Summary of mineral occurrences and mineral exploration potential of South Greenland (Sheet 1 Geological map of Greenland)

Greg Mosher

Open File Series 95/3

March 1995

GGU

GRØNLANDS GEOLOGISKE UNDERSØGELSE
Ujarassiortut Kalaallit Nunaanni Misissuisoqarfiat
GEOLOGICAL SURVEY OF GREENLAND

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Øster Voldgade 10, DK-1350 Copenhagen K, Denmark

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ABSTRACT

The South Greenland map sheet is mainly underlain by gneisses and supracrustal rocks of Archaean age as well as granitoid intrusives and supracrustals of Proterozoic age. Cryolite, graphite and copper have been mined commercially.

Assessment of known mineral occurrences and geological settings suggests that the greatest current potential for the discovery of economically viable mineral deposits is related to gold and diamonds.

Diamond-bearing kimberlite dykes have been investigated within the Archaean craton in the northwest corner of the map area. Evaluation of the known exploration efforts in this area leads to the belief that re-evaluation is warranted.

Vein-type gold mineralization, spatially associated with abundant sulphides and regional deformation, represents an attractive exploration target within this map area. Regional stream-sediment surveys have generated element anomalies in a number of areas that may indicate the presence of previously unknown occurrences of this or other types of mineralization.

CONTENTS

1. INTRODUCTION

This paper provides a brief review of the mineral occurrences and mineral exploration potential of the ice-free areas on both the east and west coasts of Greenland from the south tip, Kap Farvel, to latitude 62°30′ north. The geology of the area is summarized on the Geological map of Greenland. Sheet 1 South Greenland, published by the Geological Survey of Greenland (GGU) at a scale of 1:500 000 (Figs 1 & 6).

The area contains occurrences of gold, base metals, platinum-group elements, and diamonds as well as the former cryolite mine at Ivittuut.

These mineral occurrences, geochemical anomalies, and other features of significance described in this report are plotted on Figures 4 and 5, included at the end of this report.

The GGU has produced many reports and maps, of both a general and specific nature, of the geology and mineral occurrences in South Greenland. In addition, this data base is supplemented by reports that have been submitted to the GGU of work performed by exploration and mining companies. These industry reports have been compiled by the GGU in a computer-based database, GREENMIN. Map designations of mineral occurrences on Figures 4 and 5 use the GREENMIN code numbers.

This report is a synopsis of a small portion of this information, which is repeated here only to the extent necessary to provide an understanding of the geology and nature of the mineral occurrences within the area. All reference material used in this compilation is within the public domain. If additional information is desired, the underlying references are available at the GGU in Copenhagen, Denmark.

This report was compiled at the initiative of, and funded by, the Minerals Office of the Greenland Home Rule Government (Grønlands Hjemmestyre).

2. LOCATION AND ACCESS

The area covered by the South Greenland map sheet includes the ice-free areas on both the east and west coasts from Kap Farvel on the southern tip of Greenland to 62°30′ north latitude.

The east coast is uninhabited but there are four large communities and about 12 smaller villages on the west coast. Paamiut (Frederikshåb) in the north and Narsaq, Qaqortoq (Julianehåb), and Nanortalik to the south each have a population of about 2,500. The smaller communities have populations of from 100 to 500 persons.

There is an airport at Narsarsuaq with jet service from Copenhagen, Denmark; Keflavik in Iceland, and Nuuk, the capital of Greenland. The other, larger communities are serviced by scheduled helicopter flights from Nuuk, about 500 kilometres to the north.

Several of the communities are deep-water ports and are part of the coastal shipping route.

3. TOPOGRAPHY AND CLIMATE

The climate of Greenland is dominated by the ice cap which imparts an arctic influence to the entire island, although the weather on the southwest coast is sufficiently benign to permit commercial sheep farming.

In southern Greenland the mean temperature remains above freezing from May to September, with summer high temperatures ranging between 5 and 10 degrees Celsius. Because of the moderating influence of the Irminger Current, a branch of the Gulf Stream, winter temperatures remain between zero and –5 degrees Celsius.

Annual precipitation is high, between 200 and 300 centimetres.

On the southeast coast most of the area is covered by the ice cap, with the exception of a narrow, irregular strip five to ten kilometres wide along the coast, and the sides of the fjords that extend inland for up to 60 kilometres.

The west coast has a much more extensive ice-free land mass which is on average about 50 kilometres wide and, in the Narsarsuaq area, extends inland for more than 120 kilometres. The west coast is cut by an extensive system of northeast-trending fjords.

The entire map area is mountainous, with elevations ranging up to about 2,000 metres above sea level, although most of the coastal areas lie below 1,000 metres elevation.

4. HISTORY OF GEOLOGICAL INVESTIGATIONS

Sporadic geological investigations within the map area date from the 19th century, but systematic coverage did not begin until the 1950's when the GGU initiated a programme of regional geological mapping. By the early 1980's, 1:100 000 scale geological maps had been published for the west and southwest coastal areas. The accompanying 1:500 000 scale map was published in 1976 and represents the current level of detail available for the east coast.

An airborne radiometric survey of the west coast, from 62° north latitude southward, was flown by the GGU in 1979-80 and was followed by a stream sediment geochemical survey of the same area.

In 1992 the GGU conducted geochemical stream sediment sampling on the east coast between 60°30′ and 62°30′ north latitude.

In 1993 reconnaissance geochemical sampling of the map area was completed with a survey of the west coast between 61°25′ and 62°45′ north latitude.

Minor, areally restricted, rock geochemical sampling surveys have been conducted within selected areas of the west coast.

A regional aeromagnetic survey of the west coast between 60°00′ and 63°00′ north latitude was flown in 1967 and 1968.

In 1979 an aeromagnetic survey was flown off the east coast and although the survey boundary impinged upon the shore area, it is improbable that the onshore coverage provided meaningful data.

Between 1984 and 1987, aeromagnetic surveys were flown over the entire icecap area south of latitude 65° north. These surveys extended to the coast and therefore provide coverage of the entire exposed bedrock area exclusive that portion of the west coast that was flown previously. Because the primary objective of these surveys was an evaluation of the icecap, flight line orientation and survey altitudes were not chosen to optimize data quality in the bedrock areas.

A series of thematic maps of south Greenland at a scale of 1:1 000 000, that summarize the regional geology, geochemical and geophysical characteristics, and the location and character of known mineral occurrences, was published by the GGU in June 1994 (Thorning *et al.*, 1994). In addition to providing a compilation of data otherwise available only in separate sources, previously unpublished analytical results of a heavy-mineral sample survey of much of the map area are included as well.

5. HISTORY OF MINERAL EXPLORATION

Prospecting began in south Greenland during the last half of the 19th century. The first documented mineral exploitation within the map area commenced in 1853 at the Josva Mine, on the south shore of Kobberminebugt. Vein-type copper mineralization was mined (and smelted) here between 1853 and 1855, and also during the period 1905 and 1914. An estimated total of 90 tons of copper was produced.

The most significant mineral occurrence discovered in south Greenland to date is the cryolite deposit at Ivittuut. Cryolite is an aluminum fluoride used in the production of ceramics and smelting of aluminum. This deposit was mined continuously between 1858 and 1967, and again between 1983 and 1987. About 3.7 million tons of cryolite ore were mined. Evaluation of graphite occurrences along the southwest coast began in 1904, and intermittent mining of one of these, Amitsoq, produced more than 6000 tons of ore between 1914 and 1922.

During the period 1948 to 1950 Kryolitselskabet Øresund A/S, evaluated a magnetite-bearing carbonatite near Ivittuut as a possible source of iron ore.

Since 1971 there has been essentially continuous exploration activity in the area for base metals, gold, platinum-group elements, and diamonds. Most of this activity has been concentrated within three areas: the supracrustal rocks on the shores and east of Sermiligaarsuk in the north, the Gardar intrusive rocks near Narsarsuaq, and the supracrustal rocks of the Nanortalik peninsula in the south.

The mineral occurrences that were the focus of, or were discovered as a result of, these programmes are described below (section 7).

6. REGIONAL GEOLOGY

The following descriptions of the major geological units in the area are taken largely from the descriptive text that accompanies the map sheet 1 - South Greenland Map (Kalsbeek *et al.*, 1990). Abbreviations in parentheses that follow the major rock names refer to map unit designations.

The area is underlain by rocks that comprise three main chronostratigraphic zones: from north to south these are the southern part of the Greenland Archaean craton (2800 to 3000 Ma); the Ketilidian Mobile Belt of early Proterozoic age (1850-1740 Ma); and the Gardar Province of middle Proterozoic age (1300-1120 Ma).

The Ketilidian Mobile Belt is subdivided into four roughly east-trending belts. From north to south these are: (1) The Northern Border Zone, (2) the Granite Zone, (3) the Folded Migmatite Zone, and (4) the Flat-lying Migmatite Zone.

The Mobile Belt has been interpreted (Windley, 1991) as having formed by accretion of new crust onto the pre-existing Archaean craton. In this model, the supracrustal rocks of the Northern border zone were deposited in a shelf and base-of-slope enviroment and were then thrusted onto the Archaean foreland. The Granite Zone, renamed the Julianehåb Batholith, is seen as an Andean-type setting in which the granitic batholiths were intruded into an island arc setting; the gneissose plutons and noritic gabbros that occur in the Folded Migmatite Zone occupy a back-arc shear belt, and the Flat-lying Migmatite Zone is seen as a series of north-directed thrust stacks of metamorphic supracrustal rocks and paragneiss, derived from a source now significantly removed by plate tectonic movement.

This interpretation was carried out largely on the basis of the 1960's mapping programme, without benefit of more recent field observations. Recent field investigations (Chadwick *et al.*, 1994) have cast portions of this model into doubt: many of the mafic inclusions within the batholith, previously believed to be remnants of volcanic supracrustal rocks, are considered to be immiscible coeval melt phases. Also, putative contacts between markedly different phases of the belt, marked by shear zones tens of kilometres wide, have been found not to exist. Much narrower shear zones are present, but all occur within the batholith, and do not mark the boundary between contrasting rock types. A third possible modification to previous interpretations is that early and late granites may be members of a continuum, rather than of two separate intrusive events. Chadwick *et al.* (1994) regard the Julianehåb Batholith as the root zone of a volcanic arc that shed detritus into a forearc basin now represented by the proximal Psammitic Zone and distal Pelitic Zone in the migmatitic complex (respectively the Folded and Flat-lying Migmatite Zones). The Julianehåb Batholith was emplaced during a sinistral transpressional regime imposed by oblique northwest-wards subduction of an oceanic plate under the Archaean crust.

The Gardar Province lies within the Granite Zone (Julianehåb Batholith) and is comprised of sediments and lavas that were deposited in a continental rift zone. These rocks were subsequently intruded by alkaline syenite plutons, sills, and dykes. As well, there are several satellite intrusions of Gardar age that occur beyond the confines of the graben.

6.1 Archaean rocks

Rocks of Archaean age occupy the northwest and northeast portions of the map area and include gneiss, granite, amphibolite, mica schist, quartzo-feldspathic gneiss, and metavolcanic and metasedimentary rocks of the Tartoq Group.

Gneiss (gna, ga): Biotite and hornblende-biotite gneiss are the major components of this map unit. These rocks are inhomogeneous, irregularly banded, and contain pods and veins of pegmatitic material, as well as inclusions of amphibolite and anorthositic rocks. Most gneisses are tonalitic to granodioritic in composition, are of amphibolite metamorphic grade, and have been derived from intrusive rocks. Paragneiss occurs locally in association with amphibolite and is relatively rare.

Granite (gg): Granites are more homogeneous and generally more leucocratic than the gneisses, and there is local evidence that granites have intruded the gneisses, although the two are commonly gradational.

Amphibolite (aa) and Mica Schist (msa): Amphibolites occur as inclusions and continuous horizons up to several kilometres wide within the gneisses and occupy from 10 to 20 percent of the Archaean terrain. Locally amphibolites are associated with mica schist and paragneiss (msa), and some amphibolite bodies contain lenses of metaperidotite and hornblendite.

Only the major amphibolite belts are shown on the accompanying 1:500 000 map: many more are shown on the 1:100 000 scale maps that cover the western portion of the map area.

Local relict pillow structures indicate that the amphibolite gneisses were derived from subaqueous lava flows. Mica schists have a distinctive brown weathering, commonly contain abundant garnet and sillimanite, and are interpreted to have been derived from pelitic to semi-pelitic sediments.

Quartzo-feldspathic Gneiss (qga): The occurrence of acid volcanic rocks shown on the northeastern corner of the map area near Mogens Heinesen Fjord, was not confirmed during 1992 reconnaissance for the Suprasyd project (Nielsen *et al.*, 1993). Instead variably deformed orthogneiss with amphibolite enclaves were mapped.

Tartoq Group Metavolcanics and Metasediments (vs): These rocks occur in the immediate vicinity of Sermiligaarsuk. They are of low to medium metamorphic grade, several kilometres thick, rest unconformably upon the Archaean-aged gneisses, and are unconformably overlain by Ketilidian strata.

Most of the Tartoq Group consists of greenschist composed of hornblende, epidote, chlorite and plagioclase, with minor proportions of quartz and carbonate. Remnant pillows indicate that these rocks were derived, at least in part, from submarine lava flows. Interlayered quartz schists may have originated as quartzites and pelitic sediments or as acid volcanic rocks.

Talc-rich schists that commonly contain abundant pyrite and carbonate occur as conformable layers up to 50 metres in thickness.

6.2 Ketilidian supracrustal rocks

The Ketilidian orogenic belt occupies the largest proportion of the map sheet and supracrustal rocks within the belt unconformably overlie Archaean gneisses only in the north. Deformation and metamorphism increase in a southward direction from the northerly contact with the Archaean rocks. As mentioned above, the belt is comprised of four zones, from north to south, the Northern Border, Granite (Julianehåb Batholith), Folded Migmatite (Psammite Zone), and Flat-lying Migmatite (Pelite Zone).

On the west coast the Border Zone is about 70 kilometres wide, between Sermiligaarssuk and the south side of Kobberminebugt. This belt of rocks trends northeastward to the east coast where it is about 60 kilometres wide.

Most of the Border Zone is underlain by Archaean-aged gneisses, but on the west coast at least, these are overlain by sedimentary and volcanic rocks that have been the primary focus of mineral exploration in this area.

The best-preserved of these supracrustal rocks occur in the Midternæs and Grænseland areas north and northeast of Ivittuut. These rocks are almost unmetamorphosed and have been subdivided into two parts:

The lower Vallen Group (ms), is up to 1200 metres thick and is comprised of shale and greywacke with subordinate quartzite, conglomerate and carbonate rocks. The unconformable contact between the Vallen Group sediments and the Archaean-aged gneisses is well-exposed in both the Midternæs and Grænseland areas.

The overlying Sortis Group (ae) is up to 4,800 metres thick, and is comprised of basic pillow lavas and basic intrusive sheets and sills.

Southward from this area the sediments of the Vallen group grade into mica schists (mss) and the volcanic rocks of the Sortis Group grade into greenschists and amphibolites (a).

On Arsuk Ø (island), a lower sequence of sediments, the Ikerasarssuk Group (ms), and the overlying volcanic Arsuk Group (ae) have been correlated with the Sortis and Vallen Groups. Associated basic intrusions are shown as map unit (ai) and their metamorphic equivalents as (a).

In the Kobberminebugt area conglomerates and arkose are assigned to the Qipisarqo Group (qs,sp) and intermediate and basic volcanic rocks mixed with metasediments are assigned to the Ilordleq Group (vsk). These groups may correlate with the Vallen and Sortis Groups respectively.

Further south in the Tasermiut - Søndre Sermilik region supracrustal rocks are comprised of a lower sequence of pelitic and semipelitic gneisses (pgn) overlain by meta-arkoses (qs), that are in turn overlain by basic volcanic rocks (a). The meta-arkoses locally contain intraformational conglomerate beds up to several hundred metres in thickness, and the pelitic to semi-pelitic rocks locally contain lenses of calc-silicate or marble. These rocks are of amphibolite or granulite facies metamorphic grade.

The suggested equivalency of these Groups is shown below:

Midternæs/Grænseland	:	Sortis Group volcanics	(ae)
		Vallen Group sediments	(ms)
South of Grænseland	:	Greenschist & Amphibolite	(a)
		Mica Schist metasediments	(mss)
Arsuk Ø	:	Arsuk Group volcanics	(ae)
		Ikerasarssuk Group sediments	(ms)
Kobberminebugt	:	Ilordleq Group volcanics	(vsk)
		Qipisarqo Group sediments	(qs,sp)
Tasermiut	:	Volcanic Rocks	(a)
		Metasedimentary Rocks	(pgn,qs,qgn)

On the southeast coast, south of Kangerluluk, graphitic, sulphide-bearing pelitic rocks have been noted (Nielsen *et al.*, 1993). These rocks are rusty and can be traced for many kilometres. They are reported (Nielsen *et al.*, 1993) to be similar in appearance to the metasedimentary rocks in the Tasermiut - Søndre Sermilik area on the southwest coast where gold-bearing quartz veins were discovered in 1992 (section 7.1).

6.3 Ketilidian granites and associated mafic rocks

Granitoid rocks constitute about 90 percent of the granite zone and 50 percent of the migmatite zone to the south. These rocks have been subdivided into early granites and gneisses, which are deformed and foliated, and late granites. Late granites make up about 70 percent of the granite zone and form its centre. With minor exceptions, early granites occur in the marginal parts of the granite zone, and probably represent deformed equivalents of the so-called late granites (Chadwick *et al.*, 1994).

Rapakivi granites and charnockites are prominent in the migmatite area and are included with the late granites. Intrusive rocks of basic to intermediate composition constitute about five percent of the orogenic belt.

Early granites (ge, gje) and Gneisses (gnk), have been subdivided into hornblende-biotite granite and biotite granite, and both are characterized by tectonic fabrics.

Supracrustal rocks, most commonly feldspathic quartzite and lesser pelitic sediments form inclusion trains or layers within the granites.

In the area between Lindenow Fjord and Kap Farvel on the southeast coast, a subhorizontal sheet of early granite, up to one kilometre in thickness, separates underlying migmatized pelitic and semipelitic gneisses (pgn) from overlying quartzo-feldspathic gneisses (qgn). Many of the rocks in this area are of granulite facies metamorphic grade.

Gneisses (gnk) have a banded or veined character but are of the same overall composition as the early granites, i.e., granodioritic to tonalitic, and commonly are cut by granitic veins. These rocks are interpreted to have been derived from early Ketilidian intrusive rocks.

Late granites (gl, gjl), form large plutons, are less-deformed and more homogeneous than early granites, and are granodioritic to granitic in composition.

Rapakivi Suite Granites (grl), Norites (nr), and Monzonites (sgl), are common south of Lindenow Fjord (east coast) and east of Tasermiut (west coast), where they form large, flat-lying intrusions with steep, inward-dipping roots. These intrusions may have been emplaced along ductile extensional zones during a period of crustal stretching.

Mafic Intrusive Rocks (dg, pd, di, sgi, au): Many of the basic and intermediate plutonic rocks are appinites, i.e. contain hornblende as the main mafic mineral rather than pyroxene. These rocks have a clear genetic relationship with the granites but many were emplaced relatively late in the plutonic history of the mobile belt.

6.4 Gardar Province

The Gardar Province is of mid-Proterozoic age and encompasses episodes of rifting, sedimentation and alkaline igneous intrusive activity. The centre of this suite of rocks is located at about 61° north latitude and 46° west longitude. The Gardar graben trends east-northeast and contains alternating units of sandstone and volcanic rocks of the Eriksfjord Formation that were intruded by syenite plugs and sills. Eriksfjord sedimentation is estimated to have begun at about 1300 Ma, and the intrusive activity spanned the period 1300 to 1120 Ma.

The Eriksfjord Formation also contains carbonatite lavas and bedded carbonatite tuffs and agglomerates.

There are more than 12 Gardar intrusive centres, most of nepheline syenite composition. Several of these intrusives, in particular Ilímaussaq, are enriched in Zr, Nb, Ta, REE, U and Th. The Ivittuut cryolite deposit formed in the roof zone of a small stock of alkali granite that was emplaced during mid-Gardar time.

6.5 Phanerozoic rocks

Kimberlites, ranging in age from 1,800 Ma to 175 Ma have been found on the west coast of Greenland between 61°00′ and 72°00′ north latitude, a distance of 1,300 kilometres. Occurrences within the South Greenland map sheet area are situated at the southern end of this range, coincident with the southern margin of the Archaean craton.

Kimberlites dated at around 200 Ma, occur between Paamiut (Frederikshåb) and Ivittuut (Fig. 2). They form flat-lying sheets and dykes that cut Archaean-aged gneisses within the Northern Border Zone of the Ketilidian orogenic belt. These dykes commonly contain nodules of peridotite and various xenocrysts. Eight microdiamonds have been recovered from these rocks.

Calculated temperatures of formation for these kimberlites are in the range 1034 to 1078° Celsius, at accompanying pressures of 40 to 50 kilobars. These conditions are compatible with an origin within the diamond stability field (Larsen & Rønsbo, 1992).

Ultramafic lamprophyre dykes also occur within the area of Archaean gneisses south of Paamiut (Frederikshåb), and have been dated at about 170 Ma.

7. MINERAL OCCURRENCES

Nearly all known deposits and showings are located on the west coast. Brief descriptions of the more significant mineral occurrences are given below and are broadly grouped as metallic and non-metallic. Within each group, occurrences are listed geographically, from north to south.

7.1 Metallic

The **West Valley Showing** (41/9: GREENMIN code number) occurs in felsic volcanic rocks of the Tartoq Group, on the north side of Sermiligaarsuk. Interbedded pyrite and chert comprise an horizon up to 50 metres thick and at least 550 metres long, at the contact between footwall andesite schist and hangingwall carbonate schist. The pyrite-chert unit has been thickened through folding and may originally have been from five to 10 metres thick.

The occurrence has been sampled a number of times (Geisler, 1975); all reported assays are low. The highest gold value obtained was 550 parts per billion (ppb). Copper and zinc content is in the order of 250 parts per million (ppm).

Banded magnetite iron formation occurs about 1.5 kilometres along strike from the end of the sulphide horizon; stream sediment samples from this area were not anomalous (Geisler, 1975).

The **Nuuluk - Taartoq** (41/7) prospect area extends as a thin belt between Sermiligaarsuk and Taartoq Fiords to the south, and consists of disseminated to massive pyrite within carbonate schist hosted by chlorite and amphibolite schists of the Tartoq Group.

The carbonate schist zone is about 70 metres thick and has been traced 4.5 kilometres (King, 1983). This zone occurs within a carbonatized interval, about 400 metres thick, of a chlorite-amphibolite schist about 1,600 metres thick, that comprises the lower of two basic volcanic cycles.

The carbonate schist zone is made up of carbonate schist horizons up to 15 metres thick that are separated by thin layers of chlorite schist. Mineralization occurs as pyrite-quartz-carbonate layers, lenses, and veins, and as massive pyrite-arsenopyrite-quartz lenses. These pyrite-arsenopyrite zones are in the order of 50 centimetres thick and two to three metres long.

In 1983 Greenex A/S collected grab and chip samples from a number of the pyrite-arsenopyrite zones in the area. The highest gold assay was 19.4 grams per tonne (g/t) from a grab sample. The best chip sample value was 13.5 g/t over one metre, but most significant values were in the order of one to four grams per tonne over several metres (King, 1983).

In 1984 Greenex A/S drilled 23 short winkie holes (aggregate 460 metres) to obtain fresh samples and to test the horizon down-dip. The only significant results were 4.8 g/t over 2.5 metres, 1.1 g/t over 2 metres, and 0.5 g/t over 2.5 metres (Christensen, 1985).

In 1993 Nunaoil A/S drilled 13 holes (1,364 metres) to retest portions of the belt. The best results were 6.6 g/t over 2 metres and 8.3 g/t over 1.9 metres from two widely-separated areas (Robyn, 1993b).

In the **Midternæs** area there are two types of sulphide mineralization within rocks belonging to the Sortis Group: In **West Midternæs** (44/1), the stratigraphic sequence is comprised of chlorite-amphibolite schists with minor quartz-feldspar horizons that are overlain by massive and laminated rhyolite tuffs and coarse pyroclastics, which in turn are overlain by rusty quartz-sericite and talc schists.

Within the quartz-sericite schists, pyritic zones from one to six metres thick, and up to 200 metres long, occur intermittently along 2.5 kilometres of strike. The zones contain from 5 to 20 percent pyrite by volume and sporadic fuchsite (Geisler, 1975).

None of the samples collected from these zones has contained more than trace quantities of base metals, and gold values have ranged from 10 to 140 ppb (Geisler, 1975).

The other type of sulphide occurrence in the **Midternæs** (44/9) area consists of interflow horizons of graphitic argillite up to 16 metres thick and 1.5 kilometres long that contain up to five percent pyrite and pyrrhotite. Rare chalcopyrite occurs where the sediments are cut by gabbro or diabase sills. The copper mineralization is restricted to the area of the sills and does not extend for more than several metres from them. Copper values of about 0.5 percent and zinc values of 1.2 percent have been obtained from this area (King, 1983).

A quartz-pebble conglomerate occurs near the base of the Vallen Group sediments in the **Grænseland** (44/19) area. The conglomerate ranges from one to six metres in thickness and has been traced for 12 kilometres along strike. At the northern end, clasts are up to two metres in diameter, and the matrix of the conglomerate is magnetite. The magnetite content ranges from about 70 percent by volume at the base to about 30 percent at the top of the conglomerate unit (Geisler, 1975).

To the south the magnetite content diminishes and the matrix becomes pyritic. Only trace (5 to 10 ppb) amounts of gold have been detected within this unit.

Josva Mine (241/9) and the neighbouring Lilian Mine copper occurrences are located on the south side of Kobberminebugt within metavolcanic rocks belonging to the Ilordleq Group. Both occurrences lie on a shear zone that separates mylonitized felsic schist in the footwall from amphibolite schists in the hanging wall. The shear zone is up to 130 centimetres thick and sulphides occur as lenses up to 30 centimetres thick within it. Bornite and chalcocite are the principal copper minerals. Ilmenite, magnetite, hematite, chalcopyrite, electrum and native copper occur in minor amounts.

Production took place at the Josva Mine intermittently between 1905 and 1914, during which time total production was about 90 tons of copper (Erfurt & Lind, 1990).

There have been exploration programmes for gold and platinum group elements (PGE) on the **Nanortalik peninsula.** The GGU first found mineralized peridotite as boulders in the early 1960's, and then found mineralization in place in the early 1970's. The boulder contained 10 ppm platinum.

There are four ultramafic hornblende-peridotite intrusions on the peninsula, and these were investigated for their gold and PGE content by Platinova A/S and Boulder Gold during 1987 and 1988 (151/6).

The intrusions are dyke-like, up to 20 to 50 metres wide and 1000 metres or more in length. Pyrrhotite occurs as disseminations and as net-textured, semi-massive pods up to 5 by 20 metres in dimension. Minor chalcopyrite and pentlandite are also present.

All accessible occurrences of sulphide, both massive and disseminated, were evaluated by channel sampling, followed at one location, by drilling.

Initial surface samples contained up to 3.3 ppm platinum, 1.9 ppm palladium, 0.33 ppm gold, 0.47 percent nickel, and 1.53 percent copper.

Systematic channel sampling, both parallel and perpendicular to layering, of one sulphide pod generated average results of 0.5 ppm platinum, 0.6 ppm palladium, 0.25 ppm gold, 0.4 percent nickel, and 0.6 percent copper (Williams, 1987a,b).

Two holes were drilled to test one of these occurrences, but all values for gold and PGE were less than 0.5 ppm for each element (Smith, 1988).

During the period 1986 to 1988, Nanortalik Minerals A/S and Greenex A/S evaluated several alluvial gravel deposits (Ipatit, Kuat, Kangikitsoq, and Kirkespirdalen), for their placer gold potential. The gravels contain up to 6.5 milligrams of gold per cubic metre

(mg/m^3), but viable placer operations characteristically contain from 200 to 500 mg/m^3 gold (Appel *et. al.*, 1993).

Nunaoil A/S has had the most significant success of any of the exploration efforts on the Nanortalik peninsula. Stream sediment sampling in 1992 led to the discovery of high-grade (up to 273 ppm over 0.15 metres) gold mineralization in quartz veins. The occurrence (511/1) has been named **Nalunaq** (Gowen *et al.*, 1993; Robyn, 1993a).

The quartz veins occur above a thrust zone of regional extent within metavolcanic amphibolites. Metasedimentary gneisses form the footwall of the thrust. Chemical sediments, up to about 50 metres in thickness and comprised of chert, pyrite-pyrrhotite, carbonate and calc-silicate, occur in the immediate hangingwall of the thrust and underlie the altered amphibolites.

The Main Vein has been the source of the best gold values and has been the most intensively explored. This vein is a discontinuous sheet of quartz-filled dilation zones that have been filled by repeated injections of quartz. The best-developed portions are up to 1.5 metres in thickness and are comprised of up to five stacked veinlets. Gold, associated sulphides (chalcopyrite, pyrite, arsenopyrite), and scheelite are restricted to the margins of the composite members of the vein.

The Main Vein has been traced for about 800 metres on surface and is open on both ends. The weighted average of all channel samples taken only from the exposed portion of the Main Vein is 51.45 ppm Au over a width of 0.4m. With a mineable width of 1.4m quartz vein plus largely barren wallrock average 20.96 ppm (Gowen *et al.*, 1994).

In 1993, thirteen holes were drilled from three drill stations to test the Main Vein at depth. Only three of these holes are postulated to have penetrated the Main Vein, and the sub-surface gold content of the vein is considerably lower than at surface. The best intercept was 24.43 g/t over 0.4 metres and contained visible gold. The other two intercepts contained 1.76 g/t over one metre, and 2.36 g/t over 0.1 metre.

The drill results did demonstrate that there are significant complications, structural and/or depositional, within the target zone.

The chemical sediments, including the massive pyrite-pyrrhotite, were sampled both on surface and in drill holes (3 of 13 that penetrated it). Gold values were low in all cases (300 ppb maximum on surface and 218 ppb maximum in drill core; Robyn, 1993a).

On the **southeast coast**, south of Kangerluluk, which is underlain by rocks similar to the metasediments in the Tasermiut - Søndre Sermilik area, two chalcocite-bearing, quartz-veined boulders of metavolcanic rock contained 1.6 and 2.6 ppm gold (Nielsen *et al.*, 1993). Chip samples of sulphide-bearing, graphite-rich cherty rust zones in this area contained up to 188 ppb gold.

7.2 Non-metallic

Kimberlite dykes were found in the region south of Paamiut (Frederikshåb) in 1972 by Renzy Mines; approximately 30 in the Pyramidefjeld - Midternæs area, and one further north in the Nigerlikasik area.

The kimberlites in the Pyramidefjeld - Midternæs area occur in three groups, from three to 10 kilometres apart, as shallow-dipping (10 to 20°) dykes. The maximum thickness noted was three metres but most are less than one metre thick, commonly from several centimetres to 0.5 metres. They occur at intervals of 20 to 50 metres, and have been traced for more than one kilometre along strike.

Renzy Mines collected 11 bulk samples from the dykes; each sample contained about 100 kilograms of rock. Four samples from the Midternæs area contained a total of eight microdiamonds (Geisler, 1972).

Heavy mineral samples collected by Renzy Mines in 1972 and reported upon in 1973, contained microdiamond, pyrope garnet and chrome diopside. All samples except one were collected in the area west of Midternæs - Grænseland; the other sample was collected at the head of Eqaluit, northeast of Paamiut (Geisler, 1973).

The kimberlite at Nigerlikasik is also a dyke, about 50 centimetres thick, vertically dipping, and exposed for about 500 metres along strike.

The **Ivittuut cryolite deposit** (231/1) was mined from 1856 until 1967 and again between 1983 and 1987, during which time approximately 3.7 million tons of ore were extracted at a cutoff grade of 25 percent cryolite. Cryolite is an aluminum fluoride that was primarily used as a flux in the smelting of aluminum, but was also used in the processing of soda, and has applications in the manufacture of ceramics.

The deposit formed as the roof zone in a small (300-metre diameter), cylindrical alkali granite stock of Mid-Gardar age (1,225 Ma), within granodiorite gneiss of Archaean age.

To the depth it has been investigated (600 metres below surface), the stock displays concentric zonation. The highest and innermost zone was the cryolite body which contained about 58 percent cryolite, 25 percent siderite, 8 percent fluorite, 8 percent quartz, and several percent sulphide, principally sphalerite and galena. The orebody was about 60 metres thick.

A fluorite-rich zone with subordinate siderite and about 10 percent cryolite occurs beneath the cryolite zone, and in part, is underlain by a siderite-rich zone.

The lowest level of the roof zone is quartz-rich and immediately overlies the leucogranite stock. From surface to the base of the quartz zone is about 150 metres.

The roof zone is surrounded by a greisen that contains disseminated cryolite and is surrounded by an intrusive breccia which forms the outer shell of the roof zone (Bondam, 1991).

Exploration holes drilled by Kryolitselskabet Øresund A/S in 1985 beneath the cryolite zone, encountered a satellite zone of intrusive breccia and cryolite-bearing greisen. This suggests that massive cryolite may occur beneath the greisen at depth, but this hypothesis has not been tested (Gothenborg, 1985).

Despite exploration programmes both within the immediate area of Ivittuut and regionally, no other cryolite occurrences have been found.

The **Ilímaussaq Intrusion** is the best-known of the Gardar Province alkaline intrusions. Similar to related intrusions, Ilímaussaq is concentrically zoned. The earliest unit is a sheath of augite syenite which was intruded by nepheline syenites that are characterized by a trend to progressive undersaturation during differentiation. The roof zone is pulaskite and foyaite, underlain by a sodalite-rich layer (naujaite).

In the southeast part of the intrusion, eudialyte-rich nepheline syenite (kakortokite) has developed alternating series of black and red layers, each up to 12 metres in thickness. The black layers are rich in arfvedsonite, and the red layers are enriched in eudialyte.

The kakortokites are overlain by a succession of lujavrites up to 350 metres thick. These rocks are arfvedsonite-aegirine/acmite nepheline syenites that have intruded and brecciated earlier crystalline rocks.

The lujavrites are enriched in uranium, thorium, niobium, zirconium, tin, and rare earths. Uranium and thorium are associated with steenstrupine, monazite and thorite. The economic potential of uranium in the Kvanefjeld area of the Ilímaussaq Intrusion has been evaluated. A reasonably well-defined resource of 27,000 tons and an estimated additional reserve of 16,000 tons of uranium have been identified at an grade of 340 ppm (Nyegaard, 1979; Nielsen, 1981).

Hydrothermal analcime veins that are associated with the lujavrite contain niobium minerals, principally pyrochlore and epistolite. Niobium is also associated with zirconium in the eudialyte-rich layers of the kakortokites. Average niobium content of these layers is 0.4% Nb_2O_5. Zirconium content of one layer was calculated to be 61,000 tons at an average grade of 4% ZrO_2 (Andersen *et al.*, 1981).

In the hydrothermal veins pyrochlore is rich (3 to 13%) in rare earth metals; the cerium group predominates. Rare earths constitute from 15% to 30% of steenstrupine which is common in the lujavrites. Steenstrupine and monazite contain most of the rare earths within the Kvanefjeld radioactive zone. The predominant rare earth elements are yttrium, lanthanum, cerium, and neodymium.

In the northern part of the complex, quartz syenite and peralkaline granite are also enriched in rare elements.

The **Motzfeldt Centre**, another Gardar alkaline intrusion to the northeast of Ilimaussaq, contains very large tonnages of very low grade Nb-Ta-U pyrochlore mineralization (Thomassen, 1988, 1989).

The **Amitsoq** (156/1) graphite deposit near the community of Nanortalik, was the focus of some of the earliest exploration and mining activity in Greenland. Prospecting for graphite was carried out in the area early in the 1900's, and minor, intermittent mining of graphite from Amitsoq took place between 1914 and 1922.

Graphite occurs in schistose cordierite-sillimanite-biotite gneiss. There are four zones of which only the main vein was quarried. The main vein has a maximum thickness of 13.2 metres and an exposed strike length of about 500 metres. The vein thins to 3.5 metres at one end, and to 20 centimetres at the other.

Fine crystalline graphite occurs in a quartz groundmass with pyrite and biotite. Blocks of crenulated biotite gneiss have also been incorporated into the vein.

Limited documentation of production suggests a production grade of 20 to 25 percent graphite, with a maximum flake size of about 15 millimetres (Bondam, 1992b).

8. GEOCHEMICAL SURVEYS

Reconnaissance-scale stream-sediment geochemical sampling has been completed by the GGU for the entire South Greenland map sheet area.

The northwest section, from 61°25′ to 62°45′ north latitude, was sampled during 1993. In total, 275 samples were collected, for an average density of one sample per 26 square kilometres. Analytical results for 41 elements were presented by Steenfelt *et al.* (1994), on 1:1 000 000 scale maps with the range of values of each element shown as circles of various sizes.

The area from 61°25′ north on the west coast to 60°30′ north on the east coast (south side of Lindenow Fjord) was sampled in 1979. Initially the samples were analysed for uranium, but ultimately were reanalysed for about 40 other elements, including gold. The sample density was one sample per 6 square kilometres; 2,192 samples were collected amd analysed.

A series of colour-plot maps at a scale of 1:1 000 000 was published in 1982 for 25 elements (Armour-Brown *et al.*, 1982). Maps of gold, arsenic and antimony were published later (Steenfelt & Tukiainen, 1991).

The remaining area of the east coast, from Lindenow Fjord to 62°30′ north, was sampled in 1992 at which time 145 samples were collected with an average sample density of one sample per 50 square kilometres (7,000 kilometres^2 ice-free). These data were published by Steenfelt *et al.* (1992) as a series of circular dots on maps similar to those described above.

This information has been compiled and expanded upon in the Thematic Map Series 94/1 (Thorning *et al.*, 1994). Sixty (60) maps display the distribution of major and trace elements; 43 maps are based upon stream sediment analytical results, and 17 upon heavy-mineral sample analyses.

It is obvious that the large variation in sample density makes comparison between areas uncertain, although some generalities can be made.

The geochemical response clearly reflects compositional differences of rocks in the various lithotectonic zones. The Archaean basement generally has a subdued geochemical signature. Intercalated bands of mafic rocks contain elevated background amounts of copper, nickel and cobalt. The supracrustal rocks are enriched in copper, arsenic, zinc and to a lesser degree, uranium. The migmatite complex, both folded and flat-lying, can be characterized as a uranium province - stream sediment samples collected within this area have a background uranium content of 34 ppm relative to an average crustal abundance of 2.8 ppm. Rapakivi granites have high contents of thorium, hafnium, and niobium.

The Gardar syenites are characterized by their elevated content of niobium, gallium and zinc. Water samples from streams draining these rocks are enriched in fluorine. The elevated value for these elements obtained from the north shore of Avaqqat Kangerluat on the northeast coast may indicate the presence of Gardar-aged dykes in this area (Steenfelt *et al.*, 1992).

The quantity of sample material available in the minus 0.1 millimetre size range was highly variable, depending upon the nature of the drainage from which it was collected. Analyses for some elements were therefore ultimately performed on very small aliquots, as little as one gram in some cases, and the caution is raised that the abundance of some elements may be understated (Steenfelt, 1990).

9. GEOPHYSICAL SURVEYS

The Thematic Map Series 94/1 includes aeromagnetic, gravity, and gamma-ray spectrometry maps. The aeromagnetic map is a compilation of three separate sources of data of widely differing quality. The modest quality of some of the data coupled with the scale (1:1 000 000) limits its utility.

There are two gravity maps, Bouger and residual Bouger. The Bouger anomaly map is strongly influenced by the ice cap and effectively mimics geography. The residual Bouger map eliminates this problem but because of the low density of data points is very generalized.

The gamma-ray spectrometric maps clearly demonstrate the enrichment in radioactive elements of the Gardar Province intrusive rocks as well as of the migmatized supracrustal rocks at the southeastern end of the Ketilidian belt (Armour-Brown *et al.*, 1984).

10. DISCUSSION

The following discussion can be considered to be a departure from the factual documentation of information available for the South Greenland map sheet area. Instead, an attempt is made to interpret the available information in order to emphasize the perceived potential that exists within the area for the discovery of new mineral occurrences.

It must be pointed out that the interpretation presented is only one of many possible and different interpretations. Further, and more importantly, there is no guarantee that this interpretation is correct.

There are three available ingredients with which an analysis of the mineral potential of the area can be made: geology, known mineral occurrences, and geochemical anomalies.

On the basis of exploration success to date as represented by known mineral occurrences, and the extent of the geological settings that host them, exploration for diamonds and gold is interpreted to offer the greatest opportunity for new discoveries. As the above descriptions demonstrate, there are many other commodities that may be present in commercial quantities within the map area. However, for the purposes of this discussion these are considered to be of lesser economic interest or to appeal to a narrower, i.e. more specialized, potential exploration population.

10.1 Diamonds

The optimal setting for the occurrence of kimberlites is the Archaean craton which occupies nearly half the western coast and the upper corner of the east coast. The presence of diamondiferous kimberlite dykes in the area must be considered encouraging, although kimberlite pipes rather than dykes or sills are to be desired. Pipes and sills or dykes can occur together. Microdiamonds, pyrope garnets and chrome diopsides have all been found in the area north of Ivittuut. Although part of the map area was investigated by heavy-mineral sampling, the area of known kimberlite occurrences was not included in the survey.

Exploration for diamonds has been intense in the Lac de Gras area of the Northwest Territories of Canada during the past several years. Relative to the level of exploration sophistication that has been brought to bear on the Lac de Gras area, this area of Greenland can be considered to be relatively unexplored. It must be acknowledged, however, that the area is topographically rugged, deeply incised by fjords, and heavily glaciated. Systematic evaluation of the type that has been carried out in the flat barrenlands of northern Canada where many kimberlite pipes remain essentially intact, would be difficult to apply here.

10.2 Gold

The Thematic Map Series does not cover the most northerly portion of Map sheet 1, which is underlain by rocks of Archaean age. There are no known mineral occurrences within these gneisses that underlie the Tartoq Group, but the regional geochemical sampling programme generated two areas of abundant, coincident anomalies that clearly warrant investigation. The first is located at the head of the fiord Eqaluit east of Paamiut (Frederikshåb) (also the site of kimberlite indicator minerals), and the second is on the headland that divides the two eastern branches of Kvanefjord. Both areas are underlain by a very prominent band of amphibolite, and it appears probable that it is the same band that passes through both areas.

In addition to gold and arsenic, both areas are anomalous in chromium, copper, nickel, cobalt, vanadium, iron as Fe_2O_3, CaO, and MgO. The second area is also anomalous with respect to tungsten.

The anomalous levels of CaO and MgO may reflect carbonate alteration of the amphibolites.

Exploration has shown that supracrustal rocks in this area, in particular the volcanic and metavolcanic portions, are the preferred host for gold occurrences. This may also be true of the amphibolite bands within the Archaean-aged rocks, but the following discussion pertains principally to the supracrustal rocks that are younger than the Archaean-aged gneisses.

Common characteristics of the most attractive occurrences, the Nuuluk-Taartoq belt and Nalunaq, are the presence of abundant pyrite or pyrrhotite and quartz veins. Major tectonic features also figure prominently in both areas.

The Tartoq Group rocks occur at the edge of the Northern Border Zone and were subjected to intense dextral shearing. The now-discrete patches of Tartoq Group rocks are interpreted (Petersen, 1993) to have originated as a single basin and the sulphide occurrences on both sides of Sermiligaarssuk to be remnants of one submarine-exhalative event.

The Nalunaq occurrence is located in the hanging wall of a thrust that has been traced for four kilometres and can reasonably be expected to extend further, under cover.

At Nuuluk-Taartoq the sulphides occur within a carbonatized horizon that is considered to be the product of exhalative volcanic activity (Steenfelt *et al.*, 1994). The massive pyrite at Nalunaq is a constituent of a package of chemical sediments. The origin of these rock types is commonly ascribed to volcanic exhalative activity.

The gold content of the disseminated sulphides in the Nuuluk-Taartoq belt is in general insignificant; the economically attractive grades are associated with concentrations of pyrite or pyrite-arsenopyrite and quartz. The gold content of the undeformed sulphides at Nalunaq is detectable but low, i.e. less than one gram per tonne. The gold grade in the quartz-veined intervals can be spectacular.

Arsenopyrite is present in both locations, although not necessarily in direct association with gold. Scheelite occurs at Nalunaq as well.

A simplistic model for future discoveries, derived from the above considerations, would have as essential ingredients the presence of volcanic or metavolcanic rocks, abundant sulphides, and a strong deformational overprint.

The South Greenland area has not been mapped in sufficent detail to permit the confident identification of all localities where these factors coincide, especially on the east coast. However, the known occurrences were detected by the regional geochemical surveys and there are other areas with similar geochemical signatures, or with anomalous levels of other elements. These areas are shown on Figures 4 and 5, and are discussed briefly below. The underlying data were taken from the element maps included in Thematic Map Series 94/1.

1) The peninsula east of Narsaq: The stream sediment survey detected a large arsenic anomaly inside which there are several gold and tungsten anomalies. This area

produced only one heavy-mineral anomaly for lead. The area is mapped as being underlain by late granite.

2) The peninsula on the north side of Søndre Sermilik: This area contains known gold occurrences and the stream sediment survey produced several gold anomalies in this general area. The peninsula is very anomalous on the basis of the heavy-mineral survey, and contains high quantities of gold, tungsten, arsenic, cobalt and nickel. The bedrock is mapped as early granite with minor inclusions of mafic material.

3) The peninsula northeast of Nanortalik: This area contains several stream sediment gold anomalies as well as single nickel, chromium, and tungsten stream sediment anomalies. The heavy-mineral survey generated abundant anomalies with respect to arsenic, uranium, lead, and nickel, in addition to a number of high gold values. The area is underlain by arkosic and pelitic gneiss as well as early granite, and may have geological similarities to the Nalunaq area on the Nanortalik peninsula.

4) Eggers Ø: The stream sediment survey generated a large arsenic anomaly and a coincident gold anomaly; the heavy-mineral survey detected anomalous levels of uranium, nickel and lead, but no gold or arsenic. The island is largely underlain by very high grade paragneiss with a large sheet of (migmatitic) leucogranite.

5) The environs of Lindenow Fjord on the east coast produced both stream sediment and heavy-mineral anomalies with respect to uranium, gold, tungsten, and arsenic. The area is largely underlain by arkosic gneisses.

6) The mid-point on Danell Fjord on the east coast has coincident stream sediment gold, tungsten and arsenic anomalies. The area is underlain by a mixture of paragneisses, and subordinate mafic metavolcanic rocks.

11. EXPLORATION AND MINING LEGISLATION

Mineral exploration and exploitation in Greenland is governed by the Mineral Resources Act of 1991. This legislation is applied by the Mineral Resources Administration for Greenland (MRA). A synopsis of pertinent regulations and currently held mineral rights is given below. Existing mineral leases are summarized in Figure 3.

All mineral exploration in Greenland must be conducted under licence and the right to explore is granted with respect to specific geographic areas. There are two types of prospecting licences, non-exclusive and exclusive.

A non-exclusive prospecting licence is normally granted for five years, carries no obligations with respect to work programmes or expenditures.

Exclusive exploration licences are normally granted for a period of five years and carry obligations for expenditure. Expenditure requirements are calculated as the sum of an annual fee per licence, and an annual expenditure expressed as an amount per square kilometre of licence area.

Current expenditure requirements, in Danish Kroner, are:

Year	Amount per licence	Amount per sq kilometer
1 - 2	100,000	1,000
3 - 5	200,000	5,000
6 - 10	400,000	10,000

Additional information can be obtained from:

Mineral Resources Administration for Greenland
Ministry of Environment and Energy
Slotsholmsgade 1 (4th floor)
DK-1216 Copenhagen K
Denmark
Tel: +45 33 92 75 00
Fax: +45 33 13 30 17

12. GENERAL INFORMATION

Both the Geological Survey of Greenland and the Mineral Resources Administration for Greenland have invested considerable effort in making information available to parties interested in mineral exploration in Greenland. Most publications are produced in English, and all personnel, both technical and administrative, in both organizations are fluent in English.

A good overview of the geology can be obtained from the publication *Geology of Greenland* (Escher & Watt, 1976). The Geological Survey of Greenland provides a regularly up-dated List of Publications, available from:

Geological Survey of Greenland
Øster Voldgade 10
DK-1350 Copenhagen K
Denmark
Tel: +45 33 11 88 66
Fax: +45 33 93 53 52

An overview of the social and political aspects of the country is conveniently summarised in the *Handbook for investors in the mining and petroleum industries*, available from the MRA. The address of the MRA is given in SECTION 11.0.

13. CONCLUSIONS

The South Greenland map sheet is underlain by Archaean-aged gneisses and supracrustal rocks and granitoid intrusives of Proterozoic age. The Geological Survey of Greenland (GGU) has mapped the area geologically and has assessed it by regional stream-sediment geochemical surveys, and to a lesser extent, by airborne geophysical surveys. Both GGU and various mining exploration companies have discovered and assessed a variety of mineral occurrences including base and precious metals, industrial minerals and diamonds. Cryolite, graphite and copper have been mined commercially.

Assessment of known mineral occurrences and permissive geological settings suggests that the greatest current potential for the discovery of economically viable mineral deposits is related to gold and diamonds.

Diamond-bearing kimberlite dykes have been investigated within the Archaean craton in the northwest corner of the map area. Evaluation of the known exploration efforts in this area leads to the belief that re-evaluation is warranted.

Vein-type gold mineralization, spatially associated with abundant sulphides and tectonic deformation, represents an attractive exploration target within this map area. Regional stream-sediment surveys conducted by GGU have generated anomalies in a number of areas that may indicate the presence of previously unknown occurrences of this or other types of mineralization.

Although the topography is rugged, virtually all of the areas of known or potential interest for mineral exploration are situated within easy access of tidal waters.

Political stability and favonrable government legislation with respect to exploration for and exploitation of mineral resources makes Greenland an attractive enviroment in which to operate.

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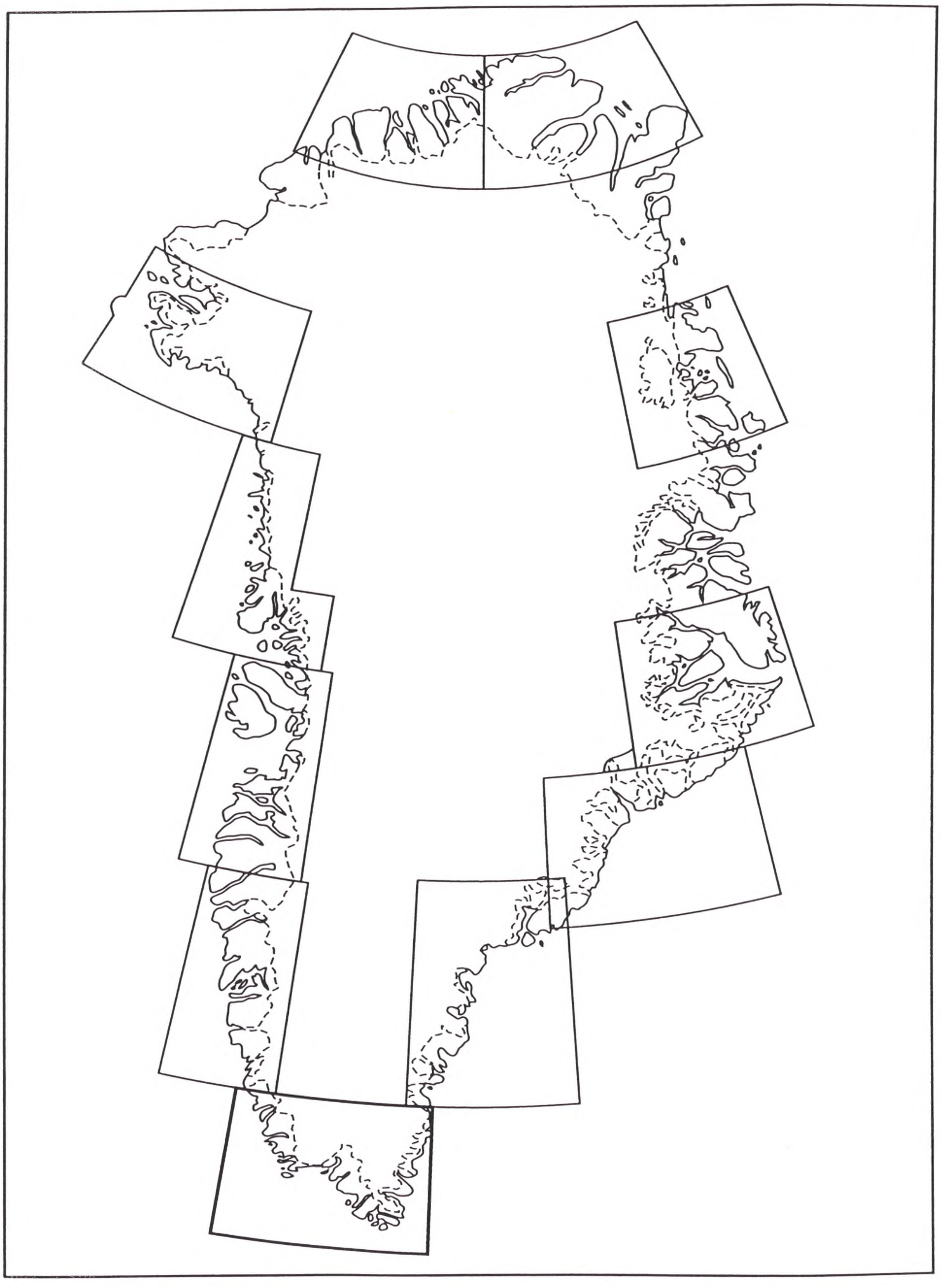

Fig. 1. Overview of 1:500 000 geological map sheets; South Greenland with heavy outline.

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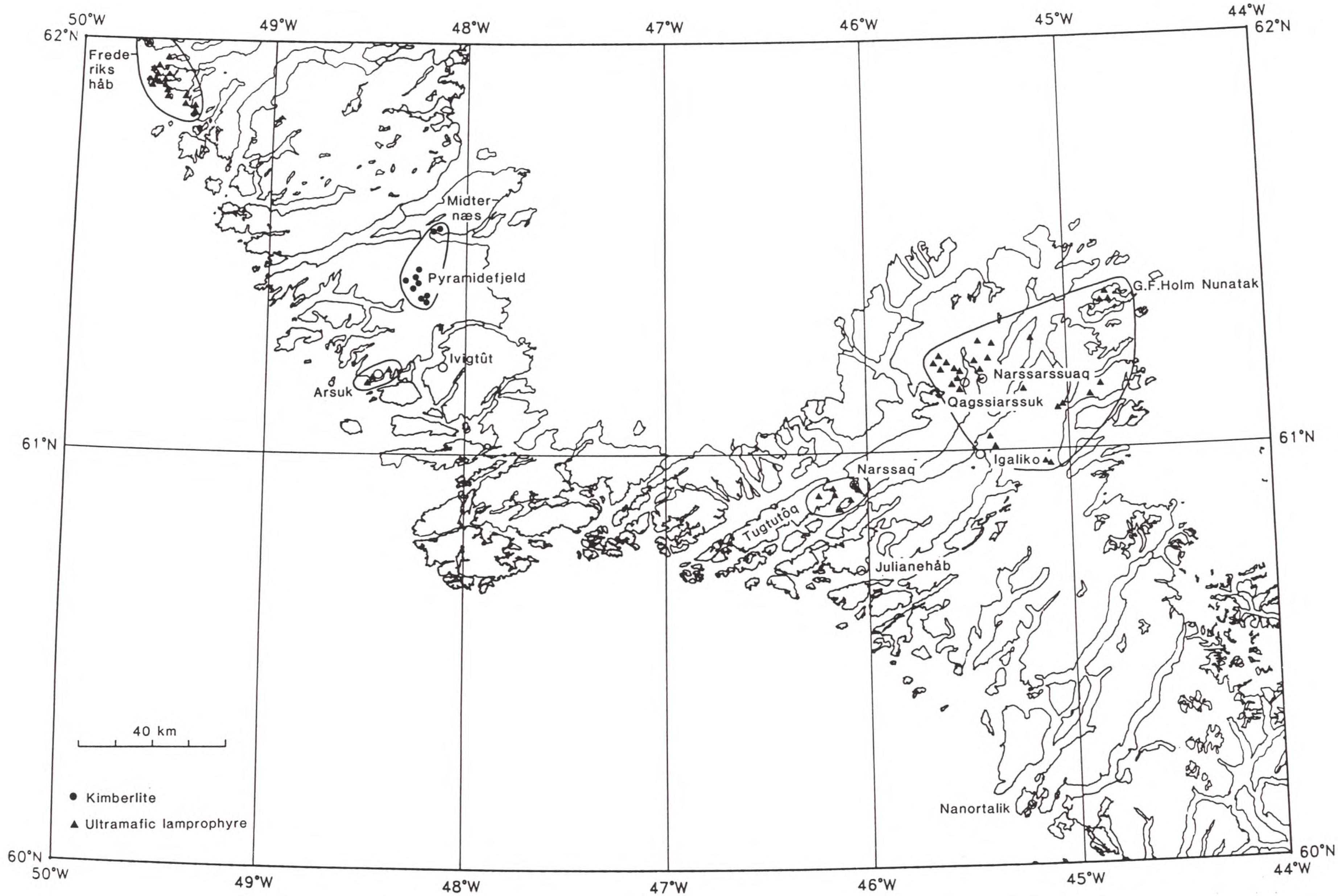

Fig. 2. Kimberlite occurrences in South Greenland, after Larsen (1991).

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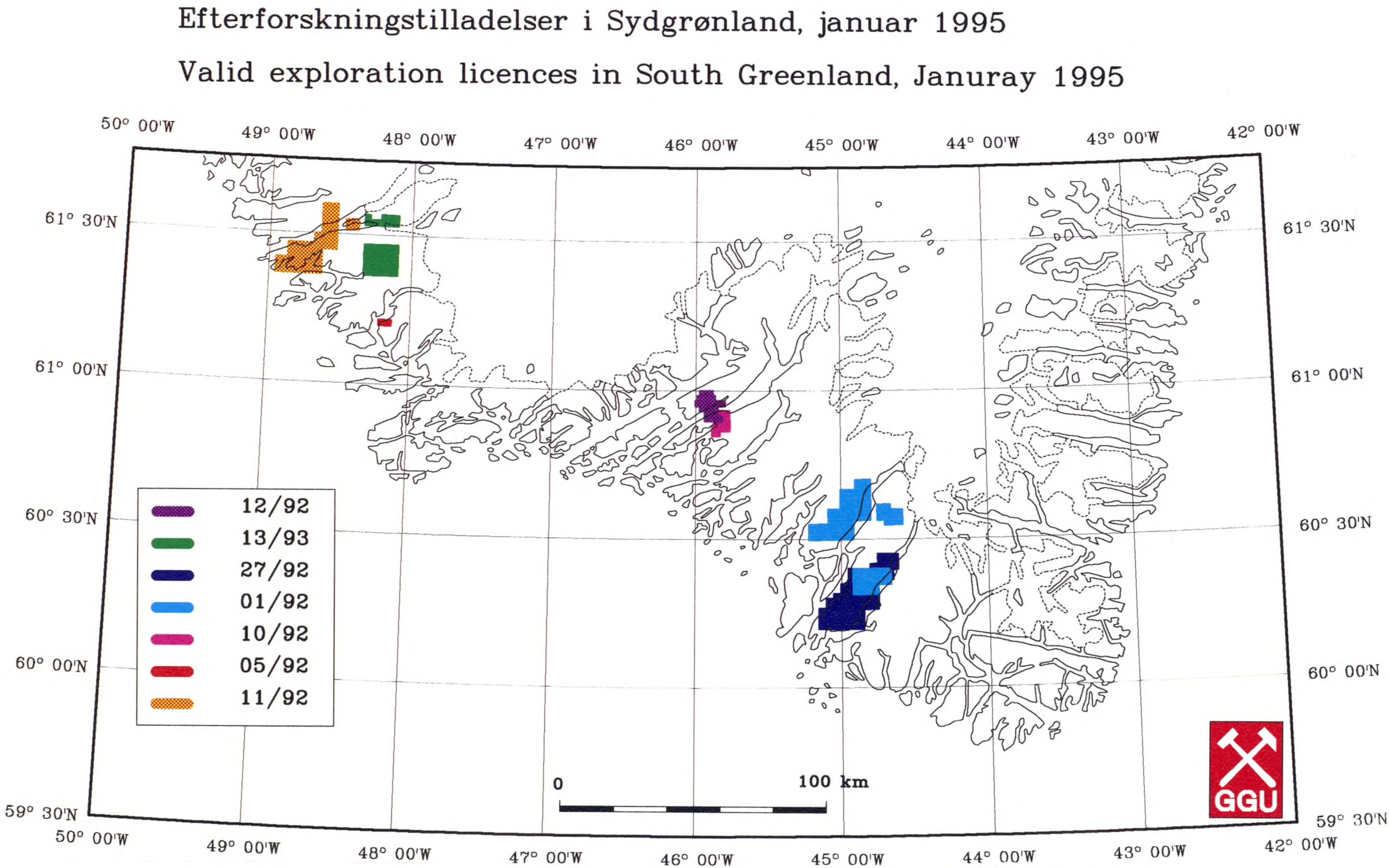

Fig. 3. Mineral exploration permits: Highwood Resources Ltd. (10/92), Ivittuut Minerals A/S (11/92), Laurel Point Pty. Ltd. (13/93), Mineral Development International A/S (12/92) & Nunaoil A/S (01/92, 05/92, 27/92).

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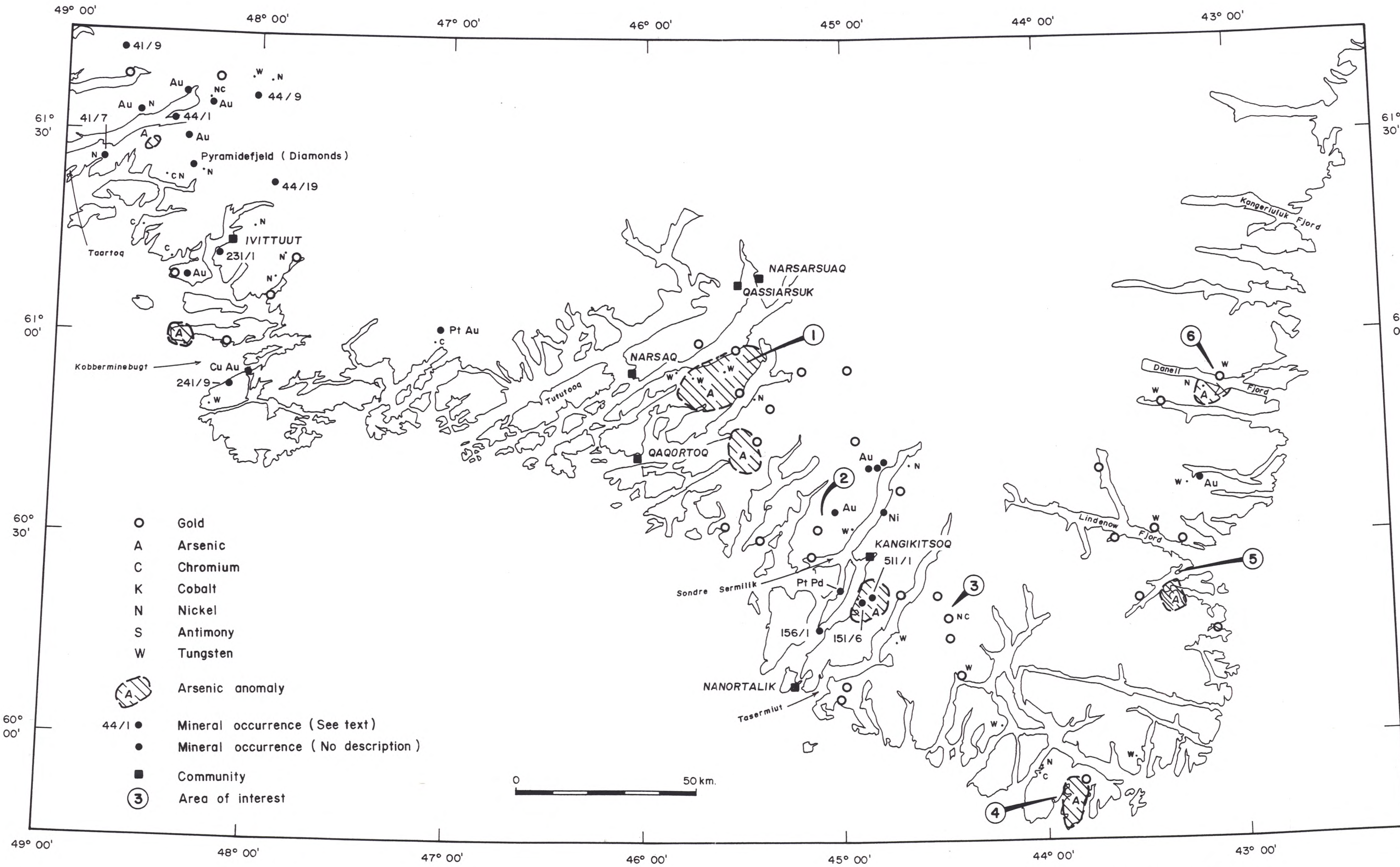

SOUTH GREENLAND
SHEET 1

FIG. 4

STREAM SEDIMENT GEOCHEMICAL ANOMALIES

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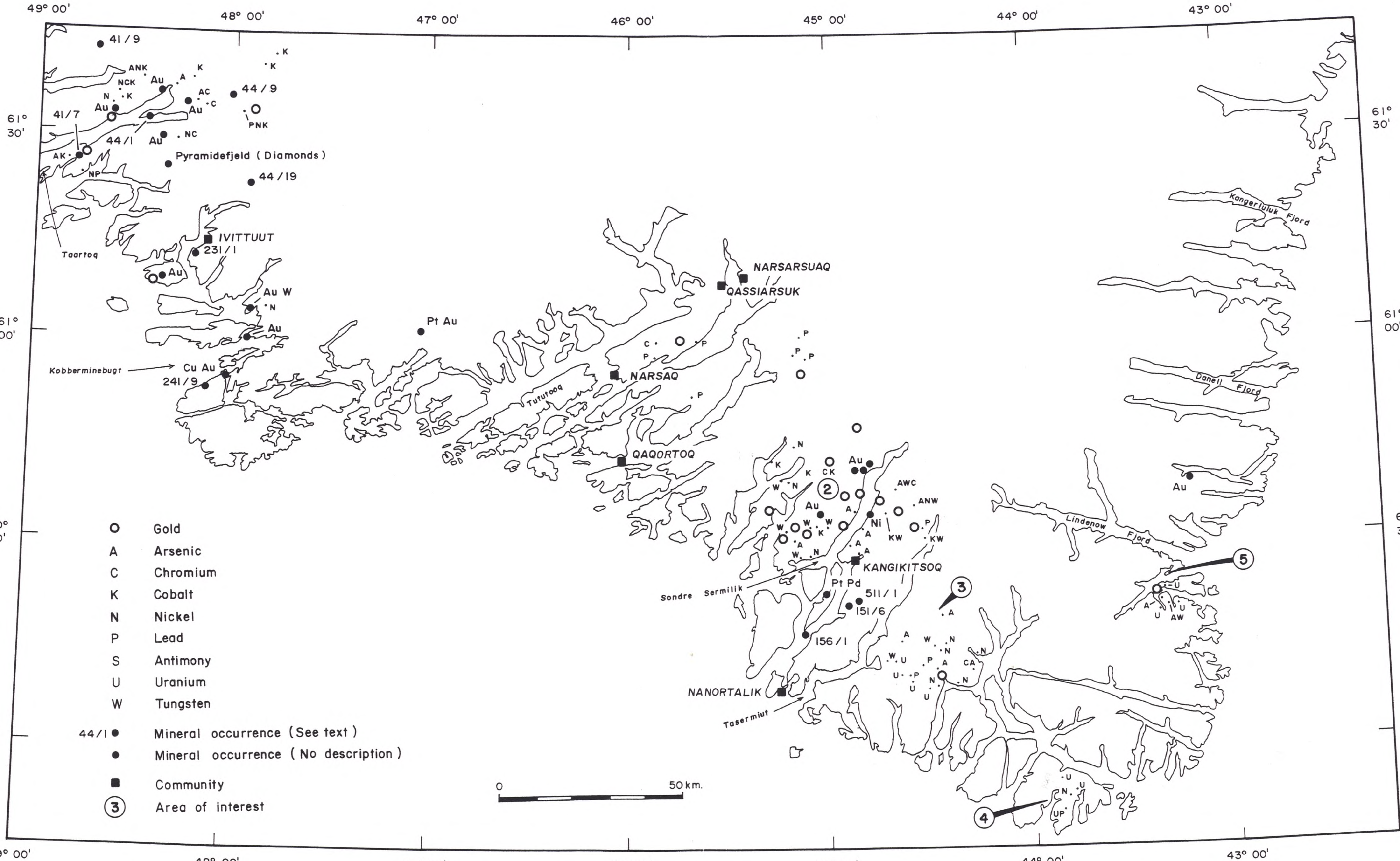


SOUTH GREENLAND
SHEET 1

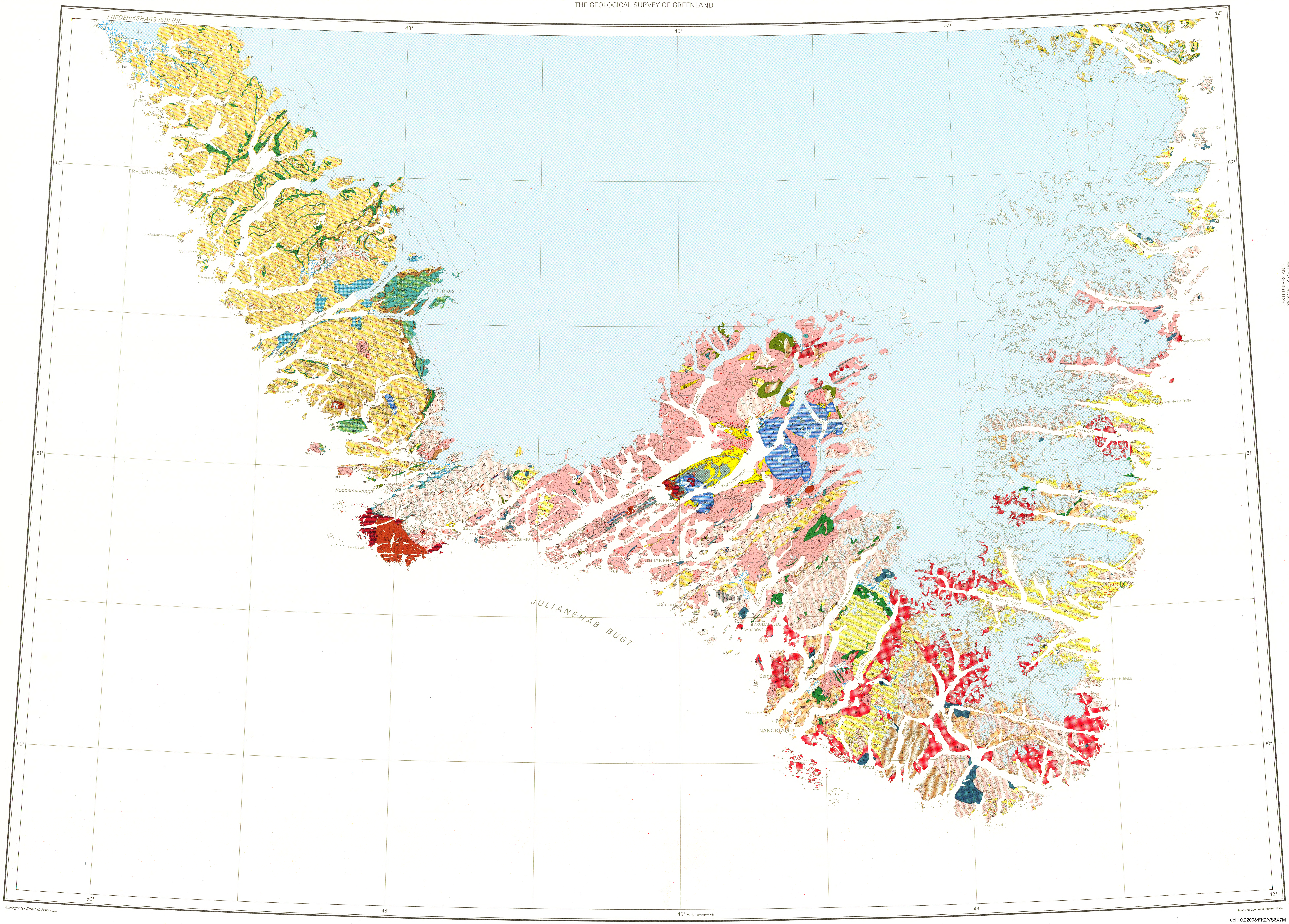
HEAVY MINEAL GEOCHEMICAL ANOMALIES

FIG. 5

DANMARK
GRØNLAND 1:500 000

GRØNLANDS GEOLOGISKE UNDERSØGELSE
THE GEOLOGICAL SURVEY OF GREENLAND

GEOLOGISK KORT OVER GRØNLAND
SYDGRØNLAND



Kartografi: Birgit H. Petersen.

Trykt ved Geodætisk Institut 1975.

doi:10.22008/FK2/VS6X7M

ICE

QUATERNARY, undifferentiated deposits

Th — DOLERITE, dykes of 3 km broad Mesozoic coast-parallel swarm

GARDAR INTRUSIVE ROCKS

ALKALI GRANITE, members of Narssaq, Ilímaussaq, Nunarssuit and Puklen intrusions

GRANITE *(sensu stricto)*, member of Nunarssuit intrusion
Xenolith inclusion zones (mainly basic metavolcanic rocks) in Nunarssuit intrusion

SYENITE, quartz syenite of composite giant dykes of Isortoq; various quartz syenite members of Tugtutôq central complex; quartz syenites of Narssaq, Ilímaussaq and Nunarssuit intrusions, saturated pyroxene-fayalite syenite of Kûngnât complex, and larvikitic and quartz syenites of Klokken intrusion. Xenolith inclusion zones in Nunarssuit intrusion

SYENITE, just-undersaturated augite syenite of composite giant dykes of Tugtutôq and Isortoq; augite syenite, heterogeneous syenite and pulaskite of Ilímaussaq intrusion

AGPAITIC NEPHELINE SYENITE, members of Ilímaussaq intrusion

NEPHELINE SYENITE, members of Igaliko intrusion (main members: Motzfeldt Centre ψ_1, North Qôroq Centre ψ_2, South Qôroq Centre ψ_3, Igdlerfigssalik Centre ψ_4

σ — MICROSYENITE DYKES

δ — DOLERITE

GABBRO, sills of olivine-free basalt in lower part of Eriksfjord Formation; mildly alkaline olivine gabbro dykes of Nunarssuit and Tugtutôq-Narssarssuaq areas

EXTRUSIVES AND SEDIMENTS OF THE ERIKSFJORD FORMATION

SATURATED EFFUSIVES WITHOUT QUARTZ (trachyte)

BASALT

CARBONATITE. Calcareous tuffs

SANDSTONE

KETILIDIAN MOBILE BELT

LATE GRANITES

GRANITE *(sensu lato)*, rapakivi suite of the Sydprøven-Kap Farvel-Kangerdluluk area

PYROXENE- AND GARNET-BEARING QUARTZ MONZONITE of variable composition; with local gneissose foliation

GRANITE *(sensu lato)*, allochthonous granites outside the area of Julianehåb granite and foreland granites in Ivigtut area; biotitic, biotitic foliated, biotite-rich enclaves, hornblendic, hornblendic foliated, amphibolitic enclaves

GRANITE *(sensu lato)*, granodiorite to adamellite; in some areas poor in quartz, late members of the Julianehåb granite, occurring between Kobberminebugt and Igaliko Fjord in the south-west and between the fjords Kangerdluluk and Napassorssuaq in the east; biotitic, biotitic foliated, hornblendic, hornblendic foliated. The Julianehåb granite on the east coast consists of several generations between which major boundaries have not been mapped. Correlation with the west coast is uncertain

APLITIC GRANITE

EARLY GRANITES

GRANITE *(sensu lato)*, early, gneissose granite, members of Julianehåb granite; biotitic, hornblendic

GRANITE *(sensu lato)*, early granites outside Julianehåb granite, biotitic, hornblendic,

LEUCOCRATIC GRANITE *(sensu lato)*, garnet-bearing alaskite and biotite-bearing charnockite south-east of Tasermiut

APPINITIC ROCKS, basic to intermediate intrusions with intimate connections to plutonic and granitic activity

HYPERSTHENE GABBRO, belonging to rapakivi suite

DIORITIC ROCKS, usually migmatitic associated with appinitic intrusions in the Qagssimiut area; composite granite-diorite intrusion between Sârdloq and Sydprøven; unfoliated dioritic rocks north of Lichtenau Fjord

DIORITE, marginal components of zoned diorite-monzonite intrusions north and east of Narssarssuaq; other independent intrusions north and east of Narssarssuaq, around Julianehåb and at Kobberminebugt

PYROXENE-BIOTITE MONZONITE, central components of zoned monzonite-diorite intrusions (two independent occurrences) north and east of Narssarssuaq

BASIC ROCKS OF UNKNOWN ORIGIN, bodies occurring in the Julianehåb granite, north-east of Sydprøven and on Amitsoq

ACID METAVOLCANIC ROCKS with occasional components of intermediate rocks from the area north-east of Narssarssuaq

INTERMEDIATE VOLCANIC ROCKS often of mixed character

BASIC METAVOLCANIC ROCKS, often with pillow structure and including hyaloclastites (Sortis Group of the Midternæs-Grænseland area and the Arsuk Group of the Arsuk Ø area

BASIC INTRUSIVES. Metamorphosed sills of the Sortis Group and Arsuk Group; occasional sills in Ketilidian sediments underlying Sortis and Arsuk Groups; intrusive bodies in the Julianehåb granite; metamorphosed basic sills in meta-arkoses west of Tasermiut

BASIC METAMORPHIC ROCKS, metavolcanic rocks mixed with meta-intrusives; (south of Arsuk Bræ: Sortis Group, Arsuk Ø: Arsuk Group); volcanics of the Ilordleq Group (Kobberminebugt); Tasermiut volcanic rocks

METAVOLCANIC ROCKS MIXED WITH METASEDIMENTS belonging to the Ilordleq Group

METASEDIMENTS of the Vallen Group of the Midternæs-Grænseland area and of the Ikerasârssuk Group of the Arsuk Ø area

MICA SCHIST in part highly metamorphosed Vallen Group; mica schists of Ilordleq Group at Kobberminebugt

METAMORPHOSED SEMIPELITES of the Qipisarqo Group

CARBONATE ROCKS

META-ARKOSES, partly with acid volcanic rocks and volcanogenic sediments from the Tasermiut region and the east coast; siliceous metasediments of the Qipisarqo Group north of Kobberminebugt

QUARTZO-FELDSPATHIC GNEISS with relics of quartzitic or acid volcanic rocks; leucocratic gneisses and aplitic gneiss in the Julianehåb granite; the brown symbols indicate pelitic gneiss horizons north-east of Lindenows Fjord

PELITIC TO SEMIPELITIC GNEISS (Late Archaean or Early Proterozoic), often with considerable pegmatite migmatisation, generally with cordierite and sillimanite and in the westernmost occurrences on Sermersôq also andalusite; the blue symbols indicate lenses of calc-silicate rock or marble

GNEISS, mainly granodioritic or quartz dioritic; biotitic, hornblendic

md — METADOLERITES

ARCHAEAN BLOCK

METAVOLCANIC ROCKS MIXED WITH METASEDIMENTS, belonging to the Tartoq Group

QUARTZO-FELDSPATHIC GNEISS with relics of quartzitic or acid volcanic rocks (Ikermit supracrustal series; Rb/Sr whole rock isochron: 2600 ± 35 m.y.)

AMPHIBOLITE, marker horizons in gneiss

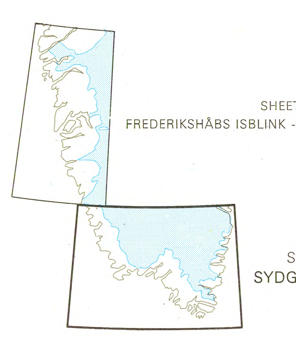
MICA SCHIST (garnet, cordierite, sillimanite bearing)

GNEISS, mainly granodioritic or quartz dioritic; biotitic, hornblendic, muscovite-bearing, with agmatites and enclaves of Tartoq Group greenschists. A concentration of the biotitic and hornblendic symbols east of Grønnedal indicates the Ika gneiss series, consisting of banded supracrustal rocks with calc-silicate lenses of unknown age

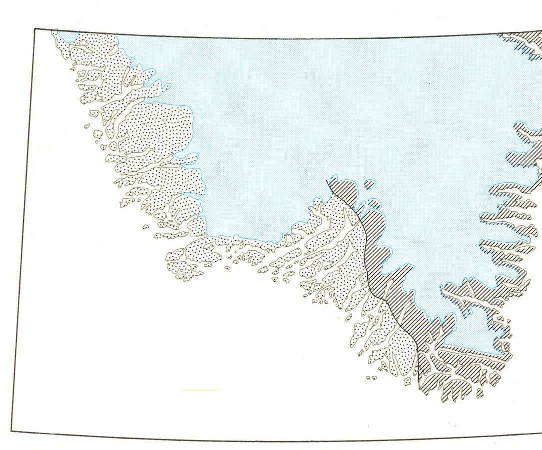
GNEISS with abundant gabbro-anorthositic enclaves. The matrix is mainly granodioritic to quartz dioritic

GRANITE *(sensu lato)*, biotitic, foliated biotitic, with enclaves of mica schist; with amphibolitic enclaves

MIGMATISATION



Topography based on maps of the Geodetic Institute, Denmark, and reproduced with permission A. 649/72.



Geological mapping mainly on scale 1:20 000 carried out by GGU teams 1958-1969.

Geological mapping by GGU teams on scales of 1:40 000 or smaller 1966-1970, and by R. H. Wallis with the St. Andrews University South Greenland Expedition 1960 and the Birmingham University Expedition to South Greenland 1961.

General compilation by J. H. Allaart.

GEOLOGICAL MAP OF GREENLAND
SHEET 1
SYDGRØNLAND

1:500 000

5 0 25 50 75 km

5 0 10 20 30 40 statute miles

Højdeforskellen mellem kurverne 200 m

Contour interval 200 m

BOUNDARY, established
BOUNDARY, inferred
STRIKE AND DIP of lithological layering of any origin
STRIKE AND DIP of foliation
FAULT AND MYLONITE
THRUST
UNCONFORMITY
CONGLOMERATE
AUGEN TEXTURE
PORPHYRITIC TEXTURE
MINE, abandoned

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