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GEOLOGICAL OBSERVATIONS ON THE TERTIARY SEQUENCE

OF THE AREA AROUND ATANIKERDLUK WEST GREENLAND

BY

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WITH 17 FIGURES IN THE TEXT AND 2 PLATES

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PREFACE

The locality of Atanikerdluk with its rich fossil floras is well-known to palaeobotanists. But as the only comprehensive treatment on that subject was finished 70 years ago, it must to-day be regarded as antiquated. I have no doubt that the famous botanist, Professor O. Heer of Zürich, gave it the best treatment possible at that time, but being without the knowledge gained since then of Tertiary floras, stratigraphy, etc., he made his mistake in determining the Arctic floras as being of Miocene age, mixing genera of different climates etc. that ecologists and plantgeographers of to-day know is irrelevant. As knowledge has gradually progressed, we are now able to clear up some of these mistakes. Already 70 years ago Heer met with opposition, and the same view as we have to-day of the age determination was set forth, but also the opponents were without means to prove their opinions.

Nevertheless, in the light of the progress made within palaeobotany the flora handed over to us by Heer gives the impression that the floras of Atanikerdluk originate from an old Tertiary age. This was established when during the last years' work carried out by the Greenland Geological Survey in northwest Greenland under the leadership of Professor A. Rosenkrantz, a flora of the same character was discovered together with a Lower Paleocene fauna. This flora I am trying to describe, and already it seems to show the Paleocene age of the classic "Upper Atanikerdluk A" flora. It only covers a 40 m series within hundreds of metres of Tertiary strata of the Atanikerdluk profile and of the northwest-Greenland sedimentary sequence. New floras have been discovered, and still more floras may be found during the surveying of the region. The unravelling of the geology of the northwest-Greenland sediments may afford new valuable information which will make it possible to place the various floras in their true relative levels of the stratigraphical scheme, which will be of great interest to the paleobotanists and stratigraphers dealing with the Tertiary. But only when the Tertiary floras of northwest Greenland have been thoroughly reinvestigated, will it reach its real value. And this is still to be done.

Unfortunately no thorough treatment on the geology of the flora localities of northwest Greenland has appeared since the last work by Heer with its supplement of information by Steenstrup was published in 1883. The present paper is written with the intention—in all modesty—to make up for this lack, though it only comprises the area around Atanikerdluk.

The field work was carried out in the summers of 1951 and 1952 at Atanikerdluk. Reconnaissances were made to Kingigtoq, Qagdlúnguaq, and Naujat in order to get supplements to the exposures of Atanikerdluk which did not suffice for making an entire profile, and in order to test the regional validity of it. More tests were planned with the purpose of enlargening the investigations to a treatment including the whole area from Naujat to Mánik and to link it to the map of Nûgssuaq under survey. However it became impossible for us to carry through this plan owing to restrictions in time and a break down of the motor of our dinghy in 1951 at the very time when wheather conditions permitted the planned expedition along the coast northwest of Atanikerdluk.

I hope that in spite of its limitations this paper may be of some value and be but the first attempt of spreading information of the Tertiary floras and their geological milieu.

The observations on which this paper is based were made when I joined the Greenland Geological Survey's expeditions under the leadership of Professor Rosenkrantz. I express my gratitude to the leader of the expeditions who made it possible for me to undertake these investigations. I also thank my friends Arne Dinesen, Kaj Raunsgaard Pedersen, and Johannes Tobiassen, who assisted me during the field work.

INTRODUCTION OF PHYSICAL CONDITIONS

Atanikerdluk is the name of the small peninsula which is situated on the southern coast of Nûgssuaq about 15 km west of Sarqaq at the position of 70°4′ N, 52°20′ W. It consists of a basaltic hummock which by a low, even isthmus is connected with the mainland. Landward the peninsula rises gently to heights of about 100 m, and towards the Vaigat strait it forms vertical cliffs of basaltic rock. The sterile isthmus consists of sand and gravel, and the sand blown together in long, low dunes tells the visitor about the windy weather that is characteristic of this locality. In fact, the visitor will notice that most often the wind blows through the pass between the hummock and the mainland, and the feared gales blowing from north and southeast reach this place at their full strength. Nevertheless, the peninsula of Atanikerdluk and the westernly situated smaller peninsula of Nũnguaq form together an excellent natural harbour, which is of great benefit to the sailors. The mainland, which rises to heights of about 1000 m above sea-level, is part of an unbroken ridge stretching along the coast from Sarqaq valley to Mánik. To the north the ridge is limited by the Tarajornitsoq valley. One of the highest points of the area is Iviangernat (1033 m) above Atanikerdluk at a distance of 3,5 km from the coast.

The coastward slope facing south has, from an arctic point of view, a luxurious vegetation which covers great areas; this together with a widespread solifluction renders geological observations at the coastal slope difficult. A most characteristic feature is landslide coulisses mostly consisting of basalt, and situated at an altitude of more than 500 m above sea-level (see pag. 31). They cover a considerable part of the uppermost sedimentary sequence. Some of the basaltic dykes which traverse the coastal slope in several directions appear as walls, low dykes, or picturesque remnants left by erosion as for instance a "cone" just above Atanikerdluk.

Towards the east of Atanikerdluk is a large gorge. In its length of about 2 km inland it cuts an excellent section through the lowermost 400 m of the sequence. The gorge is mentioned in the literature as "Atanikerdlukkløften" (the Atanikerdluk gorge). A native from Sarqaq

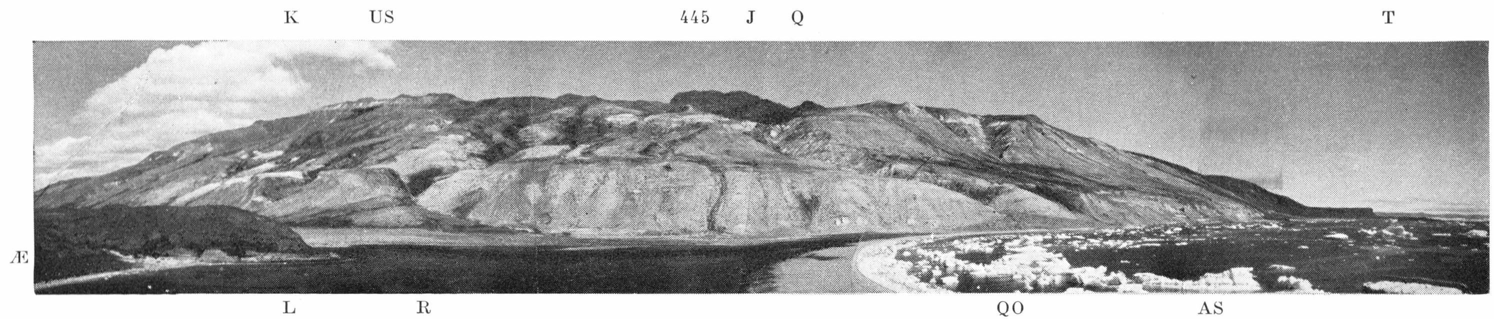

Fig. 1 a. Panorama of the country at Atanikerdluk. In the foreground the worn and rounded basalts of the peninsula (Æ). AS = Atanikerdluk Sydhavn ,J = Iviangernat, K = Keglen, L = Liriodendronkløft, Q = Quikavsaup kûa, QO = Quikavsanp kûa's outlet, R = Rhododendronkløft, T = Tartunaq, US = Uppermost sediments, 445 = point 445.

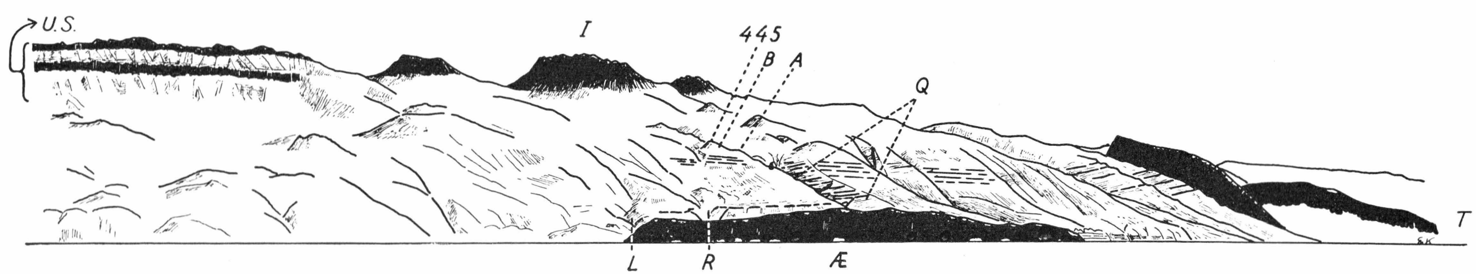

Fig. 1 b. The country around Atanikerdluk (drawn from photo by A. Rosenkrantz). A = Tertiary Lower Fluviatile Series (Upper Atanikerdluk A). B = Tertiary Lower Shale Series (not in situ) (Upper Atanikerdluk B). I = Iviangernat. L = Liriodendronkløft. Q = Quikavsâp kûa. R = Rhododendronkløft. US = Upper sedimentary exposures in the wall limiting the shelf-like depression (contains part of the Upper Fluviatile Series, Upper Shale Series, and the Top Sandstone Series). 445 = point 445. The black areas (Æ) indicate basalt.

told me that they called it Quikavsaup kûa, and this name will be used in the following. Two small ravines are situated just behind the Atanikerdluk peninsula, but only with insignificant outcrops. One was called the Liriodendronkløft, because this was the place where Nordenskiöld found the "Liriodendronbed". The other was called the Rhododendronkløft after the bulk occurrence of *Rhododendron lapponicum.* Similar small ravines are situated along the coast as far as northwest of Nũnguaq, and furthermore there are in this direction several great clearcut gorges around Qagdlúnguaq of dimensions as that at Atanikerdluk. The above-mentioned distance of about 5 km along the coast without big gorges is due to a great landslide mentioned in the following. This landslide has given the terrain its special form. The above mentioned localities is seen at fig. 1 a—b.

AN OUTLINE OF THE GEOLOGY OF THE ATANIKERDLUK AREA

Ever since it was first discovered about a century ago, Atanikerdluk has attracted attention on account of the occurrence of coal and its localities rich in plant fossils.

During this time several well-known investigators have contributed to the unravelling of the geology of the area as it appears from the following outline which is essentially based on their results. As pioneers must be mentioned K. L. Giesecke (Giesecke 1811) and H. Rink (Rink 1852, 1855), who both gave the first information of the basalts of the peninsula and the existence of the coal-bearing formations.

The Peninsula

consists of a doleritic sill-intrusion with strike in the direction of the coastline (NW), and dip towards the country (NE) (see Sole Munck 1945). The basalt was first mentioned by Giesecke in 1811, later by Nordenskiöld (Nordenskiöld 1871), and K. J. V. Steenstrup (Steenstrup 1883). At the peninsula sediments can be seen as "liegendes" and "hängendes" in relation to the intrusion. The overlying sediments are only represented by a minor occurrence of sandstone on the landward slope, the underlying are found in a section of the seaward cliff at the western part of the peninsula where there is a small bay. In the shale of this bay Steenstrup discovered an Atâne flora (Bregnelaget = the Fern Bed) (Steenstrup 1883, Heer 1883 a, b). This finding place has also been mentioned by White and Schuchert (W. & S. 1898). On the southern side of the peninsula is another small occurrence of sediments.

Morphologically the Atanikerdluk peninsula is a big "roche moutonnée", that has been affected by a glacier from the east; for this reason the eastern part of the peninsula has suffered the severest abrasion, the surface consequently tapering gently towards the sea. Especially nicely rounded and polished rocks are seen on the northeasterly part of the basaltic peninsula. The lee side is towards west and has steep cliffs.

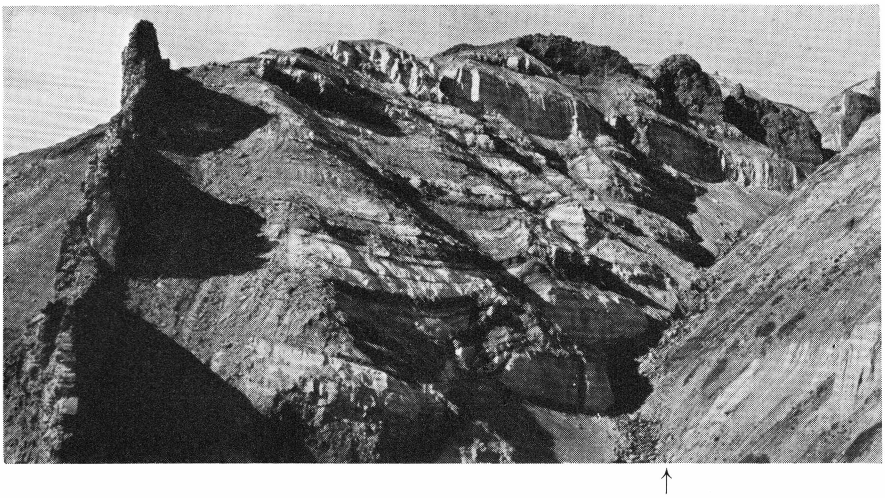

Fig. 2. Quikavsaup kûa gorge. The section of the western wall showing part of the Cretaceous sequence. To the left dyke II, in the background the great dyke III. A small fault is seen nearly bisecting the picture. The dimensions are illustrated by the person at the bottom of the gorge (At the arrow).

The Mainland.

The thickest sequence is exposed at Quikavsaup kûa, the huge gorge east of Atanikerdluk. This is demonstrated on the sketch pl. I, which represents a diagrammatic section based upon investigations from the gorge (see pl. I and also an original sketch made by Steenstrup reproduced fig. 3).

Cretaceous Beds.

From sea-level to an altitude of about 370 m there is a monotonous sequence mainly consisting of light-coloured quartz sandstone alternating with grey or black shale and silty shale together with coal. In Quikavsaup kûa (fig. 2) coal seams are few and thin. Rink (Rink 1857, pag. 172) says as follows: "Paa Fastlandskysten, ved Indløbet til Waigattet, nærmest denne beboede Plads (Atanikerdluk[1])), træde flere Kullag i Dagen i et dybt udskaaret Elvleje (Quikavsaup kûa[1])). Hovedlagene findes 1000 Alen fra Strandbredden, ere 4 i Tallet, tilsammen 1 Alen tykke og adskilte ved Leer og Sandsten . . .". (Translation: "On the mainland coast, at the entrance of the Vaigat, near this inhabited place (Atanikerdluk[1])), several coal seams appear in a deep riverbed (i. e. Quikavsaup kûa[1])). The main seams are found 1000 alen[2]) from the shore in a number of 4, together 1 alen thick and separated by clay and sandstone . . ."). These beds were not visible when the author visited the

[1]) Names added by the author.

[2]) Old Danish measurement. 1 alen = 62,8 cm.

place (1947, 1951, 1952), but were hidden by a local landslide[1]) just above the lowermost big dyke traversing the gorge (dyke I, see illustrations). In the downslid mass the natives from Tartunaq and Sarqaq collect coal from the seams mentioned by Rink. On Steenstrup's sketch (Steenstrup 1883, fig. 8) a seam is marked in the upper part of the gorge. This was observed by the author in the western wall of the gorge at an altitude of 290 m. According to the known dip we may expect that it meets the riverbed at an altitude of 270 m and below the waterfall situated at the place where the gorge cuts through the big dyke No. III (see the illustrations). The seam is 35 cm thick. To the northwest of Atanikerdluk in the gorge of Qagdlorssûp kûa there is a coal seam at an altitude of 350 m, more than 1 m thick, at which place experimental mining was made during the author's visit to Atanikerdluk 1951. Most likely the outcrops of these two coal seams represent parts of the same seam, which is in agreement with the very slight dip of the beds in an easterly direction along the coast. The conditions of terrain and climate which have acted upon the formation of the coal seam at Qagdlorssûp kûa must also at the same time have made its influence felt in the neighbourhood of Atanikerdluk. When coal is found at Quikavsaup kûa on the same stratigraphical level, there is reason to believe that the coal basin at Qardlorssûp kûa reaches Quikavsaup kûa, and that the seam stretches between the two localities. The difference in thickness of the coal seam observed at the two places indicates that Qardlorssûp kûa is in a rather central, Quikavsaup kûa in a rather peripheral position in relation to the coal basin. Unfortunately sufficiant outcrops are lacking in the intervening area to establish this opinion. As, however, the Cretaceous beds were not the object of my investigations nor of this paper, the said must suffice till later on. For this reason the Cretaceous series is not differentiated at the profile (pl. I). Instead I have added a drawing by K. J. V. Steenstrup reproduced fig. 3.

As a standard of the sediments I would regard strike as N 140°, and dip as 10—15° NE, though great variations will of course always be found in such sedimentary series of fluviatile origin. A thorough measurement was published by R. Brown (Brown 1875).

The sediments are traversed by several basaltic dykes as it appears from pl. I and fig. 3 and the map pl. II. Three large dykes cross Quikavsaup kûa (marked I, II, and III at the map), which were already mentioned by Nordenskiöld (Nordenskiöld 1871) and Steenstrup (Steenstrup 1883). The dykes pass the riverbed at altitudes of 90 m (I), 175 m (II), and 280 m (III) respectively, and the thickness is 1—3 m (I), 5 m (II), and min. 10 m (III) respectively. They are practically perpen-

[1]) Must not be confused with the above- and below-mentioned basalt coulisses and the landslides connected to them.

dicular. The strikes are N 140° (I), N 160° (II), and N 77° (III). A smaller dyke (IV) in the western wall of the gorge can be seen to cross dyke I.

So far marine fossils have not been found in these rocks, which is not surprising when we consider that the rocks and the structures of them indicate fluviatile and terrestrial origin. Nor have terrestrial animals been found. Plant fossils are very abundant in several horizons. A. E. Nordenskiöld (Nordenskiöld 1871) was the first who discovered a Cretaceous fossil flora at Atanikerdluk. It was found in a shale bed called the Liriodendronbed after the abundant *Liriodendron Meekii* Hr. The bed is situated at an altitude of 70 m in the ravine called the Liriodendronkløft (see the preceding chapter). The collection contained 55 species determined by O. Heer. It was enlarged by Steenstrup to 96 species. In the Rhododendronkløft Steenstrup discovered the same bed, but it only contained ill-preserved fossils. The bed can be followed further on to the coast section east of Quikavsaup kûa where 11 species were found by Steenstrup (Steenstrup 1883 a, b, Heer 1883 a, b). The collections of Nordenskiöld and Steenstrup were treated and published by O. Heer and together with equivalent floras from Greenland (i. e. the Fernbed from the peninsula and the flora of Atâ) named Atâne flora (Atâne = at Atâ). This designation was first mentioned by Nordenskiöld (Nordenskiöld 1871). Of the age of these beds Heer states (Heer 1883, pag. 186): "Wenn nach die vorliegenden Materialien es noch nicht möglich ist, die Atâneschichten mit voller Sicherheit mit einer der europäischen Kreidestufen zu kombinieren, können wir doch sagen, dass ihre Flora der Zeit angehöre zwischen dem Gault und den Senon und wahrscheinlich dem Cenoman einzureihen sei . . .". This age determination is shown by Nathorst to apply to the whole Cretaceous series; in following the Quikavsaup kûa gorge to the altitude of the overlying Tertiary beds he discovered 9 new horizons scattered in the whole sequence, and each containing an Atâne flora (see Nordenskiöld 1885, chapt. 6 written by Nathorst). No further descriptions are given of the finding places, but in Nathorst's account, part of a personal report by A. E. Nordenskiöld to Dr. O. Dickson (Nordenskiöld 1884), it is stated that Nathorst discovered 6 horizons containing Atâne floras at an altitude of up to 335 m. And furthermore another horizon was discovered at an altitude of 280 m "on his way to the localities of the Tertiary fossils." In an account of a lecture held by Nathorst in the Geological Association of Stockholm 1883 (Nathorst 1884) it is mentioned that the uppermost of these horizons was in a tributary ravine (to Quikavsaup kûa or to the tributary ravine running along dyke III ?) at about the same altitude as the Tertiary siderites, and besides a *Cycas* n. sp. it contained many well-known Atâne species. It is maintained that several of the horizons discovered consisted of clay-ironstone which resembles those of the Tertiary beds, a point which requires extreme carefulness when working in this area. Nathorst states further in (Nordenskiöld 1885): Hvarken Patootfloran eller någon Eocen flora finnas sålunda här, utan de miocena växtförande lagren hvila omedelbart, och utan tvifvel olikformigt på Atänelagren." (Translation: "Neither the Pautûtflora (advanced by Heer: Senonian) nor any Eocene flora exists here, but the Miocene beds containing plant fossils are deposited straight upon and without doubt unconformably upon the Atâne beds"). Later D. White and Ch. Schuchert (White and Schuchert 1898) and Seward (Seward 1925, 1926, Seward and Conway 1935) dealt with the Atâne floras. As far as the age of the Atâne beds are concerned, White and Schuchert agree to Heer's opinion, as these authors regard the Atâne floras as equivalent to Potomac or Raritan (Amboy clays) in U. S. A. Seward advances the opinion that Heer's division of the Cretaceous sequence of West Greenland does not rest on a sure foundation. Finally must be mentioned the work of Krüger (Krüger 1928) in which a sketch map of the area about Atanikerdluk is published on pag. 127. It is incomplete as it only treats the lowermost part of the sequence, and does not include the upper limit of the Cretaceous beds of Atanikerdluk.

In the area described a distinct unconformity forms the limit between the Atâne beds and the overlying beds, as already stated by Nathorst. This unconformity was recognized by A. Rosenkrantz at Naujat in 1938 (see the original sketch fig. 15 which Professor Rosenkrantz has kindly placed at my disposal) (see Sole Munck 1945, the sketch pl. 15, fig. 1). H. Gry mentions the unconformity at Quikavsaup kûa 1940 (see Rosenkrantz and others 1940).

Tertiary Beds.

Above the Atâne beds, and unconformably deposited upon them, is found a sedimentary sequence whose riches in plant fossils were known long ago. The sequence is well exposed and accessible on the western wall of the uppermost part of the Quikavsaup kûa gorge and situated above the big dyke III (see fig. 4). It is found in situ between the altitudes of 370 m and 402 m. It consists of coarse, cross-bedded quartz sand alternating with sideritic shale, siderite bands and siderite concretions, and in the uppermost 10 metres of bituminous shale and papercoal too. This series will be further considered in the following chapter. The sideritic rocks contain plenty of leaf impressions, impressions of fruits inclusive of cones, and incoaled wood. These leaf impressions are the oldest known fossils from Atanikerdluk. Even Giesecke and Dr. Rink was acquainted with them. In 1854 capt. Inglefield and lieutn. Colomb

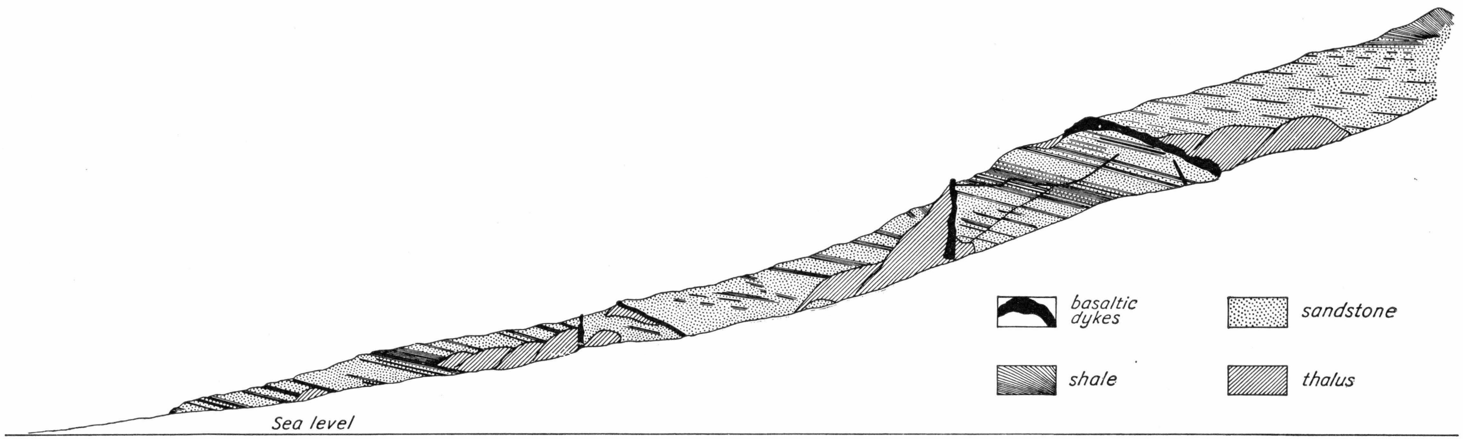

Fig. 3. The section of Quikavsaup kûa drawn from K. J. V. Steenstrup's original sketch.

collected fossils here; they were presented to the Geological Survey in London and the Royal Society of Dublin respectively. In 1858 Dr. Torell made a collection at Atanikerdluk for Stockholm. Further Mr. C. S. M. Olrik, inspector, while in office in Greenland made comprehensive collections, of which Sir MacClintock and Dr. Lyall got some samples in 1859 for Dublin and the Museum of Kew respectively. Besides Olrik's collections there are in the Mineralogical and Geological Museum of the University of Copenhagen samples collected by other Danish officials in Greenland in the 19th century, such as Pfaff, Zimmer, Krarup Smidt, Sølvtoft, and Myhre.

On his journey to Greenland in 1871, Dr. Nauckhoff bought a collection consisting of fossils from Atanikerdluk in the clay-ironstone frequently found here, and besides the collection contained well-preserved leaves in a fine brown clay. These fossils were taken to Stockholm and later on treated by Heer (Heer 1880).

The collections gathered by Inglefield, Colomb, Torell, MacClintok, and Lyall were treated by Professor O. Heer of Zürich and published in 1868. They make up a considerable part of the work "Flora Fossilis Arctica", part I, which is the first publication dealing with fossil plants from Greenland. The chapter on Greenlandic fossils contains 98 species from Atanikerdluk. On this basis Heer stated that the coal-bearing deposits of the Atanikerdluk area are of Lower Miocene age, because the Atâne floras being unknown at that time. Later on the collections gathered by Edw. Whymper from 1867 were treated and published by Heer (Heer 1869). In this connection it must be mentioned that R. Brown made detailed measurements of the sequence of Quikavsaup kûa (Brown 1875). The measurements were first published together with Whymper's collections (Heer 1869).

The sequence of Atanikerdluk was mentioned later by Nordenskiöld (Nordenskiöld 1870) and by Steenstrup (Steenstrup 1883). During his journeys to Greenland 1878 and 1880, Steenstrup made considerable collections of fossils from the Tertiary beds at Atanikerdluk besides the discoveries of Atâne fossils already mentioned. Steenstrup's collection was published by Heer in the "Flora Fossilis Groenlandica" 1883. After the discoveries of Atâne fossils by Nordenskiöld in 1870 Heer's age determination of Lower Miocene was restricted to the siderite-bearing sequence and the overlying sequence of bituminous shale. Since 1870 the flora of the siderite-bearing beds is called the "Upper Atanikerdluk A" (Heer 1883).

Heer's determination of the age of the Tertiary rocks of Greenland, based on plant fossils the bulk of which was from Atanikerdluk, gradually raised a severe opposition first offered by J. S. Gardner (Gardner 1887, 1879—1882, pag. 7—8, 1883—1886, pag. 3), W. Dawson (Dawson

1886) and G. M. Dawson together with the latter (Dawson 1887). Independently they arrived at the opinion that the "Arctic Miocene floras" by Heer which include the Atanikerdluk floras, rather belonged to the Eocene. Since then several authors have agreed upon this statement. A report on a Lower Paleocene flora from the Angmartusût valley, Nûgssuaq, northwest Greenland, which has not yet been to the press, will give a more detailed description. Furthermore I shall in this connection point out that in 1929 F. J. Mathiesen inclined to the opinion that "Upper Atanikerdluk A" must be referred to the interval of Paleocene-Eocene (see L. Koch, 1929, pag. 201). The author of this paper believes in the Paleocene age more than the Eocene. A lower Paleocene marine fauna has been found in 1939 by Professor A. Rosenkrantz in the same beds as the above-mentioned flora of Angmartusût whose relation to the "Upper Atanikerdluk A" seems indisputable; and both have the same characteristics in common with the late "Arctic Miocene", or better the "Arctic Eo-Tertiary floras" of the northern hemisphere.

Above the fluviatile series ("Upper Atanikerdluk A" beds) a sequence follows of bituminous shale with scattered bands of a brown rock and thin sideritic bands. In the section of Quikavsaup kûa the shales are severely broken, and lie in a peculiar position dipping strongly towards west though situated upon the almost horizontal fluviatile section. Above the shales there is a sandstone sequence sharply limited towards the shale. The limit is a fault. At fig. 4 the sandstone beds are seen as a structure resembling part of a syncline. The shale-sandstone sequence is disrupted, placed in its recent position by landslide activity as treated in the following (see pag. 31). The first fossils from the brown bands of the sequence was brought to Stockholm by Dr. Nanckhoff who bought them from a Greenlander at Godhavn (see Heer 1880). In the brown clay bands mentioned Steenstrup collected a flora of beautifully preserved leaf impressions, which were treated by Heer (Heer 1883). This flora was named the "Upper Atanikerdluk B" in contradiction to the underlying one from the sideritic rocks. Of the new flora Heer described 79 species of which 44 were not known from the "Upper Atanikerdluk A". Heer states that, nevertheless, it has the same Miocene character, but he expresses surprise at the small community of species.

The dislocations of this mass is connected with the many basaltic landslide-coulisses which can be traced in the terrain above an altitude of 500 m (see pl. I and fig. 14). One of them is situated just above the dislocated sediments, i. e. north of point 445. In most cases they conceal the upper part of the sediments of the coastal slope at Atanikerdluk. An exception is the sediments seen from an altitude of 750 m and upward in a steep section limiting the great shelf-shaped coulisse-area between Atanikerdluk and Qagdlorssûp kûa. Between altitudes of 730 m and 780 m are sandstone and bituminous shale; upon them there is a 80 m thick basalt sill(?) intruded into a sequence of bituminous shale, the basal beds of which are seen below the sill(?). These shales continue above the basalt with a thickness of more than 25 m. Upon the shale is found sand to an altitude of 960 m overlain with the plateau basalt. This is only represented by residues left by erosion. It makes up the highest points of the area i. e. the mountain Iviangernat (1033 m).

The age of the upper sediments has not been determined. They are mentioned by Steenstrup (Steenstrup 1883), who found some badly preserved plant fossils in the westerly occurrence at the point called "Keglen" (see pl. IV, point 942). There is at this place no clean section to-day, but more easterly there are relatively nice sections between the big sill(?) and the plateau basalt.

OBSERVATIONS ON THE TERTIARY BEDS

As mentioned in the previous chapter the Tertiary beds of the Atanikerdluk area rest discordantly upon the Cretaceous formation called the Atâne beds, a unit which according to Nathorst includes the whole Cretaceous sequence of the locality. Nathorst was the first who mentioned the possibility of an unconformity between the Cretaceous and Tertiary beds (Nordenskiöld 1885). The area from Mánik to the Sarqaq valley makes up a geological unit without greater disturbances, and it must therefore be the same unconformity which Rosenkrantz recognized in the western slope of the Sarqaq valley in 1938 (see Rosenkrantz' sketch fig. 15 of this paper, Sole Munck (1945), pl. 15, fig. 1).

The Unconformity

stands out very conspicuously in the western wall of the Quikavsaup kûa gorge above the waterfall, situated at the place where the river intersects the 10 m thick dyke III (pl. I and fig. 4). The visitor who follows the riverbed of Quikavsaup kûa upstream will find that this dyke at the waterfall prevents his further advance along the river, and hides the slope with the unconformity and the Tertiary beds so completely that he will have no idea of their existence. On the other hand he will from the terrain east of Quikavsaup kûa get the nicest general view of the Cretaceous-Tertiary sequence "en face". Fig. 4 represents a part of this view. In the foreground is the mentioned dyke III, and behind it the upper part of the Quikavsaup kûa gorge where the Cretaceous beds are seen with a rather steep northeasterly dip. At the bottom of the gorge the Cretaceous beds can be followed to an altitude of about 340 m where they are covered by scree. The uppermost visible bed is a black, bituminous shale containing a coal-band of 30 cm's thickness. The lower part of the western wall of the gorge is for the greater part covered by thalus so that the Cretaceous-Tertiary limit cannot be observed directly. This limit (the unconformity) was however found after a certain amount of digging had been made at the marked ridge which (see the sketch fig. 4) traverses the southern part of the section, and is the real limit between the western wall of the gorge and the coast slope. The unconformity is a few metres below the lowermost visible Tertiary beds at an altitude of 370 m.

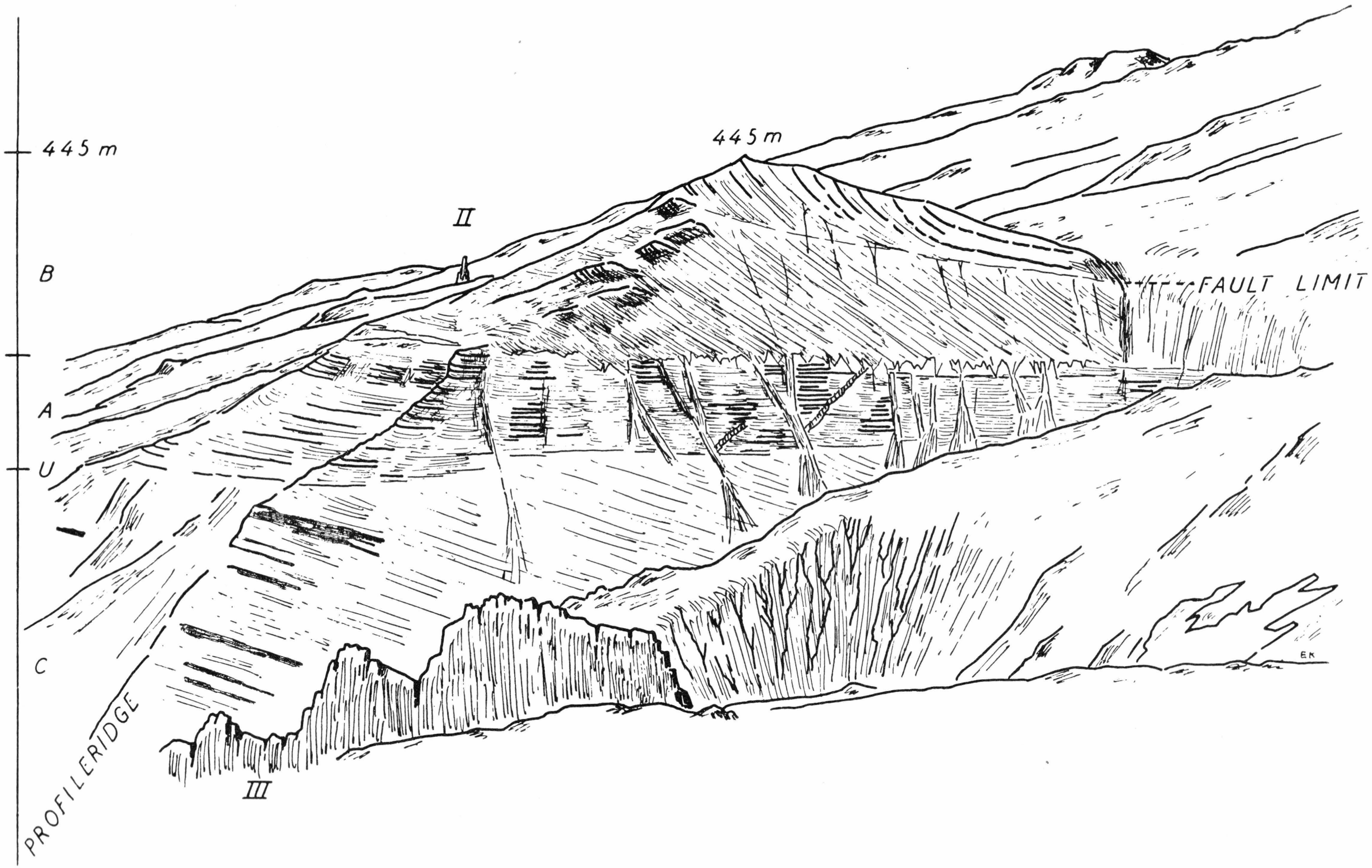

Fig 4 The profile of the western wall of the upper part of Quikavsaup kûa seen from the terrain east of the gorge. II and III are the dykes. II is a cone-shaped remnant left by erosion. C = Cretaceous, U = Unconformity, A = Lower Fluviatile Series (Upper Atk. A), B = Lower Shale Series (Upper Atk. B.)

Fig. 5. The section of the eastern wall of the upper part of Quikavsaup kûa. The black line shows the limit between the Cretaceous sandstone and the Tertiary beds. The limit rises towards south like the Cretaceous beds in the section. In the background basaltic landslide coulisses.

Below this we digged into the same bed of bituminous shale with a 30 cm's coal band, previously mentioned as the uppermost bed visible in the gorge. Above that bed there is a thin bed of sand with clay bands. These Cretaceous beds were abruptly cut through by the unconformity, which is covered with a layer of sandy clay passing into grey clay without bedding. They may represent the weathering mantle, the total thickness of which is 75 cm. The 50 cm of brown sand with yellow veins that follows on top of this may possibly belong to the same. Upon the mantle the exposed Tertiary beds are resting. From the sketch fig. 4 they appear with an almost horizontal bedding in the wall. These beds will be mentioned later on. First we shall have a look at the unconformity. It is rather uneven, which does not appear direct from the exposure in the western wall of Quikavsaup kûa on account of the thalus mantle, but can be seen in the easterly wall where an exposure has been found just above (NW of) dyke III and the waterfall (see fig. 5). Here the unconformity runs in such a manner as to form a "hill" or "bar" consisting of the characteristic, cream-coloured Cretaceous quartz sandstone. It shows a dip to the north. The discordant deposition of the Tertiary

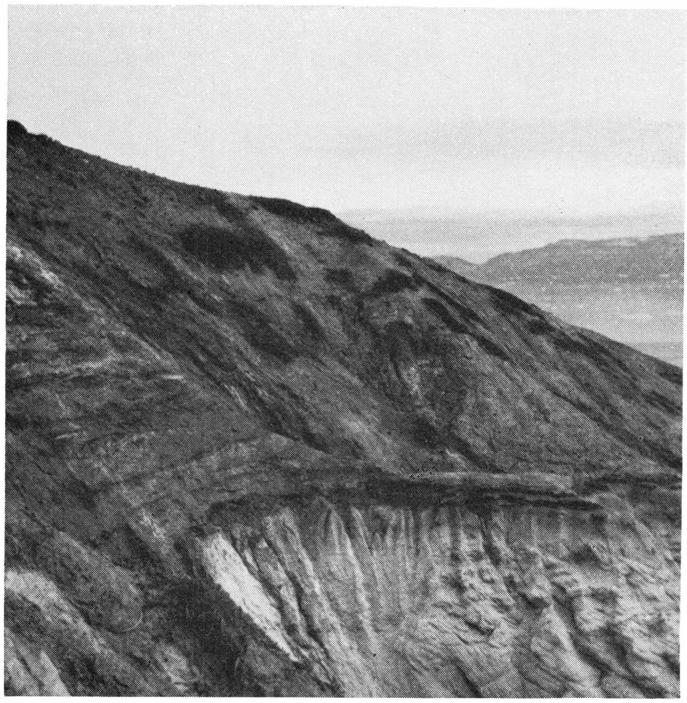

Fig. 6. Details of the section of the western side of the upper part of Quikavsaup kûa (see fig. 4). The very limit between Cretaceous and Tertiary. Below is light-coloured Cretaceous sandstone; near the limit the grey weathered zone is seen. The lowermost Tertiary is: In the very limit an iron pan-like band (light), then a black mould-like one, an iron pan-like one, and a black mould-like one. The black zones are easily distinguished. Above follows the ordinary Tertiary Lower Fluviatile Series partly covered with scree.

beds are seen direct (see fig. 6) on the northern slope of the "fossil hill" just before the section is covered with scree and vegetation, as is the case with the slopes of the uppermost part of Quikavsaup kûa. In other words, it was found where the gorge changes its course from a northeasterly one into a southerly to southwesterly one on its way to the waterfall. The sandstone just below the unconformity is at this place clearly weathered to a grey colour fading out of sight downward. At the limit and placed immediately on the Cretaceous sandstone is found what obviously represents a weathered debris mantle consisting of two ironpan like bands and two mould-like beds, placed one upon the other (fig. 6, 7). This is overlain with the ordinary Tertiary sequence as in the western wall, in which the "hill" seems to continue, though less pronounced. It only appears from the scattered exposures of the Cretaceous sandstone and the level of the lowermost exposures of the Tertiary beds and seems to reach its maximal height a hundred metres

Fig. 7. Details of the section of the western side of the upper part of Quikavsaup qùa (see fig. 4). The limit between Cretaceous sandstone and the Tertiary. The iron pan-like band show the limit uncovered by erosion at a sandstone point. The Tertiary sequence is covered with scree. In the background the basaltic landslide coulisse just above point 445.

north of the previously mentioned ridge that passes the section. From the observations made on the limit between the Cretaceous and the Tertiary formations it appears that the unconformity is formed by subaeric erosion on the Cretaceous beds after the tipping of the area. The arguments for this statement are the inequalities of the unconformity, the weathering of the surface of the Cretaceous sandstone along the unconformity together with the mould-like formations etc. forming the weathering mantle. No conglomerate or other signs of marine influence was observed.

The unconformity represents a period of Upper Cretaceous-Paleocene. The Atâne beds belong according to Heer to the lowermost Upper Cretaceous (Cenomanian), and the "Upper Atanikerdluk A" above the unconformity to the Paleocene in accordance with the floral equivalence of the Lower Paleocene of the Angmartusût valley[1]). The movements expressed by the unconformity are probably the same as

[1]) This flora has not yet been published. Ref. Dansk Geol. Foren., Vol. 12, Part 1, pag. 158.

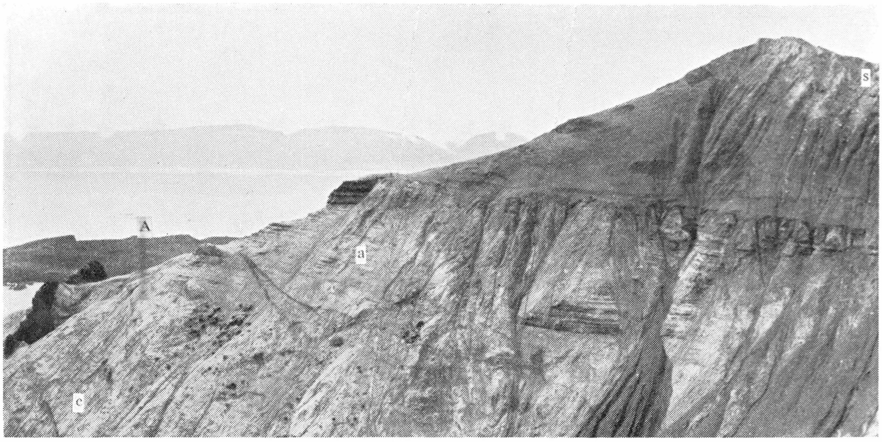

Fig. 8. The section of point 445, upper part of Quikavsaup kûa. A = Atanikerdluk peninsula, a = Lower Fluviatile Series, b = Lower Shale Series, c = Cretaceous Series, d = dyke III, s = sandstone at point 445. In the direction of the arrows 1 and 2 two small dykes are seen. Dyke 2 reaches the limit a/b where it is cut off. The Vaigat strait and the Disko island in the background.

those appearing from the large conglomerates between the Senonian-Danian and between Danian-Paleocene on the localities of the northern coast of the Nûgssuaq peninsula pointed out by Rosenkrantz (Rosenkrantz and others 1940).

Lower Fluviatile Series.

The sequence with the classic fossil flora "Upper Atanikerdluk A", found just above the Cretaceous beds, has a thickness of about 40 metres. Confronted with the section of the Quikavsaup kûa gorge these beds seem to be in a horizontal position, the section holding the same course as that of the strike. Strike is between N 40° and N 60°, dip 6°—12° NW[1]). The below mentioned measurement of the profile was made along the previously mentioned ridge running nearly from point 445 (i. e. the top of the hummock straight to the west of the gorge) and through the section down to the unconformity. The beds are exposed in the nicest way at this ridge that forms several projectings (fig. 8). The section consists of the following beds from the bottom and upwards:

Alt. 370 m. Unconformity between Cretaceous and Tertiary.

(1) Sandy clay, downwards passing into grey clay .... 0.75 m
(2) Brown sand with yellow veins .... 0.50 m

[1]) The measurements are not conclusive as the sediments are in lenses, are cross-bedded etc. as normal fluviatile sediments. After this paper was sent to the printer my investigations were carried on in the field and it was obvious that the Tertiary beds of this region has a slight eastward dip (less than 1°).

Fig. 9. Incoaled trunk transected by erosion. From the Tertiary Lower Fluviatile Series (Paleocene) (3). Quikavsaup kûa.

(3) Alternating beds of light grey quartz sand and shale with sideritic concretions and sideritic silty shale often passing into homogenous bands. The sideritic rocks (clay-ironstone) contain the amount of leaf impressions making up the "Upper Atanikerdluk A" flora. Fragments of coal are found scattered in the sand, big pieces of incoaled wood are often found in the shales. In the upper part of (3) incoaled trunks in vertical position are found (fig. 9, 10). The sand often shows cross-bedding, and the thickness of the beds range from $^1/_2$ m to 1 m; the shale beds are often thinner, about 0.25 m . . . . 25 m

Alt. 396 m.

(4) Shale with brown weathering colour, badly preserved plant fossils 0.3 m

(5) Light coloured (white-red) quartz sand of varying grain-size (sand-gravel) with some veins of coaly detritus and some thin shale bands 0.6 m

(6) Brown shale with several thin bands of coal and fissile shale, with badly preserved plant fossils . . . . 0.6 m

(7) Badly consolidated sandstone in lenses (maximum thickness 10—60 cm) separated in the upper part by shale which entwines the lenses. Almost in the middle of this series a traversing band is found, of 30 cm's thickness, in the upper part consisting of brown sandy shale, and in the lower one of black bituminous shale. Under this band the sand lenses are entwined with pure white, coarse-grained quartz-sand with coalpieces contrary to the lenses in which the sand is of an ochreous colour. The ochreous

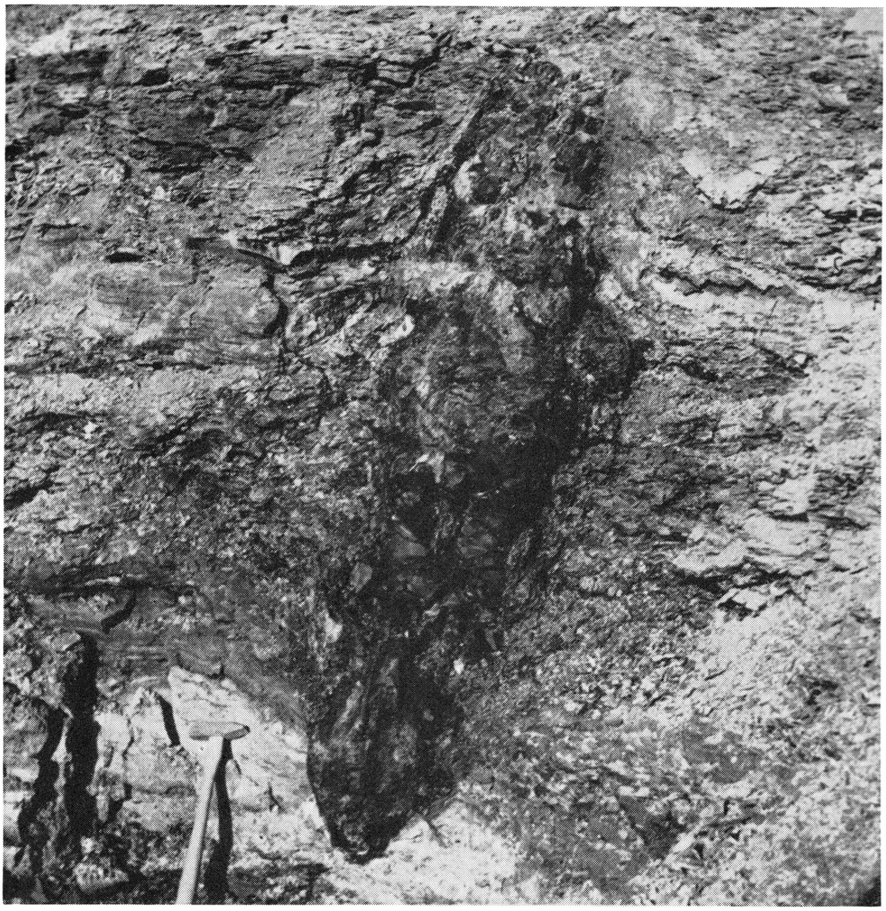

Fig. 10. Uncovered part of an incoaled trunk. The Tertiary Lower Fluviatile Series (3) of the ravine west of point 445. Atanikerdluk.

sand is so conspicuous that the horizon is easy to follow all through the section. Above the traversing shale bed the sand lenses are of a rose colour. Within the lenses coarse and fine sand bands are changing 2.5 m

(8) Black, fissile, bituminous, and a little lustrous shale with plant fossils 0.1 m

(9) Brown, fissile shale alternating with bands of black shale and thin flat lenses of coarse sand.. 0.1 m

(10) Light coloured (grey-white) quartz sand of medium size....... 0.3 m

(11) Grey, fine-grained sandstone with irregular fracture and mica grains seen on the splitting plains. At the bottom is a band of dark ochreous coloured, micaceous, fine-grained rock .... 0.9 m

(12) Badly consolidated, dark ochreous sandstone rich in angular quartz grains and with coal particles seen on the bedding plains. It contains a 5 cm thick shale band, and at the bottom a band of thin splitting sandstone as the main rock.................................... 0.4 m

(13) Ochreous, ductile, hard sandstone of medium grain-size with small, angular, bright quartz grains and coal particles in a fine-grained, dark ochreous ground .... 0.2 m

Alt. 402 m. From this altitude the shale sequence follows upward, containing Heer's "Upper Atanikerdluk B" flora.

A detailed measuring of this series and the following was made by Brown in 1867 (see Brown 1875).

The Lower Fluviatile Series is probably deposited on an alluvial plain or inland delta not far from the coast of the Paleocene sea as marine deposits are found only 40 km at the coast in a direct line northwest of Atanikerdluk[1]). The sediments show that in all probability the stream came from the easterly half of the compass card, and that the river has moved on and worn the surface of strongly eroded Cretaceous sandstone, which probably, to a great extent, makes up the Lower Fluviatile Series. The river has moved with a small gradient on a flat plain and has not had much transporting ability as the deposits are by no means coarse, gravels being excluded as far as Atanikerdluk, beds of clay (shale) and sideritic clay deposits being well represented, and the minerals of the varied metamorphic complex situated not far (min. 20 km) from Atanikerdluk playing no important role in the sandstone. It seems as if the river has often been loaded with the clay grade only, and that the transport of coarse materials has only been of local importance. The regular alternation between cross-bedded, pure quartz sandstone, and beds of clay grade of (3) is obvious. The last-mentioned deposit gives evidence of periods with a cover of slowly streaming or stagnating water to which the leaves of the vegetation, now represented by the bulk occurrence of leaf impressions, have flown extensively and through putrefaction made up the favourable possibilities of deposition of siderite. These conditions were regularly interrupted by irrigation of the stream causing deposition of sand. The picture is that of an alluvial plain or delta plain fertile to the rich vegetation of lowland forests which by their leaves have written their biography in the deposits. The regular alternation between deposition of sand and clay tells about the river's changing transport of water, but we can see nothing about the cause, namely whether it is a secular change brought about by the temperate climate of which the flora gives evidence.

From the frequent occurrence of mica grains in the silty shales it appears that the metamorphic rocks to the east of the area treated have been exposed at that time. The Cretaceous sandstone can neither have furnished the mica nor the rich supply of ferric matter which is the source of the siderite in the clay ironstone of the said type.

[1]) At Tuapaussat.

Fig. 11. The section of the small ravine west of point 445. Atanikerdluk. The exposure shows the Tertiary Lower Fluviatile Series.

The fossils are extremely well preserved leaf impressions in the sideritic rocks and incoaled gagatic wood which does not allow investigation of the wood structure, a thing well known from the Tertiary sediments of the North Atlantic Basaltic Region, i. e. Iceland where it is called "surtarbrand".

The best known exposure of the Lower Fluviatile Series is the section of the western wall of the Quisavsaup kûa gorge. As it is seen from the diagrammatic section of pl. I, the beds of the exposure disappear in the slope covered with vegetation just below a basaltic hill representing a downslid block (a landslide coulisse) situated to the north of point 445 (fig. 7). From the basaltic hill the beds can be followed in the wall of Quikavsaup kûa till it turns towards southeast i. e. towards the waterfall. If we pass the previously mentioned ridge that crosses the section, the beds are again seen in the coastal slope proceeding towards north-west to a small ravine, that passes to the west of point 445 in the direction of almost northsouth. In the eastern wall of this ravine there is a low outcrop (fig. 11), ranging from an altitude of 396 m to an altitude of 410 m. It is in outline equivalent to the section of Quikavsaup kûa, though the lowermost part is not exposed.

From this locality the beds can be traced further on towards west. The slope is entirely covered by solifluction and vegetation, and no exposures are found till the next ravine, the uppermost part of the

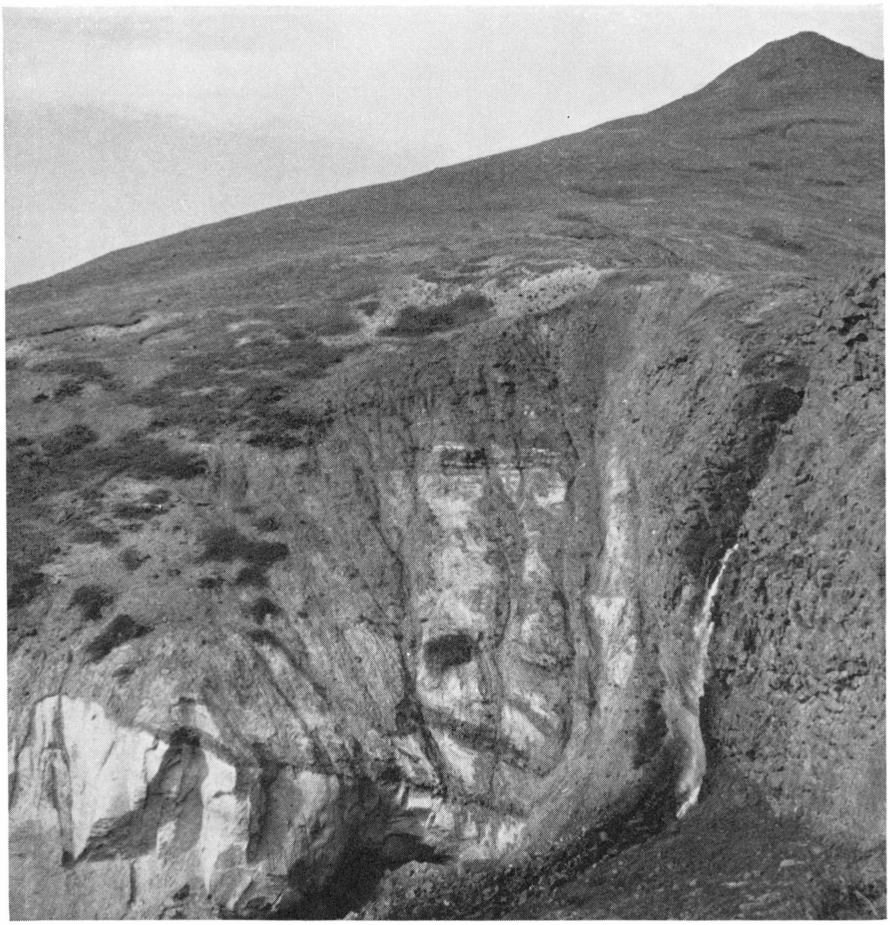

Fig. 12. The small outcrop of the uppermost part of the Liriodendronkløft. To the right dyke II. In the lowermost part of the profile the conspicuously dipping Cretaceous beds. Somewhat higher the Tertiary with almost horizontal bedding. The unconformity is to be found under the part covered with scree. A basaltic landslide coulisse is seen in the right top corner. Atanikerdluk.

Liriodendronkløft. At an altitude of about 390 m this ravine is traversed by a large dyke (dyke III previously mentioned in connection with Quikavsaup kûa); this dyke forms a 10 to 15 m high dam which suddenly brings the ravine to its close. Below this dam (to the southwest of it) and connected with it, the sediments are exposed in the western wall of the ravine (fig. 12). The basis of the section was here at an altitude of 384 m. In the lowermost part of the outcrop there are a few metres of Cretaceous sandstone. In the upper part of it follow beds of "Upper Atanikerdluk A"-facies partly covered with scree. Undisturbed beds are seen 10 metres above the brook. No metamorphism of the sediments is seen, and it is easy to recognize that these beds are equivalent to those previously mentioned. I have found no exposures further on to the west of this locality, obviously on account of the landslide movements having reached their climax in the area between the said locality and Qagdlorssûp kûa.

It was told that the beds of the Lower Fluviatile Series were also seen in the eastern wall of the Quikavsaup kûa above the waterfall and to the west of dyke III (fig. 5). In the immediate neighbourhood of the waterfall a branch of the Quikavsaup kûa gorge separates itself from the main gorge and continues alongside the dyke that forms the western wall of it. The direction of the tributary ravine is almost north-south or almost parallel with the uppermost part of Quikavsaup kûa and the section of the "Upper Atanikerdluk A" beds. As these beds are seen west of dyke III, it should be expected that they continue at almost the same altitude in the eastern wall of the tributary ravine. But at this place the Cretaceous beds continue upwards above the altitude of the Tertiary beds until vegetation covers the rocks at an altitude of about 400 m where the tributary gorge disintegrates. This is in agreement with Nathorst's discovery of horizons with Atâne fossils at an altitude of up to 335 m (Nordenskiöld 1884, Nathorst 1884), the uppermost finding place probably being situated in the tributary ravine alongside dyke III (ref. pag. 11). At a brook east of Quikavsaup kûa, running as far as the tributary ravine, is a small exposure of sand and silty shale. At an altitude of 422 m there is yellow quartz sandstone with a band of grey siltstone (silty shale) rich in mica and coal particles containing rather badly preserved Atâne fossils. The strike and dip are the same as for the Cretaceous beds. At an altitude of 425 m there follows a disrupted mass of bituminous shale dipping 20° to 30° E, which I am inclined to find equivalent to the dislocated shales in the hill of point 445 (see pag. 29).

Further an exposure was found between altitudes of 460 and about 495 m. When following the brook of the tributary ravine alongside dyke III for about half a kilometre through the swampy terrain (covered with rich vegetation) above Quikavsaup kûa, we reach this section. The beds are principally cream-coloured quartz sand, with sand beds of other colours and shale. Fossils were not found to indicate the age, but the strike (about N 130° and dip 12° NE) are the same as for the Cretaceous beds. So I am inclined to refer them to the Cretaceous. In favour of this statement can be said that according to observations made on Naujat treated later in this paper the Tertiary Lower Shale Series (i. e. the in situ series equivalent to the shales containing the "Upper Atanikerdluk B" flora) would be found at this altitude provided that the unconformity has caused no complications in the structure of the area. If this supposition holds good, the old surface represented by the unconformity rises considerably at Quikavsaup kûa. With the Atâne fossils found at an altitude of 422 m, the tendency of the Cretaceous beds to rise east of Quikavsaup kûa is proved. In this connection it must be stated that the Lower Fluviatile Series is in situ in the western wall of Quikavsaup kûa. It is an indisputable statement as two small dykes are seen to continue from the Cretaceous through the Lower Fluviatile Beds.

A search for a fault responsible for the finding of Cretaceous beds at a considerably higher level to the east of Quikavsaup kûa than to the west of this place, gave negative results. In the Quikavsaup kûa gorge the beds continue undisturbed from wall to wall, and alongside the coast is an unbroken continuity through the zone under consideration.

As the Lower Fluviatile Series is also found to the east of the Sarqaq valley, at nearly the same level as at Atanikerdluk, it is my opinion that rising over the alluvial plain a hill of sandstone had been left by erosion with a rather steep slope or cliff at Quikavsaup kûa, limiting the plain at this locality. Owing to the cover left by solifluction and basaltic debris the unconformity and the lowermost Tertiary beds are not exposed between Atanikerdluk and the Sarqaq valley. There is no lack of big ravines on this distance. At the western side of the second big ravine east of Quikavsaup kûa we collected Cretaceous plants at an altitude of 400 m. In the western wall of the same ravine the Cretaceous sandstone seemed to reach an altitude of 460 m before it was covered with a basaltic landslide coulisse. So the "hill" or elevation of the surface seems to have a considerable extension towards east.

As already mentioned in the outline, chapter 2, pag. 15, I regard the Lower Fluviatile Series as belonging to the Paleocene on account of the equivalence of the flora of these beds to the Lower Paleocene flora of the Angmartusût valley and its tributaries of the inner Nûgssuaq peninsula[1]).

Lower Shale Series.

Above the Paleocene fluviatile series, the "Upper Atanikerdluk A" beds, follows black shales with bands of a brown clay (tuff?) containing the flora named by Heer as "Upper Atanikerdluk B". Continuing upwards alongside the ridge, and passing the section of Quikavsaup kûa we meet, as previously mentioned, the shale from altitudes of 410 to about 440 m. The shale is highly cracked and seems disturbed. The same applies to

[1]) The report on this flora has not yet been published. Ref. Dansk Geol. Foren., Vol. 12 Part 1, pag. 158.

Fig. 13. From the section of point 445. The upper part of the Quikavsaup kûa gorge. A small fault of the disturbed shale sequence. Atanikerdluk.

the brown band and the many thin clay-ironstone bands of the sequence, and for this reason it is difficult to obtain complete leaf impressions from these beds. Small faults were observed at various places (fig. 13). The dip is considerable, 42° to 48° westerly were measured. The strike is averagely N 10°. The steep dip towards north applies to the whole section, and was observed by Steenstrup as shown in his sketch fig. 3. Thus there is a considerable unconformity between the Lower Fluviatile Series and the shale formation, but not an unconformity in the ordinary sense of the word. The limit itself was not observed nor reached through digging as it is covered with shale thalus.

Above the shale and forming the top of the hill of point 445 there is a sequence mainly consisting of yellow sandstone alternating with subordinate beds of siltstone. At the "profile ridge" they are found between altitudes of 440 and 445 m. Strike is N 165°, and dip 60° E. As far as the entire section in the western wall of the Quikavsaup kûa gorge is concerned, the sandstone section on top is seen to have a considerable dip towards east (60°) in the southwesterly part of the section. But if we follow the same bed towards northeast the dip decreases gradually as the bed curves towards the horizontal position which it reaches in the northeasterly part of the section. It looks like part of a syncline. This was mentioned by D. White and Ch. Schuchert 1898 (see White and Schuchert 1898, pag. 364).

As mentioned below scattered minor occurrences, probably of the same shale, are found more westerly; it is seen in situ at Qagdlúnguaq (see pag. 41) where an occurrence of the brown clay with "Upper Atanikerdluk B" fossils was found by Dr. N. Hartz at the same altitude as the ancient precipitated occurrences of red shale with fossil plants, i. e. at an altitude of about 100 metres. The brown clay and its fossils indicate that the level of the "Upper Atanikerdluk B" flora reaches Qagdlúnguaq. The best exposure of these shales "in situ" is that of Naujat mentioned later on in the paper.

Landslide-coulisses.

The "Upper Atanikerdluk B" beds are evidently dislocated, and due to considerable landslide movements replaced from their "in situ" position. During the transport a tipping has taken place shown by the dip and bending of the beds. It is also during this movement that the shale has cracked, and at the same time the shale and the sandstone, independently of each other, have undertaken movements as a distinct easterly dipping fault separates the two parts. This does not only appear from their different dips, but also from a breccie produced in the fault-zone. As previously mentioned the lower limit of the downslid block, i. e. towards the Lower Fluviatile Series, has not been exposed, but an interesting observation was made here. As shown in fig. 4, there are two small dykes which come from the Cretaceous beds, pass through the fluviatile series, and have dips of 36° SW (dyke V) and 34° SW (dyke IV) respectively, measured in the direction of the section. They do not penetrate the shale series. The northernmost can be followed as far as the limit between the fluviatile beds and the shale where it is cut off. This is another argument in favour of the movement having taken place, and it also tells us that it has taken place after the basaltic eruptions had started, or the dykes would not have stopped at the fissured shales. What is seen is connected with the several basaltic landslide-coulisses found above Atanikerdluk. One of these is situated northeast of and above the dislocated sediments which disappear under it (fig. 7). The basalt beds of this hill has a pronounced dip towards land (i. e. N). In its southern slope where the basalt is exposed, the dip is 25° to 30° N in the direction of N 40°. Between this hill and Iviangernat several hills of the same kind are seen one above the other (fig. 5, fig. 7, fig. 14). The phenomenon is known from several places on the coast of the basaltic area i. e. Qagdlúnguaq (see pag. 42), Hareøen (Qeqertarssuatsiaq), and the eastern coast of Disko island opposite Atanikerdluk. The landslide has been of a considerable extension as crushed, black shale with clay-ironstone bands have been found at several places on

Fig. 14. Basaltic landslide coulisses east of Atanikerdluk. The big one in the centre of the picture is point 819 (see map pl. II).

the coast slope east of point 445, i. e. above dyke II at the previously mentioned locality of the Lower Fluviatile Beds of the upper part of the Liriodendronkløft. A similar occurrence is seen at an altitude of 425 m, about one kilometre more westerly. No doubt the shelf-like depression of the topography between Atanikerdluk and Qagdlorssûp kûa has its origin in a great slide. Probably the dislocation at Quikavsaup kûa represents the easterly flank of this landslide. The movement has caused ignition of the bituminous shale which will be treated below.

Burnt shales.

In connection with the downslid mass burned shale and sandstone, already mentioned by Steenstrup (Steenstrup 1883), have been found on the coast slope west of point 445. At this place the slope is covered with these rocks which are unfortunately without fossils. Steenstrup mentioned the finding of some indeterminable fossils, a couple of (marine?) molluscs (Steenstrup 1883, pag. 69). They are not included in the collections of the Mineralogical and Geological Museum of the University of Copenhagen, and so far no fossils have been discovered, in spite of our attempts. The cover of this red rock debris on the slope is so dense that it must be a question of a considerable burned mass. That it is connected with the slide and the dislocated rocks of the Quikavsaup kûa and the hill of point 445 is illustrated by the discovery of transitional rocks between red, strongly burned, and fresh black shale, silty shales, and sandstone of the exposures in question. Such transitional rocks were found in the small ravine west of point 445. At the bottom of it, at an altitude of 430 m, we discovered a block of a breccie consisting of angular pieces of the burned rocks in various shades of red, partly cindered together and partly cemented by a slag, often seen to have squeezed its way into the cavities as porridge. Often it only partly fills the cavities and shows a dense cooling mantle in contradiction to its blistered interior. It is obvious that a conbustion has taken place in the interior of the downslid mass, and that the temperature was considerably high. Steenstrup mentions the red shales and slags (Steenstrup 1883, pag. 69), and states as White and Schuchert did later on (White and Schuchert 1898) that no dykes are seen in the immediate proximity that could have caused the burning. They did not give any solution as they were quite unacquainted with this kind of landslide in action. The rocks accompanying the dislocated mass are absolutely of the same kind as those seen at Pujortoq (which means the place from where smoke comes) on the northern coast of the Nûgssuaq peninsula near the settlement of Niaqornat. At Pujortoq landslide took place in 1936 causing ignition of bituminous shale. Pieces of a breccie-like rock with slag cement are exactly like those from Atanikerdluk, and the surface of the burning cliff is vermilion-red. An account of the landslide in 1936 was published by Rosenkrantz (Rosenkrantz and others 1940, pag. 2). As already mentioned the phenomenon is seen as a considerable distribution of basaltic landslide-coulisses alongside the shores of the Vaigat strait where often red spots can be seen when you go by sea through the strait, i. e. at Pautût, Qagdlúnguaq, and Kingigtoq. At these places they were observed by Steenstrup (Steenstrup 1883). The places can be recognized on Moltke's drawing of the southcoast of Nûgssuaq published 1900 (Steenstrup 1900). On the occasion of the landslide at Pujortoq in 1936 the explanation of the formation of the red shales was set forth as stated by Rosenkrantz in the paper referred to above. Thus there are several indications that the dislocation of the shales containing the "Upper Atanikerdluk B" flora is caused by the action of landslide. But then we may ask the question: to what level in the in situ sequence do these rocks belong?

As there are no signs at all of the plateau basalt at the bottom or in the dislocated mass at all, and as these dislocated sediments disappear under a basaltic landslide coulisse, the possibility that they should represent an intrabasaltic or postbasaltic series from a sequence now removed by erosion is excluded. It must be pre-basaltic, and the sequence in which we must seek for the equivalent to the downslid mass is of no considerable size. The difficulty is that the sediments situated between altitudes of 500 m and 700 m are covered with landslide masses. But the section of Naujat, which will be dealt with in the following, gives the information wanted. But first must be described the following exposed parts of the sequence at Atanikerdluk.

The upper exposures.

Between Atanikerdluk and Qagdlorssûp kûa there is a great shelf-like depression bounded by a steep wall towards northeast (fig. 1). It rises from an altitude of 700 m to 1000 m. In the wall some exposures of the sedimentary sequence are found. The best one is in the south-eastern part of the wall. Here yellow cross-bedded quartz sand with some bands of shale appear among the scree. From an altitude of 748 m we could measure a tolerably continuant profile:

A) Alt. 748—770 m: Sand alternating with fissile shale. In the upper part the sand is of an ochreous colour.
B) Alt. 770—771 m: White sand with bands of ochreous sand.
C) Bituminous shale .... 0.1 m
D) Chalky, dirty quartz sand .... 0,3 m
E) White, ochreous quartz sand................................ 0.3 m
F) Chalky, dirty quartz sand with a 5—10 cm thin basalt vein... 1,2 m
G) Alt. 773—780 m: Black, bituminous shale with bands of clay-ironstone.

The series mentioned is overlain with a basaltic sill(?) about 80 m thick, which has penetrated the shaly series. I am not quite sure whether it is a sill or a lava cover, and I have not been able to secure samples from the centre of it. It consists of at least two beds, and if a sill it must be a multiple one. But I wonder how it is that a large sill like this have no effect on the bituminous shale as the organic matter should be expected to react easily when heated. The obvious fact is that not the slightest contact metamorphism has taken place. Hard, chertlike stone is often the result of such a contact which I myself have seen i. e. at Naujat. On the other hand the bituminous shale is indicative of a water cover at the time when this basalt was erupted in the case of a lava flow. If so, a pillow lava or basalt breccie, which is the representative of pillow lava in this region (see Sole Munck 1945), should be expected. Formation of basalt-breccie was the case on the opposite side of the Vaigat strait 25 km west of Atanikerdluk at Qutdligssat where I discovered a Tertiary shale series of the same kind as those at Atanikerdluk with brown clay bands (tuff (?)) containing leaf impressions. This shale sequence must be equivalent to one of those found at Atanikerdluk as the Lower Fluviatile Series containing an "Upper Atanikerdluk A" flora indicating the same events of deposition, is situated below this series at Qutdligssat. The shale was found on a sequence of basalt breccie about 150 m thick. At this place the formation of the basalt breccie was a result of subaquatic eruptions in connection with the water-covered basin in which the shale was later deposited. Why should not this be the case at Atanikerdluk under the same conditions? I am, therefore, inclined to believing in a sill at Atanikerdluk to believing in the alternative. And considering the fact that it is multiple, and that the whole thickness of 80 m was not intruded at the same time, the heating effect has, at the time of intrusion, been less, and at the same time the risk of influence on the shale was diminished, though I am fully aware that the lack of contact metamorphism may probably have other and more weighty causes. The same lack of contact metamorphism is found in connection with the intrusion making up the Atanikerdluk peninsula. The shale containing the "fern bed" (see pag. 8) is in contact with the intrusion and is nevertheless without any sign of contact metamorphism. So the lack of contact metamorphism does not suggest that the basalt in question is not a sill.

The measurements were continued above the sill(?) at the westernmost of the many ridges which divide the section between the sill (?) and the plateau basalt. Here the upper edge of the sill(?) is situated at an altitude of 864 m. It is overlain with bituminous shale with bands of clay-ironstone and a brown rock of exactly the same facies as that containing the "Upper Atanikerdluk B" flora (tuff?). Inspite of search we did not succeed in finding any fossils in these bands. But a little higher we found pieces of petrified wood scattered on the slope. At an altitude of 903 m the shale disappears under scree of yellow sand that comes from the succeeding sand series the underlimit of which has not been established. The series mentioned consists of yellow sand and sandstone with subordinate beds of sandy shale. The sandstone is rather coarse and rich in quartz, and in the upper beds there are a plenty of concretionary sandy bodies. At an altitude of 950 m the sedimentary series is overlain with the sequence of basaltic lavas, the plateau basalt. In the uppermost part of the sedimentary ridges we found a few badly preserved leaf impressions in sandstone and fossil wood less than 10 m under the basalt. These sediments are mentioned by Steenstrup (Steenstrup 1883) from Keglen, a cone-shaped sedimentary hill with a minor basaltic residuum crumbled down by weathering to a heap of blocks forming the top at an altitude of 942 m. At this projecting point of the highland above Qagdlorssûp kûa Steenstrup found some plant fossils, i. e. almost at the same niveau as that of our own findings just mentioned. According to Heer's determination (Heer 1883 b) *Taxodium distichum* Hr., *Ouercus groenlandica* Hr., and *Juglands paucinervis* Hr. were included in the collection. They are all known from the lower situated floras and do not show any difference. But being badly preserved they are probably indeterminable. As our fossils are also indeterminable, the age of these uppermost sediments of the Atanikerdluk area cannot yet be established. But the findings in these sediments are not without promise for a more thorough search. It was mentioned that a deposit of exactly the same facies as the dislocated occurrence of shale with its subordinate bands at point 445 was found at this much higher level, the shale sequence being seen from altitudes of 864 to 903 m. As no fossils were found in the brown bands within the shale, a connection between these two occurrences cannot be established, though one might be tempted to believe in such a connection. As it will appear later on, it is only a repetition of facies and succession characteristic of the Atanikerdluk area. If the "Upper Atanikerdluk B" occurrence of point 445 had come from this level by action of landslide, we would also expect that it was intimately mixed with the basalt from the great sill(?), and that is not the case.

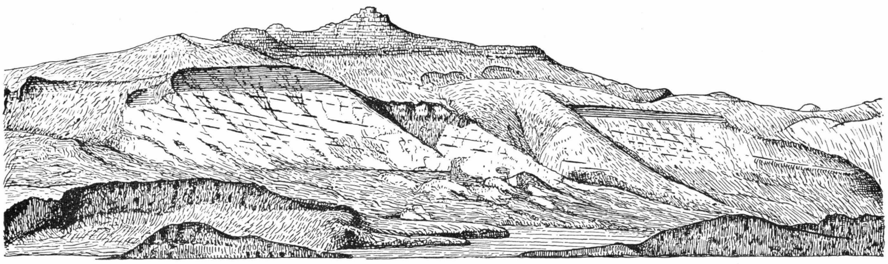

Fig. 15. The outlet of Sarqaq valley. In the foreground basaltic hummocks. In the background the western wall of the valley with the outermost sedimentary profile. Cretaceous sandstone and the Tertiary shale sequence (Lower Shale Series) are separated by an unconformity (sketch by A. Rosenkrantz).

CONDITIONS EAST OF ATANIKERDLUK

The Naujat section.

Naujat is situated 9 km east of Atanikerdluk immediately at the western side of the entrance of Sarqaq valley. The name refers to a small bay surrounded with basaltic cliffs representing one of the intrusions of the area described by Sole Munck (Sole Munck 1945). The locality was first mentioned by Steenstrup and Heer (Steenstrup 1883, Heer 1883). The exposure in question is situated in the western side and at the extreme end of Sarqaq valley at a distance of about 1 km from Naujat (fig. 15).

It is not my intention in this paper to give a detailed description of the sections in the surroundings of Naujat as I have not stayed there long enough for that. I shall only give a brief review of the conditions of the place as the section here may contribute to the understanding of the conditions prevailing at Atanikerdluk and complete the profile, which may be of value to the whole area from Sarqaq valley to Atanikerdluk. A similar review of the sections at Qagdlúnguaq and Kingigtoq northwest of Atanikerdluk will follow later on in this paper intending to show the conditions towards northwest. The whole area from Sarqaq valley to Mánik seems to be a tectonical unit. In the section of the western slope of Sarqaq valley near Naujat a sequence of about 300 metres' thickness is exposed (fig. 16). From the bottom of the section at an altitude of about 200 m to the unconformity at an altitude varying between 420 and 445 m there are Cretaceous beds of various colours from light yellow to white quartz sandstone with extremely subordinate shale beds, as opposed to the alternation which is characteristic elsewhere in the area. They have the regional, northeasterly strike and northwesterly dip varying from 10° to 15°.

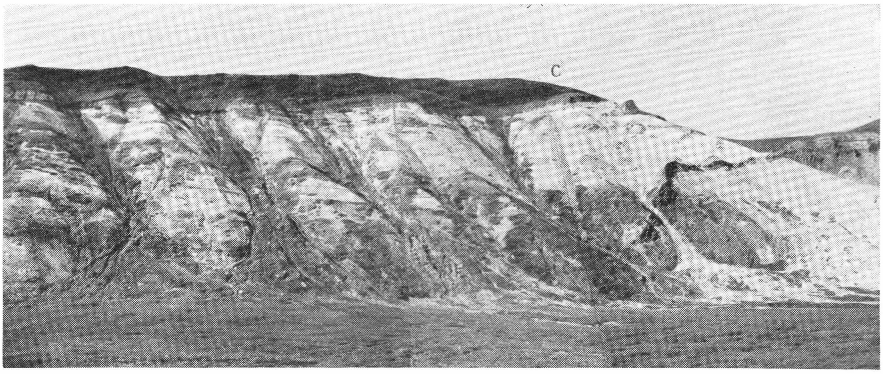

Fig. 16. The outermost sedimentary section of Sarqaq Valley. At the top the Tertiary Lower Shale Series. Just below it a 10 m high wall representing the Lower Fluviatile Series placed unconformably upon the considerably dipping Cretaceous sequence. The finding place of the "C flora" is at C.

Above the unconformity follows a wall of 10 m in height consisting of beds which I presume is the equivalent to the Lower Fluviatile Series of Atanikerdluk ("Upper Atanikerdluk A") (fig. 17). It consists locally of an ochreous-coloured conglomerate of up to 4 m, the only occurrence of the area, succeeded by cross-bedded sandstone. These beds are overlain with bituminous shale continuing to the highest part of the section at an altitude of 520 m. In the hill, which is a continuation of the section upwards, the shale is seen to an altitude of 630 m, but their upper limit may be at a higher level. The structures round the unconformity and the Lower Fluviatile Beds were studied in the centre of the extreme section of the valley where the beds are well exposed. But the search for fossils was difficult on account of the steepness of the wall consisting of Lower Fluviatile Beds. The search was resumed in the southernmost part of the section where the unconformity is not exposed, but only the uppermost parts of the Lower Fluviatile beds and the lowermost parts of the overlying shale sequence. Besides there are some divergencies in this part of the section as the limit between the fluviatile beds and the shale is here found at an altitude of 370 m in contradiction to the prevailing altitude of the section which is about 450 m. On account of the thalus further exploration proved impossible, but the exposure is sufficient for our purpose as it shows the distribution of the fossil-bearing horizons. From the abundance of pieces of this rock scattered on the slopes below the exposed parts can be seen that the sand above the unconformity contains the clay-ironstone with an "Upper Atanikerdluk A" flora. A horizon of sideritic sandy shale and ironstone is seen just at the limit of the overlying bituminous shale. It contains leaf impressions. In the

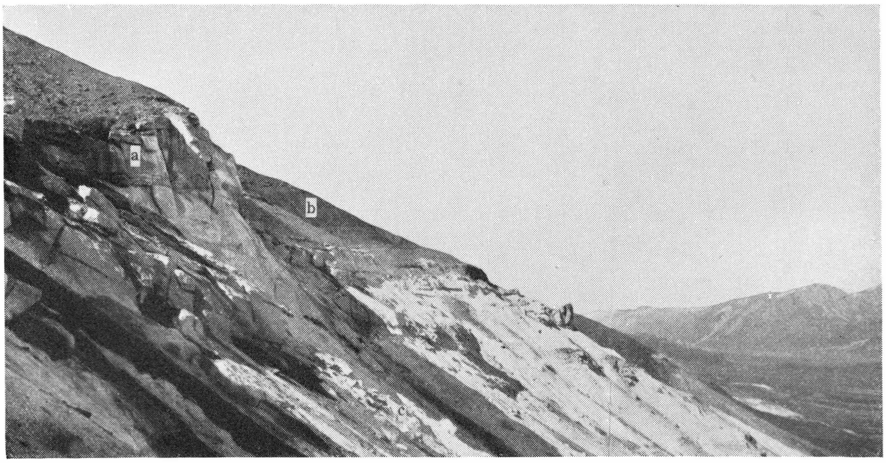

Fig. 17. Details of the outermost sedimentary section of Sarqaq valley. a = Lower Fluviatile Series, b = Lower Shale Series, c = Cretaceous.

shale just above the limit the first band of the brown clay well-known from the Lower Shale Series at Atanikerdluk (i. e. "Upper Atanikerdluk B" beds) are found succeeded upwards by others. Fossils like those of the "Upper Atanikerdluk B" were discovered, but it was difficult to obtain entire specimens.

So the conditions of Naujat show relation to the Atanikerdluk profile, the Lower Fluviatile Beds only being smaller in thickness. If this knowledge is transferred to the Atanikerdluk profile, it may be presumed that the "Upper Atanikerdluk B" beds have not undertaken any considerable vertical movement, only a merely horizontal one, and it can be stated that they originate in the Lower Shale Series.

Further it is of interest to note that another locality of leaf and fruit impressions was discovered at a higher level in the shale sequence. The fossils were found in the northern part of the big profile at an altitude of 490 m, i. e. about 50 m above the limit between sandstone and shale (see fig. 16). The flora in continuance of Heer's was named "Upper Atanikerdluk C" and is situated at a higher level than "Upper Atanikerdluk B". At this stage the flora is only preliminary treated in order to suggest the composition. Leaves of *Cercidiphyllum arcticum* (Heer) Brown have been found in considerable quantities; also the characteristic fruit of *Cercidiphyllum* is represented. Coniferous sprays, among which *Metasequoia* (cfr. *M. occidentalis*) is recognized, are frequent. Furthermore leaf impressions have been found which according to Heer's determinations are *Pteris groenlandica* Hr., *Laurus primi-*

genia Ung., and *Quercus Lyelli* Hr. together with an association of leaves distributed on the species *Juglans crossi* Knowlt. (Heer: *J. denticulata*) and *Carya Heerii* (Ett.) Hr. (Heer: *Juglans denticulata*). These species (see Heer 1883, pl. 75 and 76 etc.) of Juglandaceae must be regarded with some reservation, as they pass into each other and are difficult to distinguish; a revision is necessary.

In the outline of chapter 2 was mentioned a conspicuous difference in the composition of the A- and the B flora. The difference presents itself, for instance, by the infrequency of *Cercidiphyllum arcticum* in the B- which is so richly represented in the A flora. The C flora has much in common with the B flora, but contains an abundance of leaves of *Cercidiphyllum arcticum* and impressions of fruits of the species too which also links it to the A flora. A feature in which the B- and C floras in common differ from the A flora is the complete lack of *Macclintockia kanei* (Hr.) Sew. et Conw., the characteristic species that is so absolutely common in the A flora and the Lower Paleocene flora of Angmartusût valley (not yet published). Also the two other species of this nominal genus: *Macclintockia dentata* Hr. and *M. lyalli* Hr. of the last-mentioned floras are lacking in the B- and C floras. This seems to be a conspicuous difference, but whether it is a real change in the composition of the flora of this region useful to stratigraphy, or a result merely at random (a mere casual incident), or it is due to some ecological changes within this restricted area has not been conclusively stated at present. The occurrence of *Macclintockia kanei* in the flora of Kingigtoq (see pag. 43) may demonstrate that this species reaches a higher level than the A flora horizon in the said region. And the final impression must be that of a more homogenous flora when taking into account the composition of the floras of the whole region, contrary to what seems to be the result of the isolated Atanikerdluk floras.

The Lower Paleocene flora of Angmartusût valley, not yet published, suggests that the "Upper Atanikerdluk A" beds most likely belong to the Paleocene. According to the fascinating work by R. W. Brown of fossil leaves, fruit, and seeds of *Cercidiphyllum* (Brown 1939) the norm of the leaf shape can in a larger sense tell us something about the age of a collection of fossil *Cercidiphyllum*. According to Brown the *Cercidiphyllum arcticum* is characteristic of the period Paleocene to Middle Eocene, and so the C flora of Naujat cannot be much younger than the Paleocene A flora of Atanikerdluk, which also contains *Cercidiphyllum arcticum*. But furthermore one, perhaps two specimens of the younger *Cercidiphyllum elongatum* type may be represented in it. I dare not attach too much importance to this occurrence in a collection of leaf norm of *Cercidiphyllum arcticum*-type, all the more because the information of the distribution of *Macclintockia kanei* which I have collected, makes me believe that the said species in the arctic latitude is restricted to the lowermost Tertiary, possibly the Paleocene only. I have come to this conclusion by regarding the occurrences of *M. kanei* in the light of the southward migration of the floras of the northern hemisphere during the Tertiary as advanced by Chaney (see Chaney 1936, which subject I am going to treat later on in a report on the Lower Paleocene flora of Angmartusût valley.

CONDITIONS NORTHWEST OF ATANIKERDLUK

Qagdlúnguaq.

Qagdlúnguaq is the name of the second big ravine northwest of Nũnguaq (see pag. 5). Fossils from an occurrence of red, burned shale were determined by Heer (see Heer 1883, pl. LXVI—LXVII). This red shale is situated at an altitude of about 100 metres (260′ = 82 m according to Steenstrup 1883), i. e. below the entrance of the ravine. Dr. N. Hartz has, from almost the same altitude (270' = 85 m), brought a minor collection to Copenhagen in 1890. These samples are of the brown rock well-known from Atanikerdluk, and apparently unaffected by heat, but possibly belonging to the same landslide. I have determined the fragmentary fossils which are well-known species from the "Upper Atanikerdluk B" flora of the brown band of the Lower Shale Series of Atanikerdluk and Naujat. According to Heer's terms the following species are represented, namely: *Pteris groenlandica* Hr. *Onoclea sensibilis arctica* (L.), *Juniperus gracilis* Hr. *Sequoia langsdorfii* Brgn., *Glyptostrobus Ungeri* Hr., and *Torreya borealis* Gr. The "Sequoia langsdorfii" is probably a *Metasequoia*

In the big ravine of Qagdlúnguaq I made a reconnaissance in order to follow the Lower Fluviatile Series of the Tertiary towards northeast. The Cretaceous series of quartz sand alternating with bituminous shale was found to continue to an altitude of 460 m from where the Cretaceous beds were overlain with bituminous shale, which disappears under thalus and solifluction at an altitude of about 500 m. No signs of the Lower Fluviatile Series were found, nor in the shale any brown clay bands of the "Upper Atanikerdluk B" type. It must be admitted that the search for "Upper Atanikerdluk B" fossils was not a thorough one, the shale slope being so steep that we were in constant danger of falling down, and it was only with the greatest difficulty that we managed to pass it.

Nevertheless, the occurrence of the brown rock with "Upper Atanikerdluk B" fossils in the precipitated mass below the entrance of the ravine indicates that the level of "Upper Atanikerdluk B" reaches

Qagdlúnguaq, which opinion is also supported by the altitudes of the shale occurrences at the locality of Atanikerdluk and Naujat. The Lower Fluviatile Series is, however, not represented at this locality.

Kingigtoq

is a locality at the depression of Mánik situated 15 km northwest of Atanikerdluk. A scouting was undertaken here. On ascending a big ravine at the entrance of the Mánik depression we passed the characteristic Cretaceous sequence and reached the basaltic sill situated on the limit between the Cretaceous and the overlying shale sequence at an altitude of about 650 m. The shale is unconformably deposited upon the Cretaceous sequence; the unconformity is most clearly recognized in the exposures of the westward slope towards the Mánik depression. The shale sequence consists of bituminous shale with clay-ironstone bands and continues to an altitude of about 800 m, from which level it is succeeded by a yellow sandstone on which the basalt rests. From the heights above Kingigtoq these sequences of shale and sandstone were observed to continue at Ugpatdluk at the northern side of the Tarajornitsoq valley. The Lower Fluviatile Series at Atanikerdluk is not represented as the shale sequence rests direct on the Cretaceous beds as is the case at Qagdlúnguaq. At Qagdlúnguaq the unconformity is situated at an altitude higher than that at Atanikerdluk, and at Kingigtoq this position is still more pronounced as the altitude at this place is 650 m. The observations made at Kingigtoq show that the old surface, represented by the unconformity, rose towards northwest within the distance of 15 km from the Atanikerdluk depression, and the more so as a slight tipping has taken place later, expressed by the slight northeasterly dip of the Tertiary strata in situ.

At Kingigtoq as well as at Atanikerdluk considerable landslides have been in progress followed by corresponding combustion demonstrated by huge occurrences of red, burned shale situated about 100 m above sea-level. In this occurrence there is a locality rich in leaf impressions from which species have been described by Seward and Conway (Seward and Conway 1935) partly based on the collections gathered by Dr. Hartz. This flora must, as is the case with the red shale, originate in the shale above the unconformity, but our short visit to the place did not leave us time to look for the in situ occurrence. On making a comparison with the profile of Atanikerdluk I am inclined to regard the upper sandstone sequence of Kingigtoq equivalent to that of Atanikerdluk, that is: if any comparison is possible at all. Taking this assumption for granted, the shale of Kingigtoq must be equivalent to the Lower Shale Series of Atanikerdluk. The Kingigtoq occurrence is thicker than even the Upper Shale Series of Atanikerdluk including the 80 m of basalt which can only be included in the depositing in case of basaltic surface flow. To clear up the closer relationship between the shale at Kingigtoq and the profile of Atanikerdluk-Naujat a continued field investigation will be necessary. From aerial views, placed at our disposal by the Geodetic Institute of Copenhagen, it appears that the shale sequence ends about one km east of Kingigtoq. From this place the sediments continue in an easterly direction at the same time as the colour puts on a lighter shade, which in view of the knowledge of the facies of the localities might suggest sandstone. Whether this has its origin in the previously mentioned Cretaceous-Paleocene surface relief or in a change of facies, has not been observed. In order to get the right impression of the relationship between the many flora discoveries of the area, it is, however, necessary to acquire a more profound knowledge of the development of the sequence in the whole area than was possible on this reconnaissance.

Our reconnaissance at Kingigtoq shows that it is only with some hesitation that the Atanikerdluk profile can yet be transferred to the area northwest of Atanikerdluk. The differences are due to the rising of the unconformity, and it may be expected that also the intervening area shows considerable unevenness. At Atanikerdluk there are indications to that effect, and aerial views support this supposition too. Thus the Tertiary sequence of Kingigtoq may only in part be equivalent to the Atanikerdluk profile; and the shale facies is dominating in relation to that profile. But as the aerial views, as previously mentioned, show anomalies as far as east of Kingigtoq, it is impossible to establish a comparison at present.

As already mentioned Seward and Conway have published a collection of plant impressions from Kingigtoq (Seward and Conway 1935). The greater part of these fossils comes from the red shale which must be considered identical with the black one of a high altitude, i. e. the Tertiary beds. As pointed out by Seward and Conway there are among the described material some species which are generally found in the Upper Cretaceous, namely *Laurophyllum plutonium* and *Sciadopitytes borealis* (Heer: *Danmarites borealis*). These are, however, in clay-ironstone of a characteristic, brown shade different from that of the Tertiary Lower Fluviatile Series (Upper Atanikerdluk A). He who knows the rocks of the area well will recognize this ironstone as identical with that making up the bands in the upper part of the Atâne series (i. e. Upper Cretaceous) of Atanikerdluk containing the flora discovered by Nathorst (see pag. 11). Attention must be drawn to the fact that the fossils described by Seward and Conway are not all of the same age. Seward and Conway do state that the fossils of the clay-ironstone are of Upper

Cretaceous age, and from my experience of the rocks of the area I would regard the ironstone mentioned by Seward and Conway as belonging to the Atâne series of Kingigtoq, though I have not seen it in situ at this locality. Seward and Conway mention "the conformable succession of the plant-bearing beds in Greenland etc." which is a contributary difficulty on determining the age of the beds. The present work shows that the sentence just quoted rests on a severe misunderstanding as a pronounced unconformity has been found between the Cretaceous and the Tertiary beds of the area. If we regard the fossils from the ironstone as one flora, and those from the red shale and the black shale (the in situ, unmetamorphosed equivalent to the red shale) as another flora, we have a typical Upper Cretaceous and a Lower Tertiary one from the Kingigtoq.

SUMMARY

From the preceding chapters it appears that the Cretaceous series (i. e. the Atâne series) has its smallest thickness at Atanikerdluk (about 370 m above sea-level) as compared with Kingigtoq (about 650 m) and Qagdlúnguaq (about 475 m) northwest of it, and also with the terrain only one km east of the Quikavsaup kûa gorge (about 500 m). This reflects an uneven surface relief created during a period of vigorous erosion within the Upper Cretaceous when the erosional forces cut out this topography in the Cretaceous deposits. At the beginning of the Paleocene erosion changed to deposition, the latter continuing with a considerable surplus during that etage. This change of conditions again reflects a considerable negative epeirogenetic movement during the Paleocene as the pre-basaltic (i. e. the oldest Tertiary) sedimentation, which succeeded the Upper Cretaceous erosion, amounts to a sequence of about 600 metres at Atanikerdluk. The best evidence of this epeirogeny is the existence of the marine Paleocene deposits in the northern part of the Nûgssuaq peninsula, starting with a great transgressional conglomerate (see Rosenkrantz and others 1940). The deposition on the unsubmerged land at Atanikerdluk naturally started in the river valley represented by the maximum depression of the unconformity between Cretaceous and Tertiary beds at Atanikerdluk, and the lowermost Tertiary series is typically fluviatile. This series does not stretch as far as the more westerly situated locality of Qagdlúnguaq where the Cretaceous rocks were first covered with the succeeding deposition of clay. The former surface consists mostly of light sandstone which was gradually covered with changing deposits of fluviatile and clay sediments, two facies that change through the entire sequence, each of them every time deposited in a considerable thickness. Thus the sequence has a simple architecture, the monotony being the more outstanding when the Atanikerdluk sequence is seen in total as the fluviatile part of the Tertiary beds mostly consists of redeposited Cretaceous quartz sand.

The Tertiary sequence may be divided into 5 distinctly limited series on the basis of petrological evidence:

1) Lower Fluviatile Series with the classic flora "Upper Atanikerdluk A".
2) Lower Shale Series with the classic flora "Upper Atanikerdluk B", and the recently discovered flora "Upper Atanikerdluk C".
3) Upper Fluviatile Series.
4) Upper Shale Series.
5) Top Sandstone Series with the scattered findings of badly preserved plant fossils.

These alternations are of course due to changes in the conditions of nature, and as volcanic tuff beds as a mark of the incipient volcanism were found within the Danian etage of Nûgssuaq by Dr. Gry (Rosenkrantz and others 1940), it seems natural to put the phenomenon into connection with the accelerating volcanism; its eruptions may periodically have built up barriers for the drainage system with succeeding inundations. The negative epeirogeny formerly mentioned may have played a role too. I am inclined to attach most importance to the former cause because the change from fluviatile to clay deposits is abrupt, and because the basalt breccie northwest of the Qutdligssat valley of the eastern Disko island, opposite to the Atanikerdluk area, is situated within a series of bituminous shale containing plant fossils resembling those of the B and C floras of Atanikerdluk, i. e. the Lower Shale Series, though the Upper Shale Series cannot be excluded from this comparison.

The above-mentioned 5th section (the Top Sandstone Series) was covered with the basaltic lava flows, the plateau basalt. Whether the basalt rests conformably or unconformably on the sediments, I am not able to state.

The Lower Fluviatile Series, being accessible to closer studies in the field, shows an alternation of sand and clay sediments, the clay-ironstone of the latter containing the "Upper Atanikerdluk A" flora. Compared with a flora of well-founded Lower Paleocene age from the inner Nûgssuaq, this may belong to the Paleocene, and at this moment I cannot see any reason for separating the "Upper Atanikerdluk A" flora from the others of the area, i. e. from Naujat, Qagdlúnguaq, Kingigtoq, the Upper Atanikerdluk B and -C. As to this point I believe in Heer's statement (Heer 1883): that they belong to the same floral community. But it must be admitted that so far no well-founded solution to this problem has been found.

To come to a solution would require another investigation and revision of these old floras, known for about a century, as well as a thorough knowledge of the structure of the whole area from Mánik to Sarqaq valley, to which this paper is but a contribution. Furthermore it is of the greatest importance to know where the flora of Kingigtoq is situated within the standard profile of the area. So first and foremost: further investigation is necessary. If the Kingigtoq flora, probably belonging to the black shale at an altitude of about 650 metres, is situated at a higher stratigraphical level than the "Upper Atanikerdluk A" flora, the last-mentioned outstanding difference between this flora and those of higher levels, the existence or non-existence of *Macclintockias*, is obliterated. Only if it could be proved that the Kingigtoq flora like the "Upper Atanikerdluk A" flora is older than the "Upper Atanikerdluk B" and the "Upper Atanikerdluk C" floras, there will, on the basis of floral evidence, be an obvious reason for a bipartition of the pre-basaltic Tertiary sequence. But till then there will be every reason to believe in the former possibility.

The geology of the Atanikerdluk area is rather obscure on account of the many basaltic landslide coulisses, now visible relics of the landslides that have dislocated the sediments, i. e. part of the classic section of the Quikavsaup kûa gorge near Atanikerdluk. To these landslides can furthermore be traced the red, burned shales which is a result of combustion of the bituminous shales. The landslides must have taken place after the inland ice, which left the Atanikerdluk peninsula as a "roche moutonnée", retreated from the area, as otherwise the weak, unconsolidated landslide coulisses would easily have been removed by the powerful ice, and in case they had resisted the ice, they would have shown distinct signs of its attacks.

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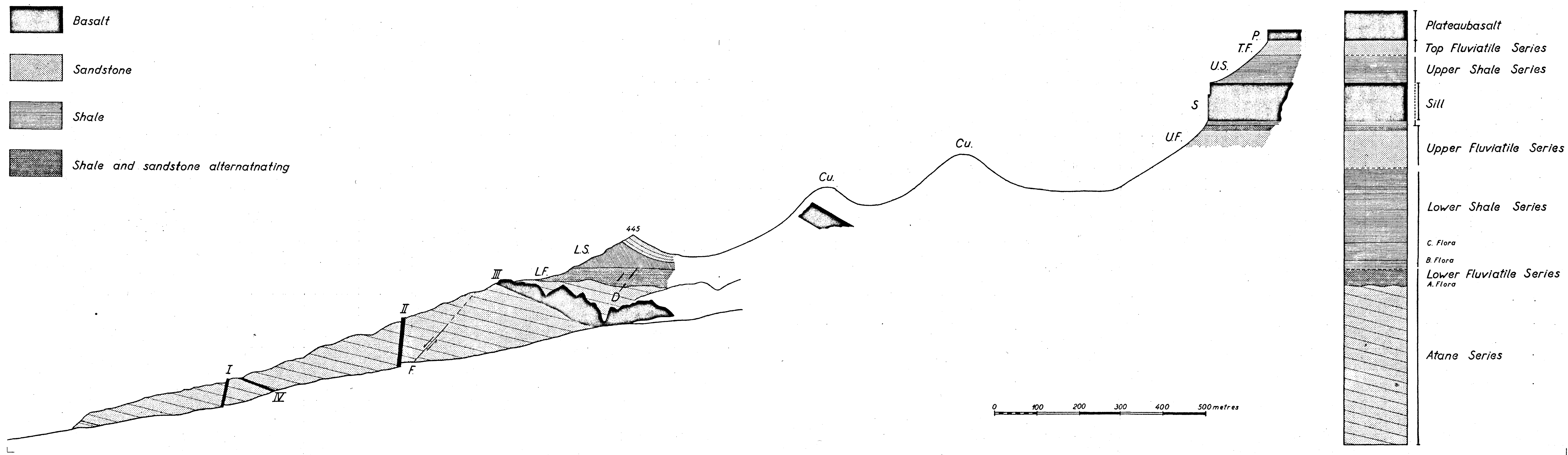
PLATES

Plate I.

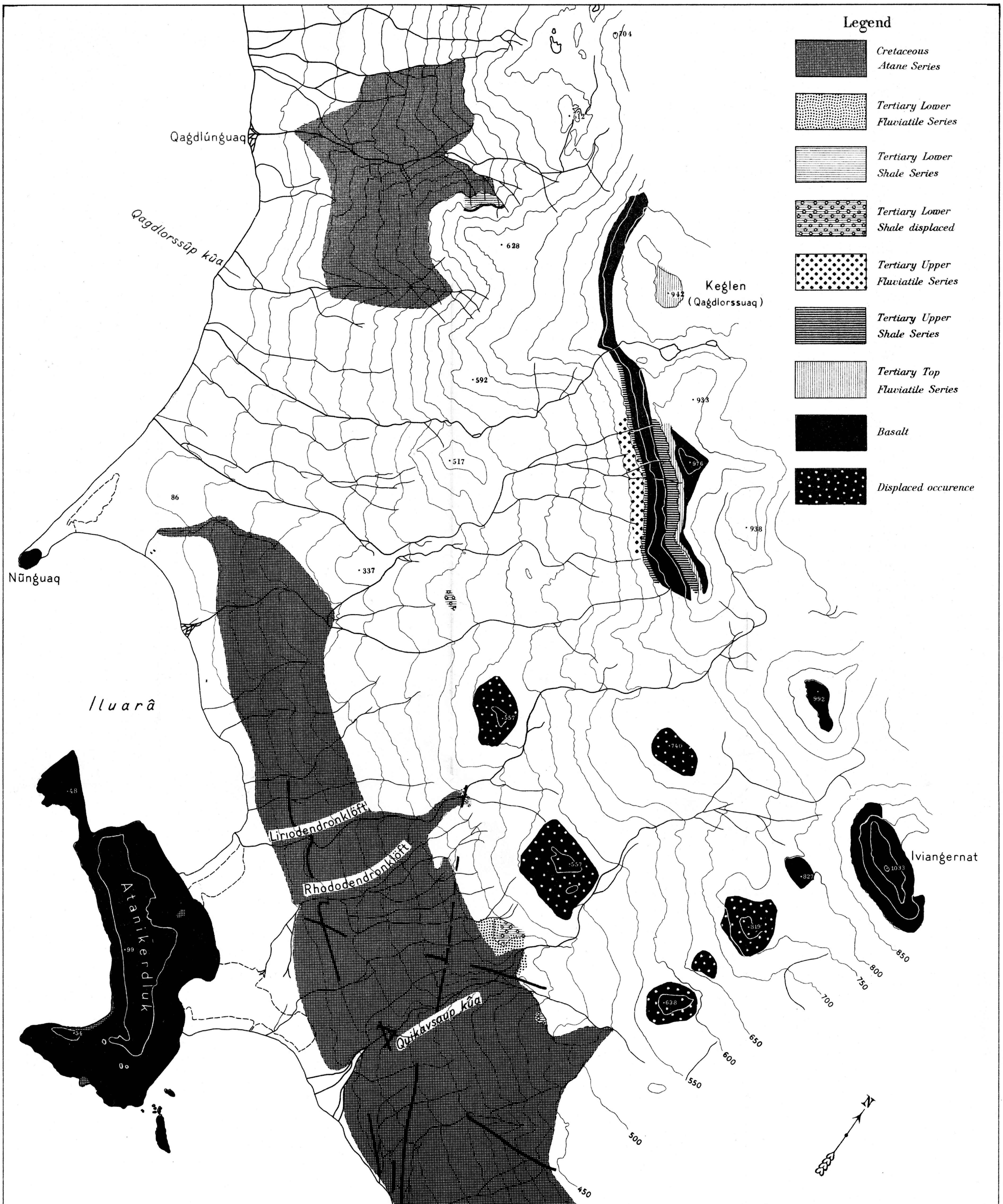
Diagrammatic section through the sequence of Atanikerdluk, NW. Greenland. I, II, III, IV marks the dykes of Quvnikavsak. Cu = landslide culisses.

DIAGRAMMATIC SECTION THROUGH THE SEQUENCE OF ATANIKERDLUK, N.W. GREENLAND



Preliminary Geological Map of the Atanikerdluk Area.

By Eske Koch.



Aerial photographs taken 1952 Not field checked.
Topography from aerial photographs by Stereoplanigraph.