

flying away from a properly organized base difficult and not a little dangerous. However, during the course of the Expedition, several large Lakes were discovered, one on Angmagssalik Island, and the other at the head of an un-named fjord in Lat. about 66°. Both of these are quite large enough for the largest type of commercial flying boat or sea-plane at present in use, and owing to the fact that they are ice free, should make ideal Bases. There was no fog, and no strong winds during the summer.

During the winter the most serious problem we had to contend with was the very large number of Föhn gales. The actual trouble was chiefly due to the fact that we were quite unprepared for them. We found that they were very local in their effect, and I consider that, given two fairly well separated bases, efficient meteorological organization, and wireless to communicate with aircraft while in flight, this difficulty could easily be overcome. Apart from these gales, the weather conditions are quite suitable. Again, the Fjords are not suitable for Bases as, in the event of the freeze up taking place during a period of on shore winds, the surface might freeze up when the fjord was full of pack ice so that it would be too rough for flying all the winter. This difficulty would not be present if the lakes already mentioned were used as bases. If the cockpits and cabins of aircraft are efficiently heated, no trouble should be experienced from cold.

The only really serious drawback to an air route over Greenland is the long period when no flying could take place from the coast due to the sea freezing over during the Autumn, and the ice breaking up again during the spring. During the years 1930--31 we were unable to fly from 15.9.30 till 19.12.30 and again from 19.5.31 till 20.6.31. These times would have been less if we had been operating from a lake, and the difficulty would have been overcome if we had had a flying base on the edge of the Ice Cap.

The total amount of flying done during the course of the Expedition was, 72 flights totalling 79 hours 05 mins.

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### **Preliminary Account of the Geology and Geomorphology of the Angmagssalik District and the Coast Northwards to Kangerdlugsuak Fjord.**

**L. R. Wager.**

The few geological specimens which had previously been collected from this area had suggested that the only rocks were Archaean

gneisses cut here and there by later dolerite dikes<sup>1</sup>). Perhaps this, combined with the especial attractiveness to the Geologist of the district immediately to the north, is the reason for the neglect of this area. During the British Arctic Air-Route Expedition, the complexities of the Archaean rocks were to some extent unravelled, but the main interest lay in the discovery, in the northern part of the area, of a phase of Tertiary igneous activity comparable with that of Northern Ireland and Western Scotland.

Rocks of Archaean type will here be named the Metamorphic Complex since their actual pre-Cambrian age cannot be proved. They consist mainly of igneous gneisses of moderately acid composition which include about 20 % of basic material, now amphibolite showing various degrees of viscous flow. In the Angmagssalik district there is an extensive development of enstatite-rich basic and ultra basic igneous rocks which, like the amphibolites, are earlier than the dominant acid gneiss. Mt. Forel and neighbouring peaks consist of an enstatite granite. Apparently there is here a suite of early igneous rocks comparable with the Charnockite Series of Southern India.

Caught up in the prevailing acid gneiss, extensive areas of metamorphosed sediments were found. The pelitic sediments are now garnet, sillimanite or kyanite, schists, often with albite porphyroblasts. Metamorphosed limestones and quartzites also occur. The sediments are sometimes intruded by garnet amphibolite, and are often intimately injected by acid gneiss. There is no evidence for the age of this sedimentary series except that it is earlier than the igneous gneisses which form over 90 % of the rocks on the stretch of coast examined.

The strike of Metamorphic Complex is variable but on the whole W.N.W.—E.S.E. and comparable, therefore, with the Lewisian Gneiss and the Connemara Schists of the British Isles. The direction of strike suggests that the rocks were not involved in the Caledonian folding which has affected much of N.E. Greenland. A Tectonic line of significance is believed to run along Kangerdlugsuatsiak Fjord as all the rocks of the Metamorphic Complex are here highly granulitised.

Two types of Early Intrusion were found which cut the Metamorphic Complex, and yet which are believed to be pre-Tertiary in age. The first type, taking the form of amphibolite sheets, cutting transversely across the structures of the Metamorphic Complex, occurs in the north of the Angmagssalik District. These sheets represent

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<sup>1</sup>) Törnebohm, A. E.: *Geolog. Foren. i Stockholm Forh.* VII, 1886, Knutsen, H. and P. Eberlin: *M. O.* IX 1889, Nordenskiöld, O.: *M. O. G.* XXVIII, 1909.

early dolerite material, post-Metamorphic Complex in age, but still old enough to have been altered to amphibolite. The second type of Early Intrusions found on, and near, Angmagssalik Is. consists of unfoliated gabbros, diorites and pink granite. These rocks are not drusy like the Tertiary plutonic intrusions, and at present they are also regarded as pre-Tertiary in age.

Except for dolerite dikes the Tertiary igneous activity was confined to the district N. of Steenstrups Bræ. The first important episode was the extrusion of basaltic lavas. On Cape G. Holm they are intercalated with a thin series of sediments in which were found the most southerly fossils yet known from Greenland. The fossils are poorly preserved owing to thermal metamorphism of the impure limestone by the abundant dikes, but Professor H. L. Hawkins, who has examined them, would compare most of them to *Cyrena gravesii*, *Deshayes* while one is an undoubted *Glycimeris*. The limestone containing them is therefore to be ascribed to the Tertiary and to be compared with Ravn's *Cyrena* bed from Cape Dalton<sup>2</sup>). Further N., only small relics of sediment were found, the lavas there overlying a series from 60—90 m, thick of tuffs which were accumulated in water. In the Kangerdlugsuak area the lower lavas are spilites and the upper lavas were not reached. Intruded into the lavas and into the underlying Metamorphic Complex, but mainly along the junction of the two, is an extensive series of plutonic rocks which are best developed in the Kangerdlugsuak, Nualik, Kilianek and Cape G. Holm areas. These rocks vary from ultrabasic to acid and include types not yet described from among Tertiary plutonic rocks of the N. Atlantic region. Subsequent, in the main, to the lavas and plutonic intrusions, there was a final phase of dike injection. Just S. of Cape G. Holm, about Aggas Is., and elsewhere the dike material is twice as abundant as the Metamorphic Complex into which it is intruded. The dikes run N.N.E.—S.S.W. and hade to the E.S.E. at angles from 10°—30°. They represent a general state of tension which is regarded as having effectively contributed to the extension of the N. Atlantic.

### Geomorphology.

The coastal mountains from Kangerdlugsuak to the Angmagssalik District have been cut from a raised peneplain which slopes S.S.E. or S.E. The dip of this peneplain seems to be due to a continuation of the movements which gave a high south-easterly dip to the sediments, tuffs and lavas in the northern part of the district. The pene-

<sup>2</sup>) Ravn, J. P. J.: M. O. G. XXIV, pp. 95—140, 1904.

plain, however, passes without modification from the Metamorphic Complex across the region of Tertiary Intrusions, on to the basalts, proving that it is later than the Tertiary igneous activity of the region. In places the peneplain undergoes abrupt changes of level due to faulting. Thus the "New Mountains", photographed from the air, to the N. of Kangerdlugsuak (plate 3, fig. 5), are probably due to faulting along a line which is a continuation of one established by Dr. Lauge Koch<sup>3</sup>) further north.

The main fjords, if we neglect Sermilik, which I believe has had a more complicated history, are cut down the steepest slope of the raised peneplain, and seem to have been but little modified by directional structures in the solid rocks. There are also valleys and fjords, e. g. Angmagssalik Fjord, which have a N.E.—S.W. direction parallel to the Tertiary dikes and the main trend of the coast. These can often be seen to be cut along Tertiary dikes, but some are probably due to faulting in the same direction. The general direction of the coast line, the direction of most of the valleys and fjords, and the general height of the land seem to be controlled by the uplift and tilting of a peneplain and this crustal movement would seem to be closely related to the preceding, Tertiary, tectonic and magmatic activity.

The shape of individual mountains and valleys depends mainly on the ice cap and its former extent. S.W. of Sermilik the lowish mountains have recently been completely overridden by the inland ice which has modified them to uninteresting rounded forms. From Sermilik to Kangerdlugsuak the coastal belt consists of mountains of spiky Alpine form. There is no evidence that the ice cap has ever covered the spiky mountains but, at several places, it comes down as broad streams through them. Here it is clear that there has been a recent shrinking of the ice cap tongues which corresponds to the recent uncovering of extensive tracts of lower country S.W. of Sermilik. This shrinking of the ice cap was apparently abrupt as there is little or no moraine material left on the uncovered surface, while round the present margin of the inland ice there is quite extensive development of moraine. There has been a slight shrinking of tongues from the ice cap which has exposed surfaces not yet colonised by juniper and crowberry.

In the neighbourhood of Forel the ice cap can be seen to be covering a slightly modified peneplain at about 3360 m, and here the development of high mountain at the edge of an ice sheet was studied. The conditions of erosion were these of a wind-swept, largely glacier-

<sup>3</sup>) Koch, L.: M. O. G. LXXIII<sup>2</sup> 1929.

covered desert. Thus on surfaces of the prevailing enstatite granite, tufts of carbonates from the decomposition of the ferro-magnesium minerals were scattered sporadically.

There is a feeble development of a raised plane of marine erosion off Cape Dan Island but this was not noted elsewhere. In the fjords, north of Angmagssalik Is., the present streams have built up deltas some 30 m above present sea level.

The meteorological data which the Expedition collected has a bearing on the problem of the maintenance of ice sheets. Hobbs and others have stressed the importance of outflowing winds in removing snow from the ice cap. Although quantitative data are lacking we have now had experience of the weather on the ice cap throughout a whole year. Precipitation is surprisingly small and rough calculations which have been made suggest that probably in 1930—1931 the accumulation of snow was insignificant. Perhaps this is usual. The movement of the ice which is small at the edge must inwards become rapidly negligible, and hence the geological work accomplished, except over very long periods and near the margin, must be correspondingly slight.

I wish to thank the Council of Reading University for giving me a year's leave of absence, the Royal Society and the Cambridge University Wurtz Fund for grants, and especially Mr. H. G. Watkins, the leader of the Expedition, for always affording me every possible facility for carrying out geological work.

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## RESUMÉ

### *Watkins-Ekspeditionen 1930—31.*

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*Formålet med „The British Arctic Air Route Expedition“ var at undersøge Mulighederne for en Lufrute mellem England og Canada via Færøerne, Island, Grønland, Baffin Bugt, Baffin Land og Hudson Bugt.*

*Fordelen ved denne Rute i Sammenligning med Ruten over Atlanterhavet er, at man undgår den lange og farlige Flyvning over Hav, samtidig med at Ruten over Grønland er kortere, da den praktisk talt følger Storcirklen gennem Skotland og Winnipeg.*

*Rutens daarligest kendte Del var Øst- og Midt-Grønland og ud fra en Basis paa den grønlandske Kyst Vest for Angmagssalik-Øen udførtes forskellige Rejser:*

*1<sup>e</sup> Rejse: Angmagssalik-Kangerdlugsuak i Sommeren 1930. Kystlinien blev opmaalt fra en Flyvebaad, og der blev taget Luftfotografier af det isfrie Land. Man opdagede en høj Bjærgkæde lige Nord for*

Kangerdlugsuak „The New Mountains“. Desuden gennemførtes en omhyggelig geologisk og ornithologisk Undersøgelse af Kystlandet.

- 2' Rejse: September—Oktober 1930 paa Indlandsisen. Der udførtes Højdemaalinger og meteorologiske Observationer.
- 3' Rejse: Et Forsøg paa i det tidlige Foraar 1931 at naa Kangerdlugsuak mislykkedes paa Grund af ondt Vejr.
- 4' Rejse: Til Mount Forel-Området i Foraaret 1931. Bestemmelse af Højden for Mount Forel, geologiske og topografiske Studier.
- 5' Rejse: Tværs over Indlandsisen fra Basis til Ivigtut; Juli 1931. HøjdemaaLING og meteorologisk Arbejde.
- 6' Rejse: Tværs over Indlandsisen fra Basis til Holsteinsborg, Sommeren 1931. HøjdemaaLING og meteorologisk Arbejde. Eskimoiske Kajakker blev ført tværs over Indlandsisen, saaledes at Deltagerne kunde blive i Stand til fra Isranden ad Søvejen (ca. 90 miles) at naa frem til Kolonien.
- 7' Rejse: Fra Basis rundt om Syd-Østkysten til Julianehaab. Detailleret Kortlægning til Umivik. Rejsen blev udført i to 18 Fods Baade med Paa-hængsmotorer. Da der imidlertid maatte føres Brændselsolie med for hele Rejsen, kunde man kun medføre yderlig lidt Proviant, og i Stedet medtoges saa Kajakker og Harpuner; det lykkedes paa denne Maade at forsyne Rejsedeltagerne med Sælkød under hele Rejsen.

Der blev desuden udført en omhyggelig topografisk Optagelse af Området omkring Basis og den sydlige Del af Sermilikfjorden, og der blev gennemført en Række videnskabelige Arbejder af anden Art; oppe paa den højeste Del af Indlandsisen blev der oprettet en Station, paa hvilken der udførtes meteorologiske Arbejder i 7 Maaneder. Ekspeditionen bestod af 14 Mand.

Udrustning. De daglige Madrationer var beregnet meget omhyggeligt i Forvejen, og der var lagt megen Omhu i at bringe Vægten af Føden ned til et Minimum. Proviant sammensætningen afveg paa et væsentligt Punkt fra den sædvanlig anvendte, idet den daglige Ration af Kulhydrat var mindre, medens Fedtningen i Form af Margarine var væsentlig større. Der var sørget for at tilføre et betydeligt Kvantum vitaminrig Føde. Paa Kystrejser ernærede Ekspeditionen sig praktisk talt af Sælkød, og efter i en Uges Tid eller saa at have levet af Sælkød havde Deltagerne vænnet sig i den Grad dertil, at saa at sige ethvert Savn af civiliseret Kost forsvandt.

Kortlægningsarbejdet falder i 3 Hovedgrupper:

- 1) Kystlinie-Forløbet fra Kangerdlugsuak til Umivik.
- 2) Kortlæggelse af Kystbjærgene.
- 3) Bestemmelse af Indlandsisens Form.

1) Kystopmaalingen foregik paa Grundlag af de allerede eksisterende Kort, udført af Gustav Holm og G. C. Amdrup, og omfattede Egne fra Kangerdlugsuak 68° 02' n. Br. til Umivik 65° n. Br.

2) Kortlæggelsen af Kystbjergene skele for største Delen ved Hjælp af Flyvefotografier og bekræftede, at det hidtidige Kendskab til Grænsen mellem Indlandsis og Kystbjerge er overordentlig mangelfuld.

3) Maalingerne af Indlandsisens Højdeforhold har givet meget interessante Resultater. Nord for „Ice Cap Station“ hæver Overfladen sig til næsten 10,000 feet (3000 m) i Egnen omkring den tyske „Station Eismille“. Omkring „Ice Cap Station“ er Højden omtrent 8000 feet (2400 m), men længere Syd paa stiger Højden igen. Paa Slæderejsen Angmagssalik—Iviglut maalttes op til 9200 feet (2800 m). Disse Jagttagelser stemte godt med den af de Quervain og Lauge Koch fremsatte Anskuelse, at der gaar en Lavning tværs over Indlandsisen ved 65°—67° n. Br., og at de højeste Dele af Indlandsisen skulde ligge paa en Linie noget Øst for den Nord—Syd gaaende Akse. Imidlertid viser Højdemaalinger, udført af Slædepartiet til Holsteinsborg, at de største Højder paa denne Linie ligger adskiltigt vestligere og gaar op til 9000 feet (2740 m). Højdeaksen faar saaledes et bugtet Forløb, fra 71°—67° n. Br. ligger den noget Øst for Midtlinien, derefter gaar den i en Bue mod Vest og fortsætter endelig mod Syd en lille Smule Øst for Midtlinien.

Indlandsisens Overflade er svagt bølget, idet der findes nogle 3—4 miles brede Rygge med en Højde af 3—400 feet (ca. 100 m). Forløbet af disse Rygge og Dale er meget vanskelig at bestemme og synes ikke at have nogen Sammenhæng med Isens Bevægelsesretning. I en Zone paa omtrent 60 miles i Midten af Indlandsisen er disse Bølger meget svagt udviklede, og Overfladen er næsten helt flad. Indlandsisens Overflade skraaner stejlere mod Øst end mod Vest med det Resultat, at Spaltezonen er smallere mod Øst, hvor den, bortset fra særlige Lokalteter, saasom Landet bag ved Sermilik Fjorden ikke er mere end 15 miles bred, medens der mod Vest findes Spalter indtil 70—100 miles fra Randen.

Denne Forskel giver sig ogsaa til Kende ved Mængden af Overfladevand om Sommeren. I den østlige Randzone danner Smellevandet kun smalle Render, der nu og da samler sig i Søer, men i den vestlige Randzone fandtes hele Floder af Smellevand 40—50 feet brede og 4—5 feet dybe i en Afstand af 25 miles fra Randbjergene.

*Flyvningerne.* Første Sommers Flyvearbejde bestod i at tage Kortlægnings-Fotografier fra Angmagssalik Ø til Kangerdlugsuak Fjord samt at foretage forskellige Rekognosceringer. Fra 3. Aug. 30—10. Sept. 30 udførtes 23 Flyvninger paa tilsammen 32 Timer og 15 Minutter. Paa Grund af ekstraordinært gode Betingelser blev næsten hele det planlagte Arbejde udført allerede i 1930.

Flyve-Programmet for Vinteren 1930—31 var ikke endelig fastlagt, for Ekspeditionen forlod England, da man ikke paa Forhaand kunde vide noget sikkert om Betingelserne for Flyvning over Grønland paa denne Aarstid, et Forhold, som maatte blive af afgørende Betydning for Etableringen af en fast Helaarsrute. Man havde paa tænkt at forsøge at flyve til Winnipeg i det tidlige Foraar, men Betingelserne var langt daarligere end ventet, og dette Forehavende maatte opgives. I Løbet af Vinteren gennemførtes 49 Flyvninger paa tilsammen 46 Timer og 50 Minutter.

De Erfaringer, man har gjort angaaende Flyvning, er i Korthed følgende: Sommeren igennem var Vejret smukt og Betingelserne for Flyvning ypperlige. De store Mængder Havis vanskeliggør imidlertid Star-

ten, men Ekspeditionen opdagede et Par Søer, som var store nok for de største Trafik-Flyvebaade, og som i den isfri Tid vilde afgive en udmærket Basis. Der var ingen Taage og ingen stærke Vinde om Sommeren.

Den største Vanskelighed i Vinteren 1930—31 var det meget store Antal Föhn-Storme. Da disse imidlertid synes at være rent lokale, kunde denne Vanskelighed overvindes ved Anlæggelsen af to Basis-Stationer i betydelig Afstand fra hinanden og ved en velorganiseret meteorologisk Tjeneste med Radio-Stationer til Underretning for de i Luften værende Maskiner. Bortset fra disse Storme var Vejrforholdene brugelige. Fjordene er imidlertid ikke anvendelige som Basis; hvis nemlig Tilfrysningen finder Sted under Paalandsvind, vil Overfladen ved Pakisens Sammenfrysning blive altfor ujævn. Den Vanskelighed vilde man undgaa ved at bruge de før omtalte Søer som Basis.

Den eneste virkelig alvorlige Hindring for en Luft-Rute over Grønland er de Perioder i Foraar og Efteraar, hvor Tilfrysning og Opbrydning finder Sted; disse Perioder vil dog forkortes noget ved Anvendelsen af Søer som Basis, og ved Anlæggelsen af en Basis ved Randen af Indlandsisen vilde man helt undgaa dem.

*Geologi og Geomorfologi i Angmagssalik-Området og i Kystlandet mod Nord til Kangerdlugsuak Fjord.*

Tidligere Undersøgelser tydede paa, at der i dette Omraade kun findes arkaiske Dannelser (Gnejs), hist og her med yngre doleritiske Gange. Det har nu vist sig, at den nordlige Del af dette hidtil lidet kendte Gebet har været Skuepladsen for en tertiær vulkansk Virksomhed ligesom det nordlige Irland og det vestlige Skotland.

De gamle Dannelser stryger V.N.V.—Ø.S.Ø. og synes ikke at have deltaget i den kaledoniske Foldning.

Den tertiære Vulkanisme er begrænset til Landet Nord for Steenstrup Bræ. Ved Kap Gustav Holm fandtes tynde forsteningsførende Lag mellem basaltiske Lavastrømme, som maa henføres til Tertiær og sammenstilles med Ravens Cyrena-Lag fra Kap Dalton.

Kystbjergene fra Kangerdlugsuak til Angmagssalik er blevet skaaret ud i en hævet Peneplan, som skraaner mod S.S.O. eller S.O. Denne Peneplan er yngre end den tertiære Vulkanisme og er visse Steder gennemsat af Spring. Saaledes er f. Eks. „De ny Bjerge“ Nord for Kangerdlugsuak sandsynligvis dannede langs en Brudlinie, der danner en Fortsættelse af den af Lauge Koch længere Nord paa fundne Brudzone.





Fig. 1.

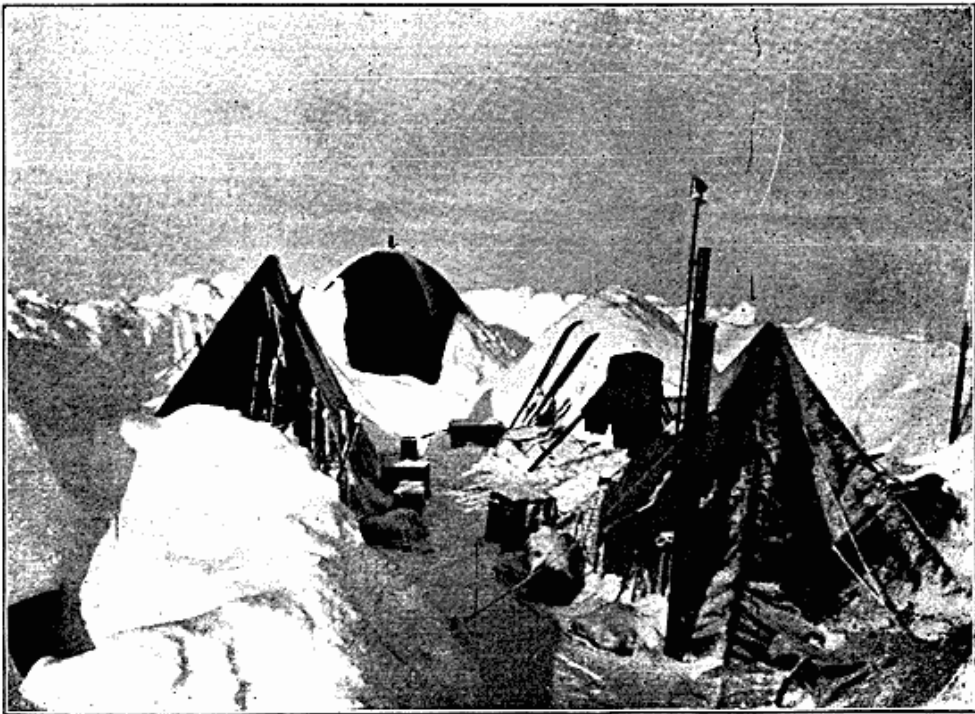


Fig. 2.

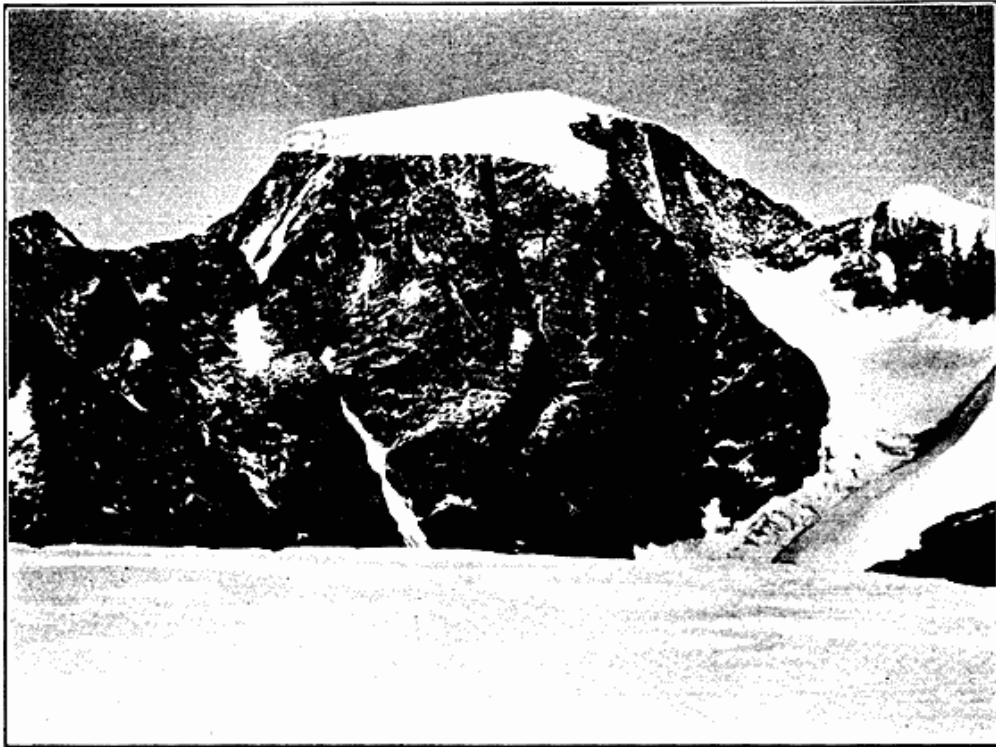


Fig. 3.



Fig. 4.



Fig. 5.



Fig. 6.



Fig. 7.

Southern Greenland, showing the Seven Journeys of  
 THE BRITISH ARCTIC AIR ROUTE EXPEDITION  
 1930-31



## Explanation of plates.

Fig. 1. The Base Fjord.  
*Basis-Fjorden V. for Angmagssalik.*

Fig. 2. Inland Ice Station and tents of relief party.  
*Stationen paa Indlandsisen (Courtauld) og Undersøvnings-Holdets Telte.*

Fig. 3. Mount Forel.

Fig. 4. Storm coming from Inland Ice. Notice the sea is still calm.  
*Storm (Föhn) fra Indlandsisen stryger ned over Bjergtoppene. Søen er endnu rolig.*

Fig. 5. The "New Mountains" north of Kangerdlugsuak seen from the air, mark an abrupt change in the level of the peneplain due probably to faulting along a general N. N. E.—S. S. W. line. The foreground mountains, about 1220 m high, are mainly cut from Tertiary basalts. The "New Mountains" are probably made of the rocks of the Metamorphic Complex, and their height is doubtful but is likely to be in the neighbourhood of 3000 m.

*De „Ny Bjerge“ Nord for Kangerdlugsuak viser en brat Overgang i Højdeforholdene, der rimeligvis skyldes Brud langs en N. N. O.—S. S. V. gaaende Linie. Forgrundens Bjerge er hovedsagelig udformet i tertiære Basaller. De „Ny Bjerge“ består sandsynligvis af Bjergarter tilhørende „the Metamorphic Complex“, og deres Højde er antagelig ca. 3000 m.*

Fig. 6. The head of Kangerdlugsuak Fjord.

Fig. 7. Umivik Island. Between Pikiutdlek and Umivik there is an island 40 miles long, which was shown as the coast-line on the map, but we found that it is separate from the mainland, and has two ice caps of its own.  
*Mellem Pikiutdlek og Umivik er der en Ø (40 miles lang), som paa Kortet var afsat som Kystlinie. Vi fandt, at den er adskilt fra Fastlandet, og at den bærer to selvstændige Isdækker.*

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