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The Cretaceous of North Greenland – a stratigraphic and biogeographical analysis

By

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With 6 text figures and 3 plates

ABSTRACT

Mapping of the Wandel Sea Basin (81–84°N) has revealed an unusually complete Late Jurassic to Cretaceous sequence in the extreme Arctic. The Cretaceous part of the sequence includes marine Ryazanian, Valanginian, Aptian, Albian, Turonian and Coniacian deposits, as well as outliers of marine Santonian in a major fault zone (the Harder Fjord Fault Zone) west of the main basin. Non-marine ?Hauterivian-Barremian and Late Cretaceous deposits are also present in addition to Late Cretaceous volcanics.

An integrated dinoflagellate-ammonite-*Buchia* stratigraphy of the Jurassic to Early Valanginian part of the sequence shows that the Early Cretaceous dinoflagellate assemblage appeared later in the Wandel Sea Basin than further south, and that a discrete "Jurassic" dinoflagellate assemblage existed for some time in the Early Cretaceous, unaffected by the general turnover at the Jurassic-Cretaceous boundary.

Ammonite occurrences show interesting palaeobiogeographical trends. Ryazanian-Valanginian ammonite faunas *(Borealites, Peregrinoceras, Neotollia, Polyptychites, Astieriptychites)* are Boreal and Sub-Boreal, related to forms primarily known from circum-arctic regions (Sverdrup Basin, Svalbard, Northern and Western Siberia), but they also have affinities to occurrences as far south as Transcaspia. The Early Albian contains a mixing of forms belonging to different faunal provinces (e. g. *Freboldiceras, Leymeriella, Arcthoplites)*, linking North Pacific, Atlantic, Boreal/Russian platform and Transcaspian faunas nicely together. Endemic Turonian-Coniacian *Scaphites* faunas represent new forms related to European species. The Valanginian and Albian ammonites are briefly described and the Early Albian correlation of North Pacific and Boreal zonations is revised.

A Late Cretaceous to Early Paleocene phase of movement has been verified by the setting of Late Cretaceous deposits in pull-apart basins of the Wandel Hav Strike-Slip Mobile Belt and by pre Late Paleocene deformation of the deposits. This has an important bearing on the early evolution of the North Atlantic and Arctic Oceans.

KURZFASSUNG

Die geologische Kartierung des Wandel Sea Basin in Nordgrönland (81°–84°) lieferte eine ungewöhnliche vollständige Abfolge des oberen Jura und der Kreide mit marinen Ablagerungen des Ryazan, Valangin, Apt, Alb, Turon und Coniac und in der Harder Fjord Störungs-Zone westlich des Hauptbeckens auch des Santon, sowie nicht-marine Serien des ?Hauterive-Barrême und einen oberkretazischen Vulkanismus.

Eine kombinierte Dinoflagellaten-Ammoniten-*Buchia*-Stratigraphie vom höheren Jura bis ins untere Valangin zeigt, daß im Wandel-See-Becken die ersten Kreide-Dinoflagellaten-Vergesellschaftungen später auftreten als weiter im Süden, und daß sich eine eigenständige ,,jurassische" Dinoflagellaten-Vergesellschaftung unbeeinflußt vom allgemeinen Umschwung an der Jura-Kreide-Grenze in die Unterkreide hinein fortsetzt.

Bei den Ammoniten zeigen sich interessante paläobiogeographische Tendenzen. Die Ryazan-Valangin Ammonitenfauna *(Borealites, Peregrinoceras, Neotollia, Polyptychites, Astieriptychites)* sind boreal und subboreal mit engen Beziehungen zu Faunen anderer zirkumpazifischer Gebiete (Sverdrup Basin, Svalbard, Nord- und Westsibirien); aber sie haben auch Ähnlichkeit mit südlichen Vorkommen wie z. B. vom Kaukasus. Das tiefere Alb enthält Mischfaunen verschiedener Faunenprovinzen (z. B. *Freboldiceras, Leymeriella, Arcthoplites)* und zeigt Verbindungen zwischen dem

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Nordpazifik, dem Nordatlantik, der borealen russischen Plattform und dem transkaspischen Bereich auf. Endemische Scaphiten-Faunen des Turon und Coniac führen neue Formen mit Beziehungen zu europäischen Arten. Die Ammoniten des Valangin und des Alb werden kurz beschrieben und die Korrelation der Zonen des unteren Alb im nordpazifischen und im borealen Bereich wird revidiert.

Es kann eine Phase spätkretazischer-frühpaläozäner Bewegungen nachgewiesen werden anhand von spätkretazischen Ablagerungen in Senkungsräumen des Wandel Hav Strike-Slip Mobile Belt und anhand einer prä-oberpaläozänen Deformation dieser Sedimente. Sie sind von großer Bedeutung für die frühe Entwicklung des Nordatlantiks und des arktischen Ozeans.

I. INTRODUCTION

The geological history of the North Atlantic region for the period leading up to the separation of the Eurasian and North America/Greenland continents naturally should be based on as much information as possible from strata on both sides of the ocean. In the extreme north, the Wandel Sea Basin in North Greenland and Svalbard constitute a pair of depositional centres, which were dissected and subsequently separated from each other by more than 500 km in connection with the complex movements along the Spitzbergen Fracture Zone and the generation of oceanic crust from the Nansen and Mohns Ridges (Fig. 1). Since actual separation along both the northern part of the Mohns Ridge and the "southern" part of the Nansen Ridge is documented by ocean crust formation at or somewhat prior to anomaly 24 time (Talwani & Eldholm 1977, Vogt et al. 1979), Cretaceous and Paleocene strata in particular are relevant in this context.

Early Cretaceous sediments are abundantly preserved in both areas, whereas Late Cretaceous strata are completely absent in the Svalbard archipelago (although recently encountered in the Troms Basin just off the Norwegian north coast [Nils Fagerland, pers. comm. 1982]). In the Wandel Sea Basin, on the other hand, recent investigations have revealed the presence of substantial on-shore Late Cretaceous deposits (Håkansson et al. 1981b), and although work is still in progress, a fairly complete biostratigraphic outline of the Cretaceous has now been established here. North Greenland, therefore, should attain a central position in attempts to establish a better understanding of the early phases in the formation of both the Atlantic and Arctic Oceans.

II. GEOLOGICAL FRAME

The eastern part of North Greenland has undergone a long and complex structural history prior to the formation of the Atlantic and Arctic Oceans (Håkansson & Pedersen in press), resulting in a high degree of patchiness in the distribution of most sediments in the Wandel Sea Basin. Cretaceous deposits in particular display an extreme separation into small, structurally determined units (Fig. 2). However, within this erratic pattern the effect of two distinctly different geological regimes is apparant.

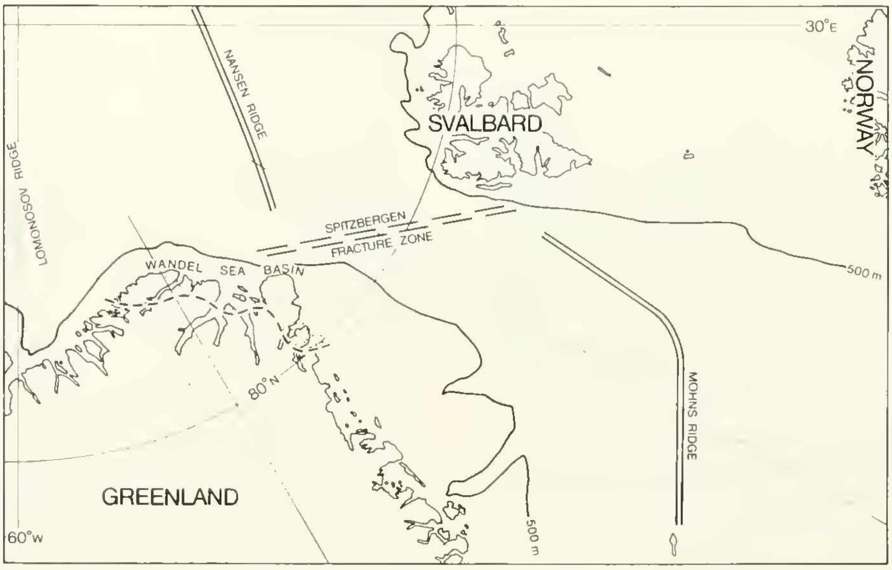

Fig. 1. Eastern North Greenland and adjacent parts of the North Atlantic and Arctic Oceans; main tectonophysic structures indicated.

Early Cretaceous deposits, in general, are characterised by high sediment maturity reflecting deposition in a comparatively quiet period subsequent to the last pulse of the Late Palaeozoic to Mesozoic episodes of transcurrent faulting (HÅKANSSON & PEDERSEN in press). In strong contrast to this picture, Late Cretaceous sediments are mainly immature, rapidly accumulated infill in pull-apart basins of the Wandel Hav Strike-Slip Mobile Belt which, furthermore, contain the only magmatic rocks known from the Wandel Sea Basin (HÅKANSSON & PEDERSEN in press).

LATE JURASSIC – EARLY CRETACEOUS DEPOSITS

Ladegårdsåen Formation (Fig. 2, locs 5 & 6). This formation is restricted to east Peary Land and has been considered in some detail by HÅKANSSON et al. (1981a), who presented an integrated ammonite-*Buchia*-dinoflagellate stratigraphy for the marine intervals. The formation records a Middle Oxfordian transgression, followed by gradually shallowing marine conditions which prevailed in Late Jurassic time and across the Jurassic Cretaceous boundary into the Early Valanginian, terminated by pre-Aptian limnic deposits. Sedimentation in the Ladegårdsåen Formation amounted to a thickness of some 250 m.

Kilen (Fig. 2, loc. 10). A parallel, apparently unrelated Late Jurassic – Early Cretaceous sequence, which has yet to be formally described, is located in part of the large semi-nunatak Kilen (HÅKANSSON et al. 1981b). The moderately folded sequence comprises some 900 m of marine sandy and silty sediments from which scattered ammonite faunas have established the presence of Kimmeridgian, Volgian, Valanginian, and Middle Albian strata. Previous reports on the presence of Bathonian strata in Kilen (Greenarctic Consortium in DAWES 1976; DAWES & PEEL 1981) were based on erroneous determination of these Middle Albian ammonites (see p. 13). The Kimmeridgian – Valanginian part of the sequence constitutes a mainly transgressive phase in which sediments accumulated in a muddy, sheltered, coastal environment, whereas subsequent sediments are dominated by shelf mud with increasing amounts of storm sand layers (HÅKANSSON et al. 1981b).

Kap Rigsdagen (Fig. 2, loc. 7). Here, at a considerable distance from all other sediments of the Wandel Sea Basin, 85 m of coarse sandstones gradually giving way to mudstones have been preserved. The sediments apparently rest directly on Ordovician sediments. Very thin coal seams and root horizons together with the very low diversity assemblages of dinoflagellate cysts suggest a prevailing near-coastal and lagoonal, mainly restricted marine environment with associated protective bar systems (HÅKANSSON et al. 1981b). The dinoflagellate floras indicate an Aptian age for most of the sequence (PIASECKI in HÅKANSSON et al. 1981b); no macrofossils are known.

East Peary Land (Fig. 2, loc. 5). From a very restricted, fault-bound locality next to the Ladegårdsåen Formation, ROLLE (1981) recorded about 100 m of black mudstones with thin sandstones and shell conglomerates at the top of the sequence. Dinoflagellates from the mudstones in general indicate Aptian ages (PIASECKI in ROLLE 1981), whereas ammonites from the top conglomerates are of early Albian ages. HÅKANSSON et al. (1981b) considered the sequence a deeper water, open marine equivalent to the Aptian nearshore sediments at Kap Rigsdagen (Fig. 2, loc. 7).

LATE CRETACEOUS DEPOSITS

Kilen (Fig. 2, loc. 9). At least 550 m of fairly strongly folded organogenic shale and fine-grained sandstones with minor redeposited biogenic conglomerate sheets are located in the northern, downfaulted part of the semi-nunatak Kilen (HÅKANSSON et al. 1981b). Marine faunas dominated by scaphitids and inoceramids are frequent through most of the sequence, whereas dinoflagellates have been severely altered due to significant thermal activity (HÅKANSSON et al. in prep.).

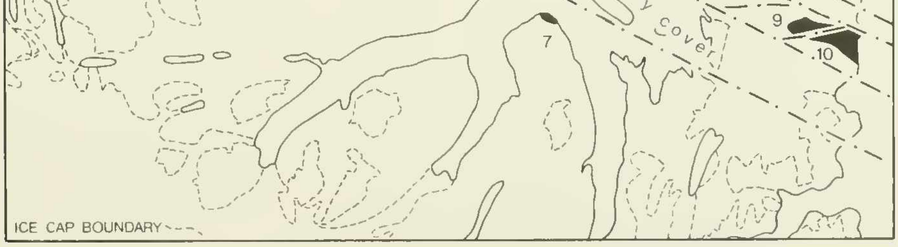

Fig. 2. Distribution of Cretaceous deposits in relation to the structural elements of the Wandel Hav Strike-Slip Mobile Belt in North Greenland. (NB: the distribution of outcrops shown by SOPER et al. (1982, fig. 2) is incorrect.)

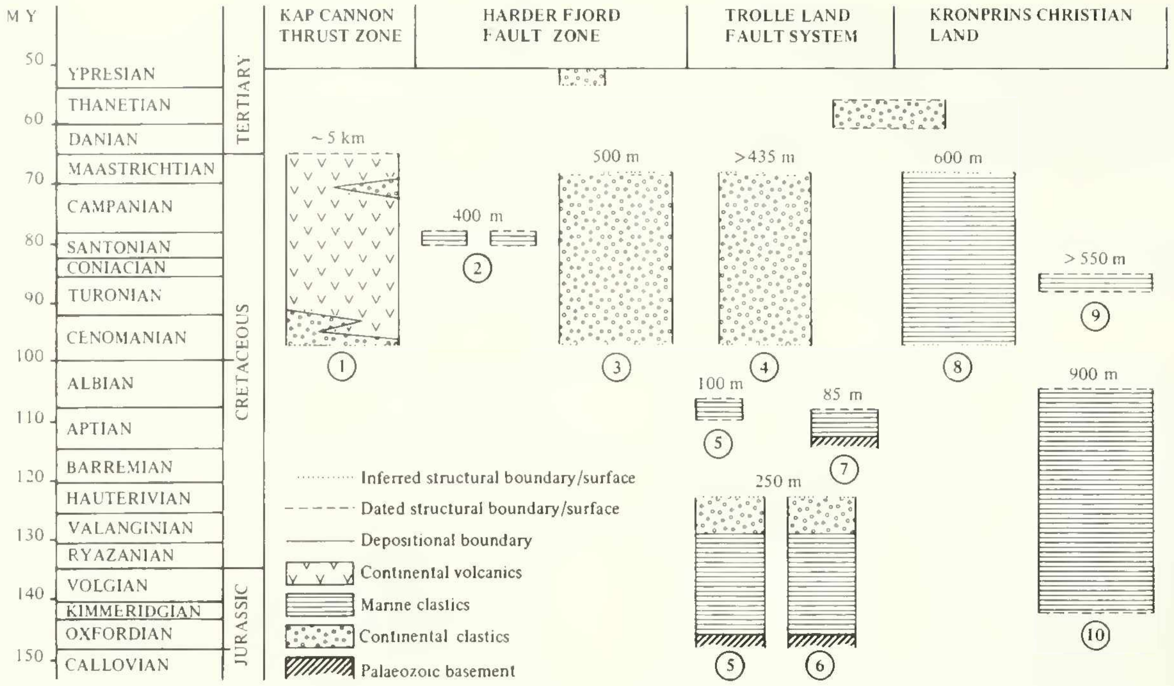

Fig. 3. Lithostratigraphy of Late Jurassic – Early Tertiary Strata in North Greenland. Encircled numbers refer to location in Fig. 2. Partly based on information from HÅKANSSON & PEDERSEN (in press), HÅKANSSON et al. (1981 b) and BATTEN et al. (1981).

The depositional environment probably was a shallowing shelf, and the inoceramid fauna indicates the presence of Middle Turonian to very Early Coniacian strata (KAUFFMAN in HÅKANSSON et al. 1981b). Among stratigraphically important species should be mentioned *Inoceramus cuvieri, I. lamarcki* and *Platyceramus mantelli.*

Nakkehoved Formation (Fig. 2, loc. 8). A gently disturbed sequence comprising at least 600 m of rapidly accumulated, monotonous, fine-grained greywackes is exposed in the complex of nunataks and semi-nunataks in northern Kronprins Christian Land (HÅKANSSON et al. 1981b). A marine bivalve fauna including posidoniid and trigoniid forms generally indicates a Late Cretaceous age of the sequence, but more precise age determinations are lacking so far. Low grade thermal metamorphism has caused pervasive recrystallisation as well as complete degradation of organic walled microfossils (HÅKANSSON et al. in prep.).

Herlufsholm Strand Formation (Fig. 2, locs 3 & 4). Variously folded and thrusted, mainly fluvial sequences referred to the Herlufsholm Strand Formation occur in two separate areas (HÅKANSSON 1979; HÅKANSSON et al. 1981b). At Herlufsholm Strand (Fig. 2, loc. 4) at least 435 m and at Depotbugt (Fig. 2, loc. 3) more than 500 m of sediments dominated by conglomerates, greywackes, and coaly shales with poorly preserved plant remains have been preserved. Only little direct evidence is at hand to document a Late Cretaceous age of the Herlufsholm Strand Formation. Palynomorphs have consistently been degraded beyond recognition, and only the presence of angiosperm wood gives an indication of the Late Cretaceous – Early Tertiary age suggested by TROELSEN (1950) for the sequence at Herlufsholm Strand. However, an additional, isolated occurrence of organogenic shales very close to the Herlufsholm Strand Formation at Depotbugt contains a very restricted, possibly Early Tertiary palynomorph assemblage (CROXTON et al. 1980). Since the thermal alteration of these shales is far less severe than recorded in the shales of the neighbouring Herlufsholm Strand Formation (PIASECKI in HÅKANSSON et al. 1981b), a Late Cretaceous age of this formation is substantiated. As discussed by HÅKANSSON & PEDERSEN (in press), the tectonic disturbance of both Herlufsholm Strand Formation sequences is consistent with the regional pattern of Late Cretaceous deformation in the Wandel Hav Strike-Slip Mobile Belt.

North-east of Frigg Fjord (Fig. 2, loc. 2). Centrally in the long-lived Harder Fjord Fault Zone, marine Late Cretaceous sediments have been preserved in more or less vertical positions in a few small fault-bound wedges (HÅKANSSON et al. 1981b). The sediments are fine-grained and dominated by greywackes and feldspar rich sandstones, and they contain a sparse fauna of protobranch and inoceramid bivalves. A sequence more than 400 m thick apparantly constitutes the most extensive interval preserved within a single wedge, and from this sequence the Late Santonian *Sphenoceramus pinniformis* has been identified (KAUFFMAN in HÅKANSSON et al. 1981b).

Kap Washington Group (Fig. 2, loc. 1). More than 5 km of extrusive volcanics and subordinate continental clastics makes up the Kap Washington Group, which is known only from a number of thrust sheets in the Kap Cannon Thrust Zone on the north coast of Peary Land (BROWN & PARSONS 1981; BATTEN et al. 1981). The volcanic suite is peralkaline and include air-fall tuffs and breccias, as well as basaltic, trachytic and rhyolitic lavas (BROWN & PARSONS 1981; SOPER et al. 1982); little is known about the clastic constituents of the group. In addition to the Kap Washington Group volcanicity, northwest Peary Land is also the centre of an intense swarm of Cretaceous basaltic dykes (DAWES & SOPER 1979; HIGGINS et al. 1981).

BATTEN et al. (1981) and SOPER et al. (1982) adopted an age of the Kap Washington Group volcanicity at or just before the Cretaceous-Tertiary boundary, and SOPER et al. (1982) refer the dyke swarm to a separate episode, entirely preceding the Kap Washington Group. However, as pointed out by HÅKANSSON & PEDERSEN (in press) these age indications are not fully substantiated. Thus, the basal, partly intervolcanic sediments of the Kap Washington Group contain an angiosperm flora of Cenomanian or later Cretaceous age (BATTEN et al. 1981); palynomorphs approximately 3 km higher in the sequence indicate a Campanian – Maastrichtian age (BATTEN et al. 1981; BATTEN in press); and, finally, whole rock Rb/Sr age determination of extrusives from the top of the group yields ages of 63–64 m. y. (LARSEN et al. 1978; LARSEN in press). The available evidence, therefore, suggests a general Late Cretaceous age for the Kap Washington Group with a termination of the volcanicity approximately at the Cretaceous-Tertiary boundary. Furthermore, HÅKANSSON & PEDERSEN (in press) argue against a clear distinction between the dyke-swarm and the extrusives of the Kap Washington Group and consider them intimately related and at least partly synchronous.

III. AMMONITE STRATIGRAPHY

Up to now, the age determinations of the Cretaceous deposits of North Greenland have been based on ammonites, dinoflagellates, *Buchia* and *Inoceramus* species, as well as pollen and leaves. In addition, Cretaceous radiometric ages have been obtained from a number of dykes and extrusive volcanics. For the Jurassic to earliest Cretaceous part of the sequence an integrated ammonite-*Buchia*-dinoflagellate stratigraphy has already been worked out (HÅKANSSON et al. 1981a), and studies of dinoflagellates and inoceramids from later parts of the sequence by S. PIASECKI and E. KAUFFMAN,

STAGES/SUBSTAGES	AMMONITE ZONATION	NORTH GREENLAND
MIDDLE ALBIAN	*E. lautus*	▨
	E. loricatus	
	H dentatus	
LOWER ALBIAN	*D. mammillatum*	
	L. regularis	
	L. tardefurcata	▨
	L. schrammeni	
LOWER VALANGINIAN	*P. michalskii*	▨
	T. syzranicus	
	N. klimovskiensis	▨
RYAZANIAN	*B. mesezhnikowi*	▨
	S. analogus	
	H. kochi	▨
	C. sibiricus	
UPPER VOLGIAN	*C. chetae*	
	C. taimyrensis	
	C. okensis	▨

Fig. 4. Upper Volgian – Lower Cretaceous ammonite zones in North Greenland.

respectively, are in progress. The hitherto undescribed Early Cretaceous ammonites have now been studied in detail and are presented here in the Appendix (p. 16).

A short account of the ammonite stratigraphy of the Cretaceous in North Greenland is given below (fig. 4).

RYAZANIAN

Hectoroceras kochi Zone: The ammonite *Borealites* sp. aff. *fedorovi* KLIMOVA, 1969, and the *Buchia* species *B. fischeriana*, *B. unschensis*, *B. terebratuloides*, *B. okensis* and *B. volgensis* characterize this zone (see HÅKANSSON et al. 1981a). The genus *Borealites* appears in the *Chetaites sibiricus* Zone of northern Siberia and becomes more diversified in the lower part of the *H. kochi* Zone according to CASEY (1973). The specimens from North Greenland are closest to forms from northern and western Siberia from the *H. kochi* Zone. Among the *Buchia* species, *B. okensis* and *B. volgensis* are thought to appear at the base of the *H. kochi* Zone and only two of them, *B. okensis* and *B. volgensis*, occur above the *H. kochi* Zone to the top of the Ryazanian according to ZAKHAROV in HÅKANSSON et al. (1981a).

Bojarkia mesezhnikowi Zone: Only *Peregrinoceras* sp. aff. *albidum* CASEY, 1973, is known from this level (HÅKANSSON et al. 1981a). The genus *Peregrinoceras* appears late in the Ryazanian and is not known from the Valanginian. *P. albidum* characterizes a zone at the top of the Ryazanian in eastern England (CASEY, 1973) and *P.* aff. *albidum* CASEY, 1973, has also been found in the top Ryazanian of Kashpur (CASEY, MESEZHNIKOV & SHULGINA, 1977).

LOWER VALANGINIAN

Neotollia klimovskiensis Zone: A few fragments of *Neotollia* sp. and a *Buchia* specimen, possibly *B. keyserlingi*, are known from this level (HÅKANSSON et al. 1981a).

Polyptychites michalskii Zone: The presence of this zone in the sequence of Kilen is verified by the find of a small, poorly preserved fauna of *Polyptychites michalskii* (BOGOSLOVSKY), *P. middendorffi* PAVLOV, *P. (Astieriptychites)* sp. and indeterminate fragments of „*Euryptychites*" (pl. 1).

LOWER ALBIAN

The early Lower Albian is here divided in three Zones: *L. schrammeni* Zone, *L. tardefurcata* Zone and *L. regularis* Zone in accordance with German usage.

Leymeriella tardefurcata Zone: In eastern Peary Land *Leymeriella trollei* n. sp. and *Freboldiceras praesingulare* n. sp. occur together a few metres below concretions containing *Arcthoplites jachromensis* (NIKITIN) and *Anadesmoceras* sp. The evolutionary stage of the *Leymeriella* species, being a progressive form of the *L. schrammeni* stock, seems to indicate that the assemblage belongs to the very base of the *L. tardefurcata* Zone or – possibly – the topmost part of the *L. schrammeni* Zone. *Freboldiceras praesingulare* n. sp. is very close to *Freboldiceras singulare* IMLAY from southern Alaska. On the basis of morphology it is supposed to belong to a slightly earlier evolutionary stage than *F. singulare* (see p. 17).

The early Lower Albian age of *F. praesingulare* n. sp. is well documented on the basis of its occurrence together with *Leymeriella trollei* n. sp. The Alaskan occurrences of *Freboldiceras singulare* IMLAY, on the other hand, belong to the so-called *Brewericeras hulenense* Zone of the North Pacific Province. Besides *F. singulare* and *Brewericeras hulenense* (ANDERSON), this zone also contains (according to JONES & GRANTZ 1967) e. g. *Arcthoplites talkeetnanus* (IMLAY), *Anagaudryceras sacya* (FORBES), *Grantziceras affine* (WHITEAVES), *G. glabrum* (WHITEAVES), *Parasilesites bullatus* IMLAY and *Puzosia alaskana* IMLAY. It overlies the *Moffites robustus* Zone of early Albian age and is referred to late Early Albian by JONES & GRANTZ (1967). The close relations between *Freboldiceras singulare* and *F. praesingulare* n. sp., together with the occurrence of early forms of *Arcthoplites* in the *Brewericeras hulenense* Zone (see below), suggest an earlier Lower Albian age of the *B. hulenense* Zone than is generally supposed.

A rich assemblage of *Arcthoplites jachromensis* (NIKITIN) and a single fragment of *Anadesmoceras* sp. occurs a few metres above the *Leymeriella – Freboldiceras* assemblage.

The exact age of *Arcthoplites jachromensis* is not known, either in the type area on the Russian platform, or in other occurrences in Svalbard and Arctic Canada. NAGY (1970) indicates a find of *Brewericeras* cf. *hulenense* (ANDERSON) together with *A. jachromensis* in Svalbard, but the affinity of that *Brewericeras* specimen is very uncertain. The Svalbard *Arcthoplites* faunas as a whole *(A. birkenmajeri* NAGY and *A. jachromensis)* can be dated to levels between the middle part of the *L. tardefurcata* Zone s. l. and the upper part of the *Douvilleiceras mammillatum* Zone according to NAGY (1970). Species intermediate between *Freboldiceras* and *Arcthoplites (Freboldiceras remotum* NAGY, *Arcthoplites birkenmajeri* NAGY) occur together with *Leymeriella germanica*. In Arctic Canada JELETZKY & STELCK (1981) tentatively correlated *Arcthoplites* bearing beds (e. g. containing *A. jachromensis)* with the upper part of the *L. tardefurcata* Zone s. l. and the *D. mammillatum* Zone of the Western European standard zonation.

The rich *Arcthoplites* fauna from Mangyschlak, described by SAVELIEV (1973), belongs to the *L. tardefurcata* Zone and does not penetrate into the *L. regularis* Zone. The Mangyschlak fauna seems to be fairly closely related to *Arcthoplites jachromensis*.

Considering all these data, combined with stages of evolution of the *Freboldiceras – Arcthoplites* stock of the faunas in question, it is concluded that the *A. jachromensis* fauna still belongs to the *L. tardefurcata* Zone and that characteristic *Freboldiceras/Arcthoplites* faunas from Alaska, Svalbard, North Greenland and Mangyschlak can be arranged tentatively in the following stratigraphic order:

The genus *Anadesmoceras* appears in the *L. tardefurcata* Zone in Germany and is also known from the *L. tardefurcata* Zone in Mangyschlak (SAVELIEV, 1973). In England it appears in the equivalent *Farnhania farnhanensis* Subzone. Its single occurrence together with *Arcthoplites jachromensis* in North Greenland is thus in good accordance with the scheme above.

L. regularis Zone	no *Arcthoplites*	
L. tardefurcata Zone	*Arcthoplites* spp. (e. g. *A. subjachromensis* Saveliev)	Mangyschlak
	Arcthoplites jachromensis	N. Greenland/ Spitsbergen
	Freboldiceras remotum/ *Arcthoplites birkenmajeri*	Svalbard
	Freboldiceras singulare/ *Arcthoplites talkeetnanus* of the *B. hulenese* Zone	Alaska
L. schrammeni Zone	*Freboldiceras praesingulare*	N. Greenland

MIDDLE ALBIAN

Euhoplites lautus Zone: Two fragments, figured in Pl. 3, one a gastroplitid, the other an *Anahoplites* comparable to *A. daviesi ornata* Spath, 1924 are of particular interest because the presence of Middle Jurassic (Bathonian) strata in Kilen was postulated on the basis of these fragments (Greenarctic Consortium in Dawes, 1976; Dawes & Peel, 1981). Until now these fragments have been the only indication of the Middle Albian in North Greenland.

MIDDLE TURONIAN – EARLY CONIACIAN

In Kilen the lower 300 m of the Late Cretaceous sequence in particular has yielded a number of faunas containing rich assemblages of inoceramids and scaphites. On the basis of the inoceramids, E. Kauffman has dated the deposits to Middle Turonian – Early Coniacian. The scaphites belong to an endemic stock related to the *Scaphites geinitzi* group, and *Otoscaphites* spp. may also be present. These faunas will be described in detail elsewhere.

IV. PALAEOBIOGEOGRAPHY

RYAZANIAN

The Ryazanian in North Greenland is dominated by Boreal and Sub-Boreal ammonites and *Buchia* species. The stage is further characterised by long-ranging species of dinoflagellates which are also present in Jurassic deposits below and belong to an extreme northern flora (Håkansson et al. 1981a).

The early Ryazanian ammonite genus *Borealites* is known primarily from northern regions (the Sverdrup Basin, Svalbard, Northern and Western Siberia), but has also been found in England. The late Ryazanian genus *Peregrinoceras*, on the other hand, has up to now only been recorded from the Mangyschlak Peninsula (Transcaspia), the Volga Region, and eastern England (Casey, 1973), and the occurrence in North Greenland is the first find of this genus in northern regions.

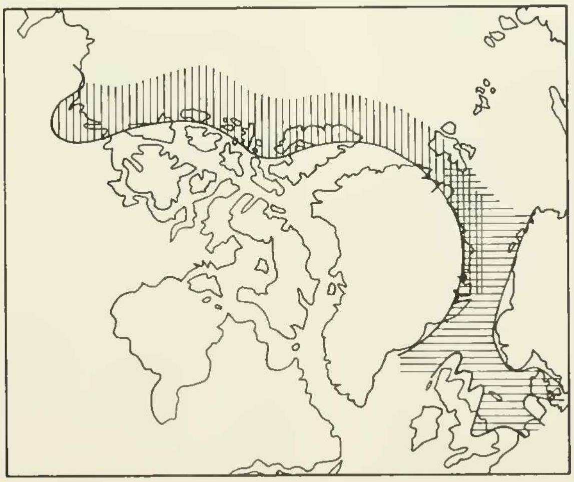

Fig. 5. Distribution of the "borealis" and North Atlantic dinoflagellate assemblages in Late Jurassic – earliest Cretaceous time.

All the Ryazanian *Buchia* species have a wide distribution in the Boreal realm from Arctic Canada to Svalbard and northern USSR. In addition, some are fairly common in the Sub-Boreal province (e. g. *B. volgensis)* and a few of them are even known from Alaska, British Columbia and California or have close allies in these areas (e. g. *B. fischeriana* and *B. okensis).*

The restricted distribution of the dinoflagellate assemblage of the Ryazanian constrasts with the macrofauna. The assemblage belongs to an "extreme arctic" flora of long-ranging species which appeared in the late Oxfordian and continued into the Early Valanginian. This "borealis assemblage" was recognized by BRIDEAUX & FISHER (1976) from Arctic Canada, extending from the McKenzie River delta to Ellef Ringness Island in the Sverdrup Basin. The assemblage further extends to East Greenland, where it is mixed with the widely distributed North Atlantic flora (PIASECKI, 1980) (Fig. 5).

VALANGINIAN

The biogeographic pattern in the *Neotollia klimovskiensis* Zone of the Early Valanginian is more or less unchanged from the Ryazanian. Poorly preserved *Neotollia* and *?Buchia keyserlingi* both belong to the Boreal and Sub-Boreal province, while the dinoflagellates belong to the restricted extreme northern "borealis assemblage".

A few metres above the *Neotollia* level the dinoflagellate assemblage changes drastically: The "borealis assemblage" was replaced completely by typical Early Cretaceous forms known from the entire North Atlantic region, including NW Europe. As this flora is known from earlier deposits both in NW Europe and the Atlantic, the appearance in North Greenland must be explained by a delayed migration to the north caused for instance by suddenly improved physical connections or by a rise in temperature (HÅKANSSON et al. 1981a). A similar invasion of southern forms apparently took place also in the Arctic Canada in the Valanginian (MCINTYRE & BRIDEAUX 1980).

Ammonites from the *Polyptychites michalskii* Zone in Kilen are completely identical with forms known from the Sverdrup Basin (pers. comm. E. KEMPER, 1982) and from northern USSR (see e. g. PAVLOV, 1914; BOGOSLOVSKY, 1902; BODYLEVSKY, 1960). This fauna has a restricted, high northern Boreal distribution as distinct from *"Polyptychites tschekanowski* Beds" of KEMPER & JELETZKY (1979), which in the Sverdrup Basin contains forms closely related to the NW German province (KEMPER, 1977; KEMPER & JELETZKY, 1979).

It is not possible to tell if the dinoflagellate invasion from the south, mentioned above, is earlier or later than the *P. michalskii* fauna, as no dinoflagellates are preserved in this part of the Wandel Sea Basin (cf. HÅKANSSON et al. in prep.).

LOWER ALBIAN

The ammonite faunas of that time from North Greenland represent a mixture of forms belonging to different provinces and showing a fairly surprising, characteristic pattern of migration routes. The composition of Lower Albian faunas from Svalbard (described by NAGY, 1970) and from East Greenland (summarized by DONOVAN, 1957) are similar in a number of respects.

Leymeriella: The early representatives are only known from Svalbard, North Greenland and NW Germany, but later representatives are widely distributed in NW Europe and connected with occurrences in Transcaspia (see SAVELIEV, 1973) and Iran (see SEYED-EMANI, 1980) via a mid-European sea-way marked by occurrences of leymeriellids in Austria, Bulgaria, Rumania, southern Russia and Kaukasus, (OWEN, 1973, 1979; SEYED-EMANI, 1980). This distribution is nearly identical with the hoplitinid province of the Middle Albian.

Freboldiceras is known from the American Northern Pacific Province of Alaska, Arctic Canada, North Greenland and Svalbard. Other characteristic forms, first described from the Pacific province: *Grantziceras, Brewericeras* and *Grycia*, are known as far as Arctic Canada, Svalbard and East Greenland *(Brewericeras),* but have not been found in North Greenland.

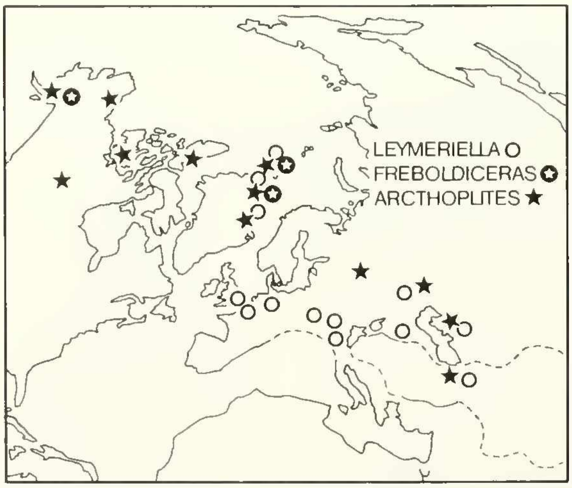

Fig. 6. Distribution of the Early Albian genera *Leymeriella, Freboldiceras* and *Arcthoplites.*

Arcthoplites is known from the American Northern Pacific Province of Alaska (early forms), Arctic Canada, North and East Greenland and Svalbard, and further from the Russian Platform, Mangyschlak (Transcaspia) and Iran (see e. g. NAGY, 1970; SAVELIEV, 1973; SEYED-EMANI, 1980). The non-occurrence of *Arcthoplites* in western Europe, and the non-occurrence of *Leymeriella* in central Russia, taken together with the occurrence of both genera in two regions far apart: the high northern Atlantic region and Mangyschlak – Iran, indicates two different routes of distribution of these two genera: An Atlantic – European sea-way for *Leymeriella* and a Russian-Arctic sea-way for *Arcthoplites* (omitted in OWEN's palaeobiogeographic maps from 1973 and 1979) (Fig. 6).

It is difficult to explain this pattern satisfactorily, but it may be mentioned that the distribution of *Arcthoplites* shows some similarity to the distributional pattern of Upper Volgian *Craspedites*. The home of *Craspedites* is the Russian Platform, but whereas the genus is apparently also widely distributed in northern Boreal regions (northern Siberia, Svalbard, North Greenland, Sverdrup Basin), it is never found in western Europe. The genus *Leymeriella*'s close connection with the Mid-European – Atlantic sea-way, and the lack of this genus in circum-Arctic regions indicate that it does not belong to the Boreal stock, but is better regarded as a primarily European form which migrated far to the north as did the hoplitinids of the Middle Albian.

On the basis of the distribution of glendonite, KEMPER & SCHMITZ (1981) and KEMPER (1982, herein) proposed the existence of Lower Valanginian and Aptian-Albian glaciations. The strong circum-arctic provincialism still present in Early Valanginian time could be considered as support for this hypothesis, but this can hardly be justified, as a similar provincialism is also seen in large parts of the Middle and Upper Jurassic. Furthermore, also the wide distribution of the Early Albian ammonites occurring in North Greenland is hardly compatible with KEMPER's hypothesis.

MIDDLE ALBIAN

The occurrence of a gastroplitid ammonite and *Anahoplites* cf. *daviesi ornata* SPATH in North Greenland is complementary to occurrences of earlier Middle Albian and basal Upper Albian in East Greenland (DONOVAN 1957) and Svalbard (NAGY 1970), belonging to the northern part of the Middle Albian hoplitinid province, described by OWEN (1979).

LATE CRETACEOUS

The fairly sporadic macrofauna from the series of local pull-apart basins developed across North Greenland through the Late Cretaceous is characterised by the occurrence of widespread Boreal inoceramids through the Turonian – Santonian interval. On the other hand, a comparison of the Middle Turonian – Early Coniacian scaphites with faunas of similar age from North America and Europe seems to show that most of the North Greenland scaphites belong to an endemic stock related, most likely, to the European *Scaphites geinitzi* group. Considering the general provincialism characterising the Late Cretaceous scaphites this result is not in any way surprising. Rare, poorly preserved scaphites from East Greenland referred to *Scaphites* sp. cf. *geinitzi* D'ORBIGNY and *S.* aff. *morrowi* JELETZKY by DONOVAN (1953) may be related to the North Greenland stock.

V. CONCLUDING REMARKS ON OCEAN DEVELOPMENT

Late Cretaceous geology in North Greenland was controlled by the series of events in the Wandel Hav Strike-Slip Mobile Belt, in which activity ceased just after the Cretaceous – Tertiary boundary. The detailed relations between these events have yet to be determined, but it would appear from the present data that 1) formation of all pull-apart basins characterising the mobile belt was initiated som time subsequent to the Albian; 2) the oldest strata so far determined from any of the basins are of Middle Turonian age, while the youngest strata correspond to the Cretaceous – Tertiary boundary; and 3) compressional deformation in all basins was apparently terminated prior to renewed deposition in the Late Paleocene (HÅKANSSON & PEDERSEN in press). In addition, the rather poorly dated dyke-swarm associated with the Kap Washington Group volcanics (K/Ar ages of 130–66 m. y. according to DAWES & SOPER 1979) may be regarded in part as precursor of the mounting transtensional forces that subsequently gave rise to the Wandel Hav Strike-Slip Mobile Belt.

Perhaps the most intriguing new result concerning the early history of the North Atlantic and Arctic Oceans is the apparent lack of evidence of post-Cretaceous compressional forces in North Greenland (HÅKANSSON & PEDERSEN in press). In both Svalbard and the Sverdrup Basin, significant Eocene and Oligocene – Miocene deformation took place – the Eurekan Orogeny in the Sverdrup Basin and the West Spitsbergen Orogeny in Svalbard (see e. g. CHRISTIE 1979) – and in spite of the general lack of observation, such phases have often been more or less customarily attributed to North Greenland as well. However, as pointed out above, the recent field work has failed to provide the anticipated evidence here.

The trend in the major faults of the Wandel Hav Strike-Slip Mobile Belt in eastern Peary Land and northern Kronprins Christian Land (Fig. 2) largely parallels the complex Spitsbergen Fracture Zone separating the Mohns and Nansen Ridges (HÅKANSSON 1979). However, the age of the Spitsbergen Fracture Zone has yet to be settled, and associated oceanic crust formation did not commence until around the time of anomaly 24 (VOGT et al. 1979), i. e. distinctly after the ceasing of activity of the on-shore part of the Wandel Hav Strike-Slip Mobile Belt. As long as the broad shelf off eastern North Greenland is still virtually unexplored, a direct relationship between these two major structural elements therefore must remain speculative (HÅKANSSON & PEDERSEN in press).

One possibility is that the activity of the Wandel Hav Strike-Slip Mobile Belt affected both the on-shore part of the Wandel Sea Basin that has now been investigated, as well as the Greenland and southern Barents shelves (with the possible continuation in the Troms Basin area). Subsequently, the megascopic shear system causing the Wandel Hav Strike-Slip Mobile Belt was released in the Spitsbergen Fracture Zone in which the majority of the actual dislocations has taken place during the Cenozoic.

The existence of mirror images on the Greenland plate of the Tertiary wrench faulting in the West Spitsbergen Orogeny, implied by for instance LOWELL (1972), STEEL et al. (1981) and SOPER et al. (1982) has not been directly substantiated by recent investigations. However, their existence on the broad Greenland shelf bordering the Spitsbergen Fracture Zone is quite likely. As pointed out by KELLOGG (1976), transpressional deformation, reflecting the opposing movement of Greenland and Svalbard, continued until late Oligocene on the eastern side of the fracture zone. In the outer part of the shelf off northeastern Greenland, it may therefore with some reason be expected that structures of the Wandel Hav Strike-Slip Mobile Belt will be found having an overprint of the West Spitsbergen Orogony.

Recently, SOPER et al. (1982) developed a detailed model for the formation of the Eurasian Basin in the Arctic Ocean assuming a direct connection between the Kap Washington Group volcanicity and the initial opening of the Eurasian Basin. As we do not fully accept these authors' interpretation of the stratigraphic position of the Kap Washington group and find their assumption that Paleocene strata are folded to be insupportable (cf. also HÅKANSSON & PEDERSEN in press), we would question their suggested order of events. Consequently, since no convincing evidence has yet been presented, we would advise the consideration of other, presumably older, relationships for the North Greenland volcanicity.

VI. APPENDIX

VALANGINIAN AND ALBIAN AMMONITE FAUNAS

Lower Valanginian polyptychites
(pl. 1, figs 16–19)

Material: Fragments of "*Euryptychites*" (GGU216119) have been found in situ together with two loose specimens of *Polyptychites michalskii* (BOGOSLOVSKY) and one specimen of *Polyptychites middendorffi* PAVLOV (GGU216118). Two metres above this level two loose fragments of *Polyptychites (Astieriptychites)* sp. have been found (GGU216117). Moreover, a few indeterminate fragments are available.

Locality: Kilen, Kronprins Christians Land (Fig. 2, loc. 10).

Remarks: The two *Polyptychites michalskii* specimens, one of which is shown in pl. 1, figs 19a–b, are fragments of microconchs and in good agreement with the type series figured by BOGOSLOVSKY (1902, pl. 15) except for a less inflated shape. The phragmocone of *P. middendorffi* PAVLOV, figured in pl. 1, figs 16a–b, shows especially close similarity with the phragmocone figured by PAVLOV, 1914, pl. 6, fig. 2. The two poor fragments of *P. (Astieriptychites)* BODYLEVSKY, 1960, figured in pl. 1, figs 17–18 show a ribbing pattern similar to the type of *P. (A.) astieriptychus* BODYLEVSKY, 1960 (pl. 39, fig. 1).

Leymeriella trollei n. sp.
(pl. 1, figs 1–5)

Holotype: MGUH15972, figured in pl. 1, fig. 1a–b belonging to the sample GGU270052A.

Type locality: East Peary Land (Fig. 2, loc. 5)

Material: Ca. 10 specimens, partly fragmentary, all from same locality and horizon. GGU270052A.

Description: All the specimens are somewhat crushed, but otherwise the preservation is good, including the nacreous shell. The holotype seems to be mature, having the complete, 200° long bodychamber preserved (pl. 1, fig. 1a–b). The diameter of this specimen is 42 mm and the diameter of the phragmocone ca 30 mm. The diameter of the phragmocone of other specimens varies from 16 to 25 mm. They may be juvenile as no signs of crowding of the last sutures have been recognized. The cross section of the whorls is compressed and slightly flattened ventrally, but cannot be described in detail because of crushing. The umbilical ratio is 26–29%. Ribbing can be recognized from a diameter of 4 mm. The ribs are prorsiradiate and strongly projected ventrally. They are usually single and extend to the umbilical edge or they bifurcate close to the umbilical edge in rare cases. They are sharp on the flanks, but grow broader and flatter ventrally. They usually form a ventral chevron of an acute shape proximally and a rounded shape distally. In certain cases, especially in early and middle growth stages, the ribs may be nearly completely flattened out ventrally, so that the venter tends to become smooth. The ribbing on the venter is more strongly developed on the internal mould than on the surface of the shell, as the nacreous layer tends to smooth out the sculpture. The presence of weak constrictions, best developed on mature bodychambers, gives the ribbing a slightly irregular appearance. The suture lines are not very incised. The external saddle is broad and bifid and the first lateral lobe has a rather symmetrical trifid shape.

Discussion: The specimens show fairly close affinity to early *Leymeriella* forms *(Proleymeriella* BREISTROFFER, 1947), but also show characters which connect them with the next evolutionary stage of the *Leymeriella* group.

The early stages of the *Leymeriella* stock are only known from Northern Germany, first and foremost described in the classical work by BRINKMANN (1937) and later by KEMPER (1975) and KEMPER & ZIMMERLE (1978). BRINKMANN showed that the earliest representative, *L. schrammeni*, evolved from the desmoceratid *Callizoniceras* and he described two diverging lineages evolving from that species: the *L. tardefurcata* lineage and the *L. acuticostata – L. regularis* lineage. BREISTROFFER (1947) established a subgenus, *Proleymeriella*, for *L. schrammeni* and other early representatives, later treated as a separate genus by CASEY (1957). Later investigations seem to show that every gradation between the two lineages occurs, both in early and later stages of evolution (KEMPER, 1975; CASEY, 1957).

On the basis of the presence of constrictions, rare occurrences of bifurcating ribs, chevrons on the venter and absence of tardefurcate splitting of the ribs on the flanks, the specimens here described are believed to belong to early representatives of the *Leymeriella* stock, related to, but not identical with *L. ("Proleymeriella") schrammeni*. The weakness of the constrictions, rare occurrence of bifurcating ribs and slightly flattened venter in early growth stages indicate that the specimens are well on the way to the next evolutionary step, e. g. as represented in part by *L. acuticostata* BRINKMANN. It should further be stressed that the umbilical ratio of the specimens here described is slightly smaller than that of *L. (P.) schrammeni* (type 31%), but considerably smaller than in *L. acuticostata* (neotype 37%). The assemblage is thus best regarded as a new species. A fragment of a *Proleymeriella* sp., described by NAGY (1970) from Svalbard, differs from the collection described here by common occurrence of ribs bifurcating on the inner third of the flanks.

Anadesmoceras sp.
(pl. 3, fig. 2)

Material: One fragment in *Arcthoplites* concretion GGU270052B.

Locality: East Peary Land (Fig. 2, loc. 5).

Description: The only specimen consists of an incomplete bodychamber and parts of the phragmocone. The diameter at last suture is 112 mm. The shell is rather scaphitoid and the whorls compressed, having the maximum width at the umbilical edge, from where the flat flanks converge towards the narrowly arched venter. The surface is smooth except for very obscure ribs on the flanks and faint constrictions.

Discussion: The fragment shows some similarity to the later *Cleoniceras discor* SAVELIEV, 1973 (p. 113, pl. 8, fig. 1; pl. 17, figs 3, 4) from Mangyschlak both in size and cross-section, but this latter species is more involute and more ornamented than the Greenland specimen.

Freboldiceras praesingulare n. sp.
(pl. 1, figs 6–15)

?1967 *Freboldiceras singulare* IMLAY; NAGY, p. 48, pl. 6, fig. 3; text-fig. 11c.

Holotype: MGUH15982, figured in pl. 1, figs 11a–b. belonging to the sample GGU270052A.

Type locality: East Peary Land (Fig. 2, loc. 5).

Material: Ca. 20 specimens, partly fragmentary, all from same locality and horizon. GGU270052A.

Description: All the specimens are somewhat crushed. The largest specimen, with most of the bodychamber preserved, is 73 mm in diameter, while the diameter of the phragmocone is 52 mm. The diameter of the phragmocones varies from 22 to 52 mm and bodychambers seem to attain a length of about half a whorl. No crowding of the last suture lines has been seen and it is therefore assumed that the assemblage represents different growth stages, although sexual dimorphism may not be completely excluded. The best preserved specimens show a compressed shape with slightly rounded flanks and with the maximum thickness close to the umbilical edge, an evenly rounded venter, a shallow umbilicus and a high expansion rate. The umbilical ratio is about 21–27%, but must be considered slightly higher in uncrushed specimens.

The mother-of-pearl of the shell is preserved, revealing fine preservation of shell sculpture. The ornamentation consists of striae, ribs and rare constrictions. The striae are fine and flexuous, bending slightly forward ventrally. The ribs are usually single and most strongly developed at the umbilical shoulder and on the outer part of the flanks. However, the ribs are highly variable in strength, shape, distance and distribution on the shell. On the inner whorls very faint ribs may be discernible at the umbilical edge and on the inner flanks from a diameter of 6 mm, but some specimens stay nearly smooth to a diameter of about 20 mm. As mentioned above, the ribs are usually single, but in rare cases they bifurcate on the outer part of the flanks. In some specimens the ribs are strongly swollen at the umbilical shoulder. The ribbing is prominent to a diameter of about 40 mm. Fragments of larger bodychambers are smooth except for the fine striation. Rare constrictions may be seen both on early whorls and on otherwise smooth bodychambers.

The suture lines are simple with a broad, shallowly incised slightly asymmetrical first lateral lobe and a small highly asymmetrical second lateral lobe.

Discussion: Some of the specimens are rather similar to *Freboldiceras singulare* IMLAY, 1959, from Alaska, as described by IMLAY (1959, p. 182, pl. 30, figs 1–7), IMLAY (1960, p. 102, pl. 14, figs 8–17) and JONES in JONES & GRANTZ (1967, p. 37, pl. 7, figs 1–25). Furthermore, suture lines are very close. However, taking the full spectrum of variation into account, the specimens from Greenland usually differ from the species from Alaska by lacking short secondary ribs, the very rare occurrence of bifurcating ribs, and the apparently more compressed shape. According to JONES (1967) *F. singulare* from Alaska includes further transitional forms between *F. singulare* and *Arcthoplites talkeetnanus*, not met with in the material here described. JONES (1967) considered that the genera *Freboldiceras* IMLAY and *Arcthoplites* SPATH, together with *Grantziceras* IMLAY, were derived from a common ancestor. The three genera seem to occur together in Alaska.

The *Freboldiceras* described here (dated to the early part of the *L. tardefurcata* Zone on the basis of occurrence together with *Leymeriella trollei* n. sp.) is believed to be slightly earlier than the Alaskan *F. singulare* (dating discussed p. 14), and the genus *Freboldiceras* may thus have evolved slightly earlier from a desmoceratid ancestor than *Arcthoplites* and may possibly have given rise to that genus.

A few poorly preserved specimens from Svalbard referred to *Freboldiceras singulare* by NAGY (1970), may belong to the species described here, as they also are indicated as lacking secondary ribs.

Arcthoplites jachromensis (NIKITIN, 1888)
(Pl. 2, figs 1–10; pl. 3, fig. 1)

1888 *Hoplites jachromensis* NIKITIN, p. 57, pl. 4, figs 1–5, 7.
1925 *Arcthoplites jachromensis* (NIKITIN); SPATH, p. 76.
?1953 *Arcthoplites* sp. cf. *jachromensis* (NIKITIN); DONOVAN, p. 117, pl. 25, figs 3, 4, text-fig. 12.
?1964 *Arcthoplites* aff. *jachromensis* (NIKITIN); JELETZKY, p. 78, figs 1A-D.
1970 *Arcthoplites jachromensis* (NIKITIN); NAGY, p. 51, pl. 8, fig. 1.

Material: A profusion of specimens in a few large concretions. GGU270052B.

Locality: East Peary Land (fig. 2, loc. 5).

Description: The presence of a large number of specimens in the same concretion provides a good opportunity of observing the variability of what must have been a contemporaneous assemblage. Most specimens are slightly crushed, but are otherwise extremely well preserved, including the nacreous shell. The diameter of the largest specimen is 135 mm, the diameter at the last suture of this specimen is 115 mm and the length of the incomplete body chamber 270°. Except for that specimen, which seems to be mature, the material contains growth-stages of all sizes, the smallest one measuring 15 mm in diameter at the last suture. The umbilical ratio shows a wide variation – from 21 to 34 %.

The whorl section is evenly rounded to a diameter of 15 mm, and from that stage becomes subquadrangular until an even rounded form returns in mature bodychambers. The umbilical slope is gently inclined and the maximum width is close to the umbilical edge. The ratio between whorl width and whorl height varies from 1.0 to 0.8.

Ribbing begins at a diameter of about 10 mm. The early ribs are rather weak and flexuous but become gradually more straight, although they continue to develop a slight forward bend ventrally. They vary somewhat in strength and sharpness, but otherwise show a very persistent pattern with marked, distant primaries bifurcating high on the flanks or with single ribs intercalated. The ribs are well developed ventrally and they persist to the peristome.

The suture line shows a wide, only shallowly incised first lateral saddle, a fairly complex, slightly asymmetrical first lateral lobe, which is somewhat deeper than the ventral lobe, a second lateral saddle with deep phylloid incisions and a strongly asymmetrical second lateral lobe.

Discussion: Some of the species here discussed closely match the type of *A. jachromensis* figured by NIKITIN in pl. 4, figs 1–2. SAVELIEV (1973) has referred (with some doubt) other specimens figured by NIKITIN to new species which he established on the basis of collections from the *L. tardefurcata* Zone of Mangyschlak (*A. nikitini* SAVELIEV [NIKITIN, pl. 4, figs 3, 4, 6]; *A. meridionalis* SAVELIEV [NIKITIN, pl. 4, fig 7]). These specimens tend to be slightly coarser-ribbed than specimens from Greenland and are all from other localities than the type. Close knowledge of the stratigraphy is necessary to justify this splitting. The *Arcthoplites* fauna from Mangyschlak described by SAVELIEV seems primarily to differ from *A. jachromensis* in a smoother ribbing pattern.

All other *Arcthoplites* from Alaska, Canada and Svalbard (e. g. *A. belli* (MCLEARN), *A. talkeetnanus* (IMLAY), *A. birkenmajeri* NAGY) tend to show relations to *Freboldiceras* in ribbing pattern, e. g. by weakening of the ribbing on venter and bodychamber. Some uncertainty still remains over the delimitation of the two genera.

Middle Albian hoplitids
(pl. 3, figs 3–4)

Material: Two fragments collected by Greenarctic Consortium and placed at our disposal by Dr. BRIAN JONES, Department of Geology, University of Alberta.

Locality: Eastern part of Kilen, Kronprins Christian Land. Exact locality unknown.

Description: One of the specimens (pl. 3, fig. 4) consists of a crushed fragment of *Anahoplites,* the sculpture of which shows some similarity to *A. daviesi ornata* SPATH (1924, pl. 14, figs 5c–d). The other fragment may be a gastroplitid. It consists of only an outer mould of the flank and umbilicus, shown as a cast in pl. 3, fig. 3.

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Plate 1

All figures natural size, arrows mark last suture. Specimens marked MGUH kept in Geological Museum of the University of Copenhagen and specimens marked UA kept in Geological Department of the University of Alberta, Edmonton.

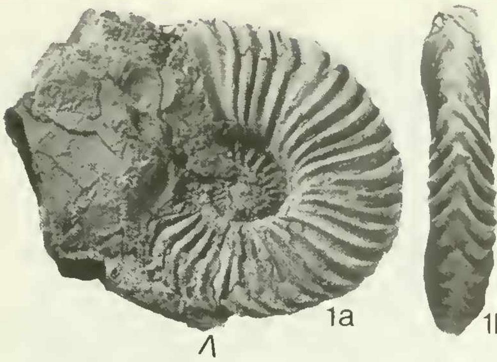
Figs 1–5. *Leymeriella trollei* n. sp. All from Sample GGU270052A.
  Fig. 1. Holotype, MGUH15972. Complete adult.
  Fig. 2. MGUH15973. Bodychamber incomplete.
  Fig. 3. MGUH15974. Presumably juvenile.
  Fig. 4. MGUH15975. Presumably juvenile, bodychamber incomplete.
  Fig. 5. MGUH15976. Presumably juvenile, bodychamber incomplete.

Figs 6–15. *Freboldiceras praesingulare* n. sp. All from sample GGU270052A.
  Fig. 6. MGUH15977. Juvenile? specimen, bodychamber incomplete.
  Fig. 7. MGUH15978. Juvenile? specimen, bodychamber incomplete.
  Fig. 8. MGUH15979. Juvenile? specimen, bodychamber nearly complete.
  Fig. 9. MGUH15980. Juvenile? specimen, bodychamber apparently complete.
  Fig. 10. MGUH15981. Juvenile? specimen, bodychamber nearly complete.
  Fig. 11. Holotype. MGUH15982. Juvenile? specimen, bodychamber nearly complete.
  Fig. 12. MGUH15983. Fragment of adult? bodychamber.
  Fig. 13. MGUH15984. Fragment of adult? bodychamber.
  Fig. 14. MGUH15985. Fragment of adult? bodychamber.
  Fig. 15. MGUH15986. Juvenile? specimen, bodychamber nearly complete.

Fig. 16. *Polyptychites middendorffi* Pavlov, 1914. Sample GGU216118. MGUH15987. Incomplete phragmocone.

Figs 17–18. *Asticriptychites* sp. Sample GGU216117.
  Fig. 17. MGUH15988. Fragment of bodychamber. Cast of external mould.
  Fig. 18. MGUH15989. Fragment of bodychamber. Cast of external mould.

Fig. 19. *Polyptychites michalskii* Bogoslovsky, 1902 [m].
  Sample GGU216118. MGUH15990.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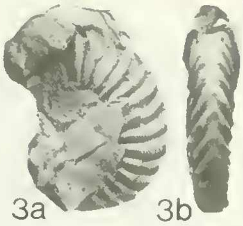
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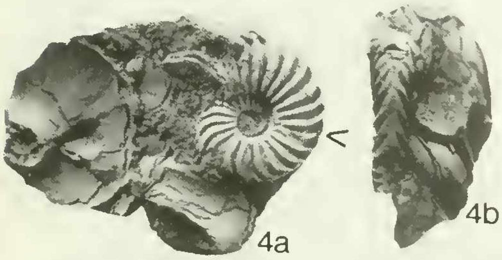
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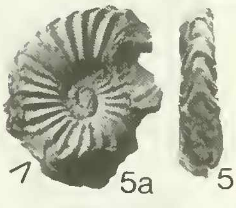
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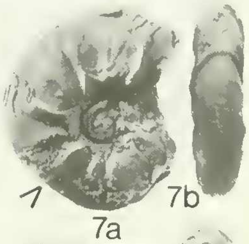
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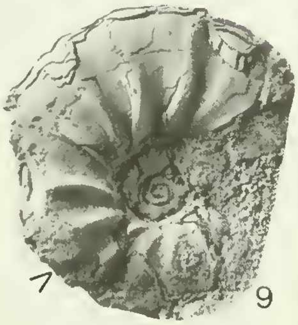
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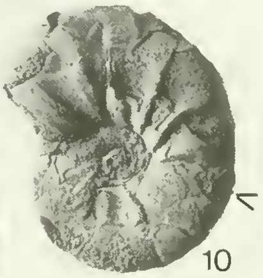
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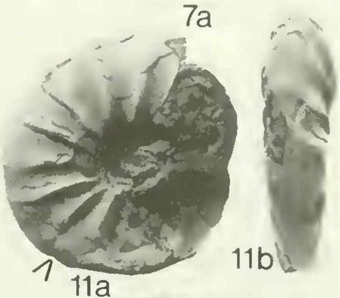
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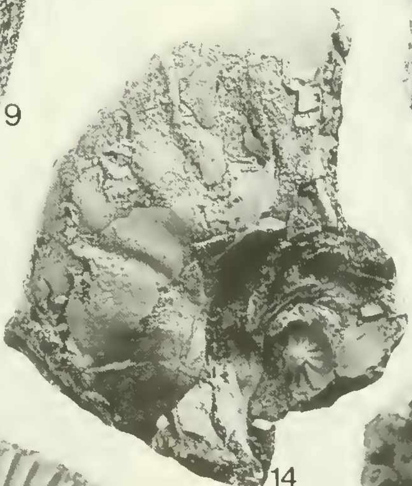
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19a


16a


16b


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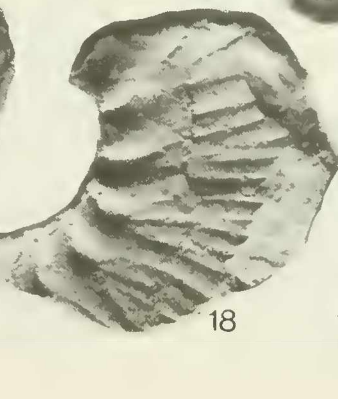
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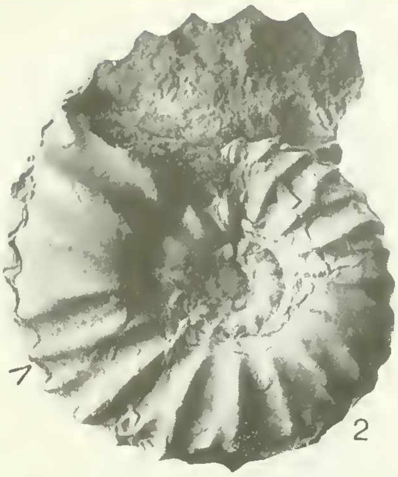
19b

Plate 2

Figs 1–10. *Arcthoplites jachromensis* (NIKITIN, 1888).
All from the same concretion, sample GGU270052B.
Fig. 1. MGUH15991. Juvenile specimen with incomplete bodychamber.
Fig. 2. MGUH15992. Juvenile specimen with incomplete bodychamber.
Fig. 3. MGUH15993. Juvenile specimen with incomplete bodychamber.
Fig. 4. MGUH15994. Juvenile specimen with incomplete bodychamber.
Fig. 5. MGUH15995. Incomplete phragmocone.
Fig. 6. MGUH15996. Incomplete phragmocone.
Fig. 7. MGUH15997. Incomplete phragmocone.
Fig. 8. MGUH15998. Juvenile specimen with incomplete bodychamber.
Fig. 9. MGUH15999. Juvenile specimen with incomplete bodychamber.
Fig. 10. MGUH16000. Incomplete phragmocone.


1a


1b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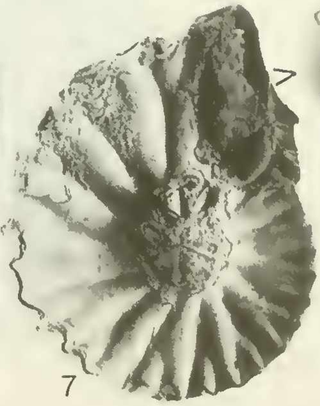
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8a


8b


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9b


10a


10b

Plate 3

Fig. 1. *Arcthoplites jachromensis* (NIKITIN, 1888).
Sample GGU270052B. MGUH16001. Nearly complete adult.

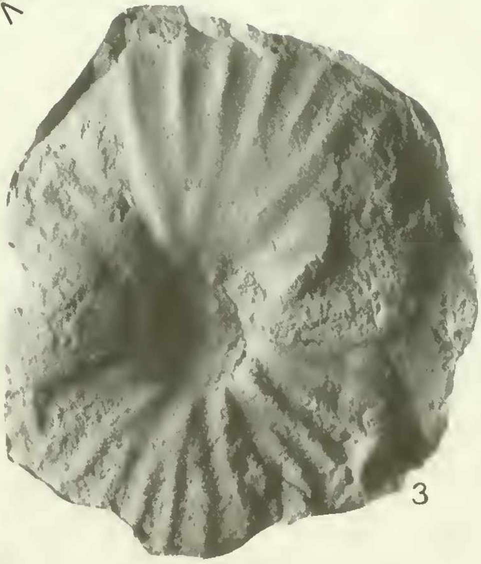
Fig. 2. *Anadesmoceras* sp. Sample GGU270052B. MGUH16002.
Incomplete bodychamber.

Fig. 3. Gastroplitid. Cast of external mould. UA7027.

Fig. 4. *Anahoplites* cf. *A. daviesi ornata* SPATH, 1924.
Fragment of phragmocone. UA7028.

1

2a



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