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BULLETIN 74

THE JURASSIC FAUNAS OF
THE CANADIAN ARCTIC
MIDDLE AND UPPER JURASSIC
AMMONITES

Hans Frebold

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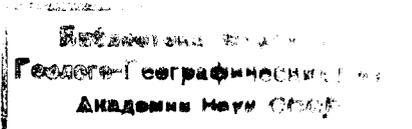
BULLETIN 74

THE JURASSIC FAUNAS OF THE
CANADIAN ARCTIC

MIDDLE AND UPPER JURASSIC
AMMONITES

By
Hans Frebald

DEPARTMENT OF
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PREFACE

This report is based on fossil collections made over a vast area of the Canadian Arctic extending from Ellesmere Island in the north to the Aklavik region of the mainland. Detailed study of these ammonite faunas permits correlation of the associated Jurassic rocks and shows their faunal and stratigraphic relationships with East Greenland and Siberia.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, June 22, 1960

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THE JURASSIC FAUNAS OF THE CANADIAN ARCTIC

Middle and Upper Jurassic Ammonites

Abstract

Middle and Upper Jurassic faunas have a wide distribution in the Canadian Arctic. The following index ammonites indicate the presence of various stages: *Leioceras opalinum*, *Pseudolioceras m'clintocki* (see Frebold, 1960), and *Erycites* cf. *E. howelli* (lower Bajocian); *Cranocephalites borealis* and *C. warreni* n. sp. (probably upper Bajocian); *Arkelloceras tozeri*, *A. mclearni*, and *Zetoceras thorsteinssoni* n. sp. (probably upper Bajocian-lower Bathonian); *Cranocephalites vulgaris* (lower Bathonian); *Arctocephalites elegans* and *A. cf. A. ornatus* (middle Bathonian), *Artioceras kochi* and *A. ishmae* (upper Bathonian); *Cadoceras* spp. (upper Bathonian-lower Callovian); *Cardioceras* ex aff. *C. mirum* (lower Oxfordian); *Amoeboceras* (upper Oxfordian-lower Kimmeridgian); *Dorsoplanites* spp. and *Pavlovia*? (? lower Volgian). No upper Volgian is indicated by ammonites, but Berriasian is present (*Subcraspedites*, *Tollia*, not described in this paper).

Some of the index ammonites have a restricted distribution in Arctic Canada as for example *Erycites*, *Cranocephalites borealis*, *C. warreni* and *Arctocephalites* that are known only from the Richardson and British Mountains region, and *Arkelloceras*, *Cranocephalites vulgaris*, *Cardioceras* and others, that seem to be restricted to some of the islands. Some of these differences may be explained by incomplete collecting, but others may be due to gaps in the sequences.

There are close relationships with other Arctic faunas, particularly with East Greenland and the Chatanga region in northern Siberia. The manifestation of the boreal fauna realm took place in the Bajocian; the main connections of the boreal sea, which were closed at various times, were through the Scandic, the north Russian seaway and the north Siberian seaway.

Résumé

Les faunes du Jurassique moyen et supérieur sont largement représentées dans l'Arctique canadien. Les ammonites caractéristiques suivantes indiquent la présence de divers étages: *Leioceras opalinum*, *Pseudolioceras m'clintocki* (voir Frebold, 1960) et *Erycites* cf. *E. howelli* (Bajocien inférieur); *Cranocephalites borealis* et *C. warreni* n. sp. (Bajocien supérieur, probablement); *Arkelloceras tozeri*, *A. mclearni* et *Zetoceras thorsteinssoni* n. sp. (Bajocien supérieur—Bathonien inférieur, probablement); *Cranocephalites vulgaris* (Bathonien inférieur); *Arctocephalites elegans* et *A. cf. A. ornatus* (Bathonien moyen), *Artioceras kochi* et *A. ishmae* (Bathonien supérieur); *Cadoceras* spp. (Bathonien supérieur—Callovien inférieur); *Cardioceras* ex aff. *C. mirum* (Oxfordien inférieur); *Amoeboceras* (Oxfordien supérieur—Kimmeridgien inférieur) *Dorsoplanites* spp. et *Pavlovia*? (Volgien inférieur?). Aucune des ammonites qu'on y trouve

n'appartient au Volgien supérieur, mais le Berriasien y est représenté (*Subcraspedites*, *Tollia*, dont la description n'apparaît pas dans la présente étude).

Certaines des ammonites caractéristiques sont réparties de façon plutôt restreinte dans l'Arctique canadien, comme par exemple *Erycites*, *Cranocephalites borealis*, *C. warreni* et *Arctocephalites*, qu'on n'a reconnues que dans la région des monts Richardson et British, et *Arkelloceras*, *Cranocephalites vulgaris*, *Cardioceras* et autres, qui semblent se restreindre à certaines îles. Une partie de ces différences peut s'expliquer du fait d'un prélèvement incomplet, mais il se peut également qu'il y ait des lacunes au sein des successions.

Il existe d'étroites relations avec d'autres faunes actiques, tout particulièrement avec celle du Groenland oriental et avec celle de la région de Chatanga (Nord de la Sibérie). La faune boréale s'est pleinement manifestée au cours du Bajocien; les principales communications de la mer boréale, qui furent fermées à diverses époques, s'effectuaient par l'ancienne mer Scandic, le passage maritime au Nord de la Russie et la voie maritime du Nord de la Sibérie.

INTRODUCTION

This report deals with the index ammonites of the Upper and Middle Jurassic of the Canadian Arctic and forms a continuation of the author's report on the index ammonites of the Lower Jurassic and lowermost Middle Jurassic of the same regions (Frebald, 1960). A previous paper on the Jurassic deposits of Prince Patrick Island (Frebald, 1957b) briefly outlines the Jurassic system in Arctic Canada.

The material described here was collected in the Richardson and British Mountains region and on the Arctic islands. Most of the Richardson Mountain fossils were found by J. A. Jeletzky, Geological Survey of Canada; others were collected by geologists of British American Oil Company and deposited in the Geology Department of the University of Alberta. The author expresses his sincere thanks to Professors Warren and Stelck for having made this material available to him.

The ammonites from the Canadian Arctic islands were collected by R. Thorsteinsson and E. T. Tozer, Geological Survey of Canada.

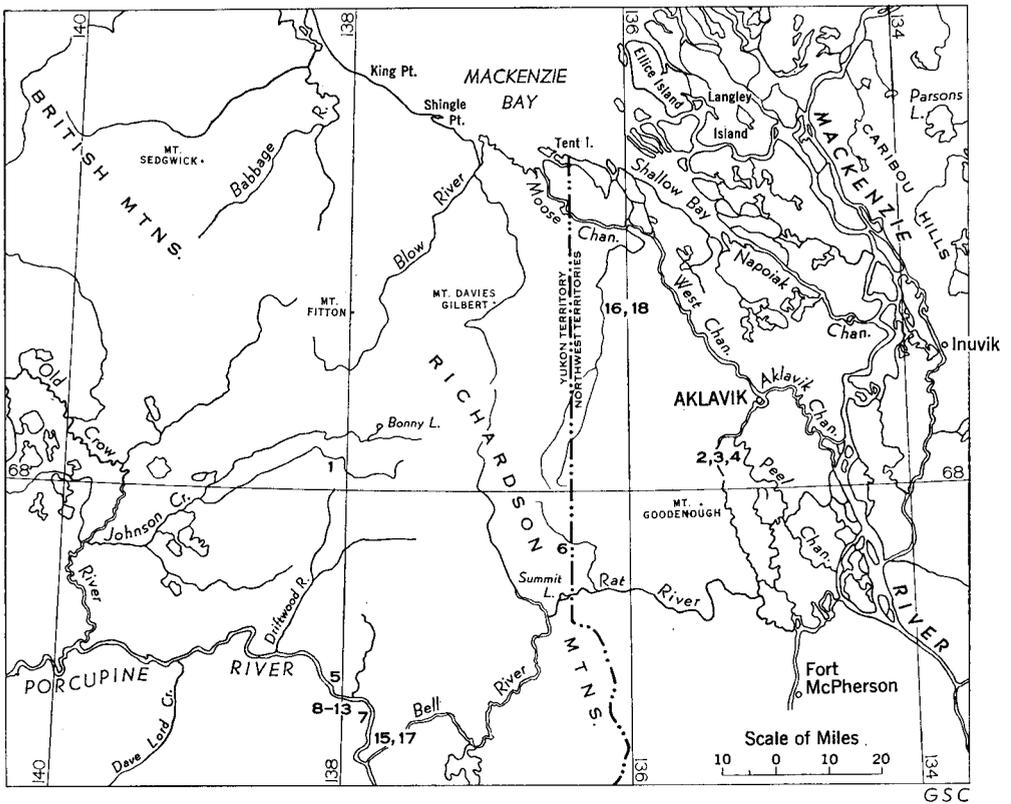


Figure 1. Middle and Upper Jurassic localities in the Richardson and British Mountains region. The exact position of locality 14 on Porcupine River between Old Crow and Bell Rivers is unknown.

FOSSIL LOCALITIES

Richardson and British Mountains Region

Numbers 1, 2, etc. correspond with those in Figure 1, p. 1

1. GSC loc. 38776 About 12 miles west-southwest of south end of Bonny Lake on south bank of the second southerly confluent of Johnston Creek south of Bonny Lake.
Erycites cf. *E. howelli* (White), *Pseudolioceras* sp. indet.
2. GSC loc. 26883 Bug Creek Canyon, Aklavik Range, about 120 to 130 yards upstream from a 100-foot high cliff on south side of stream, 4 to 5 feet above water level.
Cranocephalites borealis (Spath), *C. warreni* n. sp.
3. GSC loc. 26882 Bug Creek Canyon, Aklavik Range, west end of Canyon, loose at base of 100-foot cliff.
Cranocephalites borealis (Spath), *C. warreni* n. sp.
4. GSC loc. 26972 Bug Creek Canyon, same area as GSC locs. 26883, 26882 but loose from creek bed.
Cranocephalites warreni n. sp.
5. GSC loc. 35637 Porcupine River, northeast shore, about 21 miles downstream from mouth of Bell River, about 12 feet below top of section.
Cranocephalites borealis (Spath).
6. GSC loc. 39390 Near headwaters of Little Bell River, about 8 miles north of Summit Lake.
Cranocephalites ? sp. indet.
7. GSC loc. 37917 Porcupine River, west side, about 14 miles below mouth of Bell River.
Arctocephalites elegans Spath, Amm. gen. et spec. indet.
8. GSC loc. 35692¹ Porcupine River, northwest shore, about 19 miles downstream from mouth of Bell River, loose at base of cliff.
Cadoceras crassum Madsen, *C.* ? aff. *C. pseudishmae* Spath, *Arctocephalites elegans* Spath.
9. GSC loc. 35631¹ Same locality as GSC loc. 35692, but in situ. 3 feet above base of unit 4.
Arcticoceras kochi Spath.
10. GSC loc. 35634¹ Same locality as GSC loc. 35692, but in situ. 10 to 12 feet above base of unit 5.
Arcticoceras kochi Spath.
11. GSC loc. 35639¹ Same locality as GSC 35692, but in situ. 40 feet above base of unit 2.
Arctocephalites elegans Spath.
12. GSC loc. 35638¹ Same locality as GSC 35692, but in situ. 6 feet above base of unit 2.
Arctocephalites cf. *A. ornatus* Spath.
13. GSC loc. 35635¹ Same locality as GSC 35692, but in situ. About 9 feet above base of section.
Arctocephalites ? sp. indet.

¹The section at this locality as measured by Jeletzky (personal communication) is as follows:

Unit 5. Siltstone as in unit 2 but with several interbeds of sandy or silty shale as in unit 1 and some sandstone as in unit 4. Visible thickness to the rim of the plateau 54 feet.

Unit 4. Sandstone with clay ironstone or sandstone concretions. 18 feet.

Unit 3. Siltstone as in unit 2 but with only few concretions. 45 feet.

Unit 2. Siltstone with clay ironstone. 143 feet.

Unit 1. Shale, sandy and silty, grey with clay ironstone concretions and interbeds. Base concealed at river's level. 20 feet exposed.

14. Geol. Dept., Univ. Alberta 45413 Porcupine River, between Bell and Old Crow Rivers.
Arctocephalites elegans Spath.
15. Geol. Dept., Univ. Alberta 10097 Porcupine River, north of confluence with Bell River.
Arcticoceras kochi Spath.
Phylloceras sp. indet.
16. Geol. Dept., Univ. Alberta 10061 About 32 miles northwest of Aklavik.
Cadoceras crassum Madsen.
17. Geol. Dept., Univ. Alberta 38899 Porcupine River.
Cadoceras cf. *C. freboldi* Spath.
18. Geol. Dept., Univ. Alberta 10061 About 32 miles northwest of Aklavik.
Cadoceras sp. indet.

Canadian Arctic Islands

Numbers 1 to 9 correspond with those in Figure 2, p. 4

1. GSC loc. 35324 Prince Patrick Island. (Wilkie Point formation.¹) East side of Intrepid Inlet, 11 and 12 miles north of Cape Canning. 60 feet above beds with *Leioceras opalinum* (Reinecke).
Arkelloceras tozeri Frebold, *A. mclearni* Frebold, *Zetoceras thorsteinsoni* n. sp.
2. GSC loc. 35343 Same locality, but 120 feet above beds with *Leioceras opalinum* (Reinecke) and 60 feet above *Arkelloceras* beds.
Arcticoceras ishmae (Keyserling).
3. GSC loc. 37020 Melville Island. Wilkie Point formation. Marie Heights.
Arkelloceras tozeri Frebold.
4. GSC loc. 24664 Prince Patrick Island. Wilkie Point formation. 3 miles S30°E of Mould Bay weather station.
Cranocephalites vulgaris Spath (described in Frebold, 1957, p. 8, Pl. 7, figs. 1-2; Pl. 8, fig. 1).
5. GSC loc. 25980 Cornwall Island, mid-eastern part. Loose in river bed, derived from Jaeger formation.
Cadoceras sp.
6. GSC loc. 25864 Axel Heiberg Island. South side of Strand Fiord, 20 miles east of Cape Levvel.
Cadoceras sp. indet.
7. GSC loc. 26159 Axel Heiberg Island. Savik formation (?). 3 miles southwest of Buchanan Lake.
Cardioceras (*Scarburgiceras*) sp. indet. aff. *C. mirum* Arkell.
8. GSC loc. 35346 Mackenzie King Island. Mould Bay formation. West of Leffingwell Crags.
Amoeboceras sp. indet.
9. GSC loc. 28714 Ellesmere Island. Deer Bay formation. Reptile Creek, a little more than a mile north of Eureka weather station, Slidre Fiord area.
Dorsoplanites sp. indet. ex gr. *D. panderi* Michalski, *Dorsoplanites* sp. indet., *Pavlovia* ? sp. indet.

¹Formation names for the Jurassic rocks in the Canadian Arctic islands are used as by Tozer (Tozer, 1960).

Middle and Upper Jurassic Ammonites of the Canadian Arctic

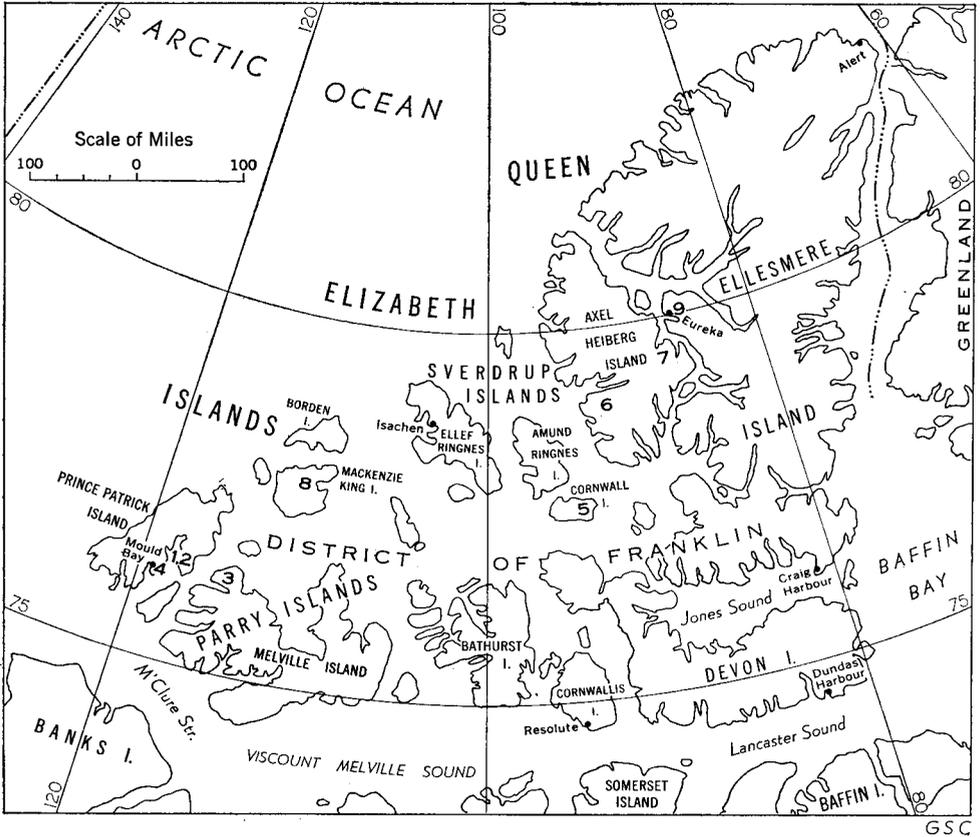


Figure 2. Middle and Upper Jurassic localities in the Canadian Arctic islands.

DESCRIPTION OF AMMONITES

Family PHYLLOCERATIDAE Zittel, 1884

Subfamily PHYLLOCERATINAE Zittel, 1884

Genus *Zetoceras* Kovacs, 1939

Zetoceras thorsteinssoni n. sp.¹

Plate VI, figure 1; Plate VII, figure 1; Plate VIII, figure 1;
Plate IX, figure 2

Holotype. GSC 15144, Plate VI, figure 1; Plate VII, figure 1; Plate VIII, figure 1.

Material. One specimen (holotype) and one fragment (GSC 15145) collected by Thorsteinsson in the *Arkelloceras* beds in the type section of the Wilkie Point formation, Prince Patrick Island, GSC loc. 35324.

Description. The maximum diameter of the holotype is 210 mm. At diameters of 210 and 143 mm the following measurements, in millimetres, were taken:

Diameter	Whorl height	Whorl thickness	Umbilical width
210	approx. 122 (0.58)	approx. 68 (0.32)	approx. 12 (0.06)
143	83 (0.58)	48 (0.33)	10 (0.06)

The specimen is septate to its end, the living chamber is unknown. The form is laterally compressed, involute, the cross-section is high oval, the flanks are only slightly convex, the greatest thickness is somewhat below half their height, the transition to the narrow venter and the umbilicus is gradational. The umbilicus is narrow, without walls. The shell is not preserved except for a small part on one side of the inner whorls, where fine striae are present.

The suture lines follow one another closely and are deeply incised, the first lateral is much deeper and the second lateral slightly deeper than the ventral lobe. The endings of the lateral saddles are typically tetraphyllic as in the genus *Zetoceras*. Owing to imperfect preservation not every detail of the suture line can be studied.

Remarks. This new species is similar, particularly in its general shape, to the type species of the genus *Zetoceras*, i.e. *Z. zetes* d'Orbigny (1847, p. 247) (= *A. heterophyllus amalthei* Quenstedt, 1846, p. 100, Pl. 6, figs. 1a, b; and *A. heterophyllus* Quenstedt, 1882-83, p. 311, Pl. 40, fig. 1). However, Quenstedt's specimen (Quenstedt, 1846, Pl. 6, fig. 1b) seems to have a steeper umbilical slope than *Z. thorsteinssoni*. Furthermore, Quenstedt's specimens have fine constrictions which are not visible (perhaps not preserved) in *thorsteinssoni*, and a slightly wider umbilicus. Quenstedt's specimens belong in the zone of *Amaltheus margaritatus* of the upper Pliensbachian and are therefore older than *thorsteinssoni*.

¹The species is named for Dr. R. Thorsteinsson, Geological Survey of Canada.

Occurrence. *Zetoceras thorsteinssoni* was found in the *Arkelloceras* beds, associated with *A. tozeri* Frebold, *A. mclearnii* Frebold and *Inoceramus lucifer* Eichwald.

Genus *Phylloceras* Suess, 1865

Phylloceras sp. indet.

Plate V, figure 3

Material. One specimen (Geol. Dept., Univ. Alberta locality 10097, GSC plastotype 15146) collected on Porcupine River, north of confluence with Bell River, Richardson Mountains.

Description. The small specimen (maximum diameter 42 mm) is very involute, the flanks are slightly convex and grade into the narrow, rounded venter. The transition to the umbilicus is more abrupt. The suture line has triphyllic saddles. No sculpture is visible.

Remarks. Specific identification of this small specimen is not warranted. The general shape and the triphyllic saddle endings indicate the genus *Phylloceras*. The specimen is clearly distinguished by its triphyllic saddles from *Zetoceras thorsteinssoni* n. sp. described above.

Occurrence. Middle Jurassic; the stratigraphic position of the specimen is unknown and accurate age determination is not possible.

Incertae sedis

Ammonites sp. indet.

Plate II, figure 3

aff. *Scaphites ventricosus* McConnell, 1891, p. 123D

Material. One specimen GSC 15137, collected by McConnell in 1888 on Porcupine River, GSC loc. 37917.

Description. The ammonite was mentioned in McConnell's report (1891, p. 123D) as follows:

They (the shales) yielded some fossils, among which is a very large belemnite, a finely ribbed ventricose scaphite, which has some resemblance to *Scaphites ventricosus*, and a peculiar ammonitoid shell, which shows a ribbed central portion, while the outer whorl is quite smooth. Mr. Whiteaves states that the fossils are probably Benton, but the specimens are too imperfect to make the correlation certain.

The specimen has been broken and is somewhat distorted. The anterior part of the last whorl was broken off and twisted, but if turned into its proper place it would seem to be the natural continuation of the preceding part of the whorl. This immediately preceding part is also broken and slightly distorted, but is still in direct contact with the remaining and best preserved part of the ammonite. This part has an almost occluded umbilicus with fairly steep but not perpendicular walls

which form a rounded obtuse angle with the convex flanks. These grade into the fairly broad and rounded venter. It is not possible to say to what degree the more or less globose shape of the specimen was caused or accentuated by secondary distortion.

On the umbilical wall are numerous fine, narrowly spaced, backward-bent ribs. On the flanks the primaries swing forward and are considerably thicker. At about the middle of the flanks the ribs bifurcate and the secondaries cross the venter almost transversely. In the two broken anterior parts of the whorl the ribs grow gradually thicker. A constriction seems to be present at the posterior end of the youngest whorl part. No suture line is visible.

Remarks. The specimen resembles in the type of ribbing, the general shape and the almost occluded umbilicus, certain forms described by Imlay (1953) as *Kheraicerias* but none of Imlay's species reaches the degree of globosity of the present specimen, which degree, however, may have been caused by secondary distortion. Also, some of the small ammonites, described by Imlay as *Xenocephalites*, as for example *X. hebetus* Imlay, (Imlay, 1953, p. 78, Pl. 29, figs. 8, 11) have a certain similarity, but have much stronger ribs and are less globose. By its greater globosity the specimen may also be distinguished from representatives of the Sphaeroceracea.

The unsatisfactory preservation of this interesting specimen does not permit generic or specific identification. It is, however, the first specimen found in the Canadian Arctic that belongs to a group hitherto unknown in this region.

Occurrence. McConnell's report (1891, p. 123D) merely states that this and the other ammonites (which belong to *Arctocephalites*) came from shales, approximately 800 feet thick. It is unknown whether these fossils came from one and the same bed or were found at different levels. It is therefore not known whether the specimen is the same age as *Arctocephalites*. Imlay's Alaskan *Kheraicerias* and small *Xenocephalites* with which certain similarities exist, were found associated with *Paracadoceras*, *Gowericeras*, and *Cadoceras* and are accordingly placed in the Callovian.

Family HAMMATOCERATIDAE Buckman, 1887

Subfamily HAMMATOCERATINAE Buckman, 1887

Genus *Erycites* Gemmellaro, 1886

Erycites cf. *E. howelli* (White)

Plate V, figure 2

Ammonites (Lillia) howelli White, 1889, pp. 68-69, Pl. 12, figs. 1, 2; Pl. 14, figs. 1-3.
Erycites howelli Imlay, 1955, p. 90, Pl. 13, figs. 12, 13.

Holotype. *Ammonites (Lillia) howelli* White, 1889, Pl. 12, figs. 1, 2.

Material. Several poorly preserved fragments and imprints collected by Jeletzky about 12 miles west-southwest of Bonny Lake, GSC loc. 38776.

Description and remarks. Only one fragment (GSC 15139) is well enough preserved for description. The whorl fragment has the same type of ribbing as White's holotype and the small part of the venter preserved shows the low blunt keel. The rubber cast made of the imprint of the venter of the preceding whorl (*see* Pl. V, Fig. 2) shows the blunt keel, the shallow smooth zones on each side and the ribs. This venter is very similar to the one figured by Imlay (1955, Pl. 13, fig. 12) of a specimen from northern Alaska.

Occurrence. Associated with poorly preserved *Pseudolioceras*. According to Imlay (*loc. cit.*, p. 90) the species is associated in northern Alaska with *Pseudolioceras* and in southwestern Alaska with *Pseudolioceras whiteavesi* (White) and *Tmetoceras*. The age is probably early Bajocian.

Family STEPHANOCERATIDAE Neumayr, 1875

Genus *Arkelloceras* Frebold, 1957

Type species. *Arkelloceras tozeri* Frebold, 1957, pp. 9-11, Pl. 9, figs. 1-3; Pl. 10, figs. 1, 2; Pl. 11, figs. 1, 2.

The description of this genus was based on specimens collected by Tozer in 1954 on Prince Patrick Island on the east side of Intrepid Inlet, 10 miles north of Cape Canning. Unfortunately none of the comparatively well preserved specimens showed a complete and fully recognizable suture line. Thorsteinsson and Tozer revisited the area in 1958 and collected more specimens between 11 and 12 miles north of Cape Canning. This new material contains some specimens with fairly well preserved suture lines.

In the definition of the genus, given previously (Frebold, *op. cit.*, p. 9) it was stated that *Arkelloceras* has some superficial similarities to certain species of *Garantiana*, but no relationship between the two genera could be established. The new material shows the suture line of *Arkelloceras* to be entirely different from that of *Garantiana*. In *Arkelloceras* it is more complicated (*see* Pl. IV, figs. 1, 2; Pl. V, figs. 1a-c) with a ventral lobe equal in length to the first lateral lobe, which is trifold and much longer than the second lateral lobe. The suspensive lobe is not much retracted. The two lateral saddles are more or less trifold and almost equal in size. The suture line of *Garantiana* is much simpler, has bifid lateral saddles and a ventral lobe much longer than the first lateral lobe. Other Parkinsoniids with certain superficial similarities to *Arkelloceras*, for example *Strenoceras* Hyatt, also have a much simpler suture line than *Arkelloceras*.

As previously stated in the definition of the genus (Frebold, *loc. cit.*), adult specimens of *Arkelloceras* are very similar to representatives of *Cranocephalites* Spath. Among the new specimens are some large ones (specimens GSC 15241, 15140, Pl. III, fig. 1; Pl. IV, fig. 1, one of them with a maximum diameter of 145 mm) which, at the end of the body chamber have a wide and fairly deep constriction similar to that of *Cranocephalites*. The umbilicus becomes consequently wider and the whorl height lower. The peristome is more or less trumpet-shaped

as is so in *Cranocephalites vulgaris* Spath (see Spath, 1932, p. 21, Pl. 8, fig. 1a). The suture lines of the two genera are not identical but they are more similar to each other than those of *Arkelloceras* and *Garantiana*. The main differences between *Arkelloceras* and *Cranocephalites* are the kosmoceratid-like younger whorls of the former, which are entirely absent in *Cranocephalites*, as can be seen from the young specimens of this genus figured by Spath (Spath, 1932, Pl. 1, fig. 3b; Pl. 5, fig. 2b; Pl. 10, fig. 3b). Furthermore, it can be stated that young and medium-sized *Arkelloceras* have a wider umbilicus than *Cranocephalites*. The systematic position of the genus is debatable. Though similar in adult stage to *Cranocephalites*, which according to Arkell (1957, p. L301) belongs to the Cadoceratinae, *Arkelloceras* cannot be placed in this family on account of its inner whorls. The suture line of *Arkelloceras* also precludes assignment to the Parkinsoniidae despite certain other similarities. The genus is here tentatively placed in the Stephanoceratidae—which include some genera with ventral furrow, as for example *Ermoceras* H. Douvillé, 1916, and *Telermoceras* Arkell. There is, however, no close relationship of these genera with *Arkelloceras*.

The stratigraphic position of *Arkelloceras* was found by Tozer (1956, pp. 19, 20; see also Frebold, 1957b, pp. 10, 24, 25) to be 45 feet above the beds with *Leioceras opalinum* and it seemed reasonable to suggest that the *Cranocephalites* beds occupy about the same position as the *Arkelloceras* beds. At that time the age of the *Cranocephalites* beds was considered to be late Bathonian or early Callovian, an opinion which seems to have been disproved by Callomon's recent stratigraphic studies in East Greenland. Callomon (1959, pp. 507, 508) has reached the conclusion that the '*Cranocephalites* beds' containing the *C. pompeckj-vulgaris* fauna are of early Bathonian age, whereas the older zones of *Cranocephalites indistinctus* Callomon and *C. borealis* (Spath) were placed in the upper Bajocian. The writer is inclined to follow Callomon in his view of an older age of *Cranocephalites* than previously assumed. If the bed with *Cranocephalites vulgaris* is actually of about the same age as the *Arkelloceras* beds, the latter would then, as a consequence, be about early Bathonian age. The author (1957, pp. 24, 25) has already mentioned the possibility that *Arkelloceras* could be late Bajocian in age, mainly because *Inoceramus lucifer* Eichwald, which in Prince Patrick Island is associated with *Arkelloceras*, is unknown from beds younger than Bajocian. It seems therefore reasonable to place *Arkelloceras* close to the Bajocian-Bathonian boundary. A Callovian age is definitely ruled out since Thorsteinsson and Tozer (personal communication, Frebold, 1958, p. 31, footnote 1) recently found *Arkelloceras* 60 feet below *Arcticoceras* which, according to Callomon (1959, pp. 507, 508), now has to be considered as late Bathonian in age.

A few fragmentary specimens were found by Thorsteinsson and Tozer in 1958 on Melville Island. Unfortunately the specimens did not give any further information on the stratigraphic position of the genus.

The definition of the genus *Arkelloceras* is repeated here with additions as to its suture line, stratigraphic and systematic position: Medium-sized (diameter as much as 145 mm), fairly evolute ammonites, whorls thicker than high. Young

specimens with fairly strong, sharp ribs, on venter forming elongated tubercle-like thickenings that border a flat almost smooth peripheral zone. In this young stage fine lines connect alternating ribs of both sides on the venter forming a zigzag pattern. At medium stages of growth venter is rounded, smooth zone reduced in size, and alternation of ribs on both sides of peripheral zone very clear. Later stages of growth, alternation irregular, mature specimens with smooth venter. Body chamber with fairly wide terminal constriction and trumpet-like peristome. Suture line fairly incised, ventral and first lateral lobes of equal length, second lateral lobe smaller than the first, suspension lobe not retracted. Lateral saddles more or less trifold. This genus is clearly distinguished from *Cranocephalites* by its kosmoceratid-like inner whorls, whose ventral region resembles that of certain species of the upper Bajocian genus *Garantiana*. In most species of *Garantiana* the ventral furrow, usually bordered on both sides by rows of tubercles, is retained in all stages of growth contrary to *Arkelloceras*. Furthermore, *Garantiana* has nodes on the flanks which are absent in *Arkelloceras*, and a much simpler suture line that has, contrary to *Arkelloceras*, a ventral lobe much longer than the first lateral. Stratigraphic position probably upper Bajocian-lower Bathonian. Tentative systematical position: Stephanoceratidae Neumayr, 1875.

Family CARDIOCERATIDAE Siemiradzki, 1891

Subfamily CADOCERATINAE Hyatt, 1900

Genus *Arctocephalites* Spath, 1928

Arctocephalites elegans Spath

Plate IX, figure 1; Plate X, figures 1a, b, 2; Plate XI, figures 1a, b, 2, 3, 4

Arctocephalites elegans Spath, 1932, pp. 37, 38, Pl. 10, figs. 4a, b.

Material. Specimens GSC 15113 and 15114 found in situ 40 feet above base of Jeletzky's unit 2 (GSC loc. 35639), specimens 15111 and 15115 at the same locality, but loose at base of cliff (GSC loc. 35692). Specimen 15108 collected by F. J. Hamilton in the Richardson Mountains no precise locality (GSC loc. 13136), specimen 15112 collected by R. G. McConnell in 1888 on west side of Porcupine River (GSC loc. 37917), specimen Geology Department, University of Alberta No. 45413 (GSC plastotype 15109) collected by F. J. Hamilton on Porcupine River between Bell and Old Crow Rivers.

Description. The dimensions in millimetres of some of the specimens are:

GSC No.	Diameter	Whorl height	Whorl thickness	Umbilical width
15111 (Pl. IX, fig. 1)	75	38 (0.51)	41 (0.55)	8 (0.10)
15113 (Pl. XI, fig. 3)	72	38 (0.53)	32 (0.44)	7 (0.10)
15114 (Pl. X, fig. 2)	72	38 (0.53)	34 (0.47)	7 (0.10)
15115 (Pl. X, figs. 1a, b)	72	38 (0.53)	34 (0.47)	approx. 8 (0.11)
15112 (Pl. XI, fig. 4)	62	31 (0.50)	31 (0.50)	8 (0.12)
15108 (Pl. XI, figs. 1a, b)	58	31 (0.53)	28 (0.48)	6 (0.10)

With the exception of the largest specimen, the whorl cross-sections of all specimens are higher than thick, the umbilicus is narrow, fairly deep and has steep walls, the umbilical shoulder is rounded, the flanks are slightly convex and grade into the arched venter.

Up to a diameter of about 60 to 70 mm the specimens have fairly sharp, more or less forwardly inclined ribs. The type of ribbing is well illustrated on Plate XI, figure 1a. Some of the ribs bifurcate, others are tripartite. The point of division is at about half the height of the flanks.

The body chamber is almost entirely smooth but at its end some faint folds may be present, particularly on the venter. In some specimens a deep strongly forwardly inclined terminal furrow that reaches down to the umbilical wall is preserved. No good suture line could be studied.

Remarks. The specimens described here are very similar in general outline and type of ribs to *Arctocephalites elegans* Spath. Unfortunately Spath figured only one specimen of this species, so that its variations cannot be ascertained. *A. nudus* Spath (Spath, 1932, pp. 35-37, Pl. 9, figs. 3a, b; Pl. 11, figs. 1a, b, 7a, b; Pl. 12, figs. 4a, b; Pl. 15, figs. 2a, b) and *A. koettlitzii* Pompeckj (Pompeckj, 1900, pp. 70-73, Pl. 2, figs. 12a-c) are related but are less laterally compressed. *A. greenlandicus* Spath (Spath, 1932, pp. 34, 35, Pl. 9, figs. 1a, b; Pl. 10, fig. 1) is a considerably larger species. The specimen of *A. elegans* GSC 15108 (Pl. XI, figs. 1a, b) that does not have the smooth body chamber preserved, has a ribbing similar to that of immature specimens of *Dolikephalites* of the *Typicus* group, but adult specimen is considerably larger and he (1932, p. 38) states that the umbilicus of the 1a, b) retain their ribs to a much larger diameter than *A. elegans*.

The dimensions of Spath's figured holotype of *A. elegans* do not compare too well with the measurements of the specimens described here, however, Spath's specimen is considerably larger and he (1932, p. 38) states that the umbilicus of the holotype narrows from 18 per cent to 7 per cent with the increase in size.

Occurrence. In East Greenland *A. elegans* Spath is one of the guide fossils of the zone of *Arctocephalites nudus* (see Callomon, 1959, p. 508). In the Richardson Mountains the species was found below *Arcticoceras* and above *Arctocephalites* ? sp. indet.

Arctocephalites cf. *A. ornatus* Spath

Arctocephalites ornatus Spath, 1932, p. 39, Pl. 8, fig. 3; Pl. 11, fig. 5.

Holotype. *Arctocephalites ornatus* Spath, 1932, Pl. 8, fig. 3.

Material. One specimen (GSC 15110) collected by Jeletzky 6 feet above the base of his unit 2 on the northwest shore of Porcupine River, GSC loc. 35638.

Description. The specimen is somewhat crushed, the last whorl belongs apparently to the body chamber. Part of the preceding whorl is visible, the size of the umbilicus is indeterminable. Most of the last whorl is entirely smooth, but in its anterior part blunt costae are present which are strongest on the fairly broad venter. Part of a strongly inclined terminal furrow is preserved on one flank.

The preceding whorl has fairly sharp ribs on its outer part, on its inner part they are faint. The ribs are bifurcating somewhat below the middle of the flank, some intercalated secondaries are present.

Remarks. The specimen is similar to the *Arctocephalites?* sp. indet. described below, but the ventral costae in the anterior part of the whorl are not as strong. *A. ornatus* Spath is similar in general shape and particularly in the re-appearance of ribs in the anterior part of the body chamber, however, as the specimen is unsatisfactorily preserved, no direct identification is warranted.

Occurrence. Six feet above base of Jeletzky's unit 2. In East Greenland *A. ornatus* Spath is common in the zone of *A. nudus*.

Arctocephalites? sp. indet.

Material. One fragmentary specimen (GSC 15107) found at about 9 feet above the base of Jeletzky's section on the northwest shore of Porcupine River, GSC loc. 35635.

Description. The specimen does not show the inner whorls and part of the last preserved whorl is missing. The posterior end of the whorl has fairly sharp, moderately forwardly inclined ribs that are divided close to the umbilical margin. The next preserved part of the whorl which belongs to the body chamber is entirely smooth, but the anterior third of the whorl has fairly strong blunt ribs that are strongest on the rounded venter where they are bent forward.

Remarks. The re-appearance of ribs after a smooth stage might suggest that the specimen belongs to the subgenus *Cranocephalites* Spath. However, none of Spath's species could be identified with it. The specimen is distinguished mainly by the shape of the ribs, which are protracted on the venter contrary to Spath's species in which the ventral ribs are more or less straight and weaker than stronger. It is possible that the specimen belongs to such forms of *Arctocephalites* Spath, as *Arctocephalites ornatus* Spath (Spath, 1932, pp. 14, 39) which are transitional to *Cranocephalites*, as indicated by a recrudescence of ribbing near the mouth border. It is probably closely related to *Arctocephalites* cf. *A. ornatus* Spath described above.

Occurrence. Nine feet above base of section on Porcupine River, about 30 feet below *Arctocephalites elegans* Spath.

Subgenus *Cranocephalites* Spath

Cranocephalites borealis (Spath)

Plate I, figures 1 to 4

Xenocephalites borealis Spath, 1932, pp. 44, 45, Pl. 14, figs. 4a-d.
Cranocephalites borealis (Spath). Callomon, 1959.

Holotype is *Xenocephalites borealis* Spath, 1932, Pl. 14, figs. 4a-d.

Material. Five specimens collected by Jeletzky in the Bug Creek formation in Bug Creek Canyon, Aklavik Range, GSC loc. 26883; two specimens collected at west end of Bug Creek Canyon, GSC loc. 26882; some small fragmentary specimens collected by Jeletzky on the northeast shore of Porcupine River (from Jeletzky's unit 18), GSC loc. 35637.

Description. Specimen GSC 15104 (Pl. I, fig. 1) is the largest in the collection from locality 26883. The dimensions in millimetres of this specimen at two different diameters are:

Diameter	Whorl height	Whorl thickness	Umbilical width
62	28 (0.45)	29 (0.47)	14 (0.23)
52	28 (0.54)	27 (0.52)	8 (0.15)

The umbilicus is narrow in early stages of growth but opens considerably near the anterior end of the whorl where a fairly shallow terminal furrow reaches the umbilical region. In the posterior part of the last whorl the umbilical wall is deep and steep, its slope becoming more gentle in the anterior part. The greatest thickness of the whorl is close to the rounded umbilical shoulder, the flanks are very gently convex and grade into the slightly rounded venter. About three quarters of the whorl belongs to the body chamber. The last whorl is entirely smooth but there are three or four faint spiral lines on the flanks which run parallel to the umbilical shoulder. These spiral elements were not seen on other specimens.

The suture line is well preserved. The first lateral lobe reaches farther down than the ventral lobe. The lateral saddles are bifid.

Specimen GSC 15103 (Pl. I, figs. 3a, b) which is smaller than the specimen described above shows that the costation disappears at a diameter of about 43 mm at about the end of the septate stage. After removal of part of the body chamber the ribs are clearly seen at the end of the preceding whorl. They are strongest on the venter from where they thin towards the half height of the flanks. At this stage of growth no ribs are visible on the inner part of the whorl. The flanks become smooth first, the last indications of ribs are on the venter.

The small specimen GSC 15102 (Pl. I, figs. 4a, b) has a deep and narrow umbilicus, a cross-section slightly thicker than high. The anterior half of the last whorl belongs to the body chamber. The posterior septate part of the whorl has ribs which at the posterior end reach down to the umbilical margin. In this part of the whorl bifurcation of the ribs at about half the height of the flanks can be seen. With increasing growth the ribs gradually disappear from the flanks and eventually from the venter also. This last stage is reached in the posterior part of the body chamber.

Fig. 2b on Pl. I shows a cross-section of a smaller specimen (GSC 15101) from GSC loc. 26882.

The specimens from GSC loc. 35637 are all very small and fragmentary but show the features characteristic of the inner whorls of the species.

Remarks. Spath (1932, pp. 44, 45) had assigned the single small specimen described by him to *Xenocephalites* Spath. On the basis of more and better material collected in East Greenland, Callomon (1959, p. 507) stated that the species actually belongs to *Cranocephalites*. Spath's and Callomon's figures of the species agree perfectly with the Canadian specimens.

Occurrence. In East Greenland *Cranocephalites borealis* is the index fossil of the zone which, according to Callomon (loc. cit.) is the lowermost Middle Jurassic fossil zone known in East Greenland. In Canada the species has not been found in the Richardson Mountains in the younger *Cranocephalites*, *Arctocephalites*, or *Arcticoceras* beds, a fact that suggests indirectly that it is older than these beds.

*Cranocephalites warreni*¹ n. sp.

Plate II, figures 1a to 2b, 4

Holotype. Specimen GSC 15105, Pl. II, figs. 1a, b.

Material. Three specimens from different localities in Bug Creek Canyon, Aklavik Range, collected by Jeletzky. Specimen GSC 15105 is from GSC loc. 26883; specimen GSC 15136 is from GSC loc. 26882; specimen GSC 15135 is from GSC loc. 26972.

Description. The dimensions in millimetres of the holotype (Pl. II, figs. 1a, b) at two different diameters are:

Diameter	Whorl height	Whorl thickness	Umbilical width
67	30 (0.45)	39 (0.58)	15 (0.22)
59	29 (0.49)	38 (0.64)	10 (0.17)

The umbilical width increases rapidly towards the end of the body chamber which comprises more than half of the last whorl. Part of a strongly inclined terminal furrow is preserved. The umbilicus has high and steep walls, the umbilical shoulder is rounded and the slightly convex flanks grade into a high, arched venter. The greatest thickness of the whorl is at the umbilical shoulder and the cross-section (see Pl. II, fig. 1b) is egg-shaped.

There is no costation on the last whorl, but one of the inner whorls exposed in the cross-section has the same coarse ribs as *C. borealis*. The suture lines which follow one another very closely are similar to those of *C. borealis*.

Remarks. This species is very similar to *Cranocephalites borealis* (Spath) in all features except that it has a distinctly oval cross-section whereas that of *C. borealis* (Spath) is more laterally compressed, has less convex flanks and an almost flat venter. These differences are also present in other GSC specimens of *C. warreni* n. sp. not figured in this report.

Occurrence. The holotype was found in situ in the bed with *Cranocephalites borealis*.

¹ The species is named for Dr. P. S. Warren, University of Alberta.

Cranocephalites ? sp. indet.

Material. One large whorl fragment (GSC 15106) collected approximately 8 miles north of Summit Lake, GSC loc. 39390.

Description. The specimen represents about two thirds of a large whorl of an evolute ammonite approximately 146 mm in diameter. The flanks are slightly convex, the venter is almost flat, slightly rounded. The transition to the umbilicus seems to be gradual. In the posterior part of the whorl are widely spaced broad but not strong ribs which disappear on the venter. In the anterior part, however, are coarse folds on the venter. The imprint of the venter and the outer part of the flanks of the preceding whorl show fairly strong ribs which are interrupted in the centre of the venter by an almost smooth zone.

Remarks. Although the specimen is not determinable, the type of ribbing suggests the subgenus *Cranocephalites* Spath.

Occurrence. Five hundred and ninety-five feet above base of Jurassic. Probable age Middle Jurassic, older than Callovian.

Genus *Arcticoceras* Spath, 1924*Arcticoceras ishmae* (Keyserling)

Plate X, figure 3; Plate XIII, figures 1a, b; Plate XIV, figures 1, 3a, b

Ammonites ishmae Keyserling, 1846, p. 331, Pl. 20, figs. 8-10.

Macrocephalites ishmae Sokolov, 1912, pp. 17, 49, Pl. 1, fig. 1.

Arcticoceras ishmae Spath, 1932, p. 50, Pl. 15, figs. 7a, b.

Holotype. *Ammonites ishmae* Keyserling (Keyserling, 1846, p. 331, Pl. 20, figs. 8, 9).

Material. Four more or less fragmentary specimens (GSC 15119, 15120, 15121, 15122) from the type locality of the Wilkie Point formation, Prince Patrick Island, 60 feet above top of *Arkelloceras* beds. Collected by Thorsteinsson, GSC loc. 35343.

Description. The best preserved specimen (GSC 15119, Pl. XIII, figs. 1a, b) has a diameter of about 84 mm, a whorl height of 44 mm (0.52), a whorl thickness of 37 mm (0.44) and an umbilical width of about 15 mm (0.18). The specimen is septate to the end of the last whorl. The umbilicus is fairly deep, the last whorl having a high perpendicular wall, the wall of the penultimate whorl is less deep. The last whorl embraces most of the penultimate one which in turn embraces less of the third whorl. The involution of the specimen is thus increased with growth.

The posterior end of the last whorl has moderately inclined ribs that cross the arched venter forming a sinus.

The suture line of the last whorl is badly worn but seems to follow the pattern of that of the figures given by Keyserling (1846, Pl. 22, fig. 15) and that of *A. kochi* Spath (Spath, 1932, p. 54, text-fig. 3a).

The fragment GSC 15120 (Pl. XIV, fig. 3a) is part of a body chamber and entirely smooth, figure 3b on Plate XIV is a squeeze of the impression of the preceding whorl, showing the comparatively fine ribs. Specimen GSC 15122 is an unseptate whorl fragment with tripartite ribs prevailing. Plate X, figure 3 is a squeeze of the impression of the preceding whorl with bifurcating, fairly fine ribs. Specimen GSC 15121 (Pl. XIV, fig. 1) shows well-preserved suture lines, and a young whorl that has a comparatively wider umbilicus than more adult specimens.

Remarks. The degree of involution and the finer ribs of all the specimens show that they belong to *Arcticoceras ishmae* (Keyserling), and not to *A. kochi* Spath which is more involute and has more robust ribs.

Occurrence. In the type section of the Wilkie Point formation on Prince Patrick Island, 60 feet stratigraphically above the beds with *Arkelloceras* and 120 feet above the *Leioceras opalinum* zone.

Arcticoceras kochi Spath

Plate IX, figure 3; Plate XII, figures 1a, b; Plate XVI, figure 2

Arcticoceras kochi Spath, 1932, pp. 53-56; Pl. 12, fig. 1; Pl. 13, figs. 4, 5; Pl. 14, figs. 1-3; Pl. 15, figs. 1, 4-6.

Holotype. *Arcticoceras kochi* Spath, 1932, Plate 15, figure 1.

Material. Specimen GSC 15116 from Jeletzky's unit 4, 3 feet above its base on the northwest side of Porcupine River, GSC loc. 35631. Specimen 15117 from the same locality, but from unit 5, 10 to 12 feet above its base, GSC loc. 35634. Geology Department, University of Alberta locality 10097 (GSC plasto-type 15118) from Porcupine River (probably same locality as above), collected by British American Petroleum Company, apparently loose.

Description. The large specimen GSC 15116 (Pl. XII, figs. 1a, b) shows secondary lateral compression and the venter is sharpened like Spath's large crushed specimen (Spath, 1932, p. 54, Pl. 13, fig. 4; Pl. 14, fig. 1). The ribs are fairly robust in the posterior half of the whorl, in the anterior part they become gradually weaker beginning with the flanks, and eventually disappear entirely. On the outer half of the whorl the ribs are inclined forward and form a sinus on the venter. No suture line is visible on the last whorl of this specimen.

The smaller specimen GSC plasto-type 15118 (Pl. XVI, fig. 2) is somewhat crushed ventrally and only one side is preserved so no reliable measurements can be taken. The umbilicus is very narrow (about 15 per cent of the diameter) and deep with perpendicular walls. The last whorl embraces all preceding ones. The flanks are convex and grade into the rounded venter. The primaries begin in the upper part of the umbilical wall, where they are thin. On the innermost part of the flanks they are almost radial, in their outer part they are strongly inclined forward. They cross the venter forming a sinus. Most of the ribs bifurcate, only a few are divided into three branches. No suture line is visible.

The small poorly preserved specimen GSC 15117 (Pl. IX, fig. 3) has a wide umbilicus and finer ribs.

Remarks. The specimens agree well with Spath's description and figures of *Arcticoceras kochi* Spath, the large compressed specimen (Pl. XII, figs. 1a, b) is very similar to Spath's large specimen (Spath, 1932, Pl. 15, fig. 1). The wide umbilicus of young East Greenland specimens of this species is also present in the Canadian young forms. Spath (op. cit., p. 53) stated that *Arcticoceras kochi* Spath is "an extremely close ally of *A. ishmae*, differing chiefly in greater inflation, more robust ornamentation and a more decided forward sweep of the ribs". The great similarity between the two 'species' is also confirmed by the Richardson Mountains material as shown by the comparison of the here described medium-sized specimen of *A. kochi* (Pl. XVI, fig. 2) with Spath's figure (op. cit., Pl. 15, figs. 7a, b) of a typical *A. ishmae* (Keyserling) from the Petschora region. The main difference of the two specimens is in the ribs which are coarser in the example described here. Specimens of *Arcticoceras* hitherto collected in Prince Patrick Island have all shown finer ribs and are accordingly described as *A. ishmae* (Keyserling).

Occurrence. Those specimens that were collected in situ came from a stratigraphic level higher than that with *Arctocephalites elegans*. In East Greenland largely the same relationships were found but an association of both genera has also been observed.

Genus *Cadoceras* Fischer, 1882

Cadoceras crassum Madsen

Plate XIV, figure 2; Plate XVII, figure 1

Cadoceras crassum Madsen, 1904, p. 193; Pl. 9, figs. 1-3; Pl. 10, fig. 1.

Cadoceras cf. *crassum* Sokolov and Bodylevsky, 1931, p. 78.

Cadoceras crassum Spath, 1932, pp. 64, 65; Pl. 16, figs. 3a, b.

Holotype. Madsen's specimen Pl. 9, figs. 1, 2, 3; Pl. 10, fig. 1.

Material. One specimen, University of Alberta locality 10061 (GSC plasto-type 15124), collected by British American Petroleum Company about 32 miles northwest of Aklavik; and one whorl fragment (GSC 15125) collected by Jeletzky loose at base of a cliff on northwest shore of Porcupine River, GSC loc. 35692.

Description. Specimen, Geology Department, University of Alberta 10061 (Pl. XIV, fig. 2) is evolute, has a wide umbilicus, rounded umbilical slope and rounded venter. It is septate to the end of the whorl. At the beginning of the last whorl the ribs are bifurcating, at its end trifurcating ribs are also present. The point of division is about half the height of the flanks. They are fairly strong on the flanks and particularly on the venter. They are thinner on the umbilical wall. The dimension in millimetres of this specimen are:

Diameter	Whorl height	Whorl thickness	Umbilical width
67	27 (0.40)	38 (0.57)	18 (0.27)

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Specimen GSC 15125 (Pl. XVII, fig. 1) which is septate to the end has the same type of ribbing and a similar whorl shape.

Remarks. The specimen from University of Alberta locality 10061 (GSC 15124) is similar to the small specimen figured by Spath but has a smaller whorl thickness. This minor difference is not considered important enough to separate this species from *Cadoceras crassum* Madsen. Madsen (loc. cit.) and Spath (loc. cit.) have already mentioned the affinities and differences of this species in comparison with *Cadoceras elatmae* Nikitin. These differences are very clear in the specimens figured by Nikitin in his first paper (1881, Pl. 11, figs. 20-23) but the smaller specimen figured by him under the same name in another paper (1898, Pl. 8, fig. 27) is so similar to both Spath's Greenland specimen and the ones described here that they are hardly distinguishable. However, the possible identity of these forms with part of Nikitin's species cannot be established on the basis of the material available to the writer. Another related species is *Cadoceras frebaldi* Spath (op. cit., pp. 65-67, Pl. 18, figs. 2a, b), which has a more arched venter and stronger ribs in an adult stage.

Occurrence. The exact stratigraphic position of the two described specimens is unknown. According to Spath (1932, p. 65) *Cadoceras crassum* occurs in East Greenland in the bed with *Keplerites tychonis* Ravn (lower Callovian), but Callomon (1959, p. 508) places this species in the zone of *Arctocephalites greenlandicus* (middle Bathonian).

Cadoceras cf. *C. frebaldi* Spath

Plate XV, figures 1a, b

Cadoceras frebaldi Spath, 1932, pp. 65-67, Pl. 18, figs. 2a, b.

Holotype. *Cadoceras frebaldi* Spath (Spath, 1932, pp. 65-67, Pl. 18, figs. 2a, b).

Material. One specimen from University of Alberta locality 38899 (GSC plastotype 15123), collected by British American Petroleum Company at Porcupine River.

Description. The maximum diameter of this specimen is about 86 mm. The anterior part of the last whorl, which is septate to its end and is slightly crushed, still shows a highly arched venter, also present in the posterior part of the whorl. The specimen is very involute, the umbilicus is deep and has steep, almost perpendicular walls. The greatest thickness of the whorl is at the rounded umbilical shoulder. The ribs are coarse, they are subdivided into two or three secondaries. In the anterior part of the last whorl the points of division are thickened. In the upper part of the umbilical wall the primaries are still present but very weak.

The visible parts of the suture line show great complexity and very slender saddles.

The dimensions in millimetres of the specimen at the same diameter as Spath's holotype of *Cadoceras freboldi* are:

Diameter	Whorl height	Whorl thickness	Umbilical width
77	33 (0.44)	56 (0.72)	18 (0.23)

Remarks. In general outline, shape of the venter, costation and apparently also in the suture line the specimen resembles the holotype of *Cadoceras freboldi* Spath. At the same diameter it has, however, a slightly higher and thicker whorl and a smaller umbilicus than the holotype. Whether these differences may be within the variation of the species can only be decided by the study of more specimens. There is also a certain similarity with *Cadoceras kialagvikense* Imlay (1953, p. 87, Pl. 41, figs. 1-7) but Imlay's species can be easily distinguished by its wider umbilicus with less steep walls, much finer ribs, and more rounded venter. *Cadoceras crassum* Madsen has a much wider umbilicus and finer ribs. As already stated by Spath (1932, p. 67), *Cadoceras freboldi* has a distinct resemblance to the forms of the group of *Macrocephalites pila* Nikitin. Nikitin's specimen of *Macrocephalites pila* (Nikitin, 1898, Pl. 8, fig. 45), which is smaller than the specimen described here, shows similarities in the general outline but has trifurcated ribs whereas the present specimen is mainly bifurcated at the beginning of its last whorl.

Occurrence. The exact stratigraphic position of the specimen is unknown. *C. freboldi* occurs in East Greenland, according to Spath (1932, p. 67), in the beds with *Keplerites tychonis* Ravn, i.e. in the lower Callovian.

Cadoceras sp.

Plate XVII, figure 3; Plate XVIII, figure 1

Material. One specimen (GSC 15127) collected by H. Greiner on Cornwall Island, derived from Jaeger formation, GSC loc. 25980.

Description. The specimen is slightly distorted, only the last and part of the preceding whorl are visible. About three quarters of the last whorl is septate, the length of the partly preserved living chamber is unknown. At the visible stage of growth the shell is moderately inflated, wider than high, widest at the sharp umbilical edge. Umbilicus deep, fairly narrow, with steps on inner whorls, crater-shaped on outer whorl with steep but not perpendicular wall. Flanks convex, grade gently from umbilical edge into arched venter. The entire last whorl is smooth, but the visible part of the preceding whorl has ribs that are fairly broad and strong on the venter and in the upper part of the flanks and very weak in their lower part. Comma-shaped umbilical swellings are present.

The suture line has long and slender lateral lobes; the first lateral is a little deeper than the ventral lobe and the second lateral shorter than the first.

Due to the distortion of the specimen only approximate measurements could be taken. These are, in millimetres:

Diameter	Whorl height	Whorl thickness	Umbilical width
119 (maximum)	54 (0.45)	66 (0.55)	25 (0.21)

Remarks. The specimen is distinguished from *Cadoceras comma* Imlay (Imlay, 1953, p. 83, Pl. 35, figs. 1-8; Pl. 36, figs. 1-5) mainly by a considerably narrower umbilicus and the type of ribs. In *C. comma* the ribs disappear first on the venter and then on the flanks whereas in the present form they are stronger on the venter than on the flanks. Another similar species is *Cadoceras catostoma* Pompeckj (Pompeckj, 1900, pp. 263-265, Pl. 5, figs. 1, 2; Imlay, 1953, pp. 82-83, Pl. 34, figs. 1-14) which is distinguished by its wider umbilicus and by the presence of ribs up to near the beginning of the body chamber. *Cadoceras glabrum* Imlay (Imlay, 1953, p. 84, Pl. 36, fig. 6; Pl. 37, figs. 1-9) is distinguished from the present form by a much wider umbilicus, more rounded venter and different ribbing. *Cadoceras stenolobum* (Nikitin) (Nikitin, 1881, pp. 121, 122, Pl. 5, figs. 28-30) is similar in general shape, suture line, and the type of ribbing, which is however weaker in *C. stenolobum*.

As the inner whorls of the specimen are unknown, identification with any known species is not attempted.

Occurrence. As the specimen was found loose, its stratigraphic position is unknown. It is believed to be of early or middle Callovian age.

Cadoceras? aff. *C. pseudishmae* Spath

Plate XVI, figure 1

Cadoceras pseudishmae Spath, 1932, pp. 77, 78, Pl. 8, figs. 6a, b.

Material. One specimen (GSC 15138) collected by Jeletzky on northwest shore of Porcupine River, loose at base of cliff, GSC loc. 35692.

Description. The specimen is worn on one side. As only the anterior part of the last whorl is preserved, part of the penultimate whorl is well exposed. The umbilicus is narrow and deep with high steep walls and rounded umbilical edge. The whorls embrace one another almost completely; the penultimate whorl is thicker than high, has moderately convex flanks that grade into the rounded venter. The fairly sharp ribs bifurcate at or somewhat below the half height of the flanks. Some of the primaries can be seen continuing on the upper part of the umbilical wall. The ribs are inclined forward and cross the venter forming a very obtuse angle. The preserved anterior part of the last whorl is moderately thicker than high, the venter is more arched than that of the penultimate whorl and there are no more sharp ribs, only some blunt and low folds, that form an obtuse angle on the venter.

The specimen is almost completely septate, only the utmost end of the whorl belongs to the body chamber. The sutures follow one another very closely and only the last suture line could be studied more in detail. The ventral lobe and the first lateral are about equal in length, the second lateral lobe is considerably shorter. The first and second lateral saddles are fairly broad. The suture line is similar to that of *Cadoceras?* sp. indet. figured by Spath (1932, p. 66, fig. 4b).

Remarks. The specimen resembles *Cadoceras pseudishmae* Spath in its general outline and the type of ribbing, but appears to have a narrower umbilicus than *pseudishmae*. Spath seems to suggest that the umbilical edge of his species is not rounded without stating that it is sharp; the umbilical wall of the specimen described here has a rounded edge. Spath states also that the ribs of *pseudishmae* have a pronounced peripheral sinus which however cannot be seen in his figure. The ribs of the specimen here described form only an obtuse angle on the venter. Unsatisfactory preservation of the two specimens prevents detailed comparison.

The specimen is somewhat similar to *Cadoceras freboldi* Spath from which it is distinguished by a less globose outline, smaller umbilicus, and more forwardly inclined and sharper ribs.

The generic position of the specimen is uncertain and its assignment to *Cadoceras* is tentative, because in some respects, particularly the costation, it shows affinities to *Arcticoceras*.

Occurrence. The stratigraphic position of the specimen which was found loose is unknown. In East Greenland it occurs in the zone of *Arcticoceras kochi*.

Cadoceras sp. indet.

Plate XIX, figures 1a, b

Material. University of Alberta loc. 10061 (GSC plastotype 15126) collected by British American Petroleum Company about 32 miles northwest of Aklavik.

Description. The specimen is a fragment, only part of the last whorl, no inner whorls are preserved. The umbilicus is very wide and has a steep, almost perpendicular wall. The convex flanks grade into the rounded venter. No primaries are visible on the umbilical wall, they begin at the umbilical shoulder with bullae, are strongly forwardly inclined, and are subdivided into two or three secondaries that cross the venter without forming a sinus. Some secondaries are intercalated. The point of division is at or below half the height of the flanks and sometimes close to the umbilical shoulder. A smaller part of the whorl, lying between 80 and 85 mm from the anterior end is almost smooth except for the bullae at the umbilical shoulder. There is a constriction close to the anterior end of the whorl. No suture line is visible.

The approximate dimensions in millimetres are:

Diameter	Whorl height	Whorl thickness	Umbilical width
106 (maximum)	49 (0.46)	—	29 (0.27)

Remarks. The fragmentary state of preservation of the specimen does not warrant detailed comparisons with any known species. There is, however, a certain similarity with some of the specimens of *Cadoceras catostoma* Pompeckj figured by Imlay (1953, Pl. 34, figs. 1-14), particularly with Imlay's specimen on Pl. 34, figs. 12, 14. The wide and deep umbilicus, the bullae on the umbilical shoulder and the forwardly inclined, irregularly divided ribs are similar in both

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specimens. There is also a smooth part of the last whorl but this unribbed part is larger than in the specimen described here. Imlay's specimen is distinguished by much stronger ribs, a much deeper umbilicus and more globose shape.

Occurrence. The exact stratigraphic position of the described specimen, found at the same locality as *Cadoceras crassum* Madsen, is unknown. The age is probably Callovian.

Subfamily CARDIOCERATINAE Siemiradzki, 1891

Subgenus *Scarburgiceras* Buckman, 1924

Cardioceras (*Scarburgiceras*) sp. indet. aff. *C. mirum* Arkell

Plate XVIII, figure 2

Material. Several specimens, most of them preserved as imprints, collected by J. Souther of the Geological Survey of Canada from the Savik formation (?) southwest of Buchanan Lake, Axel Heiberg Island, GSC loc. 26159.

Description. A rubber cast of the best preserved specimen (GSC 15128) is figured on Plate XVIII, figure 2. Shape of cross-section and suture line could not be determined. The last whorl has twenty primary ribs that are more narrowly spaced in its posterior than in its anterior part. On the middle of the flank the primaries are subdivided; there are two or three secondaries for each primary, but in some cases the third secondary does not join the primary. On the outer part of the flank and on the venter the ribs are strongly projected forward. The keel is fairly high.

Remarks. The incomplete preservation of the specimen does not warrant specific identification, it is however similar to *Cardioceras* (*Scarburgiceras*) *mirum* Arkell (Arkell, 1946, p. 301, text-fig. 104, 3, 4), in which the ribs suddenly widen out in a similar way as in the specimen described here.

Occurrence. In Souther's section 3 on Axel Heiberg Island this form occurs in a hard ferruginous sandstone. *C.* (*Scarburgiceras*) *mirum* Arkell occurs in the *praecordatum* subzone.

Genus *Amoeboceras* Hyatt, 1900

Amoeboceras sp. indet.

Plate III, figures 2, 3; Plate XVIII, figure 3

Material. Several specimens (GSC 15129, 15130, 15131) collected by Thorsteinsson and Tozer from the Mould Bay formation, Mackenzie King Island, GSC loc. 35346.

Description. All specimens probably belong to one and the same species. They are preserved as imprints and no cross-sections or suture lines could be observed. The form is rather wide umbilicate on the inner whorls with evenly

and fairly closely spaced ribs, which on one of the specimens (Pl. III, fig. 2) widen out in the anterior part of the last whorl. The small specimen (Pl. III, fig. 3) has some bifurcated primaries, others are undivided. The keel is finely serrated. In later stages of growth the primaries remain single and there are some nodes near the venter (*see* Pl. III, fig. 2; Pl. XVIII, fig. 3).

Remarks. The specimens are specifically indeterminable, and the subgenus is also doubtful. *Amoeboceras* (*Prionodoceras*) *ravni* Spath (Spath, 1935, Pl. 4, fig. 4a) from the lower Kimmeridgian of East Greenland seems to be similar both in general shape and in ribbing, particularly to the specimen figured on Plate III, figure 2, but the preservation of the latter is too incomplete to warrant detailed comparison.

Occurrence. In black shales on Mackenzie King Island, probably of late Oxfordian or early Kimmeridgian age.

Family PERISPHINCTIDAE Steinmann, 1890

Subfamily DORSOPLANITINAE Arkell, 1950

Genus *Dorsoplanites* Semenov, 1898

Dorsoplanites sp. indet. ex gr. *D. panderi* Michalski

Plate XVII, figure 2

Perisphinctes cf. *panderi* Michalski. Frebold, 1930, pp. 35-38, 39; Pl. 10, figs. 1-6; Pl. 11, figs. 1, 2; Pl. 12, fig. 1; Pl. 13, fig. 1.

Perisphinctes aff. *panderi* d'Orbigny. Sokolov and Bodylevsky, 1931, pp. 88, 89; Pl. 8, fig. 2.

Material. One specimen (GSC 15133) collected by Thorsteinsson from the Deer Bay formation near Eureka weather station, Ellesmere Island, GSC loc. 28714.

Description and remarks. The specimen is preserved as an imprint. The rubber cast of the fairly wide umbilicate ammonite is very similar to some Spitsbergen ammonites described by Frebold, and by Sokolov and Bodylevsky as *Perisphinctes* cf. *panderi* and *P. aff. panderi*. Unfortunately the preservation of both the Ellesmere Island and the Spitsbergen specimens is so unsatisfactory that no detailed comparison with the Russian or East Greenland species of the genus *Dorsoplanites* can be made.

Occurrence. Associated with other *Dorsoplanites*, *Pavlovia?* sp. indet., and according to Jeletzky (personal communication) with *Buchia fischeri* (d'Orbigny).

Dorsoplanites sp. indet.

Plate XX, figure 1

Material. One specimen (GSC 15134) collected by Thorsteinsson from the Deer Bay formation near Eureka weather station, Ellesmere Island, GSC loc. 28714.

Description. The measurable dimensions in millimetres of this specimen at a diameter somewhat smaller than the maximum diameter are:

Diameter	Whorl height	Whorl thickness	Umbilical width
130	44 (0.34)	—	52 (0.40)

The specimen seems to be somewhat laterally compressed. More than half of the last whorl seems to belong to the body chamber.

The flanks of this rather evolute form are slightly convex with gradual transition to the wide and shallow umbilicus. The transition into the moderately rounded venter is also gradual.

The equally spaced primary ribs begin on the umbilical wall and curve gently forward on the flank. At about half the height of the flank they are subdivided into two or three secondaries which are very faint. The venter seems to be almost smooth.

Only parts of the suture line, i.e. the large and deep first, and the much smaller second laterals are more or less clearly visible and seem to be similar to the corresponding parts of suture lines of some species of *Dorsoplanites*, figured by Spath (1936, Pl. 33, fig. 1a; Pl. 37, fig. 6a).

Remarks. The state of preservation of this specimen does not permit specific determination. It is similar to the specimen described above as *D. sp. indet. ex gr. panderi*. Other species of *Dorsoplanites* can be distinguished by differences in the ribbing. *D. maximus* Spath (Spath, 1936, Pl. 26, fig. 1; Pl. 28, fig. 1) has stronger ribs, *D. flavus* Spath (op. cit., Pl. 34, figs. 1a-c) has sharper ribs at medium sizes, *D. triplex* Spath (op. cit., Pl. 35, figs. 2a, b) has more widely spaced and straighter ribs.

Occurrence. Associated with *D. sp. indet. ex gr. panderi*, *Pavlovia?* sp. indet., and according to Jeletzky (personal communication) with *Buchia fischeri* (d'Orbigny).

Genus *Pavlovia* Ilovaisky, 1917

Pavlovia? sp. indet.

Plate XXI, figure 1

Material. One imprint (GSC 15132) collected by Thorsteinsson from the Deer Bay formation, near Eureka weather station, Ellesmere Island, GSC loc. 28714.

Description and remarks. This large specimen is wide umbilicate, the whorls embrace one another only a little. The fairly strong ribs are equally spaced and on the last whorl most of them are bifurcate, but there are some intercalated secondaries which almost join the primaries, thus giving the impression of being tripartite. Cross-section, venter, and suture line are unknown and the specimen is therefore indeterminable. There is some resemblance to certain representatives of the genus *Pavlovia* as for instance *Pavlovia kochi* Spath (Spath, 1936, p. 50, Pl. 15, figs. 1a, b), but no direct comparison is possible.

Occurrence. Associated with *Dorsoplanites* spp. and according to Jeletzky (personal communication) with *Buchia fischeri* (d'Orbigny).

AGE AND CORRELATION

Most of the ammonites described in this paper are present in other Arctic regions and in some cases age determinations and correlations of the beds are easy. There are, however, some faunas whose stratigraphic position is still questionable despite the great progress made as a result of recent field investigations by officers of the Geological Survey of Canada. This is one of the reasons that the author has not subdivided the Jurassic in the Canadian Arctic into zones at the present stage of knowledge. Another reason is that the Jurassic of the Canadian Arctic belongs to the same faunal province as the Jurassic of other Arctic regions, particularly that of northern Siberia, from where in recent times more and more faunas have been listed. However, as some of the faunas have yet to be described, new facts may arise that could change a tentative subdivision into zones. In this paper the author refers to 'beds' that are correlated with 'beds' or 'zones' in other regions.

As is so in the Lower Jurassic of the Canadian Arctic (*see* Frebald, 1960), there are several gaps in the Middle and Upper Jurassic sequence, some common to the whole area, others only of local significance. In some cases it is still difficult to decide whether the absence of certain faunas, as for instance some middle Bajocian faunas known from western North America or Europe, is caused by a gap in the sequence or by their replacement by other Arctic faunas. Until recently there was reason to believe that most of the Bathonian was absent in the Canadian Arctic, however, the absence of European faunas of this age seems to be explainable in a zoogeographical way. Arctic faunas replace the European ones.

In other cases the absence of certain faunas may be explained by incomplete collecting and they may yet be found in better exposed outcrops. There is, however, strong evidence that some faunas and beds are actually missing. To these belong such of the middle and upper Callovian.

The correlation chart (Table I) gives a summary of the age and correlation of the Middle and Upper Jurassic index faunas and beds of the Canadian Arctic. Further studies in the field may make necessary additions and some changes.

Lower Bajocian

Beds with *Erycites* cf. *E. howelli* (White) and *Pseudolioceras* sp.

Beds with *E. cf. E. howelli* (White) and *Pseudolioceras* sp. are known from only one locality in the Richardson Mountains. This assemblage indicates an early Bajocian age, possibly slightly older than the bed with *Leioceras opalinum* (Reinecke) known from some of the Arctic islands. The nearest occurrence of the same ammonites is in northern Alaska (Imlay, 1955, p. 73) where they are found in outcrops in the valleys of the Canning and Sadlerochit Rivers. Imlay

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states (loc. cit.) "these species are common in southwestern Alaska in the lower part of the Kialagvik formation where the associated ammonites furnish a definite correlation with the lowermost Bajocian". At Wide Bay *Erycites howelli* is associated with *Pseudolioceras whiteavesi* (White) and *Tmetoceras*. According to Imlay (op. cit., p. 90) this fauna occurs directly beneath beds containing *Emileia*, *Sonninia*, *Erycites*, and *Pseudolioceras*. *Erycites* has not been found in the Canadian Arctic islands, East Greenland, Spitsbergen or other Arctic regions.

Beds with *Leioceras opalinum* (Reinecke) and *Pseudolioceras m'clintocki* (Haughton)

The distribution of lower Bajocian beds containing *L. opalinum*, *P. m'clintocki* and other species is described in other papers (Friebold, 1957b, 1958, 1960).

Upper Bajocian?

Beds with *Cranocephalites borealis* (Spath)

Beds containing *C. borealis* (Spath) and *C. warreni* Friebold were found in the Bug Creek area, Aklavik Range, northeastern Richardson Mountains. *C. borealis* occurs also in the Porcupine River area, Richardson Mountains. These ammonites have not been found in the Canadian Arctic islands, northern Alaska or other Arctic regions except for East Greenland, where, according to Callomon (1959, p. 507), *C. borealis* is the zone fossil of the oldest *Cranocephalites* zone. Callomon (op. cit., pp. 507,511) suggested a late Bajocian age for this zone, an opinion which is tentatively accepted here. The next younger East Greenland zone of *C. indistinctus* Callomon has not yet been found in the Canadian Arctic. Callomon also assigned this zone to the upper Bajocian.

Upper Bajocian-Lower Bathonian

Beds with *Arkelloceras tozeri* Friebold and *A. mclearnii* Friebold

The stratigraphic position of the *Arkelloceras* beds in Prince Patrick Island is 45 to 60 feet above the beds with *Leioceras opalinum* (Reinecke) and 60 feet below the *Arcticoceras* beds (Tozer, 1956, pp. 19, 20; Friebold, 1957b, pp. 10, 24, 25; Thorsteinsson and Tozer, personal communication). *Arkelloceras* has not been found in the same section as any species of *Cranocephalites* or *Arctocephalites* but according to Tozer's observations in the field (see Tozer, loc. cit.; Friebold, loc. cit.) it seemed reasonable to suggest that in Prince Patrick Island the *Arkelloceras* beds and the beds with *Cranocephalites* have about the same stratigraphic position. As to the age of the *Arkelloceras* beds, the author (Friebold, 1957b, pp. 24, 25) mentioned two possibilities, i.e. that they might belong to the upper Bajocian or to the Bathonian-Callovian. The latter possibility was justified so long as the *Cranocephalites vulgaris* beds could be assumed to be of that age. This possibility has, however, now been ruled out (see under "Beds with *Cranocephalites vulgaris*"). The *Cranocephalites vulgaris* beds are not younger than middle Bathonian and are more probably of early Bathonian age, as suggested by

STAGES	RICHARDSON AND BRITISH MOUNTAINS REGION	CANADIAN ARCTIC ISLANDS	EAST GREENLAND M. Jurassic after Callomon 1959, U. Jurassic compiled	NORTHERN ALASKA after Imlay, 1955	ALASKA PENINSULA AND COOK INLET after Imlay, 1955	BARENTS SEA compiled	PETSCHORA REGION compiled	OB-JENISSEI REGION after Bodylevsky and Shulzina, 1958	CHATANGA REGION after Saks et al. 1959
Berriasian		<i>Subcraspedites</i>	<i>Subcraspedites</i>			<i>Subcraspedites</i>			<i>Subcraspedites</i>
Portlandian or Volgian resp.	?	?	<i>Craspedites, Laugeites</i>	Not known	<i>Buchia piochi</i>				<i>Craspedites okensis</i>
Upper Kimmeridgian	<i>Buchia cf. mosquensis,</i> <i>Buchia spp.</i>	<i>Dorsoplanites</i> (Stratigraphic position doubtful) <i>Buchia mosquensis</i> <i>Buchia spp.</i>	<i>Glaucolithites (Crendonites)</i> <i>Epipalassiceras</i> <i>Palassiceras</i> <i>Pectinatites</i>	<i>Buchia mosquensis,</i> <i>B. rugosa</i>	<i>Buchia mosquensis,</i> <i>B. rugosa</i>	<i>Dorsoplanites</i>	No index-ammonites	<i>Dorsoplanites</i>	<i>Dorsoplanites, Pavlovia,</i> <i>Buchia mosquensis</i>
Middle Kimmeridgian			Not known			Not known		Not known	?
Lower Kimmeridgian Upper Oxfordian	<i>Buchia concentrica</i>	<i>Amoeboceras, Buchia</i> <i>concentrica</i>	<i>Hoplocardioceras decipiens</i> <i>Rasenia borealis</i> <i>Rasenia orbigny</i> <i>Amoeboceras rosenkrantzi</i> <i>Amoeboceras ravni</i> <i>Amoeboceras transitorium</i> <i>Cardioceras caelatum</i>	<i>Amoeboceras,</i> <i>Buchia concentrica</i>	<i>Amoeboceras,</i> <i>Buchia concentrica</i>	<i>Hoplocardioceras decipiens</i> <i>Rasenia, Amoeboceras</i> <i>kitchini, E. sokolovi</i> <i>Buchia concentrica etc.</i> <i>Amoeboceras nigrum</i> <i>A. nathorsti</i>	<i>Aulacostephanus spp.</i> <i>Amoeboceras alternoides,</i> <i>A. shuravskii etc.</i>	<i>Hoplocardioceras cf. decipiens,</i> <i>Euprionoceras sokolovi,</i> <i>Buchia cf. concentrica,</i> <i>B. cf. kirghisensis</i> <i>Amoeboceras</i>	<i>Amoeboceras kitchini, Rasenia,</i> <i>Pictonia, Buchia concentrica,</i> <i>B. kirghisensis etc.</i> <i>Amoeboceras alternans</i> <i>Buchia kirghisensis</i>
Lower Oxfordian		<i>Cardioceras aff. mirum</i>	Not known, apparently absent	Not known	<i>Cardioceras distans</i> <i>Cardioceras martini</i>	Not known	<i>Cardioceras cordatum etc.</i>	<i>Cardioceras jacuticum</i>	<i>Cardioceras cordatum,</i> <i>C. jacuticum etc.</i>
Callovian	Not known	Not known	Not known	Not known	Not known	<i>Quenstedtoceras</i>	<i>Quenstedtoceras, Cadoceras</i> <i>nikitini, C. keyserlingi</i>	<i>Quenstedtoceras,</i> <i>Cadoceras nikitini</i>	<i>Quenstedtoceras,</i> <i>Cadoceras nikitini</i>
	<i>Cadoceras spp.</i>	<i>Cadoceras spp.</i>	<i>Sigaloceras calloviense</i>	<i>Reineckia</i> <i>Pseudocadoceras grewingki</i>	<i>Pseudocadoceras</i> <i>Keplerites, Lilloettia</i> <i>Paracadoceras, Gowericeras,</i> <i>Kheraiceras</i>	<i>Cadoceras tscheffkini</i>	<i>Cadoceras tscheffkini</i>		<i>Cadoceras tscheffkini</i>
	<i>Cadoceras spp.</i>		<i>Keplerites tychonis</i>			<i>Keplerites svalbardensis</i>	<i>Cadoceras elatmae</i>		<i>Cadoceras elatmae etc.</i>
	<i>Cadoceras spp.</i>		<i>Cadoceras variabile</i>			Not known			?
Bathonian	<i>Arcticoceras kochi</i>	<i>Arcticoceras ishmae</i>	<i>Arcticoceras kochi</i>	<i>Arcticoceras</i>	Not known	Not known	<i>Arcticoceras ishmae</i>	<i>Arcticoceras ?</i>	
	<i>Cadoceras crassum ?</i>	Not known	<i>Arctocephalites greenlandicus</i>			<i>Arctocephalites</i>			<i>Arctocephalites</i>
	<i>Arctocephalites elegans</i>	Not known	<i>Arctocephalites nudus</i>						
	Not known	<i>Cranoc. vulgaris</i>	<i>Cranocephalites pompeckii</i>	Not known	<i>Cranocephalites</i>	<i>Cranocephalites</i>		Not known	<i>Cranoc. vulgaris, Morrisiceras</i>
Upper Bajocian	Not known		<i>Cranocephalites indistinctus</i>		<i>Sphaeroceras</i>			Not known	
	<i>Cranocephalites borealis</i>	Not known	<i>Cranocephalites borealis</i>		<i>Chondroceras</i>				<i>Megateuthis sp., Pelecypods</i> Exact age unknown
Middle Bajocian	Not known	Not known	Not known	Not known	<i>Normannites, Teloc.</i> <i>Stemmatoceras</i> <i>Emileia</i>			Not known	Not known
Lower Bajocian	<i>Erycites cf. howelli</i> and <i>Pseudolioceras sp.</i>	<i>Leioceras opalinum,</i> <i>Pseudolioceras m'clintocki,</i> <i>Oxytoma jacksoni</i>	<i>Pseudolioceras</i>	<i>Tmetoceras, Erycites,</i> and <i>Pseudolioceras whiteavesi</i>	<i>Tmetoceras, Erycites,</i> and <i>Pseudolioceras</i>	<i>Oxytoma jacksoni</i>		<i>Pelecypods</i>	<i>Ludwigia</i>

Table 1. Correlation Chart of the Middle and Upper Jurassic sequence of the Canadian Arctic with other Arctic regions.

Imlay (1952) and Callomon (1959). Still assuming that the stratigraphic position of the *Arkelloceras* beds is close to the *Cranocephalites vulgaris* beds, the *Arkelloceras* beds could be of early Bathonian or late Bajocian age. In favour of a Bajocian age is the association in Prince Patrick Island of *Arkelloceras* with *Inoceramus lucifer* Eichwald, a species that according to Imlay (1955) is unknown from beds younger than Bajocian. The stratigraphic relationship to Callomon's new zones of *Cranocephalites borealis* (Spath) and *C. indistinctus* Callomon is unknown so there is still some uncertainty about the precise stratigraphic position of *Arkelloceras*. It can however be stated that its place is somewhere in the higher Bajocian or lower Bathonian. In Prince Patrick Island *Arkelloceras* is also associated with *Zetoceras thorsteinssoni* n. sp. In this connection it may be mentioned that in the Chatanga region, northern Siberia (see Saks, et al., 1959, p. 65) a new but undescribed *Phylloceras*, i.e. *P. subheterophyllum* Voronetz is associated with *Morrisiceras* in beds that are directly below beds with *Cranocephalites vulgaris* and are considered to belong to the lower Bathonian. As this fauna is still undescribed, no conclusions can be made at present.

Beds with *Arkelloceras* are present on Prince Patrick and Melville Islands. They are unknown elsewhere.

Lower Bathonian

Beds with *Cranocephalites vulgaris* Spath.

In the Canadian Arctic *Cranocephalites vulgaris* Spath is known from one locality only, i.e. 3 miles southeast of the Mould Bay weather station on Prince Patrick Island (Friebold, 1957b, pp. 25, 26). Other, poorly preserved ammonites that may belong to *Cranocephalites* are known from the Richardson Mountains. In East Greenland *Cranocephalites vulgaris* is very common in the zone of *Cranocephalites pompeckji* (Madsen). This zone is also known to be present in Novaya Zemlya (Sokolov, 1912, pl. 1) and in parts of northern Siberia, i.e. the Chatanga region (see Saks, et al., 1959, p. 65), and in southern Alaska (Imlay, 1952, p. 980). The age of the *Cranocephalites vulgaris* beds has been discussed repeatedly (Spath, 1932, p. 145; Imlay, 1952, pp. 980, 981; Donovan, 1953, p. 133; Arkell, 1956; Friebold, 1957b, pp. 25, 26; Donovan, 1957, pp. 132-136 and Callomon, 1959, p. 508). Most of these authors assigned the beds to the upper Bathonian or lower Callovian respectively with the exception of Imlay who already in 1952 (Imlay, loc. cit.) placed them in the lower Bathonian, and Callomon (loc. cit.) who placed the East Greenland *C. pompeckji* zone in the lower Bathonian. The reason why Imlay placed *Cranocephalites* in the lower Bathonian was that in southern Alaska *Cranocephalites* was found immediately above the assemblage containing *Sphaeroceras*, *Stephanoceras*, and *Leptosphinctes* which he considers to be of latest Bajocian or earliest Bathonian age. In his stratigraphic chart of the Jurassic of southern Alaska (Imlay, 1953, table 5) the *Cranocephalites* beds are accordingly considered to be equivalents of the zones of *Zigzagiceras zigzag*, *Procerites progradilis* and *Tulites subcontractus*.

In this connection the discovery in the Chatanga region, northern Siberia (Voronetz in Saks, *et al.*, 1959) of a new species of *Morrisiceras*, i.e. *M. sibirica* Voronetz (still undescribed and not figured) is interesting. The genus *Morrisiceras* is largely considered to be of middle Bathonian age. At any rate this association shows that the *Cranocephalites pompeckji* zone is older than lower Callovian and upper Bathonian and that both Imlay and Callomon may be correct in assigning this zone to the lower Bathonian.

Middle Bathonian

Beds with *Arctocephalites elegans* Spath

Arctocephalites elegans Spath is fairly common in sections on Porcupine River, about 19 miles downstream from the mouth of Bell River. It is unknown from any of the Canadian Arctic islands. *A. elegans* Spath and the associated *A. ornatus* Spath are according to Callomon (1959, p. 508) the commonest forms of the East Greenland zone of *Arctocephalites nudus* Spath, a species which according to Callomon (*loc. cit.*) is atypical of the faunas as a whole. This zone is also present in the King Charles Islands, Franz Joseph Land (Newton and Teall, 1897; Whitfield, 1906); and Novaya Zemlya (Salfeld and Frebold, 1924, pl. 1, fig. 1).

The age of these beds has been discussed by various authors (*see under* "Beds with *C. vulgaris*") and was considered as late Bathonian or early Callovian. Callomon (1959, p. 508) has recently placed these beds in the middle Bathonian.

In East Greenland the next younger zone is that of *Arctocephalites greenlandicus* Spath, which is unknown in the Canadian Arctic.

Upper Bathonian

Beds with *Arcticoceras kochi* Spath and *Arcticoceras ishmae* (Keyserling)

Both species are represented in the Canadian Arctic, but not associated with one another. *A. kochi* was found in the Porcupine River area, Richardson Mountains, *A. ishmae* on Prince Patrick Island where it occurs 60 feet above the beds with *Arkelloceras* and about 105 to 120 feet above the beds with *Leioceras opalinum*. The zone of *A. kochi* is present in East Greenland; *A. ishmae*, which according to Callomon (1959, p. 508) belongs to this zone occurs in the Petschora Land, northern Russia. In southern Alaska *Arcticoceras* is unknown, but it occurs in northern Alaska. Callomon (1959, p. 507) has assigned this zone in East Greenland to the lower part of the upper Bathonian.

Bathonian-Callovian

Beds with *Cadoceras*

Cadoceratids found in the Richardson and British Mountains region are *Cadoceras crassum* Madsen, *C. cf. C. freboldi* Spath, *C.?* aff. *C. pseudishmae* Spath, and *Cadoceras* sp. *indet.* Most of the specimens were not found in situ

and others came from beds of unknown stratigraphic position. None of these species was found associated with the in situ collections of *Arctocephalites* or *Arcticoceras*. According to Spath (1932, p. 65) and Donovan (1957, p. 199), *C. crassum* occurs in East Greenland in the *Tychonis* beds (lower Callovian) but both authors (Spath, 1932, pp. 124-126; Donovan, 1953, p. 131) state that the ammonites found in a horizon of calcareous concretions may actually be a condensed deposit. Callomon (1959, p. 508) places "*Cadoceras*" *crassum* in the zone of *Arcticoceras greenlandicus* (upper part of middle Bathonian). *C. freboldi* Spath occurs in East Greenland in the *Tychonis* beds, according to Spath (Spath, 1932, p. 67) and Donovan (1957, p. 199), whereas *C. pseudishmae* Spath belongs to the *Arcticoceras kochi* zone (Spath, 1932, p. 78; Donovan, 1957, p. 198). Considering these uncertainties and the fact that the Canadian specimens do not offer any information on their stratigraphic position, they are here considered to occur at the Bathonian-Callovian boundary.

Single specimens of *Cadoceras* sp. found on Cornwall and Axel Heiberg Islands respectively are true Cadoceratids. Their exact stratigraphic position relative to other Jurassic beds in these areas is unknown but they can be assigned with confidence to the lower Callovian. It is probable, however, that they belong to a different zone from the Cadoceratids of the *Keplerites tychonis* zone.

Middle and Upper Callovian

No Callovian beds younger than the beds with *Cadoceras* are known from the Canadian Arctic. In other Arctic regions beds of middle and late Callovian age are widely distributed (see Table I).

Lower Oxfordian

In Arctic Canada lower Oxfordian is only known from eastern Axel Heiberg Island where it is indicated by *Cardioceras* (*Scarburgiceras*) aff. *C. mirum* Arkell. Other Arctic occurrences of lower Oxfordian strata are in the Petschora area, northern Russia and in northern Siberia.

The characteristic ammonites of the various regions are as follows: Petschora Land (Sokolov, 1912; Khudyaev, 1927): *Cardioceras cordatum* (Sowerby); Ob-Jenissei region (Bodylevsky and Shulzina, 1958): *C. jacuticum* Pavlov; Anabar River area (Pavlov, 1914): *C. cordatum* (Sowerby) and *C. jacuticum* Pavlov; Chatanga region (Saks, et al., 1959): *C. cordatum* (Sowerby) and *C. jacuticum* Pavlov.

Lower Oxfordian strata are unknown in northern Alaska, East Greenland, and the islands of the Barents Sea.

Upper Oxfordian-Lower Kimmeridgian

Upper Oxfordian (and?) or lower Kimmeridgian is present in the Richardson Mountains, where it is characterized by *Buchia concentrica* (Sowerby). On Mackenzie King Island *Amoeboceras* sp. indet. and *Buchia concentrica* (Sowerby)

occur, and in the eastern part of Axel Heiberg Island some poorly preserved Cardioceratids, possibly belonging to *Amoeboceras*, were found. On some of the Canadian Arctic islands non-marine beds replace the marine facies. In northern Alaska (Imlay, 1955) upper Oxfordian-lower Kimmeridgian is indicated by *Buchia concentrica* (Sowerby), in East Greenland (Spath, 1935; Donovan, 1957) beds of this age are characterized by many Amoeboceratids including the subgenera *Amoebites*, *Amoeboceras*, *Euprionoceras*, *Haplocardioceras*, *Prionodoceras*, *Cardioceras* (*Subvertebriceras*) *caelatum* Spath, *Rasenia* div. sp. and *Buchia*. In Spitsbergen *Amoeboceras* (*Prionodoceras*) *nigrum* (Spath), *A. nathorsti* (Lundgren), and *Buchia* cf. *B. concentrica* (Sowerby) are assigned to the upper Oxfordian, other Amoeboceratids, for example *A. (Euprionoceras) sokolovi* (Bodylevsky) and *Rasenia* spp. to the lower Kimmeridgian. In King Charles Islands (Blüthgen, 1936) *A. nathorsti* var. *A. robusta* (Pompeckj) and *Buchia concentrica* var. *lata* (Trautschold) indicate the presence of beds of late Oxfordian-early Kimmeridgian age. In Franz Josef Land beds of equivalent age are indicated by *A. alternans* (von Buch) and *A. kitchini* Salfeld (Pirozhnikov, 1958), in Novaya Zemlya by *Amoeboceras* (*Prionodoceras*) *regulare* Spath, *A. (P.) frequens* Spath, *A. (P.) frebaldi* Spath (see Spath, 1935). In the Petschora basin, northern Russia (see Sokolov, 1912) the upper Oxfordian is characterized by *A. ovale* (Salfeld), *A. shuravskii* (Sokolov), and *A. alternoides* (Nikitin). *Amoeboceras* is also present in the Ob-Jenissei region (Bodylevsky and Shulzina, 1958) and in the Chatanga area (Saks, et al., 1959) where *A. kitchini* (Salfeld), *A. alternans* (von Buch), *Rasenia*, *Pictonia*, *Buchia kirghisensis* (d'Orbigny), and *B. concentrica* (Sowerby) are also found.

Middle Kimmeridgian

No index fossils of middle Kimmeridgian age are known from the Canadian Arctic, nor have middle Kimmeridgian beds been found in other Arctic regions (see Table I).

Upper Kimmeridgian-Lower Volgian

Beds of late Kimmeridgian or early Volgian age are indicated in the Richardson Mountains where shales containing *Buchia* cf. *B. mosquensis* (von Buch) are present. However, no ammonites have been found and a more accurate age determination cannot be made. On Ellesmere Island and in the eastern part of Axel Heiberg Island some poorly preserved ammonites were found. They are described here as *Dorsoplanites* sp. indet. and *Pavlovia?* sp. indet. Some of them resemble species described by Spath (1936) from East Greenland and by Frebald (1930), and Sokolov and Bodylevsky (1931) from Spitsbergen. A late Kimmeridgian or early Volgian age seemed possible, the associated *Buchia fischeri* (d'Orbigny), however, indicates a younger age, close to the Cretaceous boundary. In this connection it is interesting that Berriasian faunas with *Subcraspedites* spp., *Tollia* spp., *Buchia* cf. *B. terebratuloides* (Lahusen), *B. cf. B. volgensis* (Lahusen) are apparently in close stratigraphical contact with the "*Dorsoplanites*" beds.

True late Kimmeridgian or early Volgian with *B. mosquensis* (von Buch) is present in northern Alaska (Imlay, 1955); both upper Kimmeridgian and Portlandian are well represented by numerous ammonites in East Greenland, particularly Milne Land (Spath, 1936; Donovan, 1957). In Spitsbergen shales with *Dorsoplanites?* spp. have been assigned to the lower Volgian but this age determination may be subject to revision. On the King Charles Islands (Blüthgen, 1936) *Buchia mosquensis* (von Buch) indicates the presence of upper Kimmeridgian or lower Volgian beds. In Franz Josef Land lower Volgian with *Dorsoplanites* occurs (Pirozhnikov, 1958) but in Novaya Zemlya no index fossils of this age are known. In the Ob-Jenissei region beds containing *Dorsoplanites*, *Buchia mosquensis* and other species have been assigned to the lower Volgian (Bodylevsky and Shulzina, 1958). In the Chatanga region (Saks, *et al.*, 1959) both upper Kimmeridgian and lower Volgian are represented by beds containing *Buchia mosquensis*, *Pavlovia*, *Dorsoplanites*, and *Cylindroteuthis*.

Upper Volgian and Berriasian

No ammonites that could be assigned to the upper Volgian have hitherto been found in the Canadian Arctic but well preserved Berriasian ammonite faunas containing *Subcraspedites* spp. and *Tollia* spp. were found on Ellesmere Island and in the eastern part of Axel Heiberg Island (Friebold, 1958, p. 32). These faunas and their stratigraphy are not dealt with in this paper.

THE ZOOGEOGRAPHICAL POSITION OF THE MIDDLE AND UPPER JURASSIC AMMONITE FAUNAS OF THE CANADIAN ARCTIC

Most of the Middle Jurassic faunas found in the Canadian Arctic younger than the lowermost beds with *Leioceras opalinum* (Reinecke), *Erycites howelli* (White) and *Pseudolioceras* show great affinities to the corresponding faunas in East Greenland, with the exception of *Arkelloceras* at present unknown outside the Canadian Arctic islands. *Cranocephalites*, *Arctocephalites* and *Arcticoceras* are well represented in both regions by the same species; they are: *Cranocephalites borealis* (Spath), *C. vulgaris* Spath, *Arctocephalites elegans* Spath, *A. ornatus* Spath, *Arcticoceras kochi* Spath. Other species are known only from one of the two regions, as for example *Cranocephalites warreni* n. sp. from the Richardson Mountains and *C. indistinctus* from East Greenland. Such minor differences may have been caused by absence of suitable outcrops or incomplete collecting.

The faunal content of the corresponding *Cadoceras* beds has some similarities. Forms common to both regions are *Cadoceras crassum* Madsen, *C. cf. C. frebaldi* Spath, *C.?* aff. *C. pseudishmae* Spath. There is, however, one great difference between the two regions. The genus *Kepplerites*, so well represented in East Greenland, has not yet been found in the Canadian Arctic.

The Upper Jurassic ammonites of the Canadian Arctic are, as far as known, poor in number and preservation as compared with the rich faunas of East Greenland. The genus *Cardioceras*, found in Axel Heiberg Island, is unknown in East Greenland but the few other genera represented in Arctic Canada (*Amoeboceras*, *Dorsoplanites*, *Pavlovia?*, all specifically undeterminable) seem to be represented in East Greenland by similar species.

The comparison with northern Alaska is less significant because the *Cranocephalites*, *Arctocephalites* and *Cadoceras* faunas of the Canadian Arctic are unknown in that region. *Arcticoceras* is, however, common to both regions, as are at least some of the lower Bajocian ammonites, for instance *Erycites* and *Pseudolioceras*. The Callovian *Pseudocadoceras* is unknown in the Canadian Arctic, whereas the lower Oxfordian genus *Cardioceras* has not been found in northern Alaska. *Amoeboceras* is, however, represented in both regions. At least some of the differences in the respective ammonite faunas of the two regions may be explained by inadequate collecting.

There are great differences between the Canadian Arctic ammonite faunas and those in the Alaska Peninsula and Cook Inlet. None of the Alaskan middle and upper Bajocian ammonite genera such as *Emileia*, *Sonninia*, *Stemmatoceras*, *Normannites*, *Teloceras*, *Stephanoceras*, *Lissoceras*, *Chondroceras*, and *Sphaeroceras* is known in Arctic Canada. This difference is probably purely stratigraphical: the beds concerned are probably missing in the Canadian Arctic. The genus *Cranocephalites* is represented in both regions but as the Alaskan fauna is still

undescribed the comparison cannot be made at the species level. *Arctocephalites*, *Arcticoceras* and Cadoceratids characteristic of the Richardson and British Mountains region are unknown on the Alaska Peninsula, whereas all of the Alaskan Callovian ammonites such as *Kheraiceras*, *Paracadoceras*, *Gowericeras*, *Kepplerites*, *Lilloettia*, *Pseudocadoceras* and the Alaskan species of *Cadoceras* are absent in Arctic Canada. Also in this case stratigraphic differences may be the reason, as the Alaskan ammonites belong to genera common in other Arctic regions and do not indicate zoogeographical peculiarities. In the Upper Jurassic the genera *Cardioceras* and *Amoeboceras* occur both in the Alaska Peninsula and in the Canadian Arctic, but comparisons at the species level can not be made.

A comparison of the Canadian Arctic faunas with those of the islands of the Barents Sea taken as a whole is more or less favourable, although there are differences if comparison is made with the faunas of individual islands. *Cranoccephalites* is still unknown in the Barents Sea except for Novaya Zemlya, but *Arctocephalites* faunas are represented with species similar to those of the Canadian Arctic and East Greenland. *Kepplerites* and *Pseudocadoceras* known from Spitsbergen and Franz Josef Land respectively have not been found in the Canadian Arctic, where the upper Callovian *Quenstedtoceras* is also missing. At least the absence of *Quenstedtoceras* in the Canadian Arctic is due to the absence of beds of this age. *Cardioceras* is unknown in the Barents Sea area but *Amoeboceras* is well represented. In the upper parts of the Upper Jurassic similar forms of *Dorsoplanites* are common to the Canadian Arctic and Spitsbergen.

Particularly close relationships of ammonite faunas seem to exist between the Canadian Arctic and certain parts of northern Siberia. In the Chatanga region (see Saks, *et al.*, 1959) lower Bajocian faunas with *Pseudolioceras* (still undescribed) correspond with the lower Bajocian *Pseudolioceras* of the Canadian Arctic, although comparison at the species level is not yet possible. The lower Bathonian *Cranoccephalites vulgaris* Spath is common to both regions; another point of similarity is the appearance of Phylloceratids at about the horizon. The *Arctocephalites* of Arctic Canada are represented in the Chatanga region by closely related species (*A. arcticus* Newton, *A. aff. A. ellipticus* Spath) whereas representatives of *Kepplerites* are absent in both regions contrary to East Greenland and Spitsbergen. All the Cadoceratids known from the Richardson Mountains seem to be missing in the Chatanga region and conversely the Cadoceratids of this region (*C. calyx*, *C. elatmae*, *C. tscheffkini* and *C. nikitini*) have not been found in Arctic Canada. Insofar as these Cadoceratids are associated with *Quenstedtoceras*, also absent in Arctic Canada, these differences are stratigraphical, i.e. beds of late Callovian age are unknown in Arctic Canada. Lower Oxfordian *Cardioceras* and upper Oxfordian or lower Kimmeridgian *Amoeboceras* are present in both Arctic Canada and northern Siberia, where they are found in the Chatanga region (Saks, *et al.*, 1959), Anabar region (Pavlov, 1914) and Ob-Jenissei (Bodylevsky and Shulzina, 1958); comparison of them with the poorly preserved Canadian specimens on the species level is, however, not possible. A detailed comparison of the few hitherto known Jurassic ammonites of Arctic Canada that are younger

Middle and Upper Jurassic Ammonites of the Canadian Arctic

than early Kimmeridgian with ammonites of this age in northern Siberia is not possible because of their unsatisfactory preservation. It is, however, interesting that in the lower Ob-Jenissei region (Bodylevsky and Shulzina, 1958, p. 94) *Dorsoplanites?* sp. indet. and *Buchia* cf. *B. fischeriana* (d'Orbigny) are associated with one another as is so in Ellesmere and Axel Heiberg Islands.

Conclusion. The known Middle and Upper Jurassic ammonite faunas of the Canadian Arctic are closely related, very often down to species level, to ammonite faunas of the corresponding ages in other Arctic regions, particularly to those in East Greenland and probably even more closely to those in the Chatanga region, northern Siberia. During these times, with the exception of the lower and middle Bajocian the Canadian Arctic forms clearly a part of the large Arctic fauna province known as the boreal realm. The few significant differences in composition of some of the ammonite faunas of certain parts of this realm are probably of stratigraphic nature and can hardly be regarded as development of sub-provinces within the boreal realm.

THE TIME OF THE MANIFESTATION OF THE JURASSIC BOREAL REALM

In a previous report on the Lower Jurassic and lowermost Middle Jurassic index faunas of the Canadian Arctic (Frebald, 1960) the well-known fact of the uniform distribution of the older Jurassic faunas over the whole world was fully confirmed. Lower Jurassic and lowermost Middle Jurassic ammonite faunas of Arctic Canada, East Greenland, the islands of the Barents Sea, northern Siberia and northern Alaska are identical with or very similar to European and North American faunas and consequently no boreal realm was ever claimed to have existed during these times. The commonly accepted opinion, discussed by Arkell (1956, p. 607) is that these faunas migrated into the Arctic from European regions; the author, however, wishes to emphasize that the validity of this hypothesis has not been demonstrated, and faunas of this age could equally well have migrated in the opposite direction, i.e. from the Arctic into Europe.

The opinion was held that for a long time the Jurassic boreal realm manifested itself not earlier than in the Callovian. "It is with the beginning of the Callovian that peculiar endemic Boreal faunas first appear" (Arkell, 1956, p. 610), and according to the same author (loc. cit.) "the first Boreal elements are specialized Stephanocerataceae, *Cranocephalites* and *Arctocephalites*". As mentioned in the section "Age and Correlation" in this paper these two genera had actually been regarded by several authors, the writer included, as late Bathonian or early Callovian in age and as these genera were the oldest known typical boreal elements the Callovian age of the manifestation of the boreal realm was justified. However, these age determinations cannot be accepted any more, as shown on pp. 27, 28. In 1952 Imlay (1952, pp. 980, 981), when summarizing the Jurassic stratigraphy of southwestern Alaska, made a plea in favour of an early Bathonian age for the *Cranocephalites* beds, as they were found to be immediately above beds containing *Sphaeroceras*, *Leptosphinctes* and *Stephanoceras* which he believed to be equivalent in age to the late Bajocian *Parkinsoni* zone. The common belief in a younger age of the *Cranocephalites* beds and the fact that these Alaskan faunas are not yet described have prevented other authors from giving Imlay's stratigraphic evidence and conclusions the necessary consideration they merit.

The association of *Cranocephalites vulgaris* Spath with *Morrisiceras* in the Chatanga region of northern Siberia (Voronetz in Saks, et al., 1959) already referred to was further evidence that this *Cranocephalites* zone cannot be as young as late Bathonian or early Callovian. Callomon's recent studies in East Greenland (Callomon, 1959) have also demonstrated convincingly (see p. 27, this report) that the beds with *Cranocephalites* are older than late Bathonian and early Callovian and their assignment by Callomon to the lower Bathonian although reasonable is not proven. The *Cranocephalites vulgaris* fauna of the *C. pompeckji*

zone is, however, not the oldest boreal fauna found by Callomon in East Greenland. Below it are zones of *C. indistinctus* Callomon and *C. borealis* (Spath) which Callomon assigned to the upper Bajocian. This age determination could not be proven, as stated by Callomon himself, but there can hardly be any doubt that *C. indistinctus* Callomon and *C. borealis* (Spath) are close to the Bajocian-Bathonian boundary. Another boreal element is the genus *Arkelloceras* Frebold, which is only known from Prince Patrick and Melville Islands, and which in the writer's opinion (*see* pp. 26, 27) is of late Bajocian or early Bathonian age. As its exact stratigraphic position is unknown it may yet prove to be the first or one of the first manifestations of a boreal realm.

Arkell (*op. cit.*, p. 609) has already indicated that it was in the middle Bajocian that the separation of ammonites into faunal realms took place. At the time he was writing he was justified in believing that the oldest known boreal ammonites belonged to the early Callovian and he concluded accordingly (*loc. cit.*) that "no middle or upper Bajocian faunas are known from Arctic regions", "that middle and upper Bathonian faunas, so far as known at present, are confined to the Tethys and north-western and central Europe". However, he considered the existence of the boreal realm earlier than Callovian when he stated that "probably it was during this Bajocian and Bathonian regression that the Arctic was cut off from the seas of the rest of the world and the special Boreal fauna began to evolve". He was, however, mistaken in assuming that "the prototypes probably lie entombed under the Arctic Ocean and will never be known", because these prototypes had actually been found but had been wrongly assigned to a younger, i.e. Callovian age.

Summarizing all the available evidence, it can be stated that the dating of the manifestation of the boreal realm as early Bathonian or late Bajocian respectively is amply justified.

THE ARCTIC SEAS IN MIDDLE AND LATE JURASSIC TIMES

Without exception, the Jurassic deposits of the Arctic are known only from the present Eurasian and North American continents and their shelf islands, not from the vast central Arctic Sea region itself. Despite this lack of knowledge, opinions on the nature of the central Arctic during the Jurassic have been very definite and most of the palæogeographic maps show this region at least as a large sea, some even as an ocean. Some authors, the writer included, have indicated that such a central Arctic sea was also in existence during the late Palæozoic, Triassic, and at least part of the Cretaceous. Stille (1948) concluded that the central Arctic is one of the primordial oceans and Arkell (1956, p. 604) felt confident in saying "All workers on the period seem to have been agreed that it [the ocean] was in existence during the Jurassic" and (op. cit., p. 605) "The evidence from Jurassic stratigraphy requires the existence in Jurassic times of the North Pacific, North Atlantic, Scandic and Arctic Oceans."

A contrary opinion has been put forward by Eardley (1951) who considered large parts of the present Arctic Ocean as a continent in Jurassic time which possibly became temporarily invaded by transgressions originating in the periarctic seas of North America and Eurasia. Unfortunately Eardley's treatment suffered considerably from the omission of using or discussing important literature—even Stille's work (1948) remained unmentioned. On the other hand, Arkell (1956) left Eardley's hypothesis undiscussed.

Eardley's opinion of an Arctic continent in the area of the present Arctic Ocean appears hardly conceivable. Such a configuration has no parallel in recent times and would have made impossible the development of the rich marine life as is actually present in the Arctic Jurassic. It is not surprising that the distribution of land and sea in the Jurassic Arctic as suggested by Eardley has never been considered by any of the authors engaged in the study and palæogeographical evaluation of Arctic Jurassic faunas (Uhlig, 1911; Frebald, 1930, 1935, 1951; Spath, 1932; Arkell, 1956; Imlay, 1957; and others). The periarctic shelf seas of the Jurassic have on the contrary to be defined as the border seas of the central Arctic.¹

The existence of a marine region in Jurassic times in the central Arctic does not necessarily mean that this sea was an ocean with deep basins similar to those of the present Arctic Ocean. The discovery of the Lomonossov Range, made some years ago by Soviet oceanographers, has not only changed the picture of the present-day Arctic Ocean considerably but reflects also on the nature of

¹The fact that locally and temporarily a northern source of the sediments has to be accepted, as is the case in northern Alaska (see Imlay, 1955, p. 82), does not necessarily indicate the presence of a large landmass. These sediments may have come from islands.

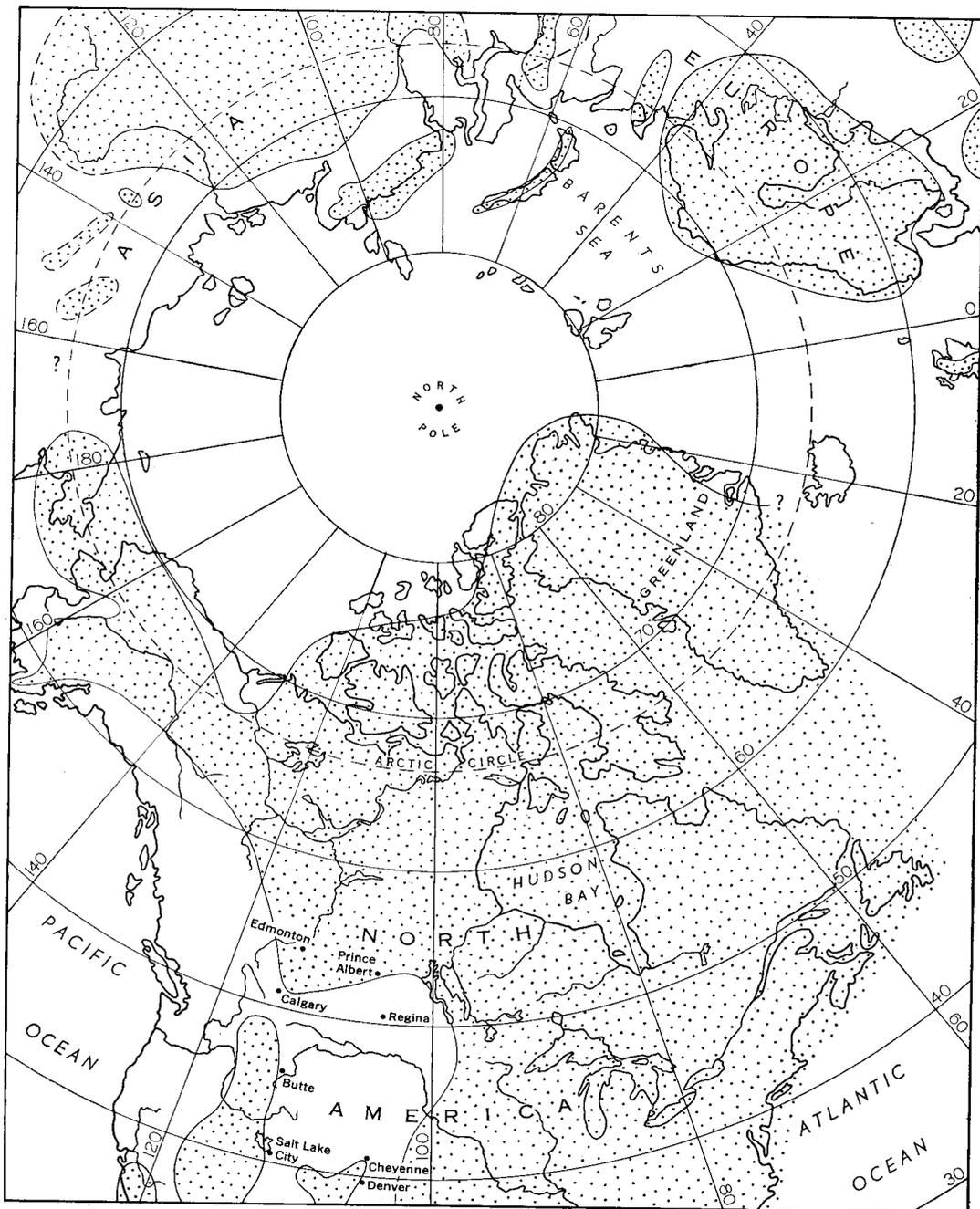


Figure 3. Oxfordian Palaeogeography of the boreal regions compiled from various sources. The term Scandic as used in this report refers to the sea between northeast Greenland in the west and Norway and the Barents Sea in the east.

this region in Jurassic times. According to Saks, Belov and Lapina (1955) the submarine Lomonossov Range that extends from Northern Siberia to Ellesmere Island is the prolongation of the Siberian Verkhojansk Range that was folded in Late Jurassic time. The same age of folding was suggested for the Lomonossov Range and if this could be proved correct, the region of the range would have been in a geosynclinal stage throughout most of the Jurassic, as claimed by Saks, Belov and Lapina (1955). Even if it should be difficult to prove the correctness of this theory, it has to be considered a possibility that would change the picture of the central Arctic region in Jurassic times considerably. As Saks has prepared another paper (now in press) on the subject and as some modifications of his preliminary publication can be expected (Saks, personal communication), the author abstains from a discussion of the matter at present, acknowledging, however, the great importance of the discovery of the Lomonossov Range for the palæogeographical concept of the central Arctic in Jurassic times.

Whether or not the Jurassic sea of the central Arctic was an ocean must remain an open question for the present.

The central Arctic sea and its border seas in the Siberian, European and American Arctic have been in connection with other marine areas. This is particularly evident for the Early Jurassic and early Middle Jurassic times with their free, world-wide fauna exchanges. The well-established seaways from the Arctic were the Scandic, the north Russian seaway, and the temporary connection through parts of Siberia with the present-day sea of Ochotsk.

Of all these seaways, the Scandic seems to have been the main link between the Arctic and other seas during the Early Jurassic. Faunas of the Scandic are present not only on both of its sides, in East Greenland and Spitsbergen, but also in its southern continuation in Scotland, in the subsurface of northern Denmark, Scania, Bornholm, and northern Germany. The north Russian seaway was not in existence in the Early Jurassic. Conditions considerably changed in Bajocian, Bathonian and early Callovian times. The Arctic *Cranocephalites*, *Arctocephalites*, *Arcticoceras*, and *Cadoceras* faunas reached parts of East Greenland, but did not penetrate farther south into northwestern Europe, where entirely different genera were living. It is reasonable to accept a suggested land area in the region between northeastern Scotland and southern Norway, that blocked the way from one realm to the other. The north Russian seaway came into existence not earlier than late Bathonian and did not then penetrate very far south.

Thus, the late Bajocian, Bathonian, and early Callovian were apparently times of strong isolation of the Arctic sea. Only through the Siberian seaway, temporary transgressions to the south seem to have taken place.

The conditions changed abruptly in the late Callovian when the land bridge between Scotland and Norway disappeared, and the sea penetrated from the Scandic to northern Germany and Poland, joining the north Russian seaway, thus encircling Fennoscandia which remained an island.

Both the Scandic and the north Russian seaways were clearly indicated during much of the Late Jurassic, but towards its end the connection between them

was again interrupted. The north Siberian seaway connecting the Arctic with the Ochotsk Sea and Japan seems to have been in existence at certain times but no detailed information has been available to the author.

A difficulty arises in connecting the boreal *Cranocephalites* and some of the Callovian faunas of southwestern Alaska with the Arctic. In his map of the Oxfordian palæogeography of the boreal region Imlay (1957, p. 471) indicates a seaway from the Arctic through the Mackenzie River region to southwestern Alaska and the western parts of North America. As stated by the author (1957a, b; 1958) there is no proof of the existence of such a Mackenzie River seaway. No Jurassic sediments are known in this region except for the Richardson Mountains in the northern part of the area. This northern part formed in the writer's opinion a bay that to the north was in direct connection with the open Arctic sea and to the west was joined by the north Alaskan epicontinental sea. Accepting the hypothesis that the Bering Strait was closed in Jurassic time by a landmass extending from northeastern Asia to the central parts of Alaska some difficulty arises in connecting the boreal occurrences in southwestern Alaska with the Arctic. It is possible that at least a part of these faunas came via the north Siberian-Ochotsk seaway. In this connection it is interesting that *Cranocephalites* and *Arctocephalites*, both typical boreal ammonites, occur in the basin of the Bureya River as far south as between latitudes 50° and 51°N (Krimholz, 1939), and that the boreal Callovian genus *Seymourites* has even been recorded from central and northeastern Honshu, Japan (see Arkell, 1956, pp. 426, 429).

From the correlation chart it can be deduced that the movements of the sea in the border zones of the Arctic did not always take place at the same time, as was so in the Early and early Middle Jurassic (Frebald, 1960). This is to be expected as the transgressions and regressions of the seas were mainly dependent on the character of the epeirogenic movements in the various areas. Some areas had a prevailing tendency of sinking, as for example Axel Heiberg and Ellesmere Islands with their marine Upper Jurassic deposits, whereas other regions such as Prince Patrick Island were in the stage of rising as indicated by contemporaneous deposition of non-marine sediments. Similar conditions were present along the east coast of Greenland (absence of several Middle Jurassic ammonite zones in its northern part), on the islands of the Barents Sea, and in northern Siberia. Some of these differences from one region to another may, however, have been caused by lack of collecting or poor exposures.

The general picture of the distribution of land and sea in the Arctic during the Jurassic is illustrated in the example of Oxfordian time (Fig. 3).

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PLATES I to XXI

PLATE I

(All figures natural size)

Types in collections of the Geological Survey of Canada.

- Figure 1. *Cranocephalites borealis* (Spath). (Page 12.) Lateral view. GSC 15104; GSC loc. 26883.
- Figures 2a, b. *Cranocephalites borealis* (Spath). (Page 12.) 2a, lateral view; 2b, cross-section. GSC 15101; GSC loc. 26882.
- Figures 3a, b. *Cranocephalites borealis* (Spath). (Page 12.) 3a, lateral view; 3b, lateral view after removal of part of last whorl. GSC 15103; GSC loc. 26883.
- Figures 4a, b. *Cranocephalites borealis* (Spath). (Page 12.) 4a, lateral view; 4b, cross-section and venter. GSC 15102; GSC loc. 26883.

PLATE I



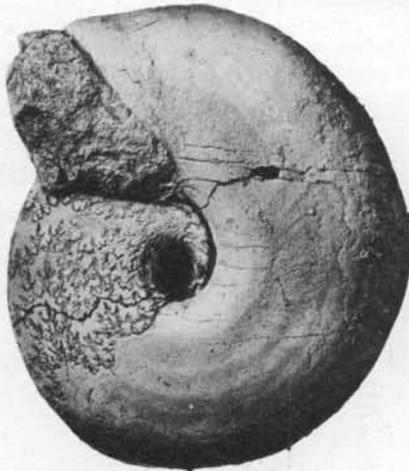
2a



3a



2b



1



4b



4a



3b

PLATE II

(All figures natural size)

Types in collections of the Geological Survey of Canada.

- Figures 1a, b. *Cranocephalites warreni* n. sp. (Page 14.) 1a, lateral view; 1b, cross-section and venter of penultimate whorl. GSC holotype 15105; GSC loc. 26883.
- Figures 2a, b. *Cranocephalites warreni* n. sp. (Page 14.) 2a, cross-section and venter of penultimate whorl; 2b, lateral view. GSC paratype 15135; GSC loc. 26972.
- Figure 3. *Incertae sedis*. (Page 6.) Lateral view. GSC 15137; GSC loc. 37917.
- Figure 4. *Cranocephalites warreni* n. sp. (Page 14.) Lateral view. GSC 15136; GSC loc. 26882.

PLATE II

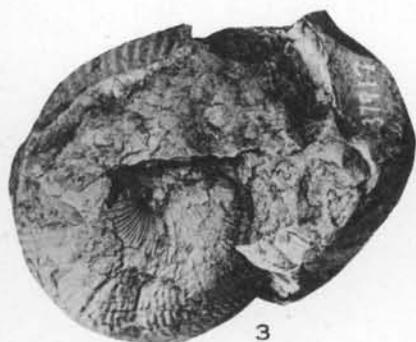
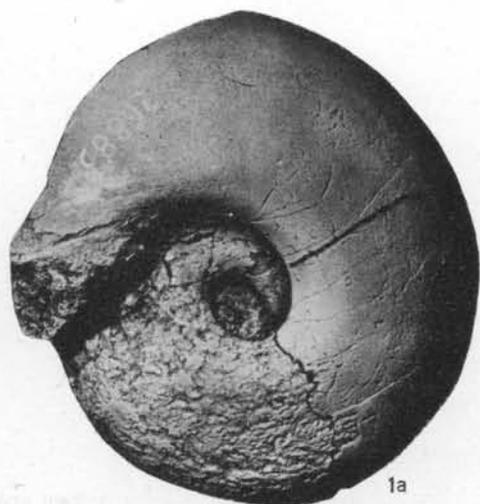
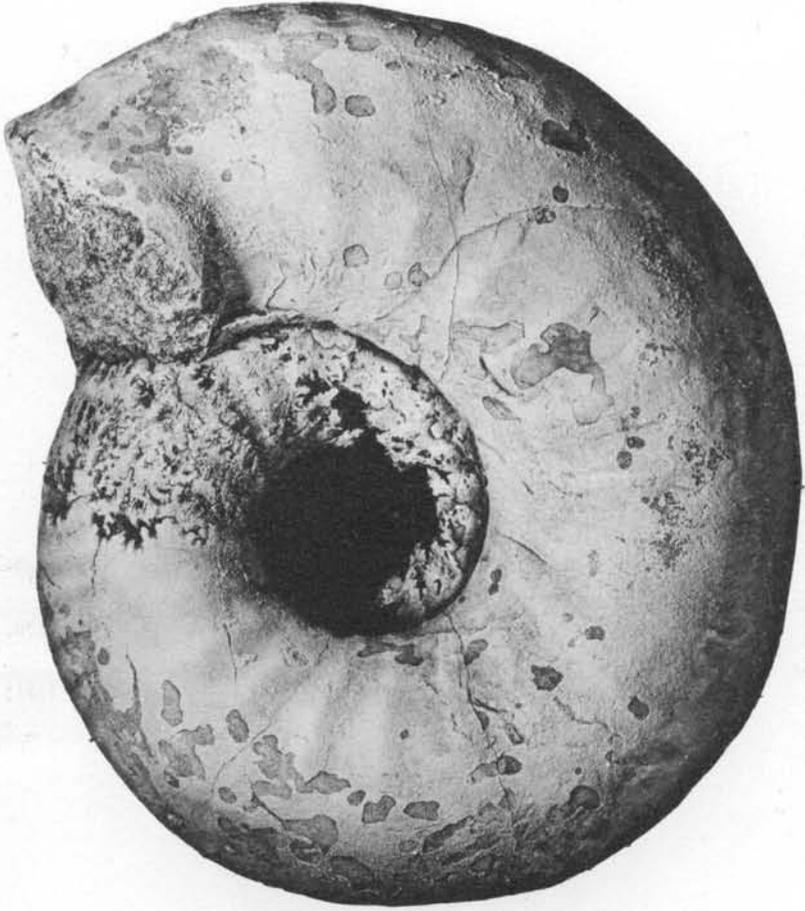


PLATE III

(All figures natural size)

Types in collections of the Geological Survey of Canada.

- Figure 1. *Arkelloceras tozeri* Frebold. (Page 8.) Lateral view. GSC 15241; GSC loc. 35324.
- Figure 2. *Amoeboceras* sp. indet. (Page 22.) Rubber cast, lateral view. GSC 15130; GSC loc. 35346.
- Figure 3. *Amoeboceras* sp. indet. (Page 22.) Rubber cast, lateral view. GSC 15131; GSC loc. 35346.



1



2



3

PLATE IV

(All figures natural size)

Types in collections of the Geological Survey of Canada.

- Figure 1. *Arkelloceras tozeri* Frebold. (Page 8.) Ventral view. GSC 15140; GSC loc. 35324.
- Figures 2a, b. *Arkelloceras tozeri* Frebold. (Page 8.) 2a, lateral view; 2b, ventral view. GSC 15143; GSC loc. 35324.
- Figures 3a, b. *Arkelloceras mclearni* Frebold. (Page 8.) 3a, lateral view; 3b, ventral view. GSC 15142; GSC loc. 35324.

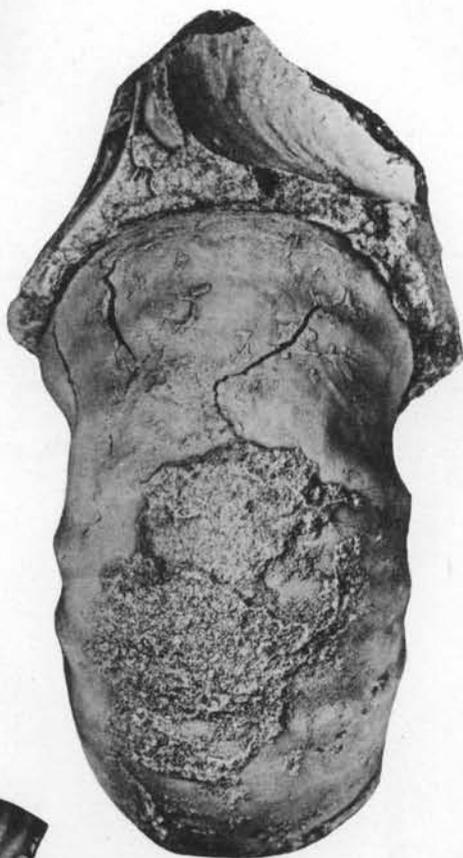
PLATE IV



2b



3b



1



2a



3a

PLATE V

(All figures natural size)

Types figures 1a-c and 2 in collections of the Geological Survey of Canada; figure 3 in collections of Geology Department, University of Alberta.

- Figures 1a, b, c. *Arkelloceras tozeri* Frebald. (Page 8.) 1a, lateral view with suture line; 1b, cross-section and venter; 1c, suture line on venter. GSC 15141; GSC loc. 35324.
- Figure 2. *Erycites* cf. *E. howelli* (White). (Page 7.) Rubber cast, ventral view. GSC 15139; GSC loc. 38776.
- Figure 3. *Phylloceras* sp. indet. (Page 6.) Ventral view. GSC plastotype 15146; U. of A. loc. 10097.

PLATE V



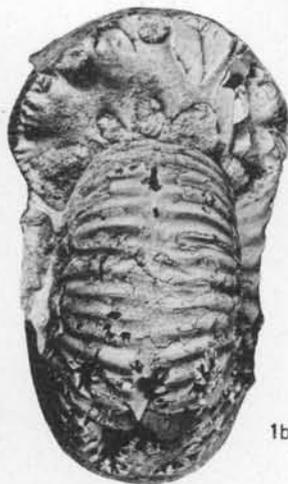
2



3



1a



1b



1c

PLATE VI

Type in collections of Geological Survey of Canada.

Figure 1.

Zetoceras thorsteinssoni n. sp. (Page 5.) Lateral view of inner whorl. GSC holotype 15144; GSC loc. 35324, x 1½.



PLATE VII

(Figure natural size)

Type in collections of the Geological Survey of Canada.

Figure 1.

Zetoceras thorsteinssoni n. sp. (Page 5.) Cross-section of inner whorl. GSC holotype 15144; GSC loc. 35324.



PLATE VIII

(Figure natural size)

Type in collections of the Geological Survey of Canada.

Figure 1. *Zetoceras thorsteinssoni* n. sp. (Page 5.) Lateral view, complete specimen. GSC holotype 15144; GSC loc. 35324.

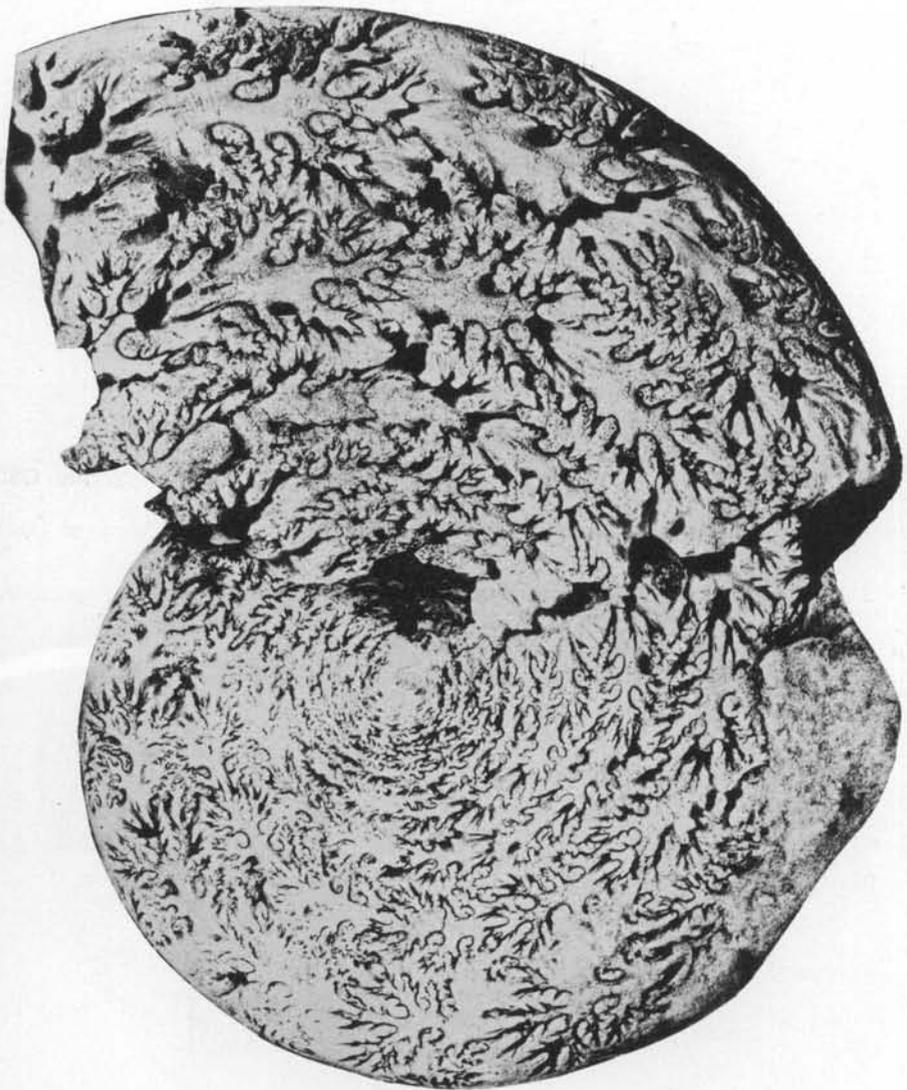
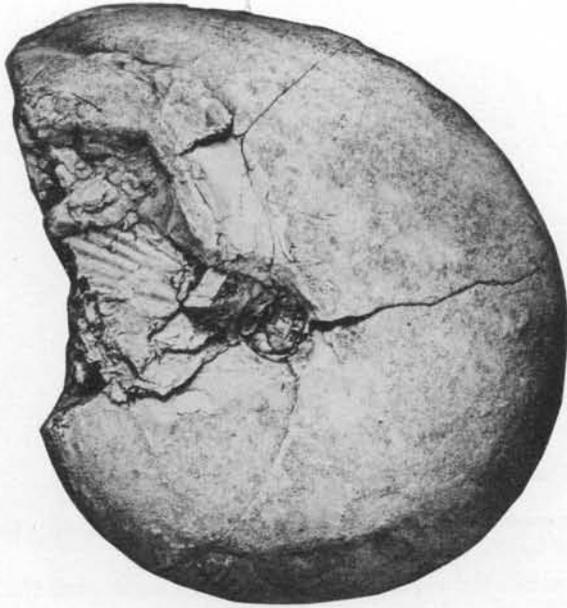


PLATE IX

(All figures natural size)

Types in collections of the Geological Survey of Canada.

- Figure 1. *Arctocephalites elegans* Spath. (Page 10.) Lateral view. GSC 15111; GSC loc. 35692.
- Figure 2. *Zetoceras thorsteinssoni* n. sp. (Page 5.) Lateral view. GSC paratype 15145; GSC loc. 35324.
- Figure 3. *Arcticoceras kochi* Spath. (Page 16.) Lateral view. GSC 15117; GSC loc. 35634.



1



2



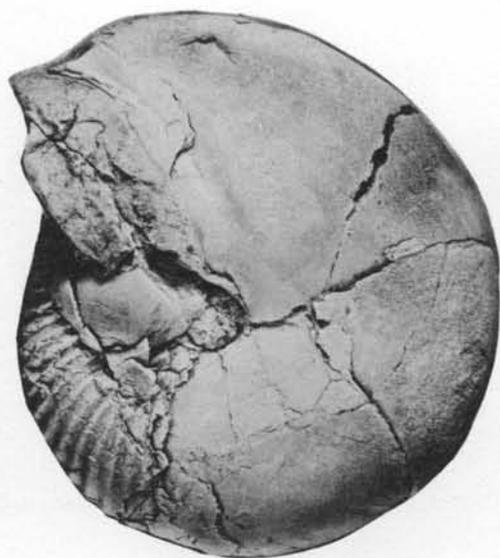
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PLATE X

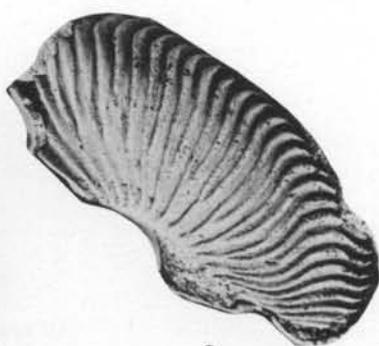
(All figures natural size)

Types in collections of the Geological Survey of Canada.

- Figures 1a, b. *Arctocephalites elegans* Spath. (Page 10.) 1a, lateral view; 1b, cross-section and venter. GSC 15115; GSC loc. 35692.
- Figure 2. *Arctocephalites elegans* Spath. (Page 10.) Lateral view. GSC 15114; GSC loc. 35639.
- Figure 3. *Arcticoceras ishmae* (Keyserling). (Page 15.) Lateral view, rubber cast. GSC 15122; GSC loc. 35343.



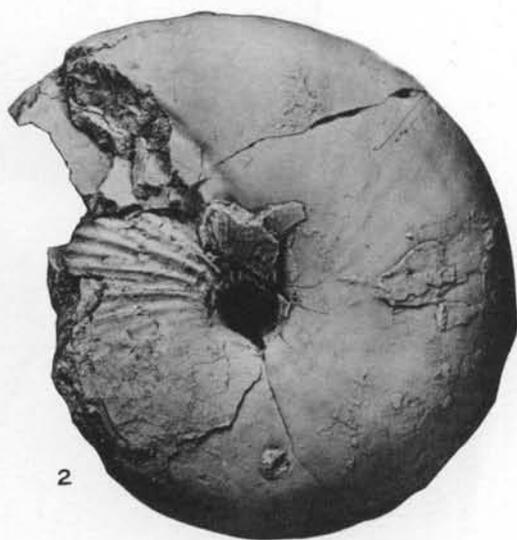
1a



3



1b



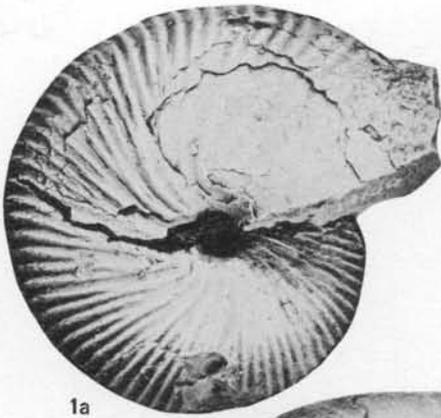
2

PLATE XI

(All figures natural size)

Type figure 2 in collections of Geology Department, University of Alberta; types figures 1a, b, 3 and 4 in collections of the Geological Survey of Canada.

- Figures 1a, b. *Arctocephalites elegans* Spath. (Page 10.) 1a, lateral view; 1b, cross-section and venter. GSC 15108; GSC loc. 13136.
- Figure 2. *Arctocephalites elegans* Spath. (Page 10.) Lateral view. GSC plastotype 15109; U. of A. loc. 45413.
- Figure 3. *Arctocephalites elegans* Spath. (Page 10.) Lateral view. GSC 15113; GSC loc. 35639.
- Figure 4. *Arctocephalites elegans* Spath. (Page 10.) Lateral view. GSC 15112; GSC loc. 37917.



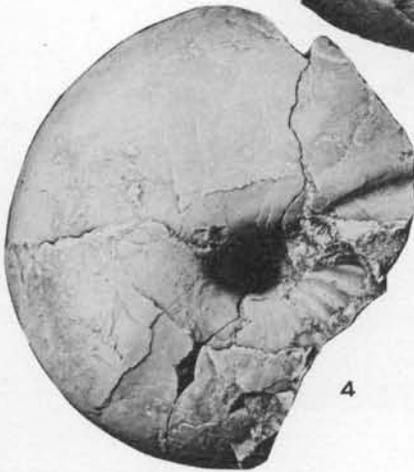
1a



2



3



4



1b

PLATE XII

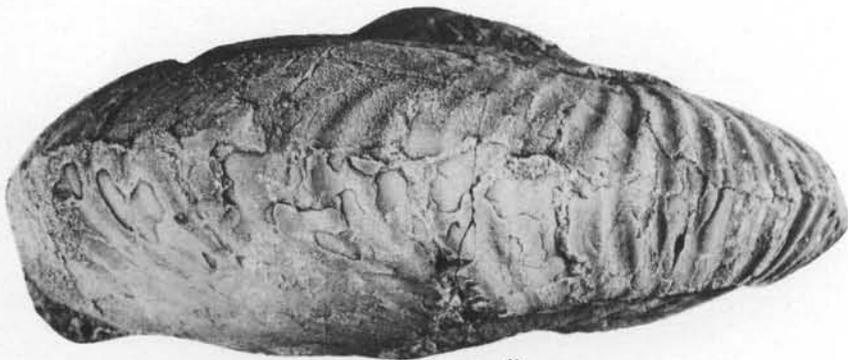
(Figure natural size)

Type in collections of the Geological Survey of Canada.

Figures 1a, b. *Arcticoceras kochi* Spath. (Page 16.) 1a, lateral view; 1b, venter. GSC 15116;
GSC loc. 35631.



1a



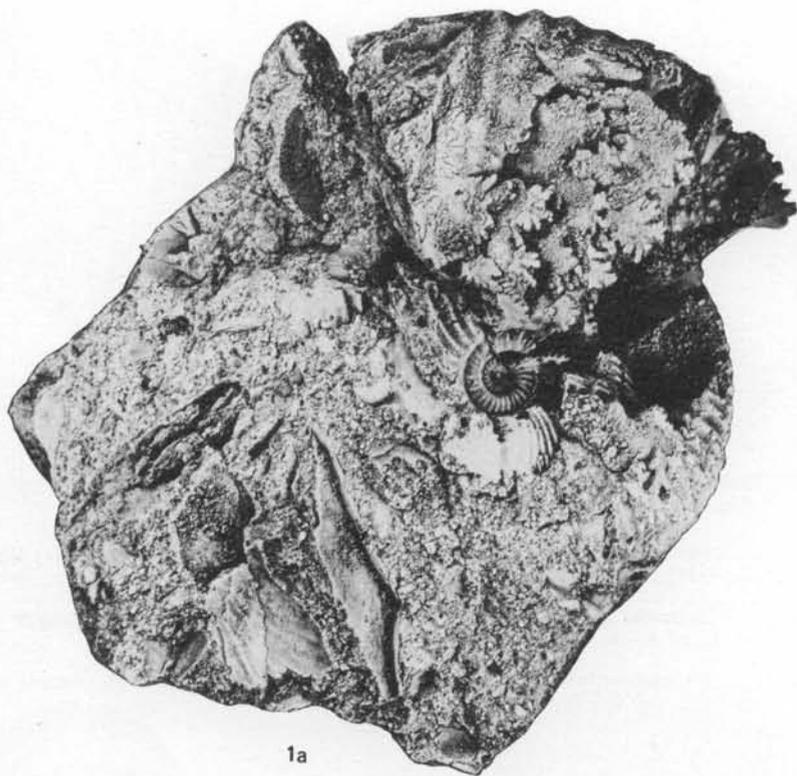
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PLATE XIII

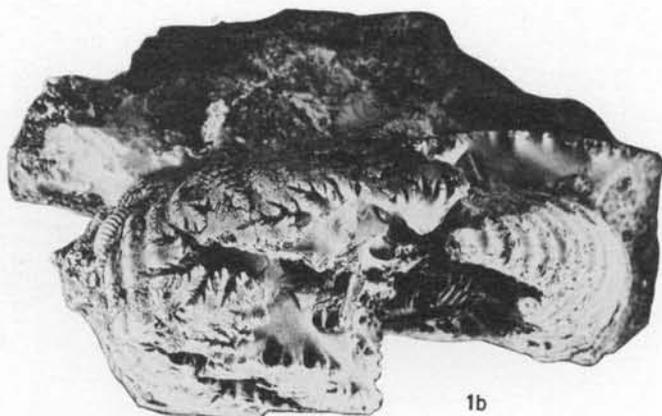
(Figure natural size)

Type in collections of the Geological Survey of Canada.

Figures 1a, b. *Arcticoceras ishmae* (Keyserling). (Page 15.) 1a, lateral view; 1b, venter. GSC 15119; GSC loc. 35343.



1a



1b

PLATE XIV

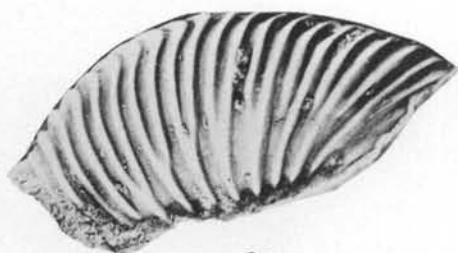
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Type figure 2 in collections of Geology Department, University of Alberta; types figures 1 and 3a, b in collections of the Geological Survey of Canada.

- Figure 1. *Arcticoceras ishmae* (Keyserling). (Page 15.) Lateral view. GSC 15121; GSC loc. 35343.
- Figure 2. *Cadoceras crassum* Madsen. (Page 17.) Lateral view. GSC plastotype 15124; U. of A. loc. 10061.
- Figures 3a, b. *Arcticoceras ishmae* (Keyserling). (Page 15.) 3a, lateral view; 3b, ventral view of preceding whorl. GSC 15120; GSC loc. 35343.



1



3a



3b



2

PLATE XV

(Figure natural size)

Type in collections of Geology Department, University of Alberta.

Figures 1a, b. *Cadoceras* cf. *C. frebaldi* Spath. (Page 18.) 1a, lateral view; 1b, venter. GSC plastotype 15123; U. of A. loc. 38899.



1a



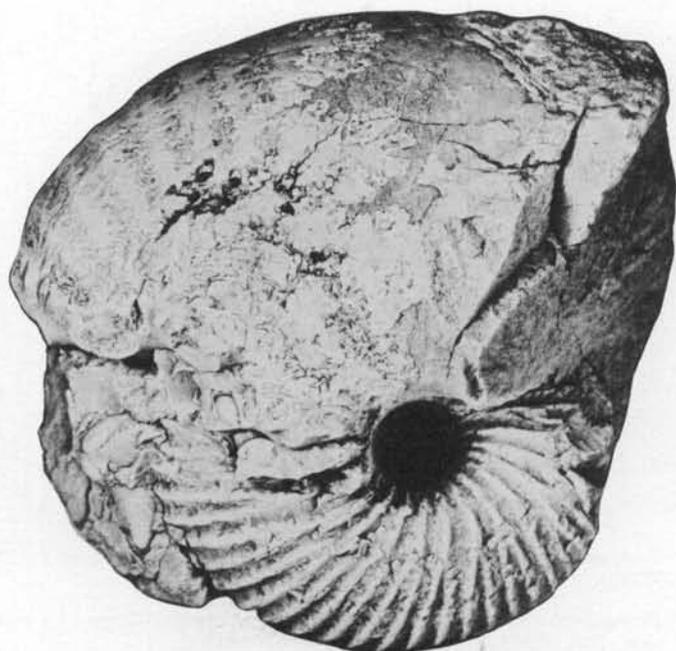
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PLATE XVI

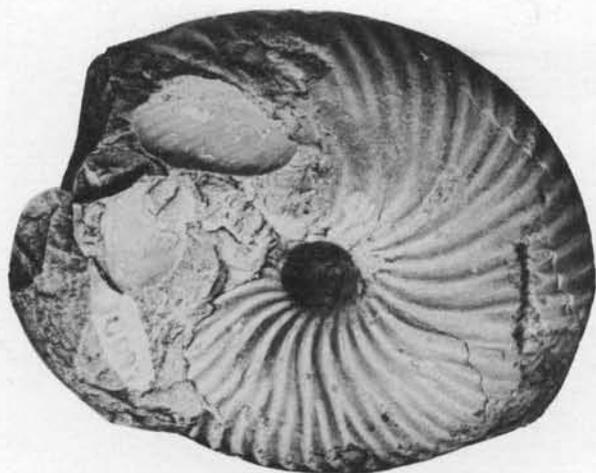
(All figures natural size)

Type figure 1 in collections of the Geological Survey of Canada; type figure 2 in collections of Geology Department, University of Alberta.

- Figure 1. *Cadoceras* aff. *C. pseudishmae* Spath. (Page 20.) Lateral view. GSC 15138; GSC loc. 35692.
- Figure 2. *Arcticoceras kochi* Spath. (Page 16.) Lateral view. GSC plastotype 15118; U. of A. loc. 10097.



1



2

PLATE XVII

(All figures natural size)

Types in collections of the Geological Survey of Canada.

- Figure 1. *Cadoceras crassum* Madsen. (Page 17.) Ventral view. GSC 15125; GSC loc. 35692.
- Figure 2. *Dorsoplanites* sp. indet. ex gr. *D. panderi* Michalski. (Page 23.) Imprint, lateral view. GSC 15133; GSC loc. 28714.
- Figure 3. *Cadoceras* sp. (Page 19.) Lateral view. GSC 15127; GSC loc. 25980.

PLATE XVII

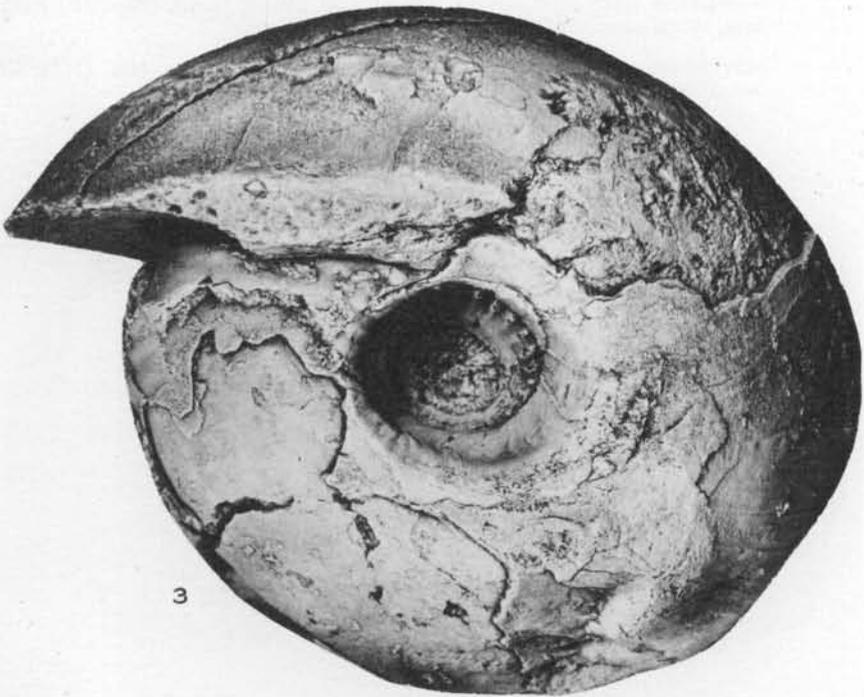
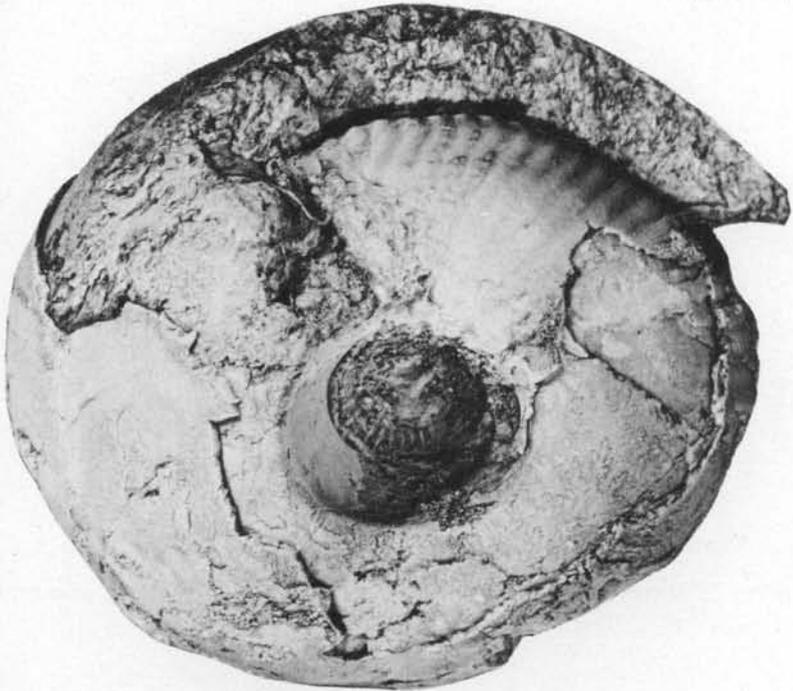


PLATE XVIII

(All figures natural size)

Types in collections of the Geological Survey of Canada.

- Figure 1. *Cadoceras* sp. (Page 19.) Same specimen as Plate XVII, figure 3 after removal of part of last whorl. GSC 15127; GSC loc. 25980.
- Figure 2. *Cardioceras* (*Scarburgiceras*) sp. indet. aff. *C. mirum* Arkell. (Page 22.) Rubber cast, lateral view. GSC 15128; GSC loc. 26159.
- Figure 3. *Amoeboceras* sp. indet. (Page 22.) Rubber cast, lateral view. GSC 15129; GSC loc. 35346.



1



2



3

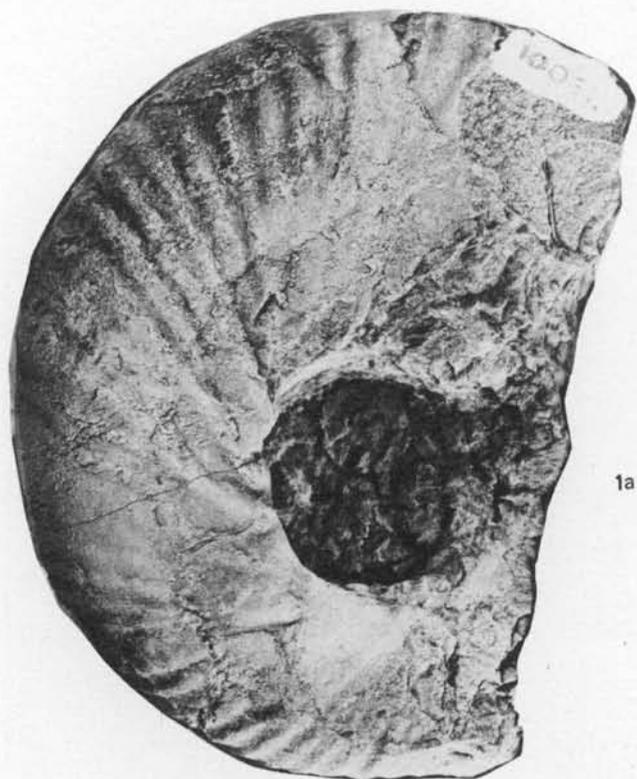
PLATE XIX

(Figure natural size)

Type in collections of the Geology Department, University of Alberta.

Figures 1a, b. *Cadoceras* sp. indet. (Page 21.) 1a, lateral view; 1b venter. GSC plastotype 15126; U. of A. loc. 10061.

PLATE XIX



1a



1b

PLATE XX

(Figure natural size)

Type in collections of the Geological Survey of Canada.

Figure 1. *Dorsoplanites* sp. indet. (Page 23.) Lateral view. GSC 15134; GSC loc. 28714.



PLATE XXI

(Figure about half of natural size)

Type in collections of the Geological Survey of Canada.

Figure 1.

Pavlovia? sp. indet. (Page 24.) Rubber cast, lateral view. GSC 15132; GSC loc. 28714.

