. 3; Pl. 10, fig. 6; Textfig. 16). It is, however, possible that a median preoral wall formed only at maturity as Denison suggests for some pteraspids.



TEXTFIGURE 28

Evidence of the vascular system, spinal cord, and other soft parts of *Torpedaspis elongata* new species, preserved as natural internal cast of dorsal shield, NMC 12745 (holotype) from GSC loc. C-10056; x1.



TEXTFIGURE 29

Evidence of the vascular system, gill sacs, and other soft parts of *Torpedaspis elongata* new species, preserved as internal casts of dorsal and ventral shields. A, dorsal shield, NMC 12744 from GSC loc. C-10050; x1. B, ventral shield NMC 12743 from GSC loc. C-10051; x1.

The mouth is ventral and lies immediately behind and on either side of the median preoral process. The rostral oral region bears ornament generally coarser than elsewhere on the shield but on the median preoral process the ornament consists of small dentine tubercles along the subrostral lamellae where the change in slope initiates the ascending lamella (Textfig. 24). Kiaer (1928, p. 124) and Heintz (1962, figs. 5, 6B) observed dentine tubercles in a similar position on the median preoral process (dental maxillary plate) of *Simopteraspis vogti* (Kiaer) with opposing tubercles on the anterior border of the oral plates. Heintz considered these tubercles to have functioned in filtering out organic particles as water was expelled from the mouth. This seems unlikely because the absence of a division (palato-subnasal lamella) between the buccal cavity and the oral-nasal sinuses would have resulted in escape of water through the latter. Dentine tubercles in this area probably prevented lateral slipping of the oral plates when the mouth was closed, as perhaps when the animal was grubbing in bottom sediment.

Kiaer (1928, p. 124) concluded that the oral plates covering the mouth behaved like jaws and worked against each other and the dental maxillary plate. Stensiö (1968, p. 49) elaborated on this theme and described a hypothetical biting apparatus consisting of a "lower jaw" containing movable plates which bit against small supralabial tooth plates attached to the lower extremity of the palato-subnasal lamella. Most authors disagree with him and, as White recently pointed out (discussion *in* Stensiö, 1968), such a dentition has not been discovered even in the best preserved fossils. Also, Denison's comments (1961, p. 180) concerning the hypothetical nature of the palato-subnasal lamella and lack of evidence of wear of denticles on the oral or rostral plates surely argue against such a jaw structure. Heterostracan oral plates were probably too fragile and the wrong shape to have assumed anything but a rudimentary and hence inefficient crushing function. It seems more probable that the oral plates of heterostracans were protrusible and formed a scoop for taking up bottom sediments rich in organic matter as suggested in the pteraspids by White (1935, p. 412, fig. 50). In this respect *Torpedaspis* was probably no different from other heterostracans although oral plates have not been found. The mouth was probably closed by small overlapping plates similar to those of *Pteraspis rostrata* (Agassiz) (White, 1935, Figs. 41-48), *Simopteraspis vogti* (Kiaer) (1928, Figs. 2, 3, Pl. 12), and *Allocryptaspis laticostata* Denison (1964, Fig. 152).

The median preoral process of *Torpedaspis* thus had two functions: first to separate the nasal sinuses, and second, as a median anterior support for the oral plates when the mouth was closed. The extreme length of the median preoral process in some individuals (Pl. 10, fig. 6; Textfig. 16B) was probably adapted to environmental conditions. It would have developed as a necessary modification of the rostrum to assist in supporting the oral plates as *Torpedaspis* assumed the habit of gently burrowing in soft sediment or algal mats as a consequence of grubbing more deeply for food.

Orbits. The size of the orbital notches indicates that the eyes in *Torpedaspis* were exceptionally small for so large an animal, as seems to have been true in all the Heterostraci (Stensiö, 1968, p. 49). Presumably the eyes were of little use and *Torpedaspis* was mostly dependent on its olfactory apparatus for detecting food in bottom sediments and on its sensory canal system for sensing further its surrounding environment. If the animal was able to burrow gently in bottom sediment as suggested, there may have been some kind of protective covering for the eyes.

Ornamentation. The dentine ridges are generally finer and show more pronounced swirling than in most other cyathaspidids. Swirled areas in *Torpedaspis* are assumed to represent vestigial epitega. Loss of epitega in *Torpedaspis* may have reached a more advanced stage than that seen in *Americaspis americana* (Claypole) but had not attained the stage of total absence seen in *Allocryptaspis*. Loss of epitega in the cyathaspidids is considered to be a late evolutionary event and is characteristic of the Poraspidinae and some of the Irregulareaspidinae.

Lateral line sensory system. The pattern of sensory canals (Textfig. 26) conforms to the general cyathaspidid pattern and, except for minor differences, the system is most similar to that of *Allocryptaspis laticostata* (Claypole) (Denison, 1960, Fig. 119; 1964, Figs. 98E, 99D). A special feature shown by both *Allocryptaspis* and *Torpedaspis* is the extended supraorbital canal which continues to the margin of the preorbital lobe. This is most marked in *Torpedaspis* in which the preorbital lobe itself is considerably enlarged. Clearly the anterior circum-oral region of *Torpedaspis* was more richly endowed with sensory canals than in other cyathaspidids.

Internal organs. Impressions of the gill chambers (or head somites pushed up by underlying gill chambers as suggested by Tarlo and Whiting, 1965), pineal organ, semicircular canals, and eyes, are well known in the cyathaspidids (Stensiö, 1964; Whiting and Tarlo, 1965). Three features are of particular interest: the transverse postbranchial elevations interpreted as myotomes, the ramifying network of blood vessels, and the long axial structure. None of these has been described previously in the cyathaspidids, nor indeed in the Heterostraci.

It is unlikely that only the few observed myotomes were present in the postbranchial region (Pl. 7, figs. 1, 2; Pl. 8, fig. 1; Textfig. 28). Bands of muscle may have occupied most of the region between the branchial opening and the posterior margin, and would account for the unusually long shields of *Torpedaspis*. Lateral marginal rows of transverse bands representing muscles in this region could have had two functions. First, those muscles closest to the branchial opening could have assisted the flow of water to and from the gills by rhythmically contracting and moving dorsal and ventral shields towards each other. Second, more posterior muscles of the postbranchial region could have assisted articulation and swimming movements of the animal, as suggested for the typical cyathaspidid by Tarlo and Whiting (1965, Fig. 1). Powerful muscles would have been necessary to provide the vigorous lateral movements of the posterior body and caudal fin, and the long postbranchial region of the dorsal and ventral shields would have been the obvious position for them.

Further argument for a respiratory movement of dorsal and ventral shields is the hypothesis that these shields were not rigidly fused together but were loosely linked by an infolded flap of skin. It is generally accepted that epidermal tissue overlay the superficial layer of the exoskeleton. The presence in one specimen of a flap of superficial layer complete with dentine ornament folded over the edge of the shield (Pl. 10, fig. 5; Textfig. 27) suggests that the epidermal tissue also overlay this region and consequently formed a fold or hinge of skin between the two shields.

Both dorsal and ventral shields are underlain by blood vessels. In the two dorsal shields illustrated in Textfigs. 28 and 29A the largest vessels are in the postbranchial region and the fine capillaries are more common in the branchial region which is of course the region of respiratory activity.

Ground serial sections of the rostral region indicate a bulbous area of finer and lighter coloured sediment within coarser sediment infilling the remainder of the shield (Textfig. 18C). This structure is tentatively interpreted as the infilling of the buccal cavity, possibly as a premortem event. It narrows towards the presumed oral opening just behind the median preoral process, expands posterolaterally and almost reaches the internal surface of the dorsal shield midway between the rostral margin and the pineal macula. If this structure is indeed evidence for the buccal cavity it is the first record of this organ in the cyathaspidids. Its dorsal and lateral extent indicates that there is insufficient space, at least in *Torpedaspis*, for an internal cartilaginous partition such as the palato-subnasal lamella postulated by Stensiö (1958, 1968).

The long, relatively wide, axial structure which extends from the hind brain almost to the posterior margin of the dorsal shield (Textfig. 28) is too superficially situated to represent a spinal cord. Whiting has observed a similar structure in *Anglaspis* and suggests that it may represent a fatty organ buoyancy mechanism (pers. com., 1971). Such an organ would have been of considerable assistance to many cyathaspidids (and particularly *Torpedaspis* which lacks spines or cornua) in reducing rolling about the long axis while the animal was swimming or stationary.

Caudal fin and mechanics of swimming. Complete specimens of ostracoderms are rare. The reconstruction of the trunk and caudal fin (Textfig. 30) based upon the entire articulated specimen of *Torpedaspis* (Pl. 9, fig. 1; Textfig. 21) resembles *Anglaspis heintzi* Heintz (Kiaer, 1932, fig. 11) and *Poraspis* sp. (Heintz, 1938, fig. 1a), the only other known entire cyathaspidids. There are, however, several differences. *Torpedaspis* is about four times larger than these genera and has a diphycercal caudal fin with a median lobe. A diphycercal caudal fin is rare in the ostracoderms, being known only in the psammosteid *Drepanaspis gemuendenensis* Schlüter whose fin differs only in details of the arrangement of the scales and in its truncate margin (Gross, 1963, fig. 11). The tail of *Torpedaspis* differs from those of pteraspids in its closer approach to symmetry and absence of an enlarged ventral lobe (Denison, 1971, p. 90).

Many authors, including Affleck (1950, p. 359), and Obruchev (1967, p. 14) consider the symmetric diphycercal caudal fin (as seen in *Torpedaspis*) to be the most primitive type from which other caudal fins were later derived. The absence of fins other than the caudal is presumably also a primitive feature for it implies that the animal was not provided with the most elementary means of controlling its angle of attack (the angle between the long axis of the animal and the path of travel). As in other cyathaspidids, the absence of pectoral fins implies that lift for upward movement was obtained entirely from the shape of the headshield and the effectual action of the caudal fin. The possibility of a buoyancy mechanism in *Torpedaspis* and other cyathaspidids has already been discussed. As pointed out by Affleck (1950) and more recently by Denison (1971) in a review of heterostracan tails, the effectual action of tails cannot be inferred only from their outline shape. Some knowledge of the extent of elevation or depression of the caudal fin is also required. Recent work by Simons (1970) on the heterocercal tails of sharks and dogfish showed that in these fishes the resultant lift is a function of the negative lift produced by the ventral lobe of the tail and the positive lift produced by the dorsal lobe. Simons further pointed out that the effective pitch produced by a tail must depend on where the line of thrust passes with respect to the animal's centre of gravity. If the thrust line passes above, the action of the tail must be epibatic, if below, hypobatic, and if through the centre of gravity, isobatic. If we relate these principles to *Torpedaspis*, and assume its centre of gravity to have been within the median part of the headshield, the effectual action of its diphycercal caudal fin in a slightly elevated position would have been hypobatic. Lateral movement of the caudal fin in this position would have driven the animal towards the surface, but slowly and at a low angle of attack because the tail is only slightly upturned, and positive lift from the dorsal part would have been small. The caudal fin also provided the only means of steering, and, in the absence of cornua or median spines it was also almost entirely responsible for minimizing rolling and yawing. Denison (1971) has recently reviewed the form and function of heterostracan tails.

Torpedaspis was therefore relatively sluggish in its swimming movement, due to the small dorsal part of the caudal fin, the lift from which was not easily adjusted because of the limited flexibility of the posterior body, and the long inflexible headshield. It was probably an intermittent swimmer, spending most of the time on or close to the bottom.

Habitat and mode of life. Sedimentological and faunal evidence in the Lower Member of the Peel Sound Formation indicate that ostracoderm faunas occupied a succession of ephemeral fluvial to shallow marine nearshore environments flanking the Boothia Arch. Periodically these short-lived environments were destroyed and filled by alluvial fans now represented by coarse clastics and boulder conglomerates eroded from the intermittently rising Boothia Arch (Brown *et al.*, 1969, p. 542; Miall, 1970b).

Torpedaspis and other ostracoderms flourished in these brackish and shallow marine environments. The elongate rigid headshield implies poor manoeuvrability and probably the animal maintained a predominantly benthonic existence and rarely ascended to higher levels. Its food probably was obtained by swallowing large quantities of organically rich fine sediment scooped up by means of its protrusible mouth plates. While searching for food it may have assumed the habit of burrowing gently in fine sediment or perhaps forcing a path through algal mats or other growths. To this end the small eyes, narrow intercostal grooves, fine sensory pores, the elongate streamlined headshield lacking projections such as spines, pectoral fins, or cornua, were all advantages. In addition the mouth may have been closed when burrowing with the anterior margins of the mouth plates pressed against the median preoral process to give them additional support.

Comparison with other ostracoderms. Torpedaspis is undoubtedly a cyathaspidid and can be assigned to the subfamily Poraspidinae because of its faint epitega, longitudinal ridge pattern, and a sensory canal system similar to *Allocryptaspis.*

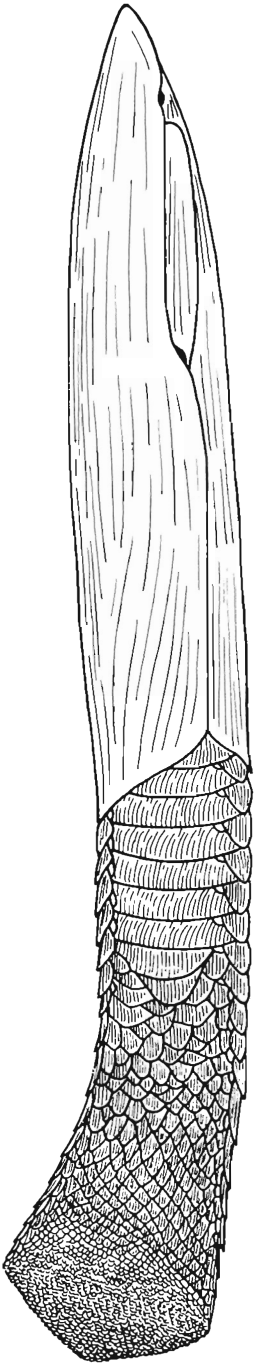
It is the largest known genus of cyathaspidid. The single complete specimen with trunk and caudal fin is 23.5 cm long, but shields up to 20 cm long indicate that other individuals were considerably larger. The unusual length of the shields is thought to be due to the powerful muscles in the greatly elongated region behind the branchial opening. Their function was probably to control respiratory movements of dorsal and ventral shields and to provide attachments for swimming muscles of the posterior body and caudal fin.

In several ways *Torpedaspis* resembles *Allocryptaspis* which was considered previously to be the largest cyathaspidid. Both genera show similarity in the size and position of the orbits and their preorbital and postorbital lobes, in the well-developed sensory canal system, the irregular but generally longitudinal ornament, and the absence or poor development of epitega. The shape of their lateral scales is also similar (*see* Denison, 1953, Fig. 65B).

Torpedaspis also shows some resemblance to *Americaspis americana* (Claypole) in the general shape of the shield and the presence of areas of irregular swirled dentine ornament.

Affinities of *Torpedaspis* extend to ostracoderms other than the cyathaspidids. Similarity in the shape of the caudal fin to that of *Drepanaspis gemuendenensis* Schlüter suggests a tenuous and probably superficial relationship with the psammosteids.

The genus is closely related to the pteraspids because of the "pteraspid-like" aspects of its rostral region, the presence of nasal sinuses and the median preoral process containing subrostral and ascending lamella and a rostral space. The possession of these characters, previously unknown in the cyathaspidids, indicates that in these respects the genus is one of the more advanced members of the family. The Cyathaspididae must now be considered to be more closely related to the pteraspids than was previously supposed. This supports Denison's (1964, p. 465) views in favour of derivation of the pteraspids from the Cyathaspididae.



TEXTFIGURE 30. Restoration of *Torpedaspis elongata* new species, based mainly on NMC 12554 from GSC loc. C-10046; x0.9.

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Appendix

List of localities from which *Torpedaspis elongata* new species was collected

Textfigure 1, loc. 7. *Prince of Wales Island*

GSC locs. C-10043 to C-10048: 11, 15, 18, 196, 200, and 368 feet above base of Peel Sound Formation; unnamed gorge 9 miles north of Transition Bay, 72°10′N, 96°55′W; NMC 12595 from C-10043; NMC 12600, 12611, 12612, 12617, from C-10044; NMC 12569, 12597, 12598, 12602, 12614 from C-10045; NMC 12537–12560, 12561–12568, 12570, 12571, 12575, 12577–12591, 12593, 12594, 12599, 12603–12610, 12613, 12615, 12616, 12618, 12619, 12742 from C-10046; NMC 12573, 12574, 12576, 12592, 12595, 12596, from C-10047; NMC 12572, 12601, from C-10048. Faunas listed in text.

Textfigure 1, loc. 5. *Somerset Island*

GSC loc. C-10049: 140 feet below top of Read Bay Formation; cliffs 400 yards east of Pressure Point; 73°58′N, 95°17′W; NMC 12711, 12712, 12715, 12719, 12734, 12749. *Boothiaspis ovata* Broad, *?Pionaspis*, a traquairaspid, acanthodian fragments.

GSC loc. C-10050: 50–103 feet above base of Peel Sound Formation; stream valley 1.2 miles east of Pressure Point, 73°59′N, 95°14′W (loc. A, Dineley, 1968, p. 51); NMC 12624, 12625; 12643–12648, 12651, 12655–12657, 12660, 12661, 12664, 12670, 12675, 12676, 12680–12682, 12685, 12692, 12701, 12716, 12723, 12737, 12744, 12747, 12748, 12752, 12755. *Boothiaspis alata* Broad, *Corvaspis*, *Pionaspis*, a traquairaspid, *Hemicyclaspis murchisoni* (Egerton), acanthodian fragments.

GSC loc. C-10051: 212 feet above base of Peel Sound Formation; cliffs on east bank of northward flowing stream, 400–420 yards east of locality C-10050, 73°59′N, 95°13′W (loc. B, Dineley, 1968, p. 51); NMC 12626, 12636, 12639, 12640, 12642, 12649, 12650, 12662, 12663, 12665, 12666, 12673, 12674, 12677–12679, 12683, 12687–12690, 12693, 12697, 12713, 12717, 12733, 12738, 12743, 12750, 12751, 12754, 12759. *Cephalaspis*, *Corvaspis*, *Pionaspis*, *Traquairaspis*, acanthodian fragments.

GSC loc. C-10052: Peel Sound Formation, lower part; crags on northeast side of stream 2.5 miles southeast of Pressure Point, 73°57′N, 95°14′W; NMC 12684, 12724, 12735, 12746. *Corvaspis*, *Pionaspis*, an olbiaspidid, a traquairaspid, cyathaspidids indet.

GSC loc. C-10053: 70 feet above base of Peel Sound Formation; near sea level in small graben 5 miles west of Cunningham Inlet, 74°53′N, 94°09′W (loc. F, Fortier and others, 1963, p. 122); NMC 12667–12669, 12694, 12695, 12698, 12726, 12740. *Anglaspis*, *Corvaspis*, *Pionaspis*, *Traquairaspis*, acanthodian fragments.

Textfigure 1, loc. 6. *Somerset Island*

GSC loc. C-10054: Peel Sound Formation; low bluff above north side of gorge of West Creswell River, 72°56′N, 93°47′W; NMC 12736, 12741. *Pionaspis.*

GSC loc. C-10055: Peel Sound Formation; south side of gorge of West Creswell River, 0.5 mile south of locality C-10054, 72°55′N, 93°47′W; NMC 12635, 12637, 12638, 12699, 12700, 12703, 12756–12758.

GSC loc. C-10056: 210 feet above base of Peel Sound Formation; north bank of small river 4 miles north of Creswell Bay, 72°50′N, 93°42′W; NMC 12620–12623, 12627–12634, 12641, 12652–12654, 12658, 12659, 12671, 12672, 12686, 12691, 12696, 12702, 12704–12710, 12714, 12720–12722, 12725, 12727–12732, 12739, 12745, 12753. *Boothiaspis ovata* Broad, *Corvaspis*, *Pionaspis*, *Traquairaspis.*

GSC loc. C-10057: Peel Sound Formation; second stream south of large coastal lakes, approximately 1 mile inland, 72°39′N, 93°49′W; NMC 12718. *Corvaspis*, *Pionaspis*, *Traquairaspis.*

PLATES 7 TO 10

PLATE 7

Torpedaspis elongata new genus and species (PAGE 60)

Figure 1. Natural internal cast of dorsal shield showing evidence of orbits, pineal macula, six pairs of gill sacs, semicircular canals, muscle bands behind the branchial notches, spinal cord, and blood vessels of the vascular system (x1.3). NMC 12745 (holotype) from GSC loc. C-10056.

Figure 2. Smallest dorsal shield showing impression of pineal macula, semicircular canals, spinal cord, and seven pairs of gill sacs (x2). NMC 12718 from GSC loc. C-10057.

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PLATE 8

Torpedaspis elongata new genus and species (PAGE 60)

Figure 1.	Left lateral view of natural internal cast of dorsal shield showing strongly arched body and evidence of orbit, pineal macula, gill sacs, semicircular canal, muscle bands behind the branchial notches, and blood vessels of the vascular system (x1.1). NMC 12745 (holotype) from GSC loc. C-10056.
Figure 2.	Outline of ventral shield (x0.8). NMC 12732 from same locality.
Figures 3, 4.	Median dorsal or ventral scales of the trunk. NMC 12738 (x3) from GSC loc. C-10051; NMC 12615 (x3) from GSC loc. C-10046.
Figure 5.	Outline of dorsal shield (x0.8); note sharp rostral margin. NMC 12731 from GSC loc. C–10056.
Figure 6.	Right branchial plate. Note slight notch at posterior extremity (x2.3). NMC 12735 from GSC loc. C-10052.

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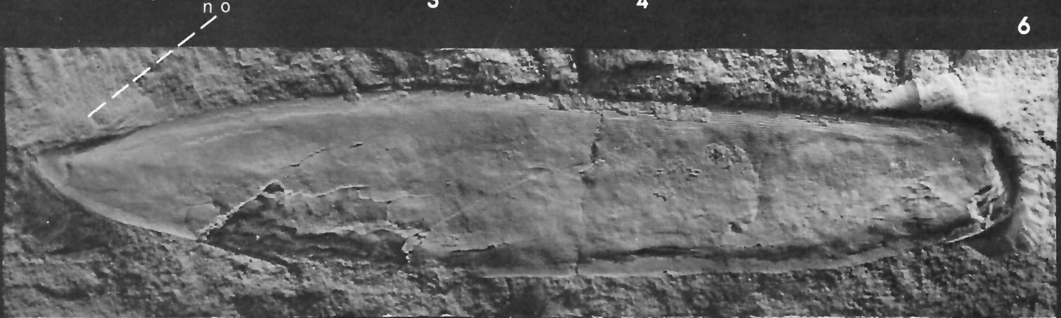

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PLATE 9

Torpedaspis elongata new genus and species (PAGE 60)

Figure 1. Trunk and caudal fin of entire individual (x1). *See* Textfigure 21 for details. NMC 12554A from GSC loc. C-10046.

Figure 2. Detail of right anterior region of dorsal shield (x3.2). NMC 12633 from GSC loc. C-10056. ns, nasal sinus; or, orbital notch; prol, preorbital lobe; rm, rostral margin; srl, subrostral lamella of median preoral process.

Figure 3. Detail of rostral region of dorsal shield. Note nasal sinuses on either side of the triangular median preoral process (x3.8). NMC 12556 from GSC loc. C-10046. srl, subrostral lamella of median preoral process; ns, nasal sinus.

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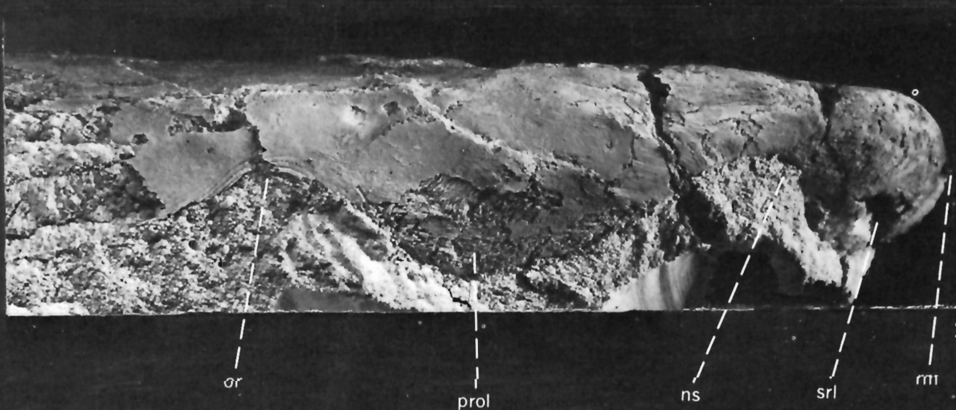

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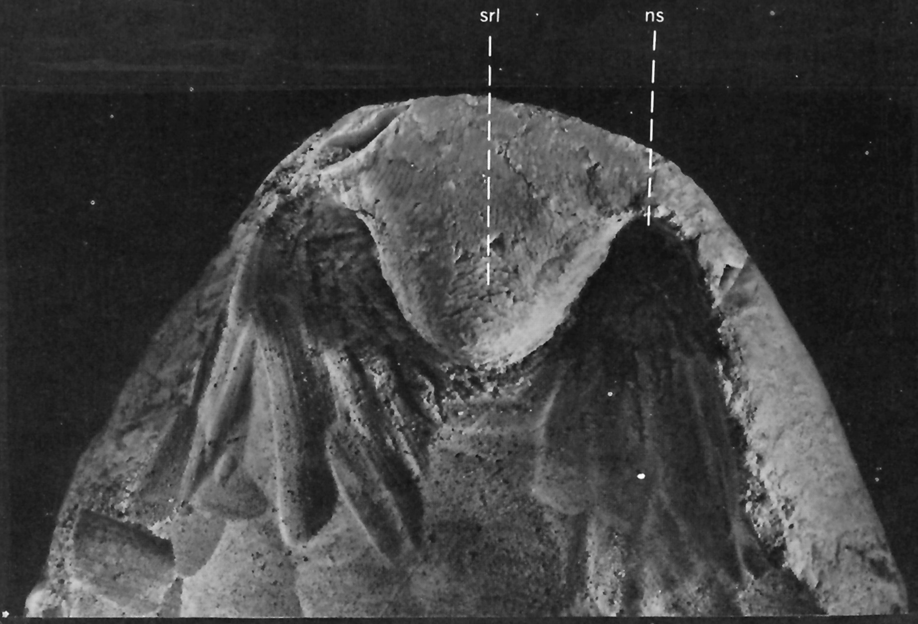

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PLATE 10

Torpedaspis elongata new genus and species (PAGE 60)

Figure 1. Right lateral scale of trunk (x3). Note tubercular ornament along anterior margin. NMC 12725 from GSC loc. C-10056.

Figure 2. Median dorsal or ventral scales of the trunk. NMC 12741 from GSC loc. C-10054. (x4).

Figure 3. Left lateral view of natural internal cast of ventral shield (x0.9). NMC 12743 from GSC loc. C-10051.

Figure 4. Transverse section through dorsal shield showing (in white) cancellous chambers, intercostal grooves, and channels of the reticular layer (x33). NMC 12718 from GSC loc. C-10057.

Figure 5. Transverse section through lateral margin of dorsal shield (x28). Note flap of superficial layer present on inner surface of shield (*see* Textfig. 27). NMC 12719 from GSC loc. C-10049.

Figure 6. Detail of somewhat damaged rostral region of dorsal shield. Note the long, narrow median preoral process and the deep nasal sinus on its right side (the left side has not been prepared) (x3.6). NMC 12731 from GSC loc. C-10056. asl, srl, ascending and subrostral lamellae of median preoral process; ns, nasal sinus; prol, preorbital lobe.

Figure 7. Longitudinal section through anterior region of dorsal shield (x9). NMC 12562 from GSC loc. C-10046. rc, rostral chamber; rs, rostral space; srl, subrostral lamella of median preoral process.

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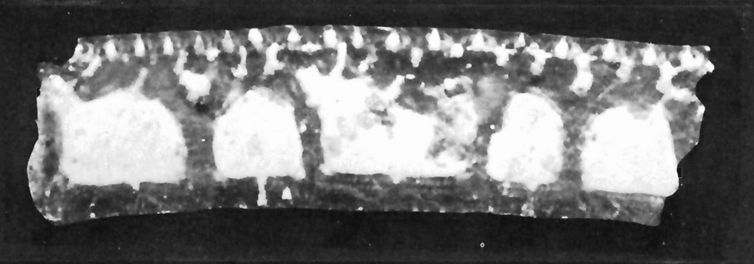

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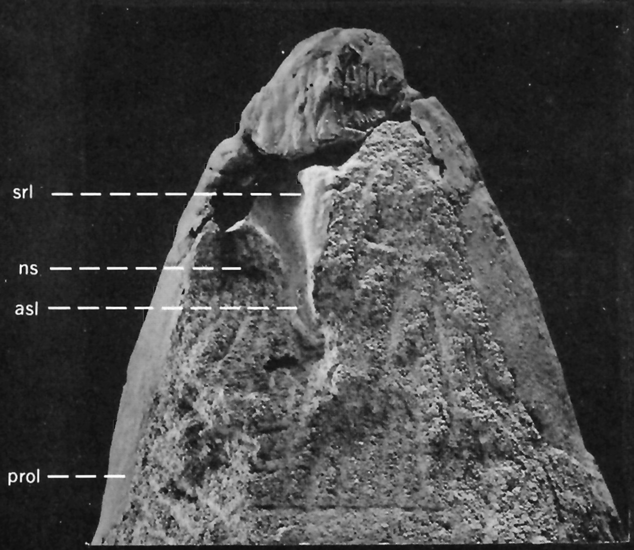

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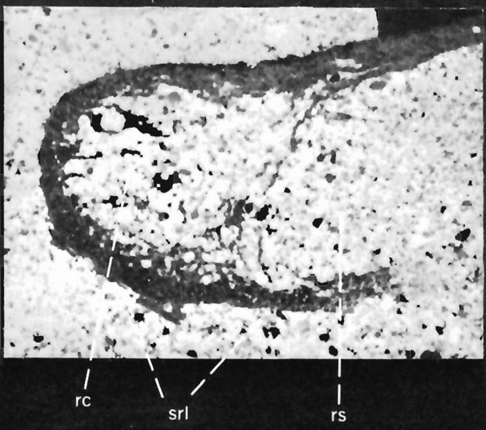


DESCRIPTION AND BIOSTRATIGRAPHICAL SIGNIFICANCE OF THE DEVONIAN CORAL GENERA *ALAIOPHYLLUM* AND *GRYPOPHYLLUM* IN WESTERN CANADA

by A. E. H. Pedder

Abstract

The morphology, systematics, species composition, and distribution of the genera *Alaiophyllum* and *Grypophyllum* are reviewed. *Alaiophyllum goryanovi* n. sp. and *Grypophyllum subtile* n. sp. are described from the late Givetian *Rensselandia laevis* and *Stringocephalus aleskanus* Zones of the central Mackenzie Valley area. *Grypophyllum aquilonium* n. sp. is described from the Givetian Hare Indian Formation of lower Mackenzie Valley, and *G. crickmayi* n. sp. is erected for specimens coming from probable Givetian strata, believed to be just younger than the *aleskanus* Zone, near Great Slave Lake. *Alaiophyllum mackenziense* Pedder is shown to be a species of *Grypophyllum* and to be an important index to the otherwise poorly fossiliferous (apart from stromatoporoids and tabulate corals) interval above Middle Devonian *Stringocephalus*-bearing beds, and below the Upper Devonian Waterways Formation or its equivalents.

The *mackenziense* Zone is equivalent to the upper *hermanni–cristatus* conodont zone, which on the basis of associated goniatites in Germany, is now taken by some workers as the lowest Upper Devonian conodont zone. If this practice is maintained, *Grypophyllum* is shown for the first time to extend into the base of the Upper Devonian.

Résumé

L'auteur revoit la morphologie, la classification, la répartition et la composition des genres *Alaiophyllum* et *Grypophyllum.* Il décrit des *Alaiophyllum goryanovi* (esp. nouv.) et des *Grypophyllum subtile* (esp. nouv.) provenant des zones de *Rensselandia laevis* et *Stringocephalus aleskanus* du Givétien supérieur de la région centrale de la vallée du Mackenzie. Il décrit des *Grypophyllum aquilonium* (esp. nouv.) de la formation de Hare Indian du Givétien de la vallée inférieure du Mackenzie et il établit une nouvelle espèce *G. crickmayi* pour les spécimens provenant probablement des strates du Givétien que l'on estime être plus récentes que la Zone *aleskanus*, près du Grand lac des Esclaves. L'auteur démontre également que l'*Alaiophyllum mackenziense* est une espèce de *Grypophyllum* et caractéristique de l'intervalle pauvre en fossiles (excepté les stromatoporoïdés et les coraux tabulata) au-dessus des couches stringocéphalifères du Dévonien moyen, et au-dessous de la formation de Waterways du Dévonien supérieur, ou ses équivalents.

La zone à *mackenziense* est l'équivalent de la zone supérieure à conodontes *hermani-cristatus*, qui, en fonction de goniaties associées en Allemagne, est maintenant considérée par certains comme la zone à conodontes la plus basse du Dévonien supérieur. Si l'on admet cette opinion, l'auteur démontre que pour la première fois, on trouve des *Grypophyllum* dans la base du Dévonien supérieur.

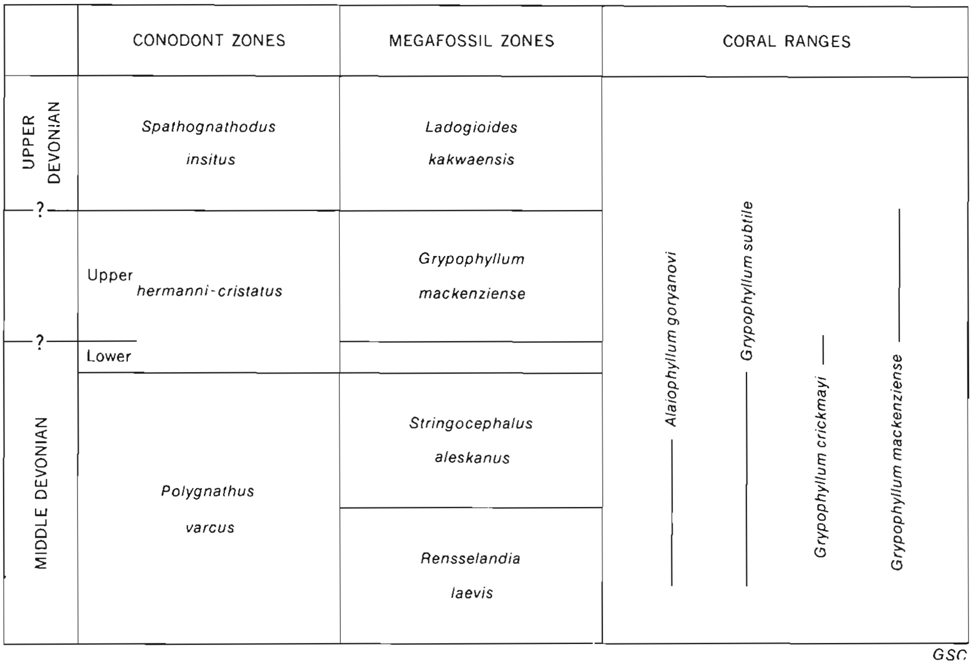
Introduction

Economically important accumulations of oil are being exploited from several reefs of late Givetian or early Frasnian age over a wide area in western Canada. Search for similar accumulations requires understanding of paleoecological conditions pertaining in western Canada at that time, and this can be achieved only if accurate correlations of the crucial stratigraphic sequences are available. Difficulties in establishing such correlations have arisen largely from the existence of significant thicknesses of strata (locally possibly as much as 650 feet) above the latest definite Givetian *Stringocephalus*-bearing beds and below the Waterways Formation or equivalents, which are the oldest western Canadian beds that can be assigned to the Frasnian with certainty (Uyeno, 1967).

Stromatoporoids and tabulate corals are the most abundant fossils in the Givetian–Frasnian boundary beds of western Canada, although tetracorals, brachiopods, ostracods, and others may be present also. In this part of the geological column, stromatoporoids and tabulate corals have little known merit as index fossils and the brachiopods are dominated by such long ranging forms as *Schizophoria*, "*Atrypa*", *Spinatrypa*, ambocoeliids, and *Cyrtina*. Preliminary studies of the ostracods (McGill, 1966; Braun, 1966) suggested a Givetian age for these boundary beds, and in the first description of a coral (*Alaiophyllum mackenziense* Pedder, 1963) from the same interval, the age suggested was Givetian or early Frasnian. More recently Fischbuch (1968) reported this coral from what he regarded as the late Givetian part of the Swan Hills Formation of central Alberta. Crickmay (1968a, 1970) also reported the same coral from numerous localities in the District of Mackenzie and Alberta, but considered the age to be early Frasnian.

This article presents some of the results of the author's more recent researches into the coral faunas of the Givetian–Frasnian boundary beds. The value of *Alaiophyllum mackenziense* as an index fossil, which was first recognized in print by Crickmay (1968a), is confirmed, although the species is now referred to the genus *Grypophyllum*. Conodonts directly associated with specimens of *Grypophyllum mackenziense*, that show no sign of having been reworked, have been identified by T.T. Uyeno as being diagnostic of the upper *hermanni–cristatus* conodont zone. This part of the zone is regarded by Kullmann and Ziegler (1970) as the earliest Upper Devonian faunal unit, on the basis of goniatites associated with it in Germany. However the Middle–Upper Devonian, or Givetian–Frasnian boundary has not been defined in terms of a type section, nor have the German conodont and ammonoid zones been correlated with the Belgian sections carrying the names Givetian and Frasnian (for further discussion *see* McLaren, 1970). If the Middle–Upper Devonian boundary is drawn between the lower and upper *hermanni–cristatus* conodont zones, *Grypophyllum*, which previously has always been regarded as a Middle Devonian genus, would extend into the base of the Upper Devonian. Documentation of the conodont evidence for the age of the *mackenziense* Zone is given elsewhere (Pedder and Uyeno, at press).

As stratigraphical nomenclatures of the Givetian–Frasnian boundary beds are still in dispute and certain to undergo changes, Textfigure 31 gives the ranges of the corals described in terms of megafossil and conodont zones only.



TEXTFIGURE 31. Approximate temporal relationships between ranges of the corals described and the megafossil and conodont zones of western Canada. *Grypophyllum aquilonium* is omitted as it is not certain whether it occurs in the *Rensselandia laevis*, or an underlying and as yet undefined, Givetian zone. It should be noted that no conodont has yet been isolated from the *Rensselandia laevis* Zone and that therefore this zone may overlap some part of the *Icriodus obliquimarginatus* conodont zone of Ziegler (1969).

Acknowledgments

I am indebted to E. W. Best, BP Oil and Gas Ltd. (previously Triad Oil Co. Ltd.), for allowing unrestricted use of specimens collected by the author while employed by that company. I am indebted also to A. C. Lenz, D. Mason, and the Management of Chevron Standard Limited for making available specimens originally collected by Lenz for Chevron Standard Limited. J. H. Craig, Imperial Oil Limited, arranged for the loan of specimens identified in publications by Crickmay. W. G. E. Caldwell, University of Saskatchewan, loaned corals studied by N. R. Fischbuch, and Fischbuch himself provided further stratigraphic data on one specimen. R. Birenheide, Natur-Museum Senckenberg, provided information concerning several of Wedekind's specimens.

D. J. McLaren read and improved the original manuscript; he also made available three previously unpublished photographs taken by him of type specimens of the type species of *Grypophyllum* and *Neostringophyllum*. The remaining photographs are the work of H. J. Hamnett of the Geological Survey of Canada.

Systematic Paleontology

One figured hypotype is deposited in the Geological Museum, University of Saskatchewan, Saskatoon. All primary types and the remaining hypotypes are deposited with the

Geological Survey of Canada, Ottawa, and bear numbers prefixed by the letters GSC. Two unfigured specimens referred to in Crickmay's publications have been returned to the collections of Imperial Oil Limited, Calgary.

Phylum *COELENTERATA*

Order RUGOSA Milne Edwards and Haime, 1850

Family CYATHOPHYLLIDAE Dana, 1846 (*sensu lato*)

Genus ***Alaiophyllum*** Goryanov, 1961

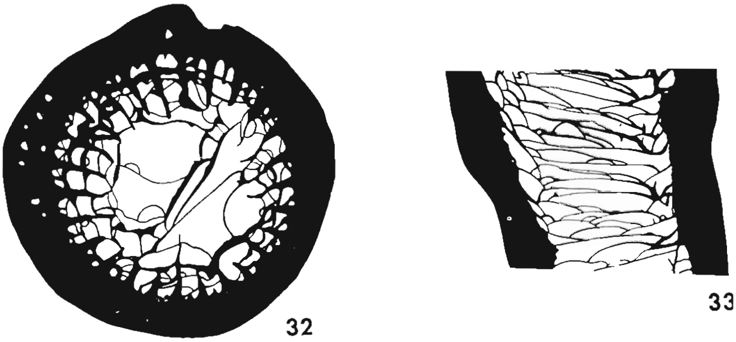
Alaiophyllum Goryanov, 1961, p. 70, 71.

Type species (by original designation). *Alaiophyllum jarushevskyi* Goryanov, 1961, p. 71–74, Pl. 8, figs. 1a–3g; Givetian strata, Boorda Ridge, southern Fergana, Tien Shan, U.S.S.R. Figures of this species are reproduced in Textfigures 32 and 33 and figures 1, 3, 5, 6 of Plate 11, of the present work.

Species assigned. Alaiophyllum jarushevskyi Goryanov, 1961: *Alaiophyllum goryanovi* n. sp.

TEXTFIGURES 32 and 33

Alaiophyllum jarushevskyi Goryanov; both x3. Holotype, Leningrad Mining Institute, Department of Historical Geology Museum 755/1; Givetian strata; southern Fergana. Drawn from Goryanov 1961, Pl. 8.



Definition. Solitary to weakly fasciculate tetracorals. Septa radially arranged, short, cuneate, and typically forming a septal stereozone. Trabeculae coarse, monacanthate, directed inwards and upwards at a low angle to the horizontal. Dissepiments globose, steeply inclined, few in number, and commonly suppressed by the septal stereozone. Tabularium wide, composed mostly of broad, rather flat-lying tabulae with some steeply inclined peripheral tabellae.

Discussion. Goryanov's original diagnosis mentions branching colonies, but these were not figured, nor was the mode of budding described. The new Canadian species is certainly solitary. Pickett (1967) merged *Alaiophyllum* with *Temnophyllum* Walther, 1928 (= *Temeniophyllum* Lang, Smith, and Thomas, 1940). The type species of *Temnophyllum*, which is *T. latum* Walther and apparently from the Givetian of Germany, has never been figured photographically and some doubt exists as to its trabecular morphology. However, even if this were shown to be identical with that of *Alaiophyllum*, the extreme brevity of the septa in *Alaiophyllum* should be sufficient reason for separating the genera.

The revision of *Alaiophyllum mackenziense* Pedder (1963) given below, shows that this species should be referred to the genus *Grypophyllum*.

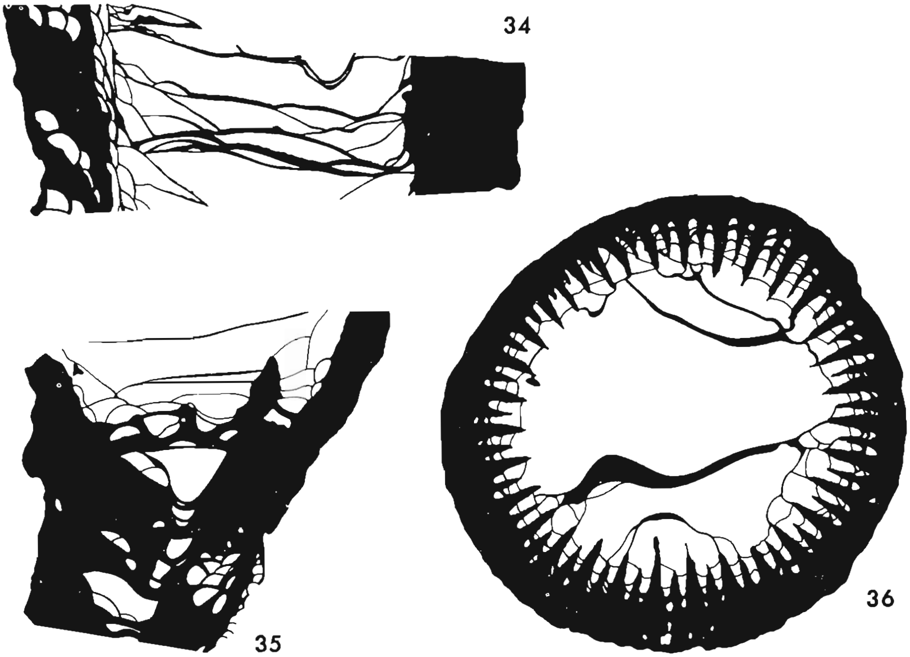
Distribution. Alaiophyllum occurs in the early Givetian zones of *Neospongophyllum* and *Stringophyllum* of Tien Shan (Brezhnev *and others*, 1968), the late Givetian zones of *Rensselandia laevis* and probably *Stringocephalus aleskanus* of central Mackenzie Valley, and questionably also in the late Givetian part of the Chudleigh Limestone of south Devon, England (Scrutton, 1969).

Alaiophyllum goryanovi new species

Plate 11, figures 2, 4, 7, 8; Textfigures 34–36

"*Cyathophyllum*" *kobehense* Stumm, Lenz, 1961 (in part, not Stumm), p. 503, 504 (excluding figured specimens).

Type series. Holotype, GSC 29532; Ramparts Formation, 0 to 15 feet above base in the Givetian *Rensselandia laevis* Zone; right bank of Mackenzie River, 2¾ miles above Fort Good Hope, lat. 66°14′N, long. 128°42½′W (Textfig. 1, loc. 9); collected by A. E. H. Pedder, June 1968, GSC loc. C-2532. Paratype, GSC 29533; Ramparts Formation, 65 to 80 feet above base and 265 to 280 feet below eroded top, probably in the Givetian *Stringocephalus aleskanus* Zone; small tributary flowing northwestwards to the right side of Mackenzie River at the downstream end of the Ramparts, lat. 66°14′N, long. 128°40′W (Textfig. 1, loc. 9); collected by A. C. Lenz, June 1958, Chevron Standard Limited L14–57, 185–200.



TEXTFIGURES 34 to 36. *Alaiophyllum goryanovi* new species; all x3. 34. Paratype, GSC 29533; Ramparts Formation, probably Givetian *aleskanus* Zone; near Fort Good Hope, District of Mackenzie. 35 and 36. Holotype, GSC 29532; Ramparts Formation, Givetian *laevis* Zone; Mackenzie River 2¾ miles above Fort Good Hope, District of Mackenzie.

Diagnosis. Corallum trochoid with known maximum diameter 23.0 mm. Septa radially arranged, smooth to very faintly carinate, and up to 33x2 in number. Length of major septa normally less than 6.0 mm; length of minor septa 2.0 to 4.0 mm. Trabeculae coarse, monacanthate, with fibres typically lengthened at the periphery to form a septal stereozone; in longitudinal section the trabeculae are seen to be directed upwards at a low angle and when traced adaxially are flexed first in a downward direction and then upwards. Dissepimentarium with as many as three rows of globose dissepiments, but locally suppressed by the stereozone. Tabularium wide with essentially flat tabularial surfaces.

Description. The corallum is solitary, trochoid and may be either erect or slightly curved. Although the length of the larger specimen was only 35.0 mm when collected, it was incomplete and probably originally measured at least 45.0 mm; the greatest diameter of the calice, which is circular in transverse section, is 23.0 mm. There is no evidence of budding or of any prominent rejuvenescences. Longitudinal sections show that the calice would have an extremely narrow peripheral platform, steep sides and a more or less flat base. Fine growth ridges, distinct septal grooves and almost flat interseptal ridges are visible on the exterior.

A peripheral stereozone, 1.0 to 2.0 mm wide, is present, although it commonly includes some interseptal loculi. It is due primarily to dilation of the septa but in places incorporates sclerenchyme. There is no epitheca, the outer wall enclosing interseptal loculi appears to be formed solely of elongated fibres emanating from adjacent septa. The septa, which number 33x2 at 20.0 mm diameter in the holotype and 25x2 at 22.0 mm diameter in the paratype are clearly, but not strongly differentiated into two orders. Normally major and minor septa are 3.0 to 6.0 and 2.0 to 4.0 mm long respectively. A weak fossula is suggested by slight elongation of two adjacent major septa accompanied by gentle depression of the tabulae on one side of the paratype (*see* Textfig. 36). Septal surfaces are smooth, especially where they are invested with sclerenchyme, or due to discrepant lengthening of trabecular fibres may be finely carinate. In transverse section some septa appear cuneate while others are fusiform. In longitudinal section the trabeculae, which have moderately divergent fibres and extend for the entire length of the septum, are seen to be directed upwards at low angles in the peripheral region and to be deflected at first downwards and then upwards as they are traced towards the axis.

Where the septal stereozone is less than fully developed, as many as three rows of small, strongly inflated dissepiments may be present. In early stages some dissepiments of the outermost row are noticeably smaller than others. The relatively wide tabularium consists mostly of large, in places complete, and essentially flat lying tabulae, supplemented peripherally by a few steeply inclined tabellae. Some small, flat-lying, vesicular tabulae are present also. In early growth stages sclerenchyme may be deposited profusely on tabularial surfaces; in later stages these deposits are much less developed.

Discussion. Alaiophyllum jarushevskyi apparently has a weakly fasciculate corallum composed of narrower (16.0 mm diameter or less) subcylindrical corallites. It also has a more uniform septal stereozone and very much less sclerenchyme than the new species.

The paratype comes from the collection identified by Lenz (1961) as "*Cyathophyllum*" *kobehense*, but that species (*see* Stumm, 1938) has much longer and thinner septa and may well be a species of *Moravophyllum.*

The trivial name is a patronym in honour of V. B. Goryanov, author of the genus *Alaiophyllum.*

Associated faunas. Forms collected with the holotype include *Argutastrea arctica* (Meek), *Moravophyllum* spp. nov., *Stringophyllum* sp. cf. *S. buechelense* (Schlüter), *Schizophoria* sp., "*Atrypa*" *hormophora* Crickmay, *Spinatrypa* sp., *Cyrtina* sp., *Rensselandia laevis* (Meek), and *Stringocephalus asteius* Crickmay. This assemblage is entirely typical of the *Rensselandia laevis* Zone in the Mackenzie Valley region.

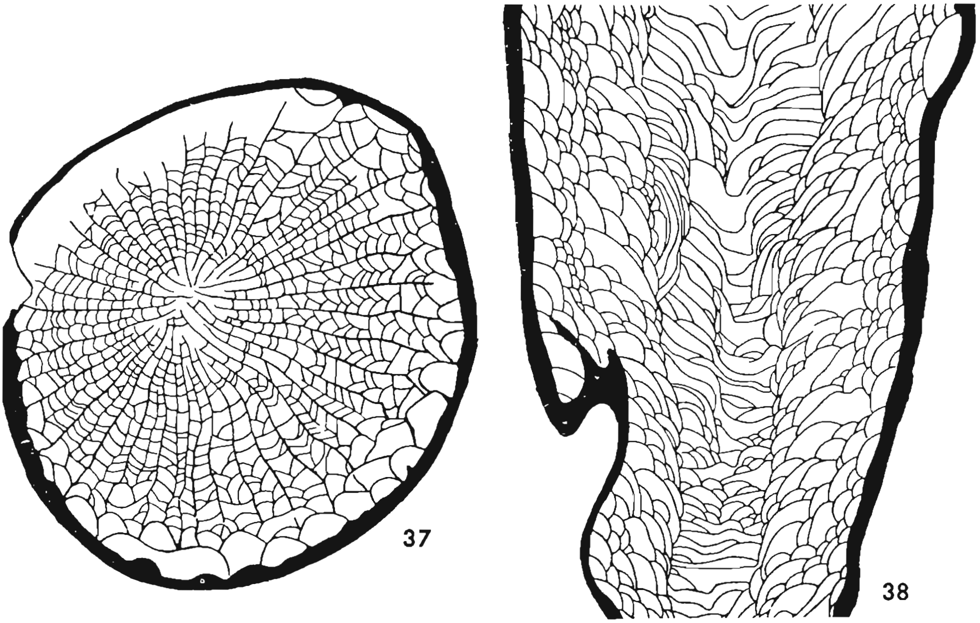
Corals associated with the paratype include specimens of *Temnophyllum richardsoni* (Meek). This and the stratigraphical data available strongly suggest that the collection is from the *Stringocephalus aleskanus* Zone.

Family SPONGOPHYLLIDAE Dybowski, 1873

Genus ***Grypophyllum*** Wedekind, 1922

Neostringophyllum Wedekind, 1922, p. 8, 16.
Grypophyllum Wedekind, 1922 (in part), p. 13 (includes a species of *Stringophyllum*).
Leptoinophyllum Wedekind, 1925, p. 4.
Stenophyllum Wedekind, 1925 (in part), p. 9 (includes species of *Dohmophyllum*).
Hooeiphyllum Taylor, 1951, p. 173, 174.
not *Stenophyllum* Verhoeff, 1897, p. 122 (a recent myriapod).

Type species (by original designation). *Grypophyllum denckmanni* Wedekind, 1922, p. 13, 14, Textfigures 13, 14; Bücheler Schichten (Givetian), Bergisch-Gladbach, Germany. The holotype of this species is refigured in Textfigures 37 and 38 and figure 5 of Plate 12 of the present work. Wedekind's (1925, p. 14) subsequent designation of *Grypophyllum isactis* (Frech) as the type species of *Grypophyllum* is invalid.

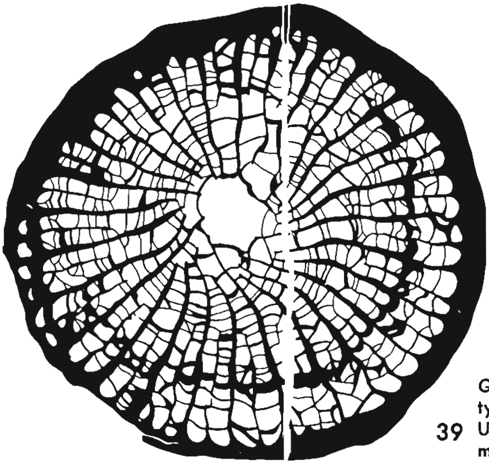


TEXTFIGURES 37 and 38. *Grypophyllum denckmanni* Wedekind; both x3. Holotype; the thin section on which figure 37 is based is registered with the Natur-Museum Senckenberg as SMF WDKD 3949; the section represented by figure 38 is now lost; Bücheler Schichten, Givetian; Bergisch-Gladbach, Germany. Copied from Wedekind, 1922, p. 14.

Taxa assigned. Cyathophyllum vermiculare Goldfuss, 1826 (holotype figured by Gräf, 1958); *Strephodes gracilis* McCoy, 1850 (lectotype figured by Pedder, 1964); *Cyathophyllum robustum* Maurer, 1885 (homonym of *C. robustum* Hall, 1876, type species of *Bethanyphyllum* Stumm); *Cyathophyllum vermiculare* mut. *praecursor* Frech, 1886 (neotype figured by Gräf, 1958); *Grypophyllum denckmanni* Wedekind, 1922; *Neostringophyllum ultimum* Wedekind, 1922 (type species of *Neostringophyllum* Wedekind, holotype refigured in this work); *Cyathophyllum torquatum* var. *orientale* Reed, 1922; *Leptoinophyllum looghense* Wedekind, 1925 (holotype figured by Birenheide, 1962); *Leptoinophyllum multiseptatum* Wedekind, 1925 (type species of *Leptoinophyllum* Wedekind); *Stenophyllum hedstroemi* Wedekind, 1925; *Stenophyllum caiqua* Wedekind, 1925; *Stenophyllum diluvianum* Wedekind, 1925 (type species of *Stenophyllum* Wedekind); *Stenophyllum convolutum* Wedekind, 1925; *Grypophyllum gracile* Wedekind, 1925 (secondary homonym of *G. gracile* (McCoy, 1850)); *Grypophyllum tenue* Wedekind, 1925; *Grypophyllum regressum* Wedekind, 1925; *Grypophyllum normale* Wedekind, 1925 (type species of *Hooeiphyllum* Taylor); *?Leptoinophyllum smyckai* Kettnerová, 1932; *Grypophyllum gorskyi* Bulvanker, 1934 (lectotype figured by Soshkina, 1949); *Grypophyllum cynacanthicum* Soshkina, 1949; *Hooeiphyllum stummi* Taylor, 1951; *Grypophyllum wedekindi* Middleton, 1959 (replacement for *G. gracile* Wedekind, 1925); *Ptenophyllum butovi* Bulvanker, 1958; *Alaiophyllum mackenziense* Pedder, 1963; *Grypophyllum unduliseptatum* Ivaniya, 1965; *Grypophyllum clarifundatum* Ivaniya, 1965; *Grypophyllum arcticum* Bulvanker *in* Bulvanker *and others*, 1968; *Grypophyllum lonsdaleioides* Tsien, 1969; *Grypophyllum aquilonium* Pedder n. sp.; *Grypophyllum subtile* Pedder n. sp.; *Grypophyllum crickmayi* Pedder n. sp.

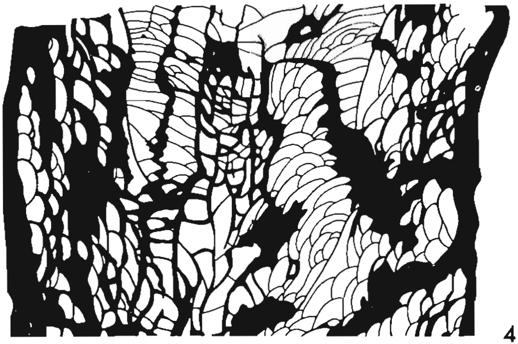
Taxa rejected. Stenophyllum intermedium Wedekind, 1925 (= *Dohmophyllum*); *Stenophyllum implicatum* Wedekind, 1925 (= *Dohmophyllum*); *Stenophyllum maximum* Wedekind, 1925 (= *Dohmophyllum*); *Grypophyllum schwelmense* Wedekind, 1925 (= *Stringophyllum*); *Neostringophyllum praecursor* Walther, 1928 (= ?"*Neostringophyllum*"); *Neostringophyllum inchoatum* Walther, 1928 (= "*Neostringophyllum*"); *Neostringophyllum planum* Walther, 1928 (= "*Neostringophyllum*"); *Neostringophyllum simplex* Walther, 1928 (= "*Neostringophyllum*"); *Neostringophyllum concavum* Walther, 1928 (= "*Neostringophyllum*"); *Neostringophyllum complicatum* Walther, 1928 (= "*Neostringophyllum*"); *Neostringophyllum coniforme* Walther, 1928 (= "*Neostringophyllum*"); *Neostringophyllum regressum* Walther, 1928 (= "*Neostringophyllum*"); *?Leptoinophyllum moravicum* Kettnerová, 1932 (= *?Acanthophyllum*); *Grypophyllum nevadense* Stumm, 1937 (= *?Moravophyllum*); *Grypophyllum giganteum* Stumm, 1937 (= *?Moravophyllum*); *Grypophyllum curviseptatum* Stumm, 1937 (= *?Moravophyllum*); *Grypophyllum aggregatum* Hill, 1940 (= *Embolophyllum*); *Neostringophyllum litvinovitchi* Soshkina, 1941 (= cyathophyllid, broad sense); *Grypophyllum compactum* Hill, 1942 (= *Embolophyllum*); *Neostringophyllum isetense* Soshkina, 1951 (= *Temnophyllum*); *Neostringophyllum pronini* Soshkina, 1951 (= *Temnophyllum*); *Grypophyllum pestereviense* Zhmaev *in* Khalfin, 1955 (= *Redstonea*); *Grypophyllum fasciculum* Zhmaev *in* Khalfin, 1955 (= *Redstonea*); *Grypophyllum vilvense* Spasskiy, 1955 (= "*Neostringophyllum*"); *Grypophyllum lebedewi* Ma, 1956 (= *Smithiphyllum*); *Neostringophyllum zintchenkoae* Ivaniya, 1957 (genus undetermined); *Grypophyllum gracile* var. *kuznetskiense* Bulvanker, 1958 (= *Redstonea*); *Grypophyllum salairicum* Bulvanker, 1958 (= "*Neostringophyllum*"); *Grypophyllum wedekindi* Ivaniya *in* Khalfin, 1961 (unadjusted primary homonym of *G. wedekindi* Middleton, 1959, applied to a species of "*Neostringophyllum*"); *Grypophyllum cornus* McLaren, *in* McLaren and Norris, 1964 (= ?cyathophyllid, broad sense); *Neostringophyllum craigi* McLaren *in* McLaren and Norris, 1964 (= "*Neostringophyllum*"); *Grypophyllum graciliseptatum* Pedder, 1964 (= *Redstonea*); *Neostringophyllum fameniense* Ivaniya, 1965 (= cyathophyllid, broad sense); *Grypophyllum* *ceriosum* Ivaniya, 1965 (= *?Redstonea*); *Grypophyllum minimum* Ivaniya, 1965 (= *Redstonea*); *Acanthophyllum* (*Neostringophyllum*) *implicatum* Strusz, 1966 (= "*Neostringophyllum*"); *Acanthophyllum* (*Neostringophyllum*) *turni* Strusz, 1966 (= "*Neostringophyllum*"); *Acanthophyllum* (*Grypophyllum*) *jenkinsi* Strusz, 1966 (= "*Neostringophyllum*"); *Grypophyllum paraagregatum* Bulvanker, 1968 (= *?Redstonea*); *Grypophyllum antiquum* Sytova, 1968 (= *?Neomphyma*); *Grypophyllum mirabile* Sytova, 1968 (= "*Neostringophyllum*"); *?Grypophyllum reimani* Lavrusevich, 1968 (*?nomen nudum*); *Grypophyllum tortum* Tsien 1969 (= "*Neostringophyllum*").

Definition. Solitary, ceratoid to subcylindrical tetracorals with an inversely conical calice (Trichterkelch of German authors). Outer surface lacks regular interseptal ridges and septal grooves. The exterior wall, which is 0.15 to 2.5 mm thick at points midway between adjacent septa, commonly appears to consist of septal ends embedded in lamellar skeleton, although the lamellar appearance is now believed to be a secondary phenomenon (Kato, 1963; Sorauf, 1971). Septa are radial to weakly pinnate in arrangement and usually have a fibro-normal fine structure. Typically they are smooth and thin throughout their length, or if thickened, as


39

TEXTFIGURES 39 and 40

Grypophyllum ultimum (Wedekind); both x3. 39. Holotype, Natur-Museum Senckenberg SMF WDKD 4044; Upper Stringocephalenkalk, Givetian; Düsseltal, Germany. 40. Holotype or paratype, Natur-Museum Senckenberg SMF WDKD 5987; Upper Stringocephalenkalk, Givetian, Düsseltal, Germany. Drawn from polaroid photographs taken by D. J. McLaren.


40

in the type species of *Neostringophyllum*, the thickening is modest and tends to continue almost to the axial tips of the septa. Carinae are exceedingly rare, and if present are invariably fine. Major septa are long and may be slightly rotated about the axis. Minor septa vary from species to species; where they are well developed they are at least one half as long as the major septa; where they are poorly developed they may be almost totally suppressed, apart from the infra-laterals (term from Hudson, 1936, p. 71) on either side of the counter septum, which are normally well developed. The adult dissepimentarium consists of one to sixteen rows of relatively large and inwardly inclined dissepiments, some of which may be lonsdaleoid. The tabularium is usually clearly differentiated from the dissepimentarium. Tabulae are typically incomplete and commonly form axially depressed tabularial surfaces. They are closely spaced so that 15 to 35 may be counted over a vertical distance of 1.0 cm. Ratios of the diameter of the tabularium to that of the entire corallite (Dt/Dc) vary from 0.25 to 0.75. Sclerenchymal deposits may periodically invest calicular surfaces.

Discussion. In Birenheide's (1961) revision of *Acanthophyllum* and related genera, *Neostringophyllum* and *Grypophyllum* were given subgeneric rank in the genus *Acanthophyllum*. The subgenera were differentiated from *Acanthophyllum*, strictest sense, primarily on the basis of calicular form, which is bell-shaped ("Krempenkelch") in *Acanthophyllum* and inversely conical ("Trichterkelch") in *Neostringophyllum*. *Grypophyllum* was distinguished from *Neostringophyllum* by having a narrower wall, finer septa and common lonsdaleoid dissepiments. Unfortunately this classification cannot be applied to species described in this work as the commonest has a wide wall, fine septa, and rare lonsdaleoid dissepiments. Furthermore, photographs of *Neostringophyllum ultimum*, the type species of *Neostringophyllum*, given to me by D. J. McLaren, show that this is not necessarily congeneric with species attributed to *Neostringophyllum* by Birenheide. In *N. ultimum* septa are smooth and not attenuated within the tabularium, whereas in species ascribed to the genus by Birenheide, and also some subsequent workers, the septa are thicker in the peripheral region than elsewhere and are markedly carinate within the tabularium. In view of this I provisionally regard *Neostringophyllum*, in the strictest sense, as being congeneric with *Grypophyllum* and distinct from the carinate forms. The carinate forms are close to *Embolophyllum* (Pedder, 1967), but are solitary rather than colonial. At the moment no generic name is available for them.

Neostringophyllum has page priority over *Grypophyllum*. However, taxonomic stability will better be served by using the name *Grypophyllum* in preference to *Neostringophyllum* (I.C.Z.N. Recommendation 24A).

Grypophyllum is distinguished from *Redstonea* Crickmay (1968b) by virtue of its solitary corallum.

Distribution. Grypophyllum has been reported from the Lower Devonian of Nevada (Oliver *in* Johnson 1965), and Queensland (Hill *in* de Keyser and Wolff, 1964). I have not seen the Nevada material, but have studied forms identified (Philip and Pedder, 1968) as *Lyrielasma* sp. cf. *L. chapmani* Pedder, which may be the same as the Chiligoe specimens reported in de Keyser and Wolff's work.

Eifelian occurrences of *Grypophyllum* are known in: south Devon, England (Taylor, 1951); Dinant Basin, Belgium (Tsien, 1969); Rhenish Mountains, Germany (Frech, 1886; Ma, 1937, 1956; Gräf, 1958; Birenheide, 1961, 1962); ? Harz Mountains, Germany (Roemer, 1855; Gräf, 1958); River Ay, southern Urals, U.S.S.R. (Soshkina, 1949); Kuznetsk Basin, U.S.S.R. (Bulvanker, 1958); Omulevsk Mountains, U.S.S.R. (Bulvanker, 1965); and southern District of Mackenzie, Canada (Pedder, 1971; age revised by Pedder and Uyeno, *in press*).

From Givetian strata the genus is known in the following areas: south Devon, England (Taylor, 1951; Middleton, 1959; Scrutton, 1966); Deux Sèvres, France (Le Maître, 1937); Pyrénées, south France (Mirouse, 1966); Dinant Basin, Belgium (Tsien, 1968); ? Vosges Mountains, France (Firtion, 1957); Rhenish Mountains, Germany (Maurer, 1885; Frech, 1886; Wedekind, 1922, 1925; Engel and v. Schouppé, 1958; Birenheide, 1961); ? Graz region, Austria (Gräf, 1958); Moravia, Czechoslovakia (Kettnerová, 1932; Špinar, 1946); Novaya Zemlya (Bulvanker, 1968); Rivers Mal. Patok and Tschugar, northern Urals, U.S.S.R. (Soshkina, 1936); River Usva, central Urals, U.S.S.R. (Bulvanker, 1934; Soshkina, 1949); Rivers Ay and Irgizla, southern Urals, U.S.S.R. (Soshkina, 1949); Chitral, west Pakistan (Reed, 1922; v. Schouppé, 1965); Kuznetsk Basin, U.S.S.R. (Zhmaev *in* Khalfin, 1955; Ivaniya *in* Khalfin, 1961; Ivaniya, 1965); central Mackenzie Valley, Canada (this paper) and Great Slave Lake, Canada (this paper). Tabularial surfaces in a specimen figured by Ma (1956, pl. 41, figs. 2a, b) as *Campophyllum traversense* (Winchell) from Michigan, sag prominently at the axis, and may indicate a species of *Grypophyllum*. Normally the tabulae of *Tabulophyllum traversense* are broadly elevated over the axial and periaxial region (Sloss, 1939; Watkins, 1959; Stumm, 1962).

Grypophyllum is described in this work from beds equivalent to the upper *hermanni-cristatus* conodont zone in southern District of Mackenzie and central Alberta, Canada. These occurrences may be either latest Givetian or earliest Frasnian depending on where the Givetian–Frasnian boundary is drawn.

Reworked specimens of *Grypophyllum* have been reported from the New Red Sandstone of Devon, England (Hutchins, 1958; Middleton, 1959) and the Permo-Carboniferous Joe Joe Formation of Queensland (Mollan *and others*, 1969). It is also possible that the coral represented by figure 9 of Termier and Termier's (1950) Plate 48, which is from a Givetian pebble in Viséan beds at Bou Zekkour, Morocco, is a specimen of *Grypophyllum*.

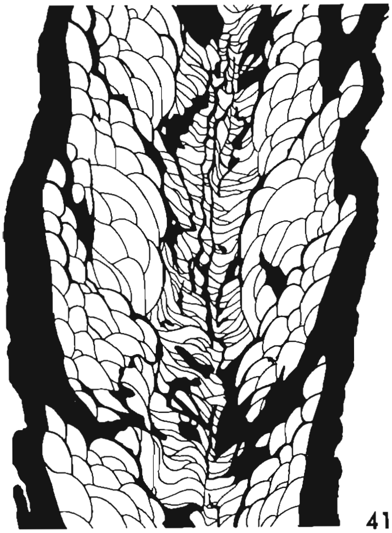
Grypophyllum aquilonium new species

Plate 12, figures 1, 4, 6; Textfigures 41, 42

Type series. Holotype, GSC 29534; Hare Indian Formation, immediately above a fault contact with the Canol Formation and 65 feet below an unfaulted contact between the Hare Indian and Canol Formations, Givetian; scarp 10¾ miles due north of the centre of Mackenzie River opposite Little Chicago, lat. 67°20½'N, long. 130°17'W (Textfig. 1, loc. 8); collected by W. S. MacKenzie, July 1968, GSC loc. C-3257.

Diagnosis. A subcylindrical species of *Grypophyllum* having a known maximum mean diameter of 14.5 mm and length of at least 55.0 mm. Wall 0.7 to 1.5 mm thick. 26x2 septa at maturity. Minor septa short. Dissepimentarium with as many as six rows of dissepiments, including some that are lonsdaleoid. Tabularium narrow, Dt/Dc 0.28 to 0.30. Calicular surfaces periodically invested with sclerenchyme.

Description. Before sectioning, the specimen, which is completely enveloped by a stromatoporoid, was 42.0 mm long and had mean diameters of 9.0 and 14.5 mm at the proximal and distal ends respectively. As some of the proximal end was missing and there was no indication of a calice, the complete coral could not have been less than 55.0 mm long. In transverse section the exterior is undulating, generally so that the outwardly convex parts are situated opposite septal bases. The exterior is also undulating in longitudinal section, and in two places there is evidence of minor rejuvenescences. The calice would be inversely conical.



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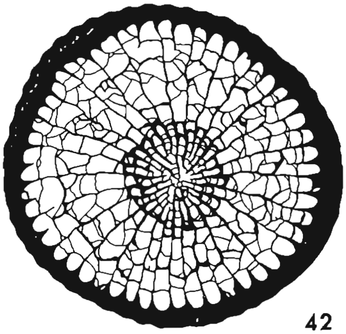


42

TEXTFIGURES 41 and 42

Grypophyllum aquilonium new species; both x3. Holotype, GSC 29534; Hare Indian Formation, Givetian; 10¾ miles north of Little Chicago, District of Mackenzie.

The wall is well developed at all stages, especially in early stages when it may attain a thickness of 1.5 mm; in late stages it is 0.7 to 1.0 mm thick. There are 25x2 septa where the diameter of the coral is 9.0 mm and 26x2 where it is 14.5 mm. At first glance the septa appear to be radially arranged, but closer inspection reveals a bilateral symmetry about elongated counter and cardinal septa. Septa of both orders tend to be wavy, without being carinate, and may be interrupted by lonsdaleoid dissepiments. Major septa extend far into the tabularium where they are noticeably dilated periodically. Some minor septa consist solely of a narrow peripherally situated lamella, typically only 0.5 to 1.5 mm long; in others this is supplemented adaxially by weakly developed septal crests; the infra-lateral minor septa on either side of the counter septum are about as long as the least of the major septa.

In adult stages there are five or six rows of moderately inflated dissepiments; the more peripherally situated dissepiments tend to be smaller and less steeply inclined than the interior ones. Transition from dissepimentarium to tabularium is sharp. Tabulae are incomplete, and although individually they may be concave, convex, or even sigmoidal, collectively they normally form axially depressed tabularial floors. Approximately 25 tabulae occur in a vertical distance of 1.0 cm. The ratio of the diameter of the tabularium to the diameter of the corallite (Dt/Dc) is 0.28 to 0.30. Periodically both tabularial and dissepimentarial surfaces were invested with sclerenchyme.

Discussion. Grypophyllum gracile (McCoy), which is probably based on a Givetian specimen from Devon (*see* Pedder, 1964), is a similar species, but is slightly larger (mean diameter 16.6 mm), has a thinner wall (0.2 to 0.5 mm), and almost totally suppressed minor septa; furthermore it seems to entirely lack sclerenchyme. *Grypophyllum wedekindi* Middleton has fewer septa (usually about 23x2), of which the minor are almost totally suppressed, and a relatively wider tabularium (Dt/Dc 0.34 to 0.41). *Grypophyllum arcticum* Bulvanker is larger (up to 19.0 mm in diameter), has more septa (29x2 to 31x2) and a relatively wider tabularium (Dt/Dc about 0.38).

The trivial name *aquilonius, a, um* is from the Latin, meaning northern.

Associated fauna. The fauna from 55 to 65 feet below the top of the Hare Indian Formation at the type locality (GSC locs. C-3256, C-3257) includes *Stachyodes* sp., *Alveolites* sp., *Tabulophyllum* sp. nov., *Schizophoria* sp., *Spinatrypa* sp., *Emanuella* sp., *Cyrtina*, and fragments of more than one species of trilobite. The precise age of this fauna has not been established; however, it is extremely unlikely to be anything other than Givetian.

Grypophyllum subtile new species

Plate 13, figures 1–3; Textfigures 43, 44

Type series. Holotype, GSC 29535; Ramparts Formation, within 8 feet of the base in the Givetian *Rensselandia laevis* Zone; right bank of Mackenzie River at the Ramparts above Fort Good Hope, lat. 66°14′N, long. 128°42½′W (Textfig. 1, loc. 9); collected by W. S. MacKenzie, June 1968, GSC loc. C-1859. Paratype, GSC 29536; Ramparts Formation, 138 to 141 feet above the base of the exposure, 0 to 3 feet below the top of the exposure, probably late Givetian; left bank of Mackenzie River, 5½ miles above Fort Good Hope, lat. 66°14′N, long. 128°50′W (Textfig. 1, loc. 9); collected by A. E. H. Pedder, June 1968, GSC loc. C-2523.

Diagnosis. Small subcylindrical species of *Grypophyllum* with mean adult diameter of 7.0 to 8.5 mm and a known maximum length of about 25.0 mm. Wall 0.2 to 1.0 mm thick. Septa numbering 22x2 to 24x2 in adult stages. Major septa weakly pinnate; minor septa reduced. Adult dissepimentarium normally with two to four rows of dissepiments. Tabularium narrow, Dt/Dc 0.29 to 0.31.

TEXTFIGURES 43 and 44

Grypophyllum subtile new species; both x3. 43. Holotype, GSC 29535; Ramparts Formation Givetian *laevis* Zone; Mackenzie River above Fort Good Hope, District of Mackenzie. 44. Paratype, GSC 29536; Ramparts Limestone, late Givetian part?; Mackenzie River 5½ miles above Fort Good Hope, District of Mackenzie.

Description. The types consist of two solitary, subcylindrical corallites, both lightly invested with stromatoporoids. Before sectioning, the paratype, which is slightly the larger specimen, was about 17.0 mm long, but as this excluded the proximal tip and the entire calice, it could not have been less than 25.0 mm long when complete; the greatest mean diameter is 8.5 mm. Longitudinal sections show numerous minor constrictions, and one rejuvenescence in the paratype. In transverse section the exterior may be either undulating or smooth. The calice would be inversely conical with a moderately wide base.

The wall varies in thickness from 0.5 to 1.0 mm; around part of the holotype it undulates in such a way that the outward convexities might be considered as interseptal ridges, and the concavities septal grooves; in other parts of the holotype and all around the paratype such undulations are absent or weak. Septal arrangement is slightly pinnate about the elongated cardinal and counter septa. Septa are thin and smooth, and in adult stages number 22x2 to 24x2. Most major septa fail to reach the axis by a distance of approximately 0.5 mm. Minor septa, including the infra-laterals, are usually between 0.2 and 0.5 mm long. The two orders of septa are not uniformly alternating, in one place two major septa occur together and in another two minor septa are side-by-side.

Two to four rows of moderately inflated, relatively large and steeply inclined dissepiments are present. The transition from dissepimentarium to tabularium is abrupt. Tabulae are incomplete and closely spaced, 30 to 35 occur in a vertical disance of 1.0 cm. Typically the tabularial surfaces are depressed at the axis, in places markedly so. The ratio between the diameter of the tabularium and that of the entire corallite (Dt/Dc) is 0.29 to 0.31.

Discussion. Grypophyllum gorskyi Bulvanker, from Givetian beds in the southern Urals, is as small as the new species, but has only 17x2 or 18x2 septa. It further differs in having well-developed minor septa and even larger dissepiments.

The trivial name *subtilis, is, e* is the Latin word meaning delicate.

Associated fauna. The holotype is from a collection that also contained *Stringophyllum* sp. cf. *S. buechelense* (Schlüter) and "*Atrypa*" *hormophora* Crickmay and is certain to have come from the *Rensselandia laevis* Zone. The collection yielding the paratype includes species of *Stachyodes*, *Thamnopora*, *Alveolites*, *Spinatrypa*, and *Emanuella.* This list is not diagnostic of any zone; however a collection (GSC loc. C-2524) made 10 to 14 feet lower in the section includes *Temnophyllum richardsoni* (Meek), which has only a slightly longer range than *Stringocephalus aleskanus* Zone, and has never been found in beds as young as the *mackenziense* Zone.

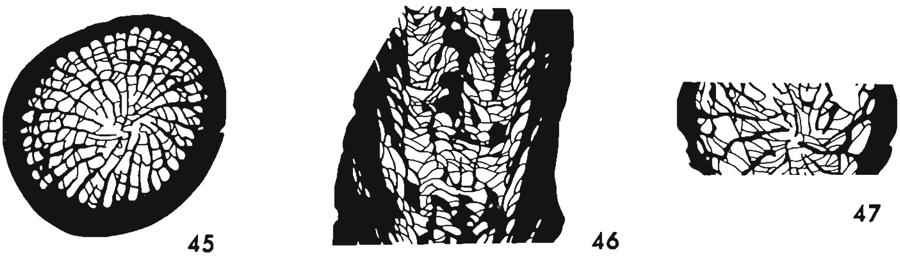
Grypophyllum crickmayi new species

Plate 13, figures 4–6; Textfigures 45–47

Type series. Holotype, GSC 29537; Sulphur Point Formation, Givetian part at a depth of 660 to 664 feet; N.W.T. Deep Bay No. 2 well, lat. 68°18'N, long. 116°48'W (Textfig. 1, loc. 17); collected from core by C. H. Crickmay, Imperial Oil Limited. Paratypes 1 and 2, GSC 29538, 29539; Sulphur Point Formation, Givetian part at a depth of 678 feet; same well as holotype; collected from core by A. E. H. Pedder, February 1971, GSC loc. C-8661.

Diagnosis. Small subcylindrical species of *Grypophyllum* with maximum known mean diameter of 9.8 mm. Wall 0.5 to 1.3 mm thick. Septa relatively thick and numbering 21x2 to 23x2 at maturity. Minor septa variable, commonly one quarter to one half as long as the major septa. Dissepiments in two to four rows, not normally lonsdaleoid. Dt/Dc 0.43 to 0.50. Sclerenchyme typically abundant.

Description. None of the type specimens is complete. The holotype, which was the largest, was a fragment of an apparently subcylindrical coral, measuring 17.0 mm long and 9.8 mm in diameter before sectioning. The paratypes have similar mean diameters of 9.5 and 9.7 mm,



TEXTFIGURES 45 to 47. *Grypophyllum crickmayi* new species; all x3. 45. Paratype 1, GSC 29538; Sulphur Point Formation, Givetian part at a depth of 678 feet; N.W.T. Deep Bay No. 2 well, District of Mackenzie. 46. Holotype, GSC 29537; Sulphur Point Formation, Givetian part at a depth of 660 to 664 feet; N.W.T. Deep Bay No. 2 well, District of Mackenzie. 47. Paratype 2, GSC 29539; same occurrence as paratype 1, Textfigure 45.

but were shorter. Transverse sections reveal a more or less smooth exterior; minor rejuvenescences are evident in longitudinal sections. The calice would be inversely conical.

The well-developed wall ranges in thickness from 0.5 to 1.3 mm, measured midway between adjacent septa. In adult stages there are 21x2 to 23x2 subradially to weakly pinnately arranged septa. They are relatively thick for the genus and may be slightly wavy, but not truly carinate. Although differing in length, major septa are sufficiently long as to leave no axial space. Minor septa also vary in length; the shortest are almost totally suppressed, whereas the longest, apart from the infra-laterals which may be almost as long as some of the major septa, are about one half as long as the major septa.

There are two to four rows of moderately long and markedly inwardly inclined dissepiments; only rarely do those disrupt septa. The transition from dissepimentarium to tabularium is abrupt, although it is not so sharp as in some species of the genus. Tabulae are mostly far from complete and some are distinctly vesicular. Tabularial surfaces may be slightly depressed or strongly elevated axially. Approximately 30 tabulae occur in a vertical distance of 1.0 cm. Moderate to thick sclerenchymal deposits commonly invest dissepimentarial surfaces. The ratio of the diameter of the tabularium to the diameter of the corallite (Dt/Dc) is 0.43 in the holotype and 0.50 in paratype 2.

Discussion. Grypophyllum crickmayi resembles *G. ultimum* (Wedekind), the type species of *Neostringophyllum*, in having septa that are relatively thicker than those of most other species of the genus and in having well-developed minor septa. However, Wedekind's species is much larger with a diameter of more than 20.0 mm and has 28x2 septa.

The trivial name is a patronym in honour of the first author to recognize the stratigraphical importance of *Grypophyllum mackenziense.*

Associated fauna. Fossils occurring with *Grypophyllum crickmayi* in the Deep Bay No. 2 well are stromatoporoids of the genera *Amphipora* and *Stachyodes.* These are not diagnostic of any narrow interval, but fortunately correlation with the nearby (lat. 61°16′N; long.116°54′W) Deep Bay No. 1 well is reasonably well established. On the basis of this correlation and on other faunas in the Deep Bay No. 2 well, it is evident that *Grypophyllum crickmayi* occurs about 290 feet below a specimen (GSC 29554) tentatively identified as *Grypophyllum mackenziense* and approximately 5 to 40 feet above strata containing *Stringocephalus parasulcatus* Crickmay (1968a). According to Crickmay (*op. cit.*) *Stringocephalus parasulcatus* is just younger than *Stringocephalus aleskanus*; provided that this is correct, *Grypophyllum crickmayi* should derive from very late Givetian beds equivalent to the lower *hermanni–cristatus* conodont zone.

Grypophyllum mackenziense (Pedder, 1963)

Plate 13, figures 7–12; Plate 14, figures 1–8;
Plate 15, figures 1–3, ?4, 5–10; Textfigures 48–58

?*Grypophyllum* cf. *G. gracile* Wedekind, McLaren, Norris, and McGregor, 1962, Pl. 4, figs. 5, 6.
Alaiophyllum mackenziense Pedder, 1963, p. 133, 134, Pl. 19, figs. 1–6.
Alaiophyllum sp., McLaren *in* Murray, 1966, p. 20.
Alaiophyllum cf. *mackenziense* Pedder, Crickmay, 1966, p. 31.
Alaiophyllum mackenziense Pedder, Crickmay, 1968a, p. 1–3.
Grypophyllum cf. *gracile* Wedekind, Fischbuch, 1968 (in part), p. 521 only (not Pl. 20, fig. 5).
?Rugose coral, Fischbuch, 1968, Pl. 20, fig. 4.
Alaiophyllum mackenziense Pedder, Crickmay, 1970, p. 76.
Grypophyllum cf. *G. wedekindi* Middleton, Pedder *in* Norford *and others.* 1970, p. 10.
"*Alaiophyllum*" sp. ex gr. "*A.*" *mackenziense* Pedder, MacKenzie, 1971, p. 491.
not *Alaiophyllum mackenziense* Pedder, Fischbuch, 1968, p. 521 (indeterminate specimen).

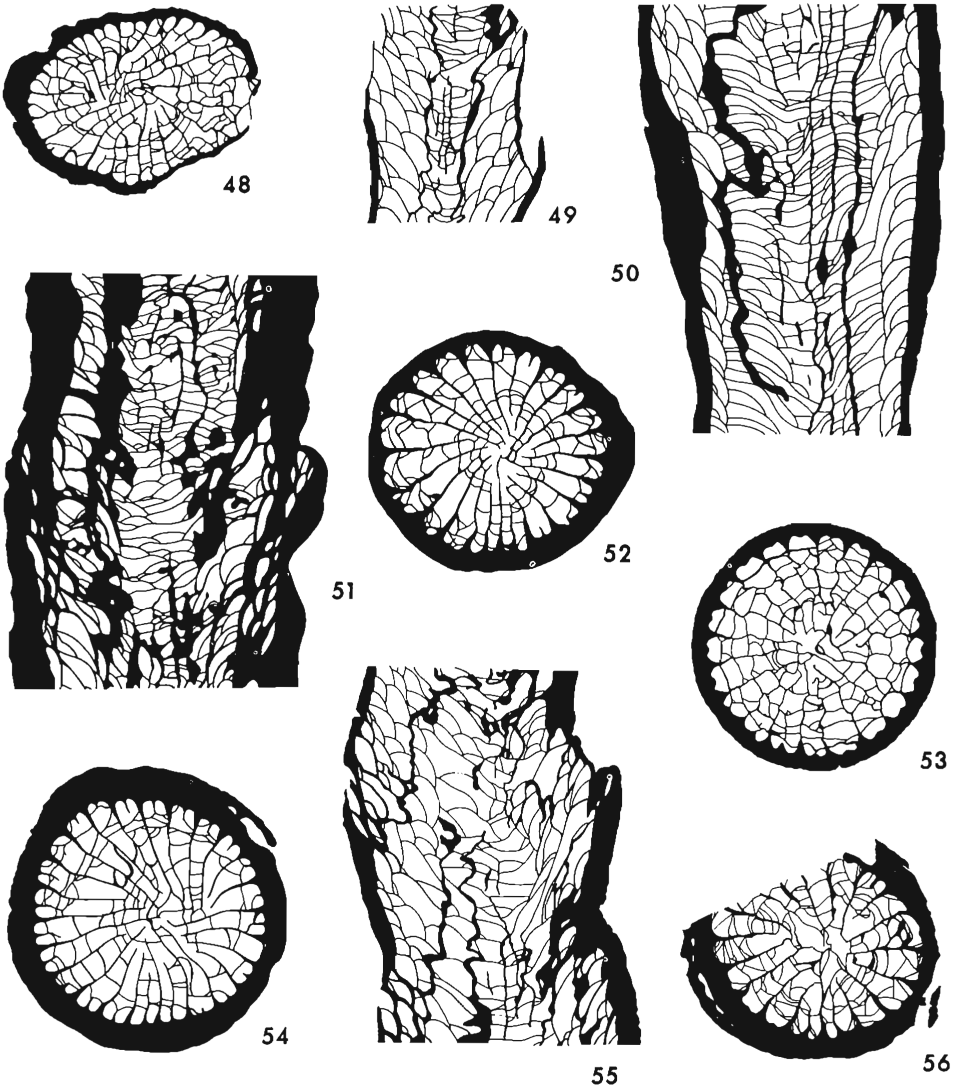
Material. Holotype, GSC 16850, paratypes 1, 2, GSC 16851, 16852; Ramparts Formation, broad sense, 0–140 feet above base of exposure; Kee Scarp, 4½ miles northeast of Norman Wells, approximately lat. 65°17½'N, long. 126°43½'W (Textfig. 1, loc. 14); collected by A. E. H. Pedder, September 1959, Triad Oil Co. Ltd. D107. Hypotype 1, GSC 29540; Ramparts Formation, broad sense, 234 to 239 feet below top, at least 177 to 182 feet above base at a depth of 1,257 to 1,262 feet; Imperial Norman Wells No. 37X well, lat. 65°16'57"N, long. 126°51'50"W (Textfig. 1, loc. 14); collected from core by C. H. Crickmay, Imperial Oil Limited. Hypotypes 2 to 6, GSC 29541 to 29545; Upper Sulphur Point Formation, isolated outcrop; Burnt Point, Great Slave Lake, lat. 61°15'N, long. 115°51½'W (Textfig. 1, loc. 16); collected by A. E. H. Pedder, September 1960, Triad Oil Co. Ltd. G10180. Hypotype 7, GSC 29546; Upper Sulphur Point Formation at a depth of 5,846 feet; Union Pan Am Trainor L-59 well, lat. 60°28'33"N, long. 120°40'50"W (Textfig. 1, loc. 18); collected from core by H. R. Belyea, GSC loc. C-3984. Hypotype 8, GSC 29547; Upper Sulphur Point Formation at a depth of 5,853; same well and collector as hypotype 7, GSC loc. C-3985. Hypotypes 9 to 11, GSC 29548 to 29550; platform of the Swan Hills Formation at a depth of 8,140 feet; Canadian Kewanee A-30 Swan Hills 2-5-69-10W5 well (Textfig. 1, loc. 22); collected from core by L. F. Jansa, GSC loc. C-5581. Hypotypes 12, 13, GSC 29551, 29552; platform of the Swan Hills Formation at a depth of 9,811 feet; Pan American A-1 Freeman 4-29-66-13W5 well (Textfig. 1, loc. 23); collected from core by L. F. Jansa, GSC loc. C-5587. Hypotype 14, GSC 29553; platform of the Swan Hills Formation at a depth of 7,903 feet; Imperial Kinakin 4-13-63-9W5 well (Textfig. 1, loc. 24); collected from core by J. W. Murray, GSC loc. 59780. Hypotype 15, Geological Museum, University of Saskatchewan, Coelenterata (Rugosa) no. 1; calcarenite at the top of the platform of the Swan Hills Formation at a depth of 9,697; Phillips Kaybob 2-15-64-19W5 well (Textfig. 1, loc. 23); collected from core by N. R. Fischbuch. Hypotypes 16, 17, GSC 29554, 29555; Slave Point Formation, 12 to 14 feet below top and 92 to 94 feet above base at depths of 4,308 to 4,310 feet; Union Red Earth 2-22-88-8W5 well (Textfig. 1, loc. 21); collected from core by H. R. Belyea, GSC loc. 37469. Hypotype 18 (questionably referred to the species), GSC 29556; Slave Point Formation, 21 to 26 feet below top at a depth of 366 to 371 feet; N.W.T. Deep Bay No. 2 well, lat. 61°18'N, long. 116°48'W (Textfig. 1, loc. 17); collected from core by C. H. Crickmay, Imperial Oil Limited (by a *lapsus calami* this occurrence is given as Deep Bay No. 1 in Crickmay 1968a). Unfigured specimen identified by Pedder *in* MacKenzie, 1971, as "*Alaiophyllum*" sp. ex gr. "*A.*" *mackenziense*; Ramparts Formation, broad sense, 5 to 10 feet below top, 90 to 95 feet above base; left side of Powell Creek Valley, lat. 65°16½'N, long. 128°46'W (Textfig. 1, loc. 15); collected by A. E. H. Pedder, July 1969, GSC C-3883. Unfigured specimen in Imperial Oil Ltd. collections identified by Crickmay, 1970, as *Alaiophyllum mackenziense*; Ramparts Formation, broad sense, 193 feet below top, 229 feet above base at a depth of 2,290 feet; Imperial Mac No. 1 well, lat. 65°15'30"N, long. 126°59'00"W (Textfig. 1, loc. 14); collected from core by C. H. Crickmay. Unfigured specimen in Imperial Oil Limited collections identified by Crickmay, 1968a, 1970, as *Alaiophyllum mackenziense*; platform of the Swan Hills Formation at a depth of 8,643 to 8,648 feet; Imperial Judy Creek 10-27-63-11W5 well (Textfig. 1, loc. 24); collected from core by C. H. Crickmay.

Diagnosis. Subcylindrical to less commonly ceratoid species of *Grypophyllum* having a mean adult diameter of 9.0 to 19.0 mm, but mostly 10.0 to 13.0 mm and only rarely greater than 15.0 mm; full length typically 40.0 to 60.0 mm. Wall 0.3 to 2.5 mm thick in adult stages. Adult septal count 18x2 to 26x2, most commonly 20x2 to 23x2. Major septa of variable length. In small to average size specimens minor septa are normally reduced, and apart from the long infralaterals on either side of the counter septum, may be totally suppressed. In large specimens (diameter > 13.0 mm) minor septa are normally well developed. Dissepimentarium with one to four, rarely five, rows of relatively large dissepiments, including a few that are lonsdaleoid. Dt/Dc 0.25 to 0.71.

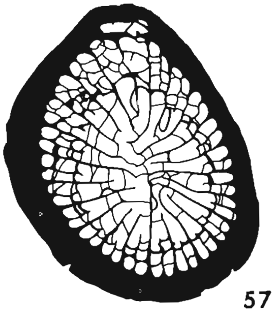
Description. Corallites, which are subcylindrical or less commonly ceratoid, may be aggregated in a manner suggesting a loosely fasciculate colony, but in the absence of budding and in view of the large number of definitely solitary specimens available, the coral is now believed to be invariably solitary. Complete specimens are not easily obtained as the species is not normally found in soft-weathering rocks. When complete, the largest would probably have been 50.0 to 60.0 mm or more long. Specimens from the Swan Hills Formation are smaller than others and have adult mean diameters of 9.0 to 12.0 mm; in others the diameter is usually 11.0 to 13.0 mm; in the two largest specimens from the Sulphur Point and Slave Point Formations the diameters are 16.0 and 19.0 mm. Transverse sections reveal a smooth, or almost smooth, exterior where the coral grew free of encrustation; where it grew in consortium with other organisms the exterior may be rough, although septal grooves and interseptal ridges are apparently never developed. Rejuvenescences are not common and usually resulted in only a modest reduction in the diameter of the coral. The calice would be deep and inversely conical with steep sides, and in many specimens would have an exceptionally wide base for the genus.

The wall may be as little as 0.15 mm thick in early stages, but later, despite considerable variation even within a single transverse section, is mostly 0.5 to 1.8 mm thick, the full range being 0.3 to 2.5 mm. Septa are smooth to wavy without ever being carinate; their arrangement is radial to more commonly somewhat pinnate about the cardinal-counter plane, which is readily apparent both from the obvious infra-lateral minor septa and the generally elongated counter septum between them. In adult stages the number of septa varies from 18x2 to 26x2; the usual number in specimens from the Swan Hills Formation is 19x2 to 21x2, and in others 21x2 to 23x2. Septa are highly differentiated. Because of their typically pinnate arrangement major septa vary in length; the longest terminate in the axial region where they may be slightly rotated; the shortest may extend only about one half of the distance to the axis. Minor septa develop late and apart from the infra-laterals are scarcely discernible in specimens of less than 6.0 mm diameter. In specimens of average size they may remain suppressed, but are more commonly about 1.0 mm long. In large specimens, with a diameter exceeding 13.0 mm, minor septa are commonly more than half as long as adjacent major septa. The infra-lateral minor septa are almost invariably longer than other minor septa in the counter lateral segments.

Mature dissepimentaria comprise one to five, usually two to four, rows of mostly relatively large, moderately inflated and steeply inclined dissepiments. Lonsdaleoid dissepiments are not common and only very rarely disrupt major septa. For brief periods following strong rejuvenescences the dissepimentarium may be suppressed locally. Dissepiments may inosculate where the minor septa are reduced. The transition from dissepimentarium to tabularium is less uniform than in many species of the genus. Tabulae vary in size and shape, and tabularial surfaces may be depressed, flat, or rarely even elevated in the axial region. In specimens from the Swan Hills Formation there are commonly only about 18 tabulae in a vertical distance of 1.0 cm; in other material the number of tabulae per cm is usually 20 to 30 and exceptionally is as high as 35. Ratios of the diameter of the tabularium to that of the corallite (Dt/Dc) range from 0.25 to 0.71. Dissepimentarial surfaces in the holotype and other topotypes bear heavy deposits of sclerenchyme; in most specimens such deposits are scarce or absent.



TEXTFIGURES 48 to 56. *Grypophyllum mackenziense* (Pedder); all x3. 48. Hypotype 7, GSC 29546; Sulphur Point Formation, Givetian or Frasnian *mackenziense* Zone at a depth of 5,846 feet; Union Pan Am Trainor L-59 well, District of Mackenzie. 49. Hypotype 8, GSC 29547; Sulphur Point Formation, Givetian or Frasnian *mackenziense* Zone at a depth of 5,853 feet; same well as hypotype 7, Textfigure 48. 50 and 54. Hypotype 3, GSC 29542; Sulphur Point Formation, Givetian or Frasnian *mackenziense* Zone; Burnt Point, Great Slave Lake, District of Mackenzie. 51. Holotype, GSC 16850; Ramparts Formation, broad sense, Givetian or Frasnian *mackenziense* Zone; Kee Scarp, near Norman Wells, District of Mackenzie. 52. Paratype 2, GSC 16852; same occurrence as holotype, Textfigure 51. 53 and 55. Hypotype 9, GSC 29548; platform of Swan Hills Formation, Givetian or Frasnian *mackenziense* Zone at a depth of 8,140 feet; Canadian Kewanee A-30 Swan Hills 2-5-69-10W5 well, Alberta. 56. Hypotype 12, GSC 29551; platform of the Swan Hills Formation, Givetian or Frasnian *mackenziense* Zone at a depth of 9,811 feet; Pan American A-1 Freeman 4-29-66-13W5 well, Alberta.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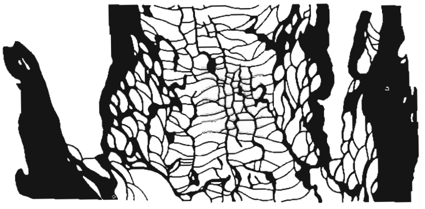
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TEXTFIGURES 57 and 58. *Grypophyllum mackenziense* (Pedder); both x3. 57. Hypotype 16, GSC 29554; Slave Point Formation Givetian or Frasnian *mackenziense* Zone at a depth of 4,308 to 4,310 feet; Union Red Earth 2-22-88-8W5 well, Alberta. 58. Hypotype 17, GSC 29555; same occurrence as hypotype 16, Textfigure 57.

Discussion. Excessive quantities of sclerenchyme in the holotype make that specimen, from the morphological point of view, very atypical of the species as a whole. Thickening resulting from the sclerenchyme influenced the author in originally placing the species in *Alaiophyllum*, however it is now clear, especially from the morphology of the tabulae, that the species is one of *Grypophyllum* rather than *Alaiophyllum*. Pickett (1967) regarded the species as a stauriid, but the dissepimentarium and tabularium certainly indicate closer relationship with the Spongophyllidae, which is here again taken to include the Ptenophyllidae of some workers.

Grypophyllum wedekindi Middleton (= *G. gracile* Wedekind, not McCoy) and *Grypophyllum aquilonium* new species are similar to some specimens of *Grypophyllum mackenziense* in size and reduction of minor septa. They may be distinguished in adult stages by their finer septa, narrower walls (generally less than 0.75 mm thick) and narrower tabularia (Dt/Dc mostly less than 0.30).

Differences noted in the description between specimens from the Swan Hills Formation and others from elsewhere, may ultimately lead to the recognition of a distinct subspecies. However, there is sufficient overlap in morphologies to suggest that taxonomic fragmentation beyond the species level might be difficult to maintain.

The specimen represented by figures 5 and 6 of McLaren, Norris, and McGregor's (1962) Plate 4 is possibly a *Grypophyllum mackenziense*. Reluctance in firmly identifying it as such stems from the fact that the wall appears to be unusually thin for the species.

Associated fauna. Apart from Fischbuch's work on stromatoporoids, few studies of the *Grypophyllum mackenziense* fauna have appeared in print. Crickmay (1967) described the ambocoeliid brachiopods *Emanuella vernilis* and *Ladjia landesi* from central Alberta and Great Slave Lake, and Pedder (1972) has described species of *Temnophyllum* from localities in the District of Mackenzie. The *Temnophyllum* is the only tetracoral genus, other than *Grypophyllum*, known from the zone.

The most critical faunal elements for determining the age of the zone are conodonts. T. T. Uyeno (pers. com.) has identified *Polygnathus norrisi*, which is indicative of the *insitus* Zone, at a depth of 4,290 to 4,296 feet in the Union Red Earth 2-22-88-8W5 well, that is 12 to 18 feet above hypotypes 16 and 17 of *Grypophyllum mackenziense*. Furthermore, conodonts diagnostic of the *hermanni-cristatus* Zone have been found with *Grypophyllum mackenziense* (unfigured specimen mentioned above) at Powell Creek (Pedder and Uyeno, *in press*).

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PLATES 11 TO 15

PLATE 11

(all figures x3 except figure 6, x 9)

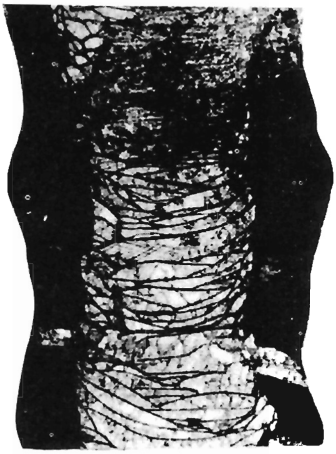
Alaiophyllum jarushevskyi Goryanov (PAGE 96)

Figure 1.	Paratype, Leningrad Mining Institute, Department of Historical Geology Museum 755. Givetian strata; southern Fergana. Copied from Goryanov, 1961, Pl. 8, fig. 2v.
Figures 3, 5.	Holotype, Leningrad Mining Institute, Department of Historical Geology Museum 755/1. Givetian strata; southern Fergana. Copied from Goryanov, 1961, Pl. 8, figs. 1a, b.
Figure 6.	Paratype, Leningrad Mining Institute, Department of Historical Geology Museum 755/2. Givetian strata; southern Fergana. Copied from Goryanov, 1961, Pl. 8, fig. 3b.

Alaiophyllum goryanovi new species (PAGE 97)

Figures 2, 7.	Paratype, GSC 29533. Ramparts Formation, probably Givetian *aleskanus* Zone; near Fort Good Hope, District of Mackenzie.
Figures 4, 8.	Holotype, GSC 29532. Ramparts Formation, Givetian *laevis* Zone; right bank of Mackenzie River, 2¾ miles above Fort Good Hope, District of Mackenzie.

PLATE 11



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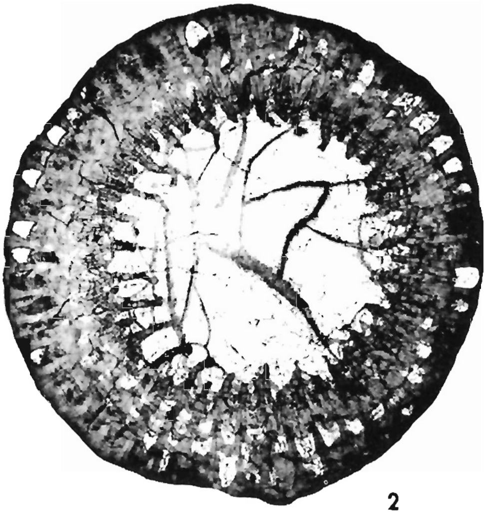

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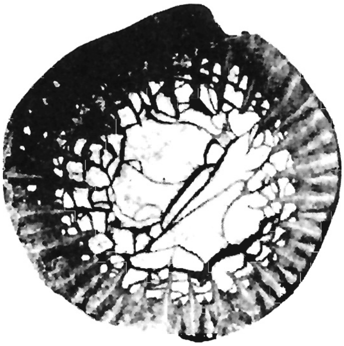

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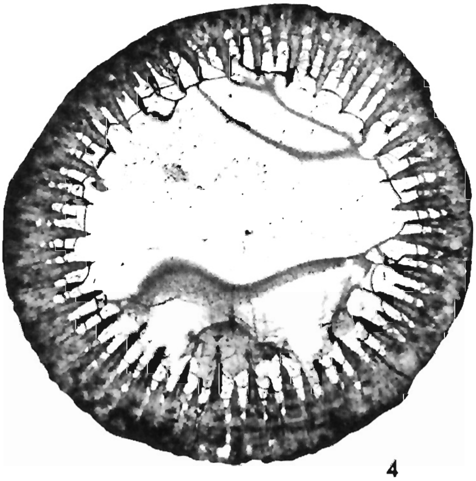

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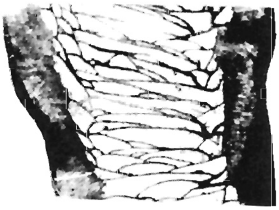

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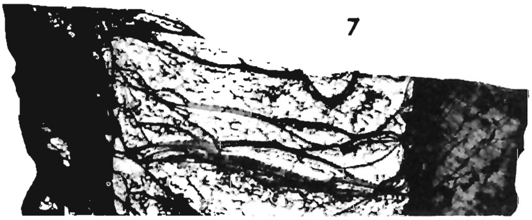

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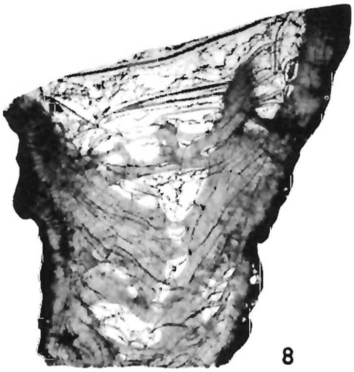

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PLATE 12

(all figures x 3)

Grypophyllum aquilonium new species (PAGE 103)

Figures 1, 4, 6. Holotype, GSC 29534. Hare Indian Formation, Givetian; 10¾ miles north of Little Chicago, District of Mackenzie.

Grypophyllum ultimum (Wedekind) (PAGE 102)

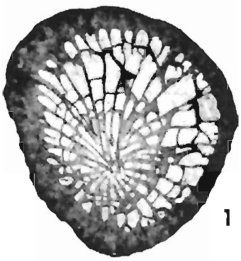
Figure 2. Holotype or paratype, Natur-Museum Senckenberg SMF WDKD 5987. Upper Stringocephalenkalk, Givetian; Düsseltal, Germany. Copied from polaroid photograph taken by D. J. McLaren.

Figure 3. Holotype, Natur-Museum Senckenberg SMF WDKD 4044. Upper Stringocephalenkalk, Givetian; Düsseltal, Germany. Copied from polaroid photograph taken by D. J. McLaren.

Grypophyllum denckmanni Wedekind (PAGE 99)

Figure 5. Holotype, Natur-Museum Senckenberg SMF WDKD 3949. Bücheler Schichten, Givetian; Bergisch-Gladbach, Germany. Copy of polaroid photograph taken by D. J. McLaren.

PLATE 12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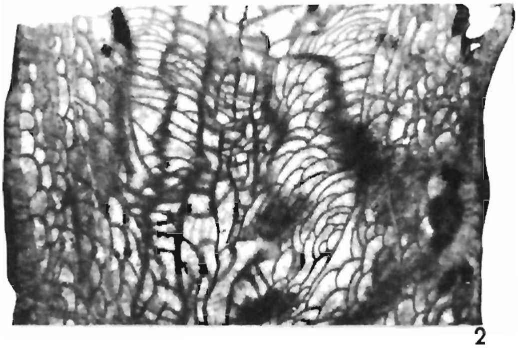
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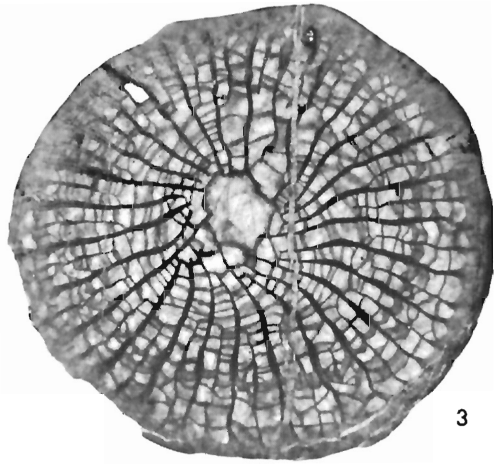
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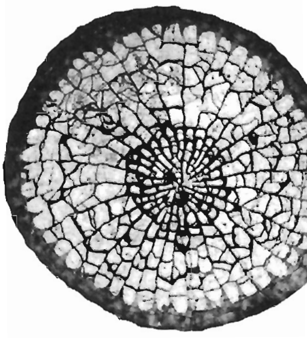
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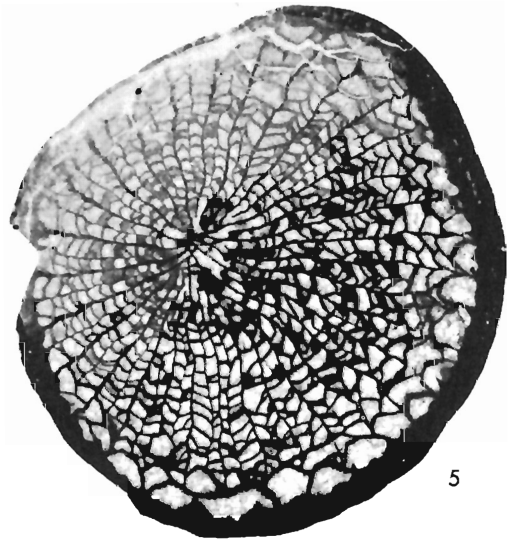
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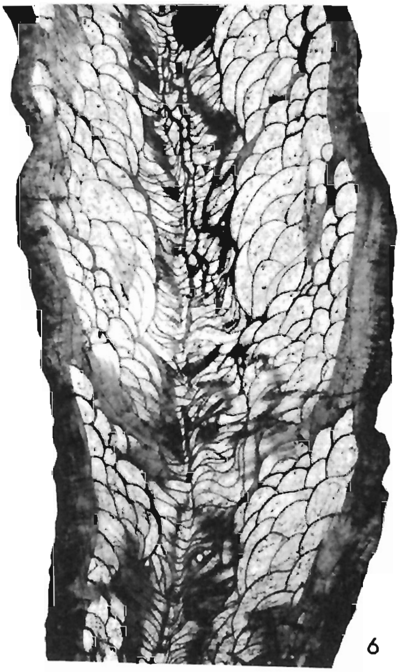
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PLATE 13

(all figures x3)

Grypophyllum subtile new species (PAGE 105)

Figures 1, 2.	Holotype, GSC 29535. Ramparts Formation, Givetian *laevis* Zone; right bank of Mackenzie River 5½ miles above Fort Good Hope, District of Mackenzie.
Figure 3.	Paratype, GSC 29536. Ramparts Formation, Late Givetian part?; left bank of Mackenzie River, 5½ miles above Fort Good Hope, District of Mackenzie.

Grypophyllum crickmayi new species (PAGE 106)

Figure 4.	Paratype 1, GSC 29538. Sulphur Point Formation, Givetian part at a depth of 678 feet; N.W.T. Deep Bay No. 2 well, District of Mackenzie.
Figures 5, 6.	Holotype, GSC 29537. Sulphur Point Formation, Givetian part at a depth of 660 to 664 feet; N.W.T. Deep Bay No. 2 well, District of Mackenzie.

Grypophyllum mackenziense (Pedder) (PAGE 107)

Figure 7.	Hypotype 12, GSC 29551. Platform of the Swan Hills Formation, Givetian or Frasnian *mackenziense* Zone, at a depth of 9,811 feet; Pan American A-1 Freeman 4-29-66-13W5 well, Alberta.
Figures 8, 11.	Hypotype 9, GSC 29548. Platform of the Swan Hills Formation, Givetian or Frasnian *mackenziense* Zone, at a depth of 8,140 feet; Canadian Kewanee A-30 Swan Hills 2-5-69-10W5 well, Alberta.
Figures 9, 10.	Hypotype 10, GSC 29549. Platform of the Swan Hills Formation, Givetian or Frasnian *mackenziense* Zone, at a depth of 8,140 feet; Canadian Kewanee A-30 Swan Hills 2-5-69-10W5 well, Alberta.
Figure 12.	Hypotype 13, GSC 29552. Platform of the Swan Hills Formation, Givetian or Frasian *mackenziense* Zone, at a depth of 9,811 feet; Pan American A-1 Freeman 4-29-66-13W5 well, Alberta.

PLATE 13


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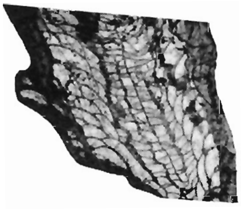
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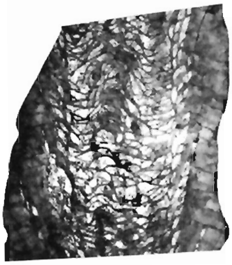
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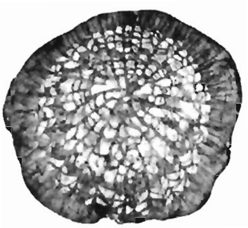
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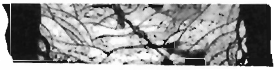
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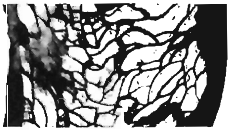
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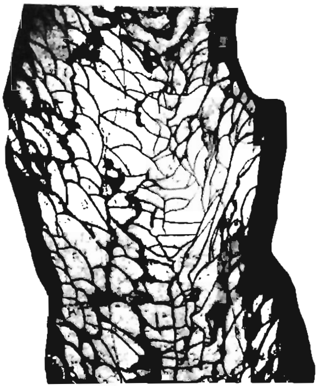
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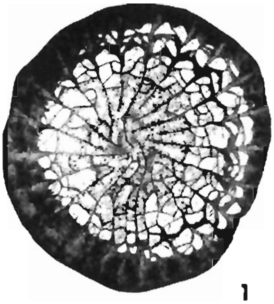
Plate 14

(all figures x3)

Grypophyllum mackenziense (Pedder) (Page 107)

Figures 1, 2, 7.	Hypotype 4, GSC 29543. Sulphur Point Formation, Givetian or Frasnian *mackenziense* Zone; Burnt Point, Great Slave Lake, District of Mackenzie.
Figure 3.	Hypotype 3, GSC 29542. Sulphur Point Formation, Givetian or Frasnian *mackenziense* Zone; Burnt Point, Great Slave Lake, District of Mackenzie.
Figures 4, 5.	Hypotype 2, GSC 29541. Sulphur Point Formation, Givetian or Frasnian *mackenziense* Zone; Burnt Point, Great Slave Lake, District of Mackenzie.
Figure 6.	Hypotype 1, GSC 29540. Ramparts Formation, broad sense, probably Givetian or Frasnian *mackenziense* Zone, at a depth of 1,257 to 1,262 feet; Imperial Norman Wells No. 37X well, District of Mackenzie.
Figure 8.	Holotype, GSC 16850. Ramparts Formation, broad sense, probably Givetian or Frasnian *mackenziense* Zone; Kee Scarp, 4½ miles northeast of Norman Wells, District of Mackenzie.

PLATE 14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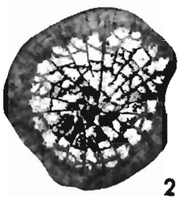
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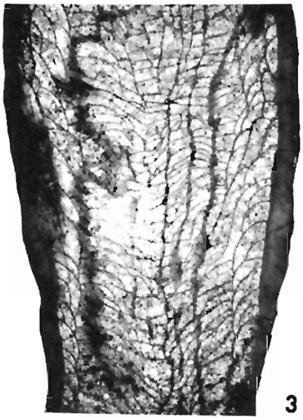
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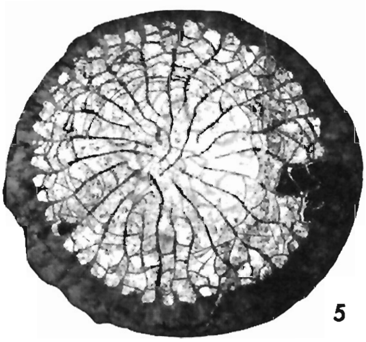
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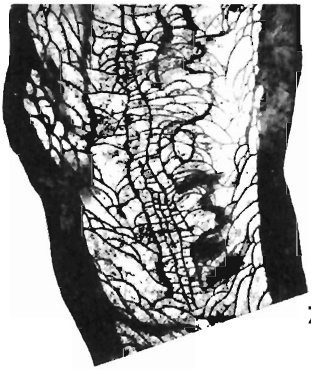
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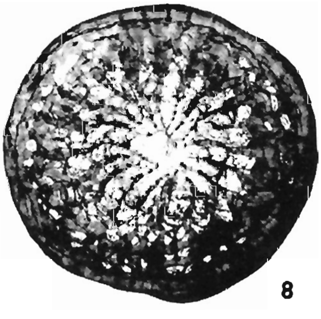
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PLATE 15

(all figures x3)

Grypophyllum mackenziense (Pedder) (PAGE 107)

Figures 1, 3. Hypotype 7, GSC 29546. Sulphur Point Formation, Givetian or Frasnian *mackenziense* Zone, at a depth of 5,846 feet; Union Pan Am Trainor L-59 well, District of Mackenzie.

Figure 2. Hypotype 8, GSC 29547. Sulphur Point Formation, Givetian or Frasnian *mackenziense* Zone, at a depth of 5,853 feet; Union Pan Am Trainor L-59 well, District of Mackenzie.

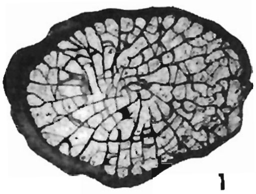
Figures 5, 10. Hypotype 17, GSC 29555. Slave Point Formation, Givetian or Frasnian *mackenziense* Zone, at a depth of 4,308 to 4,310 feet; Union Red Earth 2-22-88-8W5 well, Alberta.

Figure 6. Hypotype 15, Geological Museum, University of Saskatchewan, Coelenterata (Rugosa)1. Calcarenite at the top of the platform of the Swan Hills Formation, Givetian or Frasnian *mackenziense* Zone, at a depth of 9,697 feet; Phillips Kaybob 2-15-64-19W5 well, Alberta.

Figures 7 to 9. Hypotype 16, GSC 29554. Slave Point Formation, Givetian or Frasnian *mackenziense* Zone, at a depth of 4,308 to 4,310 feet; Union Red Earth 2-22-88-8W5 well, Alberta.

Grypophyllum mackenziense (Pedder)? (PAGE 107)

Figure 4. Hypotype 18, GSC 29556. Slave Point Formation, probably Givetian or Frasnian *mackenziense* Zone, at a depth of 366 to 371 feet; N.W.T. Deep Bay No. 2 well, District of Mackenzie.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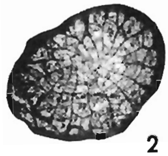
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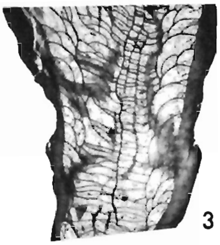
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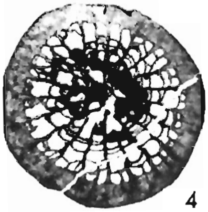
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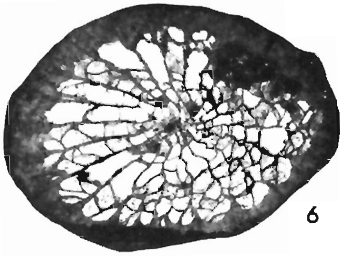
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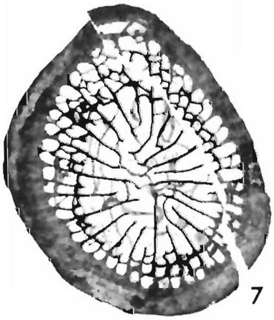
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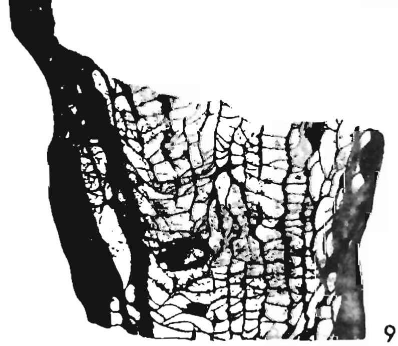
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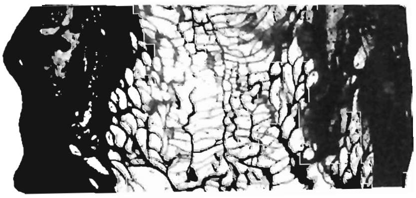
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LOWER PERMIAN TRILOBITES FROM NORTHERN YUKON TERRITORY AND ELLESMERE ISLAND, DISTRICT OF FRANKLIN

by Allen R. Ormiston[1]

Abstract

Two species of trilobites known from the Treskelodden beds of Spitsbergen are identified from the Jungle Creek Formation of the northern Yukon Territory. A new species, *Ditomopyge bjornensis*, is similar to Artinskian species of the genus from Australia and the Soviet Union and is described from the Assistance Formation on Bjorne Peninsula, Ellesmere Island.

Résumé

L'auteur identifie deux espèces de trilobites provenant de la formation de Jungle Creek dans le nord du Yukon; les espèces étaient déjà connues dans les couches de Trekelodden au Spitsberg. Une nouvelle espèce, *Ditomopyge bjornensis*, ressemble à l'espèce de l'Artinskien du genre que l'on retrouve en Australie et en Union soviétique; l'auteur décrit cette nouvelle espèce qui provient de la formation d'Assistance dans la péninsule de Bjorne, île Ellesmere.

Introduction

The small collections of Permian trilobites described in this paper were made by E. W. Bamber, W. W. Nassichuk, and D. K. Norris, all of the Geological Survey of Canada, in the course of Permian stratigraphic and biostratigraphic studies conducted in the Yukon and arctic islands. Trilobites are generally subordinate constituents of Permian faunas, and this condition is especially marked in these collections. Only two trilobite genera are represented. Brachiopods, fusulinid foraminifers, ammonoids, and corals are more abundantly and diversely represented in the Permian faunas of northern Canada (Harker and Thorsteinsson, 1960; Nassichuk, Furnish, and Glenister, 1965; Ross, 1967; Nelson and Johnson, 1968; Waterhouse, 1968, 1969, 1971; Bamber and Waterhouse, 1971). Description of the trilobites will add to knowledge of these Permian faunas.

Acknowledgments

The study was encouraged by B. S. Norford and W. W. Nassichuk of the Geological Survey of Canada. The manuscript has been critically read by E. W. Bamber, W. T. Dean, and B. S. Norford.

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[1] Amoco Production Company, Research Center, Tulsa, Oklahoma.

Stratigraphy and Correlation

The stratigraphy of Permian rocks in the northern Yukon has been the subject of preliminary studies by Nelson (1961) and Nelson and Johnson (1968), and recently has been discussed in detail by Bamber and Waterhouse (1971).

Those trilobites from the northern Yukon that are described in this paper come from the Jungle Creek Formation in the Tatonduk River, Ogilvie River, and Peel River areas (Textfig. 1, locs. 10, 11, 13; Bamber and Waterhouse, 1971, p. 60) where the Jungle Creek is the older of the two Permian rock units known from the region. *Ditomopyge spitsbergensis* Osmolska, 1968 and *Ameura trigonopyge* (Osmolska, 1968) are known from separate horizons in the Jungle Creek Formation but were originally described from the Treskelodden beds of Spitsbergen where they occur together (Osmolska, 1968). A tentative correlation of at least part of the Jungle Creek Formation can be suggested with the Treskelodden beds. The age of these beds is a matter of disagreement among specialists. According to Osmolska (1968, p. 605), students of corals, foraminifers, and brachiopods favour an Early Permian age, whereas she herself favours a Late Carboniferous age on the basis of trilobites (1968, p. 606). Certain North American species of both *Ditomopyge* (Chamberlain, 1970, p. 1053) and *Ameura* (Branson, 1961, p. 180) have been shown to range from Pennsylvanian into Permian beds. Thus age assessments of Pennsylvanian versus Permian based on occurrences of these genera seem to be unwise without exact knowledge of the total ranges of the particular species involved.

Permian beds on Bjorne Peninsula, Ellesmere Island, are the source (Textfig. 1, loc. 3) of a new species, *Ditomopyge bjornensis*, which is closely similar to Artinskian species of *Ditomopyge* from the Urals and Western Australia. The type locality of *D. bjornensis* is about 915 feet above the base of the Assistance Formation and has yielded an ammonoid fauna which is regarded (Nassichuk, Furnish, and Glenister, 1965, loc. D, p. 8-9) as possibly upper Sakmarian but probably lower Artinskian because of the presence of Artinskian fusulinaceans in the Belcher Channel Formation stratigraphically beneath the Assistance Formation. The morphologic similarity of *D. bjornensis* to other Artinskian species of *Ditomopyge* apparently reflects age equivalence.

Systematic Paleontology

Morphologic terms. Some late Paleozoic trilobites exhibit varying degrees of glabellar basisolution (Richter, R. and Richter, E., 1939) and there has been inconsistency in the application of morphologic terms to that part of the cranidium anterior to the occipital ring and posterior to the main body of the glabella. The term preoccipital lobe (Weber, 1933, p. 81; originally spelled praeoccipital by Weber) is now in general use to designate the isolated median lobe present in some genera between the occipital ring and the main body of the glabella. However, the lobes lateral to this median lobe have been designated by a variety of terms. They have been called basal lobes by Weber (1933), Weller (1944), and more recently by Chamberlain (1970). Goldring (1957) followed R. and E. Richter (1954, p. 7) in designating them glabellar lobes lp, considering them homologous with the lp lobes of other trilobites. The term lateral preoccipital lobes was used for these structures by Weller (*in* Harrington *et al.*, 1959, p. 0399) and has been subsequently used by Grant (1966, p. 71). While agreeing with Goldring that they are homologous with lp glabellar lobes of other trilobites, I choose to follow the Treatise term (*see* also, Harrington *et al.*, 1959, p. 0122), lateral preoccipital lobes, in the interests of possible stabilization of terminology. Other morphologic terms conform to those earlier (Ormiston, 1967) used.

TRILOBITA

Genus **Ditomopyge** Newell, 1931

Type species. *Ditomopyge lansingensis* Newell, 1931, p. 268, Pl. 31, figs. 31–32.

Diagnosis. See Grant, 1966, p. 66.

Ditomopyge bjornensis new species

Plate 16, figures 1–3, 5, 7

(?) *Ditomopyge* sp. Teichert, 1944, p. 461, Pl. 77, fig. 6.

Diagnosis. A *Ditomopyge* with an elongate-pyriform glabella, narrow (*trans.*) median preoccipital lobe, low-lying lateral preoccipital lobes with apices in the form of nodes, a long (*sag.*) occipital ring, and a long sulcate genal spine.

Holotype. GSC 27828, external mould of nearly complete specimen with right side eroded, from GSC loc. 55719, eastern Bjorne Peninsula, Ellesmere Island, lat. 77°36′50″N, long. 86°22′30″W (Textfig. 1, loc. 3), about 915 feet above base of "Assistance Formation," Artinskian (Nassichuk, Furnish, and Glenister, 1965, p. 9). *Paratype.* GSC 27829, internal mould of pygidium, same locality and horizon as holotype.

Description. Cranidium. Glabella of elongate-pyriform outline, anterior part not preserved so that longitudinal convexity is not determinable, length greater than maximum width. Transverse profile at maximum width a smooth arc, opposite palpebral lobes glabellar apex gently convex and lateral slopes steep. Three distinct preoccipital lobes. Median preoccipital lobe (Pl. 16, fig. 2) subrectangular, one half as wide (*trans.*) as minimum glabellar width, transversely elongated, situated below glabellar level, separated from glabella by weak furrow, from occipital ring by deep, narrow occipital furrow. Lateral preoccipital lobes bounded anteriorly by shallow, diagonally directed furrows (Pl. 16, fig. 2), lobes lack inflation except for conspicuous central node (Pl. 16, fig. 2) on each. Occipital furrow transverse, sharply incised medially. Occipital ring long (*sag.*) with posterior margin arcuate in plan, ring flat-crested in profile. Midpoint of palpebral lobes opposite posterior end of main body of glabella, lobes narrow (*trans.*) and inward sloping. Axial furrows deep behind midpoint of palpebral lobes (Pl. 16, fig. 2), abruptly shallowing anteriorly. Fixed cheek anterior to palpebral lobe very narrow (*trans.*).Posterolateral corners of main body of glabella are tuberculate (Pl. 16, fig. 3) with smooth linear areas which possibly represent incipient furrows present between tubercles (Pl. 16, fig. 3), remainder of glabella with minute pits (Pl. 16, fig. 3). Occipital ring with median tubercle, smaller tubercles along posterior margin (Pl. 16, fig. 2). Free cheek. Eye lobe large, hemispherical with distinct eye socle (Pl. 16, fig. 2) at base. Genal field plane directly adjacent to eye, descending from abrupt break in slope to broad, gently concave border furrow. Lateral border broad, angulate in cross-section. Posterior border furrow incised, turning to run along genal spine for one third its length. Genal spine as broad (*trans.*) at base as eye lobe, extending to seventh thoracic segment, anterior third weakly sulcate in cross-section.

Thorax. Nine thoracic segments, anterior one displaced slightly beneath occipital ring on holotype (Pl. 16, fig. 2). Axis of essentially same width (*trans.*) as one pleural lobe. Pleurae geniculated at midwidth. Pleural furrows short (*trans.*), all pleurae with anterior pleural band produced in a flange at point of geniculation. Rings with six transversely aligned tubercles.

Pygidium. Outline parabolic, 1.5 times wider than long, maximum axial width slightly less than half total pygidial width. Axis trapezoidal in cross-section with twelve rings (eleven on internal mould). Ring furrows transverse, only slightly deeper between anterior than between posterior rings. In longitudinal profile axis moderately convex to end of last ring where it descends vertically (Pl. 16, fig. 1). Width of flattened apical part of axis two thirds total axial width. Pleural lobes evenly convex. Seven pleural ribs, interpleural furrow present only on first rib, pleural furrows sharp. Lateral border eroded from holotype, but impression in matrix on left side (Pl. 16, fig. 2) indicates that it was broad, doublure strongly convex (Pl. 16, fig. 5) sagittally extending anterior to position of axial terminus (Pl. 16, fig. 7). Each ring crest with transverse row of five tubercles.

Dimensions (in mm)	Holotype GSC 27828	Paratype GSC 27829
maximum glabellar width	9.8	
minimum glabellar width	4.7	
preserved glabellar length	10.8	
pygidial length	15.7	14.3
pygidial width (restored)	24.5	19.0
maximum axial width	7.2	7.4

Discussion. The length and shape of the glabella, nature of the glabellar prosopon, and very small size of the preoccipital lobes distinguish the new species from most species of the genus. Comparable with *D. bjornensis* are the species *Ditomopyge meridionalis* Teichert (1944, p. 458, Pl. 77, figs. 1–5, 7–12) and *Ditomopyge* sp. (Teichert, 1944, p. 461, Pl. 77, fig. 6) both from the Artinskian of Western Australia, and *D. artinskiensis* (Weber, 1933) from the Artinskian of the southern Urals. These three taxa share with *D. bjornensis* a rapidly expanding elongate glabella, the development of tubercles at the posterolateral margins of the glabella, and very small preoccipital lobes. Further, a long genal spine is common to *D. meridionalis*, *D. artinskiensis*, and the new species, but no free cheek is known for *Ditomopyge* sp. of Teichert, 1944.

Although incomplete, the glabella in *D. bjornensis* is clearly longer than that of *D. meridionalis* as is the occipital ring. The internal mould of the pygidium of *D. bjornensis* has a less trapezoidal cross-section than does that of *D. meridionalis* (Teichert, 1944, Pl. 77, fig. 11).

The single cranidium from the Australian Artinskian which Teichert (1944, p. 461, Pl. 77, fig. 6) described as *Ditomopyge* sp. is possibly conspecific with *D. bjornensis* n. sp., but the specimen has not been examined by me.

Weber's line drawing of *Cyphinium artinskiense* (1933, p. 66, textfig. 33) shows the glabellar margin anterior to the preoccipital lobes as being inflected to produce four lobes. Goldring (1957, p. 198) regarded Weber's photograph (1933, Pl. 3, fig. 41) as too small to convincingly demonstrate such a configuration and pointed out that later photographic illustrations of this species (Weber, 1944, Pl. 1, fig. 11) do not show four lobes. Weber (1933, p. 89) mentioned a concentration of tubercles along this glabellar margin and was apparently interpreting the bunching of these tubercles in *D. artinskiensis* as representing scalloping of the margin such as is seen in the genus *Pseudophillipsia* Gemmellaro.

Ditomopyge bjornensis can be contrasted with *D. artinskiensis* (Weber, 1933, p. 66, textfigure 33, Pl. 3, fig. 41) by having tubercles present only at the posterolateral corners of the glabella (Pl. 16, fig. 3) and not extending along the posterior margin and in having a narrower (*trans.*) median preoccipital lobe.

The contrast in cephalic structure between those species of *Ditomopyge* with a prominent anterior border and large preoccipital lobes, e.g., *D. scitula* (Meek and Worthen), *D. fatmii* Grant, *D. decurtata* (Gheyselinck), and species similar to those discussed above which have no anterior border, minute preoccipital lobes, and traces of incipient glabellar lobation leads me to favour Goldring's suggestion (1957, p. 197) that two separate genera or subgenera might be recognized among species now assigned to *Ditomopyge*. Such a taxonomic revision should be coupled with a comprehensive review of all described species of *Ditomopyge* and is beyond the scope of this paper.

Ditomopyge spitsbergensis Osmolska, 1968

Plate 16, figures 4, 6, 8, 9–11

Ditomopyge roemeri spitsbergensis Osmolska, 1968, p. 606, Pl. 1, figs. 1–3, 7, text-fig. 1, 6–8.
Ditomopyge spitzbergensis Osmolska; Chamberlain, 1970, p. 1053.

Material. Hypotype GSC 27830, nearly complete specimen lacking free cheeks, and hypotype GSC 27831, a cranidium, both specimens from GSC loc. C-1928, concretions in Jungle Creek Formation, north side of Peel River, 5.2 miles downstream from mouth of Hart River, lat. 65°53.5'N, long. 136°13'W, Yukon Territory (Textfig. 1, loc. 11), collected by W. W. Nassichuk, 1968. Nassichuk (pers. com., 1969) considers this horizon as probably of Late Wolfcampian age.

Description. Osmolska's original description (1968, p. 607–609) applies well to the Yukon material, except for the thorax which was not preserved in the Spitsbergen collection.

Thorax. GSC hypotype 27830 (Pl. 16, figs. 4, 6, 8) has an intact thoracic region showing nine segments, the complement characteristic (Grant, 1966, p. 66) of the genus. Axial width 2/5 of total thoracic width (Pl. 16, fig. 4). Pleural furrows not reaching axial furrow. Anterior pleural bands produced into anteriorly pointing flange at point of pleural geniculation. Crests of rings are densely granulose.

Pygidium. The internal mould (Pl. 16, fig. 4) shows a short postaxial ridge. No such feature was described by Osmolska (1968, p. 609). Her illustrations (1968, Pl. 1, figs. 3, 5) do not permit a determination of the presence or absence of such a feature on the type material.

Dimensions (im mm)	GSC 27831	GSC 27830
maximum glabellar width	(21.2)	10.8
glabellar length	20.8	10.3
pygidial width		15.5
pygidial length		11.2
axial width		6.0

Discussion. The broad, nearly horizontally oriented pygidial border is a distinctive characteristic of the Yukon material, indicating assignment to *D. spitsbergensis*. Other morphologic details also show good correspondence with those of Osmolska's original material, which comes from the Treskelodden beds of Spitsbergen.

Ditomopyge sp.

Plate 16, figures 12, 13

Material. GSC 27832. A crushed pygidium and three fragmentary unfigured pygidia from GSC loc. 56923, between 596 and 612 feet above the base of the Jungle Creek Formation at its type section (Bamber and Waterhouse, 1971, p. 60), north bank of Tatonduk River, lat. 64°58′N, long. 140°54′W, Yukon Territory (Textfig. 1, loc. 13), collected by E. W. Bamber, 1962. This horizon is within the *Yakovlevia* Zone of Bamber and Waterhouse (1971, p. 156) and is considered of ?Late Asselian to Early Sakmarian (Early Permian) age (Bamber and Waterhouse, 1971, p. 157).

Description. Because of distortion of the specimen, proportions are only determinable in a general way. Pygidial outline semielliptical. Axial cross-section not trapezoidal (as is so typical in *Ditomopyge*) but with rounded crest (Pl. 16, fig. 13). Ring furrows straight. Ten axial rings. Axial terminus essentially vertical. Pleural fields geniculate at midwidth. Seven "ribs" present with interpleural furrows developed on anterior two. Lateral border broad and steeply inclined (Pl. 16, fig. 13). Each axial ring bears a transverse row of sagittally elongate tubercles numbering seven or eight per ring (Pl. 16, fig. 12).

Dimensions (in mm)	GSC 27832
pygidial width	15.5
pygidial length	19.1
axial width	5.4 estimated

Comparison. The axial cross-section and steep border distinguish this taxon from *D. spitsbergensis*. Like *D. spitsbergensis*, it has a broad, lateral border and can be distinguished thereby from many of the described species of the genus.

Genus ***Ameura*** Weller, 1936

Type species. *Phillipsia* (*?Griffithides*) *sangamonensis* Meek and Worthen, 1865
(=*Phillipsia missouriensis* Shumard, 1858; *see* Osmolska, 1970, p. 24 for discussion).

Diagnosis. See Chamberlain, 1969, p. 60.

Ameura trigonopyge (Osmolska, 1968)

Plate 16, figures 14–16

Paladin trigonopyge Osmolska, 1968, p. 610, Pl. II, figs. 1, 3–7; text-figs. 1, figs. 1–5.

Material. Hypotype GSC 27833, a partly exfoliated pygidium and its counterpart external mould from GSC loc. 55135, lower Jungle Creek Formation, lat. 137°47′W, long. 65°44′N, (near Ogilvie River) Yukon Territory (Textfig. 1, loc. 10), collected by D. K. Norris, 1962. This horizon is assigned (Bamber and Waterhouse, 1971, p. 150) to the *Attenuatella-Tomiopsis* Zone which Bamber and Waterhouse (1971, p. 149) consider of Asselian (Wolfcampian) age.

Description. Osmolska's (1968, p. 611) description of the pygidium of *A. trigonopyge* must be supplemented with a discussion of a distinctive rib construction (compare Osmolska, 1968, Pl. 2, fig. 6 and this paper Pl. 16, fig. 16) evident in the pygidium. The juncture between anterior and posterior pleural bands is not marked by a furrow but by a sharp break in slope anterior to which the posterior pleural band (equals anterior band of Osmolska, *see* Whittington 1960, textfig. 1, for resolution of discrepant terminologies) has a convex cross-section and posterior to which the anterior pleural band is flat and backwardly sloping. Under appropriate lighting conditions this structure (Pl. 16, fig. 14) causes the pygidium to appear to have very broad pleural furrows. The pygidia illustrated by Osmolska all have the exoskeleton stripped from the axial crest. The latex cast (Pl. 16, fig. 14) illustrated in this paper shows the presence of scattered nodes on the crests of the axial rings.

Dimensions. (in mm). Hypotype GSC 27833—pygidial width, 19.3; pygidial length, 16.7; maximum axial width, 5.9.

Discussion. Assignment of this pygidium to *Ameura* is suggested by its subtriangular outline and large number (17–18) of axial rings. Osmolska (1968, p. 612), while recognizing that the pygidial structure of *A. trigonopyge* did not conform to that of other species of *Paladin,* assigned the taxon to *Paladin* because of the separation of the anterior border from the glabella and the presence of a barely perceptible preoccipital node, characters which occur in *Paladin.* The same characters are shared by *Ameura* (*see* Chamberlain, 1969, Pl. 13, fig. 15) and cannot be used as arguments for assignment to *Paladin.*

Although Weller (1936, p. 713–714) did not recognize close relationship between the genera *Ameura* and *Paladin,* such relationship was suggested by Whittington (1954, p. 6) and has been mentioned again by Chamberlain (1969, p. 60).

Comparison. Assignment of the Yukon material to *A. trigonopyge* is possible because of the distinctive rib construction described above that is present also in Osmolska's material, as well as correspondence in all other morphologic features.

A. trigonopyge is distinguished from the type species, *A. sangamonensis* (Meek and Worthen, 1865) (*see* Osmolska, 1970, p. 24; and Chamberlain, 1969, Pl. 13, figs. 15–16, 18–19) in having a broader, less markedly tapering pygidial border and less elongate pygidial outline. From *Ameura major* (Shumard, 1858) (Chamberlain, 1969, Pl. 13, figs. 17, 20, 21) it is distinguished by having a persistent border furrow (that of *A. major* dies out anteriorly) and fewer pleural ribs.

Paladin pyriformis Chamberlain (1969, p. 54, Pl. 12, figs. 2, 7) from the early Pennsylvanian of Utah has a pygidium that resembles in outline and pleural rib configuration (i.e., steep anterior band) that of *A. trigonopyge.* The border has been crushed on the unique type specimen of *P. pyriformis* so that a critical comparison of that feature is not possible. *A. trigonopyge* is distinguished by its greater number of axial rings and straight ring furrows.

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PLATE 16

Ditomopyge bjornensis new species (PAGE 131)

Figures 1–3. Latex cast of nearly complete carapace (holotype GSC 27828) from GSC loc. 55719, about 915 feet above the base of the "Assistance Formation": eastern Bjorne Peninsula, Ellesmere Island. 1, 2. Left lateral and dorsal views; x2; 3. Enlargement of glabella to show prosopon; x5.

Figures 5, 7. Internal mould of pygidium (paratype GSC 27829), same locality and horizon, posterior and dorsal views showing convexity of axis and pleural fields and nature of pygidial doublure; x2.

Ditomopyge spitsbergensis Osmolska, 1968 (PAGE 133)

Figures 4, 6, 8. Nearly complete carapace lacking free cheeks (hypotype GSC 27830) from GSC loc. C-1928, concretion in Jungle Creek Formation, north bank of Peel River, Yukon Territory, dorsal, posterior, and left lateral views; x2.

Figures 9–11. Large incomplete cranidium with right side not preserved (hypotype GSC 27831), same locality and horizon, dorsal anterior and left lateral views showing glabellar convexities; x2.

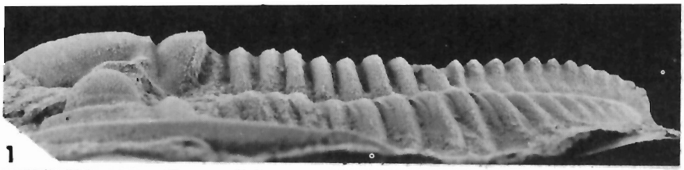
Ditomopyge sp. (PAGE 134)

Figures 12, 13. Distorted pygidium (hypotype GSC 27832) from GSC loc. 56923, Jungle Creek Formation, Yukon Territory, dorsal and posterior views showing distinctive axial prosopon and rounded axial cross-section; x2.

Ameura trigonopyge (Osmolska, 1968) (PAGE 134)

Figures 14–16. Latex cast of external mould of pygidium and corresponding partly exfoliated original (hypotype GSC 27833) from GSC loc. 55135, Jungle Creek Formation, Yukon Territory. 14, 15. Dorsal and lateral views of latex cast; x2; 16. Dorsal view of original; x2.

PLATE 16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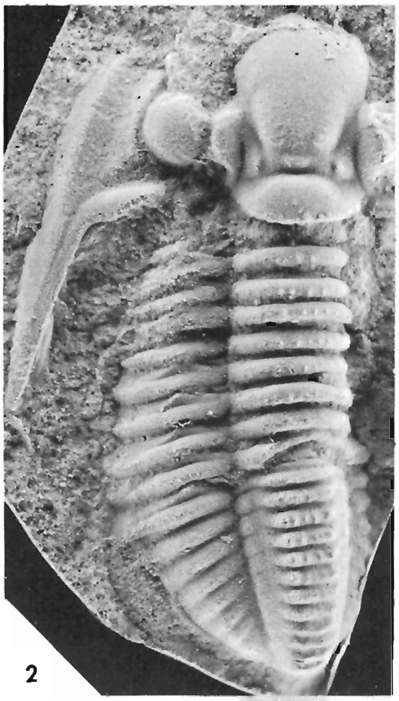
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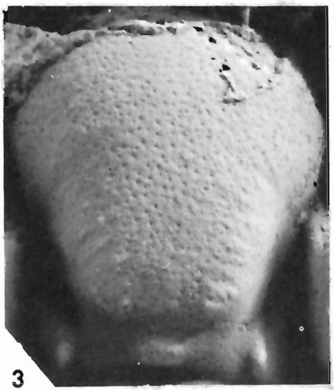
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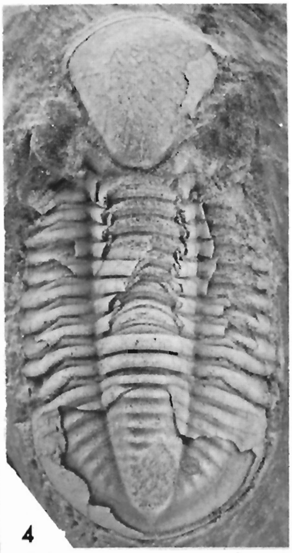
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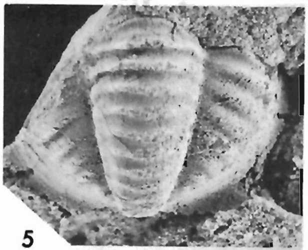
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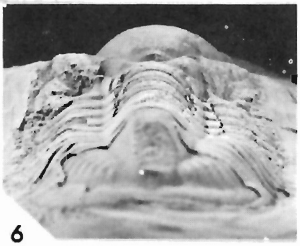
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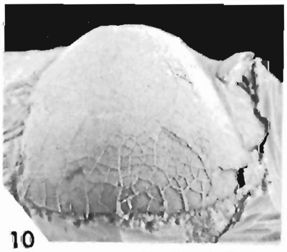
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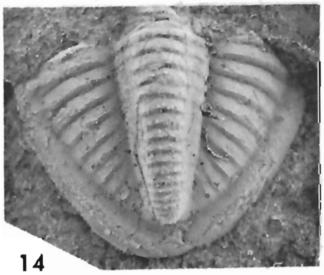
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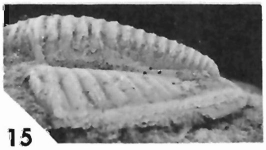
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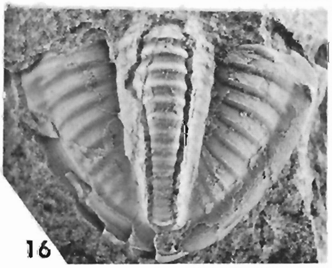
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TRIASSIC CONODONTS FROM BRITISH COLUMBIA AND THE NORTHERN ARCTIC ISLANDS

by L. Cameron Mosher[1]

Abstract

Sixty-two species (including the new species *Neogondolella crenulata*, *N. reversa*, *Xaniognathus expansus*, and *X. triassicus*) representing 16 genera are described from matrix from collections of ammonoids. The biostratigraphic relevance of these conodonts can be established by objective correlation with the standard sequence of ammonoid zones. Several Asian forms are documented for the first time in the North American Lower Triassic.

Résumé

L'auteur décrit 62 espèces (y compris les nouvelles espèces *Neongodolella crenulata*, *N. reversa*, *Xaniognathus expansus* et *X. triassicus*) représentant 16 genres; elles proviennent de matrices de collections d'ammonoïdés. La pertinence biostratigraphique de ces conodontes peut être établie par corrélation objective avec la séquence normale des zones à ammonoïdés. Plusieurs formes asiatiques sont découvertes pour la première fois dans le Trias inférieur nord-américain.

Introduction

The conodonts described in this paper were obtained from a suite of 57 samples of matrix from collections of Triassic ammonoids. The suite was selected with the assistance of E. T. Tozer and allows correlation of the conodont collections directly with the sequence of Triassic ammonoid zones established by Tozer (1967) and by Silberling and Tozer (1968). Forty-eight samples are from northern British Columbia and the other nine are from Axel Heiberg and Ellesmere Islands (Textfig. 1, for details *see* Appendix).

The biostratigraphic advantages of such a study, namely the direct correlations with the ammonoid standard made possible through the use of matrix samples, must be weighted against the disadvantages in interpreting and applying the final results. The suite of matrix samples represents many different collecting localities, and in most instances stratigraphic relationships among the samples have had to be inferred from ammonoids present and are not based on objective superpositional relationships. For such stratigraphic interpretations I have relied heavily on Tozer's expertise. The conodont biostratigraphy resulting from the study is thus tied to interpretations of the ammonoid data and does not stand independently.

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The samples allow only a reconnaissance of the Triassic conodont faunas of British Columbia and of Axel Heiberg and Ellesmere Islands. They do not represent sections across ammonoid zones but rather are isolated material associated with particular ammonoid specimens from within zones. The boundaries between ammonoid zones are not objectively correlated with the boundaries between conodont zones. Stratigraphically superposed samples are rare and the details of faunal changes between conodont collections generally are not available. Data bearing on ecologic controls of the conodont faunas virtually are lacking.

Despite these disadvantages, the conodont data provide verification and extension of the basic elements of the conodont zonation previously recognized for the Triassic, allow establishment of several new conodont taxa and recognition of index conodonts, and contribute to the understanding of evolution of conodonts in the Triassic (Mosher, 1970, 1972; Sweet *et al.*, 1971).

Acknowledgments

The study was supported by the National Science Foundation, grant GA-1569; facilities were made available by the Florida State University, Tallahassee. E. T. Tozer gave critical support in selecting the samples and providing stratigraphic and locality information.

Conodont Biostratigraphy and Faunas

A series of conodont collections are correlated with the standard ammonoid zones recognized in Canada by Tozer (1967). The conodont collections are not presented as zones because they are not defined in terms of the strata and outcrops from which they were collected. Rather they are presented as occurrences of conodont species in ammonoid zones.

Tables 2–5 give the raw abundance data of conodont specimens and taxa represented in each of the samples. The samples are arranged in the table in zonal order and the taxa are listed in order of appearance. Textfigure 59 summarizes the occurrence by ammonoid zones of several taxa regarded as the most significant stratigraphically.

By way of general evaluation of the sample coverage, the poorest coverage is in the middle of the Middle Triassic (Deleeni through Maclearni Zones) where recovery of conodonts from the samples was very poor. The Middle Triassic interval, particularly the Ladinian part, also yielded relatively less information in earlier North American studies (Mosher and Clark, 1965; Mosher 1968a, 1971), in comparison with the Lower and Upper Triassic. Generally speaking there is good agreement between the conodont sequences of this study and those reported by earlier studies in the Triassic.

A striking difference in potential stratigraphic resolving power between conodonts of the Lower Triassic and those of the Middle and Upper Triassic is apparent in the present study and that of Sweet *et al.* (1971). Whereas conodonts seem to provide an even more precise means of biostratigraphic control in the Lower Triassic than the ammonoids which form the standard, they are of relatively less value in the younger rocks. Unless additional studies develop means for distinguishing stratigraphically significant subunits of long ranging forms like *Neogondolella mombergensis* and *N. navicula* in North America (as Kozur, 1968a, b, has attempted in connection with Middle Triassic species of *Neogondolella* in Germany), conodonts must take a junior place to ammonoids for precise biostratigraphic control in the Middle and Upper Triassic. Nevertheless, enough knowledge now exists to allow stratigraphic classification with conodonts to considerable precision at certain levels, principally upper Ladinian, and upper Karnian through Norian.

	LOWER TRIASSIC										MIDDLE TRIASSIC									UPPER TRIASSIC											
	Griesbachian				Dienerian		Smithian		Spathian		Anisian				Ladinian					Karnian					Norian						Rh.
	Lower		Upper								L	M	Upper		Lower		Upper			Lower		Upper			Lower		Middle			U	
	*Concavum	Boreale	Commune	Strigatus	Candidus	Sverdrupi	Romunderi	Tardus	*Platicus	Subrobustus	Caurus	Varium	Deleeni	*Chischa	*Subasperum	Poseidon	Meginae	Maclearni	Sutherlandi	Obesum	Nanseni	Dilleri	Welleri	Macrolobatus	Kerri	Dawsoni	Magnus	Rutherfordi	Columbianus	Suessi	*Marshi
Neogondolella carinata				X							X	X				X	X														
N. mombergensis				X			X																								
Xaniognathus curvatus				X																											
Neospathodus kummeli					X	X ?																									
N. cristagalli						X																									
N. dieneri						X																									
Xaniognathus deflectens						X	X ?																								
Neogondolella crenulata							X																								
N. planata							X																								
N. nevadensis							X	X																							
Neospathodus pakistanensis							X																								
N. waageni							X	X																							
Xaniognathus expansus							X	X																							
Neogondolella milleri								X																							
N. elongata								X																							
N. jubata								X		X																					
Furnishius triserratus								X ?																							
Neogondolella regale										X	X	X																			
Xaniognathus elongatus										X																					
Neospathodus homeri										X																					
Neogondolella constricta													X			X															
Xaniognathus triassicus													X						X	X	X		X	X	X	X	X	X			
Metapolygnathus excelsa																	X														
Neogondolella navicula navicula																			X	X	X				X	X		X		X	
Epigondolella mungoensis																			X												
Metapolygnathus polygnathiformis																		X			X		X								
Neogondolella reversa																							X								
Epigondolella primitia																								X	X						
Neogondolella navicula hallstattensis																										X					
Epigondolella abneptis																										X	X			X	
E. multidentata																												X		X	
E. bidentata																														X	

* Ammonoid zones not represented in samples

GSC

TEXTFIGURE 59. Occurrences of the stratigraphically most significant conodont taxa in the sequence of ammonoid zones.

The conodont faunas are discussed in terms of the ammonoid zones. Of the 31 ammonoid zones of Tozer (1967), 5 are not represented by samples (Textfig. 59).

Concavum Zone. No samples.

Boreale and Commune Zones. Barren of conodonts.

Strigatus Zone. Sweet *et al.* (1971) characterize this zone by *Neogondolella carinata* (Clark). This conodont actually seems to range throughout most of the lower half of the Lower Triassic according to reports by Clark (1959), Sweet (1970b), and Sweet *et al.* (1971). In the present material, specimens of *N. carinata* were recovered only from the Strigatus Zone. Associated with these specimens are specimens that are referred to *N. mombergensis* (Tatge). This taxon needs further detailed study in North America. It has been reported from strata ranging from Permian through Ladinian (Tatge, 1956; Clark and Ethington, 1962; Mosher and Clark, 1965; Mosher, 1968a; Kozur, 1968a, b; and others). The type material is from Middle Triassic rocks in Germany and in the present material the species occurs at various levels from the Strigatus through the Meginae Zones. Kozur (1968a, b) has attempted to refine the stratigraphic significance of this taxon by recognition of subspecies. The species is characterized by a "generalized" gondolelloid form (Clark and Mosher, 1966, p. 391) and may therefore receive specimens which are not conspecific, only homeomorphic. This may account for its apparent long range.

A single specimen of *Xaniognathus curvatus* Sweet was recovered from the Strigatus Zone. The genus seems to be represented by stratigraphically restricted species at several levels in the Triassic and may be useful for stratigraphic work with Triassic rocks.

Candidus Zone. The total collection from the two samples of this zone consists of two fragmentary specimens, identified as *Neospathodus kummeli* Sweet. Elsewhere this form is restricted to the lower Dienerian, even to the lower part of the Candidus Zone (Sweet *et al.*, 1971, Fig. 1).

Sverdrupi Zone. Both *Neospathodus dieneri* Sweet and *N. cristagalli* (Huckriede) are represented in a sample from this zone. This is not inconsistent with the ranges given by Sweet (1970b, Fig. 4 and p. 215), however he recognizes two conodont zones based on the two forms and these correspond to the upper Candidus and Sverdrupi Zones, respectively (Sweet *et al.*, 1971, Fig. 1). *N. dieneri* was not recognized in the Candidus Zone samples from Canada and, with the low sample density, differentiation of these two conodont zones is not possible in the present study.

Xaniognathus deflectens Sweet is known from this zone and also, questionably, from the overlying Romunderi Zone.

Romunderi Zone. Neospathodus pakistanensis Sweet and *N. waageni* Sweet are represented by small numbers of specimens from both samples of this zone. Sweet (1970b, p. 216) indicated that these two forms do not have overlapping ranges in their type area, and pointed out that between their known occurrences there is a 50-foot interval from which no conodonts have been collected. Their ranges apparently do overlap in Canada.

The Romunderi Zone is characterized also by several species of *Neogondolella. N. crenulata* new species and *N. planata* (Clark) are restricted to the interval. The latter was reported by Clark (1959, p. 309) as ranging through a thick interval of the lower Lower Triassic up to the Meekoceras Zone. Tozer (1967, p. 20) indicated approximate equivalence of the Romunderi Zone in Canada to the *Meekoceras gracilitatus* beds in Idaho, and presum-

		LOWER TRIASSIC														MIDDLE TRIASSIC																
		Griesbachian			Dienerian					Smithian				Spathian		Anisian					Ladinian											
		Strigatus			Candidus		Sverdrupi			Romunderi		Tardus		Subrobustus		Caurus		Varium		Dele-eni	Poseidon		Meginae			Maclearni			Sutherlandi			
Species	Samples	47524	47527	51663	51667	56181	56205	47543	56224	28680	56279	42364	47547	56234	56256	68226	68203	68294	40109	74724	68284	74758	39907	50045	50043	42355	68237	68236	68279	68347	42354	42351
Ellisonia triassica U				1								4																				
E. triassica LA				4						8		14	29					9													2	
E. triassica LB				8						4		8	(?)5																			
E. triassica LB^2										2		2																				
E. triassica LF				2						8		20																				
E. gradata U				1			1			3		11	2	1				1											1		6	
E. gradata LA										2		24	6	3	2		1	7											2		2	
E. gradata LB										2		22	2		3			2													2	
E. gradata LC				3						2		20	2	6	2			17		3									2		18	1
? *E. teicherti* LA				2																												
? *E. teicherti* LB				3																												
Neogondolella carinata				164																												
N. mombergensis				1						22							6	525	4			13	1									
Xaniognathus curvatus				1																												
Neospathodus peculiaris				1																												
N. kummeli						2		(?)1																								
N. cristagalli							5		4																							
N. dieneri							9																									
Xaniognathus deflectens							3		(?)1		(?)1																					
X. sp. A							1																									
Neogondolella cronulata										11																						
Anchignathodus sp.										1																						
Neogondolella planata										11																						
N. nevadensis										21		215	83																			
Neospathodus pakistanensis										1	1																					
N. waageni										4	1	20	12																			
Ellisonia robusta U											1																					
E. robusta LB										4																						
Xaniognathus expansus										10		119	16																			
Neospathodus sp. A											1																					
Neogondolella milleri												24	7																			
N. elongata												25																				
N. jubata												2	(?)1	12																		
Furnishius triserratus												1																				
Prioniodella prioniodellides												16						4														
? *Pachycladina symmetrica*													3																			
Neogondolella regale														12			6	73														
Xaniognathus elongatus														2																		

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TABLE 2 *Abundance data for conodont taxa*

	MIDDLE TRIASSIC			UPPER TRIASSIC																								
	Ladinian			Karnian										Norian														
	Sutherlandi			Obesum		Nanseni		Dilleri	Welleri				Macrolobatus		Kerri		Dawsoni			Magnus		Rutherfordi		Columbianus	Suessi			
Species Samples	68264	68266	74773	42308	68217	26124	42309	68208	42306	42305	42385	51650	64627	64628	64654	68180	46505-C	46505-B	46505-A	64636	68191	46459	64659	46468	46507	68300	68304	64594	Totals
Ellisonia triassica U																													5
E. triassica LA					1										4	8							7						86
E. triassica LB																													25
E. triassica LB2																													4
E. triassica LF																													30
E. gradata U					1										3	2					1		4						38
E. gradata LA														6	4	18				1			9						87
E. gradata LB		1										1	5	3	3	(?)1					6	6	119				1		179
E. gradata LC		2	1		3				3		2		3	11	17	5			1		6	4	102	1					237
? *E. teicherti* LA																													2
? *E. teicherti* LB																													3
Neogondolella carinata																													164
N. mombergensis																													572
Xaniognathus curvatus																													1
Neospathodus peculiaris																													1
N. kummeli																													3
N. cristagalli																													9
N. dieneri																													9
Xaniognathus deflectens																													5
X. sp. A																													1
Neogondolella crenulata																													11
Anchignathodus sp.																													1
Neogondolella planata																													11
N. nevadensis																													319
Neospathodus pakistanensis																													2
N. waggeni																													37
Ellisonia robusta U																													1
E. robusta LB																													4
Xaniognathus expansus																													145
Neospathodus sp. A																													1
Neogondolella milleri																													31
N. elongata																													25
N. jubata																													15
Furnishius triserratus																													1
Prioniodella prioniodellides					2																								22
? *Pachycladina symmetrica*																													3
Neogondolella regale																													91
Xaniognathus elongatus																													2

TABLE 3

Abundance data for conodont taxa (cont.).
Totals refer to Tables 2 and 3

	LOWER TRIASSIC														MIDDLE TRIASSIC																
	Griesbachian			Dienerian					Smithian				Spathian		Anisian					Ladinian											
	Strigatus			Candidus		Sverdrupi			Romunderi		Tardus		Subrobustus		Caurus		Varium		Dele-eni	Poseidon		Meginae			Maclearni			Sutherlandi			
Species / Samples	47524	47527	51663	51667	56181	56205	47543	56224	28680	56279	42364	47547	56234	56256	68226	68203	68294	40109	74724	68284	74758	39907	50045	50043	42355	68237	68236	68279	68237	42354	42351
Hindeodella multihamata													1																		
Neospathodus homeri														3																	
Ellisonia sp. U														3																	
E. sp. LA														2																	
E. sp. LB													4	5																	
E. sp. LC														5																	
Xaniognathus sp.														2																	
Neogondolella sp.																	2		1												
Cratognathodus sp. A																	2														
Neospathodus sp. B																	1														
N. sp. C																	1														
Neogondolella constricta																			2	6	5										
Xaniognathus triassicus																			1											6	
Cypridodella conflexa																			3												
Metapolygnathus excelsa																						2		1							
Neospathodus sp. D																								1							
Metapolygnathus polygnathiformis																											6				
Neogondolella navicula navicula																												18		343	5
Xaniognathus sp. B.																												3		1	
Epigondolella mungoensis																														19	
Parachirognathus jungi																														1	
Cypridodella mediocris																														2	
Cratognathodus sp. B																														3	
Cypridodella scolosculptura																															
Neospathodus sp. E																															
Prioniodella decrescens																														2	
Neogondolella reversa																															
Epigondolella primitia																															
Hindeodella uniforma																															
Diplododella bidentata																															
Xaniognathus sp. C																															
Neogondolella navicula hallstattensis																															
Epigondolella abneptis																															
E. multidentata																															
Xaniognathus sp. D																															
Epigondolella bidentata																															
Totals	0	0	191	0	2	19	1	5	116	5	547	168	41	27	0	13	644	4	10	6	18	3	0	2	0	0	6	26	0	407	6

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TABLE 4 | *Abundance data for conodont taxa (cont.). Totals refer to Tables 2 and 4*

	MIDDLE TRIASSIC			UPPER TRIASSIC																								
	Ladinian			Karnian											Norian													
	Sutherlandi			Obesum		Nanseni		Dilleri	Welleri				Macrolobatus		Kerri		Dawsoni			Magnus		Rutherfordi		Columbianus	Suessi			
Species / Samples	68264	68266	74773	42308	68217	26124	42309	68208	42306	42305	42385	51650	64627	64628	64654	68180	46505-C	46505-B	46505-A	64636	68191	46459	64659	46468	46507	68300	68304	64594	Totals
Hindeodella multihamata																													1
Neospathodus homeri																													3
Ellisonia sp. U																													3
E. sp. LA																													2
E. sp. LB																													9
E. sp. LC																													5
Xaniognathus sp.																													2
Neogondolella sp.																													3
Cratognathodus sp. A																													2
Neospathodus sp. B																													1
N. sp. C																													1
Neogondolella constricta																													13
Xaniognathus triassicus					1		1			1			1		9	2	1				2		6						31
Cypridodella conflexa															5							3	2						13
Metapolygnathus excelsa																													3
Neospathodus sp. D																													1
Metapolygnathus polygnathiformis						3	5		43	1	2																		60
Neogondolella navicula navicula	1	20	12		2	3									36	159		2	2				28			1	2		634
Xaniognathus sp. B.																													4
Epigondolella mungoensis		1	1																										21
Parachirognathus jungi																													1
Cypridodella mediocris																						1	5				1		9
Cratognathodus sp. B																													3
Cypridodella scolosculptura		2			3																								5
Neospathodus sp. E				1																									1
Prioniodella decrescens					1									1															4
Neogondolella reversa												16																	16
Epigondolella primitia													35	366	143	53													597
Hindeodella uniforma															1														1
Diplododella bidentata															1														1
Xaniognathus sp. C																1													1
Neogondolella navicula hallstattensis																	4												4
Epigondolella abneptis																		2		15	161					1			179
E. multidentata																						55	1681				1		1737
Xaniognathus sp. D																							2						2
Epigondolella bidentata																										2			2
Totals	1	26	14	1	14	6	6	0	46	2	4	17	44	387	226	249	5	4	3	16	176	69	1965	1	0	4	5	0	5558

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TABLE 5

Abundance data for conodont taxa (conc.).
Horizontal totals refer to Tables 4 and 5.
Vertical totals refer to Tables 3 and 5

ably elsewhere in the Great Basin. Another of Clark's species, *N. nevadensis* (Clark), first appears in this zone and also occurs in the next higher zone.

A single large specimen referred to *Anchignathodus* was recovered from the zone. If this is correctly identified, it is the highest reported occurrence of this genus (Sweet, 1970b, p. 221–222, gives its upper limit as basal Triassic).

The new and distinctive species, *Xaniognathus expansus*, first occurs in the Romunderi Zone and reaches its peak of abundance in the overlying Tardus Zone, but the abundance of information from the samples must be treated with discretion because of the possible influence of unknown environmental controls.

Tardus Zone. Neospathodus waageni Sweet reaches its peak of abundance in this zone. Sweet *et al.* (1971, Fig. 2) show it to range throughout the Smithian, an observation verified in this study.

Neogondolella elongata Sweet, *N. jubata* Sweet, and *N. nevadensis* (Clark) are present. The last is especially abundant and is not found in samples from younger zones.

A fragment referred to *Furnishius triserratus* Clark was found in this zone and its biostratigraphic position agrees with that of the holotype of that species in the *Meekoceras* limestones of Nevada (Clark, 1959, p. 311).

Pilaticus Zone. No samples.

Subrobustus Zone. Neogondolella regale Mosher and *Neospathodus homeri* (Bender) characterize the fauna of this zone. The former is also present in lower Anisian samples, both in Canada and Nevada. The latter has been reported from upper Lower Triassic strata in Pakistan (Sweet, 1970b), Greece (Bender, 1968), and south Tyrol (Staesche, 1964) and seems to be a significant guide to this interval. *Xaniognathus elongatus* Sweet is restricted to this zone in the present study.

A group of elements including specimens similar to some included earlier in *Cypridodella unialata* Mosher (1968a) is present in one sample from this zone. Because specimens of the four forms represented in this group are so similar to one another in size and internal appearance and are analogous to the various parts that Sweet (1970a, b) included in *Ellisonia* apparatuses, it seems probable that they represent a single conodont apparatus. The *C. unialata* element has been reported elsewhere from this interval (Mosher, 1968a, p. 922; Bender, 1968, Pl. 1, Figs. 10, 11, 14) and the apparatus may be of stratigraphic significance. Generally speaking, with some important exceptions cited by Sweet, the *Ellisonia* species thus far recognized seem to have little stratigraphic value. Sweet (1970a, b) relied heavily on internal properties such as distribution of white matter to differentiate the elements, which are morphologically very similar and present in analogous positions in apparatuses of different species. However, such properties are obscure when specimens are opaque or black, as is frequently so. Under such circumstances, elements that are similar externally have been included within single form species that range throughout the Triassic and even into the Permian. It is unlikely that discrete species of the organism survived so long but means of distinguishing stratigraphically distinct taxa among these multielement apparatuses are not readily apparent.

Twenty of the 32 conodont species considered significant in this report occur in the Lower Triassic. Of the 22 conodont zones proposed by Sweet *et al.* (1971, Figs. 2, 3), 13 are in the Lower Triassic. The final peaks of abundance and diversity of conodonts are reflected in the faunas of the Lower Triassic and the later reduction in diversity reflects the decline toward extinction of the group.

Caurus and Varium Zones. The conodont faunas obtained allow confident differentiation neither between these two zones nor from the underlying Subrobustus Zone. *Neogondolella regale* Mosher continues from the Spathian and *N. mombergensis* (Tatge) is present. Some potentially useful neospathodids and a distinctive new cratognathodid are each represented by one or two specimens in one of the Varium Zone samples; however, from such a meager representation it is difficult to assess their true biostratigraphic value.

Deleeni Zone. Ten conodonts were recovered from this zone. Three represent *Neogondolella constricta* (Mosher and Clark) which has been reported from the upper Anisian in Nevada (Mosher and Clark, 1965; Mosher, 1968a). It was recovered also in the lower Ladinian Poseidon Zone in the present study, extending its known range upwards.

Chischa and Subasperum Zones. No samples.

Poseidon Zone. Only two taxa were recovered, *Neogondolella constricta* and *N. mombergensis.* Neither is distinctive for the interval; however, this is the youngest reported occurrence for *N. constricta.*

Meginae Zone. The youngest recovered representatives of *N. mombergensis* occur in this zone. Several specimens are present of *Metapolygnathus excelsa* (Mosher) that elsewhere is known from the upper Anisian and the lower Karnian (Mosher, 1968a, p. 907, 908; Krystyn *et al.*, 1971, p. 299, 300). The present Ladinian occurrence partly bridges the gap between.

Maclearni Zone. Mosher (1968b) suggested that *Metapolygnathus excelsa* was ancestral to the Upper Triassic evolutionary bioseries that he noted to begin with *Metapolygnathus polygnathiformis* (Budurov and Stefanov), but the morphologic transition between these taxa was conjectured. In the present study, specimens of *M. polygnathiformis* from the upper Ladinian Maclearni Zone and specimens of *M. excelsa* from the underlying Meginae Zone show such transition.

Sutherlandi Zone. This conodont fauna is the most distinctive of those of Middle Triassic zones. Specimens of *Epigondolella mungoensis* (Diebel) are abundant in the Canadian material as they are in correlative Nevada material (Mosher, 1968a), further corroborating the conclusion (Mosher, 1967; Müller and Mosher, 1971) that supposed Cretaceous conodonts described by Diebel (1956) from the Cameroons are upper Middle Triassic. *E. mungoensis* is one of the better established guide conodonts in the Triassic and, except by Diebel, it and associated distinctive forms have not been reported from other than the Sutherlandi Zone or approximately equivalent strata.

Obesum and Nanseni Zones. In Nevada, equivalent *Trachyceras* Zone strata contain a distinctive and abundant conodont fauna (Mosher, 1968a, 1971). Alpine rocks of this interval also yield distinctive conodonts. In Canada, samples from these zones yielded disappointingly sparse faunas of mostly long ranging forms. *Neogondolella navicula* (Huckriede) is present, but ranges from the Sutherlandi to the Suessi Zones and elsewhere is known from as low as the Anisian (Mosher and Clark, 1965; Mosher, 1968a). The long range reported for this taxon may result from homeomorphy and more detailed studies may reveal subtle differences which will allow distinction of a number of homeomorphic forms. *Metapolygnathus polygnathiformis* is known from the Nanseni Zone. A few specimens of *Cypridodella scolosculptura* Mosher were recovered and resemble specimens from the *Trachyceras* strata of Nevada (Mosher, 1968a, 1971). This form seems to be the only stratigraphically distinctive conodont present in the lower Karnian samples.

Dilleri Zone. Barren of conodonts.

Welleri Zone. Mosher (1968a) considered this zone to contain virtually the entire range of *Metapolygnathus polygnathiformis* but it is now clear that the species has a longer range. The Welleri Zone forms the upper limit of its known range in Canada. In stratigraphic sequences where its subsequent evolution can be observed (Mosher, 1968b), it clearly gives rise to and is replaced by *Epigondolella primitia* Mosher and *E. abneptis* (Huckriede). It likely does not range above the Welleri Zone.

Neogondolella reversa new species was recovered from a single sample from this zone; its stratigraphic limits have not been established.

Macrolobatus Zone. This zone is biostratigraphically important because it yields specimens of *Epigondolella primitia* Mosher that establish an evolutionary link between Anisian–Karnian *Metapolygnathus* and the Norian *Epigondolella* (*see* Mosher, 1970, for discussion of this linkage and of evolution of the group in the Norian). *E. primitia* itself straddles the Karnian–Norian boundary.

Kerri Zone. Canadian samples from this zone yield no zonally distinctive conodonts. *E. primitia* Mosher continues from the upper Karnian together with the long ranging *Neogondolella navicula* (Huckriede).

Dawsoni Zone. Epigondolella abneptis (Huckriede) makes its earliest appearance in this zone, together with specimens that are similar to juvenile specimens of *Neogondolella navicula hallstattensis* (Mosher) that is known from lower Norian strata at Someraukagel, Austria (Mosher, 1968a). *E. abneptis* has been reported from Karnian strata (Huckriede, 1958; Krystyn *et al.* 1971), but with one exception (Huckriede, 1958, loc. 52, p. 144, not collected by that author), these Karnian reports all refer to specimens from the problematic locality at Feuerkogel, Austria (*see* Mosher, 1968a, p. 915; also Krystyn *et al.*, 1971, p. 269). Because the development of *E. abneptis* is so clearly demonstrated in continuous stratigraphic sequences of the lower Norian, both in the region around Feuerkogel and in Nevada and British Columbia, the writer is in doubt that the stratigraphic problems at Feuerkogel are resolved even after the work of Krystyn and his co-authors, or whether homeomorphic epigondolleloids arose in the Upper Triassic, a possibility mentioned by Kozur and Mostler (1971, p. 4).

Magnus Zone. The conodont fauna simply is a continuation of that of the Dawsoni Zone. *Epigondolella abneptis* is present, but no other zonally distinctive forms.

Rutherfordi Zone. E. multidentata Mosher from this zone provides another evolutionary link in the *Epigondolella* bioseries. This form arises from *E. abneptis* and is diagnostic of the upper middle Norian and upper Norian (Mosher, 1970, p. 737, 738). Krystyn (1970, p. 500; and pers. com.) reports it in Austria as species 2 on his Table 1 with a virtually identical range beginning in the upper middle Norian.

Columbianus Zone. The fauna from samples assigned without reservation to this zone is totally without stratigraphic distinction, consisting of a single specimen morphologically similar to the LC-element of *Ellisonia gradata* Sweet. Elements like this formerly have been referred to the form species, *Enantiognathus ziegleri* (Diebel), which has been reported from the Permian and throughout the Triassic.

Suessi Zone. This is the youngest Triassic zone from which samples were available. The fauna agrees well with uppermost Triassic conodont faunas from both Nevada and Austria. ***Epi-***

gondolella bidentata Mosher is present and represents the end member of the *Epigondolella* evolutionary bioseries. It is restricted to the upper Norian wherever it has been reported (Mosher, 1968a, 1970; Krystyn, 1970). *E. abneptis*, *E. multidentata*, and *Neogondolella navicula* (Huckriede) also survive into the zone.

Marshi Zone. No samples.

Systematic Paleontology

All designated specimens are housed in the type collection of the Geological Survey of Canada, Ottawa (prefix GSC). Abundance data for all specimens and samples are given in Tables 2–5. Complete synonymies for many of the species are given by Mosher (1968a) or Sweet (1970b), which provide more complete taxonomic references than the present paper.

Order CONODONTOPHORIDA

Genus ***Anchignathodus*** Sweet, 1970

Anchignathodus Sweet, 1970a, p. 7.

Type species. *Anchignathodus typicalis* Sweet, Chhidru Formation, Salt Range, Pakistan.

Description. Skeletal apparatus of asymmetric paired conodont elements that are arched, straight, or slightly bowed blades. Denticles high, laterally compressed, forming distinctive and prominent anterior crest, decreasing in size posteriorly. Attachment surface characterized by broadly flaring sheath that tapers toward the posterior, but is confined to narrow groove toward the anterior.

Anchignathodus sp.

Plate 17, figure 1

Description. A single large specimen, 1.5 mm long, was recovered. Flaring attachment surface present at point marking anterior third. Anterior part of blade bears 5 or 6 rapidly decreasing denticles and is bowed laterally forming approximately a 30° angle with posterior blade. Lower third of blade bears lateral swelling making unit thickest about 1/3 up from base. Swelling continuous on upper margin of flare giving it bulbous appearance. Specimen bears 18 fused denticles, the posterior 7 or 8 of which are accompanied by an enlargement of the lateral swelling. Lower surface bears widely flaring attachment structure that tapers both anteriorly and posteriorly into narrow grooves.

Remarks. The occurrence of this specimen in the lower Smithian is the youngest yet reported for the genus. Sweet (1970, p. 222) reported it to have become extinct in the earliest Early Triassic. The single specimen is included in *Anchignathodus* because of the widely flaring basal cavity and blade-like character of the unit, but it also possesses characters associated with *Xaniognathus* Sweet, such as the lateral swelling and the lateral bowing. Its assignment to *Anchignathodus* must be considered tentative.

Material and occurrence. One specimen from Romunderi Zone (GSC 29924).

Genus *Cratognathodus* Mosher, 1968

Cratognathodus Mosher, 1968a, p. 918.

Type species. *Prioniodina kochi* Huckriede, Hallstätterkalk (Jul), Feuerkogel am Röthelstein, Austria.

Description. Blade-like units with broad, spike-like main denticle. Widely expanding basal cavity beneath main denticle extending anteriorly and posteriorly into distally diminishing groove. White matter restricted to upper parts of denticles.

Cratognathodus sp. A

Plate 17, figure 5

Description. Arched blade-like unit bearing 5 or 6 strongly inclined denticles. Main denticle twice as high as blade and located at posterior 1/3 of unit. Slightly bowed laterally. Blade bears ridge-like lateral swelling on anterior part at base of denticles. Entire basal surface broadly grooved. Lips of basal groove flare up at basal cavity so that margins of cavity are even with its floor.

Material and occurrence. Two specimens from Varium Zone (GSC 29925 illustrated).

Cratognathodus sp. B

Plate 17, figure 2

Description. Arched blade relatively thick giving subrounded cross-section. Broad basal groove with thick lips. Basal cavity only slightly flared. Main denticle broad and approximately twice as high as blade. Unit straight or only slightly bowed laterally.

Remarks. Distinguished from *C.* sp. A by subrounded cross-section of blade and much less flaring of basal cavity.

Material and occurrence. Three specimens from Sutherlandi Zone (GSC 29926 illustrated).

Genus *Cypridodella* Mosher, 1968

Cypridodella Mosher 1968a, p. 920.

Type species. *Cypridodella conflexa* Mosher, Hallstätterkalk, Steinbergkogel, Austria.

Description. Unit possesses long downward-projecting process on bar set with numerous inclined denticles. A shorter process may or may not be present. Basal cavity commonly small pit, but may be absent or enlarged. Inclination of main denticle such that long process is posterior.

Cypridodella conflexa Mosher, 1968

Plate 17, figure 3

Cypridodella conflexa Mosher, 1968a, p. 920, Pl. 113, figs. 8, 9.

Description. Unit bears long posterior bar that projects strongly downward approximately parallel to main denticle. Short anterior process extends at nearly right angles to main denticle and is bent laterally toward the outside at point where it joins main denticle. Both processes and the main denticle curve distally toward the inside of the unit. Basal pit present, extending distally into a groove along lower edge of both processes.

Material and occurrence. Elements referred to *C. conflexa* were recovered from Anisian and Norian (GSC 29927 illustrated from Rutherfordi Zone) strata. A long range also was reported earlier by Mosher (1968). If the form occupied a position in a multielement apparatus, as is likely (LA-elements in *Ellisonia triassica* Müller resemble some members of this genus), then biologically distinct but functionally similar homeomorphs may be present among collections of specimens of divergent ages.

Cypridodella mediocris (Tatge, 1956)

Plate 17, figure 4

Metalonchodina mediocris Tatge, 1956, p. 111.
Cypridodella mediocris Mosher, 1968, p. 920, Pl. 113, fig. 26.
Prioniodina mediocris Bender, 1968, p. 526, Pl. 59, figs. 10, 15; Budurov and Zagortschev, 1968, Pl. 1, fig. 4.

Description. Possesses long posterior process but anterior process absent. Anterior edge of terminal main denticle sharpened and prominent. Main denticle appears isolated with posterior bar attached on outer side. Main denticle, minor denticles, and posterior bar all curve inward distally.

Material and occurrence. Specimens were recovered from Ladinian (GSC 29928 illustrated from Sutherlandi Zone) and Norian samples. This distribution encompasses both that reported by Tatge (1956) and Mosher (1968).

Cypridodella scolosculptura Mosher, 1968

Plate 17, figure 7

Cypridodella scolosculptura Mosher, 1968, p. 921, Pl. 113, figs. 13, 22.

Description. Downward projecting posterior process marked by wide attachment surface on inside of unit. This attachment surface extends as sharp-pointed indentation up side of apex of unit.

Remarks. The fragmentary specimens recovered in the present study are in stratigraphic agreement with the types; however, because of fragmentary nature can be assigned only with uncertainty to the species. In Nevada the species appears to be restricted to upper Ladinian–lower Karnian strata.

Material and occurrence. Fragmentary specimens obtained from Sutherlandi and Obesum (GSC 29929 illustrated) Zones.

Genus ***Diplododella*** Ulrich and Bassler, 1926

Diplododella Ulrich and Bassler, 1926, p. 41.

Type species. *Diplododella bilateralis* Ulrich and Bassler, Chattanooga Shale, Alabama.

Description. Conodonts that are bilaterally symmetrical with posterior bar and two antero-lateral branches. Small pit present beneath main denticle.

Diplododella bidentata (Tatge, 1956)

Plate 17, figure 8

Roundya bidentata Tatge, 1956, p. 142, Pl. 6, fig. 10.
Diplododella bidentata Mosher, 1968, p. 923, Pl. 113, fig. 30.

Description. Unit consists of long posterior bar with anteriorly terminal large main denticle and series of smaller denticles whose inclination increases distally. Anterolateral branches short and upturned; bearing few if any denticles.

Material and occurrence. A single specimen was encountered in the Kerri Zone (GSC 29930).

Genus ***Ellisonia*** Müller, 1956

Ellisonia Müller, 1956, p. 822.

Type species. *Ellisonia triassica* Müller, Lower Triassic *Meekoceras* Limestone, Dinner Springs Canyon, Nevada.

Remarks. Sweet (1970a, p. 8; 1970b, p. 224) revised the concept of *Ellisonia* from the single, bilaterally symmetrical, branched form described by Müller, to a multielement species including the symmetrical element as one of its components. For a complete discussion of his concept and the reasons for its adoption, I refer the reader to Sweet's works. As conceived as a multielement species, *Ellisonia* includes morphologic types that are long ranging. By using internal properties, principally the distribution of white matter, Sweet restricted the ranges of the multielement species he proposed. Much of the material in the present study consists of black or opaque specimens, therefore internal properties are not visible. In order to avoid a duplication of names for otherwise similar specimens, I have applied Sweet's terminology even where white matter could not be observed. Continuing association of morphologically similar elements to those included in Sweet's species far beyond the stratigraphic limits shown by Sweet for those species suggests either long ranges for those taxa or functional similarity among analogous elements in biologically diverse but partly or completely homeomorphic apparatuses.

Terminology for the various elements included in each multielement species follows that of Sweet (1970b, p. 225). Synonymies for all species are contained in Sweet (1970a, b).

Ellisonia gradata Sweet, 1970

Plate 17, figures 10, 14, 16, 28

Ellisonia gradata Sweet, 1970b, p. 229, Pl. 4, figs. 1–8.

Description. Skeletal apparatus includes bilaterally symmetrical U-element (fig. 10) with straight, denticulated posterior process and downwardly projecting denticulated anterolateral processes; LA-(fig. 14) and LC-(fig. 16) elements with asymmetrical anterolateral process and lacking a posterior process; and LB-elements (fig. 28) with short posterior and long anterior processes; some of which are bifid at anterodistal end. White matter is distributed in irregular clouds so that all elements have spotted appearance.

Remarks. This species includes elements morphologically similar to several previously described. For example, the U-element resembles *Diplododella magnidentata* (Tatge), the LA- and LC-elements resemble *Cypridodella spengleri* (Huckriede) and *Enantiognathus ziegleri* (Diebel), respectively. The LB-element is similar to forms previously named *Prionio-*

dina latidentata Tatge. These forms are abundant through virtually the entire Triassic. Although the spotted nature of white matter distribution is not always apparent, even when specimens are not opaque, the external form is closely similar throughout this interval.

Material and occurrence. Several hundred specimens representing most of the zones were recovered (GSC 29936–29939 illustrated, all from Tardus Zone).

Ellisonia robusta Sweet, 1970

Plate 17, figures 22, 23

Ellisonia robusta Sweet, 1970b, p. 231, Pl. 5, figs. 6–8, 10, 12, 16.

Description. Elements have peg-like denticles; U-element with long, straight posterior process, and anterolateral processes that project downward forming an arch perpendicular to plane of posterior process. Distal ends of lateral processes curve anteriorly. LA- and LC-elements have asymmetrical anterolateral processes; LB-elements with long posterior and anterior processes, some of which are bifid. White matter densely developed and uniformly distributed throughout elements.

Remarks. Only one fragmentary U-element and four LB-elements were recovered from two samples. The peg-like, discrete nature of the denticles and the distal anterior curving of the lateral processes of the U-element were considered diagnostic. Stratigraphic position of the specimens is in good agreement with that reported for the species by Sweet (1970b, p. 226).

Material and occurrence. Five specimens from the Romunderi Zone (GSC 29942, 29943 illustrated).

?*Ellisonia teicherti* Sweet, 1970

Plate 17, figures 19, 25

(?) *Ellisonia teicherti* Sweet, 1970b, p. 232, Pl. 4, figs. 20–28.

Description. Symmetrical to slightly asymmetrical U-elements with no posterior process. L-elements with short anterior and long posterior processes, needle-like denticles and an expanded attachment surface on inner side of element. All elements opaque.

Remarks. Five fragmentary specimens were recovered representing, it is believed, LA- and LB-elements of this species. The LA-element is assigned on the basis of the long denticles, the twisting anterior and posterior processes, and the large attachment structure. Strong lateral curving of the short anterior process of the fragmentary LB-specimens formed the basis for their assignment. Stratigraphic position is in approximate agreement with that of Sweet (1970b, Fig. 4).

Material and occurrence. Five specimens from Strigatus Zone (GSC 29940, 29941 illustrated).

Ellisonia triassica Müller, 1956, *sensu* Sweet, 1970

Plate 17, figures 9, 12, 15, 17, 32

Ellisonia triassica Müller, Sweet, 1970b, p. 235, Pl. 5, figs. 9, 13–15, 17, 18, 20–22.

Description. Stout elements; U-elements with long, straight posterior process; intergradational LA- and LF-elements; LB-elements with a long posterior and a short anterior process. Uniform distribution of white matter attachment surface inverted on large specimens.

U-element bars subcircular in cross-section, with stout, peg-like denticles, which increase in size and inclination distally on long posterior process. LA-element with two asymmetrical anterolateral processes one much longer than other. Short process not denticulated, or with only 1 or 2 denticles; longer process curves posteriorly with series of 5 or 6 discrete distally decreasing denticles. Cusp laterally costate; lower posterior part of main denticle swells into posteriorly directed short non-denticulated process whose looping margin defines the edge of the expanded attachment surface.

Elements assigned to LB_1 have subequal anterior and posterior processes, and strongly inverted and laterally striated attachment surfaces. Most characteristic is that the cusp is offset to outside of unit, forming angle of 30 to 40 degrees with curving plane defined by denticles of the two processes. Denticles round in cross-section and discrete. Lower surface sharp-edged. Both processes curve distally inward.

A variant form of LB-element, here designated LB_2, was encountered in association with other specimens of the species. It is similar in size, general morphology, and stratigraphic distribution with the other components of *E. triassica*, but was not reported by Sweet. This element has a broad, flat, slightly inclined attachment area below centre of unit, facing inside of unit. Attachment area becomes inverted distally. Diamond-shaped pit beneath centre of unit is produced into anterior and posterior ridge along centre of distal parts of attachment area. Margins of surface marked by laterally extending lip or apron. Distal end of posterior process curved toward outside.

LF-elements with large main cusp and strongly downward projecting and laterally curving anterior process with 3 or 4 large, discrete, subrounded, distally larger denticles. Attachment surface inverted.

Remarks. Elements of *E. triassica* are so much larger than other conodonts in my collections that size alone almost serves to distinguish them. Virtually no small specimens referable to the species were recovered. The LA-element is identical in form with a long-ranging element variously named *Hibbardella subsymmetrica*, *Lonchodina muelleri*, and *Cypridodella muelleri* in earlier works (Müller, 1956; Tatge, 1956; and Mosher, 1968, respectively). This element ranges throughout the Triassic but except in the Lower Triassic, has not been reported in association with other elements of *E. triassica*. This would suggest homeomorphy, however it is not clear with which other analogous forms, if any, the possible later homeomorph is associated.

Material and occurrence. Over one hundred specimens; all except LA-elements restricted to Strigatus, Romunderi (GSC 29932, 29933 illustrated), and Tardus Zones (GSC 29931, 29934, 29935 illustrated). Specimens assigned to LA-elements also recovered from samples of Columbianus Zone.

Ellisonia sp.

Plate 17, figures 11, 20, 27, 31

Description. Elements small and delicate with needle-like denticles. U-element with long straight, laterally compressed posterior process; main cusp preceded by 2 or 3 small anterior denticles on downward projecting anterior process which bifurcates into forward leaning, downward projecting anterolateral processes. LA- and LC-elements with one long denticulated anterolateral process but other anterolateral process greatly reduced to absent. LB-element compressed, with short, downward arched anterior process and long, straight posterior process.

Remarks. These elements have been brought together because all are characteristically delicate with needle-like denticles, and because they are invariably associated not only in the Canadian material but also in stratigraphically equivalent Nevada samples (M-2360, M-2565, *in* Mosher, 1968a). Specimens previously assigned to *Diplododella magnidentata* (Tatge) (U), *Cypridodella conflexa* Mosher (LA), *C. unialata* Mosher (LC), and *Hindeodella triassica* Müller (LB) in the two Nevada samples would be included here. Lacking large numbers of specimens or more samples to further check associations and ratios, I will leave formal designation of the species until additional data can be gathered.

Material and occurrence. Nineteen specimens from Subrobustus Zone (GSC 29944–29947 illustrated).

Genus *Epigondolella* Mosher, 1968

Epigondolella Mosher, 1968b, p. 935.
Tardogondolella Bender, 1968, p. 530.

Type species. *Polygnathus abneptis* Huckriede, Hallstätterkalk, Someraukogel, Austria.

Description. Platform conodonts with high anterior free blade; platform bears crenulations or node-like dentition along margins. Earliest growth stages lack platform.

Remarks. Members of this conodont genus and its evolutionary predecessors in *Metapolygnathus* constitute a remarkable bioseries demonstrating gradual evolutionary changes over documented Upper Triassic stratigraphic intervals that link all known forms of the genus (Mosher, 1970). Kozur and Mostler (1971, p. 4) indicate recognition of two distinct and parallel evolutionary series, each involving "homeomorphic" members of *Epigondolella* and associated forms. The basis for such recognition, according to these authors, is to be presented in a forthcoming paper by Kozur. As this paper is not yet published, and as the writer's studies of hundreds of specimens from several localities in Europe and North America have not led him to any different conclusion than that he earlier expressed (Mosher, 1968b, 1970), he can neither adopt nor defend their point of view at this time. The species of *Epigondolella* are stratigraphically the most useful and widespread guide fossils among now known Upper Triassic conodonts.

Because specimens of the genus frequently constitute virtually the entire collection from a sample, and because all growth stages are commonly present in approximately equal numbers, it is believed the genus and its species are biologically distinct taxa. Furthermore, it appears that, at a given time, the skeletal apparatus contained elements representing several successive stages of growth.

In a paper bearing the date of 1967, but according to correspondence with several European and North American libraries and workers, first distributed through personally delivered separates in November 1968, Bender (1968, p. 530) proposed the name *Tardogondolella* for this genus. The question of priority here appears to be entirely resolvable by application of the nomenclatural code. According to personal communication with W. C. Sweet, Bender's paper is part of a volume whose title page states it is the 1968 volume. The title page also indicates the volume was not issued until 1970. The personally delivered copies of Bender's paper are unquestionably preprints. Although they bear the date 1967, evidence of distribution suggests these were unavailable until late in 1968. Since the volume was intended for 1968, it seems clear that 1968 is the earliest possible date that can be associated with the taxonomic names in this paper. Article 21 of the International Code of Zoological Nomenclature, part a, specifies that an indicated date is assumed correct in the *absence of evidence* *to the contrary.* Clearly controvertible evidence is at hand. Part e of Article 21 specifies that, lacking evidence otherwise, when only a range of dates is indicated for a work (i.e., the year 1968 of the volume) the last day of the range is to be considered the publication date. In the light of Recommendation 21A (I.C.Z.N., p. 21) which states that "editors and publishers should not put any copy or part of a work into circulation in advance of the specified date of publication," and that "authors should not distribute reprints (separata) in advance of such publication," the actions of both the publisher and author are clearly in violation of the intent if not also the letter of the Code. The earliest known copies of preprints were seen in November 1968. General private distribution of the preprints apparently did not take place until 1969, and the publisher did not issue the work until 1970. Whatever date is actually to be applied to the work, the Code seems clearly not to allow a date earlier than November 1968. *Tardogondolella* must therefore be considered a junior synonym of *Epigondolella.*

Epigondolella abneptis (Huckriede)

Plate 18, figures 6, 12, 13, 14, 16, 17

Polygnathus abneptis Huckriede, 1958, p. 156, Pl. 11, fig. 33?, Pl. 12, figs. 30–36, Pl. 14, figs. 1–3, 5, 12–14 16–22, 26, 27, 32, 47–58; Budurov and Vrabljanski, 1966, Pl. 4, fig. 22; Spassov, 1967, p. 29, Pl. 1 figs. 12–14; Budurov and Pevny, 1970, Pl. 17, figs. 13, 14.

Gladigondolella abneptis (Huckriede), Nohda and Setoguchi, 1967, p. 232, Pl. 2, figs. 1–7; Nogami, 1968, p. 122, Pl. 8, *only* figs. 1–7, ?8; Hayashi, 1968a, p. 68, Pl. 2, figs. 6, 7, 8.

Gladigondolella abneptis echinatus Hayashi, 1968a, p. 68, Pl. 2, fig. 1.

Gladigondolella abneptis spatulata Hayashi, 1968a, p. 69, Pl. 2, fig. 5.

Epigondolella abneptis (Huckriede), Mosher, 1968a, p. 936, Pl. 118, figs. 22–30; 1970, Pl. 110, figs. 14, 15, 18, 20, 21; Sweet *et al.*, 1971, Pl. 1, figs. 18, 27.

Tardogondolella abneptis (Huckriede), Bender, 1968, p. 531, Pl. 59, *only* fig. 21; Kozur and Mostler, 1971, Pl. 2, figs. 7, 9.

Description. Platform margin bears elongated nodes, oriented so as to appear to radiate from terminal node of carina; posterior end of platform squared off; low ridges extend across platform from terminal node of carina toward each corner. Anterior margins of platform upturned giving pinched-in appearance. Lower surface bears keel that bifurcates beneath terminal node, each branch lying beneath corresponding ridges on platform surface.

Remarks. This species was introduced in the early Norian as an evolutionary derivative of *E. primitia* Mosher. It gave rise to *E. multidentata* Mosher in the middle Norian and appears to have co-existed with its descendents until near the end of Triassic time.

Huckriede (1958, Pl. 11, fig. 33) showed a single specimen reportedly recovered from upper Anisian rocks. The specimen is similar to *E. abneptis*, however its morphological details are obscure in the photograph. The specimen could also be associated with *E. mungoensis* (Diebel).

Hayashi (1968a) proposed several new "varieties" of *E. abneptis*, which he later changed to subspecies (1968b). The forms he designates *E. abneptis* sensu stricto, *E. abneptis echinatus*, and *E. abneptis spatulata* are closely similar to growth stages of *E. abneptis* reported in Mosher (1968a), wherein the platform is introduced posteriorly, leaving the anterior part of the blade free. Since the specimens in Hayashi's collection came from a single or very few samples from one locality, it is likely that growth stages are represented. The establishment of subspecies is generally made on geographic or stratigraphic criteria.

Material and occurrence. Present in Dawsoni and Suessi Zone samples, and very abundant in Magnus Zone samples (GSC 29948, 29949 illustrated).

Epigondolella bidentata Mosher, 1968

Plate 18, figures 23, 24, 28

Epigondolella bidentata Mosher, 1968a, p. 936, Pl. 118, figs. 31–36; 1970, Pl. 110, figs. 27, 28; Sweet *et al.* 1971, Pl. 1, fig. 30.
Tardogondolella mosheri Kozur and Mostler, 1971, p. 15 (refers to Pl. 118, fig. 36 *in* Mosher, 1968, above).

Description. Platform represented by two lateral nodes extending outward then upward from point on blade slightly posterior of centre. A small lateral ridge commonly extends around posterior sides and end of blade as platform remnant.

Remarks. This species represents the end-point in the evolution of *Epigondolella* with the progressive reduction of the platform and apparent near return to an ancestral neospathodoid condition. This exhibition of neotony is discussed in Mosher (1970, p. 740).

Kozur and Mostler (1971, p. 15) established *Tardogondolella mosheri* apparently on the basis of a single illustrated specimen in my 1970 paper (Pl. 118, fig. 36). They distinguished it from *E. bidentata* on the basis of the position of the lateral denticle and the basal cavity. In Mosher, 1968a (Pl. 118, figs. 31–35), the position of these features can be seen to shift during ontogeny from nearly at the posterior end to slightly posterior of the centre of the unit. A slight continuation of this trend produces the next specimen, shown in figure 36 of that plate (refigured on Pl. 110 of the 1970 paper). Based on my study of specimens from both North America and Europe (Mosher, 1968a) I see no reason to distinguish separate species at an arbitrary point in what appears to be an ontogenetic development trend.

Material and occurrence. Two specimens from Suessi Zone (GSC 29950 illustrated).

Epigondolella multidentata Mosher, 1970

Plate 18, figures 15, 18–22, 25–27

Epigondolella multidentata Mosher, 1970, p. 739, Pl. 110, figs. 19, 22–26.
Epigondolella abneptis Mosher, 1968a, Pl. 118, figs. 18, 20, 21.
Epigondolella n. sp. B Sweet *et al.*, 1971, Pl. 1, fig. 21.

Description. Posteriorly tapering platform, with posterior part smooth and free of denticles. Anterolateral margins of platform bear 2 or 3 spike-like denticles.

Remarks. This species represents the evolutionary transition from *E. abneptis* to *E. bidentata.* It serves as a guide to middle and upper Norian strata. It gave rise to *E. bidentata* in the upper Norian where it co-existed with its descendant.

Material and occurrence. Over 1,700 specimens recovered from Rutherfordi (illustrations: holotype GSC 25055; paratypes GSC 25056, 25057) and Suessi Zones.

Epigondolella mungoensis (Diebel, 1956)

Plate 18, figures 31–34, 37, 38

Polygnathus mungoensis Diebel, 1956, p. 431, Pl. 1, figs. 1–20; Pl. 2, figs. 1–4; Pl. 3, fig. 1; Pl. 4, fig. 1.
Gondolella catalana Hirsch, 1966, p. 86, Pl. 1, figs. 1–4.
Polygnathus cf. *P. mungoensis* Hayashi, 1968a, p. 73, Pl. 3, figs. 2–4.
Gladigondolella abneptis Nogami, 1968, Pl. 8, figs. 10, 11.
Epigondolella mungoensis Mosher, 1968a, p. 936, Pl. 116, figs. 16–19; Huddle, 1970, p. B127, Pl. 2, figs. a–h; Sweet *et al.*, 1971, Pl. 1, figs. 14, 19.
Tardogondolella mungoensis mungoensis Kozur and Mostler, 1971, Pl. 2, fig. 8.

Remarks. E. mungoensis has been reported only from upper Ladinian strata, except for Diebel's original 1956 report from the Cameroons. Mosher (1967) and Müller and Mosher (1971) have discussed the reasons for considering these specimens to be Ladinian also. It appears that this distinctive species is an especially good index to this stratigraphic interval, having been reported from several parts of the world.

Material and occurrence. Twenty-one specimens from Sutherlandi Zone (GSC 29992, 29993 illustrated).

Epigondolella primitia Mosher, 1970

Plate 18, figures 1–5, 7–11

Epigondolella primitia Mosher, 1970, p. 740, Pl. 110, figs. 7–13, 16, 17.
Gladigondolella abneptis Nogami, 1968, Pl. 8, fig. 8.
Tardogondolella abneptis Bender, 1968, Pl. 58, figs. 29, 30.
Tardogondolella nodosa nodosa (Hayashi), Kozur and Mostler, 1971, Pl. 2, figs. 10, 11, 13; not *Gladigondolella abneptis nodosa* Hayashi 1968a, p. 69, Pl. 2, fig. 9.
Epigondolella n. sp. A. Sweet *et al.*, 1971, Pl. 1, figs. 8, 40.

Description. Platform relatively broad, occupying approximately posterior half of unit. Anterior parts of platform margins are denticulated. Juvenile forms have constriction in platform separating it into posterior and anterior sections.

Remarks. This form provides the evolutionary link between the epigondolelloids and their metapolygnathoid ancestors. It is also a guide to the upper Karnian–lower Norian boundary interval. Kozur and Mostler (1971, p. 4) indicate that this species is equivalent to (and therefore a junior synonym of) the form Hayashi (1968, p. 69) called *Gladigondolella abneptis nodosa.* They called it *Tardogondolella nodosa nodosa* (Hayashi), a designation apparently made in another work of which the writer is unaware. The specimens they figure (Pl. 2, figs. 10, 11, 13) do appear to be the same as *E. primitia* Mosher, but comparing directly with Hayashi's figured specimen (1968a, Pl. 2, fig. 9) the equivalence is not so apparent. *E. primitia* can be distinguished from *Gladigondolella abneptis nodosa* Hayashi by a greater length to width ratio in the former and a lateral constriction of the midplatform region, a carryover from a feature of early growth stages.

Material and occurrence. Several hundred specimens from Macrolobatus (paratypes GSC 25053, 25054 illustrated) and Kerri Zones (holotype GSC 25051; paratype GSC 25052 illustrated).

Genus ***Furnishius*** Clark, 1959

Furnishius Clark, 1959, p. 310.

Type species. *Furnishius triserratus* Clark, Lower Triassic *Meekoceras* Limestones, Currie, Nevada.

Description. Asymmetrical elements composed of three bars, one posterior and two anterior. Anterior bars form acute angle with each other. All bars lie in nearly same horizontal plane. Denticles subequal in size, discrete, and needle-like with no prominent main cusp.

Furnishius triserratus Clark, 1959

Plate 17, figures 24, 26

Furnishius triserratus Clark, 1959, p. 311, Pl. 44, figs. 1-6; Sweet *et al.*, 1971, Pl. 1, fig. 35.

Remarks. Although only a single fragmentary specimen was recovered, with the posterior bar broken off, the form is so distinctive as to be readily assigned to this species.

Material and occurrence. One specimen from Tardus Zone (GSC 29951).

Genus ***Hindeodella*** Ulrich and Bassler, 1926

Hindeodella Ulrich and Bassler, 1926, p. 38.

Type species. *Hindeodella subtilis* Ulrich and Bassler, Hardin Sandstone, Tennessee.

Description. Bar long, tending to be straight, bearing large main cusp near anterior end. Anterior denticulated bar or process normally present and generally curved laterally. Denticles of posterior bar often alternate in size.

Remarks. This genus apparently represents forms that occupied a functionally common position in several conodont apparatuses as similar forms have been assigned to the genus from Lower Paleozoic through Triassic. The original concept of *Hindeodella* has become somewhat blurred to include most relatively straight-barred forms whether the main cusp is anteriorly located or not. It has thus frequently become a waste basket taxon for bar-type conodonts that seem to lack distinction and are apparently considered by their workers as unworthy of much effort. I add nothing new to this usage, unfortunately, but note the LB-elements of Sweet's *Ellisonia* possess morphologic similarities to most Triassic forms commonly included in *Hindeodella*. This may provide the functional model needed to understand the taxonomic relationships of these forms.

Hindeodella multihamata Huckriede, 1958

Plate 17, figure 30

Hindeodella multihamata Huckriede, 1958, p. 148, Pl. 10, figs. 52, 53, Pl. 12, fig. 23; Mosher, 1968a, p. 925, Pl. 114, fig. 19.

Description. Unit elongate, laterally compressed, with subcentral main denticle. Bar arched slightly, anterior part curving downward. Denticles of anterior bar increase distally but with terminal denticle smaller than its neighbour. Basal groove extends length of basal margin, with conical cavity beneath cusp.

Material and occurrence. One specimen from Subrobustus Zone (GSC 29952).

Hindeodella uniforma Mosher, 1968

Plate 17, figure 13

Hindeodella uniforma Mosher, 1968a, p. 929, Pl. 114, fig. 14.

Description. Unit elongate, very thin and delicate; nearly transparent along basal edge, translucent along upper part. Anterior end bears denticles that project forward and curve upward, forming smoothly rounded anterior margin terminating at angular junction with basal edge. Remaining denticles needle-like and erect.

Material and occurrence. One specimen from Kerri Zone (GSC 29953).

Genus ***Metapolygnathus*** Hayashi, 1968

Metapolygnathus Hayashi, 1968a, p. 72.
Paragondolella Mosher, 1968a, p. 938.

Type species. *Gondolella polygnathiformis* Budurov and Stefanov, *Trachyceras aon* strata, Bezirk Burgas, Bulgaria.

Emended diagnosis (expanded from Hayashi, 1968a, p. 72). Platform elements with anterior free-blade; posterior end of unit tends to be squared off; platform margins thickened and upturned, producing deep furrows each side of carina. Lower surface bears broad keel with flaring posterior loop, which may be produced into two branches extending toward corners of squared-off posterior margin. Anterior carina high, decreasing posteriorly to distinct but low terminating node. Node surrounded by platform brim.

Remarks. Metapolygnathus is distinguished from *Neogondolella* because of the distinct anterior free blade, high anterior carina decreasing to a low posterior node, and the tendency toward distinctive bifurcation of the posterior keel in the former. The ontogenetic development of *Metapolygnathus* is distinctive also. These characters are forerunners of those typical of Upper Triassic members of *Epigondolella* for which *Metapolygnathus* was the ancestor.

Some species formerly included under *Paragondolella* Mosher, including the type species, fit within the concept of *Metapolygnathus* which is the senior synonym.

Kozur and Mostler (1971, p. 5) indicate that the presence or lack of platforms on early growth stages, formerly used to distinguish *Paragondolella* from forms now included in *Neogondolella*, does not hold true for very small specimens, which they say are platformless in both groups. Based on my collections, the manner in which the platform is introduced is clearly different between the species included in *Metapolygnathus* and those included in *Neogondolella*. Several growth sequences were presented in Mosher (1968a, Pls. 116–118; 1968b, Pls. 119–120) for species included here under these two genera. Species of *Metapolygnathus* and *Epigondolella* introduce the platform as a pair of posterolateral node-like processes that grow larger both anteriorly and posteriorly into a platform structure. In *Neogondolella* the platform appears as a lateral swelling along most or all of the length of the unit and grows larger proportionally with the unit. On the Upper Triassic species, *Neogondolella navicula steinbergensis* (Mosher), *Metapolygnathus excelsa* (Mosher), *M. polygnathiformis* (Budurov and Stefanov), *Epigondolella abneptis* (Huckriede), and *E. bidentata* Mosher, illustrated respectively *in* Mosher (1968a, Pl. 117, figs. 13–22; Pl. 118, figs. 1–8; Pl. 118, figs. 9–17, 19; Pl. 118, figs. 18, 20–30; and Pl. 118, figs. 31–36), these ontogenetic differences can be clearly observed.

Metapolygnathus excelsa (Mosher, 1968)

Plate 20, figure 8

Paragondolella excelsa Mosher, 1968a, p. 938, Pl. 118, figs. 1–8.
Neogondolella navicula Bender, 1968, Pl. 58, *only* fig. 2.
Gondolella navicula Hirsch, 1969, Pl. 1, *only* fig. 12.

Description. Platform element with platform widest near posterior end; lanceolate in plan view. Anterior carina high crested decreasing posteriorly to large node-like cusp.

Remarks. This species is common in Middle Triassic Schreyeralmkalk rocks sampled in Austria (Mosher, 1968a), but has proved to be rare, though present, in approximately equivalent strata of North America. Based on material available to me, this form seems to be an ancestral form for *Metapolygnathus polygnathiformis* (Budurov and Stefanov) and species of *Epigondolella* of the Upper Triassic. Kozur and Mostler (1971) indicate that they recognize more than one distinct phylogeny among the species of *Epigondolella*, but their arguments apparently have not yet been published. The position of the node-like cusp on the platform is reflected in its Upper Triassic descendants and is distinct from the posteriorly projecting cusp common among species of *Neogondolella.*

Material and occurrence. Three specimens from Meginae Zone (GSC 29986 illustrated).

Metapolygnathus polygnathiformis (Budurov and Stefanov, 1965)

Plate 20, figures 7, 12

Gondolella polygnathiformis Budurov and Stefanov, 1965, p. 118, Pl. 3, figs. 3–7; Budurov and Vrabljanski, 1966, Pl. 5, figs. 3, 4, 8.
Paragondolella polygnathiformis (Budurov and Stefanov) Mosher, 1968a, p. 939, Pl. 118, figs. 9–17, 19; 1970, Pl. 110, figs. 3, 6; Flügel and Ramovš, 1970, Pl. 1, figs. 1–3; Sweet *et al.*, 1971, Pl. 1, fig. 11.
Neogondolella palata Bender, 1968, p. 519, Pl. 58, figs. 6, 7, 11, 17.
Metapolygnathus communisti Hayashi, 1968a, p. 72, Pl. 3, fig. 11.
Metapolygnathus linguiformis Hayashi, 1968a, p. 72, Pl. 3, fig. 9.
Metapolygnathus noah Hayashi, 1968a, p. 72, Pl. 3, fig. 10.

Description. Elements with broad and short platform, bearing thickened and upturned margins near middle and anterior margins, giving pinched-in appearance to centre of unit. Thickened margins terminate just anterior of centre of unit producing angular corner on anterior margins of platform.

Remarks. Hayashi (1968a, p. 72) designated *Metapolygnathus communisti* as the type species of this genus. The figures published by Hayashi and by Budurov and Stefanov are not very good, but careful comparison has convinced me that *Metapolygnathus communisti* Hayashi is a junior synonym of *Gondolella polygnathiformis* Budurov and Stefanov, and must be replaced by the latter as the type species for the genus (I.C.Z.N., Art. 67e). This conclusion is supported by fairly large collections of *M. polygnathiformis* at hand, which include gradational variants among co-occurring specimens. The forms that Hayashi figured on his Plate 3, figures 9–11 are included among these gradational variants. A similar conclusion seems to have been reached by Kozur and Mostler (1971, p. 6) although they do not recognize the validity of *Metapolygnathus.*

The age of the Adoyama Formation, called Permian by Hayashi (1968) and from which he obtained his specimens, has been reinterpreted as Middle to Upper Triassic by Koike *et al.* (1971).

Material and occurrence. Sixty specimens from Maclearni, Nanseni, and Welleri (GSC 29987 illustrated) Zones.

Genus ***Neogondolella*** Bender and Stoppel, 1965

Neogondolella Bender and Stoppel, 1965, p. 343.

Type species. *Gondolella mombergensis* Tatge, Upper Muschelkalk, Momberg, Germany (*see* Sweet, 1970b, p. 239).

Description. Conodonts with elongate, asymmetrical platform elements; platform extends virtually entire length of unit and forms brim around posterior end of unit on most specimens. Upper surface bears carina with posteriorly terminal or subterminal cusp. Platform generally finely pitted but otherwise unornamented, but may be marked by laterally directed ridges or crenulations. Lower surface bears keel with longitudinal groove that terminates in flaring pit beneath cusp.

Remarks. In earlier ontogenetic studies on the type species and others formerly assigned to *Gondolella* from Triassic strata (Mosher, 1968a) the writer observed what appeared to be significant differences in ontogenetic development between forms now included in *Neogondolella* and others then placed in *Paragondolella.* As noted above under *Metapolygnathus*, Kozur and Mostler (1971, p. 5) imply that they have observed very small elements of *Neogondolella mombergensis* that lack a platform. The absence of a platform in early growth stages was a prime factor I used to distinguish *Paragondolella* (Mosher, 1968a, p. 938). *Paragondolella* has turned out to be junior synonym of *Metapolygnathus* Hayashi, but there are nevertheless distinctive ontogenetic differences between *Metapolygnathus* and *Neogondolella. Neogondolella* introduces the platform as a lateral swelling along most or all of the length of the unit. *Metapolygnathus* introduces it as two node-like posterolateral processes that enlarge into platform structures.

Neogondolella carinata (Clark, 1959)

Plate 19, figures 1–3, 9

Gondolella carinata Clark, 1959, p. 308, Pl. 44, figs. 15-19; Hayashi, 1968, p. 70, Pl. 1, figs. 4, 5.
Neogondolella carinata (Clark), Sweet, 1970b, p. 240, Pl. 3, figs. 1–17, 24, 26, 27; Sweet *et al.*, 1971, Pl. 1, figs. 1, 6, 7.

Description. Unit relatively broad, platform pinched in near posterior end, but leaving distinct, possible separated brim surrounding cusp.

Remarks. Clark (1959, p. 308, 309) distinguished three similar but distinct species of gondolelloids, which Sweet (1970b, p. 240, 241) later included under *N. carinata* noting that in his large collections the three were linked by morphologic and/or ontogenetic transitions. In my collections the three are morphologically and stratigraphically distinguishable, hence I retain the separate taxa. Clark's types for *N. carinata*, *N. planata*, and *N. nevadensis* all come from the same stratigraphic level, however he reports (Clark, 1959) that specimens of all three were recovered over intervals of several hundred feet.

Material and occurrence. One hundred and sixty-four specimens from Strigatus Zone (GSC 29954, 29955 illustrated).

Neogondolella constricta (Mosher and Clark, 1965)

Plate 19, figures 30, 31

Gondolella constricta Mosher and Clark, 1965, p. 560, Pl. 65, figs. 11, 14, 15, 18, 19, 21, 22, 24, 25; Mosher, 1968a, p. 937, Pl. 116, figs. 3, 4, 7, 11; Hayashi, 1968a, p. 70, Pl. 1, fig. 1.
Gondolella navicula Budurov and Vrabljanski, 1966, Pl. 4, fig. 17.
Neogondolella constricta (Mosher and Clark), Sweet *et al.*, 1971, Pl. 1, figs. 4, 5.

Description. Unit elongate, narrow; platform terminated or pinched-in anterior of, or adjacent to main cusp; which is usually subterminal in smaller specimens.

Remarks. This species appears to be a useful guide to upper Anisian–lower Ladinian boundary strata, having been recovered in both Europe and North America in this interval.

Material and occurrence. Eleven specimens from Deleeni (GSC 29969 illustrated) and Poseidon (GSC 29970 illustrated) Zones.

Neogondolella crenulata new species

Plate 19, figures 7, 10–14, 16

Gondolella milleri Nogami, 1968a, Pl. 10, fig. 6 (*not* figs. 7, 11–15).

Diagnosis. Platform broad, flat, marked by laterally directed crenulations, completely perforating platform in larger specimens. Carina of subequal denticles of oval cross-section. Basal keel broad, generally flat, with narrow groove and small posterior pit in widely flaring loop.

Discussion. Platform margin flat and marked by crenulations that increase from minor wiggles on margins in small specimens to parallel, laterally directed ridges on larger specimens, to extreme flutes and folds on largest specimens. Folds and flutes may become so extreme as to interrupt and perforate the platform. Cusp terminal and projects posteriorly. Platform on smaller specimens terminates anterior of cusp, but enlarges to form narrow brim around cusp in larger specimens.

Carina possesses 9–15 subequal denticles, of oval cross-section and with rounded upper points.

Lower surface bears broad keel whose lower surface is flat. Narrow longitudinal groove lies on keel and terminates in small pit in centre of widely flaring posterior loop. Flange extends laterally around loop and continues along keel margins and expanding apron.

Remarks. This species can be distinguished from *Neogondolella milleri* (Müller) by its folds and flutes on the flat platform. The latter has crenulations restricted to the upturned margins of the platforms. *N. crenulata* is restricted in the present collections to the Romunderi Zone.

Material and occurrence. Eleven specimens from Romunderi Zone (illustrations: holotype GSC 29958; paratypes GSC 29959, 29960; all from GSC loc. 28680).

Neogondolella elongata Sweet, 1970

Plate 19, figure 19

Neogondolella elongata Sweet, 1970b, p. 241, Pl. 2, figs. 4, 5, 6–8; Pl. 3, figs. 18, 23, 25.

Description. Platform typically confined to posterior half of element; denticles typically increase in length and width toward anterior end; average height to width to length ratio of 1:1.5:4.

Remarks. The most characteristic feature of the present specimens assigned to this species is the restricted platform. On several specimens the anterior denticles decrease in size. On all, the posterior cusp projects strongly posteriorly. The species was not encountered above the Smithian.

Material and occurrence. Twenty-five specimens from the Tardus Zone (GSC 29966 illustrated).

Neogondolella jubata Sweet, 1970

Plate 19, figure 27

Neogondolella jubata Sweet, 1970b, p. 243, Pl. 2, figs. 1–3, 9, 14, 16; Sweet *et al.*, 1971, Pl. 1, figs. 17, 20.

Description. Narrow, finely pitted platform, surrounding all but anterior tenth of unit; high, evenly crested carina; and height to width to length ratio of about 1:1.5:5.

Remarks. Specimens referred to this species in the present material range down into the Smithian, although most abundant in the Spathian. Sweet (1970b, p. 244) did not report it from the Smithian, but his Spathian occurrences are similar to those of the present study.

Material and occurrence. Fifteen specimens from the Tardus (GSC 29967 illustrated) and Subrobustus Zones.

Neogondolella milleri (Müller, 1956)

Plate 19, figures 22, 23, 25

Gondolella milleri Müller, 1956, p. 823, Pl. 95, figs. 1–9; Nogami, 1968, p. 124, Pl. 10, *only* figs. 1–5, 8–10.
Gondolella eotriassica Müller, 1956, p. 823, Pl. 95, figs. 10, 11.
(?)*Gondolella* cf. *milleri* Müller, Hayashi, 1968, p. 70, Pl. 2, fig. 4.
Neogondolella milleri (Müller), Sweet *et al.*, 1971, Pl. 1, fig. 37.

Description. Unit subsymmetrical, elongate; platform bearing distinct crenulations on nearly parallel, upturned margins. Carina laterally compressed, with anterior 2 or 3 denticles forming free blade; posterior cusp may be free of platform and projects strongly to posterior. Basal keel broad and flat, may bear lateral grooves parallel to central groove.

Remarks. This species was described by Müller from *Meekoceras* beds in Nevada. Tozer (1967, p. 19) considers the *Meekoceras* Zone as equivalent to the Romunderi Zone. The present occurrence of the species in the Tardus Zone establishes its range as including much of the Smithian Stage, at least the middle and upper parts.

Material and occurrence. Thirty-one specimens from Tardus Zone (GSC 29964, 29965 illustrated).

Neogondolella mombergensis (Tatge, 1956)

Plate 19, figures 4–6, 8

Gondolella mombergensis Tatge, 1956, p. 132, Pl. 6, figs. 1, 2; Wenger, 1966, fig. 2; Nogami, 1968, p. 125, Pl. 9, figs. 19–23; Hayashi, 1968a, p. 70, Pl. 1, fig. 7; Budurov and Kulaksasov, 1968, Pl. 1, fig. 5; Pl. 2, fig. 1; Mosher, 1968a, p. 937, Pl. 116, figs. 6, 9, 10, 12–15.
Gondolella (*Gondolella*) *mombergensis mombergensis* Tatge, Kozur, 1968, p. 932, Pl. 2, figs. 1, 3, 4; Pl. 3, fig. 8.
Neogondolella mombergensis (Tatge), Bender, 1968, p. 517, Pl. 58, fig. 3; Sweet *et al.*, 1971, Pl. 1, fig. 24.

Description. Unit generally narrow and elongate; platform tapers both anteriorly and posteriorly from midpoint, coming to point at or near anterior end, posterior end may be more rounded, but posterior denticle usually enlarged and projects posteriorly. Carina highest at anterior end, decreasing in height toward posterior. Basal surface bears narrow keel with groove and posteriorly terminal loop and pit.

Remarks. Specimens assigned to this species were recovered throughout the Lower Triassic interval and on up to the lower Ladinian in the present collection. The type is from the Upper Muschelkalk of Germany, and Lower Triassic specimens may turn out to be taxonomically distinct. Kozur (1968) proposed subgeneric and subspecific variations that he felt were of stratigraphic value in the Upper Muschelkalk. He subdivided this unit into seven zones based on gondolelloid conodonts including several subspecies of *Neogondolella mombergensis*. The application of these zones to North America has not yet been accomplished.

Material and occurrence. Five hundred and seventy-two specimens from Strigatus (GSC 29956 illustrated), Romunderi, Caurus, Varium, Poseidon (GSC 29957 illustrated), and Meginae Zones.

Neogondolella navicula navicula (Huckriede, 1958)

Plate 20, figures 11, 18

Gondolella navicula Huckriede, 1958, p. 147, Pl. 11, figs. 1–4, 13–19, 27, 35; Pl. 12, figs. 2–8, 10, 15–22, 24–27; Budurov and Stefanov, 1966, Pl. 4, figs. 23, 24; Pl. 5, figs. 1, 6, 7, 9–11; Budurov and Kulaksasov, 1968, Pl. 1, figs. 12, 13, 16, 17; Pl. 2, figs. 6, 7, 9–11; Budurov and Zagortschev, 1968, Pl. 1, figs. 22, 23, 30, 31; Budurov and Pevny, 1968, Pl. 17, figs. 33–36; Hayashi, 1968a, p. 70, Pl. 1, figs. 9–11; Nogami, 1968, p. 126, Pl. 8, figs. 12–26; Hirsch, 1969, Pl. 1, figs. 10, 11, 13–16, *not* fig. 12.
Neogondolella navicula (Huckriede), Bender, 1968, p. 518, Pl. 58, figs. 4, 5, 8.
Paragondolella navicula navicula (Huckriede), Mosher, 1968, p. 939, Pl. 116, figs. 20–27; Pl. 117, figs. 1–5.

Description (revised from Huckriede). Large conodont elements with heavy platforms, especially in later growth stages; part of carina posterior of first 5 or 6 denticles tends to completely fuse; node-like cusp prominent, but upright, not posteriorly projecting. Lower surface bears broad keel, but loop generally has rounded, non-flaring margins. Keel on larger specimens commonly flush with platform lower surface, and bears narrow groove with one or more fine striations parallel to it on each side of keel.

Remarks. Huckriede (1958, p. 148) diagnosed the species on the basis of a free blade that is displaced far anteriorly. Some specimens figured by Huckriede and included in the species do indeed show this free blade (his Pl. 12, figs. 22, 27); however the holotype (his Pl. 12, fig. 10) and several other specimens figured by him show a tapering platform that extends nearly to or completely to the anterior end of the unit. Based on the type material, the concept of the species must be construed to include, if not primarily applied to, specimens as described above. The species is easily recognized and Huckriede's original diagnosis seems to have caused little confusion among workers.

Material and occurrence. Several hundred specimens from Sutherlandi, Obesum, Nanseni, Kerri (GSC 29988 illustrated), Dawsoni, Rutherfordi, and Suessi Zones.

Neogondolella navicula hallstattensis (Mosher, 1968)

Plate 20, figure 19

Paragondolella navicula hallstattensis Mosher, 1968a, p. 939, Pl. 117, figs. 6–12; Sweet *et al.*, 1971, Pl. 1, fig. 22.

Description. Platform element with stout triangular denticles that stand nearly upright giving sawtooth appearance in profile view; basal keel and loop have flaring margins.

Remarks. Four well-preserved specimens were recovered, none of which bears a platform, although all have a lateral ridge in its place. These specimens apparently represent a youthful stage of the species and are almost identical to the juvenile specimen figured in Mosher (1968a, Pl. 117, fig. 7). Their stratigraphic position agrees well with that of the type material from Someraukogel.

Material and occurrence. Four specimens from Dawsoni Zone (GSC 29989 illustrated).

Neogondolella nevadensis (Clark, 1959)

Plate 19, figures 17, 18, 24

Gondolella nevadensis Clark, 1959, p. 308, Pl. 44, figs. 11–14.
Gondolella milleri Nogami, 1968, Pl. 10, figs. 7, 11–15 (*not* fig. 6).

Description. Platform broad at posterior end, tapering abruptly toward anterior; platform terminates at or in front of posterior cusp, leaving it free.

Remarks. Sweet (1970b, p. 240, 241) includes this species under *N. carinata* as indistinguishable in his material. It is morphologically and stratigraphically distinct in my collection, therefore I follow Clark's original designation (*see* "Remarks" under *N. carinata*).

Material and occurrence. Three hundred and nineteen specimens from Romunderi and Tardus (GSC 29962, 29963 illustrated) Zones.

Neogondolella planata (Clark, 1959)

Plate 19, figures 15, 20

Gondolella planata Clark, 1959, p. 309, Pl. 44, figs. 8–10; Hayashi, 1968a, p. 71, Pl. 1, fig. 2.

Description. Platform broad, extending entire length of unit. Platform may surround terminal cusp with narrow brim.

Remarks. This species, although less abundant than *N. carinata* or *N. nevadensis,* is distinctly represented in my collection (*see* "Remarks" under *N. carinata* and *N. nevadensis*).

Material and occurrence. Eleven specimens from the Romunderi Zone (GSC 29961 illustrated).

Neogondolella regale Mosher, 1970

Plate 19, figures 21, 28, 29, 32

Neogondolella regale Mosher, 1970, p. 741, Pl. 110, figs. 1, 2, 4. 5.
Gondolella mombergensis Mosher, 1968a, Pl. 116, fig. 15 (only).
Neogondolella n. sp. B. Sweet *et al.*, 1971, Pl. 1, fig. 36.

Description. Platform extends entire length of unit; carina uniformly high with large number of small, fused, subequal denticles; cusp posteriorly terminal.

Remarks. This species is a guide to strata of the Lower–Middle Triassic boundary interval, being represented in material from Nevada (USGS locality M-2359, Varium Zone) and British Columbia. The distinctive carina is the principal character.

Material and occurrence. Ninety-one specimens from Subrobustus, Caurus, and Varium Zones (illustrations: holotype GSC 25048, paratypes GSC 25050, 29968; all from GSC loc. 68294).

Neogondolella reversa new species

Plate 20, figures 9, 10, 13, 15–17

Diagnosis. Conodonts with platform elements whose full-length platform shows a distinct pinching-in near midpoint on larger specimens, but a widening at the same point on small specimens. Carina bears 8 or 9 short, stout, discrete, nearly equal size denticles; posterior cusp not much larger than other denticles. Keel prominent with flaring margins.

Discussion. Platform extends full length of unit, but on larger specimens shows a distinct lateral pinching-in near the midpoint. Platform on smaller specimens is widened at that point. Carina composed of 8 or 9 denticles, regardless of specimen size in the collection at hand; denticles are short and discrete, being oval in cross-section on large specimens, laterally compressed on smaller ones. Carina is of nearly even height for entire length. Platform widest near posterior end, but suboval in plan view, the tapering at the anterior end being quite abrupt. Keel on lower surface fairly narrow with flaring margins and loop. Size of keel does not change much during growth, thus it is relatively larger on small specimens.

Remarks. This species is named for the reversal in trend during ontogeny from a widening of the midplatform on small specimens to a constriction or pinching-in of the platform on larger specimens, apparently representing later stages of growth. Platform development was apparently accentuated on the anterior and posterior lateral margins during growth.

Material and occurrence. Sixteen specimens from Welleri Zone (illustrations: holotype GSC 29990, paratype GSC 29991; both from GSC loc. 51650).

Neogondolella sp.

Plate 19, figure 26

Description. Platform broad and suboval in plan view, extending entire length of unit and surrounding posterior end in brim. Carina set with 10 to 11 short, subequal denticles. Cusp not prominent. Lower surface bears keel with broad loop at posterior end. Basal filling material observed on one specimen.

Remarks. Although distinctive, this form is poorly represented in the collection. The basal material on the one specimen fits as a sheath inside the broad groove on the keel.

Material and occurrence. Two specimens from Varium Zone (GSC 29971 illustrated).

Genus ***Neospathodus*** Mosher, 1968

Neospathodus Mosher, 1968a, p. 929–930.

Type species. *Spathognathodus cristagalli* Huckriede from Lower Triassic rocks in Pakistan.

Description. Blade-like conodonts with posteriorly terminal or subterminal pit and loop on basal surface. Denticles form series typically highest at a point approximately a third of distance from posterior end of unit, and increase in posterior inclination from front to back of unit. Longitudinal rib present on midflanks of unit, which may develop into platform-like structure in some forms.

Neospathodus cristagalli (Huckriede, 1958)

Plate 20, figure 4

Spathognathodus cristagalli Huckriede, 1958, p. 161, Pl. 10, figs. 10–15, 18.
Neospathodus cristagalli (Huckriede), Mosher, 1968a, p. 930, Pl. 115, figs. 1, 2; Sweet, 1970b, p. 246, Pl. 1, figs. 14, 15; Sweet *et al.*, 1971, Pl. 1, fig. 31.

Description. Blade-like elements with width to height to length ratio of about 1:3:4, broad posterior cusp, greatest height slightly posterior of midpoint, and with posterior portion of basal margin conspicuously upturned.

Remarks. Sweet's (1970b) work in West Pakistan suggests that this species is restricted to the upper Dienerian. Other reported occurrences in younger rocks are of different taxa as Sweet points out (ibid., p. 249). The presence of *N. cristagalli* in Sverdrupi Zone strata in Canada supports its usefulness as a guide to that interval as proposed by Sweet *et al.* (1971).

Material and occurrence. Nine specimens from Sverdrupi Zone (GSC 29973 illustrated).

Neospathodus dieneri Sweet, 1970

Plate 20, figure 2

Neospathodus dieneri Sweet, 1970b, p. 249, Pl. 1, figs. 1, 4; Sweet *et al.*, 1971, Pl. 1, fig. 23.

Description. Blade-like conodont with width to height to length ratio of about 1:2:2.3, greatest height at or near posterior end, long terminal posterior cusp, and basal margin that turns upward beneath posterior part of unit.

Remarks. This species is morphologically close to *N. cristagalli* but can be distinguished from the latter by its higher lateral profile relative to length. In addition, *N. dieneri* has a longer posterior cusp. In the writer's collections the two have similar ranges (Sverdrupi Zone) but Sweet (1970b, p. 213) shows the range of *N. dieneri* to be considerably longer than that of *N. cristagalli.*

Material and occurrence. Nine specimens from Sverdrupi Zone (GSC 29975 illustrated).

Neospathodus homeri (Bender, 1968)

Plate 20, figure 14

Spathognathodus homeri Bender, 1968?, p. 528, Pl. 5, figs. 16, 18.
Neospathodus homeri (Bender), Sweet, 1970b, p. 245, Pl. 1, figs. 2, 3, 9, 10; Sweet *et al.*, 1971, Pl. 1, fig. 29.

Description. Blade-like elements with width to height to length ratio of 1:2:3 in early growth stages, 1:2:4 in later growth stages. Basal margin straight anteriorly, but downcurved posteriorly. Short, thin, laterally deflected secondary posterior process that bears up to 5 denticles developed on larger specimens.

Remarks. Specimens of this form have been recovered from the uppermost Lower Triassic in Nevada and West Pakistan. Bender (1968?) reports it from upper Scythian beds in Greece.

Material and occurrence. Three specimens from the Subrobustus Zone (GSC 29978 illustrated).

Neospathodus kummeli Sweet, 1970

Plate 20, figure 3

Neospathodus kummeli Sweet, 1970b, p. 251, Pl. 2, figs. 17–21; Sweet *et al.*, 1971, Pl. 1, fig. 9.

Description. Elongate blade-like comb-shaped elements with straight or downwardly convex basal margin; prominent longitudinal ridge on midflanks that may be developed into platform-like structure on larger specimens.

Remarks. Inclusion of this species in the present report is based on 3 fragmentary specimens, but two show the midflank ridge and upturned basal margin so as to support this assignment. Stratigraphic range agrees closely with that given by Sweet (1970b, p. 213).

Material and occurrence. Two specimens from Candidus Zone and one questionable from Sverdrupi Zone (GSC 29974 illustrated).

Neospathodus pakistanensis Sweet, 1970

Plate 20, figure 6

Neospathodus pakistanensis Sweet, 1970b, p. 254, Pl. 1, figs. 16, 17; Sweet *et al.*, 1971, Pl. 1, fig. 41.

Description. Blade-like elements with width to height to length ratio of 1:2:3; with short, secondary posterior process with 1 or 2 denticles; upper edge arched, lower edge straight anteriorly, downcurved posteriorly.

Remarks. This species is meagerly represented in the Canadian collections but is shown by Sweet *et al.* (1971, fig. 2) as restricted to approximately the Dienerian–Smithian boundary interval. The occurrence in the Romunderi Zone is in agreement with that interval.

Material and occurrence. Two specimens from Romunderi Zone (GSC 29976 illustrated).

Neospathodus peculiaris Sweet, 1970

Plate 20, figure 1

Neospathodus peculiaris Sweet, 1970b, p. 255, Pl. 5, fig. 19.

Description. Blade-like elements with 3 to 7 discrete denticles, cusp twice the length of any other denticle; width to height to length ratio of about 1:2.5:3.5, straight basal margin, and broadly concave lower surface.

Remarks. Only a single specimen was recovered, but it exhibits the characters of the species clearly, even though occurring in strata considerably older than those from which Sweet describes the species (1970b, p. 246). Its range therefore apparently extends down into the Griesbachian.

Material and occurrence. One specimen from Strigatus Zone (GSC 29972).

Neospathodus waageni Sweet, 1970

Plate 20, figure 5

Neospathodus waageni Sweet, 1970b, p. 260, Pl. 1, figs. 11, 12; Sweet *et al.*, 1971, Pl. 1, fig. 26.

Description. Tall blade-like elements with height to length ratio of about 1:1 in all stages of growth, unit thickening during development; upper margin arcuate, lower margin straight in anterior half, but upturned in posterior half.

Remarks. The species is represented throughout the Smithian samples, in general agreement with Sweet (1970b, p. 213). It occurs in my material together with *Neogondolella milleri* (Müller), an association noted by Sweet (ibid., p. 261) in undescribed material from Nevada and Afghanistan.

Material and occurrence. Thirty-seven specimens from the Romunderi and Tardus (GSC 29977 illustrated) Zones.

A number of forms in the present collections are represented by single specimens only, but appear to have affinity with *Neospathodus.* I have included them and figured them with brief descriptions below for completeness, although their significance and relationships are not presently clear.

Neospathodus sp. A

Plate 18, figure 39

Description. Large asymmetric specimen with 13 denticles and thick midflank platform-like expansion that widens posteriorly and surrounds posterior end. Inclination of denticles increases posteriorly. Denticles oval in cross-section. Lower surface broad and bears neogondolelloid groove and flaring loop. This form also appears to have affinities with *Neogondolella.*

Material and occurrence. One specimen from Romunderi Zone (GSC 29979).

Neospathodus sp. B

Plate 18, figure 35

Description. Blade straight, fused denticles of nearly equal length stand upright. Lower margin convex downward, with fairly broad groove. Element may be broken from more complex conodont, however evidence of breakage is obscure.

Material and occurrence. One specimen from Varium Zone (GSC 29980).

Neospathodus sp. C

Plate 18, figure 29

Description. Element small with 6 denticles. Cusp projects strongly to posterior at considerably greater angle than neighbouring denticle. Flaring lips of subcentrally located attachment cavity results in abrupt upward indentation in basal margin. The form bears resemblance to *Neospathodus peculiaris* Sweet, but is distinguished from it by the indentation of the basal margin.

Material and occurrence. One specimen from Varium Zone (GSC 29981).

Neospathodus sp. D

Plate 18, figure 30

Description. Asymmetrical form with 8 short denticles, large cusp near posterior end, and posterior process that bears bumps suggestive of secondary posterior denticle development. Lower margin gently concave with basal pit at about posterior fourth of unit.

Material and occurrence. One specimen from Meginae Zone (GSC 29982).

Neospathodus sp. E

Plate 18, figure 36

Description. Six short, upright denticles, with prominent, triangular, posterior cusp. Posterior edge of unit is vertical, forming right angle with basal margin. Flaring loop on straight basal margin terminal on posterior end. Unit laterally compressed.

Material and occurrence. One specimen from Obesum Zone (GSC 29983).

Genus ***Pachycladina*** Staesche, 1964

Pachycladina Staesche, 1964, p. 277.

Type species. *Pachycladina obliqua* Staesche, upper Campil beds, Ennenberg, South Tyrol.

Description. Transparent elements with strongly thickened bar, which bear on their upper margins distinct lateral corners or angulations; relatively few large denticles.

?*Pachycladina symmetrica* Staesche, 1964

Plate 17, figure 21

(?) *Pachycladina symmetrica* Staesche, 1964, p. 280, textfigs. 19, 20, 30, 35, 48–51; Pl. 29, fig. 1; Pl. 31, fig. 4; Pl. 32, fig. 1.

Description. Denticles arranged symmetrically with large central denticle flanked by two slightly smaller denticles. Between these large denticles may occur one or two much smaller denticles.

Remarks. A few elements with broken ends were found in one sample from the Tardus Zone which closely resemble this species defined on the basis of material from South Tyrol. Their Tardus Zone occurrence is in general agreement with the upper Campil occurrence reported by Staesche (1964, fig. 66). The specimens are not as transparent as the types seem to be, and their slight asymmetry together with the fact that one or both ends of the specimens are broken makes assignment to the species tentative.

Material and occurrence. Three specimens from the Tardus Zone (GSC 29984 illustrated).

Genus ***Parachirognathus*** Clark, 1959

Parachirognathus Clark, 1959, p. 311.

Type species. *Parachirognathus ethingtoni* Clark, *Meekoceras* Limestone near Currie, Nevada.

Description. Hand-shaped blade-like unit with cupped or concave inner surface. Seven to fifteen discrete needle-like to lenticular denticles, forming arching crest, none of which is clearly a main cusp. Lower margin straight with little or no upward bowing. Upwardly bowed lateral ridge separates denticles from basal area which resembles, then, a segment of a circle.

Parachirognathus jungi Mosher, 1968

Plate 17, figure 6

Parachirognathus jungi Mosher, 1968a, p. 933, Pl. 115, figs. 18, 19.

Description. Characters of genus, and bearing short posterior train of subequal denticles. Anterior part of unit concave on inner side, but posterior train twisted toward outside.

Remarks. In my collections from Nevada, this species is restricted to samples from the upper Ladinian and lower Karnian. Its single representative in the Canadian material extends its geographic range to Canada during the upper Ladinian. It therefore seems to be biostratigraphically useful.

Material and occurrence. One specimen from Sutherlandi Zone (GSC 29985).

Genus *Prioniodella* Ulrich and Bassler, 1926

Prioniodella Ulrich and Bassler, 1926, p. 18.

Type species. *Prioniodella normalis* Ulrich and Bassler, Upper Devonian, New York.

Description. Straight or curved bar-type element, set with series of subparallel denticles. Lacks main denticle.

Remarks. The use of this generic name appears to persist among Triassic reports because it, like *Hindeodella*, serves as a convenient receptacle for specimens bearing resemblance to the Paleozoic types, but considered by their workers as so unimportant as to be unworthy of serious consideration. Very likely, elements of this group filled a functionally generalized position in the conodont apparatus, much as *Hindeodella*, and are homeomorphic in nature. Specimens now assigned here are therefore probably related taxonomically to several as yet undescribed multielement species. For example, *Prioniodella pectiniformis* Huckriede seems to be a part of the apparatus referred to in Mosher (*in press*) as the gladigondolelloid group.

Prioniodella decrescens Tatge, 1956

Plate 17, figure 29

Prioniodella decrescens Tatge, 1956, p. 111; Budurov and Vrabljanski, 1966, Pl. 4, fig. 20; Budurov and Zagortschev, 1968, Pl. 1, figs. 10–12; Mosher, 1968a, p. 933, Pl. 114, fig. 27.

Material and occurrence. Four specimens from Sutherlandi, Obesum (GSC 29995 illustrated), and Macrolobatus Zones.

Prioniodella prioniodellides (Tatge, 1956)

Plate 17, figure 18

Angulodus prioniodellides Tatge, 1956, p. 111.
"*Prioniodella*" *prioniodellides* (Tatge), Kozur, 1968a, Pl. 1, fig. 23; Pl. 3, fig. 17; 1968b, p. 1079; Sweet, 1970b, p. 261, Pl. 5, fig. 11.
Prioniodella prioniodellides (Tatge), Mosher, 1968a, p. 933, Pl. 114, figs. 23, 26; Budurov and Zagortschev, 1968, Pl. 1, fig. 32; Budurov and Pevný, 1970, Pl. 17, figs. 27–29.

Material and occurrence. Twenty-two specimens from Tardus (GSC 29994 illustrated), Varium, and Obesum Zones.

Genus *Xaniognathus* Sweet, 1970

Xaniognathus Sweet, 1970b, p. 261.

Type species. *Xaniognathus curvatus* Sweet, Lower Triassic, Chhidru Formation, Salt Range, West Pakistan.

Description. Species with blade-shaped elements of single type having long denticulate anterior process with midlateral flanking ridge, and short posterior process with no flanking rib. Undersurface of unit grooved, at least in early growth stages. Prominent basal pit located beneath cusp.

Xaniognathus curvatus Sweet, 1970

Plate 20, figure 20

Xaniognathus curvatus Sweet, 1970b, p. 262, Pl. 3, fig. 22.

Description. Basal margin sinuous; cusp and denticles steeply reclining; posterior process small to absent, denticles of which are incorporated into posterior margin of cusp in late growth stages.

Remarks. A single fragmentary specimen is assigned with some reservation to this species. The cusp of this specimen bears a long costa on its anterior edge giving the appearance almost of a fused denticle. The short posterior process bears 2 long, but needle-like denticles.

Material and occurrence. One specimen from Strigatus Zone (GSC 29996).

Xaniognathus deflectens Sweet, 1970

Plate 20, figure 21

Xaniognathus deflectens Sweet, 1970b, p. 263, Pl. 3, fig. 20.

Description. Basal margin straight; discrete denticles; base broad and marked by conspicuous pit and broadly sheathed attachment surface beneath processes.

Remarks. The few specimens recovered appear to be early growth stages. They are small and laterally compressed and lack the broadly flaring sheaths noted by Sweet (1970b, p. 265) on very large specimens. The strongly bowed character of the blades is distinctive, however.

Material and occurrence. Five specimens from Sverdrupi (GSC 29997 illustrated) and Romunderi Zones.

Xaniognathus elongatus Sweet, 1970

Plate 20, figure 27

Xaniognathus elongatus Sweet, 1970b, p. 266, Pl. 3, fig. 19.

Description. Blade-like elements with long anterior process bearing up to 10 denticles and short, upturned posterior process with 2 or 3 denticles. Main cusp prominent at apex of unit. Basal surface narrow and shallowly grooved.

Remarks. Sweet (1970b, fig. 4) shows this species as stratigraphically restricted (to approximately the Spathian). Its occurrence in Canada in the Spathian suggests its utility in that interval.

Material and occurrence. Two specimens from the Subrobustus Zone (GSC 30001 illustrated).

Xaniognathus expansus new species

Plate 20, figures 22–24

Diagnosis. A species of *Xaniognathus* with an elongated posterior process bearing 3 to 6 (most common 4) laterally compressed denticles; prominent flanking lateral ridge on anterior process, also present but less prominent on posterior process; posterior process bent laterally immediately behind cusp.

Description. Unit blade-like with anterior and posterior processes of approximately equal length. Three to five steeply inclined, laterally compressed, discrete denticles on downward projecting anterior process. Lower margin has angular bend just posterior of cusp, forming angle approximately 120 to 135 degrees. Three to six less steeply inclined denticles on straight posterior process. Prominent flanking midlateral ridge present on anterior process at base of denticles, expanding laterally on larger specimens to become narrow platform. Ridge also present on posterior process, but less well developed. On some specimens (Pl. 20, fig. 23) ridge expressed as broad swelling on midlateral flanks and is less distinct.

Lower surface bears broad groove with flaring margins. Pit located beneath main cusp may be inverted on larger specimens (slightly developed on specimen figured in Pl. 20, fig. 22).

Posterior process bent or deflected laterally just posterior of cusp, forming angle of approximately 30 to 40 degrees with plane of anterior process and main cusp.

Remarks. This species bears close morphologic relationship to *X. deflectens* from which it is distinguished by its longer and prominently developed denticulated posterior process. The angular downward bending of the lower margin distinguishes this species from *X.*? sp. of Sweet (1970b). In my collections it is restricted to and very abundant in Smithian Stage samples.

Material and occurrence. Over a hundred specimens from Romunderi and Tardus (illustrations: holotype GSC 29999, paratypes GSC 29998, 30000; all from GSC loc. 42364) Zones.

Xaniognathus triassicus new species

Plate 20, figures 25, 29

Diagnosis. A species of *Xaniognathus* with strongly downward projecting anterior process bearing several steeply inclined denticles, and with very short posterior process bearing 1 to 3 small denticles and extending straight back or slightly downward from cusp. Lower surface bears broad but shallow groove with pit beneath apical cusp.

Description. Blade-like elements with anterior process that projects strongly downward. Denticles discrete and strongly inclined with sharpened oval cross-section. Posterior process short, bearing 1 to 3 small denticles. Posterior process extends straight back from cusp, or slightly downward, placing cusp at apex of unit. Midflanking ridge present as minor swelling at base of denticles, but not as distinctly developed as on other species of the genus. Basal surface has flaring margins which are thickened into beadlike lips on larger specimens and enclose a broad and shallow groove. Cusp 2 to 3 times as large as other denticles.

Remarks. This species is distinguished by its long anterior process and short posterior process that projects straight back or downward, in contrast to those of other species of the genus that project upward. The species ranges throughout the Middle and Upper Triassic, extending the range of the genus to these younger rocks. No representatives were recovered from Lower Triassic samples.

Material and occurrence. Thirty-one specimens recovered from Deleeni and Sutherlandi (paratype GSC 30003 illustrated) Zones and most zones of the Upper Triassic up to Rutherfordi Zone (illustrated holotype GSC 30002 from GSC loc. 64654, Kerri Zone).

Xaniognathus sp.

Plate 20, figure 28

Xaniognathus sp. Sweet, 1970b, p. 268, Pl. 3, fig. 21.

Remarks. Two specimens were recovered from Spathian rocks that coincide very closely with Sweet's description of *X.* sp. They exhibit the differential size of denticles between the two subequal processes and the twisting of the posterior process such that the denticle tips are directed outward. They are laterally compressed and thin although not particularly fragile. The midflanking ridge is developed as a slight swelling along the base of the denticles.

Sweet (1970b, fig. 4) shows this species as occurring in the upper part of his Pakistan section, considered to be Spathian. The occurrence of these two specimens in rocks of this interval in Canada suggests it may have some stratigraphic value.

Material and occurrence. Two specimens from the Subrobustus Zone (GSC 30004 illustrated).

A number of forms with apparent morphologic affinities with *Xaniognathus* are represented by a few specimens from a small number of samples. They are included and briefly described here for completeness.

Xaniognathus sp. A

Plate 20, figure 31

Description. Blade-like form with subequal anterior and posterior processes. Posterior process curves upward; denticle size thereon increases toward posterior, the denticles increasing their inclination relative to bar (remaining parallel to each other). Anterior process curves downward.

Material and occurrence. One specimen from Sverdrupi Zone (GSC 30005).

Xaniognathus sp. B

Plate 20, figure 30

Description. Thick unit with rounded to oval denticles. Anterior process long and bears 8 denticles; posterior process short, bearing 3 small needle-like denticles. Main cusp twice as large as largest of other denticles. Midflanking ridge present as swelling on sides of blade. Basal surface broad with flaring margin.

Material and occurrence. Four specimens from Sutherlandi Zone (GSC 30006 illustrated).

Xaniognathus sp. C

Plate 20, figure 32

Description. Anterior process downwardly projecting and shorter than posterior process. Posterior process extends straight back from cusp and twists so that tips of denticles lean out. Basal surface broad with shallow groove.

Material and occurrence. One specimen from Kerri Zone (GSC 30007).

Xaniognathus sp. D

Plate 20, figure 26

Description. Unit small, but with anterior process that projects downward almost parallel to trend of cusp. Specimen bears 4 denticles on anterior process (end of process broken off). Posterior process much reduced and consists of two tiny denticles tightly fused on to posterior lower margin of cusp.

Material and occurrence. Two specimens from Rutherfordi Zone (GSC 30008 illustrated).

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Appendix

During two visits to the Geological Survey of Canada in Ottawa, and with the extensive assistance of E. T. Tozer, the suite of 57 samples was selected from the Survey's collections of Triassic material. Areas emphasized in the samples are northeastern British Columbia (48 samples), which has some of the finest and most complete sequences of Middle and Upper Triassic strata in North America, and Ellesmere and Axel Heiberg Islands in the Canadian Arctic (9 samples), where Tozer has proposed four-stage subdivision of the Lower Triassic (Tozer, 1965).

Sample localities are listed below. The sample numbers are those assigned by the Geological Survey of Canada. Zonal designations were provided by Tozer and correspond to those shown in his recently proposed standard for Triassic correlation, based on ammonoid data from Canada (Tozer, 1967). Numbers and letters in parentheses (94 B, etc.) refer to 1:250,000 map-sheets of Canada (*see* Tozer, 1967, p. 5, fig. 1). References in which the localities are described or in which additional stratigraphic information can be found are also indicated in parentheses, as is the name of the collector of each sample.

UPPER TRIASSIC

Norian

Suessi Zone

46507 Pardonet Formation. High hill at headwaters of Eleven Mile Creek, east of Clearwater Creek, 20 miles south of Peace River (93 O); (unit 8, section 9, Pelletier, 1963, p. 35). (Coll. Pelletier, 1961).

Upper Suessi Zone

64594 Pardonet Formation. Rapide-qui-ne-parle-pas, Peace River (94 B). (Tozer, 1967, p. 55; McLearn, 1960, p. 6). (Coll. Tozer, 1964).

Lower Suessi Zone

68304 Pardonet Formation. Mount Ludington (94 B). (Tozer, 1967, p. 54). (Coll. Tozer, 1965).
68300 Pardonet Formation. Mount Ludington (94 B). (Tozer, 1967, p. 54). (Coll. Tozer, 1965).

Columbianus Zone

46468 Pardonet Formation. 145 feet above base of unit 2, section 16 (Pelletier, 1964, p. 88), "White Creek", east of Crying Girl Prairie (94 B). (Tozer, 1967, p. 60). (Coll. Pelletier, 1961).

Rutherfordi Zone

64659 Pardonet Formation, *Proclydonautilus* Bed, Twin Spruce Gully, Brown Hill, Peace River (94 B). (McLearn, 1960, p. 13). (Coll. Tozer, 1964). (Possibly Columbianus Zone).
46459 Pardonet Formation. 130 feet above base of unit 2, section 16 (Pelletier, 1964, p. 88), "White Creek", east of Crying Girl Prairie (94 B). (Tozer, 1967, p. 60). (Coll. Pelletier, 1961).

Magnus Zone

68191 Pardonet Formation. West of Mount McLearn (94 N). (Tozer, 1967, p. 60). (Coll. Tozer, 1965).
64636 Pardonet Formation. Talus block containing *Juvavites magnus*. "Black Bear Ridge" of McLearn (1960, p. 12) north of Peace River (94 B). (Coll. Tozer, 1964).

Dawsoni Zone

46505 Pardonet Formation. Base of unit 2, section 16 (Pelletier, 1964 p. 88), "White Creek", east of Crying Girl Prairie (94 B). (Coll. Pelletier, 1961). Three separate bags were received. Tozer could not guarantee that all represented the same sample and they were separately designated A, B, C, for purposes of this study.

Kerri Zone

64654 Pardonet Formation. West slope, west spur, Brown Hill (94 B). (McLearn, 1960, p. 13). (Coll. Tozer, 1964).

68180 Pardonet Formation. West of Mount McLearn (94 N). (Tozer, 1967, p. 60). (Coll. Tozer, 1965).

Karnian

Macrolobatus Zone

64628 Pardonet Formation. Head of Western Gully, Pardonet Hill (94 B). (Tozer, 1967, p. 61). (Coll. Tozer, 1964).

64627 Pardonet Formation. Head of Western Gully, Pardonet Hill (94 B). (Tozer, 1967, p. 61). (Coll. Tozer, 1964).

Welleri Zone

42306 Pardonet Formation. Loose block in creek on west side of hill near Mile Post 427, Alaska Highway (94 K). (Tozer, 1967, p. 62). (Coll. Tozer, 1960).

42305 Pardonet Formation. Hill at Mile Post 427, Alaska Highway (94 K). (Tozer, 1967, p. 61, 62). (Coll. Tozer, 1960).

42385 Pardonet Formation. Hill at Mile Post 427, Alaska Highway (94 K). (Tozer, 1967, p. 61, 62). (Coll. Tozer, 1960).

51650 Blaa Mountain Formation, *Jovites* bed. Buchanan Lake, Axel Heiberg Island (49 G). (Tozer, 1961, p. 20; Tozer, 1967, p. 44). (Coll. Tozer, 1962).

Dilleri Zone

68208 "Grey Beds." Mount McLearn (94 N). (Tozer, 1967, p. 64). (Coll. Tozer, 1965).

Nanseni Zone

42309 "Grey Beds." Near south summit Ewe Mountain (94 N). (Tozer, 1967, p. 62, 63). (Coll. Tozer, 1960).

26124 Schei Point Formation, Bjorne Peninsula, Ellesmere Island (49 C). (Tozer, *in* Fortier *et al.*, 1963, p. 368). (Coll. Tozer, 1955). (?Nanseni Zone).

Obesum Zone

68217 "Grey Beds." Ridge between Mount McLearn and Ewe Mountain (94 N). (Tozer, 1967, p. 63). (Coll. Tozer, 1965).

42308 "Grey Beds." Col between north and south summits of Ewe Mountain (94 N). (Tozer, 1967, p. 63). (Coll. Tozer, 1960).

MIDDLE TRIASSIC

Ladinian

Sutherlandi Zone

42354 Liard Formation. North side Liard River, 2¼ miles west of Hell Gate (94 N). (Tozer, 1967, p. 66). (Coll. Tozer, 1960).

42351 Liard Formation. North side Liard River 2¼ miles west of Hell Gate (94 N). (Tozer, 1967, p. 66). (Coll. Tozer, 1960).

74773 Liard Formation (= Dark Siltstones of McLearn). Third Gully, Mount Stearns (= Mount Wright) (94 B). (McLearn and Kindle, 1950, p. 45). (Coll. Tozer, 1966).

68266 Liard Formation, about 335 feet below Cretaceous contact. South side Liard River, 3½ miles west of Hell Gate (94 N). (Coll. Tozer, 1965).

68264 Liard Formation, about 323 feet below Cretaceous contact. South side Liard River, 3½ miles west of Hell Gate (94 N). (Coll. Tozer, 1965).

68347 Loose block. Second Canyon above Hell Gate, Liard River (94 N). (?Sutherlandi Zone). (Coll. Tozer, 1965).

68279 Liard Formation. Bluff 10 miles southeast of Mount Mary Henry (94 K). (Tozer, 1967, p. 68). (Coll. Tozer, 1965).

Maclearni Zone

68237 Liard Formation. Boiler Canyon, Liard River (94 N). (Tozer, 1967, p. 65). (Coll. Tozer, 1965).

68236 Liard Formation. Boiler Canyon, Liard River (94 N). (Tozer, 1967, p. 65). (Coll. Tozer, 1965).

42355 Liard Formation. North side Liard River, 2½ miles west of Hell Gate (94 N). (Tozer, 1967, p. 66). (Coll. Tozer, 1960).

Meginae Zone

50043, 50045 Liard Formation, 170 feet above base of unit 7, section 9. Mount Withrow (94 G). (Pelletier, 1964, p. 58). (Coll. Pelletier, 1962).

39907 Liard Formation ("Dark Siltstones"). Beattie Ledge, Peace River (94 B). (McLearn and Kindle, 1950, p. 45; Tozer, 1967, p. 67). (Coll. E. J. W. Irish, 1959).

Poseidon Zone

74758 Liard Formation, Mount Withrow (94 G). (Coll. Tozer, 1966).

68284 Liard Formation. Bluff 10 miles southeast of Mount Mary Henry (94 K). (Tozer, 1967, p. 68). (Coll. Tozer, 1965).

Anisian

Deleeni Zone

74724 Toad Formation. Chischa River, 8 miles above Muskwa River (94 J). (Tozer, 1967, p. 69). (Coll. Tozer, 1966).

Varium Zone

68294 Toad Formation. West of Mile Post 375, Alaska Highway (94 K). (Tozer, 1967, p. 70). (Coll. Tozer, 1965).

40109 Toad Formation. Chlotapecta Creek, 10 miles east of Rocky Mountain Front (94 K). (Tozer, 1967, p. 72). (Coll. Pelletier, 1959).

Caurus Zone

68203 Toad Formation. West of Mile Post 375, Alaska Highway (94 K). (Tozer, 1967, p. 69). (Coll. Tozer, 1965).

68226 Toad Formation. West of Mile Post 375, Alaska Highway (94 K). (Tozer, 1967, p. 69). (Coll. Tozer, 1965).

LOWER TRIASSIC

Spathian

Subrobustus Zone

56234 Toad Formation, 430 feet above Permian contact. Bluff 7 miles north of Mount Laurier (94 B). (Tozer, 1965, p. 6; 1967, p. 73). (Coll. Tozer, 1963).

56256 Toad Formation, 325 feet above Permian contact. 2½ miles south 7° west of Mount Laurier (94 B). (Tozer, 1967, p. 73). (Coll. Tozer, 1963).

Smithian

Tardus Zone

47547 Blind Fiord Formation. *Wasatchites* Bed, Smith Creek, Ellesmere Island (340 B). (Tozer, 1967, p. 49). (Coll. Tozer, 1961).

42364 Toad Formation. *Wasatchites* Bed, Toad River, 2 miles above Liard River (94 N). (McLearn and Kindle, 1950, p. 40; Tozer, 1967, p. 74). (Coll. Tozer, 1960).

Romunderi Zone

56279 Toad Formation. Needham Creek (94 B). (Tozer, 1967, p. 74). (Coll. Tozer, 1963).

28680 Blind Fiord Formation, 5 miles northwest of entrance to Hare Fiord, Ellesmere Island (340 B). (Tozer, 1961, p. 13; Tozer, 1967, p. 48). (Coll. Thorsteinsson and Tozer, 1956).

Dienerian

Sverdrupi Zone

47543 Blind Fiord Formation. Bluff west of Lindstrom Creek, north of Otto Fiord, Ellesmere Island (560 D). (Tozer, 1963, p. 15; Tozer, 1967, p. 49, 50). (Coll. Thorsteinsson and Tozer, 1961).

56224 Toad Formation, 101 feet above Permian contact. Bluff 7 miles north of Mount Laurier (94 B). (Tozer, 1967, p. 73). (Coll. Tozer, 1963).

56205 Toad Formation, 90 feet above Permian contact. Bluff 7 miles north of Mount Laurier (94 B). (Tozer, 1967, p. 73). (Coll. Tozer, 1963).

Candidus Zone

56181 Toad Formation, talus block, 2½ miles south 7° west of summit of Mount Laurier (94 B). (Tozer, 1967, p. 73). (Coll. Tozer, 1963).

51667 Blind Fiord Formation. South of Otto Fiord, 4 miles east of mouth of Diener Creek (560 A). (Coll. Tozer, 1962).

Griesbachian

Strigatus Zone

51663 Blind Fiord Formation. South of Otto Fiord, 4 miles east of mouth of Diener Creek (560 A). (Coll. Tozer, 1962).

Commune Zone

47527 Blind Fiord Formation. Island between Bunde and Bukken Fiords, Axel Heiberg Island (560 A). (Tozer, 1967, p. 52). (Coll. Thorsteinsson and Tozer, 1961).

Boreale Zone

47524 Blind Fiord Formation. Island between Bunde and Bukken Fiords, Axel Heiberg Island (560 A). (Tozer, 1967, p. 52). (Coll. Thorsteinsson and Tozer, 1961).

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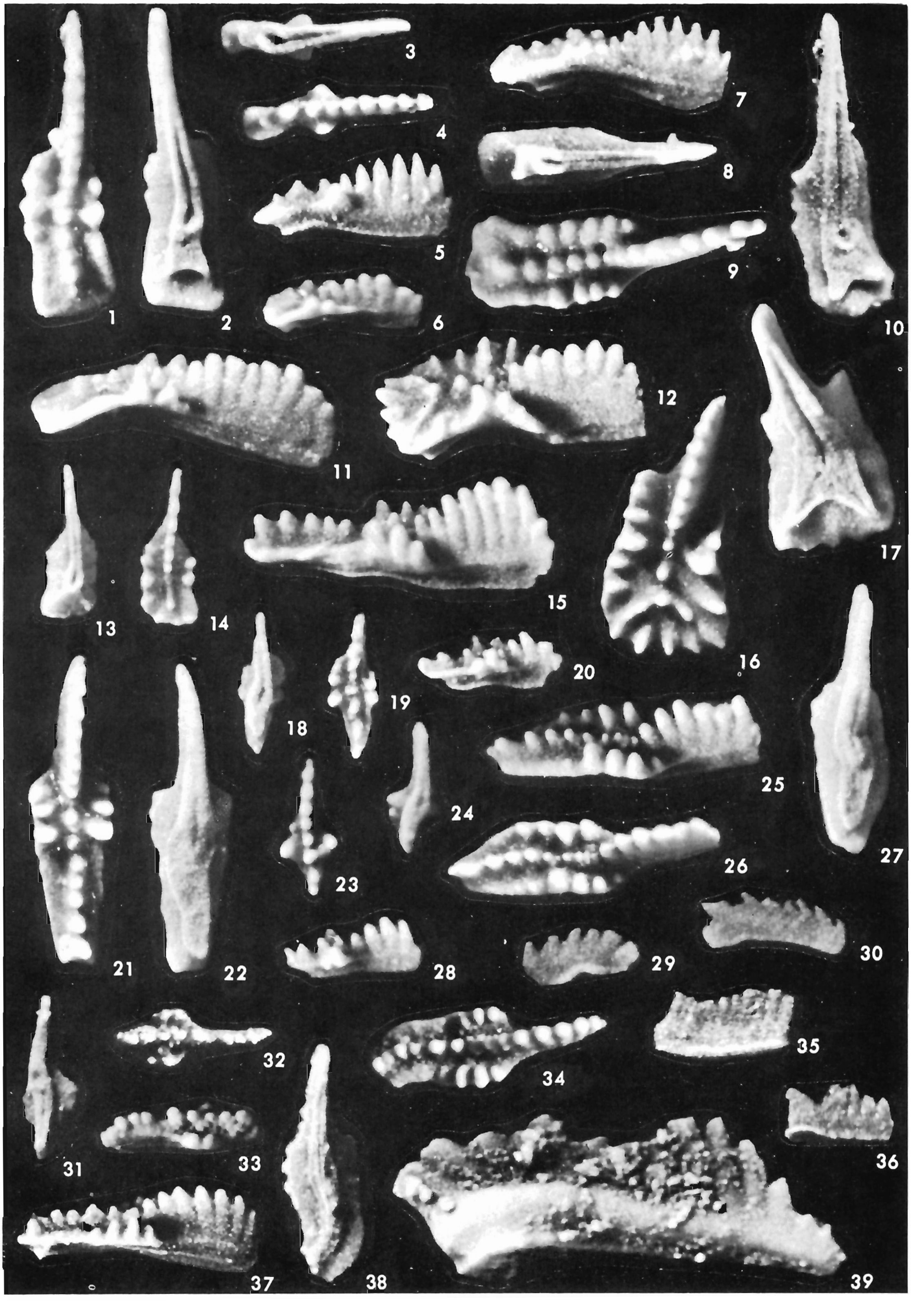
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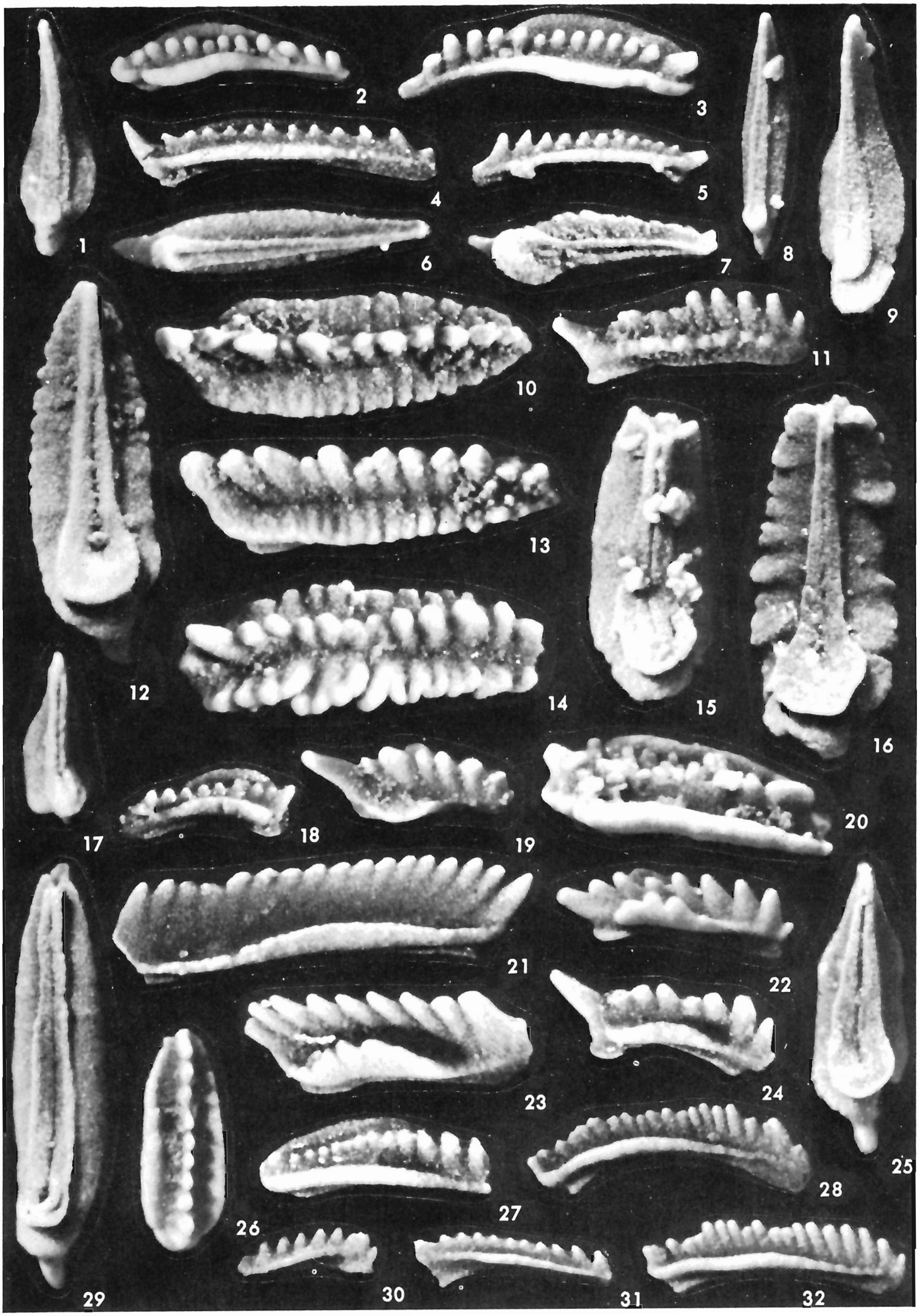
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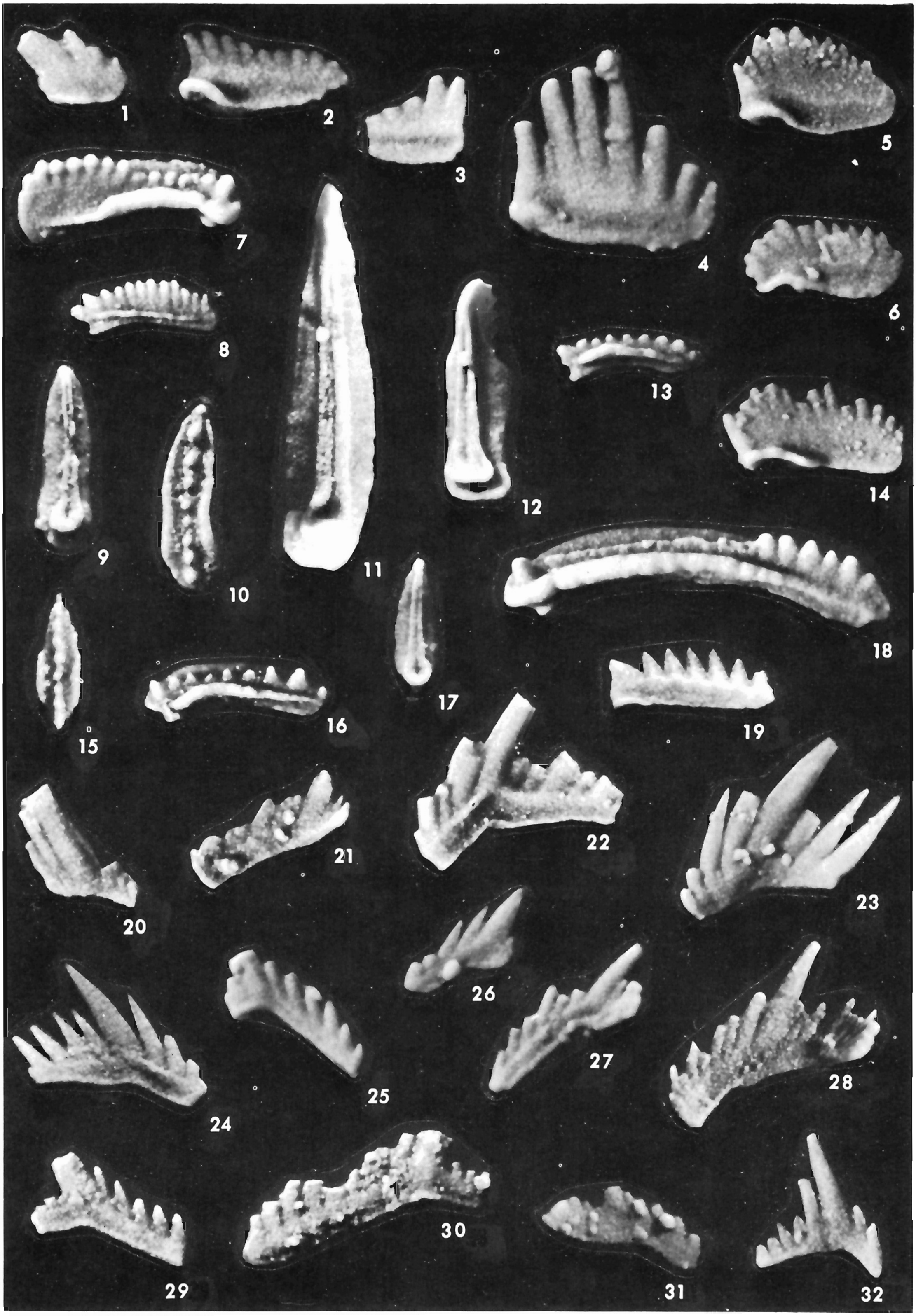
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