

Graphite occurrences in Greenland

A review

Jan Bondam

Open File Series 92/6

July 1992



GRØNLANDS GEOLOGISKE UNDERSØGELSE
Ujarassioqut Kalaallit Nunaanni Misissuisoqarfiat
GEOLOGICAL SURVEY OF GREENLAND

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ISSN 0903-7322

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Abstract

Graphitic schists commonly occur in the Proterozoic supracrustal series, incorporated in Archaean basement, in Proterozoic greywackes in central West Greenland and in rocks of the Ketilidian mobile belt of Proterozoic age in South Greenland.

A special type of graphite occurrence is found in Cretaceous coal-bearing sediments on the Nuussuaq peninsula that have been contact metamorphosed by intrusive peridotitic dykes.

This review draws on a number of reports from the beginning of this century at the culmination of the search for economically viable graphitic deposits. Only those graphite occurrences that have been assayed or more thoroughly explored are reviewed. One deposit, on Amitsoq island in South Greenland was exploited from 1914 to 1922. One deposit, named Akuliaruseq has been explored in greater detail in recent years. The geographical position of the reviewed graphite occurrences in Greenland is indicated on the index map.

Modern Greenlandic orthography of place names has generally been used in this review.

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Introduction

Occurrences of graphite and graphitic schists have been reported from many localities in Greenland, mainly in the coastal areas between Upernavik (72°N) and Nanortalik (60°N) on the west coast of Greenland, and also from the area around Ammassalik (66°N) on the east coast.

Considerable information was accumulated in the beginning of this century when a search for graphite was the focus of attention of the mining company Grønlands Minedrifts Aktieselskab. A graphite deposit situated on the southern tip of the island Amitsoq near the township of Nanortalik was eventually exploited on a minor scale for a limited number of years from 1914 until 1922. More recently Kryolitselskabet Øresund A/S has prospected a previously known occurrence between Sisimiut/Holsteinsborg and Aasiaat/Egedesminde, at a locality named Akuliaruseq, previously called Eqlugssuit. Up to now, comparatively little has been published on graphite occurrences in Greenland, and most information of economic interest has hitherto only been available in company reports.

Ball (1923) described a number of graphite occurrences and deposits previously prospected by Grønlands Minedrifts Aktieselskab. Further occurrences of graphite are referred to by Bøggild (1953). Mention of graphite occurrences is also made by Nielsen (1976) in a short review of economic minerals in Greenland.

This report reviews the available data on graphite occurrences, including that on file at the Geological Survey of Greenland in company reports.

Short historical note on graphite prospecting

Bøggild (1953) refers to several sources of information on graphite occurrences in Greenland that date back to the last half of the nineteenth century and the beginning of the twentieth.

A particular active period of prospecting for graphite was initiated in 1903 by Julius Bernburg, a merchant who financed what were then called 'expeditions'. The prospectors were, to begin with, Norwegian and Swedish mining engineers, later joined by British and American mining geologists. These prospectors followed up descriptions from earlier travellers, and often received hints on graphite occurrences that were reported to the

local authorities by the Greenland population. The Geological Survey of Greenland is in possession of single copies of these reports of the early prospecting efforts.

Exclusive rights were granted to Julius Bernburg, permitting him to mine copper, lead, graphite, asbestos and mica on the west coast of Greenland from Kap Farvel ($50^{\circ}45'N$) to $74^{\circ}30'N$ by Royal decree of 29 June, 1904 for a period of 20 years. This concession was later extended to 1 January, 1933, in the name of Grønlands Minedrifts Aktieselskab.

Prospecting for graphite lasted until 1916. A graphite deposit on the southern tip of Amitsoq in South Greenland was eventually developed. Mining was initiated in 1914 and lasted until 1922. Development activities were initiated in 1916 at a locality then called Eqalugssuit, south of Aassiaat/Egedesminde, but although a proposal to mine 2500 tons for further development was made, no further work was undertaken.

The latter locality, renamed Akuliaruseq, was chosen as a target for reappraisal of the deposit by Kryolitselskabet Øresund A/S in the years from 1982 to 1986, after the locality had been revisited by Platou (1969). Geophysical surveys, drilling and flotation tests were carried out during this period of time. Existing company reports of Kryolitselskabet Øresund A/S relating to the investigations at Akuliaruseq are listed in appendix 1.

Recently the occurrences near the township of Ammassalik in East Greenland have been sampled by the Geological Survey of Greenland.

Mode of occurrence

Occurrences of graphite and graphitic schists in Greenland are mainly confined to tracts in the Precambrian shield that have been affected by Proterozoic activity. No graphite occurrences of any significance have been observed in the stable orthogneiss-amphibolite terrain of the Archaean craton, although in the Isua supracrustal sequence of early Archaean age (c. 3800 Ma) a 5 m thick horizon of graphitic biotite schist has been observed (Nutman, 1986). Graphite-garnet-biotite schists have also been noted on Storø in the Godthåbsfjord region in the early Archaean Malene supracrustal series (McGregor, 1992).

Graphitic schists in the high grade gneisses of the Proterozoic (Aphebian/Paleo-Helikian) may include reworked Archaean supracrustal rocks

in a continental collision zone north of Søndre Strømfjord. Elsewhere the majority of graphite schist occurrences are found within epicontinental, predominantly clastic sediments deposited on Archaean basement gneisses, and infolded into the basement rocks during Proterozoic metamorphism and migmatization. This is the case for Proterozoic metasediments in central West Greenland of which the lower sequences contain quartzites, marbles and mixed volcanoclastic rocks.

Horizons of graphite-pyrrhotite schists commonly occur in metagreywackes of the Nûkavsak Formation (1740 Ma) of the Karrat Group in central West Greenland (Henderson & Pulvertaft, 1987). Thin bands of graphite have also been observed in marbles from the Qeqertarssuaq Formation of the same age.

In South and South-East Greenland graphitic schists are contained in metasedimentary units incorporated in the folded migmatite zone of the Ketilidian mobile belt that evolved between 1890 and 1740 Ma.

The Ammassalik mobile belt (previously termed Nagssuqtoqidian in East Greenland) extends along the coast of East Greenland between 64° and 66°30'N, and comprises late Archaean crust with major infolded sedimentary units of presumed early Proterozoic age. The so called 'Siportâq supracrustal association' consists mainly of psammitic to semipelitic metasediments, among which graphite schists and marbles commonly occur. Occasional graphite flakes are found in pegmatites in zones where graphitic schists do occur. In other cases graphite is concentrated in lens-shaped bodies within graphitic schists.

A different type of graphite occurrence is found on the Nuussuaq peninsula north of Ilulissat/Jakobshavn where bituminous shales of late Cretaceous age have been contact metamorphosed by Tertiary extrusives. On the nearby island of Disko accessory graphite occurs in basalts that contain telluric iron.

The parageneses in which graphite occurs will be referred to below in the descriptions of a number of occurrences that have been prospected in some detail.

The location of graphite occurrences

The majority of known graphite occurrences along the coast of Greenland were discovered or visited in the period between 1903 and 1916. Although most occurrences have been sampled, only a restricted number of the samples

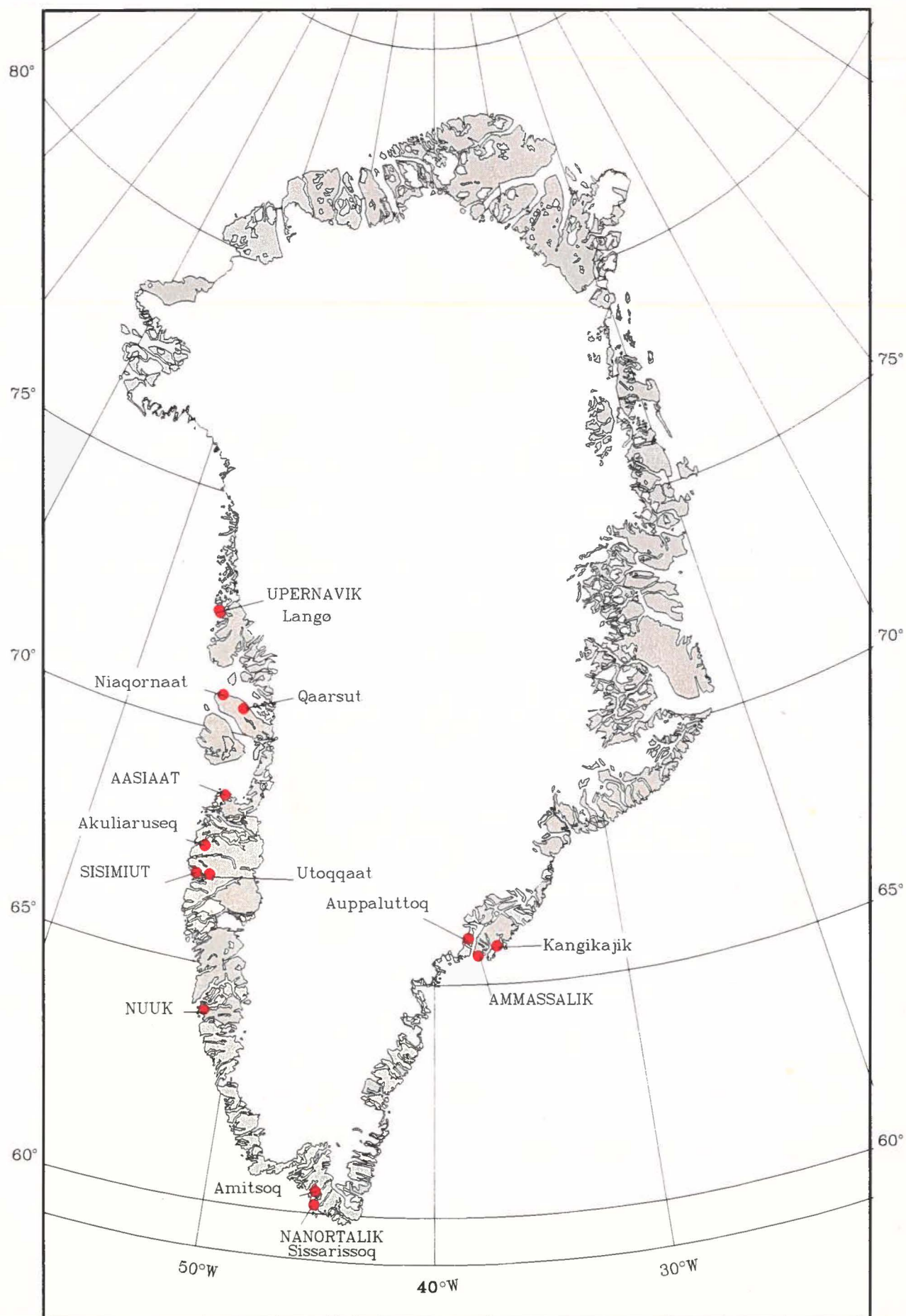


Fig. 1. Index map. Position of sampled graphite occurrences in Greenland. Some town names are added, written in capitals.

have been assayed. In the following only those localities that have been thoroughly investigated, by trenching, drilling and assaying, will be described in detail. Short reports of the remaining occurrences that have been visited are given by Høeg (1915, 1918). The position of the localities here described is indicated on the index map, cf. Fig. 1.

Akuliaruseq

The peninsula Akuliaruseq is located at 67°37'30"N, 51°45'00"W, south of Aasiaat/Egedesminde. The locality was previously named Ekalugssuit after the inlet south of the peninsula. Graphite bearing schists run parallel to the coastline, and can be followed over a distance of 7 km with a trend of 061° along the south coast of the peninsula. The occurrence of graphite at this locality was noted by Giesecke on 18.6.1808, as is recorded in his published diaries (Giesecke, 1910). Tiberg (1903) had 12 trenches dug perpendicular to the strike. The grade was estimated at about 25% C at the most promising locality, which was later mapped as a recumbent fold. Approximately 10 tons of graphite ore were quarried. Lindås (1916) revisited the deposit and quarried about 250 tons, down to a depth of 2.8 m, of which 100 tons was hand-sorted and shipped. Samples of the ore were treated by Høeg (1915). No further efforts were made to exploit the deposit.

In 1967 and 1969 the Geological Survey of Greenland carried out geological mapping around Akuliaruseq, cf. Fig. 2, as part of a regional mapping programme.

The main rock type on the Akuliaruseq peninsula is hypersthene gneiss which surrounds a downfolded synform of metasediments. The metasediments are mainly steep dipping schistose garnet-biotite gneiss and graphite bearing biotite-sillimanite gneiss. A quartzitic leucocratic-gneiss within the sequence carries disseminated magnetite. The graphite bearing schists vary considerably in width and in grade. Graphite clearly is concentrated in minor recumbent folds and within zones of mylonitic deformation.

On the basis of the renewed mapping Platou (1969) made a rough calculation of the available possible ore at three separate graphite enriched localities and concluded that 1.1 million tons down to 10 m depth could be allowed for, at an estimated grade of 30% C. On the grounds of this rather optimistic report, Kryolitselskabet Øresund A/S decided to

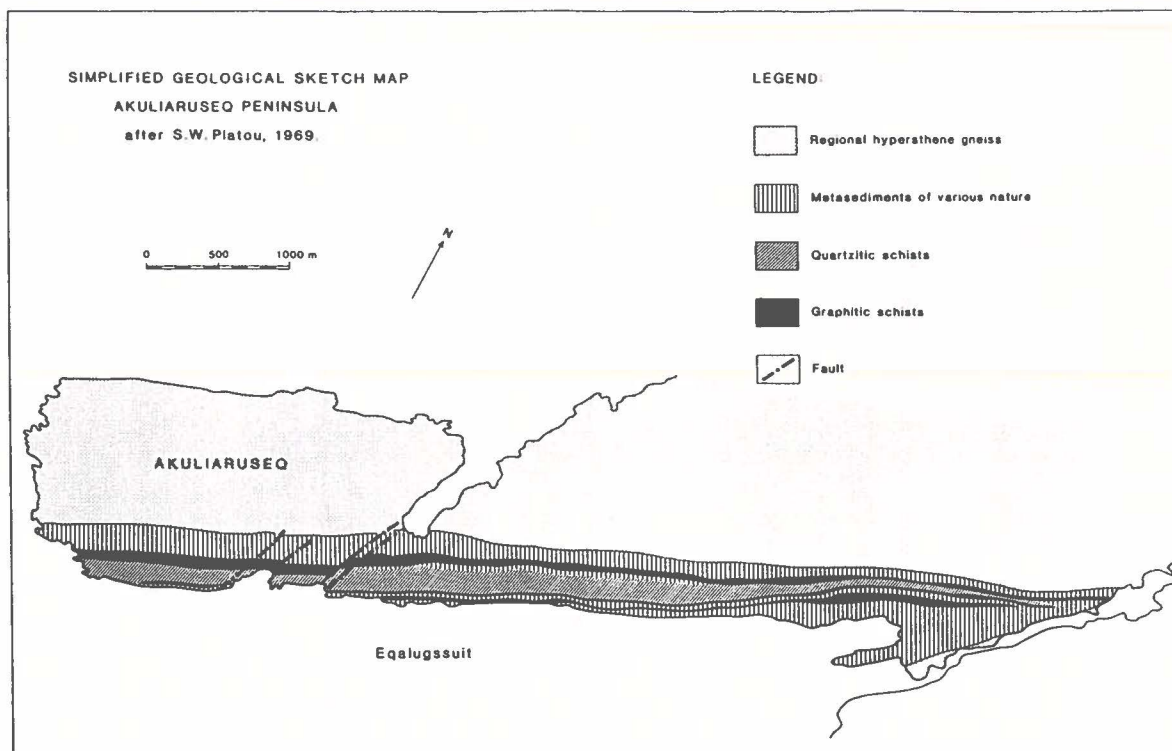


Fig. 2. Simplified geological sketch map of the Akuliaruseq peninsula.

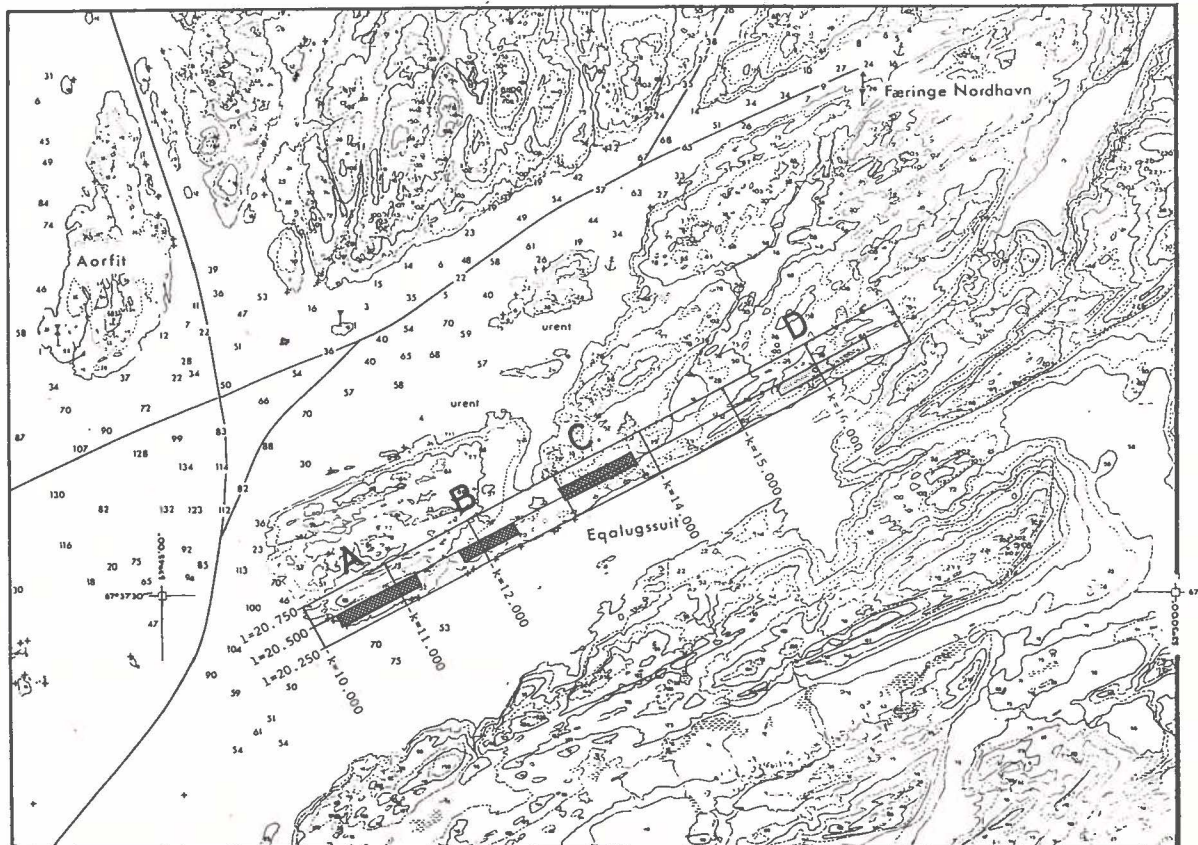


Fig. 3. Location map of Akuliaruseq, showing position of the grid for geophysical surveys with designation of coordinates, and position of the areas in which drilling was carried out in 1982 (area D), and 1983 (areas A, B and C).

carry out geophysical surveys and drilling in 1982 and 1983. In 1985 it was decided to quarry 20 tons of homogenized sample material, of 'average' grade, for further testing on a pilot plant scale.

Field investigations

A geophysical survey was carried out along a grid of 7000 by 500 m cf. Fig. 3, and included measurements of the total geomagnetic field, and of the electromagnetic conductivity, using the slingram method (Finnprospecting 1983). Due to the extreme conductivity of the graphite bearing rocks the overall picture of the electromagnetic anomalies does not properly reflect the graphite grades of the rocks in question.

Drilling was carried out on the basis of the magnetic anomaly map, along profiles perpendicular to the strike. A total of 124 drillings with a combined length of 5705 m were completed. In all 345 samples were analysed, representing about 1073 m core length (Morthorst & Keto, 1982, 1983). All drill cores are stored at the Geological Survey of Greenland and are accessible for further inspection.

Figure 4 illustrates the pattern of graphite mineralization along a profile perpendicular to the strike. The profile in question is situated at K=13600 (area C) and includes the diamond drill holes AKU-64 and AKU-65.

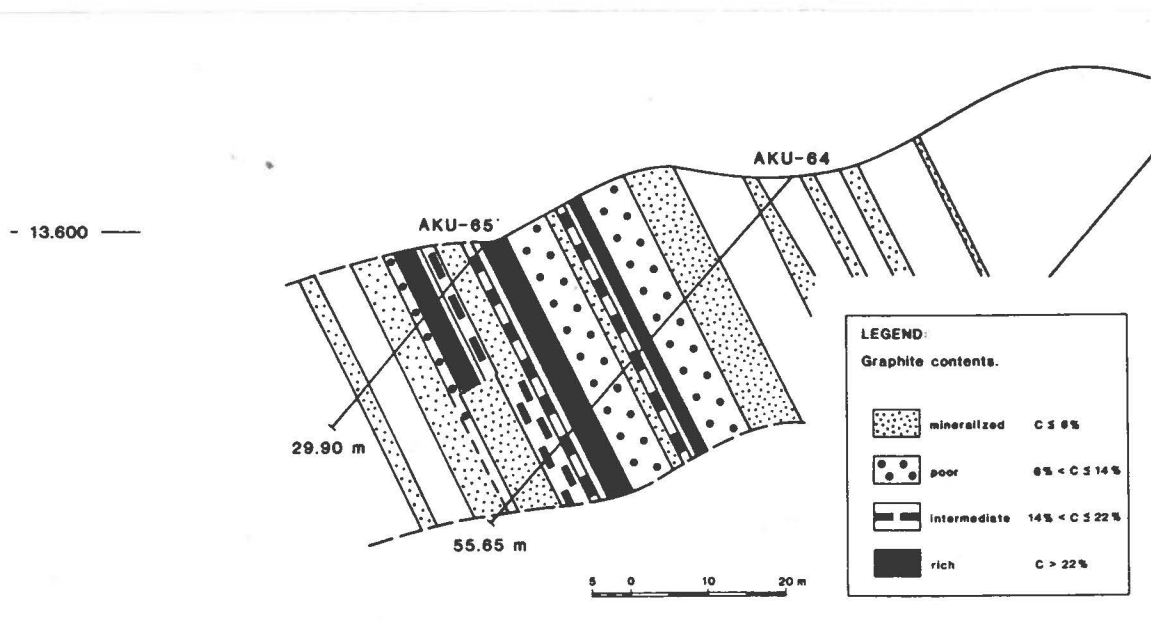


Fig. 4. Cross-section through the diamond drill holes AKU-64 and AKU-65, area C, showing the pattern of graphite distribution perpendicular to the strike of the occurrence. After Morthorst and Keto (1983).

Ч. КЛ	2,0 - 3,9	4,0 - 5,9	6,0 - 7,9	8,0 - 9,9	10,0 - 11,9	12,0 - 13,9	14,0 - 15,9	16,0 - 17,9	18,0 - 19,9	20,0 - 21,9	22,0 - 23,9	
1,0 - 1,9	13.662	30.337	32.735	44.594	41.139	12.884	6.912	9.558		4.887	5.400	202.108
2,0 - 2,9	50.674	165.117	196.975	67.764	48.373	13.662	22.944	9.936				575.445
3,0 - 3,9	65.528	116.454	162.763	89.102	131.248	76.950	40.705	41.828	18.360			742.938
4,0 - 4,9		137.670	20.617	215.896	232.645	66.327	73.440					746.595
5,0 - 5,9	28.318	169.992	171.059	145.001		27.540	42.606				26.082	610.598
6,0 - 6,9		61.703	65.027	139.698	84.591	32.400	54.783	48.339				486.541
7,0 - 7,9	38.750	148.772	80.190	119.880		38.353	78.570	19.494				524.009
8,0 - 8,9				43.470		111.888	47.520	46.116				248.994
9,0 - 9,9		49.084	53.190	23.598	51.300	44.712			49.950			271.834
10,0 - 10,9		49.680	59.130	58.860	54.000		50.177					271.847
11,0 - 11,9			55.642	64.368	63.180			61.020				244.210
12,0 - 12,9				69.984				32.454				102.438
13,0 - 13,9												-
14,0 - 14,9												-
15,0 - 15,9							83.430					83.430
16,0 - 16,9												-
17,0 - 17,9												-
18,0 - 18,9												-
19,0 - 19,9												-
20,0 - 20,9						108.756						108.756
21,0 - 21,9												-
22,0 - 22,9												-
23,0 - 23,9												-
24,0 - 24,9		119.480										119.480
	196.932	1.048.289	897.328	1.082.215	706.476	533.472	501.087	268.745	68.310	4.887	31.482	5.339.223

Table 1. Total indicated graphite resources down to 40 metres depth. The resources are classified as to grade (horizontal scale) and horizontal width of graphite mineralization (vertical scale).

Table 2. The amount and grade of indicated graphite resources included in the zones with minimum horizontal width of 4 metres and minimum concurrent grade of 12% C.

Block	tons	average grade % C.
A	210 710	15.3
B	97 030	13.0
C	579 900	14.7
D	275 610	14.9
Total	1 163 250	14.8

Table 3. The amount and grade of available graphite resources in an open pit down to a depth of 40 m with a wall slope of 65°.

Block	Wall rock		Total resources: diluted with wall rock		ore/waste ratio
	tons	grade % C	tons	grade % C	
A	135 000	11.5	346 000	13.8	1:2.1
B	107 000	10.5	204 000	11.7	1:2.0
C	131 000	12.6	314 000	14.0	1:1.9
D	39 000	12.6	314 000	14.6	1:2.0
Total	412 000	11.2	1 574 000	13.8	1:2.0
B excluded	-107 000	10.5	-204 000	11.7	1:2.0
A+C+D	305 000	11.4	1 370 000	14.1	1:2.0

Resources

On the basis of the chemically analysed drill cores calculated down to a depth of 40 m below surface, the total volume of graphite bearing schists in the investigated deposit is 5.3 million tons with a weighed average grade of 9.5% C (see Table 1).

If exploitation was based on a minimum horizontal ore width of 4 m and a minimum grade of 12% C, the available resource of graphite in four separate blocks (A, B, C and D in Fig. 3), is reduced to 1 163 250 tons with 14.8% C, down to 40 m depth (cf. Table 2).

Development of the reserves in an open pit down to 40 m depth with a wall slope of 65° (corresponding to the actual dip of the metasediments) will contribute an additional 412 000 tons with an average grade of 11.2% C, bringing the total mineable reserve to a figure of 1 574 000 tons with a grade of 13.8% C.

If block B (which has the lowest tonnage and grade) is excluded, the mineable tonnage is reduced to 1 370 000 tons at a grade of 14.1% C (cf. Table 3).

All carbon grades mentioned here have been determined as loss on ignition.

Test runs

Test runs were carried out in two stages. All tests were carried out at Norges Tekniske Høgskole (NTH) Trondheim in Norway. The first runs were bench flotation tests on three separate samples, named I, P and BS. Sample I was taken from a remaining pile of quarried ore (Lindås, 1916). The mineralogical composition of the samples is given in Table 4, on the basis of point counting of thin sections and polished sections.

Assays were made for a number of elements, the results of which are given in Table 5.

A number of bench tests were carried out before and during a full scale pilot plant run carried out on 8 tons of a homogenized sample of 20 t quarried in 1985. Three test samples of this material assayed 15.0, 15.7 and 14.7% C determined by loss on ignition.

A set of 11 runs on pilot plant scale produced a concentrate recovery of about 70%. The result of a test run on a combined sample of graphite ore

Table 4. Mineralogical composition (vol %) of the samples Aku - I, P and BS.

	Aku-I	Aku-P	Aku-BS
quartz, feldspar	44.4	57.8	59.2
biotite	11.1	10.7	10.0
sillimanite	4.8	4.5	1.2
garnet, amphibole,			
pyroxene	4.1	3.2	3.8
graphite	24.2	15.2	20.5
sulphides	8.7	7.5	4.3
oxides	2.6	1.0	1.1
	99.9	99.9	100.1

Table 5. Partial chemical analyses in weight % of the samples Aku - I, P and BS.

Elements	Aku-I	Aku-P	Aku-BS
Al	4.1	5.2	5.1
Fe	6.0	9.0	6.2
Mg	0.8	0.7	0.6
Ca	1.6	0.9	0.9
Na	0.7-1.0	0.5-0.7	0.4-0.6
K	1.3	1.4	1.3
Cu	0.015	0.03	0.02
Ni	0.02	0.04	0.02
Zn	0.02	0.02	0.01
Pb	0.003	0.005	0.003
S	2.6	3.9	3.2
C	18.3	9.4	17.9

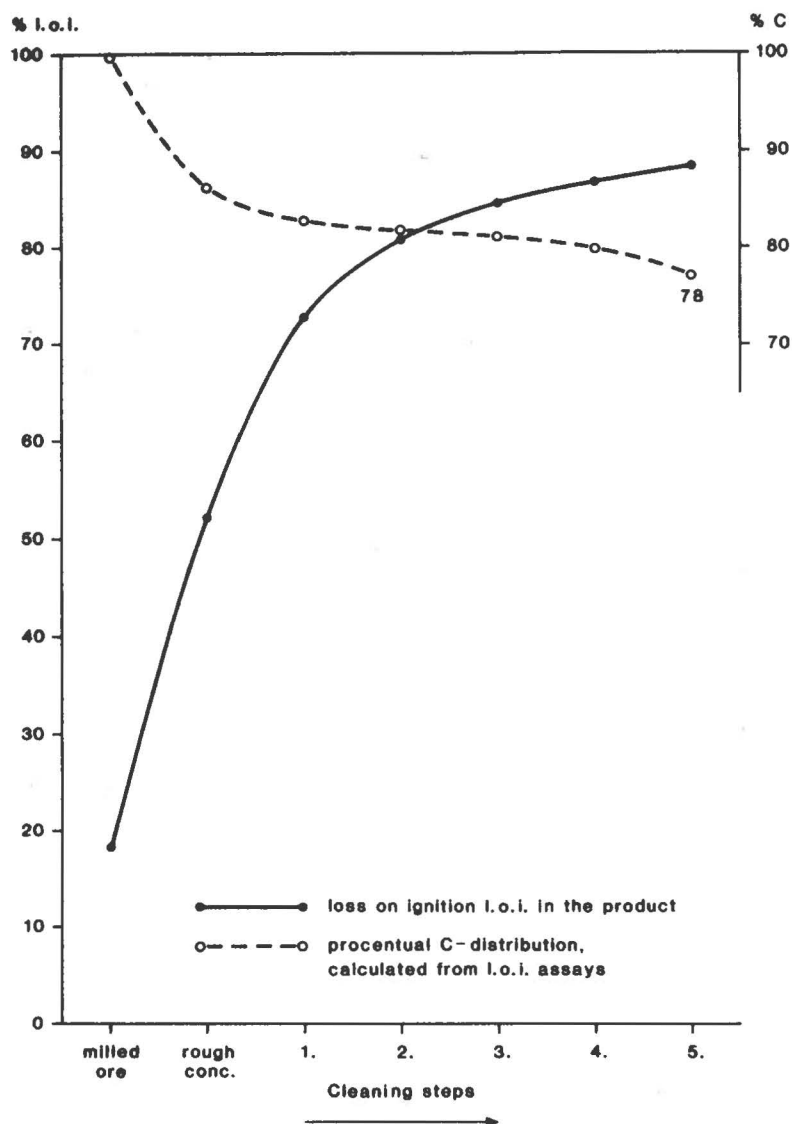


Fig. 5. Result of a test run on a sample of AKU-C, employing successive milling and re-flotation in five cleaning steps, according to Dige (1986).

collected from core samples is illustrated in Fig. 5.

An optimal recovery of graphite concentrates of ore from Akuliaruseq, based on the combined test runs is presented in Table 6, according to Dige (1986).

Typically graphite may be included in other minerals, or adheres to micas. This means that critical parameters like particle size, grade and recovery would have to be further optimized in a production stage. No further development work is anticipated.

Table 6. Optimal recovery of graphite in weight %

Size fraction mm	Quality designation	% of conc.	% C	% C in the ore
+ 0.1	flake	30	over 90	3.5
0.1-0.05	medium	20	over 88	2.5
>0.05	amorph	50	appr. 75	5.5
Sum		100	appr. 82	11.5

The ore grade is 14% C, which gives a total carbon recovery of 80%.

The graphite occurrence on the Akuliaruseq peninsula is the western extension of a zone of regional Proterozoic gneiss in which metasedimentary series are downthrust. This zone can be followed northeastward over a considerable distance. Although graphitic schists are known to exist further inland, no records are available as to their widths and grades.

Indications on the occurrence of graphitic schists are widespread in the coastal area between Akuliaruseq and Sisimiut/Holsteinsborg (ab. 67°N). Some occurrences have been recorded by Høeg (1918). However, no precise location is given. His report includes a handcoloured map, scale 1:750 000, where the occurrences are indicated.

In the following chapters a number of graphite occurrences are described of which only scant data with respect to grade, lateral extension and possible resources are on record.

Amitsoq and Sissarissok*

In South Greenland graphitic schists occur in pelitic to semipelitic gneiss of early Proterozoic age that are incorporated in the folded migmatite zone of the Ketilidian mobile belt (Kalsbeek et al., 1990). These rocks commonly occur in the area between the fjords Søndre Sermilik and Tasermiut.

* Previously spelled Sigsarisok.

Graphitic schists have been reported from several localities in this region (Bernard, 1915), and two occurrences in particular have attracted attention and been sampled. These are found on the island of Amitsoq, and at Sissarisssoq due west of the town of Nanortalik (Rasmussen, 1903).

Amitsoq

The graphite deposit on the southernmost tip of the island Amitsoq is situated at 60°17.3'N, 45°8.1'W. Graphitic schists occur embedded in strongly sheared cordierite-sillimanite-biotite gneisses in the southern half of the island. They are exposed on the steep eastern face of the mountain sloping towards Saqqaa. A steep fault separates the gneisses from aplitic granite and meta-arkoses found in the northern part of the island.

Strache (1915) delineated four graphite zones, of which one, called the 'main vein', was subsequently quarried. Bernard (1915) carried out trenching and sampling of the 'main vein'. Fig. 6 is a simplified reproduction of the site situation that year.

The ore consists of finely disseminated crystalline graphite flakes in a quartz rich groundmass, accompanied by pyrite and some biotite. The metamorphic nature of the deposit is accentuated by crenulated slabs of biotite gneiss, irregularly incorporated in the main graphite schist.

The measured width of the graphite layer reaches a maximum of 13.2 m, pinching out over 400 m to 3.5 m at its north-eastern extension along strike. Westwards the graphite layer thins to 0.2 m over a distance of only 70 m.

Although a large number of samples have been taken, there is no record of any assays.

Ball (1924) reports the grade to be 20-24% graphite and that graphite flakes reach a maximum diameter of 15 mm. He also notes that "considerable shipments have averaged 20% graphite". The only available assay of "average ore grade" is given by Høeg (1915) as 0.2% H₂O, 6.0% S and 21.0% C, based on ore quarried in 1914. A sample of 80 kg was extracted from 80 tons crushed ore. Høeg used the sample for a series of washing and screening tests, in order to obtain an upgrading of the ore. No viable results were obtained.

Although it is known that further testing was carried out in Germany and Great Britain, no results are available. Nevertheless a saleable product

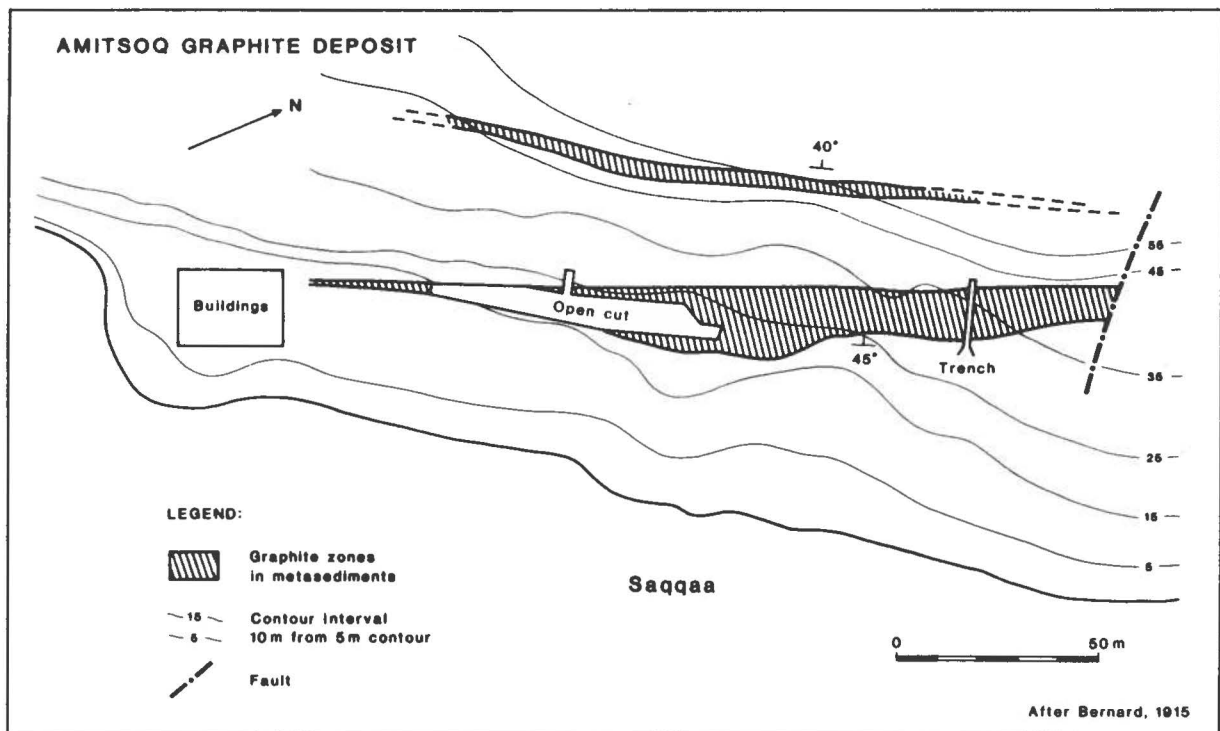


Fig. 6. Site situation of the Amitsoq graphite deposit, according to Bernard (1915).

was obtained at the mine site, primarily by hand sorting and washing. In the following the known exploitation data are given.

Quarrying was initiated in 1914 (Lindås, 1914). About 130 tons graphite ore was excavated, of which 80 tons was shipped to Denmark for testing purposes. Lindås estimated that 91 200 m³ graphite ore was easily accessible for quarrying, representing approximately 250 000 tons. The following year was used to further delineate and develop the deposit (Bernard, 1915; Strache, 1915) and some 2000 t ore was quarried. The first world war disrupted further activity. After the war mining was resumed on a very modest scale. Ball (1924) reports that between 1918 and 1921 a total of 571 tons of concentrates was produced at the mining site. Exploitation came to an end in 1922.

Sissarissoq

At Sissarissoq, about 2.5 km south-west of the township Nanortalik, at 60°8.2'N, 45°17'W, a number of lens-shaped bodies of graphite occur embedded in pelitic to semipelitic gneisses.

The occurrence was first recorded by Rasmussen (1903) who mentioned only that the graphite layer contained quartz and pyrite. Lunn (1905) visited the occurrence and reported that the graphite is very finely divided in the matrix; he considered the quality of the ore to be too poor to be of any value.

The only existing sketch map of the occurrence is that presented by Bernard (1915). Three outcrops, at an altitude of about 200 to 250 m, were trenched and sampled.

An assay of graphite ore from Sissarissoq is given in a letter to Grønlands Minedrifts Aktieselskab (GMA), dated Copenhagen, 12th of February, 1914. The analyst was the laboratory of Detlefsen & Meyers in Copenhagen.

The analysed sample contained 24.0% graphite; the sulphur content is given as 7.17% present in sulphides and 0.13% in sulphates. No further details are available whether this sample is representative for the grade of the exposed graphite lenses.

Bernard (1915) concluded that the Sissarissoq occurrence "is a flat lens, the surface of which is exposed on a sloping hill side". In all about 280 m² of exposure was investigated, indicative of a modest tonnage of 4000 t of graphite ore. From this description it is evident that the Sissarissoq occurrence is only of modest dimension.

Utoqqaat

In the vicinity of the town Sisimiut/Holsteinsborg (67°N) a number of graphite occurrences were prospected at the beginning of this century. One of these occurrences, named Utoqqaat* has subsequently been investigated in some detail.

* The locality named Utoqqaat is written according to the modern Greenlandic spelling. In older reports the name is spelled Utokak or Utokrat, while the spelling Utorqait is used on topographic maps issued by the Geodetic Institute.

The area due south of Sisimiut is a tract of the regionally widespread reworked orthogneiss-amphibolite terrain of Archaean age in which rock units of metasedimentary origin are incorporated. The regional high grade metamorphic gneiss is of tonalitic to granodioritic composition. From Sisimiut eastwards along the inner fjord system, including Amerloq, Maligiaq and Akueleq, graphite-bearing garnet-biotite-sillimanite schists and biotite-graphite schists occur frequently in a zone approximately 15 km wide. Graphite is locally enriched within this zone. A summary description of similar rock types found to the north of this area is given by Olesen et al. (1979).

The graphite occurrence explored at Utoqqaat, positioned at 66°55.0'N, 53°04.8'W, is situated on the northern shore of Amerloq. Lindås (1914) registered seven horizons of graphite bearing schists, striking 058°, in a zone of 1.2 km width perpendicular to the strike. The apparent widths of these graphite bearing schists varies from approximately 1 to 10 m.

In particular, two closely spaced zones along a narrow stream were sampled at regular intervals over a distance of 164 m. According to Høeg (1915) the sampled material, in all about 80 t, assayed 21.0% C and 5.5% S.

Lindås (1914) mentioned the occurrence of pyrite and quartz in the graphite layer. According to a sketch map included in his report the widths of the two graphite veins varies a great deal, from a minimum of 10 cm to 330 cm.

A preliminary bench test, employing sieving and washing only, was carried out by Høeg (1915). In his tests he also employed graphite samples from Amitsoq and Langø (see below). As previously mentioned, this way of testing only gave unsatisfactory results. No further efforts to resume prospecting at Utoqqaat were taken.

Ball (1923) gives a short description of the Utoqqaat occurrence as an example of "graphite in tabular bodies and irregular masses". A cross section (cf. p. 45 of his paper) reveals that over a width of 1.5 m of graphite carrying rock, two graphite rich zones 15 cm and 3 cm wide can be observed. Quartz pegmatite also occurs in the profile.

Lindås (1914) further mentions the occurrences of graphitic schists between Maligiaq and Akueleq, narrow inlets in the fjord system east of Amerloq. Samples were taken, but presumably not assayed, as no chemical analyses of these occurrences are on record.

The Maligiaq locality was briefly visited and sampled by Olsen & Kalvig (1988). The samples were taken at six localities over a distance of 800 m along strike in graphite bearing mica-schists. A rough estimate of the graphite content of seven samples is reported, with grades varying from 5 to 25% C.

Langø (Upernavik)

Graphite occurrences are found in metagreywackes of the Proterozoic Karrat Group in central West Greenland. The metagreywackes include interlayered pelitic and semipelitic schists. For information on distribution see the geological map of Greenland, 1:500 000 series sheet 4, Upernavik Isfjord.

The graphite occurrence on the island Langø/Akia is situated at 72°44.8'N, 56°08.0'W, due south of the town of Upernavik. It was first recorded by Rink (1852), who stated that the locality at Søndre Næs/Pamiua, the westernmost tip of the island, was quarried in 1845 by British merchants.

The locality was subsequently visited by Krantz (1903) and later by Sebelien (1914) and Lindås (1915). Lindås produced a sketch map of the position of the pits that had been excavated earlier. In addition a number of trenches were dug in the scree between the exposed graphite schists, but without positive results.

Apart from excavation of a 25 t sample of graphite ore, the locality was not explored under the concession issued to Grønlands Minedrifts Aktieselskab.

According to descriptions given by Lindås (1915), Ball (1923) and Bøggild (1953) graphite occurs in irregular lenses and veins in garnet bearing schists. Ball (1923) describes the mode of occurrence as "graphite masses of presumably pegmatitic origin".

According to Høeg (1915) a 2 t sample taken by Sebelien (1914) assayed 81.3% C and 1.5% S, but the sample can hardly be considered to be representative for the average grade of the occurrence. Another assay of graphite from Langø was recorded in a letter dated 13 September 1913, in which it is stated that "graphite from Upernavik was analysed by the state laboratory and proved to contain 90.4% C". However, it is evident that this assay represents hand picked graphite flakes from a sample previously

collected by Krantz (1903). Ball (1923) concludes that although graphite from the Langø occurrence is known to be of excellent quality, "the known deposits are scarcely large enough to be exploited".

In addition to the occurrence on Langø, Lindås (1915) recorded two further graphite occurrences in this part of central West Greenland. These localities are Qaneq ($73^{\circ}02'N$) in the skerries due north of Ikeq/Upernavik Isfjord, and in the northern part of the Nunatarsuaq peninsula ($73^{\circ}20'N$).

The occurrence at Qaneq is a graphitic schist enclosed in semipelitic gneiss, that can be followed over a distance of about 900 m along the south-western coast of the island. Lindås mentions that the graphite bearing schist is 5-6 m wide, dipping about $70^{\circ}W$. Samples have been taken, but no assays are available.

Ammassalik

In the district around the town of Ammassalik in South-East Greenland several occurrences of graphitic schists have been observed. Their occurrence in this part of Greenland was first documented by Nordenskjöld (1904), who described a sample of graphite schist collected along the coast of Depotfjord.

Recently samples from graphite occurrences have been collected by the Geological Survey of Greenland, and subsequently analysed. These localities are Auppaluttoq, along the west coast of Sermilik at $66^{\circ}06'N$, $38^{\circ}00'W$, and Kangikajik, a peninsula north of Ammassalik, where sampling was carried out at three different places. The Kangikajik peninsula is situated at about $66^{\circ}05'N$, $35^{\circ}50'W$.

On Fig. 7, reproduced from Dawes et al. (1989a) the sample localities are marked with the designation A for Auppaluttoq and K for Kangikajik. As apparent from this map, supracrustal rocks are incorporated as enclosures in a Precambrian gneiss complex. It is presumed that the regional gneisses in South-East Greenland represent a basement to a sequence of supracrustal rocks. Samples of retrogressed granulite facies gneiss from Storø (see Fig. 7) have given Archaean Rb-Sr whole rock ages (Pedersen & Bridgwater, 1979). Isotopically dated supracrustal rocks in the Sermilik fjord area, close to Auppaluttoq, are of early Proterozoic age (Kalsbeek & Taylor, 1989).

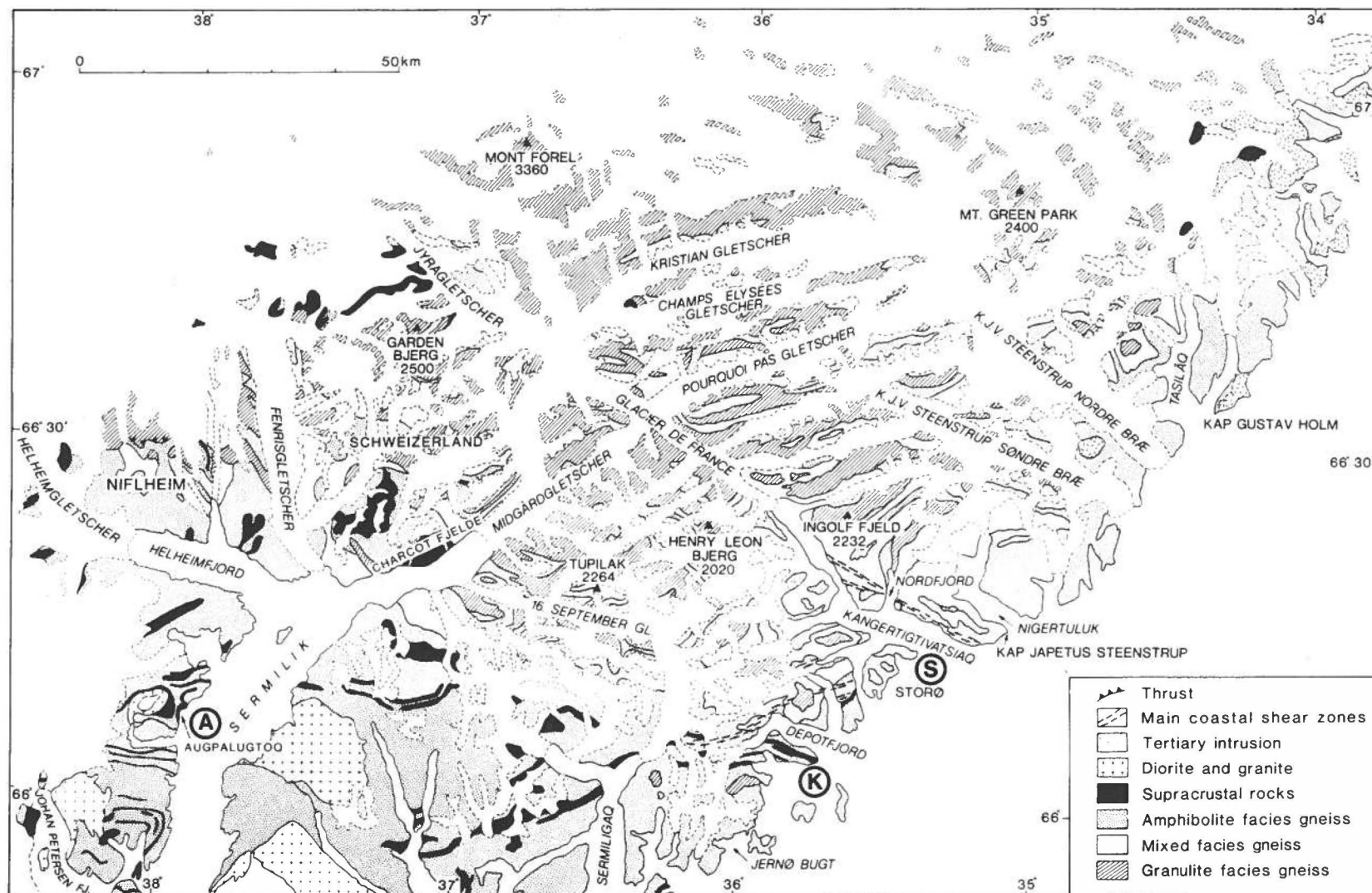
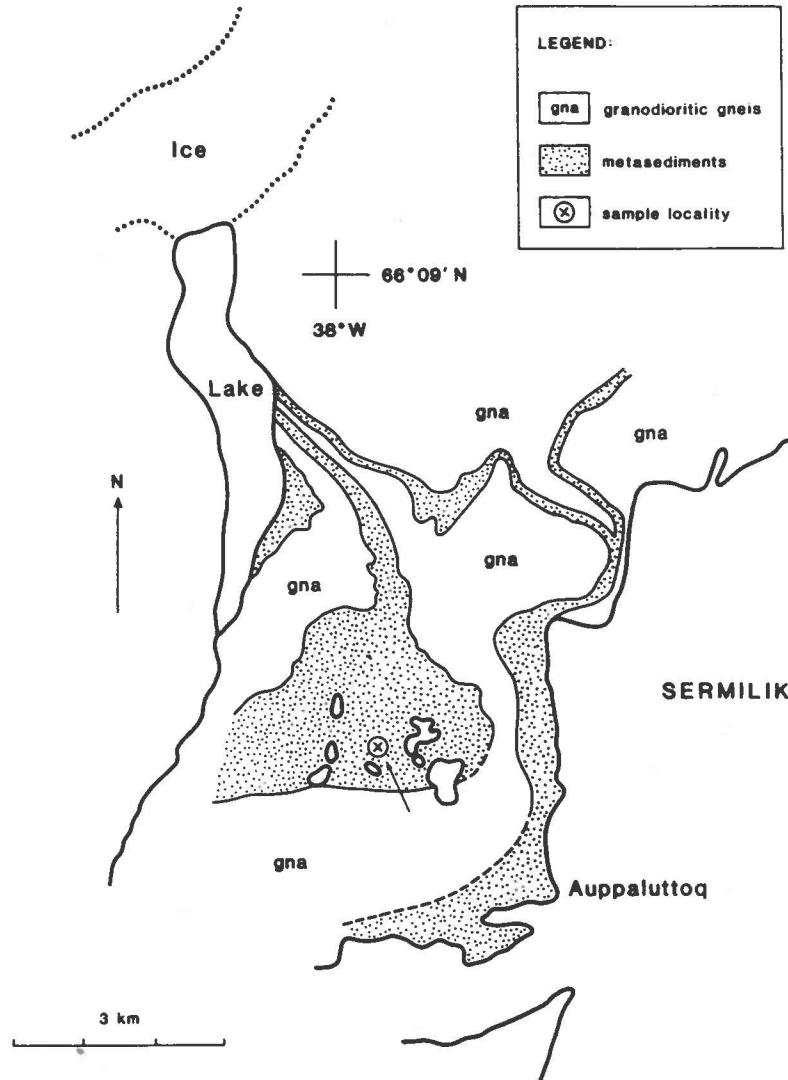


Fig. 7. The position of sampled graphite occurrences in the area around Ammassalik: A=Auppalluttoo, K=Kangikajik. S refers to Storø cf. text.

Fig. 8. Geological sketch map of graphite bearing metasediments near Auppaluttoq. The position of the sample locality is marked.



Auppaluttoq

According to the geological sketch map (Fig. 8) the metasediments at Auppaluttoq are flat lying folded horizons within the regional grey quartzofeldspathic gneisses. The metasedimentary rocks are rusty weathering, and range from biotite and graphite schists to psammitic and quartzitic schists with minor calc-silicate intercalations.

At the sample locality the graphite schist varies in width from 5 to 10 m and can be followed over a distance of at least 200 m. The metasedimentary series as a whole is between 50 and 100 m thick and may contain several graphite rich layers.

A preliminary analysis of a single sample of graphite schist (GGU 333283) gave 25% weight loss on ignition, while 5.34% of the ash content is soluble in aqua regia.

Kangikajik

The geological sketch map of the Kangikajik peninsula reproduced in Fig. 9 (after Dawes, 1989), shows the main pattern of supracrustal rock layers embedded in amphibolite facies regional quartzofeldspathic gneisses. It is possible that the outcrops of supracrustal rocks on Kangikajik represent a single stratigraphical unit.

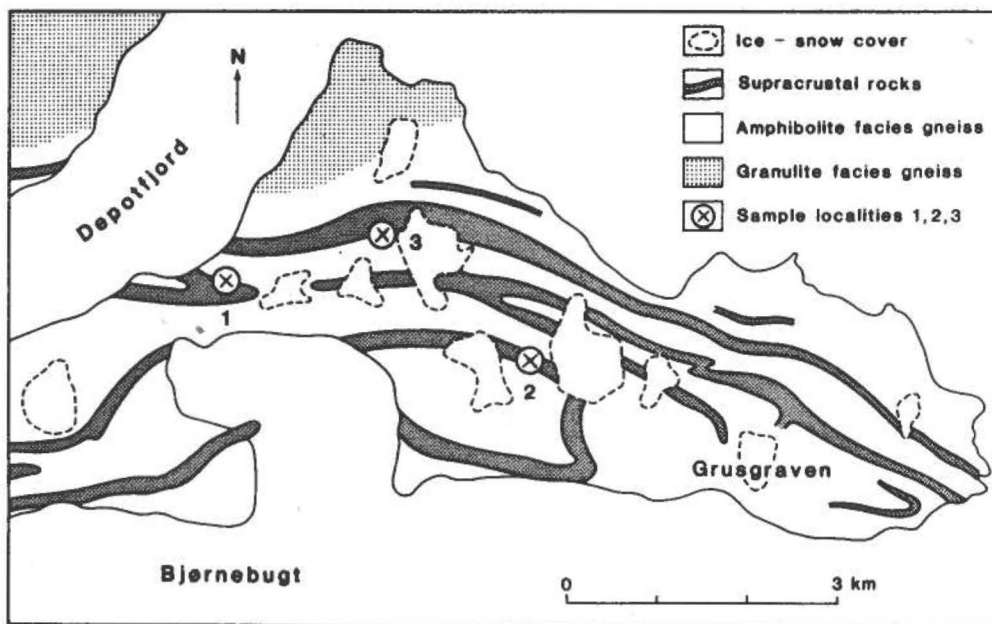


Fig. 9. Geological sketch map of graphite bearing metasediments on the Kangikajik peninsula.

Graphite is concentrated in pelitic lithologies of the metasediments, in horizons of 1-2 m thick. Samples were taken at three localities (numbered 1, 2 and 3 on Fig. 9). A sample from locality 1 (GGU 312891A) assayed about 78% weight loss on ignition and 9.15% matter in the ash content dissoluble in aqua regia. Analytical figures of a sample from locality 2 gave 18.5% weight loss on ignition; 12.09% of the ash content is dissoluble in aqua regia. At locality 3, three different samples, (GGU 348093, 348094 & 348095) were collected and chemically analysed in detail.

The results of these analyses are given in Tables 7 and 8. Graphite flakes from these localities reach a maximum of 1.3 mm across. Analyses were carried out at the chemical laboratory of Grafitbergbau Kaisersberg in Austria.

Table 7. Content of carbon and sulphur in graphite samples from the Kangikajik peninsula.

GGU no. %	348093	348094	348905
1. l.o.i.* (n=5)	67.23	56.33	80.57
2. C	63.12	50.04	71.44
diff. 1-2	4.11	6.29	9.23
S	0.59	1.14	1.98

* l.o.i.= loss on ignition.

Table 8. Content of major elements in sample material from Kangikajik after ignition, in weight per cent recalculated to 100% in total.

GGU no.	348093	348094	348905
SiO ₂	67.04	59.18	61.44
Al ₂ O ₃	9.18	10.04	8.14
Fe ₂ O ₃	10.15	14.10	9.42
CaO	5.18	9.04	11.74
MgO	3.04	4.12	5.14
Alk.	5.41	3.52	4.12

Nuussuaq (Niaqornaat, Qaarsut)

A special type of graphite occurrence has repeatedly been visited by explorers during the late 19th and the beginning of this century. This is the occurrence of graphite in bituminous shales in Early Cretaceous to Lower Tertiary (Danian) clastic sediments, deposited in the so-called Nuussuaq embayment of central West Greenland between 69°N and 72°N. Where these sediments are cut by Tertiary basic dykes the carbonaceous matter in the sediments adjacent to the dykes is either partially coked or metamorphosed to amorphous graphite. Two localities, both situated on the north coast of the Nuussuaq peninsula adjoining Uummannaq Fjord, were prospected by Heim (1909).

The outermost locality (Niaqornaat, situated at 70°45'N, 53°40'W) was previously sampled by Krantz (1903), who also mentions that the occurrence had been quarried in the late 1860s. To judge from the description given by Heim (1909), massive graphite was found beneath scree that carried graphite in loose blocks. The occurrence lies about 35 m below a thick cover of basalts. The other locality is named Qaarsut* (70°45'N, 52°45'W), situated close to an abandoned minor coal mine, Qaarsuarsuk, formerly named Qaersuarsuk, that was in production from 1908 until 1924. According to Heim (1909), quartzitic bituminous shales have been metamorphosed over a zone of 3 to 5 m on both sides of a peridotitic basic dyke. He further mentions that thin coal seams in the sedimentary sequence are completely recrystallised to graphite. It is stated that three samples from Qaarsut contained from 93.7 to 95.68% C, 0.22 to 0.69% H₂ and 3.6 to 4.92% ash (Ball, 1923). According to a brief description by Rammelsberg (1871) these samples were collected in 1870 by Nordenskiöld (1871) and analysed by T. Nordström. No further details as to the exact position of the sample localities was given.

Further descriptions of these two localities and of other geological observations of the north coast of the Nuussuaq peninsula are given by Ravn (1911) and Heim (1911). As a curiosity it is mentioned here that a titaniferous oxyhornblende variety, called kaersutit, has been named after the Qaarsut locality, cf. Bøggild (1953).

* Older spelling: Kaersut, Qaersut.

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Appendix 1

Reports from Kryolitselskabet Øresund A/S on the Akuliaruseq graphite deposit:

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- Morthorst, J. & Keto, L. 1983: Report on the graphite exploration in the Akuliaruseq area 1982. Internal report, Kryolitselskabet Øresund A/S, 33 pp., 8 plates. Drill core descriptions. Geochemical assays. Drilling statistics in a separate appendix.

Morthorst, J. & Keto, L. 1984: Report on the graphite exploration in Akuliaruseq area. 1983. Vol. I. Internal report, Kryolitselskabet Øresund A/S, 29 pp., 22 plates. Drilling statistics and core-logs in a separate vol. II.

