

MARINE UPPER CRETACEOUS AND LOWERMOST TERTIARY DEPOSITS IN WEST GREENLAND

Investigations before and since 1938

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Systematic investigations of the marine beds in the Cretaceous-Tertiary sedimentary basin of West Greenland began in 1938 when the first of a long series of expeditions to this area took place. The presence of several stages not known before 1938, viz. Cenomanian?, Upper Turonian, Coniacian, Lower Santonian, Maastriichtian and Danian, has been demonstrated by the character of the marine faunas. The ages of Heer's classic fossil floras have been fixed more exactly with the exception of the Kome flora and the interbasaltic Ivssorigsoq flora which, however, on phytopalaeontological evidence are probably respectively of Barrèman-Aptian and not younger than Eocene age.

The marine fauna from the beds throughout the succession is summarised, and the palaeogeographic implications are discussed. A few fossils of particular interest have been figured and provided with a preliminary diagnosis, viz. a remarkable cirriped from the Santonian-Campanian and some important Danian echinoids and molluscs.

The period before 1938

The Cretaceous-Tertiary basin of West Greenland, which is situated between 69° and 72°N, comprises a sedimentary sequence more than 2 km thick, overlain by a several km thick basalt pile which overlaps the sediments so as to lie directly on the Precambrian to the north and east (Svartenhuk and Nûgssuaq), and on Precambrian inliers to the west (Disko). For many years the sediments have attracted the attention of geologists all over the world on account of the plant remains found in the limnic part of the sequence. These floras have been described by Heer in his famous "Flora Fossilis Arctica" in 7 volumes (1868-1883) and later by Seward (1926), Conway (1935) and B. E. Koch (1963). The occurrence of marine strata within the thick sedimentary sequence was known long before 1938, when the author first visited the area, but the knowledge of these strata was at that time rather incomplete and the stratigraphic importance of the known strata had been partly misinterpreted.

In spite of the fact that this part of Greenland had been visited by a large number of expeditions with geological objectives, these expeditions

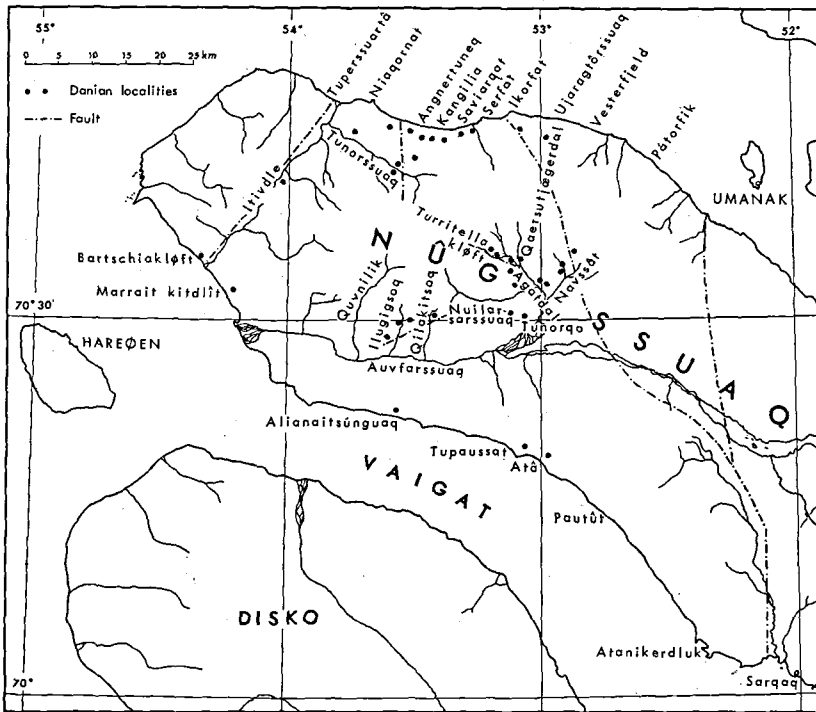


Fig. 1. Map showing part of the Nûgssuaq peninsula with the Danian localities indicated. (R. L.)

followed the coast and never penetrated into the interior of the islands and peninsulas where many of the most interesting marine strata have been discovered since 1938 when the Nûgssuaq expeditions were initiated.

From the long period before 1938 the following contributions to the knowledge of the marine Cretaceous and Tertiary may be mentioned. Some marine fossils were collected in the later part of the 19th century by G. F. Pfaff, C. F. V. Henriksen and the Greenlanders from Niaqornat (Nûgssuaq). More important collections were made by K. J. V. Steenstrup in the years 1872 and 1878-80. Later collections were brought back by D. White and C. Schuchert in 1897 and by J. P. J. Ravn and A. Heim in 1909.

The marine fossils from West Greenland collected before 1938 originate exclusively from the Nûgssuaq peninsula. The fossils were partly derived from red burnt, originally black, bituminous shales brought home from Atâ and Pautût, both localities situated on the south coast of the peninsula, and partly from concretions belonging to the black shales and, according to the collections, but not mentioned in literature, of two categories viz. concretions enclosing scaphites and crustaceans, and concretions containing predominantly pelecypods and gastropods. Most of the scaphites concre-

tions were collected as pebbles in the river deltas at Niaqornat; a few were found by Ravn in situ at 220 m above sea level at the same locality. One scaphites concretion was collected in a delta at Angnertuneq, also on the north coast of Nûgssuaq. The second category of concretions, that with the pelecypod-gastropod fauna, was found mostly as loose pebbles at Ikorfat, Saviarqat, Angnertuneq and Niaqornat on the north coast, and at Alianaitunguaq on the south coast. None of these concretions contain ammonites and the same is the case with the red shales from Atâ which have several fossils in common with the concretions of the second category.

Before 1938 several palaeontologists had been occupied with the marine fossils from West Greenland. The older collections, chiefly the collections brought together by K. J. V. Steenstrup, were examined in 1873 by C. Schlüter in Bonn. In 1874 Schlüter published his results which can be supplemented with some remarks from a letter in the archives of Mineralogical Museum in Copenhagen. The presence of inoceramids close to *Inoceramus lingua*, *cardissoides* and *cancellatus* from Pautût, and a *Hemiaster* of a type known from the Upper Cretaceous led Schlüter to the conclusion that the marine strata in West Greenland must be of late Cretaceous age. P. de Loriol (1883) associates himself with the conclusion of Schlüter. The Pautût fauna, which de Loriol found to contain at least two new species of *Inoceramus* together with such forms as *Solenomya subplicata* Meek & Hayden, *Avicula (Oxyptera) nebrascana* Evans & Schumard and *Hemiaster humphreysianus* Meek & Hayden, all known from the Fox Hills Group in North America, was considered by de Loriol to be of the same age. The fauna from the concretions from the north coast includes *Dentalium gracile* Hall & Meek, *Entalis paupercula* Meek & Hayden, *Vanikoro ambigua* Meek & Hayden, all well known from the Fort Pierre Group of North America, together with a *Scaphites* close to the species from the Fox Hills Group. From the burnt red shales at Atâ de Loriol mentions *Nuculana bisulcata* Meek & Hayden, known from the Fort Pierre Group. According to de Loriol several new species and other not determinable forms occur together with the fossils mentioned in the marine strata but de Loriol regarded all faunas from Nûgssuaq as belonging to the Upper Senonian (Fort Pierre Group: concretions from Niaqornat and red shales from Atâ; Fox Hills Group: red shales from Pautût).

The collection of scaphites from Niaqornat, which was considerably increased in 1885 by C. F. V. Henriksen, was closely examined by V. Madsen in 1897. He referred the main species to the European Upper Senonian *Scaphites rômeri* d'Orb. In the same year D. White and C. Schuchert collected marine fossils from several localities on Nûgssuaq, viz. Saviarqat, Angnertuneq, Niaqornat, Atâ and Pautût. The fossils were handed over to T. W. Stanton who in the paper by White & Schuchert (1898) remarked concerning the fossils from the north coast that, in spite of not being able to confirm actual specific identities which de Loriol recognised, he was of opinion that the collection included a number of characteristic Upper Cretaceous types which allowed the beds to be referred without question to the Montana Formation (Fort Pierre and Fox Hills) of the Western United States. Among others Stanton mentions two species of *Scaphites*, *Actæon*

aff. *attenuatus* Meek & Hayden, *Anchura* aff. *americana* (Evans & Schumard) and *Lunatia* aff. *concinna* Hall & Meek. The collection from Atâ comprises only few species of which some are known from the "true" Cretaceous on the north coast, and Stanton concluded therefore that this fauna at Atâ is probably also of Late Cretaceous age. From the red shales of Pautût Stanton reported a *Hemiaster indet.*, a new *Avicula*, a *Pinna?* and a *Dentalium*. The *Avicula* belongs to a type common in the later Cretaceous. Peculiarly enough no inocerams are mentioned; maybe the *Pinna?* belongs here. Like de Loriol, Stanton was inclined to consider the marine faunas from Nûgssuaq as belonging to the Upper Cretaceous but leaves the possibility open that the faunas from the south coast may be younger.

In 1918 J. P. J. Ravn arrived at the same conclusion as Schlüter, de Loriol and Stanton concerning the age of the marine strata in West Greenland, that is, that they are Upper Cretaceous (Senonian). This result was based upon the old material kept in the Mineralogical Museum in Copenhagen together with new collections made in 1909 by Ravn and to a lesser extent by A. Heim (Ikorfat). The collections, comprising together 54 different forms, 23 in a bad state of preservation, were described by Ravn (1918) and many species were for the first time figured. The material from 1909 originated mostly from localities known by earlier collectors. At Angnertuneq and Alianaitunguaq no collecting was carried out.

31 species were referred to 15 known and 16 new species (4 of the new species were already named by de Loriol, 1883, but not figured by him).

From Pautût Ravn mentions the following species:

Hemiaster humphreysianus Meek & Hayden (Fort Pierre Group)
Avicula nebrascana Evans & Schumard (Montana Formation)
Inoceramus steenstrupi de Loriol (European Senonian)
Inoceramus patootensis de Loriol (European Senonian)
Lucina occidentalis (Morton) (Montana Formation)
Solenomya subplicata Meek & Hayden (Fox Hill Group)
Pecten (Syncyclonema) sp.

From Niaqornat:

<i>Pecten pfaffi</i> Ravn	(concretions with
* <i>Dentalium gracile</i> Meek & Hayden	pelecypods and
<i>Dentalium groenlandicum</i> Ravn	gastropods, no am-
<i>Aporrhais sp. ?</i>	monites.)
<i>Actaeon sp.</i>	
<hr/>	
* <i>Scaphites nicolletii</i> (Morton)	(concretions with
* <i>Scaphites sp.</i>	only scaphites and
	crustaceans.)

From Angnertuneq:

<i>Pecten (Amussium) ignoratus</i> Ravn	(concretions with
<i>Modiolaria? glabra</i> Ravn	pelecypods and
<i>Pectunculus sp.</i>	gastropods, no am-
* <i>Corbula inornata</i> Meek & Hayden	monites.)
* <i>Dentalium gracile</i> Meek & Hayden	
* <i>Dentalium (Entalis?) pauperculum</i> Meek & Hayden	

- Margarita? steenstrupi* Ravn
 * *Natica (Lunatia) concinna* Hall & Meek
Aporrhais sp. 2
 * *Actaeon cretacea* Gabb
Bulla groenlandica Ravn
Cylichna rugosa Ravn
-
- * *Scaphites nicolletii* (Morton) (no other fossils in this concretion)
- From Ikorfat:
- Limopsis rinki* Ravn
 * *Lucina occidentalis* (Morton) (no ammonites)
Aporrhais sp. 3
- From Alianaitunguaq:
- Pecten pfaffi* Ravn
Pecten (Amussium) ignoratus Ravn
Arca sp. (no ammonites)
Lucina sp. (= *Thyasira (Conchocele)* sp.)
 * *Dentalium gracile* Hall & Meek
 * *Dentalium (Entalis?) pauperculum* Meek & Hayden
Cadulus groenlandicus Ravn
Atlanta primigenia Ravn (= *Cornuspira primigenia* (Ravn))
- From Atâ (burnt shales):
- Pecten ataënsis* de Loriol emend. Ravn
Pecten striatissimus Ravn
Pecten pfaffi Ravn
Pecten (Amussium) ignoratus Ravn
 * *Nucula planimarginata* Meek & Hayden?
 * *Leda bisulcata* Meek & Hayden
Axinus de Lorioli Ravn
 * *Lucina occidentalis* (Morton) (no ammonites)
Lucina pfaffi Ravn
Tellina? steenstrupi (de Loriol)
 * *Solenomya subplicata* Meek & Hayden
 * *Neaera moreauensis* Meek & Hayden
Dentalium groenlandicum Ravn
 * *Dentalium (Entalis?) pauperculum* Meek & Hayden
 * *Natica (Lunatia) concinna* Hall & Meek
Aporrhais sp. 1
- From Kingigtoq (burnt shales):
- * *Nucula cancellata* Meek & Hayden?
 * *Lucina occidentalis* (Morton)

All but two of the species mentioned from Pautût are only found at that locality. The exceptions are *Lucina occidentalis* (Morton) and *Solemya subplicata* Meek & Hayden. However the state of preservation of these fossils is rather bad so that a reliable determination must be considered out of the question. Moreover, it seems as if the *Solemyas* from Pautût and Atâ belong to different species. The presence of inocerams at Pautût shows nevertheless that the fauna here must be at least in part Senonian.

The faunas from the other localities show many similarities. Ravn thought that their age must be Upper Senonian, first and foremost because at Niaqornat and Angnertuneq *Scaphites nicolletii* (Morton) had been found together with concretions containing several species known from the Upper Senonian of North America (marked with an *). Only indirectly Ravn pointed out that, apart from remnants of crustaceans, none of the other fossils listed from these and the other localities had been collected from concretions with scaphites.

On reading Ravn's descriptions of the American species (marked with an * in the list above) one thing attracts one's attention. These fossils are either in a rather bad state of preservation or are more or less fragmentary. Therefore even Ravn considered many of his identifications somewhat dubious. The only remaining species the determination of which was not directly doubted by Ravn is *Natica concinna*, but this determination also must be regarded as doubtful on the basis of Ravn's own description. As pointed out by Stanton (in White & Schuchert, 1898, p. 357) there exist some affinities between the Greenland collections and North American Upper Cretaceous faunas, but actual specific identities had not been proved.

According to Ravn (1918, p. 330) the occurrence of American Upper Cretaceous species in the Greenland faunas (which may be true at least in case of the Pautût fauna) shows that a sea connection between West Greenland and the central part of Canada and the United States (the Montana Formation) possibly existed in late Cretaceous time, particularly as no affinities with American Coastal Plain Cretaceous fauna or the Cretaceous fauna of East Greenland seem to exist.

In 1918 Upper Cretaceous deposits were not known from East Greenland (author's comment).

Without having presented any new facts but relying on Ravn's results Teichert (1939, p. 155) came to a similar conclusion and stated it in a more detailed way: "As the marine fauna of the Senonian sediments in West Greenland shows no relations to the Cretaceous fauna of the Coastal Plain of North America, and fails to indicate any connection with the Upper Cretaceous of eastern Greenland, the transgression can not have taken place from the south, via Davis Strait. Instead, the character of the fauna suggests a connection with the Cretaceous sea of Montana; the connection must have been around the northern margin of the Canadian Shield". In an accompanying map Teichert shows the transgression of the Upper Cretaceous sea to West Greenland from the north-west.

In 1934 Frebold described a Lower Senonian fauna from East Greenland and also made some remarks on the Senonian faunas from West Greenland (p. 25). Like de Loriol he considered the Pautût fauna with *Inoceramus patootensis* and *I. steenstrupi* older than the Niaqornat fauna with *Scaphites nicolletii*, and that they belonged respectively to the "Granulatensenon" and the "Mukronatensenon" Europas. The Niaqornat fauna covered in his opinion the Montana Group of North America.

In 1938 the Danish Nûgssuaq Expeditions were started having as one of their many objectives the study of the marine strata on Nûgssuaq and in other parts of the basalt region in West Greenland. By means of the

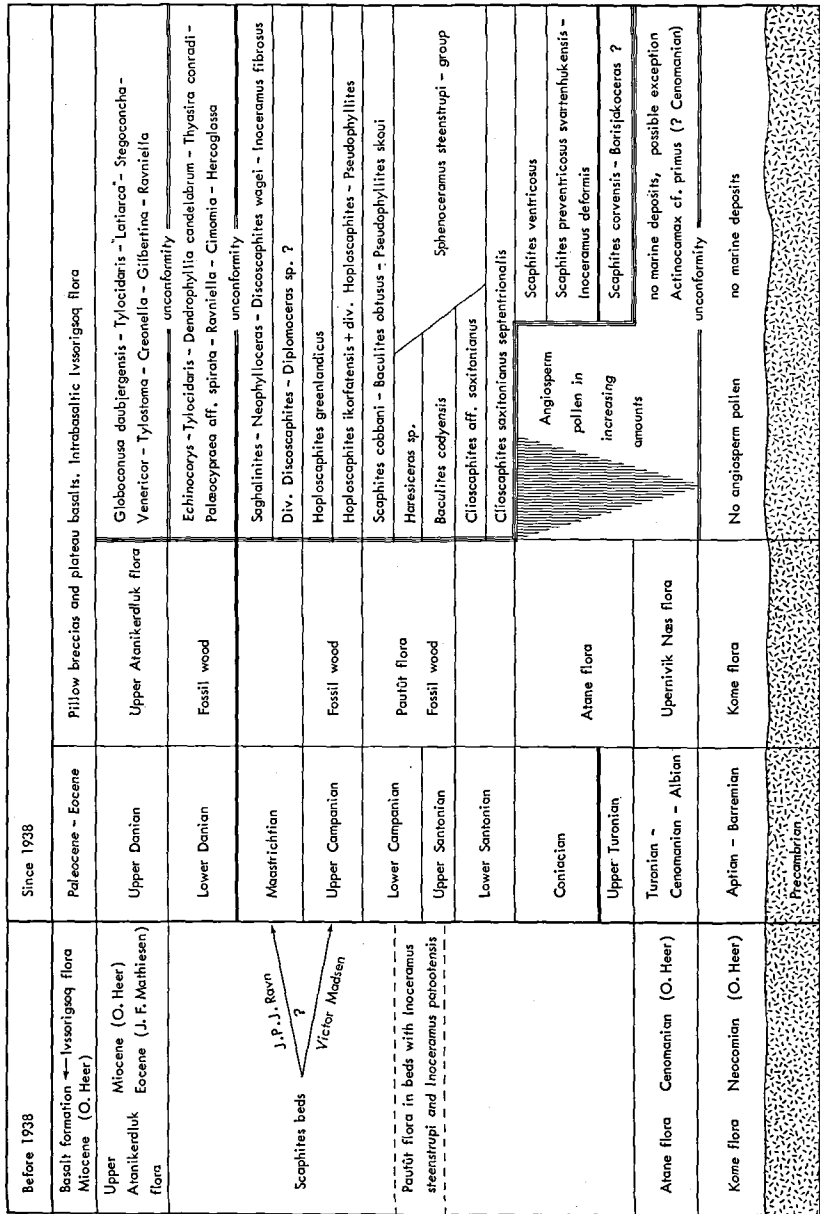


Fig. 2. Diagram showing the state of our present knowledge concerning the Cretaceous-Tertiary of West Greenland compared with that in 1938. (R. L.)

stratigraphical results we hoped to be able to fix a more exact age to the limnic beds and their famous floras. As stated above it was known before 1938 from the presence of marine fossils in the same beds that the so-called Pautût flora must be of late Cretaceous age, according to Frebald around the boundary between late Santonian and early Campanian. The ages of the older floras were regarded by Heer as Neocomian for the Kome flora and Cenomanian for the Atane flora. White & Schuchert thought that the Atane flora as well as the Pautût flora had to be placed in the Senonian and the Kome flora in the Gault (Albian). Younger than the Pautût beds are the *Scaphites* beds, as maintained by de Loriol and Frebald. If Victor Madsen was right in referring the scaphites to *Sc. roemeri* the beds would belong to the Upper Campanian; if the determination given by Ravn (*Scaphites nicolletii*) was correct the age would be Maastrichtian. According to de Loriol, Stanton and Ravn, the pelecypod-gastropod concretions collected on the north coast of Nûgssuaq and at Alianaitsunguaq as well as the red, burnt shales from Atâ also belong to the Upper Senonian. Still younger than these marine beds are limnic deposits containing the Upper Atanikerdluk flora and the interbasaltic Ivssorigsoq flora both belonging in Heer's opinion to the Miocene, while F. J. Mathiesen (see L. Koch, 1929 p. 56) considered these floras to be of early Eocene age.

In the left part of the diagram fig. 2 an attempt has been made to show the conception of the West Greenland sedimentary sequence just before 1938.

The period since 1938

In 1938 and 1939 the two Nûgssuaq Expeditions led by the author and supported by the Carlsberg Foundation and Den Kongelige Grønlandske Handel (Royal Greenland Trade Department) visited the sedimentary basin and basalt area of West Greenland. After the Second World War this work was continued under the auspices of the newly established Geological Survey of Greenland (GGU), and by 1968 16 expeditions to the area had to a greater or lesser degree been involved in the study of the marine strata; 14 led by myself and 2 by my collaborators S. Floris and K. Raunsgaard Pedersen. During these 18 summers many geologists and Greenlanders have contributed to the collecting of marine fossils from Nûgssuaq and Svartenhuk. Here I will confine myself to mention some of my collaborators within the marine field:

The late Kristian Skou, who took part in no less than 10 expeditions, the late Gregers Olsen, Th. Sorgenfrei, Johs. Troelsen, Sole Munck, A. Noe-Nygaard, Knud Eriksen, Helge Gry, Bruno Thomsen, Dan Laursen, Viggo Münther, Hilmar Ødum, B. Eske Koch, Inger M. Rasmussen, Sonja A. Hansen, A. Küllerich, V. Poulsen, Søren Floris, A. Dinesen, Chr. Poulsen, Tove Birkelund, H. Wienberg Rasmussen, K. Raunsgaard Pedersen, Gunnar Larsen, H. Bjerring, Ragna Hansen, J. Bugge, K. Schou Jørgensen, Ulla Asgaard, Esther Skou, Erna Nordmann, Jens Andersen, K. Binzer, H. J. Hansen, L. Simonarson and among the Greenlanders from Niaqornat first and foremost Abraham Løvstrøm and Andreas Tobiassen,

who have assisted me in the operations during the whole period of 30 years. Several other Greenlanders from Niaqornat have joined us in collecting marine fossils, in particular Lukas Kruse, Abel Møller, Boje Møller, Sachemann Møller, Jørgen Petersen, Johannes Tobiassen, Kristian Tobiassen, Martin Zeeb and Otto Zeeb.

In the diagram fig. 2 the results of the efforts since 1938 have been summarised to show the notable increase in knowledge of the stratigraphy of the marine strata on Nûgssuaq and Svartenhuk. Some of the more important steps in this development are the following:

In 1938 I could prove that the concretions with pelecypods and gastropods, formerly known especially from the north coast of Nûgssuaq, belonged to a horizon situated up to 600 m above the horizon with scaphites (Upper Campanian), and a Danian age was ascribed to these strata which comprise bituminous shales with a 50 m thick basal conglomerate overlying Senonian black shales with scaphites. From Ikorfat Maastrichtian ammonites were collected by S. Munck in black shales above an Upper Campanian scaphites horizon, and from Tupersuarta baculites and inocerams (Upper Santonian) were obtained in black bituminous shales by Rosenkrantz and Sorgenfrei.

In 1939 a Coniacian fauna was discovered in black shales at Umîvik on Svartenhuk by Rosenkrantz and Laursen. Numerous ammonites were collected which are identical with some old finds that have been housed since 1804 in the museums of Copenhagen; these belong to the so-called Spengler collection and are provided with a label in Spengler's handwriting "Cornu Amonis aus Grönland". They were in all probability brought to Europe before the end of the 18th century and were most likely picked up on Svartenhuk by whalers. Hoff (1865, p. 295) pointed out that these old ammonite finds indicate the presence of Jurassic strata in West Greenland and he wrote without any proof that they were collected at Kome (Kûk) on the north coast of Nûgssuaq. Heer (1868, p. 8 and p. 45 note) referred these ammonites to the Upper Oolite genus *Macrocephalites*, possibly *M. tumidus* (v. Buch). Madsen (1897, p. 48) hinted at the possibility that they may be scaphites but said that the state of preservation is so bad that they cannot be determined with any degree of certainty. Ravn (1918) expressed no definite opinion on the matter. Finally Rosenkrantz (1942, p. 8) said that the ammonites are *Scaphites* of the Coniacian *ventricosus* group. These ammonites indicate that there was a marine connection between West Greenland and Colorado in Coniacian time. Lower Danian fossils from the black shales (collected by Eriksen and Troelsen) together with tuff layers containing numerous marine fossils (Rosenkrantz) were found at Kangilia on the north coast of Nûgssuaq; in the interior of the peninsula (Agatdal) a highly fossiliferous Upper Danian series consisting of bituminous shales, sandstones and conglomerates was explored by Rosenkrantz, Eriksen and Laursen.

In 1948 Sonja Alfred Hansen found in the river bed in Agatdal a block of a very loose sandstone containing numerous rather well preserved Upper Danian marine fossils. In 1951 this rock type was found in situ by Dinesen forming the core of a sandstone lens ("the Sonja lens") coated with a hard

crust of sandstone. This exceptional rock – no similar rock has been met with in West Greenland – has yielded many thousands of fossils, mainly gastropods, which have been freed from the loose sand by a washing process. Moreover, in 1948, very rich Lower Danian deposits were discovered in Tunorssuaq valley by S. A. Hansen and Rosenkrantz.

In 1949 marine Santonian beds containing also floral elements were studied in detail in Agatdalen and in the same summer and in the same valley conglomeratic basal layers of the Lower Danian were discovered by Rosenkrantz and S. A. Hansen to be composed partly of derived Maastriichtian concretions containing numerous ammonites and other marine fossils. A rather comprehensive Upper Danian flora was secured from the marine beds in Agatdal by B. E. Koch and his assistants. This flora element was already discovered by A. Kiilerich in 1948.

The very rich Upper Danian strata in Qaerssutjægerdal (Agatdal region) were discovered by Rosenkrantz in 1951.

Among the more remarkable discoveries in 1952 may be mentioned a rich Lower Campanian ammonite fauna in Agatdalen found by H. Wienberg Rasmussen and T. Birkelund and the finds of huge Upper Santonian-Lower-Campanian inoceram (*Sphenoceras*) shells in Agatdalen and especially in Auvfarssuaq. At Alianaitunguaq Coniacian ammonites were collected by H. Wienberg Rasmussen and K. Skou below beds containing an Atane flora. North of Navssât Birkelund and Rosenkrantz found Upper Danian marine strata resting on black, bituminous shales in which E. Nordmann in 1964 found Upper Santonian-Lower Campanian inocerams.

A sequence of Lower Santonian *Clioscaphtes* beds were found in 1953 by K. Skou on Svartenhuk and the presence of a *Haresiceras* horizon was ascertained on the peninsula Itsako (Svartenhuk) by S. Floris.

In 1957 Floris made a detailed investigation of the Lower Danian beds on the north coast of Nûgssuaq, in Tunorssuaq and in Auvfarssuaq, especially with a view to finding corals.

In 1964 K. Binzer discovered a marine, presumably Upper Danian, fauna in tuffs at Marrait kitdlit on the south-west coast of Nûgssuaq far away from the previously known localities of beds of comparable age.

During GGU's 1:500 000 mapping of Svartenhuk in 1966, D. B. Clarke and T. C. R. Pulvertaft collected definite Upper Turonian scaphites west of Firefjeld.

During the period 1938–1968 large collections of marine fossils from the West Greenland Cretaceous-Tertiary sediments gradually accumulated. The treatment of the different fossil categories has been divided amongst several specialists thus: foraminifera: H. J. Hansen; corals: S. Floris; echinoderms: H. Wienberg Rasmussen; serpulids: A. Rosenkrantz; bryozoans: O. Berthelsen; brachiopods: U. Asgaard; fresh water gastropods and pelecypods: J. T. C. Yen; marine gastropods, pelecypods and nautiloids: A. Rosenkrantz; ammonites and belemnites: T. Birkelund; cirripeds: A. Rosenkrantz; ostracods: J. Szczechura; macrura, anomura and brachyura decapoda: H. Wienberg Rasmussen; fish: S. Bendix-Almgreen; insects: J. Birket-Smith; tracks and burrows: W. Häntzschel; wood: F. J. Mathiesen; pollen, spores and dinoflagellates: K. Raunsgaard Pedersen;

leaves and fruit: B. E. Koch. It ought to be mentioned here that finds of plant remains are not restricted to the limnic sediments. All categories are found also in the marine strata and often in a very good state of preservation.

The palaeontological investigations are progressing well and some results have already been published. My collaborators have provided me with unpublished information, and I am glad to be able to quote them in the following.

Lithology of the marine Cretaceous-Tertiary sequence

The marine strata of the Cretaceous-Tertiary sequence in West Greenland are built up of different lithological types among which a dark bituminous shale is dominant. Sandstone layers may be intercalated in this shale. Marine sandstones or shale layers are intercalated with a sequence of predominantly limnic sediments in some localities (for example especially in the south at Ilugissoq, Alianaitunguaq, and Pautût). In the dark shales pyritous, calcareous or clay-ironstone concretions occur in many horizons. The calcareous, somewhat dolomitic, and ferruginous concretions can reach several metres in diameter, but the majority of the fossiliferous concretions are smaller, mostly not exceeding about 30 cm in diameter. In the Santonian-Campanian shales, however, large concretions with inocerams have been met with. From the other Cretaceous levels concretions rich in ammonites have been collected (Birkelund, 1965) and from the Maastrichtian and Danian concretions with a more comprehensive fauna have been found. Excellently preserved driftwood bored by *Teredo* and other boring pelecypods has often been encountered in the black shales at different levels, especially in the Santonian, Campanian and Danian (Mathiesen, 1961).

Highly fossiliferous, often calcareous sandstone layers have delivered many good fossils, especially in the Upper Danian. From the same marine sandstones a collection of leaves, fruit and wood comprising a rather comprehensive flora has been brought back (B. E. Koch, 1963).

The Cretaceous part of the marine sequence in the West Greenland basin totals up to about 700 m in thickness. In a paper by Birkelund (1965) an outline of this series as developed in Svartenhuk and Nûgssuaq has been presented and some of the more important sections have been figured. In a paper by Henderson (1969, p. 14) I have provided some stratigraphic sections showing the marine Cretaceous and Danian on Nûgssuaq.

No conglomerates worth mentioning occur within the marine Cretaceous series and therefore the Upper Cretaceous seems to have been a rather quiet period in West Greenland. However, at the close of Senonian time this part of the world was affected by tectonic disturbances (Laramide phase) which resulted in a low-angled unconformity between the Maastrichtian and the Danian. Moreover faulting occurred and the formation in some localities (Angnertuneq and surroundings on the north coast of

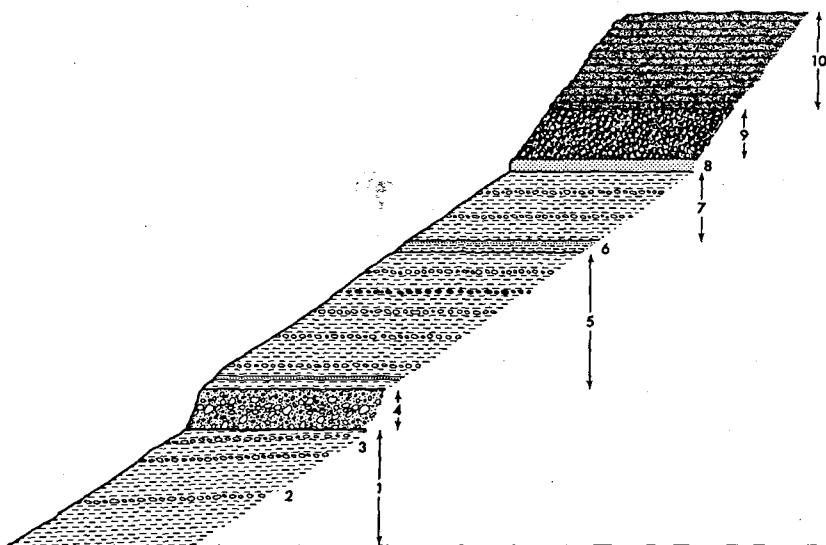


Fig. 3. Section through the Senonian-Danian sequence at Kangilia. 1. Senonian black shales with concretions. 2. Upper Campanian *Hoploscaphites* horizon. 3. Maastrichtian *Pseudophyllites* horizon. 4-7. The Lower Danian Kangilia Formation: 4. The Conglomerate Member (coarse basal conglomerate). 5. The Fossil Wood Member (black shales with concretions, those shown in black with fossil wood). 6. The *Thyasira* Member (tuffs with black shales and sandstone in between). 7. The *Propeamussium* Member (black shales with highly fossiliferous concretions). 8. The Upper Danian Agatdal Formation? (unfossiliferous sandstones). 9. Pillow breccias. 10. Plateau basalts. (R. L.)

Nûgssuaq and Agatdal in the interior of the peninsula) of Danian conglomerates was a result of these tectonic movements which in the Agatdal region caused a complete removal of the Maastrichtian by the transgressing Danian sea. The basal Danian conglomerate on the north coast is about 50 m thick (fig. 3) and is composed chiefly of Precambrian gneiss boulders up to 2 m in diameter, but derived concretions from the Senonian also occur. In Agatdal the basal conglomerate is about 5 m thick and is principally composed of derived highly fossiliferous Maastrichtian concretions, but some Campanian concretions have also been met with showing that the removal of the top of the Senonian in some degree also affected the Campanian.

The Danian series resting on the Danian basal conglomerate attains a thickness of about 600 m on the north coast of Nûgssuaq and consists chiefly of dark, bituminous shales with many concretions at many different levels (fig. 3). The often rather big concretions in the lowermost about 425 m thick black shale series are, apart from *Teredo*-bored fossil wood, very poor in fossils. On top of this infertile series rests a quite different series consisting of two fossiliferous tuff beds each up to 7 m thick, with

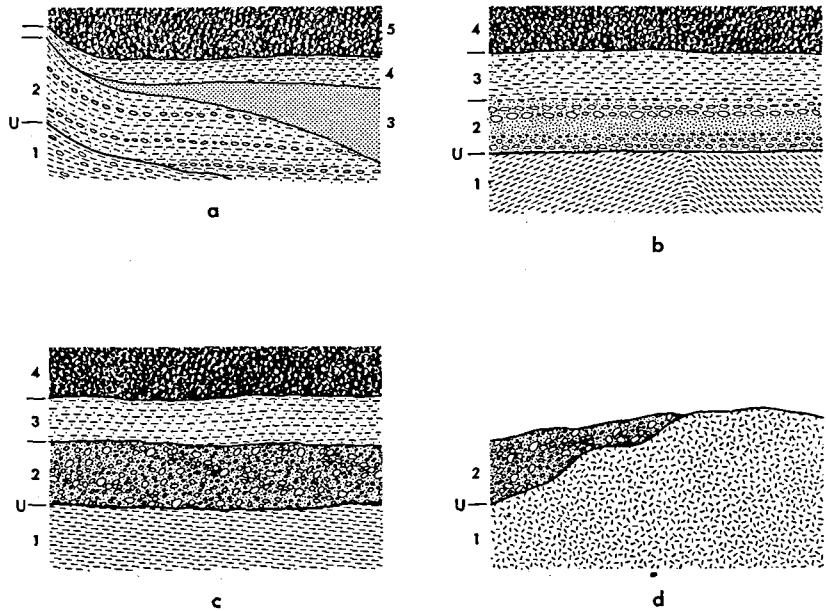


Fig. 4. 4 sections schematically showing the Agatdal Formation resting on strata of different age. a. Turritlekløft unconformably on 1. Lower Danian, *Propeamussium* Member (2. Turritlekløft Member, 3. Andreas Member, 4. Pillow breccias). b. Qaersutjægerdal, unconformably on Lower Danian, *Propeamussium* Member (2. Turritlekløft Member, 3. Abraham Member, 4. Pillow breccias). c. Navssât river northern branch, unconformably on 1. Lower Campanian-Upper Santonian *Sphenoceramus* beds (2. Basal conglomerate (Sonja Member), 3. Turritlekløft Member, 4. Pillow breccias). d. East of the Navssât river northern branch, unconformably on 1. Precambrian gneisses. (2. Basal conglomerate, Sonja Member). U = unconformity. (R. L.)

20 m black shale overlain by a thin sandstone layer in between. The tuffs date the beginning of the volcanic activity within this part of the Brito-Arctic Tertiary volcanic province as early Danian.

The concretions in the 20 m thick black shale of this series have delivered several good fossils and the tuffs are especially rich. In about 100 m of black shales resting upon the uppermost tuff bed numerous highly fossiliferous concretions have been collected. It seems as if the deposition of the thick tuff layers over black, suffocating mud, which now appears as dark bituminous shales, caused an improvement in bottom conditions and made possible an invasion of bottom-dwelling animals. The Danian series on the north coast ends in unfossiliferous sandstone beds about 20 m thick. Possibly there is an unconformity between these sandstones and the underlying dark shales but these parts of the sections are covered with till and scree.

For the Danian series described above (excepting the sandstone on top

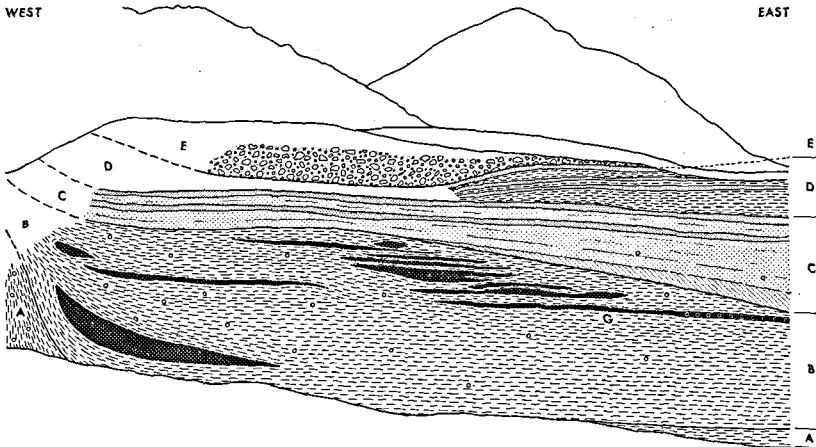


Fig. 5. Section in Turrítellakløft showing: A. Kangilia Formation. *Propeamussium* Member. B–D. Agatdal Formation: B. Turrítellakløft Member, black shales with fossiliferous calcareous concretions and sandstone lenses. G. *Gilbertina* lens, conglomeratic in the eastern part. C. Andreas Member, loose deltaic sandstone with two consolidated hard beds. D. Abraham Member, grey shales with intercalated, fossiliferous tuff beds. E. Pillow breccias. Height of section ca. 80 m.

which may belong to the Agatdal Formation) I have established the term Kangilia Formation. The Kangilia Formation can be divided into 4 members which in descending order are:

The *Propeamussium* Member; about 100 m thick, black shales locally with sandstones intercalated.

The *Thyasira* Member; ca. 35 m thick, tuffs, sandstone and black shales.

The Fossil Wood Member; ca. 425 m thick, black shales with a sandstone layer in the lower part.

The Conglomerate Member; up to ca. 50 m of coarse conglomerate.

The *Thyasira* Member can also be recognised in more southerly parts of the Nûgssuaq peninsula viz. in Ilugigsoq, Agatdal (here including the basal conglomerates) and on the south coast at Alianaitunguaq, Tuapaussat and Atâ. The *Propeamussium* Member has been followed for a rather long stretch along the north coast from Niaqornat to Ujaragtôrssuaq and has been found in Tunorssuaq, in the central part of the Itivdle valley, as numerous derived concretions in the Auvfarssuaq valley between Quvnilik and Ilugigsoq, at Qilakitsoq, in the Nuilarssarssuaq pass (burnt shales) and in Turrítellakløft (Agatdal). Furthermore this member is represented by concretions at Alianaitunguaq and by burnt shales at Tuapaussat and Atâ, all three localities on the south coast.

In the northern part of the Agatdal region the Kangilia Formation is seen unconformably overlain by the more than 75 m thick Agatdal Forma-

tion, which in other localities in this region is seen resting unconformably on the Lower Danian and the Upper Campanian (Nuilarssarsuaq), Lower Campanian-Upper Santonian (northern tributary of the Navssât river) and even on Precambrian gneisses (east of Navssat, fig. 4d). The two last mentioned localities are situated within the major fault zone which crosses the peninsula from Ikorfat on the north coast to Sarqaq on the south coast. The unconformity below the Agatdal Formation together with the formation of coarse, basal conglomerates reflect renewed tectonic activity in Danian time. Above the basal conglomerates black bituminous shales including deltaic, sandy and fine conglomeratic intercalations were deposited. The sandy components play a much bigger role in this part of the series than in the series of black shales in the older Kangilia Formation. The topmost part of the Agatdal Formation consists of black to grey shales which higher up alternate with more or less fossiliferous tuffs. The Agatdal Formation is overlain by pillow lavas and pillow breccias belonging to the several km thick basalt formation. Thermal contact phenomena are in some places clearly visible.

The Agatdal Formation is composed of the following members (Rosenkrantz in B. E. Koch 1959 p. 75), see fig. 5:

In Turrítellakløft

Abraham Member; black and grey shales with intercalated fossiliferous tuffs, about 12 m thick.

Andreas Member; deltaic deposits consisting of coarse arkosic sand and sandstone beds. Very few fossils. 10–25 m thick.

Turrítellakløft Member; about 50 m black, bituminous shales with fossiliferous calcareous concretions and numerous arkosic sandstone lenses which are highly fossiliferous.

In Agatdal

Sonja Member; about 50 m thick. At the base coarse gneiss conglomerate varying up to 10 m in thickness. Over the conglomerate a series of alternating, arkosic sandstones, shales and conglomerates with marine fossils and plant remains. 20 m above the basal conglomerate the peculiar Sonja lens mentioned on p. 414 is situated.

The Sonja Member in Agatdal equates in some degree with the Turrítellakløft Member and the Andreas Member in Turrítellakløft.

Regarding the structure of the West Greenland sedimentary basin the readers are referred to a paper by Rosenkrantz & Pulvertaft (1969).

Notes on the West Greenland Upper Cretaceous marine faunas

In the right-hand part of the diagram (fig. 2) the conception of the biostratigraphy of the marine Cretaceous in West Greenland based upon the investigations since 1938 is shown. Apart from ammonites, baculites and inocerams, only rather few categories of fossils are met with in most horizons, the Maastrichtian being an exception. The cephalopods have been treated by Birkelund (1956, 1965 and 1967) and the detailed stratigraphy of the Senonian shown in the diagram is due to the same author. A few additional comments on some ammonites and an account of the less diagnostic fossils from the different horizons is given in the following.

Cenomanian?

From the western side of the Simiútap kúa valley at Umiarfik, northern Svartenhuk, Birkelund (1956) mentions an *Actinocamax* cf. *primus* Arkhangelsky, a species known from the middle and upper Cenomanian. The sediments at this locality consist of loose sand overlain by grey shales with sandstone lenses and contain a flora not yet identified. Apart from two indeterminable scaphites fragments no other marine fossils have been found. There exists a possibility that the sediments at this locality may be of Cenomanian age and if so they constitute the oldest marine member of the West Greenland Cretaceous sequence.

Upper Turonian

From Umívik (Svartenhuk) Birkelund mentions some derived concretions containing 30 specimens of a *Borissjakoceras rosenkrantzi* Birkelund and two concretions with *Scaphites* cf. *corvensis* Cobban; the last-mentioned species is considered an index fossil of the Upper Turonian. In 1966 Clarke and Pulvertaft found some scaphites in situ in shales on Svartenhuk; these show, according to Birkelund, that Cobban's species definitely occurs in Svartenhuk. Imlay & Reeside (1954) doubted the correctness of my old identification (1942) of a *Borissjakoceras* in the Coniacian of Svartenhuk, this genus only being known from the Cenomanian to the Upper Turonian in the U.S.A. Recently Birkelund (1965) verified my determination and writes that the Greenland species is very close in size, shape and ornament to *Borissjakoceras ashurkoffae* Cobban & Gryc (Lower Turonian) but has a more complex suture and therefore may be considered a late representative of the genus. I think that *Borissjakoceras rosenkrantzi* Birkelund may safely be placed in the Upper Turonian together with *Scaphites corvensis* Cobban. It ought to be mentioned that in north-western Montana, according to Cobban (in Tourtelot & Cobban 1968, p. 4), *Scaphites mariasensis* Cobban occurs together with an early form of *Scaphites preventicosus* Cobban. This *Scaphites mariasensis* assemblage, following Cobban, should probably be assigned to the Upper Turonian. In the Svartenhuk localities

where *Borissjakoceras* has been collected there also occur derived concretions containing subspecies of the two above-mentioned Wyoming scaphites. These forms are referred by Birkelund (1965) to the Lower Coniacian.

Senonian

Coniacian

As just mentioned, the derived concretions from Umívik (Svartenhuk) with *Scaphites mariasensis umivikensis* Birkelund and *Scaphites preventricosus svartenhukensis* Birkelund have been referred to the Lower Coniacian by Birkelund. Some specimens of an *Actinocamax* sp. have also been collected. In other concretions from the same localities, in addition to a flora not yet identified, some inocerams have been found, i. a. *Inoceramus* aff. *deformis* Meek, together with an insect wing belonging to locustidae (green grasshopper) and a not yet identified teleost.

In black bituminous shale from Alianaitunguaq *Scaphites ventricosus* Meek & Hayden is reported by Birkelund, showing the presence of the Upper Coniacian. From coal-bearing beds directly overlying the Upper Coniacian black shales Heer (1883, p. 164) mentions a flora of 5 species belonging to his Atane flora. This flora must in this locality belong to the early Senonian and may be Coniacian or a little younger. In contradiction to this Imlay & Reeside (1954, p. 227) say that the Atane flora cannot be younger than the Turonian because the Atane beds are overlain by beds with the Coniacian *Scaphites ventricosus*. Heer was of opinion that the Atane flora was Cenomanian but the type locality Atâ, 14 km south-east of the old village Atâ on the south coast of Nûgssuaq, is rather close to Pautût where the corresponding beds are situated only with a short interval from the overlying Santonian-Campanian marine beds. In fig. 2 I have let the Atane flora cover Upper Turonian-Lower Senonian but it may be restricted to the Lower Senonian.

Santonian

In Svartenhuk and Ilugigsoq (Nûgssuaq) the lowermost part of the Santonian is characterised by *Clioscapites saxitonianus septentrionalis* Birkelund. In the strata on Svartenhuk a small not identified *Inoceramus* without radial ribs has been found together with a few other pelecypods. The gastropods are extremely rare but comprise an apparently new species of *Oligoptycha* provided with a strong rather short horizontal fold on the columella and a prominent swelling opposite the fold on the inner side of the smooth outer lip.

Above the lowermost Santonian beds in Svartenhuk follows a series of black shales containing rather big inoceram shells of a *Sphenoceramus* of the *steenstrupi* group. From this level *Pteria* (*Oxytoma*) *tenuicostata* (Roemer) has also been collected and is represented by large specimens up to 35 mm in length. Valves of cirripeds occur similar to valves of *Zeugmatolepas* (Withers 1935, p. 79), type *Z. mockleri* Withers, from the Ceno-

manian *varians* zone in England. Meanwhile a similar form from the Upper Santonian-Lower Campanian in Nûgssuaq and represented by a nearly complete capitulum permits the establishment of a new genus, *Eskimolepas* (see fig. 6). Possibly the Lower Santonian valves belong to this new genus but represent another species.

Strata corresponding to the Svartenhuk strata just mentioned have been recognised at Tuperssuartâ and in Tunorqo, on the north coast and in the interior of Nûgssuaq respectively. From Tupersuarta Birkelund (1965) mentions *Clioscaphtes* aff. *saxitonianus* (McLearn), *Baculites nugssuaqensis* Birkelund and (1956) *Actinocamax groenlandicus* Birkelund. At that locality many specimens of a *Sphenoceramus* related to *Inoceramus steenstrupi* de Loriol have been collected. Also *Pteria* (*Oxytoma*) *tenuicostata* (Roemer) occurs as large specimens together with a smooth *Pteria* and a *Chlamys*. *Pteria tenuicostata* has previously been recorded from East Greenland (Knudshoved) by Frebold (1934), and here also is of large size. It occurs in the Lower Campanian of Germany, England, Belgium and Russia, and in Europe is considered to be a boreal element. This is in good agreement with the fact that in Greenland this species is already represented in the Santonian on both the east and the west coast.

In Agatdal in the interior of Nûgssuaq beds with *Baculites codyensis* Reeside and *Sphenoceramus* of the *steenstrupi* group form the continuation of the sequence just mentioned. Many leaves and also fragments of fossil wood have been collected.

Santonian-Campanian

The Upper Santonian and Lower Campanian in Nûgssuaq (Pautût, Qilakitsoq, northern part of Agatdal) seem to be represented by strata characterised by *Sphenoceramus steenstrupi* (de Loriol) and *Sphenoceramus pautootensis* (de Loriol) but no determinable ammonites or belemnites are reported from these strata. Specimens belonging to the *steenstrupi* group can attain a length of almost two metres as at Qilakitsoq. Together with these huge pelecypods only bryozoans fixed to the inoceram shells and a single nearly complete capitulum of a cirriped have been found (fig. 6). This outstanding find represents a new genus related to *Zeugmatolepas* Withers.

Eskimolepas gen. nov. type: *Eskimolepas gregersi* sp. nov. named in honour of the collector, the late Gregers Olsen.

Capitulum in many respects similar to that of *Zeugmatolepas* Withers 1913 from the Cenomanian but possess only 22 valves instead of more than 34 in *Zeugmatolepas*. Three whorls of subtriangular lower latera, most of them with V-shaped growth lines, are present. A subrostrum seems to be developed. The cardinal latus reaches less than midway up to the side of the carina. Umbo of the scutum placed nearly central on the lateral margin, similar to Turonian and Middle Senonian forms of *Z. cretae* Steenstrup. The upper latus smaller than in *Zeugmatolepas* and only in the lower part covers the space between the scutum and the tergum. In

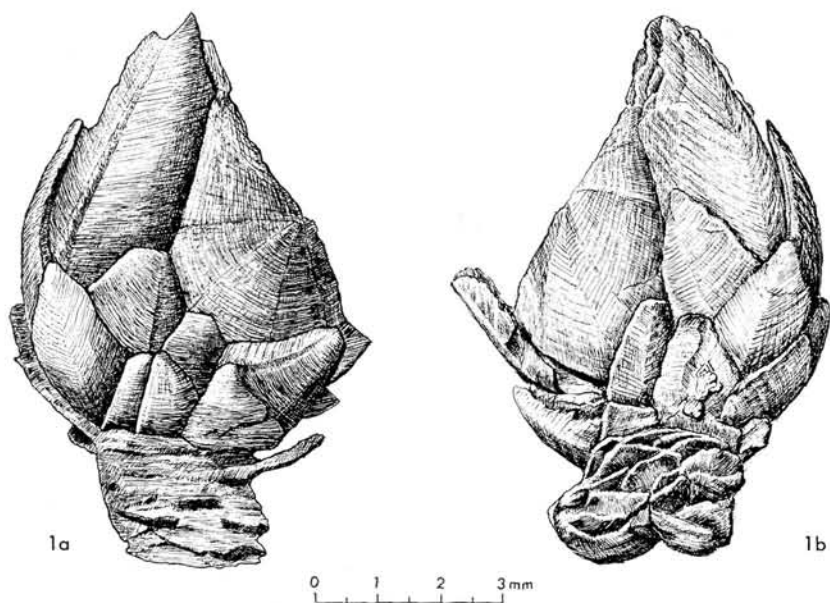


Fig. 6. *Eskimolepas gregeri* gen. nov. et sp. nov. (MMH no. 10791). A nearly complete capitulum associated with the peduncle from the Santonian-Campanian *Sphenoceramus* beds at Qilakitsoq. (1a H. E., 1b B. E.)

Zeugmatolepas the upper latus completely covers this space. Peduncle armed with small plates.

The European *Zeugmatolepas? cretae* (Steenstrup) which ranges according to Withers (1930) from the Turonian to the Danian may belong (at least the Senonian and Danian representatives) to the new genus, but only scattered valves have been found and those give no idea of the exact number of valves in the capitulum. From the Lower Santonian of Svartenhuk I have reported above a species different from the above-mentioned somewhat younger species, but neither in this case can we count the exact number of capitulum valves as the valves are found scattered in the sediment.

As already mentioned, a few other fossils have been recorded by Ravn from the burnt shale from Pautût with the associated inoceramids. They have been identified as North American species, viz. *Hemister humphreysianus* Meek & Hayden, *Oxytoma nebrascana* (Evans & Schumard), *Lucina occidentalis* (Morton) and *Solemya subplicata* (Meek & Hayden). These determinations may be correct in spite of most of the fossils not being well preserved. As far as the *Oxytoma* is concerned Ravn's specimen shows very good agreement with *O. tenuicostata* (Roemer). Maybe the two species are identical.

Lower Campanian

The Lower Campanian is represented on Itsako (Svartenhuk) by black bituminous shales with a *Haresiceras*, but no other fossils have been collected here. On Nûgssuaq an uppermost Lower Campanian horizon was discovered in Turrítellakløft (Agatdal region) containing *Pseudophyllites skoui* Birkelund, *Baculites obtusus* Meek, *Scaphites cobbani*, Birkelund and *Scaphites rosenkrantzi* Birkelund. This ammonite assemblage is attended by some other faunal elements, viz. echinoids, indeterminate gastropods and pelecypods and crustaceans as *Callianassa* and raninids.

Upper Campanian

The Upper Campanian has been found on the north coast of Nûgssuaq between Niaqornat and Ikorfat, in the interior of the peninsula and as derived fossiliferous concretions in the Danian conglomerates in the Agatdal region. It is characterised by three species of *Hoploscaphites* (*greenlandicus* Donovan, *ravni* Birkelund and *ikorfatensis* Birkelund); *Pseudophyllites skoui* Birkelund is also present. Locally the accompanying fauna becomes somewhat richer than in the older horizons and comprises echinoderms, pelecypods and gastropods, none of which are well preserved. Crustaceans, particularly crabs, occur in great number. The raninids belong to a new genus and together with raninids from the Maastrichtian and Danian form a link between the lower Cretaceous and the older Tertiary forms. Furthermore a *Homolopsis* and 13 species of *Callianassa* have been collected.

Many of the full-grown Upper Campanian *Hoploscaphites* can hardly have lived within the area where these shells have been deposited, but must be regarded as having drifted into the lagoon-like area from the fresh open sea. Dwarfed forms of the same species in the same layers possibly represent the indigenous fauna which was affected by the unfavourable bottom conditions (anaerobic black mud with a large organic content).

Conditions in the Senonian sea improved somewhat during the Maastrichtian at the same time as the amount of coarse detritus, especially large quartz grains, in the sediments increased. This improvement resulted in the invasion of a relatively rich fauna.

Maastrichtian

The Maastrichtian occurs in situ along the north coast of Nûgssuaq on top of the Campanian and is also represented in the Agatdal region as derived fossiliferous concretions in the basal conglomerate of the Danian. In this part of Nûgssuaq the Maastrichtian beds have been entirely removed together with parts of the Upper Campanian. The rather rich fauna is characterised by species of *Discoscaphites* (*waagei* Birkelund and *angmartussutensis* Birkelund), *Neophylloceras groenlandicum* Birkelund and *Saghalinites wrighti* Birkelund; most of these ammonites are in a splendid state of preservation (see Birkelund 1967; Birkelund & Hansen 1968). Fur-

thermore, from Agatdal *Baculites* cf. *meeki* Elias is reported and two cephalopods ought to be mentioned, namely the peculiar belemnoteuthid *Groenlandibelus rosenkrantzi* (Birkelund) (see Jeletzky, 1966), which recently has been found in derived concretions together with *Discoscaphites* and therefore must be of Maastrichtian age, and a large *Euthrephoceras*. In size this nautiloid is comparable with *Euthrephoceras decayi* (Morton) Meek and may represent this species.

From the Maastrichtian strata in situ on the north coast *Discoscaphites* aff. *angmartussutensis* Birkelund, *Diplomoceras?* sp. and *Pseudophyllites* sp. have been reported but no other fossils so far.

The derived concretions from Agatdal enclose in addition to the frequently occurring cephalopods an accompanying fauna much richer than in the concretions from the older Senonian levels. This fauna has not yet been analysed in detail, the Upper Danian fauna having until now had preference. The former comprises the following:

Corals: One indeterminable species.

Echinoids: Some unidentified species.

Crinoids: Stems of *Isselicrinus*.

Serpulids: *Pentaditrupe* aff. *interjuncta* (Ødum).

Brachiopods: *Carneithyris* close to Senonian forms from Europe, large rhynchonellids and a *Terebratulina*.

Scaphopods: A *Lavidentalium* and a *Fissidentalium*.

Pelecypods: *Nuculana* aff. *coloradoensis* Stephenson; *Glycymeris*; *Limopsis* aff. *meeki* Wade; *Syncyclonema*; *Inoceramus* aff. *fibrosus* (Meek & Hayden); *Lima*; *Plagiostoma*; *Cardium*; Lucinids; *Cymbophora* aff. *gracilis* (Meek & Hayden); *Cuspidaria* and other species.

Gastropods: *Acmaea*; *Calliomphalus*; *Anomalofusus?*; *Serrifusus*; *Graephidula* aff. *culbertsoni* (Meek & Hayden); *Lunatia*; *Surcula* 2 sp.; *Anisomyon* cf. *centrale* Sohl; *Nonactaeonina* aff. *gryphoides* Stephenson; *Oligoptycha* aff. *concinna* (Hall & Meek); *Oligoptycha* aff. *corrugata* Sohl; *Oligoptycha* n. sp. (with a distinct swelling on the moderate denticulate inner side of the outer lip bordering the channel. No parietal folds but a strong parietal ridge); *Cylichna*; *Cylindrotruncatum*; *Conicylichna* and other species. Turritellas and aporrhoids are completely missing in this fauna.

Crustaceans: More than 1300 specimens of a raninid belonging to a new genus different from the Upper Campanian form; according to H. Wienberg Rasmussen 5.5 % of the individuals show swellings of the carapace in the gill region produced by parasitic bopyrids. *Homolopsis* sp. and 8 species of *Calianassa* of which 4 occur also in the Upper Campanian. Numerous specimens of a well preserved decapod, possibly a new genus of *Glyphæidea*.

Fish: A spine of an elasmobranch, bones and scales of teleosts.

Notes on the West Greenland Danian marine faunas

Lower Danian

Kangilia Formation, *Thyasira* Member

The *Thyasira* Member is named after *Thyasira (Conchocele)* aff. *conradi* Rosenkrantz of common occurrence.

Concretions from the shales between the two tuff beds on the north coast have yielded many fossils, of which the following may be mentioned:

Stems of *Isselocrinus groenlandicus* Wienberg Rasmussen (1961, p. 58).

A large, thick shelled oblique *Echinocorys* with high ambulacral and interambulacral plates, belonging to a group found abundantly in the Danian of Europe and forming a transition to the Danian genus *Jeronia*. As a curiosity it may be mentioned that the cavity of the most complete specimen is filled with a peculiar crystal mixture of whewellite, barytes and calcite (Bøggild, 1953, p. 426).

Thyasira (Conchocele) aff. *conradi* Rosenkrantz (1942, p. 277) very close to the Lower Tertiary Spitsbergen form described as *Thyasira bisecta* Conrad by Hägg (1925, p. 46), (see fig. 7).

Hercoglossa groenlandica sp. n. (fig. 8) showing some similarity to a big undescribed species from the Middle Danian of Scania (*H. scanica* sp. n.) which probably is the largest *Hercoglossa* known, about 50 cm in diameter (see fig. 8).

In the tuff beds 15 species of scleractinian corals have been collected showing a relationship with Danian faunas in Denmark and even specific identity (*Dendrophyllia candelabrum* Hennig, and other Faxe species). Close connection exists between the Lower Danian coral faunas in West Greenland and the more or less contemporary faunas in Europe, the

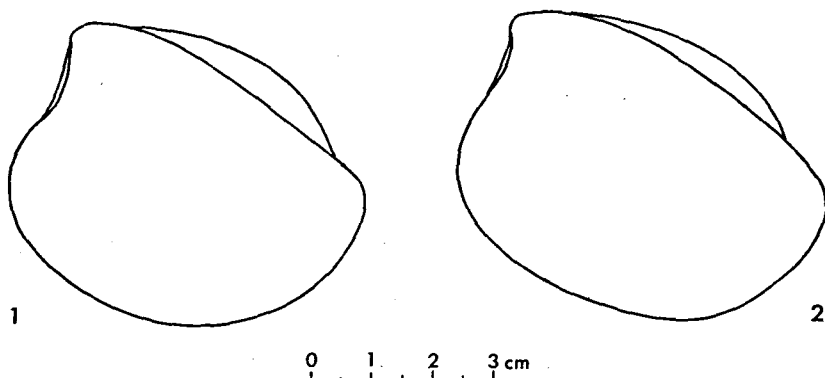


Fig. 7. 1. *Thyasira (Conchocele) conradi* Rosenkrantz. Near Cape Erikson, south coast of the Ice Fjord, Spitsbergen. (MMH, 10792). 2. *Thyasira (Conchocele)* aff. *conradi*. Kangilia (MMH, 10793). Lower Danian, Kangilia Formation, *Thyasira* Member. (R. L.)

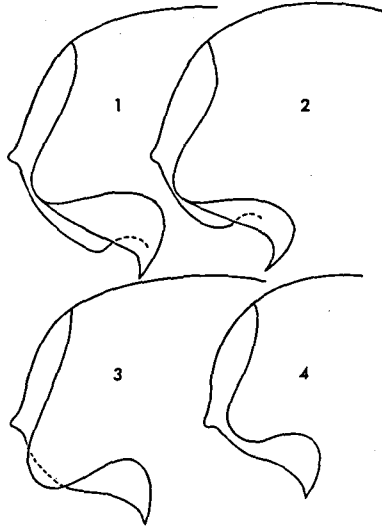


Fig. 8. 1. *Hercoglossa scanica* sp. n. Limhamn, Scania. Middle Danian. Dept. of Palaeontology and Geology of the University. Lund, Sweden. 2. *Hercoglossa groenlandica* sp. n. (MMH, 10794). Kangilia. Lower Danian, Kangilia Formation, *Thyasira* Member. 3. *Hercoglossa danica* (v. Schlotheim). (MMH, 10795). Faxø, Denmark, Middle Danian. 4. *Hercoglossa schoelleri* sp. n. (= *H. danica* Schoeller 1925, p. 589, pl. 25). (MMH, 10796). Vigny, France. (H. E.) Further characteristics of the new species will be given in a special paper.

Americas, New Zealand and Antarctica (Floris, 1967). From the Lower Danian conglomerates in Agatdal, also containing *Thyasira* aff. *conradi* in the matrix, two scleractinian corals have been collected, one in common with the tuff species.

Furthermore in the tuff beds among the remnants of echinoids a *Hemister* and spines of cidarids are represented. The occurrence of a *Tylocidaris* (fig. 16) related to the Lower Danian *Tylocidaris oedumi* Brünnich Nielsen is remarkable.

Brachiopods: A *Carneithyris* with sulcate frontal commissure and swollen cardinalia. Similar species are known from the Upper Danian in Denmark. *Terebratulina* cf. *striata* (Wahlenberg) of large size as in the Danian of Denmark.

Pelecypods: Several species occur, in many cases only as internal casts. The fauna includes *Nucula*; *Cucullaea* cf. *solenensis* White known from the Cannonball Formation; *Glycymeris* aff. *subimbricata* (Meek & Hayden) Cannonball; *Pycnodonte*; *Venericardia*; *Astarte*; *Thyasira* (*Conchocele*) aff. *conradi* Rosenkrantz (abundant); *Thyasira pfaffi* (Ravn); at least three Lucinids including a *Miltha*; *Solemya* cf. *bilix* White, Cannonball, and several more species.

Gastropods: Many species but for a great part as indeterminable internal casts. The following forms are recognisable: "*Pleurotomaria*"; *Amphine-*

rita; *Boutillieria*; *Eucyclus*; *Turritella* two species; *Palaeocypraea* aff. *spirata* (v. Schlotheim) as in the Middle Danian of Denmark; *Eocypraea* (two species); *Polinices*; *Lunatia*; "*Galeodea*" aff. *elongata* (v. Koenen) (this form, also known from the Upper Danian of Greenland and Lower Selandian of Denmark, deserves a new generic name; it represents the oldest generic forerunner to *Galeodea*); *Sassia*; *Buccinofusus?*; *Ancilla* (*Sparella*); *Mitra*; *Surcula* ("*Cochlespira*") aff. *Koeneni* (Arkhanguelsky) known from the Selandian in Denmark; *Surcula*; *Rhapitoma?*; *Cylichna?*

Nautiloids: *Euthrephoceras* and *Cimomia* (in Agatdal).

Crustaceans: valves of *Arcoscalpellum*.

Fish remains (Bendix-Almgreen, 1969), especially isolated teeth, comprise several species of the group Selachoidei within the elasmobranches, e.g. *Notidanus*; *Squalina?*; *Squalus* aff. *orpiensis* Winkler; *Scapanorhynchus raphiodon* Agassiz; *Lamna appendiculata* Agassiz; *Lamna incurva* Davis; *Lamna elegans* Agassiz; *Lamna* cf. *venusta* Leriche and *Oxyrhina* cf. *lundgreni* Davis. This fauna shows some affinity to the Senonian and especially to the Lower and Middle Danian of Dano-Scania. Remains of Actinopterygii have also been found, including a nearly complete specimen of the oldest hitherto known undoubted gadoid.

Kangilia Formation, *Propeamussium* Member

In the northern localities in Nûgssuaq this member consists of black bituminous shales with many highly fossiliferous concretions containing beautifully preserved shells, especially pelecypods and gastropods. In the southern part (Tuapaussat, Atâ and Nuilarssarsuaq) similar fossils have been collected in burnt shales; concretions seem here to be rare. The member name reflects on the very abundant occurrence of the pectinid *Propeamussium ignoratum* (Ravn, 1918). The fauna in the beds of this member is undoubtedly more comprehensive than it will appear from the following account. The very difficult preparation of the numerous very hard concretions collected is far from being brought to an end.

Foraminifera: Three species are mentioned by Ravn and *Atlanta primigenia* Ravn is a *Cornuspira*. There are many forams enclosed in the concretions but they have not been investigated. In the burnt shales at Atâ badly preserved forams are present but not of frequent occurrence.

Scleractinian corals: Two species not known from the *Thyasira* Member and one in common with this member.

Crinoids: Stems of *Isselicrinus*.

Echinoids: Badly preserved *Micraster* in the burnt shales and a *Brisso-pneustes*-like species in the concretions.

Serpulids: *Tetraditrupe?*

Brachiopods: Not observed.

Pelecypods: Most of the pelecypods mentioned by Ravn (1918) belong to the *Propeamussium* Member and the same also applies to the gastropods. Apart from erecting nine new species Ravn referred seven species to Upper Senonian forms from North America relying partly on the authority of de Loriol, but like Stanton I have been unable to confirm actual specific identities between these and the West Greenland Lower Danian species. A further nine pelecypods are listed by Ravn, but due to the bad state of preservation they are not provided with specific names. So far the following species have been recorded but the material is still not fully dealt with.

Nucula planimarginata Meek & Hayden (Cannonball); *Nuculana* (non *bisulcata* Meek & Hayden); *Limopsis rinki* Ravn; *Pecten* (*Chlamys?*) *ataensis* (de Loriol) Ravn, having according to Ravn some affinity to the Danian species *P. tessellatus* Hennig from Dano-Scania; "*Pecten* (*Chlamys?*) *striatissimus* Ravn" which are left valves of *Propeamussium ignoratum* Ravn; *Pecten pfaffi* Ravn; *Propeamussium ignoratum* (Ravn); a large smooth *Modiola*; *Crenella* aff. *stantoni* Finlay (Cannonball) = *Modiolaria?* sp. Ravn; *Solemya* n. sp. (non *subplicata* Meek & Hayden); *Cuspidaria* (non *moreauensis* Meek & Hayden); *Corbula* (non *inornata* Meek & Hayden); *Thyasira* (*Conchocele*) aff. *conradi* Rosenkrantz (= *Lucina* sp. 2 Ravn) rare; *Thyasira deLorioli* (Ravn) (*Axinus*); *Thyasira pfaffi* Ravn (*Lucina*); *Thyasira* sp. nov. = *Nucula?* sp. Ravn; *Lucina* (non *occidentalis* (Morton) possibly a *Myrtea*); *Teredo* sp. Ravn; *Turnus* sp. nov.

Scaphopods: *Dentalium groenlandicum* Ravn; *Fissidentalium* n. sp. (non *gracile* Meek & Hayden); *Laevidentalium* n. sp. (non *pauperculum* Meek & Hayden); *Cadulus* (*Gadila*) *groenlandica* Ravn.

Gastropods: *Margarita?* *steenstrupi* Ravn; *Promathilda* (*Chlathrobaculus*) sp. n.; *Mathilda* sp. n.; *Acirsa* (*Hemiacirsa*) sp. n.; *Anchura* (*Kangilioptera* subgen. nov. *ravni* sp. n.) fig. 9 (= *Aporrhais* sp. Nos. 44 and 45 Ravn); *Aporrhais* (*Aporrhais*) sp. n. (= *Aporrhais* sp. No. 46 Ravn); *Lunatia* (non *concinna* Hall & Meek); *Globisium* sp. n. (Wangaloan); "*Galeodea*" aff. *elongata* (v. Koenen); *Sassia* sp. n. large form; *Clavilites* sp. n.; *Taioma* sp. n. (Wangaloan); *Buccinofusus?* two species; *Ancilla* (*Sparella*) sp. n.; *Tudicla* (*Tudicla*) aff. *carinata* Münster (Senonian); *Bonnelitia* sp. n.; *Turricula* (*Zemacies?*) sp. n.; *Turricula* (*Surcula*) three species; *Surcula* ("*Cochlespira?*") aff. *Koeneni* (Arkhanguelsky); *Borsonia* (*Cordieria?*) sp. n.; *Genota* aff. *brevior* (v. Koenen); *Tornatellaea* (*Ravniella* subgen. nov.) *groenlandica* sp. n. (see fig. 10); *Crenilabium* sp. n.; *Gilbertina?* sp.; *Cylichna* (*Cylichnania*) sp. n.; *Roxania* sp. n. (= *Cylichna* sp. n.? Ravn); *Bulla?* *groenlandica* Ravn; *Bulla?* (*Haminea?*) 2 species; *Retusa* (*Retusa*) *rugosa* Ravn.

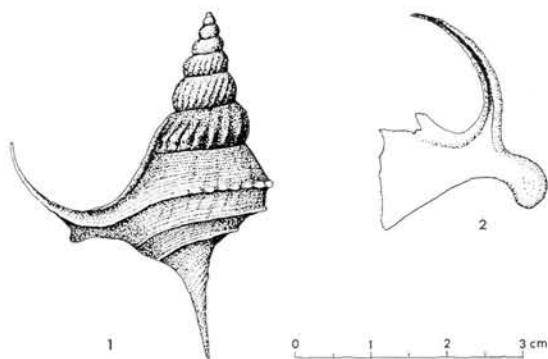


Fig. 9. *Anchura* (*Kangilioptera* subgen. nov.) *ravni* sp. n. 1. Complete specimen. (MMH, 10797). Kangilia. Lower Danian, Kangilia Formation, *Propeamusium* Member. 2. Wing seen from the inside. (MMH, 10798). Tunorssuaq. Lower Danian, Kangilia Formation, *Propeamusium* Member. (E. N.)

Kangilioptera subgen. nov. (*Anchura*)

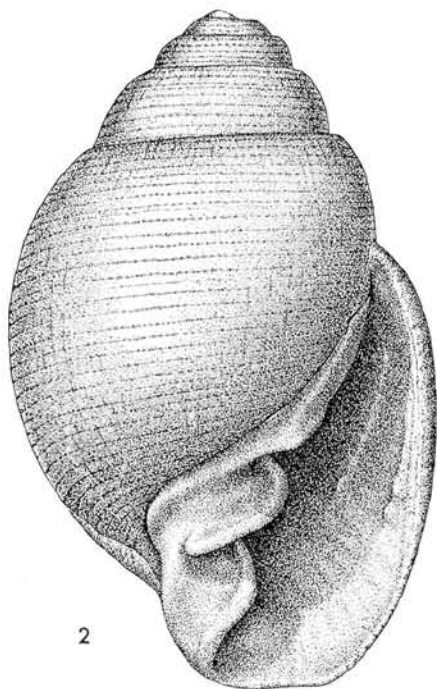
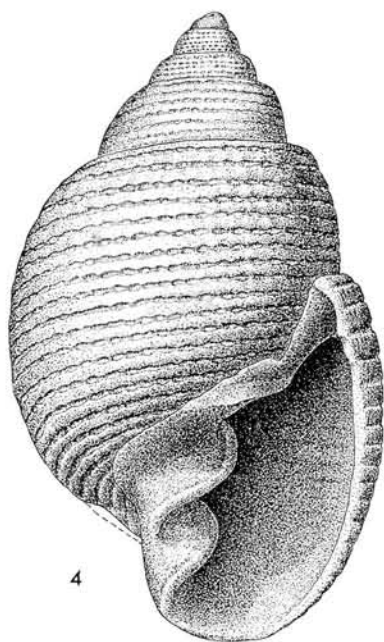
Type: *Kangilioptera ravni* sp. n. named after J. P. J. Ravn.

Preliminary diagnosis: Large-sized aporrhaid with high evenly tapering spire and protoconch as in *Anchura*. Sculpture consisting of numerous fine spiral cords of variable strength, one noded spiral zone on the penultimate whorl and three marked keels on the body, the uppermost situated well below the suture, noded and extending out onto the expanded outer lip. Collabral axial ribs on all whorls, strongest on the penultimate whorl producing nodes by intersecting the median spiral zone here and the uppermost keel on the body. Rostrum rather long but somewhat shorter than in *Anchura* s. str. This aporrhaid, like *Anchura* and *Drepanochilus*, is provided with only one lateral digitation corresponding to the upper, noded keel of the body. The two lower smooth keels attach an outer smooth lip. The wing is very oblique forming a rather large angle (about 68°) with the axis. Posterior edge of the wing as in *Anchura* and *Drepanochilus* with a very deep furrow on the inner side. Anterior edge forming a thick, prominent, blunt lobe somewhat similar to the lobe in *Perissoptera*.

This peculiar aporrhaid combines characters known from *Drepanochilus*, *Anchura* and *Perissoptera*, and may possibly be given genus rank. *Anchura* s. str. is according to Sohl (1960, p. 105) restricted to the Upper Cretaceous; *Perissoptera* ranges according to Wenz (1938-44, p. 924) from Neocomian to Danian. The new subgenus or genus shows, like *Perissoptera*, some Mesozoic features not known elsewhere in aporrhoids from the Tertiary.

Tornatellaea Conrad 1860, *Ravniella* subgen. nov. named after J. P. J. Ravn. Type: *Cinulia danica* Ravn 1902.

This new subgenus corresponds in nearly all details with *Tornatellaea* s. str. (type: *Tornatellaea bella* Conrad 1860, Eocene). It differs in being provided with a marked parietal fold. *Tornatellaea* s. str. possesses two, and



0 1 2 3 4 5mm

Triploca three columellar folds, thus *Ravniella* takes up an intermediate position. The inner lip in *Ravniella* is crenate, sharply in the type species, less sharp in the younger species (apart from a species from the Babica clay in Poland).

The new subgenus has a rather wide geographic range within the Paleocene. The type species (fig. 10) originates from the Cerithium limestone in Denmark (lowermost Danian). In the Lower Danian *Propeamussium* Member of the Kangilia Formation a stouter species (fig. 10) occurs and in the Agatdal Formation a still larger species close to *Ravniella regularis* (v. Koenen) (fig. 10) from the Lower Selandian has been met with. Furthermore *Ravniella* is represented in the Paleocene Babica clay from the Polish Carpathians and in the Paleocene from Haunsberg (Kroisbach) bei Salzburg in Austria.

The molluscan assemblages from the Lower Danian and especially the fauna from the *Thyasira* Member contain a considerable number of *Thyasira* shells. In the lower community *Thyasira* (*Conchocele*) *conradi* is very abundant and associated with the fauna including *Nucula*, *Astarte*, *Thyasira pfaffi* and lucinids (*Miltha*, *Phacoides*). This fauna lived on soft, black mud or on coarse-grained tuff. In the *Propeamussium* Member *Thyasira pfaffi*, *Th. deLorioli* and a new *Thyasira* are of rather common occurrence and often associated with the genera *Nuculana*, *Nucula*, *Myrtea*, *Pecten*, *Propeamussium*, *Astarte*, *Cuspidaria*, *Aporrhais* and *Dentalium*. This community is also comparable with modern *Thyasira* assemblages and lived on a bottom consisting of black mud (see Kaufmann 1967, p. 33).

Crustaceans: From Turritelakløft a third, new raninid has been collected in concretions from black shales. Derived concretions with the same raninid and *Propeamussium* have been found in the *Gilbertina* conglomerate (fig. 5) belonging to the Agatdal Formation together with derived *Hoploscaphtes*-carrying concretions. This means that in the upper Danian, Upper Campanian as well as Lower Danian strata were exposed to erosion. A few valves of an *Arcoscalpellum* originate from a large concretion from Serfat on the north coast.

The concretions from the *Propeamussium* Member in many cases contain coarse grains of quartz derived from the Precambrian; in two cases derived ammonite concretions from the Senonian have also been met with, one with a *Pseudophyllites?* sp. (Angnertuneg) and one with a fragment of a *Discoscaphites* (Serfat).

Fig. 10. 1. *Tornatellaea* (*Ravniella*) *danica* (Ravn). (MMH, 10799). Stevns Klint, Denmark. Lowermost Danian. 2. *Tornatellaea* (*Ravniella*) *groenlandica* sp. n. (MMH 10800). Tunorssuaq. Lower Danian, Kangilia Formation, *Propeamussium* Member. 3. *Tornatellaea* (*Ravniella*) aff. *regularis* (v. Koenen). MMH 10801). Agatdal. Upper Danian, Agatdal Formation, Sonja lens. 4. *Tornatellaea* (*Ravniella*) *regularis* (v. Koenen). (MMH 10802). Copenhagen. Lower Selandian. (G. J.)

Upper Danian

Agatdal Formation

On the north coast of Nûgssuaq this formation is possibly represented by conglomerates (Angnertuneg) and sandstones (Kangilia and Serfat) resting on shales belonging to the *Propeamussium* Member of the Kangilia Formation. So far no fossils have been collected at these localities. In 1811 K. L. Giesecke (1910, p. 343) found at "Tupaursarsoit" (= Ujaragtôrssuaq), east of Ikorfat, a piece of fossiliferous, conglomeratic sandstone (mud cake conglomerate) containing pelecypods. He thought that the pelecypods were of Quaternary age and referred them to *Venus islandica* and *Mya truncata*. Fortunately this piece of rock has been preserved in the collections of the Mineralogical Museum. The "*Venus islandica*" is in reality a *Venericor* (fragments of a right and left valve) known from the Upper Danian Agatdal Formation in the Agatdal region. The "*Mya truncata*" is the smooth internal cast of the same species. We have still not succeeded in finding this interesting rock in situ on the north coast. The youngest in situ rock at Ujaragtôrssuaq seems to be the *Propeamussium* Member of the Kangilia Formation (K. Raunsgaard Pedersen, 1967).

In the interior of the peninsula the Agatdal Formation is developed as the most fossiliferous of all the marine formations in West Greenland; more than 600 species of marine animals have so far been collected. The Agatdal Formation here rests unconformably on the Kangilia Formation or on older formations (fig. 4).

The Sonja and *Turritella* Members contain the largest fauna found and occur in particular in Turritellakløft, in northern Agatdal, Qaersutjægerdal, Nuilersarssuaq and the northern branch of the Navssât river.

In the following account only the genus name has been given for many forms; most of these forms will certainly turn out to be new species. Others are marked so as to show affinities with previously known species from the Middle Danian of Dano-Scania, the Lower Selandian (Heersian) in Denmark, the Montian in Belgium and the Paleocene-Eocene in France. The Danish aragonite molluscan fauna from the Upper Danian is only insufficiently known, the shells having been dissolved. The few species known show greater affinity to the Lower Selandian and Montian than to the Middle Danian (Faxe).

Agatdal Formation, Sonja and *Turritella* Members

Foraminifera are mostly found in the fillings of gastropods and have been treated by H. J. Hansen (1970, in press). The fauna comprises 57 species distributed among 41 genera. 8 species are new. The dominant species are in particular *Quinqueloculina plummerae* Cushman & Todd and *Q. naheolensis* Cushman. The benthonic part of the fauna shows great similarity to the Danian and Lower Selandian (Heersian) faunas in Denmark. Meanwhile the presence of *Globoconusa daubjergensis* (Bronniman) indicates Danian and *Chiloguembelina crinita* (Glaessner) as well as *Globigerina compressa* Plummer place the deposit in the Upper Danian.

Scleractinian corals: Nine species have been collected, five of which were already present in the Lower Danian. The affinity with the coral faunas from North America and Peru already mentioned for the Lower Danian was apparently reinforced during upper Danian time (Florin 1967).

Octocorallia: In the Sonja lens numerous axis-fragments of a *Graphularia* similar to *Gr. groenwalli* Brünnich Nielsen from the Middle Danian of Faxe and an axis-fragment of a *Gorgonella*, a genus also known from the Danian in Denmark, are found.

Crinoids: Stems of *Isselocrinus*.

Asteroids: Isolated marginal plates from the Sonja lens comprising *Lophidiaster* cf. *postornatus* Wienberg Rasmussen, *Teichaster* sp. and *Ceramaster* sp. Similar species are known from the Danish Danian, the *Lophidiaster* from the Upper Danian in Denmark.

Echinoids: Spines and plates of a cidarid are rather common together with a *Hemiaster*.

Serpulids: From the Sonja lens *Ditrupa* (*Ditrupa*) aff. *schlotheimi* Rosenkrantz and *Ditrupa* (*Pentaditrupa*) aff. *interjuncta* Ødum, both of which occur in the Danish Danian; *Spirorbis* div. sp.

Bryozoans mainly collected in the Sonja lens comprise numerous fragments but only few species. The character of the fauna seems to be indigenous like the ostracods, and shows no similarity to the Danish Danian. The big difference in facies between the West Greenland and the Danish Danian may be the explanation.

Brachiopods: Only a few specimens of *Terebratulina* and *Argyrotheca* have been secured from the Sonja lens.

Pelecypods: The total number of species approaches 100. In the following C. means Cannonball, D. Danish Danian, F. French Paleocene and Eocene, M. Montian and S. Selandian (Heersian). The following list gives an idea of the faunal character:

Nucula aff. *planimarginata* Meek & Hayden C.; *Nucula densistria* v. Koenen S.; a smooth *Nucula*; *Nuculana* aff. *mansfieldi* (Stanton) C.; *Nuculana* aff. *ovoides* (v. Koenen) S.; *Nuculana* aff. *thomi* (Stanton) C.; *Cucullaea* ("Latiarca"), a large species comparable in size to *Cucullaea crassatina* Lamarck F. and *Cucullaea gigantea* Conrad (Aquia) – similar but smaller species are *Cucullaea solenensis* Stanton C. and *Cucullaea dewalqui* v. Koenen S.; *Arca* (*Arca*), two species, one similar to *A. biangula* Lamarck F.; *Arca* (*Cucullaria*) cf. *heterodonta* Deshayes F.; *Arca* (*Acar*) cf. *lamellosa* Deshayes F.; *Arca* (*Barbatia*) aff. *scabrosa* Nyst F.; *Barbatia* div. sp.; *Trigonodesma* aff. *bruennichi* (Ravn) D. but larger; *Trigonodesma* (*Scapularca*); *Arca* (*Cucullaearca*) cf. *morlieri* (Deshayes) F.; *Nemodon* aff. *bruennichi* (Ravn) D.; *Nemodon* n. sp.; *Glycymeris* larger but similar to *G. subimbricata* (Meek & Hayden) C.; *Limopsis*; *Venericor* aff. *duponti* Cossmann M.; *Venericardia* cf. *roedeli* Ravn S.; *Astarte*; *Bathytormus* aff. *protexta* Conrad (Claiborne); *Verticordia* aff. *granulosa* Ravn S.; *Diplodonta*; large *Thyasira*; *Thyasira pfaffi* Ravn; *Phacoides* + div. lucinid species; *Nemocardium* aff. *semidecussatum* (v. Koenen) S.; *Arctica* aff. *ovata* (Meek & Hayden) C.; *Veniella*; *Meretrix* (*Callista*) aff. *montensis* Cossmann M.; *Meretrix* (*Pitaria*) aff. *duponti* Cossmann M.; *Dosiniopsis* aff. *deweyi* (Meek

& Hayden) C.; venerids div. sp.; *Tellina* (*Macaliopsis*); tellinids div. sp.; *Sanguinolaria*?; *Solecurtus*; *Pholadomya*; *Thracia* aff. *prestwichi* Deshayes F.; *Caestocorbula* aff. *koeneni* (Cossmann) S.M.; *Cuspidaria*; *Martesia* two species; *Turnus*; *Teredo*; *Pycnodonte*; *Crassostrea*; *Gryphostrea* aff. *lateralis* (Nilsson) D.; *Anomia*; *Plicatula*; *Spondylus*?; *Pecten* sp. anterior ear, the only remain of pectinids found; *Lima* two species; *Pteria*; *Isognomon* aff. *lamarcki* Deshayes F.; *Brachydontes* (*Arcuatula*?); *Modiola* (*Amygdalum*?); *Lithophaga*; *Pinna* close to undescribed species from the Danian and Selandian; *Stegoconcha* aff. *faxense* (Ravn) D. S. (fig. 11); *Stegoconcha* large species with coarse sculpture.

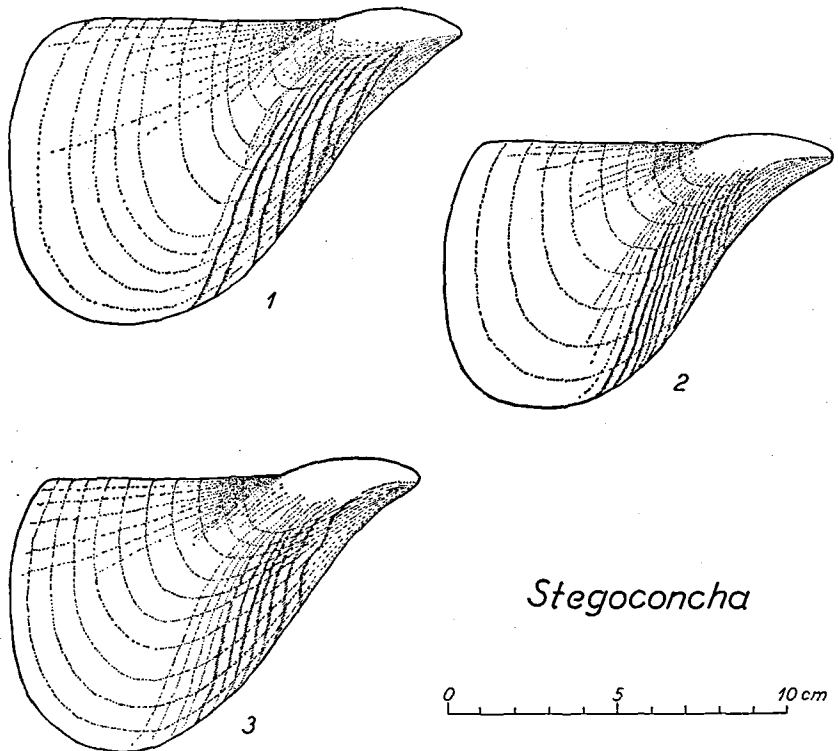


Fig. 11. 1. *Stegoconcha faxensis* (Ravn). (MMH, 4). Faxe, Denmark. Middle Danian. 2. *Stegoconcha* sp. n. (aff. *faxensis* (Ravn)). (MMH, 10803). Klintebjerg, Denmark. Lower Selandian. 3. *Stegoconcha* sp. n. (aff. *faxensis* (Ravn)). (MMH, 10804). Turritellakløft. Upper Danian, Agatdal Formation, Turritellakløft Member. (E. N.)

Apparently two species of the Mesozoic genus *Stegoconcha* are present. The smallest is very close in shape and size to *Stegoconcha faxensis* (Ravn, 1902) from the Middle Danian of Faxe and Upper Danian of Scania, but has some more radial ribs. A somewhat younger species very like these occurs in the Danish Lower Selandian but is provided with still more numerous radial ribs. These species, representing the last members of the

genus *Stegoconcha* which started in the Upper Jurassic, have not been recognised in other Paleocene deposits. The second species from the Agatdal Formation attains much bigger size than the forms mentioned and is decorated with a much coarser sculpture. *Stegoconcha faxensis* measures 131 mm in length and 95 mm in height, the large Greenland species 190 mm and 137 mm.

Scaphopods: *Dentalium groenlandicum* Ravn, *Fissidentalium*; *Laevidentalium*; *Cadulus*; *Gadila groenlandica* (Ravn); *Pulsellum*.

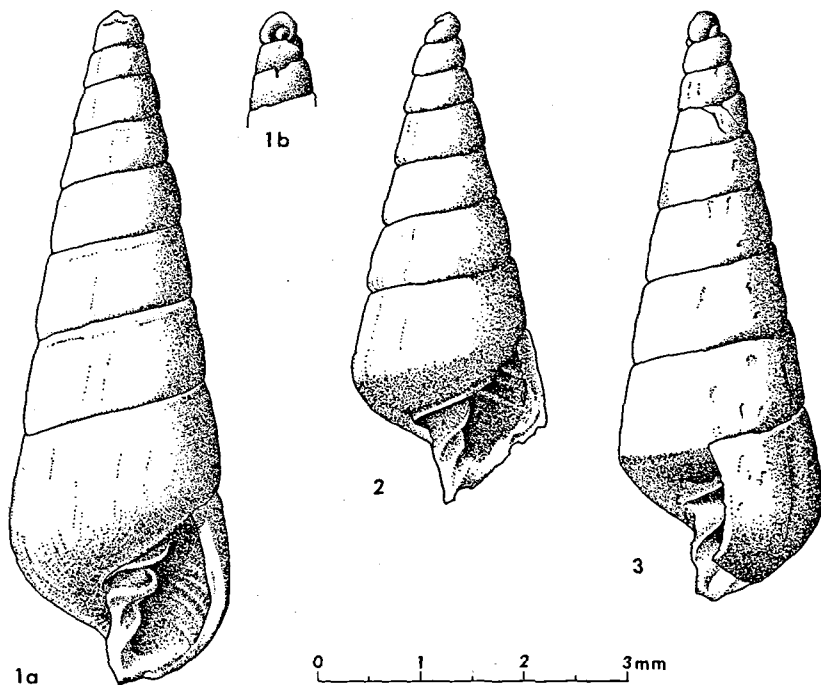


Fig. 12. 1a and 1b. *Creonella triplicata* Wade. Topotypes. U.S. Nat. Museum. No. 10198. Coon Creek, Mc Nairy County, Tennessee. Upper Senonian, Ripley Formation. 2 and 3. *Creonella sonjae* sp. n. (MMH, 10805 and 10806 (holotype)). Agatdal. Upper Danian, Agatdal Formation, Sonja lens. (H. E.)

Creonella sonjae sp. n.

This particular species, named after Sonja Alfred Hansen, accords with the diagnosis for *Creonella* given by Sohl (1964, p. 310) and is rather close to *C. triplicata* Wade from the late Campanian-Maastrichtian of U.S.A. The new species differs from *triplicata* in being less slender, in the teleconch having only nine whorls, and in having only three to four sharp spiral ridges inside the aperture. Moreover the median fold on the columella is oblique instead of horizontal.

Gastropods dominate the fauna and exceed 300 species in number.

Archaeogastropoda: *Scissurella*; *Emarginula*; *Hemitoma*; *Rimula*; *Diodora*; *Fissurella*; *Patella* div. sp.; *Scurria*? aff. *subglabra* (Ravn) S.; *Scurria* div. sp.; *Acmaea* aff. *poulsenii* Ravn S.; *Acmaea* div. sp.; *Basilissa*; *Clanculus*; *Danilia* aff. *incerta* (Briart & Cornet) M.; *Gibbula* (*Phorculus*) *briarti* (G. Vincent) M.; *Calliostoma* aff. *princeps* Cossmann M.; *Osilinus* aff. *carinata* Ravn D.; *Pseudoninella*; *Teinostoma*; *Boutilliera*?; "*Bayania*" aff. *obtusata* (v. Koenen) S.; *Nerita* s. str. div. sp.?; *Amphinerita* n. sp.; *Neritoplica* sp. n. + div. sp.

Mesogastropoda: *Valvata*; *Pseudocirsope*; *Cirsope*; *Entomope*?; *Littorinopsis*; Hydrobiidae 5–6 species; *Goniatogyra*; *Rissoina* s. str. 2 species; *Alvania* s. str.; *Taramellia* 5–6 species; *Pezantia*? 2 species; *Adeorbis* aff. *simplex* Briart & Cornet M.; *Mesalia* 3 species; *Haustator* a large species often occurs current-orientated densely covering the bedding planes of the sandstones; *Turritella* s. str. 3 species; *Promathilda* (*Clathrobaculus*); *Mathilda* div. sp.; *Fimbriatella* div. sp.; *Acrocoelum* 2 species; *Gegania* 2 species; *Pseudomalaxis*; *Architectonica*; *Metacerithium*; *Semivertagus*; *Cerithium* (*Theridium*?); *Campanile* + div. cerithids; *Cerithiopsis*; *Cerithiella*; *Epetrium*; *Triphora*; *Hemiacirsa*; *Cerithiscalca*; *Acrilla* aff. *elegans* Ravn D.; *Acrilla* aff. *bruennichi* Ravn S.; *Coniscalca*; *Margineulima*?; *Odostomia* div. sp. *Turbonilla* aff. *beyrichi* v. Koenen S.; *Creonella sonjae* sp. n. (fig. 12).

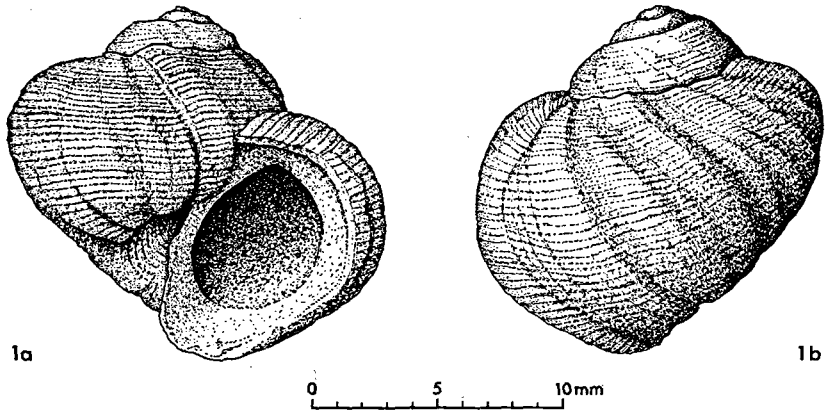


Fig. 13. 1a & 1b. *Vanikoropsis skoui* sp. n. (MMH, 10807). Holotype. Agatdal. Upper Danian, Agatdal Formation, Sonja lens. (E. N.)

Vanikoropsis skoui sp. n.

A few specimens of this peculiar species, named in honour of the late Kristian Skou, have been obtained from the Sonja lens. The diagnosis of *Vanikoropsis* given by Sohl (1967, p. 22) covers completely this thick-shelled naticiform creature. In shape and height of the spire the new species accords with the holotype of *Vanikoropsis tuomeyana* (Meek & Hayden) which also is the type of the genus, but has a finer spiral sculp-

ture like the sculpture of *Vanikoropsis nebrascensis* (Meek & Hayden). However this last species is provided with a much higher spire than the *skoui*. So far the Danian species is the last known representative of this Mesozoic genus.

Arrhoges (Latiala) paleocaenica sp. n.

This new subgenus of Sohl (1960, p. 101) has hitherto only been met with in the uppermost Cretaceous but has a late representative in the Upper Danian of West Greenland showing a somewhat similar sculpture, a terminal thickening of the outer lip and no internal grooving of the lip. The Danian species differs from the Cretaceous species in having the bilobation of the outer lip less marked, in having a shorter rostrum and some faint spiral sculpture on body and whorls.

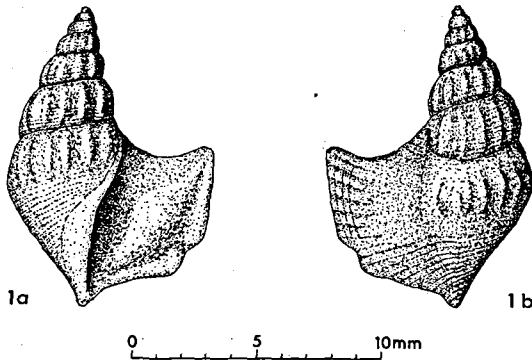


Fig. 14. *Arrhoges (Latiala) paleocaenica* sp. n. (MMH, 10808). Holotype. Agatdal. Upper Danian, Agatdal Formation, Sonja lens. (E. N.)

Hipponyx? inevolatus (Briart & Cornet) M.; *Hipponyx* div. sp.; *Vanikoropsis skoui* sp. n. (fig. 13); *Calyptraea* aff. *montensis* Cossmann M.; *Calyptraea* sp. n.; *Crepidula* a large species; *Arrhoges (Latiala) paleocaenica* sp. n. (fig. 14); *Drepanochilus* aff. *koeneni* (Grönwall) S.; *Drepanochilus* (subgenus nov?) sp. n., the wing provided with a notch near the end of the rostrum, two strong spiral keels on the body but no ribs, strong ribs on the older whorls, some of them developed as varices somewhat similar to the varices in *Drepanochilus quadriliratus* (Wade); *Aporrhais (Aporrhais)* sp. n.; *Columbellina?*; *Palaeocypraea* sp. n.; *Palaeocypraea* aff. *suecica* Schilder D.; *Eocypraea* 2 species; *Cypraeacea* div. species; *Ampullina* aff. *lavellei* (Briart & Cornet) M.; *Tylostoma* aff. *ampullariaeforme* Ravn D. (fig. 15); *Polinices* sp. n. (one specimen contained a lot of foraminifera, small gastropods and ostracods corresponding to the food of the animal in recent species); *Lunatia* aff. *detracta* (v. Koenen) S.; *Lunatia* aff. *detrita* (v. Koenen) S.; *Tectonatica* aff. *lindstroemi* (v. Koenen) S.; "*Galeodea*" aff. *elongata* (v. Koenen) S.; *Sassia* 3 species; *Hilda?*; *Ficopsis*; *Priscoficus* 2 species.

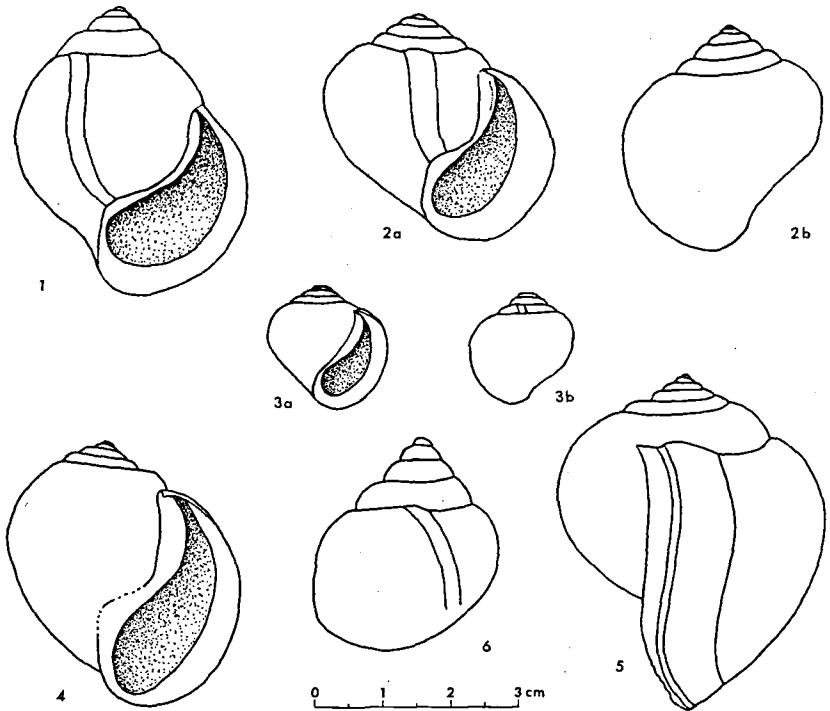


Fig. 15. 1. *Tylostoma ampullariaeforme* Ravn. (MMH, 8). Faxø, Denmark. Middle Danian. 2-5. *Tylostoma* sp. n. aff. *ampullariaeforme* Ravn. Nûgssuaq. Upper Danian, Agatdal Formation. 2, 4 and 5. (MMH, 10809, 10810 and 10811). Turritellakløft. Turritellakløft Member. 3. (MMH, 1012). Agatdal, Sonja lens. 6. *Tylostoma? ciplense* Vincent. (after Vincent 1930, p. 25). Ciplø, Belgium. Middle Danian. (E. N.)

Tylostoma sp. n.

Naticids referred to the genus *Tylostoma* Sharpe have been reported from the Middle Danian in Denmark (corallian limestone, Faxø) and Belgium (Poudingue, Ciplø), and the Danian in Austria (Bruderndorf): from Denmark and Austria *Tylostoma ampullariaeforme* Ravn (1902, p. 217), Kühn (1960, p. 164), and from Belgium *Tylostoma? ciplense* Vincent (1930, p. 25). In the Upper Danian of Nûgssuaq more than 20 specimens of a *Tylostoma* representing a new species, according to height of spire something between the two species just mentioned, have been collected.

The genus *Tylostoma* s. str. ranges from the upper Jurassic to the Maastrichtian and the Danian species mentioned are to be considered Mesozoic survivors in the lowermost Paleocene. Meanwhile the Danish and Greenlandic specimens differ from the smooth Mesozoic *Tylostoma* s. str. in possessing a delicate sculpture consisting of fine spiral cords and

numerous very faint ribs, both elements provided with small tubercles. These ribs are not to be confused with the broad varices. The outer varices (as well as the corresponding internal grooves) in *Tylostoma* s. str. are arranged in two rows at right angles to each other. In the Danish and Greenlandic species the arrangement is as a rule irregular. These differences, especially the possession of a sculpture, possibly means that the Danian forms ought to be referred to a new subgenus, but they are without doubt derived from the Mesozoic *Tylostoma* s. str. and represent the last members of the old Mesozoic stock.

Neogastropoda. *Pterochelus* aff. *nanus* (Ravn) S.; *Poirieria*; *Favartia*?; "Magilus" a dubious forerunner for the recent genus *Magilus*, also known from the Middle Danian of Faxe; *Columbellopsis*?; *Siphonalia* 2 species; *Austrofusus*?; *Laevibuccinum*; *Cominella*; *Janiopsis* div. sp.; *Polliia*; *Suessonia*; *Buccinidae* div. sp.; *Levifusus* aff. *moerchi* (v. Koenen) S. + div. sp.; *Sycostoma* aff. *striata* (v. Koenen) S.; *Clavilithes* aff. *hauniensis* (Ravn) S.; *Taioma* (Wangaloan); *Buccinofusus* 2 species; *Pseudoliva* aff. *robusta* Briart & Cornet M., same size and shape, but spiral sculpture coarser like in *P. prima* Defrance F.; *Pseudoliva*, a large species with a very low spire; *Sparella* aff. *buccinoides* Lamarck M.; *Conomitra* 2 species; *Fusimitra* aff. *glabra* Ravn D.; *Fusimitra* aff. *subglabra* Ravn D.; *Fusimitra* 2 species; *Mitra*? 2 species; *Eocithara*?; *Volutoorbis* aff. *nodifera* (v. Koenen) S.; *Cryptochorda* sp. n. provided with spiral cords all over the body and whorls and with a strong callus on the inner lip; *Scaphella*; *Volutidae* div. sp.; *Merica*; *Bonnelitia* aff. *conoidea* (v. Koenen) S.; *Bonnelitia* aff. *curta* (v. Koenen) S.; *Bonnelitia* aff. *latesulcata* (v. Koenen) S.; *Bonnelitia* div. sp.; *Sveltia* aff. *angulifera* (v. Koenen) S.; *Sveltia* aff. *multistriata* (v. Koenen) S.; *Sveltia* aff. *planistria* (v. Koenen) S.; *Surcula* aff. *hauniensis* (v. Koenen) S.; *Surcula* aff. *laeviuscula* (v. Koenen) S.; *Surcula* aff. *torelli* (v. Koenen) S.; *Surcula* ("Cochlespira") aff. *koeneni* (Arkhanguelsky) S.; *Surcula* div. sp.; *Gemmula* 2 species; *Hemipleurotoma* aff. *gryi* Ravn S.; *Graphidula* aff. *crassistria* (v. Koenen) S.; *Graphidula*? sp. n.; *Borsonia*? sp. like a species from Faxe D.; *Borsonia* (*Cordieria*), like a species from Faxe D.; *Raphitoma* 2 species; *Genota*? aff. *brevior* (v. Koenen) S.; *Genota* (*Pseudotoma*) aff. *steenstrupi* (v. Koenen) S.; *Genota* (*Pseudotoma*) aff. *inconspicua* (v. Koenen) S.

Opisthobranchia, *Acteon* aff. *pusillus* Ravn S.; *Acteon* 3 species; *Tornatellaea* (*Ravniella*) sp. n. aff. *regularis* (v. Koenen) S. (fig. 10); *Crenilabium* aff. *elata* (v. Koenen) S.; *Ringicula* (*Ringiculina*) sp. n.; *Gilbertina* sp. n. aff. *ultima* (v. Koenen) S.; *Acteocina* sp. n.; *Cylichna*? aff. *discifera* v. Koenen S.; *Roxania* aff. *clausa* (v. Koenen) S.; *Retusa* aff. *plicatella* (v. Koenen) S.; *Traliopsis* (*Traliopsis*) sp. n. M.

A preliminary calculation of the composition of the Agatdal gastropod fauna gives:

Archaeogastropoda	14.40%	} 100%
Mesogastropoda	48.15%	
Neogastropoda	37.45%	

The opisthobranchia amount to 5.82 % of the total fauna.

This preliminary result shows that compared with the fauna of the Maastrichter Tuff-Kreide (Uppermost Maastrichtian; Sohl, 1964, p. 156) the Neogastropoda are present in nearly the same strength, the Mesogastropoda are more numerous and the Archaeogastropoda less numerous than in the Maastricht fauna. The Opisthobranchia are proportionally equally numerous in the two faunas. However, compared with the late Upper Cretaceous of North America (Navarro Group and Ripley Formation) the picture is different. Here the *Neogastropoda* are much more strongly represented and the Archaeogastropoda less well represented than in the Upper Danian of West Greenland and thus these American Upper Cretaceous faunas seem to be more developed, probably due to their geographical placing.

Nautiloids are very rare. A somewhat crushed specimen of a *Hercoglossa* was collected together with some indeterminable fragments.

The molluscan fauna of the Agatdal Formation shows strong affinities with the Middle Danian (Faxe) and Lower Selandian of Denmark. The Lower Selandian is characterised by *Globorotalia angulata* White (Hansen, 1968) and is thus a little younger than the Upper Danian. Unfortunately the aragonite molluscs of the Upper Danian in Denmark are very little known. The strata consist of pure limestone and therefore the aragonite shells are extremely badly preserved. The few forms which allow me to have an opinion about their nature belong to forms which are close to the Selandian species. 11 species of molluscs with calcite shells from the Lower Selandian are identical or very close to well preserved species from the Upper Danian. This means that one may assume that the aragonite-shelled fauna of the Upper Danian of Denmark must have been similar to the rich fauna of the Agatdal Formation which for many reasons must be Upper Danian in age.

Crustaceans: The Sonja lens contained a few valves of an *Arcoscalpellum* and of a balanomorph cirriped.

Together with the foraminifera and small gastropods found in the very fine-grained fillings of a *Polinices* from the *Gilbertina* horizon in Turritella-kløft and of several gastropods from the Sonja lens, a small collection of ostracods has been procured.

This little fauna comprises, according to Szczechura (in press) 96 specimens representing 39 species distributed among 23 genera belonging to the suborders Cladocopina, Platycopina and Podocopina.

The following genera have been recognised: *Polycope*, *Cytherella*, *Cytherelloidea*, *Bairdia*, *Pontocypris*, *Argilloecia*, *Paracypris*, *Brachycythere*, *Kikliothere*, *Cytheretta*, *Cyamocytheridea*, *Cushmanidea*, *Hemicytherura*, *Orthonotacythere*, *Paracytheridea*, *Leguminocythereis*, *Loxoconcha*, *Schlerochilus*, *Munseyella*, *Bradleya*, *Hazelina*, *Xestoleberis* and *Uroleberis*.

The ranges of the genera differ markedly. Some of them are known from the Paleocene to Recent, others range from Jurassic or Cretaceous up to Recent time. The genera *Bradleya*, *Cushmanidea*, *Cyamocytheridea*, *Cythere*, *Leguminocythereis*, *Munseyella* and *Uroleberis* do not seem to have been recognised from earlier than the Paleocene or even Eocene or Oligocene. One genus, *Schlerochilus*, is not known earlier than the Miocene.

Together with the genus *Orthonotacythere*, ranging from Jurassic to Paleocene, the seven genera mentioned suggest Paleocene age for the Agatdal assemblage.

It is worth mentioning that, due partly to the state of preservation and partly to the fact that many of the carapaces belong to juvenile forms, it has not been possible to assign with certainty any of the forms found to previously known Cretaceous or Tertiary species.

Szczechura therefore considers the fauna indigenous and furthermore says that this fauna does not throw light on the question of the exact age of the deposits.

On the callianassas and crabs Wienberg Rasmussen reports: *Callianassa* is represented by numerous chelae and burrows in the light-coloured sandstones, the walls covered with small black mud balls. At least 10 species of *Callianassa* have been recognised, 7 in the Sonja lens. Crabs: *Laevirana* aff. *gottschei* Glaessner & Withers, known from the Ypressian in England and Germany. The rich representation of raninids in the West Greenland Senonian and Danian together with still undescribed specimens from the Danian and Selandian of Denmark may throw much new light on the evolution of this group. *Necrocarcinus* (*Camerocarcinus*) aff. *arne-soni* (Holland and Cvancara, 1958) is represented by 18 specimens. This species was first described from the Cannonball Formation in Dakota, U.S.A., and is closely related to a *Necrocarcinus* from the Middle Danian of Denmark (Faxe). *Xanthilites* and a few still not identified crabs are also present.

Fish (Bendix-Almgreen, 1969): A rather comprehensive fish fauna has been examined comprising:

Elasmobranchii, Order Selachoidei: *Heterodontus* sp. nov., *Synechodus eocenus* Leriche, *Squatina prima* Winkler, *Squaleus* (*Acanthias*) *orpiensis* Winkler, *Squaleus* (*Acanthias*) *minor* Daimeries, *Scyllium vincenti* Daimeries, *Scyllium minutissimum* Winkler, *Galeus* sp., *Somniosus crenulatus* Arambourg, *Lamna vincenti* Winkler, *Lamna verticalis* Agassiz, *Odontaspis* (*Odontaspis*) *rutoti* Winkler, *Odontaspis* (*Synodontaspis*) *macrota* Agassiz, premut. *striata* Winkler, *Odontaspis* (*Synodontaspis*) *hopei* Agassiz and *Odontaspis* (*Synodontaspis*) *winkleri* Leriche.

Order Batoidei: A Batoid, possibly a *Raja*.

Actionopterygii: Spines and otoliths of an *Arius*, teeth of *Sphyaenodus* and otoliths belonging to about 20 species of teleosts.

The fish fauna in the Kangilia Formation manifests great affinity to the fauna known from the Lower and Middle Danian of Dano-Scania and has some Mesozoic character. In contrast, the fish fauna of the Agatdal Formation shows affinity to the faunas in some younger Paleocene deposits in Europe and also to the Lower Selandian fauna in Denmark. The fish fauna of the Upper Danian in Dano-Scania is at present insufficiently known. Meanwhile there are good reasons to believe that at least some of the fish remains found in the Lower Selandian may be derived from the Upper Danian. That means that the Agatdal fauna may be of Upper Danian age which is in accordance with the evidence from the other faunal elements in this formation.

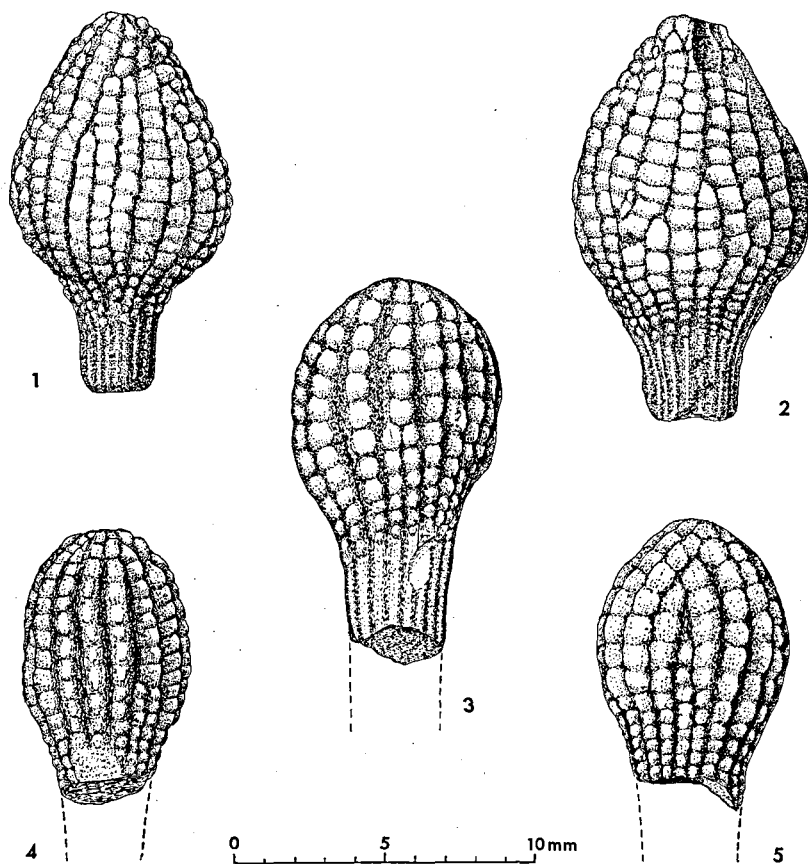


Fig. 16. 1 and 2. Spines of *Tylocidaris* aff. *vexillifera* Schlüter. (MMH, 10813 and 10814). Turritelakløft. Upper Danian, Agatdal Formation, Abraham Member (tuff). 3-5. Spines of *Tylocidaris* aff. *oedumi* Brünnich Nielsen. (MMH, 10815, 10816 and 10817). Kangilia. Lower Danian, Kangilia Formation, *Thyasira* Member (tuff). (E. N.)

Agatdal Formation, Andreas and Abraham Members

Andreas Member. This consists of deltaic deposits and is only fossiliferous in the hard upper sandstone layers. From here badly preserved dendroid corals, and spines of a cidarid have been observed.

Abraham Member. In the tuff layers a small fauna has been collected comprising:

Coral species, most of them also met with in the tuffs from the Kangilia Formation. To date *Dendrophyllia* has not been found.

Echinoids: Long spines and plates of a cidarid and spines of a *Tylocidaris* (fig. 16) in shape close to *Tylocidaris vexillifera* Schlüter, which is characteristic of the Upper Danian in Denmark, but with coarser sculpture.

They seem to be rather close to spines from the Upper Danian in Faxø figured by H. Wienberg Rasmussen (1965, pl. 9, fig. 5) and referred by him to the Middle Danian *Tylocidaris bruennichi* Ravn. In my opinion they form the transition to *Tylocidaris vexillifera* Schlüter.

Pelecypods: Aragonitic shells are badly preserved. *Cucullaea*, *Barbatia*, *Glycymeris*, *Venericardia*, *Astarte* 2 species, *Arctica* aff. *ovata* (Meek & Hayden) C., *Sanguinolaria*?, *Caestocorbula* aff. *koeneni* (Cossmann) S., *Pycnodonte*, *Crassostrea*, *Gryphostrea lateralis* Nilsson D., *Anomia*, *Pteria*. It seems as if the species in this fauna are the same as those occurring in the older members of the Agatdal Formation.

Gastropods: Only two badly preserved species have been collected.

Crustaceans: A scutum, probably of a *Pycnolepas*.

Fish: *Odontaspis (Synodontaspis) macrota* Agassiz, premut. *striata* Winkler. Scales of teleosts.

Marine beds at Marrait kitdlit

At this locality, situated on the south-east coast of Nûgssuaq, a marine, light coloured, calcareous layer, intercalated in a tuff series which is overlain by pillow lavas, was discovered in 1964. This peculiar sediment contains pillows or volcanic bombs, which undoubtedly killed off the marine animals in the sea, and also filled in more or less vertical fissures in the tuff beds. The fauna found comprises foraminifera, bryozoa, gastropods and pelecypods, especially oysters. Several spines of a *Tylocidaris* were collected in 1968 and belong to a species with identical spines found in the Abraham Member in Agatdal. The fauna therefore is undoubtedly upper Danian, but it still needs treatment. This occurrence is interesting because it is situated far from the earlier known localities and seems to embrace faunal elements not hitherto found in the Agatdal area.

The stratigraphical position of the Kangilia and Agatdal Formations

The Kangilia and the Agatdal Formations have been referred to the Danian by the author for the following reasons:

1. The sequence rests unconformably upon the Maastrichtian.
2. No ammonites, belemnites, rudistids, inoceramids or exogyras have been collected in these formations.
3. The faunas of the two formations are so close to each other that they must belong to one and the same sequence.
4. Many of the fossils are identical or closely related to fossils from the type Danian in Denmark.
5. The Kangilia Formation has yielded *Tylocidaris* aff. *oedumi* Brünnich Nielsen, a species characterising the oldest Danian in Dano-Scania; from the topmost part of the Agatdal Formation a *Tylocidaris* has been secured related with *T. vexillifera* Schlüter known from the uppermost Danian in Dano-Scania.

6. The presence of some old "Mesozoic" types such as *Creonella*, *Anchura*, *Latiala*, *Tylostoma* and *Vanikoropsis*, which are not known from younger Paleocene deposits, also support the dating as Danian.
7. The nautiloids belong to genera well known from the Danian.
8. The occurrence of *Globoconusa daubjergensis* (Bronniman) in the Sonja lens indicates Danian; *Chiloguembelina crinita* (Glaessner) and *Globigerina compressa* Plummer place the Agatdal Formation in the Upper Danian.

By means of *Tylocidaris* spines the Danian in Dano-Scania has been divided into four zones:

Rosenkrantz 1937		Brotzen 1959	Wienberg Rasmussen 1950
<i>Tylocidaris vexillifera</i> Schlüter	Upper Danian	<i>Tylocidaris herupensis</i> Wind (= <i>T. vexillifera</i> Schlüter) <i>Tylocidaris bruennichi</i> Ravn	Upper Danian
<i>Tylocidaris bruennichi</i> Ravn			Middle Danian
<i>Tylocidaris abildgaardii</i> Ravn	Lower Danian	<i>Tylocidaris rosenkrantzi</i> Brotzen <i>Tylocidaris oedumi</i> Brünnich Nielsen	Lower Danian
<i>Tylocidaris oedumi</i> Brünnich Nielsen			
Cerithium limestone + <i>Tylocidaris</i>			

Maastrichtian

The *bruennichi* Zone comprising the coral limestone in Faxø is nowadays often considered to represent the Middle Danian, and the *vexillifera* Zone alone the Upper Danian (Wienberg Rasmussen, 1950). If we then try to arrange the West Greenland Danian according to the new concept of the Danian in Denmark, we have some difficulties to contend with. Because of the *Tylocidaris* found in the *Thyasira* Member of the Kangilia Formation this member seems to be correspondent with the *oedumi* Zone and the Abraham Member of the Agatdal Formation with the oldest part of the *vexillifera* Zone. An exact correlation of the older members of the Agatdal Formation with the zones of the Danian in Denmark is difficult as no *Tylocidaris* spines are found in the former. They may be equivalent to the Middle Danian (corals, *Tylostoma* and other forms close to Faxø species), but in the Sonja lens typical Upper Danian foraminifera have been found and the majority of the gastropods are close to species from the Lower Selandian which follows the Upper Danian in Denmark and has not many parallels to the Middle Danian of Denmark. The author has chosen to divide the West Greenland Danian into a Lower part and an Upper part, which roughly may cover the old division into Lower and Upper Danian in Dano-Scania.

Climate in upper Danian time in the West Greenland area

The Agatdal flora found in the Upper Danian marine beds and described by B. E. Koch (1963) shows some analogies in composition to the contemporaneous marine fauna with its Mesozoic survivors mentioned above. Thus Koch characterises this flora in the following way (1964, p. 546): "The angiosperms, including several modern genera, are dominant. A few conifers, among which deciduous *Metasequoia occidentalis* (Newb.) Chaney is dominant, have been recorded. The early Tertiary character is due to the survival of some typical Cretaceous genera (for instance a cretaceous species) and to the occurrence of some old groups, such as Cercidiphyllaceae, Trochodendraceae, Platanaceae, Hamamelidaceae, and *Metasequoia*, now monotypic or poor on genera and species".

Based on the percentage of leaves with smooth margins to leaves with denticulate margins, and leaves with dripping point to leaves without Koch (1963, p. 102) comes to the conclusion that the climate in this part of the world in upper Danian time was temperate and that the Agatdal flora shows great similarity in composition to the recent flora from Shui-cha, Central China, the only place where *Metasequoia* is known still living.

The marine fauna of the Agatdal Formation also points to a temperate climate or more likely to a warm temperate climate. In this connection it may be mentioned that the occurrence of big Cucullaeas comparable with a species from the Upper Paleocene Aquia Formation in Maryland and a species from the Thanetian of the Paris basin seems to mean rather warm conditions, the modern relatives living in the Indopacific area. Nautiloids, Cypræids and *Isognomon* point in the same direction whereas the Astartidae, Cyprinidae and Aporrhaidae nowadays are restricted to colder seas (see i.a. Morley Davies, 1934, p. 63).

Ages of the fossil floras

During the last 30 years a certain amount of progress has been made towards the solution of the question concerning the age of the long known Greenland floras from the Cretaceous-Tertiary thanks to the study of the marine layers within the sedimentary sequence. However, up to now it has not been possible to fix the age of the Kome flora and the Ivssorigsoq flora by means of marine elements.

The Atane flora which in Heer's opinion should follow immediately after the Kome flora and be of Cenomanian age, seems according to the new information to belong to the passage Turonian-Senonian. At Ikorfat Raunsgaard Pedersen (1968) has carried out a pollen analysis of the Kome series and the sediments above. In the Kome beds here he has not been able to prove the existence of angiosperm pollen, but nevertheless in the Kome beds at Pátorfik he found a few leaves of angiosperm type and now thinks that the age of the Kome series is Barrémian-Aptian. In the beds above the Kome series at Ikorfat angiospermous pollen appear and increase gradually in number upwards. In the topmost beds of this upper

series a flora of the Atane type was discovered in 1938, for some distance overlain by marine strata belonging to the Upper Campanian. A similar flora was collected in the same year in Vesterfjeld, further east, with apparently marine shales resting on top of the plant bed. Unfortunately no fossils have been found in the shales here. At the type locality for the Atane flora, Atâ, there is only a rather short distance between the flora beds and the overlying marine beds representing the passage Santonian-Campanian. At Alianaitunguaq an Atane flora has been found in beds closely following marine Coniacian shales. It seems therefore that the Atane flora s. str. is of Lower Senonian age. Floral elements found in Upper Turonian-Coniacian marine beds at Umîvik (southern Svartenhuk) and in marine, possibly Cenomanian, shales at Umîarfik (northern Svartenhuk) have still not been analysed. In the diagram fig. 2 an Upernivik Næs flora (B. E. Koch, 1964) is inserted between the Kome and the Atane flora s. str.; this flora spans the gap between the Atane and the Kome series and is characterised by a gradual upwards increase in the amount of angiosperm pollen. The Upernivik Næs series presumably covers Albian, Cenomanian and Turonian.

The age of the Pautût flora (transition Santonian-Campanian) was known before 1938. A contemporaneous flora in marine beds in Agatdal awaits treatment.

The Upper Atanikerdluk flora from limnic beds at Atanikerdluk, Miocene in Heer's opinion (1883), Eocene according to Mathiesen (in L. Koch, 1929, p. 56), is now considered Upper Danian in age, because in Agatdal the same flora has been found in marine, highly fossiliferous beds of Lower Paleocene (Upper Danian) age (see B. E. Koch, 1963).

It has not been possible to determine the age of the interbasaltic Ivssorigsoq flora by means of marine elements. For palaeobotanical reasons B. E. Koch (1964, p. 546) considers the age to be not younger than Eocene.

Palaeogeographical relations

A comprehensive review of the conclusions which have been drawn concerning the sea connections between central West Greenland and other parts of the world during Upper Cretaceous time has been given by Birkelund (1965, p. 163 and table 3, p. 167). Briefly it may be mentioned that there have been sea connections to central North America via the Sverdrup Basin (Tozer & Thorsteinsson, 1962, 1964) and to Europe north of Greenland or through the Davis Strait; for upper Campanian-Maastrichtian time it is necessary to suggest a seaway to the Pacific also via the Arctic Sea.

In the Sverdrup Basin which according to Tozer and Thorsteinsson (1962, 1964) was an area of essentially continuous sedimentation from middle Pennsylvanian to early Tertiary time, marine strata belonging to the Lower Cretaceous (Valanginian, Aptian and Albian) and Upper Creta-

ceous (Santonian-Lower Campanian) have been met with. In the Kanguk Formation fragments of *Sphenoceras*, a genus well represented in West Greenland, have been collected. A marine connection between the West Greenland Basin and the Sverdrup Basin in Santonian-Lower Campanian time must therefore be considered a possibility, and this seaway may have continued to exist during the rest of the Senonian and probably also in Danian time. Within the Sverdrup Basin the Kanguk Formation is overlain by the Eureka Sound Formation. From carbonaceous shales in the middle of this formation some microfossils have been found. McGregor (in Tozer & Thorsteinsson, 1962, p. 67) suggests a marine environment and a Cretaceous age; this means post-Lower Campanian.

Concerning the palaeogeographical conditions in Danian time the following may be said.

On account of the fauna it is beyond all doubt that there was a sea connection with the Danian Sea in Europe and possibly also with the Spitsbergen area. A seaway connecting West Greenland with central North America as in Senonian time can not be excluded. There exists a certain, if not very extensive, faunal agreement between the Greenland Danian and the Cannonball Formation in North and South Dakota. The coral faunas in Greenland moreover show a certain resemblance to those in North America and even Peru, although the connection with the coral fauna in Denmark was much stronger. The presence of certain "Mesozoic" forms such as *Creonella*, *Latiala* and *Vanikoropsis* in the Greenland Danian, the older representatives of which genera are restricted to the Late Senonian of North America but are not known from European Senonian, also points in that direction. Possible faunal connections with Spitsbergen (*Thyasira (Conchocele) conradi* Rosenkrantz) and even with the Wangaloan of New Zealand (*Globisium* and *Taioma*) are faintly indicated. The sea connecting West Greenland with Europe is unlikely to have crossed Greenland; more probably it followed the Davis Strait. Geophysical evidence suggests that a thick sedimentary series covers the Precambrian on the continental shelf off Labrador, and it is likely that the same is the case for the West Greenland banks (see for example Holstedahl, 1970). It is to be hoped that future drilling for oil within these areas will bring forward conclusive evidence on these palaeogeographic problems.

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Dansk sammendrag

Systematiske undersøgelser af de marine Kridt- og Tertiærlag i det vestgrønlandske sedimentbassin (Nûgssuaq og Svartenhuk) tog sin begyndelse med Nûgssuaqekspeditionerne 1938 og 39 og fortsatte på en lang række ekspeditioner efter anden verdenskrig af Grønlands Geologiske Undersøgelse (GGU). Diagrammet fig. 2 giver en oversigt over vort nuværende kendskab til sedimenternes stratigrafi sammenlignet med det kendskab, man havde til lagfølgen før 1938. Heraf fremgår tilstedeværelsen af en del etager og underetager ikke kendt før 1938 karakteriseret gennem forekomsten af stratigrafisk vigtige marine fossiler, nemlig: Cenoman?, Øvre Turon, Øvre og Nedre Coniacien, Nedre Santonien, Maastrichtien og Øvre og Nedre Danien. Konstateringen af disse marine indslag i lagserien har medført, at nogle af Heer's klassiske floraer fra dette område har kunnet tidsfæstes mere nøjagtigt, det gælder Atane floraen og Øvre Atanikerdluk floraen. Derimod har det ikke været muligt på grundlag af marine indslag at tidsfæste Kome floraen og Ivssorigsoq floraen, der dog på phytopalaeontologisk grundlag nu henføres til henholdsvis Barrémien-Aptien og Øvre Eocæn.

Der gives en oversigt over den marine fauna i de forskellige horisonter og i forbindelse hermed diskuteres faunaernes palæogeografiske betydning. Til Øvre Danienets meget store fauna knyttes nogle få bemærkninger vedrørende det datidige klima. Enkelte fossiler af særlig interesse er afbildet og forsynet med foreløbige diagnoser. Det gælder en bemærkelsesværdig Cirriped fra overgangen Santonien-Campanien og nogle vigtige mollusker og echinider (*Tylocidaris*) fra Danienet.

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