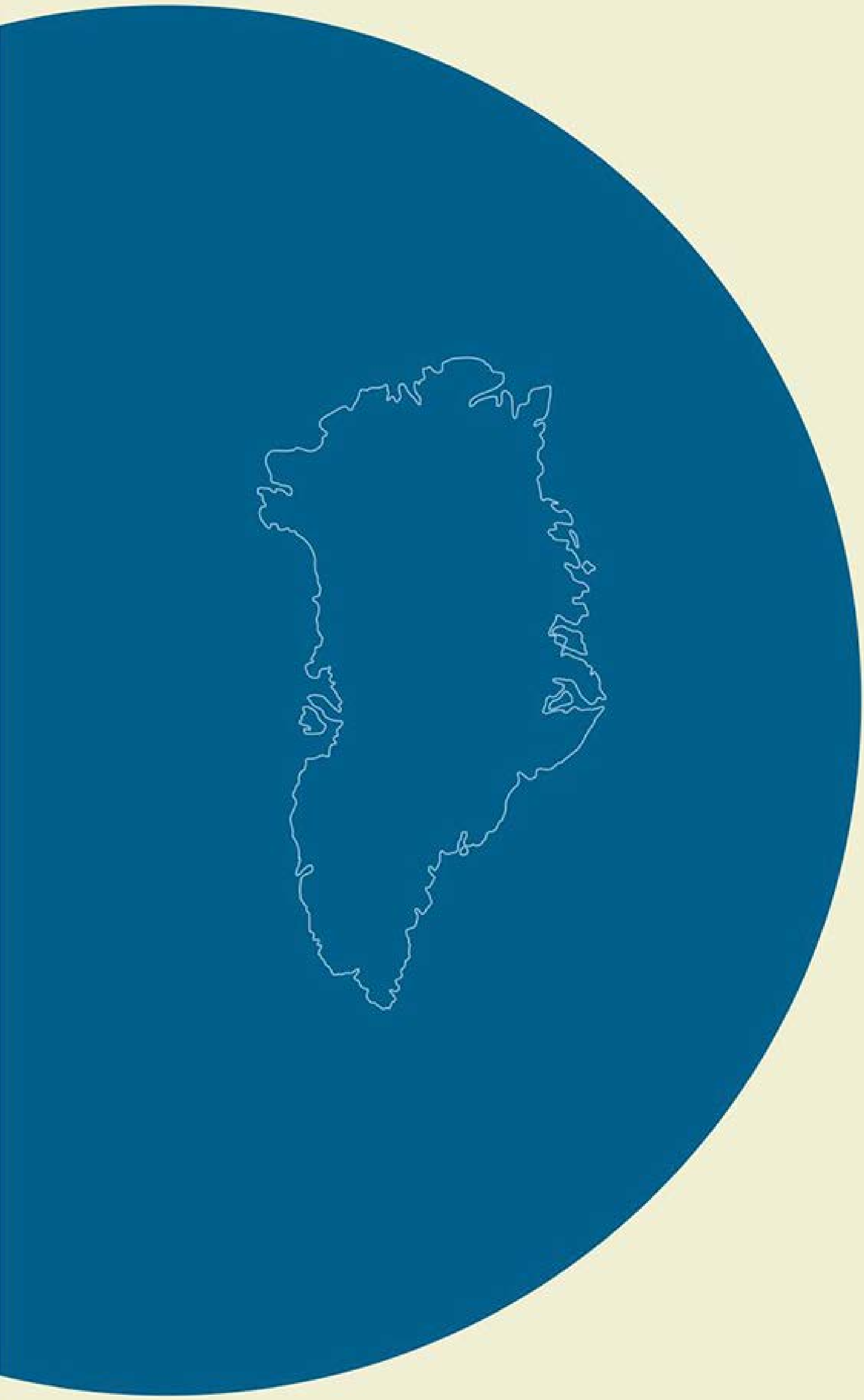
DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 1998/29

Fifty years of ore exploration in Greenland by Kryolitselskabet Øresund A/S; a memoir

Leijo Keto



GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF THE ENVIRONMENT

G E U S

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GEUS

Preface

This report gives a review of the exploration activities in West Greenland by the Danish company Kryolitselskabet Øresund A/S over the period 1938 to 1987. The company was responsible for the exploitation of the famous cryolite deposit at Ivigtut in South West Greenland. Mining operation stopped in 1987 after a 130-year era of cryolite production. The company closed down its exploration activities in Greenland and its production in Copenhagen. This report, which appeared at the end of the year 1997, is the first historical presentation of the comprehensive exploration activities, which, practically for several decades, were the only commercial prospecting of the mineral potential in West Greenland. The presentation is by a geologist who participated in the activities for more than thirty years, most of the time responsible for the activities and during the latest 9 years as the company's chief geologist. Leijo Keto has written this memoir after retirement in 1989.

The Geological Survey of Denmark and Greenland (GEUS) considers this account to be of great interest to many geologists and private companies working in Greenland. Leijo Keto has kindly given the Survey permission to publish his memoir.

Furthermore, it should be mentioned that drill cores as well as maps and reports from the company's activities were taken over in 1989 by the Survey after the close down of the Cryolite company. Most of this material is stored at the Survey's drill core library and is open for inspection and analyses to companies and prospectors working in Greenland.

Copenhagen, March 1, 1998

Martin Ghisler
Director

CONTENT

INTRODUCTION

When considered from a historical point of view, common interest in determined and systematic ore exploration in Greenland has been rather short-spanned and casual in character even as late as in the post-war period. This has been primarily due to both the geographical position and to the physical and logistic conditions prevailing in Greenland. The lack of legislation which regulated the exploration and mining of the discovered ore deposits, has been another cause contributing to the same result in the past. The situation was not improved for this part until 1965, when Greenland was given its first own Mineral Resources Act.

The history of exploration and prospecting activity by Kryolitselskabet Øresund A/S in Greenland, which has been dealt with in the present paper, covers a period of 50 years, from 1938 to 1987. Including the breaks during the war and in a short period in the 1950s, the activity represents the longest continuous period of exploration operations in Greenland.

Although the exploration work by the Company did not result in the opening of new mining operations of its own, the work constitutes however, both qualitatively and quantitatively, the most considerable contribution to the unravelling of the economic-geological prerequisites for a future exploitation of mineral resources of Greenland, accomplished by a private company in Greenland so far.

The present write-up does not even pretend to be an exhaustive historical account of the subject. The main emphasis in the presentation is laid primarily upon the description of the work and its results in the period of the author's own participation in the work. As far as that goes, the limited available basic data have further restricted the scope of the description.

This paper has arisen from the author's private interest to collect and save concise memoirs of a work, which has been composed of contributions of countless people, often made under the very harsh conditions of Greenland. It is in the nature of things, that the interest of a participant to the story is more emotionally engaged and of more durable nature than the interest of the promotor, which often is more business-minded and short-lived in its nature.

Hørsholm, november 1997,
Leijo Keto

COMPANY's EXPLORATION ACTIVITY IN THE LATE 1930's AND IN THE FIRST YEARS AFTER WORLD WAR II

Cryolite prospecting, 1938 - 1952.

There is a shortage of factual information on the Company's exploration activity in the early times before World War II. In 1931 the Company appointed Mr. Richard Bøgvad as its first professional geologist. In the first phase he was given the assignment of giving a geological explanation to the origin of the cryolite deposit at Ivigtut and, in particular, estimating the ore reserves in it. Beside his main occupation he carried out geological studies in Ivigtut and its neighbourhood almost every summer right up till the outbreak of the war.

In 1938 he started in the environs of Ivigtut on a very modest scale - himself as the only active in the field - studies, which can be considered as the beginning of the systematic cryolite exploration. His studies were based on a geochemical method for the qualitative demonstration of the element fluorine in the rocks with the help of chrome-sulphuric acid. The war broke off his work after only two summer seasons, however, as a result of these studies he was able to demonstrate, that cryolite was found as an occasional mineral in very minute amounts in some acid alkaline dike rocks at a couple of places in the vicinity of the Ivigtut cryolite deposit.

During the war, when communication between Greenland and the mother country was broken off, mining of the strategically important cryolite continued and the production was sold to USA. Even some investigations were made to gain more insight to the geological position of the cryolite ore in relation to the surrounding bedrock. Thus, for the first time in this context, the Swedish-Canadian geophysicist H. Lundberg carried out magnetic and electromagnetic measurements in the immediate surroundings of the cryolite pit.

Upon the end of the war, beginning with the summer of 1946, the Company resumed its cryolite prospecting by Mr. Bøgvad. The main interest was focussed on the zone accommodating the above mentioned alkaline dike rocks. The follow-up studies in 1946 - 1947 included a magnetic and gravimetric measuring program to start with, and ended in 1948 and 1950 with a diamond drilling program with the purpose of studying some observed gravity anomalies in the Ivigtut valley. However, new discoveries of cryolite were not made during these studies.

Studies on eudialyte in the Ilimaussaq batholit

Beside cryolite prospecting, the Company also carried out other economic-geological studies in this period. Just before the war in 1939, the Company started the studies concerning the exploitation of the mineral eudialyte from the Ilimaussaq nepheline-syenite batholit in the Julianehaab district. The idea was to produce a commercial zirconium compound from the eudialyte concentrate. Bulk samples were brought home from the eudialyte-rich outcrops in the batholit for model scale studies in the laboratory. The field studies continued for a couple of summers after the war, but efforts to develop an economic and viable extraction process failed and the project was eventually abandoned.

Iron ore prospecting at Jernhatten

The magnetite mineralization at Jernhatten, on the mountain plateau above the Grønnedal marine base in the neighbourhood to Ivigtut, had been well-known long ago when the Company started to explore the deposit, just at the beginning of the war. After the war studies were continued in a reconnaissance scale until 1948, when a systematic magnetic measurement and geological mapping of the area was carried out, together with comprehensive grab sampling.

The results of the study concluded, that the magnetite ore of Jernhatten was the only iron ore prospect encountered in Greenland at that time, which could have an economic potential.

Therefore, the Company worked out, in a mutual understanding with the Administration of Greenland (Grønlands Styrelse) of that time, an exploration project for the demonstration of the ore reserves, based on a diamond drilling program. The investigation revealed, that the ore reserves were both qualitatively and quantitatively too weak to give a basis for an economic mining operation.

- - -

The main exploration interest during this time was entirely focussed on cryolite prospecting. The sudden death of Mr. Bøgvad in the midst of his field work in the Ivigtut area in the summer of 1952 caused an unexpected interruption to the prospecting work.

As a successor to him the Company appointed Mr. Hans Pauly, who in the first years in office was engaged with mine geological duties in Ivigtut. As a consequence hereof, a pause of a few years duration was issued in the exploration work.

INTENSIFIED CRYOLITE PROSPECTING IN 1950's AND EARLY 1960's

Organization of the prospecting and exploration division in the Company

In the early 1950s a number of technical improvements was carried through at the Ivigtut cryolite pit, the most important of which was without doubt the new transportation tunnel which was put into service in 1951. Thanks to the tunnel, the ore haulage system improved in efficiency very considerably and made it possible to increase the ore stoping capacity in the pit. As a consequence hereof, the total life time for the remaining ore reserves became significantly reduced. Impressed by these circumstances a concept of a new and intensified cryolite prospecting activity ripened within the company sphere.

In the mid-1950s the Company and Ministry of Greenland made a joint proposal for the concentration of the geological mapping work by the Geological Survey of Greenland (GGU) in the region between Frederikshaab and Kap Farvel in Southwest-Greenland, which the Danish Atomic Energy Commission subsequently agreed with. The objective was to produce a new and up-to-date geological map of the area, which could serve as a support to the increasing interest which at that time was directed towards the economic mineral potential (cryolite and nuclear energy minerals, in the first instance) of the region.

As a consequence hereof, GGU started systematic geological mapping of the Ivigtut region in 1956. By combining the mapping results which were gradually accumulating, with the results of the Company's own prospecting work, it was possible to create a preliminary genetic model for the formation of the cryolite ore deposit. Though still hypothetic in many respects, it was more reliable and instructive than the previous proposals to be used as a guide in the continued prospecting work.

Under these premises the Company launched, after a standstill of five years. the cryolite prospecting campaign anew in 1957. In the same year the Company appointed to its staff Mr. Veijo Yletyinen as an exploration geologist, with the task of being responsible leader of the field work. In the following year another geologist, Miss Lea Aho, was engaged as a petrologist and laboratory geologist. At the same time the necessary working facilities in the premises of the Company were enlarged and completed.

The regular field work was carried out primarily by undergraduate geology students. As it was impossible to hire the necessary number of geology students from Denmark with a background in Precambrian and ore geology, the Company was forced to employ foreign students. Already in this period, like in many years to come, the Company employed a large number of geology students from Finland.

Cryolite prospecting in the Ivigtut region, 1957 - 1962

Cryolite prospecting came to cover the area between Tigssaluk fiord - Arsuk glacier in the north and Arsuk fiord's southern entrance - Northern Qipisarqo glacier in the south (fig. 1). In addition, the whole Ivigtut peninsula as far as to the Ika-Grønnedal alkaline massif in the east was covered by a very detailed dike rock mapping (scale 1:500). In the region between Kobbermine Bay and Julianehaab reconnaissance studies on intrusive and dike

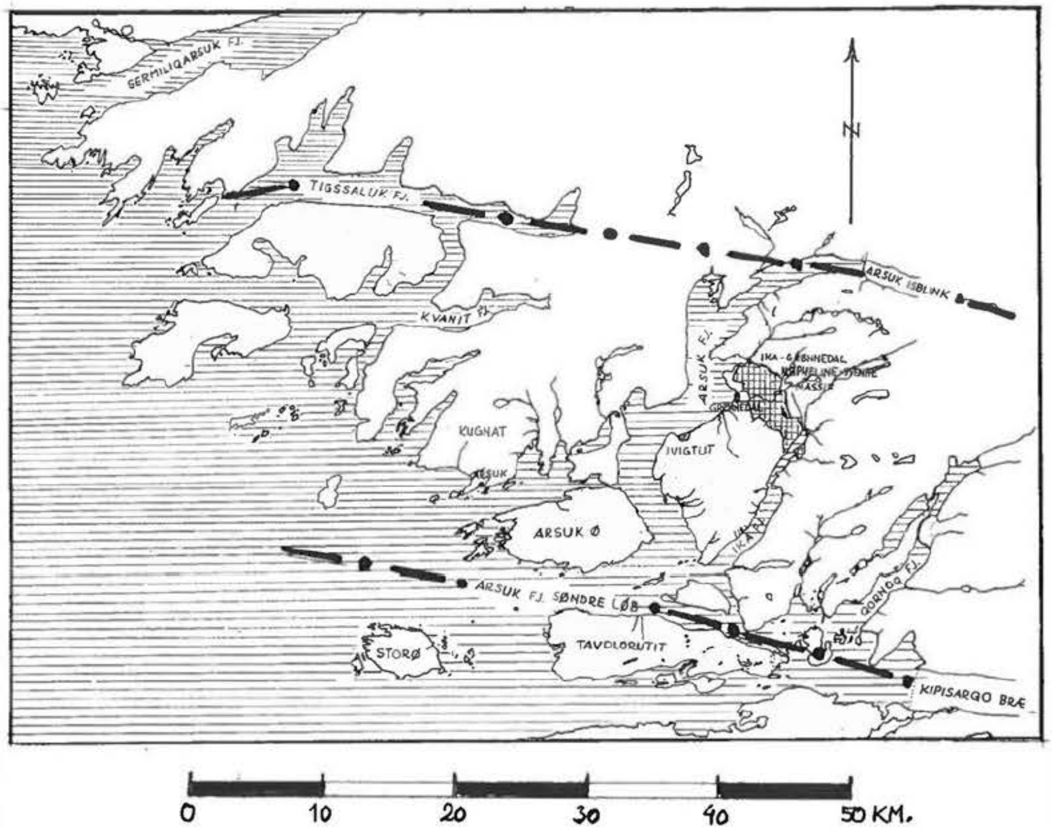


Fig. 1. Shoreline map of the Ivigtut region.

rocks were carried out.

At Ivigtut the Bunkebreccia formation was studied in greater detail by a thorough geological mapping and by drilling 4 drill holes into it.

The field studies at that time were almost exclusively based on visual geological observations, without use of any auxiliary geophysical or -chemical methods. In connection with radioactive mineralizations the observations, as a rule, were supported by Geiger counter readings, though the instrument was never used to cover any particular area with a systematic measurement.

The principal results of the cryolite prospecting in this period are summarized in the following conclusions:

– New economic cryolite deposits were not discovered.

– Cryolite (or closely related minerals) were observed in sporadic amounts in alkaline dike rocks of Gardar age at 2-3 new localities.

– Other accompanying mineralizations were also observed in the rocks of Gardar age and their regional distribution was recorded. Of this suite the mineralizations of fluorspar, carbonate minerals, radioactive minerals and sulphides of Zn-Cu-Pb-association are worthy of mentioning.

– New intrusive bodies of Gardar age were not observed. Magmatectonic structures, belonging to the Gardar period, were observed (Ika-pynt breccia, Kornoq breccia), but not studied in detail.

– The probing of the Bunkebreccia formation was discontinued because "...there was no evidence at that time to strengthen the assumption of the existence of a mineralized or non-mineralized intrusive rock body within a reasonable depth beneath the breccia...". It was acknowledged though, that it was not possible to express, based on the available evidence, what possibly could be found in greater depths below the breccia.

The Eaton Expedition, 1959

Based on the practical experience accumulated with these studies, the prospecting organization had gradually developed to meet greater and ever changing demands. The Company had thus a tool at hand, which was adapted to prospecting and exploration work in an even broader domain.

A preliminary acquaintance of this sort of activity was made in 1959, when the Company's own geologist Mr. Veijo Yletyinen participated as an observer in the so-called Eaton Expedition to West-Greenland. The expedition was a Canadian-promoted and funded exploration project which was carried out in the area between Søndre Strømfjord and Godthaab in West-Greenland.

The prospecting results of the enterprise were modest, but valuable experience was gained especially on the extensive use of a helicopter for preliminary reconnaissance work

GENERAL ORE EXPLORATION 1960 - 1987

Outline

The modest beginning in late 1930's had till the entrance of 1960's developed gradually to an all-round exploration and prospecting of mineral deposits of any type. This activity continued uninterrupted for nearly three decades, until 1987. During this period of time the Company was engaged in prospecting and exploration activity all over Greenland wherever the economic exploitation of a given mineral deposit was considered feasible.

During the past years a great number of exploration projects have been accomplished, the scope and duration of which have varied in accordance with each particular project. Arranged in chronological order, the different projects can be presented as follows:

— Molybdenite prospecting af Ivisartoq, Godthaab district, 1960.

— Airborne reconnaissance by helicopter in South-West Greenland, 1961 -1962.

— Airborne reconnaissance by helicopter in East-Greenland, 1963.

— The ore investigations at Lersletten, 1963 - 1964.

— Mineral exploration in the Søndre Isortoq area between Sukkertoppen and Godthaab, 1965 - 1973.

— The airborne magnetic survey over West-Greenland, 1965, 1967 - 1968.

— Nickel prospecting in the Søndre Isortoq area, 1965 - 1973.

— Investigations of the Isua Iron Ore Deposit, 1966 - 1967, 1971 - 1974.

— The hydroelectric power scheme with the Isua Iron Ore Project, 1974 - 1983.

— Investigations of niobium mineralisations at Qaqarssuk carbonatite complex, 1965, 1970 - 1971, 1975 - 1976.

— Investigations of the Itipilua olivine deposit at Fiskefjord, 1966 - 1967, 1971.

— Studies of kimberlite and related rocks in the Søndre Isortoq area 1970 - 1973.

— Mineral prospecting in the country between Sukkertoppen Ice Cap and Nugssuaq, 1977 - 1979.

— Studies on anorthosite rock at Qaqortorssuaq, Søndre Strømfjord, 1977.

— Prospecting in the Ata Area, 1980 - 1985.

— Exploration of graphite at Akuliaruseq, 1982 - 1985.

— Resumed cryolite prospecting in the Ivigtut region, 1984 - 1987.

The positions of a number of individual exploration projects have been shown on the map in fig. 2, and in the following chapters a short description of each project will be given together with the main results.

Molybdenite prospecting at Ivisartoq, Godthaab district, 1960

A molybdenite-bearing occurrence at Ivisartoq,

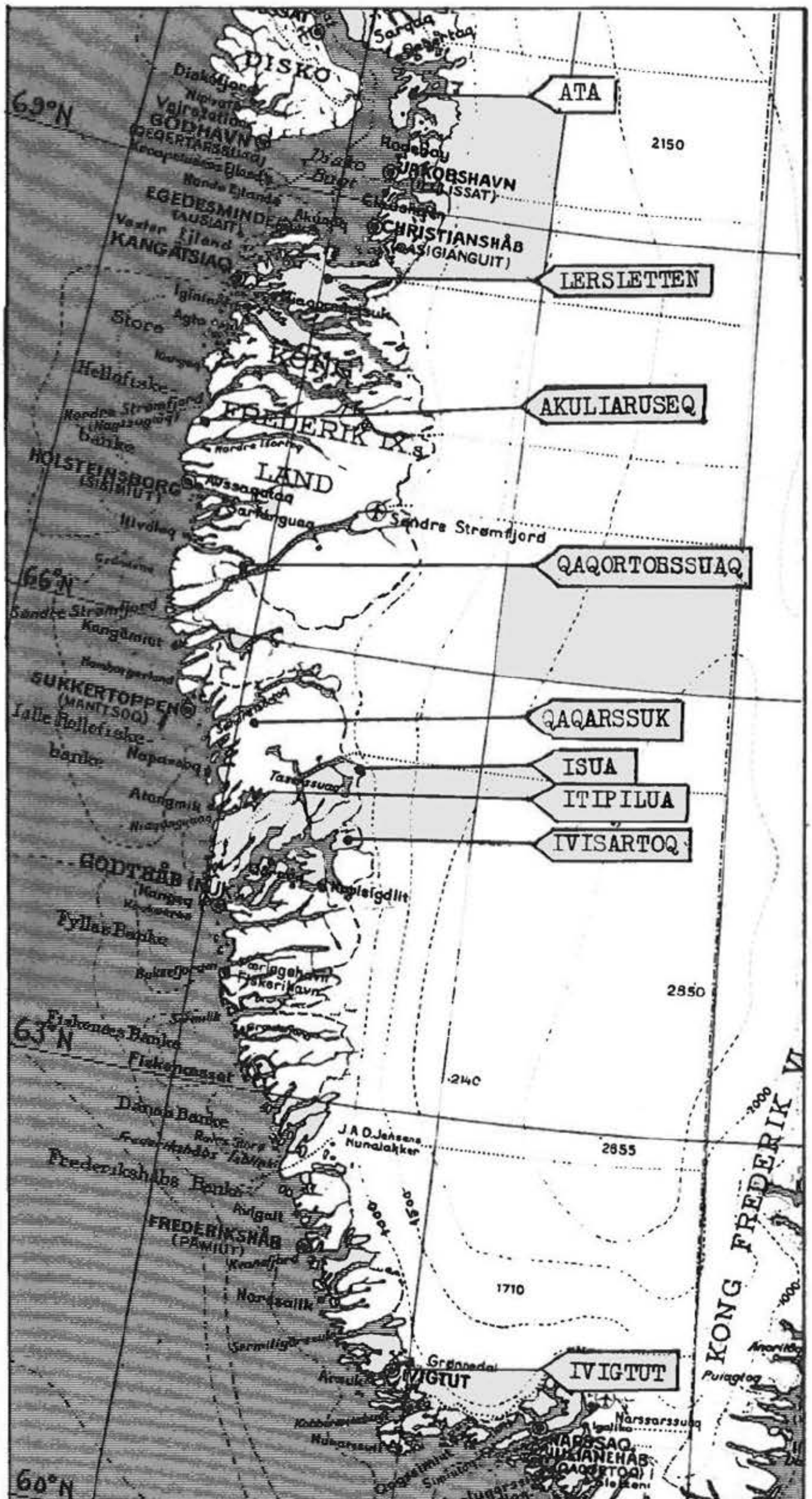


Fig. 2. Map of the SW-Greenland, showing the position of a number of individual exploration projects.

far up in the Godthaab fiord, was one of the discoveries by the Eaton-Expedition in 1959 (fig. 2). Encouraged by the assay data on the collected samples, it was decided to carry out a follow-up study in 1960, consisting of a detailed geological mapping and extensive sampling. A light portable diamond drilling unit was used for the first time on an experimental basis for the sampling. The machine could drill holes 30-35 m in length.

The geological framework of the peninsula is dominated by a supracrustal schist series and associated amphibolites, which are cut by ultrabasic bodies, younger dolerite dikes and a number of impressive, coarse-grained pegmatite dikes. The supracrustal rocks are both of sedimentary and volcanic origin.

Sulphide mineralizations occur in structure-parallel shear zones. The most marked of these forms a rusty horizon running along the contact zone between a layer of quartz-feldspar schists and an overlying amphibolite. Molybdenite is found in this zone in a pyrite mineralization as an accessory together with sporadic chalcopyrite.

The mineralization is considered as a metasomatic product formed by a reaction between the supracrustal rocks and hydrothermal agencies introduced during late-kinematic phases.

The best section of the mineralized horizon has dimensions of about 10-15 x 2500 m. Within this section the molybdenite mineralization shows an irregular distribution. Chemical assays vary from 0,10 % to 0,80 %MoS_2 in individual samples. The results proved that the occurrence is insignificant both in qualitative and in quantitative terms.

As another characteristic of the Ivisartoq area, a great number of extensive pegmatite dikes consisting of very coarse-crystalline quartz, feldspar and tourmaline was observed .

The company appointed at that time Mr. Leijo Keto as an exploration geologist, and he was entrusted with the task of leading and documenting the field work.

Airborne reconnaissance by helicopter in West and East Greenland, 1961 - 1963

At the opening of the general mineral exploration activity by the Company at the beginning of 1960s, the interest in the first instance was directed to the ice-free coastal regions in the central and southern part of West Greenland. It was commonly considered that this part of West Greenland was holding the necessary infrastructural elements for a succesful exploitation of possible ore discoveries.

The bedrock of the area in question, with the exception of the area between Disko island and Svartenhuk peninsula, was known to be made of Precambrian rocks. Yet, to start with, the knowledge of the geology was still rather insufficient and summary in character. The best available source of information to the geology of West Greenland was at that time the results of preliminary reconnaissance mapping, carried out by GGU only a few years earlier. The mapping covered the immediate coastal strip along the shores only, leaving the interior of the country untouched. Only the country between Ivigtut and Julianehaab in SW-Greenland and the western part of the Nugssuaq peninsula constituted an exception, because GGU was on the point of carrying out a systematic geological mapping of these areas just then.

The economic mineral potential of the area was in preliminary considerations evaluated on the basis of a broad general conception only . The idea behind this was that the metallogenetic processes, which generated abundant mineral occurrences on the Canadian side, equally well may have been active even in the extensive Precambrian rocks of Greenland, which constitutes a part of the Canadian Shield.

The lack of local information was considerable and it was therefore imperative for a succesful and effective mineral exploration to start the initial phase with a procurement of basic information about mineral occurrences and prospects, about their location, regional distribution etc. On the basis of this information priority could then be given to those areas which looked favorable for an exploration effort before the other, less favorable ones .

On the basis of satisfactory experiences of helicopter-borne aerial reconnaissance studies, it was supposed that it was just the right way to go about the task.

The airborne reconnaissance observations were carried out in the years of 1961 - 1963. The ice-free country between Kap Farvel in the south and the Umanak fiord in the north in West Greenland and the country between Kap Farvel in the south and the Kangerdlugssuatsiaq fiord in the north in East Greenland were traversed by reconnaissance routes with an uniform spacing of about 4 km. On a yearly basis the programme was distributed as shown in the table 3 and in the figs. 4 - 6 below.

The reconnaissance was primarily based on visual observations from the air, the results of which were continuously recorded on the base maps. The observations from the air were checked, rectified and supplemented by frequent studies and chip sampling on the ground, carried out by field teams working at the same time as the aerial reconnaissance was going on.

When the work was completed, it had resulted in the discovery and subsequent ground control of approx. 200 mineral occurrences and prospects of various type and significance. Sulphide mineralizations constituted the main part of the discoveries, while the rest included representatives of oxide mineralizations, various industrial minerals etc.

Another result of the project of utmost consequence was the direct personal experience and knowledge obtained of the general geology, geomorphology and climatic conditions of the country. The significance of these experiences to the later exploration work can not be underestimated.

1961:	West Greenland:	
	Kobbermine Bay (61° 00'N) - Godthaab fiord (63° 40'N)	27.000 sq.km.
1962:	West Greenland:	
	part of the Sukkertoppen district (65° 00'N-65° 30'N), and	
	Holsteinsborg (67° 00'N) - Umanak fiord (70° 30'N)	34.300 sq.km.
1963:	West Greenland:	
	Tasermiut fiord (60° 30'N) - Kap Farvel (59° 45'N)	4.200 sq.km.
	East Greenland:	
	Kap Farvel (59° 45'N) - Kangerdlugssuatsiaq fiord (66° 15'N)	13.100 sq.km.
	Total area, excl. fiords and glaciers	78.600 sq.km.

Table 3: Airborne geological reconnaissance in W– and E–Greenland in 1961 - 1963

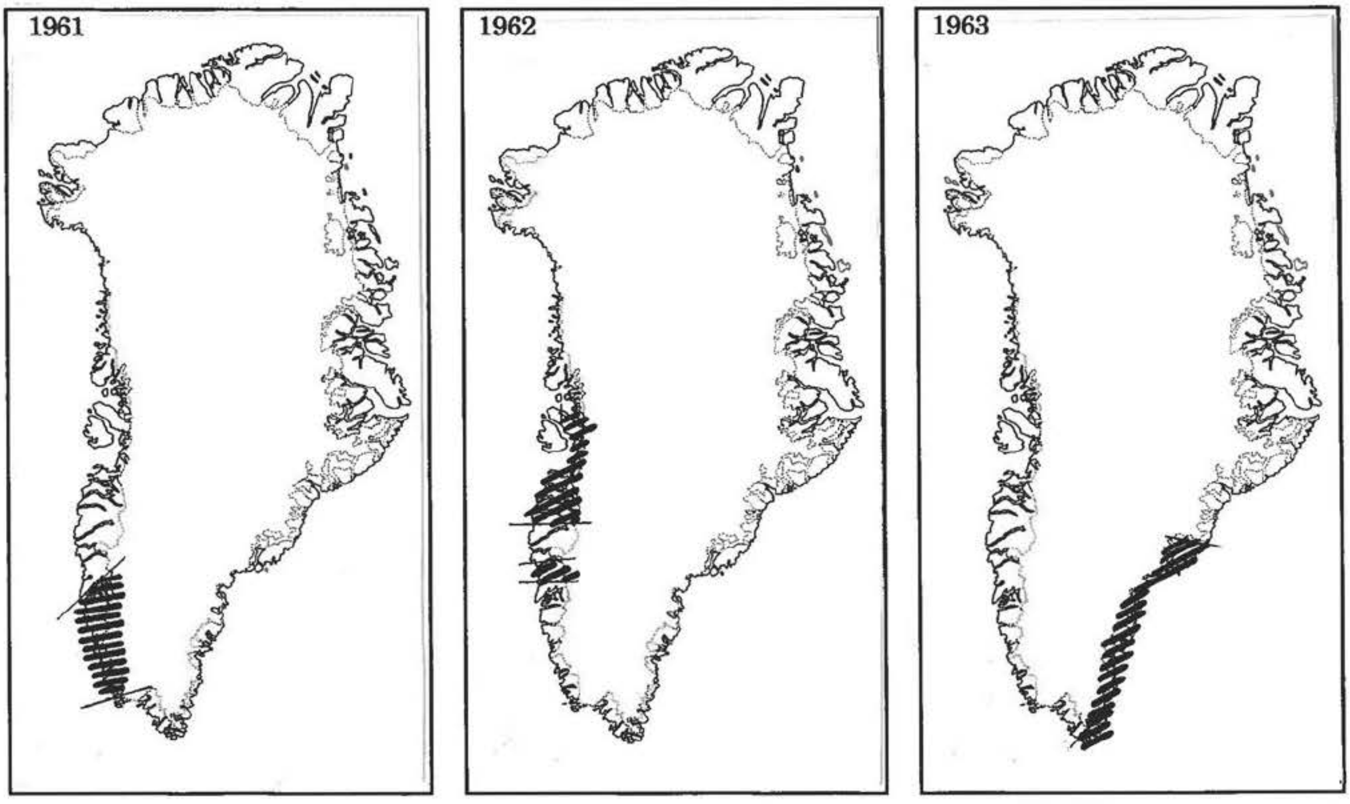


Fig. 4 - 6. Airborne geological reconnaissance in the years of 1961 - 1963

The ore investigations at Lersletten, 1963 - 1964

One of the mineral occurrences which was discovered during the aerial reconnaissance in 1962 was located at the Lersletten area in the southeastern corner of Disko Bay (fig. 2). Here a long, stratiform sulphide mineralization in a supracrustal rock series, consisting primarily of iron sulphides, was found to contain in places rised values of copper and zink. The geology of the layered rock unit with its sulphide mineralizations was mapped in detail in 1963 together with an extensive and detailed geophysical survey, including magnetic, electromagnetic and gravimetric measurements over an area of 14 sq.km. In the following summer the deposit was probed by drilling 14 holes with a total length of 1440 m. into the most promising targets within the ore zone.

The sulphide mineral assemblage was originally related to the carboniferous horizons in the metasedimentary sequence. During later deformation and metamorphism the sulphide material was remobilized and redistributed.

The main constituents of the sulphide mineral paragenesis are pyrrhotite and pyrite together with sphalerite and chalcopyrite as accessories. Arsenopyrite and molybdenite occur locally as occasional accessories.

The most intensely mineralized section of the ore zone contains several million tons of iron sulphides, mostly pyrrhotite. The copper and zink content of this extensive and very strongly mineralized zone proved however to be too low and irregularly distributed.

Concurrently with the prospecting at Lersletten a number of different mineral occurrences and prospects were studied in the adjoining areas, but the results did not give occasion to later follow-up activities.

Mr. Oke Vaasjoki worked as geological supervisor for the project and Mr. Jaakko Kurki was engaged as a geologist to the staff and both were put in charge of reporting the geological results of the Lersletten investigations

Mineral exploration in the Søndre Isortoq area between Sukkertoppen and Godthaab, 1965 - 1973

Upon the close of the Lersletten investigations, the ore exploration activity was moved in 1965 to the country between Sukkertoppen and Godthaab, (see fig.2.), where the airborne reconnaissance in 1962 had disclosed interesting nickel-copper-bearing mineralizations in the basic intrusive rocks of the area.

As the results of the first summer's prospecting activity confirmed the anticipations, the Company applied for, and was granted in 1966, an 8-year exploration concession with exclusive rights over an area of approx. 14.000 sq.km. between Sukkertoppen and Godthaab. This concession was the first one granted by the Ministry of Greenland by virtue of the first Mineral Resources Act for Greenland, which had taken effect as of May 5, 1965.

In the period of 1965 - 1973 a series of extensive and detailed exploration studies were accomplished in this area. The studies resulted in the discovery and detailed investigation of a number of different mineral occurrences, of which the following ones can be mentioned:

— Over 70 nickel-copper-bearing sulphide occurrences, associated with the norite - ultramafite complex of the area. Some ten occurrences were probed but all of them were found to be too limited in size to serve as a basis for an economic mining operation.

— The iron ore deposit of Isua (1966-1967, 1971-1974). The deposit contains at least 2 billion tons of quartz-banded magnetite ore of intermediate quality (32-33 %Fe)

— The olivine deposit of Itipilua (1966-1967,1971). A coarse-grained high-grade olivine rock occurrence with excellent refractory properties and with reserves of more than 100 mill. tons at a favorable location.

— The carbonatite complex of Qaqarssuak (1965,1970-1971, 1975-1976). Rare-earth (div.minerals), niobium (pyrochlore), vanadium, titanium (magnetite-ilmenite) and phosporus (apatite) mineralizations in a ring-dyke carbonatite complex with an area of approx. 12 sq.km.

— A kimberlite dyke-swarm and a kimberlite pipe at Suvdloq (1971-1973). The diamond potential of the occurrence has not been tested.

Of fair geological interest was the discovery in 1965 of an occurrence of Lower Palaeozoic rocks in a fault breccia at a locality called Fossilik. The breccia contained blocks of Precambrian basement rocks and of blocks of a variety of younger sedimentary rocks which were fossiliferous, containing bryozoans, echinoderms, orthacean brachiopods etc. of the Ordovician age. The discovery was first of its kind within the Precambrian terrain of Central W-Greenland.

A common feature of the activity during this period was a versatile use of most modern investigation methods, many of which were first introduced in Greenland. The large-scale use of different geophysical methods may especially be emphasized. Worth mentioning as well is the use of a lightweight drilling equipment for procuring of reliable and fresh sample material.

Due to the greatly expanded duties in the field work during this time, the staff of the Exploration Division was increased by new geologists. Messrs. Seppo Turkka (1966), Risto Juhava (1971) and Jens Gothenborg (1972) were all employed by the Company in this period.

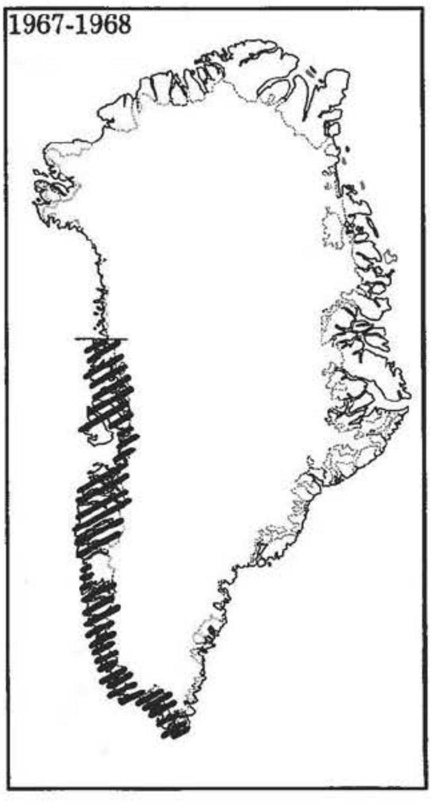
Airborne magnetic survey over West Greenland, 1965, 1967-1968

The exploration in the country between Sukkertoppen and Godthaab was to be carried out in an area which, at that time, was almost unknown. Published topographic maps of the interior of the country did not exist, and the geology of the area was described only by reconnaissance mapping along the coast. Therefore, the field work in the area was started in 1965 with an airborne magnetic survey (see fig. 7) in order to procure a general picture of the geology of the country and of the distribution of mafic rock formations in particular.

The measuring program was succesfully accomplished without any noteworthy troubles. The discovery of the iron ore deposit of Isua was one of its most noteworthy results.

The find encouraged the Company in the years of 1967 - 1968 to extend the airborne survey to enclose the whole country of West Greenland from Kap Farvel (59°47'N) in the south to Upernivik (73°46'N) in the north in order to discover and locate possible new iron ore deposits (fig. 8). The whole ice-free country in this context was measured along parallel survey profiles with an uniform spacing of 2 km. The survey covered an area of 128.500 sq. km with 74.800 profile km, and was the first of its kind in Greenland. The results of the survey were presented in the form of some 300 aeromagnetic isoanomaly map sheets on the scale of 1 : 50.000. showing the variation of the earth's total magnetic field intensity.

The survey disclosed a smaller number of iron



Figs. 7 - 8. Airborne magnetic surveys, carried out in the years of 1965 and 1967-1968 ore occurrences which were generally smaller in size and weaker in grade than the ore deposit at Isua. Isua still remains as the only noteworthy iron ore deposit in Greenland

Nickel prospecting in the Søndre Isortoq area, 1965 - 1973

During the airborne reconnaissance in 1962, a sulphide mineral occurrence was observed in a mafic rock formation, which contained noteworthy values of nickel and copper. During a visit to the area in 1964 it was confirmed that the mineralization type seemingly had a distribution which warranted a closer investigation. As a consequence of this, the exploration activity was transferred to the area in 1965. During the following period of 9 years, extensive geological and geophysical field investigations as well as drilling were carried out, from which more than 70 different nickel-bearing sulphide mineral occurrences were studied. Tentative estimates of ore reserves were made for ten occurrences, but tonnages were considered insufficient for an economic mining operation.

The most important type of mineralization from an economic point of view is an early magmatic sulphide segregation type containing nickel and copper with appreciable amounts of platinum metals.

The mineral occurrences are found in a series of plutonic rocks of predominantly noritic composition. The rocks in this series show compositional variation from ultramafite to norite in a manner which indicates in situ differentiation. The norite association is found in a north-south trending arcuate belt with an extent of about 15 x 75 km. Within this belt norites form a number of plutonic bodies which are conformable with the enclosing high metamorphic gneisses. The dimensions of the individual bodies vary from about 2 x 4 km. to only few metres across.

The rock in these bodies is medium- to coarse-grained with randomly oriented hypersthene and andesitic plagioclase as main constituents. Along the contacts and in certain zones within the noritic bodies deformation has produced foliated and partly cataclastic rock varieties, with mineral parageneses indicating retrograde metamorphism.

The sulphide mineralizations show uniform mode of occurrence and composition. The intensity of the mineralization varies from a weak interstitial dissemination to a dense network of sulphides enclosing silicate minerals. Secondary, epigenetic sulphide mineral enrichments are observed in zones of tectonic weakness but only within the noritic host rock.

The ore mineral paragenesis is the same all over: *pyrrhotite-pentlandite-chalcopyrite-pyrite*, with magnetite and ilmenite as the most common accessories. Violarite and low-temperature varieties of pyrrhotite (mackinawite) occur frequently as secondary minerals. Covellite, chalcocite, cuprite, native copper, azurite and malachite have been observed as supergene alteration products.

Pure sulphide ore has the following properties; all calculated from weight percentages:

Nickel content: 9 %

Cu : Ni : Co = 40 : 100 : 3,3

Ni : (Pt + Pd) = 43000 - 56000 : 1

Investigations of the Isua * iron ore deposit, 1966 - 1967, 1971 - 1974

It was primarily the topographic features which called attention to the area. During a short helicopter reconnaissance in 1962, it was found that a low-metamorphic schist formation formed an oval-shaped dome stucture here, which gave the topography its distinctive character.

However, it was not until 1965, that a great number of erratic blocks consisting of banded iron ore was observed at a new visit to the area, close to the Ice Cap margin (fig. 9). As the host rock of the blocks indicated that the ore possibly had its provenance in the schist formation, the aeromagnetic measurement, which at that time was going on in the adjacent area, was extended to cover the schist formation as well.

Even the very first test flights confirmed that significant magnetic anomalies were associated with the schist formation. After the measurement was accomplished, it finally turned out, that the schist formation enclosed a major arc-shaped magnetic structure with a length of approx. 40 km, the eastern end of the anomaly continuing under the Ice cap (fig 9). There was several maxima in the mag-

[* According to the official register of Greenlandic local names, the correct name of the locality is Isukasia. Since the majority of geological publications refer to Isua, the name is employed throughout this description as a name for the ore deposit.]

netic structure, the easternmost of them, just at the margin of the Ice cap, being the strongest and most extensive one.

During the following summers in 1966-1967, detailed exploration on ground was carried out in this anomaly area, which embraces the Isua ridge protruding up and through the ice and its ice covered surroundings. Besides geological mapping and grab sampling, magnetic, gravity and seismic measurements were also carried out to ascertain the detailed characteristics of the magnetic structure, the excess mass concentration associated with it, and to ascertain the thickness of the ice cover overlying the magnetic zone (figs.10 and 11).

The results showed that the lithology of the schist formation encloses a Superior-type Iron Formation, in which both iron-rich silicate rocks, oxide rocks and carbonate-magnetite-iron silicate rocks vary with each other in varying proportions in different parts of the formation. At Cape Isua the oxide facies is predominating. The main rock type here is a thin-laminated magnetite-quatzite ore with abundant skarnous laminae in some places. The chemical composition of the ore is shown in table 12.

Magnetite is the predominant ore mineral. However, concluding from the erratic boulders, hematite-dominant zones must exist under the ice. Hematite is a martitic alteration product after magnetite in these boulders.

The ore zone at Cape Isua has the form of a conformable, NNE-ly oriented sheet, dipping 60-70° to the ESE. The ore sheet has a thickness of about 200 m., disappearing under the ice at both ends.

The geophysical studies show that the main part

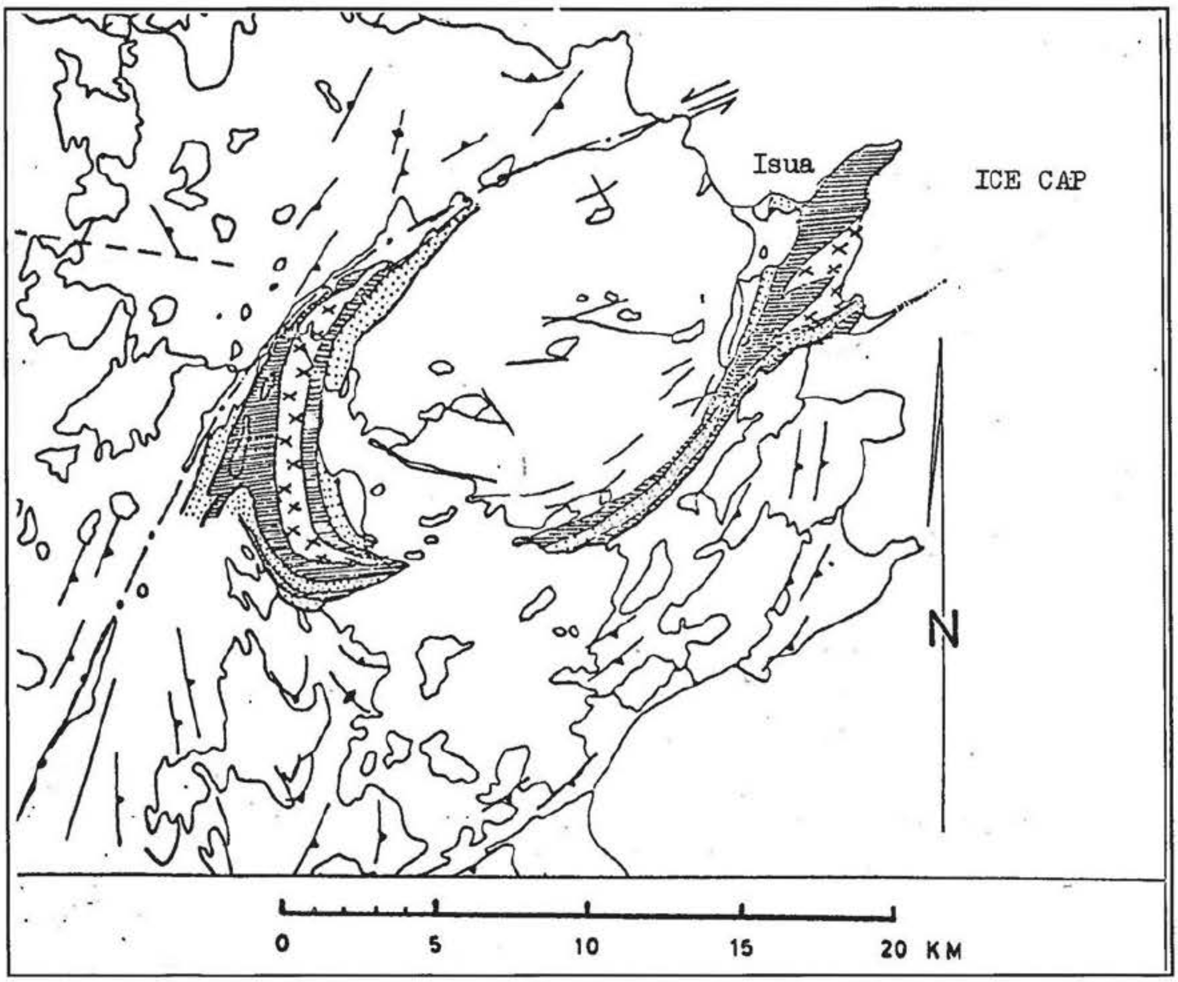


Fig. 9. General geology map, showing the position of the shist series and main tectonics. White: basement complex, stipled: siliceous bottom schist, horizontal ruling: iron formation, crossed: greenschist.

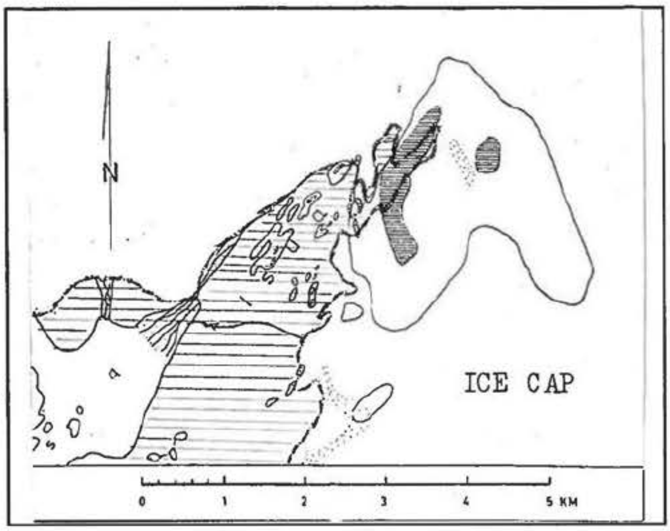


Fig. 10. Simplified magnetic map of the Isua ore field. Contour curves 10000 and 40000 (ruled areas) gammas.

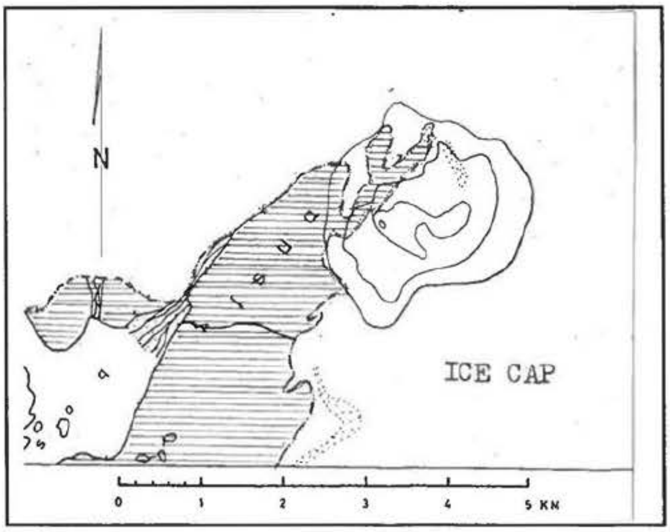


Fig. 11. Simplified gravity map of the Isua ore field. Contour curves 1, 4, 7, and 9 mgals.

of the ore sheet is buried under the ice margin. On the basis of the gravimetric survey, the total mass was estimated to 1,9 bill. tons of iron ore with a grade of 39% Fe. By an analysis of the magnetic properties of the ore material, it was possible to make an estimate of the ore reserves on the basis of the magnetic data as well. The estimate at minimum 2 bill. tons of ore with Fe= 32-34 %, proved to be very close to that obtained with gravimetry.

The Isua Iron Ore Project

The investigations of the Isua iron ore deposit were taken up again in the period of 1971 - 1974 as a joint venture project with the Marcona Corporation of San Francisco, USA. The aim of the venture, named The Isua Iron Ore Project, was to test the economic feasibility of the prospect under varying production and market parametres.

With the purpose of entering as a Partner in a general partnership, the Company designated a subsidiary, called Greenmines A/S (Grønlands Prospektering og MineselskabA/S). Mr. I.P. Danø, Vice President of the Company and responsible for the Company's exploration operations at that time, was appointed to manager of the subsidiary.

To substantiate the feasibility study, the reserves of the deposit were probed by a drilling programme, which consisted of 13 drill holes with a total length of 2719 m. Based on the drilling results and on the results of the previous magnetic survey, the ore reserves above elevation 770 m. were estimated to about 550 mill. tons of crude ore. The geological reserves were considered to be far larger, including the ore reserves below 770 m, and in the areas south and east of the drilled area. The average grade of the crude ore was found to be at 32 - 33 % Fe.

Fe (HCl sol.)	32,5 wt. %
SiO_2	46,2 wt. %
Al_2O_3	0,25 wt. %
CaO	0,88 wt. %
MgO	1,98 wt. %
MnO	0,08 wt. %
P_2O_5	0,04 wt. %
TiO	0,06 wt. %
S	0,022 wt. %

Table 12. The mean content of some important constituents of the Isua Ore Zone.

In addition, a number of beneficiation tests were run, a process flow-sheet was designed and prior to a regional layout of the main project components was decided, various plant, installation, transport system and shiploading alternatives were studied at different localities. In addition, a series of climatological and glaciological parametres, as well as the amount and movement of the drift- ice in the Godthaabsfjord were monitored through the years.

On the basis of the results an economic feasibility study was accomplished and the results of it were continuously adjusted to meet the changing market conditions.

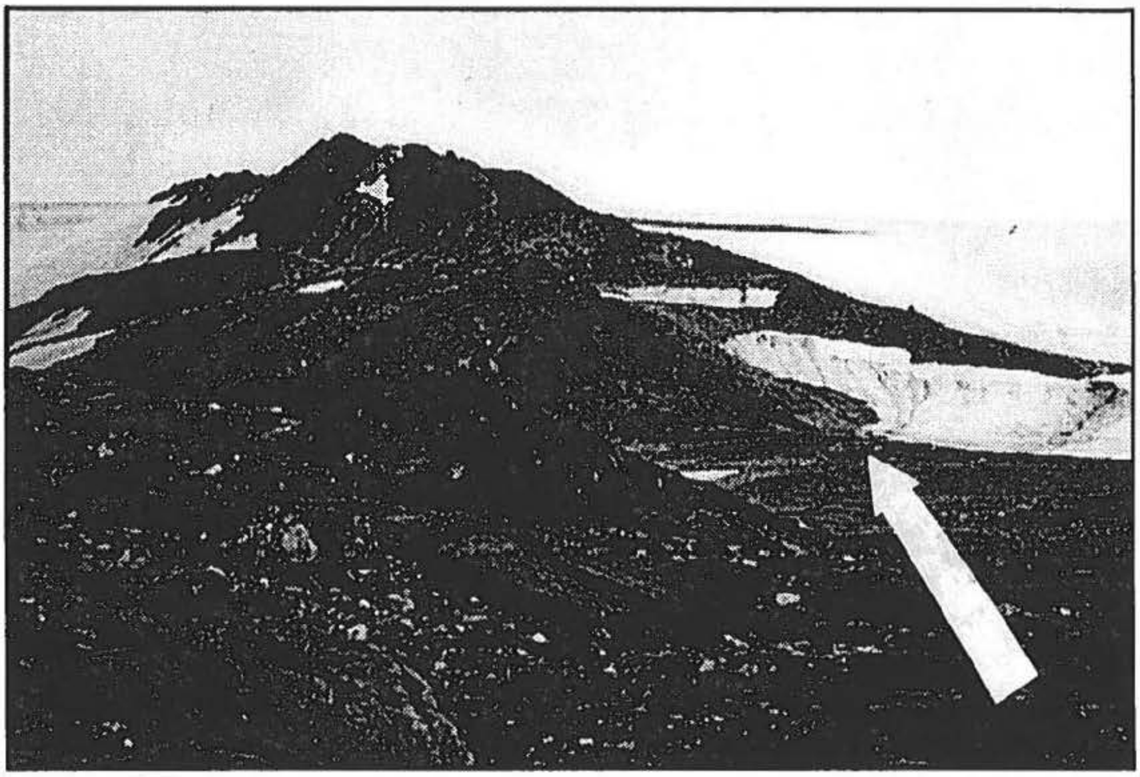


Fig. 13. General view over the Ore Zone at Isua with the Ice Cap in the background. Accommodation barracks in front of the arrowhead serve as a scale.

The year 1973 became fateful to the project. With the developing worldwide oil crisis the economic basis for the project crumbled away, and the Partners agreed to suspend the project until further notice.

The Hydroelectric Power Scheme with the Isua Iron Ore Project

To evaluate whether the main power supply for the proposed Isua iron ore project could be based on hydroelectric power production, the Company at its own cost and initiative undertook systematic hydrological runoff measurements in the catchment area of four lakes in the vicinity of Isua over a 10-year period from 1974 to 1983. The project also included a number of topographical and engineering geology investigations.

A description and general layout for the hydroelectrical power scheme, based on the accumulated field data implied that, as a main feature, the runoff from the four lakes would have been diverted from the natural outlet and conducted via canals and tunnels to the head of a branch of Godthaabsfjord, called Ujaragssuit pavat. The headrace tunnel, with a net head of about 635 m, penstock, power station and tailrace tunnel were to be located in the rock formation above the outlet.

The investigations established the fact, that the mean annual runoff available for the power scheme, was 940 mill cb.m. It was estimated that an annual amount of 740 mill. cb.m. of water could be utilized for power production. With the aforementioned net head, this corresponds to an annual power production of 1140 GWh.

Investigations of rare earth, niobium and phosphorus mineralizations at Qaqarssuk Carbonatite Complex, 1965, 1970 - 1971, and1975 - 1976

The Qaqarssuk Carbonatite Complex lies on a barren mountain plateau at an elevation of 300-400

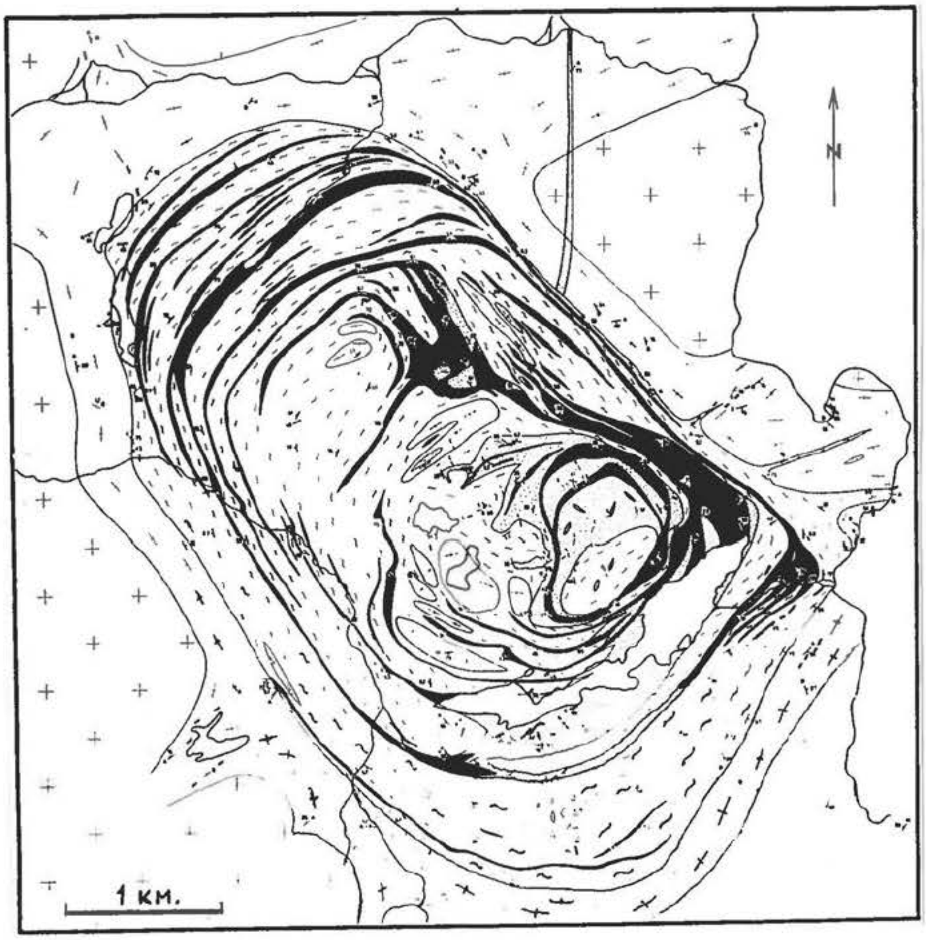


Fig. 14. Map of the Qaqarssuk Carbonatite Complex. (Map signatures: black: carbonatite, dotted: silicieous ultramafite (pyroxenite, hornblendite and glimmerite), wawy dashes: fenite with <50% carbonatite, dashes with crossbar: altered basement rocks, crosses: basement.). Map compiled from the Company and GGU data by Christian Knudsen, GGU, 1985.

m., 57 km. due east of Sukkertoppen town. The nearest point at seashore is at the head of the Kangia fjord, 17-18 km. away (fig. 2.).

Already on the first acquaintance during the helicopter reconnaissance in 1962, the widespread "rusty" staining of the rocks and weathered residual material which was visible almost everywhere as a sharp contrast to its surroundings, aroused a particular interest in the rocks in question. Compared with the surrounding region the carbonatite complex area presented rich vegetation. A prominent feature was abundant patches of willow and dwarf grove. A number of grass and flowers thrive also in the area; a special feature is a common occurrence of a tiny but hardy species of a beautiful pink catchfly *(Viscaria alpina)*.

The Qaqarssuk carbonatite intrusive (fig. 13.) has been emplaced at the intersection of a major deep seated fracture zone trending 50° with dextral faulting along this direction, and an another zone which runs approximately perpendicular to the former in a direction of 140°. At the intersection the carbonatite intrusive forms a set of concentrically arranged dikes in a noncircular complex with strongly rounded corners and with dimensions of about 3 x 5 km. The long side of the structure is parallel to the 140° direction and the shortest side follows the 50° direction, and it is enclosed in an aureole of fenitized Precambrian basement rocks.

In a vertical section the ring dike complex displays a cone structure. The outer set of concentric carbonate sheets dip generally more steeply outwards than the inner ones. In the western outer zone the dip varies between 60 - 80° W, whereas at the eastern contact zone the dip is almost vertical. Similarly, in the south and the north the dip is outwards, 70-80° in general. The inner set of carbonate sheets show generally less steeply dipping structures, the dip varying between 30-40° in general. The whole structure describes a cone with an axial orientation 260°/70°.

Carbonatite rocks are predominant in the magmatic suite. Both calcitic and dolomitic varieties are present. Both of these occur in at least two generations. Other common constituents in the rock suite are siliceous ultramafic rocks. Petrographically this group comprises mica-pyroxene rocks, mica-amphibole rocks and glimmerites. Common to them all is a clear alkalic tendency and an overprint of polyphase metasomatism. Acid siliceous rocks are represented by albite-mica pegmatites which constitute a minor group in the suite. Important rock varieties from an economic point of view are magnetite olivinites and magnetite-apatite rocks, which are concentrated in the core lying in the SE-part of the complex.

The rocks of the carbonatite suite occur as sheets, dikes and minor veinlets in the fractured and fenitized wall rock. The width of individual rock units varies from a few centimetres to several tens of metres.

P, Mn, Sr, Ba, Nb, rare earth elements (REEs), Th and U are characteristic elements of the carbonatite complex. In several places economic concentrations have been observed.

The exploration

The development of the exploration can be crystallized in the following points:

— 1. *Reconnaissance studies, 1965, 1968:* The position, general shape and size of the formation was preliminarily mapped. The origin of the formation was discussed. In 1968 the true geological origin was confirmed by chemical assays on a series of samples which indicated elevated contents of REEs, Sr, Ba, Th and U.

— 2. *Rare earth exploration, 1970–71:* Due to the first series of assay results, the interest was concentrated upon occurrence of rare earth mineralizations. As REE mineralizations were found to be associated with elevated radioactivity, the prospecting was based primarily on radiometric measurements. Magnetic measurements and geological mapping were used as additional means. Critical anomalies were checked by diamond drilling.

It was found that REE-mineralizations were associated with a younger generation of carbonatite dikes with iron-rich dolomitic composition. The dikes strike mainly in two directions, 37° and 139°, respectively. The width of these dikes varies from some centimetres to about 5 metres. The frequency of the dikes varies in different parts of the complex between 1% to 5% of the complex lithology, but generally it is about 1,5% of the bulk of carbonatites and associated rocks.

The content of the REEs in the dike rocks varies quite considerably as well. Despite assay results with 13–14 % composite rare earth oxide content locally, the amount of the mineralised rock as well as the REO-content was generally found to be too low to warrant economic considerations. It is a question of about 3-4 % of composite REO- content in the mineralized sections, in which Ce and La are the most abundant elements. Ancylite was observed as the most noticeable REE-mineral. Of other associated minerals, strontianite, monazite and pyrochlore show a positive correlation with the REO-content. The mineralized sections carry usually about 2–3 % Sr in strontianite and 3–4 % Ba in baryte, which is a very common accessory mineral. A weak sulphide dissemination may also be present locally, consisting of crystal aggregates of pyrite, pyrrhotite and accessory chalcopyrite, sphalerite and galena.

The radioactivity associated with these rocks is almost exclusively caused by the presence of Th. Generally the Th-content seems to be rather modest even in the mineralised rocks; the highest assay values indicate 2000-3000 ppm Th, but usually the Th-content is 30-300 ppm. The highest Th-anomalies occur in narrow veins and veinlets; but when the dolomitic dike rocks attain larger dimensions, the Th-content is much lower. There are several carrier minerals of Th, of which monazite seems to be the most common.

— 3. *Nb-prospecting, 1972–73, 1975–76:* Among the sample material collected for REE-studies, there was now and then occasional samples with high content of Nb. A remarkable feature of these samples was the elevated magnetite content. As an experiment, therefore, a test sampling was carried out at a number of localities in the SE part of the complex, where magnetite mineralizations were known to occur in association with magnetic anomalies. One third of the collected samples showed elevated contents of Nb, with a mean of 1,17 $\%Nb_2O_5$. The only Nb-mineral identified was pyrochlore.

As a consequence thereof, it was decided to carry out a comprehensive study of the core area in the SE part of the complex with an extent of about 2,5 sq.km. The first phase of the study in 1975 implied a lithogeochemical investigation with a view to a) locate possible Nb-concentrations of economic grade, b) describe the lithology within the magnetic anomaly, and c) define, as far as possible, the controlling factors for the formation of pyrochlore. The second phase in 1976 was intended as a follow-up study, whereby the quality and extensions of possible promising Nb-mineralizations was to be examined more closely.

Due to extensive overburden the sampling programme of the first phase was to be carried out by drilling with a light portable diamond drilling unit.

To start with in 1975, the core area was subjected to a new magnetic survey in a 10 x 25 m. grid, the results of which were to facilitate the location of the drill holes. Further, a total of 222 shallow drill holes with a spacing of about 50 m. were drilled with an entire length of 2389 m. From these 1500 m. of core in bulk was procured.

The entire length of core material was subsequently assayed for Nb, P, Fe, Ti, V, Mn, Mg, Ca, CO_2 and La. In addition, considerable number of core sections were assayed for Zr and magnetite (Fe_3O_4) content.

The main conclusions from this study resulted in a follow-up study in 1976, at which the Nb-content of the most promising sections of the area was probed by diamond drilling of 16 holes with a total length of 2659 m.

The highest concentrations of Nb were observed in association with magnetite mineralizations of the area. The magnetite mineralizations could however be divided into two groups, each with its own characteristic mineral association and lithology, namely mineralizations in 1) the western anomaly area and 2) eastern anomaly area.

In the western anomaly area the magnetite mineralizations are associated with glimmerites and other mica-rich, basic to ultrabasic siliceous rocks with less than 50 vol.% carbonatite in the rock association. The share of magnetite in the rock is generally considerably high, 30–50 % by weight being not uncommon. Apatite content in the rock varies generally from 2 to 10 % by volume.

Magnetite is typically poor in Ti and V. Pure magnetite contains 0,25–0,35 %V, and the Ti-content is <1 %

The highest concentrations of Nb have been observed with magnetite mineralizations only in the western anomaly area. The Nb_2O_5 content varies from 0,15 % to 2,8 % in the best sections. By the drilling programme, it was demonstrated that 1,2 mill. tons of probable ore with 0,8 %Nb_2O_5 existed and 3,5 mill. tons of possible ore with a content of 0,5 % Nb_2O_5.

In the eastern anomaly area magnetite mineralizations are associated with olivine-bearing ultrabasic rocks which commonly are altered to serpentine-bearing rocks. The carbonatite content represents generally more than 50 vol.% of the bulk. The share of the magnetite in the rock is approximately the same as in the western anomaly area, but the extent of the mineralizations seem to be larger than in the western part.

Here the magnetite carries more of both Ti and V than the previous type. The V content varies between 0,60–0,65 %V and the content of Ti is commonly 4–5 %.

Pyrochlore is only occasionally present in these minaralizations and the content of Nb_2O_5 only seldom exceeds 0,1 %.

lithology	frequency in vol.%	wt. %P_2O_5
leucocratic/intermed. fenite	4,3	2,1
basic/ultrabasic fenite:		
-egirine-augite ultramafite	3,5	2,1
-hornblende ultramafite	11,9	1,8
glimmerite	17,1	1,6
magnetite glimmerite	5,4	0,9
carbonatite	39,8	1,4
silicocarbonatite	2,8	1,6
magnetite olivinite/serpentinite	12,0	0,7
magnetite apatite rock	1,8	8,2
REE-dolomite dike rocks	1,4	1,1
	100,0%	mean 1,6 % P_2O_5

Table 15. The lithological composition of the core section in the Qaqarssuk Carbonatite Complex and the distribution of P_2O_5 in it. Based on 610 assayed drill core samples with a total length of 1322 m. from 222 drill holes.

Apatite mineralizations

Although encouraging discoveries did not come up during the field work, a close eye has been kept throughout the work on the variation of P_2O_5–content in the carbonatite complex rocks with the help of chemical assays.

Best known is the distribution of P_2O_5 among the rocks within the core of the carbonatite complex, in its SE-ly corner (table 15 above).

From the other parts of the complex 234 P_2O_5 assays are available. Although the assayed material is not representative as to the lithological composition of the complex, the lithological variation and the geographical distribution of the assayed samples are however sufficient to illustrate the statistical distribution of P_2O_5 within the carbonatite complex.

The interpretation of the assay results revealed that:

— about a half of the assayed samples showed P_2O_5 values <0,7 % P_2O_5

— in samples with % P_2O_5 >0,7 %, the distribution of P_2O_5 is bimodal. Two populations of P_2O_5 assays can be discerned, each of which shows a log-normal distribution, namely

1. population with geometric mean P_2O_5 = 5,7 % and stand.dev. = 4,8 - 7,1%.

2. population with geometric mean P_2O_5 = 1,4 % and stand.dev. = 0,7 - 2,7 %.

In addition to the assay results, there are 28 point-counter analyses of samples, where the apatite content has been markedly high. As a rule, it is a question of magnetite-bearing drill core samples collected from test drill holes outside the core area. The mean content in this series of samples was 8,5 vol-% apatite (stand.dev. between 4,9 - 14,8 vol-% apatite). Converted into P_2O_5 values, it gives 3,6 %P_2O_5 (stand.dev. between 2,1 - 6,2 %P_2O_5).

In conclusion, it can be stated that the qualitative distribution of phosphorus within the carbonatite complex is reasonably well elucidated. The mean content of 1,6 %P_2O_5 consists of a series of - possibly lithology-related - populations, of which the highest has a P_2O_5-content = 5,7 %P_2O_5. Thus the carbonatite complex as a whole can be regarded as a low-grade phosporus deposit.

The quantitative distribution of the above-mentioned high-P_2O_5 populations is less well known. The population with highest P_2O_5 content can be considered as notable from a prospecting point of view. It occurs commonly in association with magnetite-bearing carbonatite lithologies, the share of which in the combined lithology is not very high. It occurs most frequently in the core area, but outside of it the occurrence of the rock is much less concentrated as a whole than in the core area. The potential of considerable reserves is thereby very strongly reduced.

Investigation of the Itipilua olivine deposit at Fiskefjord1966–1967, 1971

The Itipilua olivine deposit, on the waterside far up in the northern branch of Fiskefjord (fig. 2.), is enclosed in an oblong ultrabasic massive, lying conformably in a huge layer of pyroxene amphibolite. The core of the ultrabasic mass consists of a lenticular body, 1300 x 600 m. in size, composed of dunite (olivine rock) while the enveloping shell consists of a peridotite of hartzburgitic composition The deposit was probed by geological mapping and gravimetric survey in 1966 - 1967 and by drilling in 1971.

In the core dunite three textural varieties can be discerned: a) homogenous, b) layered, and c) porphyritic dunite. The ground mass is the same in each variety: a homogenous and medium-grained rock in which the grain size varies between 1-3 mm. The porphyritic variety contains idiomorphic porphyroblasts of olivine with a size variation between 2-5 cm. The porphyroblasts appear frequently to be poikilitic intergrowths of two or more olivine crystals.

The rock is almost monomineralic; more than 90 vol.% of the rock is composed of forsteritic olivine (92-94%Fo / 8-6%Fa). The chemical composition of

n: 28 samples	mean, wt %	range, wt %
SiO_2	40,41	40,02—41,22
Al_2O_3	1,86	0,64— 2,39
Fe_2O	0,90	0,53— 1,24
FeO	6,41	6,32— 6,64
MgO	49,00	48,57—49,48
CaO	0,32	0,15— 0,51
Cr_2O_3	<0,10	<0,10
NiO	0,34	0,34— 0,36
loss of ignition	0,75	
sum	99,99	

Table 16. Chemical composition of the Itipilua olivine rock

the dunite is shown in table 16. The remaining part is made of orthopyroxene, minor chromite and of serpentine and/or chlorite as alteration products.

A number of systematic melting point determinations of the olivine rock have been carried out. The determinations, which have been made in accordance with the German DIN-norm, proved that the olivine rock possesses excellent refractory properties with a melting point above 1750°C

The reserves of the olivine rock are considerable. With the help of a gravimetric survey and shallow drillings the total reserves have been estimated at well above 100 mill. tons. In the visible part of the body the directly available reserves are estimated at 22 mill. tons.

At the northern contact of the dunite body, a chromite mineralization is met in a 600-700 m. long zone with a thickness of 5 to 9 m. In this zone the chromite-rich bands alternate with sterile bands of hartzburgitic peridotite. The average grade of the zone is 5% Cr_2O_3 only, which is too low in economic terms.

Studies of kimberlite rocks in the Søndre Isor toq area, 1970 - 1973

During the exploration work in the Søndre Isortoq area, a great number of narrow basic to ultrabasic dikes and one pipe structure were encountered on the coastal area on both sides of the outlet for the Søndre Isortoq fiord. The occurrence of the dikes was not followed up farther than up to Sukkertoppen in a NW-ly direction and from here about 55 km. in SE-ly direction along the coast.

Common to their mode of occurrence is that they fill narrow tension fractures and joints, frequently in an *en echelon* pattern in a set of parallel joints. The deeply weathered dike rock has typically been partly eroded away, leaving behind a steep-walled joint with disintegrated dike rock debris, which gradually changes into a fresh dike rock underneath. The width of the dikes vary usually between 0,1 - 2,0 m, a maximum width of 4 m. has been observed. No thermal or metasomatic effects have been observed on the wall rock

Petrographically the dikes can be divided into two main goups

1. Kimberlites
2. Lamprophyric dyke rocks

Kimberlite dykes

The share of kimberlite dikes is ab. 10 per cent of the observed dike rocks.

The strike of the kimberlite dikes varies mainly between 60° to 90°.The rock is characterized by the occurrence of rounded mineral nodules and/or mineral aggregates together with idiomorphic phenocrysts of olivine in a ground mass of carbonate or a mixture of serpentine-like material and carbonate material which is heavily disseminated with submicroscopic ore material. As monomineralic nodules forsteritic olivine, abundant Mg-rich ilmenite, Cr- and Ti-bearing pyrope garnet and less common clinopyroxene have been encountered.

The observed kimberlites are in many respects similar to those from diamondiferous kimberlite provinces of the world. In addition to the fact, that they contain nodules of indisputably deep seated upper mantle provenance, also the chemistry of selected elements show properties which are comparable to South African, Lesothoan and Yakutian kimberlites as well.

The diamond content of the Søndre Isortoq kimberlites has not been tested.

Lamprophyric dike rocks

This rock group comprises young porphyritic and amygdaloidal basic dikes and one small diatreme, called Suvdlok pipe.

The strike direction varies from 270° to 340°, with three distinct maxima around 285°, 305° and 325°, respectively. The dikes are commonly zoned, showing a few cm. broad fine-grained contact variety which turns sharply into a coarser central variety, which in turn may show zonal layering, manifesting itself as grain size variation and as an abundance of amygdules, etc.

Texturally the rocks always have a porphyritic appearance carrying euhedral or subhedral, sometimes even corroded or rounded phenocrysts of olivine, titaniferous augite, brown amphiboles and opaques. Labradoritic plagioclase is a common phenocryst in some dikes. Sometimes the phenocrysts may be totally altered into secondary minerals, appearing as pseudomorphs.

In the groundmass, composed mainly of plagioclase and augite, the texture varies from aphanitic to ophitic. Roundish or irregularly elongated rounded cavities filled with zeolite minerals and/or carbonate are very characteristic of the rock.

As for the chemistry, the notable feature is the predominance of K_2O over Na_2O, in which respect they differ from common diabases and from tholeiitic and alkaline olivine basaltic rocks. The high content of K_2O for an ultramafic rock is typical of lamprophyres as well as of kimberlites. The lack of typical kimberlite minerals, e.g. pyrope garnet and nodules of rounded picroilmenite, is a differentiating feature from kimberlites.

The Suvdlok pipe is a small diatreme, 45 x 65 m. in size. It forms a bulge in a basic lamprophyre dike, striking in N 155° direction which crosses a kimberlite dike 100 m. south of it. The pipe is rich in inclusions, especially the border zone is crowded with inclusios of surrounding basement gneiss. One inclusion of olivine-rich ultrabasic rock, resembling kimberlite has been observed.

Mineral prospecting in the country between Sukkertoppen Ice Cap and Nugssuaq, 1977 - 1979

In 1977 the Company undertook an airborne reconnaissance by helicopter in the country between Sukkertoppen Ice Cap (66° 00' N) and Arfersiorfik fiord (68° 00' N) with a view to check and partly review the ore prospects of the area. In addition to grab sampling from the many mineral occurrences in the area, orientative studies were carried out on the anorthosite complex at Qaqortorssuaq and on the carbonatite complex at Sarfartoq, both in the Søndre Strømfjord area.

As a supplement to the reconnaissance the Company carried out an airborne geophysical survey program in the following year 1978, consisting of a magnetic and electromagnetic survey over two selected areas with a total areal of 2000 sq.km. One of the areas was situated south of Christianshaab, in the southeastern corner of Disko Bay, including the Lersletten area (p. 6), and the other one at Ata, north of Jakobshavn (p. 22).

Studies on anorthosite at Qaqortorssuaq, 1977

The anorthosite body at Qaqortorssuaq (66°05' N, fig. 2.) forms a huge, conformable lenticular mass, with a surface area of about 5 x 15 sq.km. It occupies the entire mountain Qaqortorssuaq in bulk, between two fiords, and is exposed in an almost 1000 m. high vertical section.

The rock is typically very homogenous; extraneous lithologies occur in very limited amounts only. According to preliminary observations it would be fully possible to be able to point out separate homogenous blocks of anorthosite rock with reserves around 100 mill. tons or more.

Petrographically, the anorthosite is nearly monomineralic rock, containing 90 - 95 vol.% bytownitic plagioclase and 5 -10 % accessory mineral constituents, mainly clinozoisite, scapolite, amphibole minerals, chlorite, biotite and sericite. A typical chemical analysis of the anorthosite is shown in the table 17 below.

wt%	
SiO_2	46,1
Al_2O_3	33,1
Fe_2O_3	1,0
MgO	0,5
CaO	16,0
Na_2O	2,2
K_2O	0,2
access. (TiO_2, MnO, P_2O_5 etc)	0,9
sum	100,0

Table 17. Chemical composition of the anorthosite at Qaqortorssuaq, calculated from a series of grab samples:

A preliminary study was undertaken with a view to possible use of anorthosite as a raw material for future aluminium industry. The orientative laboratory tests showed that the aluminium in the bytownitic plagioclase was easily extracted by leaching with a recovery of more than 90 %.

The favorable geographical position and the large tonnages of readily available raw material are some of the attractive aspects of the deposit.

Prospecting in the Ata area, 1980 - 1985

Copper / gold prospecting

The prospecting activities were hereafter concentrated to the Ata area (see fig. 2), where the field work in the following years 1980 - 1982 was focussed on copper-bearing sulphide mineralizations. The subsequent chemical studies soon proved that the mineralised samples contained appreciable values of gold. The field investigations were therefore expanded by a geochemical study in the years of 1983 - 1985 with a view to find out the mean content and the controlling agents of the distribution of gold in the area.

The results of the study demonstrated that the gold values were linked with the hydrothermal processes, which generated the copper mineralizations together with the quartz/carbonate gangue material. They occur as small and irregular epigenetic mineralizations in zones, where the host rock has been cataclastically deformed. The share of the ore material in the mineralizations is generally less than that of the gangue. The ore minerals form a dissemination of individual ore material grains or grain aggregates in the quartz/carbonate gangue. Locally the ore material may fill a narrow vein in which the ore material envelopes small fragments of the fractured wall rock.

The most frequent ore mineral assemblage is: *chalcopyrite-pyrrhotite-pyrite*. In addition, a great number of different sulphide minerals and sulphosalts has been observed of which following paragenetic constituents can be mentioned:

- cubanite	- covellite
- mackinawite	- marcasite
- melnikovite	- electrum
- bismut	- ikunolite
- laitakarite	- ullmanite
- gersdorffite	- arsenopyrite
- pentlandite	- violarite
- millerite	- argentopentlandite
- hessite	- galena
- sphalerite	- molybdenite
- Bi-Pb-sulphosalt	- Ag-sulphosalt
$(Pb,Bi)_4(Te,Se,S)_3$	$xPbS.y(Ag,Cu)_2S$

The above mentioned sulphides, sulphosalts and metals are present, as a rule, as accessory constituents only and never present as a whole in any of the observed mineralizations. Instead, a very lively variation can be observed between the different mineralizations and even within one individual mineralization. The same holds true for the gangue minerals, in particular for the carbonate minerals.

The above described characteristics indicates that the observed mineral paragenesis is a product of a hydrothermal mineralization process. This has taken place over a wide temperature interval, the main phase extending from about 300°C to below 100°C. The highest gold values are typically met within the lowest hydrothermal mineral assemblages. A characteristic of the gold values is also the very irregular and uneven distribution as well as a rather low mean content. The observed variation of the mineral paragenesis is indicative of heterogenous thermal conditions during the formation of the mineral assemblage, which is a characteristic of a mineralization process taking place in the hypabyssic to subvolcanic depth zone.

	geom.mean	range for stand.dev.
Au, ppm	1,2	0,2 - 7,0
Ag, ppm	21,5	9,3 - 49,6
Bi, ppm	12	1 - 182
Cu, %	1,38	0,68 - 2,78
S, %	2,92	0,84 - 10,19

Table 18. The chemical tenor of the gold mineralizations in the Ata area

To illustrate the general chemical tenor of the gold mineralization, the geometric mean values for the important elements are shown in table 18 above.

The gold of the mineralizations is alloyed with silver into electrum in which the Au/Ag ratio is about 70/30. It is found as minute grains and grain aggregates, remarkably often with chalcopyrite. Grains of electrum have also been found as inclusions in silicate minerals and with pyrite and arsenopyrite.

Other mineralizations

The discontinuous arcuate magnetic structure on the aeromagnetic map of the Ata area also contains a number of magnetite and hematite mineralizations of varying size and intensity. Most often the mineralizations are made of a banded or a disseminated sequence in the sedimentary rocks of the supracrustal series.

A concentration of magnetite occurs in the banded magnetite-mica-quartzite sequence at Itivdliarssup Qaqa hill, on the southern side of Nugssuaq peninula. Here the magnetic zone runs out to the fiord waters at both ends. The ore zone is structure-parallel on the shore escarpment, and 1000 m. in length. It has been calculated to contain approx. 150 - 200 mill. tons of magnetite ore down to a depth of 500 m. The iron content of the ore is however only about 20 %Fe.

Mr. Jørn Morthorst was employed as a geologist in the Exploration Division in 1980.

Exploration of graphite at Akuliaruseq, 1982 - 1985

Concurrent with the prospecting activity in the Ata area, an investigation of a graphite occurrence at Akuliaruseq, north of the entrance to the Nordre Strømfjord fiord (see fig. 2), was accomplished in the period of 1982 - 1983. The occurrence had been known long ago, and as early as in the 1910s the deposit was subjected to unsuccesful mining attempts.

Under the new project the 7 km. long graphite-bearing formation was mapped both geologically and geophysically, and the reserves and the grade of the graphite-bearing rock were probed by a comprehensive drilling program consisting of 5704 m. drilling, divided among 124 drill holes.

Furthermore, in the period of 1983 - 1985, a number of beneficiation tests were run in the Technical University of Norway in Trondheim and a flotation scheme was worked out for the extraction of graphite concentrate.

The graphite mineralization occurs at Akuliaruseq in a tightly folded, layered, high-metamorphic gneiss series of sedimentary origin. The main lithologic unit is a graphite-bearing (garnet)-biotite-sillimanite gneiss, enclosing conformable layers of amphibolite, marble and its skarnous varieties. This layered succession is present in three parallel, SW-NE-oriented horizons which coalesce in the eastern part of the area. The thickness of the gneiss series varies between 30 - 100 m., dipping 65° NW in the western part and becoming gradually steeper, up to 70° NW, in the eastern part of the area.

The thickness of individual graphite-bearing layers varies significantly, as does the graphite content. A seemingly primary graphite dissemination holds typically 6 - 8 %C. An intense folding and cataclastic deformation has been instrumental in developing graphite concentrations which occur in the form of parallel lamellae and layers. The grade of the graphite in them may exceed 40 %C.

With a view to the most economic way of quarrying the deposit from the open pit, the ore reserves were estimated in four selected blocks, in the first phase to a depth of only 40 m. The proven reserves were then calculated to 5.340.000 tons of ore with a grade of 9,5 % C.

In the accompanying diagram, fig. 19, and table 20, data are presented which show the demonstrated in-situ reserves and the concurrent grade, together with the relation between cut-off grade, graphite content and ore tonnage.

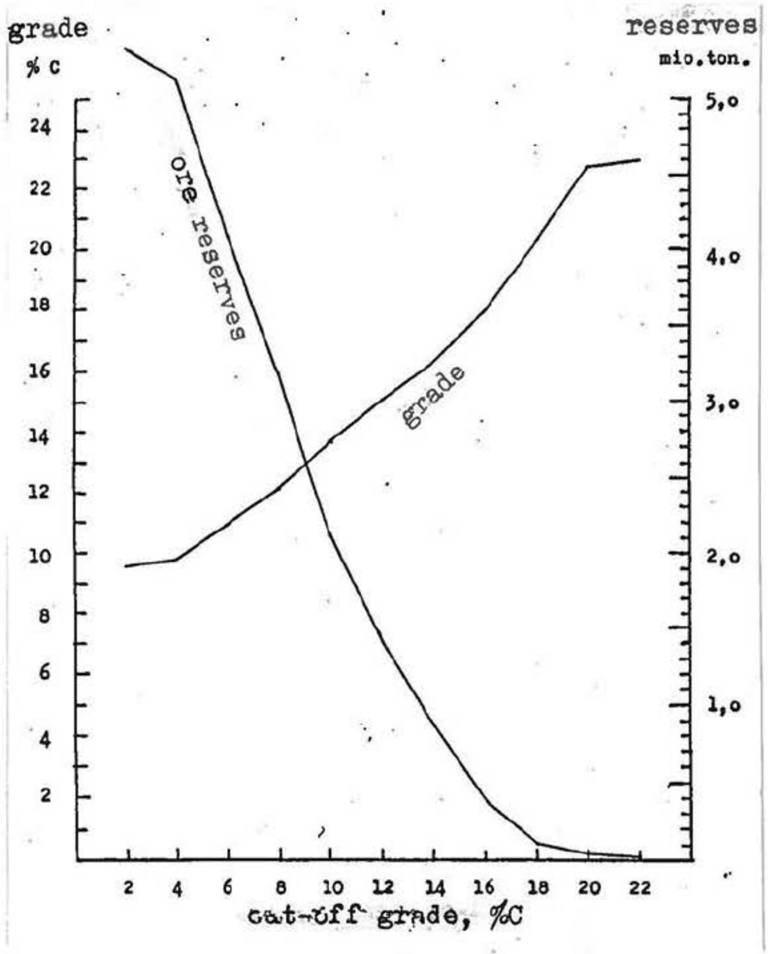


Fig. 19. Graphite ore reserves at Akuliaruseq and their dependance on cut-off grade and ore grade.

Cut-off grade, %C	ore grade, %C	ore reserves, tons
2	9,5	5.339.000
4	9,8	5.142.000
6	11,0	4.094.000
8	12,1	3.197.000
10	13,7	2.114.000
12	15,0	1.408.000
14	16,3	875.000
16	17,9	373.000
18	20,3	105.000
20	22,7	36.000
22	23,0	31.000

Table 20. Geological *in situ* reserves of graphite ore at Akuliaruseq, as calculated from drilling results down to a depth of 40 m.

RESUMED CRYOLITE PROSPECTING IN THE IVIGTUT AREA, 1984 - 1987

In the period from 1984 onward, the prospecting interest again turned back to cryolite. With prospects of an impending termination of cryolite production at Ivigtut, the Company, once again, wanted to carry out an investigation and interpretation of the most critical geological formations of the Gardar age in the Ivigtut region, in conjunction with a detailed study of all prospects which earlier had been prioritized as promising, but which, as yet, were still unexamined.

By means of three different airborne geophysical survey methods in a joint operation, provision was made for a rapid and thorough investigation of the region. The results of this survey were intended to help to identify and locate - *inter alia* - structures of the Gardar age. These structures were then to be objects of the subsequent follow-up studies.

The airborne geophysical survey program and the subsequent detail studies were carried out according to the plan, but evidence of new cryolite occurrences was not discovered.

The three previously known breccia formations, at Ika-point, at Qornoq fiord and the Bunkebreccia, respectively, as well as the so-called Corp's Klump prospect a Ivigtut, were probed by drilling, with the exception of the breccia at Qornoq fiord.

The results disclosed that the prospects, with the exception of Bunkebreccia, were characterized by a low geochemical content of fluorine, which ruled out the possibility of development of fluorine mineral occurrences in any noteworthy scale.

The drilling of Bunkebreccia, on the other hand,disclosed that the breccia formed an offshoot from the Ivigtut granite, which was penetrated at a depth of a little over 600 m beneath the breccia. In addition, the granite contained a dissemination of cryolite, which in a 90 m long drill core section varied from 2% to 11 % cryolite with 4-5 % cryolite as a mean value. The size of the mineralization remained unknown. The hatched area at a depth between 700 and 900 m. b.s.l. in fig. 22 designates the position within the newly discovered extension of the granite intrusion in which the disseminated cryolite mineralization was located.

With the exception of sporadic amounts of occasional cryolite and/or related minerals in earlier located acid alkaline dike rocks, the cryolite mineralization beneath the Bunkebreccia has been the sole discovery of cryolite on the whole which has been found outside the Ivigtut cryolite deposit during the long prospecting activity by the Company in Greenland.

Under the prevailing situation, approaching the conclusion of a 130-year period of cryolite production at Ivigtut and with a view of protracted prospecting activity ahead, the Company did not want to probe the discovered mineralization, but instead decided to close down the Exploration Division and its activities in Greenland.

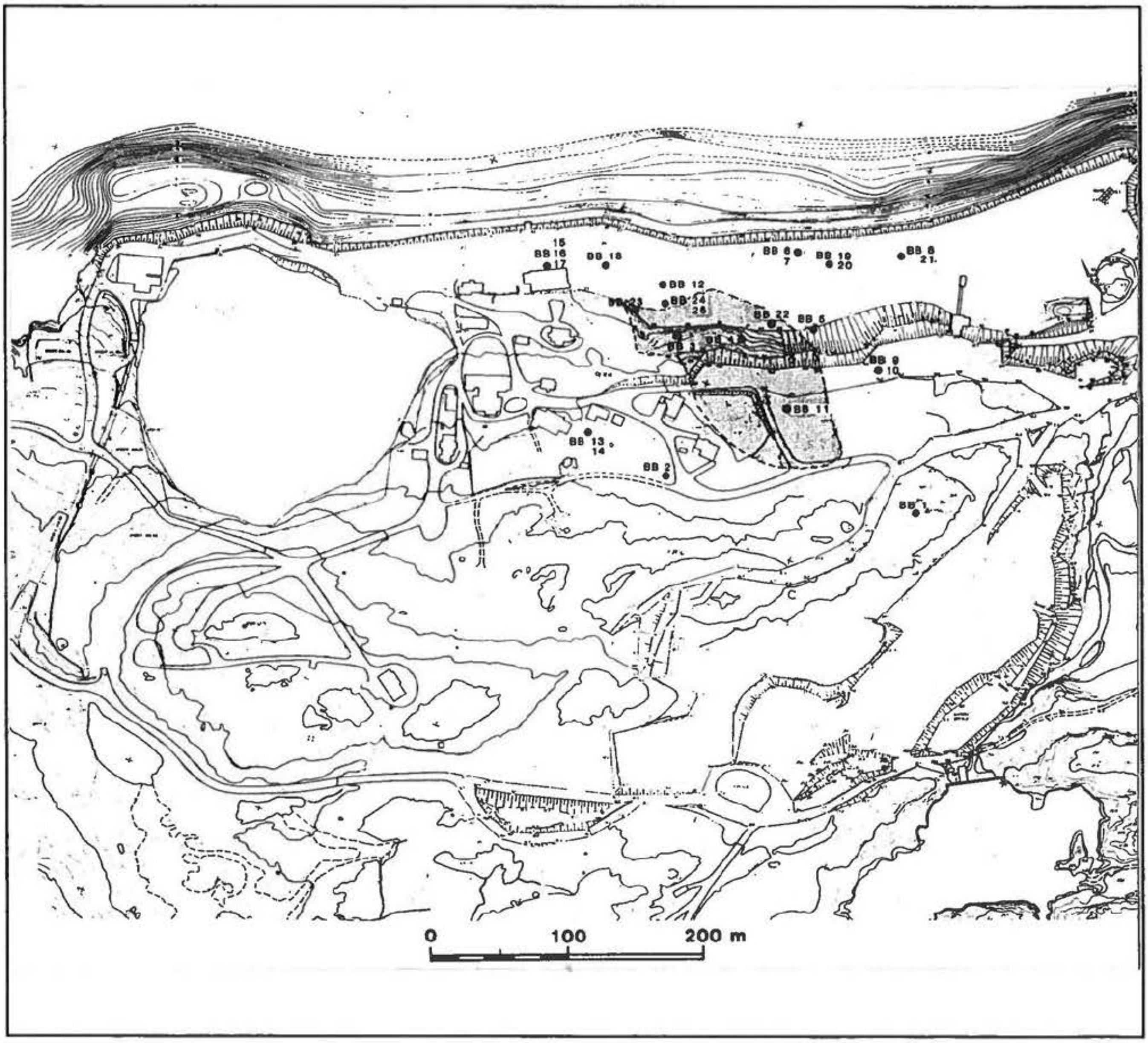


Fig. 21. The vicinity of the cryolite deposit at Ivigtut, showing the position of exploration drill holes. The shaded area indicates the exposure of an explosive breccia, called Bunkebreccia, surrounded by the local gneiss complex rocks.

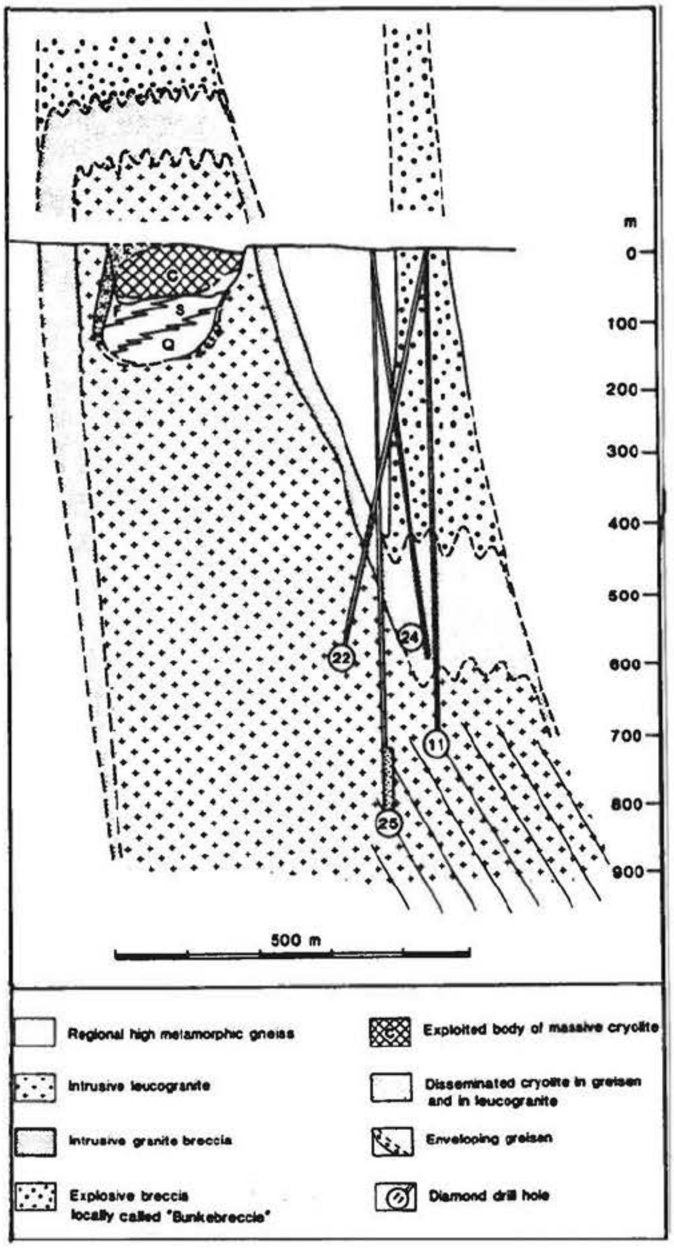


Fig. 22. Generalized section across the Ivigtut granite intrusion with the cryolite deposit and its extension beneath the Bunkebreccia. The orientation of the section is 62°, dipping 81° towards N.

THE EXPLORATION ACTIVITY IN FIGURES

Despite the fact that detailed data from early times are somewhat incomplete, the following historical data are illustrative in documenting the scope and efficiency of the exploration activity.

The staff

Throughout the years, the permanent staff of the Exploration Division has included the following persons:

Geologists:

Richard Bøgvad M.Sc. (mag.sci.) 1931 - 1952
Hans Pauly Dr. (dr.phil.) 1952 - 1963
Veijo Yletyinen M.A. (mag.phil.) 1957 - 1960
Lea Aho M.A. (mag.phil) 1958 - 1961
Leijo Keto M.A. (mag.phil.) 1960 - 1989
Jaakko Kurki M.A. (mag.phil.) 1964 - 1973
Seppo Turkka M.A. (mag.phil.) 1966 - 1969
Risto Juhava M.A. (mag.phil.) 1971 - 1974
Jens Gothenborg M.Sc. (cand.sci.) 1972 - 1988
John Pedersen M.Sc. (cand.sci.) 1975 - 1976
Jørn Morthorst M.Sc. (cand.sci.) 1980 - 1988

Laboratory staff:

Aksel Mouritsen 1953 - 1969
Anders Andersen 1956 - 1985
Reinhold Nielsen 1965 - 1986
Kjeld Hansen 1985 - 1989

Office staff:

Kirsten Mærsk 1956 - 1968
Alice Lundgren 1966 - 1972
Bente Serup 1971 - 1979
Lene Christensen 1979 - 1981
Vibeke Morthorst 1981 - 1989

Over and above the permanent staff, Mr. I. P. Danø, Vice President of the Company, held the responsible post for the Company's exploration activities from 1956 to his retirement in 1980.

In 1971 a subsidiary, Greenmines A/S (Grønlands Prospektering og Mineselskab A/S) was established with a primary intent to take care of the Company's interests in Isua Iron Ore Project, a general partnership project with Marcona Corporation of San Francisco, USA. By then, Mr. Danø was appointed to the Manager of the new subsidiary. After his retirement, Mr. L. Keto, chief geologist, succeeded him in his exploratory duties.

The extent and duration of field activities:

The field work in the 50 year period from 1938 to 1987 is distributed into occupational functions presented in the tabulation below. The year 1957 marks the changeover from the local cryolite prospecting in the Ivigtut area into a general prospecting phase on a regional scale.

	prior to 1957			1957-1987			total		
	No. of years	No. of workers	No. of man-periods	No. of years	No. of workers	No.of man periods	No. of years	No. of workers	No. of man-periods
Management:									
organization, programming	7	1	7	31	8	48	38	9	55
Exploration:									
geological	4	4	6	27	122	206	31	126	212
drilling	1	14	14	18	90	127	19	104	141
geophysics	4	14	15	17	75	134	21	89	149
Spec. studies:									
hydrology				10	15	13	10	15	13
subtotal:		33	42		310	528		343	570

(continued on the next page)

(continued from the preceding page)

	prior to 1957			1957-1987			total		
	No. of years	No. of workers	No. of man-periods	No. of years	No. of workers	No.of man periods	No. of years	No. of workers	No. of man-periods
Service:									
boarding	1	1	1	18	34	37	19	35	38
handymen	2	3	5	22	19	31	24	22	36
Transport:									
helicopter				21	63	83	21	63	83
sea transport				5	20	21	5	20	21
subtotal:		4	6		136	172		140	178
grand total:		37	48		446	700		483	748
Number of persons:									
participated in field activities:			34			420			454

The scope of the different types of investigations

The following tabulation includes a specification concerning the extent and amount of the most important types of field studies. Data referring to the period prior to World War II may be somewhat inaccurate.

I: Geological investigations:

1. Airborne geological reconnaissance:

West Greenland (59° 45' - 71° 00')	93.800 sq.km
East Greenland (59° 45' - 66° 15')	13.000 sq.km
total	106.800 sq.km (*)

(*) glaciers and ice caps are not included in the figures

2. Geological detail studies — 4000 sq.km.

II: Investigations by diamond drilling:

	number of prospects	number of drill holes	total drilling, m
1. exploration drilling	33	628	35.156
2. cryolite deposit at Ivigtut	1	195	11.237
total	34	823	46.393

(continued on the next page)

(continued from the preceding page)

III: Geophysical surveying:

1. Airborne geophysical survey:

	line km	sq.km.
a: magnetic survey	91.388	131.318
b: electromagnetic survey:		
- harmonic dipole source method, vertical coaxial rigid-coil system (Slingram)	16.527	2.818
- plane wave source method, VLF-system	3.943	493

2. Geophysical survey on the ground

	points	line km	sq.km
a: reconnaissance measurements (<400 pts./sq.km)	69.369	1.347	ca. 584
b: detailed measurements (≥400 pts./sq.km)	338.549	5.653	557
ground survey in total	407.918	7.000	1.141

3. Specification of the ground survey acc. to the survey method:

- magnetic survey	54,8 %
- electromagnetic survey:	
Slingram	28,8 %
VLF	6,7 %
Turam	0,8 %
- electrical survey:	
resistivity	0,6 % (*)
misé a la masse	1,0 % (*)
- self potential survey	0,04 % (*)
- induced polarization survey (IP)	1,9 %
- radiation survey	2,9 %
- gravity survey	2,2 %
- seismic refraction survey	0,3 %
total (407.918 meas. points)	100,0 %

(*) drill hole measurements included

IV: Geochemistry and analytical studies:

1. Chemical assays (1957 - 1987 only):
   approx. 18.000 samples, incl. drill cores, 130.400 element determinations

V: Special studies:

1. Hydrological studies:
   Continuous runoff measurements at 10 gauging stations in Isua area, 1974 - 1983, 317 gauging months
2. Monitoring of the temperature distribution and the presence of permafrost in the bedrock in Sukkertoppen area, 1968 - 1972,
3. Monitoring of the temperature distribution in the continental ice at Isua, 1972 - 1976,
4. Monitoring of the continental ice flow at Isua, 1970 - 1973, and at the glacier terminus at lake 792 near Isua, 1974 - 1981
5. Monitoring of the drift of the sea ice in the Godthaabsfjord, 1974 - 1981
6. Continuous weather observations at Isua and at Point Nua in the Godthaabsfjord, 1971 - 1979

Documentation of the results. Files.

The documentation of the accumulated results of the work has been embodied in the files mentionened below. Upon the close of the Exploration Division, all the documentary materials have been stored in the archives at the Geological Survey of Greenland.

The filed and indexed documentary materials comprise the following items:

- document file	internal company reports, accounts,memorandums etc.	437 items
- map file	various types of maps, profiles, sections and other drawings of which 3968 sheets are inherent field work maps	12500 items
- photo collection	incl. dias and paper copies	5404 items
- rock samples	incl. card index	19700 items
- thin sections	incl. card index	4225 items
- polished sections	incl. card index	1371 items
- drill cores	incl. core logs	46,4 km.

Professional expert assistance

According to the routine procedure, the exploration work has usually been arranged in such a way that the Company's Exploration Division has been responsible for the planning and programming of the field operations, as well as for the subsequent implementation and daily management of the field work. At the other end the staff has also taken care of combining and analyzing of the results as well.

In other respects, the Company has assigned the many different kinds of practical operations which, as a rule, an exploration campaign consists of, to specialist subcontractors, each duly recognized in their speciality.

Throughout the years trustful business relations have developed with a number of subcontractors, which with their professional skill and performance have been instrumental in the fact, that the planned field operations have been accomplished practically always according to plan, despite of the often very difficult Greenlandic conditions.

Following are the most noteworthy subcontractors:

Suomen Malmi Oy, Espoo, Finland	drilling, geophysics, aerogeophysics	1963-1976, 1982-1983	182 man periods
Finnprospecting Ky, Espoo, Finland	aerogeophysics, geophysics	1967-1968, 1978-1986	54 man periods
Arctic Consultant Group Virum Denmark	hydropower, ice and weather studies	1974-1983	16 man periods
Geoteknisk Institut Lyngby, Denmark	drilling	1985-1987	17 man periods
Outokumpu Oy Espoo, Finland	mining and prospecting consulting, chemical assays	1965-1987	unknown

Transport and maintenance services

Airborne transport service.

It is an indispensable prerequisite for a well-organized expedition to Greenland to have an effective air transportation system to tackle the inaccessible and trackless mountain landscape of Greenland.

Since 1961 the Company has used chartered helicopters to solve the daily transportation needs in conjunction with field operations. In addition, for particular transport purposes, hired helicopters from the local Greenlandair (Glace) company on an *ad hoc* basis have been used.

The airborne geophysical surveys in 1965, 1967-1968 were carried out by chartered airplanes.

The presentation below illustrates the extent of airborne transportation operations during the period of 1961 - 1986:

Chartered helicopter operations:			
number of pilots	35 pers.	44 work seasons	
ground crew	22 "	31 "	
total	57 pers.	75 work seasons	
number of helicopters			35
number of flight hours			5982,1 hrs.
Ad hoc helicopter operations:			
number of helicopters			19
number of flight hours			283,8 hrs.
total number of flight hours			6265,9 hrs.
Chartered airplane operations:			
number of pilots	3 pers.	5 work seasons	
ground crew	3 "	3 "	
total	6 pers.	8 work seasons	
number of airplanes			3
number of flight hours			648,3 hrs.

Charter party companies:	
Ostermans Aero, Sweden	1961-1963, 1977
Bergen Air Transport, Norway	1964-1968
Lentohuolto, Finland (airplane charter party)	1965, 1967-1968
Heli Union, France	1967-1972
Helilift, Norway	1969-1971
Heliswiss, Switzerland	1973-1974
Helikopteripalvelu, Finland	1980-1982, 1985
Greenlandair/Glace, Greenland	1975-1976, 1978, 1983, 1986

Provisioning and maintenance:

Another imperative for an expedition to Greenland is to be self-sufficient from home in all sorts of equipment and daily requirements, and to have a competent provisioning staff to take care of the physical comfort of the participants by cooking, as well as supplying provisions to the field teams. During the years, a number of handymen and assistants for their part have been in charge of keeping the current business constantly up to date, overhauling and repairing equipment and instruments etc.

The following presentation gives an idea of the extent of this activity:

Provisioning:	34 pers.	37 work seasons
Maintenance:	19 pers.	31 work seasons

Specification of the participants by nationality and occupation:

The tabulation below shows the specification of nationality and occupational distribution of the persons, who have participated in the Company´s exploration work in Greenland in the years of 1938 - 1987:

Number of persons/ Number of work seasons

	Denmark	Greenland	Finland	Sweden	Norway	France	Switzerland	New Zealand	U.S.A.	Colombia	Total
General management	3/19		5/35						1/1		9/55
Geological studies	20/40		105/171					1/1			126/212
Geophysical studies	14/15		74/133							1/1	89/149
Diamond drilling	20/25		70/102	13/13		1/1					104/141
Special studies	15/13										15/13
Air transport	4/4	2/2	13/18	21/28	9/12	11/15	3/4				63/83
Sea transport	8/9	4/4			8/8						20/21
Support activities (cooks, handymen etc.)	12/21	4/7	39/44	2/2							57/74
Grand total	96/146	10/13	306/503	36/43	17/20	12/16	3/3	1/1	1/1	1/1	483/748