MEDDELELSER OM GRØNLAND
UDGIVNE AF
KOMMISSIONEN FOR VIDENSKABELIGE UNDERSØGELSER I GRØNLAND
Bd. 200 • Nr. 5

DE DANSKE EKSPEDITIONER TIL ØSTGRØNLAND 1947–58
Under Ledelse af Lauge Koch

GEOLOGICAL MAP OF NORTHEAST GREENLAND 75°-82° N. LAT.

1:1,000,000

(COMPILED AND DRAFTED IN 1964 UNDER GRANT No. 2837 FROM THE "SCHWEIZERISCHER NATIONALFONDS ZUR FÖRDERUNG DER WISSENSCHAFTLICHEN FORSCHUNG")

BY

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WITH 4 FIGURES IN THE TEXT AND 1 MAP SHEET

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Abstract

The "Geological Map of Northeast Greenland" was compiled and drafted in 1964, and reached the stage of proof-print in 1968. It was planned as part of a two-sheet series of geologic maps on a scale of 1:1,000,000 that was to summarize the results of the *Danish East Greenland Expeditions* 1926 to 1958, conducted by LAUGE KOCH. The present map sheet covers the region from latitudes 75° to 82°N. The geological information contained in this map is based on reports published before 1964 (see list of references) and on field observations and reconnaissance flights the author had made in the summers of 1955, 1956, and 1958. In view of more recent and systematic field investigations by the Geological Survey of Greenland in the region north of latitude 80°, the present map has become more of a historical document recording the state-of-the-art as of 1960. For the region south of latitude 79°N, however, the map still is the most recent version.

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INTRODUCTION

The "Geological Map of Northeast Greenland" has a long history of its own. It was compiled and drafted in 1964 under grant No. 2837 from the "*Schweizerischer Nationalfonds zur Förderung der wissenschaftlichen Forschung*", and it reached the stage of proof-print in 1968. But due to a number of reasons, most of which were of a technical nature, final printing was delayed. I am indebted to the Commission for Scientific Research in Greenland for its efforts in securing the original color plates and for arranging the final printing of the map.

Initially, the publication of this map was planned as part of a two-sheet series of geologic maps covering the region from 70° to 82°N on a scale of 1:1,000,000. It is for this reason also that the key to the map includes rock formations marked with an asterisk, which means that they are not present on the northern sheet, namely Tertiary alkaline intrusions, Devonian molasse, and the Late Proterozoic Tillite Group. The planned map series was to summarize the results of the *Danish East Greenland Expeditions* 1926 to 1958 conducted by LAUGE KOCH. The major cartographic work of these expeditions is the "Geological Map of East Greenland 72°–76°N. Lat." on a scale of 1:250,000 (KOCH and HALLER, 1971). At the time of KOCH's expeditions, the region between latitudes 72° and 76°N. was the only part of East Greenland that was covered by a relatively adequate topographic base map (Geodetic Institute, 1938). North and south of these latitudes the World Aeronautical Chart (WAC)[1]) on a scale of 1:1,000,000 was used for field work, which in those northern and southern areas was mostly of reconnaissance nature. The WAC edition also served as principal topographic base for the "Geologic Map of Northeast Greenland". The geological information contained in this map is based on reports published before 1964 (see list of references) and on a great number of field observations that I had made in the summers of 1955, 1956, and 1958. The data were gathered during many hours of reconnaissance flights in single-engine and twin-engine seaplanes, and during spotlandings, which often were made under hazardous conditions. In addition to high-altitude oblique photographs, overlapping vertical

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[1]) Published by the U.S. Department of Commerce, Coast and Geodetic Survey, Washington, D.C.

photographs for parts of North Greenland also had become available when I began the compilation of the map in the early 1960's. At that time I hoped to furnish the map with a description of the rock material that I had collected in Northeast Greenland. After my move to the United States in the Fall of 1964, however, I was not able to continue this project, and my rock collections have since been given into custody of the Geological Museum in Copenhagen. And so the information shown on the map has to remain self-contained, at least to the extent that I have not dealt with it in the explanatory text to the "Tectonic Map of East Greenland" (1970) or in my book "Geology of the East Greenland Caledonides" (1971).

Moreover, in the summers of 1978, 1979, and 1980 the region north of latitude 80°N was the subject of detailed field investigations by the Geological Survey of Greenland (Grønlands Geologiske Undersøgelse, 1979, 1980, 1981). This work naturally resulted in a greatly improved knowledge of the region and also led to redefinitions, especially with regard to the Proterozoic sequences referred to as "Groenlandian Formations" on the legend of the map. Another area of substantial improvement involves the Upper Paleozoic through Cenozoic formations of the Wandel Sea Basin, with regard to both stratigraphy and distribution. In view of these improvements, the northern portion of the "Geological Map of Northeast Greenland" has become more of a historical document recording the state-of-the-art as of 1960. For the region south of latitude 79°, however, the present map still is the most recent version. It is in this region also that I spent considerably more time than farther north.

GEOLOGICAL INVESTIGATIONS OF NORTHEAST GREENLAND, 1870 TO 1960

Northeast Greenland has been and still is one of the most forbidding regions in the Arctic. The narrow and barren coastal belt has been uninhabited for centuries, and probably only was used as a migration route in early times (GAD, 1970). From the west, the inland ice advances, at places reaching the ice-choked sea in the form of huge tidal glaciers. From the Arctic Ocean a belt of heavy pack ice drifts along the coast and so bars ordinary ships from the waters off Northeast Greenland (Fig. 1). But the width and packing of this drift ice varies (KOCH, 1945), and occasionally, favorable seasons have allowed ship parties to gain access to the coast as far north as 79°N (KOCH, 1940). In 1905, the DUKE OF ORLEANS *Belgica-Expedition* went ashore at Île de France and at Germania Land, the southern tip of which had been reached by a trek party of the *German North Pole Expedition* 1869 to 1870 (KOLDEWEY,

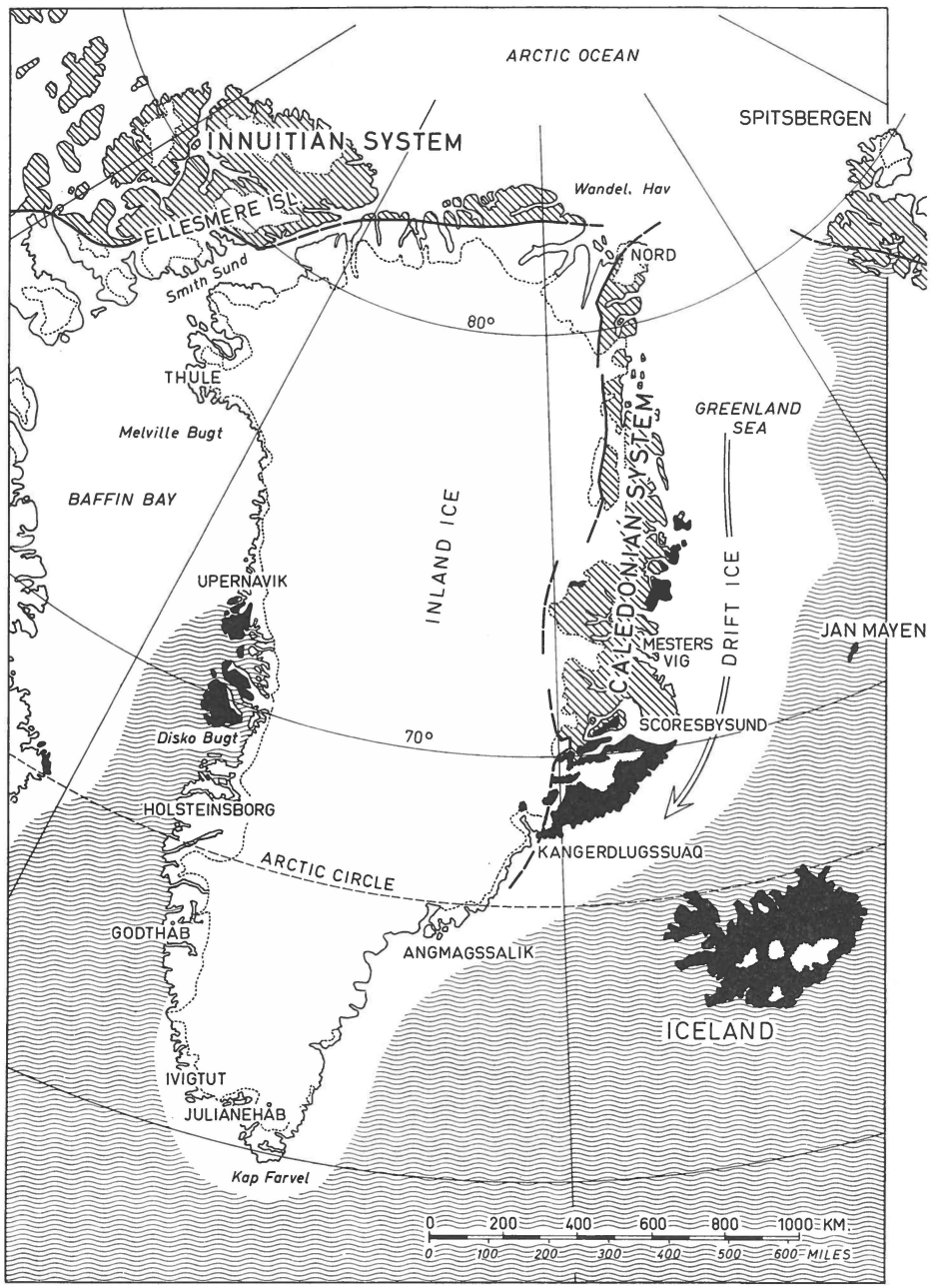

Fig. 1. Map showing physiographic-tectonic units of Greenland and maximum extent of sea-ice in Baffin Bay, of drift ice in the North Atlantic. Bedrock exposures of Laurentian craton (Precambrian basement and Precambrian to Phanerozoic cover rocks) are left blank. East Greenland Fold Belt (Caledonides) and North Greenland Fold Belt (Innuitian) are shown in ruled ornament. Black indicates Paleogene plateau basalts in Baffin Island, West and East Greenland, and Paleogene to Recent volcanics in Iceland and Jan Mayen.

1874). The rock samples collected by the Duke's party were described by TERMIER (1906) and by BØGGILD (1907). But systematic exploration of Northeast Greenland began only in the following summer when MYLIUS-ERICHSEN's *Danmark-Expedition* 1906 to 1908 erected headquarters at Danmarkshavn, Germania Land (77°N), from where two surveyor parties carried out topographic mapping as far as the northern tip of Greenland (AMDRUP, 1913; J. P. KOCH, 1916). Paleozoic and Mesozoic fossils collected by this expedition were described by NATHORST (1911), GRÖNWALL (1916), and RAVN (1911). In 1912, J. P. KOCH and ALFRED WEGENER starting out, once more, from Danmarkshavn traversed the nunataks of Dronning Louise Land on their inland ice crossing to the west coast (J. P. KOCH and WEGENER, 1930).

An occasion of particular significance arose in 1933 when, due to exceptionally light drift ice, Norske Øer (79°05′N) was reached by one ship of LAUGE KOCH's *3-year Expedition to Christian X's Land* from 1931 to 1934. It was then during the second summer that Heinkel floatplanes were introduced for aerial photogrammetric mapping. The unusual northward position of the ship then enabled LAUGE KOCH to carry out reconnaissance flights over Kronprins Christian Land and Mylius-Erichsen Land, thereby gathering geological data and improving the topographic maps of this remote region that had been explored by L. MYLIUS-ERICHSEN and Lauge's uncle, Commander J. P. KOCH. The exciting days of 1933 are pointedly narrated in "A Day in North Greenland" by KOCH (1935). Opportunities like this have characterized the geological exploration of Northeast Greenland throughout the era of the *Danish East Greenland Expeditions* conducted by LAUGE KOCH, as is apparent from the report on the pre-war expeditions 1926 to 1939 (KOCH, 1950, 1955), and from the summary accounts on the post-war expeditions 1947 to 1958 (COWIE, 1959; HALLER, 1971). The last occasion of this kind was in 1958 when I had 39 hours of flight over Northeast Greenland aboard a seaplane of the Royal Danish Air Force. The plane was on routine missions from Mesters Vig (see Fig. 1) to Station Nord and North Greenland.

KOCH's field parties that were dispatched to Northeast Greenland, first by dog-team, then by boat or aircraft, investigated the following areas: Germania Land, 77°N (KOCH, 1929a); Kong Wilhelm Land, 76°N (TEICHERT, 1933); Skærfjorden, 77°30′N (MALMQVIST, *in* KOCH, 1955, pp. 364–366); Store Koldewey Ø, 76°N (NIELSEN, *in* FREBOLD, 1935); Dove Bugt, 76°30′N (MITTELHOLZER, 1941); Mylius-Erichsen Land, 80°40′N (ADAMS and COWIE, 1953); Kronprins Christian Land, 80° to 80°30′N (FRÄNKL, 1954, 1955); Ardencaple Fjord, 75°30′N (SOMMER, 1957); Bessel Fjord, 76°N, Daniel Bruun Land, 76°50′N, Sælsøen, 77°05′N, Dronning Louise Land, 77°15′N, Nordmarken, 77°50′N, Her-

tugen af Orléans Land, 78°05′N (HALLER, 1956, 1971); Lambert Land, 79°20′N (HALLER and KULP, 1962); Kronprins Christian Land, 80°55′N (HALLER, 1970).

Apart from KOCH's parties there were four additional and independent groups that carried out geological field research in Northeast Greenland. The first one was LOUISE A. BOYD's ship-based *Hydrographic Expedition* of 1938 that sailed to Île de France and into Dove Bugt (BRONNER, 1948). The other expeditions mounted long-distance dog-team travel. These were the *Danish Expedition to Northeast Greenland* 1938 to 1939 (KNUTH, 1942), which investigated Kronprins Christian Land (NIELSEN, 1941) and Tuborgfondet Land (SØLVER, 1940), the *Danish Peary Land Expedition* 1947 to 1950 whose geologists worked north of Independence Fjord (ELLITSGAARD-RASMUSSEN, 1950, 1955; TROELSEN, 1949, 1950), and the *British North Greenland Expedition* 1952 to 1954 (SIMPSON, 1957), which fielded parties in Dronning Louise Land (PEACOCK, 1956a, 1956b, 1958; LISTER and WYLLIE, 1957) and in Germania Land (WYLLIE, 1957).

THE GEOLOGIC MAP OF NORTHEAST GREENLAND

Caledonian structures. — The map covers the northern half of the East Greenland Fold Belt or Caledonides and exposures of the western foreland (Laurentian craton). The East Greenland branch of the Caledonian orogen extends over 1,400 km, from 70° to 82°N, with a dominance of metamorphic rocks of Precambrian and Paleozoic age over most of its length (Fig. 2). The main orogenic movements and metamorphic events appear to be of Silurian age. It was thus in Silurian time that the westward translations of thrust sheets and the folding of north-northeasterly trend established the major tectonic grain that is parallelled roughly by the present coastal outlines of Northeast Greenland.

The western edge of the East Greenland Fold Belt is marked by overthrusts and by foreland folds, except for the region between 72° and 76°N, where the Caledonian front is obscured by inland ice. But also for this segment there is circumstantial evidence for thrust relationships (HALLER, 1971, p. 218). It is true that for the East Greenland Caledonides large-scale thrust systems were proposed early (PARKINSON and WHITTARD, 1931), but it was not until the 1950's that *Caledonian allochthon* was documented along the western edge of the orogen, first in Kronprins Christian Land by FRÄNKL (1954, 1955) and then in Dronning Louise Land by PEACOCK (1956a, 1958). The allochthon of Kronprins Christian Land may include some Lower Paleozoic, but it consists predominantly of Proterozoic strata that owe their present tectonic position mainly to

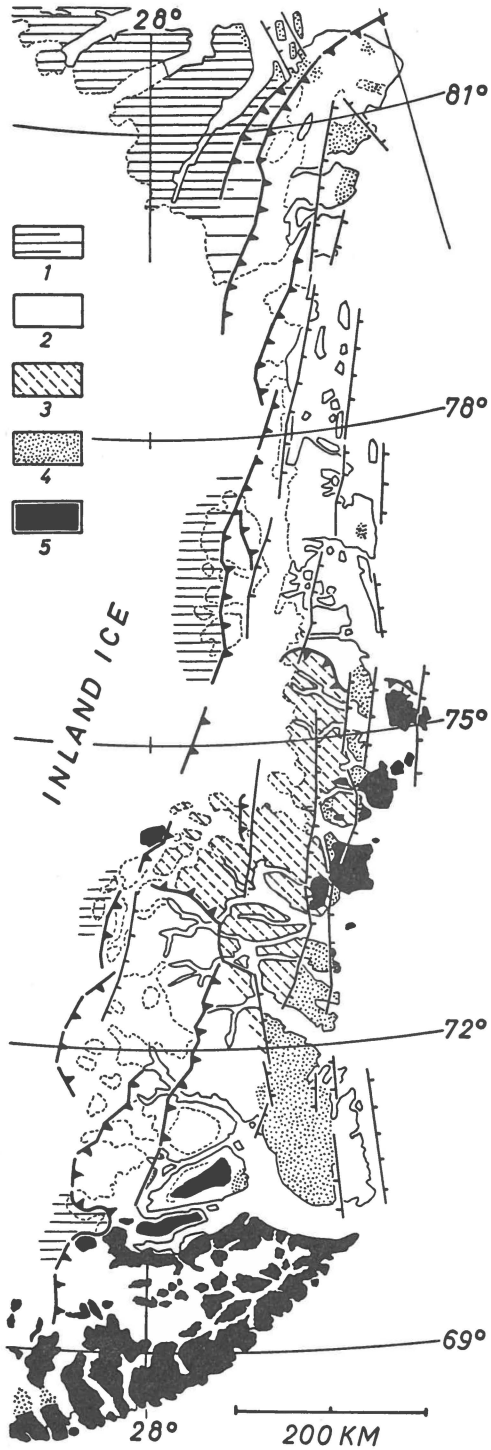

Fig. 2. Sketch map of the East Greenland Caledonides, with areas of (1) foreland, partly folded, (2) Silurian main movements, (3) Devonian movements, (4) Carboniferous through Tertiary strata, (5) Paleogene plateau basalt.

gravitational sliding. The source of these sedimentary nappes is thought to have been a deep-water trough east of the present coastal area (HALLER, 1970; HURST and MCKERROW, 1981a). The autochthon and foreland areas, on the other hand, consist of Proterozoic and Lower Paleozoic platform sediments, the youngest of which are shales and turbidites of late(?) Silurian age (FRÄNKL, 1955; COWIE, 1961; PEEL *et al.*, 1981). The latter appear to be of eastern provenance and to correlate with similar "flysch" deposits that accumulated in an east-west trending trough in North Greenland (SURLYK *et al.*, 1980; PEDERSEN, 1980; HURST and MCKERROW, 1981b). It is assumed that the source area of these detrital beds evolved during the formative stage of the East Greenland Fold Belt.

In eastern Kronprins Christian Land, in Prinsesse Elisabeth and Prinsesse Caroline-Mathilde Alper, the sedimentary nappes are underlain by upthrust wedges of the overridden platform, including both Proterozoic cover and older gneiss basement. South of 79°N, in Lambert Land and Tuborgfondet Land, westward shoved wedges of the broken platform mark the exposed edge of the orogen. South of 78°N, namely in Dronning Louise Land, the thrust front is marked by thrust plates that consist mainly of partially Caledonized basement rocks. It is assumed that the amount of tectonic transport on these basement plates increases from north to south. Moreover, the en echelon arrangement of the major Caledonian thrust systems shown in Figure 2 suggests that the basement complexes along the coastal lowlands of Holm Land, Hovgaard Ø, and Lambert Land might be structurally correlative to the allochthon in Dronning Louise Land (HALLER, 1971, pp. 42, 215). These coastal areas have been down-faulted along Late Paleozoic to Recent normal faults. In Caledonian time, therefore, these coastal complexes occupied a structurally much higher position (FRÄNKL, 1955, p. 26), possibly reflecting the highest sheet in the stack of Caledonian allochthon. Recent activity along these normal faults is expressed morphologically as well as by a coastal-parallel gravity gradient (FORSBERG, 1981) and by recurrent seismic events (SYKES, 1978).

Between 76° and 74°N the East Greenland Fold Belt is dominated over its entire width by *transverse tectonic translations* of Devonian age (see Fig. 2). In the coastal region, particularly in the area between Bessel Fjord (76°N) and Grandjean Fjord (75°N) the superimposed Devonian structures trend northwesterly. Recumbent folds and thrust sheets indicate tectonic transport from southwest to northeast. The minimum age of these structures is considered Middle Devonian, on the basis of stratigraphic and radiometric dating of post-tectonic *granite intrusions* (HALLER and KULP, 1962, pp. 50–51). Within the area of the "Geological Map of Northeast Greenland" there are several large plutons of this granite. Devonian sediments, however, are widespread only south of latitude

75°N, where Old Red molasse accumulated in intermontane basins. These depressions were subjected intermittently to compressional and extensional deformation of varying trends. The latest phase of compression occurred in the Early Carboniferous.

Post-Caledonian formations. — By Middle Carboniferous time, the northernmost section of the East Greenland Fold Belt was peneplaned to lowland, eventually transgressed by the Moscovian sea (FREBOLD, 1950; DUNBAR *et al.*, 1962) and thus became buried beneath the Late Paleozoic-Mesozoic *Wandel Sea Basin* (DAWES and SOPER, 1973; HÅKANSSON *et al.*, 1981). But south of latitude 79°N the fold belt apparently still formed highlands that stretched along extensive, north-north-easterly trending fractures. It is assumed that the plant-bearing redbeds of Hertugen af Orléans Land and of Nordmarken accumulated at that time and so would correspond to the continental Upper Carboniferous and Lower Permian strata that are found between 70° and 74°30'N in fault-bounded, linear troughs. The formation of these *epi-orogenic grabens* initiated extensional *fault-block tectonics* and subsidence that turned the eastern parts of the presently exposed East Greenland Fold Belt into an unstable shelf from Late Permian (Zechstein) through all of Mesozoic time.

At the end of the Cretaceous, a wide region south of latitude 76°N rose above sea-level, with the Mesozoic shelf being denuded by subaerial erosion, and its block-faulted Caledonian basement partly exhumed. Extensive flows of Paleocene-Eocene *plateau basalts* (Brito-Arctic province) then buried the region, the present coastal areas in particular. For the northern coastal plateau, including Shannon Ø shown on the map, the total thickness of these subaerial basalt flows is estimated to have been less than one kilometre (HALLER, 1971). In contrast to the regional uplift and the widespread igneous activity that affected the central and southern portions of the East Greenland Fold Belt, the northernmost portion, within the realm of the Wandel Sea Basin, was the site of continuing marine sedimentation (NIELSEN, 1941; HÅKANSSON *et al.*, 1981). But while the basalt eruptions commenced in the south, the region of Kronprins Christian Land, its northeastern part in particular, was subjected to folding (HALLER, 1970, p. 243; HÅKANSSON *et al.*, 1981).

In Neogene time, the entire East Greenland Fold Belt was affected by pulses of uplift that led to the present *topographic relief* with elevations of 2,000 to 3,000 m in Central East Greenland and of 1,000 to 1,500 m in Northeast Greenland.

Remarks on the "Carolinidian Orogenic Belt." — The stratigraphic subdivision of Precambrian formations that is shown on the legend of

the map accords with the division described in HALLER (1970, 1971) at which time no radiometric dates of Precambrian rocks of East Greenland were available, except for the 2 b.y. basement samples from Paul Stern Land, 70°N (HALLER and KULP, 1962).

In Northeast Greenland, a twofold division was recognized: (1) Precambrian *basement gneisses*, including minor belts of metasediments; (2) Precambrian cover rocks summarily referred to as "*Groenlandian*" (Proterozoic). The latter were subdivided on lithological and structural grounds into an older "Thule Group" and a younger "Hagen Fjord

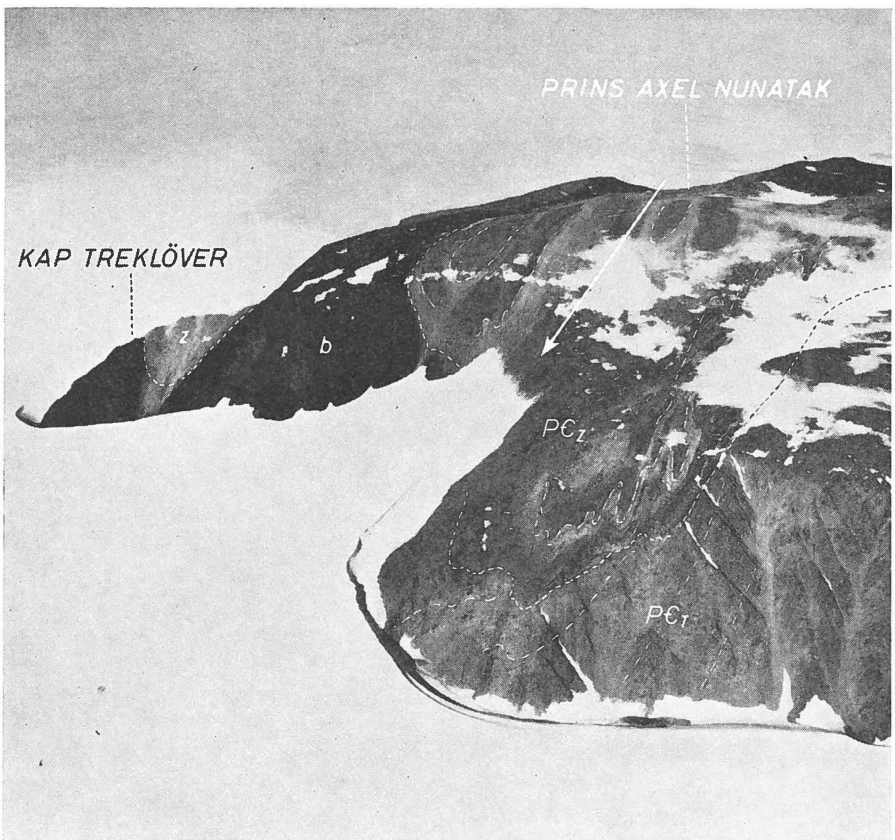

Fig. 3. Aerial view of "Carolinidian" unconformity at Prins Axel Nunatak, northwestern Dronning Louise Land. Patches of Zebra Series (PC_Z) rest unconformably on Trekanten Series (PC_T) and associated dolerite (b). The base of the Zebra Series appears to step across a truncated syncline in the Trekant Series (PEACOCK, 1956a, p. 32; 1958, p. 13). The corrugations (parasitic folds) within the Zebra quartzites are attributed to Caledonian foreland folding (HALLER, 1971, pp. 206–207). The Caledonian thrust front lies some 5 km to the east (right) of this locality (Phot. W. DIEHL, 1955).

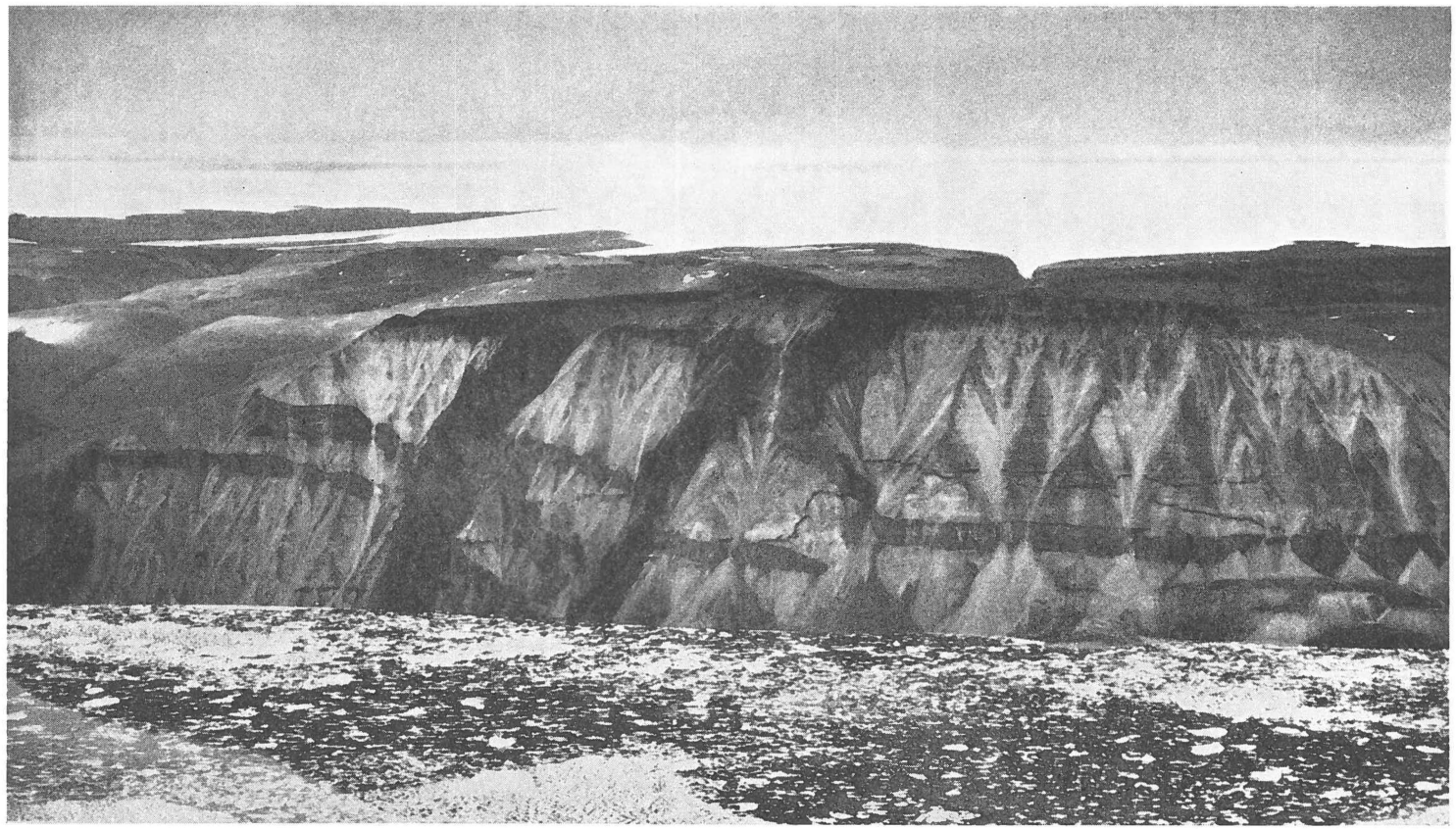

Fig. 4. Aerial view of southern coast of Independence Fjord showing "Thulean intrusives." Light-colored psammites of the "Thule Group" are penetrated by an older generation of stepping dolerite sills and a younger set of vertical feeder dikes. At the time of the dike emplacement the lithostatic parameters that controlled the intrusion process appear to have been quite different from those that controlled the emplacement of sills (cf. HALLER, 1971, p. 340). The parametric differences between the two Proterozoic intrusive patterns suggest changes in the magma-tectonic setting of the entire region (Phot. W. DIEHL, 1958).

Group." The latter was considered an equivalent of the "Eleonore Bay Group" in Central East Greenland.

The "Thule Group" includes ubiquitous *dolerite intrusions* and is widely distributed along the inland ice, from 82° to 80°N (Bøggild, 1915; Freuchen, 1915; Koch, 1925, 1929b; Ellitsgaard-Rasmussen, 1955) and from 79° to 76°N (Koch and Wegener, 1930; Peacock, 1956a, 1958; Haller, 1956). Narrow belts of deformed "Thule Group" occur also inside the Caledonian belt, namely in the coastal mountains of Kronprins Christian Land (Nielsen, 1941; Fränkl, 1954, 1955; Haller, 1970). In both the foreland area as well as inside the Caledonian belt, the "Thule Group" was found to be overlain unconformably by younger Proterozoic strata (collectively called "Hagen Fjord Group"). The profound *unconformity* was considered the result of a diastrophic event, referred to as "Hekla Sund Phase" by Fränkl (1956) and "Carolinidian disturbance" by Haller (1961).

At Hekla Sund, Kronprins Christian Land, Fränkl had observed a distinct *erosional relief* (unconformity) with pockets of conglomerate and breccia between the two groups of strata (1954, p. 29). He inferred from this an angular relationship between the two groups for the wider area and thus considered the disconformity ultimately related to compressional tectonics (Fränkl, 1954, pl. 2; 1956, pp. 26–27). Nevertheless, the regional tectonic significance of this Proterozoic unconformity became fully appreciated only after Peacock (1956a, p. 32; 1958, p. 64) had demonstrated the markedly *angular* relationship between the two groups of strata in northwestern Dronning Louise Land (Fig. 3). There, the younger group ($P\mathfrak{C}_Z$ on the map) was found to consist of quartzites and mudstones bare of fossils and hence was considered Late Proterozoic in age.

In the summer of 1958, based on aerial reconnaissance and photogeologic interpretation (Fig. 4), I distinguished two principal generations of Precambrian *mafic intrusions*, the older of which I considered affected by Carolinidian movements, the younger mainly cross-cutting feeder dikes that "fed an extensive area of plateau basalts" (Haller, 1971, p. 65). It is interesting to note that later a widespread occurrence of Proterozoic plateau basalt was identified in Mylius-Erichsen Land and J. C. Christensen Land (Jepsen and Kalsbeek, 1979, 1981). The base of these effusives largely coincides with the base of the "Hagen Fjord Group" shown on the present map. I had mapped this boundary during one long reconnaissance flight. I remember how my mind boggled over the lithology of this apparently well stratified formation, which I then related to the "Campanuladal Sandstones and Limestones" of Adams and Cowie (1953, pl. 1), because these authors had their camp right opposite Bristol Plateau which is made up of these basalt flows, according

to the "Preliminary Geologic Map of Peary Land – Mylius-Erichsen Land, North Greenland" (Grønlands Geologiske Undersøgelse, 1979).

Within the Caledonian belt of Northeast Greenland, pre-Caledonian metamorphic terranes and basement complexes are widespread (HALLER, 1971, p. 42). On the "Geological Map of Northeast Greenland" the *basement complexes* are indicated by the symbols B_A and C_F, respectively. At this point it should be remembered that the legend of the map was designed to account also for lithologies shown on the anticipated southern sheet (70° to 75°N), where Caledonian metamorphism and migmatization affected basement as well as its Proterozoic cover rocks (HALLER, 1971, p. 146). It should be noted, therefore, that with regard to the present map, the northern sheet, the symbols C_F stand principally for granitoid basement gneisses that suffered Caledonian reworking (*i.e.* various degrees of deformation) and rejuvenation (*i.e.* selective physico-chemical reactivation). In retrospect I think it was somewhat unfortunate that on the legend of this map as well as on the legend of the "Geological Map of East Greenland 72°–76°N. Lat." such rocks were designated as "synorogenic," meaning physico-chemically affected during the Caledonian orogeny. It appears that later workers were misled by this term because they seemingly overlooked the stratotectonic connotation given in my explanatory notes to the map legend (KOCH and HALLER, 1971, p. 16).

From Bessel Fjord (76°N) to Nioghalvfjerdsbræ (79°31′N) no Late Proterozoic sediments have been identified. Instead, the quartzites, quartzitic schists and minor marbles (included under symbols B_T, B_U, and C_M) were correlated with the middle Proterozoic "Thule Group." The metamorphism of these beds was considered pre-Caledonian (HALLER, 1956, p. 23; PEACOCK, 1958, pp. 114–118) and hence attributed to the Carolinidian event, which for this reason was then envisaged as an act of deep-seated orogeny (HALLER, 1970, pp. 54–61). Consequently, the pre-Caledonian fold pattern in northwestern Dronning Louise Land was assumed to represent the western margin of that Proterozoic belt, while the *pre-Caledonian metamorphic complexes* (B_A, B_U, B_T) as well as the *Caledonian rejuvenated complexes* (C_F, C_U, C_M) were considered interior portions of the belt. Obviously, all of these complexes were translated westward by Caledonian shoves, presumably a few tens of kilometres in Kronprins Christian Land, but exceeding one hundred kilometers in Dronning Louise Land. The suggested overprinting by selective *Caledonian metamorphism* is indicated on the present map by the choice of symbols and color shades. The interference of pre-Caledonian (Carolinidian) and Caledonian structural trends has been presented on sheets 1 and 2 of the "Tectonic Map of East Greenland" and is summarized in HALLER (1971, p. 204).

Subsequent to my publications, attempts were made to date the "Carolinidian event". On the basis of K-Ar whole rock ages, HENRIKSEN and JEPSEN (1970) differentiated two distinct generations of dolerite sills ("Thulean intrusives") in the foreland area, placing the event in the 1,000 to 800 m.y. range. These dates, however, appear now to be superseded by Rb-Sr ages of 1,250 m.y., according to JEPSEN and KALSBEEK (1979). Moreover, from within the Caledonian belt, in the vicinity of Danmarkshavn (76°50'N), STEIGER *et al.* (1976) extrapolated a metamorphic age of 715 m.y. and a crystallization age of 2,976 m.y. from zircon fractions in banded gneiss, a 360 ± 40 m.y. age for the formation of sphene, and a Rb-Sr whole rock age of 2,965 m.y. for the banded gneiss itself. These results confirm my conclusion about the basement origin of the area (B_A–C_F on the map) and the pre-Caledonian age of the local structure pattern. Except, however, for a strong Caledonian metamorphic imprint ("of at least lower amphibolite facies," *op. cit.*, p. 20) no indication of a significant Proterozoic thermal event was found (because the 715 m.y. metamorphic event could be explained conversely by "diffusion loss of Pb during the long history of the zircons" *op. cit.*, p. 9).

Finally, in the summer of 1980, the coastal region of Kronprins Christian Land, including the Prinsesse Caroline-Mathilde Alper (from where I had derived the name "Carolinidian" as a substitute for FRÄNKL's "Hekla Sund Phase"), was visited by helicopter parties and, as a result, JEPSEN and KALSBEEK (1981) concluded that the region had not been affected by any Proterozoic orogenic movements. It is true that on my reconnaissance flights I had no chance of landing in this coastal region, and so I am not in the position to oppose this latest interpretation, according to which the structural complications in this region can "all be ascribed to the Caledonian orogeny" (*op. cit.*, p. 14). I notice, however, that the authors agree with FRÄNKL about the profound unconformity at Marmorvigen (Hekla Sund) and that they discovered, in addition, a similar locality at Hjørnegletscher (innermost Ingolf Fjord) where "a locally irregular erosion surface in the Proterozoic sandstones with intrusions ["Thule Group"] is overlain by c. 50 m of sandstones and shales, with a thin basal conglomerate" (*op. cit.*, p. 10). But, as the authors continue, "there is no distinct angular discordance between the Proterozoic sandstones and the overlying rocks, the bedding planes in both units being subparallel over a distance of several kilometers" (*l.c.*). With regard to the "Thulean intrusives" the authors agree that intersecting intrusions are common, but they report having "not seen evidence of two major phases of intrusion" (*op. cit.*, p. 13), although they concede". It is true that some intrusions are folded and others not" (*l.c.*). In a statistical study of minor structures, the authors also demonstrate (*op. cit.*, fig. 3) that in spite of obvious Caledonian transpositions, the trends of minor

structures in the Proterozoic sandstone ("Thule Group") do indeed differ from those in the overlying ("post-Carolinidian") sediments. Nevertheless, the likely variation in the degree of Caledonian allochthony has not been differentiated in this statistical analysis, which therefore might be inconclusive in either way.

I do not wish to be dogmatic about observations I made a quarter of a century ago during a few hours of reconnaissance flight over that extremely inaccessible terrain. But, by the same token, I cannot accept JEPSEN and KALSBEEK's complete dismissal of Proterozoic disturbances in this area. I submit that the evidence for a Late Proterozoic orogeny in Northeast Greenland is, in principle, of circumstantial nature. The contemporaneity of different kinds of phenomena—stretched over a distance of over 500 km, and observed partly in the foreland, partly inside the Caledonian belt—has been assumed but not proven. In this context I should like to mention also that more recently I have come to the conclusion that in both East and North Greenland the magnitude of Late Proterozoic block-faulting and igneous activity appears to be much larger than hitherto recognized. It is true though that STILLE (1958) had stressed for some time the vast regional expanse of what he called "Assyntische Tektonik." But the transmuting aspect ("*Umbruch*," STILLE) and the regional significance in terms of continental fragmentation and the initial expansion of the Iapetus Ocean (ROBERTS and GALE, 1978) has been acknowledged only recently. In particular, I now suspect that part of the "Carolinidian" structures, especially the postulated "post-orogenic" block-faulting and its associated feeder dikes (HALLER, 1970, map 1; 1971, p. 65) should be considered in the light of the geodynamic process that initiated the formation of the Iapetus seaway in the latest Precambrian. It is tempting to include here also the more recently discovered Proterozoic plateau basalts of Mylius-Erichsen Land (the absolute age of which is not known although a genetic relationship to the above-mentioned dated dolerite sills has been suggested).

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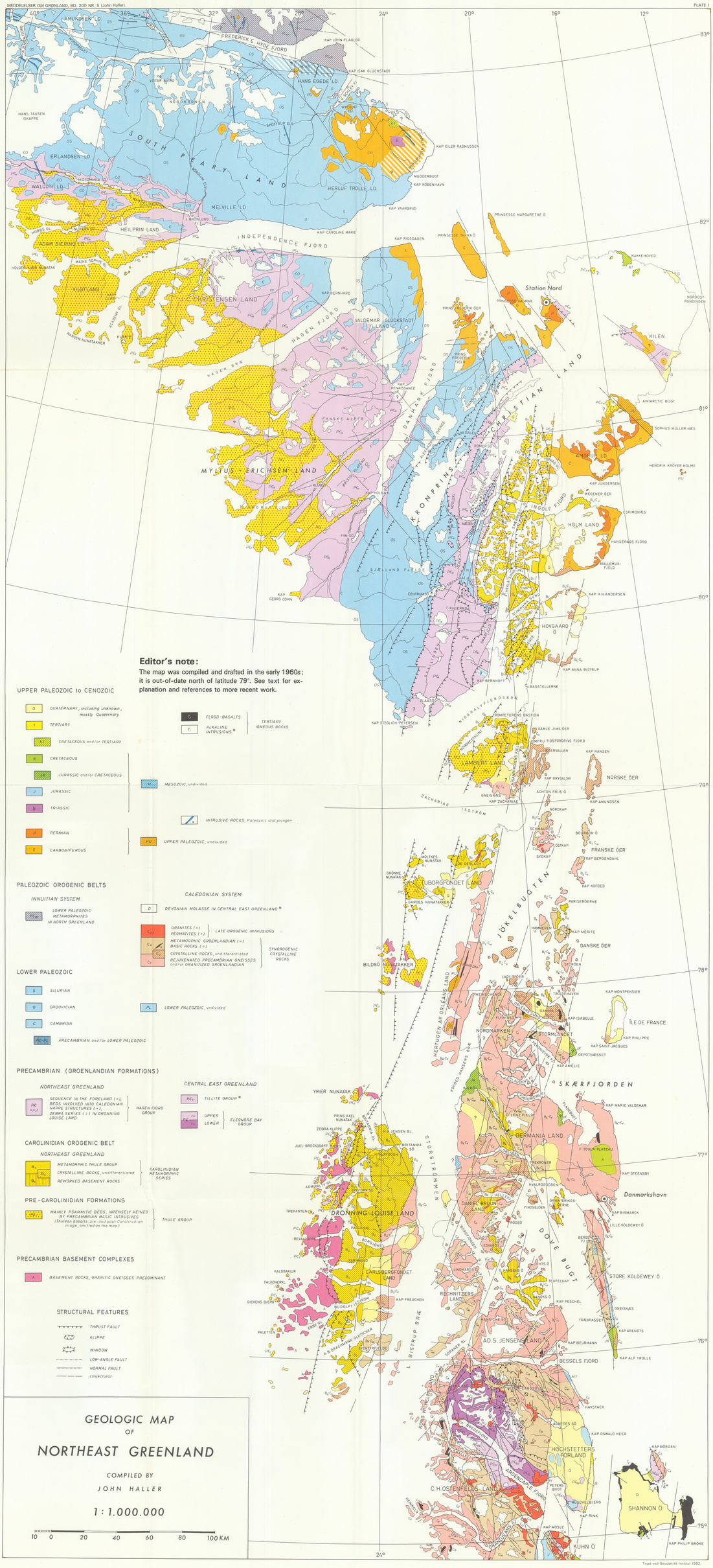

Editor's note:
The map was compiled and drafted in the early 1960s; it is out-of-date north of latitude 79°. See text for explanation and references to more recent work.

UPPER PALEOZOIC to CENOZOIC

- Q — QUATERNARY, including unknown, mostly Quaternary
- T — TERTIARY
- TC — CRETACEOUS and/or TERTIARY
- K — CRETACEOUS
- JK — JURASSIC and/or CRETACEOUS
- J — JURASSIC
- Tr — TRIASSIC
- P — PERMIAN
- C — CARBONIFEROUS

T_f FLOOD-BASALTS; T_i ALKALINE INTRUSIONS* — TERTIARY IGNEOUS ROCKS

MESOZOIC, undivided

INTRUSIVE ROCKS, Paleozoic and younger

UPPER PALEOZOIC, undivided

PALEOZOIC OROGENIC BELTS

INNUITIAN SYSTEM

LOWER PALEOZOIC METAMORPHITES IN NORTH GREENLAND

CALEDONIAN SYSTEM

D — DEVONIAN MOLASSE IN CENTRAL EAST GREENLAND*

$S_{\gamma,p}$ GRANITES (γ) PEGMATITES (p) — LATE OROGENIC INTRUSIONS

C_m METAMORPHIC GROENLANDIAN (m) BASIC ROCKS (α); C_f CRYSTALLINE ROCKS, undifferentiated; REJUVENATED PRECAMBRIAN GNEISSES and/or GRANITIZED GROENLANDIAN — SYNOROGENIC CRYSTALLINE ROCKS

LOWER PALEOZOIC

- S — SILURIAN
- O — ORDOVICIAN
- C — CAMBRIAN
- PC_1 — PRECAMBRIAN and/or LOWER PALEOZOIC

PC — LOWER PALEOZOIC, undivided

PRECAMBRIAN (GROENLANDIAN FORMATIONS)

NORTHEAST GREENLAND

PC, $PC_{x,z}$ SEQUENCE IN THE FORELAND (x), BEDS INVOLVED INTO CALEDONIAN NAPPE STRUCTURES (x), ZEBRA SERIES (z) IN DRONNING LOUISE LAND — HAGEN FJORD GROUP

CENTRAL EAST GREENLAND

PC_1 TILLITE GROUP*

PC_2 UPPER; PC_1 LOWER — ELEONORE BAY GROUP

CAROLINIDIAN OROGENIC BELT

NORTHEAST GREENLAND

B_1, B_2, B_3 METAMORPHIC THULE GROUP; CRYSTALLINE ROCKS, undifferentiated; REWORKED BASEMENT ROCKS — CAROLINIDIAN METAMORPHIC SERIES

PRE-CAROLINIDIAN FORMATIONS

PC_2 MAINLY PSAMMITIC BEDS, INTENSELY VEINED BY PRECAMBRIAN BASIC INTRUSIVES (Thulean basalts, pre- and post-Carolinidian in age, omitted on the map) — THULE GROUP

PRECAMBRIAN BASEMENT COMPLEXES

A — BASEMENT ROCKS, GRANITIC GNEISSES PREDOMINANT

STRUCTURAL FEATURES

- THRUST FAULT
- KLIPPE
- WINDOW
- LOW-ANGLE FAULT
- NORMAL FAULT
- conjectural

GEOLOGIC MAP OF NORTHEAST GREENLAND

COMPILED BY JOHN HALLER

1 : 1.000.000

10 0 20 40 60 80 100 KM

Trykt ved Geodætisk Institut 1982.