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THE PERMIAN AMMONOIDS OF ARCTIC CANADA

W. W. Nassichuk, W. M. Furnish, and Brian F. Glenister

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PREFACE

Correlation of sedimentary strata is based to a great extent on precise palaeontological information. Fusulinids have provided a sound basis for dating late Palaeozoic rocks in many parts of the world but these fossils are absent in the younger Permian rocks of the Arctic. Correlation has presented many difficulties heretofore as some of the more widely distributed faunal elements have long ranges in time and show marked provincialism.

This bulletin describes all the available Permian ammonoids from Arctic Canada together with some from equivalent strata in Alaska and Greenland. This detailed study, using modern techniques to ensure accurate identification of species and precise definition of genera, is an important contribution to ammonoid taxonomics and clearly demonstrates their usefulness in circumpolar correlation of Permian rocks of the Arctic.

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

OTTAWA, September 9, 1964

Bulletin 131—Die permischen Ammonoideen des arktischen Kanada
Von W. W. Nassichuk, W. M. Furnish, und Brian F. Glenister

БЮЛЛЕТЕНЬ 131 — ПЕРМСКИЕ АММОНИТЫ АРКТИЧЕСКОЙ КАНАДЫ
В. В. Нассичук, В. М. Фурниш, и Б. Ф. Гленистер

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THE PERMIAN AMMONOIDS OF ARCTIC CANADA

Abstract

Sixteen species of Permian ammonoids are known from Arctic North America. The present study comprises the description of all specimens secured from Arctic Canada and Alaska; additionally, the two species recorded previously from Greenland are redescribed partly on the basis of a new collection.

Cyclolobus kullingi (Frebold) and *Medlicottia malmqvisti* (Frebold) occur in the uppermost Permian (Dzhulfian) "*Martinia*-beds" of central East Greenland. In the Queen Elizabeth Islands, *Paragastrioceras* n. sp. is recorded from a Lower Permian formation on northern Ellesmere Island; *Neoshumardites* cf. *N. sakmarae* (Ruzhencev), *Paragastrioceras* aff. *P. jossae* (de Verneuil), *Uraloceras involutum* (Voinova), *Uraloceras burtiense* (Voinova), and *Metalegoceras crenatum* n. sp. are associated in the Lower Permian Assistance Formation of southern Ellesmere Island. The type Assistance Formation of Devon Island contains *Pseudogastrioceras fortieri* Harker and *Spirolegoceras harkeri* Ruzhencev, forms which are referred to the uppermost Lower Permian but are considered as younger than the ammonoid fauna of the Assistance Formation on Ellesmere Island. The Upper Permian (Guadalupian) of Cameron Island has yielded a single ammonoid, the type of *Neogeoceras macnairi* n. sp.

Unnamed Lower Permian sequences in the Richardson Mountains of the northern Yukon Territory and adjacent areas of Alaska are the source of ammonoids referable to *Eoasianites* sp., *Metalegoceras crenatum* n. sp., and *Neouddenites caurus* n. sp. *Neogeoceras* sp. occurs in an unnamed Upper Permian stratum of the Richardson Mountains in the northwestern District of Mackenzie. Poorly preserved specimens from the Sadlerochit Formation of northern Alaska are referred doubtfully to *Pseudogastrioceras*; they are of probable Upper Permian (Guadalupian) age.

Syrdenites stoyanowi n. gen., n. sp., a medlicottiin related to the representative from Greenland, is named for a form from the Upper Permian (Dzhulfian) of Soviet Armenia.

The Permian ammonoids of Arctic North America constitute an element of the "Boreal Realm". Affinities are with faunas from the Ural Mountains, Siberia, and Australia.

Résumé

Seize espèces d'ammonitidés du Permien ont été reconnus dans l'Arctique nord-américain. La présente étude inclut la description de tous les spécimens obtenus de l'Arctique canadien et de l'Alaska; de plus, les deux espèces dont la présence avait été établie auparavant au Groenland sont décrites une seconde fois à l'aide de nouveaux spécimens.

Cyclolobus kullingi (Frebold) et *Medlicottia malmqvisti* (Frebold) sont présentes dans les couches à *Martinia* les plus récentes du Permien supérieur (le Djoulfien) du centre Est du Groenland. Dans les îles Reine-Elisabeth, la présence de *Paragastrioceras* n. sp. est attestée dans une formation (Permien inférieur) au fjord Hare dans le Nord de l'île Ellesmere; *Neoshumardites,* cf.

N. sakmarae (Ruzhencev), *Paragastrioceras* aff. *P. jossae* (de Verneuil), *Uraloceras involutum* (Voinova), *Uraloceras burtiense* (Voinova), et *Metalegoceras crenatum* n. sp., sont associés dans la formation Assistance du Permien inférieur, dans le Sud de l'île Ellesmere. La formation-type Assistance de l'île Devon contient *Pseudogastrioceras fortieri* Harker et *Spirolegoceras harkeri* Ruzhencev, fossiles qui remontent au Permien inférieur le plus récent, mais qu'on considère plus jeunes que la faune des ammonitidés de la formation Assistance de l'île Ellesmere. Une formation du Permien récent (le Guadeloupéen) dans les îles Cameron a donné un seul ammonitidé, le type de *Neogeoceras macnairi* n. sp.

Les successions stratigraphiques non nommées du Permien inférieur dans les monts Richardson (Nord du Territoire du Yukon), et dans les régions avoisinantes de l'Alaska, ont fourni des ammonitidés identifiés comme *Eoasianites* sp., *Metalegoceras crenatum* n. sp. et *Neouddenites caurus* n. sp.; *Neogeoceras* sp. se présente dans une strate non nommée du Permien supérieur dans les monts Richardson (Nord-Ouest du district de Mackenzie). Des spécimens en mauvais état de conservation, et provenant de la formation Sadlerochit dans le Nord de l'Alaska, sont rattachés avec réserve aux *Pseudogastrioceras*; ils datent probablement du Permien supérieur (le Guadeloupéen).

Syrdenites stoyanowi n. gen., n. sp., un medlicottiin, parent de l'exemplaire venant du Groenland, est nommé d'après une forme provenant du Permien supérieur (Djoulfien) en Arménie soviétique.

Les ammonitidés du Permien, dans l'Arctique nord-américain, sont un des constituants du "Royaume de Septentrion". Leurs caractères les rapprochent des faunes de l'Oural, de la Sibérie et de l'Australie.

INTRODUCTION

Field Work and Acknowledgments

Permian rocks are widely distributed in Arctic North America where they include a variety of richly fossiliferous marine strata. Ammonoid cephalopods constitute a relatively rare component of these faunas, but one that assumes disproportionately great significance for Arctic and mondial correlation.

The first Permian ammonoids from Arctic North America were collected from eastern Greenland in 1929. Small but significant additional collections have been assembled from the same general area by subsequent Danish expeditions. During 1955, members of "Operation Franklin" of the Geological Survey of Canada discovered several ammonoid localities in the Permian strata of the Queen Elizabeth Islands, Canadian Arctic Archipelago. Subsequent investigations revealed additional scattered occurrences, and larger faunas have been assembled. During the course of "Operation Porcupine" of the Geological Survey of Canada in 1961, Permian ammonoids were found from several scattered areas of the northern Yukon Territory. Survey personnel and oil company geologists have made available additional collections from the northern Yukon and adjacent areas of the Northwest Territories and Alaska.

All the Permian ammonoids known from Arctic Canada and Alaska, together with a small recent collection from eastern Greenland, were examined in the preparation of this report. Specimens from Oregon, Idaho, Coahuila, the Southern Urals, Siberia, Armenia, West Pakistan, the Himalayas, and Western Australia are figured for comparative purposes. The bulk of the ammonoids described were collected by officers of the Geological Survey of Canada. Most of the specimens were found by R. Thorsteinsson in the course of geological studies on Devon and Ellesmere Islands, Canadian Arctic Archipelago. In 1963 P. Harker collected further specimens from the type locality of the Assistance Formation at Grinnell Peninsula on Devon Island. W. W. Nassichuk and R. L. Christie also made significant collections from northern Ellesmere Island in 1963. A. H. McNair of Dartmouth College provided a unique specimen from Cameron Island.

All the Permian ammonoids available from the mainland of Arctic North America originated in the northern Yukon Territory and adjacent areas of the Northwest Territories and Alaska. Most were secured by E. Wayne Bamber, but J. A. Jeletzky provided some material. Additional specimens were made available by The California Standard Oil Company and by J. Scott Dixon of Shell Oil

Company. Several specimens from Alaska were collected by J. T. Dutro Jr. of the United States Geological Survey and made available by Mackenzie Gordon Jr.

The Greenland Geological Survey generously made available the ammonoids collected from eastern Greenland by S. E. B. Almgreen and B. Bang Soltau. Eigil Nielsen of the University of Copenhagen provided comparative material of critical importance from the Himalayas.

V. E. Ruzhencev of the Soviet Paleontological Institute provided a quantity of critical comparative material from the Southern Urals. O. H. Schindewolf of the University of Tübingen lent study specimens from the Salt Range, West Pakistan.

R. Thorsteinsson shares responsibility for the stratigraphic information on specimens from the Canadian Arctic islands, and E. Wayne Bamber for material from mainland Canada. P. Harker assisted in the final preparation of the manuscript. Financial assistance was provided by the Geological Survey of Canada and by the Graduate College, University of Iowa.

Subdivision of the Permian Period

Several authors have discussed general correlations of the Arctic Permian (Frebold, 1950[1]; Harker and Thorsteinsson, 1960; Dunbar, 1960; Dutro, 1961). There is only fair agreement on stage equivalencies, based upon brachiopod occurrences for the most part. Fusulinacea have also been found to be widely distributed and useful indices, particularly in the Lower Permian. Ammonoids are rare in the Arctic but are representative of those taxa established in sequence elsewhere.

Most of the Permian cephalopods known from Canada belong in the lower half of the system and are of distinct Arctic aspect. A probable exception is found in the Cache Creek Group of south-central British Columbia (51°N), which includes strata ranging through a considerable part of the Permian and contains some brachiopods and fusulinaceans with Asian affinities. The upper Cache Creek ammonoids from near Kamloops are of a cosmopolitan nature closely similar to those of the Guadalupian Stage in various parts of the world. However, a few undescribed ammonoids from near Fernie, British Columbia (50°N) and near Carcross (60°N) close to the British Columbian-Yukon border are of Lower Permian age and Arctic aspect. In East Greenland, the Permian ammonoid-bearing strata are of Late Permian (post-Guadalupian) age based on the occurrence of an index form *Cyclolobus*.

Stage nomenclature for the Permian System and correlation of the ammonoid reference sequences was presented previously (Glenister and Furnish, 1961, pp. 678-684), and is summarized on Table I. Current nomenclature corresponds to previous usage, with the exception that the upper limit of the Lower Permian is revised to include equivalents of the basal limestone of the type Word Formation. A nomenclatorial problem still exists in the assignment of these strata.

In the Glass Mountains of West Texas, basal limestone in the Word Formation at the type locality contains a variety of ammonoids (Miller, 1945, pp. 14-19; Miller and Furnish, 1957c, pp. 1052-1056) including *Perrinites hilli* (Smith),

[1] Names and/or dates in parentheses are those of references listed pp. 52-56.

Table I

Correlation Chart of Permian Ammonoid-bearing Strata

	Stage and Substage		Arctic America	West Texas	North-Central Texas	Western North America	Timor	Urals	Other Areas
UPPER PERMIAN	Dzhulfian		Foldvik Creek (E. Greenland)						Dzhulfa (Armenia); Kuling (Himalayas)
	Guadalupian	Capitanian	Unnamed formation (Cameron Is.)	Capitan (Bell Canyon)			Amarassi		Las Delicias Beds (Coahuila)
		Wordian		Word (Cherry Canyon)		Cache Creek (B.C.)	Basleo		
LOWER PERMIAN	Artinskian		Assistance (Grinnell Pen.)	Road Canyon: Basal Word (Brushy Canyon)	Pease Riv.: Blaine	San Andres (New Mex.); Kaibab (Arizona); Phosphoria (Wyoming)	(Taë Wei)	(Kungur)	Western Australia: Coolkilya
		Baigendzhinian	Unnamed formation (Hare Fiord); (Bjorne Pen.)	Leonard (Upper Hueco): Bone Spring	Clear Fork: Choza		Bitauni	Arti	Coyrie
		Aktastinian			Clear Fork: Clyde				
	Sakmarian	Sterlitamakian		Wolfcamp (Lower Hueco): Lenox Hills	Wichita: Admiral		Somohole	Sterlitamak	Nura Nura
		Tastubian						Tastuba	
	Asselian			Wolfcamp (Lower Hueco): Neal Ranch	Wichita: Pueblo	Council Grove (Kans.-Okla.); Bursum (New Mexico)		Kurmaya; Uskalyk; Syuren	Holmwood

Glassoceras newelli (Miller and Furnish), *Medlicottia whitneyi* Böse, and *Pseudogastrioceras roadense* (Böse). The associated brachiopod fauna is characterized by *Peniculauris bassi* (McKee) according to Cooper (*in* Dunbar, *et al.,* 1960, pp. 1770, 1772). In these two groups of fossils there are such strong relationships with those found in the underlying Leonard Formation that this stratigraphic unit should logically be regarded as uppermost Lower Permian rather than basal Guadalupian as commonly assigned. Under our definition, this time boundary corresponds to the horizon of extinction in two of the most characteristic Lower Permian ammonoid elements: the Perrinitidae and the Metalegoceratidae.

Elsewhere in North America, there appear to be several widespread elements of this same basal Word fauna. The upper San Andres Formation of New Mexico and the El Reno or Pease River Group of western Oklahoma and northern Texas are to be correlated with the basal Word Formation. Also, the Kaibab Limestone of Arizona-Utah and the Meade Peak Phosphate Member of the Phosphoria in Idaho-Wyoming are regarded as of comparable age. The latter unit contains representatives of the ammonoid genera *Spirolegoceras* and *Pseudogastrioceras,* which are closely similar to species in the Assistance Formation of the Canadian Arctic.

As stated previously (Glenister and Furnish, 1961, p. 682), there is little ammonoid evidence for detailed correlation of the American sections with those of the late Artinskian in the Urals, although certain species in the upper Leonard Formation appear to be younger phylogenetically. A separate stage designation is required, but the sparsely fossiliferous Kungurian does not appear to be a logical reference. There is also an uncertainty in the use of Svalbardian (Harker and Thorsteinsson, 1960, p. 18). Chronic (1952, p. 105) was one of the first to mention that there was such a distinctive faunal element in the southwestern United States. Dunbar (1960, pp. 1776-1777) has presented a succinct discussion of the problem as it applies to the important reference sections in west Texas and New Mexico.

Ross (1962, p. 6) suggested that upper Leonard Formation Fusulinacea of the Glass Mountains are similar to species near the top of the Belcher Channel Formation of Grinnell Peninsula, below the Assistance Formation. Harker and Thorsteinsson (1960, p. 13) correlated the upper Belcher Channel with Artinskian strata. Ross (ibid.) also regarded the upper Leonard Formation *Parafusulina durhami* Thompson and Miller as being similar to *P. tschussovensis* Rauser-Chernoussova of the Artinskian in the Urals. Later, in his study of Word Formation Fusulinacea, Ross (1963, p. 22) concluded that the lowest unit in the Glass Mountains correlated with the Brushy Canyon Formation at the base of the type Guadalupian section. Ross' data thus suggest that our assignment of the basal Word-Brushy Canyon fauna to Lower Permian is arbitrary, but that probably a separate stage between Artinskian and Guadalupian could be recognized.

Permian Ammonoid Faunal Realms

Most of the Lower Permian ammonoids so far collected from Arctic Canada can be recognized as part of a "Boreal Realm". The best known faunas in this category are those from the Ural Region of the Soviet Union (e.g., Ruzhencev, 1956). In a general way, at least, this provincial unit corresponds to the brachiopod fauna with abundant representatives of *Horridonia* and *Jakutoproductus* (Ustritsky, 1961).

As the term "Boreal" has been used in paleogeography, there is no direct implication of north-polar position or glacial association. Nevertheless, Stehli and Helsley (1963) suggested that Permian poles corresponded approximately to the present position; others have regarded the fauna as of cold Arctic origin. Canadian ammonoid occurrences provide substantial evidence in support of a polar realm. Also, Western Australia, which is antipodal to northern Canada and which is associated with Lower Permian glacial phenomena, has a representation of Boreal ammonoids.

Abundance of *Uraloceras* and *Paragastrioceras* constitutes a distinctive aspect of the Boreal Realm. Species of *Metalegoceras,* as well as the related *Juresanites* and *Spirolegoceras,* characterize the same element. A few others, such as *Neoud-denites* and *Neoshumardites,* may prove to be even more diagnostic when additional occurrences are known. By contrast, none of the Perrinitidae has been noted in the northernmost and southernmost provinces; perrinitids are the most common ammonoids of Lower Permian strata in southwestern United States and northern Mexico, and have been found in western United States, Central America, northern Colombia, Middle Asia (Darwas), and Timor.

Taxonomic simplicity characterizes some Recent polar marine invertebrate faunas and has been suggested as an identifying feature in Permian faunal occurrences (Stehli and Helsley, 1963). Arctic ammonoids generally are diverse. However, an example which might fit such a Boreal pattern is found in the Phosphoria Formation of Wyoming-Idaho in which ammonoids referable to *Pseudogastrioceras simulator,* and varieties, occur with about a thousand times the frequency of all other ammonoids. This monotony is also apparent in the occurrence of *Juresanites jacksoni* in the Holmwood Shale of Western Australia. It would be misleading not to mention that the typically "non-Boreal" *Perrinites* occurs in some localities of north-central Texas and southern Coahuila almost to the exclusion of other fossils.

Size attained by mature conchs might logically have been related to temperature of the sea. Dwarfed goniatites representing *Pseudogastrioceras* and *Spirole-goceras* which occur in the Phosphoria Formation of Wyoming-Idaho have been assigned to a part of the "Alaskan faunal province" by Dunbar (1960). Of greater significance are similar species of normal and large size known from Arctic Canada, with a mature diameter about ten times those from the Phosphoria. Indeed, most of the conchs from the Arctic appear to be unusually robust, and the holotype of *Metalegoceras crenatum* n. sp. is the largest Palaeozoic ammonoid known (0.6 m). *Juresanites jacksoni* from Western Australia is nearly as large. Thus although dwarfism in Permian ammonoids might be attributed to adverse ecologic conditions, the Boreal elements attained large size.

In the Upper Permian, there is no apparent provincialism of ammonoids. Faunas of the Guadalupian Stage in Sicily, Texas-Coahuila, and Timor are so closely similar that distinct realms cannot be recognized. Curiously, most of the associated fusulinaceans may be separated into a Tethyan-Oriental assemblage dominated by Verbeekininae and Neoschwagerininae or a characteristic "Southwestern" group in which these subfamilies are generally absent and the faunas contain advanced Schwagerininae. In part, at least, distribution of the fusulinaceans was controlled by tectonic setting; the verbeekinins and neoschwagerinins are characteristic of eugeosynclinal sequences.

LOCALITIES

The present study comprises investigation of Permian ammonoids from twelve localities in Arctic North America. Geographic distribution of the faunas is sporadic, extending over 2,000 miles from eastern Greenland to northern Alaska. Both Lower and Upper Permian ammonoids are represented. Locality A is situated in central East Greenland; localities B-F are distributed in the Queen Elizabeth Islands, Canadian Arctic Archipelago; and localities G-L are in the northern Yukon Territory and adjacent areas of the Northwest Territories and Alaska.

Locality A — Central East Greenland

Several small collections of Upper Permian ammonoids have been secured from Mount Brinkley (Clavering Island) and the closely adjacent Cape Stosch (74°N, 21-22°W). All are from the "*Martinia*-beds", Foldvik Creek Formation. Frebold (1932) and Miller and Furnish (1940) have described the ammonoid fauna. The two species of Permian ammonoids known from Greenland are described herein as:

Cyclolobus kullingi (Frebold)
Medlicottia malmqvisti Frebold

Recent collections from Cape Stosch, which include four specimens of *C. kullingi,* permit a better understanding of that species.

Cyclolobus serves as the index ammonoid for the uppermost Permian Dzhulfian Stage and is unknown beyond the limits of that unit. It is relatively abundant in Madagascar, and is a rare element in the Salt Range of Pakistan, the Central Himalayas, the Dzhulfa section of Armenia, and central East Greenland. *Medlicottia* ranges from the Lower Permian Sakmarian Stage through the entire Upper Permian. It is a rare associate of *Cyclolobus* in the Salt Range and Greenland.

Locality B — Hare Fiord, Ellesmere Island

Hare Fiord is one of the major inlets connected with Nansen Sound, northwestern Ellesmere Island, Canadian Arctic Archipelago. Details of the stratigraphy are not available, but Permian ammonoids have been collected on both the northern and southern sides of Hare Fiord.

GSC locality 58302 is on the north side of Hare Fiord about a mile inland, 22 miles west of the head of the Fiord, and a mile west of the delta of a stream that flows into Hare Fiord from the southwestern end of the Conger Range (81°07′30″N, 84°18′00″W). The ammonoids were collected from ferruginous concretions in the uppermost exposed part of a sequence of interbedded dark grey limestones and shales referred to the "Hare Fiord Formation" (Thorsteinsson, MS.). The upper beds of the formation are not exposed in this section, but the ammonoid horizon is probably equivalent to that at locality C. The ammonoids are referred to:

Paragastrioceras n. sp. .... 11 specimens

Paragastrioceras is confined to the Lower Permian, appearing first in the middle Asselian and extending through the Baigendzhinian Substage of the Artinskian. The uncertain specific affinities of the Canadian species do not allow designation of a restricted age assignment.

Locality C — Northwest of Blaa Mountain, Ellesmere Island

GSC locality 47869 is south and east of Hare Fiord about 30 miles southwest of locality B and 8 miles inland from the eastern shore of Hare Fiord, at an elevation of about 2,000 feet, and on a ridge between a major stream flowing into Hare Fiord and a west-flowing tributary (80°45′30″N, 85°45′00″W). Ammonoids occur about 2,600 feet above the base of the "Hare Fiord Formation" (Thorsteinsson, MS.) which is 4,100 feet thick at this locality. They are referred to:

Paragastrioceras n. sp. .... 6 specimens

The parent horizon is probably correlative with that of locality B, to the north of Hare Fiord, but we are unable to designate a restricted age within the Lower Permian.

Locality D — Bjorne Peninsula, Ellesmere Island

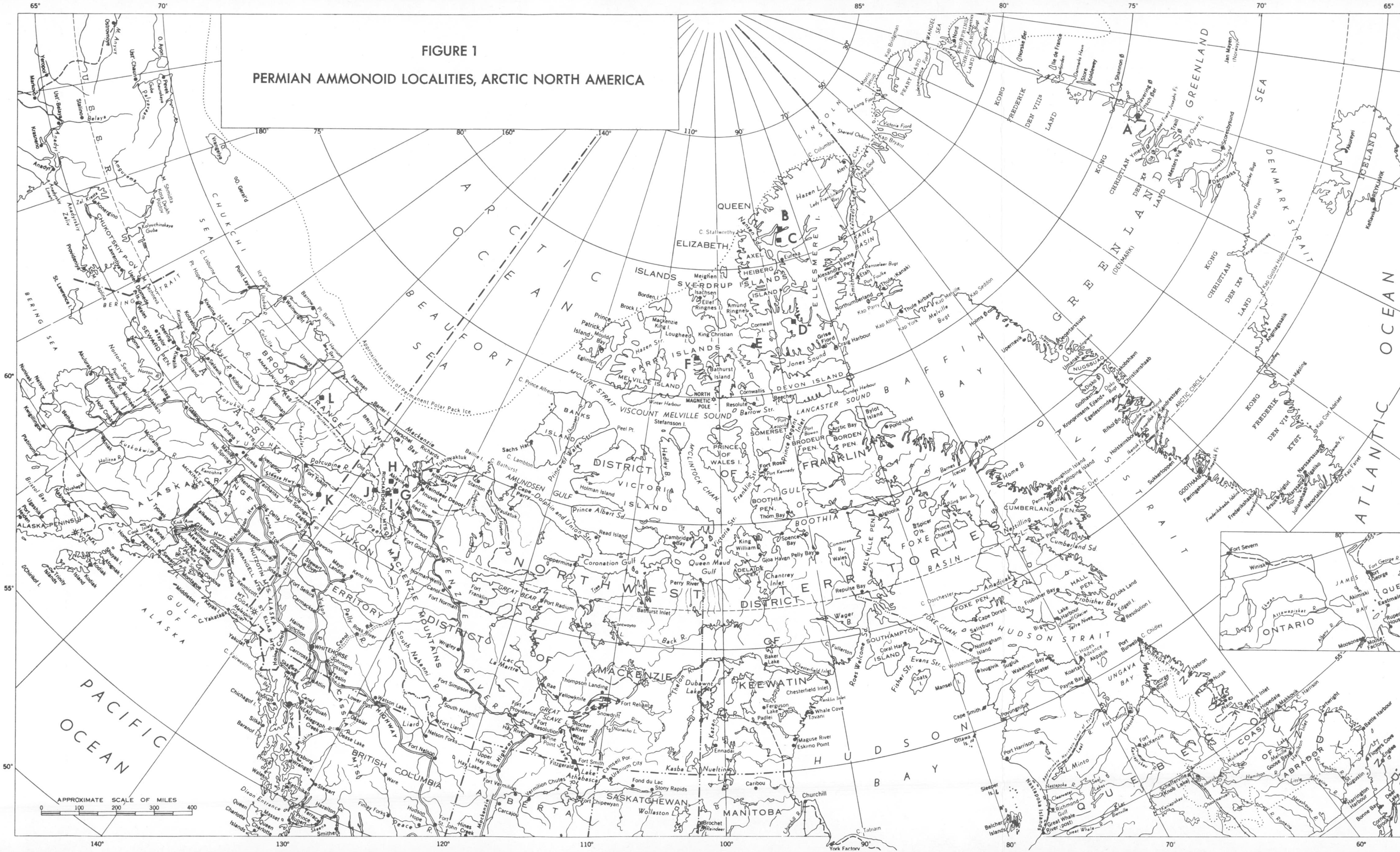
Bjorne Peninsula is a major prominence along the western coast of southwestern Ellesmere Island, Canadian Arctic Archipelago. Late Palaeozoic strata are exposed extensively but details of the stratigraphy are not available. A single horizon and site (GSC locality 57719) has yielded a variety of Permian ammonoids. This locality is near the northeastern coast of the Peninsula, some 6 miles inland from Baumann Fiord (77°36′50″N, 86°22′30″W). The ammonoids occur approximately 915 feet above the base of the unit tentatively assigned by R. Thorsteinsson to the Assistance Formation; total thickness of the formation in this area is about 1,250 feet. The ammonoid fauna is as follows:

Neoshumardites cf. *N. sakmarae* (Ruzhencev)	3	specimens
Paragastrioceras aff. *P. jossae* (de Verneuil)	1	"
Uraloceras burtiense (Voinova)	6	"
Uraloceras involutum (Voinova)	4	"
Metalegoceras crenatum n. sp.	4	"

Poor preservation of the Canadian representatives of *Neoshumardites* precludes positive specific identification. Affinities appear to be with *N. sakmarae*, a species previously restricted to the Sakmarian of the Southern Urals where it is most

FIGURE 1

PERMIAN AMMONOID LOCALITIES, ARCTIC NORTH AMERICA



abundant in the upper Sakmarian Sterlitamakian Substage (Ruzhencev, 1951). The closely related *N. triceps* Ruzhencev is known from lower Artinskian (Aktastinian) strata of the Southern Urals (Ruzhencev, 1956) and Siberia (Ruzhencev, 1961). Poor preservation of the single representative of *Paragastrioceras* does not allow designation of a restricted age within the Lower Permian. Both *Uraloceras involutum* and *U. burtiense* range throughout the Sakmarian and Artinskian strata of the Southern Urals. *U. involutum* is characteristic of the lower Artinskian Aktastinian Substage (Ruzhencev, 1956), whereas *U. burtiense* is most abundant in the upper Sakmarian Sterlitamakian Substage. *Metalegoceras crenatum* n. sp. bears close similarity to *M. rotundatum* Ruzhencev (1956) from the lower Artinskian Aktastinian Substage of the Southern Urals.

The ammonoid fauna of Bjorne Peninsula can be assigned to either the upper Sakmarian Sterlitamakian Substage or the lower Artinskian Aktastinian Substage.[1] The ammonoid-bearing horizon of the Assistance Formation on Bjorne Peninsula is thus appreciably older than that of the type area of Grinnell Peninsula.

Locality E — Grinnell Peninsula, Devon Island

Grinnell Peninsula constitutes the northwestern extremity of Devon Island, one of the larger islands in the east-central part of the Canadian Arctic Archipelago. Richly fossiliferous marine Permian strata are exposed in a narrow belt along the north coast of the peninsula. Details of Permian stratigraphy and palaeontology of these exposures were presented by Harker and Thorsteinsson (1960). Additional discussion of the ammonoid fauna is included in publications by Miller, Furnish and Clark (1957, p. 1064), Glenister and Furnish (1961, p. 701), Ruzhencev (1961, pp. 51, 52), and Harker *in* Fortier, *et al.* (1963, pp. 255-256).

All the Permian ammonoids from Grinnell Peninsula were collected from a single site (GSC locality 26406), about 3 miles upstream from the mouth of the Lyall River (76°57′30″N, 95°21′30″W), which enters Belcher Channel between Cape Ogle and Whitmore Point. The ammonoids were collected from the type section of the Assistance Formation, about 170 feet above its base. At the type locality the Assistance Formation consists of 200 feet of poorly consolidated alternating thin beds of dusky yellowish orange and medium greyish green glauconitic sandy clay and argillaceous sand.

Ammonoids from the Assistance Formation are as follows:

Pseudogastrioceras fortieri Harker, 1960 .... 8 specimens
Spirolegoceras harkeri Ruzhencev, 1961 .... 4 "

Pseudogastrioceras fortieri is almost indistinguishable from *P. goochi* Teichert (1942) from the Coolkilya Greywacke and the Lightjack Member of the Liveringa Formation of Western Australia (Glenister and Furnish, 1961). Additionally, the Arctic species closely resembles *P. mckeei* Miller and Furnish (1958) from the

[1]Thorsteinsson (pers. com.) suggests an Artinskian age for the fusulinaceans of the Belcher Channel Formation beneath the Assistance Formation on Bjorne Peninsula. This age assignment thus favours the Artinskian reference for the Assistance ammonoids, rather than the possible late Sakmarian alternative.

Kaibab Formation of Arizona. *Spirolegoceras harkeri* is also known from the Endybalsky Formation of Yakutskaya A.S.S.R. (Ruzhencev, 1961), and the closely related *S. fischeri* Miller, Furnish and Clark (1957) occurs in the Meade Peak Member of the Phosphoria Formation of Idaho. All these horizons are believed to be correlative with the basal limestone of the Word Formation. As indicated earlier, the basal Word is considered herein as uppermost Lower Permian. However, it is probably younger than the type Baigendzhinian Substage of the Artinskian.

Locality F — Cameron Island

Cameron Island is one of the small islands lying off the northwestern coast of Bathurst Island, Canadian Arctic Archipelago. It has yielded a single Permian ammonoid, the holotype of *Neogeoceras macnairi* n. sp. The type locality is near the southeastern coast of Cameron Island, about 4 miles southwest of Cape Fortune (76°27′30″N, 103°13′30″W). Stratigraphic details are not available, but the specimen is known to have come from the dark green glauconitic sandstones that overlie Upper Devonian carbonates.

Representatives of *Neogeoceras* apparently are confined to Guadalupian strata (Miller and Furnish, 1940). They occur in the Wordian Substage of Coahuila, Sicily, and Timor, as well as in the early Capitanian Substage of Texas. Species of uncertain age are known from Novaya Zemlya and the Yukon Territory. The parent strata of *Neogeoceras macnairi* therefore should be referred to the Upper Permian Guadalupian Stage.

Locality G — Richardson Mountains, District of Mackenzie

A single Upper Permian ammonoid, described herein as *Neogeoceras* sp., is known from the northeastern flank of the Richardson Mountains, District of Mackenzie, northwestern mainland Canada. The specimen is from GSC locality 53876, near the headwaters of Bear Lake (a tributary of the Rat River), 8 miles east of the Yukon border (67°58′28″N, 136°09′22″W). It was secured from a nodule in a small outcrop of siltstone, 137 feet below the base of a cliff-forming limestone sequence and 657 feet above the orange to reddish brown siltstone unit that forms the base of the section. The sequence is as yet unnamed.

Neogeoceras sp. is most closely related to *N. marcoui* (Gemmellaro, 1887) from the early Guadalupian Wordian Substage of Sicily. The genus is restricted to the Upper Permian Guadalupian Stage.

Locality H — Richardson Mountains, Yukon Territory

California Standard Company personnel collected three specimens described herein as *Neouddenites caurus* n. sp. from GSC locality 60699, in the northern "White Mountains" area on the northeastern flank of the Richardson Mountains (68°03′N, 136°38′W). This locality is in the northern Yukon Territory, 5 miles west of the Northwest Territories border. The specimens were collected from limestone concretions in an unmeasured shale unit.

Neouddenites andrianovi Ruzhencev, the only congeneric species, is known from the upper Artinskian Baigendzhinian Substage of Siberia (Ruzhencev, 1961). Too little information on the distribution of *Neouddenites* is available to allow precise age designation for the Canadian representative. However, the phylogenetic stage achieved by the genus is consistent with an Artinskian assignment.

Locality I — Richardson Mountains, Yukon Territory

GSC locality 53860 on the southwest flank of the Richardson Mountains (67°31′02″N, 136°30′10″W; air photograph #A14368-19), Yukon Territory, has yielded the Permian ammonoid described herein as the holotype of *Metalegoceras crenatum* n. sp. The locality lies near the headwaters of one of the small eastern tributaries of the Bell River and some 8 miles west of the Northwest Territories border. The specimen was collected in an unnamed Lower Permian sequence of limestone, sandstone, and siltstone, from 323 feet above the angular unconformity that marks the top of the Devonian.

Metalegoceras is locally abundant in strata ranging in age from lower Sakmarian to the upper Artinskian Baigendzhinian Substage (Ruzhencev, 1951). *M. crenatum* also occurs at locality D, Bjorne Peninsula, in strata assigned herein to either the upper Sakmarian Sterlitamakian Substage or the lower Artinskian Aktastinian Substage. A similar age can be attributed to the Yukon specimen.

Locality J — Upper Porcupine River, Yukon Territory

GSC locality 38808, situated on the northeast bank of the upper Porcupine River 15¾ miles downstream from the mouth of the Bell River (67°26′28″N, 137°45′33″W; air photograph #A14406-88), northern Yukon Territory, has yielded a single specimen referred to herein as *Eoasianites* sp. It was collected at high-water level from an ironstone concretion in the Lower Permian shales overlying the "*Spirophyton* beds" (Jeletzky, MS.).

Eoasianites sp. does not afford a basis for assignment of a restricted age. The genus is known to range from the Pennsylvanian (Moscovian or Atokan) to the Lower Permian (Sakmarian Stage), and general morphology of the Yukon specimen is consistent with derivation from any horizon within these limits.

Locality K — Kandik Area, Alaska

Shell Oil Company (Pacific Coast area, Seattle) has submitted a single ammonoid, possibly of Permian age, from eastern Alaska. It is referred to herein as *Eoasianites* sp. The specimen is from Shell locality Y-406 on the north bank of Black River (a tributary of the Porcupine River), about 27 miles west of the Yukon border and 60 miles east-northeast of Circle (65°57′N, 141°56′W). Stratigraphic details are not available.

Eoasianites ranges from Pennsylvanian (Moscovian or Atokan) to Lower

Permian (Sakmarian Stage), and the Alaskan specimen is consistent with any assignment within this range.

Locality L — Sagavanirktok River Region, Alaska

Two late Palaeozoic ammonoids are known from the Sagavanirktok River region on the north slope of the Brooks Range, northern Alaska. Neither specimen is specifically identifiable; however, they may be conspecific, and probably fall within *Pseudogastrioceras*. Details of occurrence are included in Keller, Morris and Detterman (1961), and the specimens are further discussed herein under the "Occurrence" heading of *P. fortieri*.

The two Alaskan specimens are from USGS Paleozoic localities 15811 (68°57′00″N, 148°07′30″W) and 15812 (68°48′30″N, 148°17′00″W). Both are from the Echooka Member of the Sadlerochit Formation. The specimen from the former locality does not reveal sutures, but resembles *Pseudogastrioceras roadense* (Böse) in general conch proportions and ornament. *P. roadense* occurs throughout the Guadalupian Stage of West Texas and Coahuila.

SYSTEMATICS

Family GASTRIOCERATIDAE Hyatt 1884

[*ex* Gastriocerae, interpreted as subfamilial designation]

Included in our collection are several Permian gastrioceratids. *Neoshumardites* cf. *N. sakmarae* (Ruzhencev) is described herein. Additionally, our materials contain two specimens referable to *Eoasianites*. They are discrete species, but neither specimen warrants more than general documentation. The first was provided by J. Scott Dixon of Shell Oil Company (Pacific Coast area, Seattle) and bears the sample number Y-406. It was collected during 1959 from a problematic formation on Black River in the Kandik area of eastern Alaska [locality K]. General morphology is consistent with derivation from either Pennsylvanian or basal Lower Permian strata. At a conch diameter of 40 mm the ratio U/D is 60 per cent and W/D is 75 per cent. Both the lateral and ventral lobes are relatively narrow.

The second specimen referred to *Eoasianites* (GSC No. 18784) originated some 150 miles northeast of the Kandik area. It was collected by J. A. Jeletzky, during 1959, from a concretion in the unnamed Lower Permian clastic succession exposed at GSC locality 38808 [locality J]. The specimen is a finely lirate phragmocone; at 55 mm conch diameter the ratio U/D is 50 per cent and W/D is 75 per cent. The lateral lobe is of moderate breadth and is approximately twice the width of the ventral prong. All features are consistent with a Lower Permian assignment.

Genus *Neoshumardites* Ruzhencev 1936

Type species. *N. triceps* Ruzhencev, 1936, pp. 1084-1085, text-fig. 5a, b, g; OD.

Discussion. Representatives of *Neoshumardites* are characterized by peculiarities in the suture, which is otherwise of the basic gastrioceratid type. Lateral lobes of both the internal and external sutures, as well as the dorsal lobe, have distinctive flank "pouches". The incipiently trifid nature of these lobes generally becomes less conspicuous during later growth stages of the conch.

Moderately prominent longitudinal lirae were developed on the shell surface in early Permian representatives of this genus and are present to some extent in related Pennsylvanian forms. Ruzhencev (1962) has attached basic significance to this shell feature in presenting a phylogenetic group that includes *Neoshumardites* in the Somoholitidae. That is, he places Middle Pennsylvanian *Owenoceras* Miller and Furnish, 1940 (type: *Gastrioceras bellilineatum* Miller and Owen), Upper

Pennsylvanian *Preshumardites* Plummer and Scott, 1937 (type: *Gastrioceras gaptankense* Miller), and basal Lower Permian *Somoholites* Ruzhencev, 1938 (type: *Gastrioceras beluense* Haniel) in a single evolutionary trend. Although an attractive possibility, we do not consider that the relationships of these forms have been demonstrated; a re-examination of the types of *Preshumardites* and *Somoholites* is needed.

Occurrence. Stratigraphically, typical *Neoshumardites* is found in moderate abundance in the lower Artinskian (Aktastinian) of the Ural Region. The general morphology of the conch represents an ancestral form exemplified by the abundant *Eoasianites* of earlier Permian and Pennsylvanian. The genus therefore is a "relic", as far as shell form is concerned, which contrasts strongly with the characteristically Permian Paragastrioceratidae. As we interpret the genus, the range is Lower Permian, Upper Pennsylvanian, and possibly Middle Pennsylvanian. Permian representatives of *Neoshumardites* are known from the Southern Urals and the Verkhoyan region of the Soviet Union and from comparable strata in the Canadian Arctic. These three occurrences are regarded as belonging in the same faunal province.

Neoshumardites cf. *N. sakmarae* (Ruzhencev)

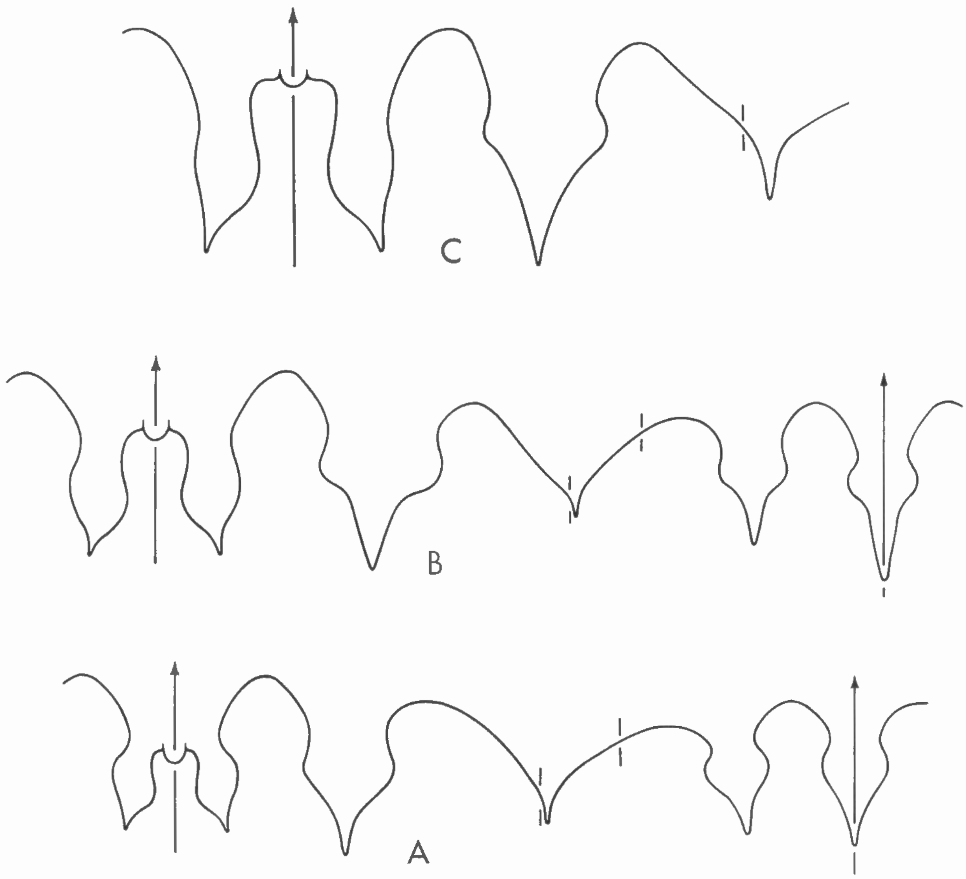
Plate I, figures 7, 8; Text-figure 2C

1938 ?*Preshumardites sakmarae* RUZHENCEV, pp. 283-284, pl. 6, figs. 22, 23; pl. 7, figs. 5-8; text-fig. 18.
1951 ?*Preshumardites sakmarae* Ruzhencev. RUZHENCEV, pp. 131-133, pl. 10, figs. 1-6; text-fig. 41.

Description. The three specimens of *Neoshumardites* cf. *N. sakmarae* from the Canadian Arctic available for study are crushed or fragmented to the extent that proportions for the whorl section cannot be determined precisely. Two of the specimens are phragmocones with maximum conch diameters of 130 mm and 80 mm; the third is a smaller fragment that preserves both the internal and external sutures. The ratio of U/D for the largest specimen approximates 50 per cent at a conch diameter of 100 mm. Originally the whorls were depressed with rounded umbilical shoulders. Ornament consists of prominent longitudinal lirae; twelve occur in a distance of 1 cm across the centre of the flanks at a conch diameter of 80 mm. Five constrictions per volution are present at a conch diameter of 60 mm; they form a shallow ventral sinus and a low lateral salient.

The sutural pattern of the Canadian forms is presented in Text-figure 2C. Although somewhat restored, this suture does not differ in any recognizable detail from that of typical representatives of *N. sakmarae* (Text-figure 2B).

Comparisons. Poor preservation of the Canadian specimens does not allow positive specific reference. However, the sutures appear to be identical with those of Soviet homoeotypes of *N. sakmarae* (Ruzhencev) in the University of Iowa collections. The umbilicus of the Canadian specimens is apparently slightly larger than that of the Soviet forms, but the difference may result from the larger size of our best preserved specimen. Absence of longitudinal sculpture and the more pronounced pouches in the mature external lateral lobe of *N. triceps* serve to



TEXT-FIGURE 2. Diagrammatic representations of sutures of *Neoshumardites*.

A. *N. merriami* (Miller and Furnish). From beds of presumed Lower Permian age, Upper Mills Ranch inlier, Crooked River Basin, Oregon; based on Univ. Oregon holotype 2202-3 at a conch diameter of 35 mm; x2½.

B. *N. sakmarae* (Ruzhencev). From Sakmarian strata, Orenburg District, Southern Urals; based on Univ. Iowa homoeotype 10584, at a conch diameter of 37 mm; x2½.

C. *N.* cf. *N. sakmarae* (Ruzhencev). From a Lower Permian unit tentatively assigned to the Assistance Formation (GSC loc. 57719), Bjorne Peninsula, southwestern Ellesmere Island; based on figured specimen GSC No. 18783 at a conch diameter of about 100 mm; x1½.

distinguish that Artinskian species. *N. merriami* (Miller and Furnish) is a closely similar species from Oregon (Text-figure 2A).

Occurrence. Prior to its discovery in the Canadian Arctic, *Neoshumardites sakmarae* was known only from the Southern Urals, where it is moderately abundant in the Sakmarian Stage. Most representatives are from the late Sakmarian Sterlitamakian Substage, but a few are recorded from the early Sakmarian Tastubian Substage.

The three Canadian specimens that we are comparing with *Neoshumardites sakmarae* were secured by R. Thorsteinsson from strata tentatively assigned to the

Assistance Formation at GSC locality 57719 [locality D]. They were found in association with *Uraloceras involutum, U. burtiense, Paragastrioceras* aff. *P. jossae* and *Metalegoceras crenatum*. The strata are considered to be of late Sakmarian (Sterlitamakian) or early Artinskian (Aktastinian) age.

Repository. Figured specimen GSC No. 18783 and two unfigured additional Canadian representatives are in the Geological Survey of Canada collection.

Family PARAGASTRIOCERATIDAE Ruzhencev 1951

Taxonomy of the family Paragastrioceratidae was discussed in detail by Ruzhencev (1951, pp. 138-141); further information has been presented by this same author (1952, p. 71; 1956, pp. 149-153) and by Glenister and Furnish (1961, pp. 712-722). These ribbed lirate goniatites characterize Permian strata; they existed throughout the period, appearing first in the Asselian Stage and extending into the Dzhulfian Stage. Lower Permian representatives are abundant only in the Southern Urals, where they constitute one of the numerically dominant faunal elements. Similarly, Upper Permian paragastrioceratids in relative abundance are known only from western United States and northern Mexico (Miller and Furnish, 1940, pp. 82-95; Miller, 1944, pp. 88-93; Miller, Furnish and Clark, 1957, pp. 1063-1064). In recent years, the new Lower Permian genus *Tumaroceras* has been proposed by Ruzhencev (1961, pp. 57-60), and the new Upper Permian genus *Daubichites* was introduced by Popow (1963, pp. 148-150). The Canadian Arctic paragastrioceratids described herein comprise species of *Paragastrioceras, Uraloceras,* and *Pseudogastrioceras.*

In general, Lower Permian representatives are characterized by a widely umbilicate conch, finely lirate test and umbilical nodes. The most nearly consistent feature of these Lower Permian forms is a moderately pronounced ventral salient of the apertural margin. Upper Permian representatives are characteristically more nearly involute and are coarsely lirate; the growth lines also form ventrolateral salients and a rounded hyponomic sinus.

Within the Lower Permian this family includes typical ribbed *Paragastrioceras* Tchernow, 1907; the closely related discoidal *Uraloceras* Ruzhencev, 1936; the lenticular *Synuraloceras* Ruzhencev, 1952; the globular *Tumaroceras* Ruzhencev, 1961; and primitive representatives of the genus *Pseudogastrioceras* Spath, 1930. Upper Permian representatives are *Pseudogastrioceras*; lenticular *Strigogoniatites* Spath, 1934; and the evolute genera *Atsabites* Haniel, 1915, and *Epiglyphioceras* Spath, 1930. The status of *Altudoceras* Ruzhencev, 1940, and *Daubichites* Popow, 1963, is uncertain.

Genus *Paragastrioceras* Tchernow 1907

Type species. *Goniatites jossae* de Verneuil, 1845, p. 371, pl. 26, fig. 2; OD.

Diagnosis. Finely lirate paragastrioceratids with trapezoidal or elliptical whorls and wide umbilicus (ratio U/D exceeds 35 per cent). Laterally attenuate ribs or prominent tubercles developed along umbilical shoulder. Growth lines and transverse constrictions form high ventral salient. Prongs of ventral lobe constricted, generally narrower than corresponding lateral lobes.

Distribution. Paragastrioceras is widely distributed in Lower Permian strata of the Southern Urals. It appears first in the middle Asselian Stage and extends into the Baigendzhinian Substage of the Artinskian. Ruzhencev (1951, pp. 142-150; 1952, pp. 72-73; 1956, pp. 153-178) recorded numerous species from the Urals where the genus is one of the most abundant faunal elements. In comparison, all other known occurrences are sporadic and are represented by few specimens. Popow (1958, pp. 148-149) reported *Paragastrioceras* cf. *P. verneuili* and the new species *P. subwandageense* in beds of Artinskian age from northeastern Siberia. Prior to its discovery in the Canadian Arctic, the only other described occurrence outside of the Soviet Union was from the Coolkilya Greywacke of Western Australia, the source of *P. wandageense* Teichert (1942, pp. 226-227). An inadequately known taxon, *P. admiralense,* was erected by Plummer and Scott (1937, p. 223) for two specimens from the Admiral Formation of the Wichita Group in north-central Texas; generic assignment of this species remains uncertain. In addition, an undescribed species is known from upper Wolfcampian strata of West Texas.

Our material from the Canadian Arctic includes *Paragastrioceras* n. sp., described herein from two localities on northern Ellesmere Island. One additional fragment, of 60 mm conch diameter, is known from GSC locality 57719, Bjorne Peninsula, southwestern Ellesmere Island. This specimen is poorly preserved but the conch form approximates that of *P. jossae* (de Verneuil); sutures are not preserved. General preservation does not warrant further study.

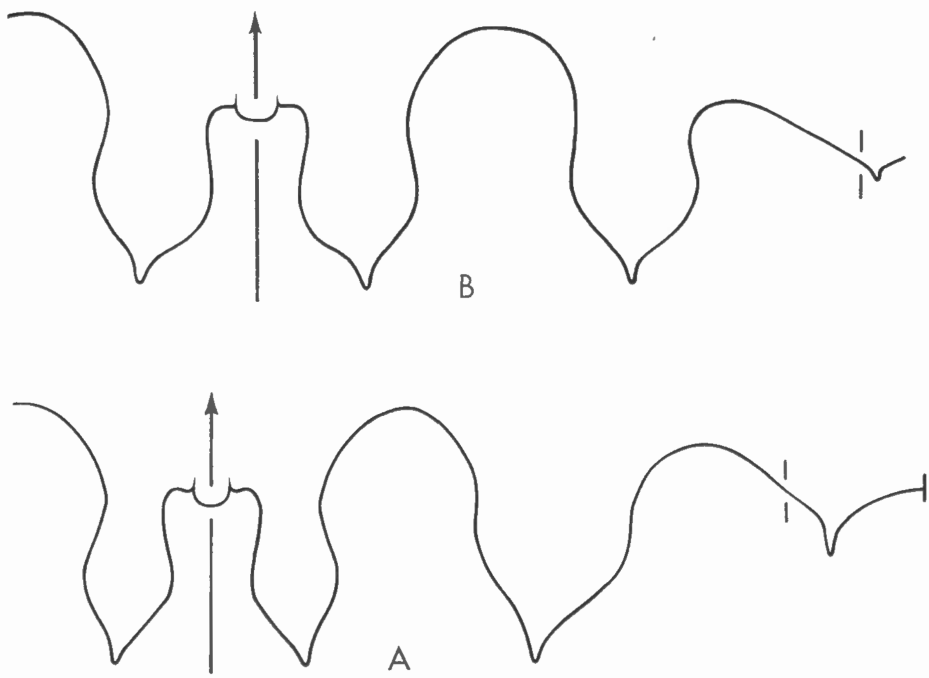
Discussion. Paragastrioceras is gradational with *Uraloceras* and difficulty is encountered in separating the two genera. However, in *Uraloceras* the mature whorls are strongly compressed and the conch is discoidal, whereas in *Paragastrioceras* whorls are relatively wide and are trapezoidal to elliptical in section. Also, the proportionate size of the prongs in the ventral lobe of the suture may be used to separate the two genera. Mature *Uraloceras* developed prongs which are nearly equal to the adjacent lateral lobes. In mature *Paragastrioceras* the ventral prongs are generally smaller than the corresponding lateral lobes.

Consistent differences separate the two genera *Paragastrioceras* and *Pseudogastrioceras*. Growth lamellae and transverse constrictions in *Paragastrioceras* form a high ventral salient, whereas in *Pseudogastrioceras* they are biconvex and form a rounded hyponomic sinus. Prongs of the ventral lobe are proportionally much smaller than corresponding lateral lobes in the suture of *Paragastrioceras*; however in *Pseudogastrioceras* the size of the prongs of the ventral lobe closely approximates that of the lateral lobe. Also *Paragastrioceras* differs from *Pseudogastrioceras* in that its umbilical nodes are much more prominent and are retained at maturity. In addition, its whorls are generally much lower and broader and are subtrapezoidal rather than elliptical in section.

Paragastrioceras n. sp.

Plate I, figure 3; Plate II, figures 1-3; Plate IV, figures 4, 5; Text-figure 3A

Description. Three relatively uncrushed phragmocones (diameters of 30 mm, 60 mm, 70 mm), two somewhat distorted conchs (both 60 mm), and twelve additional fragments (including one third of a whorl of body chamber from a specimen of about 175 mm diameter) are known. Available evidence suggests that all specimens represent a single species. However, the small phragmocones are only moderately well preserved, and larger specimens are represented by fragments. Paragastrioceratids commonly exhibit marked ontogenetic variations, so the possibility that our material includes more than one species cannot be precluded.



TEXT-FIGURE 3. Diagrammatic representations of external sutures of *Paragastrioceras* and *Uraloceras*.

A. *Paragastrioceras* n. sp. From the Lower Permian, northern Ellesmere Island; based on figured specimen GSC No. 18777, at a conch diameter of about 35 mm; x5.

B. *Uraloceras involutum* (Voinova). From a Lower Permian unit tentatively assigned to the Assistance Formation (GSC loc. 57719), Bjorne Peninsula, southwestern Ellesmere Island; based on hypotype GSC No. 18778 at a conch diameter of 40 mm; x4½.

Larger whorls are moderately depressed, the ratio H/W approximating 60 per cent in the best preserved specimen, at a conch diameter of 60 mm. The ratio H/D appears to be relatively stable, and is some 35 to 40 per cent for conch diameters ranging from 25 mm to 70 mm. Calculated ratios involving internodal whorl width are influenced considerably by distortion and by the fragmentary nature of most specimens; the proportion W/D appears to increase with the size of the conch, from 50 per cent at 35 mm to 70 per cent at 70 mm. The umbilical ratio U/D increases from about 35 to 40 per cent at a conch diameter of 40 mm to 45 per cent at approximately 60 mm.

Ornament consists of prominent umbilical nodes, broad longitudinal flat ridges, and fine transverse growth lines. All three sculptural elements are present throughout ontogeny, but the ridges become less conspicuous with increase in conch diameter. The umbilical nodes are elongate transversely up to a conch diameter of about 75 mm but are almost equidimensional at larger diameters. Some twenty occur in each volution. Internodal troughs may continue in the form of constrictions; at a diameter of 30 mm these constrictions are prominent and form a high ventral salient, whereas they are barely discernible and almost directly transverse at diameters in excess of 75 mm. Flat longitudinal ridges are prominent in all but the larger specimens. Width of these ridges generally approximates that of the intervening troughs and increases progressively from the venter towards the umbilical shoulder. Up to six delicate longitudinal lirae are present on each ridge, and several similar structures may occur in each trough. The ridges tend to lose their identity near the ventral margin of the umbilical nodes and only somewhat sinuous longitudinal lirae are present on the umbilical shoulder and wall. Growth lines are not well developed on any of the smaller specimens. The ridges are only barely discernible on specimens of conch diameters ranging from 100 mm to 175 mm; in these specimens the longitudinal lirae and growth lines are equally developed across the flanks to form a delicate reticulum. The growth lines are the more conspicuous of the two elements across the umbilicus of large specimens.

Details of the suture are presented in Text-figure 3A. At a conch diameter of 35 mm the ratio of the maximum width of V_1 to the width of L at mid-height, as well as the areal proportions, is approximately 60 per cent.

Comparisons. Presuming that all of the Canadian specimens belong in a single species, the conch form of *Paragastrioceras* n. sp. is unlike that of any adequately known taxon. Closest similarity is between the smaller Canadian specimens of *P.* n. sp. and the Australian species *P. wandageense* (Teichert, 1942; *see* Glenister and Furnish, 1961). Both possess a moderately depressed and broad whorl section, small umbilicus, conspicuous umbilical nodes and narrow prongs of the ventral lobe. However, only a single immature representative of *P. wandageense* is known, so that effective comparison with our specimens is precluded. Of the numerous species of *Paragastrioceras* described from the Southern Urals only *P. tectum* and *P. jossae jossae* (Ruzhencev, 1956) possess whorls in which the ratio W/D approximates as much as 60 per cent in specimens of moderate size (50 mm). Both Soviet species possess a proportionally larger umbilicus (more than 50 per cent); additionally, *P. tectum* has relatively broad prongs of the ventral lobe and fewer umbilical nodes.

Occurrence. All seventeen specimens are from nodules in black shale of the Lower Permian "Hare Fiord Formation" of northern Ellesmere Island.

Six, including figured specimens GSC Nos. 18771 and 18772, were collected during 1961 by R. Thorsteinsson from GSC locality 47869 [locality C]. The remaining specimens, including figured specimens GSC Nos. 18773-18777, were found by W. W. Nassichuk and R. L. Christie during 1963 from GSC locality 58302 on the northern side of Hare Fiord [locality B]. Thorsteinsson's specimens were collected about 2,600 feet above the base of the "Hare Fiord Formation" which is 4,100 feet thick at this locality. Other specimens from Hare Fiord are from a comparable horizon.

Repository. Figured specimens GSC Nos. 18771 to 18777 and all unnumbered representatives are in the Geological Survey of Canada collection.

Genus *Uraloceras* Ruzhencev 1936

Type species. *Gastrioceras suessi* Karpinsky, 1889, p. 52, pl. 3, figs. 3a-g; OD.

Diagnosis. Discoidal paragastrioceratids with rounded compressed to equidimensional whorl section and generally with wide umbilicus. Ornament is represented by numerous fine longitudinal lirae; delicate growth lines and adorally directed constrictions form a ventral salient. Umbilical nodes, present in the early growth stages, may persist to maturity.

The ventral lobe of the suture is characterized by large prongs which may be equal to or slightly greater in size than the first lateral lobe. At full maturity, representatives attain a diameter of the order of 100 mm and possess a pronounced apertural constriction and angular umbilical shoulders.

Distribution. Uraloceras ranges from the early Sakmarian Stage through the Baigendzhinian Substage of the Artinskian and is known mainly from occurrences in the Ural Mountains. From this area, Ruzhencev (1951, pp. 150-155; 1956, pp. 179-192) distinguished eleven species and Bogoslovskaya (1962, pp. 67-77) contributed an additional species. Glenister and Furnish (1961, pp. 715-718) documented two species from Australia and recorded a probable additional occurrence from British Columbia.

Discussion. Characteristically, *Uraloceras* can be distinguished from *Paragastrioceras* by its proportionally larger prongs of the ventral lobe. Also the whorl section of *Paragastrioceras* is depressed whereas in *Uraloceras* the ratio of whorl height to whorl width closely approximates unity. Both genera possess umbilical nodes during early growth stages; these structures persist or are accentuated in *Paragastrioceras* but are relatively inconspicuous in the mature whorls of *Uraloceras.*

Uraloceras involutum (Voinova)

Plate I, figure 4; Text-figure 3B

1934 *Paragastrioceras involutum* VOINOVA, p. 11, pl. 1, figs. 9-11, text-fig. 6.

1936 *Uraloceras subgerkeni* RUZHENCEV, p. 1080, text-figs. 3b-e.

1956 *Uraloceras involutum* (Voinova). RUZHENCEV, p. 180, pl. 23, figs. 4, 5; pl. 24, figs. 1-5; pl. 25, fig. 1; text-fig. 61.

1962 *Uraloceras involutum* (Voinova). BOGOSLOVSKAYA, p. 67, pl. 9, figs. 2-4, text-fig. 29.

Description. Of the four Canadian specimens of *Uraloceras involutum* available for study, only two reveal a sutural outline and do not appear to be deformed. Dimensions and proportions of the best preserved specimen are listed in Table II. Shell impressions indicate that two thirds of a volution are missing from that specimen; restored maximum diameter would have been about 80 mm.

Table II

Dimensions (in mm) and Proportions of Uraloceras involutum

Specimen	D	H	W	U[1]	H/D	W/D	U/D
GSC No. 18778	62.5	22	22	24.1	0.35	0.35	0.38
Ruzhencev, 1956, 317/6681	63.5	23	23.8	22.6	0.36	0.37	0.36

[1] Inner umbilical diameter

Ornament consists of fine, closely spaced longitudinal lirae and somewhat less pronounced growth lines. The lirae are approximately equally spaced across the flanks and venter; at a diameter of 60 mm, twenty such lirae occur in 1 cm. Prominent elongate umbilical nodes are present during the early growth stages, and they persist in subdued manner to maturity. Widely spaced shallow constrictions form a low ventral salient; in the outer whorl of the best preserved specimen four faint constrictions are present.

Comparisons. All morphologic details of the best preserved Canadian specimen (GSC No. 18778) fall within the known range of Soviet type material of *Uraloceras involutum.* Some of the associated species in the Lower Permian of the Southern Urals, such as *U. federowi* (Karpinsky) and *U. suessi* (Karpinsky) differ only in details of the suture and conch proportions.

The Arctic representatives of *Uraloceras* occurring in direct association with *U. involutum* possess coarser sculpture and a proportionally larger umbilicus than this species. They are referred herein to *U. burtiense* (Voinova).

Occurrence. Soviet representatives of *Uraloceras involutum* occur throughout the Sakmarian and Artinskian stages but are particularly abundant in the lower Artinskian Aktastinian Substage.

Hypotype GSC No. 18778 and three additional specimens were collected by R. Thorsteinsson during 1963 from GSC locality 57719 [locality D]. Canadian representatives of *Uraloceras involutum* are associated with *U. burtiense, Paragastrioceras* aff. *P. jossae, Neoshumardites* cf. *N. sakmarae*, and *Metalegoceras crenatum.* The strata are considered to be of late Sakmarian (Sterlitamakian) or early Artinskian (Aktastinian) age.

Repository. Hypotype GSC No. 18778 and all unfigured specimens are deposited with the Geological Survey of Canada.

Uraloceras burtiense (Voinova)

Plate I, figures 5, 6

1934 *Paragastrioceras burtiense* VOINOVA, p. 12, pl. 1, figs. 12, 13, text-fig. 7.

1951 *Uraloceras burtiense* (Voinova). RUZHENCEV, p. 153, pl. 13, figs. 2-4, text-fig. 51.

1956 *Uraloceras burtiense* (Voinova). RUZHENCEV, p. 179, pl. 23, fig. 3; pl. 24, fig. 1; text-fig. 60.

Description. Six moderately well preserved but crushed Canadian specimens of *Uraloceras burtiense* are available for examination. In no specimen is the suture well enough preserved for detailed study of the critical ventral lobe. Originally, the whorl sections were probably equidimensional, but flattening is so extensive that no purpose can be served in estimating widths. However, relationships between umbilical and conch diameters can be presented with a fair degree of reliability. Five of the available specimens exhibit mature modifications. Four of them achieve diameters between 80 mm and 85 mm; corresponding umbilical diameters are approximately 40 mm. The fifth mature specimen is 10 per cent larger, but the size difference probably has resulted from extensive distortion.

Ornament consists of conspicuous longitudinal lirae and fine growth lines. Spacing of the lirae increases gradually towards the umbilicus; some fifteen lirae occur in 1 cm across the centre of the flank at a diameter of 60 mm. Elongate umbilical nodes are strongly developed in early growth stages; they persist to maturity but are somewhat less conspicuous in the ultimate whorl. Thirty such nodes are present in the penultimate volution at a diameter of 50 mm. Constrictions form a shallow dorsolateral sinus and a high ventral salient. The mature modifications consist of a broad deep terminal constriction, angular umbilical shoulders, and somewhat flattened flanks in the ultimate one-half volution. The fully mature aperture forms a deep sinus, centred across the middle of the flank, and a high rounded ventral salient. There is some slight suggestion of a shallow hyponomic re-entrant, across the axis of the ventral salient, similar to that illustrated by Ruzhencev (1962, p. 258) for the related *Paragastrioceras.*

Comparisons. The Canadian specimens are strikingly similar to a homoeotype from the general type area of *Uraloceras burtiense* (University of Iowa collections). *U. burtiense* is closely comparable to the type species, *U. suessi* (Karpinsky), but differs in possession of stronger ornament. Our Canadian material was found in direct association with *U. involutum,* from which it can be distinguished by its proportionally larger umbilicus. Apparently several of the named species are distinguishable by gradational differences only.

Occurrence. Uraloceras burtiense occurs throughout the Sakmarian and Artinskian stages in the Southern Urals but is characteristic of the late Sakmarian Sterlitamakian Substage. The Canadian representatives were collected by R. Thorsteinsson from strata tentatively assigned to the Assistance Formation at GSC locality 57719 [locality D]. Canadian representatives of *U. burtiense* are associated with *U. involutum, Paragastrioceras* aff. *P. jossae, Neoshumardites* cf. *N. sakmarae* and *Metalegoceras crenatum* in beds of assumed late Sakmarian (Sterlitamakian) or early Artinskian (Aktastinian) age.

Repository. Hypotypes GSC Nos. 18779, 18780, and all unfigured specimens are in the Geological Survey of Canada collection.

Genus *Pseudogastrioceras* Spath 1930

Type species. *Goniatites abichianus* Möller, 1879, p. 225 (as figured by Arthaber, 1900, pl. 18, figs. 5a-5d); OD.

Diagnosis. Subdiscoidal to subglobular paragastrioceratids with compressed elliptical whorl section at maturity. Umbilicus typically narrow (U/D of 15 per cent) but some forms with wide umbilicus (U/D of 50 per cent) are included. Ornament represented by coarse longitudinal lirae and by biconvex growth lamellae forming a deep rounded hyponomic sinus. Constrictions and umbilical nodes present at least during the early stages but tended to diminish with growth. Proportions of sutural elements vary with the shape of the whorl and growth stage; the ventral prongs and lateral lobes generally are subequal in area. Conch form and sutural pattern are regarded as unstable, both during ontogeny and phylogeny. Mature aperture has not been observed.

Distribution. Pseudogastrioceras is characteristic of Upper Permian strata, though it ranges throughout almost all of the Permian System. The type species, *Pseudogastrioceras abichianum* (Möller), is from the Upper Permian Dzhulfian strata of Armenia. The genus is common in the Guadalupian of Texas and Coahuila (Miller and Furnish, 1940, pp. 82-93; Miller, 1944, pp. 88-92). It occurs abundantly in the Phosphoria and Park City Formations in the Rocky Mountains (Miller, Furnish, and Clark, 1957, p. 1057), and has been described from the Colorado Plateau (Miller and Furnish, 1958, pp. 682-683), the Mid-Continent Region (Clifton, 1942, pp. 697-698), and the Canadian Arctic (Harker and Thorsteinsson, 1960, pp. 74-77). It is also present in the Sosio beds of Sicily (Gemmellaro, 1887, pp. 87-89; 1888, p. 31). Glenister and Furnish (1961, p. 718) reported *Pseudogastrioceras* from the Coolkilya Greywacke and the Liveringa Formation of Western Australia. Several other inadequately documented occurrences are known from scattered areas.

Discussion. The type species of *Pseudogastrioceras, P. abichianum* from uppermost Permian strata, represents an extreme in several characters. Ruzhencev (1962, p. 385) restricted the genus to this single species by reference of most Upper Permian species to *Altudoceras*. Experience shows, however, that variability within late Lower Permian paragastrioceratids includes forms similar to *P. abichianum*. For example, some representatives of *P. simulator* from the Phosphoria Formation (Miller and Cline, 1934, pl. 39) possess a ventral lobe similar to that of the type.

Pseudogastrioceras fortieri Harker

Plate I, figures 1, 2; Plate III, figures 1, 2; Plate IV, figure 6; Text-figure 4B

1960 *Pseudogastrioceras fortieri* HARKER *in* HARKER and THORSTEINSSON, p. 75, pl. 24, figs. 3-5; pl. 25, figs. 1-3.

Description. The holotype, two paratypes, and six additional specimens from the Canadian Arctic Archipelago are available for study. Characteristics of ornament are best displayed on one of the topotypes. Dimensions and proportions of the holotype, paratypes, and topotypes are presented in Table III. One additional topotype (GSC No. 18764) is entirely septate and has a diameter of 200 mm; the mature diameter thus would have been at least 300 mm.

Table III

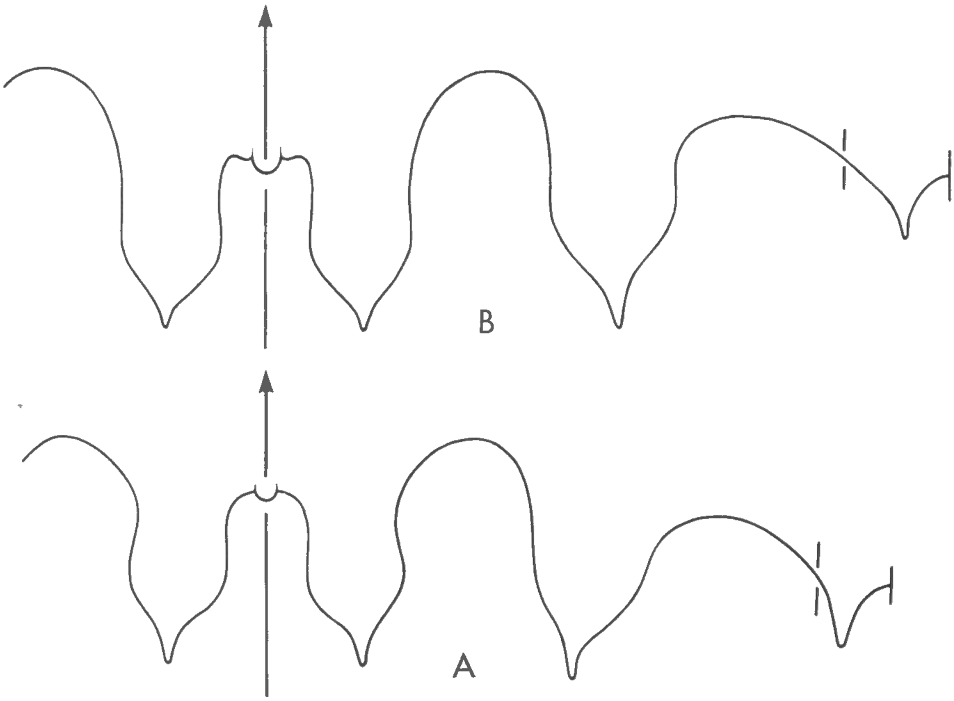
Dimensions (in mm) and Proportions of Pseudogastrioceras fortieri

Specimen GSC No.	D	H	W	U	H/D	W/D	U/D
Paratype 13774	166	72	65	48	0.43	0.39	0.29
Paratype 13773	46	22	23	11	0.48	0.50	0.24
Holotype 13772	44	21.5	24	11	0.49	0.54	0.25
Topotype 18765	32	16	19	8.5	0.50	0.59	0.26
Topotype 18766	17	6	11.5	6	0.35	0.68	0.35

Ornament consists of fine, closely spaced, longitudinal lirae on the venter (two per mm at 75 mm conch diameter), which become proportionally broader and more widely spaced from the venter across the flanks. Longitudinal sculpture is absent from the umbilical shoulder and wall. Sinuous fine growth lamellae transect the longitudinal lirae to give a delicate nodose appearance. Growth lamellae and transverse constrictions form a deep rounded hyponomic sinus. Constrictions are present to a conch diameter of 35 mm. Strong umbilical nodes and accompanying ribs are present to 20 mm diameter. The ratio of sutural elements V_1/L at a diameter of 28 mm closely approximates 75 per cent whereas this ratio is about 100 per cent at diameters in excess of 100 mm (Text-figure 4B).

Comparisons. Pseudogastrioceras fortieri resembles *P. abichianum* in general conch shape; however, the latter has a proportionally smaller umbilicus. In comparison with species of comparable age from Sicily and Texas, *Pseudogastrioceras fortieri* has finer ornament over-all and is distinguishable readily by presence of more numerous lirae. The Canadian species so closely resembles *P. goochi* Teichert from Western Australia that no satisfactory basis for differentiation is apparent. Additionally, inner whorls of *P. fortieri* show striking similarity to the strongly ribbed juvenile representatives of *P. mckeei* (Miller and Furnish, 1958, pp. 682-683) from the Kaibab Formation of Arizona.

Ruzhencev (1961, p. 57) referred *Pseudogastrioceras fortieri* with question to his new genus *Tumaroceras* on the false assumption that the Canadian form



TEXT-FIGURE 4. Diagrammatic representations of external sutures of *Pseudogastrioceras.*

A. *P. goochi* Teichert. From the Upper Permian Lightjack Member of the Liveringa Formation, Fitzroy Basin, Western Australia, at a conch diameter of 41 mm; x3½.

B. *P. fortieri* Harker. From the Assistance Formation of Grinnell Peninsula, Devon Island; based on holotype GSC No. 13772, at a conch diameter of 47 mm; x3½.

possesses a ventral salient. Conch form in the two taxa is quite different, although sutures are similar. Another Soviet paragastrioceratid species, the type of *Daubichites* Popow (1963, pp. 149-150) differs in the possession of a considerably larger umbilicus and in retention of umbilical nodes to a relatively late ontogenetic stage.

Two poorly preserved specimens with paragastrioceratid affinities have been made available to us through the courtesy of Mackenzie Gordon, Jr. Both are from the Sagavanirktok River region (U.S.G.S. locs. 15811, 15812) on the northern slope of the Brooks Range, Alaska (Gordon *in* Keller, Morris and Detterman, 1961, p. 184), and were collected by J. T. Dutro from the Permian Sadlerochit Formation [locality L]. The larger specimen (loc. 15811) is a fragment of a crushed whorl from an individual of some 200 mm diameter. Septa are not apparent, but the coarse angular longitudinal ornament closely resembles that of several Guadalupian paragastrioceratids, particularly *Pseudogastrioceras roadense* (Böse). *P. fortieri* may be distinguished by its more numerous longitudinal lirae. The remaining specimen (loc. 15812) is a poorly preserved crushed phragmocone, of 60 mm diameter, which does not satisfactorily exhibit conch proportions or ornament. The suture is of a generalized paragastrioceratid type with the element

V_1 about two thirds the size of L. Such proportions in Permian paragastrioceratids are consistent with reference to *Pseudogastrioceras,* an assignment which is supported by the relatively small umbilicus (U/D approximately 25 per cent). The two Alaskan specimens may be conspecific.

Occurrence. Representatives of *P. fortieri* are known only from the Canadian Arctic. They occur in association with *Spirolegoceras harkeri* in the type locality of the Assistance Formation at GSC locality 26406 [locality E]. The fossils occur approximately 170 feet above the base of the formation where it is about 200 feet thick. Original collections were assembled by R. Thorsteinsson, during 1955, and additional specimens were collected by Thorsteinsson and P. Harker in 1963. The Assistance Formation is probably of late Lower Permian age.

Repository. Holotype GSC No. 13772, paratypes GSC Nos. 13773 and 13774, and topotypes GSC Nos. 18765 to 18767 are deposited with the Geological Survey of Canada.

Family METALEGOCERATIDAE Plummer and Scott 1937

Taxonomy of the family Metalegoceratidae has been revised in recent publications (Ruzhencev, 1951, pp. 114-127; 1956, pp. 129-146; Glenister and Furnish, 1961, pp. 700-712). The present study contributes geographic, stratigraphic, and morphologic information on the genera *Metalegoceras* and *Spirolegoceras.*

Ancestral Metalegoceratidae appeared in the Asselian Stage of the Lower Permian and were derived from an 8-lobed gastrioceratid stock by tripartition of the element *U.* Such a subdivision produced the characteristic 12-lobed suture of *Juresanites* and *Metalegoceras.* Further tripartition of *U* resulted in the appearance of the 16-lobed representative, *Pseudoschistoceras,* of the Artinskian Baigendzhinian Substage. *Spirolegoceras* is a relatively rare taxon which differs from all other metalegoceratids in that the size ratio of sutural elements V_1/L approximates unity in mature specimens; characteristically, V_1 is proportionally narrower in other members of the family. Known occurrences of *Spirolegoceras* are confined to late Lower Permian strata that are probably younger than type Artinskian.

Metalegoceratidae are confined to the Lower Permian where they are known from the southwestern and western United States (Miller and Furnish, 1940; Miller, Furnish, and Clark, 1957); Canadian Arctic, Ural Mountains and Arctic regions of the Soviet Union (Ruzhencev, 1956, 1961); Arabian Peninsula (Miller and Furnish, 1957a); Indonesia (Haniel, 1915); and Western Australia (Glenister and Furnish, 1961).

Genus *Metalegoceras* Schindewolf 1931

Type species. *Paralegoceras sundaicum* form. *evoluta* Haniel, 1915, pp. 60-64, pl. 48, figs. 4, 6, text-figures 16, 17; OD.

Discussion. Details of taxonomy for *Metalegoceras* have been presented by

Ruzhencev (1951, pp. 119-127; 1956, pp. 129-146) and by Glenister and Furnish (1961, pp. 700-704). The sutural formula for the genus is:

$$(V_1V_1)LU_2U_1{:}U_2ID$$

Metalegoceras is not currently known in the Asselian Stage. It is locally abundant in strata ranging in age from early Sakmarian to late Artinskian (Baigendzhinian Substage).

Metalegoceras crenatum n. sp.

Plate V, figure 1; Text-figure 5

Description. Five representatives of *Metalegoceras crenatum* are included in this new taxon. The specific name refers to the notched form of external sutural element U_2. Holotype GSC No. 18786 is a moderately well preserved internal mould, of about 400 mm diameter, collected from the northern Yukon Territory. It is septate with the exception of a small fraction of the ultimate volution. Metalegoceratids generally developed about one volution of body chamber, so that the restored diameter would have approximated 600 mm. The specimen is thus the largest ammonoid known from the Palaeozoic. The paratype (GSC No. 18781) and three additional specimens are extensively crushed internal moulds from GSC locality 57719, Bjorne Peninsula, southwestern Ellesmere Island. The largest individual is a completely septate fragment from a whorl of approximately 200 mm diameter.

The specimens from Ellesmere Island are so strongly deformed that they add little to our morphologic information on the species. However, peculiarities of the suture, particularly the bizarre notched form of the dorsal flank of external element U_2, relate these specimens to the holotype. Additionally, the reconstructed whorl sections of the Ellesmere materials bear a similarity to the holotype.

No vestige either of the shell or of constrictions is preserved. The umbilical walls and shoulders are rounded, as is the remainder of the whorl section. Conch proportions are indicated in Table IV.

Table IV

Dimensions (in mm) and Proportions of Metalegoceras crenatum n. sp.

Specimen GSC No.	D	H	W	U	H/D	W/D	U/D
Holotype 18786	400	165	205	133	0.41	0.51	0.33
Holotype 18786	300	115	145	105	0.38	0.48	0.35
Holotype 18786	190	78	100	65	0.41	0.52	0.34

The sutural details are well preserved on the holotype (Text-figure 5). No significant change in sutural proportions occurs in this holotype between the smallest observed whorl (100 mm conch diameter) and the ultimate volution (400 mm diameter). The most characteristic feature of the suture is the invariable

TEXT-FIGURE 5. Diagrammatic representation of suture of *Metalegoceras crenatum* n. sp. From an unnamed Lower Permian formation at GSC loc. 53860, northeastern Yukon Territory; based on holotype GSC No. 18786, at a conch diameter of 200 mm; x0.3. Proportions of ventral lobe adjusted to compensate for compression of shell.

presence of two distinct notches on the dorsal flank of external element U_2 and the adjacent saddle.

Comparisons. The only illustrated species with comparable secondary subdivision near the umbilical shoulder are *Metalegoceras rotundatum* Ruzhencev (1956, fig. 34, p. 130) and some specimens of *M. noinskyi* Ruzhencev (1951, fig. 37d, p. 124). The former Soviet species is from the Aktastinian Substage in the Southern Urals and the latter is from the Sakmarian Stage of the same region. They differ from *M. crenatum* in possession of a proportionally much larger umbilicus (U/D of 50 per cent) and strongly depressed subtrapezoidal whorls. These differences are at least partly ontogenetic, for the Soviet specimens exhibiting the divided lobe are less than 50 mm in diameter.

In general, representatives of *Metalegoceras,* and the related *Juresanites,* attain a relatively large size for Palaeozoic ammonoids. In the Urals, sizes of about 100 mm diameter have been documented. On Timor, specimens over 200 mm in diameter have been recorded, and we have a specimen in which the restored diameter is 300 mm. In Western Australia, representatives of *Juresanites jacksoni* with a size over 200 mm have been recovered, and fragments indicate that a size of slightly over 300 mm was attained. There is no previous record, to our knowledge, of specimens approaching the 600 mm restored diameter of the holotype of *M. crenatum.* Such a difference in ultimate size of the shell is presumably significant at the specific level.

Some representatives of the schistoceratid genera *Pintoceras* and *Schistoceras* show sporadic sutural irregularities near the umbilical shoulder (Miller and Furnish, 1958, p. 255) similar to those of *Metalegoceras noinskyi.* In such specimens where additions are unstable, their presence does not constitute a basis for taxonomic differentiation.

Occurrence. Holotype GSC No. 18786 was collected by E. Wayne Bamber from an unnamed Lower Permian sequence of limestone, sandstone, and siltstone at GSC locality 53860 [locality I]; it occurred 323 feet above an angular unconformity marking the top of the Devonian. Paratype GSC No. 18781 and all unfigured specimens were secured by R. Thorsteinsson from strata tentatively assigned to the Assistance Formation at GSC locality 57719 [locality D].

Repository. Holotype GSC No. 18786, paratype GSC No. 18781, and all unfigured specimens are deposited with the Geological Survey of Canada.

Genus *Spirolegoceras* Miller, Furnish and Clark 1957

Type species. *Spirolegoceras fischeri* Miller, Furnish and Clark, 1957, p. 1064; OD.

Diagnosis. Subdiscoidal metalegoceratids with proportionally narrow umbilicus (U/D approximately 25 per cent) and weak reticulate sculpture dominated by longitudinal lirae. Sutural formula is the same as that of *Metalegoceras*:

$$(V_1V_1)LU_2U_1{:}U_3ID$$

Suture characterized by relatively wide prongs of the ventral lobe: V_1/L approximates unity in mature specimens.

Distribution. Currently, *Spirolegoceras* is known from two specimens of *S. fischeri* from the Meade Peak Member of the Phosphoria Formation of Idaho; four representatives of *S. harkeri* from the Assistance Formation of Grinnell Peninsula, Devon Island, Canadian Arctic Archipelago; and from a single specimen (cf. *S. harkeri)* from the Endybalsky Formation, Verkhoyan region, U.S.S.R. Distribution thus appears to be provincial, with restriction to an Arctic realm. In no specimen can the exact age of the parent stratum be determined, but all representatives presumably are of similar age and should probably be referred to the latest Lower Permian.

Discussion. Mode of sutural ontogeny, specifically tripartition of *U,* indicates association of *Spirolegoceras* with the Metalegoceratidae. Conch proportions of the genus somewhat resemble those of subdiscoidal species of *Metalegoceras* and *Pseudoschistoceras* (Glenister and Furnish, 1961). *Spirolegoceras* is the only metalegoceratid known to develop pronounced longitudinal lirae, although somewhat comparable ornament occurs in some species of *Metalegoceras* (Glenister and Furnish, 1961, pl. 79). The most diagnostic feature of the genus is the proportionally broad form of sutural element V_1. The ratio V_1/L only rarely exceeds 75 per cent in other metalegoceratids (Glenister and Furnish, 1961, text-fig. 9) but approximates unity in mature *Spirolegoceras.* Derivation from *Metalegoceras* is indicated by relative depths of elements U_1 and U_2 and by the narrow form of V_1 in immature whorls of *Spirolegoceras.*

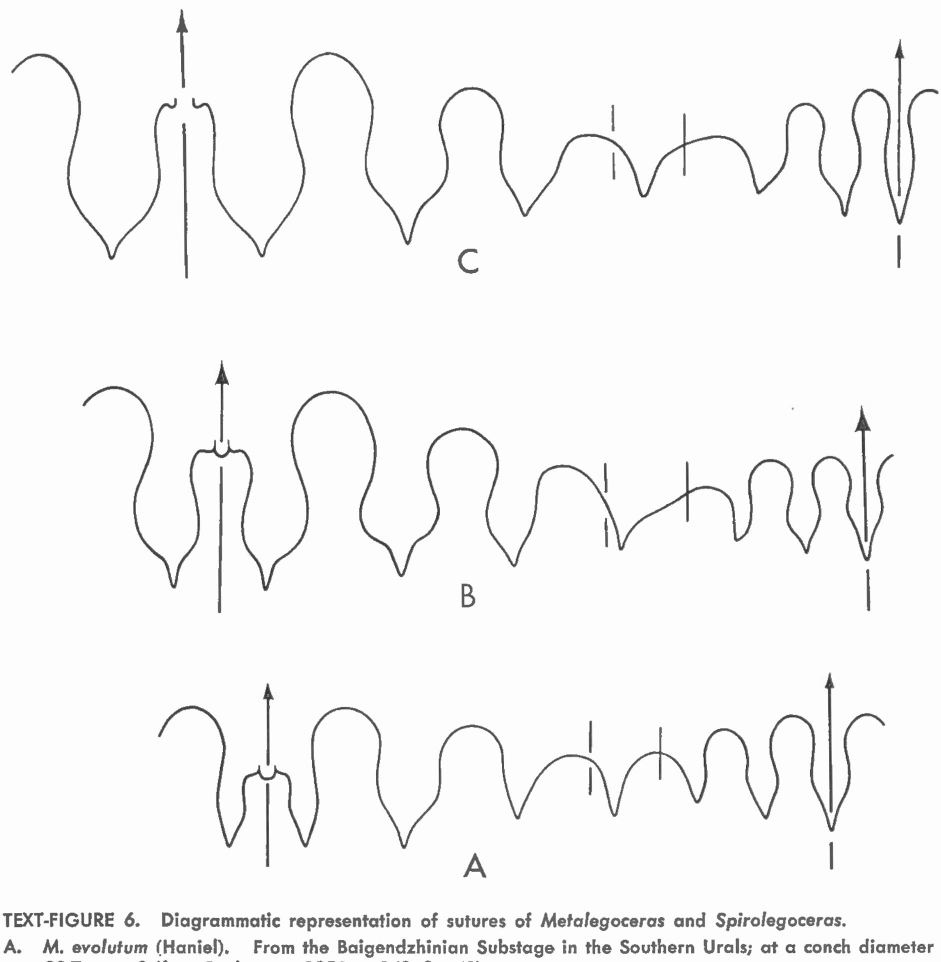
Spirolegoceras harkeri Ruzhencev

Plate III, figures 3, 4; Plate IV, figures 1-3; Text-figures 6B, 6C, 7, 8B, 8C

1957 *Spirolegoceras* sp. MILLER, FURNISH and CLARK, p. 1064.
1960 *Metalegoceras* sp. HARKER *in* HARKER and THORSTEINSSON, p. 77, pl. 25, figs. 4-6.

1961 cf. *Spirolegoceras* sp. GLENISTER and FURNISH, p. 701.
1961 *Spirolegoceras harkeri* RUZHENCEV, p. 51.
1961 *Spirolegoceras* aff. *fischeri* Miller, Furnish and Clark. RUZHENCEV, p. 52.

Description. Four moderately well preserved phragmocones of *Spirolegoceras harkeri* are available for study. The single specimen originally available to Harker (GSC No. 13775) is the holotype. Dimensions and proportions of the two better preserved specimens are listed in Table V; the conch sections are illustrated in Text-figure 7.



TEXT-FIGURE 6. Diagrammatic representation of sutures of *Metalegoceras* and *Spirolegoceras.*

A. *M. evolutum* (Haniel). From the Baigendzhinian Substage in the Southern Urals; at a conch diameter of 29.7 mm; x3 (*from* Ruzhencev, 1956, p. 142, fig. 40).

B. *S. harkeri* Ruzhencev. From the Assistance Formation of Grinnell Peninsula, Devon Island; based on holotype GSC No. 13775 at a conch diameter of 35 mm; x3.

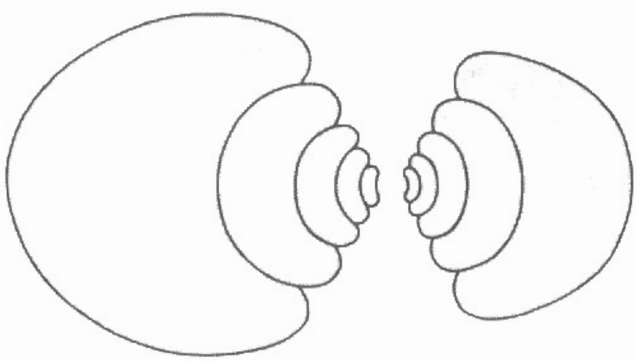
C. *S. harkeri* Ruzhencev. From Member 3 of the Endybalsky Formation, western Verkhoyan region, Soviet Union; at a whorl height of 31 mm and diameter of about 70 mm; x1½ (*from* Ruzhencev, 1961, p. 52, fig. 1).

Table V

Dimensions (in mm) and Proportions of Spirolegoceras

Specimen GSC No.	D	H	W	U	H/D	W/D	U/D
S. harkeri Ruzhencev							
Topotype 18768	105	44	44	35	0.41	0.41	0.33
Holotype 13775	36	15	20	13	0.41	0.61	0.36
Topotype 18769	21.5	9	15.5	8	0.42	0.72	0.37
S. fischeri Miller, Furnish and Clark							
Paratype Univ. Iowa 5996	20.5	10	10	4	0.49	0.49	0.19
Holotype Univ. Iowa 5997	15.5	9	8	3	0.58	0.52	0.19

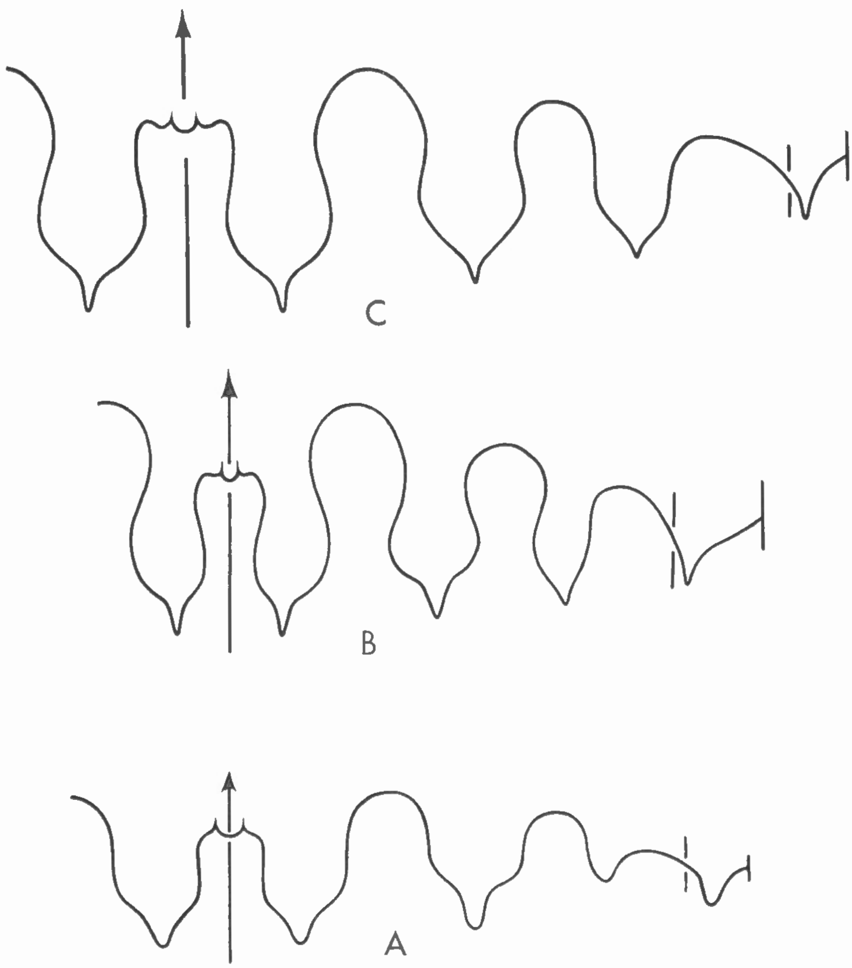
Ornament consists of pronounced longitudinal lirae that are intersected by inconspicuous growth lines to produce a subdued reticulate pattern. The lirae are broader and more widely spaced towards the umbilicus. Larger specimens possess flat longitudinal ridges with a narrow axial groove separating two rows of minute transversely elongate nodes. Low salients in the growth lamellae appear across the venter and median part of the flanks, and shallow sinuses occur on the dorsolateral and ventrolateral flanks. Three shallow constrictions are present on each of the inner whorls.



TEXT-FIGURE 7. Diagrammatic cross-section of *Spirolegoceras harkeri* Ruzhencev from the Assistance Formation of Grinnell Peninsula; based on topotype GSC No. 18769, x2, at a conch diameter of 41 mm.

The most notable feature of sutural ontogeny (Text-figures 8B, 8C) is the increase in the proportional width of V_1 in relation to L. The width ratio V_1/L is approximately 70 per cent at a diameter of 20 mm, whereas the corresponding ratio at 90 mm diameter is unity.

Comparisons. Both available representatives of *Spirolegoceras fischeri* should probably be considered as mature dwarfs, and comparisons of type *Spirolegoceras* with known representatives of *S. harkeri* are made difficult by differences in size. The width ratio of sutural elements V_1 and L is similar in *S. fischeri* at a conch diameter of 10 mm to that of *S. harkeri* at 36 mm diameter, but the slightly compressed outer whorls of *S. fischeri* are unlike the moderately depressed whorls of comparable-sized *S. harkeri*. Whorl proportions of *S. fischeri* at 20 mm diameter somewhat resemble those of *S. harkeri* at 90 mm; the umbilicus of the former is proportionally smaller. *"Spirolegoceras* aff. *fischeri"* of Ruzhencev does not resemble closely the previously illustrated type of *S. harkeri*. However, the single Soviet specimen is practically identical in suture and shell proportion to the recently secured large specimens of the Canadian species (e.g., Pl. III, figs. 3, 4) and Ruzhencev's specimen should be included therefore in *S. harkeri*.



TEXT-FIGURE 8. Diagrammatic representations of external sutures of *Spirolegoceras*.

A. *S. fischeri* Miller, Furnish and Clark. From the Phosphoria Formation just east of Montpelier, Idaho; at a diameter of 10 mm; x10.

B. *S. harkeri* Ruzhencev. From the Assistance Formation of Grinnell Peninsula, Devon Island; based on holotype GSC No. 13775 at a conch diameter of 35 mm; x3¼.

C. *S. harkeri Ruzhencev*. From the Assistance Formation of Grinnell Peninsula, Devon Island; based on topotype GSC No. 18768 at a conch diameter of 100 mm; x1½.

Occurrence. The four known Canadian representatives of *Spirolegoceras harkeri* were collected by R. Thorsteinsson from GSC locality 26406, in the type locality of the Assistance Formation, Grinnell Peninsula, Devon Island [locality E]. They occur in direct association with *Pseudogastrioceras fortieri* approximately 170 feet above the base of the formation where it is about 200 feet thick. Parent strata are referred to the late Lower Permian. The additional representative (Ruzhencev, 1961, p. 52) is from Member "D" of the Endybalsky Formation, Western Verkhoyan region, north-central Yakutskaya A.S.S.R., Siberia. Age of this horizon is believed to be comparable with that of the Assistance Formation.

Repository. Holotype GSC No. 13775 and topotypes GSC Nos. 18768, 18769 are deposited with the Geological Survey of Canada.

Family Cyclolobidae Zittel 1895

[= Timoritidae Böhmers, 1936, p. 20]

The family Cyclolobidae constitutes a group of common Upper Permian ammonoids that exhibit considerable phylogenetic progression in sutural complexity. They are all characterized by a large (up to 200 mm) subglobular or discoidal conch. The mature suture possesses a series of subequal lateral lobes with secondary subdivisions. The typical genus, which occurs in uppermost Permian strata, represents a culmination of sutural development for the Palaeozoic. *Glassoceras* (Ruzhencev, 1960), *Shengoceras* (Chao, 1955), *Mexicoceras* (Ruzhencev, 1955), *Waagenoceras* (Gemmellaro, 1887), and *Timorites* (Haniel, 1915) illustrate earlier steps of the phylogenetic sequence within the family.

Genus *Cyclolobus* Waagen 1879

Type species. *Phylloceras oldhami* Waagen, 1872, p. 3, pl. 1, figs. 1, 1a; OD.

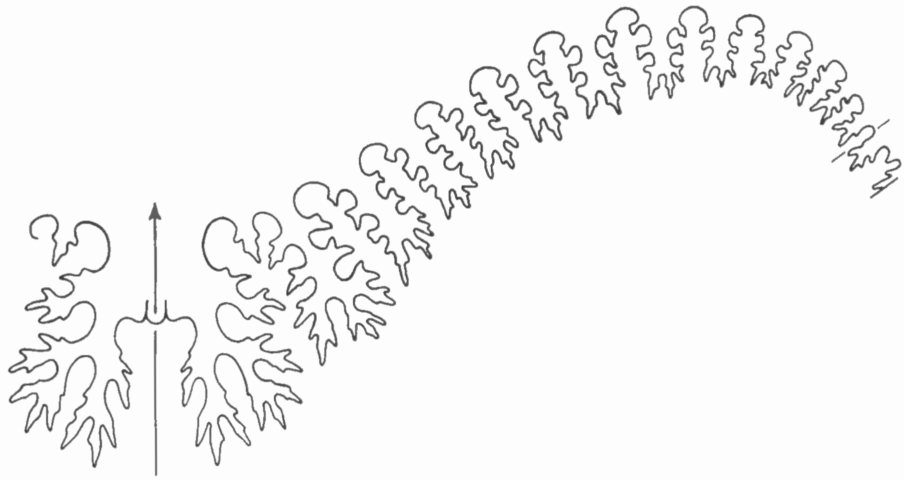
Cyclolobus WAAGEN, 1879, p. 24; DIENER, 1903, pp. 12, 164; TREAT, 1933, p. 25; BESAIRIE, 1936, p. 105; MILLER and FURNISH, 1940, p. 5; BRANSON, 1948, p. 772; SCHINDEWOLF, 1954, p. 156; MILLER and FURNISH, 1957, p. 54; JEANNET, 1959, p. 9; RUZHENCEV, 1960, p. 233; 1962, p. 397.

Krafftoceras DIENER, 1903, p. 162; BESAIRIE, 1930, p. 529; TREAT, 1933, p. 29; BRANSON, 1948, p. 786; RUZHENCEV, 1960b, p. 233; 1962, p. 398; 1963, p. 56.

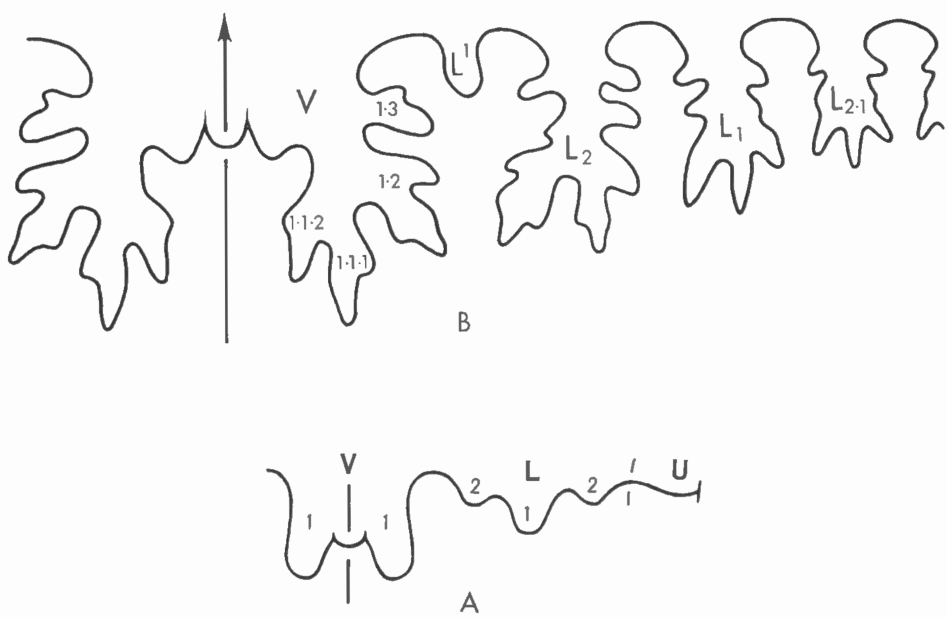
Godthaabites FREBOLD, 1932, p. 17.

Procyclolobus TOUMANSKAYA, 1939, p. 19.

Diagnosis. The conch form of *Cyclolobus* progresses from evolute in the first few whorls to highly involute. At maturity it is thinly discoidal with an umbilical ratio, U/D, of 10 to 15 per cent. The mature body chamber approximates one volution, and fully mature specimens achieve diameters of from 100 mm to 200 mm. Biconvex growth lines form prominent rounded ventrolateral and dorsolateral salients. Sinuous constrictions are present in immature whorls and a deep biconvex constriction marks the mature aperture.



TEXT-FIGURE 9. Diagrammatic representation of external suture of *Cyclolobus oldhami* (Waagen). Mature suture of the type of the genus based upon a well-preserved nearly complete topotype (Geologisches Institut und Museum, Tübingen) secured by O. H. Schindewolf from the Upper *Productus*-Limestone at Virgal, Salt Range, West Pakistan. Waagen's holotype is stated merely to have come from the vicinity of Jabi (Jabbi) a town at the base of the range some 5 miles south of Virgal. Only a few of the tertiary details are effected by weathering; diameter at the figured suture about 125 mm, width 43 mm; x2.



TEXT-FIGURE 10. Genetic terminology of suture in *Cyclolobus*. Details as for Text-figure 11 A-F.

The suture of typical *Cyclolobus* (Text-figure 9) includes numerous auxiliary units with secondary as well as tertiary elements. The type *C. oldhami* has thirteen pairs of external lateral lobes at a diameter in excess of 100 mm. These lobes originated within the umbilicus as subdivisions of the lateral lobe (Text-figure 11), and the sutural formula is:

$$(V_{1.3}V_{1.2}V_{1.1.1}V_{1.1.2}V_{1.1.2}V_{1.1.1}V_{1.2}V_{1.3})L^{1}L_{2}L_{1}L_{2.1}L_{2.1.1}[+9]\,..\,U:..\,[+8]I_{2.1.1}I_{2.1}I_{1}I_{2}(D_{2}D_{1}D_{2})$$

As noted by several authors, the multiple elements, arcuate trace, prominently divided first lateral saddle and large dorsal lobe are distinctive features of the genus.

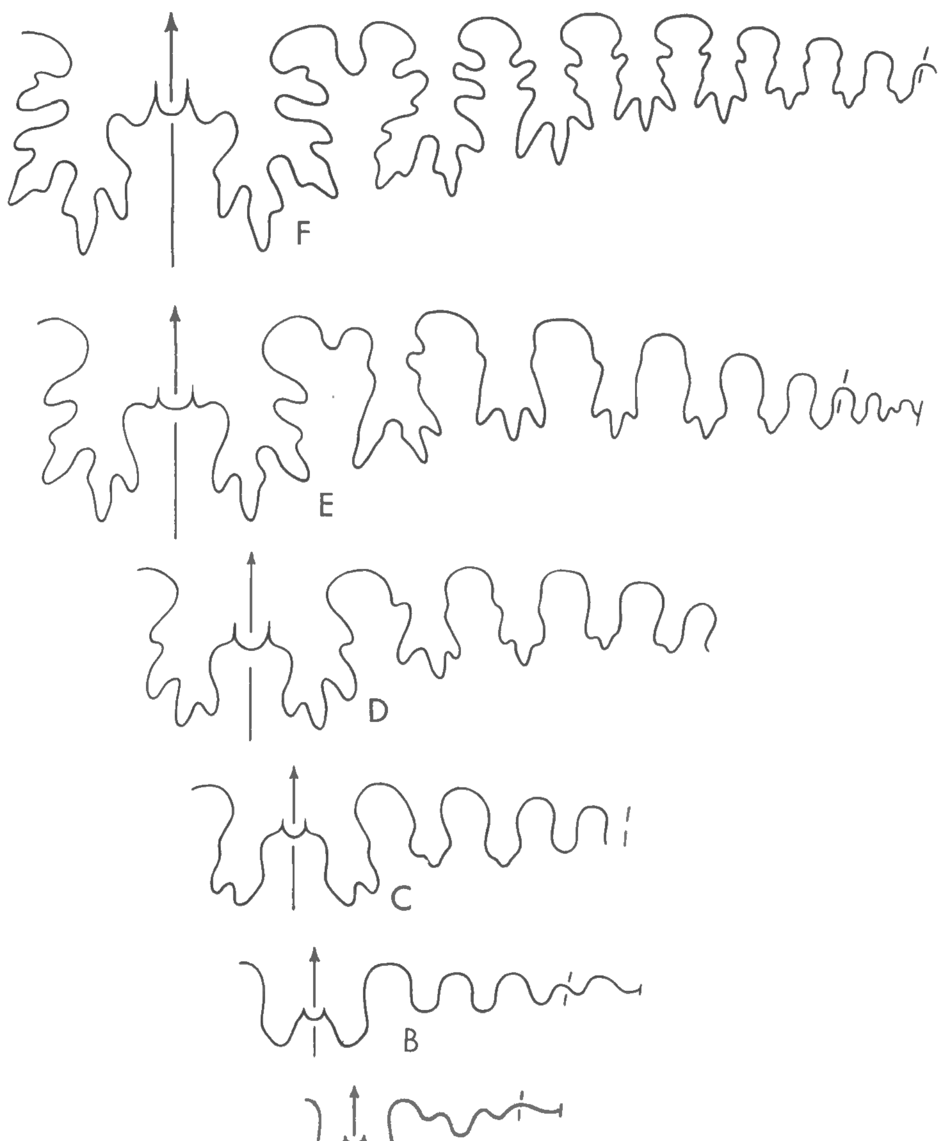
Distribution. In the few localities where this genus has been found, with the exception of Madagascar, it is a rare fossil. Stratigraphically, it is an index for the Dzhulfian Stage of the late Upper Permian. Geographically, *Cyclolobus* is known from West Pakistan (Salt Range), India (Central Himalayas), Madagascar (northern interior), Armenia (Dzhulfa), and Greenland (eastern coast). The associated ammonoids include advanced medlicottiids, xenodiscids, paragastrioceratids, and marathonitids.

Discussion. Diener (1903) suggested the name *Krafftoceras* as a subgenus of *Cyclolobus* for Himalayan forms from the Spiti area. This proposal was made despite doubt of a distinction between these forms and the type from the Salt Range. Subsequent study has shown that Diener was correct in believing Waagen's drawing of the original to be in error; the type of *Krafftoceras, C. (K.) kraffti,* is almost identical with a well preserved topotype of *C. oldhami* (Waagen) which we now have available for study. That is, the differences between these two types are of no more than specific level and are comparable to variations within specimens occurring in direct association. Similar degrees of sutural difference can be noted on opposite sides of the same specimen.

Other trivial differences purported to exist (Diener, Treat, Ruzhencev) apparently result from deficiencies in older descriptions and illustrations. In topotypes, the divided first lateral saddles of type *Cyclolobus* and *Krafftoceras* are as nearly identical as is physically possible. Relative complexity of the lobes and number of elements is also the same, if well preserved material is compared. The supposed difference in number of auxiliaries does not exist; specimens of *C. kraffti* from near the type area add lobes during early growth stages (less than 10 mm) at the rate of two per whorl. A well preserved topotype from Lilang, Spiti area, shows a total of eleven external lateral lobes at a diameter of 20 mm; another specimen has twelve lobes at 30 mm.

Cyclolobus kullingi (Frebold) represents a primitive member of the genus. Therefore, if an intermediate generic category is to be recognized, the designation must be *Godthaabites* Frebold, 1932. However, there seems to be little justification for such a distinction; in type *Godthaabites* the general complexity of sutural elements is closely similar to that in *Cyclolobus* and there are at least twelve lateral lobes in *C. kullingi* at a diameter of 75 mm.

The cyclolobid genus *Timorites* Haniel, 1915, resembles *Cyclolobus* closely and is believed to be a direct ancestor. In secondary and tertiary sutural elements of mature conchs there is virtually no difference in complexity. In the arcuate



TEXT-FIGURE 11. Diagrammatic representation of sutural ontogeny in *Cyclolobus kraffti* Diener; based upon inner volutions of two specimens secured by Eigil Nielsen from the Kuling Shale at Muth, Spiti area, Himalayas. This locality is a well-known section in the same general area as Lilang, the source of the holotype, but to the southwest and in the main strike-outcrop belt. Both hypotypes which served as a basis for these illustrations are deposited in the Mineralogical and Geological Museum, University of Copenhagen.

A. Early stage selected to show trifid subdivision of lateral lobe ($L_2L_1L_2$) at 3½ volutions of evolute conch; diameter 3.0 mm, width 2.0 mm; shell surface ribbed; x13½.

B. Stage of the suture, at 4½ volutions, in which lateral elements are independent and other unit $[L_2L_1(L_{2\cdot1}L_{2\cdot1})]$ is being added on the umbilical margin; sculpture is similar to that of earlier whorl; diameter 4.5 mm, width 3.0 mm; x13½.

C. Simple "*Stacheoceras*" stage, at 5 volutions, in which the conch is involute and subglobular; prominent transverse constrictions are nearly straight but form a ventral salient; diameter 6.5 mm, width 4.5 mm; x10.

D. Advanced "*Stacheoceras*" or "*Glassoceras*" stage in which the subdivision of the first lateral saddle (L^1) appears in the first lateral lobe; at 5½ volutions of the conch; diameter 9.0 mm, width 6.0 mm; transverse constrictions form a faint ventral sinus; x9.

E. Advanced "*Glassoceras*" stage, at 6¼ volutions, in which secondary elements of the mature ventral lobe [($V_{1.3}V_{1.2}V_{1.1.1}V_{1.1.2}$)] are evident; the secondary lobe had moved into crestal position on the first lateral saddle; the ninth lobe, an auxiliary in the $L_{s.1}$ series, appears at this stage; the transverse constrictions are only slightly sinuous but distinctly biconvex; diameter 12 mm, width 8 mm; x9.

F. Early mature *Cyclolobus* stage of 7 volutions in which tertiary elements appear and the first saddle is symmetrically divided; there are nine or ten lateral lobes at this size of 18 mm diameter and 11 mm width; an additional three or four lobes are added at the umbilicus by a diameter of 100 mm; the internal mould is smooth but there are prominent growth lines on the surface of the shell; transverse constrictions are moderately sinuous and form ventral and lateral sinuses; x7½.

course of the sutures and in proportions of major lobes, the two genera are also nearly identical. Still there are several recognizable bases for distinction:

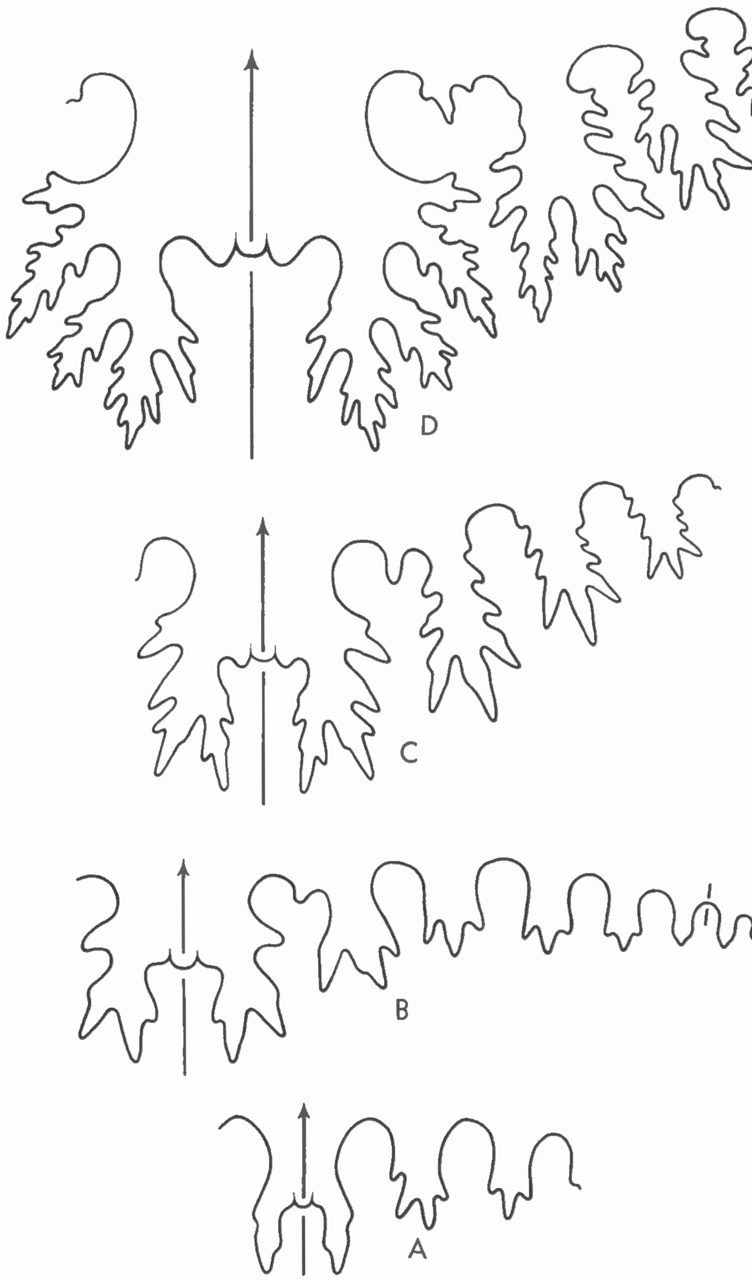
1. The secondary element (L^1) divides the first lateral saddle medially in mature *Cyclolobus* but is situated well on the dorsal flank of the saddle in *Timorites.*
2. The umbilical lobe remains relatively inconspicuous throughout sutural development in *Cyclolobus* and does not subdivide. In *Timorites* and other cyclolobids this lobe is large and tends to provide additional elements.
3. The whorls in *Timorites* are relatively broader than those in *Cyclolobus*; the proportion of width to diameter is about 65 per cent in the former and only 35 to 40 per cent in the latter. The evolute nature of early whorls in *Timorites* extends to a diameter of nearly 15 mm before the conch becomes thickly subdiscoidal.
4. Prominent shell sculpture is restricted to the early whorls in *Cyclolobus,* less than 10 mm diameter in the type and probably no more than 30 mm in *C. kullingi.* Characteristically, *Timorites* has a heavily ribbed conch, even at a diameter of 100 mm.
5. *Timorites* is found in strata of Guadalupian age in association with a variety of other Permian ammonoids (*Agathiceras, Adrianites, Neocrimites, Thalassoceras, Popanoceras,* and *Paraceltites*) which are not known to occur in younger beds. The Dzhulfian Stage, which contains *Cyclolobus,* has provided representatives of the Episageceratidae and Araxoceratidae, families which appear at this level.

Cyclolobus kullingi (Frebold)

Text-figures 12A-12D

1932 *Godthaabites kullingi* FREBOLD, pp. 17-21, pl. 1, figs. 2-3a.
1940 *Cyclolobus kullingi* (Frebold). MILLER and FURNISH, pp. 4-6, pl. 1, figs. 2-5.
1955 *Krafftoceras kullingi* (Frebold). RUZHENCEV, p. 703.

Description. In addition to the several specimens described from East Greenland by Frebold and by Miller and Furnish, four critical specimens now available to us were collected by S. E. B. Almgreen during 1959, from the same general area. In all specimens the preservation precludes the determination of exact conch proportions, and only partial sutures portray authentic detail. One of the best preserved specimens is worn, but uncrushed, and has a conch ratio W/D of approximately 50 per cent at 30 to 50 mm diameter.



TEXT-FIGURE 12. Diagrammatic representations of ontogenetic series in *Cyclolobus kullingi* (Frebold); based upon the holotype and three hypoptypes from the "*Martinia*-beds" at the same horizon and general locality, Clavering Island and Cape Stosch, central East Greenland. This material was secured by Kulling in 1929, Maync and Nielsen in 1937 and by Almgreen and Soltau in 1959; all specimens are reposited in the Mineralogical and Geological Museum, University of Copenhagen.

A. Inner whorl at about 12 mm diameter and 8 mm width, x10. This specimen (GGU No. 20313) is from Cape Stosch. Precise detail is preserved on this part of the shell and crushed parts of two additional whorls are attached. Compare with C. *kraffti* at 9 mm diameter (Text-figure 11D).

B. Immature stage represented by holotype at 18 mm diameter, x5. This specimen is slightly worn and some details, such as the secondary lobe in the first lateral saddle, have been restored. Locality is Mount Brinkley, southern Clavering Island. Compare with C. *kraffti* at 12 mm diameter (Text-figure 11E).

C. Early mature stage at about 25 mm diameter, x4½. This specimen (GGU No. 20314) is from the same general locality as *A*, but was secured loose on the slope. It represents the inner whorl of an eroded fragment some 50 mm in diameter; most of the details are considered reliable. The conch is marked by fine but distinct ribs which are less pronounced at this stage. Compare this suture with that of C. *kraffti* at 18 mm diameter (Text-figure 11F).

D. Part of a mature suture, slightly less than x2. Based upon a specimen from the same general locality as *B*, Clavering Island, at a diameter of 90 mm. A part of the body chamber is preserved, but the entire conch has been flattened and distorted. Details of the tertiary elements and general proportions may not be exact for they have been somewhat restored. Compare with the suture of C. *oldhami* (Text-figure 9).

Shell sculpture consists of coarse ribs at a diameter of 10 mm. These ribs become less pronounced but are still conspicuous at 25 mm diameter. Rounded ventral and lateral sinuses are developed progressively during ontogeny. Transverse constrictions are parallel to the ribs in immature whorls; at a diameter of 20 mm there are four constrictions in one volution. The whorls in excess of 60 mm diameter are nearly smooth.

Mature sutures of *Cyclolobus kullingi* resemble those of other representatives of the genus in most details. The critical ontogenetic stages in this species are shown in Text-figure 12.

Comparisons. The conch of *C. kullingi* is proportionally broader than that of typical *Cyclolobus*. Also, prominent shell ornament persists to a larger diameter than in *C. kraffti,* 30 mm versus 5 mm. Both these features indicate that *C. kullingi* is an early representative of the genus. The sutural development of this species (Text-figure 12) compared with that of *C. kraffti* (Text-figure 11) tends to verify this relationship. When the same stage of complexity is reached, the conch diameter of *C. kullingi* is about 50 per cent larger than in *C. kraffti*. Although considerably different from *C. kraffti* in several details, the early sutures of *C. kullingi* display a closer resemblance to *Cyclolobus* throughout than to *Timorites* (Miller and Furnish, 1940, p. 176). That is, the proportionate size of V_1 is smaller than in *Timorites*; also, the early appearance of $V_{1\cdot 2}$ and L^1 as distinct elements distinguishes *C. kullingi* from representatives of that genus.

Occurrence. *Cyclolobus kullingi* is known only from central East Greenland. The holotype described by Frebold (1932) and the topotypes studied by Miller and Furnish (1940) are from the Upper Permian "*Martinia*-beds" of Mount Brinkley, Clavering Island [locality A]. Additional specimens described herein are from the same strata of nearby Cape Stosch, just across Godthaab Gulf to the southwest. This latter collection by Almgreen and Soltau was secured at about 350 metres elevation in their "River 14" vicinity.

Repository. The holotype and all hypotypes are in the Mineralogical and Geological Museum, University of Copenhagen.

Family MEDLICOTTIIDAE Karpinsky 1889

Taxonomy of the Medlicottiidae was discussed in detail by Miller and Furnish (1940, pp. 39-40) and comprehensive studies of phylogeny and systematics were presented by Ruzhencev (1949, pp. 93-162; 1956, pp. 96-121). Miller and Furnish (1957, pp. 72-74) placed in synonymy many of the extant genera. Also, Glenister and Furnish (1961, pp. 689-690) questioned the validity of several of Ruzhencev's taxa. They stated that some of the characters on which the genera are based are unreliable as these features show less stability than is indicated by Ruzhencev.

The family makes its appearance with *Prouddenites* in the Middle Pennsylvanian. Uddenitins characterize the Upper Pennsylvanian but persist into the Artinskian Stage of the Permian. The subfamily Medlicottiinae is found throughout the Permian and is a distinctive faunal element in most strata containing ammonoids of this age. *Artinskia* is an index genus for the Lower Permian; Ruzhencev (1950, p. 85) records its rare occurrence (eight specimens) in the uppermost Pennsylvanian of the Urals.

Subfamily UDDENITINAE Miller and Furnish 1940

Genus *Neouddenites* Ruzhencev 1961

Type species. *N. andrianovi* Ruzhencev, 1961, p. 53; OD.

Diagnosis. Thinly discoidal (W/D approximately 25 per cent) uddenitins with relatively flat venter and deep ventrolateral groove. Sutural formula (Text-figure 14) is:

$$(V_2V_1V_2)a_{1.1}a_{1.1}a_1U_1U^2U^3U^4U^6\ldots U^{2n}:U^{2n-1}\ldots U^5I(D_1D_1)$$
$$[n = 4\ldots 10]$$

The first lateral saddle-and-lobe complex is distinctly below the general lineation on the flanks. Some dozen undivided "lateral" lobes are present in the external suture.

Distribution. Type *Neouddenites*, the only previously known representative, is from the Artinskian of Siberia. The Canadian occurrence is assumed to be of about the same age. All other Uddenitinae are from older strata (Desmoinesian-Sakmarian).

Discussion. *Neouddenites* was originally based upon four specimens in a relatively small collection of Lower Permian (Artinskian) ammonoids from the Tumara River area of central Yakutskaya A.S.S.R. (Western Verkhoyan). This genus constitutes a part of a faunal assemblage characterizing the Permian Arctic Province. Consequently, its discovery in northwestern Canada was to be expected, as associates had already been found. The Siberian and Canadian species show close similarities.

Upper Pennsylvanian representatives of the Uddenitinae illustrate no basic difference from *Neouddenites,* except for a few more primitive characteristics. For example, sutural subdivision of the ventrolateral saddle is comparable, although auxiliary lobes are considerably more numerous in the Permian genus. *Neouddenites* is thus to be regarded as a relic form which persisted with minor changes while the diverse Medlicottiinae evolved; some of the associated gastrioceratids are also holdovers from Pennsylvanian ancestry.

As in other medlicottiids, the mature whorls of *Neouddenites* are characterized by subparallel flanks. The association of a flattened venter and prominent ventrolateral sulci is distinctive, however. Inner whorls are rounded and evolute, as in other uddenitins. Mature features of the conch are apparent by 15 mm diameter.

Several of the shell characteristics portrayed by *Daixites* Ruzhencev (1941) suggest a direct relationship with *Neouddenites.* The former occurs commonly in strata of the Southern Urals ranging in age from Orenburgian through Sakmarian. Characteristically, species of *Daixites* possess rounded ventrolateral shoulders, but some approach *Neouddenites* in presence of a ventrolateral sulcus and flattened venter. The suture of *Daixites* is more primitive in several respects, leading to consideration of this genus as the ancestor of *Neouddenites.*

Shikhanites Ruzhencev (1938, p. 245), a taxon represented by a single small fragment from the Asselian of the Ufa Plateau (Bashkir A.S.S.R.), may bear a relationship with *Neouddenites.* The two forms have a general sutural similarity, but *Shikhanites* is more primitive in all respects. Its suture is characterized by a relatively short ventral lobe and bifid first "lateral" lobe; the ventrolateral shoulders apparently are rounded. Ruzhencev (1951, p. 98) has erected the monotypic family Shikhanitidae.

Table VI

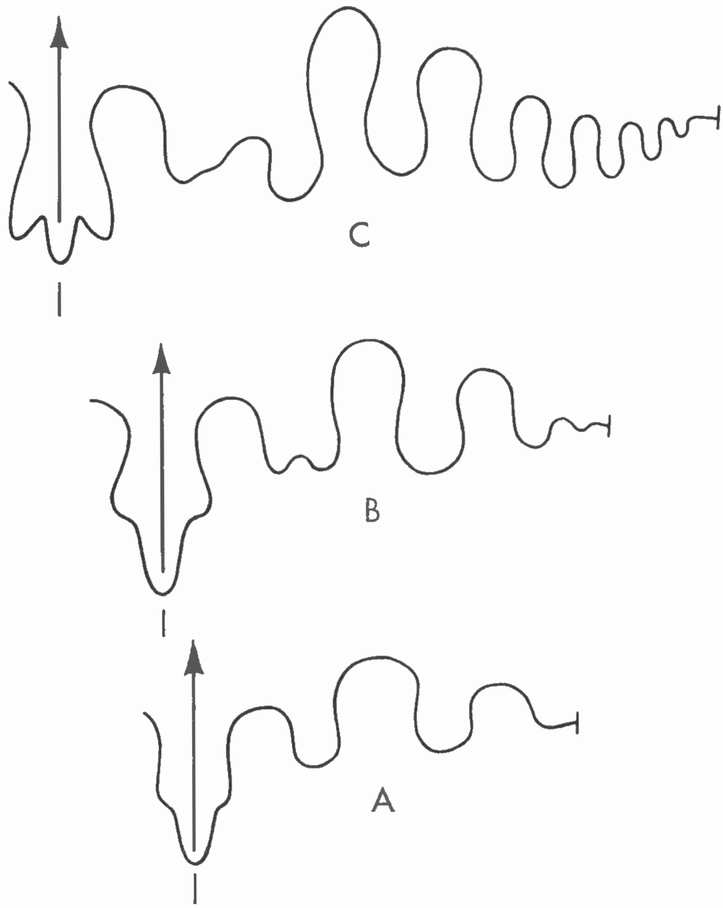
Dimensions (in mm) and Proportions of Neouddenites

Specimen GSC No.	D	H	W	U	H/D	W/D	U/D
N. caurus n. sp.							
Holotype 18787	42	24	10	2.5	0.57	0.24	0.06
Holotype 18787	30	17.5	7.5	2	0.58	0.25	0.07
Paratype 18788	42	24	10.5	3	0.57	0.25	0.07
Paratype 18788	33	18	8.5	2	0.55	0.26	0.06
Paratype 18789	14.5	7.4	3.9	2.2	0.51	0.27	0.15
Paratype 18789	9.8	3.5	2.6	4.2	0.36	0.27	0.43
Paratype 18789	5.2	1.8	1.6	2.5	0.35	0.31	0.48
N. andrianovi Ruzhencev							
[Ruzhencev, 1961, 1802/2]	36	21	7.5	3	0.58	0.21	0.08

Neouddenites caurus n. sp.

Plate II, figures 4-7; Text-figures 13A-C, 14 A

Description. The holotype and two paratypes are well preserved internal moulds with some shell preserved. They occur as partly pyritized and silicified specimens within calcareous nodules in a dark shale. All three specimens are of about 40 mm diameter and probably represent a maximum attained by the phragmocone. The mature conch would have been about 60 mm diameter, with the body chamber restored. Parts of shell that adhere to these specimens show no features except fine growth lines. They outline a shallow dorsolateral sinus, a high rounded salient across the mid-flanks, a sinus corresponding to the ventrolateral sulcus, and a ventral salient.



TEXT-FIGURE 13. Diagrammatic representation of external sutural ontogeny in *Neouddenites caurus* n. sp.; based upon paratype GSC No. 18789; from an unnamed Lower Permian formation, northern Yukon Territory.

A. "*Prolecanites*" stage of development at 3 mm diameter, x40; whorls are evolute and possess transverse constrictions.

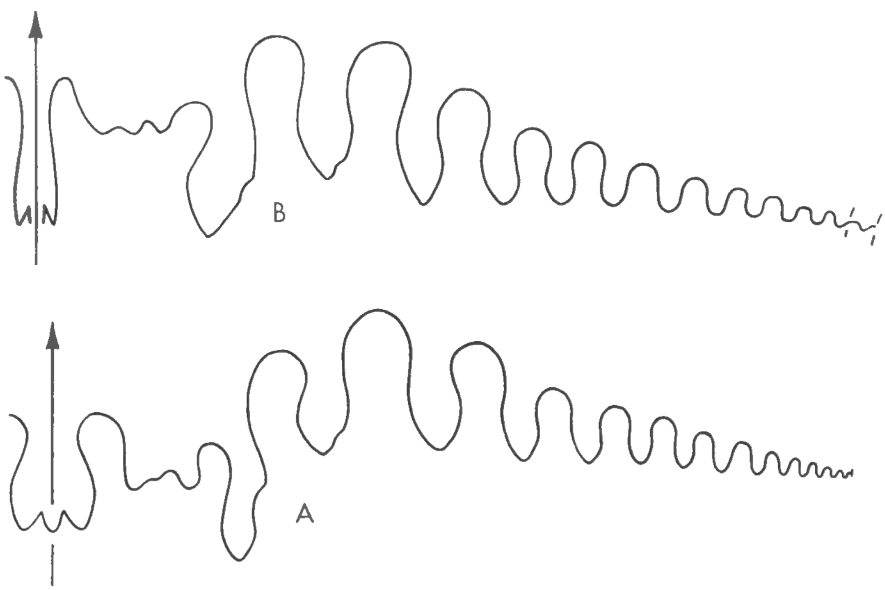
B. "*Pronorites*" stage, at 5 mm diameter, x30.

C. "*Prouddenites*" stage, at 10 mm diameter, x20; whorls are evolute, but the relative height had started to increase and the venter is flattened.

The related Upper Pennsylvanian *Uddenoceras oweni* (Miller and Furnish, 1940) passed through similar stages during development of the suture. A form comparable to *A* was reached in *Uddenoceras* at 3 mm diameter, B is comparable to *Uddenoceras* at 6 to 8 mm diameter, and C is comparable to a diameter of 8 to 10 mm in *Uddenoceras*. By contrast, the mature suture of *Prouddenites primus* Miller at a diameter of 20 mm corresponds to that of *Neouddenites* in C at 10 mm.

Paratype 18789 was broken to expose the inner volutions (Text-figure 13). There is a strong resemblance to Upper Pennsylvanian uddenitins in these whorls. Outer volutions have a nearly closed umbilicus, with whorls that cover earlier volutions dorsally.

Remarks. Neouddenites caurus n. sp. closely resembles the type species *N. andrianovi*. The only appreciable differences in the sutures (Text-figure 14) are the relatively low position of the ventrolateral elements in *N. caurus* and the broad ventral lobe of that species. Both taxa have parallel whorl flanks with a rounded ventrolateral sulcus. In addition, *N. andrianovi* possesses a depressed-flattened ventral area at full maturity; this part of the conch is not preserved in *N. caurus*.



TEXT-FIGURE 14. Diagrammatic representations of mature external sutures of *Neouddenites* from the Permian of northwestern Canada and central Siberia.

A. *N. caurus* n. sp. Holotype GSC No. 18787 secured from an unnamed Lower Permian formation in the northern Yukon Territory; diameter of 30 mm; x7.

B. *N. andrianovi* Ruzhencev. Holotype (Pal. Inst. Moscow No. 1802/1) from the middle of a 10,000-foot Lower Permian sequence, Tumara River area, Verkhoyansk Range, U.S.S.R.; diameter of 36 mm; x6 (*from* Ruzhencev, 1961).

Occurrence. Holotype GSC No. 18787 and paratypes GSC Nos. 18788, 18789 were collected by a field party of The California Standard Company from an unnamed Lower Permian shale formation at GSC locality 60699 [locality H], about 45 miles west-southwest of Aklavik, northern Yukon Territory.

Repository. Holotype GSC No. 18787 and paratypes GSC Nos. 18788, 18789 are deposited with the Geological Survey of Canada.

Subfamily MEDLICOTTIINAE Karpinsky 1889

Genus *Medlicottia* Waagen 1880

Type species. *Goniatites orbignyanus* de Verneuil, 1845, pp. 375-376, pl. 26, figs. 6a-c; SD, Foord and Crick, 1897, p. 266.

Diagnosis. Thinly lenticular medlicottiids without prominent shell sculpture. The suture has a series of subequal lobes on the flank in which more than half are prominently bifid; in some species, the sides of the intervening saddles are also notched. On the ventrolateral shoulder, the adventitious saddle complex consists of nearly parallel sides with a series of small paired secondary elements. The sutural formula is:

$$(V_2V_1V_2)v^1v^2v^3\text{-}v^6s^1s^1l^7\text{-}l^5l^4l^3l^2l^1U_1U^1 \ldots\ldots$$

Discussion. The genus *Medlicottia* rests on a type that is about average for the group. *M. orbignyana* from the Artinskian of the Urals. A simple lenticular conch with thin furrowed venter distinguishes the typical form from most other members of the family. Within the subfamily, minor differences in the suture have been employed to define members as separate genera, *Aktubinskia* and *Neogeoceras*. *Episageceras,* a related Upper Permian and Lower Triassic genus that now serves as type for a separate family (Ruzhencev, 1956) has broader whorls and consistent differences in the sutural pattern.

Occurrence. Representatives of *Medlicottia* have wide geographic distribution in rocks of both Lower and Upper Permian age (Sakmarian-Dzhulfian Stages). In all known occurrences, this genus is rare or constitutes a minor part of the ammonoid fauna.

Medlicottia malmqvisti Frebold

1932 *Medlicottia malmqvisti* FREBOLD, pp. 14-16, pl. 1, fig. 1, text-fig. 2.
1940 *Medlicottia malmqvisti* Frebold. MILLER and FURNISH, pp. 3-4, pl. 1, fig. 1, text-fig. 1.

Discussion. The holotype of *M. malmqvisti* is crushed laterally, but the sutures are clear. The size attained is nearly 100 mm, which is normal for the genus. Preservation of this single specimen precludes detailed comparisons with related species.

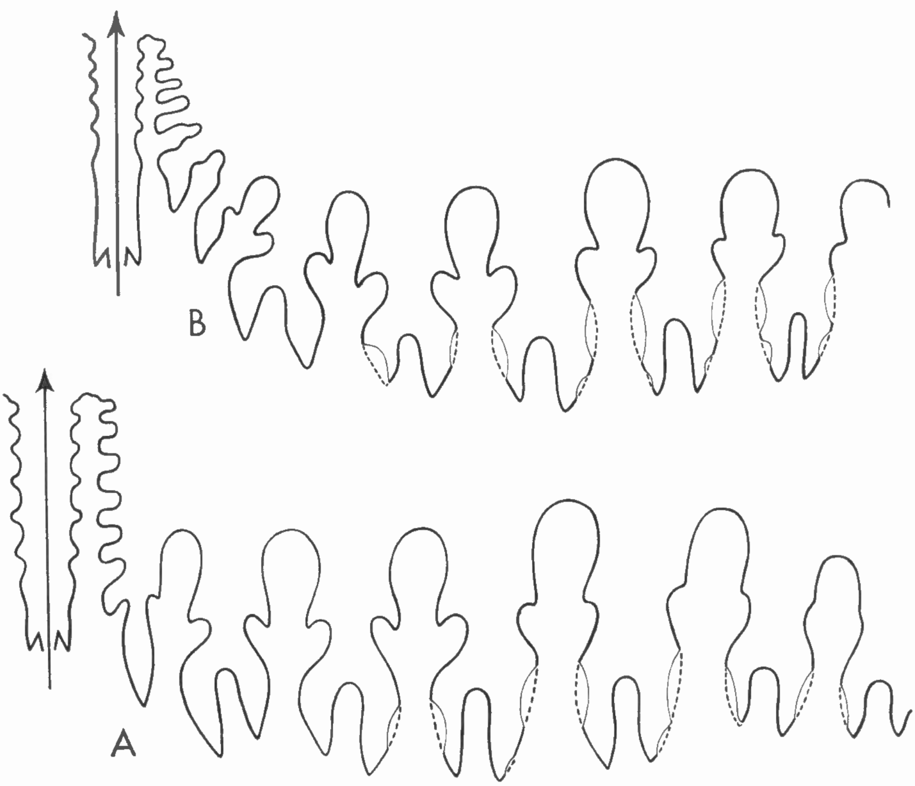
There are no features that distinguish the holotype of this species from several other Permian taxa. It falls in a group of species with subdivided saddles, characteristic of the Upper Permian, which has been designated by a separate generic category *"Eumedlicottia"* (Spath, 1934). Such a distinction has little stratigraphic significance and morphologic differentiation is difficult. In general, sutures on the flank changed during growth and were relatively unstable; other representatives of the family are defined primarily by the nature of subdivisions in the ventrolateral part of the suture.

The genus *Medlicottia* has been recorded as a rare associate of *Cyclolobus* in Pakistan, as well as in Greenland. *M. primas* (Waagen) is similar to *M. malm-*

qvisti but appears to be more advanced. A well preserved topotype available to us from the Salt Range verifies Waagen's illustration of the suture in most details. There is also a single specimen from the Caucasus, Armenian S.S.R., which has been referred to *M. primas* by Ruzhencev (1962, pl. 12, fig. 2). The suture of that Armenian form resembles the type of *M. primas* in general complexity but differs to an important degree in the ventral part of the suture (Text-figure 15B). We are designating Ruzhencev's specimen as a new taxon.

Occurrence. Medlicottia malmqvisti is known only as a single specimen from central East Greenland. The holotype is from the Upper Permian "*Martinia*-beds" of Mount Brinkley, southern Clavering Island [locality A].

Repository. The holotype is in the Mineralogical and Geological Museum, University of Copenhagen.



TEXT-FIGURE 15. Diagrammatic representation of external sutures in *Medlicottia* Waagen and *Syrdenites* n. gen. In both genera sutures are discontinuous where adjacent septa coalesced. Dashed lines represent projections of truncated septum; adjacent thinner lines are partial sutures of the preceding septum.

A. *M. primas* (Waagen). Based on a topotype from the Upper *Productus*-Limestone of Chideru, Salt Range, West Pakistan (Geologisches Institut und Museum, Tübingen). Whorl height 80 mm, x2⅓.

B. *S. stoyanowi* n. sp. Based on the holotype, from the Dzhulfian of Soviet Armenia (Paleontological Institute, Academy of Science, Moscow) ventral lobe conjectural. Whorl height about 100 mm, x2 (*from* Ruzhencev's photograph).

Genus *Syrdenites* n. gen.

Type species. *S. stoyanowi* n. sp.

Diagnosis. Advanced medlicottiins lacking prominent shell sculpture and with whorls similar to *Medlicottia.* Lateral saddles of suture possess prominently trifid pattern that extends into secondary elements of the high adventitious first lateral saddle in the ventrolateral area (Text-figure 15B). A most distinctive feature is the ventral sigmoid continuity of the over-all sutural trace.

Discussion. In general complexity of the lateral lobes, *Syrdenites* resembles *Medlicottia primas* (Waagen), a species known from only two specimens. In both these examples the ventral series of "lateral" saddles is so prominently subdivided that they appear to be trifid (Text-figure 15). However, in *M. primas* this effect has diminished considerably by the fourth and fifth saddles, whereas in *S. stoyanowi* the sixth "lateral" saddle is still prominently trifid.

The nature of subdivisions in the ventrolateral part of the suture is the major basis for classification in the Medlicottiidae. The Late Permian *M. primas* shows no appreciable differences in suture from a series of Upper Permian and some Lower Permian species. In such forms, the complex first "lateral" saddle is composed of a large asymmetric secondary element plus a paired series (three to six) of much smaller additional inflections. In *Syrdenites,* it appears that there is a uniform regression in size, and the prominent lower secondary saddles are incipiently trifid. None of the other medlicottiid or episageceratid genera illustrates such a regular alignment of the suture on the flank extending into the ventrolateral part.

Occurrence. Medlicottiids are a relatively common faunal element in strata of Guadalupian age, but are extremely rare in the younger Permian. One of the most advanced representatives, *Syrdenites,* is known from Armenia by a single specimen. The associated Otocerataceae are suggestive of Triassic affinities, but other fossils are of definite Permian aspect; the other ammonoids include *Krafftoceras* n. sp. Ruzhencev (1963, p. 56) [= *Cyclolobus* sp.], *Pseudogastrioceras abichianum* (Möller), and *Stacheoceras tschernyschewi* (Stoyanow).

Syrdenites stoyanowi n. sp.

Text-figure 15B

1962 *Eumedlicottia primas* (Waagen). RUZHENCEV, pl. 12, fig. 2.
1963 *Eumedlicottia primas* (Waagen). RUZHENCEV, p. 56.

Description. Distinguishing characters are those of the genus, which rests on a single specimen. The holotype is a well preserved fragment of an internal mould. This type is a part of a completely septate whorl with a height of about 100 mm.

Discussion. Additional material may add to the definition of this taxon. Although some unique specimens may be pathologic, this form is highly regular and fits the evolutionary pattern of Permian medlicottiids. The trivial name was chosen to honour the late Professor A. A. Stoyanow, who presented one of the early descriptions concerning the Dzhulfa Permian (1910).

Occurrence. Apparently *Syrdenites stoyanowi* is restricted to the Dzhulfian Stage, typically represented in the gorge of the Araxes River of Armenia. The strata are regarded as uppermost Permian and may include a fauna slightly younger than the "Upper *Productus*" beds of the Salt Range.

Repository. The holotype of *Syrdenites stoyanowi* is in the collections of the Paleontological Institute, Academy of Science, Moscow.

Genus *Neogeoceras* Ruzhencev 1947

Type species. *Medlicottia girtyi* Miller and Furnish, 1940, pp. 59-60, text-figs. 14, 15A; OD.

Diagnosis. Sublenticular medlicottiins with a relatively broad, shallowly concave venter, the width of which is 30 to 50 per cent the maximum width of the conch. Venter flanked by angular shoulders and shallow rounded groove. Transverse ribs may be present on the ventrolateral flanks. Sutural formula (Text-figure 16) is:

$$(V_2V_1V_2)v^1v^2v^3v^4s\ l^5l^4l^3l^2l^1U_1U^1U^2U^3U^4U^6 \ldots.$$

The first "lateral" lobe (U_1) is asymmetrically bifid and its ventral prong is significantly longer than the dorsal subdivision. The bifid second "lateral" lobe (U^1) has prongs of about equal length. The number of additional "lateral" lobes and their degree of subdivision are variable.

The ventral flank of the first lateral saddle possesses from three to five adventitious subdivisions. Four to six adventitious elements are present on the dorsal flank and the adapical two may exhibit incipient subdivision; the adapical adventitious lobe is the largest element and is markedly asymmetric.

Distribution. The holotype of the existing American species, *Neogeoceras girtyi* (Miller and Furnish, 1940, p. 59), is from the lower Guadalupian (Wordian Substage) of Coahuila, Mexico; four additional specimens are now available from the same area. Paratypes of this species were collected in the Hegler and Pinery limestones of the Bell Canyon Formation of West Texas and are of early Capitanian age. The holotype of *N. macnairi* n. sp. is from near Cape Fortune, Cameron Island, Canadian Arctic Archipelago; a congeneric specimen has been secured from the northern Yukon Territory. *N. boreale* (Tschernyschew *in* Karpinsky, 1926, p. 2) is known in strata of probable Late Permian age from Novaya Zemlya. *N. smithi* (Miller and Furnish, 1940, p. 51) is found in the Basleo beds (Wordian) of Timor. For practical purposes, all these listed species are based on isolated examples. However, the common type of medlicottiin of the classic Sosio Limestone in Sicily falls within the limits of *Neogeoceras*. Sicilian representatives comprise *N. marcoui* (Gemmellaro, 1887, p. 50), *N. canavarii* (Greco, 1935, p. 175) and *N. trautscholdi* (Gemmellaro, 1887, p. 52). Thus, all occurrences of *Neogeoceras* appear to be from the Guadalupian Stage.

Discussion. The suture of *Neogeoceras* is of an advanced medlicottiid type and is characterized by marked asymmetry in the prongs of the first "lateral" lobe (U_1). All other medlicottiins possess subequal prongs, but in some *Neogeoceras* the depth of the ventral prong approaches twice that of the dorsal prong. Subdivision of the first lateral saddle of *Neogeoceras* is comparable with that in *Medlicottia.* However, the latter genus is narrowly lenticular and possesses a deep ventral groove. *"Eumedlicottia"* differs additionally in the possession of prominent adventitious subdivisions on the flanks of some of the lateral saddles.

The position of *Neogeoceras* within the family Medlicottiidae is not known precisely. Ruzhencev (1949) indicated that during the progression of medlicottiin sutural development there is generally an increase in the size of l^1, the adapical adventitious lobe on the dorsal side of the first lateral saddle. However, *Neogeoceras* is an exception and l^1 is small. This peculiarity plus the development of a long ventral prong on the first "lateral" lobe, suggests that *Neogeoceras* represents a discrete gens within the Medlicottiidae.

Neogeoceras macnairi n. sp.

Plate IV, figures 7, 8; Text-figure 16B

Description. One excellently preserved internal mould of this species is available for study. It is named to honour the collector, Dr. Andrew H. McNair. Conch dimensions and proportions are listed with those of several other species in Table VII. The venter is shallowly concave and approximates 50 per cent of the corresponding maximum whorl width. No shell is preserved, but the internal mould is smooth.

Table VII

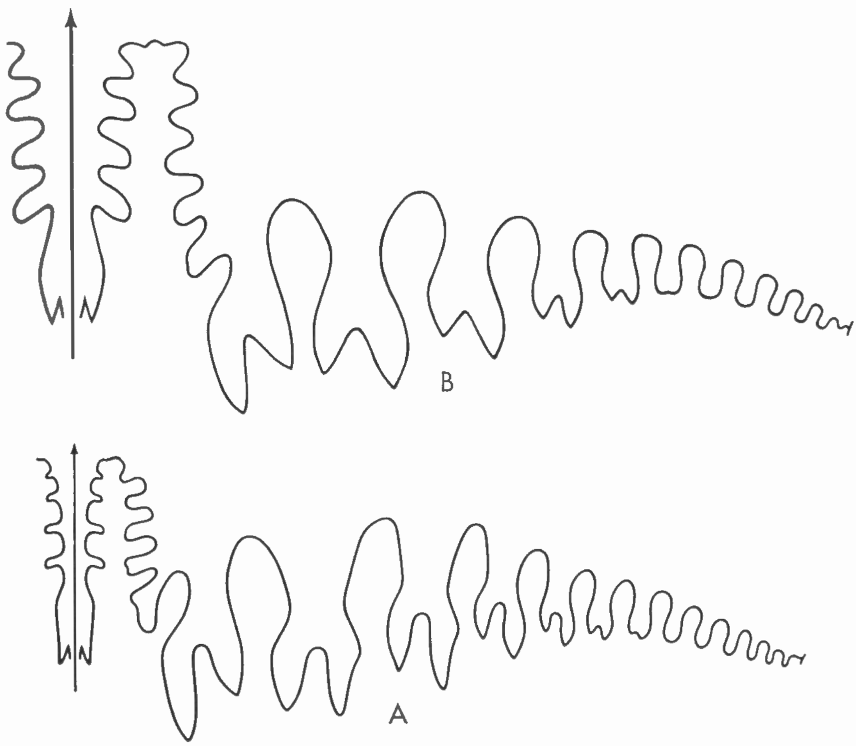
Dimensions (in mm) and Proportions of Neogeoceras

Specimen	D	H	W	W_v[1]	U	H/D	W/D	U/D	W_v/W
N. macnairi n. sp.									
Holotype GSC No. 18770	45	26	12	6	3	0.58	0.27	0.07	0.50
N. girtyi Miller and Furnish									
Holotype Yale Peabody									
Mus. No. 16810	30	18	8	3	2	0.60	0.27	0.07	0.37
N. canavarii Greco									
Museo di Pisa (from Greco)	25	15	7	3.5	2	0.60	0.28	0.08	0.50
N. marcoui Gemmellaro									
USNM Collection	51	31.5	11	4	2	0.62	0.22	0.04	0.36

[1] Width of venter

Nine "dorsolateral" lobes appear on the ultimate septum. The sixth "lateral" lobe is joined by direct septal crenulations to the third and fourth "dorsolateral" lobes. All other adjacent elements of the external and internal suture are linked directly. Thus the fourth "lateral" lobe is joined to the first "dorsolateral", and the eleventh "lateral" to the ninth "dorsolateral".

Comparisons. Neogeoceras macnairi resembles *N. girtyi* in general conch proportions, but, at comparable diameters the relative width of the venter differs in the two species. In *N. girtyi* the ratio of the width of the venter to that of the conch approximates 35 per cent. The relatively strong ribs of *N. girtyi* are absent in *N. macnairi*. *N. boreale* (Tschernyschew) closely resembles the Canadian species in sutural contours but possesses proportionally thinner flat ventrolateral flanks.



TEXT-FIGURE 16. Diagrammatic representations of external sutures of *Neogeoceras*.

A. *N. girtyi* (Miller and Furnish). From the Wordian Substage, Valle de Las Delicias, Coahuila; based on Yale Peabody Mus. holotype 16700, at a conch diameter of 22 mm; x7.

B. *N. macnairi* n. sp. From the Upper Permian of Cameron Island, Canadian Arctic Archipelago; based on holotype GSC No. 18770, at a conch diameter of 43mm; x3½.

Occurrence. The single specimen referred to *N. macnairi* was collected by A. H. McNair, during 1960, from Upper Permian strata 4 miles southwest of Cape Fortune, Cameron Island, Canadian Arctic Archipelago [locality F].

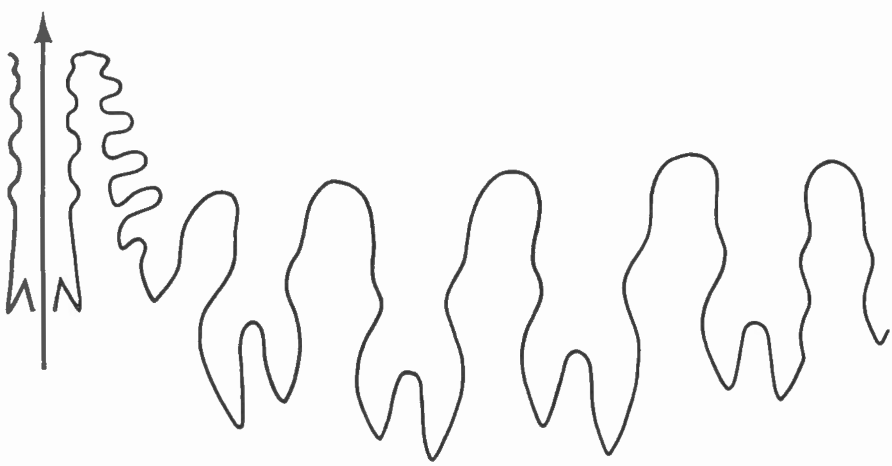
Repository. Holotype GSC No. 18770 is deposited with the Geological Survey of Canada.

Neogeoceras sp.

Text-figure 17

Description. A single septate fragment from northwestern District of Mackenzie is referable to *Neogeoceras,* although it is not conspecific with the other Canadian species, *N. macnairi.* The mainland specimen is from a phragmocone of about 150 mm diameter. The gross features of morphology are apparent but the state of preservation does not permit determination of all sutural details and conch proportions.

The venter is weathered but appears to have been only shallowly concave; its width is no greater than 35 per cent that of the corresponding whorl. The general form of the external suture is illustrated by Text-figure 17. Element U_1 is smaller and somewhat shorter than the adjacent U^1, and the ventral prong of U_1 is appreciably larger than the corresponding dorsal prong. The flanks of the "lateral" saddles show incipient subdivision.



TEXT-FIGURE 17. Diagrammatic representation of a part of the external suture of Neogeoceras sp. from an unnamed Upper Permian formation, Porcupine River area, northwestern District of Mackenzie; based on figured specimen GSC No. 18785, at a conch diameter of about 150 mm; x2½.

Comparisons. Some of the differences between *Neogeoceras* sp. and the holotype of *N. macnairi* are at least partly a function of ontogeny. However, the mainland specimen appears to lack the shallow ventrolateral groove, and sutural element U_1 is proportionally shallower and less strongly asymmetric than in *N. macnairi.* Closest affinities are with *N. marcoui* (Gemmellaro, 1887) from the Sosio beds of Sicily.

Neogeoceras sp. is somewhat intermediate between type *Medlicottia* and type *Neogeoceras* in the degree of asymmetry of sutural element U_1, but more closely resembles the latter. Additionally, the shallowly concave venter is characteristic of *Neogeoceras.*

Occurrence. Figured specimen GSC No. 18785 was collected by E. Wayne Bamber, during 1962, from a nodule in a small outcrop of siltstone, 137 feet below the base of a cliff-forming limestone sequence in unnamed Permian rocks, northern Richardson Mountains, District of Mackenzie, Northwest Territories [locality G]; collection made from GSC locality 53876 at 67°58′28″N, 136°09′22″W, 657 feet above the orange to reddish brown siltstone unit which forms the base of that section. Ammonoid evidence suggests a Guadalupian age.

Repository. Figured specimen GSC No. 18785 is deposited with the Geological Survey of Canada.

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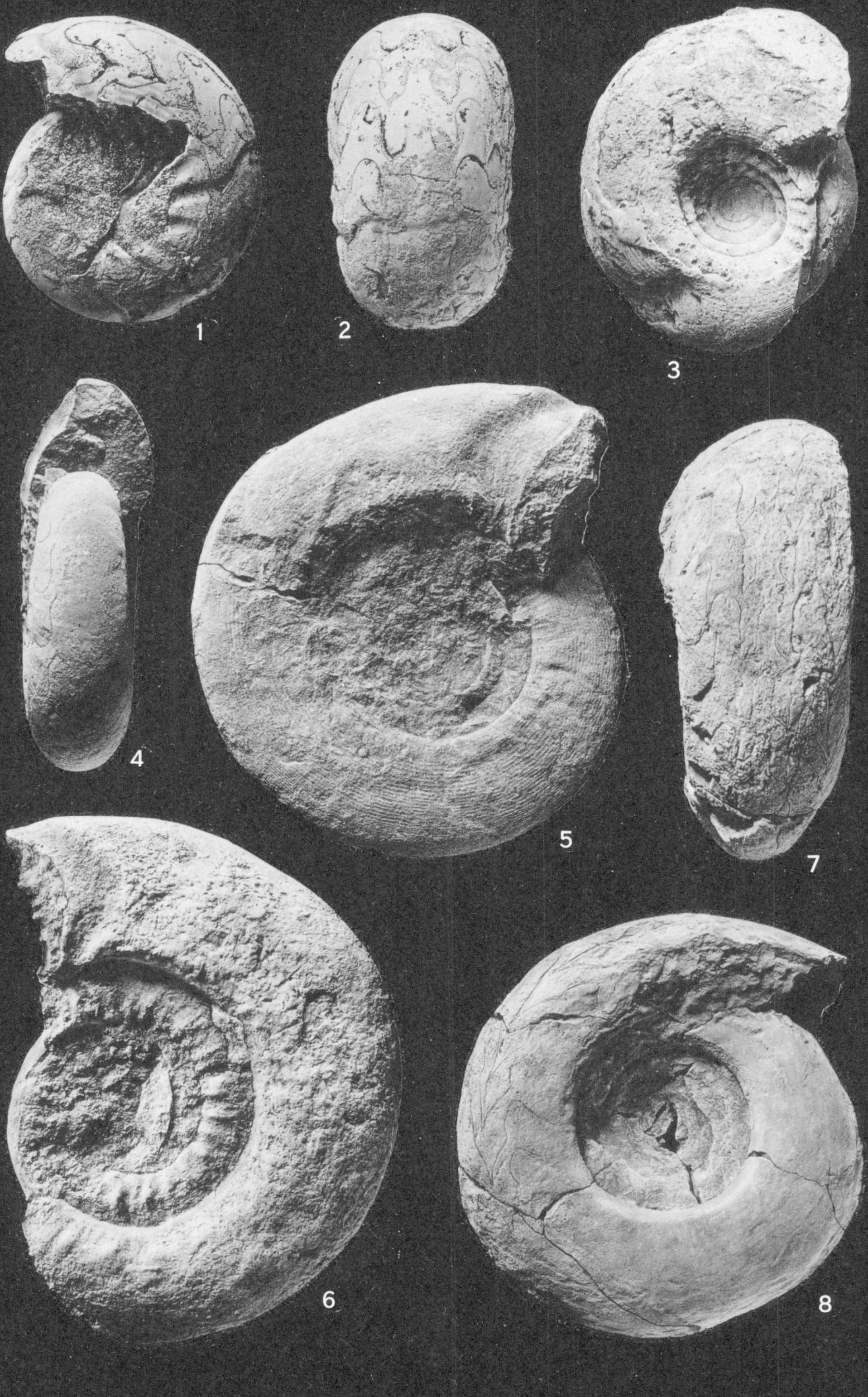
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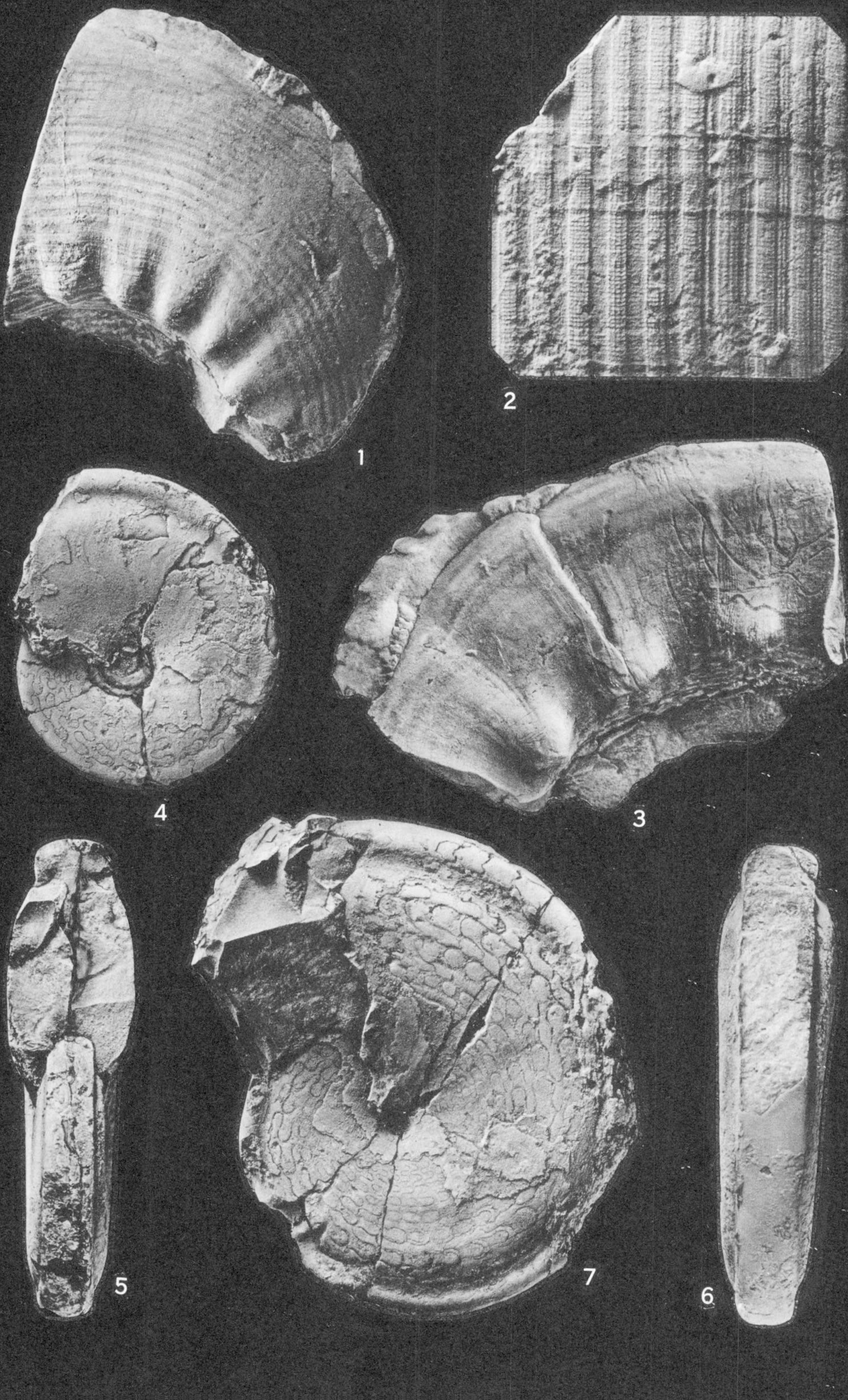
PLATE II



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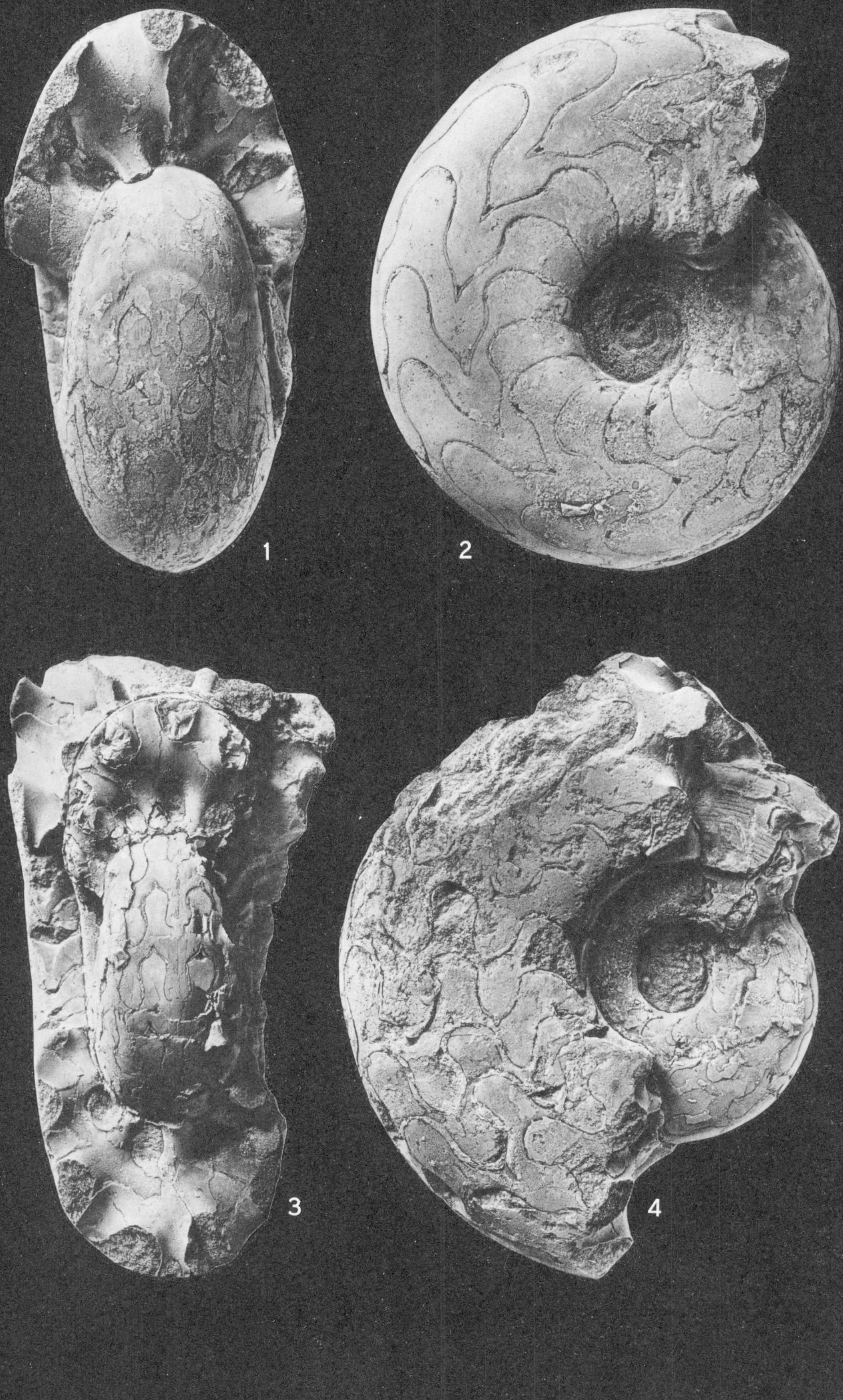
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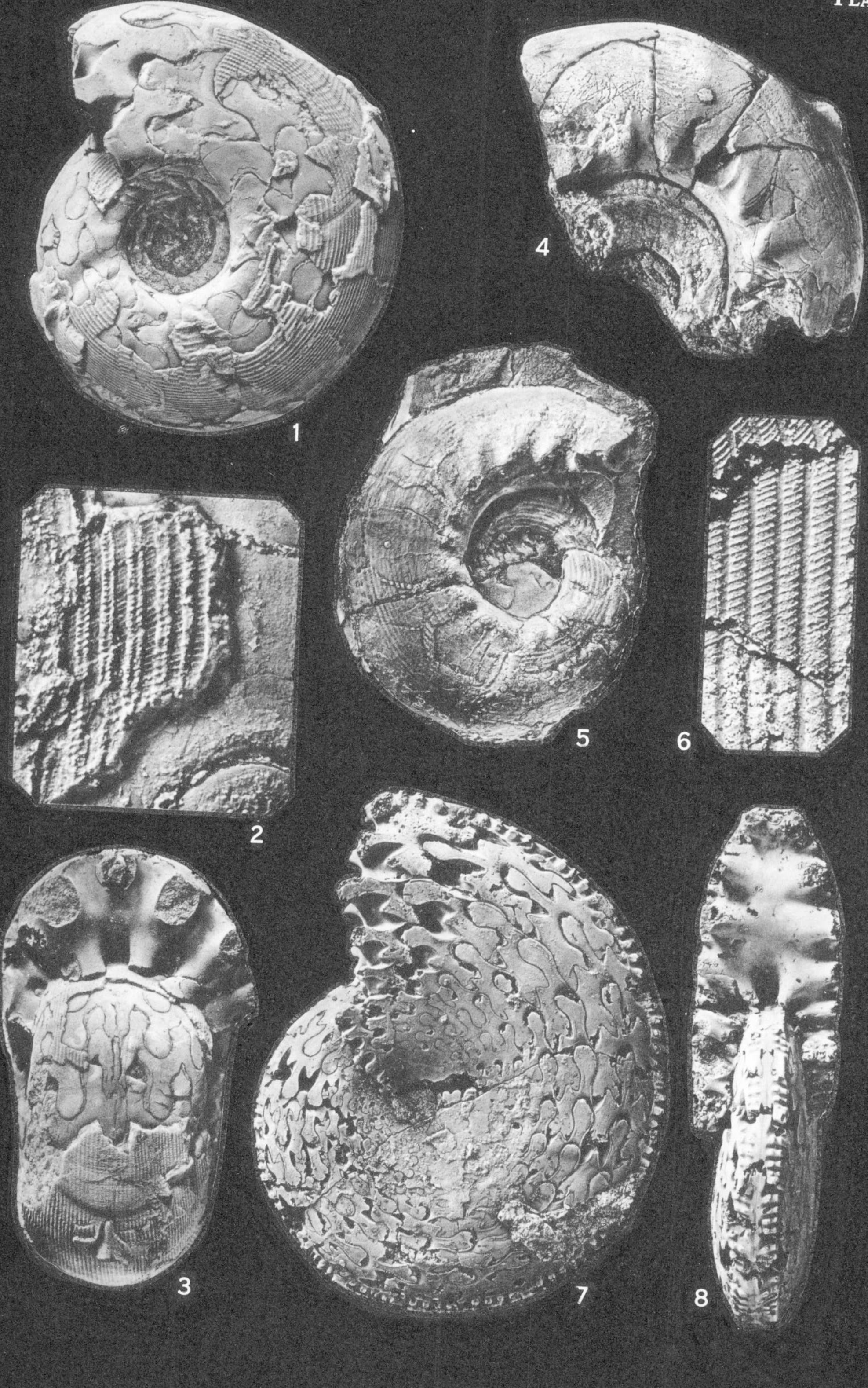

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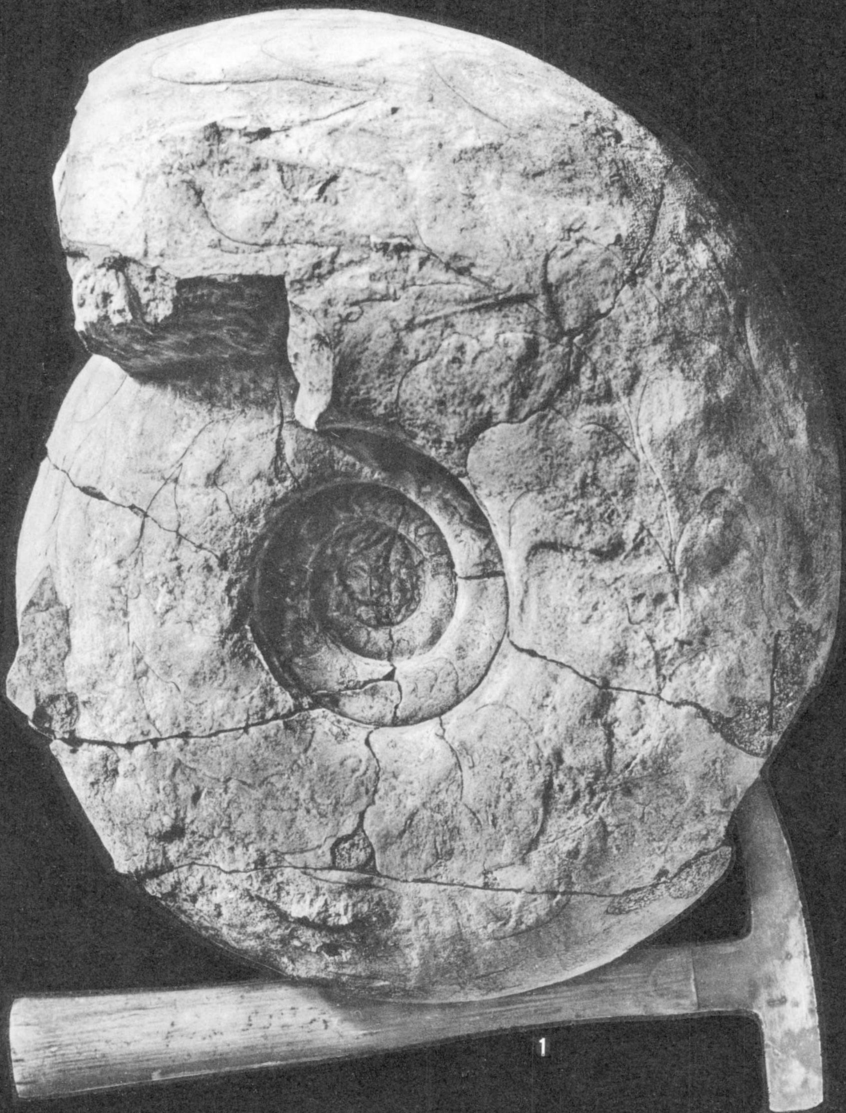
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