MEDDELELSER OM GRØNLAND
UDGIVNE AF
KOMMISSIONEN FOR VIDENSKABELIGE UNDERSØGELSER I GRØNLAND
Bd. 183

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

GEOLOGICAL MAP OF EAST GREENLAND 72°–76° N. LAT.

(1 : 250,000)

BY

LAUGE KOCH and JOHN HALLER

13 MAP SHEETS IN PORTFOLIO
EDITORIAL NOTE
WITH 1 FIGURE IN THE TEXT
AND 1 INDEX MAP

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BIANCO LUNOS BOGTRYKKERI A/S
1971

Abstract

The Geological Map of East Greenland, 72°–76° N lat. (1:250,000), is the culminating result of Lauge Koch's expeditions from 1926 to 1958. A representative segment of the East Greenland Caledonides dominates the map area. Orogenic activity climaxed in the late Silurian, waned through the Devonian and terminated in the Permian. Deposition of post-Caledonian shelf sediments began with the transgression of the Upper Permian and continued with a few breaks into the Upper Cretaceous. During this period tensional tectonics gradually broke up the shelf into a series of antithetically rotated fault blocks. Regional uplift and erosion initiated the early Tertiary history of East Greenland which was swiftly followed by the eruption of plateau basalts, the intrusion of dykes and sills, and the emplacement of plutonic centres.

ISBN 87 421 0045 3

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PREFACE

The Geological Map of East Greenland covering the region between 72° and 76° N lat. on a scale of 1:250,000 is one of the major results of the series of Danish geological expeditions to East Greenland led by LAUGE KOCH between 1926 and 1958.

JOHN HALLER, who is now Professor of Geology at Harvard University, joined KOCH's expeditions in 1949, and from 1952 to 1962 was permanently employed by Koch's organization. HALLER's responsibility was to compile the expedition's numerous detail geological maps in order to produce the Geological Map of East Greenland, presented here. Making extensive use of aerial surveying methods, including spot landings by seaplane and helicopter, he devoted the last three summers of his field work in Greenland to the completion of this mapping project. Therefore his map compilation includes much new data hitherto not published.

The manuscript maps were exhibited at the 21st International Geological Congress in Copenhagen 1960, and in the same year the final drawing of the map was delivered to the Geodetic Institute. In 1965 the 13 sheets which comprise the Geological Map of East Greenland were printed on a base of 18 colours in 57 colour tones. The individual sheets of this map are designed to be assembled into a wall map, measuring 195 by 160 cm.

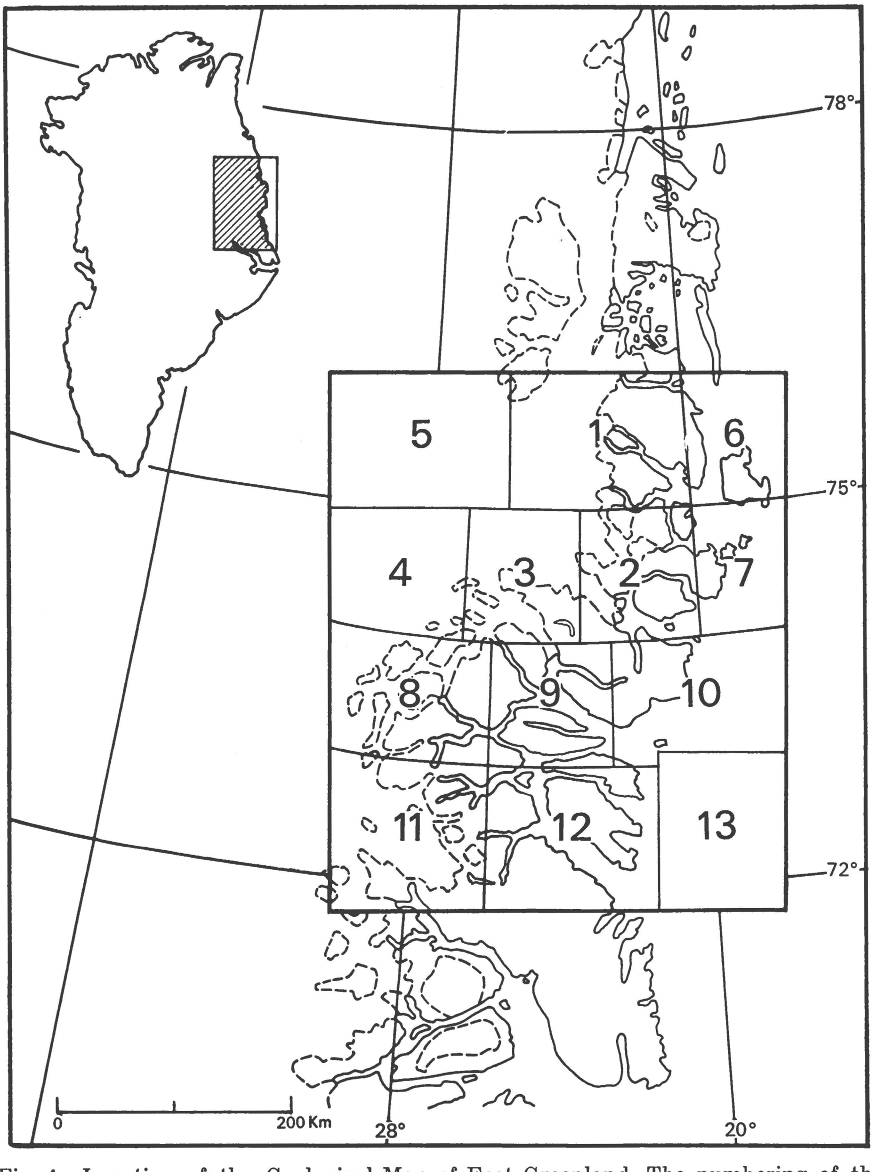

Fig. 1. Location of the Geological Map of East Greenland. The numbering of the map sheets corresponds to the order in which they should be assembled to form the wall map.

THE DANISH EXPEDITIONS TO EAST GREENLAND 1926–1958 LED BY LAUGE KOCH

LAUGE KOCH, who himself was a geologist and cartographer, spent thirty-four summers and six winters in Greenland. Prior to his involvement in East Greenland, he already had gained considerable experience in Arctic exploration through his work in North Greenland (KOCH, 1926, 1928). His geological expeditions to East Greenland can be grouped into the pre-war expeditions of 1926–39 and the post-war expeditions of 1947–58. KOCH published a comprehensive report, which included a collection of geological maps, on the activities of the pre-war expeditions (KOCH, 1950, 1955). A final report, covering all the expeditions, was to have been published by him following the close of the post-war activities. It was to have included HALLER's Geological Map of East Greenland 72°–76° N and a collection of co-ordinated papers contributed by various members of the expedition. These plans, however, were never realized, because in 1964 LAUGE KOCH died.

The region covered by the Geological Map of East Greenland is indicated on Fig. 1. KOCH's expeditions, however, ranged far beyond these limits, southwards to 70° N and northwards as far as the Polar Sea. HALLER (1970) has recently published the Tectonic Map of East Greenland covering the region from 72° to 82° N. The Geological Map of Northeast Greenland, on a scale of 1:1,000,000, is still in preparation. A comprehensive review of the stratigraphy and tectonics of East Greenland may be found in *Geology of the East Greenland Caledonides* (HALLER, 1971).

Although prior to the 20th century Dutch and British whaling voyages and a few scientific expeditions had explored the coastal region, many fjords and most of the mountainous inland areas of East Greenland were still unknown when KOCH began his investigations. A history of the early exploration of East Greenland is included in KOCH (1940); that of the later, in HALLER (1971). Although a number of foreign expeditions made important contributions to the knowledge of the geology of East Greenland, during the middle 20th century KOCH's survey was ascendant. Of these foreign expeditions the most noteworthy were led by Norges

Svalbard- og Ishavs-Undersøkelser (1937), J. B. CHARCOT (Rothé, 1941), LOUISE A. BOYD (1935, 1948), and J. M. WORDIE (1927, 1930).

LAUGE KOCH's first East Greenland expedition (1926–27), which wintered at Scoresbysund (70° N), was very small, consisting of just three geologists. Accompanied only by Greenlanders, KOCH effected two extensive reconnaissance sledge trips through the fjords of East Greenland as far as Danmarkshavn (77° N). Largely based on this work, he subsequently published a coloured outline map of the geology between Scoresbysund and Danmarkshavn (KOCH, 1929).

The expeditions sent out in the summers of 1929 and 1930 were larger and had the advantage of being ship-based. Small overnight cruisers, powered by inboard engines, and other miscellaneous small craft gave geologists access to the fjord region between 72°–75° N.

Activity was considerably expanded when financial support for a new 3-year expedition (The 3-year Expedition to Christian X's Land, 1931–34) was obtained. Geologists always outnumbered all other types of scientists on KOCH's expeditions; on this particular 3-year expedition, however, zoologists, botanists, archeologists, and topographical surveying parties were among the other disciplines represented. In addition to two ships, provided by the Greenland Administration, three winter stations built on Hochstetter Forland (75°10′ N), Clavering Ø (74° N), and Ella Ø (73° N) provided living quarters for the expedition. In 1932, three-seater Heinkel seaplanes were introduced and used successfully for aerial photography, as well as for ice-reconnaissance (KOCH, 1945). With a total strength of 109 men and a wintering party numbering 13 the summer of 1933 was the highpoint of KOCH's pre-war activity. The 3-year expedition discovered and mapped in outline all hitherto unknown land areas between 76° and 78° N and photographed from the air the entire region between 72° and 78° N. Aerial photogrammetric methods were introduced into the regional mapping program for the first time in cartographic history. The result of this survey was the topographic base-map of the present Geological Map of East Greenland 72°–76° N, consisting of fourteen sheets from the Topografiske Kort Grønland (1:250,000), which was drafted by the Geodetic Institute and published in 1938.

The last of the pre-war expeditions, with a total strength of about 50 men each year, was the 2-year Geological Expedition, 1936–38. Although small parties wintered at Clavering Ø and Ella Ø, as well as in Scoresby Sund, the expedition again was primarily ship-based. The last wintering party returned to Europe in the summer of 1939. Accurate geological mapping on a regional scale became possible during the 2-year expeditition with the advent of preliminary blueprints of the new 1:250,000 topographic map. The final result of the pre-war expeditions was a collection of preliminary geological maps published by KOCH in 1950.

Although the Carlsberg Foundation and other private sponsors donated considerable funds, much of the financial support for the pre-war expeditions was provided by various Departments of the Danish Government (see Koch, 1955, pp. 15–20). The post-war expeditions were supported almost entirely through grants from the Greenland Department of the Ministry of State.

Geological expeditions under Koch's leadership recommenced in 1947 and continued until 1958. During the period 1947–49 these were still ship-based, but in the summer of 1949 Catalina flying boats were chartered for the first time. Subsequent expeditions were air-borne and relied only on ships for supplies and heavy equipment. The open cockpit Heinkel seaplanes used on former expeditions were now replaced by Norseman cabin-seaplanes. The opening of the lead-zinc producing mine near Mesters Vig necessitated the building of an airstrip in East Greenland. This facility was completed in the summer of 1952. It now became possible to employ land-based aircraft to transport personnel and limited supplies from and to Iceland. Although these were much more economical than seaplanes, Catalina flying boats were still chartered from the Icelandic Airlines or the Royal Danish Airforce for special missions, such as establishing large base camps or depositing fuel dumps for the Norseman aircraft. In 1955–56 the Nordisk Mineselskab used helicopters to prospect the entire coastal area of Central East Greenland for ore deposits. Occasionally these helicopters were chartered by Koch's expedition for special purposes. The opening of the Mesters Vig airstrip eliminated the necessity for wintering small parties at the Ella Ø station.

In 1949–51 post-war activity reached its peak as prospecting and drilling teams investigated the Tertiary lead-zinc mineralization in the Mesters Vig area. The decisive strike there was made in the late summer of 1950, just as hope of finding an economic occurrence had virtually been abandoned. In that year the expedition's total strength was 120, of which approximately a fourth were split up into nine geological parties. Professional geologists who led such parties were drawn from a number of European countries, mostly Denmark, Sweden, Switzerland, and Great Britain. Koch (1961) mentions that a total of 1,291 persons participated in his expeditions between 1926 and 1958. By way of explanation, it should be added that this figure is derived from a count of "man-summers" and includes all support personnel in Greenland. Even so, Koch's expedition fielded a total of 152 geological teams during the summers and 31 during the winters. Since many geologists joined the expeditions year after year, the total number of principal investigators was probably around fifty.

The 1:250,000 topographical map was enlarged to a scale of 1:100,000 for use as a base map in the field. For publication most of the geological maps were prepared on a scale of 1:250,000, although some special maps were printed on a scale of 1:150,000. Oblique aerial photographs taken from high flying survey planes of the Geodetic Institute and also from the expedition's small aircraft were found to be very helpful to field parties and in subsequent map compilation.

The end of the 1958 field season saw the completion of the geological mapping between 72° and 76° N and of reconnaissance mapping in the adjacent areas to the north and south. A total of more than 20,000 pages of published results from all the expeditions and a preliminary bibliography (KOCH, 1954) may be found in the *Meddelelser om Grønland*. More recent lists of references are published in the *Geology of the Arctic* (RAASCH, 1961) and in HALLER (1970, 1971).

THE GEOLOGICAL MAP OF EAST GREENLAND 72°–76° N. LAT.

It is beyond the scope of this brief summary to describe the geological complexity of the area covered by the map of East Greenland 72°–76° N. For more complete treatment, the reader is referred to the explanatory text accompanying the Tectonic Map of East Greenland (HALLER, 1970) and to those review arcticles by LAUGE KOCH's associates published in the *Geology of the Arctic* (RAASCH, 1961). All detailed areal descriptions of the terrain covered by the map are published in the *Meddelelser om Grønland*, and are listed in the bibliography at the end of this paper. The areas covered by these descriptions are indicated on the index map. In addition to the authors listed, credit must also be given to those who contributed to the general exploration of the region, namely H. G. BACKLUND, H. FREBOLD, E. JARVIK, E. H. KRANCK, A. NOE-NYGAARD, H. STAUBER, E. STENSIÖ, C. TEICHERT, and C. E. WEGMANN. Moreover, the geology shown in certain areas of the map is drawn from unpublished sources, *e.g.* A. E. MITTELHOLZER (Clavering Ø), E. WENK (Nordvestfjord), and others.

Outline of geological history

The area covered by the Geological Map of East Greenland 72°–76° N is dominated by a complex, but representative, segment of the East Greenland fold belt, which is part of the circum-Scandic Caledonian domain. The East Greenland Caledonides roughly parallel the coast line over their entire length, approximately from 70° to 82° N. Thrust sheets and nappe structures characterize the western contact of the fold belt with the foreland in Northeast Greenland. In Central East Greenland, the area of the map, this contact is almost entirely obscured by the inland ice (see HALLER, 1971, pp. 216–218). Presumably, it traverses the north-western corner of the map, perhaps somewhere in the vicinity of the innermost nunataks. Thus truncated Caledonian structures underlie nearly all the exposed land area of the map. Indeed, they outcrop over most of the wide inner fjord region but are unconformably overlain by uppermost Permian and younger formations over most of the outer fjord and coastal region. Thus the transgression of the Zechstein sea terminates Caledonian history in East Greenland.

A long enduring geosynclinal environment preceded the Caledonian orogeny in Central East Greenland. Its character and lateral extent varied considerably from late Precambrian through Cambro-Ordovician time (HALLER, 1970, pp. 66–71). The *Central East Greenland geosyncline* included four dominant cycles of sedimentation, the last of which began with the transgression of the Lower Cambrian. The total thickness of the geosynclinal filling exceeded 16,000 m, approximately 13,000 m of which accumulated in the late Precambrian (Eleonore Bay Group and Tillite Group).

The geosynclinal phase was abruptly terminated by the extremely intense *Caledonian main orogeny*, which in the Upper Silurian / lowermost Devonian convulsed all of East Greenland from 70° to 82° N. This climactic spasm was followed by a long period of continuous tectonic activity, which fluctuated in intensity and finally died out towards the close of the Carboniferous. During the main orogeny, portions of the interior of the fold belt were mobilized by a deep-seated source of orogenic heat, resulting in progressive stages of regional metamorphism, migmatization, and granitization. This process, known as ultrametamorphism, was so intense that the old Precambrian crystalline basement was rejuvenated, remobilized, and so welded to the gneissified geosynclinal filling that the old unconformity between them has been obliterated. Although the main Caledonian unconformity in Central East Greenland spans a time from Middle Ordovician to Middle Devonian, the orogeny may be stratigraphically dated as post-Wenlock (Upper Silurian) from evidence to the north of the map area. Furthermore K-Ar determinations on metamorphic minerals give cooling ages of about 420–400 m.y. ago (Upper Silurian).

The relatively short and violent growth of the principal fold belt stands in striking contrast to the prolonged decline of orogenic activity that followed it. This activity manifested itself as *late orogenic spasms*, producing a great variety of structures, which are concentrated about several secondary foci in the region south of 76° N. In contrast to the Caledonian main orogeny, the later tectonic regimes were predominantly superficial in nature and are characterized by structures indicating a brittle mode of deformation. Although many of the resulting fold and thrust systems are closely associated in space and time with the emplacement of granitic intrusions, these late spasms were not characterized by new pulses of metamorphism and migmatization. The single exception is the *Grandjeans Fjord mountain belt*, situated between 74° and 76° N. Just prior to early Middle Devonian time the backbone of this belt was remobilized and plastically refolded about a trend that diametrically cross-cuts the old trend of the Caledonian main orogeny. Post-folding granite intrusions provide good chronological control on the Grandjeans Fjord spasm, because of their contemporaneity with the Kap Franklin granite (73°15′ N), which intrudes early Middle Devonian molasse and is unconformably overlain by Middle Devonian molasse (BÜTLER, 1954). This contemporaneity was established on the basis of similar muscovite ages, 395 m.y. The Kap Franklin granite intrudes an extensive intramontane *molasse basin* in which about 7,000 m of Middle and Upper Devonian detritus (Old Red Sandstone) accumulated. While the Grandjeans Fjord belt was rising to form a mountain range, this region, between 72° and 74° N, widened and subsided. Its boundaries are delineated by extensive zones of tensional fracture and monoclinal flexure. Folding, thrusting, and periods of erosion repeatedly interrupted subsidence and deposition within the basin. Several north-trending systems of faults, indicating a complex structural history, cross the entire basin area and extend far beyond it to the north and south. Widespread *volcanism* occurred within the basin at various times during its history (HALLER, 1971, pp. 257–265). These eruptions which must be in some way related to the intrusion of the Kap Franklin and related granites, began in the Middle Devonian and continued into the Upper Devonian. The region southwest of the basin (approximately south of the line Kong Oscar Fjord–Isfjord) was not much affected by late Caledonian movements, but large batholiths, which may be contemporaneous with the Middle Devonian intrusions in the Grandjeans Fjord belt, were emplaced here. Some of these granite plutons, however, especially those in the region northwest of Kejser Franz Josephs Fjord, may be as young as Upper Devonian. Thus the series of late Caledonian spasms with its associated plutonic and volcanic activity lasted approximately from 400 to 350 m.y. ago; crustal instability related to the Caledonian orogenic cycle, however, continued for about another 100 m.y.

These *minor succeeding episodes* of the Caledonian orogenic cycle were characterized by block faulting of the now cratonized Caledonian fold belt. This activity was restricted to the central and southern sections of the East Greenland Caledonides; in the meanwhile an Upper Carboniferous sea transgressed the northernmost section, signalling an end of Caledonian tectonic unrest in that area. Lower Carboniferous tectonic activity, resulting in warping and local thrusting, focused on the southern portion of the Devonian molasse basin. Reactivation of late Caledonian fracture systems formed new fault-bounded basins of continental deposition in the Upper Carboniferous highlands of Central East Greenland. The general disposition of these fractures and their associated basins indicates a compound rift system of north-northeasterly trend. The filling of these elongated basins is a sequence of plant-bearing clastic sediments ranging from Upper Carboniferous to Lower Permian in age.

By Upper Permian time the whole of Central East Greenland had been largely *peneplaned*. A late Permian sea (Zechstein) transgressed across the subsiding, molasse-laden Caledonian mountain stumps in the eastern half of the map area. The incursion of the sea re-established a marine regime over wide areas that had been emerged since the Caledonian main orogeny. The western portion of the map area, which coincides with the west flank of the Carbono-Permian rift system, continued to remain emerged throughout the remainder of its history. The neritic-lagoonal Zechstein deposits indicate that this was a period of quiescence, but this pause was short-lived. In the early Triassic the faults of the old Carbono-Permian rift system were revived to form a new fault-bounded basin structure between 70° and 74° N. This basin received large quantities of detritus from uplands of Caledonian folded rocks and Devonian molasse to the west and to the east. In the Lower Triassic the sedimentary environment was marine, but it began to alternate between marine and continental by the Middle and Upper Triassic. By the Middle Jurassic it finally became completely marine.

The fossil marine faunas preserved in the Jurassic sediments of East Greenland are particularly noteworthy. The Lower and Upper Jurassic ammonite faunas resemble those of northwestern Europe; the Middle Jurassic faunas, however, are peculiar to the Boreal realm (CALLOMON, 1959, 1963). The Middle Jurassic marks a major transgression of the sea over many areas that had formerly been land, especially in the region north of 74° N. From that time forth a fluctuating shelf-sea persisted over much of East Greenland until the very end of the Mesozoic. Jurassic and Cretaceous coastlines were approximately parallel to the modern coastline. Transgressions submerged the entire present outer fjord region, while regressions drew the Mesozoic shoreline back over the present Atlantic shelf. The dominant sediments of the Middle Jurassic through Cretaceous are light-coloured sandstones and black shales; limestones are rare. These rocks, together with narrow belts of coarse conglomerate, indicate that during this period the basement underlying the shelf sea gradually broke up into a complex series of antithetically rotated fault blocks. VISCHER (1943), investigating the area between 74° and 75° N, showed that this activity gave rise to fault-controlled Mesozoic coastlines and that it further implies *tensional tectonics*. Stratigraphic evidence places the major peak of block faulting and tilting activity in the Upper Jurassic. The north-trending modern coastline of East Greenland north of Scoresby Sund (70° N) still reflects fault control from this period, but the coastline south of this point is controlled by important structures of Tertiary age.

The end of the Mesozoic, perhaps, marks the most drastic change in the morpho-tectonic environment of East Greenland since the Precambrian. At the turn of the era the whole Central East Greenland region was epeirogenically uplifted and began to erode, thus exhuming what had formerly been the Mesozoic shelf. Were it not for this uplift, the late Paleozoic and Mesozoic structural history of the area covered by the map would remain hidden from view today. Eruption of enormous volumes of basaltic lava, building up plateaux exceeding 7 km in thickness almost immediately followed this period of uplift and erosion. These plateau basalts belong to the *Brito-Arctic petrographic province* which extends from the British Isles across the Atlantic through Central East Greenland and West Greenland to Baffin Island. With only few exceptions, confined to the lower portions of the eruptive section, all these lavas were subaerial. Individual flows were separated in time by periods of erosion which disintegrated and bevelled the surfaces of underlying lava sheets, giving rise to interbasaltic terrestrial beds with Paleocene and early Eocene plant fossils. South of Scoresby Sund successive eruptions built up the largest and thickest plateau in East Greenland. In the coastal region between 70° and 74° N, however, the ascending basaltic magma rarely reached the surface but tended to be absorbed by the thick Mesozoic sedimentary cover, forming innumerable sills and dikes. North of Kejser Franz Josephs Fjord, where this cover is much thinner, basaltic lavas once again built up plateaux, though not exceeding 1 km in thickness. These extend along the coast northwards as far as Shannon Ø (75° N) and also form an outlier lying far inland in the nunatak region between 73°30′ and 74°30′ N.

Towards the end of the period of basalt eruption and for some time afterwards, the large inland area south of 73° N was once again epeirogenically uplifted giving rise to the highest mountains in Greenland (Gunnbjørn Fjeld, 3,700 m). Simultaneously the basalt plateau to the east and southeast subsided, producing a tremendous flexure of regional extent. Danmark Strædet now occupies the subsided portion and the modern coastline south of Scoresby Sund is controlled by this monoclinal structure (Wager, 1947). The eruption of the plateau basalts, moreover was followed by the emplacement of *alkaline intrusion centres*. These Tertiary plutonic centres cluster into two distinct regional groups; however, all tend to be aligned along a conspicuous northeast trend. The group situated to the north of the great basalt plateau extends from the Werner Bjerge massif (72° N) to Hold with Hope (73°30′ N) and is shown on the map.

Explanatory notes to the legend

Igneous and plutonic rocks

Pre-Caledonian crystalline complexes. — *Precambrian basement rocks* (A) that were not affected by the Caledonian orogeny occur at the northern edge of the map, in Dronning Louise Land (PEACOCK, 1956, 1958). Within the Caledonian belt small areas of *pre-Caledonian gneiss complexes* (B) occur in the fjord region around 72° N and in the nunatak region around 73° N (HALLER, 1971).

Caledonian crystalline complexes. — Metamorphic and ultrametamorphic rocks related to the Caledonian main orogeny predominate over the wide area of the inner fjord and nunatak regions (HALLER, 1953, 1955, 1956a, 1956b, 1958; LEEDAL, 1952; MITTELHOLZER, 1941; WENK and HALLER, 1953; ZWEIFEL, 1959). Caledonian "metamorphic complexes" include metasediments of the Eleonore Bay Group, metavolcanics (Precambrian ophiolites) as well as remobilized Precambrian basement rocks. The latter constitute much of what is mapped as *synorogenic granites* (C), which tend to be widespread and conformable to the local structure. The *porphyritic granodiorites* (D) are also synorogenic, but they are restricted in occurrence and bear intrusive relations to the surrounding structure. Conformable *alkalifeldspar-augengneisses* (E) are extensively developed in innermost Kejser Franz Josephs Fjord, but are subordinate elsewhere. Granitoid *migmatite gneisses* (F) constitute a rather heterogeneous group in terms of detailed structures, though in general they display good gneissic foliation and are derived to a large part from psammitic Eleonore Bay beds. The rocks lumped together as *amphibolites* (Ga) have several different origins. Some are para-amphibolites, derived from marly sediments; others are ortho-amphibolites, derived from ophiolites; and still others are diabrochites, the result of basic metasomatic exudation. Peridotites and related *ultrabasic rocks* (Gp) in most cases are interpreted as reworked ophiolites. Low-grade metamorphic ophiolitic effusives occur as *green schists* (Gs) in the nunatak region around 72° and 74° N (KATZ, 1952b). All of the following rock types essentially represent metamorphosed Eleonore Bay beds: (H) *marbles*, *calcareous schists* and *gneisses* (J) *mica-schists* and *gneisses*, (K) *bedded quartzites* to *gneisses*, (L) *quartzitic schists* and *gneisses*. In many areas distinctive stratigraphic units may easily be followed through progressive stages of regional metamorphism into the Caledonian metamorphic complexes (WENK and HALLER, 1953; HALLER, 1971). In such cases the units are mapped as *metamorphic sediments* (M) with the index figure of the relevant stratigraphic stages.

Late Caledonian intrusives. — The late orogenic *granite intrusions* in the form of batholiths, stocks, and sheets are widespread wherever rocks folded in the Caledonian main orogeny outcrop. Based on their distribution, timing, and composition, they are considered to be late palingenetic products of the main orogeny (Haller, 1958). These granites were emplaced in several generations. Most are *post-tectonic* (O), because they cross-cut the structures of the invaded rock. Some, however, must be *syntectonic* (N), for their conformable relations to the local structures imply intimate connections between folding, thrusting, and intrusion. Aplites and *pegmatites* (P) are all cross-cutting. Whereas the aforementioned granite intrusions are essentially confined to the margins of the Caledonian metamorphic complexes, the pegmatites occur in scattered swarms, frequently in the interior of these complexes. *Lamprophyres* (L) and carbonatites appear to be the stragglers of the orogenic plutonic activity (Rittmann, 1940; Haller, 1958, 1971).

Devonian eruptives. — Around the southeastern tip of Gauss Halvö *intrusive granites* (R) are stratigraphically dated by their contact relations with Devonian molasse (Bütler, 1954). Volcanic rocks within the molasse basin outcrop in abundance along the outer part of Kejser Franz Josephs Fjord (Kap Graah, Kap Franklin) and on both sides of Moskusoksefjord. Both lava and pyroclastic horizons are found at many levels within the Middle and Upper Devonian section, but the centres of eruption appear to migrate over short distances from one horizon to the next. Occurrences of *felsic volcanics* (S) and *mafic volcanics* (T) are approximately equal in frequency. But the former tend to build up larger bodies, while occurrences of the latter are distributed over a wider area (Bütler, 1954, 1955, 1959; Dal Vesco, 1954; Haller, 1971; Rittmann, 1940).

Cretaceous-Tertiary eruptives. — *Basaltic flows* (Z) and plutonic centres are mostly Paleogene in age, although some may be late Cretaceous in age. Some of the *dolerite dykes* (Z) may be later than Paleogene in age. The widest variety of Lower Tertiary plutonic rocks, including *pyroxenite*, *gabbro*, and *diorite* (X), *granite* (W), *syenite* (V), and *nepheline-syenite* (U) occur in the Werner Bjerge massif, Scoresby Land (Bearth, 1959) and in the nearby Pictet Bjerge complex (Kapp, 1960). *Pyroclastic rocks* and *magmatic breccias* (Y) surely have diverse origins but are not separately distinguished. The abundance of magmatic breccia associated with each Tertiary plutonic centre seems to be directly proportional to the depth of the erosional cut.

Sedimentary rocks

Central East Greenland geosyncline (Proterozoic and Lower Paleozoic). — The term *Groenlandian* has been applied to all Proterozoic formations in North and East Greenland (Koch, 1930). In Central East Greenland this term includes the greatest bulk of the Caledonian geosynclinal filling, namely the Eleonore Bay Group and the Tillite Group. Due to the early structural complexity of the Central East Greenland geosyncline the **Lower Eleonore Bay Group**, which represents the first cycle of sedimentation, varies widely in thickness and in the relative proportions of characteristic lithologies. The *Basal Series*, with a variable thickness from 200 to 1,400 m, is predominantly thick-bedded orthoquartzite (1) and calcareous deposits (2), but may include up to 1,000 m of ophiolitic volcanics. The subdivision of the basal sequence, adopted on the Geological Map of East Greenland, differs from that shown on detailed maps by KATZ (1952b) and HALLER (1956a) and is based on new evidence from localities south of the map area. In the fjord region, the *Lower Arenaceous-Argillaceous Series* (3) consists of up to 8,000 m of quartzites and greywackes; in the nunatak region, however, approximately 1,200 m of pelites (3b) dominate the equivalent succession. These pelites are locally underlain by some 700 m of quartzites (3a) in the western portion of Frænkels Land. The *Upper Argillaceous-Arenaceous Series* (4) is particularly variable as to thickness (1,200 to 3,000 m) and lithology, though pelitic assemblages predominate. Up to 300 m of carbonate rocks (4a), restricted in occurrence to the southern fjord region only, underlie the series. Conformable ophiolitic intrusives are common. A non-evident disconformity, indicating epeirogenic movement in the source and depositional areas, separates the Lower from the Upper Eleonore Bay Group. The character of the former is markedly eugeosynclinal; that of the latter, miogeosynclinal.

The **Upper Eleonore Bay Group** is a classic transgressive succession, starting at the bottom with a thick layer of orthoquartzites, proceeding upwards through interbedded mudstones, limestones and dolomitic sandstones, and finally culminating in massive limestones and dolomites. The thickness and lithologic character of individual beds within the Upper Eleonore Bay Group is strikingly uniform over all Central East Greenland. For this reason a standard numbering sequence of bed groups (*Nos. 1–20*) was introduced for mapping purpose (EHA, 1953; FRÄNKL, 1953a, 1953b; KATZ, 1952a; SOMMER, 1957a, 1957b). The Upper Eleonore Bay Group is subdivided according to the progressive upward change in lithofacies into: (5) *Lower Quartzite Series* (*Nos. 1–2*) 1,000 m; (6) *Upper Quartzite Series* (*Nos. 2–6*) 1,100 m; (7) *Multicoloured Series* (*Nos. 7–13*) 1,000 m; (8) *Limestone-Dolomite Series* (*Nos. 14–20*) 1,000 m.

The **Tillite Group** (9), with a variable thickness of 300 to 1,300 m, is a shaly to sandy succession, incorporating two distinct boulder beds at the base. The phenoclasts of the lower boulder bed are of local origin, mainly derived from the Limestone-Dolomite Series; but those of the upper boulder bed are foreign, igneous rocks derived from an undetermined source. This complex group is correlated with the *Eocambrian* Varanger Ice Age formations in Scandinavia. Regional unconformities separate the Tillite Group from the Eleonore Bay Group below and the Cambrian above.

The transgression of the Cambrian initiated the fourth cycle of geosynclinal sedimentation which includes *Lower* and *Middle Cambrian* (10) and *Middle Ordovician* (11). Although these **Cambro-Ordovician** strata reach an aggregate thickness of 3,000 m, they are only preserved in a narrow belt in the fjords between 72° and 74°30′ N. No Silurian rocks or fossils were found in the region (Poulsen, 1930; Cowie and Adams, 1957).

Late to post-Caledonian continental deposits. — In Central East Greenland the gap in the stratigraphic record resulting from the Caledonian main folding spans from Middle Ordovician to Middle Devonian. The stratigraphic overstep of the folded geosynclinal section by the Middle Devonian basal Old Red Sandstone is nearly 8,000 m. This means that the main Caledonian mountains were deeply eroded prior to the accumulation of the *intramontane molasse.* The depositional environment within the molasse basin was strongly affected by tectonic activity resulting from the late Caledonian spasms. Based on his study of the angular unconformities within the Devonian section, Bütler (1940, 1959, 1961 a) established the following sequence of tectono-environmental units, his "orogenic series":

Mount Celsius Series (13c) *Cape Graah Series* (13b)	*Upper Devonian* (13)
Cape Kolthoff Series (13a)	*Upper Devonian and/or Upper Middle Devonian*
Ramsay Bjerg Series *Basal Series*	*Middle Devonian* (12)

Attempts have been made to correlate this "orogenic series" with the biostratigraphic subdivisions of the Old Red Sandstone (Säve-Söderbergh, 1934; Jarvik, 1950, 1961) but these have met with various difficulties, mostly arising from the continental nature of the deposits. The unique collections of Upper Devonian tetrapods from East Greenland have attracted considerable interest; their evolutionary importance is discussed in Jarvik (1963).

The *Carboniferous* (15) and *Lower Permian* (16) deposits having an aggregate thickness between 5,000 and 6,000 m are also continental in character. The lower part of the Carboniferous is not present; lower Namurian appears to be the earliest stage represented. Witzig's (1951) interpretation of the Carboniferous fossil floras implies that the succession youngs southwards from Kejser Franz Josephs Fjord. Most of the molasse beds south of 72° N are placed in the Lower Permian by BÜTLER (1957) and KEMPTER (1961).

Post-Caledonian cover rocks. — The lithofacies of the marine *Upper Permian* (17) which varies in thickness from 200 to 300 m is indicative of neritic to near-shore environments (MAYNC, 1961). These formations are assigned to the Zechstein on the basis of their rich invertebrate fauna (Dunbar, 1955) and significant fish fauna (STENSIÖ, 1961). The lower Eotriassic *Wordie Creek Formation* (18), from 500 to 800 m thick, is the only Triassic formation that is uniformly marine throughout. Extensive collections of invertebrates (SPATH, 1930, 1935) and vertebrates (NIELSEN, 1935, 1961) were obtained from the type locality near Kap Stosch (74° N). *Mount Nordenskiöld Formation* (19), approximately 700 m thick, is of Middle Triassic age, although in the Kap Stosch area uppermost Eotriassic beds (19a) are included. The *Cape Biot Formation* (20) ranges in age from Middle to Upper Triassic but the bulk of it is Upper Triassic (TRÜMPY, 1961). The *Lower Jurassic* (21) is an interbedded sequence of terrestrial and marine-deltaic deposits. Both the above formations outcrop sparsely in the map area but are more extensively developed to the south. The marine *Middle Jurassic* (22), which includes Bathonian and Callovian stages, reflects a regional transgression over most of the coastal area (DONOVAN, 1957). The marine *Upper Jurassic* (23) does not outcrop extensively in the map area, except on Wollaston Forland and Kuhn Ø. Large outcrops, including a complete transition into marine Lower Cretaceous beds, occur to the south. The *Lower Cretaceous* (24) includes Valanginian, Aptian, and Albian, except on Wollaston Forland where it also includes Berriasian. The sandy Aptian is transgressive and is followed by Albian and lower Cenomanian black shales. Outcrops of *Upper Cretaceous* beds (25), Upper Turonian and Senonian, are restricted to the coastal area between 72° and 74° N. A major stratigraphic break follows the Upper Cretaceous and precedes the Lower Tertiary.

Tertiary sedimentary formations (26) occur at various places in the coastal region between 74° and 75°30′ N. Most of them are fluvio-lacustrine sandstones containing fossil plants (MATHIESEN, 1932). The proximity of the sea is indicated by finds of marine fossils together with plant remains on Lille Pendulum Ø and Hochstetter Forland. These beds predate the major eruption of plateau basalt. Except for a fossil river bed exposed north of Mackenzie Bugt (ORVIN, 1931), interbasaltic sedimentary formations are mostly too thin to be shown on the map. No post-basalt Tertiary sedimentary deposits have been discovered in the map area.

Except for significant lateral and terminal moraines, *Quaternary* formations (27) are not differentiated on the map.

Acknowledgements.

The editor of Meddelelser om Grønland joins the authors in their great appreciation of the excellent and dedicated printing work by Mr G. Holm-Petersen and his co-workers at the Teknisk Afdeling of the Danish Geodetic Institute. Acknowledged, moreover, are those who kindly helped to prepare this editorial note and the enclosed index map namely Dr A. K. Higgins (Geological Survey of Greenland) and Claude S. Dean (Harvard University).

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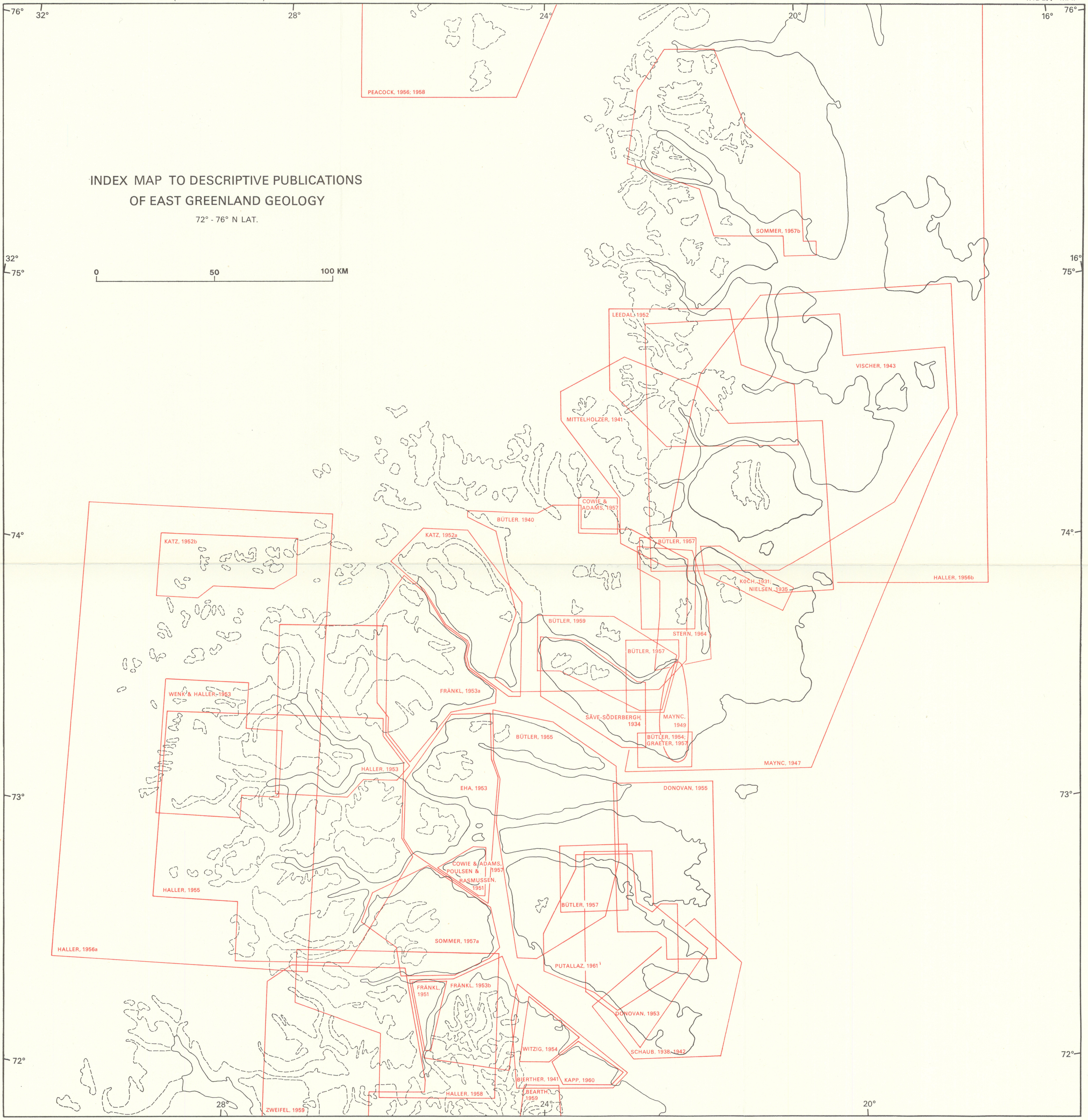
Færdig fra trykkeriet den 18. august 1971.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