Geological Survey of Canada
Commission géologique du Canada

Bulletin 358

ZONATION AND CORRELATION OF MIDDLE BOREAL BATHONIAN TO LOWER CALLOVIAN (JURASSIC) AMMONITES, SALMON CACHE CANYON, PORCUPINE RIVER, NORTHERN YUKON

T.P. Poulton

1987

Canadä

GEOLOGICAL SURVEY OF CANADA
BULLETIN 358

ZONATION AND CORRELATION OF MIDDLE BOREAL BATHONIAN TO LOWER CALLOVIAN (JURASSIC) AMMONITES, SALMON CACHE CANYON, PORCUPINE RIVER, NORTHERN YUKON

T.P. Poulton

1987

Available in Canada through

authorized bookstore agents and other bookstores

or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Canada K1A 0S9

and from

Geological Survey of Canada offices:

601 Booth Street
Ottawa, Canada K1A 0E8

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

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

Cat. No. M42-358E Canada: $13.00
ISBN 0-660-12512-9 Other countries: $15.60

Price subject to change without notice

Critical readers

T. Birkelund
J.H. Callomon
E.T. Tozer

Scientific editor

N.C. Ollerenshaw

Editor

J.M. MacGillivray

Technical editor and layout

L. Machan-Gorham
E.G. Snow

Word processing and production

P. Greener
M. Varalta
A. Seif
H. King

Author's address

Institute of Sedimentary and Petroleum Geology
3303 - 33rd Street N.W.
Calgary, Alberta T2L 2A7

Artwork by CARTOGRAPHY UNIT
Institute of Sedimentary and Petroleum Geology

Original manuscript submitted: 1982-09-07
Approved for publication: 1985-12-02

Cover

Oxycerites birkelundi from GSC locality 93570, see Plate 35.

PREFACE

Ammonites have long been recognized to be among the finest tools for correlation of Mesozoic rocks and have served as the inspiration for many current ideas on fossil species concepts, on the style and rate of evolution, and on paleobiogeographic provincialism.

This study describes the ammonites from a single, richly fossiliferous, and well exposed locality in northern Yukon where a succession of seven faunas is present. A new zonation for northwestern Canada is proposed based on this succession. The ammonites are mainly Boreal, and correlations of each zone with the published successions across the Arctic are discussed. The presence of some fossils with Pacific affinities contributes to resolution of the long-standing problems of correlation of Bathonian zones intercontinentally, via northern Yukon and Western Canada. Eight new species and one new genus are described.

Stratigraphic paleontological studies such as this lead to the development of widely accepted standards of correlation, essential tools in reconstructing the geological framework of Canadian sedimentary basins and evaluating their mineral and hydrocarbon resources.

OTTAWA, 1986

R.A. Price
Director General
Geological Survey of Canada

PRÉFACE

On reconnaît depuis longtemps l'utilité des ammonites dans la corrélation des roches mésozoïques; elles ont servi également de guide dans l'évolution de concepts traitant des espèces fossiles, par leur style et leur avancement évolutif, et ainsi que leur provincialisme palébiogéographique.

Cette étude décrit des ammonites provenant d'une localité unique, très fossilifére du Yukon septentrional où se situe une succession comprenant sept faunes. Cette succession a fourni la base de données qui nous permet de proposer une nouvelle zonation pour le Canada du nord-ouest. Les ammonites sont, pour la plupart, boréales, et des corrélations de chaque zone avec des successions de l'Arctique déjà rapportées y sont discutées. La présence de quelques fossiles ayant des affinités avec ceux du Pacifique contribue à la résolution de problèmes de longue durée portant sur la corrélation intercontinentale des zones bathoniennes, via le Yukon septentrional et le Canada occidental. On y décrit huit nouvelles espèces et un nouveau genre.

Des études stratigraphiques et paléontologiques telles que celle-ci nous mène à l'élaboration des standards de corrélation reconnus globalement. De tels standards sont essentiels à la compréhension de la structure géologique des bassins sédimentaires due Canada et à l'évaluation de leur potentiel économique en ressources minérales et en hydrocarbures.

OTTAWA, 1986

R.A. Price
Le directeur général
de la Commission géologique du Canada

CONTENTS

Illustrations

Figures

Tables

ZONATION AND CORRELATION OF MIDDLE BOREAL BATHONIAN TO LOWER CALLOVIAN (JURASSIC) AMMONITES, SALMON CACHE CANYON, PORCUPINE RIVER, NORTHERN YUKON

Abstract

The Middle Bathonian through Lower Callovian ammonites from the Salmon Cache Canyon section on Porcupine River are dominantly Boreal, represented by an upward succession of *Arctocephalites, Arcticoceras* and *Cadoceras* species. They are very similar to equivalent faunas in northern Alaska, East Greenland and northern Siberia, but differ at the species level, so that a new zonation for northern mainland Canada is proposed. In upward succession, the zones are: *spathi, porcupinensis, amundseni, frami, harlandi, ishmae* (from East Greenland; restricted), *barnstoni*, and *bodylevskyi*. Correlations with the Boreal zonations elsewhere are suggested. Additionally, a small proportion of Pacific and cosmopolitan ammonites in the collections permit further refinement of the correlation of the Boreal with the Pacific and ultimately with the Northwest European standard zonation. The Boreal Bathonian-Callovian boundary is placed in the interval between the *barnstoni* and *bodylevskyi* Zones.

One new genus is proposed – *Loucheuxia*, of subfamily Eurycephalitinae. New species erected are *Arctocephalites spathi, A. porcupinensis, A. praeishmae, A. amundseni, A. frami, A.(?) belli, Loucheuxia bartletti*, and *Oxycerites birkelundi*.

Keywords: *Bathonian, Callovian, ammonites, Yukon,* ***Arcticoceras, Arctocephalites, Cadoceras, Kepplerites, Louchuxia, Oxycerites.***

Résumé

Des ammonites d'âge Bathonien moyen au Callovien inférieur, provenan de la coupe de Salmon Cache Canyon et située sur la rivière Porcupine, sont pour la plupart boréales. Elles sont représentées par une succession ascendante des espèces d'*Arctocephalites*, d'*Arcticoceras*, et de *Cadoceras*. Elles ressemlent beaucoup aux faunes équivalentes localisées en Alaska septentrional, au Groenland oriental et en Sibérie septentrionale; cependant, elles se distinguent au niveau espèce, ce qui a mené à l'établissement d'une nouvelle zonation proposée pour le Canada continental nordique. En succession ascendante, les zones sont less suivantes: *spathi, porcupinensis, amundseni, frami, harlandi, ishmae* (du Groenland oriental; restreinte); *barnstoni*, et *bodylevskyi*. Des corrélations accompagnées de zonations boréales provenant d'ailleurs sont suggérées. De plus, une proportion mineure d'ammonites cosmopolites et due domaine pacifique présente dans les collections permet la corrélation plus précise entre le domaine boréale et le domaine pacifique, et, en fin de compte, la corrélation peut se faire aussi avec la zonation standard de l'Europe du nord-ouest. La frontière boréale du Bathonien au Callovien se situe dans l'intervalle entre les zones de *barnstoni* et de *bodylevskyi*.

On propose l'établissement d'un nouveau genre, *Loucheuxia*, de la sous-famille Erycephalitinae. Donc, les nouvelles espèces établies sont: *Arctocephalites spathi, A. porcupinensis, A. praieshmae, A. amundseni, A. frami, A.(?) belli, Loucheuxia bartletti*, et *Oxycerties birkelundi*.

Mots clés: *Bathonian, Callovian, ammonites, Yukon,* ***Arcticoceras, Arctocephalites, Cadoceras, Kepplerites, Louchuxia, Oxycerites.***

INTRODUCTION

The Boreal Bathonian section at Salmon Cache Canyon on Porcupine River is of interest for two reasons. Firstly, it exposes a succession of closely spaced concretionary layers that are richly fossiliferous, possibly the most biostratigraphically complete single section of its age anywhere in the Boreal Realm, and certainly the most complete section outside of eastern Greenland. The section, therefore, potentially provides a standard succession for the Boreal Bathonian of Arctic North America, and contributes in a major way to the development of an intercontinental Boreal Bathonian standard. Secondly, together with the predominant Boreal ammonite species, there also occur others with southern affinities. Some of these, together with a consideration of the ammonite succession elsewhere, permit some further elaboration of the correlation of the Boreal zonation with that of the circum-Pacific succession and with the Northwest European standard zonation. Unfortunately, these last ammonites belong mainly to genera that are long ranging and are too rare and poorly preserved to identify specifically, so that unequivocal correlations are not yet possible. Unlike most Boreal successions elsewhere, these faunal elements indicate access to Pacific seas to the south (Poulton, in press).

Outside of the typical area of Northwest Europe, recognition of the Bathonian-Callovian boundary remains elusive because of the absence of the critical guide fossils due to faunal provincialism. Although this interval is not well exposed in the Salmon Cache Canyon section, the ammonites present contribute to the resolution of this problem indirectly via correlation with East Greenland.

Only the Salmon Cache Canyon section and its faunas are described here. There are numerous other occurrences of equivalent faunas (see Poulton, 1978; Poulton et al., 1982), but they are mostly from localities that do not provide a succession of fossiliferous horizons or additional faunal data. They will be dealt with in a later publication. Because of their importance, the ammonite species found in this section are profusely illustrated, in order to document their variation within individual beds where possible, and their range of variation from one bed to another. Description of the ammonite faunas has required the description of many specimens collected as loose material below the section. For some of the less common, non-Boreal species, which are particularly significant forms for correlation southward, loose material is all that is available. Many of the loose specimens can be assigned confidently to the bed from which they came because of their association in a single concretion with a variety of other characteristic fossils, or because the character of the matrix of the concretion allows it to be compared with a particular lithologically distinctive bed in the section.

Faunal provincialism

Ammonoids, because of their rapid evolution displayed in a complex morphology, their abundance in marine rocks worldwide, and the wide geographic distribution of individual species, remain the principal guide fossils for correlation of Mesozoic marine rocks. Faunal provincialism, however, sets limits to what can be achieved in worldwide correlation. In practice, therefore, the succession of faunas must be recognized in each faunal province independently, and final interprovincial synthesis is achieved by correlation in regions of overlap. To this day, precise correlation of many of the zones of the Arctic Middle Jurassic with those of Northwest Europe and the western part of the Americas has not been achieved (e.g. Callomon, 1958), and a complete zonation for the Middle Jurassic of the circum-Pacific area is still lacking. Furthermore, the faunas present in the Jurassic of many areas, including some in Northern and Western Canada, are still undescribed, and the succession in some critical areas remains poorly documented.

The fact that marine Jurassic faunas exhibit provincialism was discussed extensively first by Neumayr (1883), with regard to the Upper Jurassic of Europe. He also expressed the basic principal that underlies provincialism, and gave some interpretations of its causes. That distinct faunal provinces in the Jurassic existed as far back as Bajocian time was recognized by Arkell (1956), who simplified distribution patterns into three faunal realms - Tethyan, Pacific and Boreal. Imlay (1965) discussed the evidence for, and application of, the faunal realms to North America in particular. The literature on Mesozoic marine faunal provincialism is large and is not reviewed here (see Jeletzky, 1971 for such a discussion), and hypotheses regarding its causes are many. Some amount of latitudinal climatic differentiation, together with restricted patterns of circulation in marine basins, in large part due to the interference by continental masses, seem to be widely accepted and sufficient causes for the distribution patterns as we see them.

With increasing knowledge of ammonite distributions arising from continued taxonomic work around the globe, it is apparent that neither their biogeographic patterns nor the biostratigraphy are as well understood or as clearcut as has been thought, even in Europe (e.g. Ziegler, 1980). For example, the abundance of phylloceratids and the presence of *Cadomites* in the mainly Boreal faunas described in this report is surprising, and indicates the premature character of generalizations regarding Jurassic ammonite distributions in the western Americas.

Faunal provincialism has made correlation of the European type Bathonian successions with those outside Europe difficult. Only recently have Bathonian rocks and fossils been widely recognized outside of Northwest Europe. The greatest advances were first made in the Arctic Atlantic areas, principally East Greenland.

Among the first of the Arctic species to be described was *Ammonites ishmae* Keyserling (now *Arcticoceras*), found in an isolated position in northern European Russia (Keyserling, 1846). Its similarity to European *Macrocephalites* led early workers to conclude that it was of Callovian age (the Callovian was, at that time, included in the Upper Jurassic). Other species that were ascribed to the Middle Jurassic could not be matched exactly with those of Europe, and a number of new names were introduced. Some were compared with *A. ishmae* of northern Russia. Given European generic identifications, collections over wide areas of the Arctic were dated as Callovian. Finally, it was recognized by Spath (1928, 1932) that the Arctic ammonites represented new genera – *Arcticoceras, Arctocephalites*, and *Cranocephalites* – that are entirely unknown in the classical areas of Europe. Spath (1932) dated these Arctic genera as Late Bathonian and Early Callovian, mainly on the strength of their general similarities and supposed phylogenetic relationship to the Indo-European Macrocephalitidae, at that time believed to range into the Bathonian more extensively than is currently thought.

Arkell (1956) recognized a widespread Bathonian regression and subsequent Callovian transgression over much of Europe and the circum-Tethys region. Misled by the mainly Callovian datings of faunas from the Arctic and Western North America, he concluded erroneously that the Bathonian regressive episode was worldwide. This conclusion reinforced the Callovian and Late Bathonian dating of faunas in North America and USSR which bore no relation to those of Europe, but which did resemble those of East Greenland.

Callomon (1959, 1975; Callomon and Birkelund, 1980) erected the current Boreal zonation for East Greenland (see Tables 1, 3). He proposed a Bathonian age for *Cadoceras calyx* and other faunas as old as the oldest *Cranocephalites* species, *C. borealis*. In order to emphasize the differences and the difficulty of correlating between the typical and the boreal successions, he proposed the term 'Boreal Bathonian' for the latter.

Previous work

The first Jurassic fossils that probably came from the Salmon Cache locality were discovered in the possession of Hudson's Bay Company chief factor, Mr. George Barnston, by H.Y. Hind, leader of the Assiniboine and Saskatchewan Exploring Expedition of the Northwest Territory, under instruction from the provincial secretary of Canada. The single sample contained two species of ammonite, both of which were described as new by F.B. Meek (1859), who mistakenly thought them to be Cretaceous, although he recognized their Jurassic affinities. The sample was presumed to have been carried to the trading post in Mackenzie River valley by trappers.

The next Jurassic fossils from this locality were collected along Porcupine River by R.G. McConnell in 1888. They also were misidentified as Cretaceous, by J.F. Whiteaves (McConnell, 1891, p. 123D, 124D).

Only a few sporadic regional mapping and petroleum exploration studies were conducted until 1955, when J.A. Jeletzky began a systematic stratigraphic study of the Mesozoic rocks of northern Yukon and adjacent Northwest Territories.

The Late Jurassic age of McConnell's (1891) 'Sandstone and quartzite series' was first recognized by Jeletzky (1960, Correlation Chart) who later (Jeletzky, 1977) named them the Porcupine River Formation. The ammonites collected by McConnell and Jeletzky from the underlying shales were described as Jurassic species, and a brief summary description of the section measured by Jeletzky was published (Frebold, 1961, p. 2, 6, 10). A redescription of the holotype of *Cadoceras barnstoni* (Meek) (Frebold, 1964) and a description of one specimen of *Iniskinites* collected by D.K. Norris during the course of a regional mapping project called Operation Porcupine (1962-present) have appeared since then (Frebold, 1978).

Present study and acknowledgments

At the suggestion of J.A. Jeletzky, the Salmon Cache Canyon section was studied in 1975, when the author and J.H. Callomon began a detailed regional study of the pre-Late Jurassic rocks and faunas of the area. Callomon and the author, together with T. Birkelund, R.L. Detterman, and D.H. McNeil, restudied the section in 1981. In addition to their continuing assistance and advice on the section and its ammonites, including preliminary identifications, Callomon and Birkelund made available a great deal of unpublished information, including manuscripts, and showed the writer collections from the similar East Greenland succession. The present report incorporates some of this information on East Greenland, in part paraphrased with permission. Much of the description of the Salmon Cache Canyon section itself, as well as the original base of Figure 4 (excluding the range chart), were done by Callomon. Additionally, Callomon made available to the author an unpublished manuscript reviewing taxonomically and reinterpreting the successions of Western North American Middle Jurassic ammonites (Callomon, 1984). H. Frebold made preliminary identifications of the 1975 collections from Salmon Cache Canyon. All of the results stated in this report regarding the North American faunas are the responsibility of the author however, arising from independent study or restudy of the fossils and rocks. Study of type and other material from Arctic and Western North America was facilitated by the courtesies of T.E. Bolton and R.W. Imlay.

Two preliminary reports arising from this study, and mentioning the Salmon Cache section in summary form, with since-revised ammonite identifications, have been published (Poulton and Callomon, 1976; Poulton, 1978) and other comprehensive reports on the Jurassic stratigraphy of the area are available (Poulton, 1982; Poulton et al., 1982). J.H. Callomon (1984) has summarized the ammonite succession at Salmon Cache Canyon with an independent interpretation, in a revision of Western and Arctic North American Middle and Upper Jurassic ammonites. J.A. Jeletzky and D.K. Norris have provided much advice to the writer and critical discussion on the geologic situation of the section. Particular thanks go to B.C. Rutley and W.B. Sharman for their patience and skill in the preparation of the photographs, and to P.L. Greener and H. King, for the production of the typescript. The entire manuscript, in an earlier form, was critically read by T. Birkelund and J.H. Callomon, and all but the taxonomic section was read, and significantly improved, by E.T. Tozer.

GEOLOGICAL SETTING

Regional stratigraphic relationships

The Lower and Middle Jurassic siltstone-sandstone succession at Salmon Cache Canyon is part of the nearshore, shallow marine Bug Creek Group (see Table 2), that extends southwest from west-central Mackenzie Delta to the low hills that comprise the northeastern extension of Keele Range between Old Crow Flats and Eagle Plain (figs. 1, 2). The Lower and Middle Jurassic rocks of this belt are enriched in sand and, as one progresses southeast onto the craton, the sandstone beds become pebbly. The succession is thinner and more strongly punctuated by unconformities to the southeast than it is to the northwest, where it passes into the stratigraphically more complete siltstone-shale facies of the Kingak Formation in Brooks-Mackenzie Basin (Poulton, 1978; Poulton et al., 1982; Balkwill et al., 1983).

TABLE 1

Correlation Chart, Middle Bathonian to Lower Callovian ammonite zones in Boreal Realm, and the Northwest European zonation. Double vertical line separating Northwest Europe from other columns indicates intervals of still uncertain correlation.

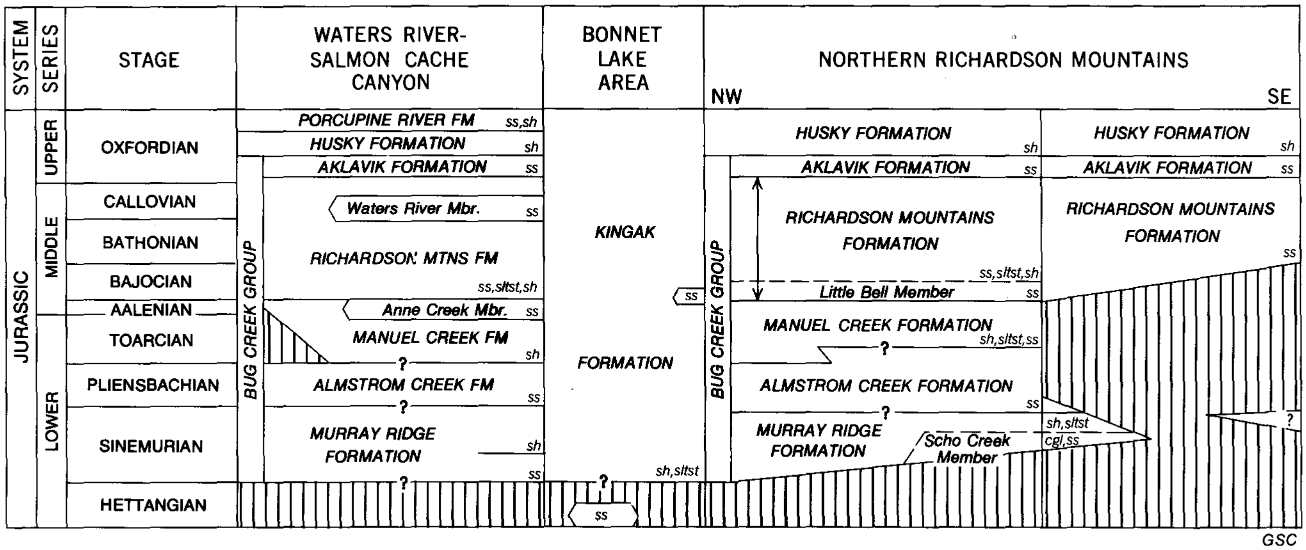
BOREAL SUBSTAGES	NORTHERN YUKON ZONES (This report)	NORTHERN ALASKA Imlay (1955, 1976)	CANADIAN ARCTIC ARCHIPELAGO Frebold (1961, 1964)	NORTH SEA Callomon (1975, 1979)	FRANZ JOSEF LAND Newton and Teall (1897) Pompeckj (1899) Whitfield (1906)	SVALBARD Sokolov and Bodylevsky (1931) Pchelina (1967) Rawson (1982)	NOVAYA ZEMLYA Frebold (1951) Bodylevsky (1967) Cherkesov and Burdykina (1981)
LOWER CALLOVIAN			*Cadoceras septentrionale*, *C. septentrionale* var. *latidorsata*				
	BODYLEVSKYI		*Cadoceras bodylevskyi*, *C.* sp. cf. *C. falsum C. barnstoni* *C. barnstoni* var. *arcuata*			*Kepplerites svalbardensis*, *K. "tychonis"*	
UPPER BATHONIAN							
	BARNSTONI						
				Kepplerites stephanoides, *Arcticoceras cranocephaloides*			
	ISHMAE	*Arcticoceras ishmae (?)*	*Arcticoceras ishmae*	*Arcticoceras* cf. or aff. *A. ishmae*, *Arcticoceras michaelis*, *Arcticoceras* sp. indet.		*Arcticoceras* cf. *ishmae (?)*	*Arcticoceras ishmae*, *A.* cf. *excentricum*
	HARLANDI					*Arcticoceras harlandi*, *Costacadoceras bluethgeni*	
MIDDLE BATHONIAN							
	FRAMI						*"Arctocephalites* aff. *groenlandicus"*
	AMUNDSENI						
	PORCUPINENSIS	*Arctocephalites* cf. *elegans*, *A.* cf. *arcticus*	*Arctocephalites "elegans"*, *A. callomoni*, *A.* cf. *A. arcticus*, *A.* aff. *A. pilaeformis* and *A. arcticus*	*Arctocephalites arcticus*, *Arctocephalites* cf. *sphaericus*	*Arctocephalites arcticus*, *A. nudus*, *A. pilaeformis*, *A. koettlitzi*, *A. ellipticus*, *A. callomoni (?)*		*Arctocephalites elegans*, *A.* cf. *ellipticus*, *A. ornatus*, *A. arcticus*, *A.* spp. — — — *Oxycerites* aff. *jugatus*
	SPATHI						

EAST GREENLAND Callomon (1959, 1975, 1979, pers. comm.) Birkelund et al. (1971) Surlyk et al. (1973) Zones		NORTHERN SIBERIA Bodylevsky (1937) Voronetz (1962) Basov et al. (1967) Meledina (1966, 1968, 1973, 1977) Saks et al. (1976) Meledina and Nal'nyaeva (1972) Dzhinoridze and Meledina (1966) Zones		NORTHERN EUROPEAN RUSSIA Bodylevsky (1960) Saks et al. (1976)	NORTHWEST EUROPE Zones	STANDARD SUBSTAGES
CALLOVIENSE	*Sigaloceras calloviense*	EMILIANZEVI	*Cadoceras emilianzevi, C. subtenuicostatum*	*Sigaloceras calloviense*	CALLOVIENSE	LOWER CALLOVIAN
	Cadoceras septentrionale					
NORDENSKJOLDI	*Cadoceras nordenskjoldi, etc.*	'ELATMAE'	*Cadoceras "elatmae", C. anabarense, C. falsum*	*Cadoceras elatmae, C.* cf. *glabrum, C. simulans, C. tschernyschevi, Kepplerites* cf. *tychonis*	MACROCEPHALUS	
APERTUM	*Cadoceras apertum, C.* spp., *Kepplerites traillensis, K.* spp.					
CALYX	*Cadoceras calyx, C.* spp. *Kepplerites vardekloeftensis, K.* spp.				DISCUS	UPPER BATHONIAN
VARIABILE	*Cadoceras variabile, C.* spp. *Kepplerites rosenkrantzi, Arcticoceras* spp.		*Cadoceras subcalyx, C. (?) excelsus, C. densicostatum, C. variabile*			
CRANOCEPHALOIDES	*Kepplerites tychonis, Arcticoceras* sp. aff. *A. cranocephaloides*					
	K. stephanoides, K. tychonis var. *fasciculata Arcticoceras cranocephaloides*					
ISHMAE	*Arcticoceras ishmae, Oxycerites birkelundi Oecotraustes*	ISHMAE	*Arcticoceras ishmae, A. excentricum, A. stepankovi, Costacadoceras* spp. *Siemiradzkia* sp.	*Arcticoceras ishmae, Costacadoceras* spp.		
	Arcticoceras spp.				HODSONI	
GREENLANDICUS	*Arctocephalites* cf. *greenlandicus A. (?) freboldi A. (?)* aff. *A. (?) crassum*				MORRISI	MIDDLE BATHONIAN
	Arctocephalites greenlandicus A. (?) crassum A. (?) aff. *crassum*					
	Arctocephalites (?) cf./aff. *crassum*	ELEGANS	*Arctocephalites kigilakhensis, A. ornatus, A.* cf. *greenlandicus, A. nudus,* and cf. *nudus, A. arcticus* and cf. *arcticus, A. callomoni, A. elegans, A. voronezae, A.* aff. *ellipticus, Siemiradzkia* sp.		SUBCONTRACTUS	
ARCTICUS	*Arctocephalites arcticus, A. nudus, A. ornatus, A. elegans, A. sphaericus, A. delicatus, A. koettlitzi, A. ellipticus, A. pilaeformis, A. platynotus*	JUGATUS	*Oxycerites jugatus, O. undatus, O.* sp. ind. *Arctocephalites callomoni, A. voronezae, A.* cf. *elegans, A. arcticus, A. ornatus, A.* aff. *ellipticus*		PROGRACILIS	

GSC

TABLE 2

Table of formations, northern Yukon Territory.



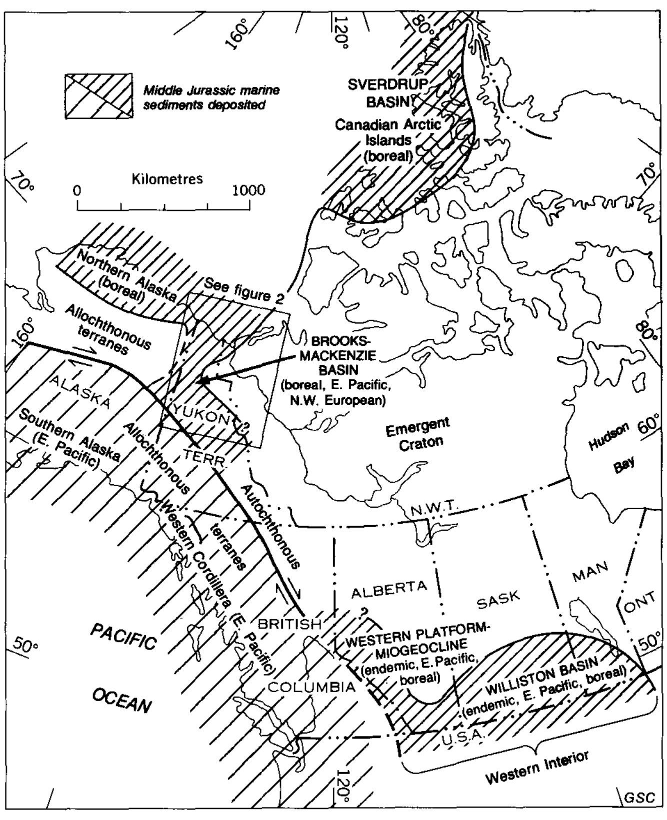


Figure 1. *Configuration of marine sedimentary basins and major tectonic features of the Middle Jurassic of Western Canada, showing basic paleobiogeographic character of Late Bathonian ammonites.*

The basin-margin sandstone succession varies in deta alongstrike, partly due to local tectonic influences (Fig. 3 The Salmon Cache Canyon locality lies southwest of the moı typical development of the Bug Creek Group, on the edge ‹ a small promontory of the Jurassic shoreline (Eagle Arch). short distance farther southwest, the sandstone facie disappears alongstrike, passing into shales and siltstones i the northern Ogilvie Mountains (Poulton, 1982). The facie changes, together with other lithological and facie variations, indicate that the probable sources of th sediments were from the southeast (Poulton et al., 1982).

The Salmon Cache Canyon locality has been interprete by Jeletzky (1975) as part of an irregular shoreline successic related to what he called the Keele-Old Crow Landmass. Th landmass supposedly formed the western margin of a narro trough that extended north-south across northern Yuko Territory, and joined Brooks-Mackenzie Basin with Jurassi seas to the south. The existence of this westerly landmas and of the trough itself in Lower and Middle Jurassic time are not now accepted by the present writer, followin detailed stratigraphic study (Poulton et al., 1982, Appendix 1 Poulton, 1982). One line of reasoning that lent support to th interpretation of the narrow seaway joining Arctic and mor southerly Western North American seas was the suppose similarity of the faunas of the two areas. However, th Western Interior and Arctic forms are not as closely relate as was thought by Imlay (1945, 1948, 1967), the former bein predominantly endemic. Most of the Bathonian faunas o southern Alaska and the Western Cordillera are now known t be vastly different from those of the Arctic, an characterize the "Eastern Pacific Realm" of Westerman (1981). At any rate, a marine connection not through th Yukon (e.g. Imlay and Detterman, 1973; Jeletzky, 1975), bu around the western edge of northern Yukon through Alaska could well explain whatever similarity there is. No landmas is now thought to have been present in central Alaska i Early and Middle Jurassic times. Instead, open ocean lay o the south edge of a northern landmass that existed in th region of the present Arctic shelf, prior to Late Jurassic or Cretaceous tectonic emplacement of allochthonous terranes from far to the south (Poulton, 1982, 1984). This picture is supported by the recent suggestion (Callomon, 1981) that Phylloceratina, present in abundance in some beds at Salmon Cache Canyon, indicates close access to oceanic environments rather than to restricted shelf seas.

All the zonal names are new except the *ishmae* Zone, which was first used for strata in East Greenland by Callomon (1975). It replaces the *kochi* Zone, following Callomon's (*ibid.*) recognition of the synonymy of *Arcticoceras kochi* Spath with *A. ishmae* (Keyserling). As used here, the *ishmae* Zone is restricted compared to Callomon's (*ibid.*) usage, comprising only the *ishmae* Subzone of his terminology.

Local stratigraphic relationships

The Bathonian and Lower Callovian rocks at Salmon Cache Canyon represent the Richardson Mountains Formation of the Bug Creek Group (Poulton et al., 1982) in an unusually condensed and richly fossiliferous facies. Norris (1981) assigned the rocks to the Kingak Formation. The difference in treatment reflects the fact that the Salmon Cache locality is near the arbitrary Bug Creek - Kingak facies boundary. The prominent Lower Callovian sandstone at the top of the section described here appears to represent the locally developed Waters River Member (see Table 2).

The Bathonian rocks described in this report are separated from older beds of the section by the Porcupine River. To the north, across the river, sandstones and shales with Sinemurian, Aalenian and Upper Boreal Bajocian ammonites overlie Permian sandstones and siltstones (Poulton, 1978, p. 451).

Twenty-two kilometres northeast of the section along structural strike, on the ridge between Waters River and Berry Creek, the Callovian and younger parts of the section are exposed. A thin sandstone with *Cadoceras*, i.e. the Waters River Member of Poulton et al. (1982), represents the topmost unit described in detail in this report, with *Cadoceras bodylevskyi*. Above it is a poorly exposed, argillaceous unit; then the Aklavik sandstone with *Cardioceras*; a black shale that represents the lower Husky Formation of the Richardson Mountains (see Poulton, 1982), and finally the thick, ridge-forming Porcupine River sandstone formation (Jeletzky, 1977). The *Cadoceras* beds and the Porcupine River sandstone (with Late Oxfordian or younger *Buchia* species) are faulted against each other at Salmon Cache Canyon so that none of the intermediate units are seen. In addition, there may possibly be some erosional truncation of these units southward, below the Porcupine River Sandstone, as it laps onto the cratonic promontory, Eagle Arch.

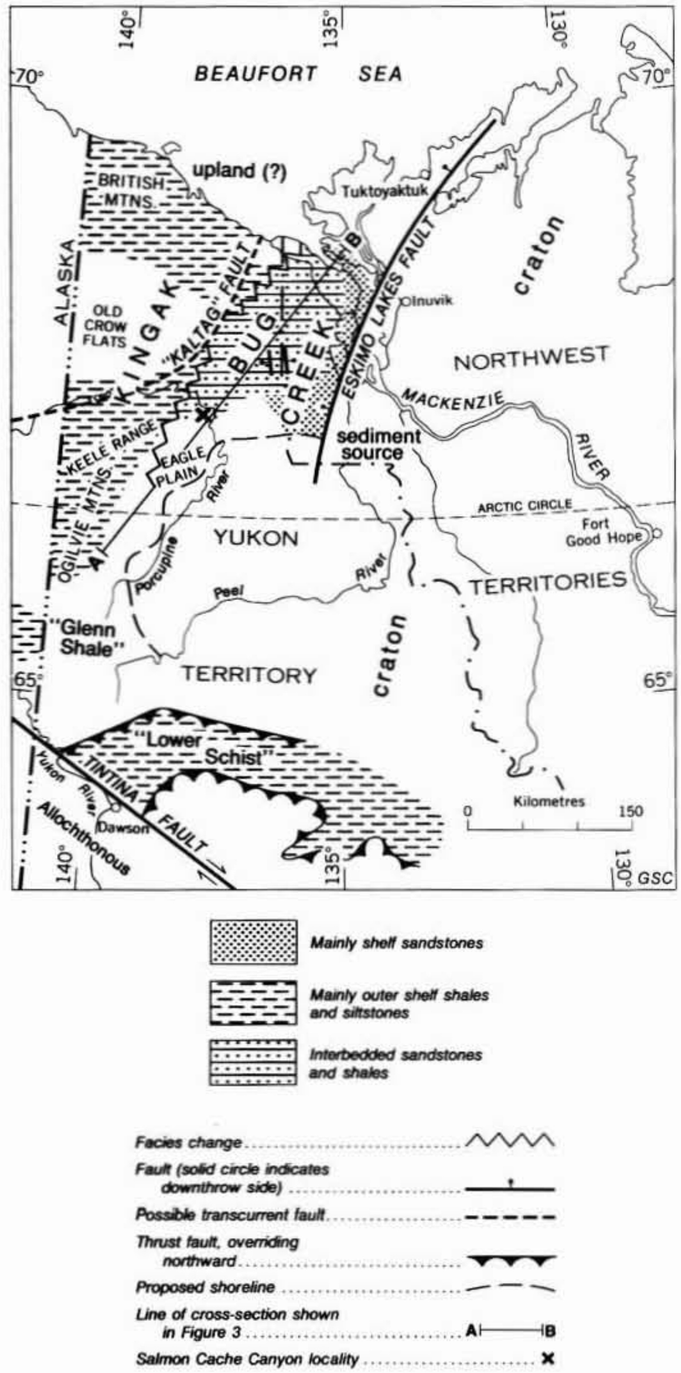


Figure 2. *Sedimentary facies belts, location of the Salmon Cache Canyon Section(X) and line of cross-section (AB) shown in Figure 3.*

BIOSTRATIGRAPHIC SUBDIVISIONS

A succession of eight zones with distinctive ammonoid faunas has been recognized at Salmon Cache Canyon. The ranges of ammonite species are shown in Figure 4. Because only a few of the East Greenland or northern Siberia species appear in northern Yukon, new zonal names are given using some of the best known faunas. These are assumed to be teilzones of regional extent. The lower part of the succession is best exposed and has yielded the most fossils, so it lends itself to subdivision into zones that are based on first appearances of species.

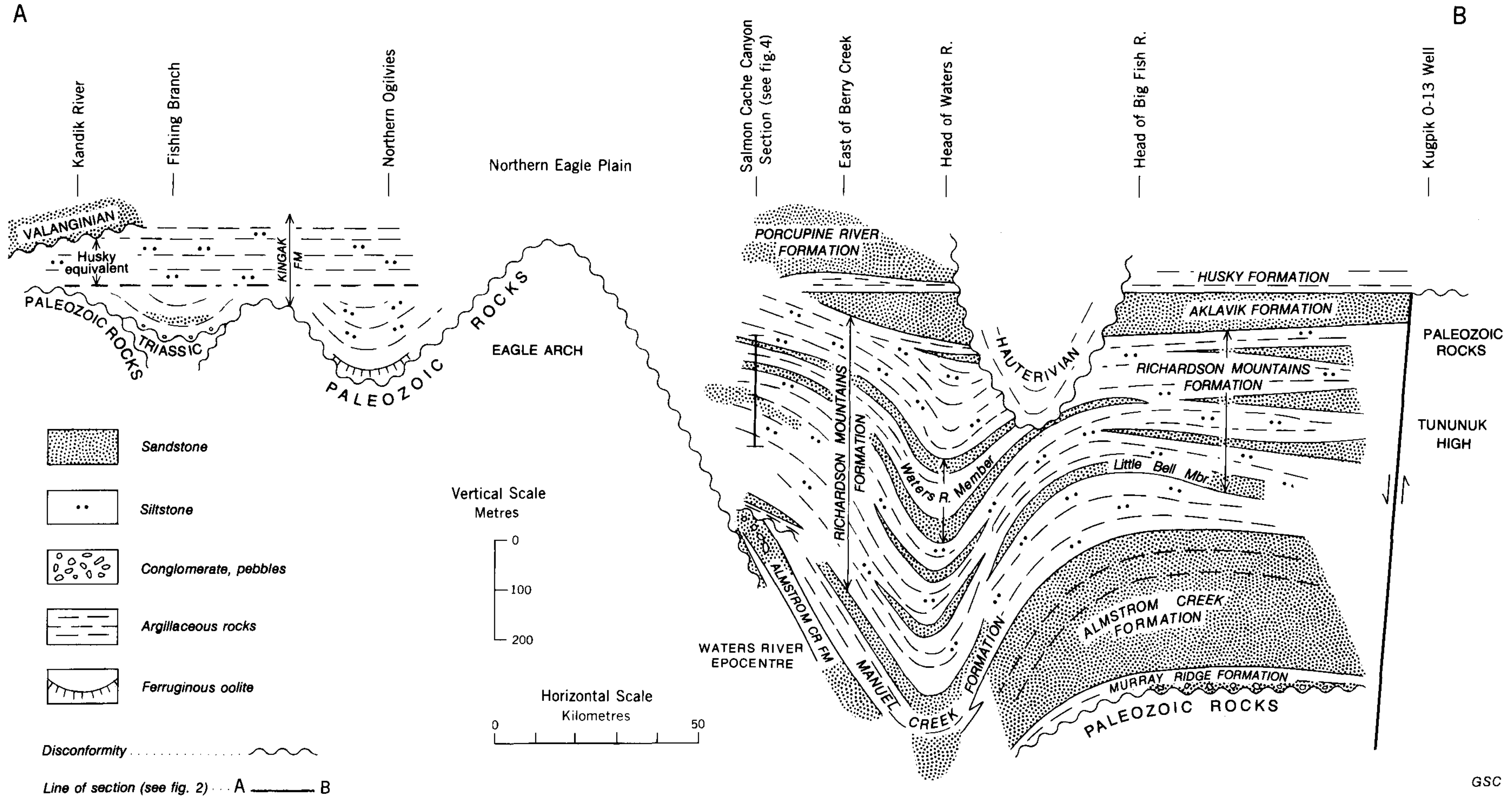
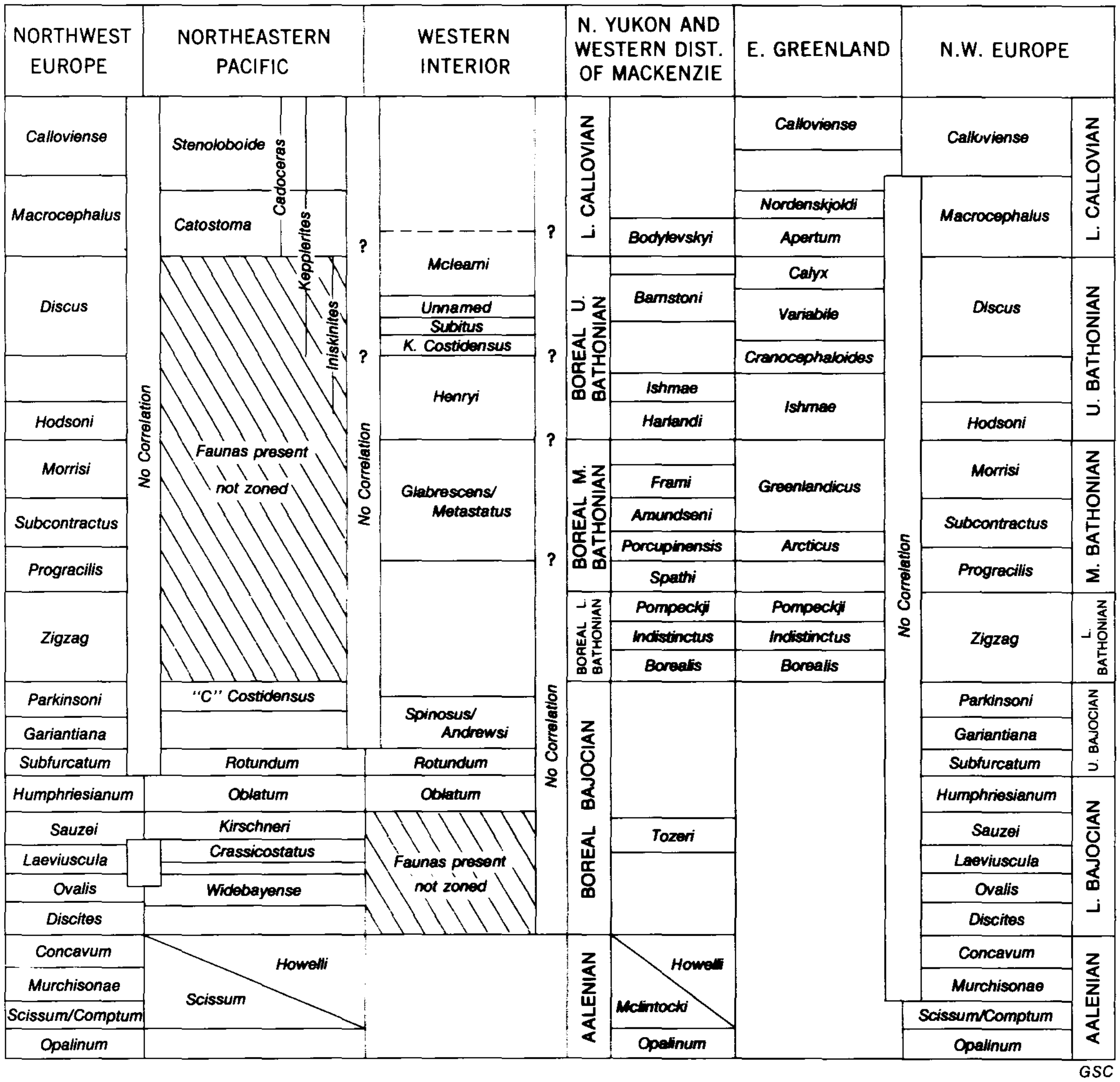


Figure 3. *Southwest-northwest cross-section of Lower and Middle Jurassic rocks along stratigraphic strike. Line of section shown in Figure 2. Bold bar indicates the section described in this report.*

TABLE 3

Chart showing the current placement of Middle Jurassic ammonite zones and their correlations in Western and Arctic North America, East Greenland, and Northwest Europe.



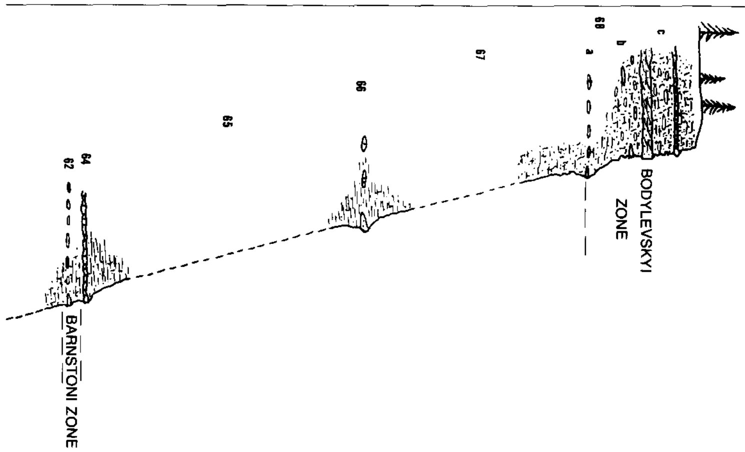
Only the ammonites are treated here. The faunas also include abundant *Inoceramus*, belemnites, and some *Oxytoma*, *Goniomya*, *Meleagrinella* and other bivalves. Foraminifera are present also, as are palynomorphs, which are being reported in a companion paper by E.H. Davies and Poulton.

Spathi Zone (Beds 2-14)

Arctocephalites spathi n. sp. is the most common form in the collections. Other species, all small and mostly, but not all compressed, include *A. ellipticus* Spath(?), *A.* sp. A aff. *A. sphaericus* Spath, and *A.* sp. B. aff. *A. nudus* Spath. The base of the zone is placed at the base of the lowest beds with *Arctocephalites*, that is, *A. spathi*. A large, ribbed body chamber of *Cranocephalites*(?) in Bed 1 immediately below it may indicate the presence there of equivalents of the *pompeckji* Zone of East Greenland.

One concretion, lying loose at the base of the section but assumed to come from this zone, contains *A. spathi*(?) and *Oecotraustes*(?) sp.

This interval is that characterized by "*Arctocephalites elegans*" in preliminary reports (Poulton and Callomon, 1976; Poulton, 1978).



LEGEND

- *Range (defined, inferred, unknown)*
- *Range brackets* ( )
- *Number of specimens* 2
- *Multiple specimens* x
- *Questionable identification* ?
- *Inferred horizon* *
- *Bed number* 32

Arctocephalites spathi n. sp.
Arctocephalites ellipticus Spath (?)
Arctocephalites sp. A aff. *A. sphaericus* Spath
Arctocephalites sp. B aff. *A. sphaericus* Spath
Arctocephalites porcupinensis n. sp.
Arctocephalites callomoni Frebold
Arctocephalites sp. A aff. *A. nudus* Spath
Arctocephalites sp. B aff. *A. nudus* Spath
Arctocephalites arcticus (Whitfield)
Arctocephalites praeishmae n. sp.
Arctocephalites amundseni n. sp.
Arctocephalites kigilakhensis Voronetz
Arctocephalites frami n. sp.
Arctocephalites sp. A
Arctocephalites sp. B
Arctocephalites sp. C
Arctocephalites sp. D
Arctocephalites sp. E
Arctocephalites (?) freboldi (Spath)
Arctocephalites (?) sp. aff. *A. (?) freboldi* (Spath)
Arctocephalites (?) belli n. sp.
Arctocephalites (?) sp. aff. *A. (?) crassum* (Madsen)
Arcticoceras harlandi Rawson
Arcticoceras ishmae (Keyserling)
Arcticoceras spp.
"Costacadoceras" sp. A
"Costacadoceras" sp. B
Cadoceras barnstoni (Meek)
Cadoceras sp.
Cadoceras variabile (Spath)
Cadoceras bodylevskyi Frebold
Paracadoceras sp.
Genus et sp. indet. A
Loucheuxia bartletti n. sp.
Loucheuxia (?) spp.
Kepplerites sp. aff. *K. rosenkrantzi* Spath
Kepplerites sp. A
Kepplerites sp. B
Kepplerites sp. C
Kepplerites (?) sp. D
Genus et sp. indet. B
Iniskinites spp.
Cadomites sp.
Oxycerites birkelundi n. sp.
Oxycerites sp.
Oecotraustes (?) sp.
Prohecticoceras (?) sp.
Parareineckeia sp.
Choffatia (?) sp.
Phylloceras sp. aff. *P. kudernatschi* (von Hauer)
Phylloceras billingsi (Meek)
Phylloceras sp. aff. *P. kunthi* Neumayr
Adabofoloceras (?) sp.
Calliphylloceras sp.
Holcophylloceras sp.

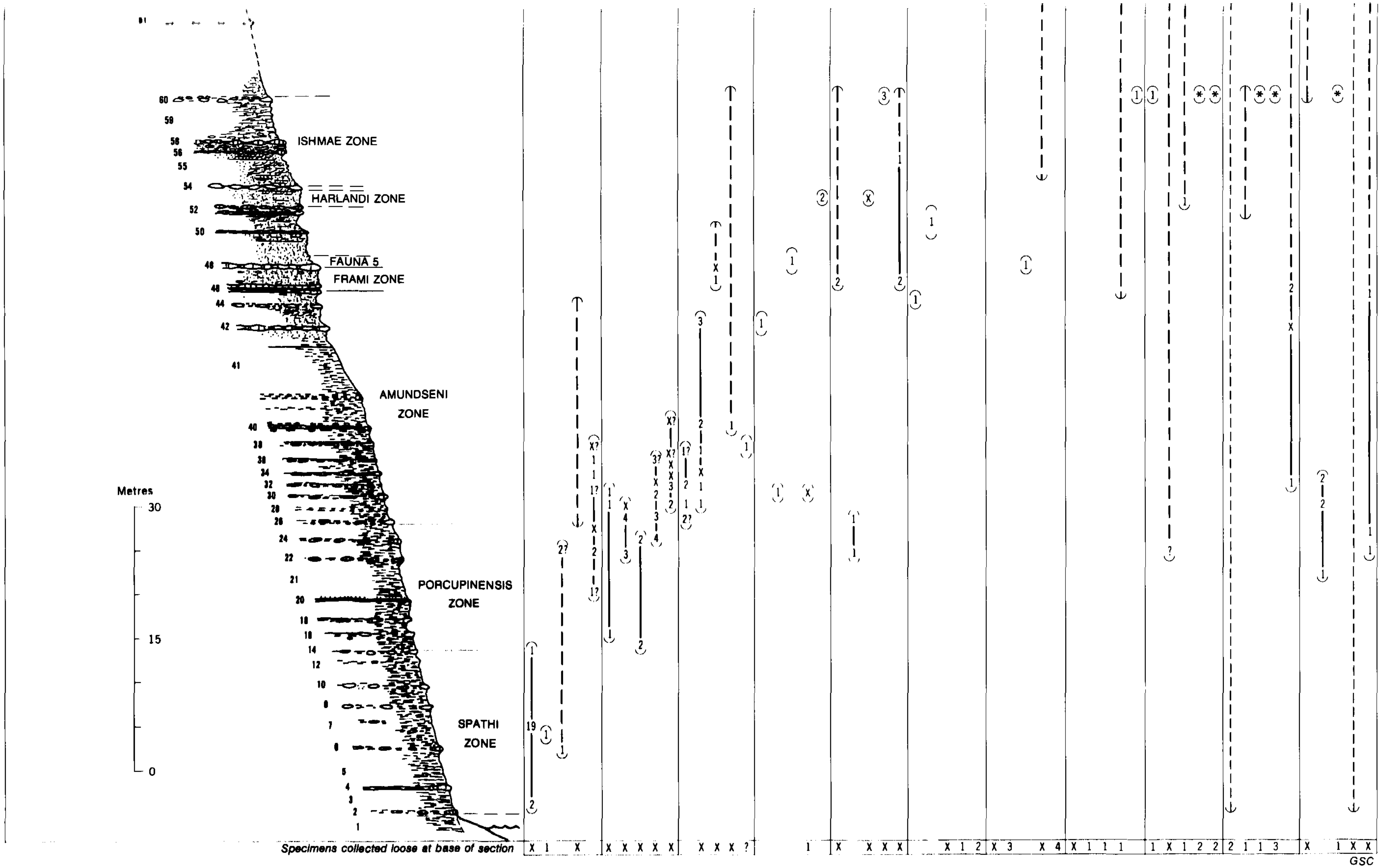


Figure 4. *Graphic illustration of the Salmon Cache Canyon section showing ammonite zones and species distribution.*

Porcupinensis Zone (Beds 15-25)

Several similar species are approximately equally abundant in this zone. *Arctocephalites porcupinensis* n. sp. is the most conspicuous in some beds in the the lower part, but was not seen in the lowest beds. The lowest appearance of the entire suite of species in Bed 15 is taken to mark the base of the zone. These include *A. callomoni* Frebold, *A.* spp. A and B aff. *A. nudus* Spath, *A.* sp. A aff. *A. sphaericus* Spath, *A. arcticus* (Whitfield) – appearing only in the uppermost part of the zone – and *Arctocephalites*(?) sp. aff. *A.*(?) *crassum* (Madsen). Thus, most specimens are still small and moderately compressed, although there is an increasing proportion of inflated forms. The lowest appearance of *Phylloceras* sp. aff. *P. kunthi* Neumayr, of Genus *Calliphylloceras*, and possibly also of Genus *Iniskinites* (represented by a single small undeterminable fragment that is now lost) is in this zone.

The lower part of this interval is that characterized by "*Arctocephalites* sp". in preliminary reports (Poulton and Callomon, 1976; Poulton, 1978).

Amundseni Zone (Beds 26-45)

The lowest bed is characterized by the appearance of the largest species, *Arctocephalites amundseni* n. sp., in a fauna that is otherwise similar to that below, with mostly smaller species. Other elements of the lower part of this zone are *A. arcticus* (Whitfield), *A. porcupinensis* n. sp., *A.* sp. A aff. *A. nudus* Spath, *A. praeishmae* n. sp., *A.* sp. D, *Arctocephalites*(?) sp. aff. *A.*(?) *crassum* (Madsen), *A.*(?) *freboldi* (Spath), and *Phylloceras* sp. aff. *P. kunthi* Neumayr.

Higher beds are characterized by a mixture of species – *Arctocephalites porcupinensis*(?), *A.* spp. aff. *A. arcticus* and *A. callomoni*, *A. praeishmae*, *A.* sp. B, and, possibly, *A.* sp. A. *Arctocephalites kigilakhensis* Voronetz becomes increasingly abundant upward so that an upper Kigilakhensis Subzone, in which *A. kigilakhensis* and *A. praeishmae* are most conspicuous and *A. amundseni* is rare or absent, can be distinguished. *Phylloceras* sp. aff. *P. kudernatschi* (von Hauer) first appears in the upper part of this interval.

Arctocephalites sp. B aff. *A. sphaericus* Spath, one specimen of which was found in loose material with *Phylloceras* sp. aff. *P. kudernatschi* (GSC locality 92546) is thought to also be present in the *amundseni* Zone.

The interval comprising the *amundseni* and *frami* Zones is that characterized by "*Arctocephalites greenlandicus*" in preliminary reports (Poulton and Callomon, 1976; Poulton, 1978).

Frami Zone (Beds 46-47)

This fauna is dominated by *Arctocephalites frami* n. sp., the lowest occurrence of which in Bed 46 defines the base of the zone. Additionally, *Arctocephalites*(?) *belli* n. sp., *Phylloceras* sp. aff. *P. kudernatschi* (von Hauer), and *Calliphylloceras* sp. occur, and the lowest occurrence of *Arcticoceras*, that is, *A.* sp. indet. is in this interval.

Unnamed Zone (Bed 48)

This fauna is represented by only one fossiliferous bed, containing a unique assemblage of *Arctocephalites*(?) sp. E, and genus et species indet. A.

Harlandi Zone (Bed 53)

This fauna, known from only one fossiliferous bed, contains *Arcticoceras harlandi* Rawson, *Cadomites* sp., *Arctocephalites*(?) sp. aff. *A.*(?) *freboldi* (Spath), and other *Arctocephalites* sp. indet., represented by small, smooth body chambers having apertural constrictions and cross-sections similar to those of *A. harlandi* shown in Plate 19 (figs. 7, 8).

This interval is that characterized by "*Arctocephalites* sp. cf. *greenlandicus*" in preliminary reports (Poulton and Callomon, 1976; Poulton, 1978).

Ishmae Zone (Beds 55-60)

The zone is represented, in three fossiliferous horizons, by *Arcticoceras ishmae* (Keyserling), *A. ishmae*(?), and *Kepplerites*(?) sp. D.

These beds have contributed many distinctive, hard, dark red, dense concretions to the talus below the section, some of which are richly fossiliferous and document the following forms in this zone (each GSC locality number, except C-95372, represents a single concretion, so that there is no doubt of the association).

GSC loc. 92552: *Loucheuxia bartletti* n. sp.
Iniskinites sp.
Phylloceras billingsi (Meek)

GSC loc. 92554: *Arcticoceras ishmae* (Keyserling)
Oxycerites birkelundi n. sp.
Loucheuxia bartletti n. sp.
Iniskinites sp.

GSC loc. 92564: *Arcticoceras ishmae* (Keyserling)(?)
Arctocephalites(?) *belli* n. sp.
Choffatia(?) sp.
Phylloceras billingsi (Meek)

GSC loc. C-95354: *Arcticoceras ishmae* (Keyserling)
Oxycerites birkelundi n. sp.

GSC loc. C-95372: (the following species occur together in a single concretion; the concretion also contains other material):

Arcticoceras ishmae (Keyserling)
Oxycerites birkelundi n. sp.
Choffatia(?) sp.

GSC loc. C-95374: *Arcticoceras*(?) sp.
Oxycerites sp.
Loucheuxia bartletti n. sp.

GSC loc. C-95382: *Arcticoceras* sp. indet.
Oxycerites sp.

The presence of *Oxycerites* in this zone represents its lowest, and apparently only, occurrence in the section, and that of *P. billingsi* represents the first appearance of that species. Other forms that were found loose but that probably come from this zone include *Parareineckeia* sp., *Adabofoloceras*(?) sp., gen. et sp. indet. B, and possibly also *Arctocephalites* sp. A(?) (University of Alberta loc. 45413). Furthermore, J.H. Callomon (pers. comm., 1975), while in the field, tentatively identified *Siemiradzkia* sp. and *Oecotraustes* sp. in loose material that he thought came from this zone but these identifications could not be confirmed by detailed studies of the collections by the writer.

Barnstoni Zone (Bed 62)

This fauna, characterized above all by *Cadoceras barnstoni* (Meek) and *Phylloceras billingsi* (Meek), also contains in place *Cadoceras* sp., *Iniskinites* sp., and the lowest *Kepplerites*, *K.* sp. aff. *K. rosenkrantzi* Spath and *K.* sp. B.

Additionally, a rich fauna is documented in distinctive, yellow-weathering concretions that occur abundantly in the talus below the section. Each number records the association in a single concretion:

GSC loc. 92553: *Cadoceras barnstoni* (Meek)
Cadoceras variabile Spath
Arcticoceras(?) sp.
Iniskinites(?) sp.
Phylloceras billingsi (Meek)

GSC loc. 92473x: *Loucheuxia bartletti* n. sp.
Phylloceras sp. aff. *P. kudernatschi* (von Hauer)

GSC loc. 92568: *Cadoceras barnstoni* (Meek)
Cadoceras sp.
Phylloceras billingsi (Meek)

GSC loc. C-95370: *Cadoceras barnstoni* (Meek)
Iniskinites sp.
Phylloceras billingsi (Meek)
Phylloceras sp. aff. *P. kudernatschi* (von Hauer)

GSC loc. C-95381: *Loucheuxia*(?) sp.
Phylloceras billingsi (Meek)

GSC loc. C-95383: *Loucheuxia*(?) sp.
Phylloceras sp.
Calliphylloceras sp.

Kepplerites sp. A, found loose in the talus, probably also comes from this bed.

Unnamed Zone (Bed 66)

No ammonites are positively identified in the material presently available for detailed study (GSC loc. 92470). J.H. Callomon tentatively identified *Paracadoceras* at this level while in the field. This genus is sparsely represented in the talus below the section but is not associated with other ammonites.

Bodylevskyi Zone (Bed 68)

This fauna contains only *Cadoceras bodylevskyi* Frebold. This is the interval characterized by *C. septentrionale* Frebold in preliminary reports (Poulton and Callomon, 1976; Poulton, 1978).

DESCRIPTION OF THE SECTION

Section PU-3-75, 81. Salmon Cache Canyon, Porcupine River, northern Yukon. Bluffs are found on the west bank, just south of the major bend where the river changes course from north to west; lat. 67°25 to 26'N, long. 137°46'30"W. The section was described and measured, and the fossils collected by T.P. Poulton and J.H. Callomon in 1975; and by T.P. Poulton, J.H. Callomon, T. Birkelund, R.L. Detterman, and D.H. McNeil in 1981. The collections and generalized description of J.A. Jeletzky (in Frebold, 1961, p. 2) have been incorporated. The section, with preliminary fossil identifications, has previously been illustrated by Poulton and Callomon (1976, p. 348, col. 5) and Poulton (1978, Pl. II, fig. 2; the coordinates given there are incorrect), and it appears in Figures 4 to 7 of this report.

Much of the slope is obscured by talus, and the section was pieced together from a study of various outcrops. Marker-beds are, however, prominent, persistent and characteristic, leaving the succession in no doubt. The lower beds (1-20), are best exposed at the northernmost end of the bluff. Beds 22 to 40 form a prominent and well exposed, regularly banded series some 100 to 200 m farther south, bounded by the most southerly of three gullies beyond which the slopes are heavily obscured by talus. The northernmost of the three gullies gives a clear section up to and including the prominent marker ironstone, Bed 58, at the top of the cliff, just under the trees. This is the highest bed exposed anywhere along the northern half of the cliff. The remaining part of the section, Beds 59 to 68, is exposed intermittently in a prominent gully some 200 m from the southern end of the cliff. This gully widens and becomes tree covered just under the highest point of the cliff. Different parts of the section were exposed in 1975 and 1981, which permitted the filling of gaps, correction of errors, and addition of greater detail in the second year. The different exposure in 1981 was due in part to heavy slumping following a forest fire that occurred between 1975 and 1981.

The section belongs to the Richardson Mountains Formation (Poulton et al., 1982) of the Bug Creek Group, in an untypically fossiliferous and ferruginous facies. The upper sandstones (Units 68a-c) probably represent the Waters River Member.

Unit	Description	Thickness (m)	Height above base (m)
	Top of section at top of bluffs near their south end.		
	LOWER CALLOVIAN		
	Bodylevskyi Zone (type locality)		
68c	**Sandstone:** dark grey, weathering medium to dark rusty grey; fine grained; argillaceous(?), carbonaceous and with wood fragments; strongly bioturbated, indistinctly bedded, with crossbedded lenses; soft, recessive, abundant rusty red concretions throughout lower 1 m; a prominent, continuous unit 2.6 m above base, comprising a 10 to 15 cm-thick upper layer and a 0.25 to 0.3 m-thick lower layer, each hard, continuous, claret coloured, separated by 15 cm of rubbly, soft sandstone GSC loc. 92544 *Cadoceras bodylevskyi* Frebold *Entolium* GSC loc. C-95367 in lower 1 m *Cadoceras bodylevskyi* Frebold belemnites *Goniomya* sp.	4	155.9
68b	**Sandstone:** buff, weathers rusty buff, blocky; fine grained; thin bedded to 0.5 m-bedded, massive or with fine, irregular laminae and ripples; crossbedded lenses; resistant	2.1	151.9
68a	**Sandstone:** dark grey, weathers medium to dark rusty grey; fine grained; argillaceous(?), carbonaceous; strongly bioturbated, indistinctly bedded; soft, recessive; crossbedded lenses; abundant, fossiliferous, 0.2 to 0.3 m, flattened, ovoid concretions between 0.8 and 1.2 m below top of unit, weathering rusty orange-red and vertically fractured; a similar row of less flattened concretions also occurs at base of unit GSC loc. C-95384 *Cadoceras bodylevskyi* Frebold	3	149.8

Unit	Description	Thickness (m)	Height above base (m)
	Unnamed Zone		
67	**Siltstone** to fine grained **sandstone:** light grey, weathers buff, rubbly, blocky; strongly bioturbated at base, becoming finely laminated to 0.3-0.6 m-bedded upwards; resistant	6	146.8
66 65	**Silty mudstone** (probably): recessive; covered by slumping and talus from above	38	140.8
64	**Ironstone concretionary layer**	0.3	102.8
63	**Silty mudstone** (probably): recessive, covered	1.5	102.5
	UPPER BOREAL BATHONIAN		
	Barnstoni Zone (type locality)		
62	**Concretionary layer:** large, ochre-yellow weathering concretions GSC loc. 92543 *Cadoceras barnstoni* (Meek) *Cadoceras* sp. *Kepplerites* sp. aff. *K. rosenkrantzi* Spath *Iniskinites* sp. *Oecotraustes*(?) sp. *Phylloceras billingsi* (Meek) *Retroceramus* sp. *Goniomya* sp. *Camptonectes* sp. belemnites GSC loc. C-86389 *Cadoceras barnstoni* (Meek) *Kepplerites* sp. One loose concretion lying on the beach (GSC loc. C-95381) resembles Bed 62 lithologically and, like it, contains *P. billingsi*, but is unique in containing small angular to subangular chert pebbles, not seen in the section itself	0.3	101
	Unnamed Zone		
61	**Silty mudstone** (probably): recessive, mostly covered by slumping. Concretions in this interval (e.g. GSC loc. 92542) are thought to come from Bed 62 (see above)	17	100.7
	Ishmae Zone (type locality: East Greenland)		
60	**Siltstone/mudstone:** two rows, 0.2 m to 0.3 m thick; weathering dark rusty red; indurated, concretionary, hard; lower layer continuous, top layer containing concretions 0.6 to 1.5 m long, closely spaced; layers separated by 0.15 to 0.2 m of soft siltstone/mudstone; fossil wood, fossils in nests GSC loc. 92540 *Arcticoceras ishmae* (Keyserling) *Kepplerites*(?) sp. D *Astarte* sp. *Retroceramus* sp. belemnites	0.7	83.7
59	**Siltstone/mudstone:** medium grey; and fine grained **sandstone:** argillaceous; laminated or bioturbated; weathering fine 'chippy'; recessive; scattered ironstone concretions in lower 0.6 m		

Unit	Description	Thickness (m)	Height above base (m)
	GSC loc. C-95366 near base *Arcticoceras* sp.	4.8	83
	Underlying beds (56-58) at this location are continuous along the length of the bluff to the north end, where they were measured, and they are described below; this part was measured previously by Jeletzky (<u>in</u> Frebold, 1961, p. 2)		
	Lower part of section measured near north end of bluffs; top of bluffs just below trees; higher beds here are totally obscured by slumping		
	Note: units 56-58 form prominent ironstone marker horizon extending entire length of bluffs; subdivided as follows:		
58	**Ironstone:** brown; concretionary; more or less continuous; vertically fractured; belemnites	0.15	78.2
57b	**Ironstone:** lenticular; soft and rubbly; locally thickened to include claret coloured or black concretions	0.7	78.05
57a	**Silty mudstone** and **siltstone:** varies to fine sandstone; pyritic, ferruginous; belemnites	0.2	77.35
56	**Ironstone:** weathers claret; sideritic, concretionary, continuous; vertically fractured GSC loc. 92468 *Arcticoceras ishmae* (Keyserling)(?)	0.15	77.15
55	**Siltstone:** light buff-grey; argillaceous, sandy; hard; and **sandstone:** thin bedded, crosslaminated and crossbedded, in 0.15 m layers alternating with soft sandy and silty mudstone and siltstone, grading up to harder, thin sandstone at top; yellow weathering; small-scale crossbedding; unit soft, forms gentle slope GSC loc. 35634 *Arcticoceras*(?) sp. (*A. kochi* of Frebold, 1961) GSC loc. C-95373 collected 0.15 m below top of unit *Arcticoceras* sp. belemnites *Belemnoteuthis*	3.4	77
	Harlandi Zone (type locality)		
54	Layer of **ironstone concretions:** claret coloured; large, flattened, ovoid; forms top of steep slope of Bed 53	0.3	73.6
53	**Sandstone:** fine grained; argillaceous; 'chippy' and rubbly, or distinctly bedded, crossbedded; somewhat pyritic; forms a steep slope GSC loc. 92539 *Arcticoceras harlandi* Rawson GSC loc. C-95365 at base *Cadomites* sp. *Arcticoceras harlandi* Rawson *Arctocephalites*(?) sp. aff. *A.*(?) *freboldi* Spath	2.1	73.3

Unit	Description	Thickness (m)	Height above base (m)
	MIDDLE BOREAL BATHONIAN		
	Unnamed Zone		
	The beds in the interval comprising beds 41 to 51 have a slight northerly dip, at odds with those below and above (Fig. 5). This discrepancy may be due to slumping in the cliff-exposure situation, or to deposition as large-scale foresets, but no significant faunal gaps or erosional surfaces are detectable below or above them.		
52	**Sandstone:** grey; fine grained; ferruginous; soft, rubbly; low-angle crossbedding; widely spaced, ovoid, claret coloured concretions throughout; passes laterally into a thinner (0.7 m) package of two rows of red-brown ironstone concretions separated by soft sandstone/siltstone; the lower concretionary band is continuous GSC loc. 92538 *Arctocephalites*(?) sp. *Retroceramus* sp. belemnites *Belemnoteuthis*	1.1	71.2
51	**Silty mudstone** and **siltstone:** grades up into alternating thin layers of ripple-bedded sandstone and siltstone/mudstone; soft; micaceous; clayey nests of belemnites, especially at top	1.75	70.1
50	**Ironstone:** claret coloured; concretionary; continuous GSC loc. 92537 "*Costacadoceras*" sp. indet. B *Retroceramus* sp.	0.25	68.35
	Approximate top of Unit 4 of Jeletzky (in Frebold, 1961, p. 2)		
49	**Sandstone:** light grey-buff; fine grained; distinctly bedded, soft, rubbly; grades up into alternating thin layers of ripple-bedded sandstone and mudstone/siltstone	3.6	68.1
48	**Ironstone:** in rounded concretions; continuous, forming top of sandstone bluff GSC loc. C-95364 gen. et sp. indet. A *Arctocephalites*(?) sp. E	0.3	64.5
	Frami Zone (type locality)		
47	**Sandstone:** grey; fine grained; rubbly; scattered burrows in lower part; some round ironstone concretions about 0.3 m above base and others 0.3 m below top; bluff-forming; belemnites common; nests of *Retroceramus* GSC loc. C-95363 *Arctocephalites frami* n. sp. GSC loc. 92536 *Arctocephalites frami* n. sp. GSC loc. 35631 from beds 47 to 50 *Arctocephalites frami* n. sp.	2.1	64.2
	Approximate top of Unit 3 of Jeletzky (in Frebold, 1961, p. 2)		

Unit	Description	Thickness (m)	Height above base (m)
46	**Ironstone:** red-brown; two layers separated by thin mudstone/siltstone; blocky, vertically fractured; continuous; prominent; forming base of sandstone bluff		
	GSC loc. 92535 *Arctocephalites frami* n. sp.		
	GSC loc. C-95362 *Arctocephalites*(?) *belli* n. sp. *Arcticoceras* sp. indet. *Phylloceras* sp. aff. *P. kudernatschi* (von Hauer) belemnites *Belemnoteuthis*	0.6	62.1
	Amundseni Zone (type locality)		
45	**Siltstone/mudstone:** rubbly, bioturbated; soft, recessive		
	GSC loc. C-95368 collected 0.6 m below top *Holcophylloceras* sp.	1.2	61.5
44	**Siltstone/mudstone:** bioturbated; indurated; contains a row of large, widely spaced, rounded, ferruginous concretions		
	GSC loc. C-95361 *Retroceramus* sp.		
	GSC loc. 92534 "*Costacadoceras*" sp. A	0.3	60.3
43	**Siltstone:** fine grained; grades upward into alternating thin layers of ripple-laminated sandstone and siltstone/mudstone; recessive; belemnites	2.2	60
42	**Ironstone:** concretionary, nodular; continuous, resistant; pockets of belemnites at base, bivalves		
	GSC loc. 92532 *Arctocephalites kigilakhensis* Voronetz *Arctocephalites* sp. indet. C *Phylloceras* sp. aff. *P. kudernatschi* (von Hauer)	0.4	57.8
	A distinctive, recessive slope between banded series above and below, subdivided as follows:		
41g	**Siltstone:** fine grained; grades upward into alternating thin layers of ripple-laminated sandstone and siltstone/mudstone; belemnites	2.175	57.4
41f	**Clay:** light grey; soft; bentonitic?	0.025	55.225
41e	**Siltstone** or **mudstone:** soft, recessive; forms gentle slope	5.2	55.2
41d	**Siltstone:** grey; continuous; indurated, hard, resistant	0.4	50
41c	**Siltstone:** light grey; moderately hard	1.1	49.6
41b	**Siltstone:** ferruginous; slightly harder and more resistant than Unit 41a	0.3	48.5
41a	**Siltstone:** light grey; moderately hard; a row of yellow-weathering concretions at base containing nest of small ammonites – *Arctocephalites* sp.	1.9	48.2
	Top of moderately resistant, regularly banded series. This series comprises ten alternations of recessive siltstone/mudstone and hard ironstone or ferruginous mudstone.		
	Top of Unit 2 of Jeletzky (in Frebold, 1961, p. 2)		

Unit	Description	Thickness (m)	Height above base (m)
40	**Mudstone:** indurated; with a persistent bed of hard ironstone concretions 0.15 m thick; resistant, prominent GSC loc. 35619 *Arctocephalites praeishmae* n. sp.(?) *Arctocephalites* sp. A *Arctocephalites kigilakhensis* Voronetz GSC loc. C-95359 *Arctocephalites praeishmae* n. sp.(?) *Arctocephalites* sp. indet. pectinid bivalve, indet.	0.3	46.3
39	**Siltstone:** light grey; softer than the others, recessive; pockets of belemnites in centre	1.5	46.0
38	**Mudstone:** indurated and resistant; with concretions	0.3	44.5
37	**Siltstone:** light grey; soft, recessive; with a prominent, rusty weathering, consolidated bed in centre, 0.1 to 0.15 m thick	1.4	44.2
36	**Siltstone:** indurated and resistant; with brown ironstone concretions at base GSC loc. C-95358 *Arctocephalites amundseni* n. sp.(?) *Arctocephalites kigilakhensis* Voronetz *Arctocephalites arcticus* (Whitfield)(?) *Arctocephalites praeishmae* n. sp.(?) *Arctocephalites* spp. indet. aff. *A. nudus* Spath GSC loc. 35616 from beds 36, 37 or 38 *Arctocephalites porcupinensis* n. sp.(?) *Arctocephalites* sp. B	0.3	42.8
35	**Siltstone:** light coloured; bioturbated; soft, recessive; with a thin bed of indurated shale containing small concretions 0.6 m above base; belemnites	1.3	42.5
34	**Concretions:** two resistant layers; rusty weathering; discontinuous; layers 0.1 to 0.15 m thick, separated by 0.3 m of indurated but more recessive siltstone; local pockets of fossils, partly preserved in barite; abundant pyrite GSC loc. 92458 *Arctocephalites praeishmae* n. sp. *Arctocephalites porcupinensis* n. sp.(?) abundant *Retroceramus* sp. *Pleuromya* *Corbula* *Meleagrinella* belemnites *Belemnoteuthis*	0.6	41.2
33	**Silty mudstone** and **siltstone:** light coloured; sandy; soft, recessive, bioturbated	0.7	40.6
32	**Mudstone/siltstone** and fine grained **sandstone:** weathers rusty brown; argillaceous; indurated and with ironstone concretions at base; locally abundant ammonites, belemnites GSC loc. C-95357 *Arctocephalites porcupinensis* n. sp. *Arctocephalites praeishmae* n. sp. *Arctocephalites kigilakhensis* Voronetz *Phylloceras* sp. aff. *P. kudernatschi* (von Hauer) *P.* sp. aff. *P. kunthi* Neumayr *Retroceramus* sp. belemnites *Belemnoteuthis*		

Unit	Description	Thickness (m)	Height above base (m)
	GSC loc. 92531 *Arctocephalites arcticus* (Whitfield) *Arctocephalites praeishmae* n. sp.	0.3	39.9
31	**Silty mudstone** and **siltstone:** bioturbated; soft, recessive; locally concentrated large belemnites GSC loc. C-86396 from top of unit *Arctocephalites kigilakhensis* Voronetz *Arctocephalites praeishmae* n. sp. *Arctocephalites porcupinensis* n. sp.(?) *Arctocephalites arcticus* (Whitfield) *Arctocephalites* sp. indet. D *Arctocephalites callomoni* Frebold *Phylloceras* sp. indet. *Passaloteuthis*(?) sp. GSC loc. 92457	0.9	39.6
30	**Siltstone** and fine grained **sandstone:** weathers rusty red and brown; argillaceous; strongly bioturbated; indurated and with abundant concretions grading to continuous concretionary band; calcareous; hard; sparsely fossiliferous GSC loc. C-86395 *Arctocephalites amundseni* n. sp. *Arctocephalites*(?) *freboldi* Spath *Arctocephalites* sp. indet. *Arctocephalites callomoni* Frebold *Phylloceras* sp. belemnites *Passaloteuthis*(?) sp. GSC loc. 92530 (loose, but not far fallen) *Arctocephalites arcticus* (Whitfield)	0.3	38.7
29	**Silty mudstone** or **siltstone:** recessive; belemnites common	0.9	38.4
28	**Siltstone:** weathers rusty grey and slightly resistant; slightly indurated and with concretions; bioturbated; ammonites partly preserved in barite GSC loc. 92529 *Arctocephalites praeishmae* n. sp. *Arctocephalites kigilakhensis* Voronetz GSC loc. C-86394 *Arctocephalites amundseni* n. sp. *Arctocephalites* sp. A aff. *A. nudus* Spath *Arctocephalites praeishmae* n. sp. *Phylloceras* sp. aff. *P. kunthi* Neumayr *Retroceramus* sp. *Belemnoteuthis*(?) sp.	0.4	37.5
27	**Siltstone** and **silty mudstone:** argillaceous; soft, recessive; layer of belemnites in middle GSC loc. 92528 belemnites	1.0	37.1
26	**Siltstone** or **silty mudstone:** weathers rusty red and resistant; indurated and with some concretions; strongly bioturbated; prominent GSC loc. C-86393 in concretionary layer at base *Arctocephalites arcticus* (Whitfield) *Arctocephalites amundseni* n. sp. *Arctocephalites* sp. A aff. *A. nudus* Spath *Arctocephalites*(?) sp. aff. *A.*(?) *crassum* (Madsen)	0.4	36.1

Unit	Description	Thickness (m)	Height above base (m)
	Porcupinensis Zone (type locality)		
25	**Siltstone** and **silty mudstone:** as in Unit 23 at base; becomes light coloured and soft upward	2.1	35.7
24	**Silty mudstone:** red-brown; indurated; contains large concretions; fractures into blocks GSC loc. 92527 *Arctocephalites porcupinensis* n. sp. *Arctocephalites arcticus* (Whitfield) *Arctocephalites* sp. B aff. *A. nudus* Spath *Holcophylloceras* sp. *Retroceramus* sp. *Meleagrinella* sp. *Corbula*(?) sp. belemnites *Cylindroteuthis* *Passaloteuthis*(?)	0.3	33.6
23	**Siltstone/mudstone:** very sandy; becomes argillaceous, fine grained sandstone; hard, strongly bioturbated and with abundant trace fossils, some belemnites	1.2	33.3
22	**Siltstone** and **mudstone:** weathers slightly resistant and rusty brown; slightly indurated, some hard patches and widely spaced concretions with blocky fracture GSC loc. 92525 *Arctocephalites* sp. A aff. *A. nudus* Spath *Arctocephalites porcupinensis* n. sp. *Arctocephalites* sp. A aff. *A. sphaericus* Spath(?) *Arctocephalites*(?) sp. aff. *A.*(?) *crassum* (Madsen) *Iniskinites*(?) sp. *Phylloceras* sp. *Holcophylloceras* sp. belemnites *Corbula*(?)	0.3	32.1
	Base of regularly banded series		
21	**Silty mudstone:** sandy, with pebble bed at base comprising small, rounded, phosphatic nodules and worn ammonite and belemnite fragments; unit slightly more resistant than the other recessive beds below GSC loc. C-86398 at base *Arctocephalites* sp. indet. aff. *A. porcupinensis* n. sp. *Phylloceras* sp. aff. *P. kunthi* Neumayr	4.65	31.8
20	**Ironstone:** red-brown; hard; lenticular but continuous GSC loc. C-86392 *Arctocephalites porcupinensis* n. sp.(?)	0.15	27.15
19	**Silty mudstone:** light to dark grey; sandy; bioturbated; weathering rubbly, more resistant than lower recessive units; a few ferruginous mudstone/siltstone concretionary lenses 0.2 m thick and 1.0 to 1.5 m long; abundant, large belemnites *Pachyteuthis*(?), *Cylindroteuthis*(?), mainly concentrated about 1 m above base; unit forms steeper slope GSC loc. 92524 belemnites GSC loc. C-86391 belemnites	2.05	27
18	**Siltstone/mudstone:** ferruginous; indurated; with lenses of red-brown ironstone	0.15	24.95
17	**Silty mudstone:** very light; soft	1.075	24.8

Unit	Description	Thickness (m)	Height above base (m)
16	**Silty mudstone:** ferruginous; indurated; weathers red-brown, soft, friable, some concretions; *Belemnoteuthis* GSC loc. C-86390 *Arctocephalites callomoni* Frebold	.025	23.725
15	**Silty mudstone:** a slightly more indurated ferruginous mudstone layer with widely spaced concretions lies 0.5 m below top of unit; scattered nests of fossils including *Arctocephalites* sp. cf. *A. arcticus* (Whitfield), belemnites, "*Ostrea*"	2.5	23.7
	Spathi Zone (type locality)		
14	**Ferruginous mudstone:** weathers red-brown; indurated but not prominent; widely spaced, red ironstone concretions; minor ammonites and *Retroceramus* GSC loc. 92456 *Arctocephalites* sp. indet. GSC loc. 35639 *Arctocephalites* sp. B aff. *A. nudus* Spath GSC loc. 92484 *Arctocephalites spathi* n. sp. GSC loc. C-86388 *Arctocephalites*(?) sp. indet.	0.2	21.2
13	**Silty mudstone**	1	21
12	**Ferruginous mudstone** or **siltstone:** concretionary, hard, weathering rusty, not prominent	0.3	20
11	**Silty mudstone:** a few concretions	2.25	19.7
10	**Ferruginous mudstone:** a hard layer with some red weathering, hard, grey concretions; pyritic; poorly preserved ammonite body chamber fragments and belemnites; *Belemnoteuthis*	0.25	17.45
9	**Silty mudstone:** some scattered ferruginous mudstone concretions	2.2	17.2
8	**Ferruginous mudstone:** medium grey, weathers rusty brown and red; locally with concretions; fine vertical jointing; unfossiliferous	0.35	15
7	**Silty mudstone** (as in Unit 1): some scattered ferruginous mudstone concretions; lower part better indurated; weathers with yellow and white (?jarosite) powder; ammonites and belemnites in lowest 2 m GSC loc. 35638 *Arctocephalites spathi* n. sp. GSC loc. 92523 from base of Bed 7 and Bed 6 *Arctocephalites spathi* n. sp. *Arctocephalites* sp. A aff. *A. sphaericus* Spath *Arctocephalites ellipticus* Spath(?)	4.45	14.65
6	**Mudstone concretions:** large; ovoid; ferruginous; layer as thick as 0.2 m, and 0.3 to 1.5 m long, spaced at intervals of 2.4 to 6 m in an indurated mudstone layer; fine vertical fracturing with calcite veining; common, variously oriented ammonites and large belemnites	0.2	10.2

Unit	Description	Thickness (m)	Height above base (m)
5	**Silty mudstone** (as in Unit 1): soft	3.95	10
4	**Siltstone:** medium grey; argillaceous; ferruginous; hard; weathering rusty brown and red with fine vertical joints; continuous, unfossiliferous	0.15	6.05
	Approximate top of Unit 1 of Jeletzky (in Frebold, 1961, p. 2)		
3	**Silty mudstone** (as in Unit 1): soft; mostly covered	2.7	5.9
2	**Mudstone concretions:** light to medium khaki-grey; lenticular; widely spaced; weather ochre-brown, hard; resistant; splintery fracture, with calcite fill; only a single 1.5 m long concretion is exposed; a few ammonites and belemnites		
	GSC loc. 92522 *Arctocephalites spathi* n. sp.		
	GSC loc. 35635 *Arctocephalites spathi* n. sp.	0.2	3.2
	LOWER BOREAL BATHONIAN(?)		
	***Pompeckji* Zone(?)**		
1	**Mudstone:** light to medium grey; silty, bioturbated; soft, weathers to mud; a few ammonites and belemnites; only 1 m exposed		
	GSC loc. 92521 *Cranocephalites*(?) sp. indet.	3	3
	Lowest beds are exposed just above river level.		

Additional Loose Material

The rubble lying loose at the base of the section contains many specimens, some of which are better preserved or show more morphological detail than those of the same species collected in place in the section. In other cases, individual, richly fossiliferous blocks in the rubble permit documentation of particular associations of ammonites that cannot be seen clearly or at all in the section itself. In other cases, species not found in the section appear in these blocks in association with ammonites that permit recognition of the interval from which they were derived, at least approximately. In addition to the evidence of faunal associations, many of the large blocks can be traced to the bed from which they originated by their distinctive lithology.

The rubble is differentiated from south to north, the northern part being dominated by material from low in the section (Bed 60 and below), the southern part by higher beds.

Other material, collected by earlier workers and thought to have come from the Salmon Cache locality but for which precise locality data is unavailable, was also studied. Much of it has been previously described by Frebold (1961).

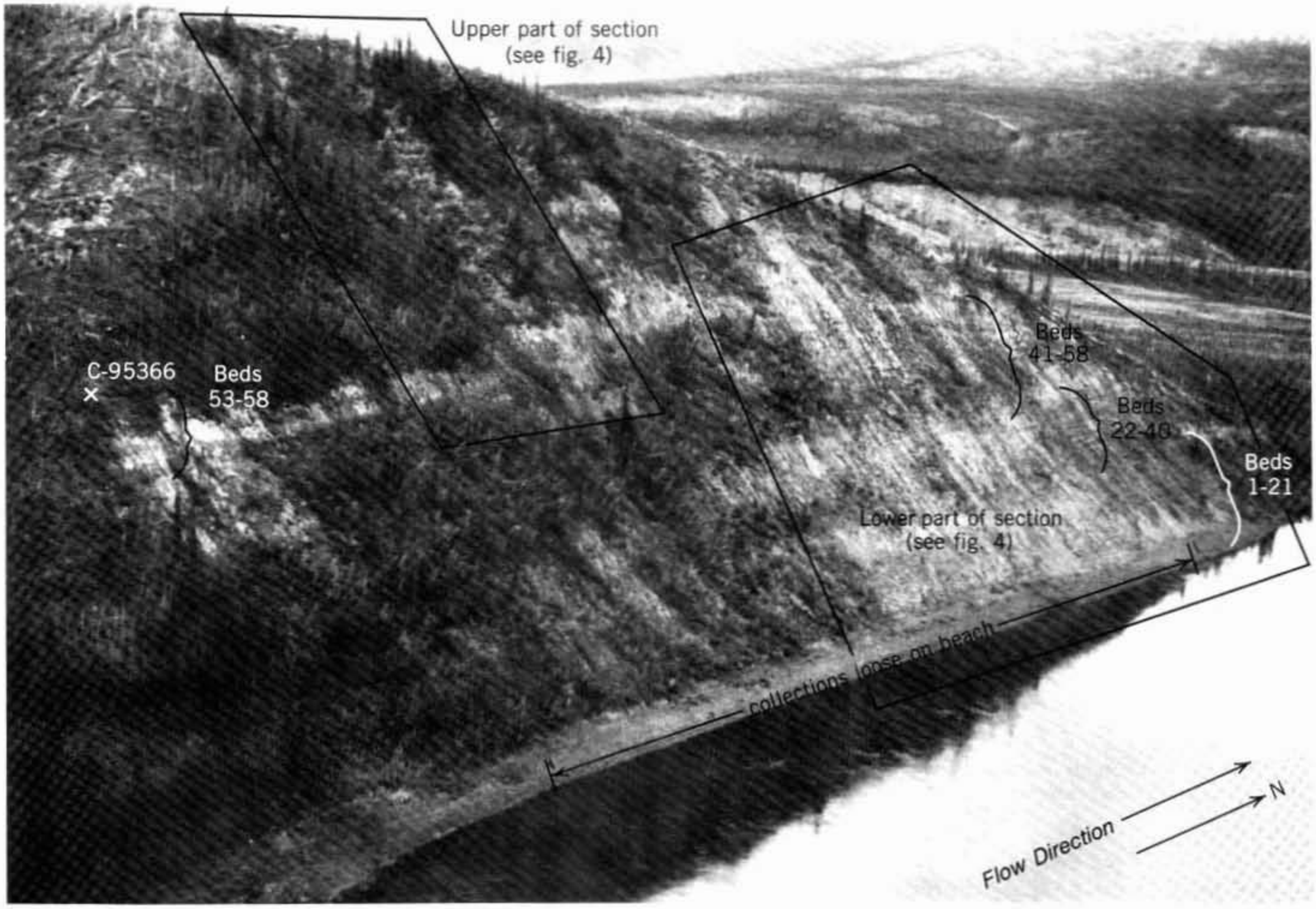


Figure 5. Aerial view of the entire Middle Bathonian to Lower Callovian section at Salmon Cache Canyon. Enlargements of areas indicated are shown in Figures 6 and 7.

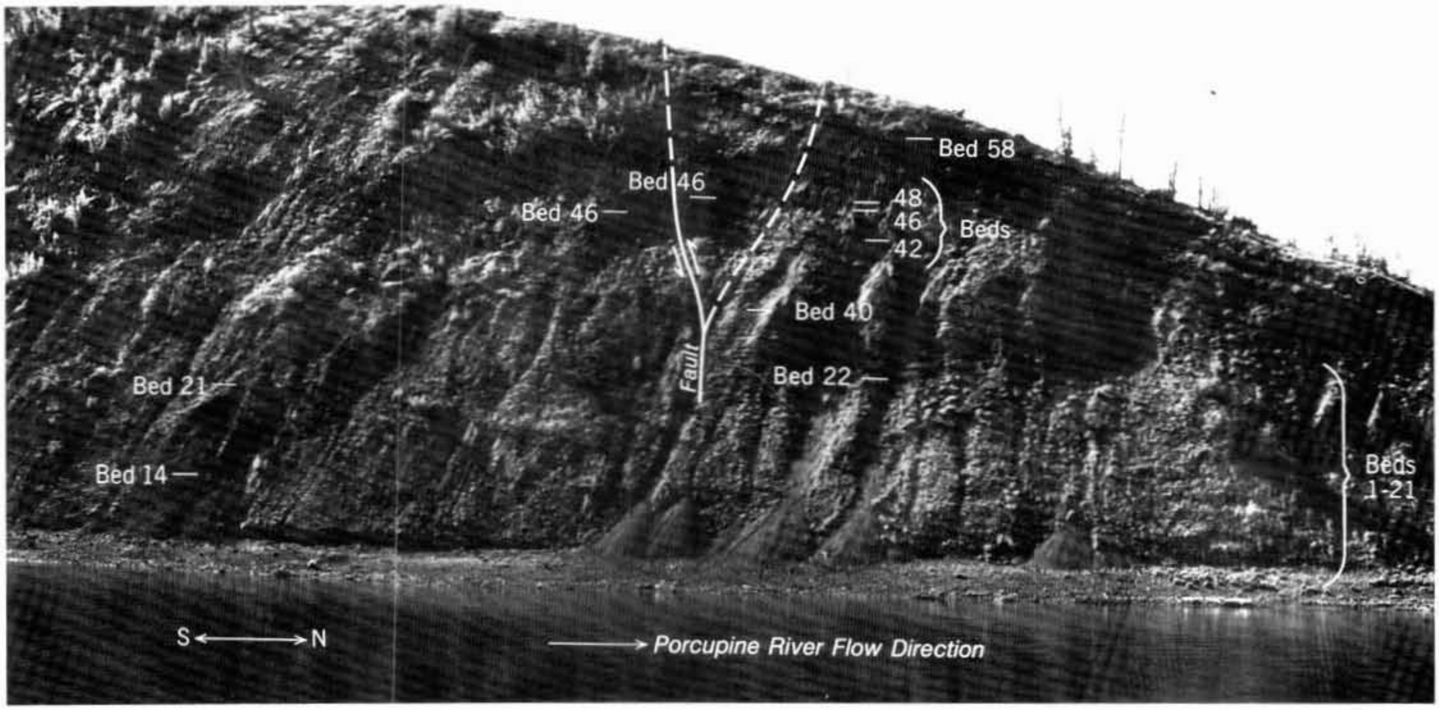


*Figure 6. Lower part of section (**spathi** through **ishmae** Zones), at north end of exposure.*

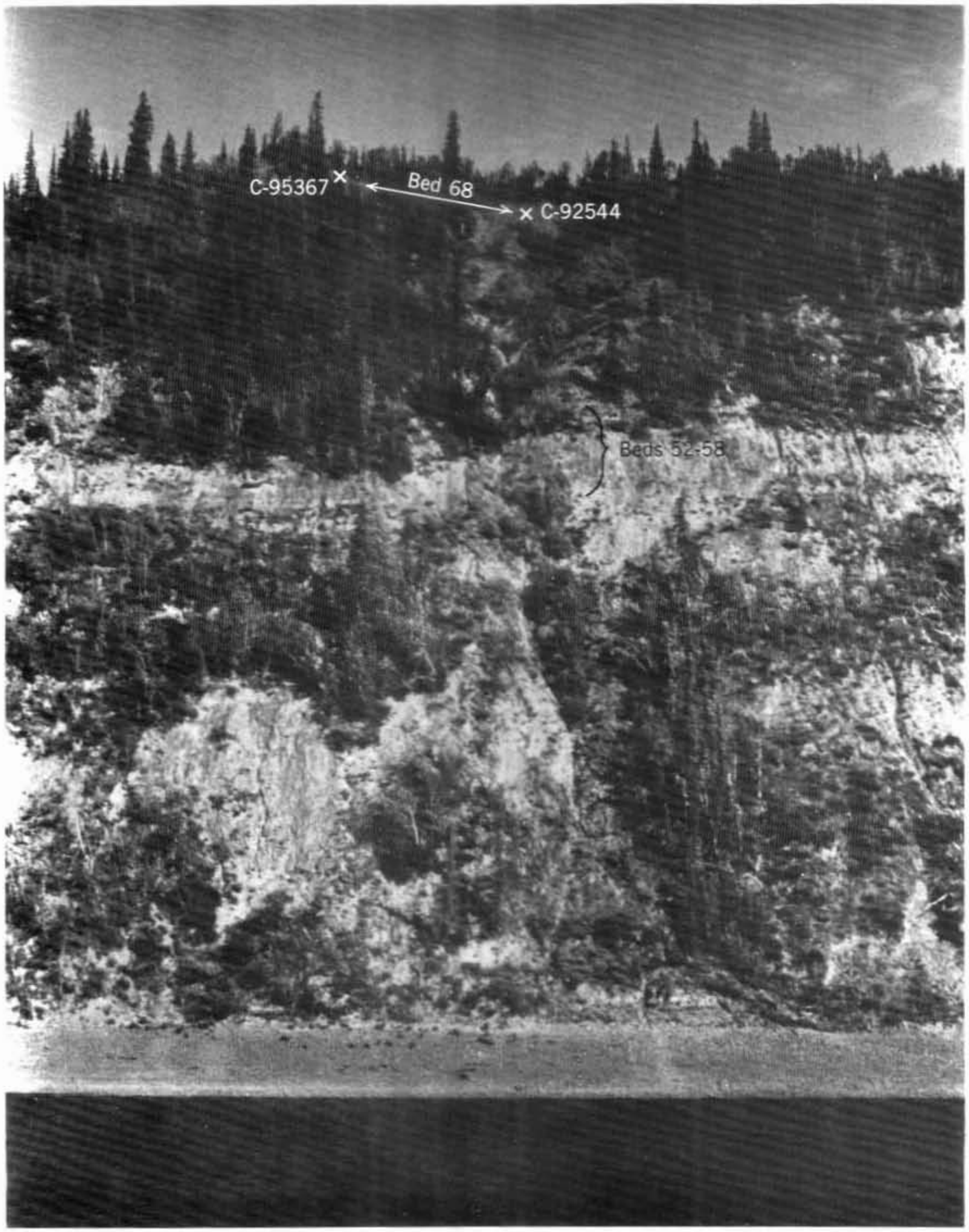


Figure 7. *Upper part of section (**ishmae** through **bodylevskyi** Zones), at south end of exposure.*

FOSSIL LOCALITIES

The fossil localities from which useful ammonite specimens were derived are listed below, and their stratigraphic position or situation in talus is indicated. All localities are in the section at Salmon Cache Canyon, or on the beach below it.

GSC loc. Number	Collector, date, stratigraphic and locality data
20510	R.G. McConnell, 1888. "Porcupine River". Assumed to be from talus on beach below the Salmon Cache Canyon section.
35616	J.A. Jeletzky, 1958. "Unit 2, 132-133 feet above its base". From beds 36, 37, or 38 of this report.
35619	Same as above. "Unit 2, 141-143 feet above its base". From Bed 40 of this report.
35631	Same as above. "Unit 4, 3 feet above its base". From some part of beds 47 to 50 of this report.
35634	Same as above. "Unit 5, 10-12 feet above its base". From Bed 55 of this report.
35635	Same as above. "9 feet above base of section". From Bed 2 of this report.
35638	Same as above. "6 feet above base of Unit 2". From Bed 7 of this report.
35639	Same as above. "40 feet above base of Unit 2". From Bed 14 of this report.
35692	Same as above. Talus on beach below section.
92458	T.P. Poulton and J.H. Callomon, 1975. Bed 34.
92467	Same as above. Loose on section below Bed 68 and clearly fallen from there.
92469	Same as above. Loose on section below Bed 60, derived from beds 60 and 62.
92473	Same as above. Talus on beach below section.
92473a	Same as above. An individual concretion, derived from Bed 62.
92473x	Same as above. An individual concretion, probably derived from Bed 62.
92484	Same as above. Outcrop on beach at about its centre, traced into Bed 14 at north end of bluff where lower part of section was measured.
92520	Same as above. Talus on beach below section.
92521	Same as above. Bed 1.
92522	Same as above. Bed 2.
92523	Same as above. Bed 7.
92525	Same as above. Bed 22.
92527	Same as above. Bed 24.
92529	Same as above. Bed 28.
92530	Same as above. Loose on section at Bed 30, not far fallen.
92531	Same as above. Bed 32.
92532	Same as above. Bed 42.
92534	Same as above. Bed 44.
92535	Same as above. Bed 46.
92536	Same as above. Bed 47.
92537	Same as above. Bed 51.
92538	Same as above. Bed 52.
92539	Same as above. Bed 53.
92540	Same as above. Bed 60.
92543	Same as above. Bed 62.
92544	Same as above. Bed 68c.
92545	Same as above. An individual concretion in talus on beach, coming from low in the section.
92546	Same as above. An individual concretion in talus on beach, coming from low in the section.
92551	Same as above. An individual concretion in talus on beach, coming from Bed 62.
92552	Same as above. An individual concretion in talus on beach, derived from Bed 60.
92553	Same as above. An individual concretion in talus on beach, derived from Bed 62.
92554	Same as above. An individual concretion in talus on beach, derived from Bed 60.
92561	Same as above. Talus on beach.
92563	Same as above. An individual concretion in talus on beach, probably derived from Bed 60.
92564	Same as above. An individual concretion in talus on beach, derived from Bed 60.
92565	Same as above. An individual concretion in talus on beach.
92566	Same as above. An individual concretion in talus on beach, derived from Bed 60.
92567	Same as above. An individual concretion in talus on beach, probably coming from low in the section.
92568	Same as above. An individual concretion in talus on beach, derived from Bed 62.
92570	Same as above. An individual concretion in talus on beach, probably derived from or just below Bed 60.

FOSSIL LOCALITIES (cont.)

GSC loc. Number	Collector, date, stratigraphic and locality data
C-27140	D.K. Norris, 1973. Talus on beach below section.
C-86389	R.L. Detterman, 1981. A single concretion loose on section near its south end, derived from Bed 62.
C-86390	T.P. Poulton, J.H. Callomon, T. Birkelund, R.L. Detterman, D.H. McNeil, 1981. Bed 16.
C-86392	Same as above. Bed 20.
C-86393	Same as above. Bed 26.
C-86394	Same as above. Bed 28.
C-86395	Same as above. Bed 30.
C-86396	Same as above. Bed 31.
C-86398	Same as above. Bed 21.
C-95354	Same as above. An individual concretion in talus on beach, derived from Bed 60.
C-95357	Same as above. Bed 32.
C-95358	Same as above. Bed 36.
C-95359	Same as above. Bed 40.
C-95361	Same as above. Bed 44.
C-95362	Same as above. Bed 46.
C-95363	Same as above. Bed 47.
C-95364	Same as above. Bed 48.
C-95365	Same as above. Bed 53.
C-95366	Same as above. Bed 59.
C-95367	Same as above. Bed 68c.
C-95368	Same as above. Bed 45.
C-95369	Same as above. Talus on beach below section.
C-95369a	Same as above. An individual concretion, derived from Bed 62.
C-95370	Same as above. An individual concretion in talus on beach, derived from Bed 62.
C-95372	Same as above. Talus on beach below section.
C-95372x	Same as above. An individual concretion.
C-95373	Same as above. Bed 55.
C-95374	Same as above. An individual concretion in talus on beach, derived from Bed 60.
C-95375	Same as above. An individual concretion in talus on beach, derived from beds 60 or 62.
C-95381	Same as above. An individual concretion in talus on beach, possibly derived from Bed 62.
C-95382	Same as above. An individual concretion in talus on beach, derived from Bed 60.
C-95383	T.P. Poulton and J.H. Callomon, 1975. An individual concretion in talus on beach, derived from Bed 62.
C-95384	T.P. Poulton, J.H. Callomon, T. Birkelund, R.L. Detterman, D.H. McNeil, 1981. Bed 68a.

CORRELATION

The current status of interprovincial ammonite correlations for most of the Middle Jurassic is shown in Table 3. Due to extreme faunal provincialism, the Boreal successions of the Arctic cannot be entirely correlated in detail in the entire interval between the Lower Aalenian and the Lower Callovian *calloviense* Zone with the 'International Standard' based on Northwest Europe (see Cox, 1964; Westermann, 1958; Torrens, 1974).

Ammonites described here that also occur in Northwest Europe, such as *Cadomites*, are long ranging at the generic level and they apparently differ from their European counterparts or are unidentifiable at the specific level. Others, such as *Oecotraustes*(?), *Prohecticoceras*(?) and *Choffatia*(?) are not identifiable with certainty even at the generic level in the Arctic collections. Excluding the Aalenian from the Bajocian, the only Arctic ammonite that is almost certainly early Bajocian is *Arkelloceras*. The name tozeri, after *A. tozeri* Frebold (1951) can be used as a zonal name if any is needed; its detailed correlation outside Arctic North America and Siberia remains uncertain, but Sei and Kalacheva (1974) reported *Arkelloceras* in association with *Bradfordia*, and occurrences of *Arkelloceras* in Alberta (Westermann, 1964) and southern Alaska (Imlay, 1964, 1976) further indicate an Early Bajocian age.

Similarly, confident detailed correlation of only a few horizons in the Bajocian of the Northeast Pacific province with Northwest Europe are possible (e.g. Hall and Westermann, 1980; Westermann, 1980).

The northern Yukon Bathonian collections contain, in addition to the dominant Boreal faunas, forms such as *Iniskinites* and *Parareineckeia*, which are characteristic of the northeastern part of the Eastern Pacific Realm. Their presence permits some statements regarding correlation with the successions of the Canadian Western Cordillera and southern Alaska, although their ranges in those areas are not well resolved. Certain *Cadoceras* and *Kepplerites* species of southern Alaska offer correlations with the Boreal Realm, and still higher, the uppermost Callovian *Quenstedtoceras* fauna of southwesternmost British Columbia (Frebold and Tipper, 1975) can be correlated in detail outside of the Western Cordillera. Hence the northern Yukon faunas described in this report offer some clues to the correlation of Pacific and European successions via the Boreal Realm. Insufficient study and differing faunas from one outcrop area to another in southern Alaska and the Western Cordillera, are largely responsible for the absence still of a zonation that is widely applicable. Recent comprehensive attempts at such correlations have been made by Westermann (1980), and Callomon (1984).

The sequence of Western Interior North American faunas can be correlated with that from parts of the Western Cordillera and the International Standard through much of Bajocian time (e.g. Westermann, 1980). *Kepplerites* species suggest certain correlations in the Upper Bathonian and basal Callovian, shown in Table 3. Most species of other genera are too long ranging to be of significance for detailed correlations. Not until the Lower Oxfordian *Cardioceras* faunas occur is more confident correlation possible. Additionally, reassignment of at least some of the Western Interior *Warrenoceras* faunas (*henryi* Zone on Table 3; after Westermann, 1980) to *Eurycephalites* may indicate further correlations in the Bathonian with South American *Eurycephalites* faunas.

In the Middle Jurassic of the Western Interior, the Upper Bathonian or Lower Callovian *Kepplerites* faunas are similar to Arctic species, but the correlation shown in Table 3 is still uncertain. *Ammonites henryi* is not *Arcticoceras*, as was indicated by Westermann (1980) following previous authors (see section on 'Taxonomic Paleontology - *Arcticoceras*'), thus correlation with the widespread zone of *Arcticoceras ishmae* is not certain. Nevertheless, the general similarity of these species, and their stratigraphic positions above also mutually similar species groups of homeomorphic subfamilies – *Paracephalites glabrescens* in the south and *Arctocephalites* in the north – lead to the correlation shown in Table 3.

Regional correlations within the Arctic Jurassic, and attempts to correlate its zones with those of the Northwest European Standard, occupy many pages in the literature. Only brief summaries, which are necessary to evaluate the contribution of the Salmon Cache section, to update certain previous statements, or to justify and explain the correlation charts (Tables 1, 3) are presented here.

The most important tools for correlation within the Arctic are the Cadoceratinid genera *Arctocephalites*, *Arcticoceras* and *Cadoceras*. The few poorly preserved specimens of the Kosmoceratid genus *Kepplerites* are also of outstanding importance because of their well known succession in East Greenland, and their occurrence in the Western Interior and Western Cordillera of North America, and in Europe.

Lower Boreal Bathonian

The *Cranocephalites* faunas may be Lower Boreal Bathonian in age. Several species, including what is probably the youngest one, *C.* sp. aff. *C. pompeckji* (Madsen), occur in the northern Richardson Mountains, at localities in which their stratigraphic relations with other species cannot be determined in detail (Poulton, 1978). *Cranocephalites*(?) sp. in Bed 1 of the Salmon Cache Canyon section probably represents this interval, immediately below the *Arctocephalites* faunas which are the subject of this report. Extended discussion of the *Cranocephalites* faunas is beyond the scope of this report; further references to them are found in Meledina (1973) and Callomon (1975, 1985).

Middle Boreal Bathonian

This substage is characterized by *Arctocephalites* faunas. Different zonations have been published for East Greenland (Callomon, 1959, 1985; Callomon and Birkelund, 1980) and northern Siberia (e.g. Meledina, 1973) and the present report presents yet another for northwestern Canada. These different regional zonations reflect the different specific content of the *Arctocephalites* evolutionary plexus from one area to another, and, in its lower part in northern Siberia, the association with *Oxycerites* spp.

The ammonites from East Greenland have been described particularly extensively (Madsen, 1909; Ravn, 1911; Spath, 1932; Donovan, 1957; Callomon, 1959, 1975, 1979; Birkelund et al., 1971; Callomon and Birkelund, 1985). A detailed zonation has been published (Callomon, 1959; Callomon and Birkelund, 1980; Callomon, 1985).

It is not yet possible to correlate any of the Middle Boreal Bathonian zones with those of Northwest Europe or elsewhere with any confidence. Ammonites other than *Arctocephalites* are uncommon, and the majority of them are not well enough represented to be specifically identified; in addition, they belong to genera that are long ranging in Europe. These include *Oxycerites* and *Siemiradzkia* in Siberia (e.g. Ershova and Meledina, 1968) and *Oecotraustes*(?), *Prohecticoceras*(?) and *Choffatia*(?) in northern Yukon.

Following Imlay (1980) and Westermann (1980), the Middle Boreal Bathonian Interval is presumed to be approximately correlative with the *glabrescens/metastatus* Zone of the Western Interior of North America, although no ammonite genera occur in common between them. This correlation is based on the general position of these faunas in the biostratigraphic sequence. Differences between the Arctic and Western Interior homeomorphic genera that are indices for these zones – *Arctocephalites* and *Paracephalites* – are given under 'Taxonomic paleontology – *Arctocephalites*'.

No detailed correlations are possible yet with the Western Cordilleran faunas of North America.

Spathi Zone

The characteristic, small ammonites of the *spathi* Zone of this report apparently do not occur in a discrete interval elsewhere in the Boreal Realm. The zone may therefore be represented by a non-sequence elsewhere in Arctic North America and in East Greenland and Siberia (see Table 1). Correlation with the Northwest European Standard zonation, with the Pacific Realm, or the Western Interior is not possible in detail because of the complete absence of any ammonites in common (Table 3).

Porcupinensis Zone

The association of *Arctocephalites arcticus* (Whitfield) and other small to medium sized species with a few large and inflated specimens such as *A.*(?) sp. aff *A.*(?) *crassum* (Madsen) and *A.* sp. aff. *A. sphaericus* Spath suggests correlation of this zone with the *arcticus* (formerly *nudus*) and lower *greenlandicus* Zones of East Greenland. The differentiation of those two zones was based on the larger size of ammonites in the latter. No such consistent size change is seen in Salmon Cache Canyon, where the zones are based on first appearances of species, diagnosed by other characteristics as well as size. Nevertheless, there is a gradual increase in the numbers of larger species upward in the succession, so that the *arcticus* Zone of East Greenland may well correlate with only the lower part of the *porcupinensis* Zone.

The greatest variety of forms in East Greenland is in the lowest part of the *arcticus* Zone, immediately above the zone of *Cranocephalites pompeckji*, and comprising *Arctocephalites arcticus*, *A. koettlitzi*, *A. ellipticus*, *A. pilaeformis*, *A. nudus*, *A. elegans*, *A. ornatus*, *A. ornatus* var. *pleurophora*, *A. sphaericus*, and *A. platynotus*. This varied assemblage of small to medium size ammonites is closest to that of the *porcupinensis* Zone of northern Yukon. In contrast to the succession in East Greenland, *A. arcticus* is not the earliest *Arctocephalites* species found in northern Yukon, although two early species, *A.* spp. A and B aff. *A. nudus*, from the upper part of the *spathi* Zone, may be among the forms that would be considered variants of *A. arcticus* by Callomon (1975). Typical examples of *A. arcticus* do not appear until high in the *porcupinensis* Zone of northern Yukon, just below the first appearance of much larger *A. amundseni*, a look-alike of *A. greenlandicus*, and *A. arcticus* or *A.* sp. aff. *A. arcticus* are present nearly to the top of the *amundseni* Zone. *A.* spp. aff. *A. nudus* occurs throughout the *spathi* and lower *amundseni* Zones. Apparently no such overlap is present in the East Greenland succession. This diminished value of *A. arcticus* for biostratigraphic subdivision in northern Yukon, and the absence of typical *A. greenlandicus* itself, necessitated the new, local, zonal nomenclature presented here. The appearance, in northern Yukon, of *A.* spp. aff. *A. nudus* lower in the succession than *A. arcticus* suggests also that the synonymy of the two species proposed by Callomon (1979) may not be in the best interest of their stratigraphic utilization.

The various *Arctocephalites* faunas described from northern Alaska (Imlay, 1976), western Axel Heiberg Island of Arctic Canada [Frebold, 1964; one specimen (Pl. I, fig. 2a, b) is wrongly labelled *Cadoceras septentrionale* there], the subsurface of the North Sea (Callomon, 1975, 1979), Franz Josef Land (Newton and Teall, 1897; Pompeckj, 1899, 1900; Whitfield, 1907; Spath, 1932; Samoilovich and Bodylevsky, 1933; Ognev, 1933; Frebold, 1951, p. 80) all contain only small to medium sized species. They are therefore correlated with the *arcticus* Zone of East Greenland and the lower part of the *porcupinensis* Zone of northern Yukon.

The two specimens described as *Arctocephalites*? spp. from Prince Patrick Island (Frebold, 1957a), one of which was found with *Cranocephalites vulgaris*, are not sufficiently well preserved to be identified generically or to allow confident correlation with zonations established elsewhere. The record of *Arctocephalites* in Svalbard (Spath, 1932; Frebold, 1930) was based on an unfigured specimen from Svenskøya cited by Pompeckj (1899) as *Macrocephalites ishmae* var. *arcticus*, and, according to Rawson (1982), requires further confirmation.

Judging by the *Arctocephalites* fauna reported, the lower '*elegans*' Zone and the '*jugatus*' Zone of northern Siberia (Voronetz, 1962; Ershova and Meledina, 1968; Meledina, 1973) and Novaya Zemlya (Cherkesov and Burdykina, 1981) are correlative with the *porcupinensis* Zone.

The correlation of the northern Siberia *jugatus* Zone with the *aspidoides* Zone by Ershova and Meledina (1968) and subsequent Soviet workers, places inordinate emphasis on the presence of the long ranging genus *Oxycerites* (Late Bajocian to Callovian; see Westermann, 1958; Elmi and Mangold, 1966). Furthermore, *O. aspidoides* Oppel, with which some of the northern Siberian specimens were compared, has recently been found to come from Bajocian-Bathonian boundary beds in its type area in southern Germany (Dietl, 1982) rather than from the Upper Bathonian. Another associate of *Arctocephalites* spp. in the lower Lena River region was reported by Tuchkov (1972) as *Procerites (Phaulozigzag) procerus* (Seebach) and correlated with the lower Bathonian Zigzag Zone of Northwest Europe. Its re-identification as *Siemiradzkia* by Meledina (1968) renders its age significance less meaningful, the genus ranging throughout the Bathonian.

The presence of small specimens in older beds and large ones in younger beds seen in East Greenland (i.e. *arcticus* vs. *greenlandicus* Zones) is not seen in northern Siberia either. Rather, medium sized species such as *A. kigilakhensis* Voronetz are among the lowest representatives, and large species such as *A. greenlandicus* Spath or *A. amundseni* n. sp. are represented by only one reported specimen, that is, *A.* sp. cf. *A. greenlandicus* (see Voronetz, 1962; Meledina, 1973).

In Novaya Zemlya, several undeterminable specimens and others that are probably *Arctocephalites arcticus* are present (Salfeld and Frebold, 1924; Frebold, 1930, 1951; Bodylevsky, 1967).

Amundseni and Frami Zones

Correlation of the base of the *amundseni* Zone with some level in the lower part of the *greenlandicus* Zone of East Greenland (Table 1) is based on the first appearance of large compressed species, *Arctocephalites amundseni* and *A. greenlandicus*, respectively. The lowest beds of the *greenlandicus* Zone of East Greenland contain only "*Arctocephalites* sp. cf. or aff. *A. crassum*" (J.H. Callomon, pers. comm.). Similar, large, inflated species in northern Yukon, including *Arctocephalites*(?) *belli*, range throughout the *porcupinensis* through *frami* Zones, indicating that they serve only for the most general correlation of this interval with the *greenlandicus* Zone. The varied assemblage of small to medium sized species that continues upward through the *amundseni* Zone in northern Yukon has not been reported in association with the larger species in East Greenland.[1]

Reports of '*Arctocephalites* aff. *greenlandicus*' in Novaya Zemlya (Bodylevsky, 1967), of *A.* cf. *greenlandicus* in northern Siberia (in the '*elegans* Zone') (e.g. Meledina, 1977) and of '*Cadoceras* sp. cf. *crassum*' in Svalbard (Pchelina, 1970, p. 185) may indicate that correlative beds are present in those areas as well. *Arctocephalites* sp. aff. *A. sphaericus* or aff. *A. callomoni* and *A.*(?) sp. indet. ['*Oligocadoceras* cf. *tetonense*' and '*O.* aff. *muelleri*' respectively of Meledina (1977); = '*Cadoceras declinatum*' of Meledina (1973)], occurring just below the lowest *Arcticoceras* (Meledina, 1973, Fig. 35) or with '*Arcticoceras* sp. indet. cf. *kochi*' (Meledina, 1977, p. 190) may represent one of the *amundseni* or *frami* Zones.

---

[1] Following fieldwork by the writer in 1985 on western Axel Heiberg Island in Arctic Canada, it is now clear that there is a much more complete succession of faunas than was reported by Frebold (1964). In particular, beds equivalent to the *greenlandicus* Zone are well developed there. The faunas are currently being described.

Upper Boreal Bathonian

This substage is characterized across the Arctic by *Arcticoceras* species in its lower part and by the earliest species of *Cadoceras* and *Kepplerites* in its upper part. These latter genera occur in the Northeast Pacific, North American Western Interior, and Northwest European faunal provinces as well, and their first appearances everywhere, as well as the similar morphological characters of these early representatives of the two genera in different areas, suggest the general correlations shown in Table 3.

The lowest occurrence of *Kepplerites* in the *ishmae* Zone in northern Yukon, and its profusion in the *barnstoni* Zone, is paralleled by approximately the same distribution of *Iniskinites*, although the latter genus may possibly be represented also by small, undeterminable fragments in older beds. Thus, the oldest beds with both *Kepplerites* and *Iniskinites* in the Western Cordillera of North America are tentatively correlated with these two zones of Northern Yukon. They are present in Oregon and western Idaho (Imlay, 1964, 1980, 1981), southern Alaska (Imlay, 1962, 1975, 1980, 1981), central British Columbia (Tipper and Richards, 1976; Frebold, 1978), and Queen Charlotte Islands (Tipper and Cameron, 1980; Frebold, 1979). In southern Alaska and Queen Charlotte Islands, *Iniskinites* may appear below *Kepplerites*, as it seems to do in northern Yukon (see also Imlay, 1980; Westermann, 1980). More detailed correlations between the Boreal and Eastern Pacific faunal realms is not yet possible because the precise sequence of ammonites in the latter region is still being worked out. Other genera in common, such as *Parareineckeia* and *Choffatia*, are generally poorly represented and their significance uncertain, although they seem to support the general correlations shown in Table 3.

No early *Cadoceras* species closely resembling *C. barnstoni* occur in the Western Cordillera. The earliest representatives, such as *C. catostoma* and *C. glabrum*, are close in the character of their umbilicus to *C. bodylevskyi* and other, probably Lower Callovian Arctic species, and they first occur well above the lowest *Kepplerites* and *Iniskinites*.

The correlations indicated here and in Table 3 have implications for the stratigraphic range and significance of *Eurycephalites* in the Eastern Pacific Faunal Realm, if that genus is truly synonymous with *Lilloettia* Crickmay and *Warrenoceras* Frebold as is stated elsewhere in this report. Thus, this genus first appears in the Upper Bathonian *henryi* Zone of which it is characteristic in the Western Interior, but in the Western Cordillera, it occurs in younger beds, above the lowest *Iniskinites* and *Kepplerites*. Significantly perhaps, only those (oldest) specimens from the Western Interior of the United States have septal suture patterns that closely resemble the one figured for *Eurycephalites* by Arkell et al. (1957). They are of low amplitude and are relatively simple in contrast to the sutures of those specimens from Canada, and of the Cardioceratidae (this report) and other Macrocephalitidae (Thierry, 1978). Clearly, the lowest occurrences of *Kepplerites*, *Iniskinites*, and *Cadoceras* on the one hand, and *Eurycephalites* on the other are inconsistent from one area to another, rendering difficult and uncertain any correlations proposed at the present time.

Harlandi Zone

The index species was first named from Svalbard (Rawson, 1982), and similar if not identical species occur in the lower part of the *ishmae* Zone of East Greenland, thus identifying the zone in those areas. Closely similar, if not synonymous, *Arcticoceras excentricum* Voronetz (1962; see also Meledina, 1973, 1977) from northern Siberia probably indicates the presence of the zone there, as does *A.* cf. and aff. *excentricum* in Novaya Zemlya (Cherkesov and Burdykina, 1981). This fauna has not been separated from that of *A. ishmae* in Siberia, however. *Macrocephalites ischmae* (sic) var. *arctica* (Pavlow, 1914), from the Lena River of northern Siberia, is probably an *Arcticoceras* of the type that includes *A. excentricum* Voronetz and *A. harlandi* Rawson. The characteristic species of *Arcticoceras* have coarsely spaced, strong ribs, which are not strongly projected on the venter.

Correlation of the *harlandi* Zone with any particular zone in Northwest Europe is entirely unsupported, the only genus in common, *Cadomites*, being long ranging in Europe. Nevertheless, the correlation of the *ishmae* and what was the *aspidoides* (or *orbis*) Zone discussed in the following pages, supports a general correlation of the immediately underlying *harlandi* and *hodsoni* Zones (Table 3).

Ishmae Zone

The index species, *Arcticoceras ishmae* (Keyserling), described first from the Ishma River of northern European Russia (Keyserling, 1846) is now known to be present right across the Arctic, providing a firm basis for correlation within the Boreal Realm (Table 1; see also Bodylevsky, 1960; Saks et al., 1976). Callomon (1975) showed *A. kochi* Spath to be a junior synonym of *A. ishmae*, and replaced the earlier zonal name to recognize this synonymy. He also erected a distinct zone, the *cranocephaloides* Zone, for beds in East Greenland that had earlier been included in the upper part of the *ishmae* Zone. The present writer further restricts the *ishmae* Zone by separating the *harlandi* Zone from its lower part. *Oxycerites birkelundi* n. sp. is present with *A. ishmae* in northern Yukon and East Greenland.

The *ishmae* Zone has been identified in the Canadian Arctic Archipelago on Prince Patrick Island (Frebold, 1961) and western Axel Heiberg Island (Frebold, 1964). The *ishmae* Zone may be represented by small fragments of *Arcticoceras* in northern Alaska (Imlay, 1976, p. 3, figs. 22, ?17, 18) and is present in the subsurface of the North Sea (Callomon, 1975), Svalbard (Pchelina, 1967, 1970), and northern Siberia (e.g. Bodylevsky and Kiparisova, 1937; Meledina, 1973, 1977) where it has not been differentiated from the beds with *A. excentricum*. *A. ishmae* is also present in Novaya Zemlya (Cherkesov and Burdykina, 1981), although earlier described specimens, '*Macrocephalites ischmae*' (Salfeld and Frebold, 1924) are probably undeterminable (Bodylevsky, 1967). Specimens identified as '*Macrocephalites*' *ishmae* and '*M.*' cf. *ishmae* by Samoilovich and Bodylevsky (1933) and Ognev (1933) are not positively identifiable.

Reports of *Pseudocadoceras* spp. with *Arcticoceras* in northern Siberia have been taken as confirmation of the Callovian age of *Arcticoceras* (Meledina and Nal'nyaeva, 1972). The identifications of *Pseudocadoceras* (Meledina, 1972, p. 109, Pl. VIII, fig. 2-5; Meledina, 1973, 1977) refer to evolute small specimens of the type described by Rawson (1982) as probable microconchs of *Arcticoceras* under the name *Costacadoceras*. The same is true of specimens of *C. ognevi* Bodylevsky (1960, p. 57) figured by Voronetz (1967, Pl. XXIII, fig. 2). *Cadoceras* cf. *ognevi* had been considered (Bodylevsky, 1960, p. 51; Meledina and Nal'nyaeva, 1972, p. 71) to characterize an interval between *Arcticoceras* below, and other *Cadoceras* species above. The stratigraphic significance of '*Pseudocadoceras*' s.l. is therefore diminished and certainly these microconchs no longer are considered to be reliable indicators of Callovian age.

Correlation of the Boreal *ishmae* Zone with the *codyense/henryi* Zone of the Western Interior of North America (Imlay, 1980; Westermann, 1980) was based on their general stratigraphic position below the first occurrences of *Kepplerites* and above mutually similar *Paracephalites* and *Arctocephalites* faunas discussed elsewhere in this report. Although the index genera of these zones – *Arcticoceras* and *Eurycephalites* (i.e. *Lilloettia* and *Warrenoceras*), respectively, are now assigned to different subfamilies, as are the somewhat older genera *Arctocephalites* and *Paracephalites*, the general morphological similarities between the Arctic and Western Interior genera are striking, and the general correlation of morphologically similar members of the two parallel-evolving but independent lineages is supported by the present study (Table 3).

The general similarity of the *Eurycephalites* faunas with *Arcticoceras* even extends to the ventrally projected ribs of some species of *Xenocephalites* such as *X. crassicostatum* and *X. saypoensis*, which may be the microconch dimorph of the Western North American Subfamily Eurycephalitinae.

Although the lowest well developed *Kepplerites*, and the greatest abundance of the genus are in the *barnstoni* and *K. costidensus* Zones, two undeterminable species of *Kepplerites*(?) occur in the *ishmae* Zone of northern Yukon, and *K.* sp. indet. occurs with the *henryi* Zone fauna of western United States. The distributions support the correlation just stated, *Kepplerites costidensus* and higher *Kepplerites* species occurring above the *Warrenoceras* (i.e. *Eurycephalites*) beds of Western Interior United States, but with a zone of overlap in and just above the *Gryphaea* bed of southern Alberta. An interval of overlap of *Kepplerites* with *Arcticoceras* in East Greenland comprises the *cranocephaloides* and earliest part of the *variabile* Zones there (Callomon, 1975).

Correlation of the Arctic *ishmae* Zone with any particular interval in Northwest Europe remains tenuous, but the correlation suggested by Birkelund et al. (1971; see also Westermann, 1981) with the *aspidoides* (*orbis*, see Dietl, 1982) Zone is reasonable. Some support for this correlation is offered by the presence of *Choffatia*(?) in northern Yukon. Most Bathonian *Choffatia* species occur in the *aspidoides* or *orbis* Zones (e.g. Hahn, 1969; Deitl, 1981) in southwestern Germany. Only one species each of *Choffatia (Choffatia)* and *C. (Homeoplanulites)* occur in the *hodsoni* (or *retrocostatum*) Zone of southwest Germany, the former only in the uppermost beds (Hahn, 1969), although Torrens (1974) reports the genus to be common in the *retrocostatum* Zone of England.

Prohecticoceras is questionably identified in a loose boulder which may come from the *ishmae* Zone or just below it in Salmon Cache Canyon. This is consistent with its appearance being the guide for the *hodsoni* (or *retrocostatum*) Zone of Northwest Europe (Torrens, 1974).

The correlation of the *ishmae* and *macrocephalus* Zones, still followed by many Soviet writers, was based on general similarities between *Arcticoceras* and *Macrocephalites*, and led to identification by early workers of the Arctic ammonites with their European homeomorph. This correlation is not supported by any other data.

Upper parts of the *ishmae* Zone, characterized by a particularly large and coarsely ribbed species of *Arcticoceras*, and the interval between the *ishmae* and *barnstoni* zones, are not exposed at Salmon Cache Canyon. Some large specimens of *Arcticoceras* found loose below the section may indicate that equivalents of the upper *ishmae* and *cranocephaloides* Zones of East Greenland (Callomon and Birkelund, 1980) are, in fact, present at Salmon Cache Canyon.

***Barnstoni* Zone**

Frebold (1964) described one specimen of *Cadoceras barnstoni* from Ellef Ringnes Island, indicating the presence there of the *barnstoni* Zone.

The *variabile* Zone of East Greenland is correlated approximately with the *barnstoni* Zone of northern Canada, based on the similarity of the *Cadoceras* species. The East Greenland zone was restricted, compared to previous usage, by the separation of the *calyx* Zone from its upper part (Callomon, 1975). The lowest occurrence of *Kepplerites* in East Greenland is in the *cranocephaloides* Zone (Callomon, 1975), but the genus is not common in the Salmon Cache Canyon section until the *barnstoni* Zone, the *cranocephaloides* equivalents not being exposed if they are present. Although some of the *Kepplerites* from Salmon Cache Canyon closely resemble *K. rosenkrantzi* from the *variabile* Zone of Greenland, they have runcinate venters with ventrolateral nodes in the juvenile and intermediate growth stages, a development not seen in East Greenland until the *calyx* or *apertum* Zones. Other northern Yukon specimens are similar to specimens from these East Greenland zones, but in a more general way. Thus, the *barnstoni* Zone of northern Yukon may well be slightly younger than the restricted *variabile* Zone of East Greenland.

In northern Siberia, the assemblage of *Cadoceras subcalyx*, *C.*(?) *excelsus*, *C. densicostatum* and *C. variabile* (Voronetz, 1962), as well as the isolated species *C. ventroplanum*, probably represent the *barnstoni* or *variabile* Zones. *C. subcatostoma* Voronetz (1962) resembles certain elements of this fauna but its associates do not, so it may be younger. Bodylevsky (1960) thought *Cadoceras laptievi* to be among the oldest *Cadoceras* species, characterized by coarse ribs that persist over the entire extent of the body chamber, and a rounded umbilical edge, even on the body chamber. This age assumption may be correct judging by the stratigraphic occurrence of similar *C. barnstoni* (Meek) and *C. variabile* Spath, but the age of *C. laptievi* is not proven.

The interval between the *barnstoni* and *bodylevsky* Zones is not well exposed at Salmon Cache Canyon, but equivalents of the *calyx* Zone of East Greenland are assumed to be present.

Two *Cadoceras* beds, about 77 m apart stratigraphically, have been recognized on Axel Heiberg Island (Frebold, 1964). The lower of them contains *Cadoceras bodylevskyi*, *C.* sp. cf. *C. falsum* and *C. barnstoni* var. *arcuata*, species that are represented in at least two distinct faunas, the *barnstoni* and *bodylevskyi* Zones at Salmon Cache Canyon. They are separated by an interval of about 55 m at Salmon Cache Canyon, so that the Lower *Cadoceras* bed on Axel Heiberg Island may be correlated with some level intermediate between the two *Cadoceras* beds at Salmon Cache Canyon. *Kepplerites svalbardensis* and *K. tychonis*

Ravn probably represent this interval in Svalbard (Frebold, 1929, 1930, 1951; Sokolov and Bodylevsky, 1931; Pchelina, 1970).

Lower Callovian

Bodylevskyi Zone

None of the *Cadoceras* species in East Greenland are sufficiently similar to those of the *bodylevskyi* Zone at Salmon Cache Canyon to permit a confident correlation of the two areas, although the juvenile and intermediate growth stages of some *C. apertum* and some *C. bodylevskyi* are very similar. Similarly, the *C. elatmae* (Nikitin) fauna of northern European Russia may be correlative, judging by *C. elatmae* itself, although some of the associated *Cadoceras* species and *Kepplerites* cf. *tychonis* Ravn (see Bodylevsky, 1960; Saks et al., 1976) resemble the older *barnstoni* fauna of northern Yukon, so that no firm correlation is indicated. It is not clear that specimens from northern Siberia identified as *Cadoceras 'elatmae'* are indeed synonymous with their namesake in northern European Russia. *C. 'elatmae'* from the Anabar River of northern Siberia (Pavlow, 1914) and the widespread Siberian assemblage in which *C. 'elatmae'*, *C. falsum*, and *C. anabarensis* are most commonly reported, and which represent the *'elatmae'* Zone of Meledina (1977), are probably in part equivalent to the *bodylevskyi* Zone of northern Yukon, judging by the similarity of some of those species (particularly those identified as *C. elatmae* itself) to *C. bodylevskyi*. Nevertheless, the variation in morphotypes, and differences in assemblages from one place to another in Siberia indicate complex, poorly understood relationships, so the correlation is not straightforward. Additionally, these species, including *C. 'elatmae'* (Voronetz, 1962, Pl. XII, figs. 1a, b; Pl. XXVI, figs. 1a, b; Meledina, 1977) have a wider umbilicus than the specimens of *C. bodylevskyi* from Salmon Cache Canyon. The subdivision of *Cadoceras* beds into only two zones (Meledina, 1977) suggests that they may be overly comprehensive. The assemblage of *Cadoceras emilianzevi*, *C. subtenuicostatum*, *C. falsum* (Meledina, 1977, p. 189, 190) and another associate *C. lenaense* (*ibid.*, p. 192) is probably younger than those in the Salmon Cache Canyon section.

The Saratov region on the Lower Volga has yielded *Parkinsonia* repeatedly (Arkell, 1956, p. 484; Kamysheva-Elpatyevskaya et al., 1959). It is about the northeasternmost locality with Northwest European faunal character, narrowly separated from the Boreal areas by the Russian Platform. *Cadoceras elatmae* is reported to occur with *Macrocephalites macrocephalus* (Kamysheva-Elpatyevskaya et al., 1959), indicating the correlation of the Boreal and Northwest European zones, in an area where they may intermix. Apparently, neither species from this critical area has been figured. The correlations presented in this report are consistent with such an interpretation however, based primarily on space considerations in filling the pre-Calloviense, post-*ishmae/aspidoides* interval on the correlation chart.

The *macrocephalus* Zone of Northwest Europe is taken to be basal Callovian, following Callomon (1964), although some small ammonites in the Upper Bathonian beds of Germany may be *Macrocephalites* (Dietl, 1981). Since Callomon (1959) interpreted the *tychonis* Zone of East Greenland to be equivalent to the Northwest European *macrocephalus* Zone, the true level from which *Kepplerites tychonis* Ravn came has been discovered (Callomon and Birkelund, 1980). It occurs in the upper part of the *cranocephaloides* Zone, and the earlier interpretation is no longer valid.

Younger zones

J.H. Callomon (pers. comm., 1981) has identified *C. septentrionale* in East Greenland from the beds between those with *C. nordenskjoldi* below and *Sigaloceras calloviense* above. *C. septentrionale* is thought to be younger than the beds with *C. bodylevskyi* at Salmon Cache Canyon, based on the stratigraphic relationships of these two species on Axel Heiberg Island as reported by Frebold (1964). The higher *Cadoceras* fauna on Axel Heiberg Island, containing *C. septentrionale* and *C. septentrionale* var. *latidorsata* (Frebold, 1964), does not appear in the Salmon Cache Canyon section, although the ammonites from it have been described from other isolated localities in the northern Richardsons (Frebold, 1964). *Cadoceras arcticum* Frebold (1961, 1964) from Cornwall Island and isolated localities in northern Yukon is probably younger than any species in the Salmon Cache Canyon section. The specimen of *C. arcticum* from Cornwall Island has an abrupt umbilical edge and a relatively deep, steep-sided, narrow umbilicus as does *C. septentrionale*. Beds equivalent to those with *C. arcticum* may be represented in Franz Josef Land by *'Ammonites (Cadoceras) modiolaris'* (Newton and Teall, 1897).

TAXONOMIC PALEONTOLOGY

Publication of the Ammonoidea volume (L) Mollusca 4 of the Treatise on Invertebrate Paleontology (Arkell et al., 1957) has expedited and prompted a large number of studies aimed at formulating a more complete and widely accepted taxonomic scheme for the ammonites. A preliminary general taxonomic scheme has been presented by the compilers of the second edition of the Treatise (Donovan et al., 1981). The most significant changes relevant to the present report are by J.H. Callomon (in Donovan et al., 1981; 1985) for the superfamily Stephanocerataceae. His suprageneric taxonomy is adopted here, although he pointed out that uncertainties remain and that some arbitrary decisions are involved. The overall effect is a simplification of the taxonomy, reducing the number of higher taxa to a necessary minimum, based on relationships deduced from tracing lineages wherever bed-by-bed successions have been collected, and with consideration for the co-occurrence of dimorphic pairs and of the loci of evolution, that is, of faunal provincialism. The phylogenetic relationships of what was a complex hodge-podge of many homeomorphic genera scattered around the globe, each being treated differently by different authors, have thus been clarified to a large extent.

As a trade-off for a simpler taxonomic and phylogenetic scheme, the identification of isolated specimens has become more subjective. To a certain extent then, correct identification of a particular ammonite in certain groups may require not only knowledge of its morphology but also that of its associates, indicating its morphological variability, and that of its dimorph partner. Also, knowledge of its stratigraphic position (situation within lineage) and its geographic position [which lineage(?), considering extreme faunal provincialism to be the case] may be necessary. This is a phylogenetically based taxonomy (see Sylvester-Bradley, 1962, for example).

Principal among the morphological criteria for differentiating between major taxa are the modifications of the adult mouth border: a ventral projection or lappet and apertural constriction in Cardioceratidae; little or no modification, often constrictions only on the flanks in Sphaeroceratidae; lateral lappets in Stephanoceratidae and Kosmoceratidae. With regard to Sphaeroceratidae, the weak ventrolateral lappets seen on two microconchs of *Iniskinites* from Salmon Cache Canyon may be significant.

Species concept

When large numbers of fossils occur together in a single bed, a continuous range of morphological variation between individual specimens may indicate their assignment to a single or a small number of species (e.g. Reeside and Cobban, 1960). This approach is further upheld by observations of modern populations, in which the number of species of a genus present is generally one, and is further supported by theoretical considerations.

In this report, however, the author describes the co-occurrence of as many as six or seven species of *Arctocephalites* (e.g. Beds 31, 36). Some of the species exhibit considerable morphological variation; others do not. They are delimited where little or no morphological overlap was recognized between them, and for the most part where more than one characteristic feature distinguishes them. In particular, a significant difference in size, inflation, or shape of the cross-section is almost invariably accompanied by a difference in orientation, branching character or spacing of the ribs at equivalent growth stages, so that no simple, continuous variation from one species to another, or co-relation of variation of two features is readily apparent. The morphologically defined yet somewhat variable species thus recognized, regardless of what, if any, relation they have to biological species, co-occur in different combinations from one bed to another, and have different, mostly short, stratigraphic ranges. They are, therefore, the most useful units for identification and/or correlation of isolated or small samples, and for comparison and correlation of the assemblages with those from the regions. The author's approach at the species level is thus typological, except where sufficient material is present to demonstrate continuous variation between different, co-occurring morphotypes.

A comparison with the equivalent assemblages in East Greenland, northern Siberia, and other Arctic areas, indicates only a limited proportion of morphospecies thus defined that are in common with those of northern Yukon, throughout the stratigraphic extent of the evolutionary plexus. At the same time, the overall similarity between the morphospecies in those regions within the same faunal realm indicates nearly continuous marine connections and provides data on the effect of long distances in separating them.

Dimorphism

Sexual dimorphism has now become a widely accepted concept. The major tenets and problems of the assignment of two different morphotypes to macroconch and microconch of the same species, even where traditional typological methods have placed them in different genera or even families, have been stated by Callomon (1963, 1981) and Makowski (1963). Microconchs are smaller than macroconchs of the same species, and are generally ribbed to their aperture. As adults, they exhibit more elaborate development of lappets, as well as incipient uncoiling and septal approximation or other modification. Microconchs are commonly in a minority with respect to macroconchs.

Only a few certainly recognizable microconchs of the Cardioceratidae have been illustrated previously – for *Arcticoceras ishmae* and *Arctocephalites arcticus* (Callomon, 1975), for *Arcticoceras/Cadoceras* sp. nov.? aff. *variabile* Spath (Callomon and Birkelund, 1980, Pl. 1, fig. 2a, b), and for *Arcticoceras harlandi* Rawson (1982). Rawson (*ibid.*) gave a new specific name to the presumed microconch of *A. harlandi* and a new generic name, *Costacadoceras*, to the morphotype that is thought to represent the microconch of the entire lineage of *Arcticoceras* and many *Arctocephalites*. Definitely identifiable microconchs are rare in the Salmon Cache Canyon section. Two have been been illustrated here, as "*Costacadoceras*" spp. The numerous, very small ammonites that occur prolifically in pods at several horizons generally exhibit neither lappets nor uncoiling, and are considered to represent episodes of juvenile mortality. The taxonomic implications associated with the recognition of sexual dimorphism have been discussed by Callomon (1981).

Another type of dimorphism exhibited by several of the species of *Arctocephalites* and *Arcticoceras* is described here. Consistently, the larger dimorph becomes smooth at or close to the beginning of the body chamber, and exhibits a well defined constriction on the internal mould, and a ventral lappet at the aperture. In contrast, the smaller dimorph remains ribbed to its termination just beyond the apertural constriction, at a diameter that corresponds more or less precisely with that at which the body chamber of the larger dimorph begins. The small dimorphs, therefore, are about three quarters to a full whorl smaller than the macroconchs and about half their diameter, or slightly more. No other significant difference in the larger dimorph or other adult modification has been seen. Most of the species are based on the larger dimorphs. The smaller ones, much in the minority in the collections, are recognized in the abundantly represented species *Arctocephalites porcupinensis*, *A. kigilakhensis*, possibly *A. frami*, and in *Arcticoceras ishmae*. In a few cases (e.g., *A. porcupinensis*, GSC loc. 92525), the two dimorphs occur together in the same sample. This type of dimorphism is assumed to represent a limited sort of polymorphism. The more extensive East Greenland collections of subfamily Cadoceratinae exhibit a more complete variation in the size of adult shells and in the persistence of ornament.

Other examples of dimorphism in the material described here might be the association of the assumed dimorphic pair – *Oxycerites* and *Oecotraustes*, as well as the presence of both large and small specimens (with ventrolateral lappets) of *Iniskinites*.

Suborder AMMONITINA Hyatt, 1889

Superfamily STEPHANOCERATACEAE Neumayr, 1875

Family CARDIOCERATIDAE Siemiradzki, 1891

The genera *Arctocephalites*, *Arcticoceras*, *Paracadoceras*, and *Cadoceras* are of primary concern in this report. For the most part, the separation of one from another is based on arbitrarily delimited morphological criteria. Together with a consideration of the different stratigraphic positions of *Arctocephalites*, *Arcticoceras* and *Cadoceras* in a continuous succession with intermediate forms at the boundary horizons, they lead to the current, widely accepted definition of those genera. *Costacadoceras* was erected recently (Rawson, 1982) for small, evolute ammonites that are probably microconchs of associated *Arcticoceras* and *Arctocephalites* species. Two specifically and otherwise generically unidentifiable specimens are referred here to *Costacadoceras*.[1]

[1] Since this report was written, an important review of family Cardioceratidae has appeared (Callomon, 1985).

Subfamily ARCTOCEPHALITINAE Meledina, 1968

The subfamily was erected because of a reported difference from other Cardioceratidae in the number of umbilical lobes of the septal suture pattern (Meledina, 1968). Although this does not appear to be a significant enough difference for separation of the northern Yukon *Arctocephalites* species from members of the younger subfamily Cadoceratinae, the subfamily differentiation is convenient in separating other genera from *Cadoceras* on the basis of their narrower umbilici and usually more compressed cross-sections. An extended discussion of the subfamily and its affinities has been published by Meledina (1973).

Stronger and more asymmetrical subdivision of the first lateral saddle characterizes the suture patterns of *Cadoceras* and *Paracadoceras* species figured here compared to those of *Arctocephalites* and *Arcticoceras*, except for *Arctocephalites* sp. B, which has sutures closer to those of *Cadoceras barnstoni* (Meek). A general evolutionary trend to greater differentiation of the first lateral saddle may be present.

It is beyond the scope of this report to discuss in detail the genera *Cranocephalites* Spath, *Boreiocephalites* Meledina or *Umaltites* Sei and Kalacheva, because they are older than the faunas treated here. However, the differences between *Cranocephalites* and *Arctocephalites* are mentioned briefly under the latter genus, and *Umaltites* is described under *Loucheuxia* (subfamily Eurycephalitinae).

Genus *Arctocephalites* Spath, 1928

The genus is based on *Ammonites ishmae* var. *arcticus* Newton and Teall (1897) from Franz Josef Land.

Arctocephalites is currently considered to comprise those members of the continuous Boreal cadoceratinid succession that link older *Cranocephalites* Spath with younger *Arcticoceras*. The older genera are distinguished principally and most readily by being strongly ribbed on the entire body chamber, whereas *Arctocephalites* becomes smooth. Spath (1932, p. 14, 15, 32), in his first extensive report dealing with *Cranocephalites* and *Arctocephalites*, following the original definition of the latter genus, distinguished *Cranocephalites* by its excentric body chamber and tendency to simplified sutures and to show little or no loss of ornamentation.

Following the interpretation of Callomon (1959), *Arcticoceras* Spath (1924) is distinguished somewhat more arbitrarily by having ribs that are strengthened and projected over the venter. This distinction, like that separating *Arctocephalites* from *Cranocephalites*, has stratigraphic significance. Intermediate forms do occur however, as is noted below under the specific descriptions, and the morphological and stratigraphic separation of the two genera is not entirely abrupt.

The species of *Arctocephalites* clearly form a single, complex evolutionary plexus in which some morphotypes are widely recognized and others are apparently local. Their biostratigraphic utility and, in particular, the finer subdivision of the succession given here justifies the continued use of specific nomenclature for each of the major morphotypes.

Most of the morphospecies of subfamily Arctocephalitinae from the Arctic are compressed forms; however, inflated varieties occur with them at all levels. Too few inflated forms are present in the northern Yukon collections to prove whether or not they are closely related to the compressed forms they occur with. However, the opportunity provided by T. Birkelund and J.H. Callomon to see the more extensive East Greenland collections has convinced the writer of the general correctness of their approach – that complete variation between the compressed and inflated forms exists at each level. The inflated forms associated with typical *Arctocephalites* are therefore assigned here to *Arctocephalites*(?). Nevertheless, intermediate forms are rare, perhaps for paleoecological reasons, and other characters generally accompany the greater inflation; notably, larger adult size and phragmocone, coarser spaced and stronger ribbing, and persistence of coarse, umbilical tubercles. Additionally, projected ribbing on the venter of compressed specimens in the *Arcticoceras*-bearing levels generally does not appear on the inflated specimens at the same level. Hence the query following the generic assignment and the differentiation at the specific level.

Reports of *Arctocephalites* in several areas of Western North America are based on specimens that are not sufficiently well preserved to extend the range of the genus south of the Boreal Realm, or that have been reassigned to other taxa, as summarized below.

Arctocephalites has long been reported from the Fernie Group of southern Alberta and from the Western Interior of United States. These occurrences have been disputed however (Frebold, 1957, 1963), and are no longer generally accepted, but they are of interest when defining the paleobiogeographic distribution of the genus, so that a discussion of them is in order. Spath (1932, p. 13) mentioned "young Canadian examples of *Arctocephalites*", referring to Buckman's (1929) genera *Metacephalites* and *Miccocephalites*, but elsewhere (Spath, 1932, p. 33) correctly indicated that they are almost impossible to identify and cannot stand as genera. Imlay (1945, 1948) quoted the report of *Arctocephalites* in the Fernie Group and described other specimens from Western Interior United States as *Arctocephalites*. He (Imlay, 1945, 1948, 1967) emphasized the similarity of some Western Interior species with *Arctocephalites* species from Greenland. Westermann (1980) has recently identified an "*A. glabrescens* Zone" and correlated it with that of *A. elegans* of the Arctic, and Imlay (1980) has accepted Frebold's (1963) arguments for treating *Paracephalites* Buckman (1929) as a distinct genus. The newer specimen, which Frebold (1963, p. 12, Pl. 1, fig. 2; Pl. II, fig. 2; 1964, Pl. 29, fig. 2) described as *P. metastatus*, has differently curved ribbing than the original material, and appears to show gradual ventral loss of ribbing toward the aperture, suggesting its possible affinities with *Eurycephalites* instead of *Paracephalites* but certainly allying it with subfamily Eurycephalitinae. The present writer considers *Paracephalites*, including *Metacephalites* Buckman (1929) and *Miccocephalites* Buckman (1929), to be an endemic Western Interior genus, and assigns it to the subfamily Eurycephalitinae. Imlay (1962) had assigned other Western Interior species to *Arctocephalites*? or *Arctocephalites (Crancocephalites)* but later (1967; 1980, p. 27, 28) accepted their re-assignment to *Paracephalites*, quoting from Frebold (1963) its generic differences from *Arctocephalites* and *Cranocephalites*. These differences include a wider umbilicus that opens up at a later growth stage, and retention of ribbing to a later stage on the adult body chamber. Donovan (1957, p. 134) stated that North American specimens (i.e., *Paracephalites*) do not closely resemble *Arctocephalites* because of the coarse ribbing in the inner whorls and concave-backward ribs on the middle whorls displayed by the former. These differences are supported by the present writer's restudy of the original type material.

Elsewhere in non-Arctic North America, *Arctocephalites* has been reported from southern Alaska (Imlay, 1962, 1980) and has been questionably identified in central British Columbia (Frebold and Tipper, 1973; Tipper and Richards, 1976). The assignment of the three specimens from central British Columbia to *Arctocephalites*? is indeed questionable. They occur in a fauna the general characteristics of which suggest an age older than *Arctocephalites* beds elsewhere and have been assigned to an enigmatic genus *Umaltites*, originally described in far eastern USSR by Sei and Kalacheva (1979). Certain small forms from southern Alaska earlier assigned to *Arctocephalites*, *Arctocephalites*? and possibly others to *Arctocephalites* (*Cranocephalites*) by Imlay (1962) have been reassigned to *Chinitnites* Imlay (1975) and *Tuxednites* Imlay (1980). The determination of another, only partially preserved specimen figured from southern Alaska (Imlay, 1980, Pl. 8, figs. 18-21) is uncertain.

Arctocephalites spathi n. sp.

Plate 1, figures 1-17; Plate 2, figures 1-10

?*Arctocephalites elegans* Spath. Frebold, 1961, Pl. XI, fig. 1a, b.
?*Arctocephalites* cf. *A. ornatus* Spath. Frebold, 1961, p. 11, 12.
?*Arctocephalites*? sp. indet. Frebold, 1961, p. 12.
Arctocephalites elegans Spath. Poulton and Callomon, 1976, Fig. 61.3; Poulton, 1978, Fig. 2.
?*Arctocephalites elegans* Spath. Meledina, 1973, p. 67, Pl. XV, figs. 2, 3, Pl. XVIII, fig. 1.

Material and occurrence. Eighteen poorly- to well-preserved specimens, including: holotype GSC 68261 and paratypes GSC 68262, 68264 and 68652, from GSC locality 92523 (Bed 7); one (paratype GSC 68267) from GSC locality 92484 (Bed 14); one fragment (paratype GSC 68263) from GSC locality 92522 (Bed 2); and probably two specimens previously described but not figured by Frebold (1961, p. 11, 12) from GSC localities 35635 and 35638 (figured specimens GSC 15107 and GSC 15110 from Beds 2 and 7, respectively). Thus the species is present in Beds 2 to 14, and characterizes the *spathi* Zone. Other specimens have been found loose below the section (GSC loc. 92520; for example, paratypes GSC 68265, 68266, 68269). One unfigured specimen found loose (GSC loc. 92567) occurs in the same concretion with *Oecotraustes*(?) sp.

Description. There is little variation in the strength, spacing, nature of subdivision, or orientation of the ribs. The ribs persist longer on the ventral half of the flanks and on the venter. The shell becomes smooth approximately at the beginning of the body chamber, although there appears to be considerable variation from one specimen to another. The body chamber varies from about two thirds to three quarters of a whorl in length.

Up to a whorl height of about 20 mm, the ribs are fine, nearly straight, and subradial. At about that size, the ribs become slightly falcoid, curving forward just above the rounded umbilical edge, and becoming straight or nearly straight over the ventral two thirds of the flank. Most ribs bifurcate about one third of the way up the whorl. There is some trifurcation and some intercalation of secondary ribs, so that a distinct appearance of trifurcation results. This is true at all growth stages seen.

There are two distinct size ranges, but other characters and the stratigraphic range indicate that they represent the same species. The average adult diameter of the smaller specimens (Pl. 11) is 65 to 70 mm. The best of the larger specimens (Pl. 2, figs. 1, 2) is 90 mm in diameter, although distortion of this specimen cannot be entirely discounted because it is incomplete. In part, the larger size is associated with the significantly higher cross-section of the early parts of the body whorl. Otherwise there is little variation in the cross-section of the shell, in any of the material.

The suture is typical of the genus (see figs. 8, 9).

The strongly developed terminal constriction on the internal mould is preserved in several specimens (e.g. Pl. 1, figs. 3, 13). Reappearance of weak ribs on the apertural few centimetres of the body chamber is seen in two specimens (Pl. 2, figs. 3, 6).

Figure 8. *Septal suture pattern of* ***Arctocephalites spathi*** *n. sp.; figured specimen GSC 68652, from GSC locality 92523; whorl height 2.5 cm.*

Figure 9. *Septal suture pattern of* ***Arctocephalites spathi*** *n. sp.; figured specimen GSC 68267, from GSC locality 92484; whorl height 2.7 cm.*

The typical shape and cross-section of the species is best shown in an undistorted specimen that is preserved in a matrix identical to that of Bed 7 (Pl. 1, figs. 14, 15), but was collected loose below the section (GSC loc. 92520). The typical curvature of the ribs is not well seen on this specimen, however. Slightly straighter and stronger ribs are seen on another, otherwise typical specimen collected loose in the identical matrix (Pl. 1, figs. 16, 17). These ribs approach in appearance those of *A. elegans* Spath (1932, Pl. 10, fig. 4), although the specimens differ from that species as described below.

Discussion. The somewhat falcoid shape and forward slope of the ribs in the adult, the regular intercalation of secondaries or trifurcation of primaries, combined with the size and shape of the shell, separate this species from all others. In particular, the shape of the ribs and their more abrupt disappearance on the body chamber separate it from *A. elegans*, *A. ornatus* Spath and *A. arcticus* Spath. The primaries are longer in *A. elegans* and are strengthened where they subdivide. The cross-section of the body chamber is narrower than in the latter species.

Many of the specimens from the lower part of the section listed as *A. elegans* in preliminary reports (Poulton and Callomon, 1976; Poulton, 1978) are reassigned to the present species. Additionally, judging by the figures of Meledina (1973), it seems likely that many reports of *A. elegans* in northern Siberia may also refer to the new species. Judging by the strength and orientation of their ribbing, the specimens figured by Voronetz (1962, Pl. X, fig. 3) and Efimova et al. (1968, Pl. 94, figs. 1, 2) probably have closer affinities to *A. spathi* n. sp., *A. arcticus* and *A. porcupinensis* n. sp., respectively, although none is identifiable with certainty from the figures given.

A. voronezae Meledina is more inflated and the ribs appear to be more nearly radial.

Name. In recognition of the contributions of L.F. Spath to Mesozoic paleontology in general and to the Boreal Middle Jurassic ammonites in particular.

Arctocephalites ellipticus Spath(?)

Plate 3, figures 1-6

?*Arctocephalites ellipticus* Spath, 1932, p. 33, Pl. XIII, fig. 6a, b.

Material and occurrence. One fragment (figured specimen GSC 68270) from GSC locality 92523 (Beds 6, 7; *spathi* Zone) and another specimen (figured specimen GSC 68271) collected loose below the section (GSC loc. 92520).

Discussion. The cross-section is nearly as wide as it is high and the flanks are flat, as in *A. ellipticus* Spath. The low profile and curvature of the ribs are also similar. For these reasons, the northern Yukon specimens are questionably identified with Spath's species although it is based on a single fragment and another, only partially preserved specimen. The regular bifurcation of ribs in the earliest growth stages of that species illustrated by Spath cannot be seen in the Yukon material. The flanks of the northern Yukon specimens appear to be flatter in the intermediate growth stages than those that Spath illustrated.

Among the specimens collected from loose material below the section, one (Pl. 3, figs. 4-6) is apparently identical to that described from Bed 6 (Pl. 3, figs. 1-3) in its intermediate growth stages, and occurs in an identical matrix. It illustrates the oral portions of the body chamber, cross-section, and ribbing at an intermediate growth stage. The suture pattern is shown in Figure 10.

Figure 10. *Septal suture pattern of* ***Arctocephalites ellipticus*** *Spath(?); figured specimen GSC 68271, from GSC locality 92520; whorl height 2.5 cm.*

Arctocephalites sp. A aff. *A. sphaericus* Spath

Plate 3, figures 7-10

aff. *Arctocephalites sphaericus* Spath, 1932, Pl. VIII, fig. 1.
Arctocephalites cf. *sphaericus* Spath. Callomon, 1979, Pl. 1, fig. 2a, b, c and possibly 3a, b.

Material and occurrence. A fragment (figured specimen GSC 68272) from GSC locality 92523 (Bed 6; *spathi* Zone) in which parts of two whorls are preserved, the largest exposing the oralmost septum; possibly also two still smaller fragments (e.g. figured specimen GSC 68273) from GSC locality 92525 (Bed 22; *porcupinensis* Zone).

Description. The shell is wider than high, and is coarsely ribbed to a whorl height of 35 mm. The ribs are strong and coarse. They bifurcate regularly about one third of the way up the flank. They are gently and continuously curved forward.

At the oralmost end of the largest preserved fragment, very fine, irregular corrugation (growth lines) is superimposed on the ribs of the venter (Pl. 3, fig. 7).

Discussion. This form is distinguished from *Arctocephalites spathi* n. sp. with which it is associated, by its wider than high cross-section, the coarser ribs at an equivalent diameter, and the somewhat greater and continuous forward inclination of the ribs. The difference in the cross-section is seen even in the smaller whorls preserved in the largest fragment. It does not have flattened flanks as does the widest of that species.

The inflated cross-section separates this form from all species except *A. callomoni* Frebold and *A. sphaericus* Spath. The nearly straight and subradial ribs of *A. callomoni* further distinguish that species.

The inner whorls of the holotype of *A. sphaericus* (Spath, 1932, Pl. XVII, fig. 1) have not been illustrated, so that an exact comparison with that species cannot be made. The curvature of ribs is much less in a paratype from East Greenland (Spath, 1932, Pl. XVI, fig. 5) and in specimens described by Spath (*ibid.*, Pl. VIII, fig. 2, Pl. VI, fig. 3) as *A.* aff. *sphaericus* and *A.* cf. *sphaericus* than it is in the present specimens. Also, only one of the specimens figured by Spath (*ibid.*, Pl. VIII, fig. 2) shows regularly bifurcating ribs similar to those of the present specimens, whereas Spath (1932, p. 40) considered triplicate ribs to characterize *A. sphaericus*.

In the curvature and regular bifurcation of ribbing, this form resembles the specimen with a similar sphaerocone cross-section described by Callomon (1979, Pl. 1, fig. 2a, b, c) as *A.* cf. *sphaericus* from the North Sea. It differs from them in the greater arching of the ribs over the venter. The ribs of a chorotype of *A.* cf. *sphaericus* from East Greenland figured by Callomon (1979, Pl. 1, fig. 3a, b) are slightly falcoid rather than being continuously curved forward. Thus, the forward curvature of the ribs illustrated by Callomon (1979, Pl. 1, figs. 2, 3) and seen in the present form may justify their specific separation from Spath's concept of *A. sphaericus*.

Arctocephalites sp. B aff. *A. sphaericus* Spath

Plate 4, figures 3-6

aff. *Arctocephalites sphaericus* Spath, 1932, p. 40, Pl. XVII, fig. 1.

Material and occurrence. One complete specimen (figured specimen GSC 68281) from GSC locality 92520 and several fragments collected from loose material below the section (GSC locs. 92520, 92473, 92561, 92546). None can be confidently assigned to a particular horizon in the section, but the lithologies of the matrix are compatible with those of the *amundseni* Zone. One fragment (unfigured; GSC loc. 92546) is associated in a single block with a specimen of *Phylloceras* sp.

Description. The large specimen (Pl. 4, figs. 3-6) has a terminal constriction at the end of a body chamber that is smooth for about three quarters of a whorl. Although the shell is distorted, its diameter was approximately 11 cm (whorl height 5.5 cm).

The inner whorls are strongly recrystallized. The smallest that can be clearly seen has a height of about 3.8 cm, and is located about one quarter of a whorl before the beginning of the body chamber, about where the ribs begin to fade. It is strongly ribbed. The ribs bifurcate regularly about a third of the way up the flank. They are nearly straight, pass over the venter without projection, and are inclined slightly forward. The primaries are strengthened nearly into bullae; the secondaries are of equal strength or perhaps slightly weaker over the venter, as on the flank.

At this intermediate growth stage and on the body chamber, the greatest thickness is around the umbilicus, and the venter is somewhat acuminate. The umbilicus is intermediate in size, steeply walled and deep, and the umbilical walls meet the flank in a rounded edge. Several unfigured specimens at intermediate growth stages found loose below the section conform well with the above description.

Discussion. The adult diameter is like that of the holotype of *A. sphaericus* Spath (1932, Pl. XVII, fig. 1). The inner whorls are inflated, but the adult cross-section less so. In the combination of these characters the species differs from *A. frami* n. sp., *A. amundseni* n. sp. and *A. kigilakhensis* Voronetz. The species is more inflated than most other *Arctocephalites* species, including *A. greenlandicus* Spath, but less so than *A. callomoni* Frebold. In the intermediate growth stages, the venter is slightly acuminate, more so than in other specimens described above as *A.* sp. A aff. *A. sphaericus*. Adult *Arctocephalites*(?) *freboldi* and *A.*(?) *crassum* are more inflated and have wider umbilici, although their juvenile and intermediate stages are similar to the present species.

Arctocephalites porcupinensis n. sp.

Plate 3, figures 11-22; Plate 4, figures 1, 2

Arctocephalites sp. Poulton and Callomon, 1976, Figure 61.3; Poulton, 1978, Figure 2.

Material and occurrence. Two reasonably well preserved specimens (including holotype GSC 68274 and paratype GSC 68277) and many fragments from GSC locality 92525 (Bed 22); four partial specimens (including paratypes GSC 68275, 68276 and 68279) and many fragments from GSC locality 92527 (Bed 24); one fragmentary specimen (figured specimen GSC 68280) from GSC locality C-95357 (Bed 32). One small fragment (unfigured) from GSC locality 92458 (Bed 34), one (figured specimen GSC 68278) from GSC locality C-86392 (Bed 20), another from GSC locality C-86396 (unfigured; Bed 31); others from GSC locality C-86398 (unfigured; Bed 21) and from GSC locality 35616 (unfigured; Beds 36 to 38) may possibly represent this species also. Thus the species is present in Beds 22, 24, and 32, and possibly also occurs as low as Bed 20 and as high as Bed 38, characterizing some beds in the lower part of the *porcupinensis* Zone, for which it is name-bearer, and extending high into the *amundseni* Zone. Two poorly preserved imprints are present in the earliest collections made along Porcupine River by R.G. McConnell in 1888 (GSC loc. 20510).

Description. Two specimens (Pl. 3, figs. 17, 22) have a constriction on the internal mould at a whorl height of 20 to 25 mm (diameter of 45 mm), indicating adulthood. At this size, the shell is still strongly ribbed on the venter. One other specimen (Pl. 3, fig. 11) is still strongly ribbed to a maximum preserved diameter of 60 mm, and lacks any constriction, and there are similar fragments of large shells in the collection from GSC locality 92527. The first two specimens (Pl. 3, figs. 17, 22) and the last (Pl. 3, fig. 11) are therefore described as smaller and larger dimorphs respectively, of the same species. The termination of septae cannot be seen on any of the specimens, but the sediment fill of the body chambers occupies nearly a complete whorl. The compressed cross-section and character of the ribbing ally these specimens and differentiate them from other species. No sutures are preserved.

On the best preserved of the two smaller dimorphs available in Bed 22 (Pl. 3, figs. 17-20), strong but finely spaced, nearly rectiradiate ribs that bifurcate regularly about halfway up the flank characterize the shell up to a whorl height of 14 mm, although their character on the innermost whorls is unknown. The regular bifurcation is accomplished by intercalation in that specimen (Pl. 3, fig. 20). At a whorl height of approximately 14 mm, the ribs become strongly inclined forward, that is, prorsiradiate, the bifurcation becomes irregular and takes place lower on the flank, intercalation of secondary ribs occurs, and the ribbing as a whole becomes weak, particularly on the flanks. This smooth stage of growth persists for about one quarter of a whorl length and is replaced at a whorl height of approximately 18 mm (diameter 41 mm) by strong, prorsiradiate ribs which bifurcate irregularly halfway up the flank and have intercalated secondaries. The ribs are stronger over the venter, where they also are somewhat projected, the flanks being dominated by fine growth lines. The ribs persist, at least on the internal mould, to the terminal constriction.

The same description applies also to a specimen from Bed 24 (Pl. 3, fig. 22) that has a constriction at a diameter in excess of 48 mm and another in which the terminal constriction is absent. In this specimen however, the regularly bifurcating, nearly rectiradiate ribs persist farther, and the smooth stage is short and weakly developed. Also, the adult prorsiradiate ribs are stronger over the entire flank on the internal mould than those of the previous specimens.

For the two poorly preserved specimens from Bed 22 that are larger dimorphs (Pl. 3, fig. 11), the same description of ribbing given for the smaller dimorph applies, except that the loci of change of ribbing character are retarded. Thus, the demise of strong, rectiradiate ribbing with regular bifurcation halfway up the flank occurs at a whorl height of approximately 20.5 mm, and the resumption of strong ribbing that is, however, distinctly prorsiradiate, occurs at a whorl height of 25 mm. These adult ribs are stronger and more coarsely spaced than those of the microconch, and bifurcate more regularly, at a point about half of the height of the whorl. On the internal mould, they are equally strong over the full height of the whorl, perhaps stronger near the umbilicus.

One of the two specimens of larger dimorphs from GSC locality 92527 (Pl. 3, figs. 13, 14) shows strong ribbing of the last two to three centimetres on the internal mould, following a short, smooth stage. The external shell surface is ornamented by fine growth lines only on the umbilical half of the whorl. On the other specimen (unfigured) the internal mould is smooth in its last 1.5 cm. Both of these specimens, although distorted, exhibit the inflated cross-section of the adult. The largest specimen in Bed 22 (Pl. 3, fig. 11) is strongly ribbed in its last 3.5 cm, and is assumed to be nearly complete, although no terminal constriction is seen, because the entire three quarters of the whorl that is preserved is nonseptate. No terminal constriction can be unequivocally identified on these specimens due to the broken character of the aperture.

One specimen from GSC locality C-95357, tentatively identified as *A. porcupinensis*, gradually becomes smooth at a whorl height of about 2.1 cm. After a smooth stage of about one third of a whorl, strong ribbing resumes. It curves forward smoothly and relatively strongly, and bifurcates regularly. This may well be the apertural part of an adult specimen, although no constriction is apparent. If this specimen is not adult, it may well be the juvenile of its associated species, either *A. praeishmae* n. sp. or *A. kigilakhensis* Voronetz. These species do not characteristically exhibit the smooth growth stage at a whorl height of about 2.3 to 2.6 cm, however.

Discussion. Characteristic features of this species are the change of the ribbing character at successive growth stages, and the compressed cross-section in intermediate growth stages. These characters, together with the regularly bifurcating, strong ribbing at intermediate growth stages, differentiate it from all other species.

In four specimens identified as *Arctocephalites* sp. A aff. *A. nudus* Spath from Bed 26 (Pl. 6, figs. 10, 11), the shell is small and compressed, like typical *A.* sp. A aff. *A. nudus* Spath, and like *A. porcupinensis* n. sp. The ribs bifurcate regularly and pass from a rectiradiate to a gently forward-sloping orientation at a whorl height of about 1.6 cm. Also like *A. porcupinensis*, the umbilicus is small and steep-sided, with a reasonably abrupt edge. Resumption of ribbing after an intermediate smooth stage does not occur as it does in *A. porcupinensis*, however. The forward slope of the ribs in later growth stages, shell cross-section, and character of the umbilicus, ally this species with *A. praeishmae* n. sp., which is, however, larger, and has ribs that are more curved in their forward-sloping orientation.

Name. From Porcupine River.

Arctocephalites callomoni Frebold

Plate 4, figures 7-9; Plate 5, figures 1-13;
Plate 6, figures 4, 5

Arctocephalites callomoni Frebold, 1964, p. 4, 5, Pl. III, figs. 1a to 2; Pl. IV, fig. 1, Pl. V, fig. 3, Pl. VIII, fig. 3.
?*Arctocephalites callomoni* Frebold. Meledina, 1973, p. 66, Pl. XIII, fig. 1a, b.

Material and occurrence. One fragmentary specimen (hypotype GSC 68282) from GSC locality C-86390, (Bed 16), one poorly preserved, partial specimen (hypotype GSC 68283) from GSC locality C-86396 (top of Bed 31), a juvenile specimen (hypotype GSC 68284) from GSC locality C-86395 (Bed 30), and one nearly complete specimen and several fragmentary specimens (including hypotypes GSC 68285, 68286, 68287 and 68288) found loose below the section (GSC locs. 92520, C-95369, C-95372). The species is thus represented in the *porcupinensis* and *amundseni* Zones.

Description. In the best preserved specimen (Pl. 5, figs. 6-9), the smallest growth stage clearly seen has a whorl height of 2.3 cm. It is inflated, and is widest around the umbilical edge. Around this locus, strong, slightly swollen, short, primary ribs subdivide into two or three secondaries each. These are straight, nearly radial, and pass over the venter without deflection.

The ribs and shape are the same until a whorl height of 3.5 cm is reached, where the ribs begin to fade out gradually, first on the ventral parts of the shell, at about the beginning of the body chamber. At this growth stage there are three secondaries to each primary rib.

The body chamber is smooth and about three quarters of a whorl or possibly slightly more in length. It is widest around the umbilicus. It becomes slightly depressed and excentric near the apertural end, and there is indication of an apertural constriction on the umbilical part preserved.

The umbilicus is deep and steep-walled, with a rounded but distinct edge.

The smallest part of the shell that is preserved in the specimen found in Bed 16 (Pl. 4, figs. 7-9) has a whorl height of 1.8 cm. It is highly inflated, and nearly subcircular in cross-section. The umbilical margin is rounded, the umbilicus deep and apparently nearly straight sided. The ribs taper off a short distance into the umbilicus.

Ribs are strongly defined and nearly radial or with a very slight adoral slant. They bifurcate more or less regularly halfway up the flank.

The ribs nearly disappear before a whorl height of 3 cm is reached, just before the beginning of the body chamber. Only those parts of the primary ribs nearest the umbilical margin are preserved; they are strong and slightly inclined forward.

The body chamber is nearly circular in cross-section, and is widest around the umbilicus. Only its adapical portions are preserved. It bears very faint corrugations that are very gently inclined forward, and that may be irregular in their distribution.

The internal whorls of the best specimen found in place in Bed 31 (Pl. 5, figs. 1, 2) are dissolved away, but enough can be seen to state that they are evenly rounded in cross-section, moderately inflated, and perhaps slightly acuminate, with finely spaced rectiradiate ribs. Part of the body chamber has a similar cross-section, and a small umbilicus with steep walls and a rounded edge. The greatest width is around the umbilicus. Weak and finely spaced, forward-curved primary ribs can be seen, which appear to fade out orally within the fragment, and ventrally about halfway up the flank. Very weak, forward-projected ribs also appear on the venter.

The inner whorls of another specimen from Bed 30 (Pl. 5, figs. 3-5) are inflated and carry fine, rectiradiate ribs that bifurcate near the rounded umbilical edge. These characters ally it with the specimen described above, although neither specimen is specifically identifiable.

Intermediate and adult growth stages are preserved in another, larger specimen (Pl. 5, figs. 10-13). The ribs are strong, nearly straight, inclined gently forward and appear to bifurcate regularly. They fade out on the early part of the body chamber, of which more than an entire whorl is preserved, with no sign of an apertural constriction.

In one of the loose fragments (Pl. 6, figs. 1-3), the cross-section is strongly inflated. The ribs are strong and coarse and bifurcate regularly, with some intercalated secondaries. They are nearly straight and subradial.

Another fragment (Pl. 6, figs. 4, 5) exhibits part of an intermediate growth stage with a diameter of 5 cm, and the first part of the body chamber. The first part is strongly ribbed, with swollen short primaries bifurcating near the umbilical edge and with minor intercalation of secondaries. The ribs are nearly radial, inclined very gently forward. The last septum appears at a whorl height of 4 cm. The body chamber is smooth and evenly rounded. The umbilicus is vertically walled, deep, and with a distinct, rounded edge. This fragment is clearly somewhat more inflated than the best specimen described above.

Discussion. The primary type material described from Axel Heiberg Island exhibits considerable difference in inflation and maximum adult size from one specimen to another (Frebold, 1964), even though the specimens were all collected in one bed. This same variation is seen in the northern Yukon specimens, all collected loose, which exhibit no significant differences from the primary type specimens. There seems also to be a minor difference in the size of the umbilicus. The specimen from Siberia figured by Meledina (1973, Pl. XIII, fig. 1a, b) may well represent a somewhat compressed form of the species.

The orientation of the ribs, and greater inflation separate this species from *A.* sp. cf. *sphaericus* Spath from the North Sea and East Greenland (Callomon, 1979, Pl. 1, fig. 2a, b, c and Pl. 1, fig. 3a, b respectively). The regular bifurcation of the ribs separates it from most of the various specimens compared by Spath (1932) to *A. sphaericus* except one (*ibid.*, Pl. VIII, fig. 2), which is less inflated. No other species are closely similar.

The shell of one specimen (Pl. 5, figs. 1, 2) appears to be a bit more compressed and more acuminate than other specimens, but it is more inflated than most other *Arctocephalites* species.

Arctocephalites sp. A aff. *A. nudus* Spath

Plate 6, figures 6-14

aff. ***Arctocephalites nudus*** Spath, 1932, p. 35, Pl. XI, fig. 1.
?***Arctocephalites elegans*** Spath. Frebold, 1961, Pl. XI, fig. 3.

Material and occurrence. Four specimens, including figured specimens GSC 68291 and 68292 from GSC locality C-86393 (Bed 26), one complete specimen and probably several fragments, including figured specimen GSC 68290, from GSC locality C-86394 (Bed 28), and probably also three fragments, including specimens GSC 68289 and 68293, from GSC locality 92525 (Bed 22). The species thus occurs in the upper part of the *porcupinensis* Zone and lower part of the *amundseni* Zone, and it is also abundantly represented in loose material below the section.

Description. Up to a whorl height of 1.7 cm (diameter 4 cm), the ribs are fine, rectiradiate, and bifurcate regularly about halfway up the flank. There are many secondaries; only a few are intercalated. Over a distance of about 3 cm, up to a whorl height of about 2.1 cm, the ribs become gently inclined forward, and fade out onto the smooth body chamber.

The last three quarters of the shell is smooth, the apertural constriction is well displayed. Adult diameter is 5.5 cm. At intermediate growth stages, the cross-section is compressed, flanks flattened, venter slightly acuminate, and umbilicus relatively wide, steep-sided, with rounded edges. The greatest thickness is around the umbilical edge.

The body whorl becomes somewhat more inflated although it remains higher than wide.

Discussion. This species bears a close resemblance to *A. nudus* and *A.* sp. B aff. *A. nudus* in its size, cross-section, and ribbing, but it is smaller, and the ribs disappear at a correspondingly smaller size. The body chamber does not become as strongly inflated as it does in *A. nudus* and *A.* sp. B aff. *A. nudus*, and the umbilical margin is less rounded.

The fragments from Bed 22 (e.g. Pl. 6, figs. 6, 7, 14) comprise only small-diameter, smooth body chambers, with cross-sections and umbilici like those of the specimen from Bed 28 (Pl. 6, figs. 5, 9). One of them (Pl. 6, figs. 6, 7) and one of the specimens figured as *A. elegans* Spath by Frebold (1961, Pl. XI, fig. 3) have a moderately inflated body chamber, characters indicating their intermediate status between *A.* spp. A and B aff. *A. nudus*. Additionally, the specimen figured by Frebold (1961, Pl. XI, fig. 3) has forward-curved ribs, allying it with *A. praeishmae* n. sp. One specimen (Pl. 6, figs. 10, 11) is identical to the others except for its compressed, acuminate body chamber.

Arctocephalites sp. B aff. *A. nudus* Spath

Plate 6, figures 15-18

aff. *Arctocephalites nudus* Spath, 1932, p. 35, Pl. XI, fig. 1.
?*Arctocephalites* aff. *nudus* var. *magna* Spath, 1932, Pl. XI, fig. 7a, b.
?*Macrocephalites koettlitzi* Pompeckji, 1900, p. 70, Pl. II, fig. 12a-c.
Arctocephalites elegans Spath. Frebold, 1961, Pl. X, fig. 2, Pl. XI, fig. 4, Pl. IX, fig. 1(?).
?*Arctocephalites nudus* Spath. Voronetz, 1962, p. 42, Fig. 15, Pl. VIII, fig. 3.

Material and occurrence. Two specimens (figured specimens GSC 68294, 68295) from GSC locality 92527 (Bed 24). The best specimens, from GSC locality 35639 (Bed 14), have already been illustrated by Frebold (1961, Pl. X, fig. 2, Pl. XI, fig. 4). Thus, the species occurs in the *spathi* and *porcupinensis* Zones and occurs in loose material below the section (GSC loc. 92520).

Description. One whorl fragment from Bed 24 (Pl. 6, figs. 17, 18) shows the loss of ribbing at a whorl height of approximately 25 mm. The ribs are fine on the internal mould, and bifurcate regularly halfway up the flank, where there is also consistent intercalation of secondaries. The ribs are nearly straight and are only slightly inclined forward. They persist farther on the venter than they do low on the flanks. The cross-section is rounded, but in the earliest portion of a whorl seen, is slightly acuminate.

Another, more complete specimen from the same bed (Pl. 6, figs. 15, 16) shows the adult shell to be three quarters of a whorl long, and essentially smooth to the aperture, where there is a terminal constriction. Ribbing persists to a whorl height of approximately 23 mm.

Discussion. This species is similar to *A. spathi* n. sp., particularly in the character of the ribbing, with its intercalated secondaries. However, the ribs are not as sinuous as in that species; they are nearly straight and with a greater degree of trifurcation or intercalation of ribs. The cross-section is more inflated than in *A. spathi*. Other species, such as *A. porcupinensis* n. sp. and *A. arcticus* (Whitfield) do not exhibit the regular intercalation of secondaries.

Particularly characteristic of this species is the small size at which the shell becomes completely smooth. In this it differs from most other species, but is allied with the holotype of *A. nudus* Spath (1932, Pl. XI, fig. 1a, b) and with *A. koettlitzi* (Pompeckj). They have similar cross-sections, with rounded flanks that merge smoothly with the steep umbilical slopes, and with complete enclosure of earlier whorls by the final whorl. Spath's (1932, p. 35) separation of those two species was probably based on insufficient criteria, but the broad acceptance that his specific name has received justifies its use even if the two are conspecific. The umbilicus of the present species appears to be a bit more open than in Spath's holotype.

Callomon (1975, p. 383) has stated that new collections from East Greenland show that *A. nudus* is only a variant of *A. arcticus*. The northern Yukon specimens, although not certainly synonymous with the holotype of *A. nudus*, are apparently different from *A. arcticus* in the early size at which they become smooth, the finer ribbing, and the trifurcate or intercalated rather than bifurcate ribbing.

The specimen from northern Siberia figured by Voronetz (1962) is closely similar, but is larger in diameter than either the East Greenland holotype of *A. nudus* or the Canadian specimens.

Arctocephalites arcticus (Whitfield)

Plate 7, figures 1-12; Plate 8, figures 1-4

Ammonites (Macrocephalites) ishmae Keyserling var. *arcticus* Newton and Teall, 1897, p. 500-501, Pl. XL, fig. 1.
Ammonites (Cadoceras) arcticus Whitfield, 1906, p. 132, Pl. XVIII, figs. 1, 2.
Arctocephalites arcticus Newton. Spath, 1928, p. 174.
?*Macrocephalites* cf. *ishmae* Keyserling var. *arctica* Newton and Teall. Frebold, 1930, Pl. XXIII, fig. 1, 1a only.
Arctocephalites arcticus (Newton) Spath, 1932, p. 32, PL. XII, fig. 2.
?*Arcticoceras* sp. nov.? Spath, 1932, p. 58, Pl. XI, fig. 3a, b.
?*Arctocephalites elegans* Spath. Frebold, 1961, Pl. XI, fig. 2.
Arctocephalites arcticus (Newton and Teall). Meledina, 1973, p. 65, Pl. XII, fig. 1a, b, ?fig. 2.
Arctocephalites arcticus (Newton-Whitfield). Callomon, 1975, p. 383, fig. 5C-G.

Material and occurrence. Four fragmentary specimens (hypotypes GSC 68296, 68297, 68298, 68299) from GSC locality 92527 (Bed 24); several fragments together with a nearly complete specimen (hypotype GSC 68301) from GSC locality 92531 (Bed 32); a crushed but complete specimen (hypotype GSC 68300) from GSC locality 92530 (loose at Bed 30 level): three complete but crushed specimens from GSC locality C-86393 (Bed 26) and another (hypotype GSC 68304) from GSC locality C-86396 (Bed 31); possibly three poorly preserved specimens from GSC locality C-95358 (Bed 36). The species range from Beds 24 to 32 and possibly as high as Bed 36. Upper *porcupinensis* and lower (and middle?) *amundseni* Zones. It is also common in the loose material below the section (e.g. hypotype GSC 68305 from GSC loc. 92520).

Description. All the specimens available in which the adult status can be determined are macroconchs; Callomon (1975) has illustrated microconchs from East Greenland and the North Sea. Two partial specimens (Pl. 7, figs. 4, 5, 8, 9) in Bed 24 are strongly ribbed to a whorl height of approximately 25-30 mm, corresponding to a diameter of 65 mm. One of them (Pl. 7, figs. 4, 5) becomes smooth at that stage; corresponding parts of the other fragment are not preserved.

The ribs are nearly straight and are nearly rectiradiate, or inclined slightly forward in large specimens. They are strong and coarsely spaced. They bifurcate regularly one third to halfway up the flank, at which point they are enlarged in 2 specimens (Pl. 7, figs. 4, 5, 8, 9) to form incipient bullae. There is only a minor degree of intercalation of secondary ribs, and this mainly in the larger growth stages.

A partial body chamber in Bed 24 (Pl. 7, figs. 6, 7) has a whorl height of 43 mm and maximum width of 38 mm. The terminal constriction and apertural margins are exposed. The shell has only fine growth lines, and the internal mould is smooth except for irregularly developed weak ribbing here and there.

This description applies also to the several specimens in Bed 32, one of which (Pl. 7, figs. 11, 12) shows the entire body chamber and part of the ribbing on the largest inner whorl. The oralmost few centimetres are weakly and irregularly corrugated. The body chamber, judging by the sediment fill, is three quarters of the whorl length. This specimen does not appear to have any apertural constriction, but another, poorly preserved specimen from this bed (unfigured) shows the apertural constriction to be present at approximately the same growth stage as is shown in Plate 7, figures 6, 7.

Except in the extreme apertural area, where the cross-section is more rounded, the cross-section of the shell is somewhat acuminate, the flanks sloping markedly toward the venter. One fragment from Bed 24 (Pl. 7, figs. 1-3) is more inflated than the other specimens.

A complete but poorly preserved specimen from Bed 31 conforms well with the above description (Pl. 8, figs. 1, 2). It shows the apertural constriction, and the gradual loss of ribs about 2 to 3 cm beyond the last septum. This specimen also shows the typical, exceptionally rounded character of the umbilical edge.

The gradually increased forward curvature of the ribs orally, and other typical characters described above, as well as gradual loss of ribs well before the oralmost septum, are nicely displayed in a specimen (Pl. 8, figs. 3, 4) collected loose below the section. It occurs in a matrix similar to that of specimens described above from the section itself.

The position at which the ribs fade out in relation to the oralmost septum appears to vary considerably from one specimen of this species to another.

Discussion. Characteristic of the typical forms of *A. arcticus* are the moderate but not large size to which coarse ribbing with regular bifurcation persists, the straightness and nearly rectiradiate orientation of the ribs, the low position on the flank at which they bifurcate, and the tendency to form incipient bullae there. These characters differentiate it from most other species of *Arctocephalites* and ally it with *A. greenlandicus* Spath, which is, however, larger. One specimen (Pl. 7, fig. 10) is transitional to *A. praeishmae* n. sp.

The three specimens figured by Newton and Teall (1897) are different from one another in their cross-section as pointed out by Pompeckj (1900, p. 73). Following Pompeckj (1900), Spath (1928, p. 174) and Callomon (1975, p. 383), only Newton's figures 1 and 1a are taken to represent the species, and the specimens described here conform best to that specimen in their cross-section, although most are even more compressed. They also conform well in ribbing character to the much more inflated specimen figured by Newton and Teall (1897, Fig. 2; i.e. *Arctocephalites pilaeformis* Spath, 1932, p. 33), however, so that Whitfield's (1900, p. 132) inclusion of them all as one species does not seem totally justified on morphological grounds alone. The adult specimens from northern Yukon resemble the one figured by Whitfield (1900, Pl. XVIII, fig. 1) so that Spath's (1928, p. 174) and Callomon's (1975, p. 383) rejection of that specimen from the species is perhaps unwarranted. Most recently, Callomon has also considered *A. arcticus* not to include Whitfield's species at all, and he has also considered *A. nudus* Spath to be only an extreme variant of *A. arcticus*.

The adult ribs of one specimen collected loose below the section (Pl. 8, figs. 3, 4) are curved forward as in *A. elegans* Spath (1932, Pl. 10, fig. 4), but they bifurcate more regularly than in Spath's specimen, and the secondaries are stronger.

Arctocephalites praeishmae n. sp.

Plate 7, figures 13-16; Plate 8, figures 5-12

Arctocephalites elegans Spath. Frebold, 1961, Pl. 10, fig. 1a, b.

Material and occurrence. One fragment (paratype GSC 68303) from GSC locality 92529 (Bed 28); one nearly complete but poorly preserved specimen (paratype GSC 68307) from GSC locality C-86394 (Bed 28); three complete specimens, including paratypes GSC 68308 and 68309, and several fragments from GSC locality C-86396 (Bed 31); many specimens from GSC locality C-95357 (Bed 32); a crushed but complete specimen (paratype GSC 68302) from GSC locality 92531 (Bed 32); a crushed but nearly complete specimen (holotype GSC 68306) and several fragments from GSC locality 92458 (Bed 34); possibly several fragments from GSC localities C-95358 (Bed 36), 35619 and C-95359 (both Bed 40). Thus the species is well represented from Beds 28 to 34, and possibly occurs also as high as Bed 40 (*amundseni* Zone). Other specimens were found in float below the section (GSC loc. 92520).

Description. All the reasonably complete adult specimens, and the specimen figured as *A. elegans* Spath by Frebold (1961, Pl. 10, fig. 1a, b) have similar, strong, smoothly and gently forward-curved ribs to a whorl height of about 2.6 cm, corresponding to a diameter of 5.6 cm. At smaller growth stages (e.g. Pl. 7, fig. 15), the forward curvature of the ribs is less pronounced.

The ribs bifurcate regularly about one third to halfway up the flank. Intercalation of secondary ribs occurs but is uncommon. There may be slight swelling at the point of bifurcation. There is some minor variation in their spacing from one specimen to another. The ribs die out over a short interval of two or three ribs duration, at a whorl height of about 2.6 cm. There is some tendency for the flanks to become smooth at a smaller growth stage than the venter.

The body chamber, three quarters of a whorl to nearly an entire whorl in length, is ribbed on its early parts, then is entirely smooth for slightly over half of a whorl length, except for fine growth lines on the external surface. A prominent apertural constriction on the internal mould occurs at a whorl height of 3.5 to 4 cm (adult diameter 7.2 to 7.5 cm). Very weak corrugations reappear on the venter near the aperture on one specimen (Pl. 8, fig. 7) and primary ribs on another from GSC locality C-86396 (not figured).

The umbilicus is small and steep-walled, with a rounded but distinct edge.

The greatest thickness is about a third of the way up the flank. The shell is compressed and markedly acuminate.

Discussion. This species is distinguished from associated typical *A. arcticus* (Whitfield) by its moderate to strong, smooth, forward curvature of the ribs, generally smaller adult size and more compressed cross-section. One specimen, however (Pl. 7, fig. 10), found loose at the level of Bed 30, is intermediate between typical *A. arcticus* and *A. praeishmae* n. sp. in its adult size and the character of the few ribs exposed. The majority of the specimens fall readily into one or the other form however, so that two distinct species are considered to be present.

It is about the same size as, or slightly larger than, *A. porcupinensis* n. sp., but apparently lacks the intermediate smooth stage during ontogeny. The rectiradiate orientation of early ribs is less pronounced, and persists to a larger growth stage than in *A. porcupinensis*. Some forms (e.g. Pl. 7, figs. 13, 14; Pl. 8, figs. 5, 6) resemble that species in that their compressed cross-sections are similar. The more compressed cross-section, smooth forward curvature of the ribs, and greater predominance and regularity of their bifurcation distinguish this species from *A. spathi* n. sp., although a similar, very slight tendency to a falcoid character can be seen in one specimen (Pl. 8, fig. 11). The curvature of the ribs and smaller size separate it from *A. greenlandicus* Spath and similar Canadian forms, although *A. kigilakhensis* Voronetz has similarly shaped ribs. It is distinguished from the holotype of *A. elegans* figured by Spath (1932, p. 37, Pl. X, fig. 4a, b) in the more abrupt and earlier loss of ribbing, and in the consistent presence of two rather than three secondary ribs to each primary, although the orientation of the ribs of the two species is similar.

Some specimens particularly resemble *Arcticoceras ishmae* (Keyserling) in shell shape and in the forward curvature of the ribs, which resemble the projected ribs on the venter of that species. *A. ishmae* is much larger, however, and the coarse ribbing persists to a correspondingly much larger growth stage.

Name. From its superficial similarity to the much larger and younger species *Arcticoceras ishmae.*

Arctocephalites amundseni n. sp.

Plate 9, figures 1-4; Plate 12, figures 5, 6

?*Cadoceras* aff. *C. pseudishmae* Spath. Frebold, 1961, p. 20, Pl. XVI, fig. 1.

Material and occurrence. A broken but nearly complete specimen (holotype GSC 68324) from GSC locality C-86394 (Bed 28), another (paratype GSC 68310) and a fragment, from GSC locality C-86395 (Bed 30); possibly also a poorly preserved specimen (figured specimen GSC 68311) from GSC locality C-95358 (Bed 36); possibly two fragments (unfigured type specimens GSC 68654, 68655) from GSC locality C-86393 (Bed 26). *Amundseni* Zone (lower part).

Description. The two best preserved specimens (Pl. 9, figs. 1, 2; Pl. 12, figs. 5, 6) are about 13 cm in adult diameter, and exhibit apertural constrictions.

The shell is moderately compressed and acuminate to a very slight degree. It is tightly coiled, with a small, steep-sided umbilicus that has an abruptly rounded edge. The greatest thickness is about one fifth of the way up the flank.

The smallest growth stage preserved has a whorl height of approximately 2.5 cm. It is strongly ribbed; the ribs bifurcate just below halfway up the flank, and are inclined gently forward. They pass over the venter nearly without projection.

At or near the beginning of the body chamber, at a whorl height of about 4 cm (diameter about 8 cm), the ribs gradually fade out over a distance of about 1 cm. The last ribs are inclined forward perhaps slightly more than in smaller growth stages. The body chamber is three quarters of a whorl in length. It bears fine growth lines on the external shell surface and becomes weakly corrugated in the apertural 2 to 3 cm. The corrugations are mainly irregular but are regular on the lower part of the flank. The specimen from Bed 36 (Pl. 9, figs. 3, 4) is apparently identical but cannot be positively identified because of the recrystallized inner whorls and its higher stratigraphic position.

Discussion. These specimens are closely similar to *A. frami* n. sp. described below, and to the holotype of *A. greenlandicus* Spath (1932, p. 34, Pl. IX, fig. 1a, b; Pl. X, fig. 2). They are strongly ribbed to a slightly larger diameter, however, and have a somewhat less acuminate cross-section. These differences would not justify their separation from *A. frami* were it not for the large stratigraphic difference between the two forms. This species is more inflated than *A. greenlandicus.* However, several unidentifiable fragments of body chambers occur in Bed 30 with *A. amundseni* that have more compressed cross-sections, flattened flanks, and an adult size like that of *A. greenlandicus*, although the last whorl of these fragments is entirely smooth, unlike the holotype of *A. greenlandicus.*

Two small fragments (unfigured type specimens GSC 68654 and 68655) of large, involute shells (from Bed 26) have high, nearly flattened flanks, and one appears to have a compressed cross-section. The ribs curve forward smoothly and gently. In one, they bifurcate high on the flank, in the other bifurcation cannot be seen. The large whorl height at which coarse ribbing still occurs, and the shell shape and ribbing character ally these fragments with the apertural part of the body chamber of the holotype of *A. greenlandicus.*

The specimen found in loose material below the section (Frebold, 1961, p. 20, Pl. XVI, fig. 1) is questionably assigned to this species because of the large growth stage to which ribbing persists.

Name. To commemorate the polar explorer who first reached the South Pole, first sailed through the Northwest Passage, and who died while engaged in an Arctic rescue mission.

Arctocephalites kigilakhensis Voronetz

Plate 10, figures 1-8; Plate 11, figures 1-12;
Plate 12, figures 1-4

Arctocephalites kigilakhensis Voronetz, 1962, p. 44, Pl. IX, fig. 2a, b.

Arctocephalites kigilakhensis Voronetz. Meledina, 1973, p. 70, Pl. XVI, figs. 1, 2.

Material and occurrence. One nearly complete but broken specimen (hypotype GSC 68316) from GSC locality C-86396 (Bed 31); another from C-95358 (Bed 36), three nearly complete specimens (hypotypes GSC 68314, 68312, 68313) and many fragments from GSC locality C-95357 (Bed 32); probably also a well preserved, complete, smaller dimorph from each of GSC localities 92529 and 35619 (hypotypes GSC 68315 and 68318; Beds 28 and 40); three fragmentary specimens from GSC locality 92532 (Bed 42); and another fragment (hypotype GSC 68319) from GSC locality 35619 (Bed 40); and several found loose below the section (e.g. hypotypes GSC 68317, 68322, 68323 from GSC locs. 92473, 35692, 92520).

Description. The inner whorls of the specimen from Bed 31 (Pl. 11, figs. 1-4) cannot be seen well because they are completely recrystallized and partly dissolved away. At a whorl height of about 1.5 cm, they are very slightly higher than wide, with strong but relatively finely spaced rectiradiate ribs. The degree of bifurcation compared to trifurcation or intercalation of secondaries cannot be seen clearly, but bifurcation seems to be predominant.

At a whorl height of 2.5 cm, the whorl is significantly higher than wide (less than 2 cm wide). The cross-section is very slightly acuminate, with flattened flanks that are widest a third of the way up the flank. The ribs are strong, relatively finely spaced, and bifurcate about one third of the way up the flank. They slope gently forward, crossing the venter with slight forward curvature. The forward slope increases gradually adorally. The ribs end fairly abruptly, leaving an entire whorl smooth. Slightly less than three quarters of the last whorl is occupied by the body chamber. It is markedly acuminate. The maximum adult whorl height is 6 cm, diameter 11 cm, and maximum width around the umbilicus 4.5 cm. The umbilicus is small and steep-sided, with an abruptly rounded edge.

In one specimen from Bed 36, (unfigured), very faint rib impressions persist over the venter for nearly the entire body whorl.

The several specimens from Bed 32 (Pl. 10, figs. 1-7) conform well with the above description. One specimen, which is missing the body chamber and which is badly crushed (Pl. 10, fig. 1) shows the shape of the ribs at a whorl height of about 2.5 cm, as well as the bifurcation, adoral coarsening, and forward slope. This specimen and others exhibit the coarser spaced, gently adorally curved, mainly bifurcating ribs at a whorl height of about 4 cm, and the gradual fading of the ribs onto the smooth body chamber. There is some slight variation in the spacing of ribs. The body chambers show slight differences in the degree of compression and roundness of the venter, but are otherwise uniform. One specimen from Bed 32 (Pl. 10, figs. 2-4) is unusually strongly compressed.

The suture pattern is poorly exposed on one specimen (Pl. 11, figs. 11, 12), but cannot be traced.

The smaller dimorphs are assigned to this species because of their closely similar although not entirely identical ribbing and size at the stage at which the terminal constriction appears with that at which the larger dimorph becomes smooth. At a whorl height of about 2.6 cm, in two of the smaller dimorphs (Pl. 10, fig. 8, Pl. 11, figs. 7, 8) and 3 cm in the others, the final stages of the outer whorl become slightly excentric, an apertural constriction occurs, and the whorl height is depressed. There is some variation in these specimens in the degree to which the cross-section is acuminate, and in the forward slope and spacing of the ribs, so that their assignment to a single species, or to *A. kigilakhensis* is tentative.

Discussion. The present material differs from the northern Siberian specimens (Voronetz, 1962; Meledina, 1973) only in having a slightly more compressed cross-section.

This species most closely resembles *A. frami* n. sp. and *A. amundseni* n. sp., and differs from *A. greenlandicus* Spath in the same ways that they do. It is, however, slightly smaller in adult diameter, becomes smooth at a significantly smaller whorl height, and above all, has much finer, more forward-sloping ribs. In this, it is morphologically transitional between these species, and coeval *A. praeishmae* n. sp. *A. praeishmae* has a much more compressed cross-section but is otherwise similar at equivalent growth stages. The ribbing of *A. kigilakhensis* is intermediate in the degree of forward curvature between that of *A. arcticus* (Whitfield) and that of *A. praeishmae*. In size and stratigraphic position the species is intermediate between *A. arcticus* and *A. frami*.

Arctocephalites frami n. sp.

Plate 12, figures 7-10; Plate 13, figures 1-11

?*Macrocephalites ishmae* Keyserling. Madsen, 1897, Pl. VIII, figs. 7-9.
Arcticoceras kochi Spath. Frebold, 1961, Pl. XII, fig. 1a, b, Pl. IX, fig. 3.

Material and occurrence. One partial specimen each from GSC localities 92535 (paratype GSC 68328; Bed 46), 92536 and C-95363 (paratypes GSC 68327 and 68325; both Bed 47) and two from 35631 (Beds 47 to 50, including paratype GSC 68330). The other from the last locality was described by Frebold (1961) as *Arcticoceras kochi*. The species comes from Beds 46 and 47, and possibly also as high as Bed 50 (*frami* Zone). The lithology of one fragment found loose below the section (paratype GSC 68329 from GSC loc. C-95369) indicates its probable source in these beds also. Other loose specimens come from GSC localities 92473 and C-95372 (e.g. paratype GSC 68326).

Description. Up to a whorl height of about 3 cm, corresponding to a diameter of approximately 6 cm, the shell is strongly ribbed. The ribs are coarsely spaced, and each bifurcates at or just below the middle of the whorl. There is minor intercalation of secondaries between them. The ribs are nearly straight and rectiradiate, although the oralmost of them slope gently forward. Except for these oralmost ones, the ribs cross the venter without deflection. There is a slight tendency for the ribs to be strengthened at their point of bifurcation. After about a diameter of 8 cm or so, there is almost a full whorl that is smooth. The ribs disappear first on the flanks, so that the last few centimetres of phragmocone are ribbed only on the venter. The loss of ribs thus more or less corresponds with the beginning of the adult body chamber. Weak and somewhat irregular ribs reappear on the venter near the peristome. The apertural constriction is seen on two specimens and is strongly projected on the venter. Similarly, the ventral part of the peristome is strongly projected, and may justify the term "ventral lappet" used by Spath (1932) to describe *A. greenlandicus*.

The cross-section is somewhat acuminate in all growth stages seen. The umbilicus is small, with a relatively sharp margin and steep walls.

Part of an inner whorl, 2.2 cm high, and 1.6 cm wide, can be seen (Pl. 13, figs. 8, 9). It is compressed and slightly acuminate, with a rounded but distinct umbilical edge. The umbilicus is a relatively wide 1 cm. It is finely ribbed; the ribs appear to be curved forward strongly and subdivide only a short distance above the umbilical edge.

At a whorl height of 4 cm, the shell is nonseptate, compressed and markedly acuminate, with convex flanks. It is widest at about one third of the height of the whorl. The umbilical edge is more rounded. The main part of this whorl fragment is nearly smooth, with fine growth lines. Parts of weak, prorsiradiate ribs are present on the venter. Strong ribs, strongly curved forward, reappear on the oralmost part of this fragment. This characteristic, together with a suggestion of uncoiling and of an apertural constriction, indicate that this fragment is the apertural part of an adult body chamber. The ribs are strengthened and projected over the venter.

The suture pattern is shown in Figure 11.

Discussion. Two of the specimens (Pl. 13, figs. 1-4 and 5-7) conform reasonably well with Spath's (1932) description and illustration of the holotype of *A. greenlandicus*, which was the only specimen available to him. They are a bit smaller, however, and the ribs do not persist to a diameter of 90 mm as he described for that specimen. They have a steeper umbilical wall, at least on the outer whorl, and a more compressed, somewhat acuminate cross-section. Furthermore, the body chamber appears to constitute approximately three quarters rather than half of a whorl, and at least the full length of the outer whorl is smooth.

They are larger than the otherwise apparently identical specimens of *A. arcticus* (Whitfield) from the northern Yukon with which they are allied in the regular bifurcation of the ribs and nearly straight, strong ribbing. The other differences between *A. greenlandicus* and *A. arcticus* cited by Spath (1932, p. 34) do not apply in the separation of *A. arcticus* from *A. frami* n. sp.

Figure 11. *Septal suture pattern of* ***Arctocephalites frami*** *n. sp.; paratype GSC 68326, from GSC locality 92473; whorl height 3 cm.*

Except for the slightly smaller size, the specimen shown in Plate 13, figures 8, 9, resembles *A. frami*, for which it could be a smaller morphotype. The projected ribbing may ally it with *Arcticoceras*, although this characteristic can only be seen near the aperture, where it also commonly appears in species of *Arctocephalites*.

The present species differs from younger *Arcticoceras* species and from older *Arctocephalites praeishmae* n. sp. and *A. kigilakhensis* Voronetz in the straight and nearly rectiradiate orientation of the ribs, although those few nearest the peristome are projected strongly forward as in those other species. It differs from most other species of *Arctocephalites* in its larger size, as well as in the strong, coarsely spaced, bifurcating ribs, and in their orientation. The specimen figured by Frebold (1961, Pl. XII, fig. 1a, b) appears to be larger than the others, although the others are broken and their true size difficult to judge. Furthermore, in the growth stages where the ribs gradually weaken on the flanks of the body chamber, the ribs are strong and slightly arched forward on the venter. All these characters ally the specimen with *Arcticoceras* to which genus Frebold (1961) assigned it. Its stratigraphic position and association with the other specimens described here prompted its reassignment to *Arctocephalites* however, as did the acuminate venter and somewhat more abrupt umbilical edge, typical of the other large *Arctocephalites* species described here. It is thickest near the umbilical margin, whereas specimens assigned here to *A. ishmae* are thickest about halfway up the flank. This specimen and that described from a higher level, Bed 55 (GSC loc. 35634) by Frebold (1961, Pl. IX, fig. 3) are transitional between *Arctocephalites* and *Arcticoceras*.

Name. After the vessel in which Nansen was frozen into Arctic pack ice for three years; which was used by Otto Sverdrup on his two Arctic exploration journeys, and later by Amundsen for transport to Antarctica.

Arctocephalites sp. A

Plate 14, figures 1-9; Plate 15, figures 7-9

Material and occurrence. One nearly complete specimen (figured specimen GSC 68331) and other, poorly preserved, questionably identified specimens (e.g. figured specimens GSC 68333 and 68337) collected loose below the section (GSC locs. 92520, 92561, 92565). They cannot be definitively assigned to a particular horizon in the section although the lithologies suggest their derivation from the upper *amundseni* through *ishmae* Zones. One small ventral fragment (figured specimen GSC 68336) occurs in Bed 40 (GSC loc. 35619; upper *amundseni* Zone). One specimen found loose (University of Alberta No. 45413) questionably assigned to this species occurs in a rock type like that of the *ishmae* beds. Another small fragment (figured specimen GSC 68332), found loose below the section (GSC loc. 92473), occurs in a yellow weathering matrix that cannot be assigned to any particular horizon.

Description. The large specimen (Pl. 14, figs. 1-4) has a diameter of at least 14.5 cm (whorl height 6 cm). No apertural constriction can be seen. Approximately the last three quarters of a whorl is nonseptate and smooth, the ribs beginning to fade out at about the beginning of the largest whorl preserved. The last part of the body chamber is slightly excentric.

The smallest growth stage seen has a whorl height of approximately 1.7 cm and a width of 2.4 cm. It is strongly depressed, with a slightly acuminate venter. The ribs are strong, bifurcate near the umbilical edge, and pass over the venter with a very slight forward projection.

At a growth stage with a whorl height of about 3.8 cm, the cross-section is higher. The ribs are strong and coarse, and bullate where they bifurcate about one third of the way up the flank. They are nearly straight, inclined slightly forward, and pass over the venter without forward projection.

At all growth stages, the greatest width is near the umbilical edge. The umbilicus is of moderate size, deep and steep-walled, with a rounded umbilical edge.

The suture pattern of one small fragment questionably assigned to this species is shown in Figure 12.

Discussion. The ribbing is much coarser at an equivalent growth stage and persists longer than in *A.* sp. B aff. *A. sphaericus* Spath. It is allied to *Arctocephalites*(?) *freboldi* (Spath) and differentiated from the only other similar species, *A.*(?) *crassum* (Madsen), by its slightly acuminate venter and coarser ribbing. The cross-section of *A.*(?) *freboldi* Spath is wider and more depressed however, and the same appears to be true of *A.*(?) *crassum*, judging by Madsen's (1909) figure (Pl. X, fig. 1).

The ventral fragment from Bed 40 (Pl. 15, fig. 7) shows the acuminate venter, coarse, very slightly projected ribs, and probably also the depressed cross-section, but it is not specifically identifiable.

Most of the small fragments found loose are allied in the coarseness of the ribbing and in the slightly acuminate venter. One, however (unfigured; U. of A. loc. 45413), is finer ribbed.

Arctocephalites sp. B

Plate 15, figures 1-6

Material and occurrence. One specimen (figured specimen GSC 68334) from GSC locality 35616 (Bed 36, 37 or 38; *amundseni* Zone) and possibly another (figured specimen GSC 68335) found loose (GSC loc. C-95372) in a matrix whose source cannot be identified with certainty.

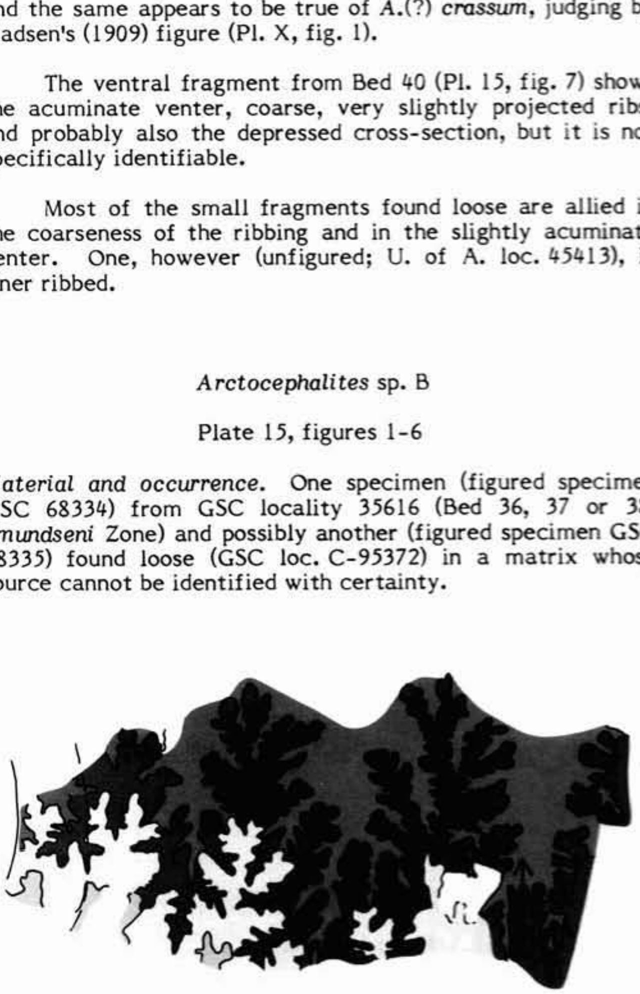


***Figure 12.** Badly corroded septal suture pattern of **Arctocephalites** sp. A; figured specimen GSC 68337, from GSC locality 92520; whorl height 2.5 cm.*

Description. The internals of the larger specimen (Pl. 15, figs. 1-4) are recrystallized and broken so that only small ribbed fragments can be seen. One, with a whorl height of 2 cm, is coarsely and strongly ribbed. The ribs bifurcate and trifurcate just below halfway up the flank. They are very gently curved forward in their ventral parts. This fragment is moderately inflated; the flank, the umbilical margin, and ventrolateral edge are smoothly rounded.

The only other, and the largest whorl fragment available from the same specimen, is 4.7 cm high. It is nonseptate and nearly smooth, with very weak, irregular corrugations and fine lirae that are very gently inclined forward. The cross-section is smoothly rounded, although the thickness is greater at the umbilical margin than it is higher up on the flanks. The umbilicus is relatively open, perhaps by extraumbilication, the umbilical edge relatively abrupt, the umbilical wall steep, and the umbilicus deep.

The second specimen, found loose (Pl. 15, figs. 5, 6) consists of most of a whorl varying from 2 to almost 3 cm high, and a very small part of the overlapping, nearly smooth whorl, which is greater than 4 cm in height and bears the last septum. The ribs in the intermediate whorl are strong and coarsely spaced, and bifurcate regularly along a locus which shifts from about a third of the whorl height to near the umbilical edge adorally within the specimen. The points of bifurcation are slightly swollen into weak, elongated bullae. The ribs are nearly radial or very weakly sloped forward, and pass straight over the venter. The cross-section is evenly rounded, about as wide as it is high. The umbilicus is wide, nearly vertically walled, and the umbilical edge is abruptly rounded, the sharpness increasing adorally. Small fragments from the interior of the shell are moderately coarsely- and straight-ribbed, with an evenly rounded cross-section.

The ribs are weak and are absent near the last septum. The cross-section appears to be higher, with somewhat flattened flanks on the lower parts. The umbilicus is wide, and vertically walled, with an abruptly rounded edge.

Discussion. The coarse ribbing of the juvenile whorl fragment of the complete specimen resembles that of *A. arcticus* (Whitfield) although there is less regular bifurcation, and the cross-section is not at all acuminate. The greater degree of inflation and more rounded cross-section is even more pronounced in the body whorl, which is also larger in overall diameter. The adult umbilicus is much larger than in *A. arcticus*, and the lirae of the body whorl are not seen on that species. (The interpretation of *A. arcticus* is that preceding; the primary type does not show the adult stage.) In the inflated inner whorls, and coarse, nearly straight, partly trifurcating ribs, the inner whorls resemble *A. pilaeformis* Spath (1932, p. 33; Newton and Teall, 1897, Pl. XL, fig. 2, 2a) but, like *A. arcticus*, the outer whorls of that species are unknown. The inflated, nonacuminate cross-section separates this species from *A. frami* n. sp., which resembles it in size and ribbing. *A. voronezae* Meledina (1973) is similar in shape, coiling and ribbing but is a bit smaller. The coarse, bifurcating ribbing allies this species with *Arcticoceras harlandi* Rawson. *A. harlandi* is a larger species than *Arctocephalites* sp. B, judging by the ribbed and septate material available in the present collections, and the large body chamber figured by Rawson (1982), and it appears to have a slightly more compressed cross-section.

The first lateral saddle (Fig. 13) is more strongly and asymmetrically subdivided than is typical of the genus, resembling that of *Cadoceras.*