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GEOLOGY OF THE NORTH STAR BUGT AREA, NORTHWEST GREENLAND

BY

WILLIAM E. DAVIES, DANIEL B. KRINSLEY
ALLEN H. NICOL

WITH 25 FIGURES IN THE TEXT
AND 4 PLATES

KØBENHAVN
C. A. REITZELS FORLAG
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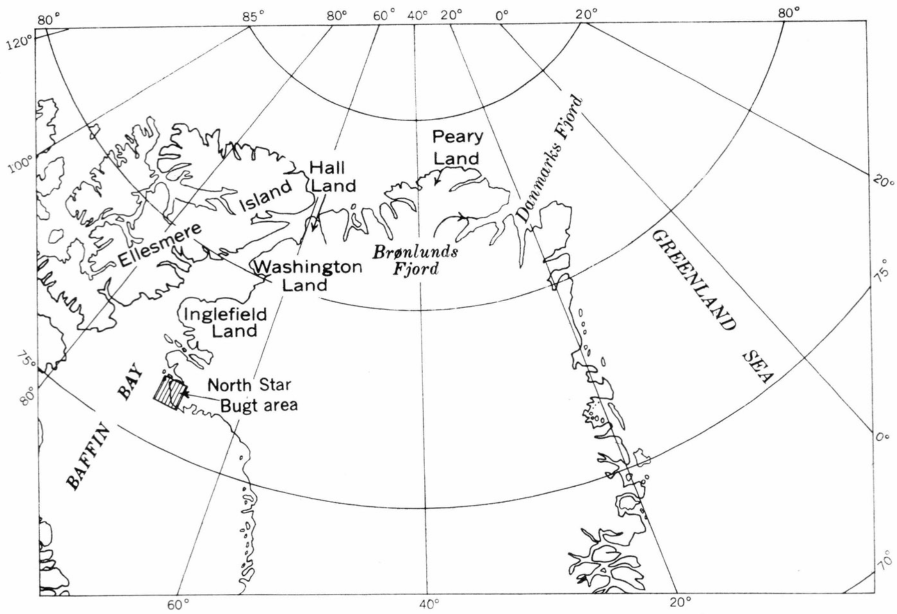

Fig. 1. Map showing location of North Star Bugt Area.

GEOLOGY OF THE NORTH STAR BUGT AREA NORTHWEST GREENLAND[1])

William E. Davies, Daniel B. Krinsley, Allen H. Nicol

INTRODUCTION

The North Star Bugt Area for purposes of this report includes the ice-free land area extending from Sermipaluk to Wolstenholme Fjord (Figure 1). In general, the area is the same as that formerly known as the Thule area. The moving of the village of Thule to Qânâq on Inglefield Bredning in 1953 and the subsequent renaming of Qânâq as Thule makes it necessary to apply a new name to the area adjacent to the former site of Thule.

The North Star Bugt Area constitutes about 500 square miles (1,280 sq. km.) of ice-free land. To the south it is separated from southern Greenland by the numerous outlet glaciers of the inland ice which restrict the exposed land to small nunataks. Northward the ice-free land is extensive as far as Inglefield Bredning but it is divided into a series of long east-west segments by fjords extending inland almost to the inland ice. The heads of the fjords are occupied by large outlet glaciers.

[1]) Publication authorized by the Director, U. S. Geological Survey.

Previous Work. The history of exploration in the vicinity of North Star Bugt goes back as far as 1616 when William Bylot as commander and William Baffin as pilot sailed along the coast in the *Discovery*. No further exploration was done until 1818 when John Ross in the *Isabella* and *Alexander* followed roughly the route of Bylot. After Ross' expedition, visits to the area became more frequent. Whalers regularly operating around Kap York occasionally penetrated into the upper reaches of Baffin Bay, but the more notable contributions to exploration came from several expeditions searching for Sir John Franklin. The ship *North Star* commanded by James Saunders wintered in North Star Bugt in 1849–1850. Captain E. A. Inglefield in the *Felix* in 1852 examined the area around Wolstenholme Fjord, and the first account of the geology of the area was produced by P. C. Sutherland (Sutherland 1853) who accompanied Captain Inglefield.

Nathorst hastily examined the rocks at Ivssuvigsôq during the cruise of the *Sophia* in 1883 (Nathorst 1884, Nordenskiöld 1885). During 1893 and 1894 Robert E. Peary sledged along most of the coast in the area (Peary 1898). In 1903 and 1904 the Danish Literary Expedition under the leadership of L. Mylius-Erichsen was stationed on Saunders Ø and explored much of the area in detail (Mylius-Erichsen 1906). Knud Rasmussen, a member of the Literary Expedition, established the trading station at Thule in 1910. In 1915–16 the *George B. Cluett*, a relief ship for MacMillan's Crocker Land Expedition wintered in Parker Snow Bugt but apparently very little in the way of exploration resulted from the sojourn (MacMillan 1918). With the establishment of the Thule station activity in the area greatly increased; numerous expeditions to Northern Greenland and Ellesmere Island were staged from the station. The activities of the station drew to a close in 1953 with the completion of the U. S. Air Force Base at Thule and the subsequent movement of the Danish Station to Qânâq.

Even though the Danish Station at Thule was the base for mounting many scientific expeditions during its 43 years of existence little attention was given to the geology in its immediate vicinity. Before 1916 geologic investigations were spotty and included those of Sutherland and Nathorst, which have been cited, as well as those of A. P. Low who visited Parker Snow Bugt in 1904 aboard the Canadian ship *Neptune* (Low 1906). He briefly remarked on the metamorphic rocks exposed there. In 1914 and 1916 Ekblaw as a member of MacMillan's Crocker Land Expedition spent considerable time at Thule and investigated the geology in the vicinity of the station (MacMillan 1918). However, no report was published.

In 1916 Lauge Koch commenced his extensive geological studies of Greenland as a member of the Second Thule Expedition. During the years 1916–18 and 1920–23 (Jubilee Expedition) the fundamentals of the geology from Kap York northwards were established by KOCH (KOCH 1920, 1926, 1933). However, data on the geology south and east of the Thule Station were published at a small scale in little detail.

SOLE MUNCK visited the area in the vicinity of the Thule Station for 11 days in 1936. During this period she gathered considerable information on the petrology of the rocks between the Thule Station and Narssârssuk, along Wolstenholme Fjord and inland from the Sioraq (MUNCK 1941). ROBERT NICHOLS, while a member of U. S. Navy Task Force 80, visited the North Star Bugt Area for 5 days in 1948 and made observations on the geomorphology (NICHOLS 1953). In 1949 VINCENT E. KURTZ and D. B. WALES while on assignment to the U. S. Navy Icebreaker *Edisto* spent 10 days in the vicinity of Thule during which they carried on a rapid survey of the geology by use of helicopters.

A brief visit to the highlands northeast of Parker Snow Bugt was made by ALFRED ROSENKRANTZ and other members of the Geological Survey of Greenland in 1950 to determine whether sedimentary rocks of Triassic age existed in place there. Two years previously a piece of fossiliferous rock containing Upper Triassic *Monotis* shells, said to be found in that area, was brought to Copenhagen. The search for similar rocks was in vain, but the party succeeded in ascertaining hematite and magnetite occurrences connected with the crystalline bedrock (BØGGILD 1953, p. 439).

Fieldwork for this Report. The fieldwork for this report was accomplished by members of the United States Geological Survey during the summer of 1953. The fieldwork was made possible by support of the Corps of Engineers and the Transportation Corps, U. S. Army.

Much of the North Star Bugt Area was covered by ground traverses out of Thule, Narssârssuk, and from camps 4 miles (6 km.) north of Igdluluarssunguit, on Saunders Ø, and on Wolstenholme Ø. Areas not accessible on foot from these points were covered by helicopter traverses in which the geologist was transported to selected points for short traverses on foot. In some areas the helicopter was used to make numerous, closely spaced landings for the purpose of examining the rocks. The area south of Parker Snow Bugt was covered in a single helicopter traverse supplemented by photointerpretation.

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Dr. J. C. Troelsen and Dr. Alfred Rosenkrantz, Universitetets Mineralogisk-Geologiske Institut, Copenhagen, Dr. Arthur T. Fernald and Dr. William S. Benninghoff, U. S. Geological Survey, have been most helpful in reviewing the manuscript and in offering many suggestions for its improvement.

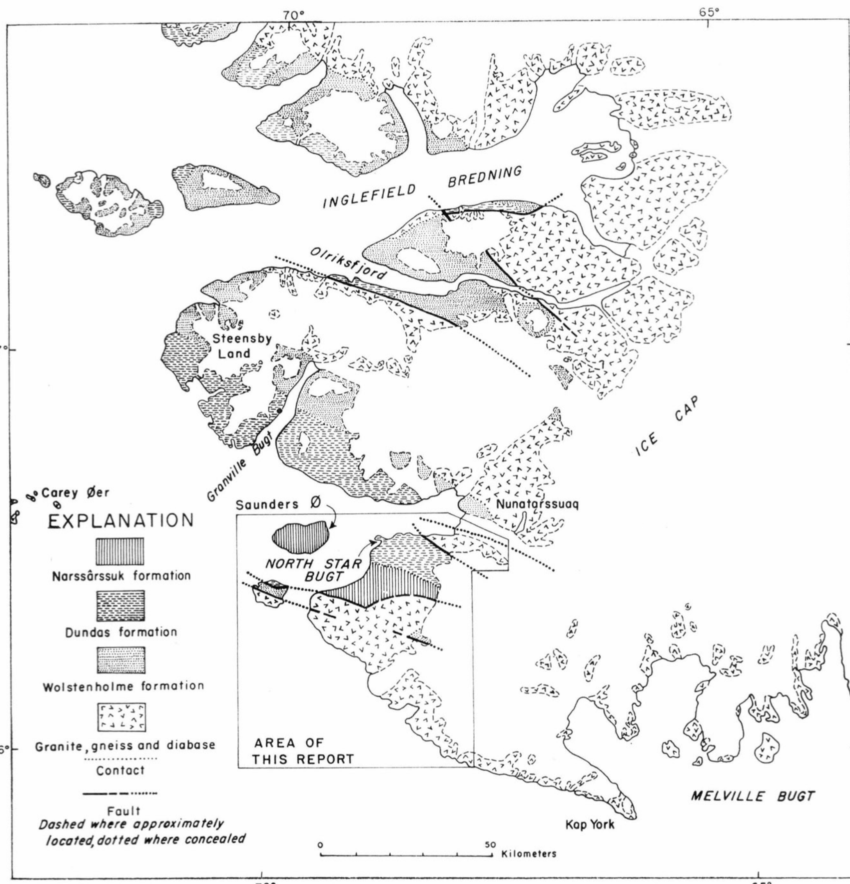

Fig. 2. Map of the geology, Kap York-Inglefield Bredning.

GENERAL GEOLOGIC RELATIONSHIPS

The North Star Bugt Area lies along the southern remnant of the large Franklinian or Smith Sound geosyncline. This geosyncline extends across the northern part of the Canadian Arctic Islands, through central and northern Ellesmere Island and along the coastal zone of Northern Greenland. The foreland area of Precambrian basement rocks and unfolded Precambrian and lower Paleozoic sedimentary rocks lying south of the folded rocks of the Franklinian geosyncline extends throughout northwestern Greenland as far north as Hall Land and northern Peary Land. The southernmost extent of the sedimentary rocks is in the North Star Bugt Area. For over 300 miles (480 kms.) to the south only metamorphic or igneous rocks are encountered along the west coast of Greenland. To the north as far as Inglefield Bredning are alternating areas of Precambrian sedimentary rocks, similar to those in the North Star Bugt Area, and the basement complex (Figure 2). Farther north in the coastal area of Inglefield Land are lower Paleozoic sedimentary rocks while in Washington Land and Hall Land there are sedimentary rocks of middle Paleozoic (Devonian) age. In the zone of folding along the north coast of Greenland sedimentary rocks equivalent to those of the foreland have been intensely folded and metamorphosed. The folding is primarily Late Devonian (Caledonian and Acadian) in age.

PHYSIOGRAPHY AND DRAINAGE

William E. Davies

The topographic features in more than three quarters of the North Star Bugt Area are a direct reflection of the bedrock. Glaciation has modified the gross forms very little except in areas where the glacial deposits are so thick that they bury the bedrock landforms.

The land area considered in this study, primarily that between Sermipaluk and Wolstenholme Fjord, is a high plateau which is locally dissected into broad ridges.

Along Wolstenholme Fjord the land is a scarped, ridge-like remnant of the plateau standing 800 to 1,000 feet (240 to 300 meters) above the sea. The upland is rolling with gentle slopes to the south. North slopes are scarps 10 to 50 feet (3 to 15 meters) high formed by the outcrop of resistant diabase sills. The north side of the ridge along Wolstenholme Fjord is a step-like cliff up to 800 feet (240 meters) high. The "steps" are formed by diabase sills between which black shale forms a steep talus-covered slope. Dundas Fjeld is an isolated remnant of the ridge and is capped by a diabase sill which forms a cliff 20 to 40 feet (6 to 12 meters) high that completely circles the summit. Below this cap the talus slopes drop off to the sea at an angle of 40°.

South of the Sioraq is a zone in which the plateau is highly dissected. This area is about 3 miles (4.8 kms.) wide and extends 6 miles (9.6 kms.) inland to where it is buried beneath a thick cover of glacial deposits. The upland is 500 to 1,000 feet (150 to 300 meters) in elevation and is formed of a series of scarps that face to the north. These scarps are 10 to 50 feet (3 to 15 meters) high trending NNW. The scarps are formed of outcrops of resistant dolomite (Figure 3). Between the scarps are broad flat areas covered with numerous fragments of dolomite and some glacial deposits. The valleys cutting this part of the plateau are 300 to 500 feet (90 to 150 meters) deep and are narrow with very steep or precipitous sides. They trend NNW with a few major tributary valleys trending north. In their headwaters area several of the main NNW valleys intersect the north trending tributaries. At the point of intersection the valley is fully developed and remains as a hanging valley, a hundred or more feet (30 meters) above the tributary. The

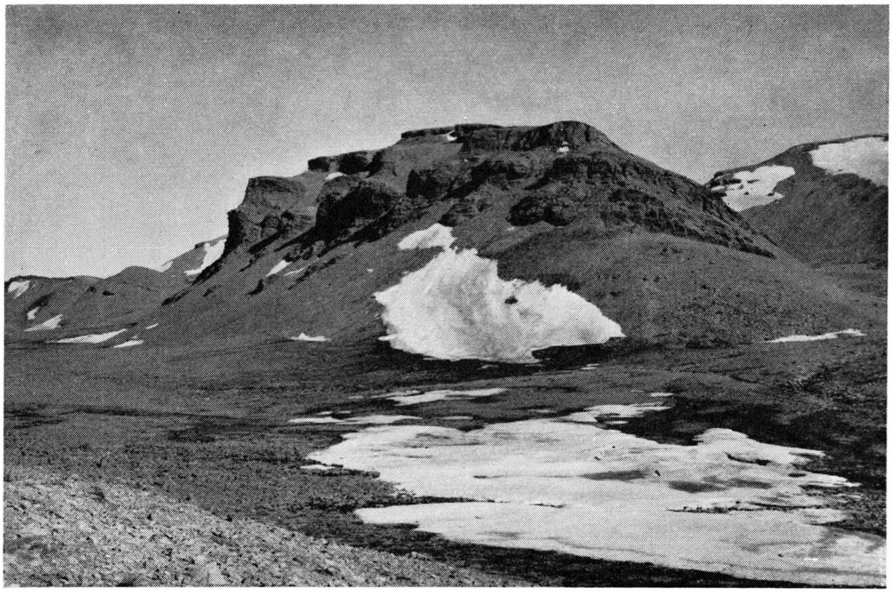

Fig. 3. Hill of dolomite typical of the scarped plateau area south of Siorqap kûa (South River).

slope of the floor of the hanging valley is uniform and in a direction away from the tributary.

Along the front of the ice cap and in the area drained by the Narssârssuk Elv the plateau is dissected very little. In this area broad rolling uplands 800 to 1,200 feet (240 to 360 meters) in elevation extend for great distances. In the lower courses of streams in this area the valleys are narrow with steep sides but in the upper courses the valleys are broad and shallow with gently sloping sides.

In the southern half of the North Star Bugt Area, where the basement complex is at the surface, the land is a highly dissected upland with extensive level areas 1,100 to 1,300 feet (330 to 390 meters) in elevation (Figure 4). Above this level numerous rounded hills and mountains have summits 200 to 1,300 feet (60 to 390 meters) above the upland surface.

South of Parker Snow Bugt the area of ice-free land is reduced to a coastal strip 2 or 3 miles (3 to 4.8 kms.) wide. This strip is the outer remnant of an upland and has concordant summits of 1,700 to 2,300 feet (520 to 700 meters) elevation.

Wolstenholme Ø is a continuation of the gneissic upland of the mainland. The concordant upland surface is 700 to 1,000 feet (210 to 300 meters) in elevation above which mountains rise to 1,800 feet (550 meters). Saunders Ø has a flat, slightly dissected surface 1,000

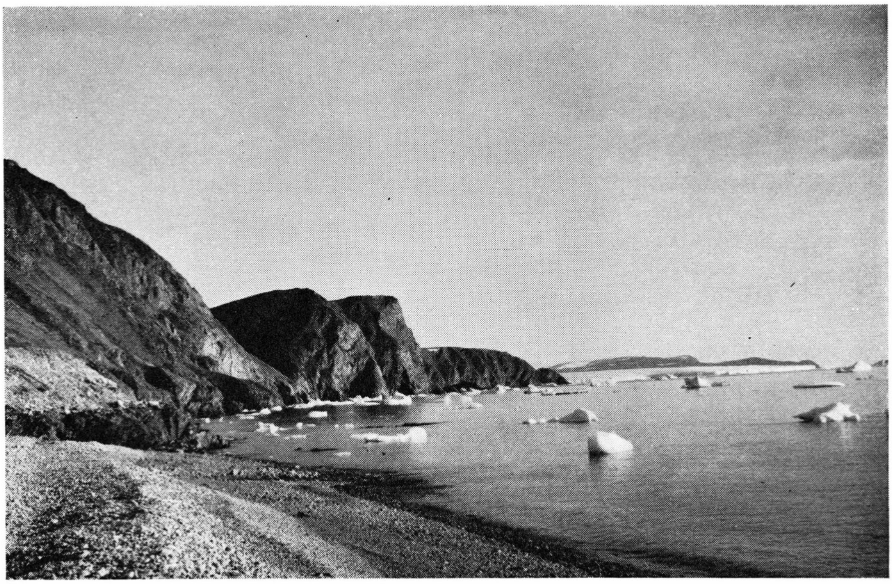

Fig. 4. Dissected plateau in area of basement rocks at Igdluluarssúnguit; view southeast.

to 1,500 feet (300 to 460 meters) above the sea. On all but the north side it is bounded by cliffs that descend sheer to the sea. Valleys cut into the plateau are narrow, vertical-sided and steep.

Dalrymple Rock and Conical Rock are small islands with extremely rugged landforms consisting primarily of serrate peaks, pinnacles, and cliffs. Edderfugleøer are low, rounded islands that stand but 25 feet (7 meters) above the sea.

Only one distinct upland surface is recognizable in the North Star Bugt Area. This surface forms the summit of the plateau that stands 1,000 to 1,300 feet (300 to 390 meters) above sea level. A surface at altitudes up to 3,500 feet (1,100 meters) forms much of Inglefield Land (Troelsen 1950, p. 13). However, in the area between North Star Bugt and Inglefield Land and to the south of the North Star Bugt Area the upland is much higher, reaching 3,000 feet (1,000 meters) or more. In the gneiss plateau in the southern part of the area many hills and mountains rise above the level of the upland surface and reach altitudes of 2,700 feet (820 meters).

It is probable that no widespread uniform upland surface exists in Northwest Greenland. The summits that are common at about 3,000 feet (1,000 meters) altitude may be the remnant of a surface of erosion that is now highly dissected. The lower concordant levels at 1,000 to 1,300 feet (300 to 390 meters) are probably local uplifted and dissected erosion surfaces of relatively recent origin. The overlying glacial drift indicates at least an early Pleistocene date for the surface, and the broad slightly dissected uplands indicate the surface is probably not older than late Pliocene.

Polar areas, because of their relatively low temperatures, are seldom thought of as having extensive surface drainage. However, during the brief summer period, when thaw is at a maximum, practically every valley contains a flowing stream. In the North Star Bugt Area three rivers and many minor streams have developed extensive drainage systems. The rivers, the Siorqap kûa, Pitugfiup kûgssua, and Narssârssuk Elv, are fed by meltwater from the ice cap while the smaller streams are nourished by the melting of large perennial snowbanks that are formed along parts of their valleys.

Two distinct periods of thaw exist in the area. In May or at times as late as early June the snow cover melts. This thaw is of short duration because of the thinness of the snow mantle, and the meltwater results in little or no runoff since that which is not evaporated is absorbed into the ground or the large perennial snowbanks. From late June through early September the large perennial snowbanks and the ice cap melt. During this period the streams receive a large and fairly constant volume of water.

The valley of the Pitugfiup kûgssua (the Pitugfik river) is broad and open. Only in short stretches in its course, for a few miles west of the ice cap and a mile near its mouth, does it flow in a narrow steep-walled valley where the stream completely fills the bottom. Siorqap kûa (South River) is in a wide shallow steep-walled valley in its upper course. In its central part the valley is shallow and wide for a few miles until it enters the hilly area of Akínarssuaq where it flows in a steep-walled, narrow valley. The Narssârssuk Elv and its branches are in broad, steep-walled valleys with wide flat floors (Figure 5). The stream occupies only a part of the valley floor and generally flows along several interlacing channels.

The short streams fed from perennial snowfields are mainly in narrow steep-sided valleys, and their channels occupy most of the valley bottom.

In addition to the streams in the ice-free area, there are several large melt streams on the surface of the Pitugfik Gletscher. These streams, several feet deep and 5 to 10 feet (2 to 3 meters) wide, flow along much of the glacier before discharging into the lateral moraines.

The major streams in the North Star Bugt Area have a width of 50 to 200 feet (15 to 60 meters) in the middle and lower part of their courses. They are generally 2 or 3 feet (0.6 to 1 meter) deep and flow very swiftly. Discharge in gallons per minute at their mouths at the height of the melt season in July and August, 1953, is estimated as:

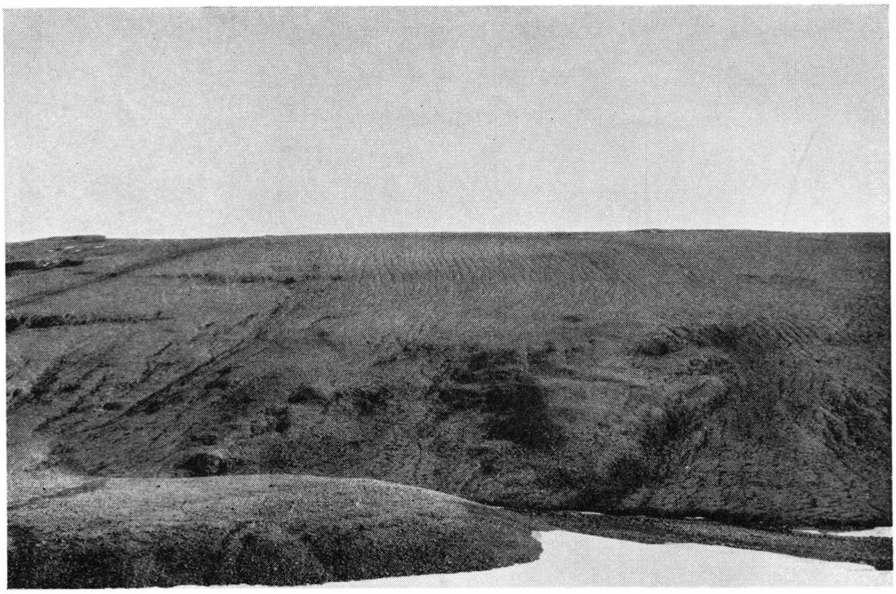

Fig. 5. Valley of the Narssârssuk Elv at the junction of the Middle and South Branches

Pitugfiup kûgssua 150,000 ($\simeq$ 11,5 cu.m. per sec.); Siorqap kûa 250,000 ($\simeq$ 19 cu.m. per sec.); Narssârssuk Elv 135,000 ($\simeq$ 10 cu.m. per sec.). The minor streams draining perennial snow banks are from 5 to 15 feet (1.5 to 4.5 meters) wide and from a few inches to a foot deep. Their discharge ranges from a few gallons per minute up to 9,000 gallons per minute ($\simeq$ 0,7 cu.m. per sec.).

Numerous lakes occur in the North Star Bugt Area. They are largest and most numerous in the upper broad valley south of Uvdle and on the upland between Diabas Ås and Nordfjeld (North Mountain). Most of them are shallow; the area covered ranges from several thousand square feet to half a square mile. Crescent Sø, however, is over 45 feet (14 meters) deep with very steep sides.

Small shallow lakes, a few feet deep and about 100 to 200 feet (30 to 60 meters) in diameter are in the valley southeast of Aorfêrneq near its connection with Sønderbæk and on the upland a mile south of the Narssârssuk Elv, 3 miles (4.8 kms.) southeast of Narssârssuk.

The glacially dammed lake adjacent to the Pitugfik Gletscher is the largest in the area. It was 3 miles (4.8 kms.) long, a half mile (0.8 km.) wide and over 100 feet (30 meters) deep in 1953. Several other small, deep lakes are developed in the area of the lateral moraines along the Pitugfik Gletscher.

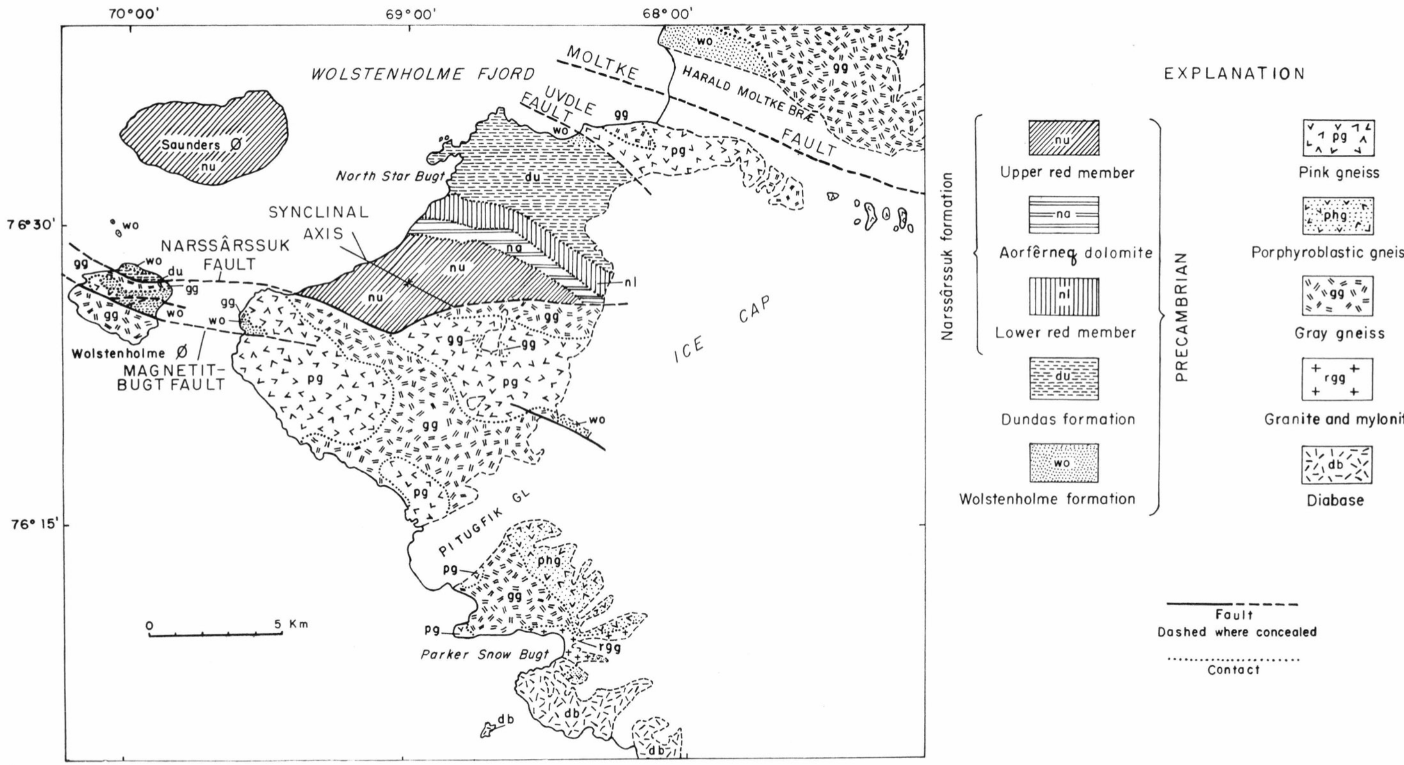

Fig. 6. Generalized map of bedrock geology of North Star Bugt Area.

BEDROCK GEOLOGY

William E. Davies and Allen H. Nicol

The rocks of the North Star Bugt Area are generally divisible into three main types (Figure 6): (1) the Precambrian basement complex of granitic gneiss, schist, and other types of metamorphic rocks; (2) the sedimentary rocks, mostly dolomites, sandstones, shales, and quartzites; and (3) the diabase dikes and sills (Figure 7). By far the greatest portion of the North Star Bugt Area is underlain by Precambrian metamorphic rocks; the sedimentary rocks are second in extent, and the diabase sills and dikes probably underlie less than 5 percent of the area.

Basement rocks.

The basement complex includes the following: pink granitic gneiss, gray banded gneiss, amphibolite, porphyroblastic gray gneiss, serpentine, gray aplite gneiss, mylonite, red granite gneiss, and garnet-chlorite schist. These rocks form the southern half of the North Star Bugt Area and are also along the south side of Harald Moltke Bræ. The basement complex unconformably underlies the sedimentary rocks of the Thule Group and is postulated as being Middle Precambrian.

Pink granitic gneiss. The pink granitic gneiss and the gray banded gneiss are the most prominent basement rocks of the Greenland Shield in the North Star Bugt Area. The pink granitic gneiss is the more widespread unit of the two and underlies the northeast part of the area near Wolstenholme Fjord, and large areas south of Narssârssuk Elv (Figure 13). Small bodies of garnet-chlorite schist, amphibolite gneiss and schist, epidote gneiss, and augen gneiss occur in isolated areas in the northeast, associated with the pink granitic gneiss, and adjacent to Wolstenholme Fjord at Uvdle and 6 miles (9.6 kms.) east of Uvdle; other small bodies of similar types of rocks occur in the east part of the land mass at the ice cap front at the head of Siorqap kûa, south of Pitugfik Gletscher and on Wolstenholme Ø. Inclusions of small

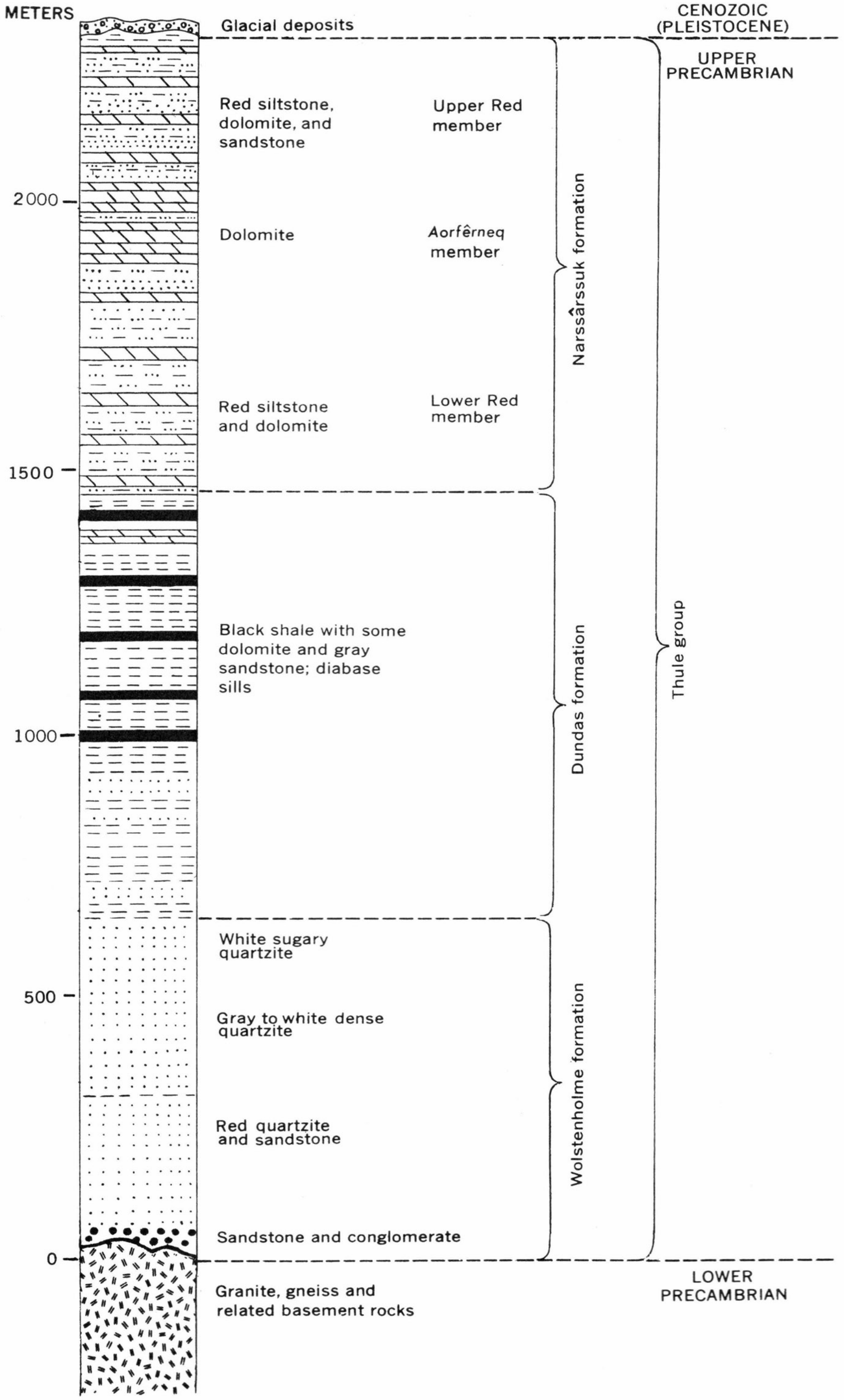

Fig. 7. Columnar Section of rocks in North Star Bugt Area.

Fig. 8. Cliffs formed by the Upper red member, Narssârssuk formation, north of Narssârssuk.

Fig. 9. Red siltstone, sandstone (dark colored beds) and dolomite (light colored beds) of Lower red member, Narssârssuk formation exposed along Siorqap kûa (South River), 3 miles (4.8 kms) from its mouth.

areas of gray banded gneiss are common in the pink granitic gneiss especially on Peder Marcus Fjeld and the nunataks along Harald Moltke Bræ.

The pink granitic gneiss is fine- to medium-grained, and composed essentially of microcline, oligoclase-albite, quartz, and biotite. The

Fig. 10. Massive dolomite in upper part of Lower red member, Narssârssuk formation, west end of Akínarssuaq (South Mountain).

microcline is usually fresh and clear, whereas the plagioclase is commonly turbid, partly sericitized. Biotite is chloritized in part, and contains occasional brown allanite inclusions with pleochroic halos. Minor constituents observed include epidote (as a replacement of biotite), apatite, and sphene. A specimen from $^1/_2$ mile (0.8 km.) east of Uvdle contains small pink garnets and muscovite. A sample of pink gneiss obtained near a diorite dike 4 miles (6.4 kms.) due west of Peder Marcus Fjeld shows very abundant myrmekite, and highly

Fig. 11. Gray sandstone and black shale of Dundas formation exposed in valley of Pitugfiup kûgssua at front of ice cap.

Fig. 12. Black shale of Dundas formation exposed along Wolstenholme Fjord, 2 miles (3.2 kms.) southwest of Uvdle.

Fig. 13. Pink gneiss exposed along the coast 4 miles (6.4 kms.) southwest of the mouth of Narssârssuk Elv.

sericitized feldspars. Along the front of the ice cap at the head of Siorqap kûa and 2 miles (3 kms.) east of Freuchen Nunatak the pink gneiss is coarse grained and is composed of feldspar and quartz almost to the exclusion of other minerals. In this area it closely resembles the red granite gneiss exposed along Parker Snow Bugt.

The pink granitic gneiss is less deformed than the gray banded gneiss. Lineation parallels cleavage or parting, and trends east-west nearly everywhere in the unit. Throughout much of the unit, the pink granitic gneiss is a fairly uniform rock, varying but little in texture and composition; this contrasts markedly with the deformed, heterogeneous gray banded gneiss which underlies the pink granitic gneiss.

Gray banded gneiss. This gneiss which underlies and is older than the pink granitic gneiss occurs in the area around Søkongedal eastward to the Pitugfik Gletscher and on Wolstenholme Ø. It is generally coarse grained, well banded, gray with black biotite streaks conspicuous in a white, feldspathic matrix. The gray banded gneiss carries much more biotite than the pink granitic gneiss, and the biotite plates are as much as a millimeter in size, which gives the rock a gray appearance. Specimens from Wolstenholme Ø and a mile (1.6 kms.) south of the junction of the Middle and South Branches of Narssârssuk Elv contain pink feldspar, but the overall color of the rock remains gray. An exception

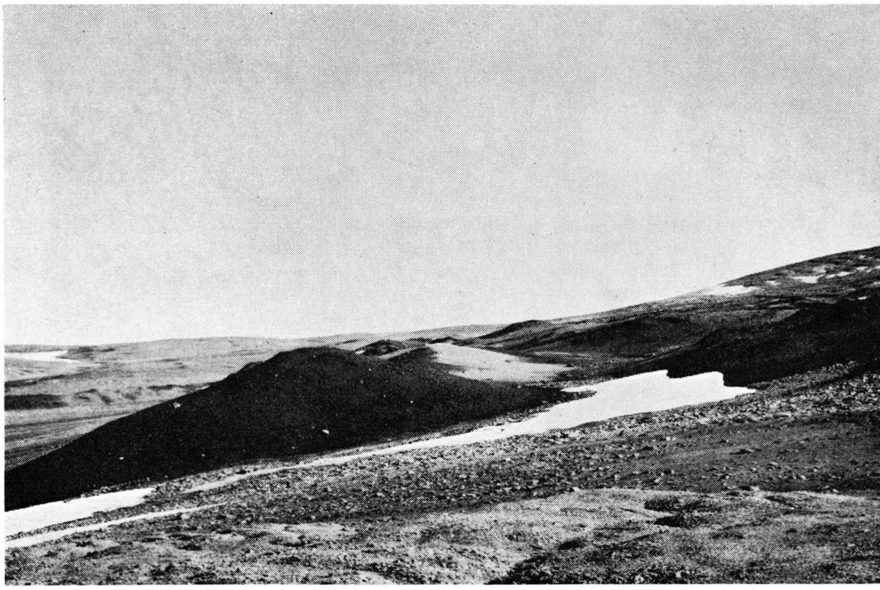

Fig. 14. Pegmatite and diabase dikes in headwater areas of Middle Branch, Narssârssuk Elv.

to this is the gray gneiss that crops out a mile (1.6 kms.) south and 3 miles (4.8 kms.) east of the front of Harald Moltke Bræ. It contains a large quantity of reddish feldspars that impart a distinct purplish tinge to the rock. In thin section the gray banded gneiss is composed essentially of quartz, microcline, oligoclase-andesine, and brown biotite, with minor amounts of allanite, epidote, apatite, sphene, and zircon. Much of the quartz appears fractured, sutured, and shows undulose extinction. The microcline appears very fresh, clear, and unaltered, whereas the plagioclase shows turbid, partly sericitized borders and areas, and a limited amount of myrmekite. Brown biotite is abundant, partly chloritized, and carries occasional brown allanite; it shows limited epidote replacement. Green biotite is abundant in some specimens. Allanite is especially abundant in specimens from the northeast side of Wolstenholme Ø and from Søkongedal. Hornblende was observed in limited amount in specimens from Wolstenholme Ø and from a mile (1.6 kms.) south of Narssârssuk. Microcline is abundant in a sample from 3 miles (4.8 kms.) west of Freuchen Nunatak, but was lacking in the one from a mile (1.6 kms.) south of Narssârssuk. Calcite, zircon, apatite and opaque minerals are minor constituents.

Petrographic comparison of the gray banded gneiss and the pink granitic gneiss shows only two prominent differences: (1) the gray banded gneiss contains a higher percent of biotite, and is more coarse-grained and conspicuously banded; and (2) the plagioclase of the gray banded gneiss is more white than pink. A third possible difference is the higher amount of allanite in the gray banded gneiss, attributed to the greater amount of biotite. Although both basement gneisses contain minor amounts of apatite, epidote, and zircon, these are somewhat more prevalent in the gray banded gneiss. Hornblende was observed in two specimens of the gray banded gneiss, but was not found in the pink granitic gneiss.

The gray banded gneiss is highly deformed and contorted. It was observed underlying the pink granitic gneiss in the vicinity of Pitugfik Gletscher, in the Peder Marcus Fjeld area, and at one point west of Narssârssuk. No distinct cleavage or parting was noted on the surface of this unit. The absence of partings permits the rock to break into large, arcuate blocks. The structural trend and lineation is east-west but is less distinct than in the pink granitic gneiss. Amphibolite and highly schistose bodies, too small to be shown on the map, are associated with the gray banded gneiss; pegmatite dikes are rather common in some parts of the unit and consist chiefly of quartz and feldspar, occasional biotite and garnet; graphic intergrowths were also observed (Figure 14). Pegmatites are common in the gray gneiss near the contact with the pink granitic gneiss but they do not occur in the pink gneiss. Lit-par-lit gneiss occurs in highly deformed and contorted rocks of the unit in the sea cliffs at the mouth of the Søkongedal. In this complex sequence are various gneisses and schists, abundant pegmatite dikes, and limited mylonitic zones.

Amphibolite and Hornblendite. Tabular and dikelike masses of amphibolite are associated with the gray banded gneiss. Nearly all of these masses are too small and discontinuous to be shown on the map. Samples from eight different exposures are described here. One mile (1.6 kms.) east of the northwest headland of Parker Snow Bugt is a contact zone between the pink and gray gneisses. Included within the gray gneiss near this contact is an irregular dike of amphibolite. In thin section it is fine grained, dark gray with a "salt and pepper" appearance; it consists chiefly of green euhedral hornblende and turbid, highly sericitized feldspar—probably plagioclase—rarely showing unaltered nuclei, finely disseminated sphene and apatite, and thin calcite and scapolite(?) veinlets.

In the center of Robert Bartlett Land is a complex zone of gray gneiss and amphibolite. The fine-grained, dark gray, banded amphibolite lacks the "salt and pepper" appearance of the amphibolite described above. Under the microscope it is seen to be chiefly green, euhedral hornblende, calcic plagioclase, and quartz. Most of the feldspar is fresh and clear, but some laths are turbid from sericitization. Minor constituents include sphene, apatite, and opaque mineral grains. The freshness of the feldspar, and the presence of quartz in this rock also distinguish it from the amphibolite previously described.

A second sample obtained from the complex in Robert Bartlett Land is a fine-grained, gray, schistose rock with calcitic lenses and felsitic porphyroblasts. It consists of pale green hornblende and colorless amphibole, with much penninite, and disseminated opaque mineral grains. The penninite occurs in large, fresh grains that show lamellar twinning, anomalous "Berlin Blue" interference colors, nearly parallel extinction, and very weak birefringence.

Amphibolites from complexes adjacent to serpentinized dikes on the mainland 6 miles (9.6 kms.) east of Magnetit Bugt are very coarse grained consisting chiefly of pale green hornblende, anthophyllite, and penninite. The opaque minerals, chiefly magnetite, are abundant, together with pleonaste (picotite?). Minor sphene and apatite are present.

Another amphibolite in this complex is a dark, fine-grained rock, with black laminae, veinlets and lenses. In thin section, these black areas have been identified as antigorite, with disseminated opaque minerals. The matrix consists of tremolite, antigorite and pleonaste, with minor amounts of sphene and apatite.

A third type of amphibolite from the complex is a dark, grayish green, coarse-grained rock showing obscure banded structure. It consists chiefly of green euhedral hornblende (approximately 85 $^0/_0$), some colorless tremolite, very little brown biotite, and opaque mineral grains.

A fourth amphibolite from the complex is very coarse grained, dark greenish gray, consisting of coarse actinolite and anthophyllite, with minor green hornblende and finely disseminated opaque minerals. Anthophyllite is altered in part to talc.

An amphibolite adjacent to a serpentinized dike on the southwest side of Wolstenholme Ø is a coarse-grained, dark greenish gray rock, with long bladed metacrysts of actinolite in a groundmass of serpentine. Fine, opaque mineral grains are disseminated throughout the rock. Calcite occurs in minor amount.

Amphibolites are common within the area of gray gneiss in the middle and upper parts of Søkongedal. Like other amphibolites they are black with some bands and granular aggregates of quartz and feldspar. Texture is generally fine or medium. They are composed of hornblende that is strongly pleochroic in deep green, yellow, and brown. Calcic plagioclase and quartz are common. Brown biotite is present in small quantities. Accessory minerals include titanite, apatite, epidote, sphene and some allanite.

Hornblendite occurs as lenses in the gray banded gneiss and in the biotite-hornblende schist. The lenses are irregular and seldom are large enough to map except on the west summit of Peder Marcus Fjeld and on the nunatak east of Freuchen Nunatak. The hornblendites are gray green to black in color and are aphanitic to medium grained. Green to blue-green hornblende is the dominant mineral. Quartz, calcic plagioclase are present. Green spinel and anthophyllite(?) are present in hornblendites associated with amphibolite dikes.

Porphyroblastic gray gneiss. This unit of the Precambrian basement complex occurs south and east of Pitugfik Gletscher in the vicinity of Parker Snow Bugt. Adjacent to the ice cap, the rock exposed is augen gneiss with only a small amount of intercalated amphibolite zones or layers. To the southwest (toward the central part of the main mapped unit) it is intercalated with both gray gneiss and amphibolite. The small mass of the unit southeast of Parker Snow Bugt is similar to the main body to the north. Surface exposures are generally broken into slabs averaging about 2 feet (0.6 meter) by 6 inches (15 cms.). Reddish porphyroblasts in this rock give it a pink or reddish appearance at a distance. Banding is distinct where porphyroblasts are well developed. The structural trend of this gneiss is N45°E, and the dip of the parting planes is 80°SE, as observed in an exposure south of Pitugfik Gletscher. At the head of Parker Snow Bugt (Cluett Gletscher) the banding and parting trend N45°E, and the parting planes dip 40°NW; on the south side of Cluett Gletscher, banding and parting trend N45°E, and the parting planes dip 80°NW. In general, the porphyroblasts are larger and more abundant in the southern part of the mapped area.

Two samples of this unit were examined in thin section. One sample from near the front of the ice cap, 4 miles (6.4 kms.) due north of Parker Snow Bugt is a finely laminated, dark gray porphyroblastic gneiss containing pink feldspar augen as much as 1 centimeter in length. In this respect it resembles the specimen described below. In thin section, the dark laminae consist essentially of concentrations of olive-brown biotite and epidote grains, with minor sphene and apatite. The augen are microcline, poikilitic with quartz and turbid plagioclase. The augen and the dark laminae are embedded in a fine granular quartz and alkalic-plagioclase matrix. Plagioclase of the matrix appears clear and fresh. A sample from the amphibolite of the gray gneiss complex in the center of Bartlett Land is similar. The rock is a finely laminated, dark gray, porphyroblastic gneiss. In thin section, epidote is less abundant than in the sample described above, but occurs in large, ring-shaped grains, many with allanite cores. Chlorite and chloritized biotite are abundant. Augen as much as 1 centimeter, and small, lenticular masses as much as 2 centimeters, consist of orthoclase, microcline, with various mafic minerals.

Serpentine. Serpentinized dikes and plugs occur at several points in the North Star Bugt Area. The largest are on the southwest side of Wolstenholme Ø, on the mainland 6 miles (9.6 kms.) east of Magnetitbugt, and at the front of the ice cap at the head of Siorqap kûa. The dikes are generally less than a mile in length. They are 10 to 40 feet (3 to 12 meters) wide and are distinguished by their dirty brown color. The plug 6 miles (9.6 kms.) east of Magnetit Bugt is 100 yards (100 meters) in diameter and is light green. Three different specimens were examined petrographically. A specimen 6 miles (9.6 kms.) east of Magnetit Bugt is a banded, black serpentine. It consists chiefly of antigorite, with some tremolite, pale green hornblende, and opaque mineral grains, probably chromite. Another specimen from the same locality is a yellowish-green, compact rock, composed chiefly of brown mesh antigorite with some large, pale blue chlorite and minor disseminated opaque mineral grains and veinlets, probably chromite. Three serpentinized dikes are exposed at the front of the ice cap at the head of Siorqap kûa. They are black, fine-grained serpentine rock consisting almost entirely of mesh antigorite, with occasional microveinlets of magnesite, and much disseminated opaque mineral grains, probably chromite.

Garnet-biotite and biotite-hornblende schists. Within the area of the pink granitic gneiss are several bodies of garnet-biotite schist. Most of these bodies, with the exception of ones at Uvdle and 4 miles (6.4 kms.) to the east, on the southwest and north sides of the hill 2 miles (3.2 kms.) south of the front of Harald Moltke Bræ, and at the front of the ice cap at the head of Siorqap kûa, are too small to show on the geologic map.

The schist exposed near Uvdle and south of the front of Harald Moltke Bræ is coarse grained with garnets a centimeter or more in diameter; also present are sheared lenses of pink feldspar of similar size. Microscopically the schist consists of quartz, biotite, some muscovite, poikilitic pale pink garnet and albite-oligoclase. Apatite and green tourmaline are accessory minerals.

The schist at the head of Siorqap kûa is similar mineralogically but is very fine grained and has a phyllitic appearance. Large garnets are present.

The biotite-hornblende schist is on the southwest side of the hill 3 miles (4.8 kms.) south of the front of Harald Moltke Bræ and on nunataks to the east. It is black with contorted bands of white feldspar and quartz as much as $^1/_2$ inch (1.3 cm.) thick. Hornblende and biotite plus very small quantities of quartz form the black bands. Muscovite is present in some of the bands. Small bodies or zones of hornblendite and amphibolite are commonly associated with the schist.

Aplite gneiss and quartz muscovite schist. Along the beach on the northeast side of Parker Snow Bugt is an outcrop of massive gray gneiss with included zones of gray micaceous schist. The aplite gneiss is fine grained with thin micaceous layers. In a hand specimen it has the appearance of a dense quartzite but in thin section the rock consists of microscopic bands or layers of equant quartz grains and less perfect layers of sericitized alkalic feldspar. Apatite, chloritized biotite, and zircon are minor.

The schist is apparently a more micaceous phase of the aplite gneiss. In a hand specimen layers of dark minerals about $^1/_8$ inch (3 mm.) thick are separated by irregular bands of light minerals $^1/_{64}$ inch (0.4 mm.) thick. The light colored bands are mainly muscovite and feldspar.

The red granite gneiss cuts the aplite gneiss. Relation of the aplite gneiss to other rocks could not be discerned. No other contacts were exposed.

Mylonite. A body of mylonite, large enough to be mapped, occurs in the southeast corner of Parker Snow Bugt. It is in very sharp contact on the north with the red granite. However, the contact with porphyroblastic gray gneiss to the south is poorly exposed and partly concealed by talus and snowbanks. Where well exposed, the mylonite shows distinct cleavage and banding, largely horizontal, even on weathered surfaces. Major shear planes trend east. Secondary shear planes trend northwest, and dip 45°NE. Two specimens of this unit were examined. The mylonite is a black, sheared and slickensided rock with hackly fracture and the appearance of anthracite. Under the microscope it is composed of extremely fine-grained alkalic feldspar, with innumerable schlieren and whirls of a dark brown, impalpable material, and very abundant finely disseminated opaque mineral grains, probably magnetite. Although the rock shows a pronounced schistosity, with numerous slickensided surfaces, the absence of lineation indicates that the probable cessation of heat and pressure after deformation prohibited recrystallization. Quartz(?) shows undulose extinction. One grain of andesine showed twinning, but the remainder of the groundmass is unidentified.

Red granite gneiss. This unit occurs in a lenticular or tabular mass on the north side and southeast side of Parker Snow Bugt. It is confined between the underlying gray aplite gneiss and the overlying gray gneiss. The mass of red granite gneiss is approximately 250 feet (75 meters) thick and extends about 2 miles (3.2 kms.) along the north side of the bay. On the southeast side of the bay the body is about 2 miles (3.2 kms.) long, and ranges from 50 to 200 feet (15 to 60 meters) in thickness. The outcrop to the southeast is cut by a quartz-gabbro intrusion, and is bounded on the west and south by mylonite. The rock is massive but is fractured on exposed surfaces. The structural trend is easterly, and the dip of the parting planes is 45°N. It forms long, extensive talus slopes, which support low, dense vegetation. Fractures are spaced on an average of 6 to 12 inches (15 to 30 cms.) apart, but minor cleavages are only a few inches apart. The rock is chiefly coarse grained, and red feldspar and dark glassy quartz are easily discernible in the hand specimen. Under the microscope, it consists of remarkably fine perthite, with reddish, turbid, interstitial oligoclase, and quartz. Perthite shows a striking micrographic texture. Minor constituents include black mineral grains, chlorite, and zircon.

Sedimentary rocks.

The sedimentary rocks in the North Star Bugt Area were originally assigned to a single unit, the Thule formation (Koch 1920). However, the great diversity of lithology warranted further definition and subdivision. Troelsen (1950) redefined the Thule as a group and included three formations in it. This definition applied mainly to Inglefield Land where the upper part of the Thule group is well developed. Kurtz and Wales (1950) also considered the Thule a group and subdivided it into three distinct formations recognizable in the area of North Star Bugt. The formations recognized by Kurtz and Wales are primarily in the lower part of the group, much of which is not present in Inglefield Land.

Wolstenholme formation. The oldest sedimentary formation (Late Precambrian) in the area is a thick series of quartzites and conglomerates on Wolstenholme Ø and at Magnetit Bugt. Small areas of outcrop of the formation are along the front of the ice cap south of the South Branch of the Siorqap kûa and in a small valley east of Uvdle. The outcrop of red sandstone (either Wolstenholme or Narssârssuk formation) reported by Koch (Koch 1920, p. 17) northeast of Parker Snow Bugt is nonexistent. Banded pink porphyry that crops out there could be mistaken easily at a distance for a red sandstone.

A white sugary quartzitic sandstone, 300 feet (90 meters) thick, is at the top of the formation. This is underlain by gray to white orthoquartzite 600 feet (180 meters) thick. A few beds of white pebbly conglomerate are present but inconspicuous as the quartz pebbles blend closely with the matrix. The quartzites are even textured with secondary enlargement of quartz grains. Accessory minerals include pale brown and blue rounded tourmaline and small, rounded zircons.

The lower part of the formation is a pink to red quartzite with beds of pebbly and cobbly conglomerate. The conglomerate is formed of quartz pebbles (1 to 5 cms. in size) and cobbles up to a foot (0.3 meter) in size in a matrix of arkosic sandstone. The matrix is a siliceous cement and contains a small number of mica and zircon grains. Both the conglomerate and quartzite are distinctly crossbedded and in some places liesegang rings are present. The thickness of the pink and red quartzite and conglomerates is about 700 feet (210 meters).

Near the base the formation consists of several sandstones and conglomerates. Below the pink quartzite is a bed of hematite sandstone 2 feet (0.6 meter) thick underlain by 2 feet (0.6 meter) of yellow shale. A purple quartzite 30 feet (10 meters) thick, with prominent liesegang rings is below the yellow shale. The banding of the liesegang rings is at right angles to the bedding and because of its prominence is easily mistaken from a distance for bedding. Kurtz and Wales (1950) believe that the rings were brought about by solutions from a diabase dike. This postulation does not seem adequate to explain the fact that the rings are common in the formation throughout the region from Wolstenholme Ø to Inglefield Bredning. They are probably a result of solution activities related to regional metamorphism. Beneath the quartzite is a pebbly conglomerate 30 feet (10 meters) thick formed of rounded quartz pebbles with a maximum size of one inch (2 cms.) in a matrix of light brown arkosic sandstone. An orange red, fine-grained quartzitic sandstone, 15 feet (4.5 meters) thick, is below the conglomerate. Red platy fine-grained hematite sandstone underlain by red platy hematite gneiss are at the base of the formation and rest on the older gray or pink gneisses. The hematite gneiss is impregnated with large quantities of quartz in a sericitic matrix. The quartz is a vivid green or yellow in color and the angular and rounded contours of the grains suggest solution origin or corrosion by the sericitic matrix. A fault gouge origin of this quartz is a possibility.

Dundas formation. Kurtz and Wales (1950) applied the name "Danish Village formation" to the thick series of black shales and dolomites exposed in Nordfjeld (North Mountain). In 1954 the Danish village was moved to Qânâq (now renamed Thule) and the continued use of the term Danish Village as a formation name is awkward. In this report, therefore, the term Dundas formation, named from Dundas Fjeld where the formation is well exposed, is used as a replacement for the name Danish Village. The type locality for the Dundas formation is essentially the same as that given by KURTZ and WALES for the Danish Village formation, namely Dundas Fjeld and Nordfjeld (North Mountain).

The Dundas formation (Late Precambrian) is a thick series of black, fragile shales with thin gray, carbonaceous sandstones and black or dark gray dolomites in the upper part. Moderately thick sills of diabase are intruded into the shales. Its base is the lowest black shale bed in the quartzite beds gradational with the Wolstenholme formation. Its upper contact is not exposed. The formation is exposed in Nordfjeld (North Mountain) and Dundas Fjeld along the south shore of Wolstenholme Fjord west of Uvdle (Figure 12), and in the middle course of Pitugfiup kûgssua (Figure 11).

The uppermost beds of this formation exposed in the area consist of 100 feet (30 meters) of black fissile shale and dull gray sugary sandstone below which are 600 feet (180 meters) of black fissile micaceous shale and thin beds of dark gray to black dense dolomite. The sandstone consists of a sutured aggregate of quartz grains with interstitial brownish chloritic material and opaque limonitic grains. Mud chips are common. The middle and lower portion of the formation contains black fissile shale and dull gray sandy shale about 1,400 feet (425 meters) thick. The latter occurs as zones of small lenslike beds. The sandy shale has highly contorted bedding surfaces formed of furrows, mud-crack fillings, scallops, and small irregular ridges as much as a quarter of an inch (0.6 cm.) high and wide. Black bituminous shale chips are common in the sandy shale.

At the base the black shale is interbedded with quartzite and the contact with the underlying Wolstenholme formation is gradational. In a zone 100 feet (30 meters) thick the quartzite beds become more numerous, thicker and lighter in color. The quartzites in the transitional zone are dense, blocky, with beds 2 to 4 inches (5 to 10 cms.) thick. They are a dull, dirty gray and distinct from the dazzling white quartzites of the upper part of the Wolstenholme formation. These quartzites are exposed on the north side of Wolstenholme Ø, on the shore of a small bay a half mile (0.8 km.) north of the site of the old Danish village of Thule and along Wolstenholme Fjord $1^1/_2$ miles (2.4 kms.) west of Uvdle.

The upper part of the black shale is exposed 9 kilometers east of the Sioraq at Akínârssuk where it is capped by a medium-grained diabase sill 20 feet (6 meters) thick. The middle portion is well exposed along the North Branch of the Pitugfiup kûgssua (Figure 11) and in Nordfjeld (North Mountain) where nine sills, each 20 to 50 feet (6 to 15 meters) thick, are interbedded with the shale. The lower part occurs only on the northwest side of Wolstenholme Ø where no sills are present. The total thickness of the formation is about 2,400 feet (730 meters) of which 400 feet (120 meters) are sills of diabase. No fossils were observed in the Dundas formation.

Narssârssuk formation. The Narssârssuk formation (Late Precambrian) as originally defined by KURTZ and WALES (1950) included all the siltstones and dolomites lying above the black shale series exposed in Nordfjeld (North Mountain); the base of the formation was taken as the top of a 58-foot (18 meters) thick diabase sill exposed at the site of Thule village. Based on the fieldwork of 1953, it is possible to subdivide the formation into three members: the Lower red member, the Aorfêrneq dolomite, and the Upper red member.

Lower red member. The lower red member of the Narssârssuk formation contains a cyclic repetition of sediments and is somewhat similar to the Upper red member (Figures 9, 10). The repetition in the Lower red member, however, is less uniform than in the upper member and a gray sandstone, common in the upper member, is generally lacking in the lower member. The top of the Lower red member is placed at the highest red siltstone or sandstone. This horizon is uniform throughout the area and is readily determined in the field.

The upper part of the Lower red member is exposed on the north flank of the hills on the south side of the Siorqap kûa. The exposures are interrupted by numerous concealments and the best section is from cores taken from a well drilled at the west end of Akínarssuaq. A summary of the well log is as follows:

ABRIDGED WELL LOG AKÍNARSSUAQ

Pleistocene:

0–25 feet (0–7 meters) Surficial deposits of gravel and sand.

Narssârssuk formation, Lower red member:

25–330 feet (7–100 meters) Alternating red limy shale and gray shale or sandy limestone; a few beds of red sandy shale limestone (dolomite).

330–473 (100–142) Gray or gray-green calcareous shales alternating with minor amounts of white to dark gray limestone (dolomite); occasional beds of pink or red sandstone.

473–499 (142–150) White, light gray or translucent orange gypsum.

499–641 (150–208) Gray to black calcareous shale and dark gray limestone; some beds of shale have a waxy appearance.

573–625 feet (174–198 meters) contains several sills of dense diabase.

641–777 (208–235) Alternating reddish-brown siltstone, gray dolomite and limestone, and gray shale; gypsum present in fractures or as thin beds.

777–849 (235–274) Dark gray to black shale and gray dolomite or limestone.
849–1,005 (274–301) Alternating brownish-red siltstone, gray calcareous shale and gray argillaceous limestone; gypsum common in fractures or as thin beds in the siltstone.
Bottom of well.

The top of the well is approximately 50 feet (15 meters) below the top of the Lower red member. The interval above the top of the well is formed of alternating red sandstone and dark gray platy dolomite and limestone that are poorly exposed at the top of the hill at the north end of Aorfêrneq Dal.

An analysis of limestone from the Lower red member 3 miles (4.8 kms.) ESE of the junction of the North and South Branches of Siorqap kûa is as follows:

	CaO	40.2		
	MgO	11.2		
	Fe_2O_3	0.42		
	CO_2	43.7		
Mol. $^0/_0$	$CaCO_3$	72.5	$MgCO_3$	27.5

A limestone obtained from near the top of the Lower red member along the Sønderbæk 100 yards (100 meters) from its junction with Siorqap kûa was analysed as follows:

	CaO	43.2		
	MgO	8.0		
	Fe_2O_3	0.46		
	CO_2	42.2		
Mol. $^0/_0$	$CaCO_3$	79.5	$MgCO_3$	20.5

The total thickness of the Lower red member is not known as the contact with the Dundas formation is not exposed nor was the member penetrated by the well. From structural trends, however, it is inferred that either the bottom part of the formation is faulted on the north or a distinct unconformity exists between the Narssârssuk and the underlying Dundas formation east of the Sioraq.

Aorfêrneq dolomite member[1]. The Aorfêrneq dolomite member is well exposed in the high valley leading northeast from Aorfêrneq and in the hills and valleys to the east. This area is one of east trending ridges standing 50 to 100 feet (15 to 30 meters) above a plateau that has an elevation of 700 to 750 feet (210 to 225 meters) (Figure 3). The

[1]) The term Aorfêrneq dolomite is identical with the term Arferfik dolomite used in previous literature.

ridges have steep cuesta slopes facing north and are gentle dip slopes on the south.

The Aorfêrneq dolomite member is primarily a thick series of fine-grained dolomites with irregular bedding. Subordinate strata of limestone are present. Gypsum is prevalent throughout the member either as incrustations along fractures and bedding planes or as thin beds or veins. Oolitic structures are common throughout the member. In addition, many weathered fragments of dolomite show that it is composed in part of brecciated fragments that have been recemented. The fragments are angular and up to an inch (2 cms.) in size. In addition to carbonate minerals up to 15 % detrital quartz and alkalic feldspars are common. The dolomite has been slightly altered adjacent to diabase dikes. The altered zone is generally narrow, seldom more than 2 feet (0.6 meter) wide. In these altered zones the dolomite is greenish or bluish and porcelanic; it contains considerable chalcedonic quartz and talc plus some chloritic material. Excellent sections across the dolomite are exposed in Aorfêrneq Dal and along Sønderbæk.

SECTION ALONG SØNDERBÆK

Top of section is in cliffs 2 miles (3.2 kms.) south of the mouth of Sønderbæk; base of section is in stream bank 1/2 mile (0.8 km.) south of the mouth:

Top:

Upper red member, Narssârssuk formation

Red sandstone and siltstone overlain by gray dolomite —

	Feet	Meters
Concealed	25	7
Aorfêrneq dolomite member		
(1) Dark gray vuggy dolomite	10	3
(2) Dark gray, irregularly bedded dolomite	30	10
(3) Light gray massive calcareous sandstone	30	10
(4) Dark gray vuggy dolomite	15	4.5
(5) Shaly dolomite, wavy bedding, weathers to gray shale	10	3
(6) Dark gray massive dolomite, weathers light tan	6	2
(7) Dark gray, laminated dolomite	12	4
(8) Dark gray, massive dolomite	3	1
(Diabase dike, 105 feet (31 meters) thick cuts 6 to 9)		
(9) Gray, crumbly, porous shaly dolomite	5	1.5
(10) Concealed	15	4.5
(11) Light brown dolomitic sandstone	5	1.5
(12) Dark gray, slabby dolomite	5	1.5
(13) Gray, porous, crumbly shaly dolomite	5	1.5
(14) Gray, with violet tint, sandy dolomite; weathers brown	4	1.3
(15) Red silty sandstone	3	1
(16) Concealed	35	11

	Feet	Meters
(17) Gray blocky to massive dolomite; irregular beds 2 to 6 inches (5 to 15 cms.) thick; wavy laminations; few vugs...	35	11
(18) Dark gray, poorly bedded, vuggy dolomite; gypsum along fracture planes..	80	26
(19) Gray, vuggy dolomite, beds 6 to 12 inches (15 to 30 cms.) thick; distinct laminations on weathered surfaces. Cryptozoon(?) structures present............................	4	1.3
(20) Concealed...	25	7
(21) Gray, vuggy dolomite, beds 6 to 12 inches (15 to 30 cms.) thick At base 2 feet (0.6 meter) of violet tinted gray dolomite with wavy bedding. (Dike of fine-grained diabase 15 feet (4.5 meters) wide cuts sediments at this point)		
(22) Gray, laminated, blocky dolomite with wavy bedding; poorly exposed.......................................	80	26
Total Thickness Aorfêrneq dolomite.........................	447	133.6

Lower red member, Narssârssuk formation

Red massive silty sandstone, weathers to irregular-shaped slabs.

In a similar but less well exposed section along Aorfêrneq Dal, the lower 250 feet (75 meters) of the dolomite is much more gypsiferous than along Sønderbæk. At a prominent hill in the central part of the valley, an irregular bed of white gypsum, 6 to 12 inches (15 to 30 cms.) thick is present. To the north along the valley (lower stratigraphically) the dolomite is highly fractured and the openings are filled with soft, powdery gypsum. On weathering the slabs and plates formed in fracturing develop rough surfaces of many conical shaped spines.

The dolomites are generally free of chert except at the gypsum locality in Aorfêrneq Dal where a bed of black banded chert 2 to 4 inches (5 to 10 cms.) thick occurs a few feet below the bed of gypsum.

Weathering of the dolomite produces numerous slabs and plates. Most of the weathered fragments are irregular in shape because of fracturing and irregular bedding common throughout most of the member. Slabs with relatively straight sides develop from weathering of the massive beds only. Loose, weathered fragments and exposed bedrock show the effect of solution on their surfaces. Rillenstein (Laudermilk and Woodford 1932; Nichols 1953; Davies 1957) in the form of grooves, pits, scallops and flutings is present. Effects of solution are absent within the rock. Caves, solution channels and related features, so common in thick calcareous rocks in temperate and tropic climates, are not present in the dolomites of the Aorfêrneq member.

Table 1.
Partial analyses of the Aorfêrneq dolomite member.

No. of sample	TD10	TD24	TD30	TD31	TD32
CaO	29.7	29.2	7.6	23.5	23.5
MgO	19.5	19.2	5.6	15.7	15.6
Fe_2O_3	0.6	0.28	1.3	0.36	0.37
CO_2	44.0	43.0	10.6	34.6	35.6
Mol. $^0/_0$					
$CaCO_3$	52.0	51.6	49.1	51.2	51.8
$MgCO_3$	48.0	48.4	50.9	48.8	48.2

Location of samples:

TD10 – Dolomite, summit of hill 1 mile (1.6 kms.) south of delta of Siorqap kûa.
TD24 – Dolomite, Aorfêrneq Dal, $^1/_2$ mile (0.8 km.) south of Siorqap kûa.
TD30 – Dolomitic sandstone, measured section along Sønderbæk, Bed 11.
TD31 – Sandy dolomite, measured section along Sønderbæk, Bed 3.
TD32 – Dolomite, measured section along Sønderbæk, Bed 8.

Upper red member. The youngest sedimentary rocks in the North Star Bugt Area are a series of red beds which are exposed on Saunders Ø and along an unbroken line of cliffs from Aorfêrneq to Narssârssuk (Figure 8). The upper red beds are a cyclical alternation of red siltstone, gray dolomite, and gray-green sandstone. Each unit is 130 to 160 feet (40 to 49 meters) thick and consists of red sandstone and siltstone 40 to 70 feet (12 to 21 meters) thick underlain by platy gray or gray-green sandstone 30 to 40 feet (10 to 12 meters) thick, dense dark gray dolomite 5 to 20 feet (2 to 6 meters) thick and, at the bottom, gray platy and blocky sandstone 10 to 25 feet (3 to 7 meters) thick. In several of the cycles, dense gray dolomite as much as 35 feet (11 meters) thick, underlies the gray sandstone and forms the base of the unit.

The red sandstone and siltstone are generally poorly bedded and break into irregularly shaped slabs. In zones 1 foot or 2 feet (25 or 50 cms.) thick they are laminated. Thin layers of gray sandstone or dark gray dolomite are commonly contained within the red sandstone or siltstone beds. The siltstone consists of angular particles of quartz, and a minor amount of feldspar in a ferruginous matrix. The matrix contains a considerable amount of flaky fresh biotite with much ankeritic carbonate. Scattered throughout the siltstone are dense masses, probably mud blebs.

The dolomites are irregularly bedded, the beds being 1 to 3 inches (2 to 8 cms.) thick separated by undulating bedding planes. The sandstones are well bedded with individual beds 1 to 4 inches (2 to 10 cms.) in thickness.

Analyses of dolomites from the middle and upper parts of the member were made by SOLE MUNCK (1941 p. 22) and are shown in Table 2. Additional analyses of dolomites from this member are in Table 3.

Table 2.

Analyses of Dolomites from Upper red member, Narssârssuk formation.

No. of sample (as in MUNCK)	30	31	33I	33II	33IV	33VII
Insoluble Residue	29.6	8.5	10.9	9.9	12.9	4.7
CaO	26.2	28.2	27.2	27.7	26.9	29.9
MgO	7.9	17.5	17.4	16.3	15.9	18.1
Fe_2O_3	1.3	1.0	1.1	1.1	1.1	1.1
CO_2	29.2	41.2	40.4	39.5	38.5	43.2
Total	94.2	96.4	97.0	94.5	95.3	97.0
Mol. %						
$CaCO_3$	70.31	53.51	52.72	54.81	54.71	54.11
$MgCO_3$	29.69	46.49	47.28	45.19	45.29	45.89

Sample numbers 31, 30 are from west of the dike at Núngarutipaluk, while 33I, II, IV, VII are from successive dolomite beds 2 miles (3 kms.) south of the seaward end of Aorfêrneq Dal.

Table 3.

Additional partial analyses of dolomites collected in 1953.

No. of Sample	N36	P32
CaO	17.6	23.5
MgO	12.6	16.4
Fe_2O_3	1.6	0.71
CO_2	26.8	35.6
Mol. %		
$CaCO_3$	50.0	49.7
$MgCO_3$	50.0	50.3

Sample N36 is a sandy dolomite from the upper part of the Upper red member near the large diabase dike at Núngarutipaluk. P32 is from the lower part of the member on the South Branch of the Siorqap kûa, 3 miles (4.8 kms.) southeast of the junction with the North Branch.

The upper red member as exposed on Saunders Ø and in the cliffs north of Narssârssuk consists of 10 distinct cycles with a total thickness of about 1,500 feet (460 meters). What portion of the original thickness of the Upper red member is represented by these exposures is unanswerable as no younger formations are in the area and a considerable thickness of the red beds has probably been removed by erosion.

Stratigraphic Relations of the Thule Group. Systematic descriptions of the Thule group are lacking except for incomplete sections in Peary Land (TROELSEN 1949) and Northeast Greenland (FRÄNKL 1954; ADAMS and COWIE 1953). Along the coast of Inglefield Land the group is well exposed but descriptions have been in vague, general terms that do not permit recognition of individual units within the group. KOCH's descriptions of the Thule group in Inglefield Land (KOCH 1933) contain no mention of black shale, and the three-fold division of the group (quartzite, black shale, and red beds with dolomite) seems to be lacking there. The Wolstenholme formation is probably equivalent to KOCH's basal conglomerates and part of his lower red sandstone. The black shale has no equivalent in Inglefield Land although it is well exposed with considerable thickness as far north as Inglefield Bredning. The Lower red member of Narssârssuk formation apparently embraces the remainder of the Lower red sandstone as well as the upper light-colored sandstone of Inglefield Land. The Aorfêrneq dolomite member may possibly be equivalent to the Kap Leiper dolomite and Kap Ingersoll dolomite that form the top of the Thule group in Inglefield Land. The great thickness of the Aorfêrneq dolomite and difference in lithologic sequence make this postulation unlikely and it is probably more correct to equate all of the Narssârssuk formation to the upper part of the lower red sandstone and the upper light-colored sandstone of Inglefield Land.

The Thule group in Northeast Greenland (head of Danmark Fjord) and Peary Land (Jørgen Brønlund Fjord) seems to be more closely equivalent to North Star Bugt Area than to Inglefield Land. The Wolstenholme formation is correlated with the Norsemandal sandstone at Danmark Fjord and the red and gray quartzites at Jørgen Brønlund Fjord. As in Inglefield Land, the Dundas black shale is absent at both Jørgen Brønlund Fjord and Danmark Fjord. However, in both areas black shale occurs locally, but it is much higher in the stratigraphic column than the black shales at North Star Bugt. The Narssârssuk formation is probably represented by the upper part of the red sandstone, the overlying dolomite and the upper sandstone and dark-colored shales at Jørgen Brønlund Fjord and the Campanuladal sandstone, the Fyn Sø dolomite and the Kap Holbæk sandstone at Danmark Fjord.

The absence of the Dundas black shale at places other than near North Star Bugt is of considerable interest. In the past these shales were described as younger than the Narssârssuk red beds by LAUGE KOCH (KOCH 1925) and T. C. CHAMBERLIN (CHAMBERLIN 1895). However, the field evidence places the shales much lower in the stratigraphic column. On the north side of Wolstenholme Ø, at Uvdle, on the north side of Harald Moltke Bræ in the western part of Nunatarssuaq, and in the vicinity of Chamberlin Gletscher and Salisbury Gletscher on the north side of Wolstenholme Fjord the Dundas black shales are in contact with the underlying Wolstenholme formation. The contact is gradational and conformable. The black shales found near the top of the Thule group at Jørgen Brønlund Fjord and Danmark Fjord therefore are much younger than those at Thule and are in no way equivalent. KOCH's assumption that the red beds exposed between Thule and Narssârssuk (the Narssârssuk formation) are part of the base of the Thule group also is not in line with the field evidence. On Wolstenholme Ø and on Nunatarssuaq the Wolstenholme formation rests directly on the basement complex of gneiss. Since the Wolstenholme is succeeded by the Dundas black shale the red beds of the Narssârssuk formation have no place in the stratigraphic column unless they are placed above the black shales.

Diabase dikes and sills.

Diabase dikes are abundant in many parts of the North Star Bugt Area. Most of the dikes are dark gray to black at a distance, but hand specimens are gray or greenish gray. Margins and contacts with the country rock are chilled, and of very limited extent, usually less than one foot (0.3 meter) and commonly less than an inch (2.5 cms.) thick. Texturally, the dikes range from medium to coarse grained. The texture is essentially uniform across the dike. Similarly, there is no observed difference in the condition of weathering in crossing the dikes. Joints and fractures are, on an average, less than 2 inches (5 cms.) apart. The narrowest dike, observed at the ice front north of the Pitugfik nunataks, was about 6 feet (1.8 meters) thick; the widest dike observed was approximately 315 feet (100 meters) in the central western part of the area 5 miles (8 kms.) northeast of Savigssuaq. The longest dike observed in the mapped area, southeast of Narssârssuk, is approximately 8 miles (12.8 kms.). Most of the mainland dikes dip 40° to 70° to the north; on Wolstenholme Ø one dike along the north coast dips 27° S but the others are almost vertical; on Saunders Ø, the northern dikes dip steeply SW, and the others are almost vertical. The dikes generally are more coarse grained than the sills. Although little is known of the dikes, one diabase dike 2.5 miles (4 kms.) north of Magnetit Bugt is evidently much older than the other dikes, as it has been structurally deformed in the same way as the basement rock. In the vicinity of Kap Atholl, the east-trending dikes are younger than the north-trending dikes.

Samples were collected from a great number of dikes; thirteen of them are described here. A specimen from the long east-trending dike near Siorqap kûa obtained at the coast (Figure 15) is a medium-grained, gray rock with greenish and brown discoloration on fractured surfaces. It consists of plagioclase, augite, chloritized biotite, and opaque mineral grains. The plagioclase laths are labradorite; many show turbid, sericitized cores with relatively clear borders. Augite is relatively fresh, euhedral to anhedral, occasionally showing undulose extinction. Biotite occurs in all stages of alteration to chlorite, with brownish epidote inclusions; little fresh biotite is present. Opaque minerals, presumably magnetite, occur in elongated, plumose masses, skeletal crystals, and small individual grains. Minor micropegmatite is present, also zircon and sphene. The texture is ophitic.

A specimen from the same locality described above but from the chill zone is an aphanitic black rock, consisting chiefly of labradorite and augite porphyroblasts, and magnetite, in a fine-grained matrix. Many labradorite laths appear fairly fresh on their borders, but the cores are turbid; the augite is fresh, but curved and deformed. Magnetite is very abundant and occurs as long needles, skeletal crystals and individual crystals and grains. Highly chloritized biotite is a minor constituent.

Three and one-half miles (5 kms.) east along the same dike the diabase is a medium-grained, dark gray rock with greenish discoloration on joints and fractured surfaces. It is seen under the microscope to consist chiefly of plagioclase, augite and opaque mineral grains. It is similar to the first diabase described, except that the opaque grains are larger, euhedral to anhedral, but not elongated. Also, micropegmatite is commoner.

A small dike, 15 feet (4.5 meters) wide parallels the larger dike described above. A sample from the smaller dike obtained 5 miles (8 kms.) from the mouth of Siorqap kûa is medium-grained and dark gray. Under the microscope the feldspar is seen to be turbid and highly sericitized; no fresh laths were observed, whereas the augite appears quite fresh. Opaque mineral grains occur mainly as skeletal crystals. A little micropegmatite is present. This rock differs from those previously described in the intense alteration of the feldspar.

A specimen from the easternmost dike on the north side of Saunders Ø is a medium-grained, dark gray rock with greenish discoloration

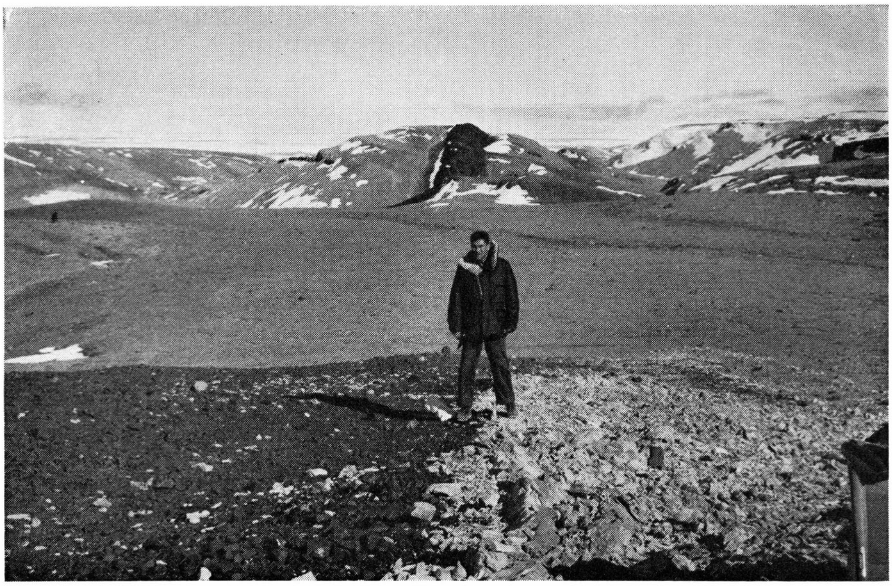

Fig. 15. Diabase dike intruding dolomite on coast near mouth of Siorqap kûa (South River); contact zone sharp with little alteration.

along joints and fractured surfaces. Under the microscope relatively fresh, euhedral augite phenocrysts in a groundmass of highly turbid, sericitized plagioclase were seen. Magnetite is abundant and occurs as skeletal crystals, some cubes and isolated grains. Occasional augite shows replacement along borders to hornblende-chlorite. Some brown biotite, apatite, and micropegmatite are present.

The dike on the north shore of Wolstenholme Ø is a medium-grained, dark gray rock, consisting chiefly of plagioclase and augite with abundant magnetite. The plagioclase is labradorite with partly sericitized centers and clear borders surrounding the laths. Augite is euhedral and fairly fresh. The magnetite occurs in elongated skeletal crystals and masses and as small grains. Small isolated patches of micropegmatite border a few plagioclase laths. Chlorite, brown biotite, sphene, and apatite are minor constituents.

A sample from the large dike at Núngarutipaluk is coarse-grained, gray with greenish discoloration on joints and fractured surfaces. It consists of partly turbid, sericitized labradorite, and augite, with abundant skeletal crystals and grains of magnetite, chloritized biotite, and chloritic masses. Occasional quartz grains were observed, showing undulose extinction. Myrmekite, biotite, and euhedral apatite are present in minor amounts. The texture is ophitic.

Two diabase dikes intersect at a point 3 miles (4.8 kms.) east of Kap Atholl. A specimen from the north-trending dike is coarse-grained, grayish green, consisting chiefly of very turbid plagioclase, fresh augite, and large skeletal crystals and masses of magnetite. Myrmekite, biotite and chloritized pyroxene are accessory; euhedral apatite, quartz and sphene are minor constituents. The texture is ophitic.

A specimen from the younger east-trending dike is coarse-grained, grayish green, very similar to the north-trending dike. It consists of highly turbid, sericitized plagioclase, fresh augite, and skeletal magnetite. Accessory minerals and minor constituents are the same as those noted for the north-trending dike, which, however, contains more apatite. This dike rock also contains small garnet inclusions and clusters associated with some of the chlorite. The texture is ophitic.

A specimen from a dike 6 feet (1.8 meters) wide in gray gneiss, 3 miles (4.8 kms.) east of the junction of the Middle and South Branches of Narssârssuk Elv is coarse-grained, gray consisting of fresh, clear labradorite, fresh augite, with fairly abundant magnetite in large skeletal crystals. Minor constituents are brown biotite, partly chloritized, and apatite. The remarkable freshness of this rock is unusual compared with samples from other dikes. The texture is ophitic.

A sample from the dikes at the northwest base of Peder Marcus Fjeld is coarse grained, gray green, similar to those of the crossed dikes previously described. The plagioclase is turbid and sericitized; the pyroxene is chloritized in part; biotite also is partly chloritized. Myrmekite is abundant. Minor euhedral apatite and opaque mineral grains are present. The texture is ophitic.

Information obtained in shallow test pits about 4 kilometers east of the Sioraq indicates that one or possibly two sills extend SSE beneath the cover of glacial deposits. The sills are about a mile (1.6 kms.) south of Pitugfiup kûgssua and the diabase exposed at the prominent point a mile (1.6 kms.) WSW of the mouth of this river is probably the western part of one of these sills.

On the coast 4 miles (6.4 kms.) north of Kap Atholl is an older diabase that has structural deformations similar to the gneiss that encloses it. It is medium grained, grayish green, containing partly sericitized plagioclase and chloritic hornblende after augite, with minor amounts of skeletal magnetite. The texture is ophitic.

On the south side of Neptune Gletscher, extending to Kap York, is a large body of quartz diorite that cuts the red granite gneiss and the porphyroblastic gneiss. The diorite is gray, medium grained with much perthitic feldspar, quartz, and ragged hypersthene(?). Between Parker Snow Bugt and Kap York bands up to 50 feet (16 meters) wide contain large crystals of pink feldspar. The contact between the diorite and the surrounding rock is sharp and there is no alteration. On

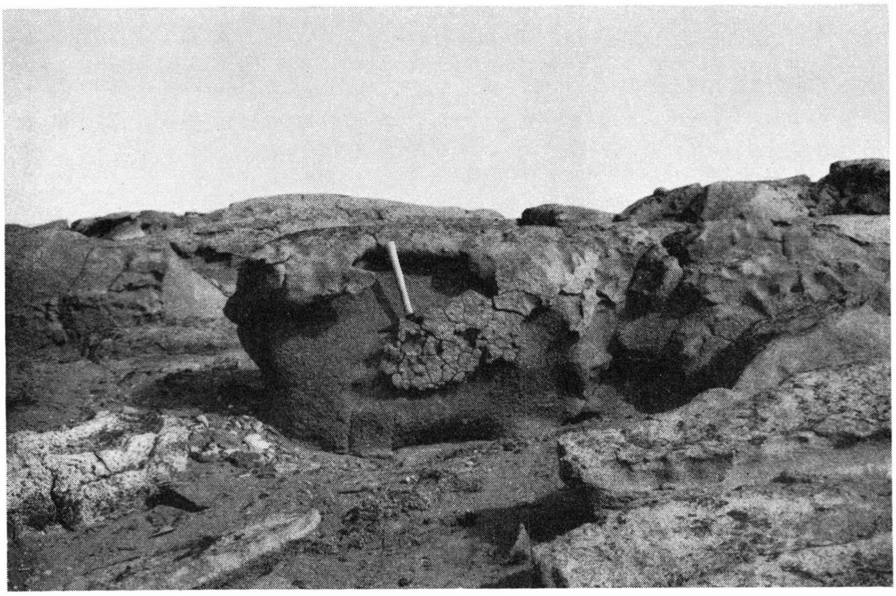

Fig. 16. Deeply weathered diabase, summit of Nordfjeld (North Mountain).

weathering the surface is stained a deep red. Because of this it is easy to mistake this rock for red granite gneiss in the field.

The diabase sills intrude the black shales of the Dundas formation in Diabasås, Nordfjeld (North Mountain), Dundas Fjeld and in the headwaters of Pitugfiup kûgssua. In this area five distinct sills are present and range from 10 to 50 feet (3 to 15 meters) in thickness, and average 20 feet (6 meters). The sills dip in accord with the bedding of the host rock. In the southern part of the North Star Bugt Area a sill-like body caps Sortetoppe and dips 12° to the south.

In all the sills the chilled margins are very narrow, measuring only a few inches in width. The texture of the sills is similar. Weak columnar jointing is visible with the joint planes about a foot (30 cms.) apart and the fracturing in sills is much less than in dikes.

Where the sills are exposed for considerable distance as on the dip slope of hills the weathering is severe. On Nordfjeld (North Mountain) (Figure 16), Dundas Fjeld, and Akínârssuk the weathering gives rise to a deep decay and disintegration of the diabase. For several inches from the surface the rock is weak and crumbly. Wind blast or gravity removes large fragments of the rock leaving hollows, pinnacles, and other features typical of such erosion. The detrital materials are deposited near the source rock as coarse sand several inches deep. Where the edge of the sill is exposed in bluffs there is little weathering.

The sills are commonly green gray to dark gray with textures ranging from fine- to coarse-grained. Plagioclase is generally heavily sericitized and turbid. The pyroxene (generally augite) is partly replaced by chlorite or at times by hornblende. Magnetite in angular masses or euhedral and skeletal crystals is present. Euhedral hypersthene is occasionally present in large fresh grains. Myrmekite is present in most specimens. Minor amounts of pyrite, apatite, and biotite are present. Metamict allanite is present in small amounts in two sills on the Trædeklippe.

In talus slopes on Dundas Fjeld blocks of fibrous calcite are common. This calcite is probably from veins in the sills on the mountain although none was found in place. The calcite is a mass of packed calcite fibers $^1/_8$ to $^1/_4$ mm. in diameter and $^1/_2$ to 1 cm. long. The fibers are equally developed on both sides of plates and join along a straight line at their intersection.

Many samples from sills were collected. Details of nine representative samples follow:

1. Four samples from four sills from Diabas Ås, Wolstenholme Fjord: Fine- to medium-grained, turbid, sericitized plagioclase (andesine or oligoclase-andesine), altered pyroxene (augite) replaced by chlorite and partly by hornblende; sill at top has badly deformed augite grains; euhedral and skeletal crystals of magnetite, myrmekite present, minor amounts of apatite and pyrite; texture ophitic.
2. Sample from Sortetoppe: Fine grained, greenish gray; plagioclase-fresh, clear oligoclase-labradorite, some long acicular laths, augite colorless to faintly greenish partly altered to hornblende and chlorite; coarse, angular, anhedral to euhedral magnetite, minor amount of apatite; texture ophitic.
3. South side Nordfjeld (North Mountain): Coarse-grained, gray; fresh oligoclase-andesine, augite partly chloritized, skeletal and euhedral magnetite abundant, euhedral hypersthene in large fresh grains, minor amounts of myrmekite, pyrite, biotite and apatite; texture ophitic.
4. South end of Trædeklippe: Fine-grained, dark gray; plagioclase chiefly oligoclase-andesine, partly turbid and sericitized; augite partly replaced by chlorite and hornblende, some grains deformed and zoned similar to specimen from top sill on Diabasås; skeletal and euhedral crystals of magnetite.
5. Two samples from top sills on Trædeklippe: Aphanitic, dark gray; coarse augite phenocrysts, deformed, zoned with hourglass structure, some partially chloritized; matrix fine grained of turbid, partly sericitized plagioclase, acicular and skeletal magnetite, biotite and metamict allanite present in small quantities.

Economic minerals.

No deposits of ore minerals in economic quantities were observed in the North Star Bugt Area. The magnetite vein trending east across Wolstenholme Ø and on the mainland at Magnetit Bugt contains considerable quantity of low grade iron deposits. Analyses of random samples are contained in Table 4.

Table 4.
Partial Analyses of Magnetite Ores.

Sample No.	N8i	P300	W32	W45
SiO_2	45.4 %	52.0	34.9	45.0
P_2O_5	0.24	0.28	0.30	0.22
Fe_2O_3	53.2	45.9	65.0	56.2

Location of samples:

N8i Magnetit Bugt
P300 Front of Ice Cap, 1 mile (1.6 kms.) south of Siorqap kûa
W32 Wolstenholme Ø, 3 miles (4.8 kms.) southwest of Kap Travers
W45b Wolstenholme Ø, 3 miles (4.8 kms.) southwest of Kap Travers

The iron vein is 20 to 50 feet (6 to 15 meters) wide and can be traced intermittently across Wolstenholme Ø, easterly through the center of the island, eastward for several hundred yards at Magnetit-Bugt, on the east flank of Peder Marcus Fjeld, and at the front of the ice cap a mile (1.6 kms.) south of Siorqap kûa. The ore is formed of equal parts of magnetite and quartz with small amounts of feldspar, chlorite and apatite present. It is deep purplish-red on weathered surfaces and dark gray on fresh faces. The rock is distinctly gneissic with alternating bands about 1 mm. thick of quartz and magnetite.

Chromite is common in many of the basement rocks of the area. It is most prevalent in the serpentinized rocks, but no concentrated ore bodies were observed.

STRUCTURAL GEOLOGY

William E. Davies

Structurally the area between Parker Snow Bugt and Wolstenholme Fjord can be divided into two distinct units. South of Narssârssuk is an area of metamorphic rocks which is separated from gently flexed sediments on the north by a fault (Figure 8).

The sedimentary rocks form a shallow, slightly asymmetrical syncline, the axis of which trends east from a point 3 miles (4.8 kms.) northeast of Narssârssuk. The dips on both the north and south limbs of the syncline are approximately the same, varying from 8° to 20° along the outer flanks. No fault displacements or unusual changes of dip occur within the southern half of the syncline where the Narssârssuk formation is present. However, along the Middle Branch of Narssârssuk Elv where the edge of the syncline is bordered by a fault the beds are folded into a series of local anticlines and synclines with dips as steep as 45°.

On its north side the syncline is bounded by a fault that trends southeastward from a point just south of Uvdle. In a short, narrow valley a half mile (0.8 km.) south of Uvdle this fault brings the white quartzite of the upper part of the Wolstenholme formation in contact with the gneiss of the basement complex. Eastward of this exposure the bedrock is buried under a thick mantle of glacial deposits.

On Wolstenholme Ø and the adjacent mainland north of Kap Atholl is a small syncline containing the Wolstenholme formation. Dips on the north flank are from 20° to 60°. The south flank is cut off by a fault close to the axis of the syncline and in the small segment remaining the dip is 20° to the north. The syncline is shallow and the outcrop of the Wolstenholme formation is limited by steep plunge of the axis towards the center of the syncline at the eastern edge of Wolstenholme Ø.

Although the contact between the Dundas black shale and the overlying Narssârssuk formation is obscured by the glacial deposits east of the Sioraq an unconformity or fault between them is inferred. The strike of the Narssârssuk formation on Akínarssuaq and along Siorqap kûa is S70°E. The strike of the Dundas shale is S70°E in the lower part of the Pitugfiup kûgssua, but eastward the strike progressively swings

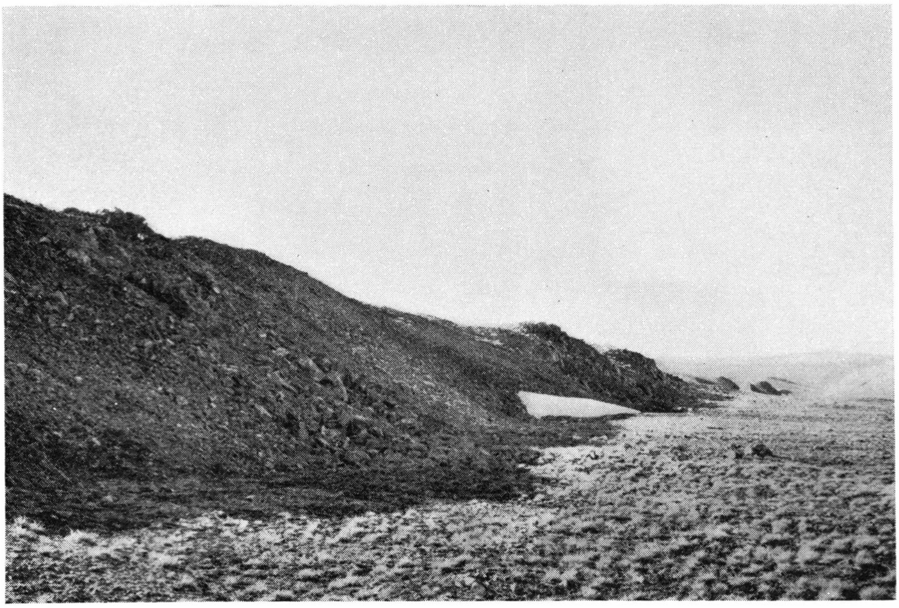

Fig. 17. Low fault scarp, 20 feet (6 meters) high along upper part of Middle Branch of Narssârssuk Elv.

towards the south until at Akínârssuk it is S40°E. This divergence in strike between the Dundas and Narssârssuk formations can be interpreted as either a fault or an unconformity. For lack of contrary evidence the discordance is accepted as an unconformity.

Structures within the metamorphic rocks are complex. The gray gneiss series has extremely contorted banding at all its exposures. The pink gneiss, in general, is more massive and banding, where present, is less disturbed. Cleavage is well developed in the pink gneiss and in the area north and east of Kap Atholl it strikes due east and dips 30° to the north. Banding in this area follows the cleavage.

Faults. The area between Parker Snow Bugt and Wolstenholme Fjord is crossed by several major faults. The most prominent fault is the one separating the sedimentary rocks from the metamorphic rocks in the vicinity of Narssârssuk. This fault is along the south side of the valley of Narssârssuk Elv. Six miles (9.6 kms.) east of Narssârssuk the direction of the fault swings northeast following the general direction of the Middle Branch of Narssârssuk Elv (Figure 17) and gradually curves to the east. It crosses the headwaters of Siorqap kûa $3^1/_2$ miles (5 kms.) west of the ice cap. This fault actually may be two faults intersecting 6 miles (9.6 kms.) east of Narssârssuk where the direction of the line of contact between the sediments and the basement complex changes rapidly. The paucity of outcrops does not permit an accurate determination of the conditions. Vertical movement along the fault is at least 7,000 feet (2,100 meters) and along its entire length the Upper red member of the Narssârssuk formation is brought in contact with gneiss. The downthrown side is to the north.

On the north side of Wolstenholme Ø fault, the plane of which dips 70°N., the upper part of the Wolstenholme formation and the Dundas black shale are in contact with the basement complex. The vertical movement here is at least 2,000 feet (600 meters) with the downthrown side to the north. The easterly trend of this fault coincides closely with the Narssârssuk fault, and the fault is probably a continuation of the latter. Kurtz and Wales (1950) indicated the Narssârssuk fault as continuing westward along the south side of Saunders Ø. Current topographic maps indicate that the simplest extension of the Narssârssuk fault would bring it close to the north side of Wolstenholme Ø. Hydrographic soundings show a shallow, uniformly level bottom between Wolstenholme Ø and Saunders Ø with no abrupt changes that would indicate extensive faulting.

Another prominent fault cuts easterly through the center of Wolstenholme Ø and can be traced for a short distance on the mainland at Magnetit Bugt. The upper part of the Wolstenholme formation is brought in contact with the basement complex and the vertical movement along the fault is about 1,000 feet (300 meters). The downthrown side is to the north.

Within the Wolstenholme formation on Wolstenholme Ø are several small block faults. The faults bring the upper part of the formation into contact with the lower part. Vertical movements along the faults are slight, probably less than 500 feet (150 meters).

South of Wolstenholme Fjord, near the front of the Harald Moltke Bræ, a fault trending southeast from a point $^1/_2$ mile (0.8 km.) south of Uvdle brings the upper part of the Wolstenholme formation in contact with the basement complex. Throw along this fault is about 2,000 feet (600 meters) with the downthrown block to the south.

A zone of intense faulting along the southern part of the head of Parker Snow Bugt has changed a large area of coarse red granitic gneiss into a dense black mylonite. Direction and degree of movement along this fault could not be determined because of the complexity of the rocks and the extensive glacial cover.

A fault apparently exists in Wolstenholme Fjord and under Harald Moltke Bræ. In Nunatarssuaq, on the north side of the glacier near its front, the Wolstenholme formation with a gentle southern dip rests in normal sequence on the basement complex. On the south side of the glacier the basement complex crops out on a plateau 1,000 feet

(300 meters) in elevation. A fault would account for such a condition. This hypothetical fault, however, would extend but a short distance west of the front of the glacier for at the mouth of Wolstenholme Fjord the Dundas black shale can be projected from Nordfjeld (North Mountain) to its counterpart in the hill between Salisbury Gletscher and Chamberlin Gletscher on the north shore with no apparent displacement or change in dip.

The extensive area of outcrop of the Upper red member of the Narssârssuk formation on Saunders Ø is difficult to bring into accord by projection with the outcrops directly opposite on the mainland. Continuation of the various formations from the mainland to the island requires a large displacement to the north which is out of accord with the strike of beds. To account for the displacement, a fault is postulated to the east of Saunders Ø.

GLACIAL GEOLOGY

Daniel B. Krinsley

The North Star Bugt Area has probably been glaciated several times during the Pleistocene period, but field examination has produced evidence for only one major glaciation and several minor recent glacier fluctuations. This apparent incompleteness of the glacial record may be the result of removal of glacial deposits by subsequent ice advances, or oscillation of the ice front in sea water.

Surficial deposits.

The surficial deposits, which cover more than 90 percent of the North Star Bugt Area, are almost entirely of glacial origin, but they have been structurally disturbed and mechanically altered by frost processes that are currently active. These materials, grouped into eight units, include boulder fields, coarse and fine till, outwash, beach gravel, talus, silt, and peat (Plate III, Surficial Deposits Map).

Boulder fields. The boulder fields consist of angular and subrounded rocks that are generally 12 inches (30 cms.) in smallest dimension. Large boulders measure as much as 60 inches (1.6 meters). Frost-split boulders quarried from the underlying bedrock are slablike or rectangular, with sharp corners; glacially transported boulders range in shape from subrounded cubes to well-rounded spheres. Materials of boulder size are composed of pink and gray granite gneisses, diabase, quartzites, and small amounts of sandstone and pegmatite. Boulder fields range in thickness from 1 foot (30 cms.) over diabase to perhaps 20 feet (6 meters) in gullies cut into the gneissic rocks. It is estimated that ninety-five percent of the boulder fields containing gneissic rocks overlie gneissic rocks at shallow depth. Boulder concentrations of transported materials generally overlie all rock types; diabase boulder concentrations are restricted to outcrops of either sills or dikes. Boulder fields occur on hills, plateaus, and plains, on slopes as steep as 60°, and in gullies or stream channels. The boulders are subject to frost splitting and frost

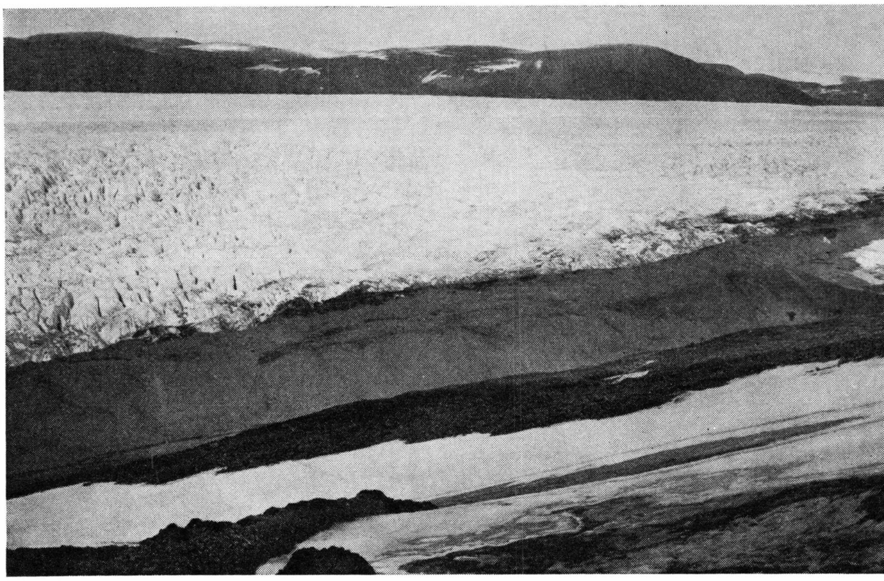

Fig. 18. Recent lateral moraine along Harald Moltke Bræ.

heaving, and many boulder fields contain polygonal patterns, stripes, and large solifluction lobes in which the boulder-strewn margin borders the central zone of saturated fines.

Coarse till. The coarse till is composed of boulders and cobbles in a matrix of sandy pebble gravel, with local concentrations of sand and silt. Particles of all sizes are subrounded to well rounded, with a few angular particles among the larger sizes. The coarse till contains gneiss, diabase, quartzite, and small amounts of sandstone and dolomitic rocks. Coarse till overlies metamorphic and sedimentary rocks at moderate to shallow depths south of Wolstenholme Fjord. The thickest deposits occur north of Crescent Sø, whereas only a thin veneer of coarse till overlies pink granite gneiss south of Harald Moltke Bræ. North and south of Pitugfik Gletscher, coarse till covers metamorphic rocks at shallow depths. Coarse till covers hill tops and slopes and fills broad valleys in the land area south of Harald Moltke Bræ and south of Pitugfik Gletscher, where these deposits are concentrated. Along the front of the Store Landgletscher extensive ice-cored moraines are veneered with coarse till. Less extensive deposits of coarse till occur on Wolstenholme Ø, near Kap Atholl and Peder Marcus Fjeld, and along the ice cap. Soil polygons, garlands, and stripes are well developed in those areas of coarse till where the percentage of fine material is high. Patterned ground due to frost action in coarse till is conspicuous northeast of

Crescent Sø and at the ice front. Permafrost occurs from 1 to 7 feet (0.3 to 2.2 meters) below the surface, and the depth of its upper surface varies directly with the coarseness of the material.

Fine till. The fine till contains cobbles, pebbles, and some boulders in a matrix of sand and silt. Particles of all sizes are subrounded to well rounded, with a few angular particles among the boulder sizes. The fine till is composed of gneiss, diabase, quartzite, sandstone, shale, and dolomite. Fresh till at both Harald Moltke Bræ and Pitugfik Gletscher contains large amounts of silt, derived from previously deposited glacial silt (contains pelecypods). Fine till generally overlies the sedimentary rocks southeast of North Star Bugt and east of Narssârssuk. Metamorphic rocks covered by fine till, such as occurs southeast of Narssârssuk, suggests an ice movement from the sedimentary area to the metamorphic zone. Deposits of fine till are moderately thick (30 feet) (10 meters) east of North Star Bugt and rather thin (10 feet) (3 meters) in the Narssârssuk area. Locally at both Harald Moltke Bræ and Pitugfik Gletscher, lateral moraines composed of fine till are 60 to 80 feet (20 to 24 meters) high. Fine till covers an extensive plateau east of Narssârssuk, the plain east of the Sioraq, and the top and slopes of Akínarssuaq. Permafrost begins at a depth of 1 to 2 feet (0.3 to 0.6 meters), and ice lenses are common in the North Star Bugt Area. The ice in many places is 1 foot (30 cms.) thick. Soil structures due to frost action are conspicuous in the Narssârssuk area.

Outwash. The outwash is composed of cobbles in a matrix of sandy pebble gravel, with few boulders. Particles of all sizes are well rounded and are composed of gneiss, diabase, quartzite, sandstone, shale, and dolomite. Adjacent to the ice cap, northeast of Peder Marcus Fjeld, outwash overlies metamorphic and sedimentary rocks at moderate depths. Local deposits south of Harald Moltke Bræ and at the snout of Pitugfik Gletscher are probably thin to moderately thick over gneiss. The outwash occurs along stream channels or covers outwash plains, as at Parker Snow Bugt and near Peder Marcus Fjeld. The surface of the outwash is flat to gently undulating. Permafrost occurs at a depth of 3 to 5 feet (1 to 1.6 meters), and ground ice may occur within 3 feet (1 meter) of the surface and cause slumping after thaw.

Beach deposits. The beach deposits contain material that ranges in size from silty sand to cobble gravel, in which there are numerous boulders. Beach deposits bordering areas of sedimentary rocks consist chiefly of well-rounded to elliptical particles of dolomite, sandstone,

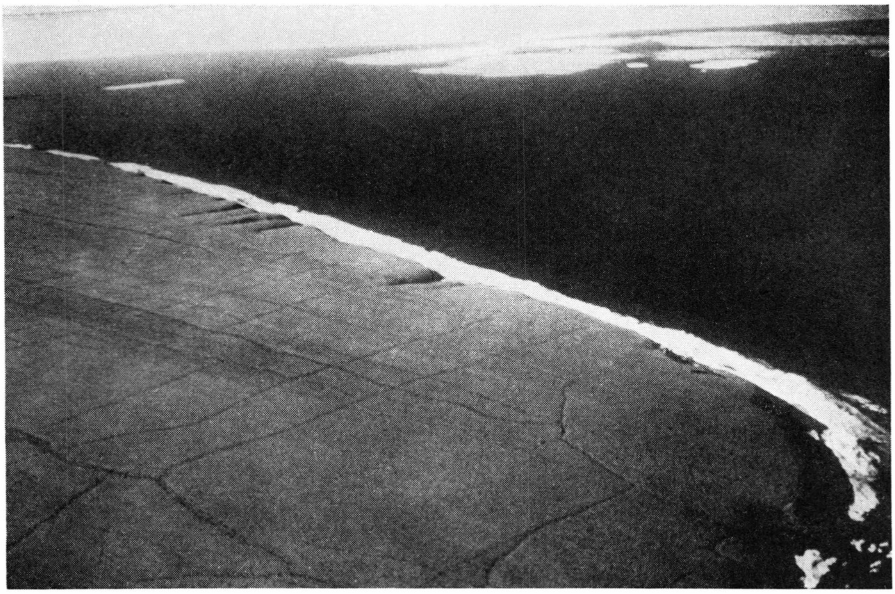

Fig. 19. Aerial view of raised beach at Narssârssuk. Polygons are 20 to 40 meters on a side.

and minor amounts of gneiss, schist, and quartz; deposits bordering metamorphic rock areas consist largely of well-rounded pebble and cobble gravel of gneiss and quartzite. Beach materials that are dissimilar to the local bedrock have been derived from reworked moraines. Beach deposits overlie sedimentary and metamorphic rocks or till and are 10 to 60 feet (3 to 19 meters) thick. Raised beaches (Figure 19) are common at the mouth of major streams and are well bedded, with beds or layers ranging from 1 to 4 feet (30 to 120 cms.) in thickness. Most raised beaches contain shell zones. Permafrost occurs in the silty-sandy beach gravels at North Star Bugt, 1 to 4 feet (30 to 120 cms.) below the surface. Slumping of these materials after thaw indicates the presence of ground ice at shallow depth.

The raised beach deposits generally contain large quantities of shells. At Narssârssuk the following were collected from the strand that is now 35 feet (11 meters) above the sea:

Chlamys islandicus (MULLER)
Serripes groenlandicus (BRUGUIÈRE)
Macoma balthica (LINNÉ)
Hiatella arctica (LINNÉ)
Mya truncata LINNÉ

In comparison the following shells were collected from the present tidal beach:

Chlamys islandicus (Muller)
Musculus discors (Linné)
Astarte borealis (Schumacher)
Astarte striata (Leach)
Serripes groenlandicus (Bruguière)
Hiatella arctica (Linné)
Mya truncata Linné
Mya arenaria (Linné)

Silt. The silt is composed of silt with fine to medium sand, and contains pebbles, cobbles, and some boulders. Particles are generally well rounded to tabular. The silt is best developed in areas underlain by either black shale or alternating beds of siltstone and dolomite, but foliated gneisses also break down to form areas of silt overlying metamorphic rocks. Deposits range in thickness from 1 to 5 feet (30 to 150 cms.). Northeast of Crescent Sø and southeast of Narssârssuk 2 to 5 feet (60 to 150 cms.) of silt overlie black shale and metamorphic rocks respectively. At Saunders Ø the entire upper surface is veneered with 1 to 2 feet (30 to 60 cms.) of silt overlying sedimentary rocks. Areas of silt cover hilltops, as at Saunders Ø, but most commonly veneer slopes and fill saddles and troughs, as in the metamorphic zone south and west of Peder Marcus Fjeld. Silt is particularly susceptible to frost action and has a shallow permafrost table. The active layer is generally 6 to 18 inches (15 to 45 cms.) below the surface; maximum thaw occurs in August but is subject to diurnal variations in temperature.

Peat. Peat accumulates in closed depressions and on slopes and flats where environmental conditions are suitable for the growth of plants. Deposits of peat range in thickness from 6 inches to 3 feet (15 to 90 cms.) and overlie coarse or fine moraine and outwash. Peat fringes the ponds and lakes north and northeast of North Star Bugt, where it reaches its most extensive development. Local concentrations of peat were observed south of Harald Moltke Bræ, at Narssârssuk, and in a fertile valley north of Pitugfik Gletscher. Permafrost occurs 8 to 30 inches (20 to 75 cms.) below the surface.

Talus. Talus is composed of coarse, broken, angular bedrock blocks and fragments ranging in size from a few inches to several feet. The size and shape of individual fragments depend upon bedrock properties such as texture, layering, jointing and fracturing. Several types of rock may be found in a single deposit. Talus formed from shale, schist, and other weak, friable rocks generally contains much fine-grained material. Deposits may approach a thickness of 100 feet (30 meters) along the lower slopes of Diabas Ås on Wolstenholme Fjord, where they rest on sandstone and diabase. Talus deposits assume the form of cones with slopes as steep as 43° or merge into a continuous front with a 20° average slope. Permafrost occurs in talus on steep and on gentle slopes, 1 to 3 feet (30 to 90 cms.) below the surface. The coarser talus is less susceptible to frost action but moves rapidly downslope

Fig. 20. Trenching on talus slope, north side of Narssârssuk Dal, 3 miles (4.8 kms.) east of Narssârssuk.

because of avalanching and normal creep. Talus is best developed in the sedimentary rocks northeast of North Star Bugt and at the sea cliffs of Saunders Ø. On the talus slopes on the north side of Narssârssuk Dal, 3 miles (4.8 kms.) east of Narssârssuk, several channels have resulted from earth flow (Figure 20).

Character and pattern of the glacial record.

Geologic features formed during glaciation of the North Star Bugt Area include glacial erratics, moraines, marginal channels, polished and quarried bedrock, strand lines of previously existing ice-dammed lakes, and isostatically elevated marine beaches (Plate IV).

The highest surfaces of Saunders Ø and Wolstenholme Ø are covered with frost-disturbed soils containing glacial erratics derived from the mainland. Boulders composed of pink and gray granite gneiss, chlorite schist, and quartzite rest on sedimentary rocks at Saunders Ø and in the northwestern part of the North Star Bugt Area. Boulders composed of pink and gray granite gneiss and serpentine rest on quartzite at an altitude 200 feet (60 meters) below the highest point on Wolstenholme Ø (1,801 feet) (550 meters). Quartzite and diabase boulders overlie pink and gray granite gneiss on the hills north of Pitugfik Gletscher. Glacial deposits, widely distributed over the entire North Star Bugt Area, indicate that it was completely covered by glacier ice at least once during the Pleistocene.

Compound end moraines, convex upvalley, which were formed at the front of an ice lobe that spilled onto the mainland from Wolstenholme Fjord, are preserved in the broad trough northeast of North Star Bugt. Smaller, less extensive end moraines form arcuate ridges around the valley mouths at Aorfêrneq, Narssârssuk, and Savigssuaq. Lateral moraines are preserved on the walls of Wolstenholme Fjord, on the slopes adjacent to the present surface of Pitugfik Gletscher, and on the flanks of numerous hills in the North Star Bugt Area. Ablation moraines occur in the valley east of the Sioraq and are preserved near the present ice front and on the upland surface north of Peder Marcus Fjeld.

Marginal channels, which were formed by meltwater streams along the retreating ice margins, have been cut into the bedrock cliffs of Saunders Ø and Wolstenholme Ø and along the mainland coast from Harald Moltke Bræ to Sermipaluk. Marginal channels are preserved in all lithologic units within the North Star Bugt Area, and some can be traced continuously for as much as 20 miles (32 kms.). Their wide distribution and continuity throughout the area provide the most important data for the detailed reconstruction of the last deglaciation. Quasi-barbed tributaries occur along the Narssârssuk Elv in a zone 10 to 14 miles (16 to 22 kms.) from the sea. These tributaries and others similar to them in the lower valley near Savigssuaq are the extensions of marginal channels that intersect the valley axis and have not been formed as the result of drainage diversions.

Glacially abraded bedrock surfaces are best preserved in those parts of the North Star Bugt Area that are underlain by granite gneiss, quartzite, or diabase (head of Wolstenholme Fjord). Polished surfaces are common along the walls of Wolstenholme Fjord and the slopes adjacent to Pitugfik Gletscher. Evidence of glacial quarrying or plucking is conspicuous on the lee slopes of diabase dikes and sills and in those areas underlain by granite gneiss with rectangular joint systems as in the valley above Savigssuaq.

The strand lines of a recently drained ice-dammed lake are preserved and accentuated by zones of successively more meagre lichen growth in the deep gorge north of Pitugfik Gletscher. Similar recently lowered lakes occur adjacent to Knud Rasmussen Gletscher and Harald Moltke Bræ. The strand lines of a recently drained ice-dammed lake are preserved at the front of the ice cap near the head of the Pitugfiup kûgssua.

Indirect evidence of the presence of glacier ice may be found in the distribution of raised marine beaches with different altitudes (Figures 21, 22). Assuming no marked differential uplift, it can be postulated that currently exposed beach sites were not exposed to marine erosion or were exposed later than other beach sites because they were initially occupied by glacial ice.

Except for the presence of submarine ridges south of Salisbury Gletscher, Wolstenholme Fjord may be traced continuously as far south as Kap Atholl. This large glacial trough, which is 900 feet (275 meters) below sea level in the strait between Wolstenholme Ø and the mainland, suggests that the offshore islands were separated from the mainland by a large ice stream that was nourished primarily from the Wolstenholme Fjord area. Paired marginal channels on opposite sides of this large trough indicate that the ice stream receded north and northeast (Plate IV).

Plate IV (Ice Front Features Map) shows a regular marginal channel pattern indicating concentric diminution of the ice perimeter. There is no evidence of intersecting marginal channels to suggest a complex glacial history of alternate recession and readvance with different ice sources. Marginal channel lineation suggests that the deglaciation of the mainland area was initiated along an ice divide that coincided with the present ridge line of Akínarssuaq. The north lobe was nourished primarily by "North Cap" (a small ice cap north of Wolstenholme Fjord and currently independent of the Greenland Ice Cap), which is currently advancing over the margin of the Greenland Ice Cap north of Wolstenholme Fjord. The south lobe was nourished by the main Greenland Ice Cap, but from an area east of Parker Snow Bugt which appears to have been independent of the main ice drainage.

Glacial stratigraphy.

Marine transgressions contemporaneous with the uncovering and isostatic uplift of the North Star Bugt Area truncated moraines along the coast, or accelerated the glacier withdrawal at calving ice fronts. Littoral sands containing organic materials were deposited either above the moraines or mixed with glacial flour and larger rock particles at ice fronts discharging into sea water. The organic materials, dated by the carbon-14 method, indicate the age of the associated marine deposits and consequently place an upper limit on the age of the adjacent glacial deposits. Dated raised marine beaches may be compared to other raised marine beaches of similar altitude and geomorphic development and the known date extended coastwise by extrapolation. Similarly, dated moraines may be traced inland and compared with other moraines of similar geomorphic development. Thus the glacial stratigraphy and chronology in the North Star Bugt Area has been developed from organic-rich marine deposits in the absence of terrestial organic remains.

The following is a description of the most significant stratigraphic sections and relationships observed, in order of decreasing age. The importance and interrelationships of these sections are collectively discussed under the glacial chronology.

The oldest glacial drift that has been observed in the North Star Bugt Area is exposed in a 50-foot (15 meters) section of marine till that is overlain by 50 feet (15 meters) of marine sand and beach shingle on the north coast of Saunders Ø (Figure 21). The lower part of the till contains numerous large boulders of exotic metamorphic rocks in a matrix of structureless gray silt with lenses of sand, and a faunal zone containing pelecypods at an altitude of 15 feet (4.5 meters). These generally unsorted sediments grade upward into a rudely stratified silty sand with few scattered small erratics, all of which lie below a second faunal zone containing pelecypods at an altitude of 50 feet (15 meters). Stratified marine sand and beach shingle overlying the till contain a faunal zone of pelecypods at an altitude of 80 feet (24 meters). A well-developed marine terrace above this sand and shingle extends 50 yards (50 meters) inland to where smaller, less distinct terraces are being overridden by talus at an altitude of 125 feet (38 meters).

Shells of *Mya truncata* and *Hiatella arctica* were collected from each of the three above-mentioned faunal zones at Saunders Ø. Shells of *Mya truncata* from the 80- and 50-foot (24 and 15 meters) zones and shell fragments of both *Mya truncata* and *Hiatella arctica* from the 15-foot (4.5 meters) zone were analysed by the radiocarbon method (SUESS 1954, samples W72, W74, and W75). The two lower shell zones were dated older than 32,000 years; the shells collected at 15 feet

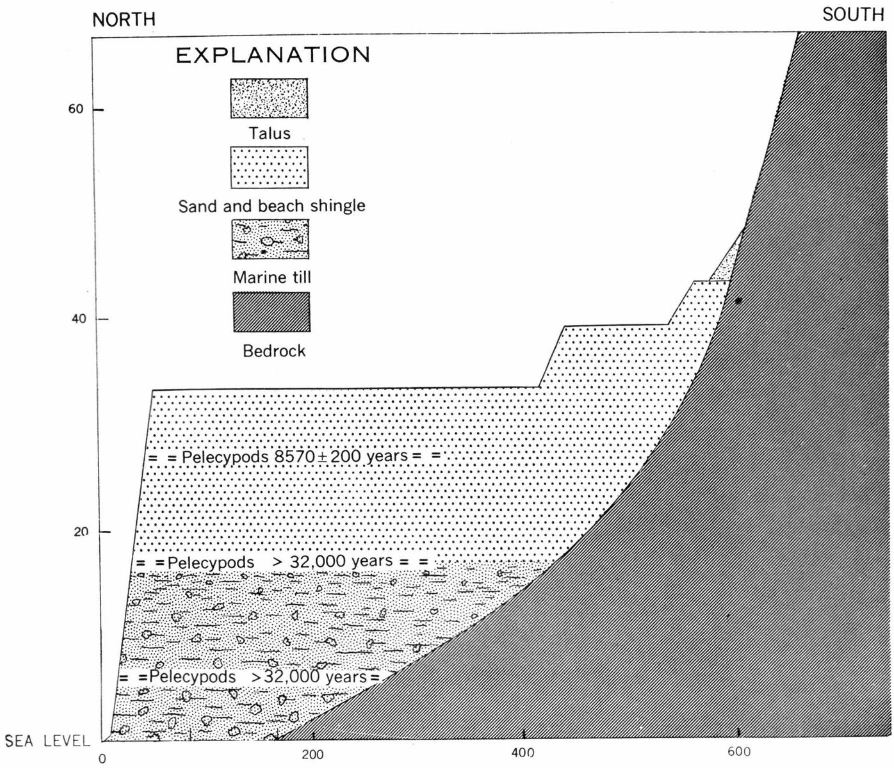

Fig. 21. Profile of beach section at Saunders Ø.

(4.5 meters) gave a slightly lower count per minute than those collected at 50 feet (15 meters). The shells from the 80-foot (24 meters) zone were dated 8,570 ± 200 years. A sample containing modern pelecypod shells from the North Star Bugt Area was also analysed by the same radiocarbon method; the results were in agreement with the standard count per minute for modern pelecypod shell material collected at several places in the Atlantic Ocean (i. e. < 100 years old).

Along the mainland coast, from the mouth of Wolstenholme Fjord south to Ivnaqtugdleg, sedimentary bedrock is covered locally by 2 to 10 feet (0.6 to 3 meters) of till composed of structureless, indurated gray silt containing erratics of pink granite gneiss and chlorite schist (Figure 22). No evidence for oxidation of the upper part of this deposit was found. Inland this till is represented by coarser materials containing large boulders of the metamorphic rocks and angular fragments of locally derived sedimentary rocks. Depressions in the associated moraine are occupied by disconnected shallow lakes, some of which are partly filled with peat.

This moraine, formed during the retreat of the north lobe, may be differentiated from the older moraine deposited by the main ice cap to

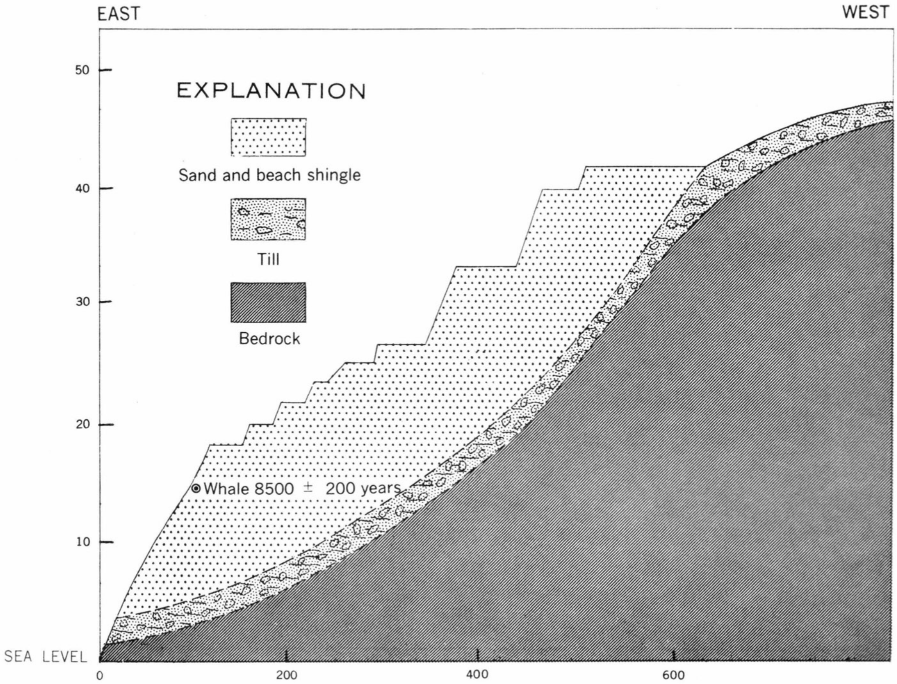

Fig. 22. Profile of beach section at North Star Bugt.

the east on the basis of the following criteria: (1) it includes morainal ridges and marginal channels with concentrically diminished perimeters, concave toward the source area "North Cap"; (2) the moraine associated with the main ice cap contains marginal channel systems concave toward the main ice cap; the moraine is topographically more subdued, drift is more weathered and lichen encrusted, frost features are better developed, and drainage is better integrated than are comparable features in the moraine of the north lobe.

Many large bones and a small quantity of baleen, all of which were identified as belonging to a Greenland bowhead whale (*Balaena mysticetus*), were excavated from a raised marine delta of Siorqap kûa during August 1953. The assemblage of bones, their conspicuous lack of erosion, and their relative position indicate that the whale was probably intact when rapidly buried by fluviomarine sand. Pelecypod shells (*Mytilus edulis* Linné) found with the bones indicate that burial occured within the littoral zone. Baleen found near one of the jawbones and at an altitude of 43 feet (13 meters), 12 feet (3.6 meters) beneath a prominent 55-foot (17 meters) marine terrace, was dated 8,500 ± 200 years old (Suess 1954, sample W48). A sample containing modern baleen was also analyzed by the same radiocarbon method; the result indicated

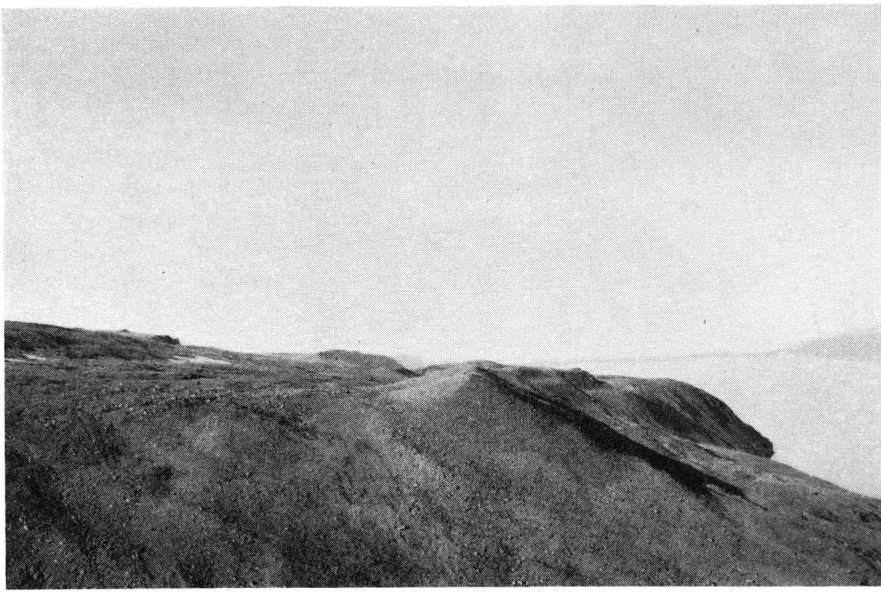

Fig. 23. High lateral moraine along south side of Wolstenholme Fjord.

that the modern baleen was less than 100 years old—well within the range of the possible error listed for the buried baleen.

The highest pelecypod zone at Saunders Ø (80 feet) (24 meters) is contemporaneous with the 43-foot (14 meters) level of the whale at Siorqap kûa (South River), and both organic materials were buried near the then existing strand (littoral zone). The vertical difference of 37 feet (11 meters) may represent the amplitude of isostatic readjustment between the offshore islands and the mainland which is 2.4 feet per mile (0.48 meters per kilometer) toward Saunders Ø. Although the preserved marine limit at Saunders Ø (125 feet) (37 meters) is equal to the preserved marine limit at North Star Bugt (125 feet) (37 meters), it appears likely that the highest marine limit at Saunders Ø during the last eustatic maximum exceeded the highest marine limit at North Star Bugt. Field evidence suggests a less favorable environment for the preservation of raised marine terraces at Saunders Ø (vertical sea cliffs and peripheral marine erosion), and it is known that raised marine terraces on the mainland north of Saunders Ø are at least 150 feet (45 meters) above sea level.

From 1,000 feet (305 meters) above the present terminus of Harald Moltke Bræ a conspicuous lateral moraine can be traced downfjord to where it has been truncated by marine terraces as high as 75 feet (23 meters) above present sea level (Figure 23). Several of the valleys that terminate at the sea north of Pitugfik Gletscher are partly blocked by glacial moraines. These moraines are terraced by raised marine beaches at altitudes as much as 125 feet (37 meters) at Narssârssuk, 75 feet (23 meters) at Quarautit, and 45 feet (14 meters) at Savigssuaq. Immediately south of Pitugfik Gletscher, at Kaminski Bugt, the marine limit is at least 85 feet (26 meters) but the highest marine terraces observed at Parker Snow Bugt are 57 feet (18 meters) above present sea level.

An ice-cored lateral moraine may be traced along the south wall of Wolstenholme Fjord from a position 10 miles (16 kms.) east of the front of Harald Moltke Bræ to a point 2 miles (3.2 kms.) west of the ice front. This moraine does not intersect the raised marine terraces that are 2 miles (3.2 kms.) downfjord to the west.

In the hills north of Pitugfik Gletscher concentric ridges of rock debris block the mouths of narrow valleys, some of which are now occupied by glacierettes or perennial snowbanks. Three north-facing gullies at Saunders Ø and one northeast-facing gully at Wolstenholme Ø are now occupied by small glaciers, all of which are close to arcuate moraines and ridges of debris that mark a relatively recent oscillation.

Glacial Chronology.

The North Star Bugt Area was glaciated more than 32,000 years ago as the result of an ice expansion from the northeast and southwest. Deglaciation patterns suggest that the sources of this ice expansion were independent of the ice cap due east of the area. At the maximum extent of this glaciation Saunders Ø and Wolstenholme Ø (see Plate IV for place names) were covered by ice. Considering the highest summit and the lowest trough adjacent to the east side of Wolstenholme Ø, and assuming a minimum ice gradient of 100 feet per mile (19 meters per km.) from the northeast, the ice that occupied the strait between Wolstenholme Ø and Kap Atholl was at least 2,700 feet (825 meters) thick (Figure 24-1).

Deglaciation of the North Star Bugt Area was initiated by the disappearance of ice from the western half of Wolstenholme Ø. The ice front thinned and separated at Angerdlartorsiorfik on the mainland, uncovering the adjacent highland. The front of the north lobe receded to Kap Atholl, where paired marginal channels on both sides of the strait mark the gradient of the lowering ice surface. Hydrographic charts suggest the development of a threshold off Kap Atholl.

Saunders Ø was then uncovered, and Wolstenholme Ø and the mainland adjacent to Kap Atholl became ice free. Small valley glaciers probably remained at Saunders Ø and Wolstenholme Ø. As the ice

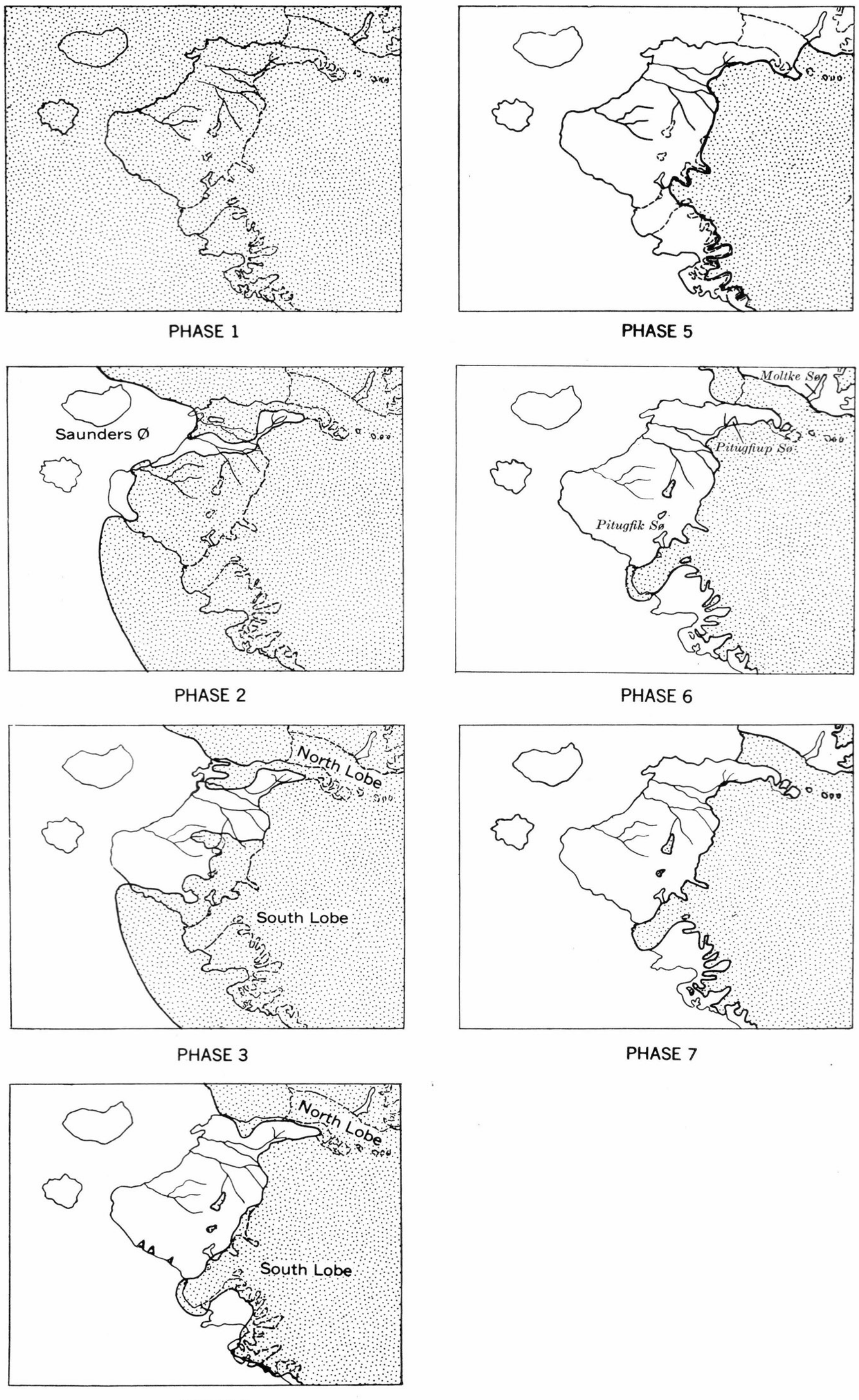

Fig. 24. Glacial Succession North Star Bugt Area.

front receded northeastward, more than 32,000 years ago, a pelecypod fauna became established in the newly developed littoral zone adjacent to the ice front at the north strand of Saunders Ø. Northeast of Akínarssuaq the marginal channel perimeters exhibit concentric diminution towards the north; south of Akínarssuaq the marginal channel perimeters exhibit concentric diminution towards the southeast. A line drawn between these two opposing marginal channel systems from Ivnaqtugdleq east and north to Uvdle represents the boundary between two recessional ice lobes (Plate IV). Raised marine beaches on either side of this boundary truncate moraines that are associated with the marginal channel systems, at altitudes of approximately 125 feet (37 meters). Along the interlobate boundary, the ice thinned and separated. Local glaciers immediately south of Akínarssuaq did not persist, as the large volume of interlobate meltwater cleared the valleys and cut 200-foot (60 meters) gorges across the strike of the sedimentary rocks (Plate IV). An irregular wedge opened to the west as the two lobes retreated toward their source areas. Dundas Fjeld became ice free at the same time that Nordfjeld (North Mountain) was uncovered as a nunatak. Hydrographic charts indicate a 200-foot (60 meters) submarine ridge below and parallel to the reconstructed ice front northwest of Dundas Fjeld (Figure 24-2).

Any fluctuations of the front of the north lobe between 32,000 and 8,500 years ago must have been north of Saunders Ø and North Star Bugt, for the following reasons: (1) There is no apparent unconformity between the marine till (> 32,000 years old) and stratified sand ($8{,}570 \pm 200$ years old) at Saunders Ø. The change in facies is transitional. (2) There is no indication of glacial reentrants, nor are there any intersecting marginal channels at Saunders Ø. No stratigraphic or topographic evidence was found to suggest that Saunders Ø had been glaciated during the last 32,000 years. (3) Immediately north and south of North Star Bugt one till rests directly on bedrock. This till is locally covered with marine sand that was deposited in shallow water $8{,}500 \pm 200$ years ago.

Contemporaneous with the disappearance of glacial ice from the offshore islands and the mainland coast between Wolstenholme Fjord and Pau, marine sand and beach shingle were deposited under conditions suggesting a rising sea level. Radiocarbon analysis indicates that these marine sediments were deposited during a period from more than 32,000 to less than 8,500 years ago. The seaward extension of the north lobe receded northeastward to the present mouth of Wolstenholme Fjord, where a 200-foot (60 meters) submarine ridge now lies below and parallel to the reconstructed ice front (Figure 24-3). The east and west margins of the Sioraq projection of the north lobe retreated toward the middle course of the valley as the adjacent slopes of Nordfjeld (North Mountain) and Akínarssuaq were uncovered. From Narssârssuk the south lobe retreated eastward to a position 7 miles (11.2 kms.) from the sea. East of Kap Atholl the down-melting ice became isolated from the principal source when the ice surface south of Peder Marcus Fjeld was lowered to an altitude of 1,750 feet (530 meters). Southeast of Pau a deep marginal channel was cut across the headlands by water from the south-flowing streams, which was diverted westward at the ice front (Plate IV).

The north lobe, close to its source and protected somewhat by high, north-facing cliffs, receded slowly. In Wolstenholme Fjord the ice front retreated to a position 1 mile (1.6 kms.) west of Iperautaq. Push moraines convex upvalley from Wolstenholme Fjord at the east end of Nordfjeld (North Mountain) indicate oscillations of the north lobe during this phase of the deglaciation. The south lobe, more extended over high bedrock surfaces, farther from its source and discharging into sea water along a broad front, retreated rapidly eastward. The coast became ice free from Pau to Pitugfik Gletscher and then south to Parker Snow Bugt.

The presence of glacial drift at the mouths of valleys at Quarautit and near Savigssuaq and the absence of high marine beaches suggest that small glacierettes remained at these points. These glacierettes prevented the development of beaches. To the north and south are 125- and 100-foot (37 and 30 meters) beaches. At this time the marine limit at the mainland was approximately 130 feet (40 meters) above present sea level (Figure 24-4).

The North Star Bugt Area was then elevated and marine terraces were cut at successively lower levels. Wolstenholme Fjord and Quarautit contained glacier ice until the time of formation of the 75-foot (23 meters) marine terrace. Parker Snow Bugt contained ice until the 57-foot (18 meters) marine terrace was formed. Subsequently the ice front receded to a position at least 10 miles (16 kms.) east of its current position at the front of Harald Moltke Bræ, and streams cut deep gorges in the fjord walls. At Pitugfik Gletscher the ice front receded at least 7 miles (11.2 kms.) east of its current position. This major recession took place less than 8,500 years ago and may represent the effect of the climatic optimum (Figure 24-5).

The maximum marine transgression in the North Star Bugt Area preceded the period of maximum deglaciation (climatic optimum?). This apparent discrepancy may be resolved by considering the effect of isostatic readjustment, which may locally mask and minimize the broader effects of eustatic rise.

Following this period of glacial recession with concurrent gorge development, Harald Moltke Bræ readvanced at least 15 miles (24 kms.)

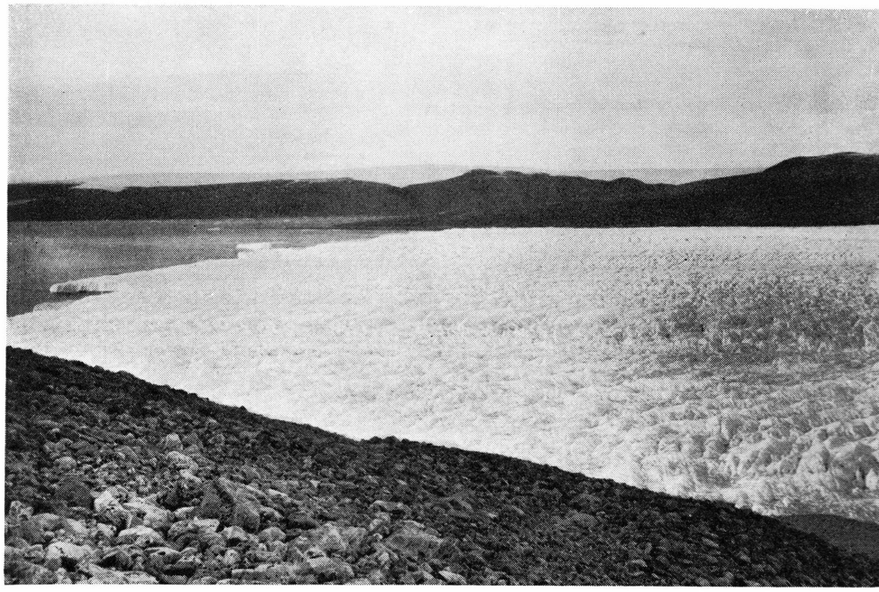

Fig. 25. Front of Harald Moltke Bræ.

down Wolstenholme Fjord. A large gorge that had been cut in front of the previous ice margin was effectively blocked by the ice. An extensive ice-dammed lake (Moltke Sø) developed in the gorge as a result of the impounded drainage (WHITE 1956). Similarly, a lake was formed at the north margin of Pitugfik Gletscher when it had advanced approximately 8 miles (12.8 kms.), and at the head of the Pitugfiup kûgssua when its gorge was blocked by the advancing ice front (Figure 24-6). In the rugged terrain between Peder Marcus Fjeld and Pitugfik Gletscher small glacierettes developed in north- and east-facing gullies and narrow valleys.

This late glacial advance was followed by a retreat of the ice front at Harald Moltke Bræ, a distance of 5 miles (8 kms.) to its current position. At Pitugfik Gletscher the ice-dammed lake was lowered approximately 300 feet (90 meters) and Pitugfik Sø was completely drained (Figure 24-7). The glacierettes north of Pitugfik Gletscher were reduced in size, but concentric rings of rock debris down-valley from the current ice fronts indicate recent cold periods of glacierette expansion. Similarly, morainal rings and debris cones down-valley, but close to the present glacierettes at Saunders Ø and at Wolstenholme Ø indicate recent climatic fluctuation.

Currently the ice front from Harald Moltke Bræ to Sermipaluk is receding. The front of Harald Moltke Bræ is 9 miles (14.4 kms.) east of Iperautaq and calving into the fjord (Figure 25) (KIILERICH 1929, WRIGHT 1939, SCHYTT 1956). Along Store Landgletscher the ice cap is terminated by a compound moraine with seven ridges (BISHOP 1956). East of Peder Marcus Fjeld the front spills over freshly deposited glaciofluvial debris in which frost polygons have developed. Pitugfik Gletscher with a frontal ice cliff 50 feet (15 meters) high is calving into the sea at the margin of the coast. Its smooth crevasse-free surface is broken only by meltwater channels. In Parker Snow Bugt, the glacier is one-half mile (0.8 km.) from the strand where marine terraces 30 feet (10 meters) above sea level are still preserved.

Throughout the North Star Bugt Area, rocks are covered by a dense growth of black lichens where they have been exposed for long periods of time. In striking contrast to the dark, dull, old surfaces are the fresh, light-toned surfaces of lichen free rocks that occur in some hollows and valleys. This freshness is due in most instances to recent removal of snow banks or glacierettes.

Table 5.

Summary of episodes during the last deglaciation of the North Star Bugt area.

Episode	*Illustrations*
1. North Star Bugt Area completely covered by ice.	Figure 24-1
2. Pelecypod fauna is established at Saunders Ø, adjacent to the retreating ice front, more than 32,000 years ago. Saunders Ø and Wolstenholme Ø become ice free. Kap Atholl, Dundas Fjeld, Nordfjeld (North Mountain) are uncovered. Recessional lobes separate at Akínarssuaq (South Mountain).	Figure 24-2
3. Pelecypod fauna at Saunders Ø and a whale at Sioraq are buried in currently elevated marine terraces, approximately 8,500 years ago. Mainland is slowly uncovered as north lobe recedes toward Wolstenholme Fjord, and south lobe recedes eastward.	Figure 24-3
4. The maximum marine transgression is approximately 130 feet (40 meters) above present sea level. North lobe retreats to the mouth of Wolstenholme Fjord, but a southern projection oscillates over the adjacent south mainland. South lobe retreats rapidly eastward and southward.	Figure 24-4
5. North Star Bugt Area elevated and marine terraces cut at successively lower levels. Front of north lobe retreats at least 20 miles (32 kms.) to a position 10 miles (16 kms.) east of its current position at the front of Harald Moltke Bræ. At Pitugfik Gletscher ice front recedes at least 9 miles (14.4 kms.) to a position 7 miles (11.2 kms.) east of its current position. Gorges cut in the fjord walls in front of the ice margin. Climatic optimum(?).	Figure 24-5

(continued)

Table 5 (cont.).

Episode	*Illustrations*
6. Harald Moltke Bræ readvances at least 15 miles (24 kms.) down Wolstenholme Fjord. Pitugfik Gletscher readvances approximately 8 miles (12.8 kms.). Lakes are formed in the previously cut gorges, which are now dammed by the ice. Glacierettes develop in some valleys north of Pitugfik Gletscher.	Figure 24-6
7. Ice retreats approximately 5 miles (8 kms.) up Wolstenholme Fjord to its current position at the front of Harald Moltke Bræ. Pitugfik Gletscher retreats approximately 1 mile (1.6 kms.). Ice-dammed lakes are lowered as much as 300 feet (90 meters). Minor advances during this general retreat are indicated by end moraines and rock debris near the present termini of numerous glacierettes.	Figure 24-7

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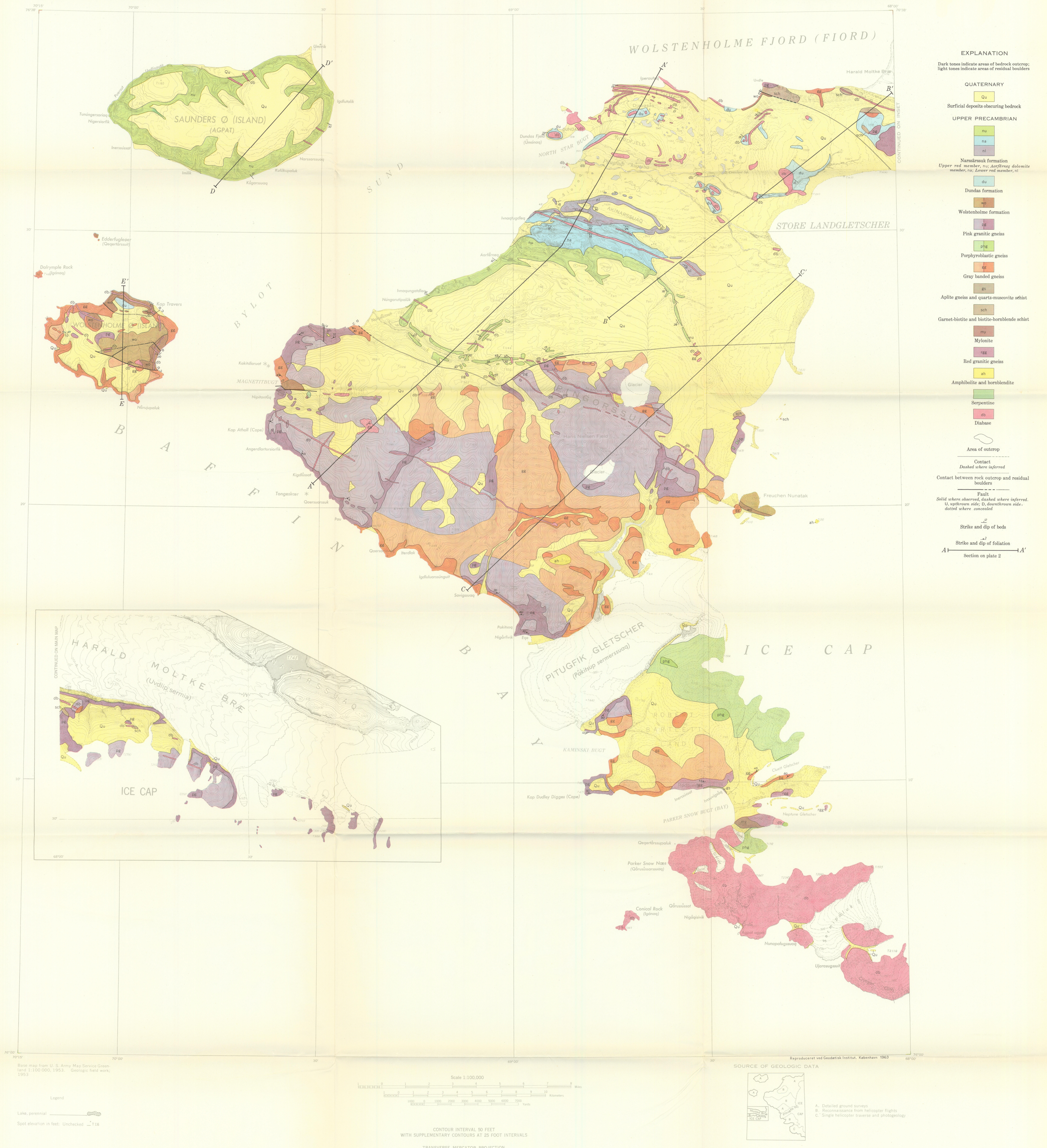
Færdig fra trykkeriet den 18. juni 1963.

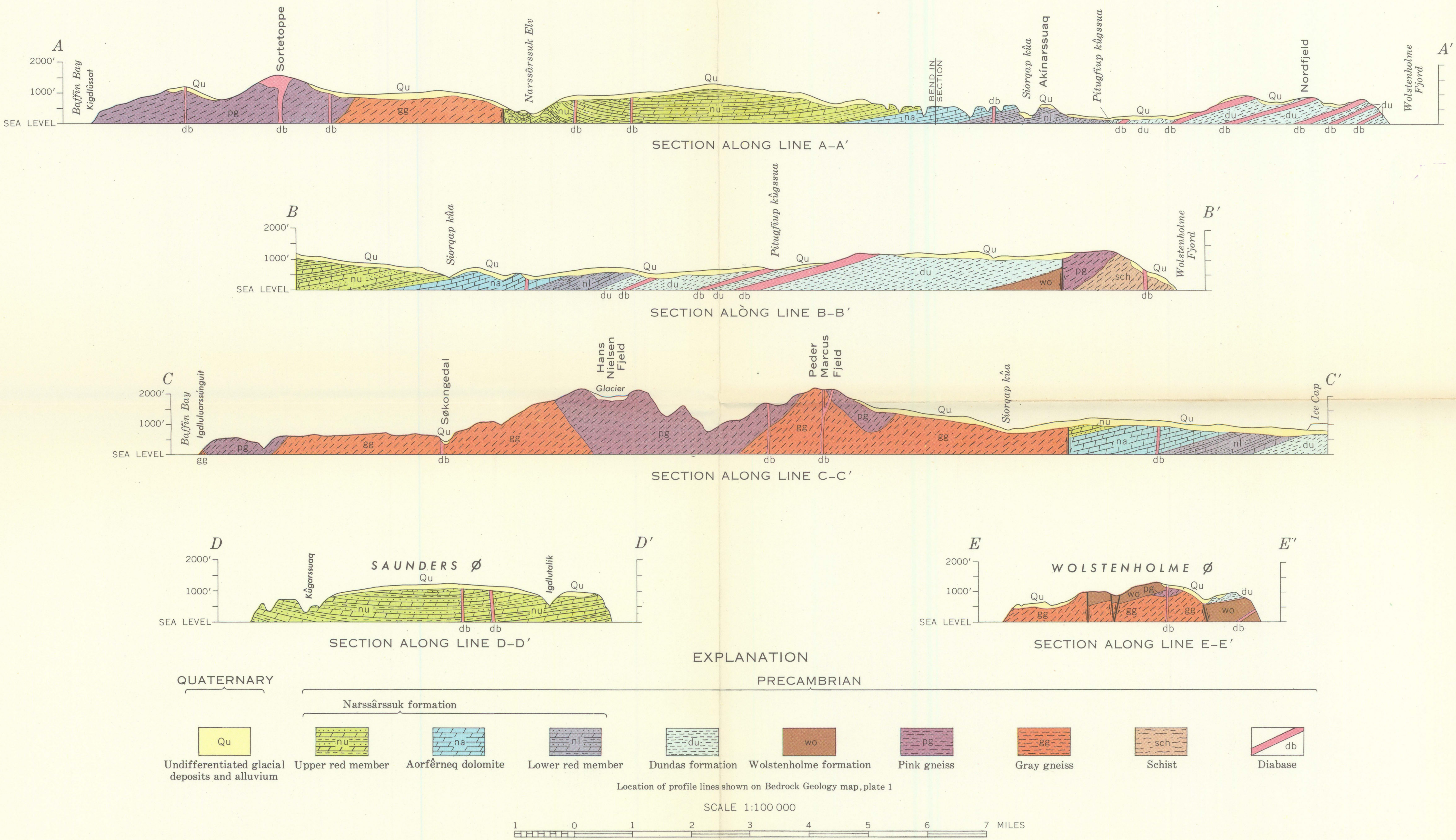
NORTH STAR BUGT AREA, GREENLAND

PLATE 1 BEDROCK GEOLOGY



NORTH STAR BUGT AREA, GREENLAND

PLATE 2 INTERPRETIVE STRUCTURAL PROFILES



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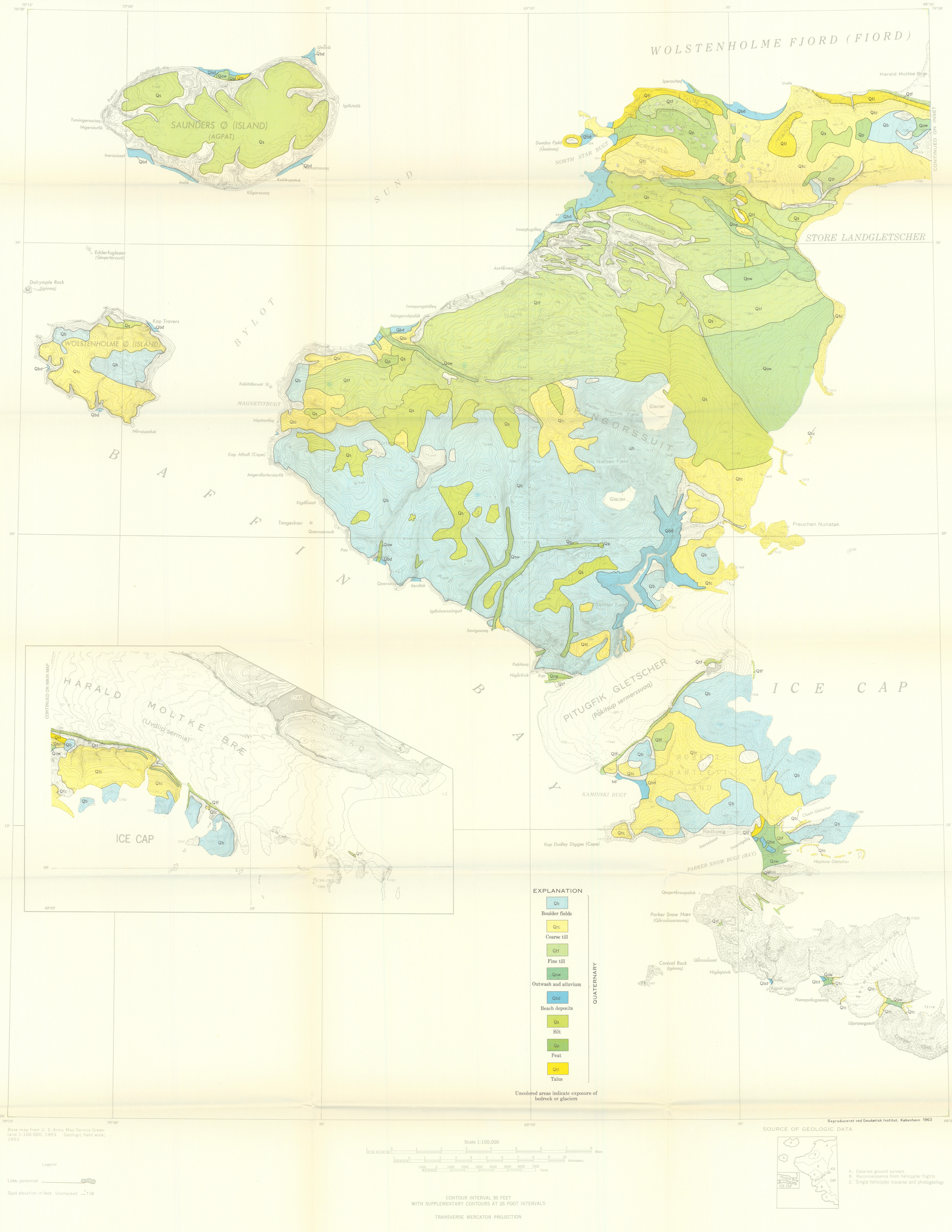
Medd. om Grønl. Bd. 162, Nr. 12 [W. E. Davies, D. B. Krinsley og A. H. Nicol]. Pl. 3

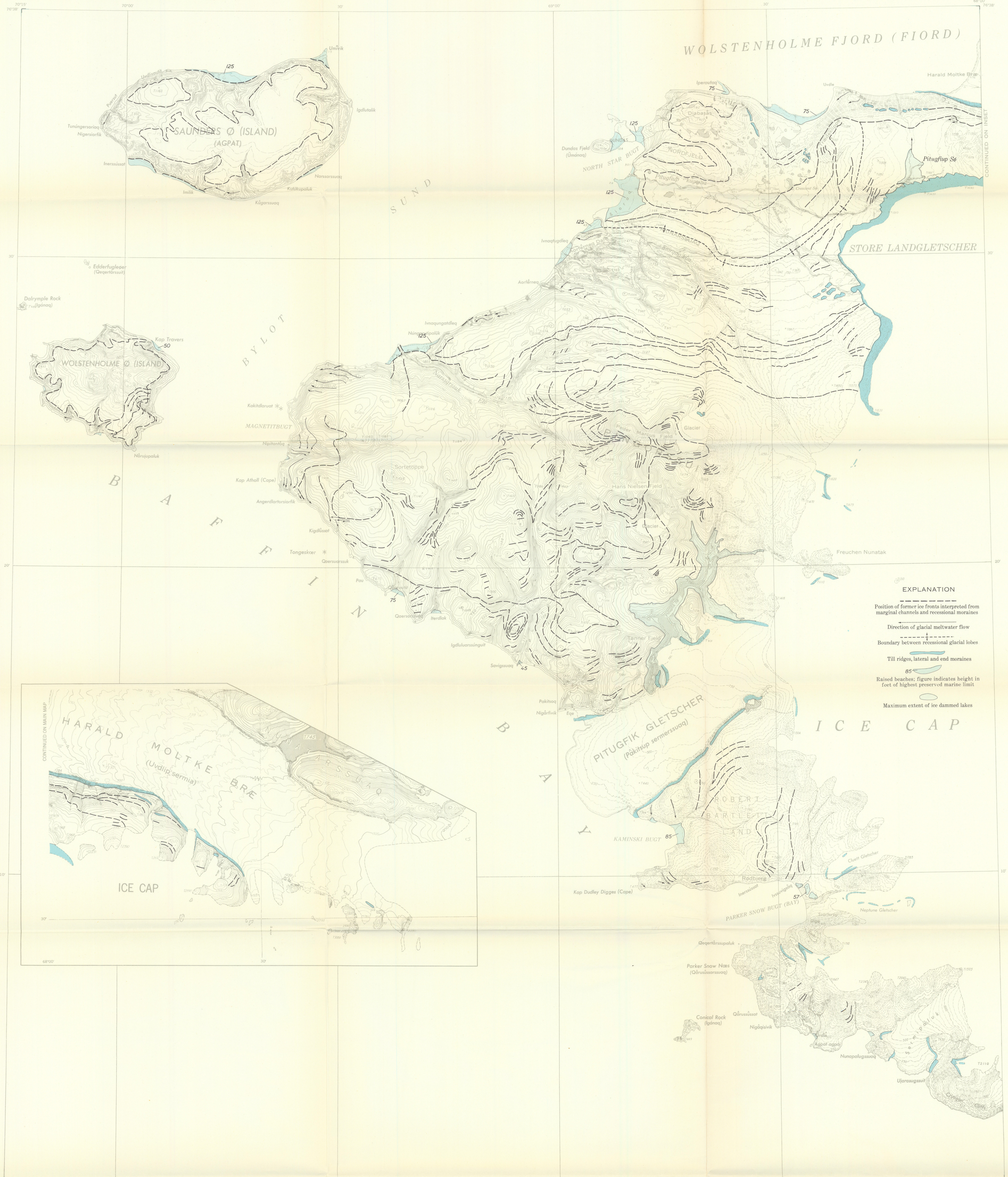
NORTH STAR BUGT AREA, GREENLAND

PLATE 3 SURFICIAL GEOLOGY



NORTH STAR BUGT AREA, GREENLAND

PLATE 4 GLACIAL AND RELATED MARINE FEATURES



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Base map from U. S. Army Map Service Greenland 1:100 000, 1953. Geologic field work; 1953

Legend

Lake, perennial

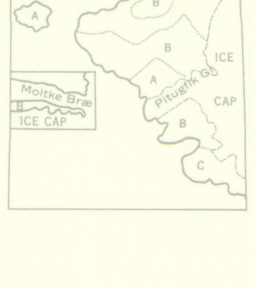
Spot elevation in feet: Unchecked T 136

Scale 1:100,000

CONTOUR INTERVAL 50 FEET
WITH SUPPLEMENTARY CONTOURS AT 25 FOOT INTERVALS

TRANSVERSE MERCATOR PROJECTION

SOURCE OF GEOLOGIC DATA



A. Detailed ground surveys
B. Reconnaissance from helicopter flights
C. Single helicopter traverse and photogeology