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DE DANSKE EKSPEDITIONER TIL ØSTGRØNLAND 1947—56
Under Ledelse af Lauge Koch

THE JURASSIC AND CRETACEOUS SYSTEMS IN EAST GREENLAND

BY

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WITH 25 FIGURES IN THE TEXT AND 4 PLATES

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BIANCO LUNOS BOGTRYKKERI A/S
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PREFACE

This account has been compiled at the request of Dr. Lauge Koch, leader of the Danish Expeditions to East Greenland from 1926 to 1938 and from 1947 up to the present. For a limited part of the area I have been able to draw on my own experience as a member of several of Dr. Koch's expeditions, but the greater part of the work is necessarily a compilation from the reports of the geologists who preceded me in the study of the Jurassic and Cretaceous rocks of East Greenland. I have also incorporated a certain amount of unpublished information from several sources.

I am indebted to Dr. Lauge Koch for his encouragement, and for information and discussion of various problems. While I must take full responsibility for the accuracy of the facts, and the soundness of the opinions, which follow, I have been greatly helped by a number of friends, specialists in various fields, who have given me the benefit of their views and have in most cases read and criticised the appropriate parts of the typescript. They include Dr. W. J. Arkell, especially in the field of Upper Jurassic stratigraphy; Dr. J. H. Callomon, who has placed his knowledge of Callovian ammonites at my disposal; Mr. R. Casey, on Aptian and Albian faunas; Prof. T. M. Harris, who read the draft of the section on the Kap Stewart Formation; and Mr. C. W. Wright, who has given me his views on Berriasian and Valanginian stratigraphy. I am grateful to these people for their willing help. Prof. W. F. Whittard and Mr. J. W. Cowie have kindly read other parts of the typescript.

Dr. H. Bütler, the senior geologist of the Lauge Koch Expeditions, kindly sent me notes on localities visited by him. Dr. J. Sornay, of Paris, who studied the collections of *Inoceramus* made by the Two-Year Expedition (1936—38), generously sent me a list of his unpublished identifications with permission to use them as necessary. Through the courtesy of Dr. L. F. Spath I was able to examine some of the ammonites described by him in his publications on the collections made before 1939.

It remains to pay a tribute to the field geologists who have made this account possible. Their names will be found in the historical and stratigraphical chapters and need not be repeated here. They often

worked under considerable difficulties, and the information now assembled is a testimony to their efficiency and their enthusiasm.

Finally, I would like to thank Miss Ingrid Beck for her assistance during the preparation and publication of the work, and my father for reading the proofs.

Bristol, *May 1956.*

Note on Geographical Names.

As it is obligatory for all place-names mentioned in the *Meddelelser* to be in the Danish form, the following equivalents may be useful to English-speaking readers:

Bjærg = Mountain	Klinter = Cliff
Bugt = Bay	Kløft = Cleft
Dal = Valley	Næs = Ness, point
Elv = Stream	Ø, Øer = Island(s)
Fjeld = Mountain	Pynt = Point
Flod = River	Sund = Sound
Kap = Cape	Vig = Small inlet

I. INTRODUCTION

In Pleistocene times the whole of Greenland was doubtless covered by the ice-cap, but the post-glacial recession has resulted in considerable ice-free areas in which rocks from Pre-Cambrian to Tertiary date are exposed. Recent geophysical work[1]) has shown that the ice-cap is contained between mountain ranges near the east and west coasts. The folding of these ranges is of Lower Palaeozoic or 'Caledonian' date, and on the east coast they are flanked by Upper Palaeozoic, and these in turn by Mesozoic formations. The geological variety in the east is much greater than in the west, where metamorphic rocks are succeeded immediately by Upper Cretaceous sediments. Plateau basalts of Tertiary age, associated with small areas of sediments, are prominent in both East and West Greenland.

The principal outcrops of Jurassic and Cretaceous rocks lie in Central East Greenland[2]) between latitudes 70°25′ and 76°20′ north, that is, between the northern shore of Scoresby Sund and Store Koldewey island, a distance of about 700 km. In this part of East Greenland, which is intersected by fjords, Jurassic and Cretaceous formations constitute a belt up to 80 km in width, which generally forms the easternmost part of the continent. For the purposes of description three regions are recognised, the southern, from Scoresby Sund to Kong Oscars Fjord, comprising Jameson Land and part of Scoresby Land; the central, consisting of Traill and Geographical Society Øer and the peninsula of Hold with Hope; and the northern region, from Clavering Ø to Store Koldewey. The divisions are arbitrary, although Kong Oscars Fjord marks the southern limit of Middle and Upper Cretaceous rocks, and Hold with Hope separates the two principal areas of Jurassic sediments.

South of Scoresby Sund, there are only one certain and two possible occurrences of Mesozoic. At Kap Brewster, which flanks the entrance to the Sund to the south, and at Kap Gustav Holm, undated sediments,

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[1]) See, for instance, Bauer, 1955.

[2]) The term Central East Greenland is here used, as by Koch (1955), for the east coast between latitude 70° and 77° north. In earlier publications this region is sometimes included in North-east Greenland.

possibly Cretaceous, underlie the plateau Basalts. At Kangerdlugssuaq, between latitudes 68° and 69° north, late Cretaceous sediments occur. Except for these solitary occurrences, neither Palaeozoic or Mesozoic sediments are known from East Greenland south of Scoresby Sund, and it is unlikely that any extensive areas of Jurassic or Cretaceous rocks are present, although there may be minor outcrops which have escaped detection.

Very little is known of the coastal region north of latitude 77°. Not a single outcrop of proved Jurassic or Cretaceous age has been reported, but nevertheless the likelihood of new discoveries is probably greater in this area than on the south-east coast. There are several indications that Mesozoic sediments occur, and the principal reason for our present lack of knowledge is the small amount of geological exploration in the region.

II. HISTORY OF RESEARCH

The study of the Jurassic and Cretaceous rocks of East Greenland falls into two periods. Before 1926, the country was visited at irregular intervals by a number of expeditions, some of which carried out geological work. These established the presence of Jurassic and Cretaceous rocks and made known a few faunas in some detail. In 1926 began the series of geological expeditions organised by Dr. Lauge Koch, which pursued systematic investigation of East Greenland geology with an ability and a singleness of purpose which is probably unparalleled in the history of scientific work in the Arctic. The secret of the success of these expeditions has been specialisation, and much of the field work was done by the experts who later carried out the laboratory examination of the collections.

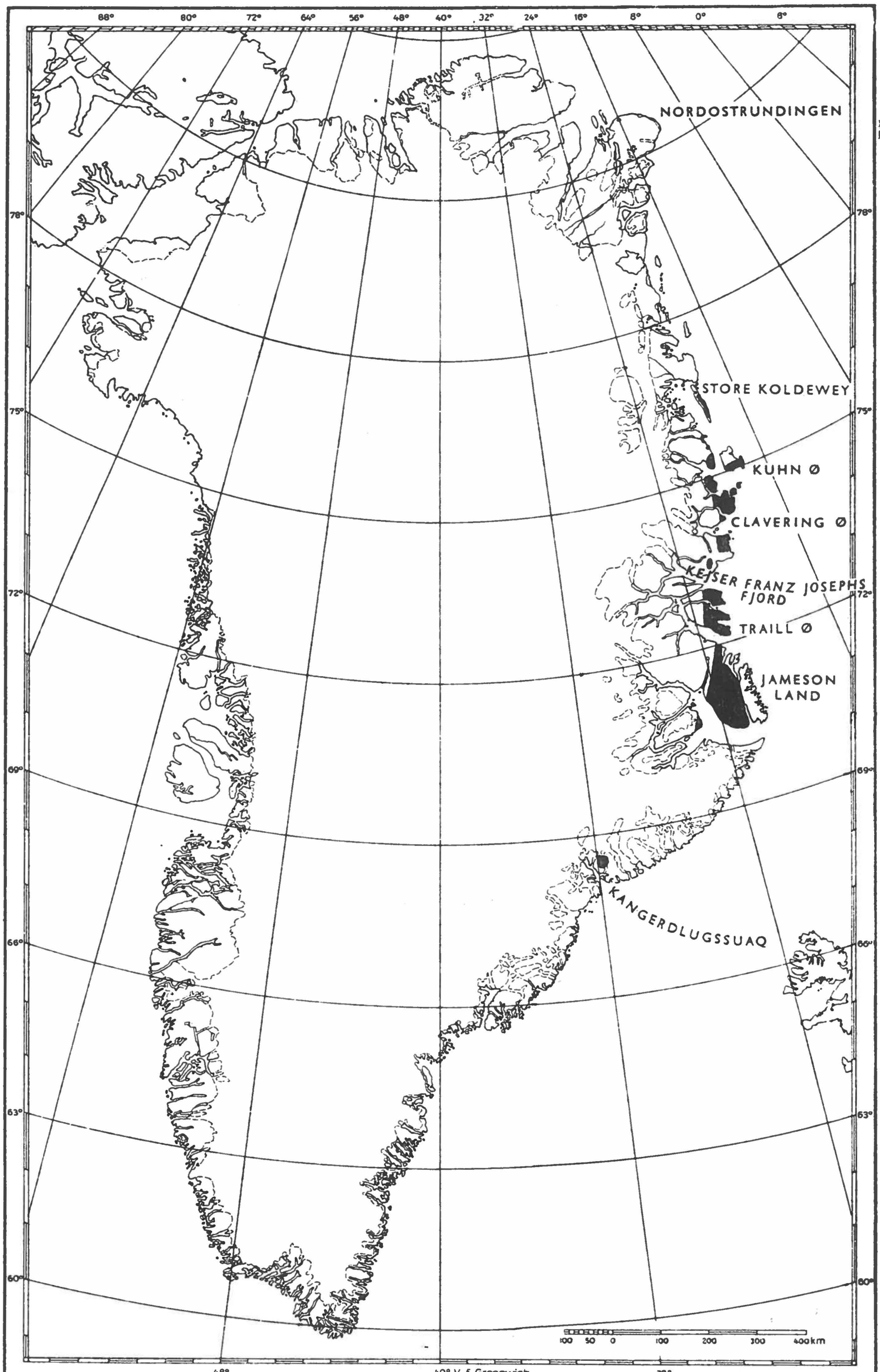
During the first period, the list compiled by Koch (1939, pp. 76—81) shows that eleven expeditions visited the east coast of Greenland north of Scoresby Sund and brought back geological information, but only eight studied Jurassic or Cretaceous rocks. The first to do so was the Second German North Polar Expedition under Captain K. Koldewey, which wintered 1870—71 in the region 75—77° N. lat. and carried two geologists, Copeland and Payer. Their work has been described in some detail by Koch (1929, p. 155 *et seq.*). Hochstetter, to whom the fossils were sent (1874, p. 472), and Koch (*loc. cit.*) have commented that the geological work was carried on in a rather uncoordinated fashion, and in fact practically nothing was established as to the structure or the geographical extent of the outcrops. The fossils collected were described by Toula (1874) and demonstrated the presence of formations of probable Middle Jurassic age in southern Kuhn Ø, and of Lower Cretaceous beds, now known to be Berriasian, near the east coast of the same island. Furthermore, the Jurassic age of some of the sandstones on Hochstetters Forland was guessed correctly, although the beds were wrongly referred to the Lias, together with other occurrences of sandstone which are probably of Tertiary date (Koch, 1929, pp. 156—57; Maync, 1949, pp. 41—42). Toula surmised the presence of marine Rhaetic at Falskebugt, Wollaston Forland, on the basis of a brachiopod identified by Suess, but the beds have since proved to be Valanginian.

The palaeontological results of the German expedition were of little note, with the exception of the new ammonite species described as *Perisphinctes Payeri* by Toula from Kuhn Ø, which has since been included in the genus *Tollia* and is a characteristic fossil in the boreal Berriasian.

The next expedition was the Danish one led by V. Ryder to Scoresby Sund in 1891—92, and was noteworthy for the discovery by N. Hartz of the rich Rhaetic and Lower Liassic flora at Kap Stewart. Hartz published an illustrated account of the flora, recognising 18 species (Hartz, 1896). Marine fossils from a formation above the plant-bearing series were submitted to Lundgren who described and figured an extensive fauna, principally of lamellibranchs, which he assigned to the Callovian (Lundgren, 1895), although his figures include an ammonite fragment which, in the light of later knowledge, is recognisable as belonging to the Pliensbachian *Uptonia*. A general account of the geology was written by E. Bay (1895) who made the first geological map of the area (*op. cit.*, pl. 2), of considerable accuracy for the time.

Ryder's was the first of a long series of expeditions to carry out research in Jameson Land and adjoining areas. In 1899 A. G. Nathorst, leading a Swedish expedition, examined the Jurassic rocks on the western side of Hurry Inlet, and discovered the Oyster Bed near its northern end, 514 m above sea level (Nathorst, 1901), now known to be of Toarcian age. Nathorst also examined the area around Antarctics Havn and guessed that the sandstones there might be Jurassic, although he did not find any diagnostic fossils. His collections were apparently never studied by a palaeontologist (Rosenkrantz, 1934, p. 13).

In 1900 Hartz returned to East Greenland as a member of the Danish Expedition (1898—1900) led by G. C. Amdrup, and conducted extensive work on the western shore of Hurry Inlet. The most important outcome was the discovery of the Callovian ammonite fauna at Vardekløft and other localities, described and figured by Madsen (1904). Fossils from the marine Liassic Neill Klinter Formation were also brought back, but the full sequence of marine Jurassic faunas in the Neill Klinter was still not recognised; for while Lundgren had mistakenly assigned the Liassic mollusca to the Callovian, Madsen, having correctly established the presence of genuine Callovian, thought that all the marine Jurassic fossils were of this date. The Oyster Bed found by Nathorst in the previous year was independently discovered, and was thought by Madsen to be of Upper Bajocian or Lower Bathonian age. Lastly, in connection with the discoveries in Hurry Inlet, may be mentioned the vertebrate remains, the vertebra from Vardekløft identified by Fraas (1904) as of *Ophthalmosaurus*, and an object found near Kap Stewart, believed by the same authority to be a dinosaur footprint, which led to the locality



GENERAL MAP OF GREENLAND. Reproduceret ved Geodætisk Institut. København 1942

Areas of Jurassic and Cretaceous outcrops in East Greenland shown in black.

Fig. 1. General map of Greenland. The outcrops of Jurassic and Cretaceous rocks in East Greenland are shown in black.

being called Dinosaurus Elv; the aptness of this exciting name has been questioned by Rosenkrantz (1934, p. 15) who thought the 'footprint' an accidental mark.

In addition to the discoveries in Hurry Inlet, the 1900 expedition demonstrated an inland extension of the Jurassic beds. Deichmann and O. Nordenskiøld made a journey on foot into the region north and west of the head of Hurry Inlet, and discovered that the whole district up to Fossil bjerget was composed of monotonous, light coloured sandstone "in which fossiliferous banks are not rare, and ammonites are now and again so plentiful that the ground ... is thickly strewn with them" (Nordenskiøld, 1907, p. 187), but few specimens were brought back from these tantalising areas. In south-western Jameson Land, Nordenskiøld discovered a new formation with "*Aucella*" and poor ammonites, believed by Madsen (1904, p. 202) to be the equivalent of the Lower Volgian of Russia. Hartz did more work on the Rhaetic-Lower Lias plant beds, but his collection had to wait a quarter of a century for description by Harris (1926), who studied it at the suggestion of Sir Albert Seward, to whom it had been sent in mistake for a West Greenland collection.

With the Danmark Expedition of 1906—1908, attention was shifted back to the northern area which had been neglected since the visit of the Second German Expedition, nearly forty years before. The geologist was H. Jarner who collected fossils in the course of several sledge journeys, principally from Store Koldewey. Jarner himself never published any observations, nor was any attempt made to construct a geological map. The collections were fortunately submitted to J. P. J. Ravn, of the University of Copenhagen, who published an account of them in 1911. His well-illustrated paper established the presence of Callovian, Oxfordian-Kimeridgian and Valanginian strata and was thus a notable advance on the tantalising, but meagre, results of the Second German Expedition. Ravn's work remains to this day the only work of reference for most of the Jurassic and Cretaceous faunas of the northern part of the east coast.

There was an interval after the Danmark Expedition during which no progress was made with the study of the Jurassic and Cretaceous rocks, and when this period of inactivity ended attention was focussed again on Scoresby Sund, always easier of access than the more northerly part of the east coast, and now with the added convenience of the colony founded in 1925. In 1924 T. Bjerring Pedersen arrived at Scoresby Sund with the party that was shortly afterwards to found the new colony, and collected Jurassic fossils. He died in the summer of 1925, and his notes were edited and published by Rosenkrantz (1929). Pedersen discovered the sedimentary rocks in the Kap Hope area, at the southern end of Liverpool Land, later described in detail by Rosenkrantz (1942) and shown by him to be of Liassic age. In 1925 a French expedition led by J. B. Charcot visited Scoresby Sund, and collected fossils from the marine strata above the Rhaetic-Lias plant beds at Kap Stewart, discovered by Ryder's expedition long before. These were published by Haug (1926), to whom goes the credit for recognising the Pliensbachian age of the fauna which had many years previously been assigned by Lundgren to the Callovian. Haug listed 27 species, including several which he believed to be new, but he thought that some of the forms to which Lundgren had given new names should be attached to well-known European species. Haug's paper is only a summary of his conclusions and Charcot's collection has not been described in detail.

Lauge Koch's first expedition to East Greenland, heralding the second stage of geological investigation, took place in 1926—27. In addition to Dr. Koch himself, who carried out extensive geological reconnaissances by sledge, the expedition comprised two specialists in the Mesozoic: T. M. Harris, the palaeobotanist who concentrated on the Rhaetic-Lower Liassic floras, and A. Rosenkrantz, who studied the marine Jurassic rocks. They worked principally in Hurry Inlet, although Rosenkrantz also visited Kap Leslie, on Milne Land, where sediments had been discovered by Ryder's expedition in 1891—92. For three days in August, 1926, they visited Kap Stewart in company with Charcot, who had returned to Scoresby Sund, and his geologist J. Lacoste, who published a detailed section of the Liassic rocks at this locality (Lacoste, 1928).

Koch made a number of discoveries during his sledge journeys northwards from Scoresbysund to Danmarks Havn and was able to begin to form an idea of the distribution of the Jurassic and Cretaceous rocks, which had not previously been possible. In addition to working on the sediments along the eastern shore of Store Koldewey island, he discovered Valanginian and what were at the time thought to be Portlandian (actually Kimeridgian) fossils to the south of Kap Maurer, on eastern Kuhn Ø, and demonstrated the presence of Kimeridgian and Valanginian rocks on Wollaston Forland.

Harris and Rosenkrantz both came back with collections of great importance. The Rhaetic-Liassic flora, known since Hartz's first visit to Scoresby Sund, was monographed by Harris, and its great variety and excellent preservation made fully known (Harris, 1931—1937). Rosenkrantz published a preliminary account of his findings (1929), and Spath (1932) described the Callovian fauna and its stratigraphic occurrence, including some ammonites collected at Antarctics Havn by M. M. L. Parkinson and W. F. Whittard, members of J. M. Wordie's Cambridge

East Greenland Expedition of 1929. Spath's paper is important, both for the excellent series of Arctic Macrocephalitids and Kosmoceratids figured, including a number of new species, and for its detailed review of occurrences elsewhere. The correlation of the zones recognisable in Greenland with the classical European succession proved to be a difficult problem on account of the almost complete absence of any genera in common to the two areas.

The remainder of the marine fossils collected by Rosenkrantz, of Pliensbachian and Toarcian age, have not received detailed treatment. The outcrops to the west of Hurry Inlet were described by Rosenkrantz in 1934, with long lists of fossils. Some illustrations of the ammonites were published (*op. cit.* pls. 5—8), but the rest of the fauna, numbering over 130 species from the Pliensbachian and over 50 from the Toarcian, remains undescribed, except for the species which had already been dealt with by Lundgren in 1895. The second area of Liassic sediments, in the neighbourhood of Kap Hope at the southern end of Liverpool Land, was also studied, was revisited by Rosenkrantz in 1934 and 1936, and finally described by him in 1942.

In the summer of 1929 Rosenkrantz returned to East Greenland with Lauge Koch's next expedition, but was concerned mainly with pre-Jurassic rocks (Rosenkrantz, 1930b, p. 364). Some collecting was done in the Jurassic but no report was published.

In 1929—30 R. Bøgvad wintered in the northern part of East Greenland in search of possible cryolite occurrences, and during his travels collected Cretaceous fossils from several places. The fossils which he found revealed the presence of Lower and Upper Aptian rocks in eastern Kuhn Ø, and the presence of Albian strata in East Greenland was proved for the first time. Bøgvad's finds were briefly announced by Rosenkrantz (1930) and were later described in full (Bøgvad & Rosenkrantz, 1934).

The first of the two biggest expeditions[1]) led by Lauge Koch before the war, the Danish Three-Year Expedition to North-east Greenland, left Copenhagen on June 16th, 1931, with a varied and extensive geological programme. Many of the members collected Mesozoic fossils and recorded sections, and the results were published by H. Frebold in a number of papers. Frebold himself worked in Hochstetters Forland, establishing the Upper Jurassic age of the coal-bearing sandstones which had been discovered by the Second German Expedition (Frebold, 1932), and in south-western Wollaston Forland where he studied a detailed section through the Jurassic and Cretaceous strata, demonstrating the presence of Upper Jurassic (Callovian and Oxfordian) and Lower Cre-

[1]) A general account of these expeditions has recently been published by Koch (1955).

taceous (Valanginian and Albian) strata (Frebold 1932a, 1932b). The foundations of our knowledge of the Jurassic and Cretaceous in Wollaston Forland were thus laid, although Frebold's work has been criticised by Maync who himself carried out the most thorough examination of the area (Maync, 1949, p. 65). In 1931 also A. Noe-Nygaard and G. Säve-Söderbergh mapped the north-eastern part of Clavering Ø and found Mesozoic rocks which they attributed to the Cretaceous (Noe-Nygaard & Säve-Söderbergh, 1932), but here again their interpretation has been later corrected (see Maync, 1947, p. 106; 1949, p. 102). Noe-Nygaard wintered 1931—32 and surveyed Mesozoic as well as older rocks between Carlsberg and Fleming Fjords (Noe-Nygaard, 1934).

Frebold did not himself return to East Greenland, but he published several more papers describing the collections made by others. The first, on the Upper Jurassic of Kuhn Ø and Hochstetters Forland (1933), was based on material collected by C. Teichert, H. G. Backlund and D. Malmquist in 1932, as well as a collection made by Bøgvad during his wintering already mentioned, and described and figured some species from the northern area in addition to those already known since Ravn's publication of 1911. Most of Frebold's fossils, however, were poorly preserved. The next paper followed in 1934 and was devoted to the Upper Cretaceous (Senonian), which had been discovered in Hold with Hope peninsula, at Knudshoved and Home Forland, by Teichert and Nielsen respectively. This was the first intimation that the Upper Cretaceous, long known in West Greenland, was present also in East Greenland. In his next paper (1935) Frebold published a systematic account of an important Upper Aptian fauna, numbering about 50 species, which had been discovered on the east coast of Store Koldewey by Nielsen in 1933, the third summer of the Three Year Expedition. Nielsen also made a collection of fossils from other formations, principally Upper Jurassic, which has not been described. Frebold's last publication on East Greenland, in collaboration with Noe-Nygaard (1938), described investigations in Traill Ø by the latter in 1932 and 1933 and demonstrated the presence of Jurassic (thought to be Bathonian) and Cretaceous (Neocomian) rocks on the island.

While the members of the Three Year Expedition were collecting Jurassic and Cretaceous fossils in the northern part of the outcrop, another French expedition led by J. B. Charcot revisited the outcrops at Kap Leslie, Milne Land, in the inner reaches of Scoresby Sund, which had been discovered (although not dated) by Bay on Ryder's 1891—92 expedition, and whose Jurassic age had been established by Rosenkrantz (1929, p. 147). After a day's visit to Kap Leslie in 1932, at the suggestion of Dr. Koch, a longer stay was planned for 1933 when M. Parat, P. Drach and others spent ten days there. A short note first made known the

Upper Jurassic age of the sediments and a longer paper followed with details of the sections (Parat & Drach, 1933, 1933a, 1934). In 1933 H. Aldinger, a vertebrate palaeontologist on the Danish expedition, spent a month at Kap Leslie to look for vertebrate fossils, prompted by the find of a Eugnathid by Rosenkrantz in 1927 (Aldinger, 1932). He was disappointed in the primary object of his search, but made large invertebrate collections which were submitted to Spath, who did full justice to the astonishing wealth of fossil material, largely ammonites (Aldinger, 1935; Spath, 1935, 1936). Spath showed that the section covered a period from Upper Jurassic to earliest Cretaceous, many fossil horizons being present. Unhappily it was impossible to establish a succession of ammonites based on field evidence, or to reconcile Aldinger's interpretation with that of Parat & Drach, in spite of the fact that the two parties had co-operated in the field. In 1936 Parat spent two more days on Milne Land, but he and his observations were lost when Charcot's expedition ship, the "Pourquoi-pas?", was tragically wrecked near Reykjavik on the night of the 15/16th September, 1936, with the loss of all hands but one (see Charcot, 1938).

Aldinger also worked on the shores of Hurry Inlet, and in southwestern Jameson Land where he collected basal Cretaceous ammonites from the outcrops discovered by Nordenskiøld in 1900. These were not published until after the Second World War when Spath (1947) announced them to be of probable Berriasian age.

The achievement of the Three-Year Expedition, so far as the Jurassic and Cretaceous systems were concerned, was to make known in detail the stratigraphy of a number of important localities, so that some general conception of the Jurassic and Cretaceous history of East Greenland could be formed. Palaeontological monographs of the first importance had been published by Spath, and a number of fossils were figured in Frebold's papers. The next expedition, also planned and led by Lauge Koch, was the Danish Two-Year Expedition which started in 1936, and had a very ambitious programme. This was the geological mapping, accompanied by stratigraphical investigation, of the coastal area of East Greenland from Scoresby Sund, at latitude 70° N., to Kuhn Ø at 75° N, and was accomplished largely by means of extensive spring travelling by sledge, the parties concerned staying for two successive winters in Greenland. In the northern area—Kuhn Ø, Wollaston Forland, Clavering Ø and Hold with Hope—the mapping was done by W. Maync, and A. Vischer. Jameson Land, Traill Ø and Geographical Society Ø were mapped by H. Stauber, and Scoresby Land by W. Bierther, who joined the expedition for the second winter. Maync systematised the Jurassic and Cretaceous stratigraphy of his area, gave names to all the formations and worked out the lateral changes of facies and the unconformities. The role of tectonics in controlling sedimentation was studied by Vischer, and the history of the Mesozoic transgressions elucidated. Many new and important geological localities were naturally discovered, notably the thick Berriasian and Valanginian section at the Niesen (inner Wollaston Forland), important for the study of these stages, and the more condensed representative of the Valanginian around Albrechts Bugt, further east; and the stratigraphy of localities already known was clarified, as in the case of the uppermost Jurassic rocks in south-west Kuhn Ø, discovered by Teichert in 1932, where Maync found the rare genus *Laugeites* which had been first described by Spath (as *Kochina*) from Milne Land. The results have been published in a structural paper by Vischer (1943) and two stratigraphical papers by Maync (1947, 1949); the maps were published by Koch (1950, pls. 5, 6).

In the southern area, publication of the results has been less complete. Several brief accounts appeared by Stauber (1938, 1939, 1940) and maps by him of northern Jameson Land and the Mesozoic parts of Traill and Geographical Society Øer were published by Koch (1950, pls. 3, 4). A re-examination of Traill and Geographical Society Øer by the present writer has shown that a number of exposures of importance were missed by Stauber, who has, furthermore, several major errors on his map. These are probably due to the limited amount of field evidence which was available, and to the subsequent completion of the map from air photographs. To Stauber belongs the credit of establishing the great extent of Upper Cretaceous shale formations in the two islands, and of recognising some of the principal structural features. Stauber's map of northern Jameson Land remains the only source of information on the greater part of this area, which has not since been revisited. The map is probably more reliable than that of Traill and Geographical Society Øer. Bierther's researches in Scoresby Land have given rise only to a short paper (1941) with a roughly drawn map.

The Two-Year Expedition has not, as yet, produced palaeontological results comparable to those of Koch's earlier expeditions, for although many of the fossils were sent to specialists the almost immediate intervention of the Second World War hindered the working out of the collections, and some of the material was destroyed. Spath, however, has produced a paper (1952) on an important Berriasian ammonite fauna collected by Maync in Wollaston Forland, and Harris has published an account of the Rhaetic and Lower Liassic plants collected in Jameson Land by Bierther and Stauber.

Finally, in the review of expeditions before the war of 1939—45, should be mentioned the Scoresby Sund Committee's Second East Greenland Expedition to Kong Christian IX Land, in 1932, led by Ejnar Mikkelsen, and the British East Greenland Expedition, 1935—36, led by L. R. Wager. Geological work on these expeditions, which explored the coast south of Scoresby Sund, was in the hands of W. A. Deer and L. R. Wager, and was principally concerned with igneous rocks. A late Cretaceous series was discovered in the Kangerdlugssuaq area, the only proved Mesozoic sediments known to exist south of Scoresby Sund. Full details have been published (Wager, 1934, 1947).

Since the war Dr. Lauge Koch has led expeditions to East Greenland yearly since 1947, and it has been the present writer's privilege to join several of them and continue the study of the Jurassic and Cretaceous rocks. Work has been concentrated on the eastern parts of Geographical Society and Traill Øer, as it was soon realised that many discoveries remained to be made there. Intensive examination of selected areas in 1947, 1949, 1950 and 1952 has led to the discovery of an important Valanginian ammonite fauna, and the establishment of several Upper Cretaceous horizons which were not previously known. The youngest of all Mesozoic formations in East Greenland, belonging to a horizon high in the Senonian, occurs in the islands. The results of this work have been published in several papers (Donovan, 1949, 1953, 1954, 1955), and for the first time Mesozoic brachiopods from East Greenland have been described by a specialist (Muir-Wood, 1953).

In 1954 a journey was planned to visit the interior of northern Jameson Land, which is still unknown except for Stauber's geological map, but ice conditions prevented it from being carried out. Likewise, attempts at further investigation of some of the localities discovered by Maync in Wollaston Forland have not been favoured by weather and ice conditions, although A. J. Standring and E. W. Roberts spent a few days at the Niesen section in the summer of 1952 and brought back notes and collections.

The foregoing review shows that the East Greenland coast between 70° and 77° N. latitude has received a great deal of geological attention, of which the Jurassic and Cretaceous rocks have had their full share, and while many details remain to be worked out, there are probably few important discoveries yet to be made. Along the coast south of Scoresby Sund sediments are inconspicuous, although it is possible that the Upper Cretaceous rocks discovered by Wager and Deer may prove to be of greater extent when this part of the coast becomes better known. To the north of Danmarks Havn, however, the geology is almost unknown over large areas, but there are a few indications that Mesozoic sediments are present.

Stages of the Jurassic and Cretaceous.

Systems	Stages
Upper Cretaceous	Senonian { Maestrichtian Campanian Santonian Coniacian } Turonian Cenomanian
Lower Cretaceous	Albian Aptian Barremian } Hauterivian } 'Neocomian' Valanginian } Berriasian ('Infravalanginian')
Upper Jurassic	Portlandian Kimeridgian Oxfordian
Middle Jurassic	Callovian Bathonian Bajocian
Lower Jurassic	Toarcian Pliensbachian { Domerian Carixian } Sinemurian Hettangian
Upper Triassic	Rhaetian

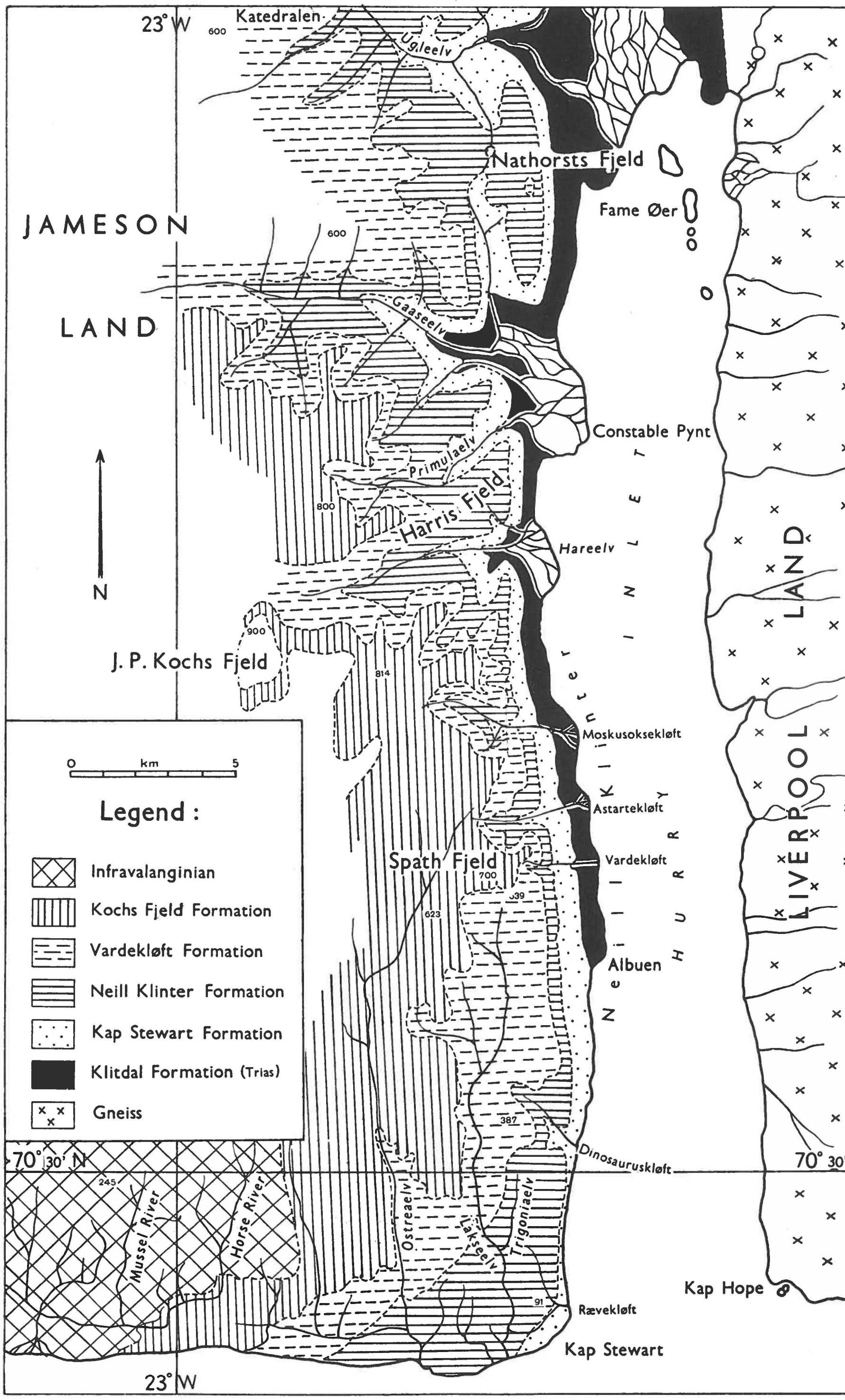


Fig. 2. Geological map of the neighbourhood of Hurry Inlet. Scale: 1:250,000. Compiled from all available sources, especially the maps of Aldinger (1935) and Stauber (in Koch, 1950, pl. 4) and information in papers by Rosenkrantz (1934) and Spath (1932). *For* Infravalanginian *read* Berriasian.

III. SYSTEMATIC ACCOUNT OF THE STRATIGRAPHY

Lower Jurassic.

Rhaetian, Hettangian and ?Lower Sinemurian: The Kap Stewart Formation.

1. Type Locality and exposures in Hurry Inlet.

At Kap Stewart, the south-eastern point of Jameson Land, only the upper part of the formation lies above sea-level. A detailed lithological section has been published by Lacoste (1928, p. 93) and is here reproduced (fig. 3), and further observations were added by Rosenkrantz (1934a p. 38, pl. 9). These authors' sections refer to Rævekløft at the mouth of Lakseelv. The formation is exposed along the coast southwards to Kap Stewart, but a short distance west of that headland it disappears beneath the Neill Klinter Formation which descends to sea level. Northwards the beds rise until at Astarte Kløft the whole of the formation outcrops in the steep face of Neill Klinter (fig. 2), and has been traced thence to Nathorsts Fjeld at the head of Hurry Inlet (Rosenkrantz, 1934, fig. 8; Aldinger, 1935, pls. 1, 2). A study of the whole of this outcrop is necessary in order to form a complete picture of the formation and the occurrence of its fossil flora, and this was made by Harris who has monographed the flora (1931, 1932, 1932a, 1935, 1937), his stratigraphical description and conclusions being included in the last paper.

Harris gives the following general subdivision of the formation:

Neill Klinter Formation (marine Pliensbachian)

Kap Stewart Formation { Plant-bearing series: 90 m
Barren sandstone: 85 m

Klitdal Formation (Trias)

The base of the formation has been taken by Harris and by Rosenkrantz at the lithological change from the red, marly shales, which predominate in the upper part of the Klitdal Formation, to false-bedded sandstones. Sandstones occur, however, interbedded with the red beds, bands of red and green marls occur throughout the Kap Stewart Formation, and there is a transition between the two formations. The boundary plane is therefore an arbitrary one, taken by Harris 85 m below the horizon at which the first fossil plants are met with, and corresponding to the level at which false-bedded sandstones begin to predominate (1937, p. 70). The Kap Stewart Formation is composed of massive grey, yellow or green sandstones, soft friable or rubbly sandstones, and shaly sandstones. Beds of quartz conglomerate occur in the southern part of the area. The lithology shows great variation both vertically and laterally. There are innumerable local breaks in sedimentation, none of widespread significance.

Plants have been found in the upper 90 m of the formation, and their mode of preservation ranges between two extreme types. The most perfect specimens occur in well-bedded shales, sometimes actually preserved in the places where they grew with the roots still in position in the lower part of the bed. At the other extreme are coarse sandstones with mainly fragmentary plants, including some species not known from the more perfect material. Not all the shale beds contain plants, and there is a great variety of plant-bearing strata between these two extremes. Coal seams up to 50 cm thick occur in the series (Harris, 1937, p. 74). Fossil remains apart from plants are extremely rare, and the intensive collecting carried out by Harris produced only a fish spine (*Hybodus* sp.), a freshwater lamellibranch, an ostracod (*Estheria* cf. *minuta*) and fragments of insects (Harris, *loc. cit.*).

The fossil flora which has been obtained from the shores of Hurry Inlet, chiefly by Harris, comprises about 200 named species, of which some are represented by isolated reproductive organs which may belong to the same plants as leaves which have been described, according to usual palaeobotanical practice, under different specific names. In addition there are nearly 200 wood fragments which could not be named. The vertical position of each fossiliferous bed was noted with reference to a marker horizon (the succeeding Jamesoni Bed) and when the vertical ranges of all the species were entered in a table it was seen that the fossiliferous part of the formation fell into two well-marked floral zones (Harris, 1937, table 1). A number of species occur throughout (more than those shown in Harris's table, which does not include all species), but a significant number are restricted to the lower 30 m and a group of new ones appear in the upper 50 m. There is a zone of transition about 5 m thick. Harris has named the lower zone the *Lepidopteris* Zone, the upper the *Thaumatopteris* Zone (1931a, pp. 154—158, and later publications).

The conditions of deposition of the Kap Stewart Formation have been discussed by Harris (1937, pp. 71—72). He deduced that south-

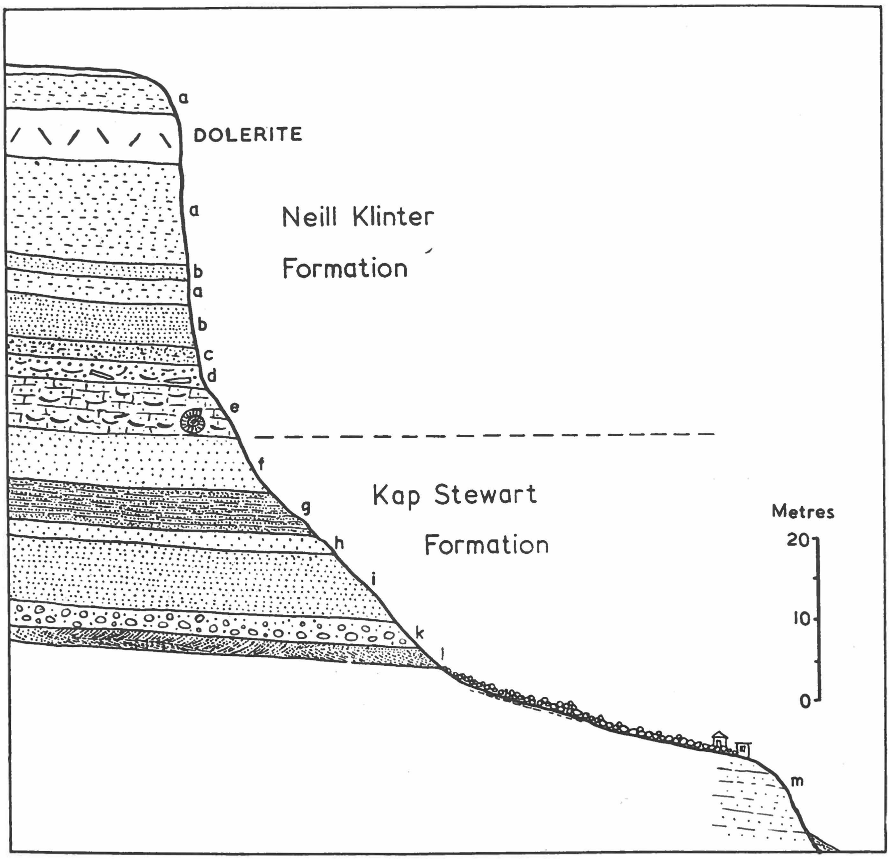


Fig. 3. Geological section north of Kap Stewart, Jameson Land. Redrawn from Lacoste, 1928, fig. 9 (p. 93). The lower border of the figure represents sea-level. Explanation of letters: a: Fine-grained micaceous sandstone; b: Compact, grey unfossiliferous sandstone; c: 'Greywacke'; d: Coarse-grained sandstone with Belemnites and *Entolium*; e: Grey calcareous sandstone; the Jamesoni Bed; f: Barren sandstone; g: Black, laminated sandstone with plant impressions and lignite; h: White, compact sandstone; i: Pink, compact sandstone; k: Conglomerate with plant remains; 1: Friable, pink cross-bedded sandstones; m: White sandstone.

eastern Jameson Land was the site of a delta, probably composite and supplied by a number of rivers descending from the hinterland. The area was subsiding throughout the deposition of the formation, but the delta surface was almost always maintained above sea-level by the sedimentation. The surface of the delta was colonised by plants and was probably largely forest. Deposition of the fine-grained plant beds took place in lagoons formed by disused river-channels, and their contents indicates the flora living in and around these lagoons. The coarse-grained plant beds presumably originated as masses of vegetable debris concentrated by the action of the streams on the delta surface, and some of the species may have been brought down from higher reaches of the rivers.

Harris has shown (1937, pp. 90—91, table 3) that the East Greenland flora from the Kap Stewart Formation bears a strong resemblance to floras from south Sweden and Germany, and moreover that the two zones can be recognised in these countries. The lower *Lepidopteris* Zone can be demonstrated to be approximately equivalent to the marine Rhaetic in north-western Europe, while the upper *Thaumatopteris* Zone is Hettangian, and perhaps younger.

2. *The Kap Hope area.*

The Kap Stewart Formation outcrops in a small area east of Kap Hope, the headland opposite Kap Stewart at the mouth of Hurry Inlet, and has been described by Rosenkrantz (1942, pp. 16—21). The rocks include conglomerates and coal seams (Rosenkrantz, 1934, figs. 52, 53) and both of the floral zones are present. No estimate of thickness has been published. The outcrop is shown in figure 4 (as "Plant Beds").

3. *Northward and westward extension of the Kap Stewart Formation.*

The 1926—27 expedition traced the continuation of the Hurry Inlet outcrop northwards to a point west of the head of Carlsberg Fjord (Rosenkrantz, 1934, fig. 4). Noe-Nygaard mapped the formation to the south and west of Fleming Fjord and northwards to Antarctics Havn (1934, pl. 2), but his mapping in the latter neighbourhood, which was on the boundary of his area, is known to be inaccurate, as the western side of Antarctics Havn is shown as Carboniferous whereas it is, in fact, Jurassic. If the top of the underlying Triassic red beds be assumed to represent a constant horizon, then the sandstones which immediately succeed the red beds presumably belong to the Kap Stewart Formation, but Noe-Nygaard found no diagnostic fossil plants and his attribution of some hundreds of metres to the formation (*op. cit.* pp. 60—61) seems rather arbitrary. Noe-Nygaard seems to have included any sandstones containing traces of plants, albeit unidentifiable, in the Kap Stewart Formation, but this is hardly justifiable. The lithology does not agree exactly with that of the Kap Stewart Formation; Noe-Nygaard (p. 60) says that ripple-marks are common in his sandstones, whereas they are rare in the typical Kap Stewart Formation (Harris, 1937, p. 72). Likewise, it is unsafe to accept Stauber's record of 500 m of Rhaetic-Lias in northern Jameson Land (1939, p. 170; 1940, p. 20) without more evidence than is at present available. The only certain evidence as to the northward extension of the formation is provided by plants collected in the Pictet Bjærge by Bierther and which provide definite evidence of a basal Liassic age (Harris, 1946, pp. 34—35). Bierther shows two small areas of "Rhät-Jura" in the Pictet Bjærge but does not give any information as to thickness or lithology (Bierther, 1941, p. 12, pl. 1). There is at present no proof that the formation occurs north of Kong Oscars Fjord. Work by Stauber and by the writer has failed to produce any diagnostic fossils, and the "*Equisetites* sp. A. indet." found by Stauber at Kap Palander and recorded by Harris (1946, p. 6) may have come from a later horizon. The question has been recently discussed by the writer (1953, p. 17).

The evidence is slightly better for western Jameson Land, studied by Stauber who gives a section in southern Major Paars Dal, on the eastern side of Schuchert Flod (1940, p. 19). Stauber attributes a thickness of 300 m to the Rhaeto-Lias, divisible into a lower series of coarse sandsones, 200 m thick, succeeded by a more shaly plant-bearing series, 100 m. In the shaly parts of the upper subdivision Stauber found lenticular concentrations of fish remains, coprolites and plant fragments, and in beds of ferruginous sandstone nearly complete fish skeletons attributed to *Gyrolepis*. Higher beds in the series contained marine molluscs. Higher still followed fine-grained sandstones and sandy shales with marine fossils, said by Stauber to belong to the marine Lias, but no diagnostic fossils are cited. The plant fossils were determined by Harris (1946, p. 34) who recognised both Rhaetic and Lower Liassic species. The flora of western Jameson Land has close affinities with that of Hurry Inlet but includes several species unknown from the eastern area, a fact considered significant by Harris since the Hurry Inlet flora is known in great detail.

The facies of the Kap Stewart Formation in western Jameson Land is clearly different from that in Hurry Inlet, but more information is desirable. Harris remarked on the barrenness of the plant beds compared with eastern Jameson Land, and suggested that the predominant conditions were those of a swamp growing on mud flats. These must have been flooded by the sea from time to time to allow of the accumulation of the fish remains recorded by Stauber, and the marine intercalations seem to be more frequent than at Hurry Inlet, where they are rare.

Pliensbachian and Toarcian: The Neill Klinter Formation.

1. Type Locality and exposures in Hurry Inlet.

The formation is best exemplified by two sections measured by Rosenkrantz in the middle region of Neill Klinter, at Albuen and at Vardekløft (Rosenkrantz, 1934, pp. 53—63) (fig. 2). About 200 m thick, it is composed predominantly of sandstones, with subsidiary shales which make up about one-quarter of the total thickness. The rocks are well stratified, and the lithology is variable laterally. The base of the formation, consisting of conglomeratic and felspathic sandstones, is marked by a zone, about 3 m thick, with more or less common fossils, from which a very large fauna has been obtained. Called the Jamesoni Horizon after rare examples of *Uptonia jamesoni*,[1]) this bed yielded about 140 species of cephalopods, gastropods, lamellibranchs, brachiopods and other fossils to Rosenkrantz's intensive collecting. A list has been published by Rosenkrantz (1934, pp. 111—114) but the only systematic account of the fauna, which was then much smaller, is by Lundgren (1895), who figured some of the species. Lundgren's determinations have been commented on by Haug (1926) and revised by Rosenkrantz (*op. cit.* pp. 11—12), and a few more fossils were illustrated by Rosenkrantz (*op. cit.* pls. 4—8). Rosenkrantz attributed the majority of the fossils to well-known European Liassic species, but regarded some of them as new species, most of which are as yet unpublished. Until the fauna is fully described it is profitless to comment at length on its affinities, but they seem to be predominantly European. The ammonites fix its age securely as equivalent to the Jamesoni Zone of the European succession.

At one locality only, Dinosaurus Kløft about 8 km north of Kap Stewart, Pliensbachian ammonites of later date have been found, at a horizon separated from the basal fossil bed by 2 m of barren sandstones. The ammonites were figured by Rosenkrantz (1934, pl. 5, figs. 2, 3, pl. 7, figs. 1, 2) and were identified as *Androgynoceras*? sp., *Beaniceras* sp. and *Lytoceras fimbriatum* (J. Sowerby), the fauna being attributed to the Ibex zone of the Lower Lias (Lower Pliensbachian). In the opinion of the present writer it is difficult to be certain whether the '*Beaniceras* sp.' (a poor and apparently distorted specimen) is really a *Beaniceras* or the inner whorls of an *Androgynoceras*; certainly the whorls are much thinner than in typical species of *Beaniceras*. This uncertainty, and the presence of the ammonite identified as '*Androgynoceras*? sp.' (which appears to be a good enough *Androgynoceras* from the figures) makes a later date for the fauna equally plausible, and it may well belong to the Davoei zone, the highest zone in the Lower Lias in the English usage. These rare ammonites are accompanied by numerous other molluscan species, mostly forms already known from the beds below but including *Æquipecten bierringi* Rosenkrantz which is not found at other levels in the succession. The ammonites have not been found elsewhere, but a molluscan fauna in a corresponding position, including *Æ. bierringi*, is known from Rævekløft, near Kap Stewart, and Vardekløft.

[1]) Haug (1926) also recorded *Tropidoceras stahli* (Oppel) in material collected by the Mission Charcot in 1925. Rosenkrantz, who re-examined the specimen, believed it to be merely a crushed *Uptonia*.

The basal beds of the Neill Klinter Formation, described above, are succeeded by about 150 m of beds, forming the bulk of the formation, which have yielded no fossils. From the limits provided by the fossils above and below these beds presumably represent the Upper Pliensbachian (= Domerian) and the early part of the Toarcian. The lithology, summarised by Rosenkrantz (1934, pp. 115—116), consists predominantly of sandstones, with sandy shales and subordinate conglomerates, clay ironstone and black shales with plant remains. The sandstones are frequently cross-bedded in the upper part, and cross-bedding characterises lower horizons north of Nathorsts Fjeld. Rosenkrantz interprets the beds as shallow water marine deposits alternating with lagoon and deltaic sediments.

The uppermost part of the Neill Klinter Formation is again fossiliferous, and at the sections at Albuen and Vardekløft already mentioned there are about 50 m of sandstones at the top with fossils at a number of horizons. The fauna has been listed by Rosenkrantz (1934, pp. 116—118). Ammonites have been found at a few places, notably Nathorsts Fjeld (*op. cit.* pp. 80—85) where beds forming the summit of the mountain yielded *Dactylioceras* and *Pseudolioceras*. *Catacoeloceras* was found at Hjørnefjeld and a species named by Rosenkrantz *Dactylioceras groenlandicum* at Ryder Elv. The fossils other than ammonites number about 60 species. It is unfortunately not possible to establish the relative stratigraphic positions of the ammonites found at different places, except that *D. groenlandicum* occurs 5 m below *Pseudolioceras* sp. nov. at Ryder Elv and the two genera occupy the same relative positions at Nathorsts Fjeld (locality 1). The *Catacoeloceras* and *Dactylioceras* must be not later than the Bifrons Zone, and *Pseudolioceras compactile* indicates a horizon about equivalent to the Striatulum Subzone in the lower part of the Jurense Zone. *P. lythense* does not necessarily indicate an earlier horizon, as Rosenkrantz suggests (1934, p. 118), for in Yorkshire it ranges up into the Jurense Zone (see Dean, 1954, p. 178). Rosenkrantz's age assignments of *P. beyrichi* and *P. dumortieri* are not necessarily to be accepted, as in the present writer's opinion the identifications of these species require confirmation. The presence of horizons higher than the Striatulum Subzone is regarded, at present, as unproved.

Features of the Toarcian part of the Neill Klinter Formation are a crinoid sandstone, at or near the top of the formation, seen at Vardekløft and Nathorsts Fjeld, and oyster beds, first observed by Nathorst (1901, p. 284) at Nathorsts Fjeld. Subsequently Rosenkrantz found oyster beds at various places from Trigonia Elv, not far from Kap Stewart, to Hjørnefjeld, west of the head of Carlsberg Fjord, where the fossiliferous Toarcian (to the whole of which the term "Oyster Bed" is applied by Rosenkrantz) is about 80 m thick. The oysters seem never to have been figured and it is unknown to what species they belong. Rosenkrantz (1934, p. 81) listed *Liostrea* cf. *erina* (d'Orbigny), but the writer has previously pointed out the difficulty of interpreting this species (Donovan, 1953, p. 72).

The Neill Klinter Formation is present at Kap Stewart, the south-easternmost point of Jameson Land (fig. 3) and outcrops continuously along the western shore of Hurry Inlet (fig. 2).

2. Sediments near Kap Hope.

The Neill Klinter Formation occurs in the small area of sediments east of Kap Hope, Liverpool Land and has a more extensive outcrop than the other formations (fig. 4). Both coastal and inland sections have been studied by Rosenkrantz (1942). The total thickness is nearly 200 m. A basal conglomerate which rests, as in Hurry Inlet, on the Kap Stewart Formation, is succeeded by highly fossiliferous sandstones with an extensive molluscan fauna including the ammonite *Uptonia*, which are therefore of Lower Pliensbachian age. The beds, which are best seen on the coast at Igterajivit and Kumait, are clearly equivalent to the basal fossiliferous beds on the western shore of Hurry Inlet, but are thicker than at any locality in Hurry Inlet with the exception of Kap Stewart. Fossils occur throughout about 20 m of beds. Rosenkrantz believes (1942, p. 42) that the Ibex Zone fauna of Neill Klinter may also be represented, on the basis of finds of *Æquipecten bierringi* (see p. 28).

The upper Pliensbachian or Domerian is probably represented by sediments which succeed the fossiliferous basal beds, but no fossils have been found. The rocks are sandstones and sandy shales with mud-cake conglomerates; trails occur on some of the bedding planes, and indeterminable plant fossils were found in the upper part of the series. The beds have an extensive outcrop in the inland part of the sediment area, but are much obscured by scree, so that the details are little known.

The highest part of the Neill Klinter Formation is of Toarcian age, as in Hurry Inlet. The lithology is summarised by Rosenkrantz (1942, p. 44) as 'chiefly . . . greyish-green, fine to medium-grained sandstone with dark mud planes. The strata . . . are frequently cross-bedded, are calcareous and contain concretions formed round marine shells.' Ammonites are known from one inland locality where *Pseudolioceras dumortieri* (S. S. Buckman) was found, probably indicating the late Bifrons or early Jurense Zone. The remainder of the fauna consists of molluscan and other fossils all known from the main outcrop in Neill Klinter.

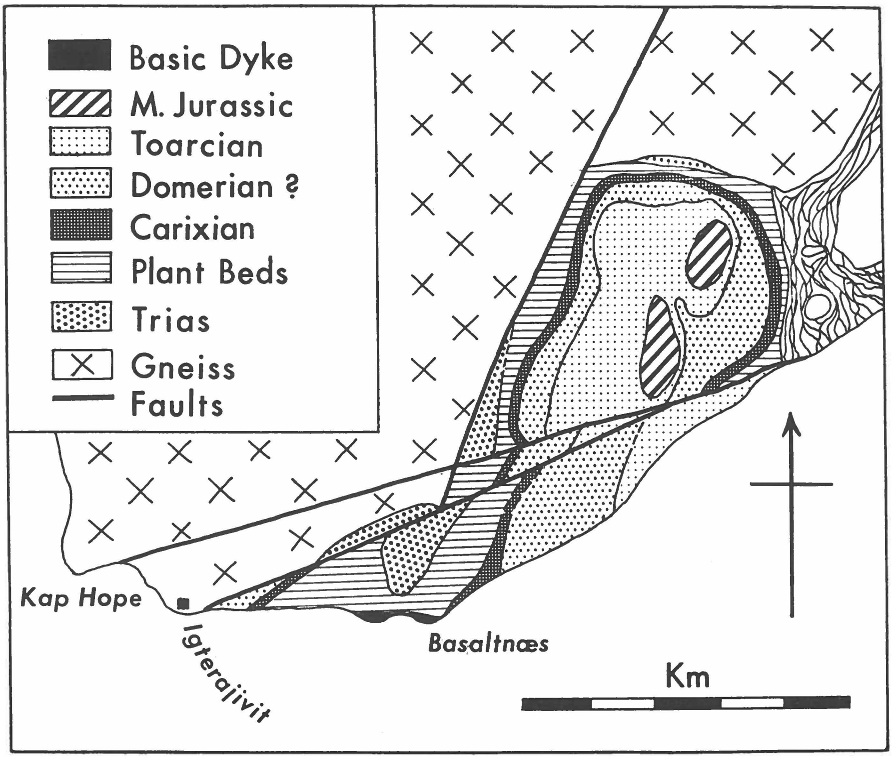


Fig. 4. Geological map of the area north-east of Kap Hope, Liverpool Land. Redrawn from Rosenkrantz (1942, pl. 4).

3. *Northward and westward extension of the Neill Klinter Formation.*

The Neill Klinter Formation was mapped by Rosenkrantz as far north as the country west of the head of Carlsberg Fjord (1934, fig. 4), the Toarcian fauna in the upper part being reported from Hjørnefjeld (*op. cit.* p. 93). No certain Liassic fossils have been reported farther north, and Rosenkrantz says (1942, p. 22) that the fossiliferous basal Jamesoni Beds, 20 m thick at Kap Stewart and near Kap Hope, become thinner to the north and wedge out in Klitdal, being last seen at Dusén's Bjerg not far north of the head of Hurry Inlet (Rosenkrantz, 1934, p. 88). Stauber has mapped the marine Lias as an irregularly arcuate outcrop curving through north-central Jameson Land and down the western side; but few details are available. In Klitdal Stauber found a Plesiosaur skeleton, and at a higher level large pyritic concretions with Liassic ammonites from 1 to 30 cm diameter (Stauber, 1940, pp. 20—21). The ammonites, unfortunately, have not been determined and do not seem to be in the collections from the Two-Year Expedition sent to Dr. Spath in London (verbal information from Dr. Spath). They were possibly misidentified in the field and really belonged to a younger formation. For the remainder of the Jameson Land outcrop there are no precise fossil records at all. Stauber found beds with marine fossils at various places above the Kap Stewart Formation, but says (*loc. cit.*) that the sections are poor and that his mapping of the Lias in the northern part of its outcrop is uncertain. Until the fossils are known the attribution of these beds to the Neill Klinter Formation, and its extension into north and west Jameson Land, must remain provisional. Around Antarctics Havn, where Stauber shows marine Lias on his 1940 map, no fossil evidence for it could be found by the present writer.

Middle Jurassic.

Upper Bathonian and Lower Callovian: The Vardekløft Formation.

1. Southern Jameson Land: The Vardekløft Formation.

The Vardekløft Formation at the type locality consists of about 190 m of strongly micaceous shales, with a few bands of sandstone and horizons of calcareous concretions. It rests on the Toarcian Oyster Bed (see p. 29), and is succeeded by a bed of coarse sandstone, forming the base of the Kochs Fjeld Formation. Fossils are abundant at two levels: 45 m above the base, fragments of *Cylindroteuthis* occur, while 160 m above the base a band of calcareous nodules has yielded ammonites. The fauna includes various species of *Cadoceras*, one of *Paracadoceras*, *Seymourites tychonis* Ravn and other species. The full list is given by Spath (1932, p. 126). This fauna is clearly of Lower Callovian date. In addition, examples of *Arcticoceras* were found, not, apparently, *in situ.*

Southwards along the 18 km of outcrop to Kap Stewart no detailed sections have been published. Aldinger found areas of black, micaceous shales and marls with calcareous concretions west of Kap Stewart, and his identification of these beds with the Vardekløft Formation was strengthened by his discovery of an ammonite fragment cited as ? *Keplerites* (Aldinger, 1935, pp. 35—36, pl. 2). No great thickness was seen at any one exposure, and the probable thickness of about 200 m (*op. cit.* p. 44) seems to be based on the assumption that the thickness is the same as at the type locality.

In the neighbourhood of Astartekløft, about 2 km north of the type locality, Aldinger measured a section (fig. 6) in which the Vardekløft Formation (divided arbitrarily into 'Oberes Bathonian' and 'Callovian') extends from 441 m up to 647 m altitude, giving a thickness of 206 m (no mention of the dip is made, so it cannot be allowed for). 64 m above the base is a hard, splintery bed with concretions which contain ammo-

Fig. 5. Distribution of Callovian rocks in East Greenland. Black = known outcrops; Diagonal shading = Callovian presumed buried beneath younger rocks.

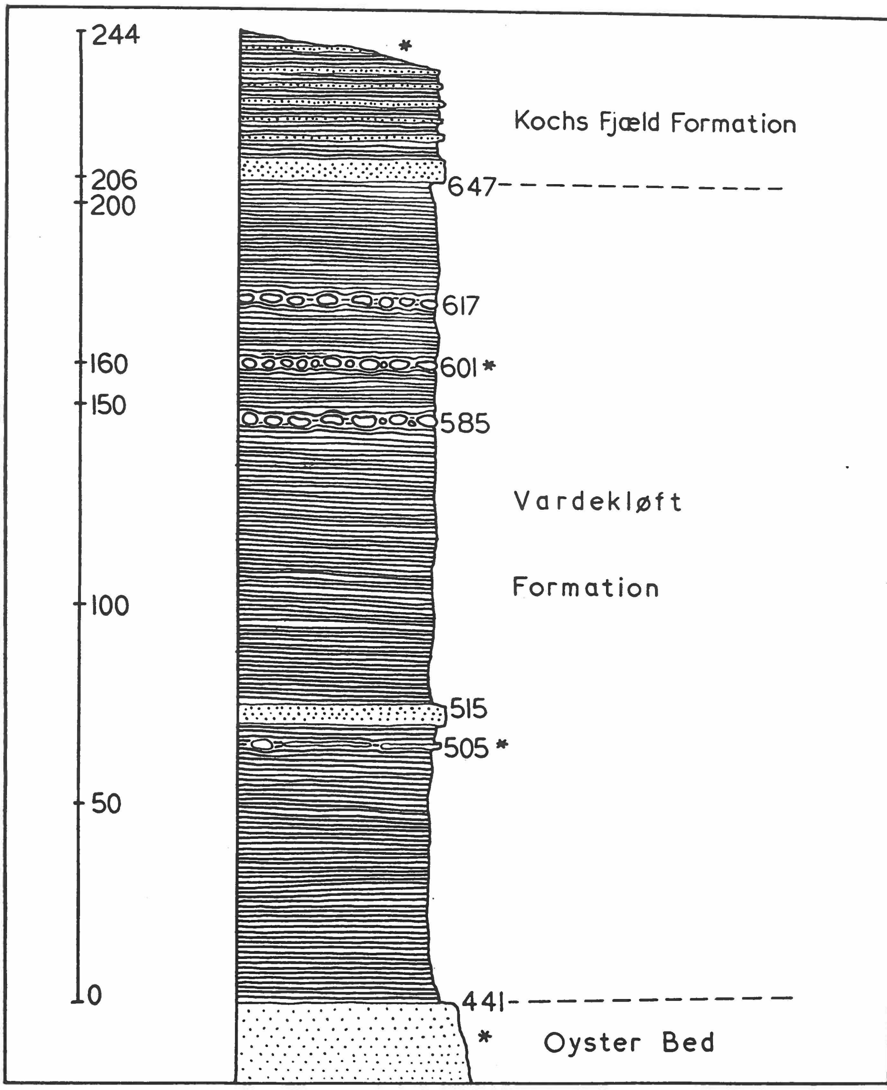


Fig. 6. Diagrammatic section through the Vardekløft Formation at Astarte Kløft, Jameson Land. The left-hand scale shows the thickness in metres, figures to the right of the section altitudes above sea-level. For explanations of conventions see figure 18, page 95. Drawn from data in Aldinger (1935, pp. 28—30).

nites, belemnites and bivalves. The ammonites are listed by Aldinger as 'cf. *Cranocephalites*'. Unfortunately they have not been reported on in detail by a specialist. 131 m above the base is another level with concretions yielding ammonites, but no identification is given by Aldinger. 160 m above the base is a bank of concretions with *Seymourites*, *Cadoceras*, belemnites and fossil wood, representing the fossil band of the type locality. Immediately above the bank of concretions are nodules with *Seymourites* (Aldinger, 1935, pp. 25—26, 29).

About 11 km north of Astartekløft, on the peak west of Harris Fjeld, the formation is still recognisable in its typical development, probably more than 200 m thick if allowance is made for the dip (Spath, 1932, fig. 11). Nodules about 150 m above the base yielded *Cadoceras* in identical preservation with the ammonites from the fossil horizon at the type locality. Only two species are recognised, however, one peculiar to this locality, and *Seymourites* was not found. In the same preservation, also, was found the unique specimen of *Kosmoceras* (*Gulielmiceras*) *pauper* Spath.

At Nathorsts Fjeld Rosenkrantz has noted the probable base of the formation at one place, but the greater part of it has been removed from this mountain by denudation (1934, p. 85). Stauber's map (in Koch, 1950, pl. 4) shows 'Dogger' outcropping in the country to the west, but there is no account of it in the literature.

By the time we reach Katedralen (Cathedral Mountain in Spath, 1932) the Vardekløft Formation is no longer a lithological unit, nor can the limits of the Callovian rocks be recognised, owing to the absence of the Toarcian Oyster Bed and of any deposits proved to be later than Callovian. Spath (1932, fig. 12) gives the following section, measured by Prof. T. M. Harris:

Yellow sandstone, with thin bands of shale. Fossil wood	130 m
Black shales. Fossil wood	40 -
Dolerite sill	(a few m)
(Scree, probably covering sandstone	30 -)
Horizon with *Cranocephalites*	— -
Sandstone, possibly interbedded with blue clay. Belemnites	170 -
Blue clay, no fossils	70 -

As diagnostic fossils were found only at one horizon, it is impossible to say how much of this section is the equivalent of the Vardekløft Formation; but as the Toarcian Oyster Bed, usually prominent and fossiliferous, was not noticed, it may be presumed that it lies below the base of the section. By comparison with localities further north, where later fossil horizons occur, it may be that the whole thickness of about 440 m exposed at Katedralen belongs to the Callovian. At Ammonitbjerg, on the opposite (northern) side of Ugleelv from Katedralen, no section is available, but it was here that the type material of *Cranocephalites pompeckji* (Madsen) was found by Hartz in 1900. One thing is clear from the limited amount of evidence available from the neighbourhood of Ugleelv: the purely argillaceous facies of the Callovian represented by the typical Vardekløft Formation has gone; in particular, a prominent group of sandstones has appeared, nearly 200 m thick, with the ammonite *Cranocephalites* near the top. The age of this genus, and its relative *Arctocephalites*, in terms of the classical European succession is not well established, but is likely to be high Bathonian or early Callovian. The problem is considered at length on page 136.

2. *The Kap Hope area, southern Liverpool Land.*

At Aage Nielsens Fjeld and Bjerring Pedersens Fjeld the Toarcian sandstones of this area are succeeded by the following sediments:

a) Dark grey, micaceous sandy shales with concretions: 160 to 210 m
b) Greenish-grey, fine grained micaceous sandstone: 210 to 235 m
c) Rusty brown sandstone: 235 to 295 m altitude.

The concretions in bed a) yielded a few bivalves including *Meleagrinella* aff. *doneziana* (Borissjak) (Rosenkrantz, 1942, pp. 46—49). The rocks probably represent the Vardekløft Formation, in which *M.* aff. *doneziana* also occurs, but their age is unproved by ammonites. They are shown in figure 4 as ?Bathonian, the age assigned to them by Rosenkrantz.

3. *Northern and western Jameson Land and Scoresby Land: The Fossil Mountain Formation or Yellow Series.*

Between the head of Hurry Inlet and that of Carlsberg Fjord, a distance of about 45 km, there is no information about the Callovian. The next area where sections have been studied is to the west of the head of Carlsberg Fjord, where rocks of this age are known from Mikaels Bjerg, Hjørnefjeldet and Fossilbjerget. The formation described by Rosenkrantz as the Fossil Mountain Formation (Rosenkrantz, 1919, p. 146) and believed by him to be Oxfordian, is now known to be of Callovian age, but the name may be used for this facies of the Callovian. The lower part is known from Hjørnefjeldet, the upper from Mikaels Bjerg. The thicknesses on Mikaels Bjerg are not published, Spath's section (1932, fig. 13), based on information supplied by Rosenkrantz, being obviously not to scale. If one accepts, with Spath, the suggestion of Rosenkrantz, that his "*Macrocephalites* Beds" at Mikaels Bjerg are equivalent to the beds at the summit of Hjørnefjeldet, a composite section for the Callovian in this area may be constructed as follows:

Sandstones. Unfossiliferous	100 m
Shales and sandstones. *Seymourites*, *Cadoceras*?, at the top . . . . . . c.	80 -
Coarse, micaceous sandstone, with concretions. *Arcticoceras*, *Cadoceras* c.	50 -
(Beds unexposed on Mikael Bjerg and higher than those on summit of Hjørnefjeld; exposed at 'locality 1'; *Arctocephalites*, *Articoceras*.	?)

Sandstones with fossils at a number of levels: *Arctocephalites* 110 m above the base, *Cranocephalites* 90 m above the base, bed with *Entolium* and belemnites 50 m above base .... 115 m
Micaceous shales, unfossiliferous .... 130 -
Coarse, yellow sandstone. Indeterminate belemnite .... 95 -
(Toarcian Oyster Bed).

There are here probably more than 600 m of sediments above the Toarcian Oyster Bed which may belong to the Callovian, although the lowest 225 m and the uppermost 100 m or so are not dated by fossils. The Callovian ammonite succession in the area is more complete than anywhere else in East Greenland.

There is again little information about the Callovian between the area just described and the shores of Kong Oscars Fjord, about 80 km to the north. The area has been mapped by Stauber, who has published no detailed account of his findings. In a preliminary report (1940, pp. 21—22) he says that the Callovian ("Dogger") is about 400 m thick in north-central Jameson Land, the lower limit being ill-defined, and claims to have found all the ammonite faunas recognized by Spath. Around Antarctics Havn the mountains are composed of about 1000 m of sandstones, in which Parkinson and Whittard, on the 1929 Cambridge Expedition, succeeded in finding *Cranocephalites* between 400 and 500 m altitude. The present writer, on the opposite or western side of the bay, was less successful, and it can only be said that a great thickness of sandstones here may belong to the Callovian, although the lowest part is possibly of Liassic age (Spath, 1932, p. 136; Donovan, 1953, p. 45). No later rocks have been proved in the area.

Nothing is known of the Callovian in western Jameson Land. Stauber has shown the outcrop (marked as 'Dogger' on his maps: 1940, pl. 1, and pl. 4 in Koch, 1950) running parallel to Schuchert Flod, with its western limit about 10 km from that valley, but no sections have been published. The exploration of this area as well as the north and central part of Jameson Land is much to be desired.

4. Traill and Geographical Society Øer: The Yellow Series.

The Callovian in these islands is represented by a sandy series identified with the Yellow Series of Wollaston Forland, and has been recently described by the writer (Donovan, 1953, pp. 18—28; 1955, pp. 12—19). In contrast to the continuous outcrop in Jameson Land, from Kap Stewart to Antarctics Havn, the Callovian in Traill and Geographical Society Øer is only exposed in a few small inliers in the Cretaceous rocks. The most southerly area, also the largest, is traversed by the valley Bjørnedal (1953, pp. 20—25, pl. 2). At the base of the

Yellow Series is a group of sandstones and dark shales with abundant, but unfortunately unidentifiable, plant remains, termed the Plant Beds, which have been attached to the Yellow Series on the grounds of lithological resemblance, but whose age is unproved. They are succeeded by a varied group of sandstones, coarse, fine, micaceous and sometimes conglomeratic, with subsidiary shales. The lithology is thus closely similar to that of the Fossil Mountain Formation in northern Jameson Land. Near the northern end of Bjørnedal a dominantly shaly group of beds, over 100 m thick, occurs in the succession below sandstones with *Cranocephalites*, and recalls the shales in a similar position at Hjørnefjeldet. Altogether a minimum thickness of about 700 m was assigned to the Yellow Series, including the Plant Beds at the base. All the common ammonite genera in Jameson Land—*Arcticoceras*, *Arctocephalites*, *Cadoceras*, *Cranocephalites* and *Seymourites* have been found in the Bjørnedal area, but not all in the same section.

In the Mols Bjerge the Yellow Series has been proved, but is not well known; the position of the junction with the Trias below is obscure, and the upper part of the series may have been removed by Cretaceous denudation. Beyond saying that there are several hundred metres present, there is little more concrete information which can be given. The only ammonite genus which has been found here is *Cranocephalites*.

Still further north, at Laplace Bjerg, about 400 m have been assigned to the Yellow Series, principally on the basis of lithological similarity to the development elsewhere. Although the dating of the sandstones of the Laplace massif leaves much to be desired (see also Donovan, 1955, pp. 16—18), the presence of Callovian rocks is proved by the finding of a fauna with *Arcticoceras* and *Cadoceras* in a derived boulder in the Cretaceous basal conglomerate, 6 km north of the summit of Laplace Bjerg.

The Yellow Series also outcrops near the boundary fault which formed the western limit of some of the Mesozoic transgressions in this area. In the Svinhufvuds Bjerge and the Rold Bjerge the outcrops are confined, so far as our present knowledge goes, to narrow wedges along the faults. In the first area *Cranocephalites* was found in coarse, micaceous sandstone debris. In the second, no Callovian fossils have been found, but a strip of sandstones with quartz conglomerates may well be of that date. In Geographical Society Ø the outcrop of the Yellow Series crosses Tværdal about half-way between the north and south coasts of the island; and here strong beds of quartz conglomerate occur, associated with sands and sandstones which have yielded a fauna with Arcticoceratids, the only Callovian fauna as yet found *in situ* in this island (Donovan, 1955, p. 18). The thickness is believed to be at least 500 m; it may well be greater. In Tværdal, and in the Rold Bjerge if the sandstones there are correctly dated, the conspicuous quartz conglomerates, and the probable insignificance of shale in the succession, betray the proximity of the source of the sediment, which was probably derived from the Carboniferous rocks which lie to the west of the Tværdal Fault.

Rocks of Callovian age are unknown between 73° and 74°15′ North latitude, a distance of about 150 km. The interpretation to be placed on their absence is discussed on page 106.

5. *Clavering Ø, Wollaston Forland and Kuhn Ø: The Yellow Series.*

The Yellow Series of the northern area has been described by Maync (1947), and the following account is based entirely on his publication. Maync has stressed that the whole area falls into a single facies province for the Callovian (*op. cit.* p. 123), and it is, indeed, closely similar to that farther south. Maync summarised the lithology as principally yellow or whitish, moderately fine-grained sandstones, with beds of rusty, ironshot, often coarse-grained and muscovite-rich varieties, and conglomerates. Masses of coarse, strongly micaceous sandstone with small pebbles of crystalline rocks may be embedded in the finer grained sandstones, and are the most fossiliferous part of the succession; they have been termed 'Mauersandsteine' (lit. wall-sandstones) by Frebold (1932, p. 21) on account of their tendency to form steep or precipitous slopes. They are attributed to intraformational erosion. There are also shell-beds, and many beds of plant debris and coaly material. The thickness of the Yellow Series in north-west Wollaston Forland is 528 m. Elsewhere it is thinner (except, perhaps, on north-eastern Clavering Ø), but this is partly due to Pre-Cretaceous denudation. There is, however, a real thinning towards the north; at Kingofjeldet, in southern Kuhn Ø, where the Yellow Series transgresses on to crystalline rocks, it is only 216 m thick, and according to Maync's diagram (*op. cit.* pl. 4) it wedges out almost completely further north.

The faunas collected from the Yellow Series in the Northern area have not been described or fully listed. As far as available information goes, there is no reason to think that they are different from those further south. *Arcticoceras*, *Arctocephalites*, *Cadoceras* and *Kepplerites* (*Seymourites*) are all recorded from a bed no more than 4 m thick at Cardiocerasdal in Wollaston Forland, which is presumably a condensed deposit. It is clear that the series coincides in date, at least in part, with the Lower Callovian formations farther south. The upward extension of the series into the Lower Oxfordian, based on supposed *Quenstedtoceras*, has already been rejected by the present writer (Donovan, 1953, p. 48). No authentic *Quenstedtoceras* has yet been produced from East Greenland, although *Arcticoceras* has on several occasions been mistaken for it.

6. Store Koldewey: The Trækpas Formation.

Here are scattered patches of hard, reddish-brown, usually barren sandstone, in which the Danmark Expedition found fossils which were reported on by Ravn (1911). Ravn described three species of ammonites, of which one, *Seymourites tychonis*, has since become well-known from the East Greenland Callovian and serves to securely date the beds. The other two were recorded as *Kosmoceras boreale*, which Spath (1932, p. 85) believed to be merely a young *Seymourites*, and ?*Quenstedtoceras* sp. which may be a fragment of a *Cadoceras*. These ammonites and a few other fossils were found only at one place, near the east coast below the valley named Trækpasset about 16 km north of the southernmost point of the island (fig. 10). Koch did not rediscover the fossils (they were mainly collected from loose blocks) but was able to map the beds, which he named the Trækpas Formation, by means of their distinctive lithology. The formation is about 50 m thick, and forms disconnected outcrops along about 30 km of coast (Koch, 1929, pp. 166, 172, pl. 5). The formation presumably rests on the crystalline rocks which form the greater part of Store Koldewey, and is the earliest Mesozoic formation which has been discovered on the island.

Upper Jurassic.

Upper Oxfordian and Kimeridgian.

1. The Succession in Milne Land.

The fullest succession in the Oxfordian, Kimeridgian and Portlandian stages is found in Milne Land, between Kap Leslie and Charcots Havn. This important area has been studied by Rosenkrantz in 1927, Parat and Drach in 1932 and 1933, and Aldinger in 1933, but unfortunately it has proved impossible to correlate their field observations satisfactorily (see Spath, 1936, pp. 142—150). This, while it is disappointing in view of the importance of the faunas recovered, is hardly surprising, for anyone who has worked on weathered, slipped and scree-covered slopes such as those of the East Greenland Mesozoic country would not be astonished to learn that three people, working on different sections, had produced different interpretations of the evidence. A valiant attempt to reconcile the various accounts was made by Spath (*loc. cit.*), who confessed, however, that 'since the ammonites are nearly all new, I had to find their probable positions merely by comparison with known European successions' (p. 142). Much of the uncertainty attaches to the positions of various ammonite faunas in the succession, and in this connection Parat and Drach's records (1934) present an added difficulty, since their ammonite determinations are evidently based on a classification different from that employed by Spath, who described the material collected by Aldinger and by Rosenkrantz.

As far as the lithological succession is concerned, it seems best to accept the account of Aldinger, who spent over a month in Milne Land, and who has published a geological map. His version may be summarised as follows:

		m
Hartzfjeld Sandstone, 330 m	Coarse sandstones and sandy clays, clay-ironstone concretions in the lower part. Plant remains, no marine fossils	c. 100
	Coarse and fine sandstones and sandy clay, rhythmically bedded, with isolated fossil horizons: the Lingula Bed about 40 m above the base	c. 200
	Massive sandstones with plant remains	c. 30
Glauconitic Series 50—80 m	Sandy clay, glauconitic sands and sandstones; the glauconite mainly in the lower half of the series. Phosphatic and ferruginous concretions. Many fossil horizons.	
Kimeridgian Clays c. 240 m	Dark, sometimes micaceous, sandy clays, with lines of concretions. A horizon of hard, black, bituminous marls about 70 m above the base	c. 200
	Grey and brown, sometimes sandy, micaceous marls.	19
Pecten Sandstone	False-bedded sandstones with fossil lamellibranchs. A shell-bed 11 m above the base	70
Cardioceras Shales 200 m	Dark, micaceous clays and marls. Lines of concretions.	
Charcot Bugt Sandstone 200 m	Coarse and fine grained, false-bedded, light-coloured sandstone. Conglomeratic beds, ferruginous concretions, plant remains. A polygenetic conglomerate at the base.	

Granite Basement.

The Milne Land Granite at the base is exposed around Charcots Havn (fig. 11). The sediments dip gently southwards, and although the thickness of the succession given above is about 1100 m, the country nowhere rises above an altitude of 700 m.

The Charcot Bugt Sandstone outcrops only in the country immediately south of Charcots Gletscher and near the western end of Charcots Havn, where it has been mapped resting on the Milne Land Granite. Aldinger believed (1935, p. 57) that it reappeared at Mudderbugt, on the south coast of Milne Land about 30 km south-west of Charcots Havn, although he had not visited the locality himself. Bay (1895,

p. 162) recorded his Kap Leslie Sandstone here, a formation much higher in the succession, but Aldinger, who did not revisit the area, thought from Bay's description and his statement that it rested on gneiss, that it was probably Charcot Bugt Sandstone.

The Charcot Bugt Sandstone is about 200 m thick. The basal conglomerate, up to 7 m thick, includes angular pieces of red and grey granite, rounded pebbles of quartz and crystalline schists, and rounded pebbles of various sedimentary rocks; sandstones, including types possibly derived from the "Old Red Sandstone" of East Greenland, and a grey, micaceous marly shale which can have suffered little transport, and which Aldinger thought must have been derived from earlier Jurassic rocks, of which no outcrops have so far been found. The basal conglomerate passes up into about 60 m of medium-grained, false-bedded sandstones and arkoses, with fresh felspars, kaolin, and ferruginous concretions. About half-way up this series is a bed of very hard, blue-grey, fine-grained calcareous sandstone, with fossil wood. Then follow brown sandstones, and abundant ferruginous concretions with fossil wood. The uppermost part of the formation consists of white, false-bedded, more or less coarse-grained sandstones with irony layers and ironstone concretions. No fossils, apart from wood, have been found in the Charcot Bugt Sandstone and there is thus no direct evidence as to its age. According to Aldinger there is a gradual passage into the clays of proved Upper Oxfordian age (the Cardioceras Shales) above, and the sandstone is to be regarded as a rapidly-deposited basal member of the Upper Oxfordian succession.

The Cardioceras Shales succeed the Charcot Bugt Sandstone without a break, as remarked above. They outcrop to the south of the Charcot Bugt Sandstone, and are also exposed for about 2.5 km southwards along the coast from the southern corner of Charcots Havn (fig. 11). In general exposures are poor. The formation, 200 m thick, consists of black and grey micaceous marls and clays, with occasional sandy beds and a number of concretionary horizons. According to Aldinger (1935, p. 57), crushed Cardioceratids and fossil wood are abundant at some places; nevertheless Spath only had four fragmentary ammonites from the formation, all collected by Rosenkrantz in 1927. The exact horizon of one, identified by Spath as *Cardioceras* aff. *zenaidae* Ilovaisky, is unknown. The other three, *Amoeboceras* (*Prionodoceras*) aff. *pseudocaelatum* Spath, *A.* (*P.*) *transitorium* Spath and *Ringsteadia* sp. ind., came from a level a few metres below the top of the formation, presumably the 'blauschwarze Konkretionen mit *Cardioceras*' about 190 m above the base in Aldinger's table (1935, p. 52). They date the beds as Upper Oxfordian but little more can be said (Spath, 1935, pp. 68—69).

The Pecten Sandstone has an outcrop which is probably continuous, apart from cover of Quaternary deposits, from the coast about 2 km south of Charcots Havn to the valley of West-Fluss, about 8 km inland to the west (fig. 11). It consists of about 70 m of grey, yellow and white medium-grained, micaceous sands and sandstones, alternating with sandy marls. Lamellibranchs are abundant, especially in a fine-grained, strongly micaceous sandstone 11 m above the base. Again, unfortunately, few fossils were submitted to Dr. Spath, and it is not even known which species of *Pecten* is responsible for the name of the formation. Two fragments of ammonites are attributed, like those of the Cardioceras Shales, to the subgenus *Prionodoceras*, and indicate an Upper Oxfordian date.

The Kimeridgian Clays consist principally of black, micaceous clays and marls, with lines of nodules at a number of horizons. Aldinger divided them into Lower and Upper Kimeridgian, and published a number of detailed sections (1935, pp. 81—91) which unfortunately include very few fossil records, presumably because the identifications had not been completed by Spath when they went to press. Spath (1936, pp. 142—150), having the advantage of Aldinger's and Rosenkrantz' collections before him, discussed some of the sections recorded by these workers and by Parat and Drach in the Upper Kimeridgian.

The lowest fossil horizon in the Kimeridgian Clays is the nodule bed labelled δ by Aldinger. It yielded *Rasenia*, *Pictonia*, *Amoebites* and, doubtfully, *Euprionoceras* and *Prionodoceras*. The *Pictonia* were not identifiable specifically. All the other species were new except *Rasenia orbignyi* (Tornquist), closely related to, if not identical with, *R. cymadoce*, the index fossil for the second zone of the Kimeridgian. This provides a fairly secure date for horizon δ. *Amoebites* suggested a higher zone to Spath, but he seems to have been restrained from drawing the obvious conclusion, that the nodules contain fossils of more than one date, by the persistence of *Rasenia* to a higher horizon, referred to below.

Nodule Bed γ yielded only one species of ammonite, a giant form represented by two examples, made a new species, *Rasenia borealis*, by Spath. If the generic assignment is correct, this horizon still belongs to the Cymadoce Zone.

About 70 m above the base of the formation the lithology is varied by the presence of hard, black, bituminous marls (Aldinger, 1935, p. 59; 'Oil Shale' of Spath, 1935), from which Aldinger collected ammonites and vertebrates. The ammonites are chiefly *Amoeboceras*, the vertebrates include plesiosaurs and fish recorded by Aldinger as cf. *Leptolepis*. Spath believed these beds to belong to the upper part of the Lower Kimeridgian.

The lower part of the Kimeridgian Clays, up to and including the oil shales, was named the Amoebites Shales by Spath (1935).

The middle part of the Kimeridgian Clays is largely barren of fossils and there is some confusion in the records. Aldinger records a horizon of clay-ironstone concretions, bearing large ?*Cardioceras*, about 120—130 m above the base between Pinna and Astarte valleys, about 5 km north of Kap Leslie. The material was presumably not brought back, for Spath records no Cardioceratids above the oil shales. According to information supplied to Spath, however, there is a bed with crushed ammonites at about the same level and position. The ammonites, Perisphinctids but not fully identifiable (see Spath, 1936, pl. 1), were believed by Spath to be of Middle or Upper Kimeridgian date. The level was taken by Spath to mark the boundary between Lower and Upper Kimeridgian, presumably non-sequential. No certain evidence for Middle Kimeridgian has been discovered.

The upper part of the Kimeridgian Clays contains several nodule beds of which one, said to be about 30 or 40 m below the top, was labelled β by Aldinger. Horizon β is said to be very prominent along the coastal slopes north of Kap Leslie, the concretions reaching a diameter of 3 m. Spath, however, recognised several different ammonite assemblages from nodules all of which had been labelled β by Aldinger (Spath, 1936, pp. 144—146), so several nodule beds may have been confused. Aldinger also described nodule beds at the base of the series, and about 25 m higher. It is clear that stratigraphical collecting was difficult in these soft beds, and the student must bear in mind that the division by Spath of the upper part of the Kimeridgian Clays into two watertight compartments, the *Pectinatites* Beds below and the *Pallasiceras* Beds above, is not based on field evidence, as Spath pointed out (1936, p. 152). Spath places a series of Indurated Shales at the base of the *Pectinatites* Beds, but this horizon is not mentioned by Aldinger, and it is not clear whether Spath's use of the term is based on information supplied by Aldinger, or merely on the matrix of the fossils. The *Pectinatites* and *Pallasiceras* Beds were correlated by Spath with the upper part of the Kimeridge Clay of England, of Upper Kimeridgian date. *Pallasiceras* ranges up into the lowest part of the overlying Glauconitic series (p. 54), the base of which is believed to be of Upper Kimeridgian date.

2. *Southern and Central Jameson Land: The Kochs Fjeld Formation.*

The Jurassic above the Callovian is the least well-known part of the succession in Jameson Land, and has never been systematically studied. The presence of Upper Oxfordian and Kimeridgian rocks is proved by a few ammonites.

In the hinterland of Kap Stewart are a number of outcrops of grey sandstones with interbedded dark shales which Aldinger, on the strength of lithological similarity to the beds of known age near Spath Fjeld (see below), believes may represent the Oxfordian and/or Kimeridgian (1935, p. 36). The distribution of these strata is shown on Aldinger's map (*op. cit.* pl. 2, as Kimeridgian); their stratigraphic relationship with other formations is not proved, but as they appear to lie above the Vardekløft Formation Aldinger's suggestion may well be correct. They may, therefore, be the beds from which was derived a loose block of sandstone, found in the lower reaches of Lakseelv, which contained bivalves and a specimen of *Cardioceras* (*op. cit.*, p. 36). This is doubtless the fragment figured by Spath (1935, pp. 14, 68, 69; pl. 15, figs. 3a, b) as *Cardioceras caelatum* Pavlow and stated by him to be from Storgaards Elv[1]). The species is closely allied to the well-known *Cardioceras cordatum* (J. Sowerby) and indicates the presence of the Cordatum Zone at the base of the Upper Oxfordian.

More satisfactory information is available from Spath Fjeld, between Astartekløft and Moskusoksekløft, about 20 km to the north of the spot where the loose block with *Cardioceras* was found (fig. 2). On the southern side of this mountain Aldinger has recorded 5 to 6 m of light-coloured, micaceous, cross-bedded sandstone, overlying the black shales of the Vardekløft Formation, and succeeded by about 32 m of similar sandstones interbedded with black shales. The beds carry many large pieces of fossil wood, and at a horizon 5 m below the top Aldinger found a fragmentary *Amoeboceras* which indicates a Lower Kimeridgian age. These beds were named the Kochs Fjeld Formation by Rosenkrantz (1929, p. 147) after J. P. Kochs Fjeld where about 100 m thickness is said to be preserved. The formation is also present at Vardekløft (bed c in Rosenkrantz's section published by Spath, 1932, fig. 10; see Spath, 1935, p. 69).

In the summer of 1933 Bütler collected Lower Kimeridgian ammonites a little farther north, and these were recorded by Spath who figured three examples (1935, pp. 25, 69, 78, pl. 13, figs. 5—7). Bütler's ammonites were obtained at 'Basalt Table Mountain'[2]), which is the western summit of Harris Fjeld (600 m +), whence Spath noted *Amoeboceras* (*Prionodoceras*) *rosenkrantzi* and 'some very good matches of Ravn's examples' of *Amoeboceras alternans*; and 'Jagged Mountain' or 'Zackenberg', which is on the opposite, northern side of Primulaelv from the last locality, which

[1]) Aldinger said that the block was found on the valley side of Lakseelv, a short distance above the junction of Trigoniaelv. Storgaards Elv joins Lakseelv on the eastern side, about 6 km downstream from the junction of Trigoniaelv.

[2]) These names are not shown on the Geodetic Institute map. Their positions were kindly communicated to me by Dr. Bütler.

only yielded poor impressions of *Amoeboceras* indicative of Lower Kimeridgian rather than Upper Oxfordian age. The latter is the northernmost record of Kimeridgian fossils in Jameson Land, and there is no positive evidence for the northward extension of the rocks of this age. Stauber has mapped dissected outcrops of 'Malm' from the head of Hurry Inlet northwards to Olympen (1350 m) in the map published by Koch (1950, pl. 4), although part of the area in question had been shown as 'Dogger' (and part left blank) in a map accompanying an earlier paper (Stauber, 1940, pl. 1), and in the same paper (p. 22) it was stated that the Upper Jurassic was absent from central and northern Jameson Land. In fact, this area awaits full investigation.

Jurassic rocks higher than the Lower Kimeridgian have not been found in place in Jameson Land, but a loose block of hard, light grey micaceous sandstone from Aucellaelv, about 38 km west-north-west of Kap Stewart, yielded *Pectinatites* and other fossils (Spath, 1936, p. 175) and is probably of Upper Kimeridgian age.

3. Traill Ø. The Black Series.

No Oxfordian or Kimeridgian rocks are known in northern Jameson Land and Scoresby Land; but on the opposite shore of Kong Oscars Fjord, in Traill Ø, black shales with Cardioceratid ammonites are attributed to the Black Series of Maync (Donovan, 1953, pp. 28—29). The only important exposures are in Bjørnedal, in the south-east of the island. On a spur immediately east of Barrikadegletscher a thickness of 500 m was measured, and this does not represent the full thickness of the formation, for the upper limit is unknown. The rocks are soft, dull black shales, with crushed fossils at a few levels. The ammonites are principally *Amoebites* of Lower Kimeridgian age, but two possibly Upper Oxfordian ammonites were found. Unfortunately they were inadequate to prove the presence of the Upper Oxfordian beyond doubt. Almost the only other fossil is *Buchia concentrica* (J. de C. Sow.), but an interesting feature of an exposure near the apparent top of the series was the finding of large Cephalopod hooks or '*Onychites*', indicating the presence of some large and otherwise entirely soft-bodied Dibranchiate Cephalopod.

The Black Series to-day is restricted to south-eastern Traill Ø except for a possible faulted wedge in the Rold Bjerge, whose age is unproved by fossils, and a tiny remnant sandwiched between the Yellow Series and the unconformable Cretaceous on the eastern side of Nordenskiølds Ø, from which Cardioceratids were recovered. The conditions at the latter place suggest that the restricted outcrop of the Black Series in Traill Ø at the present day is due to late Jurassic or early Cretaceous denudation, and to Cretaceous overstep. It is quite impossible to say how much further north or south the series may originally have been deposited.

4. Upper Oxfordian and Lower Kimeridgian between 74° and 75° Lat.: The Grey Series and the Black Series.

After a complete absence of Oxfordian and Kimeridgian rocks in Geographical Society Ø, Hold with Hope, and the greater part of Clavering Ø and southern Wollaston Forland, deposits of the black shale facies found in Traill Ø reappear in the north-eastern corner of Clavering Ø, and are well developed in northern Wollaston Forland and in Kuhn Ø. The immediate reason for the disappearance at either end of the gap is overstep by younger formations; the question whether Oxfordian and Kimeridgian strata were ever deposited throughout the intervening area is discussed on page 106.

The outcrop in Clavering Ø consists of a minute wedge of black shales with bands of sandstone, discovered by Noe-Nygaard and Säve-Söderbergh and shown in their large-scale map (1932, pl. 5) as 'Inoceramusschiefer' on the coast 3.5 km north of Djævlekløft. These authors thought the shales to be Cretaceous, but Maync discovered *Buchia concentrica* ('*Aucella* (*Buchia*) *bronni* Lah.') which demonstrates that they belong to the Black Series. About 20 m of the beds is exposed; the relationship to other formations is not seen (Maync, 1947, p. 117).

In Wollaston Forland and Kuhn Ø Maync recognised two formations, of Upper Oxfordian and Lower Kimeridgian age respectively (figs. 7, 8). The lower is the Grey Series, consisting of sandstones and sandy shales with fossil wood, belemnites (*Pachyteuthis*) and *Amoeboceras* (*Prionodoceras*). The series contrasts sharply in colour with the Yellow Series below, upon which it rests non-sequentially with a sharp junction. The thickness is generally about 40 m. The Grey Series passes up into the Black Series, the base of which is taken arbitrarily at the lowest limestone band (Maync, 1947, p. 129). The Black Series consists of black shales, with occasional thin bands of yellow-weathering limestone and hard, fossiliferous, calcareous nodules. In Kuhn Ø, where it is thickest, the series is notable for the absence of coarse sediment, but in Cardiocerasbjerg, western Wollaston Forland (see fig. 9), the upper part of the formation is sandy shales with subsidiary bands of sandstone. The original thickness of the Black Series is unknown, since it is everywhere succeeded unconformably by later deposits, and an unknown thickness has been removed. In the only area where the next higher formation, the Kuhn Beds, occurs, the Black Series is absent. In Cardiocerasbjerg 155 m of the Black Series is present; at Sauruspasset,

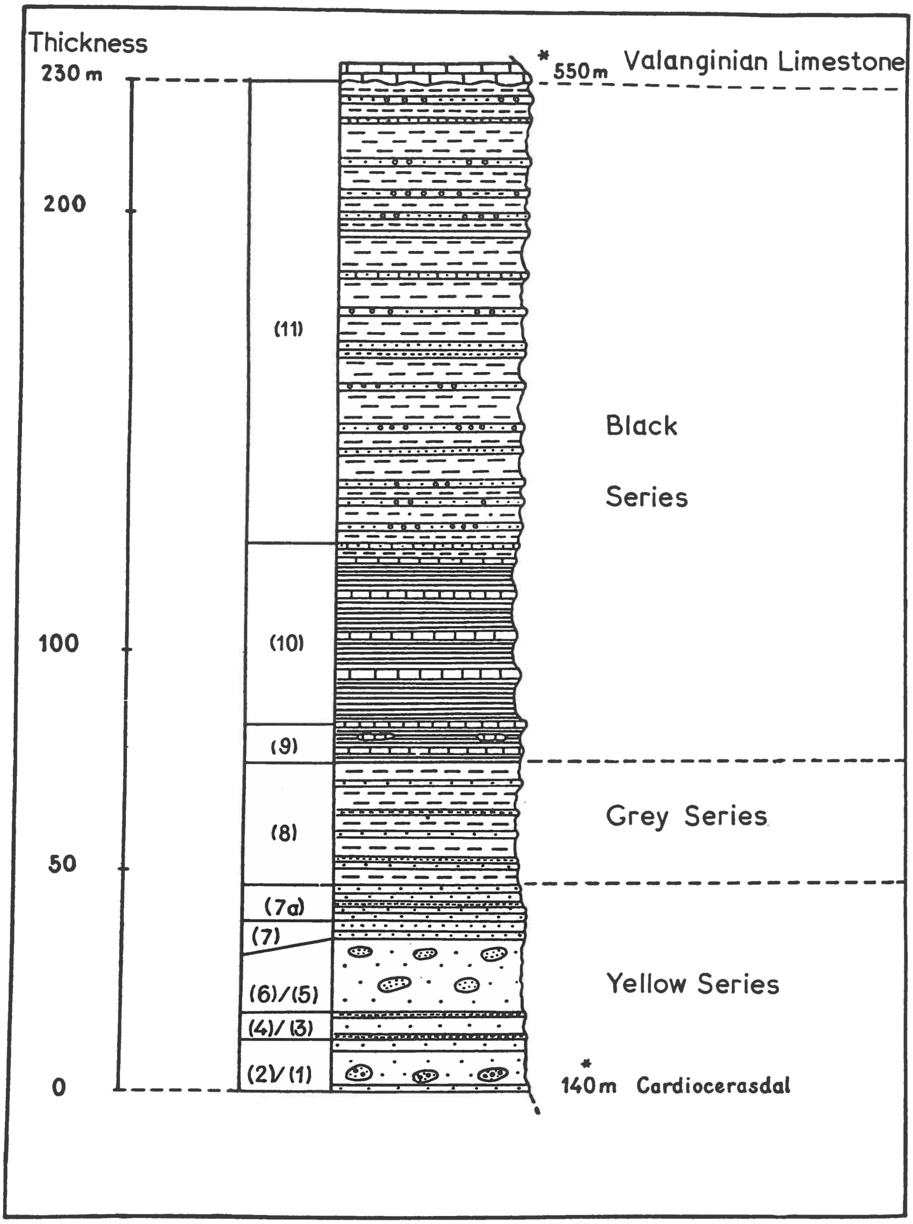


Fig. 7. Diagrammatic section through the Jurassic rocks at Cardiocerasbjerg, Wollaston Forland. For explanation of conventions see figure 18, page 95. Adapted from Maync (1947, fig. 29).

about 14 km to the north, 370 m is seen. The thickest section is at Bernbjerget in southern Kuhn Ø (point 620 m on the Geodetic Institute map) where a thickness of 630 m was measured by Maync, the

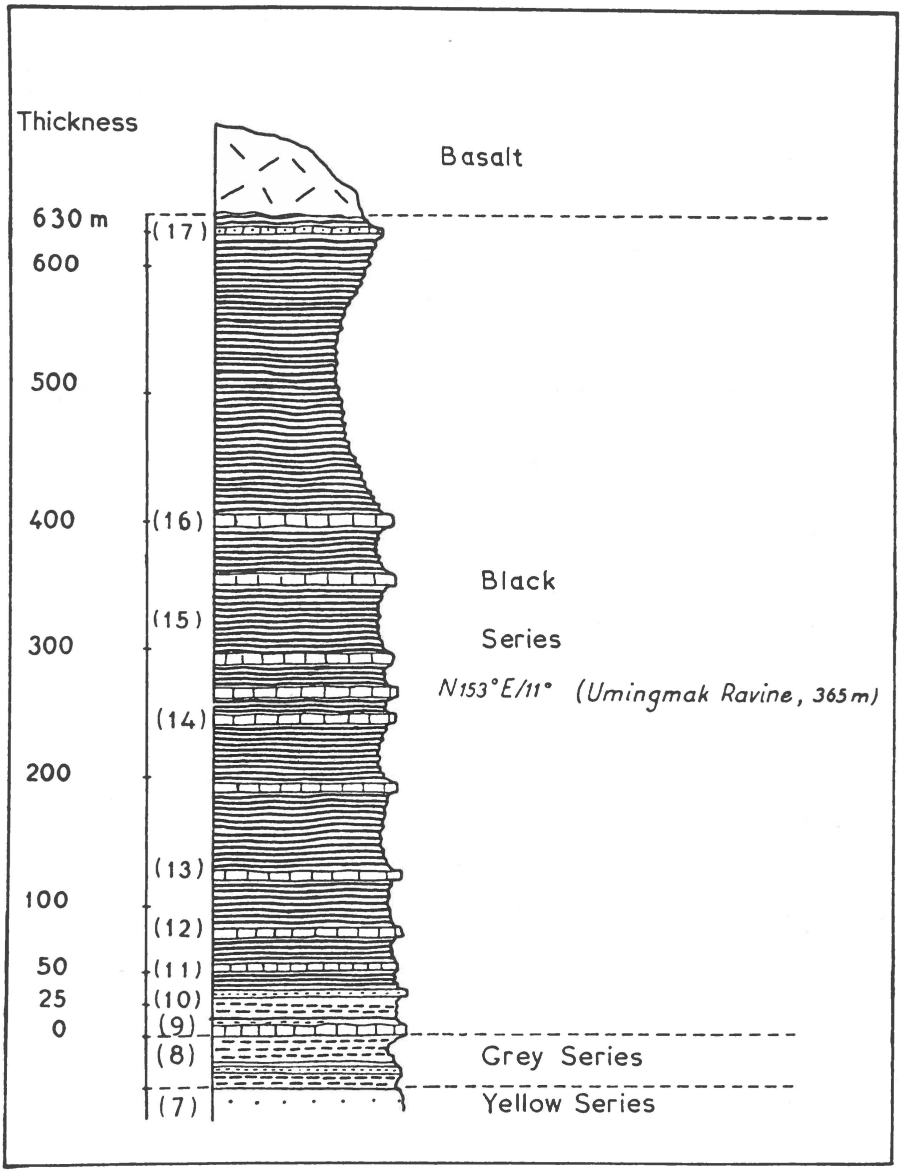


Fig. 8. Diagrammatic section through the Grey Series and Black Series near Bern Plateau (point 620 m), northern Wollaston Forland. For explanation of conventions see figure 18, page 95. Adapted from Maync (1947, fig. 6).

upper limit being formed by a basic sill. A study of the faunas might show whether the series is, in fact, thinner in Wollaston Forland, or whether the thinness there is due to removal of the upper part of the formation.

On the east coast of Th. Thomsens Land, opposite the westernmost point of Kuhn Ø and from 1.5 to 3.5 km south of Blaabærhytten, Upper Oxfordian beds were discovered by Teichert and Backlund in 1932. There are a few exposures along the coast, separated and surrounded by Quaternary deposits; they have been described by Maync (1947, pp. 43—51). Observing a consistent, if not constant, dip to the north-west, Maync constructed a diagram (*op. cit.* fig. 14, p. 50) showing that, if the same dip was assumed to continue between the exposures, a thickness of about 270 m must be present. On account of the possibility of folding or faulting it seems unwise to place much reliance on this figure. The beds exposed consist of sandstones and sandy shales, often micaceous, coaly and pyritic. Fossil wood occurs, and a fairly large fauna has been collected which corresponds closely to that of the Pecten Sandstone in Milne Land. Presumably the beds should be regarded as belonging to the Grey Series.

The fossils collected by Maync from the Grey Series and Black Series on the 1936—38 Expedition have not been published, so that little can be said as to the fauna and correlation of these two formations. A few fossils are listed by Maync in his stratigraphical sections; they were presumably identified by Spath (Maync, 1949, p. 6). The Grey Series has yielded Upper Oxfordian ammonites at Kingofjeldet (point 1034 m) near the southern tip of Kuhn Ø (Maync, 1949, p. 16), and the assemblage from the beds south of Blaabærhytten, in Th. Thomsens Land, is of similar date (*op. cit.*, p. 51). An example of *Amoeboceras* (*Prionodoceras*) *rosenkrantzi* Spath (1935, pl. 12, fig. 4) collected by Rosenkrantz from Cardiocerasdal in Wollaston Forland probably also came from the Grey Series. Lower Kimeridgian fossils are perhaps more common, and presumably the various records of *Amoebites* sp. by Maync are of this date. Maync's records also include *Amoeboceras* (*Amoebites*) cf. *elegans* Spath, and *A.* (*Hoplocardioceras*) *decipiens* Spath, both known from Milne Land; the latter had already been recorded and figured from western Kuhn Ø by Frebold (1933, p. 120 pl. 1, figs. 1—4, *Aspidoceras* sp.).

5. Upper Kimeridgian of Kuhn Ø: The Kap Maurer Formation.

The formation is exposed along the south-eastern coast of Kuhn Ø, and Maync has given a composite section showing 496 m of black shales, with sandy portions and with occasional bands of calcareous sandstone, here reproduced in figure 9. The base of the formation is not seen; the upper limit is formed by unconformable Valanginian limestones (Maync, 1947, pp. 36—42, figs. 10—12). These beds were discovered in 1927 by Lauge Koch, who found a few fossils on the basis of which Rosenkrantz assessed the age as Middle Portlandian (Koch, 1929, pp. 177—78), and

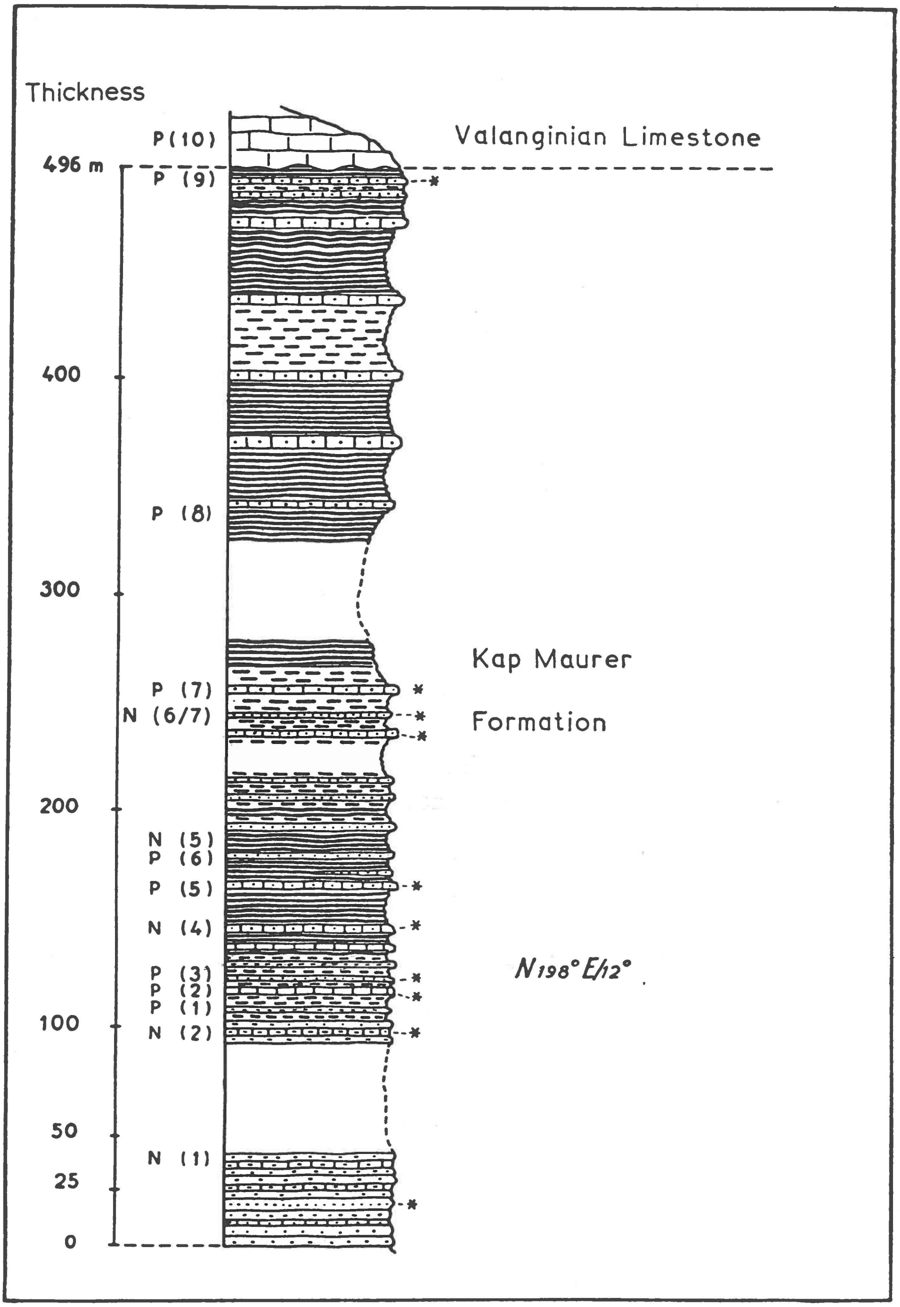


Fig. 9. Composite diagrammatic section through the Kap Maurer Formation (Kuhn Beds) in the neighbourhood of Perisphinctes Ravine, south-eastern Kuhn Ø. For explanation of conventions see figure 18, page 95. Adapted from Maync (1947, fig. 11).

who named the beds the Kap Maurer Formation. Maync discovered ammonites of the genus *Pectinatites* and of the subfamily Pavlovinae, which show the rocks to be of Upper Kimeridgian date (Maync, 1947, p. 38). He proposed the name Kuhn Beds on the grounds that the name 'Kap Maurer Formation' was misleading, since the outcrop of the beds lies from about 8 to 10 km south of Kap Maurer.

Maync believes (*op. cit.*, p. 39) that part of the Black Series in the neighbourhood of Albrechts Bugt, northern Wollaston Forland, will be found to belong to the Kuhn Beds, but there is so far no positive evidence for this hypothesis. Both formations are essentially of the same facies.

6. Hochstetters Forland: The Muschelbjerg Formation.

Several areas of Upper Jurassic rocks have been discovered on the western side of Hochstetters Forland, facing Ardencaple Fjord, and they are mainly to be attributed to the Kimeridgian, although the evidence is inadequate. The northernmost area of sediments is around Peters Bugt, where Backlund found loose slabs of sandstone with *Camptonectes broenlundi* Ravn, *Tancredia jarneri* Ravn and *T. curtansata* (Phillips), and greyish-black sandy shale with a small *Oxytoma* and *Buchia* of the group of *B. concentrica* (J. de C. Sow.) ('*Aucellen* aus der *bronni*-Gruppe') (Frebold, 1933, pp. 33—34). The species found in the sandstone are all known from the Upper Oxfordian to Lower Kimeridgian deposits of Store Koldewey, and of those found in the shale, the *Buchia* suggests a similar date.

About 8 km south of the last locality, fossils were again found in loose blocks in the neighbourhood of Karls Pynt. The ammonites described and figured by Frebold (*op. cit.*, pp. 34—35; pl. 3, figs. 31, 32) are probably to be referred to *Amoeboceras* and *Rasenia*, although they are badly preserved. An Upper Oxfordian or Lower Kimeridgian date is again indicated.

The third, and best-known, area of sediments is at the Muschelbjerg, and a map has been published by Frebold (1932, fig. 3, p. 13). There is one large, and several small areas of sediments surrounded by the pre-Cambrian Eleonora Bay Formation, but the relationship of the two, where seen, is faulted, and Frebold could not find any direct evidence that the Jurassic sediments rest directly on the pre-Cambrian. It seems probable that they do, for no other formations have been discovered in the area. The sediments are sands and sandstones; the thickness is not given by Frebold, but judging from his map and panorama (1932, fig. 16, p. 81) must be at least 250 m. A noteworthy feature is a group of three coal seams which are exposed in faulted outcrops at and near the coast. The average thickness of each seam is about 2 m, but one reaches 4.2 m including a shaly intercalation 45 cm thick. The group of seams is capped by a marine band which carries *Isognomon groenlandicus* Ravn and *Camptonectes lens* (J. Sow.). These former species is known from the Upper Oxfordian to Lower Kimeridgian Kløft I Formation of Store Koldewey, and a similar age has therefore been assumed for the sediments at Muschelbjerg. The coal has been analysed by Pedersen (1955), who concludes that it is technically a lignite and not a true coal.

As the sediments of the Muschelbjerg area cannot be definitely correlated with any of the well-known Jurassic formations, the name 'Muschelbjerg Formation' is here proposed for them, for convenience of reference.

At Kap Oswald Heer, on the east side of Hochstetters Forland, the Danmark Expedition discovered ammonites, which were too poor for Ravn to identify, in micaceous sandstone (Ravn, 1911, p. 493). Koch revisited the locality, and found that the cape and its immediate surroundings were made up of sandstones; he shows an area about 7 km long on his map (Koch, 1929, p. 176, pl. 4). Koch did not find any fossils and the age of the sediments, which may reach 100 m or more in thickness, remains unknown.

To sum up, there is evidence for four areas of sediments on Hochstetters Forland, of which only one, at Muschelbjerg, is at all well-known. Rocks of Upper Oxfordian or Lower Kimeridgian age are proved, but other stages may be present. Other areas of Mesozoic rocks may await discovery, and the area will certainly repay attention from future expeditions.

7. Store Koldewey: The Kløft I Formation.

Upper Oxfordian and Lower Kimeridgian deposits were discovered along the eastern coast of this island by the Danmark Expedition in 1906—08 (Ravn, 1911) and were visited by Lauge Koch in 1927. Collections were also made by E. Nielsen in 1933, but have not been described. The rocks have been referred to (Koch, 1929a, p. 254) as the Kløft I Formation, and a detailed section at Kløft I, on the eastern coast of the island about 45 km from the southern end, was published by Koch (1929, pp. 167—68). Here are seen about 60 m of sands and sandstone, the latter with calcareous cement, often micaceous and highly fossiliferous. Fossils were collected at a number of levels, and show that the lower part of the section is of Upper Oxfordian age, with *Prionodoceras*[1]), while the higher beds belong to the Lower Kimeridgian, proved by the presence of *Aulacostephanus*. The rocks were evidently deposited, like the other Mesozoic formations in Store Koldewey, in a

[1]) '*Cardioceras alternans*' of Ravn and Rosenkrantz. See Spath, 1935, p. 78, pl. 13, figs. 5—7.

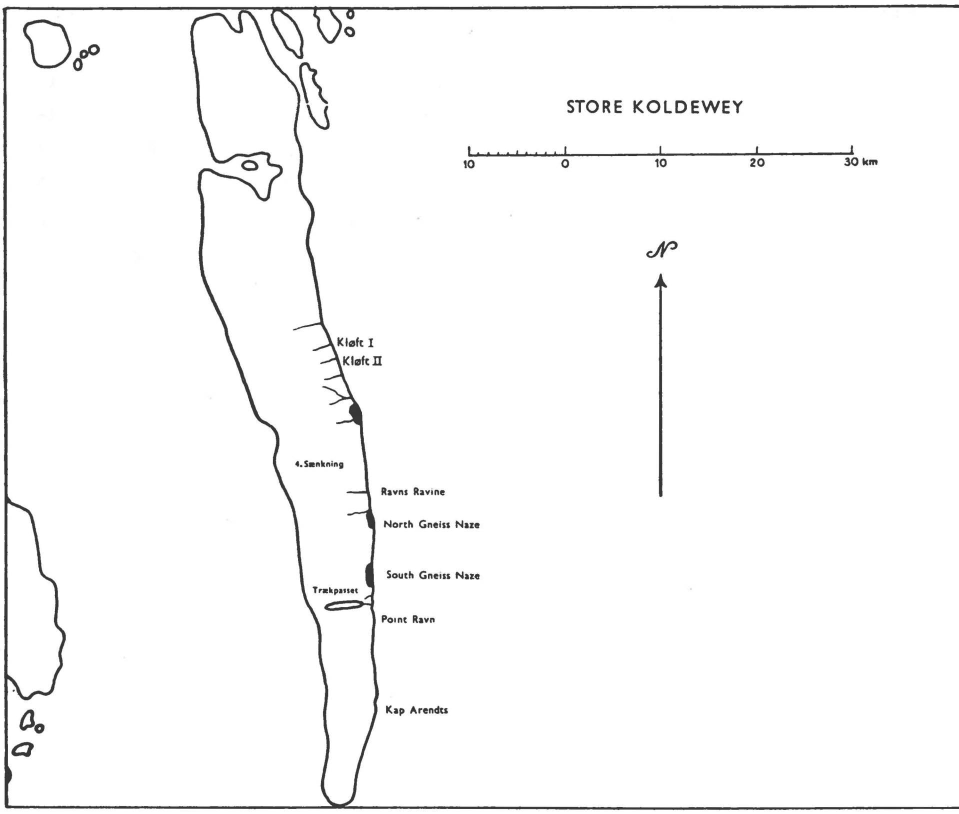


Fig. 10. Map showing the positions of Jurassic and Cretaceous localities in Store Koldewey. Scale 1:500,000. The gneiss outcrops on the east coast shown by solid black

shallow sea which lapped over the eastern edge of the island only. The outcrops, which extend discontinuously about 20 km south of Kløft I, are shown in Koch's map (1929, pl. 5). It appears probable that the Kløft I Formation rests on the Callovian Trækpas Formation. Ravn (1911, p. 444) says that at the southern Gneissnæs Jarner found sandstone, believed to belong to the formation, resting directly on the crystalline basement. These localities are shown in figure 10, on this page.

Portlandian.

1. Milne Land: The Glauconitic Series and Hartzfjeld Sandstone.

To the north and west of Hartzfjeld the Glauconitic Series consists of from 70 to 80 m of glauconitic sands and sandy clays. The succession may be summarised, from Aldinger (1935, p. 64) as follows[1]:

[1]) Spath (1936, p. 155) uses the term 'Glauconitic Series' in a more restricted sense than Aldinger. Spath's 'Sandy Shales with horizon α' are equivalent to the highest part of the series in Aldinger's sense. Aldinger's usage is followed in the present work.

(Hartzfjeld Sandstone above)	
Grey sandy clays, with bands of glauconitic sand	40—50 m
Sandy clays with grey, micaceous and phosphatic concretions....	20 -
Glauconitic and ferruginous sands with hard, iron-rich concretions.	7 -
Hard, coarse, cross-bedded glauconitic sandstone...............	2—3 -
(Kimeridgian Clays below).	

On the eastern or coastal side of the Hartzfjeld the uppermost 30 m is not glauconitic. Here the succession is (Aldinger, 1935, p. 63):

(Hartzfjeld Sandstone above)	
Sandy micaceous shales, the base marked by a reddish-brown-weathering clay ironstone nodule layer, or a rusty, ferruginous sandy marl. About 15 m above the base a bed of large, hard, sandy and micaceous phosphatic nodules, (horizon α) with ammonites, bivalves and abundant fossil wood...............	c. 30 m
Alternating beds of glauconitic sand and sandstone, clay ironstone. The *Pinna* Bed near the top	c. 13 -
Soft, brown sandstones..	c. 7 -

The series is remarkably fossiliferous, with ammonites, lamellibranchs, gastropods, brachiopods, crustaceans and wood. The commonest fossil is *Pinna constantini* de Loriol, forming the *Pinna* Bed in which these bivalves have been preserved in the vertical growth-position.

Aldinger mentioned the possibility that the increase in thickness of the series towards the north and west was due to the incoming of a glauconitic facies at the top of the Kimeridgian Clays (1935, p. 64) and Spath also seems to favour this possibility (1936, p. 160). Unfortunately the ammonites, which Aldinger hoped would decide the point, were inadequate to do so.

In the Glauconitic Series, as in the beds below, the field evidence is inadequate to establish a detailed ammonite succession, although there is little doubt that a number of successive faunas are present. Spath correlated the series with the uppermost Kimeridgian and the Lower Portlandian (*i. e.* the Portland Sand series of Dorset, England). The ammonites include well-preserved examples of *Glaucolithites*, *Dorsoplanites* and *Pavlovia* and are accompanied by a large suite of other mollusca.

The Hartzfjeld Sandstone is the youngest formation present in Milne Land. The Hartzfjeld, the type locality, is the central peak of a narrow ridge which extends, in an arcuate form, from near Kap Leslie to Kronen Bjerg, 7 km to the north-west (fig. 11). The basal part consists of medium to coarse-grained, cross-bedded sandstone, up to 40 m thick, without bedding planes (Aldinger, 1935, fig. 17, p. 65). This is presumably the 'Hard Sandstone' of Rosenkrantz's section published by Spath (1936, fig. 1, p. 145). There are no marine fossils in these basal beds.

The main part of the formation displays rhythmic sedimentation, each unit being as follows:

Medium to coarse-grained, light coloured, cross-bedded sandstone, sometimes felspathic or conglomeratic. Usually with numerous ferruginous beds	10 to 30 m.
Dark, micaceous sandy shale or fine sand, becoming more sandy upwards and passing into yellow and white sands and sandstones. Calcareous and clay ironstone concretions. The sandy shales and sandstones are weakly cross-bedded............	

These cycles are repeated to make up a total thickness of about 200 m. This is the only part of the formation which has yielded marine fossils, and a list of the fossiliferous horizons, with their heights above the base, is given by Aldinger (1935, pp. 67—68). A prominent horizon in the southern part of the outcrop is the Lingula Bed, with *Lingula zeta* (Quenstedt) and many other fossils. The majority of fossils, unfortunately from the point of view of correlation, are lamellibranchs, the only ammonites, besides a fragment of a very large individual reminiscent of the giants found in the Portland Stone of England (Spath, 1936, p. 67: *Titanites*? sp. ind.), being two new species of *Craspedites*, a new genus *Laugeites*[1]), which was later discovered by Maync in south-western Kuhn Ø (see p. 60), and a new species *Subcraspedites groenlandicus*. The latter is comparable to forms found in the English Spilsby Sandstone, and is therefore probably Berriasian. The species of *Craspedites* and *Laugeites*, which were found at lower horizons than the *Subcraspedites*, are believed by Spath to be uppermost Jurassic, although they cannot be exactly dated. The main part of the Hartzfjeld Sandstone must lie near the boundary between Jurassic and Cretaceous.

The uppermost 100 m of the Hartzfjeld Sandstone commence with dark, micaceous clays, followed by alternating beds of sandstone and sandy clay. These divisions are presumably the beds between 535—590 m and 590—630 m respectively in Rosenkrantz's section (Spath, 1936, fig. 1, p. 145). They have yielded no fossils except poor plant remains, and the stratigraphical age is therefore unknown.

2. *South-western Jameson Land.*

South-western Jameson Land is mostly low-lying country mantled by Quaternary deposits, and nothing is known of the 'solid' geology. At Aucellaelv, about 38 km west-north-west of Kap Stewart, fossils

[1]) Described as *Kochina* (Spath, 1936, p. 81). The name was found to be preoccupied and was changed to *Laugeites* by Spath (1936a).

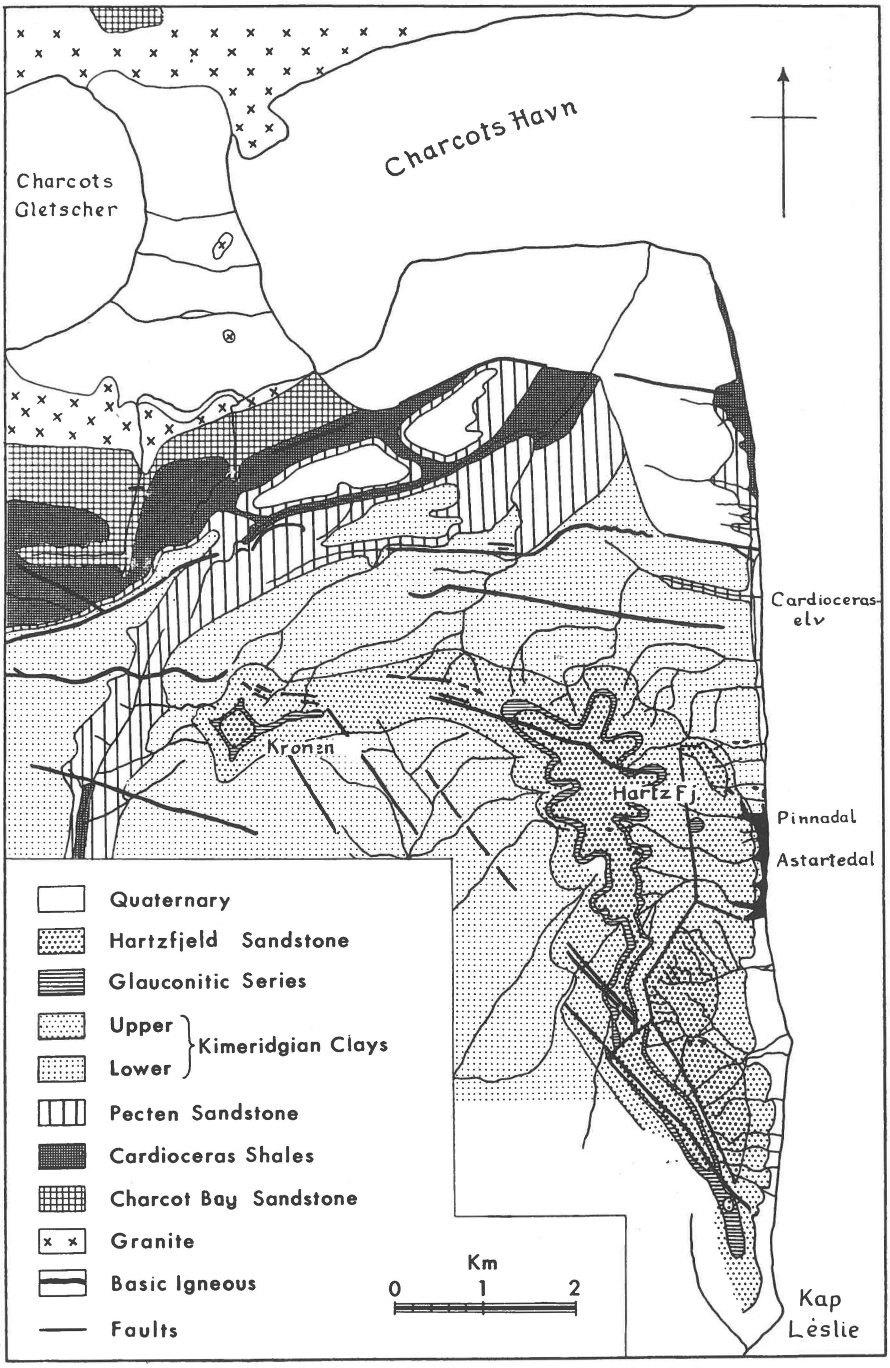


Fig. 11. Geological map of part of Milne Land. Scale 1:80,000. Redrawn and adapted from Aldinger (1935, pl. 3).

have been collected from loose blocks by Amdrup's expedition (Madsen, 1904) and by Rosenkrantz in 1926. The records have been summarized by Spath (1936, pp. 176—77). One block yielded probably Upper Kimeridgian ammonites, referred to on page 46. The other contained no identifiable ammonites, but a fauna of about 20 species of lamellibranchs, brachiopods and other forms. The list includes *Pinna constantini*, which is abundant in the Glauconitic Series of Milne Land, a number of other species in common with that formation, and half a dozen forms unknown in Milne Land. There is little doubt that the block was derived from a Portlandian formation, in Spath's view probably not one of those recognised in Milne Land. Portlandian rocks may therefore be expected to occur in southwestern Jameson Land, and indeed part or all of the clays and sandstones of unknown age, mapped by Aldinger (1935, pl. 2) nearer Kap Stewart, may belong to the stage. Further work in the area is desirable, but might not be very rewarding.

3. The Rigi Series of the northern region.

Wollaston Forland.

The Rigi Series is a coarse clastic formation which is found in the westernmost part of Wollaston Forland. It rests with strong discordance and overstep on the earlier Jurassic formations as shown in figure 14; see also Maync's diagram (1947, pl. 4). At the type locality it consists of conglomerates and sandstones with occasional boulder beds, seen to a thickness of 564 m (Maync, 1947, pp. 73—77, fig. 23). The constituents of the conglomerates were derived from the crystalline rocks to the west of the Lindemansdalen Fault. The position and relationships are shown in a block diagram by Maync (*op. cit.*, pl. 5), and the whole clearly accumulated along a steep, rocky, fault-line coast, after the planation of the faulted and tilted earlier Jurassic rocks, presumably by wave action. As it rests unconformably on the Black Series, the Rigi Series must be later in date than Lower Kimeridgian, and allowing time for the tilting and erosion of the older rocks it is likely to have been laid down towards the end of the Jurassic, at the earliest. At the 'Niesen' (point 688 m) what appears to be the same formation appears below Berriasian rocks, but it is impossible to draw a precise boundary line (Maync, 1949, p. 98) and, indeed, sedimentation seems to have been continuous, Maync basing his attribution of the lowest beds to the Rigi Series on the fact that they contained species of *Buchia* which seemed akin to *B. volgensis* and *B. mosquensis*, which in Kuhn Ø are associated with *Laugeites*. The only fossil recorded from the Rigi itself is *Buchia* of unnamed species.

On the western side of Palnatokes Bjerg, about 6 km south of the Rigi, an accumulation of crystalline boulders about 130 m thick was observed by Maync resting on crystalline rocks, and the top of the section yielded *Buchia* said to be similar to species found associated with *Laugeites* in western Kuhn Ø (Maync, 1947, pp. 78—82, figs. 24—26).

The Falskebugt Beds in eastern Wollaston Forland may belong to the Rigi Series, although regarded by Maync as probably Valanginian. They are described on page 70.

Clavering Ø.

A possible occurrence of the Rigi Series is in a section measured by Maync about 2 km south-east of the mouth of Dolomitdal (Maync, 1947, pp. 108—113, fig. 36). The Yellow Series is overlain by 160 m of barren conglomerates composed of crystalline rocks and Permian dolomite, attributed to the Rigi Series by Maync on the basis of their lithology. A short distance to the south, however, Maync has described a Valanginian conglomerate, dated by *Buchia keyserlingi*, which seems to be of exactly similar structure and composition, and it is difficult to see why the other occurrence should be attributed to the Portlandian rather than to the Valanginian.

Kuhn Ø.

A small area of the Rigi Series is preserved on the western coast of Kuhn Ø, and the best section is exposed in the northern branch of Laugeites Ravine, about 1 km north-west of the trappers' hut referred to as 'Haakonshytta' by Maync. Here is a series of conglomerates and banded shales and sandstones, which Maync has interpreted as an example of cyclic sedimentation, a conglomeratic 'transgression phase' passing up into a sandy and shaly 'inundation phase' which is abruptly succeeded by the next transgression phase; it seems uncertain to the present writer whether this regular interpretation of the sequence is entirely justified. The conglomerates are fossiliferous and have yielded *Laugeites*, a very late Jurassic ammonite otherwise known in East Greenland only from Milne Land, and *Buchia*. *Subcraspedites*, a Berriasian genus, occurs in the uppermost part of the succession and on one interpretation of the evidence (see page 143) these conglomerates and associated beds span the Jurassic-Cretaceous boundary. They rest unconformably on Lower Kimeridgian strata. The following is a summary of the section in the northern branch of Laugeites Ravine, after Maync (1947, pp. 32—34):

Banded shales with bands of hard, grey, micaceous sandstone: *Buchia*	
Coarse-grained sandstone with ammonites and *Buchia*	10 m
Dark, sandy shale, with a 2 m bed of sandstone	5 -
Alternating beds of black, friable, sandy shale and light-coloured sands and sandstone; also a yellowish-white band of sandstone	10 -
Yellow-grey, coarse sandstone, alternating with coal-black, sandy shales	7 -
Conglomerates and micaceous sandstones; *Laugeites*, *Buchia*	12 -
(Unexposed	20 -)
Banded shales and rusty brown sandstones	8 -
Coarse sandstone with conglomeratic base	2
Hard conglomerate in matrix of micaceous sandstone	0.3 -
Sandstone with conglomeratic base	2
Banded shales	8
(Unexposed	?)
Banded shales	3 m
Hard, slabby sandstone	1 -
Friable conglomerate	2.5 -
Yellow, banded sandstone, with a bed of black shale	2.5 -
Grey, rusty-weathering coarse, micaceous sandstone, with *Buchia*, passing up into grey, coarse sandstone with quartz pebbles	12 -

The upper horizon with ammonites has yielded identifiable fossils in the southern branch of the ravine, and it is here that *Subcraspedites* and *Tollia* were found as well as *Laugeites* (Maync, *op. cit.*, p. 34). The interpretation of this association of ammonites is discussed on page 143.

4. Portlandian(?) of Germania Land.

The outcrops on Store Koldewey are the northernmost exposures of proved Jurassic and Cretaceous rocks. Germania Land and the coast further north, however, are almost unknown geologically, and discoveries probably remain to be made here. The loose boulders from which Upper Aptian fossils were recovered by the Danmark Expedition near Danmarks Havn are mentioned on page 76. Other boulders, in the same region, yielded a lamellibranch fauna of late Jurassic age, described by Ravn (1911), and discussed by Maync (1947, p. 152) who thought that the list included a mixture of fossils from different horizons. Ravn had considered the assemblage to be Portlandian, on the strength of *Buchia mosquensis*, and *Parallelodon schourovskii*, also recorded, occurs in the Upper Kimeridgian and Portlandian of Milne Land. It is true, as Maync points out, that other members of the fauna are best known from earlier horizons, but in view of the fact that many lamellibranch species are notoriously long-ranging it seems unprofitable to speculate further on the date of the fauna.

Ravn thought (1911, p. 445) that the fossiliferous blocks near Danmarks Havn might have been glacially transported from Jøkelbugten, discussed on page 93. In view of the distance involved (about 150 km) and the fact that the transport would have to be parallel to the margin of the ice-cap, such a derivation seems improbable, and it is perhaps more likely that some of the extensive low-lying country in Germania Land itself is underlain by Mesozoic rocks. Ravn says that no trace of sedimentary formations was found in the immediate neighbourhood of Danmarks Havn.

Lower Cretaceous.

Berriasian.

1. Milne Land.

The uppermost portion of the succession in eastern Milne Land, given on page 41, is of Berriasian age. The Lingula Bed, about half-way up the Hartzfjeld Sandstone, contains the ammonite *Laugeites* and is thus regarded as still Jurassic, but the beds above have yielded *Subcraspedites* and are supposed to be Cretaceous. The sequence of ammonites is reviewed on page 56. Unless the Lingula Bed itself marks a break, there was here more or less continuous sedimentation from Jurassic into Cretaceous; at least, there is no lithological change at which the boundary can be drawn.

2. South-western Jameson Land.

The study of the area west of Kap Stewart by Aldinger in 1933 resulted in the discovery of a new ammonite genus, *Hectoroceras*, which was described in 1947 by Spath who has also discussed the stratigraphy. Aldinger's map (1935, pl. 2) shows an extensive area of Lower Cretaceous from about 10 km west of Kap Stewart westwards, unfortunately largely masked by Quaternary debris. The best section was found in Mussel River. The sequence (Aldinger, 1935, p. 38; Spath, 1947, p. 48) is:

Cross-bedded, greyish-white to yellow, medium to coarse-grained sandstone; near the top, poor coasts of *Tancredia* and crinoid ossicles occur	100 m
Coarse sandstones with casts of *Buchia*; at the base, fine to medium-grained, grey-brown, micaceous, glauconitic sandstone, with abundant fossils: *Hectoroceras* and various other molluscs	5 -
Sandy shales with beds of hard sandstone; at the top are large, fossiliferous concretions, up to 2 m in diameter; *Hectoroceras*, *Subcraspedites*, asteroids, fossil wood	80 -
Sandy shales with pyritic concretions and plant fragments	70 -

The succession tabulated above appears to be principally of Berriasian date; the top beds, however, yielded an ammonite fragment which Spath thought was probably a later Desmoceratid (1947, pp. 51—52). Presumably sedimentation in south-west Jameson Land was continuous with that in Milne Land, but no correlation can yet be attempted, and it is doubtful whether, for instance, the 'undated sandstones with plant remains' at the top of the Milne Land succession can be regarded as equivalent to the lowermost, barren beds of the Jameson Land sequence, although it is possible. The fact that *Hectoroceras* has not been found on Milne Land may be due to the removal of the *Hectoroceras* horizon by denudation, or it may merely indicate that the corresponding beds are not fossiliferous.

3. Traill Ø.

The presence of Berriasian beds on Traill Ø has been claimed by the present writer (1953, p. 32), but is not proved by ammonites. The Pachyteuthis Beds are a series of dark, micaceous shales, accompanied by black, micaceous sandstones, at least 50 m thick. The principal fossils are *Buchia* and *Pachyteuthis*, the latter identified as *P.* aff. *partneyi* (Swinnerton), a species from the English Spilsby Sandstone, which suggests a Berriasian date for the formation. The *Buchia*, however, appears to be the same species as that from the Valanginian of Traill Ø. Dr. J. A. Jeletzky, who has examined the fossils, prefers (*in litt.*) to regard the *Pachyteuthis* Beds as Valanginian.

The *Pachyteuthis* Beds are exposed in the Rold Bjerge and in Bjørnedal, but their relationship to the other Mesozoic formations on the island is unknown.

4. The succession at the 'Niesen', Wollaston Forland.

The thickest and most complete section through the Berriasian and Valanginian is found at the mountain named the Niesen by Maync and Vischer, in north-western Wollaston Forland, marked as point 688 m on the Geodetic Institute map. The section was measured and collected from by Maync (1949, pp. 95—101), and the ammonites which he collected from the Berriasian part of the succession have been identified and figured by Spath (1952). In 1952 a further study of the mountain was made by Messrs. A. J. Standring and E.W. Roberts on behalf of the present writer. Their results have not been published, but are incorporated in this account as far as possible. There are obvious pitfalls in trying to combine Maync's and Standring's data into a single succession, since they probably did not examine exactly the same sections and there may be discrepancies between their altitude measurements.

Maync's section is reproduced in figure 13, with the addition of the ammonite records which have since become available. Exposures begin about 45 m above sea-level. The first 70 m consist of yellow sandstones and black shales, with a band of conglomerate[1]) near the top, capped by a grey, red-brown weathering micaceous sandstone, 1 to 2 m thick, which is said to carry *Buchia* similar to the species from the Rigi Series of Laugeites Ravine on Kuhn Ø (see p. 60). There is a non-sequence above this bed, for pieces of it have been found in the conglomerates of the next series. Maync classed the beds below the non-sequence with the 'Volgian' Rigi Series, those above with the Cretaceous. The same species of *Buchia* is said to occur both below and above the non-sequence (*B.* cf. *volgensis* (Lahusen)).

The beds above the non-sequence commence with about 95 m of black, micaceous shales with bands of yellow sand, alternating with coarse conglomerates containing well-rounded boulders of 'Caledonian' crystalline rocks as well as pieces of the underlying sandstone. The highest conglomerate lies at an altitude of 220 m and contains an impersistent bed of *Buchia* limestone. Just above this level the first ammonites are found, belonging to the genus *Praetollia*, and collected by Maync from sandy limestones interbedded with calcareous sandstones. From this level to the summit (688 m) are sandstones, with beds of limestone, marl and shale, which are fossiliferous at a number of levels. At 248 m Maync found a single example of *Hectoroceras*[2]), common in southwest Jameson Land, and Standring recovered several more impressions at an altitude recorded as 285 m, which may or may not be the horizon found by Maync. Standring's specimens were associated with poor Subcraspeditid ammonites. At 320 m Standring found a partial internal mould of an ammonite in coarse sandstone which closely resembles *Subcraspedites* (*Paracraspedites*) *stenomphaloides* Swinnerton, and at 360 m a comparatively well-preserved (crushed, but retaining the shell) example of *Praetollia.* At 380 m Maync found a small *Tollia*[3]) and probable examples of the same genus were found by Standring at an altitude recorded as 376 m, probably the same horizon as that which yielded Maync's example. At 388 m Standring found poor ammonites which are probably *Subcraspedites.* At this level also were found poor impressions which resemble *Praetollia*, but the identification is doubtful.

The succession from 235 m up to this point is clearly shown to be Berriasian by the ammonites. At 400 m Maync recorded a bed of *Buchia* limestone with *B.* aff. *keyserlingi* and other species, which marks the base of the Valanginian part of the section. Maync's interpretation is confirmed by Dr. Jeletzky, who has examined the *Buchia* collections

[1]) This is the lowest bed shown in figure 13.

[2]) Figured by Spath, 1947, pl. 3, fig. 2. The locality of this specimen was given wrongly as Kuhn Ø, and was later corrected (Spath, 1952, p. 13).

[3]) Figured by Spath, 1952, pl. 4, fig. 8.

made by Standring. The first Valanginian ammonites are some poor fragments of Polyptychitids found by Standring at 443 m, which may represent the fauna found in Traill Ø (p. 65). Maync's record of *Polyptychites* at 460 m may or may not refer to the same fossil horizon. Above this level there are a number of levels with *Buchia* and several with Polyptychitid ammonites, found by Standring at 520—530 m and again at various places just below the summit, between about 640 and 670 m. At the summit itself Maync found a *Lyticoceras*[1]) indicating the presence of the Upper Valanginian.

Maync has named the Cretaceous rocks of the Niesen the Niesen Beds, divided into the Lower Niesen Beds, corresponding to the Berriasian part of the succession, from 120 m (according to Maync) up to 390 m; and the Upper Niesen Beds for the remaining, Valanginian, part. The position of the base of the Berriasian in the section is discussed elsewhere (p. 144). The transition from Berriasian to Valanginian is well-defined by the ammonite fauna, but no physical evidence for a break in sedimentation has been reported. It will not be possible to say whether such a break may be present until the ammonites have been fully studied.

5. Other Berriasian outcrops in the northern region.

Maync believes that the Lower Niesen Beds can be traced to 'Palnatokes Bjerg' (point 1056 m), about 12 km south of the 'Niesen', but fossils have not been found to confirm this (Maync, 1949, p. 94). Further to the south and east the Berriasian appears to be cut out by the overlap of the Valanginian conglomerates and limestones on to Jurassic rocks. Berriasian fossils are again met with, however, in south-western Kuhn Ø, where *Subcraspedites* occurs in the uppermost conglomerate of the succession exposed in Laugeites Ravine. This section has been described on page 60, and the problems of the correlation of these beds on page 144.

Berriasian strata exist somewhere in eastern Kuhn Ø, for Toula (1874b) described an ammonite from here which is now known as *Tollia payeri* and is diagnostic of the Berriasian. The beds were said to be calcareous marls and fine-grained quartz sandstones, which yielded abundant bivalves of the group of '*Aucella*' (*recte Buchia*) *concentrica* and varieties as well as the ammonite (Toula, 1874a, pp. 477—78). The lowest Cretaceous recognised in this area by Maync is Valanginian (1949,

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[1]) Described by Spath, 1946, p. 6. Spath's statement that this ammonite and the Polyptychitid fauna mentioned by him (Maync's 460 m horizon) are separated by 65 feet of deposits is clearly a mistake; according to Maync's section the difference in altitude is 228 m or about 700 ft.

p. 19); it is conceivable that the lower part of his section is of earlier date, or alternatively that the Second German Expedition collected from a locality unknown to Maync.

Valanginian.

1. Traill Ø.

The most southerly occurrence of Valanginian rocks in East Greenland is in Traill Ø, where their existence was deduced by Frebold & Noe-Nygaard (1938, p. 31) from a loose block of *Buchia*-bearing limestone which they found in Bjørnedal. This clue was followed up by the present writer who discovered a number of occurrences of *Buchia*-bearing rocks which he divided between the Berriasian and the Valanginian. The only outcrops attributable with certainty to the Valanginian are on the western flanks of the Mols Bjerge, in the north-east of the island, and unfortunately their stratigraphic relationships are unknown. The northern occurrence is about 4 km due south from the coast immediately west of Kap Palander, the southern about 3 km inland from the northern shore of Mountnorris Fjord. The same rocks and fossils occur at both places. At the southern locality they are not seen in place, but at the northern one a bed of hard, grey fine-textured limestone, about 30 cm thick, lies at or near the surface over a considerable area, and the ground is littered with weathered-out fossils. These two occurrences belong to the calcareous Albrechts Bugt facies of the Valanginian recognised by Maync in Wollaston Forland, to judge from the identical preservation of the fossils from the two areas (Donovan, 1953, pp. 33—34, 49—50; 1955, pp. 20—22).

The fossils are excellently preserved. The ammonites are usually internal moulds lacking the body chambers, but the specimens of *Buchia* sometimes retain part of the shell. The fauna, which has been partially described (Donovan, 1953), includes over 30 species. A full description, including records of species discovered since the first account was written, has been postponed in the hope of obtaining more material for comparison from Wollaston Forland. The most interesting feature of the fauna, discussed more fully on page 149, is the number of 'southern' or Mediterranean genera, which have not been found in any other northern locality.

The fossiliferous limestone is interbedded with dark shales, and it is possible, but not certain, that more than one bed of limestone occurs. It is quite impossible to say what thickness ought to be assigned to the Valanginian, although a more intensive study of the western Mols Bjerge might produce the information. The extremely restricted distribution of the Valanginian in Traill Ø at the present day is attributed to the destruction of the beds by the late Neocomian denudation, and to concealment by Middle Cretaceous overstep. There is some evidence for the former extension of the Valanginian. Hard calcareous nodules, containing examples of *Buchia* which are difficult to extract but apparently identical with the ones from the known Valanginian outcrops, have been found further east in the Mols Bjerge, in Lycett Bjerg on the opposite side of Mountnorris Fjord, and in the Svinhufvuds Bjerge[1]). These are interpreted as blocks of Valanginian limestone subsequently incorporated in basal conglomerates of the Middle Cretaceous Shales, although the stratigraphic relationships are not in all cases clear, and the Svinhufvuds Bjerge occurrence may be derived from an actual wedge of Valanginian rocks. The blocks are unlikely to have been transported far and indicate that the Valanginian may have originally extended over the greater part of eastern Traill Ø. No rocks of this stage have been found in Geographical Society Ø, where the area of pre-Albian rocks is very small.

2. Valanginian of the northern region.

Two facies have been distinguished by Maync (1949, p. 185) in the Valanginian of Wollaston Forland and the neighbouring areas, and named by him the Young Sund Facies and the Albrechts Bugt Facies. The Young Sund Facies accumulated near steep coast-lines (and possibly islands) in the Neocomian seas. A noteworthy feature of this coarse clastic series is the inclusion, as brecciated fragments, of grey *Buchia* limestone which is also found in normal beds interbedded with the clastic rocks. The series thus appears to have accumulated under conditions alternately of comparative quietness, when practically no sediment was deposited and the *Buchia* limestones were formed, and vigorous erosion along the coast-lines resulting in the sandstones and conglomerates. Wave action was presumably responsible for breaking up the limestones already formed.

The Albrechts Bugt Facies accumulated away from sources of coarse sediment, and consists of 'grey or yellowish-pink marls and marly shales with limestone bands and nodules, which .... bear rich faunas of the Upper Polyptychitan' (Maync, 1949, p. 185). Both facies are strongly transgressive, resting with marked unconformity on earlier rocks; sometimes the basal beds are of the Young Sund Facies, followed by the Albrechts Bugt Facies; but elsewhere the Albrechts Bugt Facies rests

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[1]) In 1953 (p. 30) the writer classed the first two of these occurrences as "? Upper Portlandian". He now believes that they are probably derived from the Valanginian deposits.

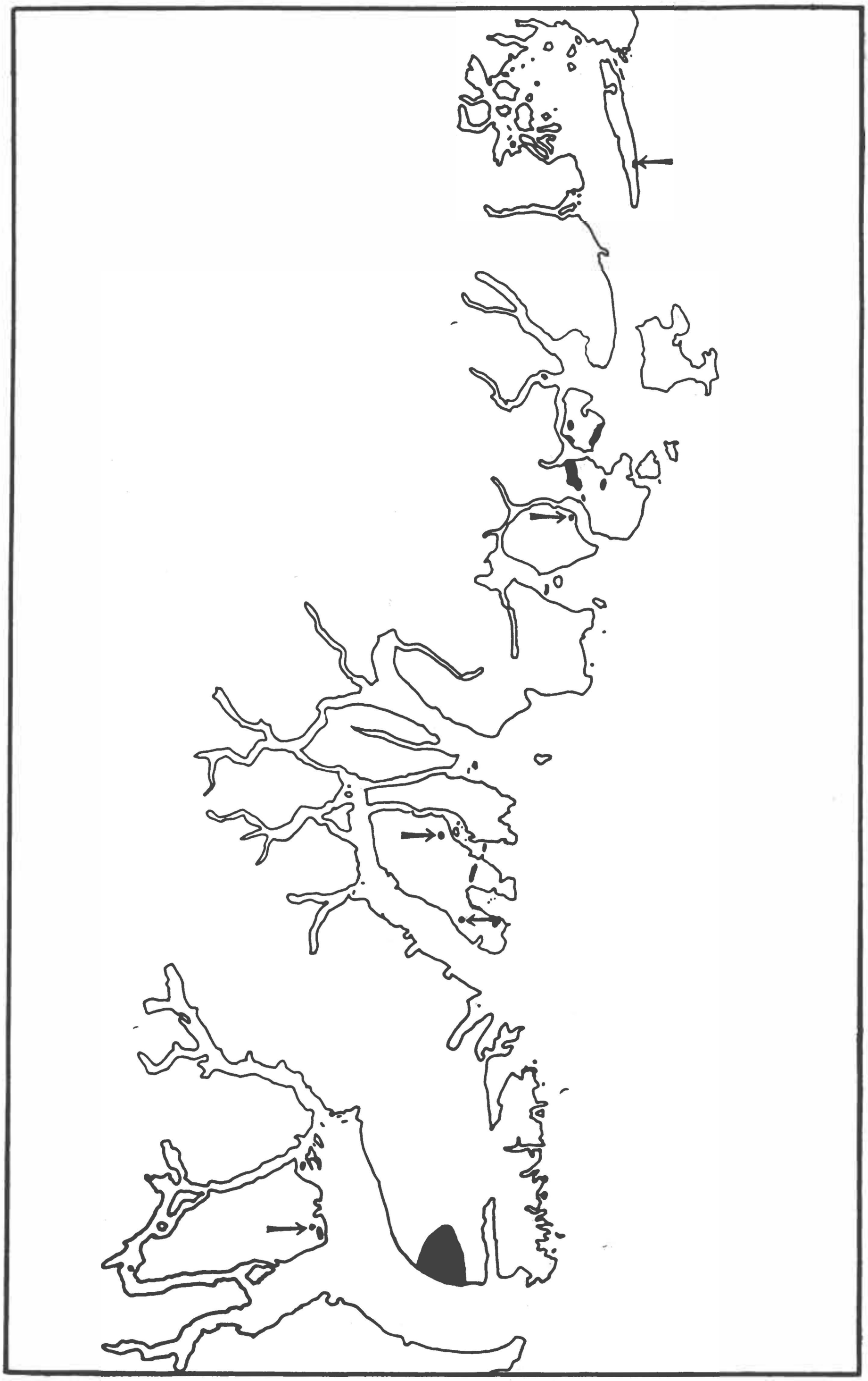

Fig. 12. Distribution of Berriasian and Valanginian rocks in East Greenland. Known outcrops shown in black. Arrows indicate the smaller outcrops.

immediately on the underlying formations without any basal conglomerate. The two facies are essentially contemporaneous (Maync, 1949, p. 86) and in fact the limestone bands in the Young Sund Facies represent intercalations of Albrechts Bugt Facies.

Clavering Ø.

The Valanginian in Clavering Ø is restricted to a small patch of *Buchia*-bearing conglomerate north of Djævlekløften, in the north-east of the island. It may be correlated with the conglomerates on Cardioceras Bjerg on Wollaston Forland, about 16 km to the north-east.

Wollaston Forland.

The thickest development of the Albrechts Bugt Facies is found at the 'Niesen', described on page 62 (fig. 13), where nearly 300 m of interbedded limestones and sandstones are present, succeeding coarse clastic beds dated as Berriasian. About 12 km to the south, at 'Palnatokes Bjerg' (summit 1056 m on the Geodetic Institute map) the same arrangement is believed by Maync to be present, although here no ammonites have been found and the correlation rests on lithological similarity and on species of *Buchia*. Further south again, in the Cardiocerasbjerg area, there is a sharp differentiation into conglomerate, or Young Sund Facies, below, and limestones of the Albrechts Bugt Facies above (fig. 14). The limestones, however, overlap the conglomerates and come to rest directly and discordantly on Jurassic rocks. The basal conglomerates, which might well be correlated with those in the lower part of the Niesen section, of Berriasian date, are believed by Maync to be Valanginian on the evidence of the species of *Buchia*, stated to be of the *B. keyserlingi-piriformis* group. Final decision on this point must rest on critical examination of the *Buchia* collections, which may or may not provide an unequivocal answer. It seems unwise to separate too rigidly the Berriasian and Valanginian conglomerates for, as stressed elsewhere (p. 111), both probably belong to successive stages in the progress of the same transgression.

The Albrechts Bugt Facies is typically seen in the country bordering Albrechts Bugt, where it is much thinner than on the 'Niesen', consequent upon the smaller supply of clastic sediment. Maync has given useful comparative sections, which are reproduced here (fig. 15). Grey

Fig. 13. Diagrammatic section through the Berriasian and Valanginian rocks (Niesen Beds) at the Niesen (point 688 m), north-western Wollaston Forland. For explanation of conventions see figure 18, page 95. From Maync (1949, fig. 30) with ammonite records added.

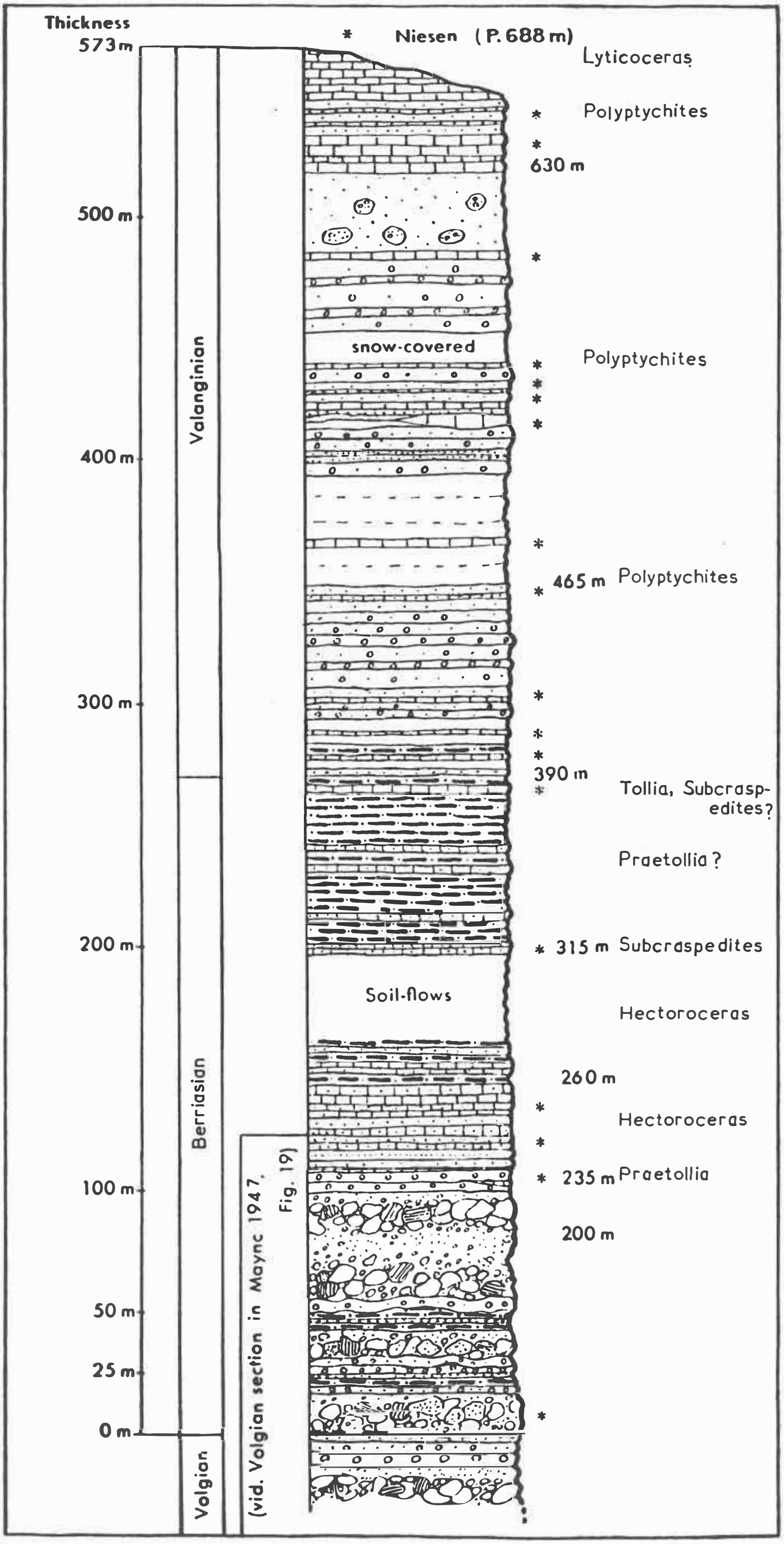
Thickness
573 m
500 m
400 m
300 m
200 m
100 m
50 m
25 m
0 m
Valanginian
Berriasian
Volgian
(vid. Volgian section in Maync 1947, Fig. 19)
Niesen (P. 688 m)
Lyticoceras
Polyptychites
630 m
snow-covered
Polyptychites
465 m Polyptychites
390 m
Tollia, Subcraspedites?
Praetollia?
315 m Subcraspedites
Soil-flows
Hectoroceras
260 m
Hectoroceras
235 m Praetollia
200 m

Fig. 13.

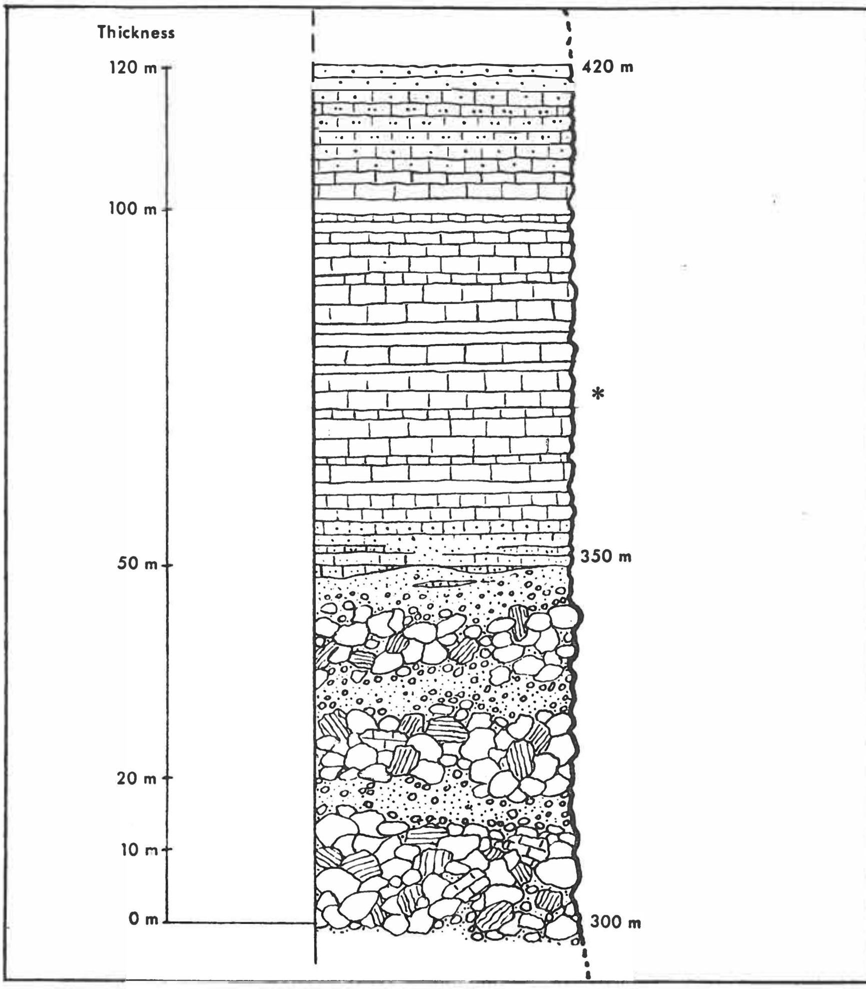

Fig. 14. Diagrammatic section through Valanginian rocks on the western slopes of Cardiocerasbjerg, western Wollaston Forland. Polyptychitid ammonites were found at the horizon indicated by the asterisk. For explanation of conventions see figure 18, page 95. From Maync (1949, fig. 26).

limestones and marls, which unconformably overlie the Jurassic, are dated as Valanginian by Polyptychitid ammonites, and are succeeded by red calcareous sandstones and impure limestones, containing *Buchia*. These are the Rødryggen Beds of Maync, and are overlain, with an abrupt lithological change to black shales, by Aptian strata. There is no significant lithological change, apart from the colour, at the base of the Rødryggen Beds and they are presumed to belong to the Valanginian.

At Falskebugt, in eastern Wollaston Forland, conditions are reminiscent of Cardioceras Bjerg, for here again coarse, poorly bedded con-

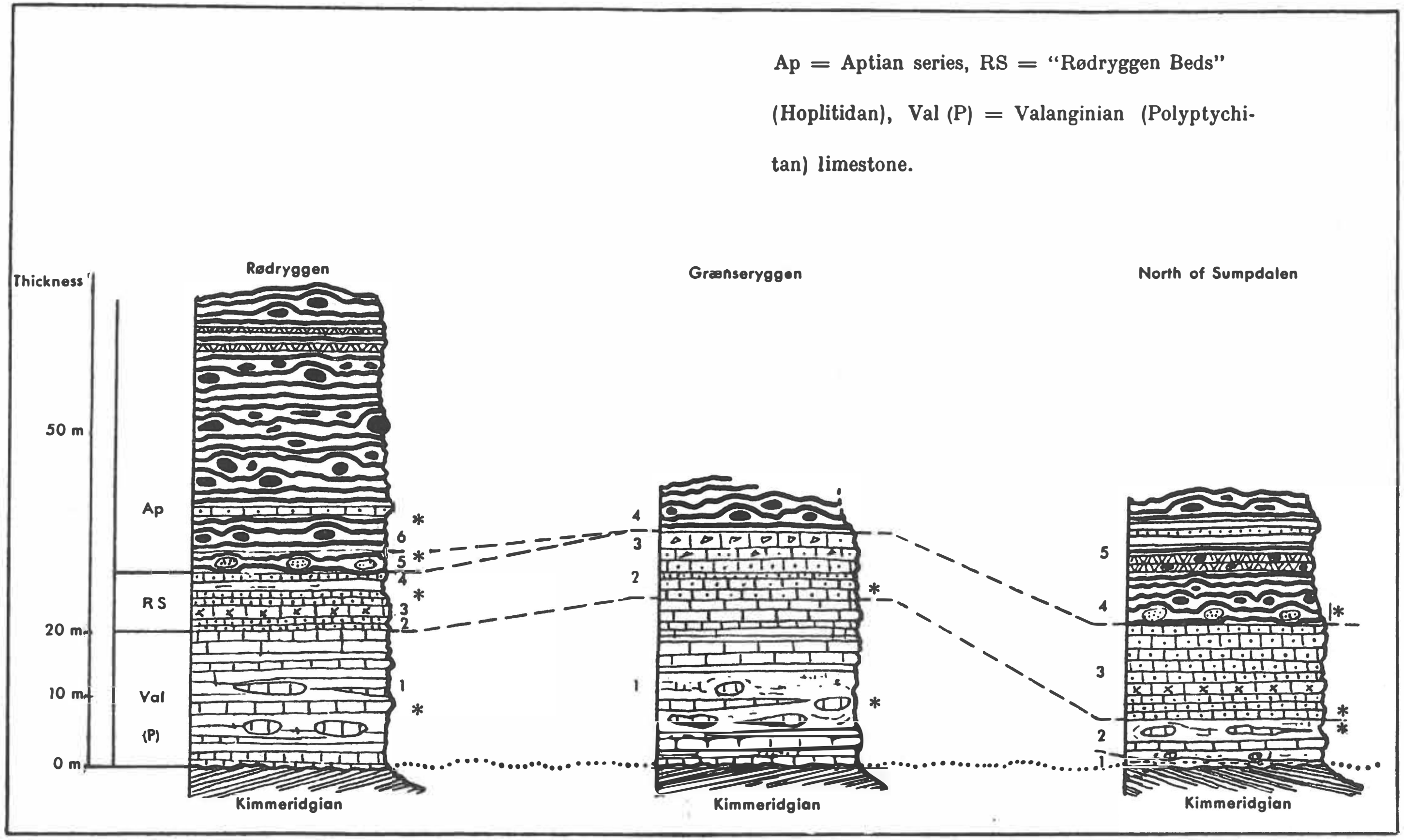

Fig. 15. Diagrammatic sections through the Lower Cretaceous rocks south-east of Albrechts Bugt, northern Wollaston Forland. For explanation of conventions see figure 18, page 95. From Maync (1949, fig. 19).

glomerates rest discordantly on the crystalline basement, and pass up into a more fine-grained, more calcareous facies with *Buchia* and belemnites. About 50 m thickness may be present, but could not be measured accurately (Maync, 1949, pp. 55—60, fig. 14). The series was named the Falskebugt Beds by Maync. Spath, quoted by Maync, thought that their fauna was Jurassic rather than Cretaceous, but Maync claims that the *Buchia* species is the one found in the beds of proved Valanginian date, and assigns the beds to that stage, although he acknowledges a lithological resemblance to the Rigi Series. The Falskebugt Beds are also exposed at the foot of Bern Plateau, as Maync and Vischer named the heights west of Falskebugt (spot height 428 m on Geodetic Institute map).

Kuhn Ø.

In south-eastern Kuhn Ø the Albrechts Bugt Facies of the Valanginian is present, and its relationships are exactly analogous to those around Albrechts Bugt. About 80 m of grey and yellow limestones, with *Buchia* and Polyptychitid ammonites, unconformably succeed the Upper Jurassic Kuhn Beds and are themselves succeeded, non-sequentially, by Aptian rocks. A composite section is given by Maync (1949, fig. 4, p. 18). The topmost 11 m consist of red sandstone and limestone which may represent the Rødryggen Beds of Wollaston Forland.

Store Koldewey.

Valanginian rocks have been found at several places on the east coast of Store Koldewey, resting on the crystalline rocks of the 'Caledonian' basement (see fig. 10). They show a coarse, sandy and conglomeratic facies, and were named the Kap Hamburg Formation by Koch (1929, p. 256). The southernmost exposure is at Aucellabjerget, where the Danmark Expedition found a conglomerate containing enormous blocks of gneiss, with abundant *Buchia* shells in the matrix. *Buchia crassicollis* (Keyserling) and allied species were identified by Ravn (1911). Ravn was puzzled by the stratigraphic section given by Jarner, the field geologist (Maync has attempted to interpret it: 1949, p. 168), and when Lauge Koch revisited the locality in 1927 it was largely snow-covered, so a better section could not be obtained. The next outcrop is at Point Ravn, 5 km to the north, where Koch measured a section which has been reproduced by Maync (Koch, 1929, p. 171; Maync, 1949, p. 170). It shows a thickness of 75 m of sandstones, with a breccia at the base. Koch found ammonites here, identified by Rosenkrantz as *Polyptychites* (*Euryptychites*) sp. cf. *gravesiformis* Pavlov, and these fix the age of the beds as Valanginian. Further north still Nielsen in 1933 measured sections in the neighbourhood of the northern Gneissnæs which have been published by Frebold (1935, pp. 20—28, figs. 8—13) and translated by Maync (1949, pp. 171—172); these rocks had been mapped as Kimeridgian by Koch (1929, pl. 5). The Valanginian rests directly on crystalline rocks, and consists again of sandstones and conglomerates, of which a thickness of about 25 m is seen. The fossils, which include *Buchia* and other bivalves, belemnites, ammonites, brachiopods and fossil wood, have not been identified, but it is presumed that the beds are to be correlated with the similar development at Point Ravn.

The locality just described is the northernmost known outcrop of Valanginian in East Greenland. The Neocomian which Ravn identified from loose blocks near Danmarks Havn (1911, p. 446) has since proved to be of Upper Jurassic age.

Aptian.

1. South-eastern Traill Ø.

The southernmost occurrence of the Aptian in East Greenland is in Bjørnedal, south-eastern Traill Ø, where black shales have yielded *Sanmartinoceras ?haugi* (Sarasin), indicating the upper Aptian, and *Lytoceras polare* Ravn. The fossils were found in isolated patches of shale in a faulted area, and nothing is known as to the thickness of the series or its relation to other formations (Donovan, 1953, p. 34). The small area of outcrop at the present day is doubtless a result of Middle Cretaceous overlap.

2. Northern Hold with Hope.

Lower Aptian sandstones unconformably overlie the Eotriassic strata and have been traced by Koch from Stensiös Plateau to a point east of Dieners Bjerg (Koch, 1931, p. 98, pl. 1); part of the area is given in more detail by Nielsen (1935, pl. 1), whose inset of Dieners Bjerg shows Cretaceous overstep across different subdivisions of the Trias. A photograph of the Trias-Cretaceous junction on the northern side of Steensbys Bjerg was also included by Nielsen (*op. cit.*, fig. 29, p. 71). Nielsen remarked that it was difficult to draw the boundary between Trias and Cretaceous on Stensiös Plateau, but Maync found an angular unconformity here (Nielsen, *op. cit.*, p. 69; Maync, 1949, p. 130). A section at Stensiös Plateau measured and published by Maync (*op. cit.*, p. 128, fig. 44) shows 176 m of yellow, friable, coarse-grained and micaceous sandstones with conglomeratic horizons. Fossil wood and carbonaceous matter are common, but marine fossils also occur, unidentified bivalves and the ammonites *Deshayesites* aff. *laeviusculus* (von Koenen) and *Lytoceras polare* Ravn (Koch, *loc. cit.* and Spath, 1946, p. 8). In Rødeelv, according to Maync (1949, pp. 211—212), the Aptian rocks are seen to be succeeded by the Home Forland Beds, and a short distance to the east the Aptian (and the Eotrias) is carried below sea-level by fault 9, for between rivers 25 and 26 the Home Forland Beds occur nearly down to sea-level (Maync, 1949, p. 132) (the faults and rivers are marked on Koch's pl. 1).

For a possible eastward extension of the Aptian, on the western side of Loch Fyne, see page 93.

3. *Wollaston Forland.*

The thickest development of Aptian rocks in Wollaston Forland is found on the eastern slopes of the Aucellabjerget, where coarse-grained and sometimes conglomeratic sandstones carry fossiliferous clay-ironstone concretions. The apparently extensive fauna has not yet been studied in detail, but Maync's records (based on identifications by Spath) include abundant *Lytoceras polare*, a single *Ancyloceras* sp., the nautiloid *Cymatoceras* aff. *radiatum*, lamellibranchs, gastropods and fossil wood (Maync, 1949, pp. 86—90, 227; Spath, 1946, p. 7). The fossils are preserved with white, iridescent shells and the fauna sounds as if it would repay further collecting and study. The position of the fauna within the Aptian cannot be yet determined. The thickness of the Aptian, which overlies Valanginian limestones, is uncertain, as the exact position of the junction cannot be decided. Maync believes that in all probability 310 m of strata should be included in the stage. This includes 30 m of shales with concretions which abruptly succeed the sandstones. The section is terminated by plateau basalt.

At Cardiocerasbjerg, about 5 km south of the section just described, 14 m of black shales with clay-ironstone concretions carry abundant *Neohibolites* and are believed to be Aptian in age. They rest with abrupt lithological change, though apparently no discordance, on Valanginian limestones, and are succeeded by 10 m of conglomerates and sandstones of unknown age (Maync, 1949, pp. 84—85, fig. 25).

Aptian sediments are also known from the country east and south of Albrechts Bugt, where the Rødryggen Beds, of probable Valanginian age, are succeeded, with a sharp lithological break and angular discordance, by black shales with clay-ironstone nodules and belemnites, seen to about 50 m (fig. 15). At Rødryggen these beds yielded a well-preserved ammonite identified as *Phylloceras rouyianum* (d'Orbigny), included under the heading 'Aptian', although Spath remarks that it is known also from the Upper Barremian (1946, p. 7). East of Kap Berlin a doubtful *Sanmartinoceras* is recorded which, if correctly identified, established the presence here of Aptian beds at the base of the succession which is principally of Albian date (see p. 83) (Maync, 1949, p. 46).

4. Kuhn Ø.

Aptian beds are exposed along the south-east coast of Kuhn Ø for about 7 km southwards from Kap Maurer, beyond which they are cut off by a fault. The evidence from a number of small exposures has been combined by Maync (1949, fig. 4, p. 18; pp. 22—27), who concludes that a thickness of about 220 m can be demonstrated. The beds are predominantly black shales, with layers and nodules of clay-ironstone, and horizons of marly limestone showing cone-in-cone structure in the lower part. They are fossiliferous, and well-preserved ammonites collected by Bøgvad, who discovered the occurrence, were made the types of the new species *Deshayesites boegvadi* and *Sanmartinoceras groenlandicum* by Rosenkrantz (1934, pp. 20—23, pls. 3—5). These ammonites prove the presence of Lower and Upper Aptian respectively, but no subdivision of the beds has been established in the field. A number of other fossils have also been found, of which some records are given by Maync and by Spath (1946, p. 7), but the fauna has not been fully studied.

5. Shannon.

This island consists predominantly of low-lying country mantled by Quaternary debris, but near Kap David Gray, on the south-coast, Bøgvad found in 1929 a clay-ironstone nodule, not *in situ*, containing fossils which Rosenkrantz identified as *Inoceramus* cf. *ewaldi* Schlüter, indicating the presence of sediments, probably shales, of Upper Aptian age (Bøgvad & Rosenkrantz, 1934, pp. 11, 19).

6. Store Koldewey.

A narrow band of Aptian sediments lies along the east coast of Store Koldewey, from approximately 20 to 30 km north of Kap Alf Trolle, the southernmost point of the island (see fig. 10). At Ravns Ravine the sediments are seen to lie, without apparent discordance[1]), on the Valanginian, and further south they lie directly on, and are banked up against cliffs of, the crystalline rocks which form the greater part of the island, and which had been dissected into an uneven form prior to the deposition of the Cretaceous rocks. The outcrop is therefore discontinuous, being interrupted by masses of gneiss. The beds are predominantly sandstones, becoming conglomeratic at some horizons, and there is a subsidiary amount of shale. Limestone lenses and concretions occur and are sometimes fossiliferous, but fossils occur in all

[1]) Maync (1949, p. 177) says they are unconformable, but this is not supported by Nielsen's sketch (in Frebold, 1935, fig. 10, p. 24), although there is obviously a non-sequence present.

the rock-types. The sections measured by Nielsen were published by Frebold (1935, pp. 12—30, and diagramatically in figs. 16—19, pp. 33—36) and are reproduced by Maync (1949, pp. 174—176). As would be expected in such a situation, the beds are variable and there is no correlation between the different sections. In addition to an abundant marine fauna of about 50 species the beds carry plant remains and coaly fragments. They clearly represent a deposit formed close inshore, in gullies and hollows along a rocky coast of crystalline rocks which had been newly submerged by the Upper Aptian transgression. Frebold believed that the ammonites which were found had drifted in from the open sea, but no doubt most of the species lived close to the coast in shallow water; for instance, some of the belemnites figured by Frebold, although broken, are unworn, and could not have been rolled any distance along the sea floor. Some of the delicate gastropods, too, are quite well-preserved, and were presumably species which enjoyed a rocky habitat, while the bivalves may have lived in the accumulating sediment. The preservation, in Store Koldewey, of this almost littoral deposit must account for the presence of such a large fauna, the greater part of which is unknown from any of the other Upper Aptian rocks of East Greenland.

The fauna was exhaustively monographed by Frebold (1935) who deduced an Upper Aptian (Parahoplitan) age from the ammonites (table, *op. cit.* p. 53). The critical species is *Sanmartinoceras pusillum* (Ravn). *Lytoceras polare* Ravn, which is also known from Lower Aptian deposits (in Hold with Hope), is believed to be a long-ranging species.

7. *Germania Land.*

In 1908 the Danmark Expedition collected fossils from loose boulders in the neighbourhood of Danmarks Havn, about 76°45′ N. Lat., which are evidence for the most northerly undoubted Mesozoic rocks in East Greenland. The material was studied by Ravn (1911), but was not correctly interpreted until Rosenkrantz re-examined it and deduced an Aptian date for some of the fossils. As a result the following species are known (Rosenkrantz, 1934, p. 24):

Lytoceras polare (Ravn)
Sanmartinoceras pusillum (Ravn)
Crenella bella (J. de C. Sow.)
Aporrhais spp.

This is clearly an Upper Aptian fauna. The matrix is black, argillaceous limestone, which Ravn (1911, p. 445) thought might have been glacially transported from the area of black shales said to exist in Jøkelbugt, between 78° and 79° N. Lat. In any case, the boulders show that Upper Aptian rocks are to be found either in Germania Land or farther north.

Albian and Cenomanian[1]).

1. Introduction.

Although enough ammonites have been found at different places in East Greenland to indicate the stratigraphical range of the Albian and Cenomanian sediments, the great majority of exposures do not yield diagnostic fossils and it is not possible to establish a standard succession in any one locality. For this reason the Albian and Cenomanian beds must often be treated as a lithological unit in the field, but before describing their characters and distribution a summary of the faunas will be given.

The earliest Albian fauna has been found only in the neighbourhood of Vega Sund, in southern Geographical Society Ø and northern Traill Ø. It is characterised by *Leymeriella*, *Arcthoplites* and a new Desmoceratid species which may belong to an undescribed genus. The last two ammonites are of no use for dating in terms of the European succession, but the *Leymeriella* enables the fauna to be correlated with the Tardefurcata Zone of the western European Lower Albian. The ammonites are accompanied by an assemblage of lamellibranchs, gastropods, belemnites, brachiopods, echinoids and a simple coral (?*Caryophyllia* sp.) probably numbering a dozen species or more, but largely unidentifiable on account of defective preservation and subsequent damage by igneous intrusions.

Middle Albian faunas are more widely distributed than Lower Albian, but the identifications are even more unsatisfactory. A locality with abundant fragments of *Euhoplites* was found in Geographical Society Ø by Stauber, and indicates the presence of the Lautus Zone of the Middle Albian (beds V–VIII of the English Lower Gault). Associated with the above-mentioned ammonite were *Dimorphoplites*, *Dipoloceras* and a Desmoceratid species. Indeterminate Hoplitids ('*Hoplites* spp.' of Spath) were found near Albrechts Bugt, northern Wollaston Foreland, and further east, on Sabine Ø, *Gastroplites* probably indicates the upper part of the Middle Albian.

The Upper Albian has not been proved by ammonites, but its presence is strongly suspected. Spath (1946, p. 10) reported a doubtful young *Hysteroceras* collected by Stauber in Geographical Society Ø,

[1]) The conventional boundary between Lower and Upper Cretaceous is placed between the Albian and Cenomanian stages. In describing East Greenland it is convenient to group the two stages together, for where they are both present they form one lithological unit.

which suggests a basal Upper Albian date, and the writer has recorded ammonite fragments in north-eastern Traill Ø which, although not precisely identifiable, seem to have no parallels earlier than Upper Albian (Donovan, 1953, pp. 35, 120).

Of the fossils other than ammonites, only two are at all common: *Inoceramus anglicus* Woods, and *Aucellina* of one or more species, attributed by the present writer to *A. caucasica* (Abich) and *A. gryphaeoides* (J. de C. Sowerby).

Aucellina ranges up into the Cenomanian, but *Inoceramus anglicus* is diagnostic of the Albian where ammonites fail, although there are probable passage-forms to the Cenomanian *I. crippsi*.

The Cenomanian is known only from Traill and Geographical Society Øer, whence it was first reported by Spath (1946, p. 10) on the basis of the ammonite *Schloenbachia* found by Stauber. Soon after the publication of this identification, the present writer visited the islands and found relatively abundant material at a number of places, belonging to the Varians Zone or Lower Cenomanian. A fortunate discovery of uncrushed material (the exception for the East Greenland Upper Cretaceous) in northern Geographical Society Ø showed that the species of *Schloenbachia* found in Greenland are identical with European forms (Donovan, 1954, pp. 9—13). Other ammonites from the Cenomanian include *Phylloceras*, *Lytoceras*, and *Mesogaudryceras*. Of the other fossils, *Inoceramus crippsi* Mantell is ubiquitous, but the remainder, chiefly lamellibranchs and echinoids, are mostly known from only one or two localities in each case. The fossils have been described in the writer's publications (1953, 1954). In view of the stratigraphical importance of the echinoids in Europe it is unfortunate that, so far, none of the Greenland material collected has been good enough for proper determination of the species.

2. The Middle Cretaceous Shale Series of the Vega Sund area.

In Traill and Geographical Society Øer no break in sedimentation has been detected between rocks of Albian and those of Cenomanian age. Exposures are poor and it is possible that a break exists, but for practical purposes the two stages must be considered together. The rocks are normally black shales, but subsidiary sandstones occur in south-western Traill Ø, and sandstones and conglomerates along the western margin of the area of deposition, where older clastic rocks were undergoing destruction. A basal conglomerate is present in the few places where the base of the series is exposed.

The base generally lies below sea-level, and has only been seen in the eastern Vega Sund area, but the author has recently suggested that deposition began, in the Lower Albian, in central Traill and Geographical Society Øer, and that the sea transgressed eastwards up the dip-slopes of westwardly-tilted tectonic blocks of Jurassic and older rocks, which formed islands not completely submerged until the Lower Cenomanian. There is probably a progressive overlap of higher and higher beds further east. Where the base of the series is exposed, about 25 km east of the western limit of the area of deposition, in the neighbourhood of Kap Palander and the Mols Bjerge on Traill Ø, it is of probable late Albian age, and near the summit of Laplace Bjerg on Geographical Society Ø, one of the highest points of the Laplace Block, Cenomanian shales rest directly on the Jurassic.

The Middle Cretaceous Shales have a wide outcrop in eastern Geographical Society and Traill Øer, overlain in places by later Cretaceous rocks. The thickness of the series cannot be estimated with any accuracy. In the Sortefjelde, southern Traill Ø, there are at least 350 m of Cenomanian alone, and at Lycett Bjerg about 300 m represent an unknown fraction of the Albian. Where thickest the Middle Cretaceous Shales are probably over 700 m thick.

3. *Albian(?) of the Giesecke Bjerge.*

Black shales of Cretaceous age lie on the dip-slope of the Giesecke Bjerge in Gauss Halvø, resting unconformably on Permian and Eotrias. Their outcrop is shown, at least partially, in the map by Vischer and Maync (Koch, 1950, pl. 5) and by Bütler (1949, figs. 2, 3), and Maync has given a few notes (1949, p. 161). No great thickness appears to be exposed, but as the formation is the youngest in the area an unknown amount may have been removed by denudation. The shales carry subsidiary sandstone bands, and concretions of clay ironstone. Unfortunately, they are not satisfactorily dated. The record of '*Aucella*' by Orvin (1930, p. 25) is to be discounted, for the specimen on which it was based was re-examined and figured by Frebold (in Frebold & Noe-Nygaard, 1938, p. 32, pl. 1, fig. 2) and stated to be an *Inoceramus* which, as far as one can judge from the illustration, it probably is. Frebold compared this fossil with material from Home Forland and suggested, with reservations, that it might be Upper Cretaceous, but the present writer follows Koch (1935, p. 104) and Maync (*loc. cit.*) who think that the beds are probably Aptian or Albian, for Dr. Sornay (*in litt.*) notes *Inoceramus* aff. *neocomiensis* (juv.) or *I.* aff. *anglicus*, or perhaps both species, in the Maync collection, which indicate Aptian and Albian date respectively. It should be possible to solve the problem quite easily by a thorough search for fossils; meanwhile, an Albian date will be assumed for these strata.

Cretaceous sediments have also been found on the scarp or eastern face of the Giesecke Bjerge, and have been described by Maync (1949, pp. 154—161). The rocks are black shales with thin bands, and concretions, of limestone, and they contain boulder-beds composed of an assortment of pre-Cretaceous rocks, both 'Caledonian' crystallines, quartzite, and Permian limestone, embedded in shale. The boulder-beds have clearly resulted, as Maync points out, from the fact that the fault-scarp which forms the eastern side of the Giesecke Bjerge was already in existence when the sediments were deposited, but the present writer does not agree that the rounded form of the boulders necessarily indicates transport over a long distance (*op. cit.*, p. 155). In the Cretaceous conglomerates of eastern Vega Sund there are rounded boulders of the underlying Jurassic sandstones, which have probably not travelled far, and are interpreted as having been rounded by wave-action along the shores of islands of Jurassic rocks (Donovan, 1955, p. 25). In the same way, part of the Giesecke Bjerge may have protruded above sea-level and been subject to wave action.

Maync did not record any fossils of stratigraphical value from the deposits on the scarp face of the Giesecke Bjerge, although he attributed them to the 'Aptian-Albian series' on the basis of lithology. Dr. Sornay informs me that the fossils sent to him for identification included *Inoceramus* aff. *anglicus* from Suhms Bjerg (point 1250 m on the Geodetic Institute map), which demonstrates that the Albian is present. Maync also noted a 'large-sized lamellibranch hitherto unknown in the Cretaceous of East Greenland' (*op. cit.* p. 155), but the form has not been described.

4. Albian of Hold with Hope.

Kap Broer Ruys.

An isolated outcrop of Cretaceous rocks lies on the south coast of Hold with Hope, at Vardefjeld 12 km south-west of Kap Broer Ruys, surrounded by Tertiary igneous rocks and Quaternary deposits. Maync (1949, pp. 145—150) has recorded a section displaying about 350 m of black shales, with thin limestone bands. *Inoceramus* aff. *anglicus* Woods was found near the base of the section, and denotes an Albian date.

Jackson Ø.

Sediments, much disturbed by basic igneous intrusions, are found in the eastern part of the island, and a section through about 135 m of beds was measured by Maync (1949, pp. 137—141, fig. 50). They are interbedded sandstones and shales with clay ironstone and cone in cone, and Maync was fairly confident, on account of the close correspondence

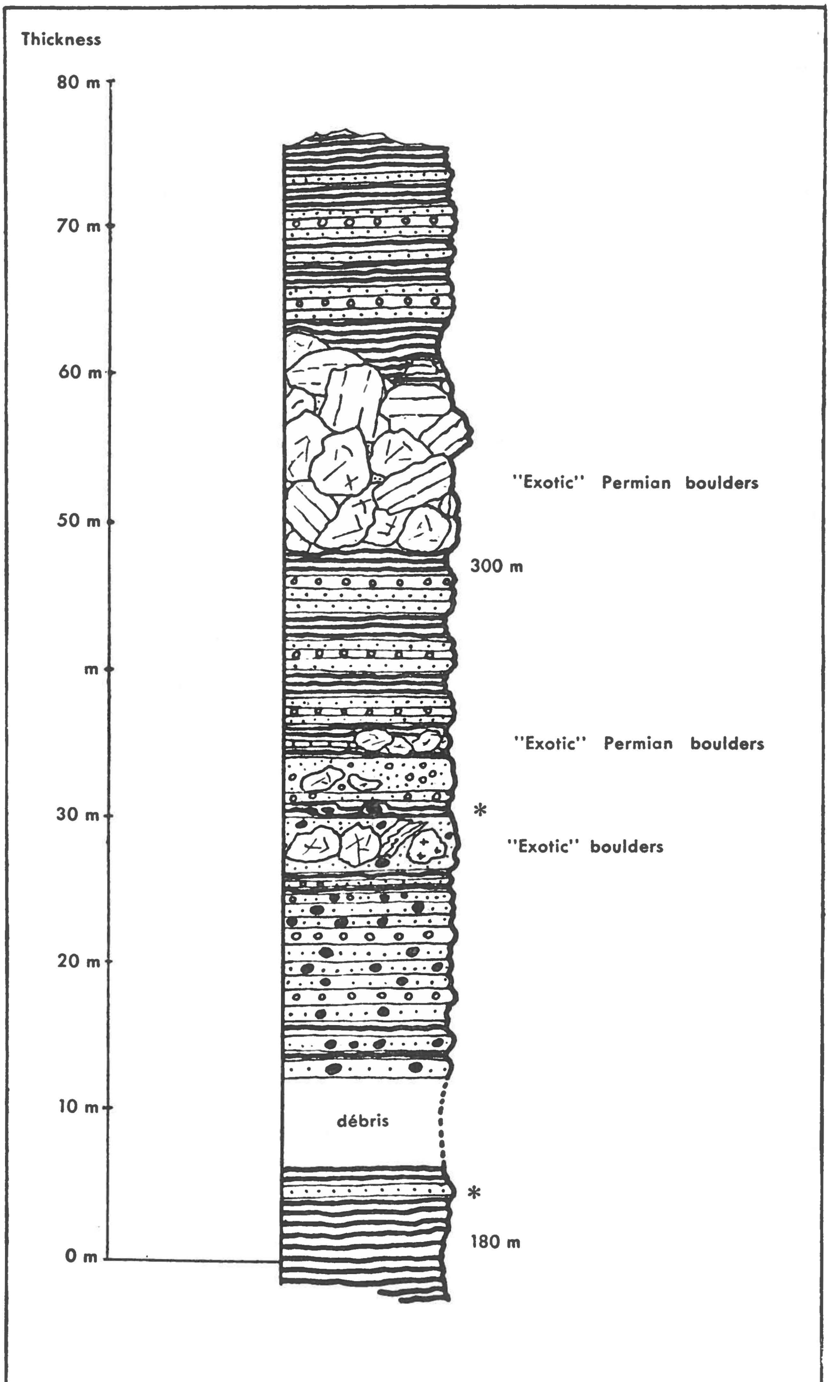

Fig. 16. Diagrammatic section through the Inoceramus Beds (Aptian and/or Albian) of 'Boulder Ridge', north-east Clavering Ø. For explanation of conventions see figure 18, page 95. From Maync (1949, fig. 35).

in lithology, that some, at least, of the rocks on Jackson Ø are of 'Aptian-Albian' date. No fossils have been found.

5. Albian of the Northern Region.

In Clavering Ø Albian rocks have a wide extension in the down-faulted eastern end of the island. Their base is strongly unconformable, and oversteps from Valanginian, across Jurassic on to 'Caledonian' crystalline rocks. A number of sections have been published in detail by Maync (1949, pp. 121—125), and one is reproduced here (fig. 16). The greatest thickness appears to be preserved in the central part of the area, and on Langelinie Bjerg, where the base is not seen, and Maync calculated a thickness of 646 m. The sediments are fine and coarse sandstones, with clay ironstone concretions and layers of cone in cone, interbedded with a subsidiary amount of black shale. There is a higher proportion of black shale in the upper than in the lower part of the succession. *Inoceramus anglicus* occurs in the lowest beds exposed, which are therefore of Albian age. At the south-eastern corner of the island (Brisbane Bjerg) sediments extend down to sea-level, and are predominantly shaly, with interbedded sandstones. *Inoceramus* cf. *anglicus* was collected. At Rundetaarn, about 10 km to the west, abundant *Inoceramus anglicus* and *I.* cf. *concentricus* were found in black, slightly sandy, shales.

In the northern part of the Cretaceous area of Clavering Ø, a marginal facies is found near the boundary fault zone which limited the basin of deposition to the west. Here, in Dolomitdal and 'Dislokationsdalen', Cretaceous sediments are seen to lie with violent unconformity on an irregular topography of earlier rocks (Maync, *op. cit.*, figs. 32, 33). They consist of black shales with clay-ironstone concretions, and sandstones and conglomerates. A short distance to the south, near Djævlekløften, the base is not seen but the sediments include boulder beds of Permian limestone and 'Caledonian' crystalline rocks, some of the boulders being 'the size of a house' (*op. cit.* p. 113). Here, therefore, the deposits along the actual Cretaceous coastline, which consisted of high cliffs, are preserved. Unfortunately no fossils have been found[1]) which enable them to be dated. The fact that all the dated occurrences on the island are Albian suggests that the coastal facies may also belong to this stage; on the other hand, the base is nowhere visible where an Albian age is proved, and earlier (*i. e.* Aptian) rocks may well be present. A third possibility is that the occurrences are to be compared with the Turonian conglomerates on Traill Ø (see page 84), and were a product

[1]) The list kindly sent to me by Dr. Sornay includes '*Inoceramus* indet.' from Dislokationsdalen.

of the same episode of coastal rejuvenation. This argument does not necessarily carry much weight, as coastal boulder beds were formed at several periods in the Mesozoic, repetition of the same conditions producing identical facies. As the rocks have to be described somewhere, they are included with the Albian until more evidence is available.

Wollaston Forland.

Albian rocks have a wide extension in outer Wollaston Forland, but here, as elsewhere in the northern area, they cannot be clearly separated from the Aptian. At 'Gyldenspids Bjerg' (point 660 m on the Geodetic Institute map) Maync measured a thickness of about 620 m of rather rapidly alternating sandstones and black shales, with many layers of cone in cone, and his section is reproduced in figure 25. About 180 m above the base of the section (which cannot be far above the base of the series, which is unconformable on Valanginian and Jurassic) Maync recorded 'poorly preserved ammonites probably of Aptian age,' but these ammonites were not among those identified by Spath (1946); neither was the one found a few metres higher, associated with *Inoceramus anglicus* and fossil wood. The *Inoceramus* suggests that the greater part, if not the whole, of the sequence here is of Albian date.

Evidence for dating is slightly better at 'Mt. Hammeren' or 'Antoinettes Bjerg', a few kilometres to the south-west, where beds of similar lithology to those at Gyldenspids Bjerg yielded Hoplitid ammonites (Maync, 1949, p. 76).

In the Kap Berlin area, 390 m of black shales with bands of cone in cone at many levels, and sandstones in the lower part, were recorded by Maync, who collected Hoplitid ammonites and *Inoceramus* aff. *anglicus* about 90 m below the top of the succession. The age of the lower part is unknown; Maync supposed the whole to be Albian.

In Sabine Ø a good section through the Albian is seen at Kronebjerg, near the western point of the island (Maync, 1949, pp. 34—37, fig. 8). Sandstone is absent from this succession, which consists of black shales with clay ironstone nodules and numerous bands of cone in cone. The thickness exposed is about 400 m. *Inoceramus* cf. *anglicus* and *I.* aff. *concentricus*[1]) were found at the base, and the ammonite *Gastroplites* at several higher levels (Maync, *loc. cit.* and Spath, 1946, p. 8). The ammonites denote a Middle Albian age.

From the recorded sections and from the geological map by Vischer and Maync (Koch, 1950, pl. 6) the Albian is seen to have extensive outcrops in eastern Wollaston Forland, east of the broad valley which

[1]) Identifications by Maync. The list sent to me by Dr. Sornay does not include any specific identifications from this locality.

coincides with the 20° West Longitude line, and it is likely that rocks of the stage were originally deposited over the whole of this area. The base is not often seen, and we do not know whether Aptian is invariably present beneath the Albian, or whether the basal unconformity is in some places of Albian age. The Aptian(?)-Albian series as a whole lies unconformably on Valanginian, Jurassic and probably older rocks throughout the area. The Albian is the youngest Cretaceous stage represented in this part of East Greenland, and in several places is succeeded unconformably by Tertiary conglomerates, remnants of which remain on the summits (*e. g.* Kronebjerg, Gyldenspids Bjerg).

Upper Cretaceous[1]).

Turonian.

Turonian rocks have been found only in north-eastern Traill and eastern Geographical Society Øer (fig. 17). They are best known in the Rold Bjerge, in Traill Ø. A series of coarse clastic beds is believed to be the basal conglomerate of the Turonian, but the junction with the underlying strata is nowhere seen. Along the coastal flank of the Rold Bjerge, however, overlooking Vega Sund, conglomerates, sandstones and shales at a slightly higher level than the Cenomanian rocks yield *Scaphites* aff. *morrowi* Jeletzky, *Scaphites* sp. cf. *geinitzi* d'Orbigny and other fossils, indicative of a horizon at about the middle of the Turonian. Higher up, the mountainside consists of shales with *Inoceramus lamarcki* Parkinson. The succession is much obscured by screes and dolerite intrusions but the writer previously estimated a minimum thickness of 300 m for the Turonian beds here (Donovan, 1953, pp. 38—40).

A most impressive series of conglomerates and associated rocks, about 80 m thick, is exposed along the Maanedal stream about 4 km south of the occurrences just described. A series of sandstones is punctuated by breccias and quartz conglomerates, four principal conglomeratic horizons being separated by less well-exposed intervals (Donovan, 1953, pp. 41—43). After quartz and sandstone pebbles one of the most prominent constituents is Permian limestone, of which one boulder is about 2 m high (Donovan, 1953, pl. 12, fig. 2). Permian rocks occur on the Bordbjerget and in the country to the south, which could also have yielded the other ingredients of the conglomerate, which is interpreted as a boulder-bed flanking a faulted coast-line of Turonian times. A single example of *Inoceramus lamarcki* was fortunately found near the base of the series, enabling it to be dated as Turonian or basal Senonian.

[1]) Less Cenomanian; see note on page 77.

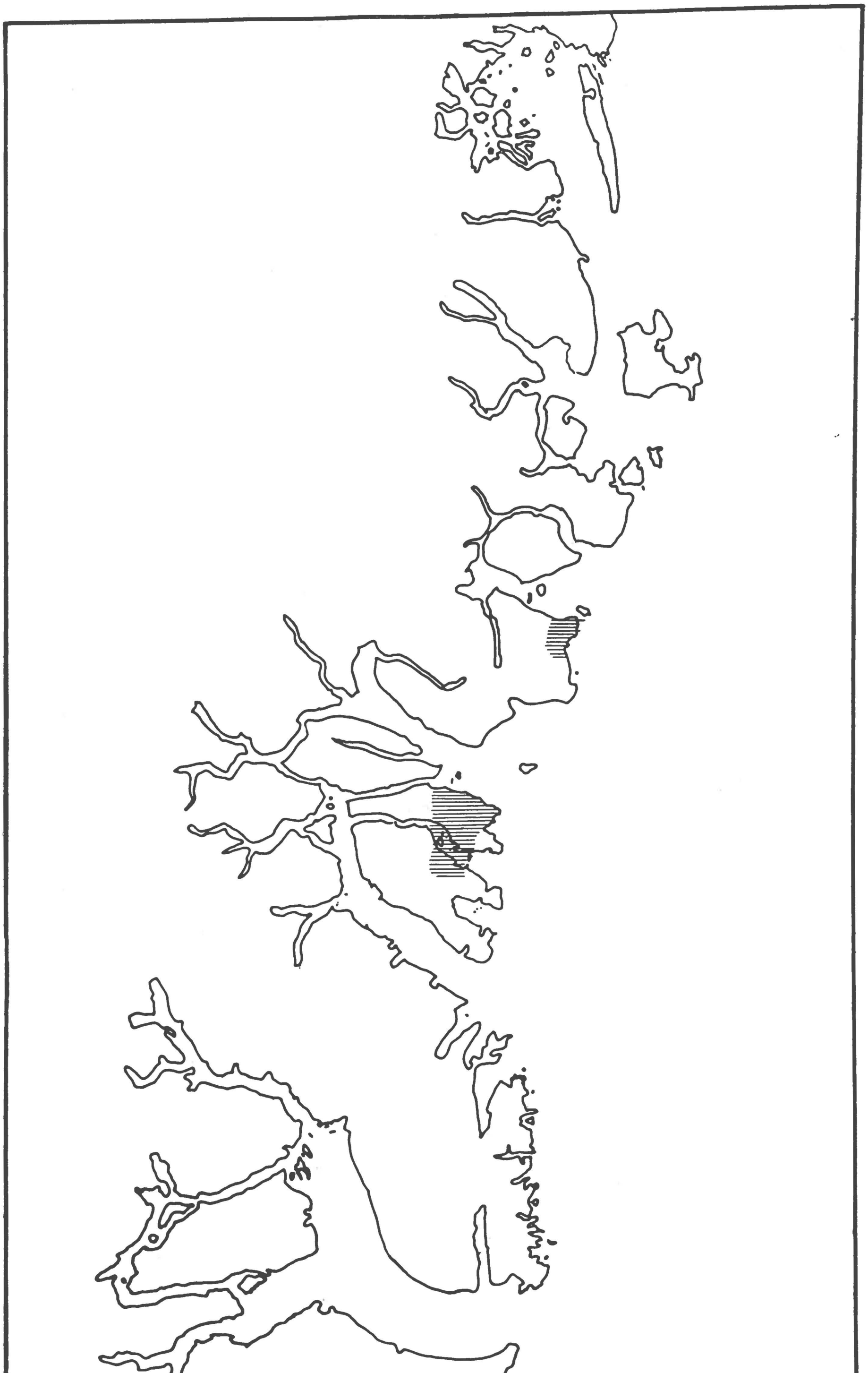

Fig. 17. Distribution of Turonian and Senonian rocks in East Greenland between latitudes 70° and 77° north. Horizontal shading indicates the areas in which outcrops of Turonian and Senonian rocks have been found.

In view of the occurrence of the conglomerates proved to be Turonian on the opposite side of the Rold Bjerge, the earlier alternative is adopted.

Several isolated outcrops of conglomerate, of unproved age, occur in the islands and shores of eastern Vega Sund. They have been summarised by the writer (Donovan, 1955, pp. 31—35) who has suggested that they may be Turonian; further evidence is, however, desirable.

Turonian rocks, shales with subsidiary thin sandstones, are found in the Scott Kelties Øer and south-eastern Geographical Society Ø, and have been named the Inoceramus lamarcki Beds after the only recognisable fossil. They are of Turonian or earliest Senonian date, and are presumed to correspond to the beds with *I. lamarcki* which overlie the Turonian conglomerates in the Rold Bjerge. No extensive sections are known and the contact with other formations has not been seen. The thickness is probably several hundred metres (Donovan, 1955, p. 35). Turonian shales occur in north-eastern Geographical Society Ø, west of Laplace Bjerg, but nothing is known as to their distribution or thickness.

Senonian.

1. The Kangerdlugssuaq Sedimentary Series.

The formation has been described by Wager and Deer (1939, pp. 12—14) and Wager (1947, pp. 12—19) and the following summary is entirely based on their accounts. The series outcrops below the Plateau Basalts in the country south and east of the inlet of Kangerdlugssuaq, between 68° and 69° north latitude, and lies unconformably on a metamorphic complex believed to be of pre-Cambrian date. A section in Mikis Fjord is:

Plateau Basalts	— m
Conglomerate	6—16 -
Sandstones and sandy shales	80 -
False-bedded, often calcareous, sandstone	30 -
Ferruginous sandstone	65 -
(base not seen)	

The principal area of sediments lies north-east of Mikis Fjord, outcropping principally as nunataks, and this fact and the prevalence of igneous intrusions made the study of the formation a matter of some difficulty. The lithology is highly variable, but is predominantly silty and sandy shales, with associated sandstones. There is often a horizon of sandstone and conglomerate near the top. The rocks are sometimes micaceous, often carbonaceous. The greatest thickness seen in any one section is about 250 m; the full thickness may well be greater.

The principal sediment area is divided into two parts by the Sorgenfri Gletscher. To the west of the glacier the sediments have yielded belemnites at one locality, and fragmentary marine fossils elsewhere. East of the glacier sandstones in the upper part of the series have yielded plant fossils, and associated conglomerates include abundant pebbles of basalt, showing that igneous activity had begun while the series was still being deposited. Wager says that the field evidence suggests that "the plant bearing beds followed the marine shales containing belemnites with but a short time interval between". He envisages the earlier, marine part of the series being laid down in a narrow arm of the sea, and then being covered by estuarine sediments which were deposited over a more extensive area. There seem to be two other possible interpretations; first, that the estuarine beds are lateral equivalents of the marine series. The absence, in the marine succession, of any beds as late as the top of the estuarine series seems to be proved by the absence of basalt pebbles, and this hypothesis need not, perhaps, be seriously considered. The second possibility is that the two groups of beds, marine and plant-bearing, are in fact separated by a considerable gap in time. Unfortunately the fossils are not adequate to settle this point.

The belemnites found in the marine part of the succession were identified by Swinnerton (1943) as *Actinocamax* cf. *blackmorei* Crick and *A.* cf. *plenus* (de Blainville), and recognised by him as Senonian. In view of the recent recognition of Senonian formations of more than one date elsewhere in East Greenland, it seemed important to try to date the fossils as accurately as possible. The material is poor, but Dr. Jeletzky has kindly informed me that Swinnerton's identifications imply a late Santonian or Lower Campanian date. The rocks containing the belemnites are, therefore, of approximately the same age as the Sphenoceramus Beds described below.

The plants from the eastern part of the outcrop were described by Seward and Edwards (1941), and include *Cercidiphyllum richardsoni* (Heer), *Elatocladus* sp. cf. *eungeri* (Heer), and *Sequoia langsdorfi* (Brongniart). They have affinities with the very early Eocene flora of West Greenland, but a very late Cretaceous age is not excluded. If the flora is assumed to be Eocene, then the Upper Campanian and the whole of the Maestrichtian stages are unaccounted for, and must be represented either by a non-sequence or by deposits largely hidden beneath the Sorgenfri Gletscher. At present it seems reasonable to assume that the flora is late Cretaceous, not much later in date than the belemnites. Only further evidence can show, however, whether we have to do with a single formation, marine at the base and estuarine at the top, or whether the Kangerdlugsuaq Sedimentary Series really includes two formations, one Santonian or Campanian, one Eocene in date.

2. The Sphenoceramus Beds (U. Santonian or L. Campanian) of Traill and Geographical Society Øer.

No ammonites have been found in the beds now to be described, and their dating depends on lamellibranchs and principally on the presence of *Inoceramus* (*Sphenoceramus*) *steenstrupi* and *patootensis*. The matter has already been discussed by the writer (Donovan, 1953, p. 138; 1954, p. 26), who believes that in spite of the appearance of accuracy which may be given by the supposed refinements of Heinz (*e. g.* table in Maync, 1949, p. 279), these species can only be taken as indicating either Upper Santonian or Lower Campanian.

The Sphenoceramus Beds are shales, or shales with thin bands of sandstone. Known outcrops are confined to the islands in Vega Sund and the adjacent parts of Traill and Geographical Society Øer, and an island off the north-east coast of Geographical Society Ø (Donovan, 1955, p. 36). The stratigraphical data are as inadequate as the palaeontological. On account of the generally ill-exposed nature of the country, no section has been found in which any of the Upper Cretaceous formations is seen in natural relationship to the formations above or below. The thickness can therefore hardly be guessed at. Only the finding of *Sphenoceramus* enables one to assert that the formation is present, the lithology being indistinguishable from that of other Upper Cretaceous formations. *Oxytoma tenuicostata* is occasionally abundant, and appears to be restricted to the formation.

In Tværdal, near the north coast of Geographical Society Ø, belemnites identified as *Belemnitella*(?) sp. indet. were found in abundance at one place, associated with an unindentifiable *Inoceramus*. The rocks which yielded them have not been seen in place. The belemnites indicate an age about the same as that of the Sphenoceramus Beds, so that this occurrence may belong to that formation. The question has been fully discussed by the writer (Donovan, 1954, pp. 12—13; 1955, p. 36).

3. The Knudshoved Beds (U. Santonian or L. Campanian) of Hold with Hope.

Senonian rocks are preserved in the north-eastern part of Hold with Hope. Near the Danish hut which lies about 4 km south-west of the basalt promontory Knudshoved a series of westerly-dipping sandstones forms a low scarp along the coast (Frebold, 1934, fig. 2, p. 8). About 40 m thickness is exposed here of light-coloured, micaceous sandstones, with some black, coaly beds and reddish-brown clay ironstone concretions, overlain by black shales, with clay ironstone concretions, which appear to be at least 90 m thick but are, however, poorly exposed (Frebold, 1934, fig. 4, p. 11; Maync, 1949, pp. 142—43). The series has been named the Knudshoved Beds by Maync. Fossils, collected from debris, include two new species of *Inoceramus* (*Sphenoceramus*), and *Oxytoma tenuicostata* (Römer) (Frebold, *op. cit.*). They indicate an Upper Santonian or Lower Campanian age, but a more exact correlation with the European Cretaceous, or with the Sphenoceramus Beds in Traill and Geographical Society Øer, is not possible (Donovan, 1954, p. 26). About 2 km south of the Danish hut, Vischer discovered 'dark calcareous-marly slates' under the Knudshoved Beds, which rested on them with a thin basal conglomerate. Maync, who recorded this observation, believed that the dark beds represent the Home Forland Beds (Maync, 1949, p. 144) and this was one of his arguments that the Home Forland Beds are older than the Knudshoved Beds. Only the discovery of fossils can settle the date of the underlying strata, lithological correlations in East Greenland being most unsatisfactory.

The geological map (Koch, 1950, pl. 5) restricts the Knudshoved Beds to a small area near Knudshoved, but they may well have a wider distribution. If the writer's interpretation given in the next paragraph is correct, the Home Forland Beds are synonymous with the Knudshoved Beds, which would thus extend to the north coast of Hold with Hope. The area south of Knudshoved is insufficiently known, and the few outcrops of sediments which have been found are undated. They are described on page 92.

4. The Home Forland Beds (?Senonian) of Hold with Hope.

Sediments are exposed beneath the plateau basalts on the north side of Home Forland and sections through them have been published by Frebold (1934, pp. 13—14) and Maync (1949, pp. 132—137). The beds consist of ferruginous sandstones and black shales, with clay ironstone concretions. Frebold (whose section was measured by E. Nielsen) records an thickness of 385 m, Maync, measuring in a different place, 320 m. The series was named the 'Home Forland Beds' by Maync (1939, p. 137). Nielsen found a number of fossils, of which only *Oxytoma tenuicostata* was identifiable by Frebold. This would indicate a Senonian age for the formation. Maync, however, records *Inoceramus* aff. *labiatiformis* Stolley (1949, pp. 135, 144) and, on the basis of this fossil and the lithological similarity between the beds and the *Inoceramus* Beds, of Aptian and Albian age, of Clavering Ø and areas further north, rejects the Senonian dating of the Home Forland Beds, suggesting that Nielsen or Frebold had confused specimens of *Oxytoma tenuicostata* from the Knudshoved Beds with the Home Forland material. The writer has already commented on the difficulty of arriving at the correct interpretation (1953, p. 53), and has stressed the dangers of correlations based primarily on lithology. While Maync's view, that the lithological facies is so similar to that of the Aptian-Albian, must be given due weight in view of Maync's extensive experience in the Mesozoic of this part of East Greenland, it seems a little unjust to reject a fossil record by previous workers in favour of a purely lithological correlation. Maync certainly failed to refind *O. tenuicostata*, but the present writer could cite several instances in which later workers in East Greenland have been unable to find localities or sections described by earlier ones. This may be due partly to the rapid weathering and movement of screes, and in large part, probably, to mere chance. The record of *Inoceramus* cf. *labiatiformis* was presumably based on a field identification, as no records from Home Forland appear in the list of *Inoceramus* identifications kindly sent to me by Dr. Sornay, who studied the material[1]).

5. The Scaphites Beds (U. Campanian) of Geographical Society and Traill Øer.

The presence of Upper Campanian rocks, named the Scaphites Beds, is proved by fossils found loose at a few places in Geographical Society and Traill Øer. All the occurrences have been metamorphosed by Tertiary intrusions. The characteristic fossils are crushed examples of *Scaphites greenlandicus* Donovan, and '*Lucina*' *laminosa* (Reuss). Neither the thickness of the beds, nor their stratigraphical relationship to earlier formations, is known, and no actual exposures have been found. Evidence for the formation is known from Maanedal, in northern Traill Ø, from the downfaulted area east of Laplace Bjerg and from a point south of Kap Mackenzie, both in Geographical Society Ø. The original lithology appears to have been sandy shales or argillaceous sandstones, sometimes, at least, glauconitic or chloritic[2]). The occurrences and fauna have been described by the writer (Donovan, 1953, p. 44; 1954, p. 27; 1955, p. 37).

Formations of unknown or uncertain date.

1. Sediments at Kap Gustav Holm.

At Kap Gustav Holm, at about 66°35′ north latitude, and about 200 km south-south-west of Kangerdlugssuaq, metamorphosed sediments were discovered by the British Arctic Air-route Expedition in

[1]) The fossils figured by Maync (1949, fig. 48, p. 136) from the Home Forland Beds as '?*Aucellina*' appear to be crushed *Inoceramus*, unidentifiable specifically from the figure and probably even from the specimen.

[2]) Previously recorded by the writer as shale only. Microscopic examination has since revealed the lithology now recorded, the rocks having been mistaken for baked shales in the field.

1930, and an account published by Wager (1934, pp. 22—25). Wager's examination was very brief and, according to him, the area was re-examined in 1933 by R. Bøgvad. No description of Bøgvad's work has been published. The sediments were presumed to rest on peneplained ancient metamorphic rocks, but the contact was not seen. The lowest 15 m consists of impure grit with quartz and gneiss pebbles up to 5 mm in diameter, and is succeeded by shales and fine-grained sandstones, about 9 m thick, interbedded with two thin lava flows. The shales and sandstones yielded poor fossils, some of which were referred to *Glycimeris* sp. and others compared with *Cyrena gravesii* from the Eocene of Kap Dalton. Wager was inclined to discount the latter comparison when it was realised that the Kap Dalton sediments lay above a thick series of basalts while the Kap Gustav Holm beds lie at the local base of the basalts. *Glycimeris* ranges from Lower Cretaceous to Recent and is therefore no use in deciding the question of a Cretaceous versus a Tertiary date. Wager provisionally regarded the series as late Cretaceous on account of the sub-basaltic position. Ravn (1933, p. 9), who examined a block of the sediment, was unable to extract any of the fossils, but thought that some might be brachiopods, and was inclined to think that the sediments are 'much older than the Tertiary'. There is thus a consensus of opinion in favour of a pre-Tertiary date, but on very slender evidence.

If the Kap Gustav Holm sediments are not Tertiary, they are likely to be late Cretaceous, and Wager (*op. cit.* p. 27 & 1947, p. 18) thought that they might be the metamorphosed equivalent of the Kangerdlugssuaq Sedimentary Series (see p. 86), the lower part of which, at least, is of Senonian date. The question cannot be decided until better fossils are available, and it is to be hoped that a future expedition will revisit the place. The problem of the age of the beds, if it can be solved, will be important with regard to the date of the commencement of igneous activity, discussed on page 166.

2. *The Infra-Basalt Sediments at Kap Brewster.*

The country behind Kap Brewster, which flanks the mouth of Scoresby Sund to the south, is chiefly notable for the Tertiary sediments studied in 1951 by D. Mackney and F.W. Sherrell, who collected faunas published by Hassan (1953). Beneath the Plateau Basalts which form the most conspicuous element in the scenery, Mackney and Sherrell discovered a sedimentary series which unfortunately yielded no determinable fossils. The rocks were thin-bedded, friable, blue-grey micaceous shales, with occasional beds of hard grey mudstone, about 3.5 cm thick, and bands of yellow-grey micaceous sandstone, the latter seen in the screes only. The thickness is believed to be greater than 126 m. Very badly preserved, crushed Spatangid echinoids were found, which proved to be unidentifiable.

The lithology of the series corresponds closely with that of some of the Upper Cretaceous formations of Geographical Society and Traill Øer, and in view of the fact that the sediments immediately above the basalts (the Cyrena Beds) are of Eocene date (albeit probably late in that period) a late Cretaceous age is possible for the Infra-Basalt Sediments. Further collecting is desirable and would probably solve the problem.

3. Cretaceous (?) of Central Hold with Hope.

The monotonous lowland of Østersletten is mantled by Quaternary deposits, but in a few places streams have cut down into earlier sediments. Several outcrops occur along the river Lygnaelv and are shown on the geological map by Vischer and Maync (in Koch, 1950, pl. 5). They were mapped by Vischer during a journey in the spring of 1938 (see his report, published by Koch, 1955, p. 595), and described by Maync (1949, p. 144) as 'gray or greenish thin-bedded micaceous sandstone with carbonaceous material, plant remains, and clay partings'. Vischer's report also described how Cretaceous, 'exposed in a few places', was mapped along the river Glommen, the next important river to the south of Lygnaelv. These exposures are not indicated in the map published in 1950. It is presumed that Østersletten is underlain by Cretaceous sediments, and a careful examination of the stream beds, by a summer party, would probably yield more information about them. The sediments are shown on the 1950 map as Aptian-Albian, but there is no fossil evidence as to their age. The *Inoceramus* collections sent to Dr. Sornay for study included nothing determinable from Hold with Hope, according to the notes which he has kindly sent me. It is conceivable that the Senonian rocks, known at Knudshoved, will be found here, or rocks intermediate between the Albian and Senonian. Vischer thought that at Knudshoved the Upper Cretaceous (*i. e.* Senonian) rested unconformably on Lower Cretaceous (*i. e.* Aptian or Albian), but there is not yet any fossil evidence for this (*loc. cit.*, 1955). Along the south coast of Hold with Hope Tertiary igneous rocks descend to below sea-level[1]), and it is possible that the sediments discovered by Vischer in the hinterland represent an 'infrabasaltic' series, comparable to that at Kangerdlugssuaq (p. 86) and at Kap Brewster, described above.

[1]) Quaternary only is shown along the coast in the map of 1950. A visit by the writer in 1954 resulted in the finding of a fairly large number of small igneous outcrops along the shore.

4. Cretaceous(?) of Loch Fyne.

There is an area of sediments along the west coast of Loch Fyne, discovered by Lauge Koch and shown in his map (1929, p. 186, pl. 3), and visited later by Maync (1949, p. 144). The outcrop is not shown on the latest geological map of the area, by Vischer and Maync (in Koch, 1950, pl. 5). The sediments are seen about 10 km north of the head of the fjord and overlie a basic sill which is shown on the 1950 map. At the time of Maync's visit only 4 or 5 m were exposed, of grey, yellow and whitish micaceous sandstones, with carbonaceous seams and partings of dark sandy shale. No fossils have been found. Maync referred the beds to the Cretaceous on account of lithological resemblance to the outcrops in Lygnaelv, but the latter are not dated by fossils either (see above). He mentioned a Triassic date as an alternative. The present writer is struck by their similarity to the Lower Aptian of northern Hold with Hope, but the coarse facies to which the beds belong recurred a number of times during the Mesozoic in East Greenland. Koch even thought it possible that they are Tertiary, but considered a Mesozoic age more probable.

5. Sediments at Jökelbugten.

Ravn (1911, p. 445) speaks of sediments with badly preserved fossil plants at Jökelbugten, about 78°30′ north latitude, from which he thought that the fossiliferous boulders (of late Jurassic and Aptian age) found in Germania Land might have been derived. I can find no other reference to this occurrence, but Ravn presumably had the information from a member of the Danmark Expedition. Koch's topographic map (1950, pl. 1) shows inland ice coming right down to sea-level in the area, except for one ice-free zone, rising to over 500 m (about 78°40′ to 79°), and a number of ice-free islands. From about 79° latitude northwards the country is composed entirely of pre-Mesozoic rocks, according to the sketch map by Fränkl (1955, fig. 1).

6. Mesozoic(?) sediments at Nakkehoved.

At Nakkehoved, 50 km north-west of Nordostrundingen (the latter place is shown on Koch's map, 1950, pl. 1), and about 81°40′ N. lat., is an area of sediments about which very little is known. An ice-free area is shown here on Koch's map, rising to over 200 m. Sediments were discovered by the Danmark Expedition and revisited by Nielsen on the Danish North-east Greenland Expedition of 1938—39. Nielsen (1941, pp. 28—32) reported dark, often hard, sandstones, dipping to the south-west at about 14°, and estimated that a thickness of about 300 m might be present. A few bivalves were collected, recorded as *Barbatia* sp., *Nucula* sp. and *Yoldia* sp. They are inadequate to date the beds. Nielsen thought the rocks to be either Cretaceous or Tertiary, more probably the latter. A Cretaceous or, indeed, Jurassic age nevertheless remains a possibility. It is to be hoped that this doubtless uninviting area will be revisited and more fossils recovered.

In Peary Land, which forms roughly the north-east corner of Greenland, there are extensive ice-free areas and a good deal of geological work has been done. No Jurassic or Cretaceous rocks have been found.

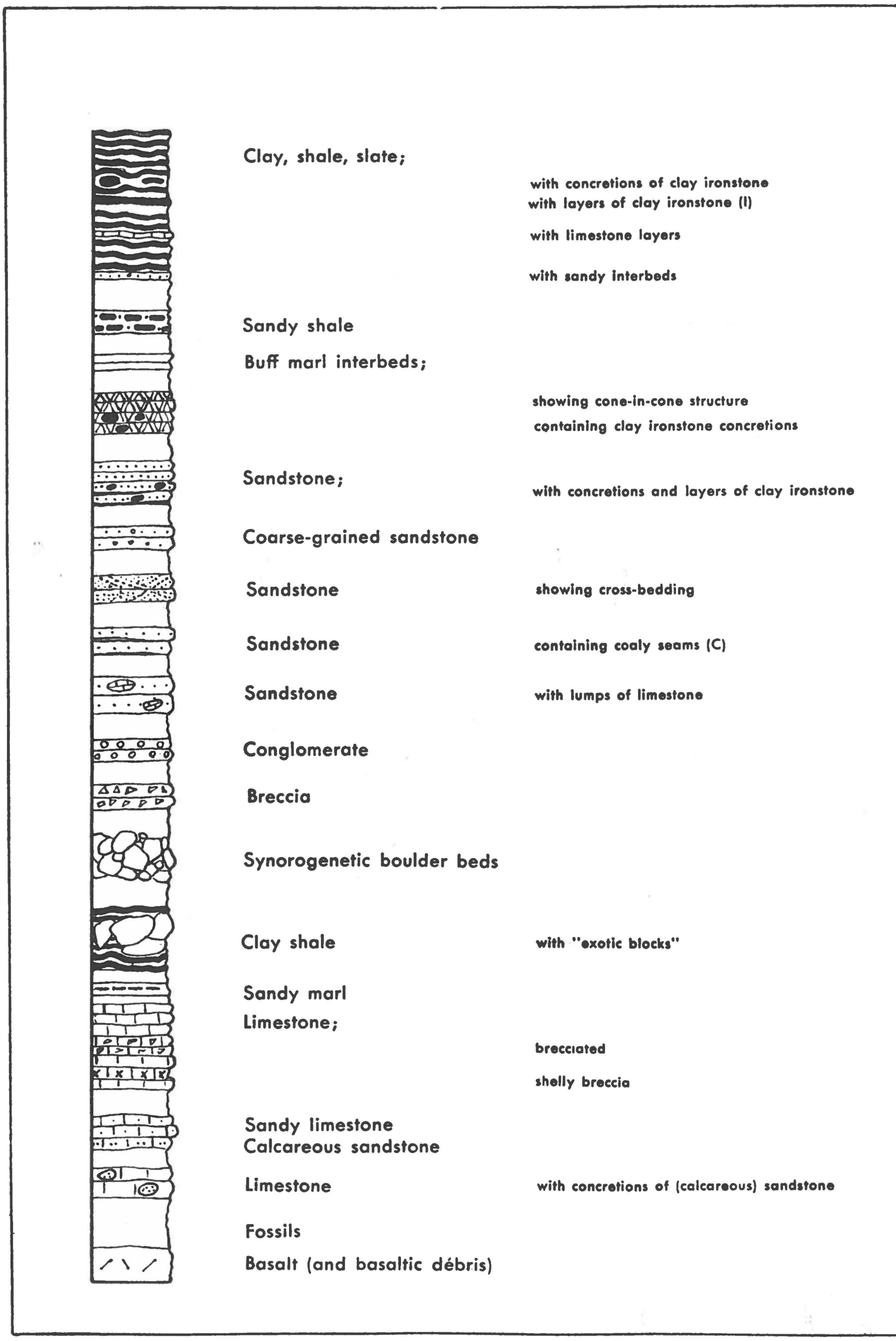

Fig. 18. Key to the symbols used in the diagrammatic sections.

IV. TECTONIC STRUCTURE AND HISTORY OF EAST GREENLAND DURING THE JURASSIC AND CRETACEOUS PERIODS

The structure of the Jurassic and Cretaceous area of Central East Greenland is dominated by major faults which trend a little east of north, nearly parallel to the continental margin. There is also a set of faults transverse to this direction, but they are more difficult to detect, as they seem in many cases to have formed lines of weakness along which the fjords were eroded.

The zone of north-south faults is bounded to the west by faults named the 'Post-Devonian Main Fault' in the northern region (Vischer, 1939, p. 154), and known as the Staunings Alper Fault (also Skeldal Fault, Fränkl, 1953, fig. 15, p. 39) south of Kong Oscars Fjord. Bütler (1948a, p. 81; and see 1955, pp. 80, 127) has termed this series of faults the 'Highland Border Fault,' remarking that it separates a 'high, inner fjord district from a lower, northward narrowing, coastal zone' and that it gives rise to a conspicuous topographic feature at the present day. Bütler also pointed out that what has been termed the Post-Devonian Main Fault in Traill and Geographical Society Øer (e. g. Stauber, 1942, pls. 5—7) is really a diagonal fault, connecting the Staunings Alper Fault with the true 'Post-Devonian Main Fault' which continues southwards across the island as the Tværdal Fault and Maanedal Fault of the present writer (1955, fig. 1). No Jurassic or Cretaceous transgressions penetrated west of the Post-Devonian Main Fault, which can be traced from C. H. Ostenfelds Land in the north to Traill Ø in the south.

The faults generally downthrow to the east, while the regional dip is to the west. Vischer has therefore developed the theory of tilted blocks ('antithetische Schollentreppen') bounded by faults, and the present writer (1955) has claimed that the structure can be traced southwards from the region investigated by Vischer into Traill and Geographical Society Øer. It is also possible to regard Jameson Land as a single block, although it is much larger than the others. In some areas the structure is obscure, but throughout much of Central East Greenland the disposition of the tilted blocks controlled sedimentation and the distribution of land and sea during the Mesozoic. There can be no doubt that the structure directly reflects that of the Caledonian metamorphic basement which is known to underlie much, and presumably underlies the whole, of the area with which we are concerned.

The tilted blocks came into being long before the period with which we are concerned. Bütler has suggested that the breaking up of the present coastal area into fault blocks began in early Carboniferous times (1954, p. 121), and Vischer (1943, p. 156, pl. 6) indicates that further westward tilting of the blocks took place between Upper Carboniferous and Upper Permian times, giving rise to the unconformity at the base of the Upper Permian. Tilting again occurred between Upper Permian and Lower Trias (*op. cit.* pl. 6, profile ii).

Principal tectonic episodes.

The Jurassic period was uneventful tectonically, and there is no evidence to suggest that the comings and goings of the sea were due to local earth movements rather than to eustatic changes in sea-level. No discordance has been discovered anywhere between any of the Jurassic formations below the Rigi Series, and the marginal part of the continent seems to have remained stable during this time. The period of quiescence was brought to a close by earth movements which were probably the most important during the Mesozoic in East Greenland. They resulted in the discordance which is almost everywhere present where the Rigi Series or later formations rest on Kimeridgian or earlier rocks (fig. 19). The date of these movements is marked by the beginning of the deposition of the Rigi Series; unfortunately this is open to two interpretations (see p. 59), but is either late Portlandian (Upper Volgian) or Berriasian. These movements were important in the northern region of Central East Greenland, which is the only area where they can be dated. It is reasonable to assume that the main episode of westward tilting in Traill and Geographical Society Øer was contemporaneous, although here the dating is less precise as the only visible unconformity is between Albian—Cenomanian and early Upper Jurassic rocks[1]).

In the extreme south of Central East Greenland, the succession in Milne Land is remarkable in that it does not show evidence of tectonic activity although it covers a range in time from Upper Oxfordian to Berriasian, the very coarse breccias which are such a feature of the deposits around the Jurassic-Cretaceous boundary in the northern region

[1]) In a recent paper (1955, p. 52) the writer placed the main tectonic episode in this region as Hauterivian-Lower Aptian. Viewed in relation to the northern region, an uppermost Portlandian or early Berriasian date seems more probable.

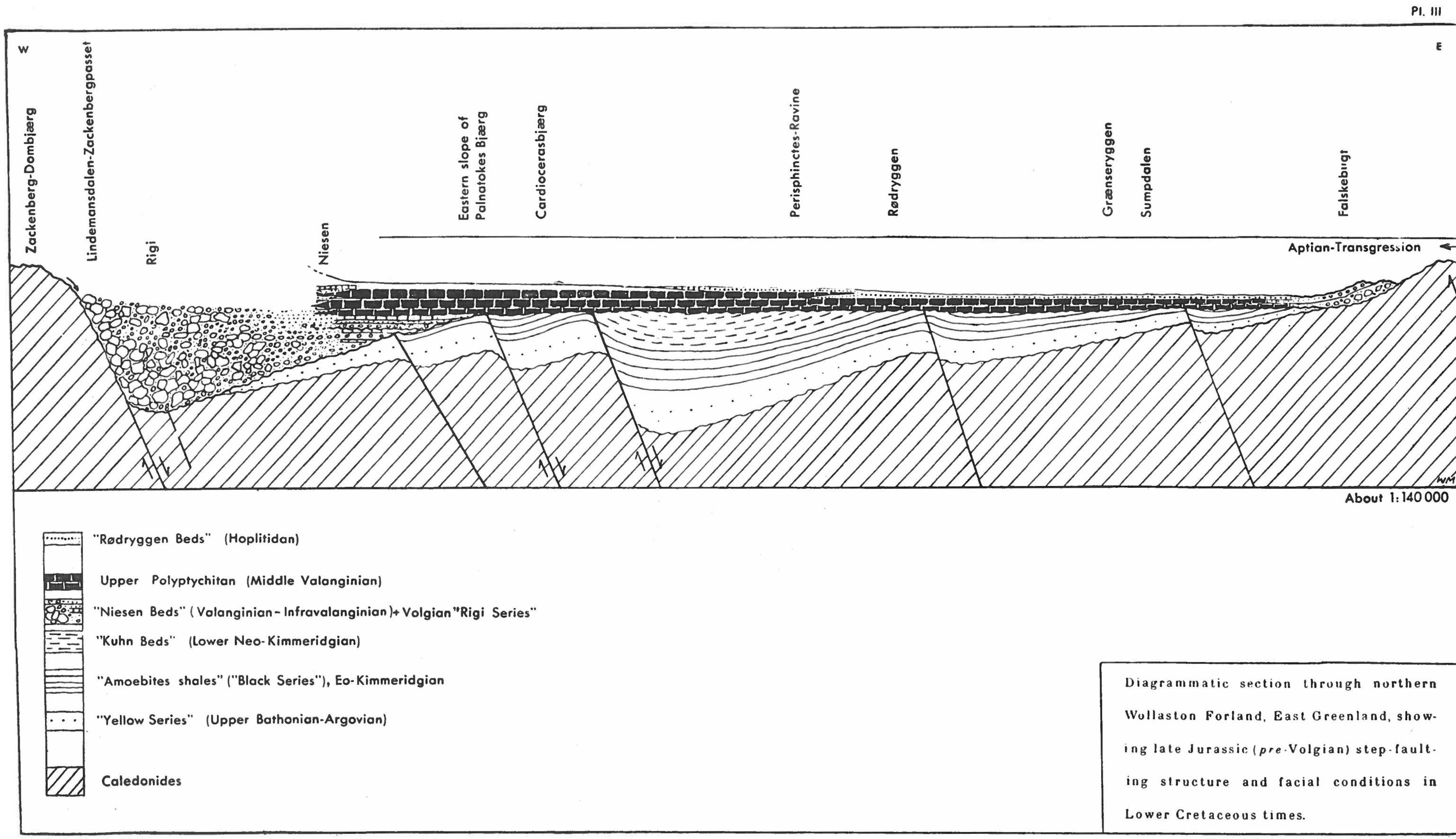

Fig. 19. Diagrammatic section through northern Wollaston Forland, showing the relationship of the Rigi Series, Berriasian (= Infravalanginian) and Valanginian to earlier formations. Note that the Yellow Series is not regarded by the present writer as extending into the Argovian (= Oxfordian), and the presence of Kuhn Beds (= Kap Maurer Formation) in Wollaston Forland is conjectural. From Maync (1949, pl. 3).

being absent. This may be an accident due to the position of the very small area of sediments which remains, for the dip of the Upper Jurassic rocks in Jameson Land shows that westward tilting has taken place since the Lower Kimeridgian.

In the northern region, where the effects of the late Portlandian or Berriasian movements has chiefly been studied, the further westward tilting of the blocks, accompanied by displacement along their boundary faults, resulted in the deposition of the breccias of the Rigi Series, often containing blocks of enormous size, near the foot of the scarps formed by the eastern edges of the blocks. No comparable accumulations have been found in Geographical Society and Traill Øer, but this may be due to concealment by the cover of Middle Cretaceous Shales, which is much more complete here than further north.

No earth movements seem to have occurred during the Berriasian and Valanginian, which are conformable in northern region, which again is the only area where relationship can be studied. Nor was there any widespread tectonic activity preceding the Aptian transgression, for in most places the Aptian rocks rest non-sequentially, but without discordance, on the Valanginian. Where the Valanginian is absent there is an unconformity at the base of the Aptian, but this is clearly due to the pre-Valanginian tilting. In one place, Bern Plateau in north-eastern Wollaston Forland, there is an angular discordance between the Aptian (or Albian) and the Falskebugt Beds, believed by Maync to be Valanginian (see p. 72). If this dating of the Falskebugt Beds is correct, the Hühnerbjerg Block alone underwent a westerly tilting in post-Valanginian, pre-Albian time. It is possible, however, that the Falskebugt Beds are equivalent to the Rigi Series.

There is no further direct evidence, from unconformities, for earth movements later in the Cretaceous, but one important episode remains to be noted. The conglomerates in northern Traill Ø, assigned to the Turonian (p. 84), are probably comparable in importance with the Rigi Series, and must have resulted from renewed activity along the Maanedal Fault which here formed the western limit of the Cretaceous transgressions. It is unfortunate that the Turonian is only known from a very small area in East Greenland, and even in this area there is no evidence as to its relationship with earlier rocks. Consequently we do not know whether the Turonian movements were local or widespread. If there is really an unconformity below the Senonian Knudshoved Beds (Vischer, in Koch, 1955, p. 595), it may be due to the same episode of movement.

V. THE JURASSIC AND CRETACEOUS GEOGRAPHY OF CENTRAL EAST GREENLAND

1. Limits of the Triassic basin of Jameson Land.

The deposition of the Kap Stewart Formation was continuous with that of the underlying Triassic Klitdal Formation, but was marked by the change from a terrestrial environment to a deltaic one. An account of the Jurassic and Cretaceous geography may therefore begin with a consideration of the basin in which the late Triassic rocks were deposited. The lithology of the Klitdal formation described by Rosenkrantz (1929, p. 140) agrees closely with that specified by Pettijohn (1949, pp. 449—451) as characteristic of his 'Terrestrial piedmont facies'. The evaporites and non-marine clastic sediments including arkoses and purple siltstones show that the Klitdal Formation was deposited in an inland basin which extended from Scoresby Sund northwards to Traill and perhaps to Geographical Society Ø. The basin was bounded on the west by highlands of crystalline and palaeozoic rocks which to-day form the Staunings Alper, and by the mountains of western Traill and Geographical Society Øer, bounded by a fault zone. The probable western limit of the basin is shown in figure 20; in the present state of knowledge it is hypothetical. In Traill Ø the Triassic rocks do not extend west of the Bordbjerget Fault (Donovan, 1955, fig. 1) which has been taken as the limit in this region; the westward extension into the area of the Rubjerg Knude shown by Stauber (pl. 3 in Koch, 1950) was found not to exist by the writer during a recent visit (1954) to this area. It is, of course, possible that Trias formerly overlay the Permian, which is the youngest system present west of the Bordbjerget Fault, but it seems preferable not to assume an extension for which there is no evidence. In western Jameson Land it is unknown whether the Trias, which rests unconformably on Palaeozoic rocks according to Stauber (1942, p. 140), ever extended over the area of the present Carboniferous belt which to-day separates the Trias from the crystalline rocks of the Staunings Alper, but it fairly certainly did not extend into the crystalline area. Koch (1950, p. 7) believes that the elevation of the Staunings Alper began about the beginning of the Trias, supplying sediment to the Jameson

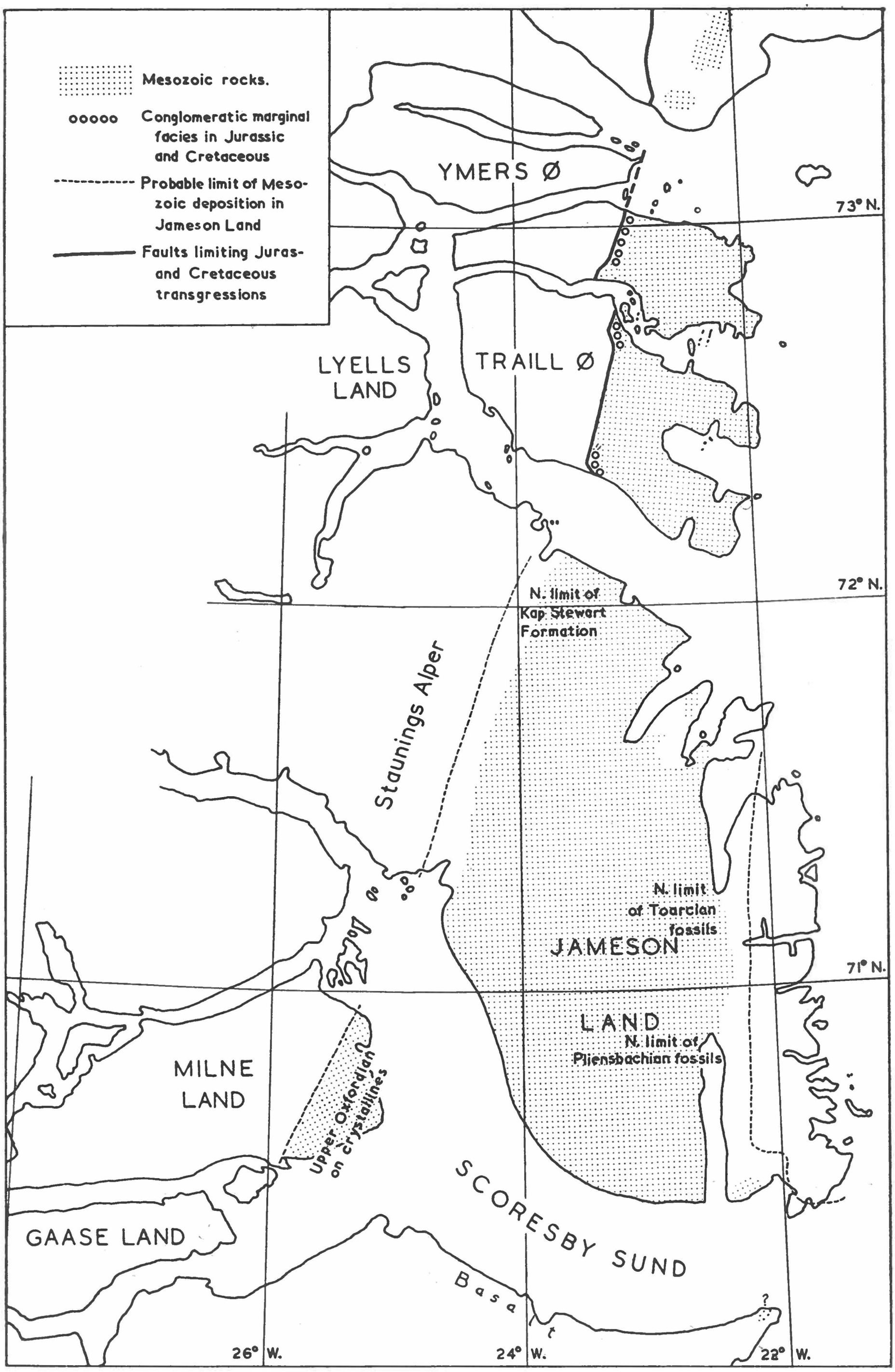

Fig. 20. Map illustrating some of the features of the Jameson Land Basin of deposition discussed in the text. Scale approx. 1:2 million.

Land basin; if this was the case the Trias probably did not extend far west of Schuchert Fløđ.

South of the Staunings Alper the western margin of the Triassic basin may have lain east of the eastern end of Milne Land, where Upper Jurassic rocks rest directly on metamorphics which rise westwards. Further south still, the position of the western limit may be indicated by the appearance of metamorphic rocks from under the Tertiary basalts, on the south side of the mouth of Gaasefjord. This region is little known, however, and further information is desirable.

The eastern boundary of the basin in which late Triassic deposition took place was formed by the crystalline mass of Liverpool Land. The western face of Liverpool Land is a remarkably even surface, sloping to the west at an angle of about 5°, which has been noted by a number of writers (summarised by Rosenkrantz, 1942, pp. 8—12). The slope is said to be about the same as the angle of dip of the Mesozoic sediments on the opposite side of Hurry Inlet, and has been generally interpreted as a continuation of the surface on which these sediments were deposited, laid bare by denudation. The surface terminates eastwards against the higher peaks of eastern Liverpool Land, which represent the eroded remnants of the original eastern limit of the Jameson Land basin (Koch, 1902, p. 294). A continuation of the Liverpool Land massif north of Kong Oscars Fjord, which has been postulated for other reasons (see page 109), is probably necessary to account for the northward persistence of the Upper Triassic continental facies into Traill Ø.

There is insufficient evidence to show whether the basin had an outlet to the north, for the small areas of Trias which do occur in Traill and Geographical Society Øer have not been systematically studied. The early Jurassic history of the basin, when marine incursions seem to have come from the south, suggests that it did not. The same consideration implies that the basin was open to the south, and the area of Trias and Lower Jurassic sediments at Rosenvinges Bugt, on the south coast of Liverpool Land, suggests that southern limit of the crystalline mountains of Liverpool Land was the same in Mesozoic times as it is to-day. No evidence is to be found south of Scoresby Sund, for the former Knud Rasmussens Land[1]) is composed of Tertiary basalts and sediments as far west as the mouth of Gaasefjord and for many kilometres southwards along the outer coastline. It is to be hoped that an expedition in the near future may find evidence for the age of the sediments discovered beneath the basalts near Kap Brewster in 1951 (p. 91) which might throw important light on the palaeogeography.

The floor of the Jameson Land basin falls steadily to the south,

[1]) Knud Rasmussens Land is now the northernmost part of Greenland, from Melville Bugt to Danmark Fjord.

resulting in broadening of the basin, and the appearance of younger and younger formations. Thus the youngest Mesozoic sediments (Berriasian) are found on the south coast of Jameson Land. The same process may largely account for the appearance of the Tertiary basalts south of Scoresby Sund, although a fault or flexure along the Sund, downthrowing to the south, seems to be a necessity.

2. *Rhaetian and Lower Jurassic.*

At about the beginning of the Rhaetian stage of the Trias conditions changed in the part of this basin which is now Jameson Land, and deltaic deposition became established, with extensive forest growth. Perhaps the chief change was a climatic one, permitting the establishment of the flora. If the Klitdal Formation accumulated under hot conditions with seasonal rainfall, the change would have been to a more temperate climate with a more even distribution of rainfall throughout the year. We cannot at present say what happened north of Kong Oscars Fjord, where the Kap Stewart Formation has not been recognised; but probably eastern Traill and Geographical Society Øer formed higher ground outside the area of growth of the flora found in the Kap Stewart Formation.

Deltaic conditions persisted through the Rhaetian and Hettangian stages. The occasional marine beds in the Kap Stewart Formation show that sedimentation was taking place at about sea-level, so that the surface of the delta could occasionally be flooded by the sea. At about the end of the Hettangian there was probably a regression of the sea from the coast, for no Sinemurian marine fossils have been found. It is impossible to say how long into the Sinemurian continental sedimentation may have continued.

The Jamesoni Bed of the Neill Klinter Formation indicates a new marine incursion into the southern part of the Jameson Land basin, which reached at least as far north as Duséns Bjerg. There is no reason to doubt that the basal Jamesoni horizon is of the same age throughout south-eastern Jameson Land, and that in this area the transgression was rapid. Marine conditions may have persisted until late in the Toarcian (early Jurense Zone) (p. 29), for although only a few of the intervening faunas have been found this may be a result of the unsuitability of the facies for the preservation of recognisable fossils. It is equally possible, however, that there were some recessions of the sea from the basin, and that the Neill Klinter Formation is only partly marine. Toarcian fossils have been found further north than Pliensbachian ones, and during the later part of Liassic time the sea may have transgressed further north, although there is at present no evidence that it ever reached the northernmost part of Jameson Land. Marine conditions were certainly well established at the end of this period of deposition, as testified by the extension of the Oyster Bed as far north as the head of Carlsberg Fjord (fig. 21).

The withdrawal of the sea immediately after the deposition of the Oyster Bed must have been rapid and complete, for the latter is everywhere succeeded abruptly, although without any detectable unconformity, by the Vardekløft Formation and its lateral equivalent the Fossil Mountain Formation or Yellow Series, of late Bathonian and early Callovian age. For almost two whole stages, the Bajocian and most of the Bathonian, there was no sedimentation within the present land area of East Greenland. This interval marks an important change in the palaeogeographical picture, for during the late Trias and Lias deposition was restricted to the Jameson Land basin, open to the sea probably at its southern end only. From the Callovian onwards, transgressions invaded the coastal belt at least as far north as latitude 77°.

3. Callovian: The southern region (figs. 20, 21).

The Jameson Land Basin continued in existence, so far as the evidence goes, during the Bathonian-Callovian episode of sedimentation. The salient feature of the deposits in it is the change from a thin argillaceous facies, the Vardekløft Formation, in the south-east, to the thicker, largely arenaceous development or Yellow Series north of Hurry Inlet, probably reaching its greatest thickness around Antarctics Havn. The absence of coarse detritus along the coast of Hurry Inlet indicates that the crystalline rocks of Liverpool Land were not an important source of sediment. The present writer believes that the raw material for the Yellow Series, in the southern area at least, was chiefly provided by the destruction of the Upper Palaeozoic rocks, which are continuously exposed along the western side of the basin, and on the eastern side are preserved in Canning Land and Wegener Halvø (Bütler, 1948, pl. 4). These rocks are largely sandstones, which would have been much more rapidly destroyed by denudation than the crystalline rocks. In Geographical Society and Traill Øer the Carboniferous and Permian rocks to the west of the Mesozoic area were certainly an important source of sediment in the Jurassic and Cretaceous, and their influence can be traced in the conglomerates and coarse sandstones which occur along the western boundary of the transgression (see p. 39). It must be emphasised that this suggestion as to the source of the Yellow Series, which may apply also to the earlier Jurassic formations, is merely a hypothesis resulting from the writer's knowledge of the geological circumstances. A study of the sedimentary petrology of the rocks would provide confirmation or otherwise, and would be a most interesting undertaking.

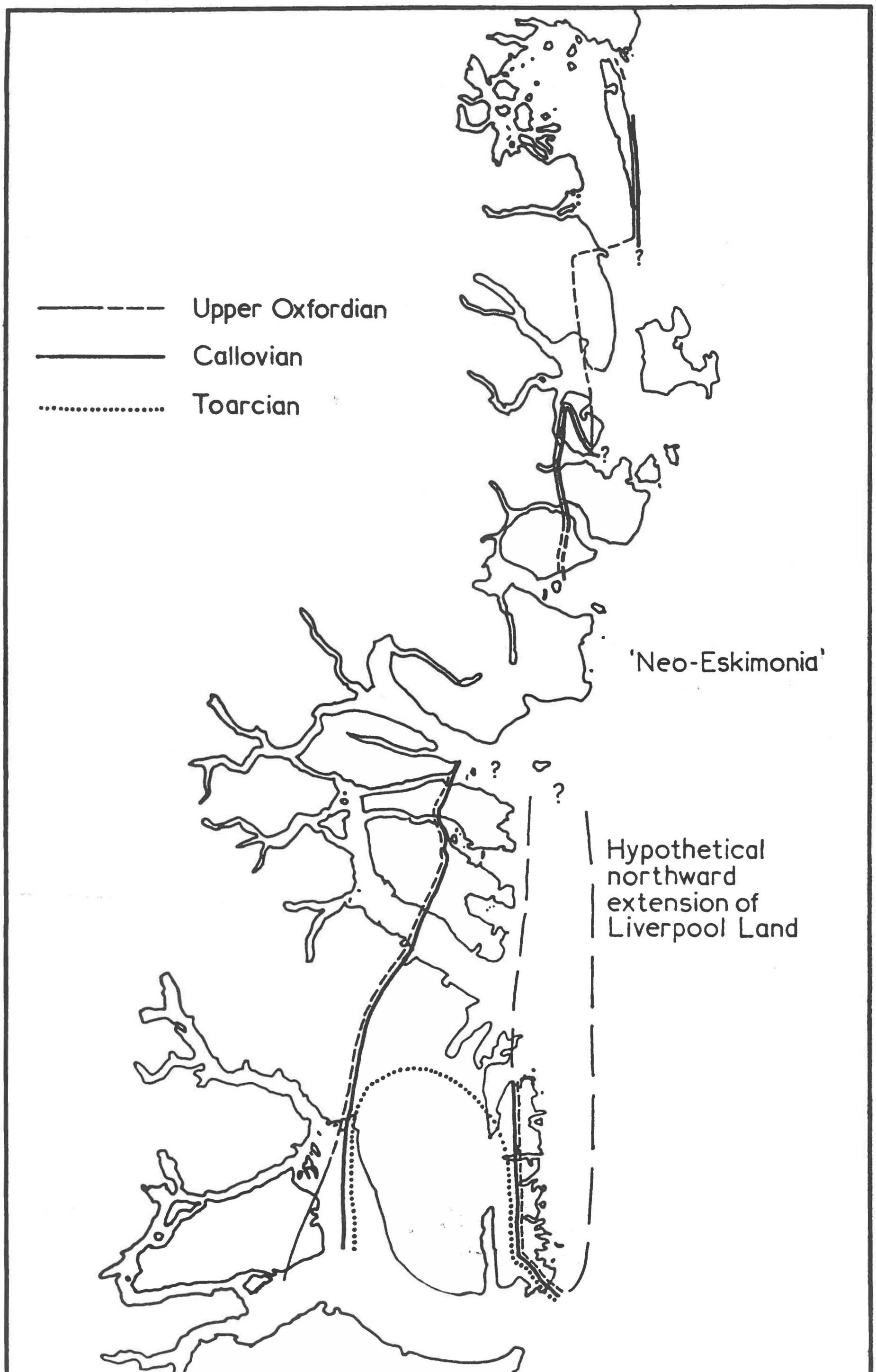

Fig. 21. Map showing the probable coastline of Central East Greenland in Toarcian, Callovian and Upper Oxfordian times.

For the first time since the Trias there was an extension of the area of sedimentation north of Kong Oscars Fjord, at least as far as Kejser Franz Josephs Fjord. The thickest deposits were probably laid down in the country immediately south of Kong Oscars Fjord, but the geology of this area is poorly known. It is impossible to say, from evidence at present available, whether the deposition area of Traill and Geographical Society Øer was in direct connection with the sea to the east, or not. If the hypothesis of a northward extension of the Liverpool Land massif, postulated for Oxfordian and Kimeridgian times (see p. 109), is correct, this barrier probably existed also during the Callovian. So far as we are informed on the variations in thickness and facies, they accord with sedimentation in a basin open to the south, the sandy deltaic deposits accumulating to their greatest thickness in the Kong Oscars Fjord region, becoming thinner southwards, and passing into shales nearer to the mouth of the basin in the area now occupied by eastern Scoresby Sund.

The earliest Callovian (or late Bathonian) fauna, characterised by the ammonite *Cranocephalites*, has been found throughout the southern area, from Katedralen, near the head of Hurry Inlet, to Traill Ø. Deposition had started before the time marked by this fauna, as shown by the sandstones and shales below the *Cranocephalites* horizon in Jameson Land, and the Plant Beds, almost certainly of truly deltaic origin, in Traill Ø. It continued, with intermittent marine incursions, throughout the Lower Callovian.

4. The Region between 73° and 74° North Latitude in the Jurassic Period.

During the Upper Jurassic, according to Maync, (1947, p. 144), two regions of deposition, a southern and a northern, were separated by the landmass 'Neo-Eskimonia', corresponding roughly to the Giesecke Bjerge and Hold with Hope at the present day. Over the supposed area of Neo-Eskimonia (fig. 21) Jurassic sediments have not been found, and the Cretaceous (Aptian and later) rocks rest directly on the Eotrias. It is impossible at present to decide whether the absence of Jurassic rocks is due to non-deposition or to pre-Aptian denudation. In northern Geographical Society Ø the Yellow Series of the Jurassic is present, and probably at least 400 m thick, but all higher members of the Jurassic, and in places the Yellow Series also, have been removed by pre-Albian denudation (Donovan, 1955, p. 18). It is clear that this denudation was most intense in the Giesecke Bjerge and northern Hold with Hope, as shown diagrammatically in figure 22, and may there have resulted in the complete removal of the Jurassic rocks. There is no positive evidence, such as shore-line facies, for the existence of Neo-Eskimonia, and it

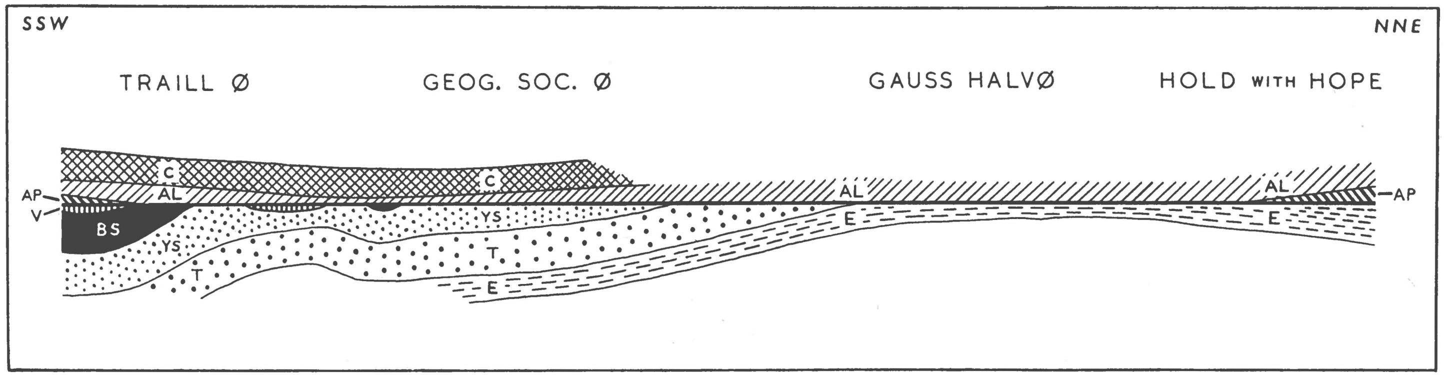

Fig. 22. Diagrammatic section from Traill Ø to Hold with Hope to show the relationships of the Triassic, Jurassic and Cretaceous formations. The basal Aptian and Albian unconformity is shown as a horizontal line. Explanation of abbreviations:— E = Eotrias, T = non-marine Trias, YS = Yellow Series, BS = Black Series, V = Valanginian, AP = Aptian, AL = Albian, C = Cenomanian. The section shows that the immediate reason for the disappearance of the Jurassic rocks north of Geographical Society Ø is overstep by the Cretaceous unconformity. Horizontal scale is about 1:1 million. Vertical scale about 20 times the horizontal.

must remain hypothetical. The chance of finding evidence to settle this question does not seem to be very good.

5. Callovian: The northern region.

In the region between 74° and 77° N. latitude the Yellow Series is the earliest Jurassic formation. It overlaps the Eotrias, and comes to rest unconformably on Palaeozoic and crystalline rocks. During the later Triassic and the Lower and Middle Jurassic periods, therefore, this was probably an area of emergence, the continental edge lying some distance to the east.

The principal outcrop of the Yellow Series is in Wollaston Forland, with extensions into eastern Clavering Ø and western Kuhn Ø. It is bounded on the west by the zone of faults comprising the Clavering Fault, Dombjerg Fault and Thomsensland Fault of Vischer (1943, p. 25). On the east, with the possible exception of a doubtful occurrence at Permpasset (Maync, 1947, p. 97), the Yellow Series does not outcrop east of the line marked by the Kuppel, Canyon and Kuhn Faults. According to Vischer (1943, pl. 6) the area of deposition did not extend far east of this line (the faults were not yet in being), being delimited by the elevated part of the tilted crystalline basement. The accumulation of the Yellow Series thus took place in a narrow basin elongated north and south, open to the south but probably not to the north, the state of affairs existing in the southern area being reproduced on a smaller scale. The northern and eastern margins of this basin would have been formed by the 'Eskimonia' of Maync (1939; 1947, p. 140) which had been an area of emergence during the late Palaeozoic and Trias. The Yellow Series becomes thinner towards the north in Kuhn Ø (see p. 39), probably indicating that the limit of the area of deposition lay near the present limit of the outcrop.

In Store Koldewey the present Callovian deposits, lying in a narrow strip at the foot of the steep eastern coast of the island, mark the westward limit of the Jurassic sea at this point. It is unknown whether or not the Callovian and later Mesozoic seas invaded the dipslope of the tilted block of which Store Koldewey is interpreted as the eastern edge; the area concerned is poorly known and largely below present sea-level.

The facies of the Yellow Series in the northern region is similar to the sandstone facies in the south, and may be similarly interpreted, as representing deltaic deposits, with marine intercalations, deposited by rivers discharging from the highlands, principally from the west, into the basin already described.

On account of the absence of any deposits dateable to the Middle or Upper Callovian or Lower Oxfordian, it is assumed that there was a break in sedimentation during this time. The alternative view, that there was continuous sedimentation, is held by Maync (1947, pp. 184—185, pl. 7), but has been rejected by the present writer. As Spath has remarked (1936, p. 151), it is extremely unusual for a series of unfossiliferous beds, lying between two dated formations of markedly different ages, to form a complete transition between them. The supposed 'transitional beds' usual belong to the end of the earlier formation or the beginning of the later. Lastly, Maync himself has pointed out that there is a sharp lithological break at the base of the Grey Series, the lowest Oxfordian formation in the northern region (Maync, 1947, p. 127).

6. *Upper Oxfordian and Lower Kimeridgian.*

At the beginning of the Upper Oxfordian there was a new transgression of the sea into both the southern and the northern regions. Upper Oxfordian fossils have only been found in a few places, and it is not clear whether the maximum extent of the transgression was reached rapidly, or whether it was a more gradual process. In contrast to the earlier Jurassic formations, conditions were now fully and continuously marine.

In the southern region, the Upper Oxfordian transgression overlapped earlier formations westwards, and in eastern Milne Land the first deposit of the transgression, the Charcot Bugt Sandstone, rests on the metamorphic basement with a basal conglomerate. Little is known as to the original extent of the transgression in the other parts of the southern and central regions; in Jameson Land on account of removal by denudation and lack of investigation, in Traill and Geographical Society Øer on account of concealment by Cretaceous rocks. We can only assume that the Jameson Land basin, with its northward continuation as far as Geographical Society Ø, at least, was again flooded by the Upper Oxfordian marine incursion (fig. 21). There is little doubt that the massif of Liverpool Land was already elevated, forming an eastern margin to the southern part of the basin (see p. 102). The presence of well-developed black shale facies in Traill Ø has led the writer to claim that this massif was continued northwards across Davy Sund and Foster Bugt, either as an exposed ridge or a submerged sill, thus restricting the circulation of the bottom waters in the basin and providing the conditions usually believed to be necessary for the deposition of black shales (Donovan, 1953, p. 65). Whether the basin was now open at the northern end as well as the southern, cannot be decided, on account of the absence of Jurassic rocks north of Kejser Franz Josephs Fjord.

In the northern region the present outcrops of the Upper Oxfordian and Kimeridgian rocks are confined to a narrow belt between the Clavering-Dombjerg Fault, on the west, and the Hühnerbjerg Fault on the east. This may represent the original trough of deposition, the rise of the crystalline basement to the east forming the ridge or sill which resulted in the accumulation of the black shale facies. This arrangement is shown by Vischer in his diagrammatic representation of the geological history of this part of East Greenland (1943, pl. 6, section III). Vischer shows the crystalline surface continuing eastwards uninterrupted by the Hühnerbjerg Fault, and this may well have been the case, since if a fault scarp had been in existence at this time one would expect to find breccias of Upper Jurassic age along it. There is at present no evidence to show whether this trough was open to the sea at the northern or southern end, or both. The marginal deposits along its western side are seen at Blaabærhytten (p. 50).

In Hochstetters Forland the coarse-grained, shallow water and partly non-marine deposits of Upper Oxfordian-Lower Kimeridgian age must have accumulated under deltaic conditions, and the area was presumably open to the sea to the east or south-east. Here, as in Milne Land, the Upper Oxfordian or Lower Kimeridgian sea probably transgressed on to the pre-Cambrian basement. In Store Koldewey the deposits lie along an old coast-line, as do the other Mesozoic rocks on the island.

7. Upper Kimeridgian to Valanginian.

In Milne Land Lower and Upper Kimeridgian ammonite faunas occur in the bottom and top of the Kimeridgian Clays, but no Middle Kimeridgian ammonites have been found. It is an open question, which the field evidence is inadequate to answer, whether the sea receded from the area during the Middle Kimeridgian, or whether there was merely non-deposition, or even some sedimentation without the preservation of identifiable fossils. The only other Upper Kimeridgian sediments are in Kuhn Ø, and their base is not seen. Portlandian rocks (excluding the Rigi Series) are restricted to Milne Land, where sedimentation appears to have been continuous from the Upper Kimeridgian into the Portlandian. It is arguable that the absence of these rocks throughout the greater part of Central East Greenland is due not to restricted deposition, but to removal by denudation following the late Portlandian earth movements, in the same way that the discontinuity in the outcrop of the Yellow Series across the Giesecke Bjerge and Hold with Hope may be due to denudation and not to non-deposition. There is no evidence as to the relations between Milne Land, where there is no discordance between the Upper Jurassic and the basal Cretaceous parts of the succession, and the northern region where late Portlandian earth movements caused the succeeding rocks to rest with marked unconformity on earlier formations.

In the southern region virtually nothing is known as to the geography of late Jurassic and earliest Cretaceous time. There was apparently continuous submergence during the Portlandian and Berriasian in Milne Land, and presumably in south-western Jameson Land; but throughout the rest of the area of the Jameson Land basin no outcrops remain to show the former extension of the deposits. In the central region the picture is almost a complete blank, for Portlandian and Berriasian rocks are not certainly known and the only well-dated outcrops are the two small exposures of Valanginian in north-eastern Traill Ø.

In the northern region, between 74° and 75° latitude and perhaps further north, the renewed activity along the faults, described on page 97, was accompanied by the flooding of the downthrown areas by the sea. Along the new faulted coastline, the breccias of the Rigi Series accumulated, often with enormous constituent blocks, while further from the shore sandstones were laid down. According to Maync these deposits were formed in a narrow arm of the sea, corresponding closely to that in which the Upper Jurassic rocks are believed to have been deposited (Maync, 1949, fig. 68, p. 213). The new deposits were laid down with strong unconformity on the Jurassic and older rocks. In the centre of the basin, represented by the section at the mountain 'Niesen' (p. 69), sedimentation was more or less continuous from about the Jurassic-Cretaceous boundary into the Valanginian. The western boundary of the basin remained in the same position during this time, but eastwards there was a gradual encroachment of the sea over much of the Wollaston Forland area during the Valanginian, so that in central Wollaston Forland Valanginian rocks rest unconformably on tilted Jurassic sediments. Maync has traced a lateral passage from the coarse clastic and conglomeratic near-shore facies of the Valanginian to the thinner marl and limestone facies further east. He believed the latter to have been laid down in shallow water, but away from the supply of terrigenous sediment (1949, p. 187).

The deposits of early Cretaceous age in Traill Ø cannot at present be fitted into a broader picture. The facies which are present correspond closely to those in Wollaston Forland, but there is no clue as to the extent of the sea in which they were deposited.

In Store Koldewey island, the Valanginian sea lapped against the base of a steep coastline which was in much the same position as the present-day east coast of the island, as it had done in the Upper Jurassic and was to do again in the Aptian.

The end of the earliest Cretaceous inundation is not well-marked. At the summit of the 'Niesen' an Upper Valanginian ammonite was found, and presumably an unknown thickness has been removed from the mountain by denudation. There is, however, no positive evidence for the presence of either Hauterivian or Barremian strata, as Maync has emphasised (1949, pp. 193—195), and a regression of the sea during these two stages has been assumed by him and by the present writer. There is evidence for a period of denudation prior to the Aptian transgression, for Aptian and later formations often rest on Jurassic rocks, the Berriasian and Valanginian being absent. This might be held to indicate restricted deposition of the earlier Cretaceous formations, and subsequent overlap by the Aptian and Albian. This explanation is not plausible, however, in Traill Ø, where Valanginian of the calcareous Albrechts Bugt Facies, with no coarse detritus, is found only about 4 km from an exposure where Albian is unconformable on sandstones of the Yellow Series (Donovan, 1955, fig. 2, p. 13).

8. Aptian, Albian and Lower Cenomanian (fig. 23).

During the Lower Aptian there commenced a new transgression which reached its widest extent in the Cenomanian. The account of it which will be given here is doubtless unduly simplified, but until further stratigraphic work has been done this is inevitable. In spite of the period of denudation which preceded it, the country invaded by the transgression still exhibited considerable relief. Its earliest deposits (Lower Aptian) are sandstones, sometimes indistinguishable from the Yellow Series of the Jurassic, probably derived from the same source and possibly from the Yellow Series itself which may in places have been exposed to denudation. These Lower Aptian deposits occur in Hold with Hope, Wollaston Forland and Kuhn Ø. It is probable that most of the area of eastern Clavering Ø, Wollaston Forland, and eastern Kuhn Ø was submerged at this time, but in many places the age of the basal beds of this transgression is unknown.

By the Upper Aptian a much wider area had probably been invaded by the sea, for we find Upper Aptian rocks in Traill Ø, Shannon, Store Koldewey and Germania Land, as well as Kuhn Ø and probably Wollaston Forland. It may be that by this time the transgression had reached its maximum extension in the northern region, but we cannot trace its progress in detail. Further south, however, in Traill and Geographical Society Øer, the sea continued to creep up the dipslopes of the tilted blocks of Jurassic rocks during the Albian and early Cenomanian stages, and it was only during the latter period that the area was completely submerged (Donovan, 1955, p. 54). There is no evidence that sediment-

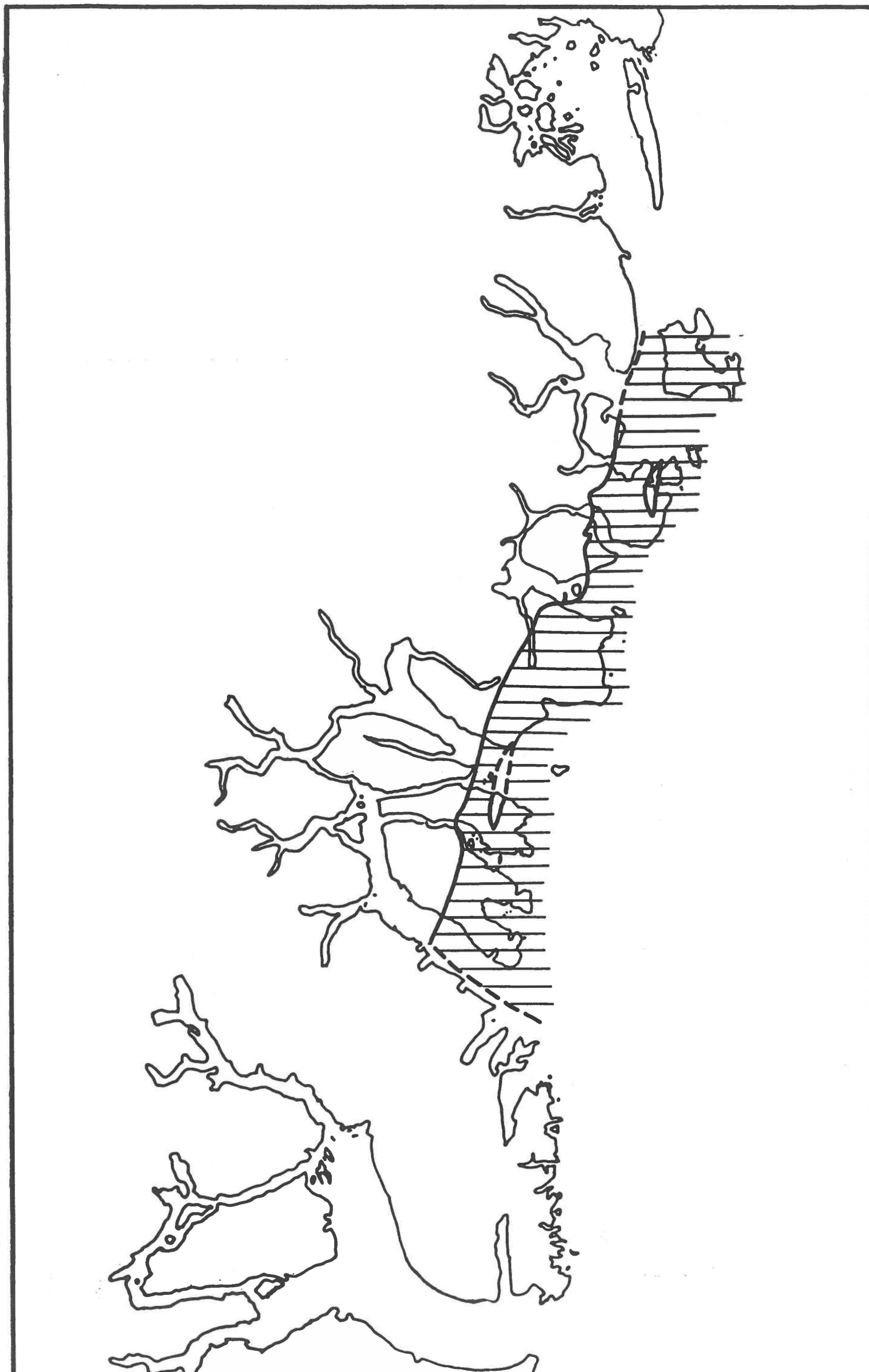

Fig. 23. Map showing the probable extent of the sea (horizontal shading) in Central East Greenland during Upper Albian times.

ation was continued into the Cenomanian in the Wollaston Forland area, although it seems likely that it was.

The western limit of the Middle Cretaceous transgression was formed, in the northern region, by a series of faults lying to the east of the Post-Devonian Main Fault (Maync, 1949, fig. 69, p. 215), and in Traill and Geographical Society Øer by the Post-Devonian Main Fault itself (see page 97), along which sandy deposits are intercalated with, and sometimes replace, the normal shaly facies of the Cretaceous (Donovan, 1955, p. 54). To the west of the faults Upper Palaeozoic and crystalline rocks stood above sea-level.

Some of the Aptian deposits are sandy, but the Albian and Cenomanian rocks are black shales, sometimes with subsidiary layers of sandstone, except where the nearness of the coastline has given rise to coarser facies. The black shales may be attributed to deposition in basins between the tilted and faulted blocks, which in the central region, at least, continued to form islands until the Cenomanian.

To-day the southern limit of post-Berriasian Cretaceous rocks in central East Greenland is Kong Oscars Fjord. Recent writers agree that this fjord conceals the line of a fault (Bütler, 1948, p. 79, pl. 3; Donovan, 1953, p. 59) along which considerable late- or post-Jurassic movement has taken place. One may believe either that this movement was also post-Cretaceous, and that Cretaceous rocks deposited south of the fault have been removed by denudation consequent upon the elevation of the area to the south, or that it occurred late in the Jurassic or early in the Cretaceous, in which case the resulting scarp would have formed the southern limit of the Cretaceous transgressions. There is little evidence at present to decide between the two hypotheses. The second is adopted in the interpretation offered here (fig. 23), because it is known that the late Jurassic was an important period of tectonic activity.

9. *Turonian.*

As there are no sediments of proved Upper Cenomanian or Lower Turonian date in East Greenland, it is presumed that the sea receded from the coastal area during this time. Nowhere, however, has the contact between the Upper Turonian and earlier strata been seen, so that the hypothesis of a new transgression in the Upper Turonian cannot be proved. Neither is the duration of the transgression proved by fossils. Taking into consideration the rapidity of sedimentation usual in East Greenland, it is unlikely that it lasted much longer than the end of the Turonian.

In Traill Ø the western limit of the Upper Turonian transgression was the fault scarp of the Maanedal Fault. To the west lay (and lies at the present day) a region of Carboniferous and Permian rocks, the active denudation of which gave rise to the Turonian conglomerates in the Rold Bjerge and the Vega Sund area. Further from the coast, black shales were deposited, with subsidiary bands of sandstone some of which show structures suggestive of the flow of sediment down a sloping bottom, and isolated patches of conglomerate which may have reached their present position in the same way.

There is little other palaeogeographical evidence for the Turonian, but it may be assumed, pending the production of further evidence, that the important fault zone of which the Maanedal Fault was a component also formed the limit of the transgression in Geographical Society Ø and in southern Traill Ø, as it had done in Cenomanian times. North of Kejser Franz Josephs Fjord Turonian rocks are unknown, although it is possible that they may yet be found. The question of the southward limit of the Upper Cretaceous transgressions has already been discussed (p. 114).

10. Senonian.

The Sphenoceramus Beds in Traill and Geographical Society Øer mark a marine incursion during the Upper Santonian, but here again the limits are quite ill-defined, for the dating is by lamellibranchs only and the relationships of the formation have not been observed in the field. If the writer's interpretation of the stratigraphy is correct (p. 88), the eastern part of Hold with Hope, as well as the eastern parts of Traill and Geographical Society Øer, was submerged in Santonian times. This transgression thus had a wider known geographical extent in Central East Greenland than others in the Upper Cretaceous; but in point of fact if earlier transgressions had left deposits in eastern Hold with Hope they would lie, at the present day, below sea level, except perhaps in the country between Kap Broer Ruys and Knudshoved, which has not been closely examined.

The Kangerdlugssuaq Sedimentary Series (or at least the lower, marine part) denotes an incursion of the sea over the metamorphic basement of south-east Greenland. Whether this transgression and the one in Central East Greenland were mere local submergences, or whether they formed part of an extensive transgression in East Greenland, cannot be determined. If Upper Cretaceous rocks were ever deposited more extensively in East Greenland, then they have either been removed by denudation or concealed by Tertiary basalts.

The Upper Campanian is known from only a few places in Traill and Geographical Society Øer, and the stage may mark a continuation of deposition from the Upper Santonian or a fresh invasion of the sea. Nothing is known of the original extent of the sedimentation, but it is unlikely that it extended west of the Maanedal and Tværdal Faults, which formed the limit to the earlier transgressions.

VI. THE SEDIMENTARY FACIES

The Jurassic and Cretaceous rocks of East Greenland are not especially remarkable for their lithological variety, for two rock-types predominate: light-coloured sandstones and black shales. Conglomerates occur along old coastlines, and possibly along submarine fault-scarps. Limestones are rare and insignificant, except during the Valanginian stage when they attain a limited development. The recurrence of a few sedimentary types throughout the succession denotes the persistence of a very limited selection of environments, and indeed the general picture, of sedimentation off a steep, often faulted, coastline, backed by a mountainous hinterland, remained the same throughout.

No study of the sedimentary petrology has been made, and so it is not possible to present any quantitative information as to either texture or composition. A little attention has been paid to the conditions of deposition of the formations, for instance by Aldinger who attempted to find present-day parallels for structures in the Hartzfjeld Sandstone (1935, pp. 104—109), and Maync who has considered the origin of cone in cone structure (1949, pp. 206—209). Some heavy mineral assemblages have been published by Kleiber (1944). The present account will be confined to a summary of the lithological features and the probable conditions of deposition of the formations.

Sandstone Facies.

The sandstone facies is examplified *par excellence* by the Jurassic Yellow Series, which extends from northern Jameson Land ('Fossil Mountain Formation') to Kuhn Ø. It consists largely of quartz sandstones, sometimes well cemented with calcite, sometimes soft and friable. The usual colours are white to grey and yellow, but brown and red sandstones also occur. Many beds are micaceous, although other horizons are remarkable for their purity. Pebbles may occur, and in the coarser beds there seems to be every gradation from sand grains to pebbles. Samples brought back from Traill Ø show that the quartz grains are not usually well rounded; subangular and even quite sharp grains are common. Felspar is not usually present.

Fossil wood and impressions of plants, usually unidentifiable, often occur in the sandstones. Marine fossils occur only at a few horizons, where they may be fairly abundant, although often poorly preserved. The marine faunas include a wide variety of bottom-dwelling lamellibranchs and brachiopods, and abundant ammonites in some cases.

Shales are sometimes interbedded, though usually subsidiary and frequently absent. It is not always easy to determine the amount of shale in a sandstone succession, for the shale outcrops are obscured by debris from the sandstones. Ferruginous nodules sometimes occur, though in other areas the series is completely free from them. On the whole, highly ferruginous beds are the exception.

There is a good deal of variety in the structure of the sandstone. Often massive, it also shows, perhaps less commonly, thin, platy bedding. Cross-bedding is often developed.

The features outlined above for the Yellow Series would serve to describe a number of other formations. The Charcot Bugt Sandstone and the Pecten Sandstone, in Milne Land, are of essentially the same type; the Hartzfjeld Sandstone, in the same succession, is more argillaceous. The Kap Stewart Formation, famous for its fossil plants, is also broadly similar; its special characters have already been described (page 24). The sandstone facies of the Aptian in northern Hold with Hope (the 'Yellow Series' of Koch, *non* Maync), is so similar to the Jurassic Yellow Series that Maync said that he could not distinguish between them on the basis of the lithology (1949, p. 131).

Glauconitic sandstones are uncommon in East Greenland, but are well developed in the lower part of the Glauconitic Series in Milne Land.

Black Shale Facies.

Black shales constitute the greater part of the Black Series (Upper Oxfordian-Lower Kimeridgian) and the Kuhn Beds (Upper Kimeridgian); they occur extensively in the Aptian and Albian stages, and the Upper Cretaceous rocks are predominantly composed of them. The shales are often micaceous, and are soft where they have not been baked by Tertiary igneous intrusions. The black shale facies is often extremely uniform, as in the Black Series of Traill Ø, where about 500 m of shales are exposed without interruption (Donovan, 1953, p. 28). In other cases, as in the Aptian and Albian of Wollaston Forland, clay-ironstone bands and concretions are abundant. Another feature of the same series is the prominence of beds of buff marl showing well-developed cone in cone structure; Maync has discussed the origin of the cone in cone (1949, pp. 206—209), and supports the hypothesis of Shaub (1937) that the cones were formed by drainage of tidal flats during ebb tide, the draining away of moisture having been observed in Recent instances to give rise to small inverted cones, which are supposed to be filled with sediment at the next tide and thus preserved. The present writer cannot accept this theory, and prefers to join Pettijohn and the authors cited by him in thinking cone in cone structure to be secondary, and in some way produced by pressure (Pettijohn, 1949, pp. 155—156). The following factors cannot be reconciled with Maync's view: 1) there is no evidence that any of the Greenland black shales were deposited between tide-marks, 2) the presence of cones with their apices directed upwards, admitted by Maync as unexplained. In other cases the black shales are punctuated by subsidiary bands of sandstone (e. g. the Albian and Cenomanian of Lycett Bjerg, Traill Ø) or limestone (e.g. the Black Series of Wollaston Forland).

Fossils are not normal constituents of the black shales any more than they are of the sandstones, and they are restricted to occasional horizons. They are chiefly ammonites, which may have been free-swimming or surface living animals, and a few genera of lamellibranchs (*Buchia*, *Aucellina*, *Inoceramus*) which appear to have been able to live on a muddy, somewhat oxygen-deficient bottom. The normal bottom-dwelling fauna is absent.

Breccias and Conglomerates.

The rudaceous rocks fall into three principal groups. The most impressive are the breccias or boulder-beds, often containing blocks of enormous size, which are found near the coast-lines of the various formations. They are often interbedded with sandstone or shale and presumably resulted from periodic cliff falls, or slips of boulders from the beach into the waters offshore. These rocks are well-developed in the Rigi Series and in the Lindemans Bugt facies of the Valanginian, in the Wollaston Forland area, where they consist predominantly of crystalline rocks and Permian dolomite and limestone (Maync, 1947, pp. 133—137; 1949, pp. 188—190). The Turonian conglomerates of Traill Ø are probably to be grouped in the same class; some of the isolated occurrences, far from the postulated shore-line, may have arrived at their present positions by submarine sliding or slumping (Donovan, 1953, pp. 38—42; 1955, pp. 31—35). Conglomerates of this group are sometimes fossiliferous, for instance in the Rigi Series where they contain *Buchia*.

Basal conglomerates, consisting of fragments of the underlying formation, are found associated with several of the unconformities. Examples are at the base of the Charcot Bugt Sandstone, in Milne Land (Aldinger, 1935, pp. 54—55), the Yellow Series in southern Kuhn Ø

(Maync, 1947, p. 14), and the base of the Middle Cretaceous Shales in the Vega Sund area (Donovan, 1955, pp. 22—27). Sometimes basal conglomerates are conspicuously absent, as at the base of the Albrechts Bugt Facies of the Valanginian in Wollaston Forland (Maync, 1949, p. 187).

Conglomerates of the third group are found interbedded in the sandstone formations, and consist of well-rounded pebbles of quartz and quartzite, usually up to a few cm in diameter. They occur in the Yellow Series and in most of the other coarse clastic formations, and are presumably the result of the destruction of pre-existing conglomerates in the Palaeozoic rocks.

Limestones.

The only significant development of limestone in the area is found in the Valanginian, where the Albrechts Bugt facies consists of marly limestones and shales. The limestones are sometimes fossiliferous, but the bulk of the rock is fine-grained and not made up of shell fragments. Where the facies is typically developed there is little coarse sediment, but elsewhere limestones with *Buchia* are interbedded with sandstones.

Limestones are found interbedded in the Black Series in Wollaston Forland, in very subsidiary amount. They perhaps denote temporary reductions in the supply of sediment.

General Remarks.

All the East Greenland sediments of the Jurassic and Cretaceous periods were deposited in close proximity to the land. In some cases the position of the shore-line is known, and few of the rocks visible at the present day could have been deposited more than 50 km from the coast.

The Yellow Series was clearly deposited along a coast backed by country of considerable relief, whose denudation provided the sediment. The sediment has been thought by Maync (1947, p. 120) to represent disintegrated crystalline rocks, which are exposed at the present day in the Wollaston Forland area which he studied. In Traill and Geographical Society Øer no crystallines are exposed even to-day, and they can be ruled out as a direct source of sediment. Here, the area in which the Yellow Series occurs is bounded to the west by an extensive area of Carboniferous and Permian rocks, predominantly sandstones, and it was the destruction of these, and perhaps the Devonian rocks further west, which doubtless provided raw material. The younger Palaeozoic rocks also contain numerous conglomerates which form a likely source of those in the Yellow Series; they are especially prominent in Maanedal and Tværdal, close to the Palaeozoic outcrops. It is probable that the younger

Palaeozoic rocks of the Wollaston Forland area also contributed to the Yellow Series, for although they are to-day almost confined to a down-faulted area in western Clavering Ø, in Jurassic times their outcrop may have been more extensive. The relative importance of different sources of sediment in this area could only be found by a study of the heavy mineral content of the Yellow Series and the source rocks.

There is a good deal of evidence for regarding the Yellow Series as a deltaic deposit, largely non-marine in origin. This has been suggested by Maync (1947, p. 122) and the writer (Donovan, 1953, p. 64). The coarse and variable nature of the sediment, the absence of marine fossils throughout the greater part of the thickness, and the abundance of plant remains are all in accordance with such an origin. In Traill Ø the Jurassic commences with the Plant Beds which are entirely barren of marine fossils. The main mass of the Yellow Series which follows has occasional horizons with ammonites and other marine shells, suggesting that periodic subsidence allowed marine incursions, after which the deposits were again built up to or above sea level. The association of ammonites and fossil wood has been noticed by several writers on East Greenland, and the author has suggested that since the ammonites are sometimes abundant it is likely to be the wood rather than the ammonites which has drifted to its present position (Donovan, 1953, p. 64). It is possible, however, that accumulations of ammonite shells and drift-wood were sometimes formed along the shore, and this may be an alternative origin for the fossil beds. The boulder of fossiliferous conglomerate derived from the Yellow Series and found in the basal Cretaceous conglomerate in Geographical Society Ø (Donovan, 1955, p. 17) may be a a beach deposit.

Similar conditions appear to have existed at other times when sandstone formations were being laid down. The Kap Stewart Series, bearing not only fossil plants but also coal seams, has been interpreted as a true deltaic deposit (see p. 25), and similar conditions may have led to the accumulation of the Muschelbjerg Formation (? L. Kimeridgian) in Hochstetter Forland, again with coal seams. In these instances there is little doubt that swamp vegetation flourished in the actual areas where deposition was taking place.

The black shale facies was deposited in quiet water under reducing conditions, not necessarily at great depth. It is generally accepted that a black shale facies denotes sedimentation in basins with poor water circulation, which are usually connected with the open sea by shallow channels only. The writer has previously suggested (1953, p. 65) that such basins may have formed tectonically off the East Greenland coast in Mesozoic times. The dominant structures of the coast are fault lines running parallel to it, separating blocks tilted to the west. In the area between 73° and 75° N. Latitude this structure is known to have been in existence by late Palaeozoic times (Vischer, 1943, pl. 6), and in Traill and Geographical Society Øer is believed to have influenced the deposition of the Middle Cretaceous Shales and may have been present in the Jurassic (Donovan, 1955, pp. 54—55). After a renewal of tectonic activity, resulting in the sinking of the western sides of the tilted blocks while their eastern sides remained at least partly above sea level, basins with restricted outlet could have been formed. Moreover, the elevated edges of the blocks to the west, which formed the boundary of the Mesozoic seas, may when newly rejuvenated have acted as barriers to rivers carrying sediment from the hinterland, so that coarse sediment was denied access to the sea except at a few places.

VII. COMPARISON WITH WEST GREENLAND AND SPITSBERGEN

West Greenland and Spitsbergen are the nearest places to East Greenland where Jurassic and Cretaceous rocks are found, and both show important resemblances to the East Greenland succession. Comparison may be made with the aid of the folding table (pl. 1), in which the West Greenland and Spitsbergen formations have been entered in the two right-hand columns. Research has recently been renewed on the West Greenland Cretaceous sediments (Rosenkrantz 1942a, 1951) but is not yet fully published. There is a chance that when details are available they will help with the understanding of the Upper Cretaceous formations of East Greenland. A considerable amount of work has been done in Spitsbergen and many fossils collected, which have been subjected to a diversity of interpretations by various authors. The most recent account of the succession is by Frebold & Stoll (1937).

1. West Greenland.

No Jurassic rocks are known from West Greenland, and the Cretaceous is, indeed, the oldest fossiliferous system present, resting directly on crystalline rocks. The earliest formation is the Kome Beds, in the Nûgssuaq peninsula, a non-marine series which has yielded a fossil flora. The affinities and correlation of the Kome Beds have been briefly reviewed by Imlay & Reeside (1954, p. 227). They are Lower Cretaceous, possibly Aptian and/or Albian, and are paralleled in western North America by the Kootenai Formation of Montana, U.S.A. and the Lower Blairmore Formation of Alberta, Canada. No comparable deposits are known in East Greenland, although marine sedimentation was probably taking place while the Kome Beds were being deposited.

The next formation in West Greenland, the Atâne Beds, is also of non-marine facies. It is shown by its stratigraphical position to be pre-Senonian and is probably of Turonian age. It may, therefore, be partly equivalent to the marine Inoceramus lamarcki Beds in East Greenland. Again no corresponding facies is known.

Rocks dated as Coniacian by the presence of *Scaphites* of the *ventricosus* group are known from the Svartenhuk peninsula (Rosenkrantz, 1951), but have no equivalent, so far as is known, in East Greenland.

The Pâtût Beds, in the Nûgssuaq peninsula, have long been known for species of *Sphenoceramus* which have more recently been identified from East Greenland (Donovan, 1953, p. 95), and *Oxytoma tenuicostata* is also common to the two areas. Rosenkrantz (1951) also records baculitid and scaphitid ammonoids. A fossil flora is also present. The Pâtût Beds correspond in date to the Sphenoceramus Beds of East Greenland, in which, however, neither ammonoids nor fossil plants have yet been found.

The Upper Campanian is known from both East and West Greenland, the same species of *Scaphites* being present in both areas (Donovan, 1954, p. 7).

West Greenland possesses higher Cretaceous beds than have so far been detected in East Greenland, a large fauna said to be Danian (i. e. Maestrichtian) and a higher one of Danian and/or Palaeocene age having been reported by Rosenkrantz (1951). The latter fauna is above the upper limit of the table (pl. 1) and is not included therein.

If the non-marine formations of West Greenland are included, there is a considerable, although not complete, parallelism between East and West Greenland as to the times when sedimentation was taking place. Knowledge of the Upper Cretaceous of East Greenland is not so complete as to preclude the discovery of new horizons, and the presence of additional horizons in West Greenland provides a slight hope that they may yet be found in the east.

2. Spitsbergen.

Both Jurassic and Cretaceous rocks occur in Spitsbergen and all the formations of which the age is definitely known correspond in date to formations in East Greenland. The earliest is the Toarcian which has been found at a number of isolated spots in the south of the island (Frebold & Stoll, 1937, fig. 1). Harpoceratid ammonites have been found, including *Pseudolioceras* near to *P. compactile* (Simpson), the type species[1]) and *Grammoceras*. These both indicate a date near the base of the Jurense Zone of the Toarcian, comparable to the highest part of the Neill Klinter Formation in East Greenland. *Catacoeloceras* is known from Thumb Point (Frebold, 1930, p. 61, pl. 22, figs. 4, 4a).

[1]) The Spitsbergen example, figured by Frebold (1930, pl. 6, figs. 1a, b) is close to *P. compactile* in side view. It was referred to *P. pumilum* S. S. Buckman by Frebold on the basis of the venter, which seems to have more pronounced shoulders than *P. compactile*. The figured specimen of *P. pumilum*, however, is small and comparison with the Spitsbergen ammonite is difficult.

The next fauna is marked by *Seymourites*, which has been figured by Frebold (*op. cit.* pl. 2) and indicates a horizon in the upper part of the Lower Callovian. One species, at least, *S. svalbardensis*, is found both in Spitsbergen and East Greenland, and the two faunas are doubtless of closely similar age. The presence of Upper Callovian has also been recorded on the strength of supposed *Quenstedtoceras*; specimens have been figured by Sokolov & Bodylevsky (1931, pl. 5, figs. 3, 4), but are very poor, and the present writer believes that they could be *Arcticoceras*, so that the presence of Upper Callovian is unproved. A similar misidentification in East Greenland has led to records of Upper Callovian from time to time.

The "Upper Callovian" and much of the rest of the succession is well exhibited by a nearly continuous section on the southern shore of Isfjorden, described by Hoel & Orvin (1937). The Upper Oxfordian and Lower Kimeridgian are represented by about 90 m of sandy shales, with Cardioceratid ammonites similar to those from East Greenland. They are succeeded by about 120 m of shales, with some sandstone, of unknown age; it seems most probable that these beds form either an upward continuation of those below, or the basal part of the next series.

The shales of unknown date are continuous upwards with a further thickness of about 35 m of shales, of which the lower part has yielded ammonites variously interpreted but recognised by Spath (1936, p. 170) as *Dorsoplanites*, and indicative of a late Kimeridgian or an early Portlandian age. The ammonites are close to those described by Spath from beds of comparable date in Milne Land, East Greenland.

Spath (1952, p. 20) has recently reviewed the claims for the presence of later Jurassic and earliest Cretaceous ammonite faunas in Spitsbergen, and has concluded that there is no evidence for the presence of higher Portlandian ('Upper Volgian' and 'Riasan') or Berriasian forms, the fossils which had been so identified belonging mainly to later genera. It appears, therefore, that there is a non-sequence in the main section between Lower Portlandian and Valanginian.

The earliest Cretaceous beds consist of a series, disturbed by folding and faulting but at least 200 m thick, of sandy shales with concretions, most or all of which is of Valanginian date. Polyptychitid ammonites probably belonging to more than one zone have been collected at a number of levels, but there is nothing which corresponds exactly with prolific Valanginian fauna from Traill Ø, East Greenland.

The marine Valanginian is succeeded by a plant-bearing series, at least partly non-marine, about 155 m thick and made up of shales and sandstones, and commencing with a hard, prominent bed of sandstone (the Festungssandstein; Hoel & Orvin, 1937, pl. 2, fig. 2). A flora has been collected including *Ginkgo* and a number of other genera (Nathorst, 1913), but cannot be dated more exactly than is indicated by the marine formations above and below. There is no parallel for this formation in East Greenland, although it might be compared with the Kome Beds in West Greenland.

The uppermost part of the main section consists of about 165 m of varying lithology including shales, sandstones and marls, with a number of fossil horizons. The age has been discussed by Frebold (in Frebold & Stoll, 1937, pp. 63—66), and it is probable that only Upper Aptian (Gargasian) can be considered proved.

Albian rocks are known elsewhere in Spitsbergen, and *Arcthoplites*, indicating Lower Albian, has been figured by Frebold (1930, pl. 19). This is the youngest Cretaceous fauna in the island, and there is nothing comparable to the Upper Cretaceous formations of East Greenland.

VIII. CORRELATION AND AFFINITIES OF THE FOSSIL ASSEMBLAGES

The following notes should be read in conjunction with the faunal lists for the various stages which are printed in Appendix II, page 196. Before embarking on detailed discussion it is desirable to emphasise one or two points. Very few of the Jurassic or Cretaceous faunas from East Greenland are known at all completely. This is principally a result of the limited time which has been available during expeditions for collecting. For instance, Maync and Vischer on the 1936—38 Expedition accomplished very fine work on stratigraphy and mapping, which was rightly given priority, but the collections brought back, on account of limitations of time and also of transport, were probably only a fraction of what could be obtained in the area. Even in a comparatively well-collected area like Milne Land, from which Spath monographed a large Upper Jurassic fauna (1935, 1936), it is probable that further work would produce a number of additional species. In many formations fossils are not very well-preserved, a factor which would be of less importance if unlimited time were available to search for fossil localities where preservation was exceptionally favourable, but which is significant under the circumstances already described. A sandstone, for instance, may be full of fossil lamellibranchs, preserved as moulds, but few can be prepared in a state suitable for identification. Lastly, a certain amount of material already collected has not yet been identified and published, for example, some of Nielsen's collections from Store Koldewey (1933), some material from the 1936—38 Expedition (see, for instance, Spath, 1952, p. 5), and the Valanginian collections made in 1952 by the writer.

In view of the circumstances just outlined, it is unwise to draw any conclusions from the small number of species present in some of the faunas. Where shallow-water deposits of suitable facies have been preserved, as in the case of the Upper Jurassic of Milne Land, or the Upper Aptian of Store Koldewey, large numbers of species have been collected, and the shortness of some of the other lists is to be attributed, in the writer's view, to lack of collecting, or deposition of unsuitable facies, rather than to any general impoverishment of the marine fauna off the East Greenland coast.

1. Rhaetian and Hettangian.

The stratigraphical position and relationships of the flora collected from the Kap Stewart Formation have been fully dealt with by Harris (1937), and it is unnecessary to repeat his remarks here. The two floral zones recognised by Harris have many species in common with European localities, particularly Sweden and Franconia. This makes correlation with European sections a comparatively easy matter, especially as the abrupt transition from the Lepidopteris to the Thaumatopteris Zone is present in both areas. The European sections in turn are well placed in the standard marine succession, and the two zones correspond approximately to the Rhaetian and Hettangian stages respectively. The dates of the base of the lower zone, and of the end of the upper, are uncertain, and indeed may be different in different areas. The Lepidopteris flora may have existed during the pre-Rhaetian Trias but as fossil plants are rare during that period this cannot be decided. In Germany the Thaumatopteris Zone is the equivalent of the Planorbis Zone of the marine succession, being overlain by beds of the Angulata Zone, and recently a species of the ammonite *Psiloceras* characteristic of the Planorbis Zone has been found in a marine intercalation in the plant beds in Franconia (Kuhn, 1955). The impossibility of accurately fixing the upper limit of the flora in East Greenland has been remarked on elsewhere, although in view of the comparative uniformity of the flora at different horizons within the zone (six new species appear in the upper part of the zone: Harris, 1937, p. 77) a total duration of much longer than the Hettangian stage seems improbable. Harris warns (1937, p. 71) that "No significance can yet be given to this unconformity [at the base of the *Jamesoni* horizon] because the plant bearing series has numberless local unconformities", but it is difficult to resist the conclusion that there is a non-sequence at the junction of the Kap Stewart Formation and the Neill Klinter Formation whose base is marked by the *Jamesoni* Limestone. The *Thaumatopteris* Flora in Sweden is restricted to the Hettangian, and most or all of the Sinemurian must be represented by a non-sequence below the Jamesoni Bed at the base of the Neill Klinter Formation.

2. Lower Pliensbachian.

The few ammonites recovered from these beds are indistinguishable from European species, and the *Uptonia* in the basal beds of the Neill Klinter Formation dates them securely as equivalent to the Jamesoni Zone of Europe. The rest of the large fauna has not been described. Many forms were ascribed by Rosenkrantz (1934) to European species, while a smaller number were regarded by him as new species. It is impracticable, on the basis of the information at present available, to make a detailed comparison between the non-ammonite fauna of Greenland and Europe. The brachiopods, however, are of interest from the point of view of zoological provinces. Dr. D. V. Ager states that to the best of his knowledge East Greenland is the only place outside the British Isles where the genus *Grandirhynchia* has been recorded. This genus was a consistent northerly element of the British fauna. In the Upper Pliensbachian it was virtually restricted to the Hebridean area; in the Lower Pliensbachian it is found occasionally in Yorkshire and in Gloucestershire, but it never reached the south coast (Ager, 1956, pp. 170, 178—81)[1]. The occurrence in East Greenland is consistent with the hypothesis of a northerly origin, deduced from the British distribution.

3. *Toarcian.*

The Toarcian ammonites agree well with European species, but this fact is of limited significance since there appears to have been little geographical differentiation of ammonite faunas in the Toarcian, and the Greenland specimens are identified with European species because the latter have long been described, while the faunas from North America, for example, are little known. The remainder of the fauna is undescribed, but the majority of lamellibranchs, which predominate, were referred by Rosenkrantz to European species.

The following table shows the European zones in the Pliensbachian and Toarcian, and the equivalents recognised in East Greenland.

<table>
<tr><th>Stages</th><th>Zones</th><th>East Greenland</th></tr>
<tr><td rowspan="4">Toarcian</td><td>Jurense</td><td>Pseudolioceras fauna in upper part of Neill Klinter Formation</td></tr>
<tr><td>Bifrons</td><td>Catacoeloceras and Dactylioceras faunas in upper part of Neill Klinter Formation</td></tr>
<tr><td>Serpentinum</td><td rowspan="4">Unrecognised</td></tr>
<tr><td>Tenuicostatum</td></tr>
<tr><td rowspan="5">Pliens-
bachian</td><td>Spinatum</td></tr>
<tr><td>Margaritatus</td></tr>
<tr><td>Davoei</td><td>Fauna with Androgynoceras and Aequipecten bjerringi</td></tr>
<tr><td>Ibex</td><td>Unrecognised</td></tr>
<tr><td>Jamesoni</td><td>Basal fossil bed, or Jamesoni horizon, of Neill Klinter Formation</td></tr>
</table>

[1]) I am indebted to Dr. Ager for kindly informing me of his conclusions on this subject prior to the publication of his paper.

4. Bathonian and Callovian.

The Callovian ammonite faunas present a strong contrast to those of the Lower Jurassic. Whereas the latter are readily recognisable as members of European[1]) genera and species, the nearest relatives of the Callovian ammonites are to be found in America and Arctic Europe, and there are hardly any genera, let alone species, in common with the classical Jurassic areas of Europe. This was probably a result of the widespread contraction of the seas during the Middle Jurassic, mentioned elsewhere (p. 156), which led to isolation and differentiation of faunas in different provinces. The distribution of the principal ammonite genera known from East Greenland is shown in plate 2[2]), with the exception of *Cadoceras* which has a world-wide distribution. The other four genera are all restricted to North America, East Greenland, the European Arctic islands (Spitsbergen and Franz Josef Land), Russia and the northern fringe of Asia. The other members of the fauna show little evidence of such restricted geographical affinities, but being for the most part much more slowly-evolving than the ammonites, they were presumably little affected by the Middle Jurassic regression. The palaeogeographical implications of the ammonite distribution are discussed on page 165.

The correlation of the ammonite faunas from the Vardekløft Formation and the Yellow Series of East Greenland with those of other areas, and especially with the classical succession of Europe, has always presented considerable difficulty. The following is the sequence of genera with zonal terms proposed by the writer (1953, p. 130):

Tychonis Zone:	*Seymourites* and *Cadoceras*. *Kosmoceras* (*Gulielmiceras*) at about this horizon.
Kochi Zone:	*Arctocephalites*[3]), *Arcticoceras*, *Cadoceras*.
Nudus Zone:	*Arctocephalites*, ?*Arcticoceras*[3])
Pompeckji Zone:	*Cranocephalites*.

All the genera except *Gulielmiceras* can be found in the islands of the Barents Sea or the adjoining northern lands of the Eurasian continent, although there seems to be no other area where such a complete sequence is present. *Seymourites* is well known from Spitsbergen,

[1]) The uniformity of Lower Jurassic faunas, mentioned above, must, however, be remembered.

[2]) Records of a supposed *Seymourites* from Japan, and of *Arcticoceras* near Kuibyshev, in Russia about 650 km north of the Caspian, are outside the map. References in Arkell, 1956, pp. 426, 498.

[3]) According to Spath, *Arctocephalites* is restricted to the Nudus Zone and *Arcticoceras* to the Kochi Zone. The genera are here interpreted differently, see page 133.

one or more species being common to that island and East Greenland. The type species of *Arcticoceras* was first described from Petchora Land, west of the Ural Mountains. *Arctocephalites* has been found also in Petchora Land, in Franz-Joseph Land, King Charles Land (really the easternmost islands of the Spitsbergen Archipelago) and perhaps Novaya Zemlya. *Cranocephalites* has been found in Novaya Zemlya, although not *in situ*[1]). *Cadoceras* has a wide distribution, both in Arctic and more southerly parts of Eurasia.

With the exception of *Cadoceras* and *Kosmoceras* (*Gulielmiceras*), none of the genera mentioned in the last paragraph are found in the classic areas for Jurassic stratigraphy, France, Germany and England. Nor are any of the Kosmoceratids, Macrocephalitids or Perisphinctids, on which the zonal scheme is based on those countries, found in any of the Arctic localities. In considering the problem of correlation, it is convenient to start at the top of the Greenland succession, for the Tychonis Zone, at least, is clearly of Callovian date. The genus *Seymourites* is a Kosmoceratid generally regarded as related in some way to *Kepplerites*, perhaps a geographical replacement of the latter genus[2]). It is therefore, unlikely that the genera were very different in date. *Kepplerites* is restricted, according to Callomon (1955, p. 254, table 3), to the Calloviense Zone in northwestern Europe, and the Tychonis Zone of East Greenland may be approximately equivalent to the Calloviense Zone. Spath (1932, p. 145) placed it as equivalent to the top of the Koenigi Zone, but the latter has now been included by Callomon as a subzone of the Calloviense Zone.

The most critical ammonite from East Greenland from the point of view of dating is *Kosmoceras (Gulielmiceras) pauper*, and it is unfortunate that it was not found *in situ.* It was found on scree west of Harris Bjerg, in Jameson Land, and the only other ammonites found on the scree were two species of *Cadoceras.* The mode of preservation is identical with that of the ammonites from the fossiliferous nodule bed of the Tychonis Zone at Vardekløft, and one of the species of *Cadoceras* occurs also in the Vardekløft Nodule Bed. As nodule beds may occur at different levels in different sections, it is not possible to say whether the *Kosmoceras* belongs to the Tychonis Zone, although it is certainly from the Vardekløft Formation. The subgenus *Gulielmiceras* in north-western Europe ranges from the Calloviense Zone at the top of the Lower Callovian, through the Middle into the Upper Callovian. According to

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[1]) It is cited from Siberia by Arkell, 1954, p. 117, but the figure that he cites is not a typical *Cranocephalites.*

[2]) *Seymourites* was placed as a subgenus of *Kepplerites* by Spath (1932) and the writer (1953). It is cited as a genus here to free it from any definite implication as to the relationship, and for the sake of brevity.

Callomon's table (*loc. cit.*) it is first known from the uppermost or Planicerclus Subzone, but museum specimens suggest that it may also occur, very rarely, in the subzone of Calloviense *s. s.*, in which is the well-known Kellaways Rock of Wiltshire, England. This appears to be reasonably good evidence that the upper part, at least, of the Vardekløft Formation in the Hurry Inlet area, and possibly the Tychonis Zone, is not earlier than the middle of the Calloviense Zone of Europe. As *Seymourites*, which bears no close resemblance to any of the Middle Callovian Kosmoceratids, seems unlikely to be later than Lower Callovian, one may assume that the Tychonis Zone either corresponds to part of the Calloviense Zone in Europe, or, at least, is very little older.

In considering the age of the remainder of the succession by direct comparison with non-Arctic Europe, there are hardly any clues to follow. The best, and it is a slender one, is the genus *Cadoceras*. None of the East Greenland species are found in the classic areas, and the range of the genus alone is available as evidence. In East Greenland, *Cadoceras* is common in association with *Seymourites* in south Jameson Land (although not in Traill Ø), and one specimen was found (at Mikael Bjerg) at the highest horizon with *Arcticoceras*, in the Kochi Zone. In non-Arctic Europe *Cadoceras* is common from the Calloviense Zone onwards, as shown in Callomon's table, but *Paracadoceras* has been found in the English Upper Cornbrash, belonging to the Macrocephalus Zone at the base of the Callovian (*e. g.* Blake, 1905, p. 48, pl. 5, fig. 1). Now it is probable that *Cadoceras* evolved from *Arcticoceras* or *Arctocephalites*, and the single specimen found associated with *Arcticoceras* at Mikael Bjerg was, in fact, named *C. pseudishmae*[1]) by Spath. If it be assumed that *Cadoceras*, once evolved, spread rapidly westwards (into North America) and eastwards (into Europe), then the top of the Kochi Zone in East Greenland would fall at about the beginning of the range of *Cadoceras* in Europe; that is, in the Macrocephalus Zone. The Kochi Zone would therefore be basal Callovian or topmost Bathonian, lower than the place assigned to it by Spath (1932, p. 145)[2]). Spath's dating was based partly on the presence, in the Kochi Zone, of two indifferently preserved gas-chambers (Spath, 1932, pl. 19, fig. 5) which he assigned to *Pleurocephalites*, a genus characteristic of the Calloviense Zone in Europe; but the specimen is quite unidentifiable. The supporting reasons were derived from the fact that *Macrocephalites (Indocephalites) krylowi*, the only ammonite said to be associated with *Arcticoceras* in its type area, has been reported in its turn to be associated with *Cadoceras*; but

[1]) *Amm. ishmae* is the type species of *Arcticoceras*.

[2]) Note that the Bathonian-Callovian boundary as generally understood, and as used in this paper, would fall between the 'Herveyi' (*recte* Macrocephalus) and Discus Zone in Spath's table, a zone lower than he places it.

these associations, based on old identifications and stratigraphy, cannot be given much weight.

The two remaining zones in East Greenland cannot be correlated in any way with the classic European succession; Spath, on the strength of the apparently close relationship between the genera *Cranocephalites*, *Arctocephalites*, and *Arcticoceras*, placed the Pompeckji and Nudus Zones immediately below the Kochi Zone, so that the lowest (Pompeckji) zone was equivalent to the Discus Zone of Europe, at the top of the Bathonian. The writer (1953, p. 133) even suggested that all might be fitted into the Callovian, but this was consequent on acceptance of Spath's dating of the Kochi Zone, which is now questioned. The correlation of these lower zones will be further discussed when the question of correlation with North America has been considered.

Stages	European Zones	East Greenland Zones
Lower Callovian	Calloviense Zone	'Pauper Horizon' Tychonis Zone
	Macrocephalus Zone	Kochi Zone
Upper Bathonian	Discus Zone	Nudus Zone *
	Hollandi Zone	Pompeckji Zone *
	Aspidoides Zone	

* Date very uncertain.

The publication by Imlay in 1948 of preliminary notes on some Middle and Upper Jurassic faunas of the Western Interior of the United States led the writer to hope that the correlation of the East Greenland sequence might be aided by comparison with North America, for well-known European genera were reported associated with, or in sequence with, Arctic genera including all those found in Greenland. It cannot be said that this hope has been fulfilled, for the publication of full details of some of the faunas (Imlay, 1953) has not confirmed that such associations are present, although it has revealed most interesting assemblages of species and genera which pose a whole series of new problems. Since Imlay has proposed correlations with the classic succession for both the North American and the East Greenland sequences, his faunas and their correlation must be briefly considered here. In the Western Interior of the United States, Imlay recognises the following succession of faunas (the generic identifications cited are Imlay's and are not fully accepted, as will be explained below):

Zonal Species:	Other Ammonites:
Kepplerites (Seymourites) mclearni	*Kosmoceras (Gulielmiceras), Lilloettia, Xenocephalites*
K. (S.) tychonis	*Grossouvria*
Gowericeras subitum	*Cadoceras, Procerites, Grossouvria*
G. costidensum	” ” ”
Articoceras codyense	*Cadoceras, Procerites*
Arctocephalites	

The comparison with East Greenland may be considered first. Imlay correlated his Tychonis Zone with Spath's *Seymourites* horizon (Tychonis Zone of the present writer) in East Greenland, and it is certain that the fragments of *Seymourites* figured by Imlay as *S. tychonis* are the only members of the genus from the Western Interior which bear any resemblance to the Greenland forms. The figured material, however, comprises only two body-chamber fragments and is inadequate for full comparison. The larger fragment (Imlay's pl. 20, fig. 3) can hardly be separated from *S. tychonis*. The smaller (figs. 1, 2), from an individual only 6 cm or so in diameter, may have come from a distinct species[1]). The Mclearni fauna, with very distinctive species of *Seymourites* characterised by giant size (33 cm), very evolute outer whorls, body-chambers of more than a whorl, and compressed inner whorls with tabulate venter, has no parallel in East Greenland.

None of the ammonites of the 'Gowericeras' zones correspond to anything in East Greenland. *Cadoceras*(?) is the only genus from these zones which occurs in East Greenland, but there do not seem to be any species in common. At first sight correlation would seem to be resumed with the two lowest zones, of '*Arcticoceras codyense*' and '*Arctocephalites*', equated by Imlay with the Kochi and Nudus Zones of East Greenland, but examination of the ammonites figured by him does not give encouragement.

The genera *Arctocephalites* and *Arcticoceras* provide classic examples of the confusion which arises when the type-species are based on incomplete or immature specimens. In such cases the distinction between macro- and microconchs (see Callomon 1955, p. 238)—which seems particularly clearly defined in the group of species under consideration—must remain forever in doubt at generic level, unless the generic definitions can be subsequently amplified. This is essential before attempting a comparison with Imlay's figures. Fortunately, the choice seems fairly clear. Newton and Teall's figures (1897, pl. 40, figs. 1, 1a) of the holotype of *Arctocephalites arcticus* show a shell wholly septate at about

[1]) The adult size of *S. tychonis* varies from about 9.0 to 12.0 cm, the larger sizes being apparently the more common. As Callomon has recently remarked (1955, p. 237), size is usually a fairly constant feature of ammonite species.

7 cm diameter, becoming smooth; and it seems likely that the complete adult resembles Sokolov's (1912) pl. 1, fig. 1 ("*Macrocephalites Ishmae*"), and is a macroconch. *Arctocephalites greenlandicus* Spath supports this interpretation. At about the same diameter, Keyserling's *Arcticoceras ishmae* is still sharply ribbed with no loss of strength. Spath's topotype (1932, pl. 15, fig. 7) is well chosen, and would fit very well into the body-chamber (pl. 12, fig. 1a–c, with excentrumbilication) which he included in *A. kochi*, to give a typical microconch. A supporting species is *Arcticoceras michaelis* Spath, with similar ontogeny. In consequence, *A. kochi* itself (holotype) is an *Arctocephalites*, and in this interpretation *Arctocephalites* and *Arcticoceras* do partly occur together in the same beds in East Greenland.

From what has been said, it is immediately clear that most of Imlay's "*Arcticoceras*" (*A. codyense* group) should, if anything, be called *Arctocephalites*, but the inner whorls and suture-lines are so dissimilar from typical species that it seems doubtful whether they belong to this genus. The same may be said of the only forms which do at all resemble *Arcticoceras*, namely Imlay's *A. crassicostatum* and *loveanum* (pl. 3, figs. 1—12, 14), but which seem more closely related to "*Cadoceras*" *shoshonense* (pl. 6). It seems safer to regard most of the forms from the Western Interior as forming a local fauna unrelated directly to that of Greenland or of Alaska; although a connection of some kind is suggested by their only constant common feature, namely, the constriction near the peristome.

The lowest of the Western Interior faunas correlated by Imlay with East Greenland, said to be characterised by *Arctocephalites*, is not fully described, but three examples of the typical ammonite were figured in Imlay's preliminary paper (1948, pl. 6, figs. 1—3, 5, 7). They bear a certain similarity to true *Arctocephalites*, but generic identity seems doubtful. The inner whorls have coarse ribbing and do not greatly resemble those of *Arctocephalites*, while the ribs on the middle whorls are concave backwards, a feature unknown in the genus. The body-chamber seems to show excentrumbilication with opening out of the umbilicus (the only figured specimen with body-chamber is distorted, however), while in *Arctocephalites* this feature is absent and the tendency is for the umbilicus to become smaller in the adult.

Even if the Western Interior sequence could be correlated with the classic succession, such a correlation would be, in view of what has been said above, of limited interest for East Greenland. In fact, it is as difficult (or as impossible) to find the position of the North American zones in the European scheme, as it is for the East Greenland sequence. Imlay thought that the Mclearni Zone was securely dated, by the presence of ammonites identified as *Gulielmiceras* and *Gulielmites*, as equivalent to the upper part of the Calloviense Zone, the level at which these genera appear in Europe. His *Gulielmiceras*, however, does not agree with European species of the genus, for the ribs cross the flat venter undiminished in strength, with faint tubercles on the ventrolateral angles, whereas in the true *Gulielmiceras* the tubercles are prominent, but the ventral band smooth. The North American species have no counterparts among European Kosmoceratids. Like *Gulielmiceras*, they are clearly microconchs, adult at a small diameter (ca. 5.0 cm) with no modification of ornament and lateral lappets on the aperture. They correspond exactly (except for the lappets) with the innermost whorls of the large *Seymourites mclearni*, which could be regarded as the corresponding macroconch form (for discussion of this question see Callomon, 1955, pp. 237—241).

The other foundation of Imlay's correlation was the presence of ammonites described as *Gowericeras*, suggesting close affinity with the Calloviense Zone in Europe. The identity of the American species with *Gowericeras* was already questioned, however, in 1953 (Donovan, p. 132), and the full series of illustrations now available (Imlay, 1953) only confirms the impression then formed, that these forms are not directly connected with the European genus *Gowericeras*. The inner whorls are quite different in the two groups: *Gowericeras* has Kosmoceratid inner whorls, while the form from the Western Interior has a rounded venter from the start and in some species even sphaeroconic inner whorls (*e. g.* Imlay, *op. cit.* pl. 21, figs. 8, 9; pl. 23, figs. 5—7, 10—12, 18). It seems to be more closely connected with *Seymourites* on the one hand, and some of the species assigned by Imlay to '*Gowericeras*' seem to be typical *Seymourites* (e. g. his pl. 22, figs. 10—13). On the other hand, the resemblance to other Stephanoceratids seems suggestive (compare Imlay's "*Gowericeras*" *subitum* var. *distinctum*, pl. 22, figs. 5, 6, with *Cranocephalites maculatus* var. *transitoria* Spath, 1932, pl. 3, figs. 6a, b and *C. furcatus* var. *pygmaeus* Spath, 1932, pl. 6, figs. 2a, b).

The foregoing considerations show that there is, at present, nothing to be gained by trying to correlate East Greenland *via* North America. A few words may be said as to the comparison between the East Greenland fauna and that from Alaska, also described by Imlay. The Chinitna Formation has yielded a group of species of *Seymourites* which are closely similar to those from East Greenland[1]), and are presumably of about the same date. It also contains *Cadoceras*, and "*Gowericeras*" which seem

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[1]) The writer cannot agree with Imlay's view (1953, p. 3) that the species of the Mclearni assemblage of the Western Interior resemble East Greenland forms more than Alaskan species. The Alaskan and East Greenland species show considerable resemblance, but those from the Western Interior Mclearni fauna seem to stand well apart from either.

to be close to *Seymourites*. A single ammonite, found loose, may be identified as a *Torricelliceras* (Imlay, 1953, pl. 53, figs. 4, 5: "*Cosmoceras*"), and if derived from the Chinitna Formation, as seems probable, would indicate that the formation is partly, at least, of Calloviense Zone age. The remainder of the ammonite fauna, including *Phylloceras*, *Oxycerites*, *Lilloettia*, "*Xenocephalites*", "*Kheraiceras*", and "*Reineckeia*" is unrepresented in East Greenland or in the more eastern part of the Boreal Province.

There is thus a general agreement of the evidence that the *Seymourites* faunas, including the Tychonis Zone in East Greenland, correspond to the Calloviense Zone in Europe. Below this, it is practically impossible to correlate the East Greenland succession. If *Arcticoceras* characterises a horizon at about the Bathonian-Callovian junction, as suggested above (p. 131), and if *Cranocephalites*, *Arctocephalites* and *Arcticoceras* are closely related and not widely separated in time, as Spath thought, then the Pompeckji and Nudus Zones would be expected to be Upper Bathonian; however, Spath's arguments were speculative and largely based on supposed lineal relations between *Arctocephalites*, *Arcticoceras* and *Macrocephalites*, and on the possible origins of *Cranocephalites*. Imlay (1953, table 2) spreads out *Cranocephalites* and *Arctocephalites* so that between them they cover the whole of the Bathonian; such a long time span for two faunas, although improbable, cannot be ruled out.

East Greenland, the Barents Sea islands and the Petchora basin fall into one province so far as the ammonites are concerned, but, apart from the similarity of certain species of *Seymourites*, this province has little in common in Bathonian/early Callovian times with North America. In Alaska and the Western Interior there are a number of genera which appear to be peculiar to the North American province, and are unknown elsewhere. It seems, therefore, that a more exact correlation can only be hoped for in the future if additional evidence can be obtained in two regions: Mexico, where it might be possible to relate the Western Interior faunas to the more conventional Tethean Callovian fauna occurring there; and the Petchora, where systematic collection from measured sections should relate the arctic faunas to the better-known boreal ones of Russia, and hence to the classic areas of Europe.

5. *Upper Oxfordian.*

The extreme local differentiation of ammonite faunas, which gives rise to so much difficulty in long-distance correlation of the Bathonian and Callovian, had become much less intense by the Upper Oxfordian. Little material is available from East Greenland, and there is only one detailed succession, in Milne Land where the Cardioceras Shales and the Pecten Sandstone are of Upper Oxfordian date. Only a few fragments of ammonites were in the collections studied by Spath (1935). *Cardioceras (Subvertebriceras)* aff. *zenaidae* is known from the Cardioceras Shales, and the closely allied form attributed by Spath to *C. (S.) caelatum* was found loose in south-east Jameson Land, possibly derived from the lower beds of the Kochs Fjeld Formation. *Cardioceras zenaidae* is recorded from the Plicatilis Zone in England (Arkell, 1942, pp. 241—243), and the earliest dated beds of the Milne Land succession are thus placed at the base of the Upper Oxfordian.

A higher horizon is represented by *Amoeboceras (Prionodoceras)* aff. *pseudocaelatum* and *A. (P.) transitorium*, from the top few metres of the Cardioceras Shales. These indicate that the top of that formation falls within the Decipiens Zone of the European succession, for *A. (P.) pseudocaelatum* is found with abundant *Decipia decipiens* in Cambridgeshire, England (Arkell, 1947, pp. 354—356).

The Pecten Sandstone yielded two ammonites identified by Spath as *Amoeboceras (Prionodoceras)* aff. *alternoides* and *A. (P.)* aff. *superstes*. They are presumed to belong to the Pseudocordata Zone at the top of the Oxfordian. The Black Series in Traill Ø has yielded possible Upper Oxfordian ammonites (Donovan, 1953, p. 86) but they cannot be exactly dated.

In the northern region, the Grey Series is said by Maync to be Upper Oxfordian, but the ammonites have not been figured or described except for one collected by Rosenkrantz in Cardiocerasdalen, Wollaston Forland, in 1929, and figured by Spath as *Amoeboceras (Prionodoceras) rosenkrantzi* (1935, pl. 12, fig. 4), and those described from Store Koldewey by Ravn (1911). The latter, now identified as *Amoeboceras (Amoeboceras)* cf. *alternans* and *A. (A.)* cf. *ovale*, belong high in the Oxfordian, and suggest equivalence of the lower part of the Kløft I Formation with the Cautisnigrae Zone in Great Britain.

The zonal succession in the European Upper Oxfordian, with approximate East Greenland equivalents, is therefore as follows:—

Zones	East Greenland
Pseudocordata	Pecten Sandstone in Milne Land
Decipiens	Cardioceras Shales, *pars.*, in Milne Land
Cautisnigrae	Kløft I Formation (lower part) on Store Koldewey
Plicatilis	Cardioceras Shales, *pars.* Probably Koch Fjeld Formation, *pars.* in south Jameson Land

6. *Lower Kimeridgian.*

The Lower Kimeridgian ammonites are better known than the Upper Oxfordian ones, again mainly from Milne Land. Spath (1935) assigned them largely to new species, and correlation with European zones is not very close. The earliest assemblage, from horizon δ near the base of the Kimeridgian Clays, consists principally of *Amoeboceras (Amoebites)* and *Rasenia*, and belongs to the comprehensive Cymodoce Zone as suggested by Arkell (1946, p. 15), although evidence for correlation with one or other of the European subzones is conflicting, and such correlation is probably too much to expect over a long distance. The next ammonitiferous layer, horizon γ, yielded only a new species, *Rasenia borealis*, with distinctive inner whorls, and is not dateable from intrinsic evidence. The highest group of ammonites, not all from the same horizon, consists of the subgenera *Amoebites*, *Euprionoceras* and *Hoplocardioceras* of the genus *Amoeboceras*. It is difficult to decide whether they are still of Cymodoce Zone date, or to be placed in the succeeding Mutabilis Zone. Spath adopted the second view in his table (op. cit., p. 74)[1]).

Crushed *Amoebites* have been found in south Jameson Land and in Traill Ø, and the latter area has also yielded a poor *Euprionoceras*. A number of Cardioceratids were figured by Frebold from the northern region (1933, pls. 1, 2, figs. 1—12) but most are so poorly preserved as to be of little interest. One species (*op. cit.* pl. 1, figs. 1—4) was named *Amoeboceras (Hoplocardioceras) decipiens* by Spath (1935, p. 36) and has also been found in Milne Land, where it occurs in the highest assemblage of the Lower Kimeridgian. This evidence suggests that the Black Series extends to the top of the Cymodoce, or into the Mutabilis Zone.

In Store Koldewey, Lower Kimeridgian ammonites have been figured by Ravn (1911), including *Aulacostephanus groenlandicus*, from the higher part of the Kløft I Formation. The fossil on which this species is based is not well-preserved, but presumably indicates an age corresponding to the Mutabilis or the Pseudomutabilis Zone of Europe.

The fossils apart from the ammonites are insignificant except for *Buchia concentrica*, which is ubiquitous in the shale facies. This species had a wide distribution in the 'Boreal' province, and is found in North America, Spitsbergen, Russia and Scotland. Compared with the ammonites it is of no value for correlation.

As in the Upper Oxfordian, ammonite faunas showed much less regional differentiation than during the early Callovian, and Spath has

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[1]) His zone of *Aulacostephanus yo* and *Aspidoceras longispinum* is included in the Mutabilis Zone in the broad sense. Arkell (1946, p. 14) doubts whether *A. yo* is of zonal significance.

surveyed the distribution of *Amoeboceras*, which is found from Siberia westwards to northern Europe and thence via East Greenland to Alaska and the Western Interior of North America (1935, p. 75). The affinities of the Greenland fauna are clearly with these 'boreal' assemblages, marked by the presence of *Buchia* and the absence of the ammonite *Aspidoceras*. There are close affinities with Spitsbergen, as might be expected, but on the whole it would probably be unjustifiable to stress similarities with one or another part of the 'Boreal' Province.

7. *Upper Kimeridgian.*

For our knowledge of Upper Kimeridgian faunas we depend entirely on Milne Land, and on the collections made by Rosenkrantz and Aldinger and monographed by Spath (1936). Two assemblages have been recognized, a lower, consisting of species of *Pectinatites*, in the upper part of the Kimeridgian Clays, and the upper, with *Pavlovia*, in the top of the Kimeridgian Clays and the base of the Glauconitic Series. A still lower horizon in the Kimeridgian Clays with crushed Perisphinctids was thought by Spath to be possibly basal Upper Kimeridgian, but he was not sure of this date, and speculation about these wretchedly preserved ammonites (Spath, 1936, pl. 1) would be a waste of time.

Out of the six or seven species of *Pectinatites* represented by the material, four were attached to European species, although absolute identity was not asserted in any case. The assemblage (not all the species necessarily come from the same horizon in Milne Land) clearly corresponds to the Pectinatus Zone of Europe.

The assemblage of species of *Pavlovia* (*s. s.*) and its subgenus *Pallasiceras* does not come from a single horizon either, but in view of the weakness of the stratigraphical information no useful succession of species can be established, and it is indeed possible that the base of the Glauconitic Series is of variable date, so that the collections from the sandy top of the Kimeridgian Clays at some localities may be contemporaneous with those from the lower part of the Glauconitic Series elsewhere in eastern Milne Land (Spath, 1936, pp. 153, 160). In contrast to the *Pectinatites* assemblage, all the *Pavlovia* species were described by Spath as new, probably because they are better preserved. They are very close to, although not in Spath's opinion identical with, various European species, and on this account a mere list of species can give a misleading impression of individuality to a local fauna such as that of East Greenland. There is no doubt that the assemblage corresponds in age to the Rotunda Zone of Europe (Spath, 1936, p. 153).

The non-ammonite fauna of the Upper Kimeridgian calls for no special comment. As far as the ammonites are concerned, the fauna falls closely into line with those of north-west Europe and Russia, and there was comparatively little geographical differentiation of faunas at this time. Upper Kimeridgian ammonites are unknown from Spitsbergen or North America, so that comparisons cannot be made with these areas.

The following table shows the correlations which can be recognized between European zones and East Greenland faunas:

Stages	Zones	East Greenland
Upper Kimeridgian	Pallasioides	Unrecognised
	Rotunda	*Pavlovia* faunas of Glauconitic Series and upper part of Kimeridgian Clays, Milne Land
	Pectinatus	*Pectinatites* fauna of upper part of Kimeridgian Clays, Milne Land
Middle Kimeridgian	Wheatleyensis	Unrecognised
	Subplanites spp.	
	Gigas	
	Gravesiana	
Lower Kimeridgian	Pseudomutabilis	Upper part of Kløft I Formation, Store Koldewey
	Mutabilis	? ?
	Cymodoce	Horizons γ and δ in Kimeridgian Clays, lower part, of Milne Land. Black Series (upper part) of northern region

8. *Portlandian.*

Spath was not very confident about his placing of the Kimeridgian-Portlandian boundary in East Greenland, for the genus *Pavlovia* probably occurs both above and below the boundary, as it does in the type area for the stages in southern England. Spath regarded the species of *Pavlovia* which he included in the subgenus *Pallasiceras* as principally Upper Kimeridgian, while those included in the subgenus *Epipallasiceras* he regarded as Portlandian. Apart from the question of distinguishing late Kimeridgian from early Portlandian forms in this group, however, the stratigraphical information as to the relative horizons of most of these ammonites in Milne Land was inadequate, and until more information is available it is unprofitable to discuss the position of the Kimeridgian-Portlandian boundary in detail.

The sandy shales with Aldinger's horizon α, above the Glauconitic Series, contain an ammonite fauna consisting principally of *Glaucolithites*[1]), all described as new species by Spath, but close to forms from the upper part of the Portland Sands of Dorset, England. This horizon in Milne Land is therefore believed to be equivalent to the Gorei Zone of Europe.

The only ammonites recorded from above the *Glaucolithites* level are *Laugeites*, found in the Lingula Bed near Kap Leslie by Rosenkrantz, and *Craspedites*, found in the lower part of the Hartzfjeld Sandstone near Hartz Bjerg, by Aldinger. The relative ages of the two finds are not known from field observations. According to Nikitin (1884) *Laugeites* (recorded as *Perisphinctes stschurowskii*) occurs in the Virgatus Zone at the top of the Lower Volgian in Russia, equated by Arkell (1946, p. 24) with a horizon between the Albani and Gorei Zones in Europe. The genus apparently ranges higher in Russia, into the Upper Volgian (see p. 143), but the record does not necessarily indicate a date for the Lingula Bed much later than that of the *Glaucolithites* assemblage. *Craspedites* in Russia occurs throughout the Upper Volgian, which is generally regarded as lying entirely above the marine Portlandian succession in England. The Milne Land *Craspedites* are so poorly preserved that it is not advisable to try to correlate them more definitely with one or other of the Upper Volgian assemblages.

The genus *Dorsoplanites* is found in the top of the Kimeridgian Clays (with *Pavlovia*) and throughout the Glauconitic Series. It does not occur in the English succession[2]) and has therefore been omitted from the discussion of the correlation with northwest European zones. *Dorsoplanites* is, however, found in Russia in the Lower Volgian, and may be restricted to the Dorsoplanus Zone, equated by Arkell with the Pallasioides Zone of northwest Europe (Arkell, 1946, pp. 24, 26). Spath had hoped that the occurrence of *Dorsoplanites* in East Greenland, associated with north-west European genera, would help towards the exact correlation of the Volgian with the north-west European sequence, but his hope was not realised (1936, p. 165). The disappointment was due, at least in part, to the absence of exact zoning of the Milne Land succession and the doubt as to the horizons at which many of the ammonites were found. It seems that in East Greenland, *Dorsoplanites* must range higher than in Russia, for it is found in the upper part of the Glauconitic Series along with *Glaucolithites* and is therefore, presumably, at earliest of Gorei date, while the Gorei Zone is well correlated,

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[1]) According to Arkell (1947a, p. 93, n. 5) the preferable name for the group. Spath described them as *Crendonites* (1936, pp. 62—66).

[2]) Except for a possible representative in the Hartwell Clay at the top of the Kimeridgian (Spath, 1936, p. 76).

in Arkell's view (1946, p. 27), with the Blakei Zone (*pars*) of Russia, at the top of the Lower Volgian and well above the supposed range of *Dorsoplanites* there. It is possible that more exact stratigraphical collecting in Milne Land might resolve this apparent contradiction.

It will be seen from the foregoing remarks that the Portlandian ammonite fauna has factors in common with north-west Europe, on the one hand, and with Russia on the other, and although most of the species were described by Spath as new many of them are very close to species known from the old world. The relationships of these areas have been discussed at length by Spath (1936, pp. 165—175).

The Jurassic — Cretaceous Boundary.

In 1947 Spath (p. 8) observed that 'It is possible that the knotty problem of the demarcation of the limits between the Jurassic and Cretaceous systems may yet be solved by future discoveries in East Greenland.' The problem has not been solved yet, and in 1952 (p. 19) Spath was less sanguine, but as he has raised and discussed the problem, readers may expect a summary of it here.

Two formations in East Greenland appear to span the Jurassic-Cretaceous boundary; the Hartzfjeld Sandstone in Milne Land and the conglomerates and associated rocks of Laugeites Ravine in Kuhn Ø. The succession of ammonite genera in each of these cases may be summarized.

In Milne Land the succession is:[1])

Hartzfjeld Sandstone	*Subcraspedites groenlandicus* (Spath, 1936, p. 84) *Craspedites* spp. *Laugeites groenlandicus*
Glauconitic Series	*Glaucolithites* spp.

The series of conglomerates and other clastic rocks in Laugeites Ravine, south-western Kuhn Ø, has been summarised on page 60. Ammonites were found by Maync at three horizons, and the sequence of genera is as follows:

S. branch	N. branch	
Bed 6a	[Bed 18]	*Subcraspedites* aff. *preplicomphalus*, *S.* aff. *spasskensis*, *Laugeites* sp. nov.
[not exp.]	Bed 12	*Laugeites groenlandicus*, Pavlovids
Exp. near 'Haakonshytta'	[Beds 1—5]	*L. groenlandicus*, Pavlovids

[1]) The *Titanites?* sp. ind. recorded by Spath (1936, p. 67) in association with *Craspedites* is omitted, as the identification is too uncertain to be included in any discussion of the problem.

The two lower faunas are taken from Spath (1946, p. 4) and Maync (1949, p. 31), the upper one is given as revised by Spath (1952). Beds within square brackets are supposed equivalents of the beds in which the fossils were found, but have not yielded fossils.

Maync thought that the section provided a series of strata which was deposited continuously from the latest Jurassic into the earliest Cretaceous, and he was unable to detect any break in sedimentation, being explicit on this point (1949, p. 32). The critical horizon is bed 6a, containing a supposed Jurassic ammonite (*Laugeites*) associated with a supposed Cretaceous one (*Subcraspedites*). Spath thought (1952, p. 19) that all the ammonites in bed 6 were derived, but in view of the fact that this bed, like the other fossiliferous ones, carried abundant fossils a derived origin for all of them seems unlikely. If, as Spath thought, bed 6a was already younger than the *Subcraspedites* beds of the Berriasian, there must have been an interruption in sedimentation during which *Subcraspedites*-bearing beds were deposited nearby, followed by their destruction and incorporation of fossils from them, as well as from the earlier *Laugeites*-bearing beds, in new deposits. It is improbable that such a series of events would have produced no physical break in the succession. Spath's identifications of the *Laugeites* are also against the interpretation, the species in bed 6a being different from the species in the lower beds. It is possible, however, that bed 6a is a condensed deposit. The difference in date between *Laugeites* and *Subcraspedites* need not, in fact, have been great. Although *Laugeites* is characteristic of the Lower Volgian in Russia, Spath has remarked that one species is recorded from the Nodiger Zone at the top of the Upper Volgian, and that it may be a long-ranging genus (1952, p. 19). In Russia the Upper Volgian and the Rjasan Beds, with *Subcraspedites*, are separated by a slight unconformity, according to Bogoslovsky's section[1]) (1897, p. 122).

If bed 6a is a condensed deposit (or if the *Laugeites* in it are derived), then clearly the succession in Kuhn Ø does not help to fill in the gap between the *Laugeites* fauna and the *Subcraspedites* fauna. Similarly, the apparently fuller section in Milne Land does not tell us more than we know already: that *Laugeites* and *Craspedites* in the Upper Jurassic are replaced by *Subcraspedites*. There is, therefore, no evidence for higher Jurassic beds in East Greenland than are known elsewhere, nor for earlier Cretaceous rocks than occur in England or Russia.

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[1]) It should be borne in mind that this section, recently reproduced by Arkell (1956, fig. 77, p. 493), is presumably a diagrammatic one constructed from observations scattered over an extensive tract of country.

9. *Berriasian.*

The ammonites from the Berriasian rocks all belong to the family Craspeditidae. Two genera, *Hectoroceras* and *Praetollia*, are known only from East Greenland. Of the other two, *Subcraspedites* is fairly widely distributed in the northern hemisphere, being found also in California, England, and Central Russia. *Tollia* is known from East Greenland, Novaya Zemlya, Central Russia and Siberia. In more southerly areas the Craspeditidae are largely replaced by the family Berriasellidae; the subfamily Garniericeratinae is known from south-western France, but none of the Greenland genera are found so far south. Similarly the Berriasellidae are almost entirely absent from the areas where the Craspeditidae flourished, although one genus penetrated into Central Russia (see below) and, at a later date, the subfamily Neocomitinae are found as far north as Speeton in Yorkshire, England. This geographical segregation of the ammonite genera renders long-distance correlation practically impossible.

There is only one place in East Greenland where Berriasian ammonites have been collected at a number of levels in a succession: the mountain 'Niesen', in northern Wollaston Forland, described on page 62. The succession of ammonite genera may be summarised as follows, *Subcraspedites* being placed in the right-hand column and other genera on the left:

Tollia payeri	*Subcraspedites?*
	Subcraspedites
Hectoroceras	*Subcraspedites*
Praetollia	
	(*Subcraspedites* in Kuhn Ø).

Subcraspedites, not found by Maync, is now known to occur, as a result of Standring's collecting (p. 63), alongside and above *Hectoroceras* and perhaps even up to the level of *Tollia*. This is not surprising in view of the association of *Subcraspedites* with *Hectoroceras* in Jameson Land (p. 61).

The correlation between the Laugeites Ravine succession (p. 60) and that of the Niesen cannot be established with certainty. In 1947 Maync regarded the 190 m or so of conglomerates and other clastic beds at the base of the Niesen section (see p. 69) as 'Volgian', *i. e.* as equivalent in date to the similar rocks exposed in south-western Kuhn Ø. There is certainly a strong lithological similarity, including the 'cyclical' alternation of conglomerates, sandstones, and shales in both sections. In 1949 the top of the 'Volgian' at the Niesen was moved down by about 120 m to a non-sequence, as explained on page 63. In any case, the presence of the Jurassic ('Volgian') is not proved palaeontologically at the Niesen, and the Laugeites Ravine succession may either be equivalent to the basal series at the Niesen, or may be older than anything exposed at the Niesen. Whichever interpretation is correct, the Kuhn Ø conglomerates, with the Jurassic *Laugeites* throughout, presumably belong to horizons lower than the lowest fossiliferous bed at the Niesen, as assumed by Spath (1952).

It is clear that the Lower Niesen Beds, with the faunal succession noted above, are approximately equivalent in date to the Rjasan Beds of central Russia, and the Spilsby Sandstone of England. The Rjasan Beds contain a fauna composed chiefly of *Subcraspedites* and *Riasanites*, the latter a Berriasellid genus with southern affinities (Bogoslovsky, 1897)[1]). They vary from 0.5 m to 2.0 m in thickness, and Bogoslovsky maintained, contrary to the opinion of Pavlov, that no faunal subdivisions could be recognised. This is conceivable, the beds being generally regarded as a condensed, and perhaps a reworked, deposit.

All the ammonites from the Spilsby Sandstone belong to *Subcraspedites*. The cephalopod faunas of two successive beds almost at the base of the Spilsby Sandstone, from a boring at Fordington in eastern Lincolnshire, were described by Swinnerton (1935). Although the beds were only 14 inches and 1 foot in thickness respectively, no species was common to both beds. This is in harmony with the fact that the rocks are strongly glauconitic, and presumably accumulated slowly. The fauna of the lower of the two beds (bed C) is characterised by the subgenus *Paracraspedites*, with strong, coarse primary and secondary ribs on the outer whorls, as well as typical *Subcraspedites*. The latter alone occur in the upper bed (bed D). Swinnerton recognised the affinity of his faunas with those of the Rjasan Beds and thought that the differences were due to lateral variation in the fauna from one area to another, rather than to a difference in date. One species from bed C (*Subcraspedites preplicomphalus* Swinnerton) was thought by its author to be close to *S. spasskensis* (Bogoslovsky), a Rjasan species, and specimens from Bed D were identified as *S.* aff. *subpressulus* (Bogoslovsky), another Rjasan species.

There is little published information as to the distribution of ammonites in the higher parts of the Spilsby Sandstone. Spath states (1952, p. 18) that the species *Subcraspedites (Subcraspedites) stenomphalus (Pavlov)*, *S. (S.) plicomphalus* (J. Sow.) and *S. (S.) sowerbyi* Spath occur 'in the upper beds'. Mr. C. W. Wright (*in litt.*) kindly informs me that at Nettleton (Lincs) the fauna with *S. plicomphalus* and *S. stenom-*

[1]) *Subcraspedites* was recorded as *Olcostephanus* by Bogoslovsky; *Riasanites* was proposed by Spath (1923, p. 306), for *Hoplites rjasanensis* (Lahusen) in Bogoslovsky.

phalus occurs between 20 and 30 feet above the fauna characteristic of Swinnerton's bed D.

Lincolnshire therefore offers evidence for three distinct Subcraspeditid horizons: the lowest, characterised by the presence of the subgenus *Paracraspedites*; the next with *S.* aff. *subpressulus* and a number of species not recognised from other countries; and the highest with *S. stenomphalus.*

Spath figured two *Subcraspedites* from the uppermost conglomerate at Laugeites Ravine, Kuhn Ø. The first (1952, pl. 4, fig. 1) he identified as *S.* aff. *preplicomphalus* Swinnerton, which would link the horizon with the lowest fossiliferous horizon (bed C at Fordington) in the Spilsby Sandstone. The other (*op. cit.* pl. 4, fig. 3) is a mere fragment of an impression and probably unsafe to rely on for correlation. There is thus some reason to believe that the lowest Cretaceous faunas in East Greenland and in Lincolnshire were approximately contemporaneous.

The *Subcraspedites* from the Niesen are not well enough preserved for specific identification, so that the horizons there cannot be correlated with those of the Spilsby Sandstone. As the Russian Rjasan Beds also are unzoned, it is not possible to devise any zonal scheme of general application for the boreal Berriasian. A table of corresponding zones in East Greenland and Russia has been given by Spath (1952, p. 20), as follows:

East Greenland:	Russia:
Tollia payeri	Tollia tolli
Hectoroceras zone	— —
Praetollia zone	— —
Subcraspedites	Stenomphalus zone
S. (Paracraspedites)	Spasskensis zone

The Hectoroceras and Praetollia Zones may be valid in East Greenland, but the index genera have been found nowhere else, and may have been local evolutionary developments, in which case there are not necessarily non-sequences corresponding to them in the Russian succession. Since *Subcraspedites* has been found at higher levels at the Niesen a "Subcraspedites Zone" below *Praetollia* cannot be upheld. The basal zone with *Paracraspedites* is deduced from the correlation between Laugeites Ravine and Fordington, mentioned above. The separation of the Spasskensis and Stenomphalus Zones in Russia is presumably inferred from the Lincolnshire evidence, and the position of *Tollia* in the Russian sequence is presumably derived from the position of the genus in East Greenland.

We reach the conclusion that there is some reason to believe in a zone of *S. spasskensis* at the base of the boreal Berriasian, recognisable in East Greenland, Lincolnshire and the Rjasan area of Russia. Above this, there is evidence for at least two more Subcraspedited faunas in Lincolnshire, but they cannot yet be correlated with sucessions elsewhere. The general validity of a zone with *Tollia* has not yet been proved. It is possible that some advance from this state of affairs could be made by systematic collecting in East Greenland, for if better material could be found specific identifications would be possible and a sequence of species of *Subcraspedites* might be established.

The zonal subdivision of the southern or Berriasellid province of the Berriasian in the classic area of southern France is scarcely any better than that of the boreal area. Mazenot (1939) recognises only one main zone of *Subthurmannia boisseri*, with subsidiary horizons at the base and top. Successions have been published from several widely-separated parts of the world, and summarised by Spath (1952, pp. 29—32). In view of the absence of satisfactory zoning in either the French or the boreal area, it is not to be expected that any detailed correlation between the two is possible. Spath has made a number of attempts to arrange the faunal elements in the correct order and set up Ages and Zones. His earlier attempts were summarised, and criticised rather severely, by Mazenot (1939, 259—261). Since that date Spath has returned to the problem and his latest synthesis was published in a paper on one of the East Greenland faunas in 1952. Spath does not believe in the existence of zoological provinces as far as the ammonites were concerned (1939, pp. 146—147; 1952, pp. 32—33), and has consequently been led to construct correlation tables (e. g. 1952, p. 33) in which the 'boreal' and 'southern' faunas alternate; for he believes that they would be found in each other's areas if suitable fossiliferous deposits could be found, and appears to regard the absence, for example, of the Berriasellids from East Greenland as due to stratal failure. The present writer accepts the existence of ammonite provinces at certain times (including the lowest Cretaceous) and has argued elsewhere in this work for their reality (p. 155). The complete absence of the Berriasellidae from England and Greenland can only be explained, in the writer's view, on the basis of limited geographical distribution. The family flourished throughout the uppermost Jurassic and the Berriasian and it is too much to assume that, if universally distributed, it withdrew from the northern areas whenever fossiliferous beds were being laid down. As for the world-wide dispersal of empty shells, also invoked by Spath, it has also been argued elsewhere (p. 156) that the facts do not support this supposition.

If the existence of zoological provinces is accepted, Spath's mode of correlation must be regarded as unsound. This is not to deny that there are many gaps in our fossil sequences. But different faunas, in different areas, may well have been approximately contemporaneous at a time of maximum geographical differentiation, so that the principle of 'dissimilar faunas', although it may be applicable (as S. S. Buckman used it) to a small area such as the British Isles, cannot be extended, as was done by Spath (*op. cit.* p. 35), across continents.

The expression 'faunal province' is probably too rigid, and it would be more correct to say that the geographical distribution of individual ammonite genera was restricted, for the geographical limits of different genera were not the same, and the ranges of some were wider than those of others. The distributions of certain genera, though not co-extensive, were not necessarily mutually exclusive either. The Craspeditidae and the Berriasellidae were almost mutually exclusive, but their ranges overlapped in the Rjasan area of Russia and elsewhere. Within the Craspeditidae, the distinctive genus *Hectoroceras*, known only from East Greenland, may have been a local evolutionary development. The abundance of *Praetollia* in East Greenland may also indicate that it was in this part of the world that the genus *Tollia* was evolved, prior to its spread through a wider area in northern regions. Within the southern or Berriasellid province there seem to be similar phenomena, including the case of *Groebericeras* which is known only from Iraq and the Argentine. Spath uses this genus to support his theory of the world-wide distribution of ammonites (1952, p. 32), although he admits that *Argentiniceras* and *Cuyaniceras*, known only from the Argentine, may have been local elements (op. cit. p. 29). *Groebericeras* presumably lived in the intervening area, and may or may not be discovered elsewhere in the future. As the facts stand they can hardly be used to support any theory of ammonite distribution. It is probable that this faunal fragmentation in the Berriasian, which persisted during the Valanginian, was a result of the well-known contraction of the seas at about the end of the Jurassic, communities of ammonites being isolated in different areas and undergoing divergent evolution. The question is discussed in more detail below (p. 155).

10. Valanginian.

East Greenland has recently become, as a result of discoveries by the writer and his colleagues, a station of major importance for Valanginian ammonites, but the fauna is only partially studied and more field work is needed before a full account can be given. No data on the stratigraphical distribution of the Polyptychitid fauna are yet available, although the work of Standring and Roberts on the Upper Niesen Beds shows that several horizons with well-preserved ammonites are present, and when their collections are worked out, and supplemented, if possible, by another visit, much more information should be available. As it is, the only ammonite assemblage known in detail is that from Traill Ø partly described by the writer in 1953. Before discussing the correlation of this fauna it will be necessary, as with the Berriasian, to review the problem of long-distance correlation in the boreal province during the Valanginian.

A scheme of zones was devised by von Koenen (1902, 1909) as a result of his work in North Germany. In 1924 (table facing p. 80) Spath listed eight 'zones' for the Valanginian, which he evidently regarded as an incomplete set. Spath's table appears not to be based on the actual succession in any one area, but on the presumed correlation between different faunas in several areas, although no explanation or definition of the scheme was offered. Some of Spath's zonal index species appear to be merely alternatives for those of von Koenen, and others to be subdivisions of von Koenen's zones. For the time being it seems best to refer to von Koenen's zones, which are as follows:

Saynoceras verrucosum & Hoplitides (*recte* Leopoldia) arnoldi
Polyptychites terscissus & P. obsoletecostatus
Polyptychites clarkei & P. kayseri
Polyptychites brancoi and P. keyserlingi
Polyptychites latissimus [and Platylenticeras gevrili].

The zone of *P. brancoi* and *P. keyserlingi* has a distinct upper division, at least at Jetenburg, characterised by *P. ascendens*. The first three zones are noteworthy for many species of *Polyptychites*, whereas in the '*P. terscissus*' zone the genus *Dichotomites* appears, and the other Polyptychitid derivatives *Euryptychites* and *Neocraspedites* are also characteristic of the upper zones.

The Traill Ø assemblage clearly falls in the upper part of the succession, for species of *Polyptychites* of the type found in the earlier zones in Germany are absent, while *Euryptychites* and *Neocraspedites* are prominent, albeit the latter are not typical and *Dichotomites*[1]) may not be present. In general, the assemblage may correspond approximately to the Terscissus Zone of von Koenen.

The composition of the Traill Ø fauna is of great interest. The commonest fossils are Polyptychitid ammonites and specimens of *Buchia*, but besides these and belemnites of the genus *Pachyteuthis* ('*Acrotheuthis*'), also well-known from Boreal localities, there are several elements which appear to be out of place so far north. The most striking is a single specimen of the brachiopod *Pygope*, well-known from the Mediterranean area. Among the ammonites 'southern' elements are *Phylloceras*,

[1]) It was recorded in my paper of 1953, but the species then referred to it are not characteristic members of the genus.

Lytoceras, and *Leopoldia* (or an allied genus). *Lytoceras* is known as far north as Speeton (Yorkshire, England) at a slightly later date[1]) but *Phylloceras* and *Leopoldia* have not been found there. Among the belemnites, *Pseudobelus* is out of place in a 'Boreal fauna'. All these genera are represented by a few specimens only, but they must have been normal, if subsidiary, members of the fauna living in the area at the time. The comparative scarcity of the 'southern' elements suggests that they were near the limit of their range. It seems unlikely that their range was controlled entirely by ocean temperature (although this factor cannot be excluded), and it may have been affected, partly at least, by geographical barriers. It is conceivable that, if the British, German and Russian seas in the Valanginian were connected with the open ocean only to the north, East Greenland was in closer connection with the Tethys than any of the other Boreal areas.

11. Aptian.

Aptian ammonoid faunas from Greenland, with the exception of one or two species, are not well-known. The only genera of service for dating in the Lower Aptian are *Ancyloceras* and *Deshayesites*. Both *Ancyloceras* aff. *matheronianum* and *Deshayesites* aff. *laeviusculus* are known from the upper part, or Deshayesi Zone, of the Lower Aptian of England (Spath, 1930). *Deshayesites* is known from Russia, Germany, France and England, and a possible example has been figured from Spitsbergen by Sokolov and Bodylevsky (1931, pl. 11, fig. 3).

A number of ammonoids are listed from the Upper Aptian but most of the records are founded on very poor material and are hence of little value except as indicating the size of the fauna. The only genus important for stratigraphical correlation is *Sanmartinoceras*, of which two, or perhaps three, species are recognised. This genus has recently been commented on by Casey who noted that the distribution—North-west Europe, Russia, Greenland, Australia and Patagonia—although widespread, is sporadic (1954, p. 268). The absence of intervening occurrences may, of course, be due to the absence of suitable strata, since the Aptian is not among the most widespread of geological systems; even so the absence of the genus, for example, from East Africa, where its ally *Aconeceras* is found, is surprising. Casey has also remarked (p. 269) that knowledge is too incomplete for speculation on the geographical distribution of the Aconeceratidae, so the facts must merely be recorded without explanation. *Sanmartinoceras* is usually regarded as diagnostic of

[1]) One example recorded by Whitehouse and Brighton, 1924, p. 360, bed C6. Several more specimens have been found since, in beds D2 and C8 (C.W. Wright, *in litt.*).

the Upper Aptian, but it would probably be rash to attempt a more exact correlation on the basis of the material available from East Greenland. In Europe the genus ranges up into the base of the Albian and perhaps higher (Casey, *op. cit.* p. 273). The remaining records from the Upper Aptian are all based on fragments of heteromorphs and do not call for further comment. A curious record is that of (?) *Pascoeites* cf. *crassus* Spath, recorded by Spath himself in the collection from eastern Kuhn Ø (1946, p. 7), as possibly Upper Aptian. *Pascoeites* is a little-known genus first described by Spath (1933, p. 827) from the Neocomian, probably Barremian, of Peninsular India. If the East Greenland example is correctly identified, it merely adds another record to the insufficiently understood Aptian ammonoid distributions.

Lytoceras polare is believed to be characteristic of the Upper Aptian in East Greenland, but appears to range through both divisions. It is, in any case, unhelpful for distant correlations and appears not to have been recognised from any other area. The single nautiloid, *Cymatoceras* aff. *radiatum*, is near to a common English species. The few belemnoids are either not specifically identified (*Neohibolites*) or referred to new species (*Oxyteuthis*). *Neohibolites*, recorded from several places in the northern region by Maync (1949), has been usually regarded as diagnostic of the Aptian. The presence of belemnites identified as *Oxyteuthis* in the Upper Aptian fauna of Store Koldewey is of interest, for in Europe the genus does not go higher than the Lower Aptian, and Mr. R. Casey informs me that its range in Britain ends at the base of the Deshayesi Zone.

Knowledge of the non-Cephalopod fauna of the Aptian is entirely restricted to the shallow-water fauna described by Frebold (1935) from Store Koldewey. It is composed of a number of long-ranging genera, mostly of lamellibranchs and gastropods, mostly referred to new species by Ravn or by Frebold. Comparison with other regions would not be profitable without an extensive analysis of Aptian faunas.

12. Lower Albian.

The ammonite fauna is characterised by *Arcthoplites*, a genus characteristic of the Lower Albian of Central Russia, Spitsbergen, and East Greenland. The fauna is dated by *Leymeriella*, fairly common at one locality in Geographical Society Ø (Spath, 1946, p. 9), which is a well-known European Lower Albian genus found in the Tardefurcata Zone in Britain. No other European ornamented ammonites have been found in the Lower Albian among the indifferently preserved assemblages known from a number of places. Several species, or even genera, of Desmoceratids may be present in the Lower Albian fauna but all are poorly preserved and difficult to study. Examination of some of the writer's material by Mr. R. Casey suggested the presence of a new un-named genus most nearly related to species from Alberta, Canada (Donovan, 1953, pp. 116, 136).

The Lower Albian ammonoid fauna, therefore, shows distinct local characters, and the absence of other Lower Albian genera may be significant. The remainder of the fauna includes a number of shallow water mollusca, and it is probable that a longer list would be available were it possible to collect more and better material. The list as it stands is inadequate for conclusions to be drawn.

13. Middle Albian.

Several Hoplitid genera have been recognised among the Middle Albian fauna but all are in poor preservation which makes detailed comparisons impossible. Some of the fragments are close to European genera and species, and there is also *Gastroplites* which is characteristic of the Middle Albian of North America, although it has been found in Britain. None of the other North American genera have been recognised in Greenland. On the whole the fauna is of European aspect, with additional elements.

Later Albian faunas include *Inoceramus anglicus* and *Aucellina gryphaeoides* as the most prominent members. *Inoceramus anglicus* was a widely distributed species, well-known from Europe, perhaps replaced geographically, in North America, by the form known to American palaeontologists as *I. comancheanus* (see Donovan, 1954, p. 23). *Aucellina* of the same or closely allied species had a world-wide distribution, with the apparent exception of North America, at about the same time as their maximum in East Greenland (see Donovan, 1953, p. 91).

14. Upper Albian.

The presence of the Upper Albian in East Greenland is not proved by identifiable fossils. A few ammonite fragments found by the writer in Traill Ø, including a probable Mortoniceratid genus (Donovan, 1953, p. 120), do not seem to be comparable to anything earlier than Upper Albian in Europe, and it is possible that some of the beds with *Aucellina gryphaeoides* and *Inoceramus anglicus* are of this date.

15. Cenomanian.

The dating of the Cenomanian rocks in East Greenland (upper part of the Middle Cretaceous Shales) is securely accomplished by the various species of *Schloenbachia*, which are identical with forms well-known from

Europe. In Europe the genus characterises the Lower Cenomanian, or Varians Zone of the English succession. So far, attempts to subdivide this zone have met with little practical success.

The faunal list as a whole is predominantly of European aspect, principally on account of the presence of *Schloenbachia* which is unknown from America. The list of ammonites, however, is remarkable more for what it lacks than for what it contains. *Schloenbachia* is abundant and there is no question, therefore, that ammonites could live and be fossilised under the conditions locally obtaining. There is no sign, however, of the genera *Acanthoceras* and *Calycoceras*, which are well-known from the Cenomanian of both Europe and North America, and it must be presumed that some factor, possibly ocean temperature, prevented these genera from making the journey to East Greenland. Such an explanation is not wholly convincing in view of the fact that fragments of *Phylloceras* and *Lytoceras* were found in the shallow, marginal facies of the Lower Cenomanian of East Greenland, perhaps the last place in the world where one would expect them. *Mesogaudryceras*, known by a single impression from Traill Ø (Donovan, 1953, p. 120), had not previously been recorded outside the British Isles.

With regard to the rest of the faunal list two factors must be kept in mind. First, that the fossil material is for the most part indifferently preserved, and identity with described species is accordingly difficult to prove; second, the known fauna is very small. It is difficult to say whether the latter phenomenon is real or apparent. The black shales which form the greater part of the Cenomanian rocks are poorly fossiliferous, and barren throughout much of their thickness. The only place where uncrushed fossils have been found in reasonable abundance is Tværdal, in Geographical Society Ø, where a marginal sandy facies replaces the normal shale (Donovan, 1955, p. 30), and it is likely that intensive collecting here would produce a larger fauna.

16. Turonian.

The correlation of the Turonian rocks (Inoceramus lamarcki Beds) has been recently reviewed in detail by the writer (Donovan, 1954, pp. 24—26). The ammonoids are few and indifferently preserved, but they all agree in indicating the upper half of the Turonian stage. The fauna is so small that geographical affinities are hardly significant, but as far as they go they are about equally divided between the old and the new worlds. Ammonoids are rare in the outcrops so far discovered, so that no importance can be attached to the absence of various genera familiar from the Turonian elsewhere.

17. Upper Santonian—Lower Campanian.

The Sphenoceramus Beds and the Knudshoved Beds have yielded no ammonoids and are dated by *Inoceramus (Sphenoceramus)* of the group of *patootensis* and *steenstrupi*. The question has been discussed by the writer (1953, pp. 94—95), who believes that the poorly preserved material from East Greenland can only be dated as Upper Santonian or Lower Campanian, the approximate range of this group of species in areas whose stratigraphy is well-known. The complex scheme of *Inoceramus* zoning produced by Heinz, and reproduced by Maync (1949, p. 279), cannot be applied to material of the poor quality of that from East Greenland, even if it is applicable in areas which have yielded better-preserved faunas.

As in the case of the Turonian, the fauna is not large enough for geographical affinities to be very significant. *Inoceramus (Sphenoceramus) patootensis* and *I. (S.) steenstrupi* are found in Europe, West Greenland, and probably North America. *I. (S.) geltingi* and *I. (S.) teicherti*, from the Knudshoved Beds, have not been recognised elsewhere, but they may prove to be identical with some of the large species of *Sphenoceramus* known from Europe and America, if a critical study of the group is at any time made. *Oxytoma tenuicostata* has not been reported from North America, although it is found in West Greenland. In view of the extensive researches now proceeding on the North American Mesozoic it is likely that many new records will be forthcoming.

18. Upper Campanian.

The fauna to which this date is assigned includes scaphitoid ammonoides of the group of *Scaphites roemeri* d'Orbigny. The commonest form has been named *S. greenlandicus* by the writer[1]) and a specimen very close to *S. quadrangularis* Meek & Hayden has also been found. This group of ammonoids occurs in the Upper Campanian rocks of Europe and North America. Identical forms are found in both East and West Greenland, and the type of *S. greenlandicus* is, in fact, a West Greenland specimen. The remainder of the fauna is inadequate for profitable comparison.

As in the Cenomanian, the absentees from the ammonoid fauna may be significant. *Scaphites* is reasonably common (if only as fragments showing the characteristic ornament) at several localities, but no trace of any other ammonoids, such as *Baculites* and *Placenticeras* which are well-known from beds of the same age in North America (and

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[1]) Dr. J. A. Jeletzky (*in litt.*) prefers to include these forms in a comprehensive *S. roemeri*.

Europe?), has been found. It is possible that some local cause may have operated to discourage other genera from approaching the East Greenland coast, but it is also tempting to suppose that differences in tolerance of low ocean temperatures between different genera may have been the cause. Further collecting might enable such speculations to be placed on a firmer basis.

19. Conclusions.

A few remarks may be made on the subject of faunal provinces, which have received mention in a number of instances in the foregoing discussion. The provinces in question mainly concern the ammonites, although certain other fossils, such as the lamellibranch *Buchia*, may also have a restricted geographical distribution. The post-Triassic ammonite faunas show two periods of extreme local differentiation, in the late Middle and early Upper Jurassic, and in the early Cretaceous. At other times, although not all genera may have had a world-wide distribution, far wider geographical ranges are commonly found among genera and species. On this subject the writer takes the opposite view to that of Spath, the authority on many East Greenland Mesozoic faunas, who has consistently denied the existence of faunal provinces, and who says that 'Zoological provinces may be very real . . . for extreme organisms like the belemnite *Duvalia* or the Rudistae. They may be negligible in the case of ammonites whose dispersal was fairly rapid . . .' (1952, p.33). It is arguable that rapidity of evolution rather than rapidity of dispersal is the important factor in determining whether or not organisms will show marked differentiation into provinces. Dispersal, even of 'sedentary' organisms or bottom dwellers, is widely believed to be rapid in comparison with the smallest units of geological time, and it is doubtful whether there was much difference in migration rate between, for instance, bottom-dwelling lamellibranchs and those ammonites which had a similar mode of life. In both cases effective dispersal was dependent on the larval stages. Dispersal was, however, controlled by actual physical barriers, and by physical and chemical conditions in the ocean, which were more important at some times than at others, consequent on geographical changes. At times when the seas were restricted and certain parts of the ocean were partly or completely isolated from the point of view of interbreeding and dispersal of marine animals, communities of slowly-evolving organisms such as lamellibranchs, in which perhaps half a geological period is often required for the production of a new species, would show little difference from other communities until a considerable time had elapsed. In the case of the ammonites, however, which were notoriously rapidly-evolving animals, quite a brief isolation of a community would have been sufficient for the production of new species or even genera (according to the present-day classification), and once the group had become genetically distinct it would continue to evolve along its own lines after communication with the open ocean was restored.

Spath cites, in support of his view, several ammonite genera of world-wide occurrence (1952, p. 32); but the fact that some genera are known to have had a very wide distribution at certain times is no argument that other genera, at other times, were similarly distributed. Nor does the statement that the empty shells of ammonites 'could have been transported across all the seas of the time' (op. cit. p. 33) bear close scrutiny. It has long been known that certain facies were uncongenial to ammonites, and if some of the non-ammonitiferous facies of the English Inferior Oolite or Great Oolite, for example, have never yielded an empty shell of any of the ammonites which were undoubtedly living in the same region at the same time, then it is very unlikely that drifted shells of ammonites will ever be found outside the area in which the animals lived[1]).

The two periods of geographical differentiation of ammonite faunas mentioned above correspond to the two principal times of shrinkage of the oceans during the Jurassic and Cretaceous. It is not surprising that the effects of the Middle Jurassic regression, which began in the Bajocian or even the late Toarcian, were most strongly marked in the ammonite faunas of the Bathonian and early Callovian. Similarly, the regression which began about the middle of the Portlandian stage, as a result of which the Upper Portlandian deposits throughout much of extra-alpine Europe are non-marine (Purbeckian beds), resulted in a complete differentiation of the Berriasellid and Subcraspeditid faunas in the Berriasian, occupying almost mutually exclusive areas.

Zoological provinces of the kind discussed in the last paragraph depend for their existence primarily on the distribution of land and sea, and secondarily, perhaps, on currents and other oceanic features. They must not be confused with features in the distribution of marine organisms dependent on the general zonation of ocean temperatures, and other properties, between the equator and the poles. This zonation may be at its most extreme at the present time on account of the existence of polar ice, but it existed during earlier geological periods and well-

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[1]) This is not the place for a full discussion of the question, but the writer believes that the supposed dispersal of cephalopod shells by currents, after death, much in favour with some authorities, took place, if at all, within strictly limited areas. Shells of the Recent *Nautilus*, which lives in the south-western Pacific, are found washed up in Japan and New Zealand (Stenzel, 1948, pp. 84—85); but they have never been found on European beaches, nor even, so far as I know, on African or Indian ones.

demonstrated instances of its effect are known—for example, the distribution of the reef-building corals in the Jurassic (Arkell, 1935). In theory, East Greenland should be an ideal place for investigating the existence of such zones in the Mesozoic, for there is a sufficiently large difference of latitude—over 20°—from the classic European areas whose faunas are well-known. In practice, few inferences can safely be drawn on account of the drawbacks mentioned at the beginning of this chapter, as a result of which few of the faunal lists are likely to be representative of the assemblages living off the East Greenland coast during the various stages. A few indications in the ammonite faunas, already enumerated, point towards the existence of selective factors which may have operated to prevent certain widespread genera from reaching East Greenland, and which may have been dependent on temperature. The evidence for the Lower Cenomanian and Upper Campanian stages is suggestive. Since, however, the conclusions depend on negative evidence, it is desirable that they should be founded on much more extensive collecting than has hitherto been carried out.

An independent line of evidence on past ocean temperatures is provided by the palaeotemperature studies recently begun in the U.S.A. So far, only one specimen from East Greenland, an *Inoceramus* from the Knudshoved Beds, has been tested (Lowenstam & Epstein, 1954, pp. 222, 232), and the result is probably vitiated by defective preservation; in any case, deductions cannot be drawn from a single analysis. More material for analysis has now been supplied to Prof. Lowenstam, and his work may make an important contribution to the study of conditions in East Greenland during the Cretaceous period.

IX. THE NORTH ATLANTIC OCEAN DURING THE MESOZOIC ERA

In this chapter the evidence from East Greenland on the question of the conformation of the northern part of the Atlantic Ocean, and its neighbouring coasts, during Mesozoic times, will be examined. The views put forward are bound to be speculative, but at least they may form a basis for discussion.

East Greenland and Continental Drift.

The hypothesis of Continental Drift must first be examined, for according to whether it is accepted or rejected two completely different conceptions of the configuration of the North Atlantic area before the drift occurred will be obtained. In the following paragraphs the hypothesis that drift has occurred during or since the Cretaceous will be briefly considered. Arguments for a different position of Greenland relative to Europe during the Palaeozoic era will not be discussed.

Drift of Greenland away from Europe has been assumed by a number of writers, summarised by Wegmann (1948, pp. 18—20), who also suggested lines of investigation which might show whether or not drift had occurred. Exponents of the drift hypothesis seem mainly to have been influenced by the desire to bring the Caledonian fold belts on either side of the North Atlantic together into one continuous zone, the place of the North Atlantic during Lower Palaeozoic times being occupied by a geosyncline. Aldinger (1937) thought that the Atlantic Ocean probably began to form during the Upper Jurassic, basing his views on the fact that the Upper Jurassic rocks of East Greenland are more definitely marine than earlier Mesozoic deposits. In the present writer's opinion this is not a valid argument, the changes of facies being explainable by changes in local geography and in sea-level. Moreover, it is inconceivable that drift could have occurred without being accompanied by vulcanicity, and it is reasonable to assume, with most authors, that if it did occur it took place in latest Cretaceous and early Tertiary

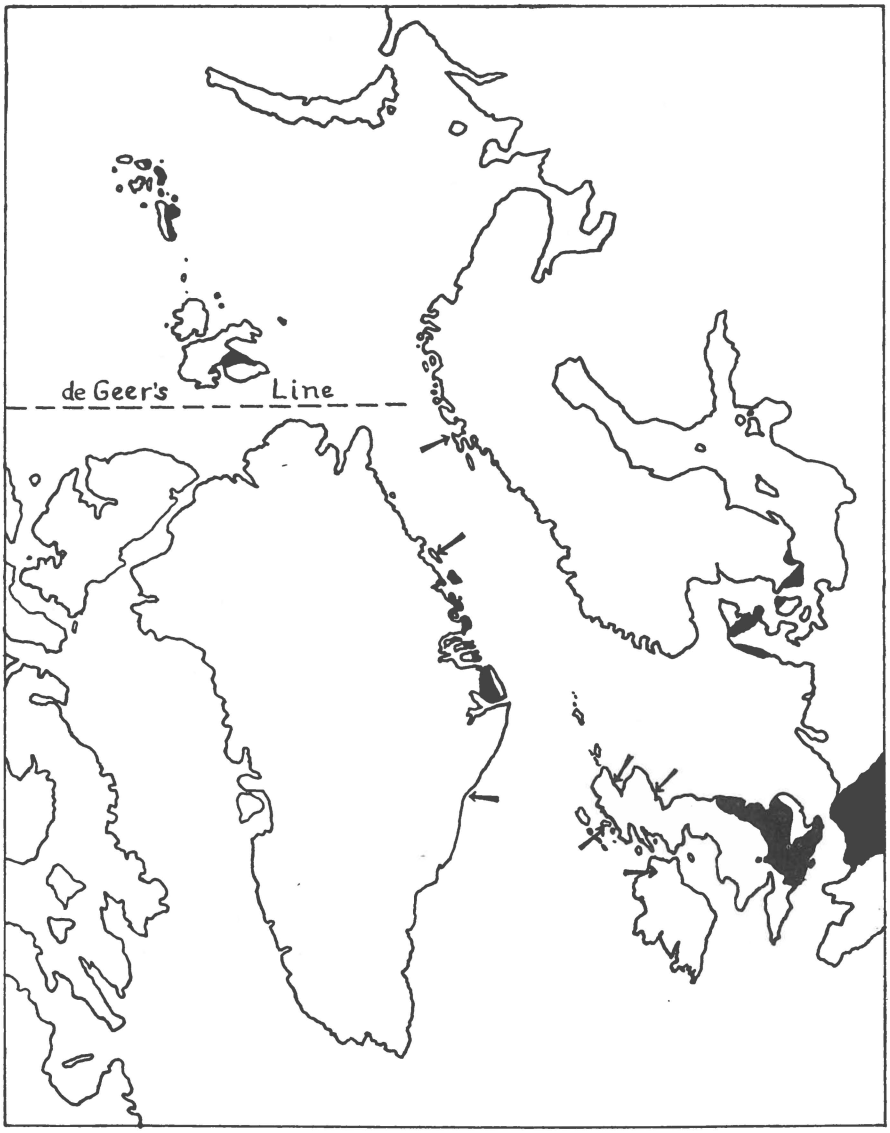

Fig. 24. Reconstruction of the relative positions of Europe and Greenland, prior to drift, on the assumption that drift has occurred parallel to De Geer's Line. Jurassic and Cretaceous outcrops are shown in black (not shown for West Greenland and Russia). Small outcrops are indicated by arrows.

time and was associated with the extensive igneous activity which characterised the North Atlantic area at that time.

Wegmann suggested that, if drift has occurred, the most easily acceptable direction of movement is parallel to de Geer's Line, which lies along the north coast of Greenland and the southern margin of the

North Polar Basin (*op. cit.*, p. 22, pl. 1). He included a map drawn on a special projection to illustrate his point, but did not show the position which Greenland is assumed, on this hypothesis, to have occupied before it drifted. This has been done and the result is shown in figure 24. In theory, slight distortion is present because the construction was carried out on a flat surface and not on a globe, but in practice this is believed to be negligible on the scale employed. The outer limits of the continental shelves have been brought into contact, and islands consisting of Tertiary igneous rocks have been ignored.

It will be seen from figure 24 that, if Greenland indeed occupied such a position in Mesozoic times, a nearly parallelsided arm of the sea lay between East Greenland and western Norway and Scotland. If the writer's assumptions explained below (p. 163) are correct, then the western margin of the trough would have extended further south in the Mesozoic; the eastern margin may, or may not have been more continuous than it is to-day. The Jurassic and Cretaceous sediments in East Greenland, in western Scotland and in Andøya, north-western Norway, would have been deposited in this trough, all under similar conditions; that is, off coastlines possessing considerable relief. The Jurassic and Cretaceous succession in each of the three areas is summarised diagrammatically in figure 25. Such a comparison is oversimplified but serves to bring out the contrasts between the areas.

In western Scotland there was, in some places, nearly continuous marine sedimentation from the Hettangian to the Bajocian and from Callovian to the Kimeridgian; the Bathonian is represented by non-marine deposits. It is possible that deposition continued later than the early Kimeridgian, but that the evidence for it has since been destroyed. This state of affairs bears no resemblance to that in East Greenland, where sedimentation was intermittent, and marine fossiliferous horizons rather rare, except in the Kimeridgian and Portlandian when there was probably continuous submergence of eastern Milne Land. In the Cretaceous there are no deposits in western Scotland until the late Albian or early Cenomanian, after which formation of Chalk may or may not have been continuous; there is no parallel for the Lower Cretaceous transgressions in East Greenland.

There are no pronounced faunal similarities between Scotland and East Greenland. At the time of maximum differentiation of the ammonite faunas, in the Middle and early Upper Jurassic, the Scottish ammonites are all of genera well-known from the English outcrops, while in East Greenland the majority of genera are unknown in Europe. If Scotland and East Greenland were as close as they are in figure 24, such a marked faundal difference would be most surprising provided that there was a marine connection; it is conceivable, however, that

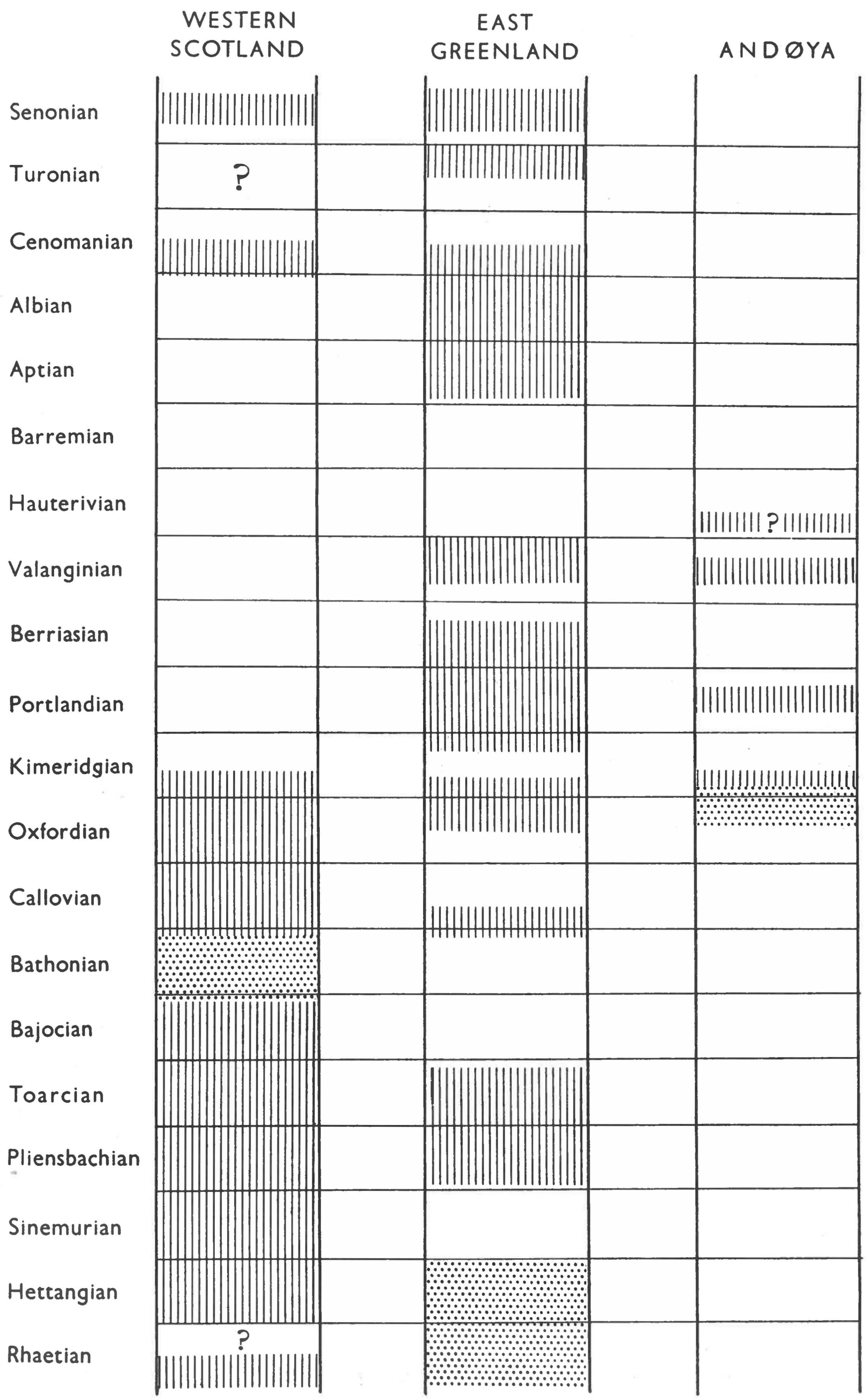

Fig. 25. Comparative diagram of the Jurassic and Cretaceous successions in Western Scotland, East Greenland and Andøya. Vertical shading = marine deposits. Stippling = non-marine deposits. The Pliensbachian-Toarcian and Bathonian-Callovian deposits in East Greenland may be partly non-marine.

the connection was interrupted even if the two countries were in close proximity.

The succession in Andøya shows a slight correspondence to that in East Greenland, in the presence of marine early Kimeridgian, probable late Kimeridgian or Portlandian, and Valanginian. The supposed Hauterivian (which is not well established) has no known parallel in East Greenland. The faunas from Andøya are not sufficiently well-described for comparison. Knowledge of the Jurassic and Cretaceous in Andøya is probably too incomplete for any conclusions drawn from this comparison to be valid, but as far as it goes the similarity with East Greenland is less striking than that between Spitsbergen and East Greenland.

To the present writer the facts reviewed above do not offer any reason to suppose that Greenland was closer to Europe in Jurassic and Cretaceous times than it is now[1]). There are no resemblances, such as might be expected if the rocks in East Greenland and Scotland were laid down on opposite sides of a narrow trough; on the contrary, there is a strong contrast both as regards the extent in time of the episodes of sedimentation, and the facies deposited in the two countries.

The East Greenland coast during the Jurassic and Cretaceous Periods.

It has been shown in Chapter V that from Scoresby Sund northward to Store Koldewey the Jurassic and Cretaceous coastlines of East Greenland lay approximately parallel to the existing coast; during times of marine transgression the shore lay to the west of the present outer coast, during regressions it may have lain to the east; but, these matters of detail apart, the relationship of continent to ocean was the same during the Mesozoic Era as it is now. The structure of this part of the continental edge has been shown to consist of tilted and faulted blocks.

Southward from Scoresby Sund the structure is quite different. Wager has shown (1947, pp. 30—38) that from Kap Dalton to Angmagssalik the coast coincides with a major monoclinal flexure, downthrowing to the south-east, which is later than the plateau basalts and therefore of Tertiary date. The line of the flexure is marked by an impressive dyke swarm which came into being at about the same time. Between Scoresby Sund and Kap Farvel, the southernmost point of Greenland, there are no sediments of earlier date than the late Cretaceous, and the rocks of this age rest unconformably on the metamorphic basement.

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[1]) Arkell (1956, p. 604) has independently reached the same conclusion. See also footnote on page 165.

It is clear that while the east coast of Greenland north of Scoresby Sund dates back at least to the Upper Palaeozoic Era, the coast to the south is entirely of Tertiary origin. The two sections meet at the mouth of Scoresby Sund and make an angle of about 135° with one another. There is no trace of a coastal flexure north of Scoresby Sund, nor of step-faulting to the south. In the writer's view the two structural zones intersect at Scoresby Sund. On this hypothesis the step-faulted zone is visualised as continuing southward beyond its present limit in Mesozoic time. When the Tertiary flexuring took place, the part of the step-faulted zone to the south of the point where the flexure crossed it was completely submerged. To the north of the point of intersection, the area east of the step-faulted zone was already below sea-level, so that it is the flexure which is entirely under the sea in this region. Some support for this view is forthcoming from a prominent feature on the sea-floor. East of Central East Greenland there is a shelf beneath a maximum depth of water of about 1000 m, bounded to the east by a steep slope occupying a narrow zone which runs from a point near the Liverpool coast, about 18° W. and 72° N., to a point north of the 78° N. circle of latitude, which it crosses at about 6° W., and north of which the submarine relief become more complicated. For part of its length this submarine feature has a slope of nearly 3°, and a relief of over 1500 m. At its southern end, where it is admittedly lower than further north, it is aligned with the coastal flexure, which here strikes out to sea. Along the known part of the flexure, the dip ranges from 2° to more than 20°, and the difference in level on the two sides from about 6 to 8 km. Taking into account the reduction of relief and slope by silting up at the foot of the flexure-slope, assumed to be about 2 km by Wager in his area (1947, p. 30), the submarine feature just described accords well with a continuation of Wager's coastal flexure.

The views expressed above are in opposition to those of Wager, who considered (1947, p. 51, & fig. 11) that the 'tectonic conditions of Middle East Greenland [the part south of lat. 70°] extend northwards' into the fjord region. He thought that the coastal flexure and the step-faulted structure were different responses to similar stresses in the earth's crust, and that the step-faulted zone formed a northward continuation of the flexure. The writer prefers to regard the flexure as a new structure, independent of pre-existing structures. There have certainly been post-basaltic movements along some of the major faults in the step-faulted zone (*vide* Maync, 1949, p. 154), but they are regarded as unconnected (although possibly contemporaneous) with the flexure.

Geography of the Callovian Stage.

In an attempt to form an idea of the geography during the Jurassic Period, a map of the distribution of land and sea at the beginning of the Callovian Stage is offered in plate 2. At this time there was a long, blind inlet stretching from the Arctic Ocean through the extreme north-west of Canada into the Western Interior of the United States, and a parallel arm of the sea in the neighbourhood of the present west coast. The rest of North America appears to have been land. A transgression from the Arctic Ocean into the Canadian Arctic Archipelago is demonstrated by the recent discovery of *Cranocephalites* and an unnamed Callovian ammonite in Prince Patrick Island by Tozer (see Arkell 1956, p. 529). The sea just overlapped the eastern edge of Greenland, the coast being presumed to continue southward from Scoresby Sund as explained above. The Barents Sea was at least partly submerged, although the ancient rocks forming the northern part of the Spitsbergen archipelago were above sea-level.

So far, the picture is not essentially different from other recent reconstructions, such as that of Imlay (1953, fig. 2) from whom the North American details have been taken. The eastern side of the Atlantic is less satisfactory in existing reconstructions. Most of these show a continent of 'North Atlantis', lying to the north and west of the British Isles (*e. g.* Wills, 1951, pl. 14). The writer believes that this continent is unlikely to have existed as a land mass of any size, and that a more acceptable view is that Europe in the Mesozoic era, as now, was bounded to the north-west by the Caledonian mountain chains which can be traced from northern Norway to western Ireland. These chains, and the Hercynian ones which later intersected them in the south of Britain, underwent extensive denudation from the time of their elevation onwards. During the Trias was finally formed the relief which was invaded by the Jurassic sea. This can be fairly accurately reconstructed (Wills, 1951, pl. 13 C) and the principal feature of its western margin is the gap through the palaeozoic rocks in the region of Cheshire and Lancashire which later allowed the Jurassic sea to penetrate into northern Ireland and western Scotland. Further south there were smaller westward extensions of the lowland, following the Hercynian strike, in the region of the Bristol and English Channels. At times of maximum submergence, these channels may have penetrated the Palaeozoic mountains and connected with the Atlantic; at times of minimum submergence, such as the Middle Jurassic, they may have failed to do so. There is practically no evidence as to the extent of the channel which lay to the east of Scotland, neither is there any satisfactory evidence as to the time when the gap between Scotland and Norway came into being, although by analogy with the state of affairs further south-west it may have been in existence in the Triassic Period.

The state of affairs suggested above would explain the great contrast in ammonite faunas between East Greenland, on the one hand, and Britain, France, and Germany on the other. Genera such as *Cranocephalites*, *Arctocephalites* and *Seymourites*, which ranged from East Greenland to Spitsbergen and Russia, would be expected to occur in Britain if there was a direct sea route open. It is therefore postulated that the connections with the Atlantic were closed at this time, either by dry land, or by areas of non-marine sedimentation as indicated by Wills (1951, pl. 16 A). The fundamental difference between the present reconstruction and that of Wills is the rejection of 'North Atlantis' by the writer, its place being taken by the remnants of the Caledonian chains, to the west of which lay the Atlantic Ocean, as it does today[1]). The writer also considers that the non-marine facies is likely to have been more restricted, and of more local origin, than Wills indicates.

The origin of the North Atlantic Ocean.

Wager has observed that one of the extensive geological changes which took place at the end of the Cretaceous Period may have been the formation of the North Atlantic Ocean, and has referred to the two principal hypotheses of its origin, by foundering of a 'Thulean Continent' and by drift of Greenland and Europe away from one another (Wager, 1947, pp. 57—58). Wager demonstrated, as already noted, that the south-east coast of Greenland came into being by large-scale flexuring in Tertiary time, and after considering the known facts as to the early Tertiary history of the North Atlantic, concluded that the evidence from East Greenland was 'about equally favourable' to a hypothesis of drift and one of foundering.

Fränkl (1956, pp. 28, 38) rejects continental drift, but assumes, without stating his reasons, the existence of an 'Arctic Continent' which occupied the area of the North Atlantic Ocean. He believes that this land gradually subsided from the north southwards, and adduces the fact that the East Greenland coast is formed by younger and younger structures from north to south (cf. p. 163). He also cites the distribution of marine and non-marine sediments in East Greenland in support, and states that the southward marine transgression over the Arctic Continent

[1]) Arkell (1956, pp. 602—04), arguing from more general considerations, independently reaches the same conclusions as the present writer regarding the non-existence of 'North Atlantis', and the unlikelihood of continental drift having occurred since the Jurassic. This chapter was written before Dr. Arkell's book was published.

reached latitude 74° (on the Greenland side) by the Permian, but did not penetrate further south until the Jurassic. In order to assess this hypothesis it should be examined in detail, but there is room here for only a few comments. The hypothesis is not supported by the facts that the earliest marine Jurassic (Pliensbachian) is found only in the southernmost part of Central East Greenland, that the main (if not the only) opening of the Jameson Land Basin was to the south, and that successive Lower and Middle Jurassic formations extend further and further north (pp. 103—6, figs. 20, 21). It is true that the only sediments found in south-east Greenland (Kangerdlugssuaq) are very late Cretaceous, but they are nevertheless earlier than the present coast-line, the youngest part of the East Greenland coast. The southern edge of the land mass is said to be represented by the South Greenland-Iceland-Scotland ridge, and to have been finally submerged in the Oligocene (Fränkl, *op. cit.* p. 40). The visible parts of the ridge are, of course, composed entirely of igneous rocks with a few late Tertiary sediments, and there is no evidence as to whether there was a land or a submarine ridge in this position before igneous activity started. Before the Oligocene the ridge 'may have served as a migratory path for various faunas' (Fränkl, *loc. cit.*), presumably terrestrial ones, but the faunas are not discussed (fossil land animals are almost unknown from East Greenland) and do not seem to be relevant. In conclusion, it cannot be said that the Mesozoic rocks offer any good evidence in favour of the subsidence hypothesis, at least in the form expounded by Fränkl.

In the writer's view it is unnecessary to seek an explanation for the formation of the North Atlantic Ocean, either by drift or by subsidence, in late Mesozoic or in Tertiary time. East Greenland north of Scoresby Sund has been bounded by the sea since Upper Palaeozoic times. On the European side, there is no evidence for any continent of 'Atlantis'; the Caledonian mountain chains were doubtless at one time more complete, but their north-westward extension is unproved. Since the Mesozoic, at least, there is no reason to suppose that the North Atlantic has not had approximately the configuration which it shows at the present time. On this view, the formation of the south-east Greenland coast by flexuring was an incidental event which locally affected the configuration of the ocean, and not a representative of events which gave rise to the whole North Atlantic at this time.

The date of the beginning of igneous activity.

The question of the date of the beginning of igneous activity, and especially of the outpouring of plateau basalts, in the North Atlantic Tertiary Igneous Province is one of considerable interest. The evidence from East Greenland bearing on the question will be summarised here, for it is closely concerned with the Upper Cretaceous sediments.

Basalts have been observed resting on sediments at three places in East Greenland: at Kap Gustav Holm, at Kangerdlugssuaq and at Kap Brewster. The sub-basaltic sediments at Kap Gustav Holm and at Kap Brewster have not been dated; the lower part of the Kangerdlugssuaq Sedimentary Series is proved by marine fossils to be of Senonian, probably Upper Santonian or Lower Campanian (p. 87), age. The upper part of the series, which contains basalt pebbles and was being laid down at the time that volcanic activity was beginning, has yielded fossil plants, but the flora cannot be placed exactly in the marine succession and may be late Cretaceous or early Tertiary. The evidence from the coast south of Scoresby Sund proves, therefore, that the production of the plateau basalts was certainly later than Upper Santonian, but could have been Campanian or Maestrichtian.

Slender evidence is forthcoming from Traill and Geographical Society Øer. The basic igneous rocks throughout the greater part of the two islands are intrusive, but at Kap Mackenzie a small area of lavas has been preserved (Donovan, 1955, p. 41), and it is clear that the lava field of which larger areas remain in Hold with Hope and the Giesecke Bjerte extends southwards to Geographical Society Ø. Examination of the matrix of the Upper Campanian fossils collected in the islands gives no reason to believe that volcanic activity was in progress, or that basalts were being denuded, when the sediments were laid down[1]). In Central East Greenland, therefore, there is reason to believe that volcanic activity did not begin before the Maestrichtian.

Sediments which were deposited after the commencement of igneous activity have been described from a number of places in East Greenland. The best-known fauna is that from the Kap Dalton Series, of Kap Dalton and Kap Brewster, described by Ravn (1903, 1933) and Hassan (1953). The most recent review of the date by Hassan indicates middle or late Eocene for the sediments. According to the evidence at present available, therefore, igneous activity may have begun at any time in the Maestrichtian, Palaeocene or early Eocene. Future work at Kap Brewster and along the coast to the south-west may provide a more exact dating, if additional fossiliferous sedimentary horizons can be found.

[1]) I am greatly indebted to Dr. F. Coles Phillips and to Dr. D. J. Shearman for examining and discussing thin sections of the Upper Campanian sediments.

X. PROBLEMS AND PROSPECTS FOR THE FUTURE

This account began with a history of the researches which have been made into the Jurassic and Cretaceous rocks of East Greenland; it concludes with a survey of the work which has yet to be done. In writing this the author is faced with a dilemma; the problems in question are academic in the sense that little or no economic importance is attached to them, and their importance can only be assessed by academic standards; yet to write an account of them as if they concerned an inhabited country, where access to all parts is taken for granted, would be unrealistic. Accordingly reference will be made to the physical conditions of work and the accessibility of different parts of the country.

Lower Jurassic.

The fossil flora of the Kap Stewart Formation has been intensively collected along the shores of Hurry Inlet, and there may be few new discoveries to be made along this outcrop. The same is true of the Neill Klinter Formation, although in this case the fossils which have been collected have not yet been fully published. Along the western outcrop in the Jameson Land basin, and in northern Jameson Land, the state of knowledge is very different, and neither the lithology nor the faunas of the formations is known. The fact that the small collection of plants submitted to Harris from western Jameson Land contained several species unknown in Hurry Inlet encourages the belief that systematic collecting from the Kap Stewart Formation there would be profitable, and it is also to be hoped that the fossil fish, *Gyrolepis*, may be re-discovered and fully described[1]). The Neill Klinter Formation is entirely unknown except for the outcrops of south-eastern Jameson Land.

Bathonian and Callovian.

There is little doubt that further work along the Hurry Inlet outcrop of the Vardekløft Formation would yield interesting results, for

[1]) Dr. Koch informs me that the specimens collected by Stauber were sent to Stuttgart, and were destroyed during the 1939—45 war.

much of the original work was carried out under unsatisfactory snow conditions. The main features of the ammonite succession seem clear, but many details are unknown. When Spath monographed the fauna only one ammonite horizon was known in the formation, the line of nodules with *Seymourites* and *Cadoceras*. In 1935 Aldinger reported a lower one with *?Cranocephalites*, but the ammonites thus recorded have not been described. *Arcticoceras* also occurs at Vardekløft but the horizon is uncertain (Spath, 1932, p. 127). Further north, at Constable Pynt, the section which yielded *Kosmoceras (Gulielmiceras)* demands renewed study. At Katedralen, where the lithological change to the sandy 'Fossil Mountain Formation' has begun, the section is also tempting, for there is little doubt that a number of fossil horizons are present. At Mikael Bjerg, where Rosenkrantz obtained a wider selection of ammonite genera than at any other locality, detailed stratigraphical collecting is again called for, for during Rosenkrantz's visit the ground was largely snow-covered and little detail could be recorded. At all these places it is desirable that field work should be carried out in August when the area concealed by snow is likely to be a minimum.

At Hjørnefjeldet was obtained the curious ammonite referred by Spath to *Xenocephalites* (1932, p. 44), and although only one specimen was found, in scree which also yielded a *Cranocephalites*, there must be more fossils to be collected here. Further north still, along the eastern outcrop of Jameson Land, nothing is known except for the record of *Cranocephalites* from Antarctics Havn, found by Parkinson and Whittard in 1929. The present writer was less successful during a visit in 1949, and the immediate surroundings of Antarctics Havn are not very promising. The country to the south, however, awaits investigation. The reader will have realised from the foregoing remarks that all the localities which yielded the well-known fauna described by Spath (1932) await full study, which may be expected to yield both interesting stratigraphical results, and new fossil records.

The Bathonian-Callovian rocks of north-central and western Jameson Land are unknown, and a geological investigation of this area is desirable from the point of view of these, as well as of older and younger rocks. Examination of aerial photographs shows that a number of sections are available, expecially in deep valleys immediately to the north of the small ice-cap or snowfield at 'Olympen', the highest point in Jameson Land.

In Traill Ø most of the fossil localities reported by the writer are not worth revisiting, but the Svinhfvuds Bjerge, easily accessible from Kong Oscars Fjord, might repay thorough examination. Here *Cranocephalites* and many lamellibranchia have been found in loose boulders, but the outcrops are unknown. At Tværdal, in Geographical Society Ø, a locality in the Yellow Series discovered by the writer (1955, p. 18) yielded well-preserved fossils, but little time could be spent collecting and a longer visit would doubtless yield more fossils.

In Wollaston Forland and Kuhn Ø no systematic identifications or description of the faunas from the Yellow Series have been published, and it is doubtful whether Maync and Vischer made large collections, as they were preocupied with establishing the stratigraphy and structure. The geological mapping of the area is well advanced as a result of their work, but there remains the need for collecting to establish the succession of ammonites in the Yellow Series and to investigate whether the same species are present as in Jameson Land.

In Store Koldewey the Callovian Trækpas Formation has not been investigated since the visit of the Danmark Expedition. Koch, in 1927, was unable to find any fossils at the type locality, although he found a few at Kap Arendts (Koch, 1929, pp. 166, 172). He was travelling in the spring, however, while much of the country was covered by snow, and it is likely that a summer party would have considerable success with fossil collecting, and might also be able to establish a zonal succession within the Trækpas Formation. Access to the east coast of the island, where the Jurassic outcrops lie, is not easy in the summer, on account of pack ice; it might be possible to land on the west coast and cross to the east coast by Trækpasset or one of the other passes, if open water could be found to the west of the island.

Oxfordian, Kimeridgian and Portlandian.

The shortcomings of the succession available from Milne Land have already been mentioned (p. 40). The major features of the succession are well-known, but the sequence of ammonite faunas within the several formations is obscure, and the information available to Spath, when he monographed the fauna (1935, 1936), was inadequate and sometimes contradictory. From some of the horizons, reported to be highly fossiliferous in the field accounts, only a few fragments were brought back (*e. g.* Spath, 1935, p. 69). As this is one of the most complete and fossiliferous successions in the Arctic Upper Jurassic, it may be hoped that further collecting will be undertaken. A future expedition would have the benefit of the geological map made by Aldinger, and of Spath's monographs by which fossils could be identified in the field. This would remove one source of difficulty encountered by the original field parties, who seem to have confused different nodule bands containing similar, but not identical, ammonites Even with these advantages, however, the difficulties of bed-by-bed collecting would be considerable, and the success of an attempt would depend largely on finding suitable sections unobscured by superficial debris and uncomplicated by slips and soil flow. In the clay formations the chances of finding such sections are not very good.

In Jameson Land the formations above the Vardekløft Formation are almost unknown. In the east, the attractive and easily accessible outcrops along the shore of Hurry Inlet have absorbed almost the entire attention of the expeditions which have visited the area, so that the younger rocks lying to the west have not been studied. The Kochs Fjeld Formation in the type area should be easy of access from Hurry Inlet *via* Hareelv (see fig. 2). Westward from the type locality it is likely that exposures deteriorate, but if Stauber is right in extending the outcrop northward to Olympen, study of the formation would be part of the programme of a party working in the interior of northern Jameson Land. Any information regarding the stratigraphical limits of the formation, and the sequence of its contained faunas, would be of great interest.

In Traill Ø the Black Series has yielded few fossils, and the known outcrops give little hope of extensive new finds. The fossils are all crushed, and considerable thicknesses of rocks are completely barren. The outcrops would be worth revisiting, in the hope of finding more certain Upper Oxfordian fossils, and of establishing the upper limit of the formation (see p. 46), if a party was in the area.

The remarks which have been made about the Yellow Series in the northern region apply equally to the later Jurassic formations. The Grey Series and Black Series of Wollaston Forland and neighbouring areas contain ammonites at a number of localities, but few identifications are available, and careful collecting is desirable. The Rigi Series also awaits further study, both at Laugeites Ravine in south-western Kuhn Ø, where the ammonite faunas urgently require elucidation (see p. 143), and in the outcrops on the mainland which have not yet yielded ammonites. The Laugeites Ravine section, and neighbouring exposures, are easy of access from Fligelys Fjord.

In Hochstetters Forland the Jurassic sediments, of probable Oxfordian or Kimeridgian age, have not yielded ammonites, but systematic mapping and collecting would probably produce information as to the stratigraphy and the palaeogeography of this area. It is unlikely that all the outcrops of Mesozoic rocks on the Forland have been discovered, and there may be discoveries to be made between the outcrops in the south, studied by Frebold (see p. 52), and the sediments of unproved age at Kap Oswald Heer. Much of the country is low-lying and exposures may be disappointing, but some evidence should be available, and this area remains one of the least-known Mesozoic regions of East Greenland.

Berriasian and Valanginian.

The fossils brought back by Aldinger from the Berriasian of southern Jameson Land, including the new ammonite genus *Hectoroceras*, are of the greatest interest, but practically nothing is known as to the stratigraphy of the lowest Cretaceous rocks here. Conditions are not very favourable for obtaining better information. The country is of low relief, and exposures, largely confined to the stream valleys, are separated by wide tracts of superficial deposits. Aldinger worked here for about a fortnight and produced a map (1935, pl. 2), which should be of help to future workers, but prospects for establishing a better succession should not be rated too high.

In Traill Ø the Berriasian (?) and Valanginian outcrops are small and the relationship of these rocks to other formations has not been observed, but it is doubtful whether much more information could be obtained except on the western slopes of the Mols Bjerge, in north-eastern Traill Ø, where a careful examination might improve knowledge of the Valanginian stratigraphy. Nothing is known as to the stratigraphical distribution of the large and interesting fauna which has been collected (p. 149), and an investigation should be worth while, although it is also possible that the desired information will be more easily obtained in Wollaston Forland. Systematic exploration of the western Mols Bjerge would not be difficult and the area is easily reached from the shore of Vega Sund at Kap Palander.

In Wollaston Forland interest centres principally on the section at the Niesen (p. 62), where a number of ammonite horizons in the Berriasian and Valanginian have already been discovered by Maync and by Standring. The chief need here is to try to find better-preserved fossils, especially in the Berriasian, for the study of the faunas is at present handicapped by the poor state of much of the material. When the ammonites have been studied the section will probably be an important addition to the rather meagre knowledge of Berriasian and Valanginian stratigraphy in the boreal regions.

In the country south of Albrechts Bugt, about 22 km south-east of the Niesen, the much thinner calcareous facies of the Valanginian has yielded a fauna which seems to be identical with that from Traill Ø, but little material has been collected. A detailed study of the exposures on Rødryggen would provide collections for study, and add to stratigraphical knowledge.

A Polyptychitid fauna is reported from Store Koldewey, but the Valanginian fossils from this island have never been described or figured, except for a few studied by Ravn (1911). If investigations are renewed there at any time, the collection of Valanginian fossils should be one of the objectives.

Aptian.

Only one Aptian fauna is well-known: the Upper Aptian assemblage from Store Koldewey described by Frebold (1935). In Traill Ø the poorly fossiliferous Aptian shales do not hold promise for further collecting, but in northern Hold with Hope the Lower Aptian localities discovered by Koch (p. 73) have received little attention since, and collecting here might yield results. In Wollaston Forland the Aucellabjerget fauna (p. 74) awaits attention, and there is also a possibility of finding fossils at some of the other localities described by Maync (1949), although in general the beds appear not to be very fossiliferous. In Wollaston Forland, also, a more accurate delimitation of the Aptian and Albian stages is needed, although in some of the poorly fossiliferous sections this may not be possible.

Albian and Cenomanian.

In Traill and Geographical Society Øer precise information as to the thickness and limits of the Albian and Cenomanian formations is lacking, but it cannot be said that there is much chance of improving on present knowledge. The shaly formations are badly exposed, and greatly disturbed by igneous intrusions. The most profitable area for continuing investigations would be Tværdal, in Geographical Society Ø, where a sandy marginal facies in the Cenomanian has yielded unusually well-preserved fossils. There is a possibility that a sandy facies may be developed here in other Cretaceous formations, with similar results. A visit devoted to a systematic search for exposures and to collecting would probably produce additions to the Cretaceous fauna.

In the Giesecke Bjerge very little is known about the Cretaceous sediments, which are assumed, on slender grounds, to be Albian (p. 79). The facies is similar to that of Traill and Geographical Society Øer, and by analogy with conditions in the islands it should be possible to find enough fossils to date the rocks. The finding of Upper Cretaceous rocks in the islands to the south, deposited on what is believed to be a continuation of the tectonic block of the Giesecke Bjerge, raises the hope that the formations may also occur in the latter area. Although Vischer and Maync accomplished important pioneer work here, there is a good chance of future discoveries.

Little is known about the Cretaceous sediments throughout the greater part of Hold with Hope. The area is unattractive, for much of the country is occupied by plateau basalts and the remainder is mantled by Quaternary deposits. Along the south coast the writer's observations in 1954 have shown that the igneous rocks descend to sea-level. In the interior, however, in the plain of Østersletten, a few Cretaceous outcrops are exposed along the streams, and a search for fossils in them, although it would be a tedious occupation, might yield information on the distribution of the Cretaceous formations between the Albian of Kap Broer Ruys and the Senonian of Knudshoved. The small outcrop of supposed Mesozoic sediments on the western shore of Loch Fyne (p. 93) also awaits another visit, and it is possible that more extensive sediments would be discovered here by a summer party.

The Inoceramus Beds or Aptian-Albian series were mapped in Clavering Ø, Wollaston Forland and Kuhn Ø by Maync and Vischer, but practically nothing is known of the fossil faunas except for the few identifications of cephalopoda published by Spath (1946). It is clear that many of the exposures are barren or poorly fossiliferous, as in Traill and Geographical Society Øer, and would not repay further attention.

A glance at the list on page 209 will reveal the sad state of our knowledge of the Albian fauna. Fairly abundant fossils have been found at some places, but the lithology is almost always shaly and the fossils crushed and fragmentary. A number of interesting genera, especially among the ammonites, have been recognised, but cannot be fully described on account of inadequate preservation. At present, the chances of finding better material do not seem to be good.

Turonian.

Although the information gained from the study of the poor exposures in Traill and Geographical Society Øer by the writer leaves much to be desired, there are few indications that better evidence could be obtained. There is a chance that the conglomeratic marginal facies of Maanedal may be found in the Svinhufvuds Bjerge, which have not yet been fully examined.

Senonian.

The rocks of presumed or known late Cretaceous date along the coast between Kap Farvel and Scoresby Sund have received comparatively little attention. The age of the Kap Gustav Holm Series is still unknown, as is that of the Infra-Basalt Sediments at Kap Brewster. Neither formation has yielded identifiable fossils, but a careful search might produce the desired evidence, and should be made if these areas are revisited at any time. In addition to the known outcrops, others may await discovery, for considerable areas of this part of East Greenland are geologically almost unknown.

The fossils available from the Sphenoceramus Beds of Traill and Geographical Society Øer, and from the Knudshoved Beds of Hold with Hope, are all indifferently preserved, but little hope can be entertained of finding better ones, or of establishing the field relationships of these formations. The question of the age of the Home Forland Beds is unresolved (p. 89), but should be answerable by fossil-collecting.

It would be of great interest to have more information about the Scaphites Beds, of Upper Campanian date, for comparison with West Greenland and with North America. Up to the present, the beds have not even been seen in place, and their existence is only known from fossils collected in screes. There will be little to be gained by revisiting the known occurrences, but there is a modest possibility of finding outcrops in north-eastern Geographical Society Ø, between Laplace Bjerg and Cambridge Bugt. This country, which is almost unknown geologically, is unattractive and wide areas are concealed by Quaternary deposits, but there are doubtless a few sections.

General Remarks.

Much of the pioneer work on the Jurassic and Cretaceous rocks up to 1939 was done in the spring or autumn, when almost all areas are easily accessible by sledge. There is a limit to the amount of information which can be obtained at these seasons, for country and exposures may be covered by snow. Detailed work in the future must be undertaken principally during the summer, when new discoveries and additional information may be expected from areas which have not been examined since the earlier expeditions. As a result of the information now available as to the location of the outcrops, the loss of mobility which results from working in the summer should not be too serious, and in many places should be compensated for by the better working conditions. The majority of Jurassic and Cretaceous areas can be worked from camps on the coast, set down by boat or aircraft. A few areas, notably the interior of Jameson Land, demand inland travelling, but with the development of supply from the air this should be possible in the summer. In due course, the use of helicopters as well as aircraft will doubtless revolutionise the exploration of areas which were formerly difficult of access.

XI. REFERENCES TO LITERATURE

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Appendix I.

INDEX OF FORMATION AND FACIES NAMES

WHICH HAVE BEEN APPLIED TO THE JURASSIC AND CRETACEOUS ROCKS OF EAST GREENLAND

The names are given in English form. The reference to the author of the name follows, with the original form, if the name was published in a language other than English, in brackets after it. The type locality, stratigraphical age, and geographical distribution follow, and reference is made to the pages in this work where further details may be found.

Albrechts Bugt Facies. Vischer, 1943, p. 88.

Type locality: The country south of Albrechts Bugt, Wollaston Forland.

Age: Middle Valanginian.

Geographical distribution: Northern Wollaston Forland, south-eastern Kuhn Ø.

Remarks: Maync maintains (1949, p. 185) that Vischer's Kuhnpas-Facies of the Valanginian should be regarded as synonymous with the Albrechts Bugt Facies. Vischer's Albrechts Bugt Facies included the red beds at the top removed into the Upper Valanginian by Maync (1949) as the Rødryggen Beds.

See page 66.

Amoebites Shales. Spath, 1935, p. 67 (diagram).

Type locality: Milne Land, between Kap Leslie and Charcot Bugt.

Age: Lower Kimeridgian.

Geographical distribution: Eastern Milne Land.

Remarks: The name was applied by Spath in his stratigraphic diagram to the lowermost 70 m of the shales succeeding the Pecten Sandstone, the top being marked by an oil shale horizon. The formation is a subdivision of the Kimeridgian Clays of the present writer (see p. 43). It was not mapped as a separate unit by Aldinger, but forms the lowest part of his 'Untere Kimeridgetone' (1935, pl. 3).

See page 43.

Black Series. Maync, 1940, p. 23 (Schwarze Serie).

Type locality: The series was first described from Clavering Ø, Wollaston Forland and Kuhn Ø. No particular type locality was specified.

Age: Lower Kimeridgian. In Traill Ø the series may include beds of Upper Oxfordian age.

Geographical distribution: The formation occurs in Traill Ø as well as in the type area.

See page 46.

Cardioceras Shales. Spath, 1935, p. 63.

Type locality: The country south and south-west of Charcot Havn, Milne Land.

Age: Upper Oxfordian.

Geographical distribution: Eastern Milne Land.

Remarks: Aldinger (1935) did not coin a formation name for this lithological unit, which comprises the shales between his Charcot Bugt Sandstone below and Pecten Sandstone above. It therefore seems desirable to adopt Spath's name for the beds, mapped as 'Oxfordtone' by Aldinger (1935, pl. 3), and referred to as 'Oxfordmergel' in his text (p. 57).

See page 42.

Charcot Bugt Sandstone. Aldinger, 1935, p. 54 (Charcotbucht Sandstein).

Type locality: The country south and south-west of Charcots Havn, Milne Land.

Age: Unproved, probably Oxfordian.

Geographical distribution: Eastern Milne Land.

Remarks: The sandstone appears to be succeeded conformably by the Upper Oxfordian Cardioceras Shales.

See page 41.

Falskebugt Beds. Maync, 1949, p. 55.

Type locality: Falkebjerg, north of Falskebugt in north-eastern Wollaston Forland.

Age: Maync regarded the age as Valanginian, on the basis of species of *Buchia* similar to those from known Valanginian beds. Spath (in a letter) had said that the fauna seemed to him Jurassic rather than Cretaceous. The facies is similar to that of the Rigi Series. See Maync, 1949, pp. 55—56.

Geographical distribution: North-eastern Wollaston Forland.

See page 70.

Fossil Mountain Formation. Rosenkrantz, 1929, p. 146.

Type locality: Fossil Mountain, north-eastern Jameson Land.

Age: Upper Bathonian(?) and Lower Callovian.

Geographical distribution: Central and northern Jameson Land.

Remarks: No detailed account of the type locality is available. The formation is the lateral equivalent of the Vardekløft Formation, in more sandy facies, and is probably to be regarded as synonymous with the Yellow Series, *q. v.*

See page 36.

Glauconitic Series. Aldinger, 1935, p. 62 (Glaukonitserie).

Type locality: The country north of Kap Leslie, Milne Land.

Age: Portlandian and uppermost Kimeridgian. See Spath, 1936, ch. iv.

Geographical distribution: Eastern Milne Land.

Remarks: This is the glauconitic beds of Rosenkrantz's Kap Leslie Formation (1929, p. 147). Note that the Glauconitic Series in Spath's diagram (1936, p. 149) is not the whole of the Series, the Sandy Shales which Spath separates from the top being included in the Series by Aldinger.

See page 54.

Grey Series. Maync, 1947, p. 7 (Graue Serie).

Type locality: The series was described from western Wollaston Forland and western Kuhn Ø. No particular type locality was specified.

Age: Upper Oxfordian.

Geographical distribution: Wollaston Forland and Kuhn Ø.

Remarks: The formation was described by Maync (1947, p. 7) as a transition (übergangszone) between the Yellow Series and the Black Series. The considerable gap in the ammonite faunas, however (Middle and Upper Callovian and Lower Oxfordian), suggests that there must have been a hiatus in sedimentation (see page 108), although no disconformity has been detected.

See page 47.

Hartz Fjeld Formation. Rosenkrantz, 1929, p. 149.

Type locality: Hartz Fjeld, north of Kap Leslie, Milne Land.

Age: Portlandian(?).

Geographical distribution: Eastern Milne Land.

Remarks: The formation was defined by Rosenkrantz as "a series, about 180 meters thick, devoid of marine horizons" overlying his Kap Leslie Formation. This seems to be the same as the "Undated sandstones with plant remains (180 m ?)" at the top of Spath's section (1936, p. 149), and is presumably equivalent to the upper part of Aldinger's Hartzfjeld Sandstone (1935, p. 51), but if so Rosenkrantz obtained a much exaggerated thickness for the latter formation. Note that Rosenkrantz's Hartz Fjeld Formation and Aldinger's Hartzfjeld Sandstone are not synonymous.

See page 56.

Hartzfjeld Sandstone. Aldinger, 1935, p. 65 (Hartzfjeldsandstein).

Type locality: Hartz Fjeld, north of Kap Leslie, Milne Land.

Age: Portlandian and Berriasian.

Geographical distribution: Eastern Milne Land.

Remarks: The formation is equivalent to part of the Kap Leslie Formation of Rosenkrantz, and the upper part is probably the Hartz Fjeld Formation of the same author. It comprises all the sediments in Milne Land above the Glauconitic Series.

See page 55.

Hectoroceras Beds. Spath, 1947, p. 48.

Type locality: Neighbourhood of Hesteelv, "Mussel" and "Rauk" rivers, southern Jameson Land.

Age: Berriasian.

Geographical distribution: Southern Jameson Land.

Remarks: Not a lithological unit, but the beds in the succession characterised by *Hectoroceras*; see Spath, 1947, fig. 8, p. 49.

See page 61.

Home Forland Beds. Maync, 1949, p. 137.

Type locality: The north coast of Home Forland, Hold with Hope.

Age: Senonian (probably Upper Santonian or Lower Campanian).

Geographical distribution: Home Forland.

Remarks: The age of these beds, suggested by Frebold (1934), was questioned by Maync (1949, p. 212), but the present writer accepts Frebold's interpretation (Donovan, 1953, p. 53).

See page 89.

Infra-Basalt Sediments. Hassan, 1953, p. 10.

Type locality: Bopladsdalen, about 8 km west-southwest of Kap Brewster.

Age: Unknown, possibly Upper Cretaceous.

Geographical distribution: Known only from the type locality.

See page 91.

Inoceramus Beds. Maync, 1938, p. 13 (Inoceramenschichten).

Type locality: None specified. Typically developed in the area between 74° and 75° N. Lat.

Age: Aptian and Albian.

Geographical distribution: Clavering Ø, Wollaston Forland and Kuhn Ø.

Remarks: Maync did not use this term generally, and more often referred to the beds as the 'Aptian-Albian series'. In parts of his discussion, however, he uses '*Inoceramus* Beds' (e. g. Maync, 1949, p. 212). The term is useful for his 'Aptian-Albian' series, often not more exactly dateable.

See pages 74, 82.

Inoceramus lamarcki Beds. Donovan, 1954, p. 4.

Type locality: Rold Bjerge, Traill Ø.

Age: Upper Turonian and possibly lowermost Senonian.

Geographical distribution: North-eastern Traill Ø and eastern Geographical Society Ø.

See page 86.

Kangerdlugssuaq Sedimentary Series. Wager, 1934, p. 25.

Type locality: Country east of Kangerdlugssuaq, south-east Greenland.

Age: Senonian (probably Upper Santonian or Lower Campanian) and possibly Eocene.

Geographical distribution: Known only from the type area.

Remarks: The series comprises a lower, marine part, proved to be Cretaceous, and an upper, plant-bearing division possibly of Eocene date.

See page 86.

Kap Gustav Holm Series. Wager, 1934, p. 22.

Type locality: Kap Gustav Holm, south-east Greenland.

Age: Unknown, probably either Cretaceous or Tertiary.

Geographical distribution: Known only at the type locality.

See page 90.

Kap Hamburg Formation. Koch, 1929a, p. 256.

Type locality: The east coast of Kuhn Ø north of Kap Hamburg.

Age: Middle Valanginian.

Geographical distribution: Wollaston Forland, Kuhn Ø and Store Koldewey.

Remarks: Koch (1929, p. 256) described the formation as a coarse clastic series, but as interpreted by the type locality the name ought to be applied to the thin, calcareous "Albrechts Bugt Facies" of the Valanginian. On account of the refinements of Valanginian stratigraphy which have taken place since the name was proposed in 1874, and the fact (mentioned by Maync, 1949, p. 16) that the term has never become popular, it is probably better not to employ the name "Kap Hamburg Formation" at the present day.

Kap Leslie Formation. Rosenkrantz, 1929, p. 147.

Type locality: Kap Leslie, Milne Land.

Age: Upper Kimeridgian and Portlandian.

Geographical distribution: Eastern Milne Land.

Remarks: It is difficult to interpret Rosenkrantz's definition in terms of the later and more detailed accounts of the Milne Land succession by Aldinger (1935) and Spath (1935, 1936). The Kap Leslie Formation appears to include the Glauconitic Series, some beds below it, and the Hartzfjeld Sandstone of Aldinger (1935, pp. 51, 53), but as the name was not used or even mentioned by Aldinger or Spath it seems best to allow it to remain disused.

Kap Leslie Sandstone. Bay, 1895, p. 162.

Type locality: Kap Leslie, Milne Land.

Age: Portlandian.

Geographical distribution: Milne Land.

Remarks: According to Rosenkrantz (1929, p. 148) the formation is the uppermost part of his Kap Leslie Formation; that is, the uppermost part of the Hartzfjeld Sandstone of Aldinger.

Kap Maurer Formation. Koch, 1929, p. 256.

Type locality: Coast south of Kap Maurer, eastern Kuhn Ø.

Age: Upper Kimeridgian.

Geographical distribution: Eastern Kuhn Ø.

Remarks: Koch, when he described this formation, thought it to be Middle Portlandian. Maync (1947, p. 38) claimed that Koch's Kap Maurer Formation was Upper Kimeridgian, but rejected the term as he thought it might be misleading, Kap Maurer itself being composed of Cretaceous rocks and the Jurassic only being exposed some kilometres to the south. Maync's Kuhn Series is equivalent to the Kap Maurer Formation.

See page 50.

Kap Stewart Formation. Koch, 1929a, p. 251.

Type locality: Kap Stewart, at the south-western end of Hurry Inlet, Jameson Land.

Age: Rhaetian and Hettangian.

Geographical distribution: The formation occurs in a north-south outcrop in eastern Jameson Land and the characteristic fossil flora has been found in the Pictet Bjerge, in Scoresby Land. The formation has not been detected north of Kong Oscars Fjord.

Remarks: A non-marine formation with abundant and well-preserved flora at certain horizons and localities, monographed by Harris (1926, 1931, 1931a, 1932, 1935, 1937, 1946).

See page 23.

Kimeridgian Clays. New name (see p. 43).

Type locality: The country between Kap Leslie and Charcots Havn, Milne Land.

Age: Kimeridgian.

Geographical distribution: Eastern Milne Land.

Remarks: It is convenient to have a name for the important series of clays, about 240 m thick, between the Pecten Sandstone below, and the Glauconitic Series above, in Milne Land. They are referred to merely as 'Unteres Kimmeridgian' and 'Oberes Kimmeridgian (Liegender Teil)' by Aldinger, and mapped by him as 'Untere Kimeridgetone' and 'Obere Kimeridgetone' (1935, pp. 59—62, pl. 3). Spath's Amoebites Shales, Pectinatites Beds and Pallasiceras Beds form part of this formation.

See page 43.

Kløft I Formation. Koch, 1929a, p. 254.

Type locality: Kløft I, Store Koldewey.

Age: Upper Oxfordian and Lower Kimeridgian.

Geographical distribution: Store Koldewey.

Remarks: Spath (1935, p. 69) employed this name for the post-Callovian beds in Jameson Land, but it is here restricted to the development in Koldewey Ø.

See page 53.

Knudshoved Beds. Maync, 1949, p. 144.

Type locality: The country around the Danish hut 4 km south-west of the headland Knudshoved, Hold with Hope.

Age: Senonian (Upper Santonian or Lower Campanian).

Geographical distribution: Known only at the type locality.

See page 88.

Kochs Fjeld Formation. Rosenkrantz, 1929, p. 147.

Type locality: J. P. Kochs Fjeld in south-eastern Jameson Land.

Age: Lower Kimeridgian.

Geographical distribution: Jameson Land, southern part.

Remarks: The name was originally applied by Rosenkrantz to unfossiliferous shales and sandstones overlying his "Fossil Mountain Formation" at J. P. Kochs Fjeld. The Fossil Mountain Formation is now known to be of Callovian age, and the term Kochs Fjeld Formation is adopted for the Lower Kimeridgian beds which overly the Callovian in Jameson Land. (See Aldinger, 1935, pp. 26, 36, and Spath, 1935, p. 69).

See page 44.

Kuhn Beds. Maync, 1947, p. 8 (Kuhn-Schichten).

Type locality: Sections in the vicinity of Perisphinctes Ravine, south-eastern Kuhn Ø.

Age: Upper Kimeridgian, lower part.

Geographical distribution: South-eastern Kuhn Ø, possibly Wollaston Forland.

Remarks: Proposed as a substitute name for Koch's Kap Maurer Formation (*q. v.*), which Maync considered unsuitable on account of the distance of the outcrops from Kap Maurer.

See page 52.

Kuhnpasset Facies. Vischer, 1943, p. 87 (Kuhnpas-Facies).

Type locality: Kuhnpasset in western Wollaston Forland.

Age: Middle Valanginian.

Geographical distribution: Western Wollaston Forland.

Remarks: Vischer distinguished this facies from the Albrechts Bugt Facies of the Valanginian on the grounds that it was thicker and was deposited in deeper water. Maync denies the second distinction and maintains that the term should be regarded as synonymous with "Albrechts Bugt Facies" (Maync, 1949, p. 185). Maync also maintains that Vischer probably included Aptian strata in the beds referred by him to the Kuhnpasset Facies.

Lindemanns Bugt Facies. Vischer, 1943, pp. 87, 88.

Type locality: No type locality was mentioned by Vischer. The facies is developed in north-western Wollaston Forland and western Kuhn Ø, to the north and south of 'Lindemans Bugt'. The latter name is not marked on the Geodetic Institute map at 1-250,000, but is shown by Vischer (pl. 1, etc.).

Age: Portlandian.

Geographical distribution: North-western Wollaston Forland, western Kuhn Ø.

Remarks: The name was proposed by Vischer for the coarse, often rudaceous facies of the Middle Valanginian, but Maync subsequently

(1949, p. 186) claimed that the beds referred to by Vischer were, in fact, of Volgian (Portlandian) age. Maync used Young Sund Facies (*q.v.*) for the clastic facies of the Valanginian.

Lower Niesen Beds. See Niesen Beds.

Middle Cretaceous Shale Series. Donovan, 1953, p. 148.

Type locality: Eastern Traill Ø.

Age: Albian and Lower Cenomanian.

Geographical distribution: Eastern Traill and Geographical Society Øer.

Remarks: The base of the series is unconformable and transgressive, and varies in age from Lower Albian to Lower Cenomanian.

See page 78.

Muschelbjerg Formation. New name.

Type locality: The Muschelbjerg, Hochstetters Forland.

Age: Probably Kimeridgian.

Geographical distribution: Known for certain only at the type area: the equivalence of other Mesozoic sediments on Hochstetters Forland with the formation is unproved.

Remarks: The series is partly non-marine, with coal seams, but also includes marine horizons.

See page 52.

Neill Klinter Formation. Rosenkrantz, 1929, p. 143.

Type locality: Neill Klinter (Neills Cliff) on the west side of Hurry Inlet, Jameson Land.

Age: Pliensbachian and Toarcian.

Geographical distribution: South-eastern Jameson Land. Said by Koch (1929, p. 252) to extend as far north as the head of Carlsberg Fjord. Also at Kap Hope in southernmost Liverpool Land.

Remarks: Extensive fossil lists were published by Rosenkrantz, 1934, including some new species, but the fauna has not been fully described. For occurrences at Kap Hope see Rosenkrantz, 1942.

See page 27.

Niesen Beds. Maync, 1947, p. 64 (Niesen-Schichten).

Type locality: The mountain 'Niesen' (point 688 m on the Geodetic Institute map), north-western Wollaston Forland.

Age: Berriasian and Valanginian.

Geographical distribution: Wollaston Forland, Clavering Ø and Kuhn Ø.

Remarks: Divided on palæontological grounds into Lower Niesen Beds, of Berriasian age, and Upper Niesen Beds, with Valanginian fossils. There is, however, no lithological break. See Maync, 1949, pp. 95—101 for detailed description of the type locality.
See pages 62, 68.

Pachyteuthis Beds. Donovan, 1953, p. 32.

Type locality: Bjørnedal, Traill Ø.

Age: Berriasian or Valanginian.

Geographical distribution: Eastern Traill Ø.

Remarks: Characterised by *Pachyteuthis ('Acroteuthis')* aff. *partneyi* (Swinnerton) and *Buchia.* No ammonites have been found in these beds, and the dating is subject to revision.
See page 62.

Pallasiceras Beds. Spath, 1936, p. 149 (diagram) (Pallasiceras Nodules of ch. iv.).

Type locality: Milne Land, between Kap Leslie and Charcot Havn.

Age: Upper Kimeridgian.

Geographical distribution: Eastern Milne Land.

Remarks: Spath used this term for the uppermost part of the Upper Kimeridgian clays of the Milne Land succession, characterised by the ammonite *Pallasiceras*, and said to be 'sandy clays, with layers of nodules'. It is doubtful whether the subdivision could be used in the field. The uppermost part of the Kimeridgian Clays of the present writer (see p. 43) and of the 'Obere Kimmeridgetone' of Aldinger (1935, pl. 3).
See page 44.

Pecten Sandstone. Aldinger, 1935, p. 58 (Pecten-Sandstein).

Type locality: The country south-west of Charcot Havn, Milne Land.

Age: Upper Oxfordian.

Geographical distribution: Eastern Milne Land.
See page 43.

Pectinatites Beds. Spath, 1936, p. 149 (diagram), ch. iv.

Type locality: The country between Kap Leslie and Charcot Havn, Milne Land.

Age: Upper Kimeridgian.

Geographical distribution: Eastern Milne Land.

Remarks: The term was used by Spath for part of the Kimeridgian Clays characterised by *Pectinatites*, but the formation is not well distinguished lithologically from the rest of the clays. There is said to be a band of indurated shales at the base. The formation forms part of the Kimeridgian Clays of the present writer (see p. 43), and of the 'Obere Kimmeridgetone' of Aldinger (1935, pl. 3).

See page 44.

Rigi Series. Maync, 1947, pp. 9, 133 (Rigi-Serie).

Type locality: The mountain 'Rigi', Wollaston Forland.

Age: Portlandian(?).

Geographical distribution: Clavering Ø and Wollaston Forland. There is a coarse, marginal facies in southern Kuhn Ø.

See page 58.

Rødryggen Beds. Maync, 1949, p. 72.

Type locality: Rødryggen (*i. e.* Red Ridge) in northern Wollaston Forland. The feature is not named in the Geodetic Institute 1:250,000 map but is shown in Maync's map (1949, pp. 42—43).

Age: Presumed to be Valanginian. See remarks, below.

Geographical distribution: Northern Wollaston Forland, southeastern Kuhn Ø.

Remarks: Maync regarded these beds as Upper Valanginian, and stated that there is a transition to them from the underlying beds, of proved Middle Valanginian age. The age is not yet proved by fossils, but *Buchia* and belemnites were found which would presumably give an indication; determinations have not been published.

See page 70.

Scaphites Beds. Donovan, 1955, p. 37.

Type locality: Rold Bjerge, Traill Ø (locality 58: Donovan, 1953, p. 44).

Age: Upper Campanian.

Geographical distribution: Rold Bjerge, Traill Ø, and northeastern Geographical Society Ø.

Remarks: Not known *in situ.* The characteristic ammonoid is *Scaphites greenlandicus* Donovan, a species allied to *S. roemeri* d'Orbigny.

See page 90.

Sphenoceramus Beds. Donovan, 1953, p. 43.

Type locality: Rold Bjerge, Traill Ø.

Age: Upper Santonian or Lower Campanian.

Geographical distribution: Eastern Traill and Geographical Society Øer.

See page 88.

Trækpas Formation. Koch, 1929a, p. 253.

Type locality: Trækpasset, in the southern part of Store Koldewey.

Age: Lower Callovian.

Geographical distribution: Eastern side of Store Koldewey island. The beds of approximately equivalent age in Kuhn Ø and near Tyroler Fjord, included in the formation by Koch (1929a, p. 253), probably belong to the Yellow Series.

Remarks: Koch attributed this formation name to Ravn's publication of 1911, but Ravn did not propose a formation name for the Callovian beds of Koldewey, this being done by Koch.

See page 40.

Upper Niesen Beds. See Niesen Beds.

Vardekløft Formation. Rosenkrantz, 1929, p. 145.

Type locality: The Vardekløft, a ravine cutting Neill Klinter, on the west side of Hurry Inlet, Jameson Land.

Age: Upper Bathonian and Lower Callovian.

Geographical distribution: South-eastern Jameson Land. Northwards (in the region west of Carlsberg Fjord) the formation passes laterally into the more sandy Yellow Series, via the "Fossil Mountain Formation".

Remarks: The Fossil Mountain Formation, named by Rosenkrantz who believed it to be Oxfordian in age, has been shown by Spath (1932, p. 124) to be the lateral equivalent of the Vardekløft Formation; it is regarded by the present writer as a transition from the argillaceous Vardekløft Formation to the arenaceous Yellow Series.

The limits and correlation of the Vardekløft Formation have been discussed by Spath, 1932, who described the extensive ammonite fauna; see also Donovan, 1953, pp. 130—133.

See page 32.

Yellow Series. Maync, 1940, p. 21 (Gelbe Serie). ("Gelbe Sandstein Serie" of Frebold, 1932, p. 21).

Type locality: The formation was first described in the area of Clavering Ø, Wollaston Forland and Kuhn Ø. There is no type section.

Age: Upper Bathonian and Lower Callovian.

Geographical distribution: This sandy facies of the Lower Callovian can be traced north to Store Koldewey, where it has been called the Trækpas Formation, and south into Jameson Land as far as the head of Carlsberg Fjord, where it has been called the Fossil Mountain Formation; see Maync (1947, p. 149) and Donovan (1953, p. 46).

Remarks: On the grounds of priority it might be claimed that the term "Fossil Mountain Formation" or "Trækpas Formation" should be used for this series. Neither of these names, which happen to have been applied to the extreme northern and southern parts of the outcrop, has ever been used in a more general sense, and there are advantages in Maync's purely descriptive name "Yellow Series" for the sandy facies of the Callovian, wherever developed. The earlier names may be retained for use in their original local sense, if desired.

See page 37.

Young Sund Facies. Maync, 1949, p. 185, etc.

Type locality: There is no type locality.

Age: Middle Valanginian.

Geographical distribution: Western Wollaston Forland.

Remarks: This name was applied by Maync to the coarse clastic, often rudaceous, facies of the Middle Valanginian, in contrast to the thin, calcareous Albrechts Bugt Facies.

See page 66.

Appendix II.

FOSSIL LISTS FROM THE JURASSIC AND CRETACEOUS OF EAST GREENLAND

The following lists have been compiled from the literature, and no attempt has been made to re-examine the original collections, for while this would doubtless have produced more reliable results, publication would have been unduly delayed. As far as was possible the nomenclature has been revised, and identifications by previous authors checked, but in cases where figures were not given it has naturally been impossible to confirm identifications. The result is that the lists are not entirely consistent, but it seemed preferable to revise as far as possible than to leave a number of old-fashioned or invalid names. Changes of specific names used by earlier authorities have usually been noted in parentheses after the entry. Changes in generic name have not usually been noted.

Not all the records embodied in the lists are of equal value, ranging as they do from identifications by specialists who have monographed some of the fossil faunas, to those merely published in faunal lists of assemblages which have not been fully studied. It is not possible to indicate the reliability of the identifications, but a number which were so imprecise as to be little value have been omitted.

The references for each stage indicate the works from which records have been extracted, and will enable the user to trace descriptions and illustrations, where these exist. A few notes have been provided.

Rhaetian and Hettangian.

(Kap Stewart Formation).

Since the extensive flora from this formation is described in a single monograph (Harris, 1932—37), with a few later additions (Harris, 1946), it has seemed unnecessary to take up space by reprinting the floral list here. Animal fossils from the formation are very few and comprise the following (Harris, 1937, p. 74, & Stauber, 1940, p. 19):

Estheria sp. cf. *minuta*.
Gyrolepis sp.
Hybodus sp.
Insect wings.
Todites sp.
Unnamed gastropoda.
Unnamed lamellibranchia.

Lower Pliensbachian.

(Neill Klinter Formation, basal beds).

Cephalopoda (Rosenkrantz, 1934).

Androgynoceras sp.
?*Beaniceras* sp.
Lytoceras fimbriatum (J. Sowerby).
Uptonia jamesoni (J. de C. Sowerby).
Hastites? sp.
Passaloteuthis cf. *apicurvata* (de Blainville).
Prototeuthis cf. *pennicillata* (Dumortier).

Brachiopoda, Gastropoda and Lamellibranchia.

Rosenkrantz (1934, pp. 111—114) listed a large number of brachiopod, gastropod and lamellibranch species, including some said to be new. Apart from a limited number of specimens figured by Lundgren (1895), some of which are too imperfect for identification, the fauna has never been figured or described, and it is not possible to revise Rosenkrantz's list. For this reason, and in order to economise in space, it is not reprinted here. One species was described by Rosenkrantz (1956).

Toarcian.

(Neill Klinter Formation, upper part).

Cephalopoda (Rosenkrantz, 1934).

Catacoeloceras sp.
Dactylioceras groenlandicum Rosenkrantz.
Pseudolioceras aff. *compactile* (Simpson).
— cf. *lythense* (Young & Bird) (*P.* sp. nov., Rosenkrantz, 1934, pl. 6, fig. 3).
— cf. *whitbiense* S. S. Buckman (*P. dumortieri*, Rosenkrantz, 1934, pl. 6, fig. 2).
Megateuthis aff. *conoidea* (Oppel).
— cf. *quenstedti* (Oppel).
— *rhenana* (Oppel).
Passaloteuthis cf. *subaduncata* (Voltz).

Brachiopoda, Gastropoda and Lamellibranchia.

Rosenkrantz (1934, pp. 116—118) listed 5 species of brachiopoda, 3 of gastropoda and 43 of lamellibranchia, including many new species which were not described. In order to economise in space the list is not reprinted here. The fauna has never been systematically published.

Crustacea (van Straelen, 1929).

Glyphea rosenkrantzi van Straelen.
Glyphea sp.

Upper Bathonian and Lower Callovian.

(Vardekløft Formation, Yellow Series, Traekpas Formation).

References: Ravn, 1911; Spath, 1932; Maync, 1947; Donovan, 1953; Muir-Wood, 1953; Donovan, 1955. Fossils recorded by Toula, 1874 (see Maync, 1947, p. 12) have not been included on account of the impossibility of verifying the identifications.

Note: The numerous varieties of ammonites named by Spath (1932), and a few by the writer (1953, pp. 81—83) are not included in the list.

Cephalopoda.

Pompeckji Zone.

Cranocephalites furcatus Spath.
— *gracilis* Spath.
— *inconstans* Spath.
— *inversus* Spath.
— *kochi* Donovan.
— *maculatus* Spath.
— *parvus* Donovan.
— *pompeckji* (Madsen).
— *subbullatus* Spath.
— *subextremus* Spath.
— *vulgaris* Spath.
'*Xenocephalites*' *borealis* Spath (horizon uncertain).

Nudus Zone.

Arcticoceras (?) *platynotus* (Spath).
Arctocephalites elegans Spath.
— *greenlandicus* Spath.
— *nudus* Spath.
— *ornatus* Spath.
— *sphaericus* Spath.

Kochi Zone.

Arcticoceras michaelis Spath.
— *pseudolamberti* Spath.
— sp. (*A. kochi* pars, Spath, 1932, pl. 12, figs. 1a—c).
Arctocephalites kochi (Spath).
Cadoceras aff. *frearsi* (d'Orbigny) (horizon uncertain).
— *pseudishmae* Spath.
— *simulans* Spath (horizon uncertain).

Tychonis Zone.

Note: Under this heading have been included all the ammonites found in the horizon of calcareous concretions in Jameson Land, which may be a condensed deposit (Spath, 1932, pp. 124—26: Donovan 1953, p. 131).

Cadoceras calyx Spath.
— *crassum* (Madsen).
— *dubium* Spath.
— *franciscus* Spath.
— *freboldi* Spath.
— *variabile* Spath.
— *victor* Spath.
Kosmoceras (*Gulielmiceras*) *pauper* Spath.
Paracadoceras ammon Spath.
Seymourites antiquus Spath.
— *nobilis* Spath.
— *peramplus* Spath.
— *rosenkrantzi* Spath.
— *svalbardensis* Sokolov & Bodylevsky.
— *traillensis* Donovan.
— *tychonis* (Ravn).

Not restricted to one zone:

Cylindroteuthis subextensa (Nikitin).
— *subrediviva* (Lemoine).

Lamellibranchia.

Astarte ovata Wm. Smith.
— *squamula* (d'Archiac).
— sp. indet. cf. *elegans* (J. Sowerby).
Camptonectes giganteus Arkell.
— *rigidus* (J. Sowerby).
?*Cercomya* sp. juv. (*Anatina* sp. juv., Spath, 1932, p. 121).
Entolium corneolum (Young & Bird) (*E. demissum*, Ravn, 1911, p. 463 and Spath, 1932, p. 112).
Exogyra cf. *reniformis* (Goldfüss).
Goniomya literata (J. Sowerby) (*G. v-scripta*, Spath, 1932, p. 120).
Gresslya peregrina (Phillips).
Homomya sp. indet.
Inoceramus aff. *ambiguus* Eichwald.
— *retrorsus* Keyserling.
Isognomon sp. (*Perna* aff. *rugosa*, Maync, 1947, p. 19).
Lima sp. indet.
Liostrea? sp. indet.
Mactromya aceste (Cottreau ex d'Orbigny).
Meleagrinella cf. *lycetti* (Rollier) (*Pseudomonotis braamburiensis* Sow., Frebold, 1932b, p. 22).
Meleagrinella aff. *doneziana* Borissjak (*Pseudomonotis*, Spath, 1932, p. 105).
Modiolus sp. indet. cf. *bipartitus* (J. Sowerby).
Nucula sp. indet. (age doubtful: see Donovan, 1953, p. 26).
Osteomya dilata (Phillips) (age doubtful: see Donovan, 1953, p. 26).
Ostrea (*Liostrea*) ?*erina* (Thevenin ex d'Orbigny) (age doubtful: see Donovan, 1953, p. 26).
Oxytoma cf. *expansum* (Phillips).
— cf. *inaequivalve* (J. Sow.) (*O. inaequivalvis* var. *macroptera*, Ravn, 1911, p. 454).

Parallelodon keyserlingi (d'Orbigny).
Pholadomya aff. *aequalis* (J. de C. Sowerby).
— cf. *angustata* (J. Sowerby).
Pinna lanceolata J. Sowerby (*P. sublanceolata* Spath, 1932, p. 108).
Pleuromya aff. *burnsi* Warren.
— cf. *calceiformis* (Phillips).
— *uniformis* (J. Sowerby) (*P. decurtata*, Spath, 1932, p. 117).
— sp. (?*uniformis* (J. Sowerby)) (*P. securiformis*, Spath, 1932, p. 118).
Posidonia ornati Quenstedt.
Protocardia aff. *lycetti* Rollier (*P.* aff. *subtrigona*, Spath, 1932, p. 116).
— cf. *stricklandi* (Morris & Lycett).
Pseudolimea duplicata (J. de C. Sowerby) (age doubtful; see Donovan, 1953, p. 26).
Rosenbuchia? sp. indet.
Tancredia jarneri Ravn.
— *planata* Morris & Lycett.
— cf. *subcurtansata* Lycett? (*T.* cf. *curtansata* Phill., Maync. 1947, p. 18).
Trigonia sp. indet.
Velata sp. indet.

Gastropoda.

Amberleya groenlandica Ravn.
'*Chemnitzia*' sp. nov.?
Katosira cf. *hamptonensis* (Morris & Lycett)? (*Chemnitzia* cf. *hamptonensis* Maync, 1947, p. 84).
Natica sp. nov.? aff. *chauviniana* d'Orbigny.
Procerithium spp. indet.

Brachiopoda.

Lingula beani Phillips.
Orbiculoidea reflexa (J. de C. Sowerby).
'*Rhynchonella*' cf. *atla* Oppel.
— cf. *triplicosa* Quenstedt.
'*Terebratula*' sp. (Muir-Wood, 1953, pl. 1, fig. 8).

Cirripedia.

Eolepas sp. nov. aff. *bathonica* Withers.

Annelida.

Ditrupa nodulosa Lundgren.

Upper Oxfordian and Lower Kimeridgian.

(Cardioceras Shales, Pecten Sandstone, Kimeridgian Clays (lower part), Black Series, Grey Series, Kløft I Formation).

References: Ravn, 1911; Spath, 1935; Maync, 1947; Donovan, 1953.

Cephalopoda.

(O = Upper Oxfordian, K = Lower Kimeridgian)

K *Amoeboceras* (*Amoebites*) *elegans* Spath.
K — — *irregulare* Spath.
K — — cf. *kitchini* (Salfeld).
K — — *pseudacanthophorum* Spath.
K — — *subkitcheni* Spath.
O — (*Amoeboceras*) cf. *alternans* (von Buch) (*Cardioceras alternans*, Ravn, 1911, pl. 36, figs. 1—3).
O — — cf. *ovale* (Quenstedt) (*Cardioceras Nathorsti* Lundgren, Ravn, 1911, pl. 35, fig. 10, and *Amoeboceras marchense* Spath, 1935, p. 17).
K — (*Euprionoceras*) *kochi* Spath.
K — — ? *aldingeri* Spath.
K — (*Hoplocardioceras*) *decipiens* Spath.
O — (*Prionodoceras*) aff. *alternoides* (Nikitin).
O — — aff. *pseudocaelatum* Spath.
O — — cf. *ravni* Spath (*Cardioceras* sp., Ravn, 1911, pl. 25, fig. 11; the inner whorls in Ravn's specimen seem to have been damaged).
O — — *rosenkrantzi* Spath.
O — — aff. *superstes* (Phillips).
O — — *transitorium* Spath.
K — — ? *prorsum* Spath.
K *Aulacostephanus groenlandicus* Ravn.
O *Cardioceras* (*Subvertebriceras*) *caelatum* Pavlov.
O — — aff. *zenaidae* Ilovaisky.
K *Pictonia* sp. indet. (Spath, 1935, pl. 14, fig. 4).
K *Rasenia borealis* Spath.
K — *inconstans* Spath.
K — *orbignyi* (Tornquist).
O *Ringsteadia* sp. indet. (Spath, 1935, pl. 9, fig. 2).
Cylindroteuthis sp. nov.? (Spath, 1935, p. 50).
Pachyteuthis aff. *panderiana* (d'Orbigny).

Lamellibranchia.

Astarte alta (Ravn).
— *contejeani* de Loriol (= *A. phillis* d'Orb.) (*A. striatocostata*, Ravn, 1911).
— *extensa* (Phillips).
'*Astarte*' *retrotracta* Rouillier.
Buchia concentrica (J. de C. Sow.).
— *kirghisensis* (Sokolov).
— *sinzovi* (Pavlov).
Camptonectes broenlundi (Ravn).
— aff. *lens* (J. Sow.).
Exogyra nana (J. Sow.).
Entolium corneolum (Young & Bird).

Goniomya sp.
Isognomon groenlandicus (Ravn).
Lima (*Plagiostoma*) cf. *mutabilis* Arkell.
Lucina substriata Römer?
Meleagrinella sp. indet.
Modiolus strajeskianus (d'Orbigny).
Parallelodon keyserlingii (d'Orb.).
Pinna aff. *lanceolata* (J. Sow.).
Pleuromya cf. *tellina* (Agassiz).
— *uniformis* (J. Sowerby) (*P. peregrina* d'Orb., Ravn, 1911).
Pronoella (?*Eocallista*) sp. cf. *P. ravenscarensis* Cox (*Cyprina kharoschovensis* & *C. Syssollae* of Ravn, 1911).
Protocardia sp.
Tancredia angulata Lycett (*T. axiniformis* Phillips, Ravn, 1911).
— aff. *curtansata* (Phillips) (*T. curtansata* Ravn, 1911).
— *jarneri* Ravn.
— aff. *planata* Morris & Lycett.

Gastropoda.

Katosira hamptonensis (Morris & Lycett).
Nerinella (?) cf. *stricklandi* (Morris & Lycett) (*Turritella* sp., Ravn, 1911, pl. 35, figs. 5a, b).
Pseudomelania (?) *undulata* (Tullberg).

Scaphopoda.

Dehtalium nodulosum Lundgren.

Brachiopoda.

'*Rhynchonella*' sp. (Ravn, 1911, p. 453).
'*Terebratula*' sp. (Ravn, 1911, p. 453; Frebold, 1933, p. 23, pl. 3, figs. 20, 20a).

Ophiuroidea.

Ophiurites sp. indet. (Spath, 1935, pl. 11, fig. 2).

Annelida.

Serpula cf. *lacerata* Phillips.

Upper Kimeridgian.

(Kimeridgian Clays, upper part).

Reference: Spath, 1936. All these records are from Milne Land; no account of the fauna of the Upper Kimeridgian of Kuhn Ø (Kap Maurer Formation) has been published.

Cephalopoda.

Dorsoplanites aldingeri Spath.
— *antiquus* Spath.

Dorsoplanites crassus Spath.
— *dorsoplanoides* Spath.
— *flavus* Spath.
— *jamesoni* Spath.
— *subpanderi* Spath.
— *transitorius* Spath.
— *triplex* Spath.
Pavlovia allovirgatoides Spath.
— *communis* Spath.
— *inflata* Spath.
— *jubilans* Spath.
— *kochi* Spath.
— *perinflata* Spath.
— *regularis* Spath.
— *rugosa* Spath.
— *similis* Spath (age doubtful).
— *subaperta* Spath.
— *variabilis* Spath.
— ? *alterneplicata* Spath.
Pectinatites cf. *boidini* (de Loriol).
— aff. *devillei* (de Loriol).
— aff. *eastlecottensis* (Salfeld).
— *groenlandicus* Spath.
— aff. *tricostulatus* (Buckman).
Pachyteuthis aff. *panderiana* (d'Orb.).

Lamellibranchia.

Anomia? (*Placunopsis*?) sp. indet. (Spath, 1936, pl. 10, fig. 3a).
Buchia mosquensis (von Buch).
'*Lucina*' sp. nov. aff. *inaequalis* d'Orb.
Ostrea bononiae Sauvage.
Parallelodon schourovskii (Rouillier).
— sp. nov.? aff. *keyserlingi* (d'Orb.).
Pseudisocardia? sp. indet. (Spath, 1936, pl. 48, figs. 9a, b).

Gastropoda.

'*Turritella*' sp. indet. (Spath, 1936, pl. 39, figs. 8a, b).

Brachiopoda.

Orbiculoidea aff. *latissima* (J. Sowerby).

Annelida.

Ditrupa nodulosa (Lundgren).
Serpula sp. indet.

Portlandian.

(Glauconitic Series, Hartzfjeld Sandstone).

References: Spath, 1936; Van Straelen, 1929 (Crustacea). All the records except *Laugeites* sp. nov are from Milne Land; the Portlandian fossils from the northern area have not been systematically studied. The fossil records of Parat & Drach (1934) have not been incorporated since some of them are irreconcilable with Spath's interpretation of the sequence, and as their collection has not been illustrated their identifications cannot be confirmed. Species marked* are known only from a loose boulder in south-west Jameson Land (Spath, 1936, p. 177).

Cephalopoda.

Behemoth groenlandicus Spath.
Craspedites ferrugineus Spath (age uncertain).
— *leptus* Spath (age uncertain).
Glaucolithites anguinus Spath.
— *euglyptus* Spath.
— *lesliei* Spath.
— *subregularis* Spath.
Dorsoplanites crassus Spath.
— *gracilis* Spath.
— *maximus* Spath.
— *triplex* Spath.
Pavlovia costata Spath.
— *praecox* Spath.
— *pseudaperta* Spath.
— *rotundiformis* Spath (age doubtful).
— *tumida* Spath.
Laugeites groenlandicus (Spath).
— sp. nov. (Spath, 1952, pl. 4, fig. 4).
Cylindroteuthis? aff. *explanata* (Phillips).
Pachyteuthis aff. *panderiana* (d'Orb.).

Lamellibranchia.

Arcomya? sp. indet. cf. *helvetica* (Thurmann).
Astarte cf. *duboisiana* d'Orb.
— sp. nov.? aff. *michaudiana* d'Orb.
* — cf. *panderi* d'Orb.
— aff. *saemanni* P. de Loriol.
Buchia mosquensis (von Buch).
— *rugosa* (Fischer).
Camptonectes praecinctus Spath.
— *morini* (P. de Loriol).
— *suprajurensis* (Buvignier).
Corbicella aff. *portlandica* Morris & Lycett.
Corbula sp. indet. (Spath, 1936, pl. 48, figs. 8a—c).
**Dicranodonta groenlandica* Spath.
Entolium nummularis (Fischer).
Goniomya aff. *sulcata* Agassiz.
Homomya aff. *hortulana* Agassiz.
Isocyprina sp. nov.? aff. *albida* Casey (1952, p. 137; nom. nov. for *I. elongata* Cox, cit. Spath, 1936, p. 118).
Isognomon aff. *listeri* (Brown) (*I.* aff. *bouchardi* (Oppel): Spath, 1936, p. 101).

Lima (*Plagiostoma*) sp. nov.? indet. (Spath, 1936, pl. 46, fig. 5, pl. 47, fig. 10).
'*Lucina*' sp. nov. aff. *inaequalis* d'Orb.
* — sp. indet. (Spath, 1936, pl. 48, fig. 7).
Mactromya verioti (Buvignier).
Modiolus aff. *boloniensis* (P. de Loriol).
— *strajeskianus* (d'Orb.).
**Mytilus jurensis* (Merian) Roemer.
Ostrea bononiae Sauvage.
Oxytoma expansum (Phillips).
Parallelodon schourovskii (Rouillier).
— sp. nov.? aff. *keyserlingi* (d'Orb.).
Pholadomya aff. *inaequiplicata* Stanton.
Pinna constantini P. de Loriol.
Placunopsis aff. *lycetti* P. de Loriol.
Pleuromya tellina Agassiz.
Pronoella? sp. indet. aff. *nuculaeformis* (Römer).
Protocardia sp. juv. indet. (Spath, 1936, pl. 43, figs. 5a—c, pl. 50, fig. 5).
Pseudolimea aff. *blakei* Cox.
Pseudotrapezium groenlandicum Spath.
**Quenstedtia* sp.
Tancredia hartzi Spath.
Thracia cf. *depressa* (J. de C. Sow.).
— *incerta* (Deshayes).
Trigonia aff. *thurmanni* Contejean.

Gastropoda

Acteonina (*Ovactaeonina*) *groenlandica* Spath.
Ampullina sp. juv. cf. *hemisphaerica* (d'Orb.).
Delphinula? sp. indet. (Spath, 1936, pl. 40, figs. 3a—h).
Pleurotomaria cf. *rozeti* P. de Loriol.
Pseudomelania cf. *delia* (d'Orb.).
"*Turbo*" sp. indet. (Spath, 1936, pl. 39, fig. 13).
Vanikoro sp. nov.? (Spath, 1936, pl. 40, figs. 1a, b).

Brachiopoda.

Lingula zeta Quenstedt.
Orbiculoidea aff. *latissima* (J. Sowerby).
'*Rhynchonella*' aff. *grosesulcata* Eichwald.
Rugithyris rosenkrantzi Spath.
— sp. indet. (Spath, 1936, pl. 49, figs. 2a, b).

Annelida.

Ditrupa nodulosa (Lundgren).

Crustacea.

Eryma sp.

Crinoidea.

**Pentacrinus* sp.

Berriasian.

(Hartzfjeld Sandstone (upper part), Hectoroceras Beds, Lower Niesen Beds).

References: Donovan, 1953; Muir-Wood, 1953; Spath, 1936, 1947, 1952.

Note: Species attributed by Swinnerton to *Paracraspedites* are here included in *Subcraspedites*, in view of the difficulty in delimiting to two genera; see Spath, 1947, p. 26.

Cephalopoda.

Hectoroceras kochi Spath.
— sp. nov. (?) (Spath, 1947, pl. 3, fig. 2).
Praetollia aberrans Spath.
— *maynci* Spath.
Subcraspedites groenlandicus Spath.
— aff. *preplicomphalus* Swinnerton.
— aff. *spasskensis* (Nikitin).
— cf. *stenomphaloides* (Swinnerton).
— spp. (Spath, 1947, pl. 2, fig. 5, pl. 4, figs. 1a, b).
Tollia payeri (Toula).
Pachyteuthis aff. *partneyi* (Swinnerton) (age uncertain).
— sp. indet. (Spath, 1947, pl. 5, figs. 13, 14).

Lamellibranchia.

Arctica sp. nov.? (Spath, 1947, p. 44).
Astarte cf. *polymorpha* (Contejean).
— cf. *saemanni* P. de Loriol.
Buchia volgensis (Lahusen).
Camptonectes sp. indet. (Spath, 1947, pl. 5, fig. 7).
Corbicella (?) sp. indet. (Spath, 1947, p. 45).
Dicranodonta groenlandica Spath.
Entolium nummularis (Fischer).
Exogyra cf. *contorta* Eichwald.
Inoceramus sp. indet. (Spath, 1947, pl. 5, fig. 3).
Lima (?) sp. indet. (Spath, 1947, pl. 2, fig. 6).
Lucina aff. *fischeriana* d'Orbigny.
Oxytoma sp. indet. cf. *semiradiata* (Fischer).
Trigonia sp. indet. (Spath, 1947, p. 41).

Gastropoda.

Acteonina (*Ovactaeonina*) sp. indet. (Spath, 1947, pl. 3, fig. 6).
Natica (?) sp. indet. (Spath, 1947, pl. 1, figs. 7, 8).
Vanikoro sp. nov.? (Spath, 1947, pl. 5, fig. 17).

Scaphooda.

Dentalium sp. cf. *moreanum* d'Orbigny.

Brachiopoda.

Orbiculoidea sp. indet. (Spath, 1947, pl. 5, fig. 15).
'*Rhynchonella*' cf. *decipiens* d'Orbigny (Muir-Wood, 1953, p. 8).

Asteroidea.

Astropecten(?) sp. indet. (Spath, 1947, p. 46).

Crinoidea.

Pentacrinus cf. *tenellus* Eichwald.

Valanginian.

References: Donovan, 1953, and as given after individual entries.

Note: A number of species of *Buchia* have been recorded by different authors. The writer (1953, p. 90) preferred to regard most of these as members of one variable species, *B. crassicollis.* In the opinion of Dr. J. A. Jeletzky (*in litt.*) the assemblage should rather be assigned to *B. keyserlingi* (d'Orbigny).

Cephalopoda.

Leopoldia spp. (Donovan, 1955, p. 21; not yet worked out).
Lytoceras sp. cf. *exoticum* Uhlig.
Neocraspedites evolutus Donovan.
— *greenlandicus* Donovan.
Phylloceras sp. (Donovan, 1953, p. 100).
Polyptychites cf. *euomphalus* von Koenen (Spath, 1946, p. 6).
— *michalski* aff. var. *tuberculata* (Bogoslovsky).
— cf. *middendorfi* Pavlov.
— *mokschensis* (Bogoslovsky).
— aff. *triptychiformis* (Nikitin).
— *undulatocostatus* Donovan.
— ('*Dichotomites*') *gregerseni* Anderson var. *paucicostatus* Donovan.
— ('*Dichotomites*') *petschoraensis* Bogoslovsky.
— (*Euryptychites*) *laevis* Donovan.
— (*Euryptychites*) *traillensis* Donovan.
— sp. cf. *diptychoides* Pavlov & *variisculptus* Pavlov.
Lyticoceras sp. (Spath, 1946, p. 6).
Paracymatoceras sp. (Donovan, 1955, p. 21; not yet studied).
Hibolites sp. (identification from Dr. J. A. Jeletsky, in litt.).
Pachyteuthis subquadratus (Römer).
Pseudobelus sp. (identification from Dr. J. A. Jeletzky, in litt.).

Lamellibranchia.

Avicula sp. (Frebold, 1935, p. 28).
Buchia keyserlingi (d'Orbigny) (See note above).
Ostrea sp. (Koch, 1929, p. 171).
Pinna(?) sp. (Maync, 1949, p. 20).

Gastropoda.

Unnamed gastropods, according to Maync (1949, p. 20).

Brachiopoda.

Pygope sp. (Donovan, 1955, p. 21; not yet worked out).
'*Rhynchonella*' spp.
'*Terebratula*' spp.

Anthozoa.

Isastraea sp. (Frebold, 1932b, p. 31, fig. 11).

Echinoidea.

Collyrites (*Tithonia*) sp. nov. (Maync, 1949, p. 67).

Aptian.

References: Bøgvad & Rosenkrantz, 1934; Donovan, 1953; Frebold, 1935; Muir-Wood, 1953; Ravn, 1911; Spath, 1946.

(L = Lower Aptian, U = Upper Aptian).

Cephalopoda.

L *Ancyloceras* aff. *matheronianum* (d'Orbigny).
U '*Crioceras*' sp. indet. (Frebold, 1935, pl. 2, fig. 4).
L *Deshayesites boegvadi* Rosenkrantz.
L — aff. *laeviusculus* (von Koenen).
U '*Hamites*' sp. indet. (Frebold, 1935, pl. 2, fig. 5).
L *Lytoceras* sp. nov. (?) cf. *phestum* (Matheron).
— *polare* Ravn.
?U *Pascoeites* (?) cf. *crassus* Spath.
Phyllopachyceras rouyianum (d'Orb.).
U *Sanmartinoceras groenlandicum* Rosenkrantz (possibly a synonym of *pusillum* Ravn: Spath, 1946, p. 7).
U — *haugi* (?) (Sarasin).
U — *pusillum* (Ravn).
?U *Tonohamites* spp.
U *Tropaeum arcticum* (?) (Stolley).
L *Cymatoceras* aff. *radiatum* (J. Sowerby).
Neohibolites spp.
U *Oxyteuthis gracilis* Frebold.
U — (?) *borealis* Frebold.
U — (?) *jarneri* Frebold.

Lamellibranchia (all from U. Aptian, Store Koldewey).

Inoceramus aff. *ewaldi* Schlüter.
Isocardia (?) *erichseni* Frebold.
Lima ravni Frebold.
— *rosenkrantzi* Frebold.
— (*Mantellum*) cf. *parallela* (J. Sowerby) (*L.* cf. *gaultina*, Frebold, 1935, p. 88).
Nucula freucheni Frebold.
— *friisi* Frebold.
— sp. indet. cf. *subtrigona* Römer.
Opis wegeneri Frebold.

Parallelodon hagenii (Ravn).
— *mylii* (Ravn).
Plicatula kochi Frebold.
Turnus(?) sp. indet. (Frebold, 1935, pl. 7, fig. 4).

Gastropoda (all from U. Aptian, Store Koldewey).

Cerithium(?) (*Cerithidea*?) aff. *dupinianum* d'Orbigny.
Claviscala clementina (Michelin).
Emarginula sp. indet. (Frebold, 1935, pl. 4, fig. 3).
Fusus(?) sp. indet.
Neritopsis nielseni Frebold.
Pleurotomaria spp. (Frebold, 1935, pl. 4, figs. 5, 6).

Scaphopoda.

Dentalium sp. indet. (Frebold, 1935, pl. 4, fig. 10).

Brachiopoda.

U *Kingena groenlandica* Frebold.
L '*Rhynchonella*' *antidichotoma* Buvignier.
U '*Terebratula*' *biplicata* J. Sowerby & vars.
U *Terebratulina*(?) aff. *striata* Wahls.

Anthozoa.

U *Trochocyathus* sp. (Frebold, 1935, pl. 6, figs. 19, 20).

Annelida.

U *Ditrupa* aff. *decorata* Stolley.
U *Serpula* spp. (Frebold, 1935, pl. 4, fig. 11).

Crustacea.

U *Pollicipes* sp.

Note: Aptian faunas in East Greenland are undescribed except for that from Store Koldewey (Frebold, 1935). Apart from this fauna, only a few isolated identifications are available.

Albian.

(Middle Cretaceous Shales, lower part).

References: Frebold, 1932b; Bøgvad & Rosenkrantz, 1934; Spath, 1946, pp. 8—10; Donovan, 1949; 1953, p. 35.

(L = Lower Albian, M = Middle Albian).

Cephalopoda.

L *Arcthoplites* cf. *jachromensis* (Nikitin).
L *Beudanticeras* cf. *hulenense* Anderson.
M *Dimorphoplites* sp.
M *Dipoloceras* sp. (*subdelaruei* group).
M *Euhoplites* spp. (*opalinus* group).
M *Gastroplites* spp. nov.?

M *Hoplites* spp. cf. forms figd. by Nikitin and Bogoslovsky as *H. dentatus* and *H. engersi.*
Hysteroceras? sp. juv.
L *Leymeriella* aff. *tardefurcata* (d'Orbigny).
L — aff. *rencurelensis* (Jacob).
Lytoceras sp.
Puzosia (*Callizoniceras*?) sp.
L '*Puzosia*' (? gen. nov.) *sigmoidalis* Donovan.

Lamellibranchia.

Aucellina caucasica (Abich).
— *gryphaeoides* (J. de C. Sowerby).
Cucullaea nana Leymerie.
?L *Entolium* cf. *orbicularis* (J. Sowerby).
Inoceramus anglicus Woods.
Isognomon cf. *rauliniana* d'Orbigny.
Placunopsis sp.
Pholadomya decussata (Mantell).
L *Spondylus* cf. *gibbosus* d'Orbigny.
Variamussium sp.

Gastropoda.

Gyrodes gentii (J. Sowerby).
'*Phasianella*'? *ervyna* d'Orbigny.
Pleurotomaria sp.

Brachiopoda.

Lingula subovalis Davidson.

Echinoidea.

Hemiaster (s. l.) sp.

Anthozoa.

?*Caryophyllia* sp.

Lower Cenomanian.

(Middle Cretaceous Shales, upper part).

References: Donovan, 1953; 1954, p. 23: Spath, 1946, p. 10.

Cephalopoda.

Gaudryceras sp. indet. (age doubtful).
Lytoceras sp. nov. cf. *vicinum* (H. Douvillé).
Mesogaudryceras cf. *leptonema* (Sharpe).
Phylloceras sp. cf. *velledae* (Michelin).
Schloenbachia aff. *subplana* (Mantell).
— *subtuberculata* (Sharpe).
— *subvarians* Spath.
— cf. *varians* (J. Sowerby).
— *varians* var. *tetrammata* (J. de C. Sowerby).
Indeterminate baculitid ammonoid.

Lamellibranchia.

Inoceramus crippsi Mantell.
I. pictus J. de C. Sowerby.
'*Lucina*' *tenera* (J. de C. Sowerby).
Nucula pectinata J. Sowerby var. *cretae* Gardner.
Oxytoma pectinata (J. de C. Sowerby).
Variamussium ignoratum (Ravn).

Upper Turonian.

(Inoceramus lamarcki Beds).

References: Donovan, 1953; 1954, p. 24; Spath, 1946, p. 11.

Cephalopoda.

Collignoniceras cf. *woolgari* (Mantell).
Scaphites sp. cf. *geinitzi* d'Orbigny.
— aff. *lamberti* (de Grossouvre).
— aff. *morrowi* Jeletzky.

Lamellibranchia.

Inoceramus lamarcki Parkinson.
Lucina sp. indet.
Nucula whitfieldi Weller.

Upper Santonian — Lower Campanian.

(Sphenoceramus Beds and Knudshoved Beds).

References: Donovan, 1953, p. 43; 1954, p. 26; Frebold, 1934; Maync, 1949.

Cephalopoda.

Nautilus sp. (Maync, 1949, p. 142).
Actinocamax? verus Miller.
Belemnitella? sp. indet.

Lamellibranchia.

Inoceramus (*Sphenoceramus*) *geltingi* Frebold.
— — *patootensis* de Loriol.
— — *steenstrupi* de Loriol.
— — *teicherti* Frebold.
Oxytoma tenuicostata (Römer).
Pteria? aff. *pectinoides* Ravn.

Arthropoda.

Linuparus dülmensis (Geinitz).

Upper Campanian.

(Scaphites Beds).

References: Donovan, 1953, p. 44; 1954, p. 27.

Cephalopoda.

Scaphites greenlandicus Donovan.
— *quadrangularis* Meek & Hayden.

Lamellibranchia.

'*Lucina*' *laminosa* (Reuss).
Nucula cancellata Meek & Hayden.
Nuculana? *panda* (Nilsson).
Tellina steenstrupi de Loriol?

Scaphopoda.

Dentalium sp. indet.

Appendix III.

COAL IN THE JURASSIC OF EAST GREENLAND

The only product of any economic value which has so far been discovered in the Jurassic of East Greenland is coal. Two groups of seams are known: in the Kap Stewart Formation of southern Liverpool Land and south-eastern Jameson Land, and in the Muschelbjerg Formation of Hochstetters Forland. The seams in the Kap Stewart Formation have been briefly described by Harris (1937, p. 74) and Rosenkrantz (1942, p. 19). Harris mentioned a thin seam of shaly coal at Vardekløft, composed mainly of fossil leaves, and one at Ammonitbjerg composed of fusainised wood and parenchyma, which he suggested could be charcoal washed down from a forest fire. He also notes that the upper part of the formation contains bituminous coal, in seams up to 50 cm thick, some, and probably all of which are composed of tree-trunks 50 cm and more in diameter. These outcrop on the coast of southern Liverpool Land, near the settlement of Igterajivit and at a place about 3 km due east, and also inland. Rosenkrantz, who published analyses of the coals, states that they are composed of durain with numerous veins of vitrain. The analyses confirm the identification as bituminous coal, carbon being about 80 % and oxygen 10—14 % of the organic content. All contain a high proportion of mineral matter (10—30 %). These seams have been worked by the Greenlanders of Scoresbysund but increasing difficulties with the overburden have been encountered.

The seams which outcrop on the western side of Hochstetters Forland were the subject of a paper by Frebold (1932a). They outcrop for a distance of about 1 km along the coast, bounded to the north and south by faults which bring in the pre-Cambrian Eleonora Bay Formation. The locality is known as 'Jarners Kulmine' after the geologist of the Danmark Expedition. Three seams were recognised by Frebold, dipping north-westward. A composite stratigraphical section is given by Frebold (*op. cit.*, p. 27), but with no scale. It appears that the greatest thickness reached by any seam is about 2 m, and that the seams are close together, being separated only by 2 or 3 m of sandstones and shales. The uppermost seam is capped by a marine horizon with fossil bivalves, which suggest an Oxfordian or Kimeridgian age for the coals. The seams form part of the Muschelbjerg Formation, described on page 52.

Thin sections were figured by Frebold, who gave a description of the physical characters of the coal, and show the presence of vitrain, durain and fusain. Analyses were made by H. L. Pedersen and have been recently published by Koch (1955, pp. 609—615). The mean of 9 analyses gives a carbon content of 59.6 % of the whole sample, or about 70 % of the organic content, and the coal is therefore a lignite. The sulphur content is appreciable (mean 3.1 % of whole sample) and the ash is considerable (5.6 to 23.6 %, mean 14.8 %). The calorific value was also determined and varies between 5600 and 7300 cal./gm., the mean being 6740 cal./gm.

Coaly matter is fairly common in other Jurassic and Cretaceous rocks in East Greenland, in the yellow sandstone facies (p. 116), but, apart from the two cases described above, no occurrences have been found which are thick enough to be dignified by the name of seams, or to be capable of being worked.

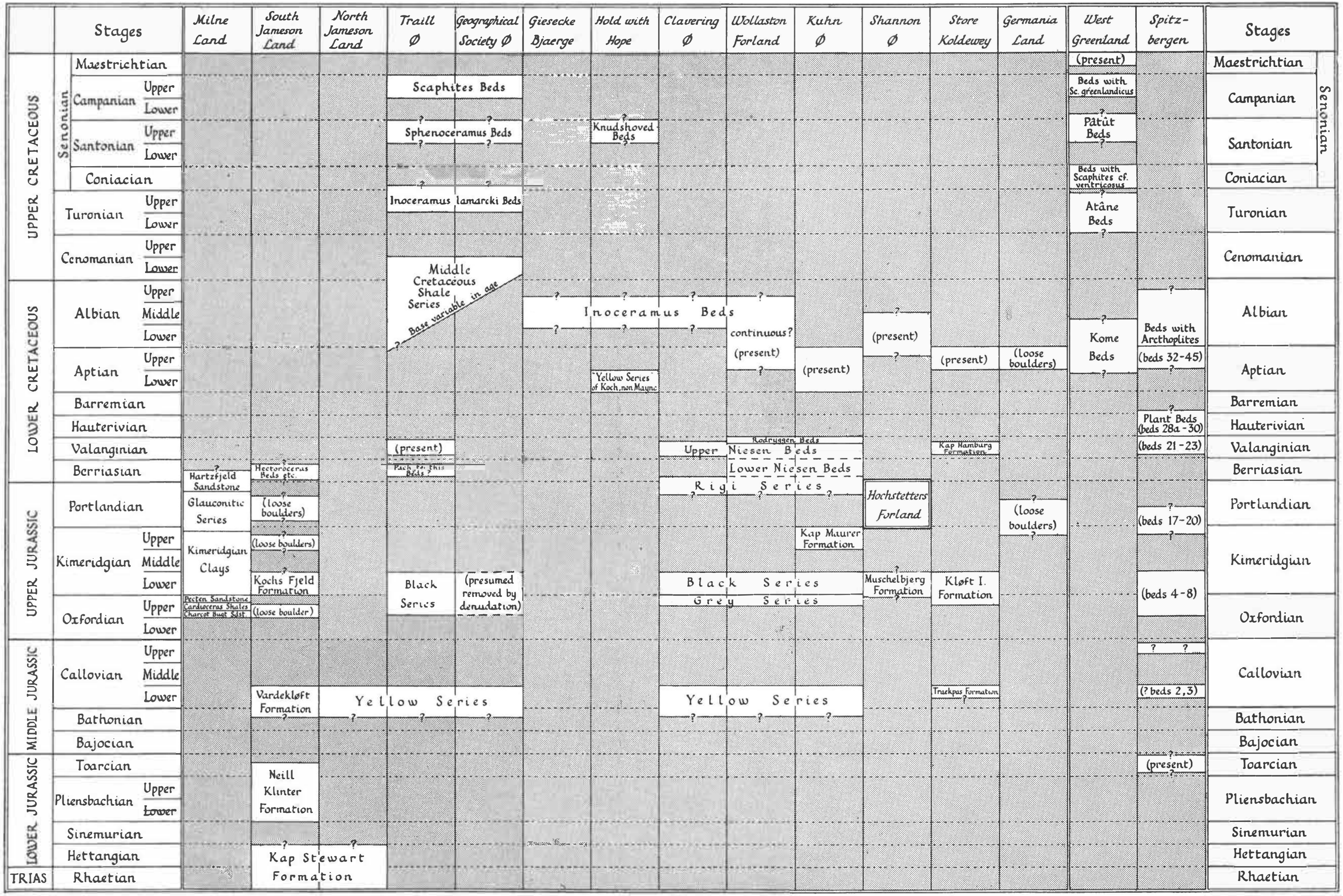
Færdig fra trykkeriet den 25. april 1957

PLATES

Plate 1.

Correlation chart of the Jurassic and Cretaceous formations in East Greenland between latitudes 70° and 77° north. For explanation see Chapter III and Appendix I. The principal formations recognised in West Greenland and Spitsbergen are also included; numbers of beds in the Spitsbergen column refer to the section given by Hoel and Orvin (1937).

PLATE 1.



Stages
Milne Land
South Jameson Land
North Jameson Land
Traill Ø
Geographical Society Ø
Giesecke Bjerge
Hold with Hope
Clavering Ø
Wollaston Forland
Kuhn Ø
Shannon Ø
Store Koldewey
Germania Land
West Greenland
Spitzbergen
Stages
UPPER CRETACEOUS
Senonian
Maestrichtian
Campanian
Upper
Lower
Santonian
Upper
Lower
Coniacian
Turonian
Upper
Lower
Cenomanian
Upper
Lower
LOWER CRETACEOUS
Albian
Upper
Middle
Lower
Aptian
Upper
Lower
Barremian
Hauterivian
Valanginian
Berriasian
UPPER JURASSIC
Portlandian
Kimeridgian
Upper
Middle
Lower
Oxfordian
Upper
Lower
MIDDLE JURASSIC
Callovian
Upper
Middle
Lower
Bathonian
Bajocian
LOWER JURASSIC
Toarcian
Pliensbachian
Upper
Lower
Sinemurian
Hettangian
TRIAS
Rhaetian
Scaphites Beds
Sphenoceramus Beds
Knudshoved Beds
Inoceramus lamarcki Beds
Middle Cretaceous Shale Series
Base variable in age
Inoceramus Beds
continuous?
(present)
(present)
(present)
(present)
(loose boulders)
"Yellow Series" of Koch, non Mayne
(present)
Rodryggen Beds
Upper Niesen Beds
Lower Niesen Beds
Kap Hamburg Formation
Hartzfjeld Sandstone
Hectoroceras Beds etc.
Pach for this Beds?
Rigi Series
Glauconitic Series
(loose boulders)
Hochstetters Forland
(loose boulders)
Kap Maurer Formation
Kimeridgian Clays
(loose boulders)
Kochs Fjeld Formation
Black Series
(presumed removed by denudation)
Black Series
Muschelbjerg Formation
Kløft I. Formation
Pecten Sandstone
Cardioceras Shales
Charcot Bugt Sdst.
(loose boulder)
Grey Series
Vardekløft Formation
Yellow Series
Yellow Series
Trækpas Formation
Neill Klinter Formation
Kap Stewart Formation
(present)
Beds with Sc. greenlandicus
Pâtût Beds
Beds with Scaphites cf. ventricosus
Atâne Beds
Kome Beds
Beds with Arcthoplites
(beds 32-45)
Plant Beds (beds 28a-30)
(beds 21-23)
(beds 17-20)
(beds 4-8)
(? beds 2,3)
(present)
Maestrichtian
Campanian
Santonian
Senonian
Coniacian
Turonian
Cenomanian
Albian
Aptian
Barremian
Hauterivian
Valanginian
Berriasian
Portlandian
Kimeridgian
Oxfordian
Callovian
Bathonian
Bajocian
Toarcian
Pliensbachian
Sinemurian
Hettangian
Rhaetian

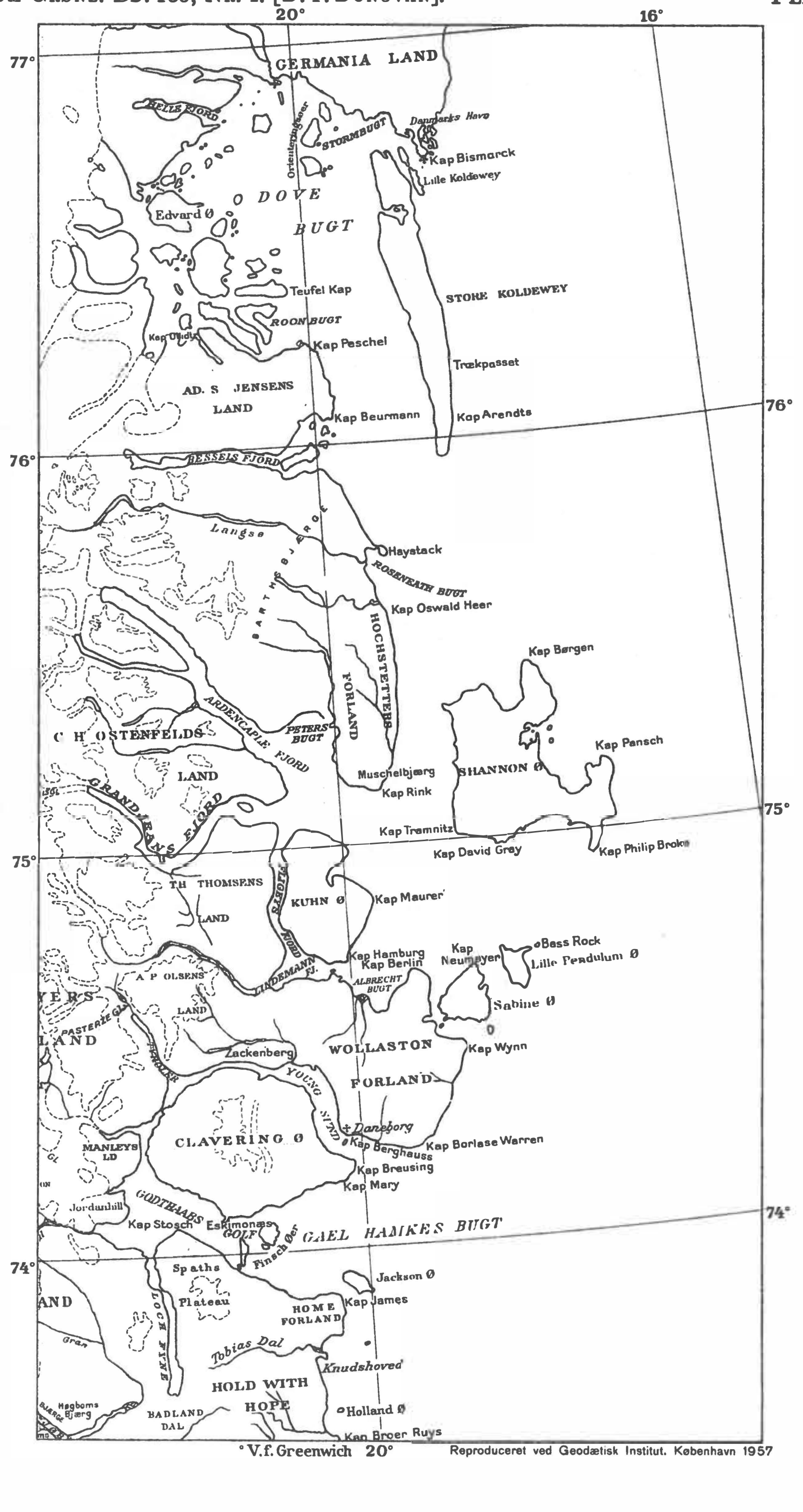
Plate 2.

Hypothetical reconstruction of the geography of parts of Europe and North America at the beginning of the Callovian Stage. Heavy lines indicate coastlines, continuous where well-established, broken where conjectural. Horizontal ruling indicates land. The occurrence of certain ammonite genera is shown by letters: A = *Arctocephalites* and/or *Arcticoceras*; C = *Cranocephalites*; S = *Seymourites*. The North American area is after Imlay (1953, fig. 2), the Barents Sea largely from data in Frebold (1951). The extension of the sea over part of the Canadian Arctic archipelago is inserted on the basis of Tozer's discovery, published by Arkell (1956, p. 529), of marine Callovian on Prince Patrick Island.


A
C A
A?
C?
A
A S
C A S
C
A
S C
A? S
S.

Plate 3.

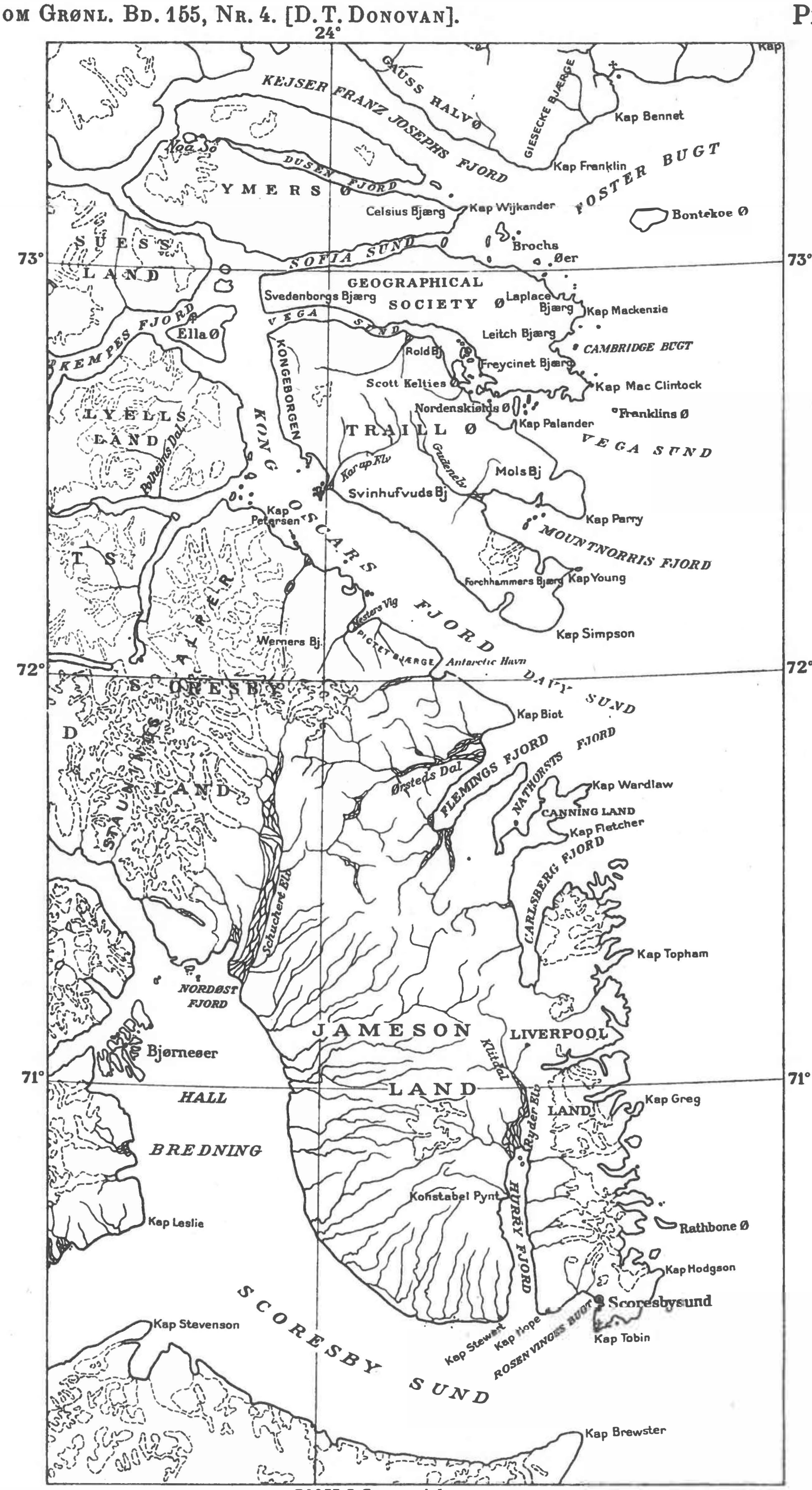
Map of Central East Greenland (northern part), showing places mentioned in the text.



° V. f. Greenwich 20°

Plate 4.

Map of Central East Greenland (southern part), showing places mentioned in the text.



24° V. f. Greenwich Reproduceret ved Geodætisk Institut. København 1957