DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2003/7

Investigation for garnet sand in Sioraq, South-West Greenland, and analyses of garnet sand from central West Greenland

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MINISTRY OF THE ENVIRONMENT

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1. Summary

During a field programme in the summer of 2002 the coast of South-West Greenland was scanned for the occurrence of garnet sand deposits from 62°34´59˝N 50°16´09˝W at the northern end of Sioraq to 61°37´48˝N 48°34´13˝W at Neria Kujalleq. The work was focused on Sioraq (the sand deposits in front of Frederikshåb Isblink). No significant occurrence of garnet sand (or heavy minerals) was found.

Other GEUS field parties collected ten garnet sand samples in central West Greenland. Although some of the samples had high garnet contents, none of the samples represent deposits with sufficient volume for large-scale mining.

2. Introduction

This report describes the garnet sand investigations conducted in 2002 for Greenland Resources A/S by the Geological Survey of Denmark and Greenland (GEUS).

A field programme in the period 18th July 2002 - 31st July 2002 conducted by Jan Bernth Sørensen was focused on garnet sand at Sioraq (the land strip in front of Frederikshåb Isblink), South-West Greenland.

In addition ten samples collected in central West Greenland by Henrik Stendal, Karsten Secher and Christian Knudsen were analysed as part of the project.

Garnet is a heavy mineral (HM). The specific gravity of garnet is 3.4 - 4.3 g/cm^3. Heavy minerals are normally deposited in the swash-backwash zone of the beach. Dark HM dominated layers represent storm situations and layers with less HM represent fair-weather situations (Fig. 1).

Fig. 1. Alternating layers of dark heavy minerals (HM) and light quartz sand can be seen in the wind-eroded beach sand.

The 2001 investigations (Sørensen & Kalvig 2002), which were also carried out for Greenland Resources A/S, concluded that garnet sand prospects should be based on studies of aerial photographs and geological maps and reports indicating that a deposit of a signifi-

cant size could be present. Thomas V. Rasmussen conducted a study of aerial photographs, maps and available literature in the spring 2002. The result of this study was:

- Sand sediments cover an area - Sioraq - of about 150 km^2 in front of Frederikshåb Isblink.
- No literature exists about the geology of Sioraq.
- No geologists were found with personal knowledge of earlier investigations at Sioraq.
- Amphibolites containing garnets have been reported by Dawes (1970a, b) on Ikkattup Nunaa north of Sioraq and Dalager Nunatakker on Frederikshåb Isblink.

The conclusion was that it would be worthwhile to set up an investigation of Sioraq. This was done in appointment and in collaboration with Greenland Resources A/S.

Sioraq (which means sand in greenlandic) is the 100-300 m wide and 40 - 50 km long beach barrier and the shallow tidal lagoon between the beach barrier and the glacier lobe at Frederikshåb Isblink (Fig. 2). The sediments in the lagoon are also sand, but it was not possible to investigate this, even at low tide.

Fig. 2. View of the beach barrier and the tidal lagoon looking west towards the sea.

3. Field investigations

3.1 Sioraq, South-West Greenland

The field programme north of Paamiut (Fig. 3) was carried out by Jan Bernth Sørensen assisted by Willy Frederiksen from Paamiut with his 26 feet Nimbus *Angaju*.

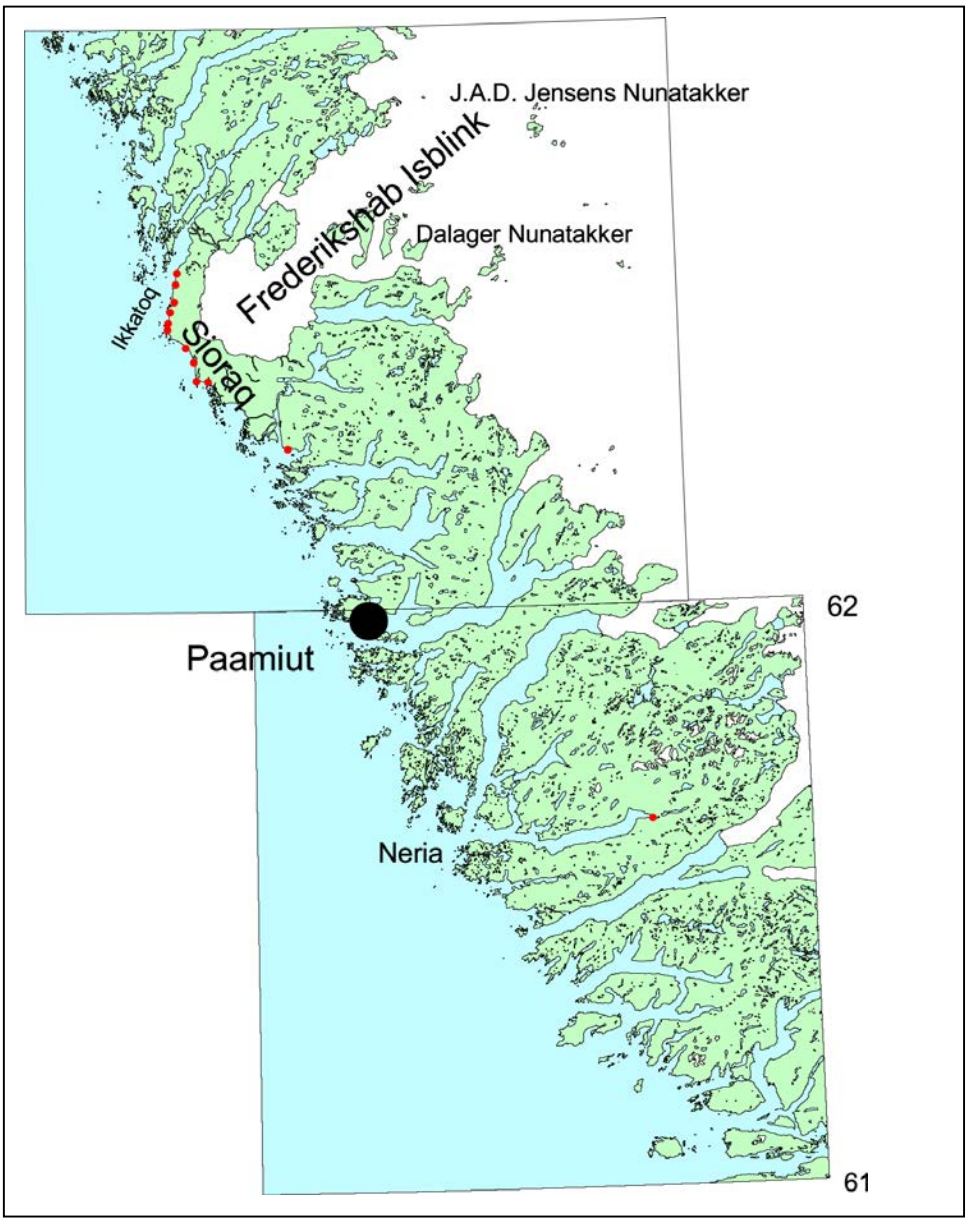

Fig. 3. Overview map of the study area in South-West Greenland. Sample sites are indicated with red dots. See Fig. 4 for detailed map of Sioraq.

18/7 02

Travelled with Greenlandair from Copenhagen to Narsarsuaq.

19/7 02

Travelled from Narsarsuaq to Paamiut by helicopter.

Upon arriving in Paamiut I had coffee with Willy Frederiksen (the skipper of *Angaju*) and his wife Pauline. Willy was not too happy about the weather forecast and preferred to postpone the departure for a while. He promised to keep me informed about the weather situation on the coast and told me that I could get information about the weather on tel. 154. At that point Willy seemed rather pessimistic about the nearest days.

I arranged accommodation in a house close to the heliport owned by Pauline Frederiksen's parents.

20/7

In the morning the weather was better than forecasted the night before and we decided to go. The weather was grey with wind speed about 5-10 m/s. Willy and I left Paamiut at 10.30 am on *Angaju*, heading for Sioraq (Fig. 4).

On the way to Sioraq we had a good conversation. Willy gave the impression of a very responsible and thorough man. One of the subjects that came up was the navigability of the waters around Sioraq.

Certain conditions make the sea around Sioraq particularly unsuitable for sailing:

- The weather is unpredictable.
- The weather is usually worse around Sioraq than other parts of the coast.
- The shallow waters around Sioraq make the waves higher here compared to other parts of the coast.
- There is hardly any shelter on a 50-60 km long stretch of coast.

It was those conditions that made Willy confide to me that at first he was very reluctant to accept to go on this trip at all.

Sioraq is 2-3 hours away from Paamiut by boat. The plan was to make two trips to Sioraq each of 3-4 days duration and return to Paamiut between the trips for fresh supplies. Willy had to go to Denmark the 26th to enlist on a shrimp trawler and would be replaced on the second trip by his brother Ole and nephew John Erik.

The way I planned to work was to make a reconnaissance walk along the coast and record the variability of the HM content in the sand and the garnet content in the HM fraction. At a minimum I would collect a sample every 5 kilometres. If an area looked interesting, more

detailed investigations would then be made of that area. During the reconnaissance walk Willy would follow me in *Angaju* and help me across the tidal channels that could not be crossed by foot.
Because of the tricky weather situation it was decided to consider the wind direction when planning which part of Sioraq should be next on the itinerary and hope that at some point even the less accessible areas of Sioraq could be visited.

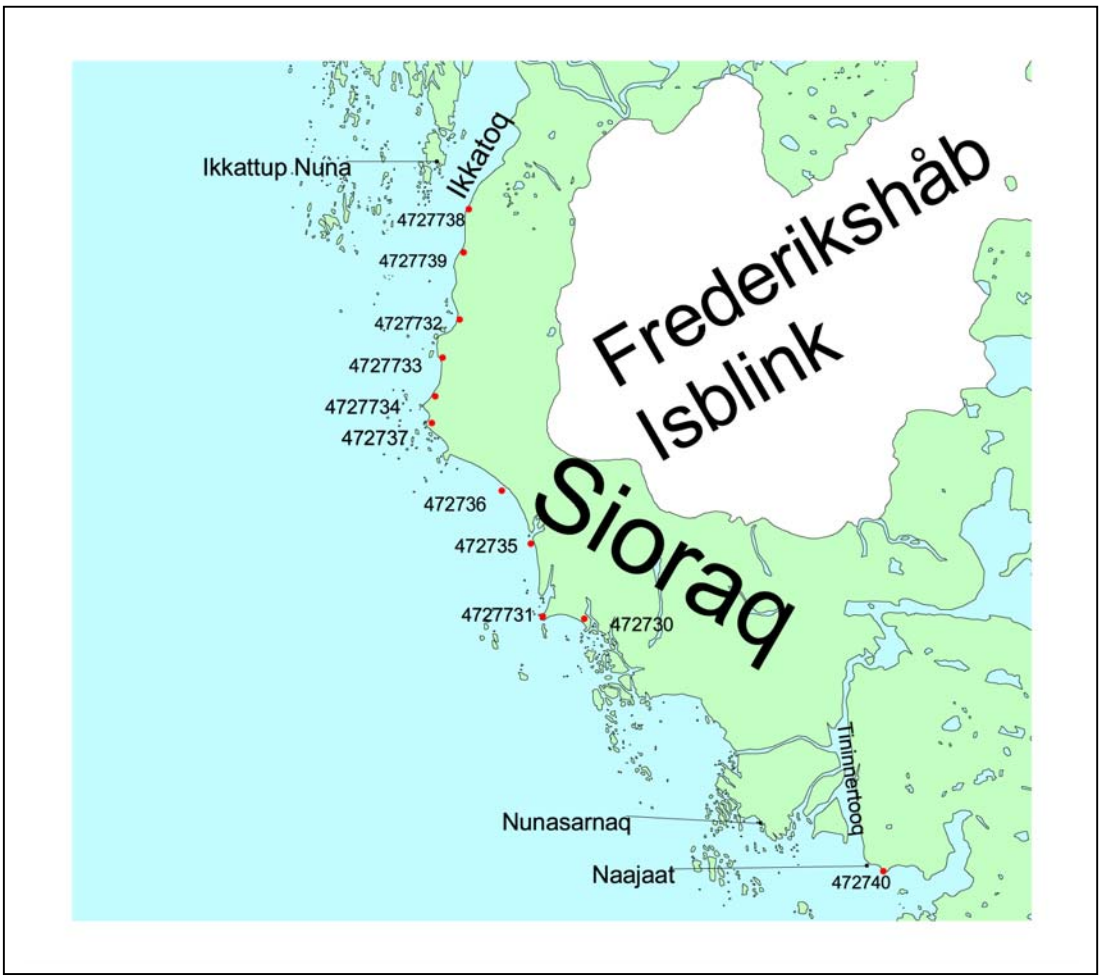

Fig. 4. Map of the Sioraq area. Sample sites are indicated with red dots along with sample numbers.

The southern end of the beach barrier is made up of a tombolo formed behind a rock outcrop (Fig. 5). At 12:00 am we anchored up by that tombolo. The coordinates on my handheld GPS were checked with those from the GPS on *Angaju*. They matched perfectly.

HM and particularly garnets are very sparse in the sand on the tombolo. The HM is present as centimetre-thick veneers (Fig. 6) and locally as small lenses (Fig. 7). The HM content is visually estimated to make up about 2-5% of the total volume of sand. The content of garnet in the HM is only 5-10% and the rest is predominantly magnetite.

Fig. 5. View of the tombolo seen from *Angaju*. The tombolo is formed behind the small rock in front of the bigger sand-covered rock.

Fig. 6. Thin veneers of HM can be seen on the active shoreface of the tombolo where the HM is concentrated in the swash-backwash zone.

Fig. 7. A small lens of HM on the tombolo.

The following day strong wind was expected from the south-west. Therefore it was decided to go to Ikkattoq (north of Sioraq) for the night and the next day anchor at a locality where some shelter from south-westerly winds can be found.

21/7 02

Weather grey and drizzling. The wind stronger than the day before (more than 10 m/s).

We left 9:00 am for a locality approximately at the middle of Sioraq (62°31´44˝N 50°17´50˝W) where a few rocks provided a little more shelter than could be found anywhere else on the coast along Sioraq. We anchored in the lee of a rock (Fig. 8).

I walked as far as I could to the north (62°31´58˝N 50°16´46˝W) where further walking was inhibited by a tidal channel.
The HM is sparse and dominated by magnetite. Sample 472732 (Table 1) was collected in the bank of the tidal channel (Fig. 9).

Most of the tidal lagoon of Sioraq is inaccessible even during low tide. However, in a few places the Sioraq can be traversed along rocks emerging from the sand (Fig. 10). I walked along some of these rocks towards the ice front. The HM content in the sand decreased as I walked further away from the coast. I turned back at 62°31´28˝N 50°16´28˝W about 3 kilometres from the ice front.

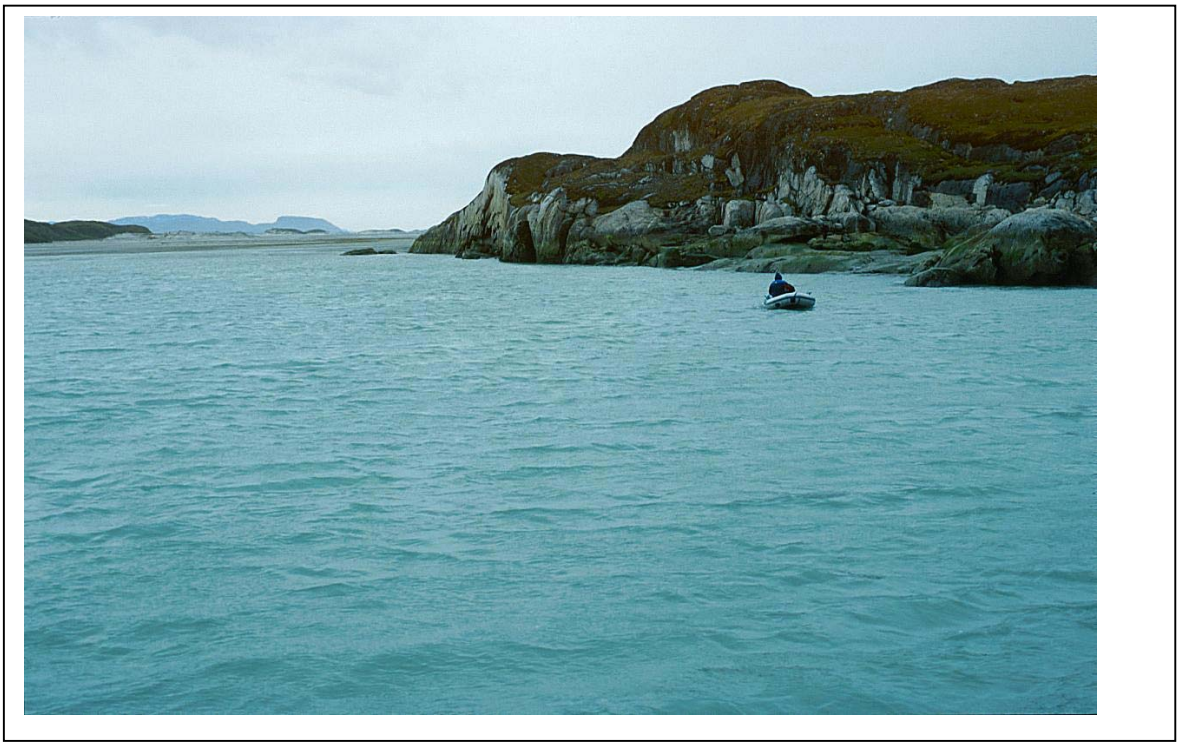

Fig. 8. The anchor site at 62°31´44˝N 50°17´50˝W

Fig. 9. The tidal channel where sample 472732 was collected.

Fig. 10. View north from 62°30´01˝N 50°18´07˝W. Frederikshåb Isblink can be seen in the right side of the photo. I walked along the rocks in the middle distance towards the ice front.

Walking south of the anchor site an area was found with relatively high amounts of HM at 62°30´55˝N 50°17´49˝W (Fig. 11). A sample representing the upper 30 cm was collected (472733). The sample contains 18.2 weight % HM of the total weight (Table 1). The area is 20 - 40m wide and extends about 2 kilometres towards 62°29´51˝N 50°18´15˝W. A sample from there, representing the upper 30 cm, (472734) also yielded high HM values - 19.7 weight % HM of the total weight (Table 1).

When I reached the next impassable tidal channel, the wind had suddenly increased significantly and I had to return to *Angaju*. I hurried back and was aboard *Angaju* at 15:00 pm.

The wind increased in strength and we had to stay overnight. In the evening the wind reached well above 20 m/s.

22/7 02

During the night the wind calmed down, but increased again in the morning. We headed off to Paamiut while we still had the chance. After a rough ride we arrived in Paamiut 12:30 pm. The weather forecast was not good, and we had to wait on the weather.

Fig. 11. The sand at 62°30´55˝N 50°17´49˝W with relatively high amount of HM.

23/7 02

Arranged shipment of samples to Denmark with Royal Arctic.

Since Willy had to leave on the 26th he was replaced by Ole and John Erik. We agreed to sail again the next day. The weather forecast was rain with wind speed of 10 m/s from west.

24/7 02

Departed with Ole and John Erik from Paamiut in *Angaju* 9:00 am.

We anchored at 62°24´48˝N 50°12´49˝W. I was ashore 12:45 pm.

As we were now three people, a more efficient search of the area could be made: I would walk on the beach, John Erik would follow me in the rubber-dingy and ferry me over the tidal channels and Ole would follow in *Angaju* (Fig. 12).

On the stretch from 62°24´27˝N 50°12´10˝W to 62°25´09˝N 50°12´25˝W very little HM could be found. Sample 472735 was collected from a 30-40 m wide zone of relatively HM rich sand that could be followed for about 300m up to 62°25´48˝N 50°12´42˝W (Fig. 13).

Fig. 12. *Angaju* at the right and the rubber-dingy at the left can hardly be seen in the fog. It was impossible to use *Angaju* in the shallow water close to the coast, whereas the rubber-dingy was well suited for landing through the surf.

Fig. 13. A zone of relatively HM rich sand stretching from a point at 62°25´48˝N 50°12´42˝W and approximately 300m southwards.

A tidal channel was crossed and from 62°26´14˝N 50°13´05˝W to 62°19´08˝N 50°18´38˝W only very little HM could be observed.

We went to Ikkattoq for the night and anchored at 62°40´46˝N 50°12´02˝W by the island Ikkattup Nunaa from where Peter Dawes (1970a) reported of garnets of almost gem quality.

25/7 02

Ashore at Ikkattup Nunaa by 7:00 am. Collected a few garnets from the approximately 5m wide belt of vertical garnet-rich mica schist (Fig. 14). Although the mica schist is very garnet-rich, the volume of the mica schist is not sufficient to generate a possible garnet sand deposit.

Fig. 14. Garnet-bearing mica schist on Ikkattup Nunaa.

After breakfast we left for Sioraq at 9:00 am.

I was ashore at the northernmost end of Sioraq – 62°34´59˝N 50°16´09˝W at 10:00.

On the stretch from 62°34´59˝N 50°16´09˝W southwards to 62°33´48˝N 50°16´29˝W the amount and composition of HM is very similar to that at the southern end of Sioraq - that is: low in HM and garnet.

I was collected by John Erik in the rubber-dingy and ferried aboard *Angaju*. We went to the islands south of Sioraq to investigate the remaining short stretches of the beach barrier.

Short stop by the beach on Nunasarnaq west of Tininnertooq (62°20´45˝N 50°01´53˝W) (Fig. 4). Shallow water in the southern end makes it impossible to get close to the beach in *Angaju*. The surf was far too rough for the rubber-dingy, so I had to make do with a view using binoculars. This revealed that the HM is sparse and black like on the rest of Sioraq.

We managed to get ashore on a small beach on Naajat at 62°16´40˝N 49°52´08˝W (Fig. 4). A sample (472740) was collected from an approximately 10x10m spot with HM (Fig. 15). The HM looked slightly more garnet-rich (10-15%) than the HM from other parts of Sioraq.

After investigating all accessible parts of Sioraq without finding any significant HM I decided to follow the information from Oles cousin, who (according to Ole) had observed “red sand” at Neria Kujalleq in the fjord Neria.

Fig. 15. Small spot of HM at Naajat. Footprints for scale.

We made plans to set off in the afternoon and then stay in Neria overnight. However, the boat engine started to leak cooling water (3 l/h) and we were forced to stop over in Paamiut for repair.

Upon arriving in Paamiut I contacted Willy Frederiksen who would try and get *Angaju* ready for a trip to Neria by Sunday the 28th.

29/7 2002

It was not possible to get *Angaju* ready during the weekend because a spare part was needed from Nuuk. Fortunately I had an agreement with the local outfitter Birger Knudsen, who would take me to Neria in his Draco speedboat.

We left Paamiut 13:00 pm. We made a short stop about 5 kilometres south of Paamiut to watch a couple of humpback whales.

The "red sand" at Neria Kujalleq (61°37´48N 48°34´13W) turned out to be rust-coloured gravel (Fig. 16). A small area of the beach is covered by sand (sample 472741). No further investigation was considered worth while.

On the way back to Paamiut we visited two sites where Birger knew that there is sand. The sites were two beaches at 61°36´40˝N 49°01´35˝W and 61°36´52˝N 49°01´35˝W with rust-coloured gravel.

Fig. 16. Stone-moraine at Neria Kujalleq with a narrow gravel-beach in front.

30/7 2002

Travelled from Paamiut to Narsarsuaq by helicopter.

31/7 2002

I met Hans Kristian Olsen from Greenland Resources A/S in Narsarsuaq Airport and informed him about the results of the expedition.

Travelled with Greenlandair from Narsarsuaq to Copenhagen.

3.2 Central West Greenland

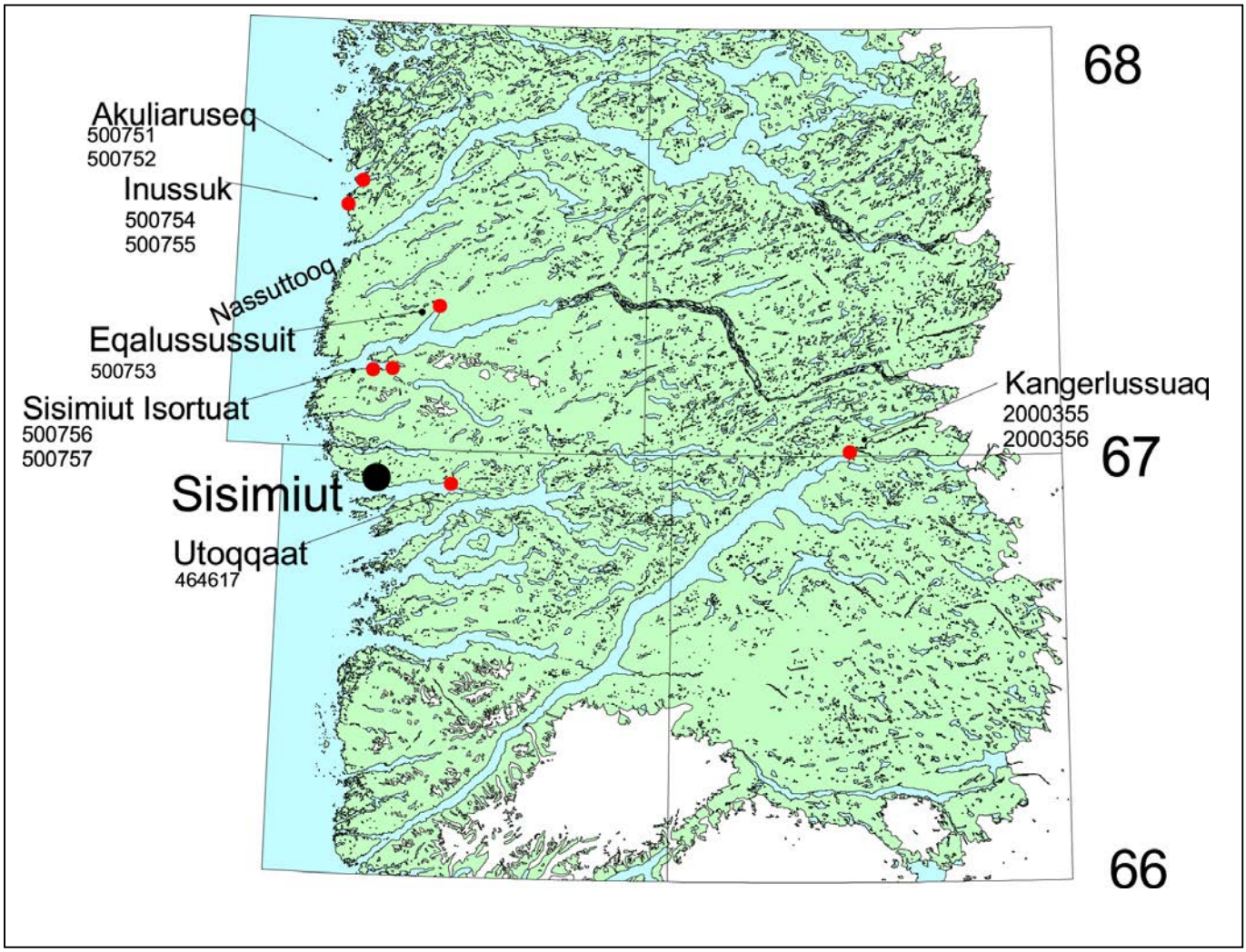

Fig. 17. Overview map of the study area in central West Greenland. Sample numbers are given and sample sites are indicated with red dots.

Akuliaruseq (Fig. 17) (Henrik Stendal)
Beach (15 x 60m) in a cove by the old graphite mines. The garnet sand layer is 30-50cm thick. An uplifted terrace extends approximately 50m inland and has a 30-50cm thick layer of garnet sand.

500751: 50cm thick garnet sand from shoreface.
500752: Uplifted terrace - 50cm thick layer of garnet sand.

North coast of Eqalussussuit (Fig. 17) (Henrik Stendal)
500753: Garnet sand in upper tidal zone. The sand body is up to 1m thick; and alternating layers with and without garnet are 1-5cm thick. The beach is rather stony on the lower shoreface. The beach with relatively pure sand is 5 x 100m. Similar stretches can be found along the fjord. The sample represents 0-80cm depth.

Inussuk (Fig. 17) (Henrik Stendal)
Garnet sand in a small cove with 20-30% garnet. The stone content in the sand is 10-20%. The layer of garnet sand is up to 1.5m thick, and the beach is 15 x 25m. Above the tidal zone the garnet sand can be followed inland on an elevated beach. However, 20m inland the thickness decreases to 30cm.

500754: Upper shoreface (1.5m thick).
500755: Uplifted terrace 20m inland (30cm thick)

South coast of Sisimiut Isortuat (Fig. 17) (Henrik Stendal)
500756: Garnet sand from stony 20 x 100m beach with 30cm "massive" layer of garnet sand and millimetre-thick garnet layers. The sample represents 0-50cm depth.
500757: From shoreface on 5-10 x 100m beach with 1m thick sand layer containing garnets. The sample represents 0-100cm depth.

Kangerlussuaq (Fig. 17) (Karsten Secher and Christian Knudsen)
Two samples have been collected in the river in Kangerlussuaq. The sample 2000355 (67°00´20˝N -50°41´11˝W) is collected by Karsten Secher; and 2000356 is collected by Christian Knudsen. The samples are not representative of the river sand. The overall concentration of garnet in the river sand is less than in the beach sand from other localities.

Utoqqaat (Fig. 17) (Karsten Secher)
Sample 464617 is collected on a beach on Utoqqaat 66°55´14˝N -53°04´06˝W. The size of the beach is approximately 10 000m^2. Sample 464617 represents the upper 20-30cm of about 0.5-1m and consists of garnet rich sand. The locality at Utoqqaat has not been systematically investigated, but it is Karsten Secher's impression that the sample is representative of the entire beach.

3.2.1 Concluding remarks on central West Greenland

The garnets in central West Greenland belong mainly to two distinct populations:

- Brownish red garnets from garnetamphibolites.
- Garnets from metasediments.
- Apart from this there will are few garnets from calc-silicates and kimberlites etc.

In general the localities are too small to yield large-scale garnet production.

It is likely that hyperspectral remote sensing can be used to detect surface occurrences of garnet. If exploitation of the Utoqqaat deposit is viable, this method could be used to identify similar beaches in the area that was covered with hyperspectral remote sensing in 2002 (pers. comm. Karsten Secher). This area lies just to the east of Utoqqaat and the geology of the area is similar to the geology of the Utoqqaat area. Such hyperspectral analyses could be conducted by one geologist in 1-1½ month.

4. Analytical methods

For each sample a heavy-minerals (HM) separate was produced by heavy liquid separation. The heavy liquid separation is carried out by pouring washed and dried sand (sample material) into a liquid with a specific gravity of 2.8 g/cm^3. Particles with a specific gravity greater than the liquid will fall to the bottom and the rest will remain floating. Garnet has a specific gravity of 3.4 – 4.3 g/cm^3 and will make part of the heavy minerals separate.

Computer Controlled Scanning Electron Microscopy (CCSEM) was used to analyse the individual grains for chemical composition and selected grain shape parameters. The results of the CCSEM analyses are further used when classifying individual grains into mineralogical categories and computing grain size curves and statistical values. The grain size shown is the apparent grain size in the (random) section in the mount. This will be slightly lower compared to “true” grain size. This can be corrected mathematically, but as this process is complicated and can be done in different ways, we have chosen to present the observed apparent grain size.

The proportional content of Mg (pyrope), Fe (almandine) and Ca + Mn (grossular and spessartine) is computed on the basis of the chemical composition of mineral grains classified as garnets and the results are plotted in ternary diagrams (Appendix 1).

5. Results

The garnet investigations conducted for Greenland Resources A/S in the years 2001 and 2002 have focused on different regions of Greenland (Fig. 18).

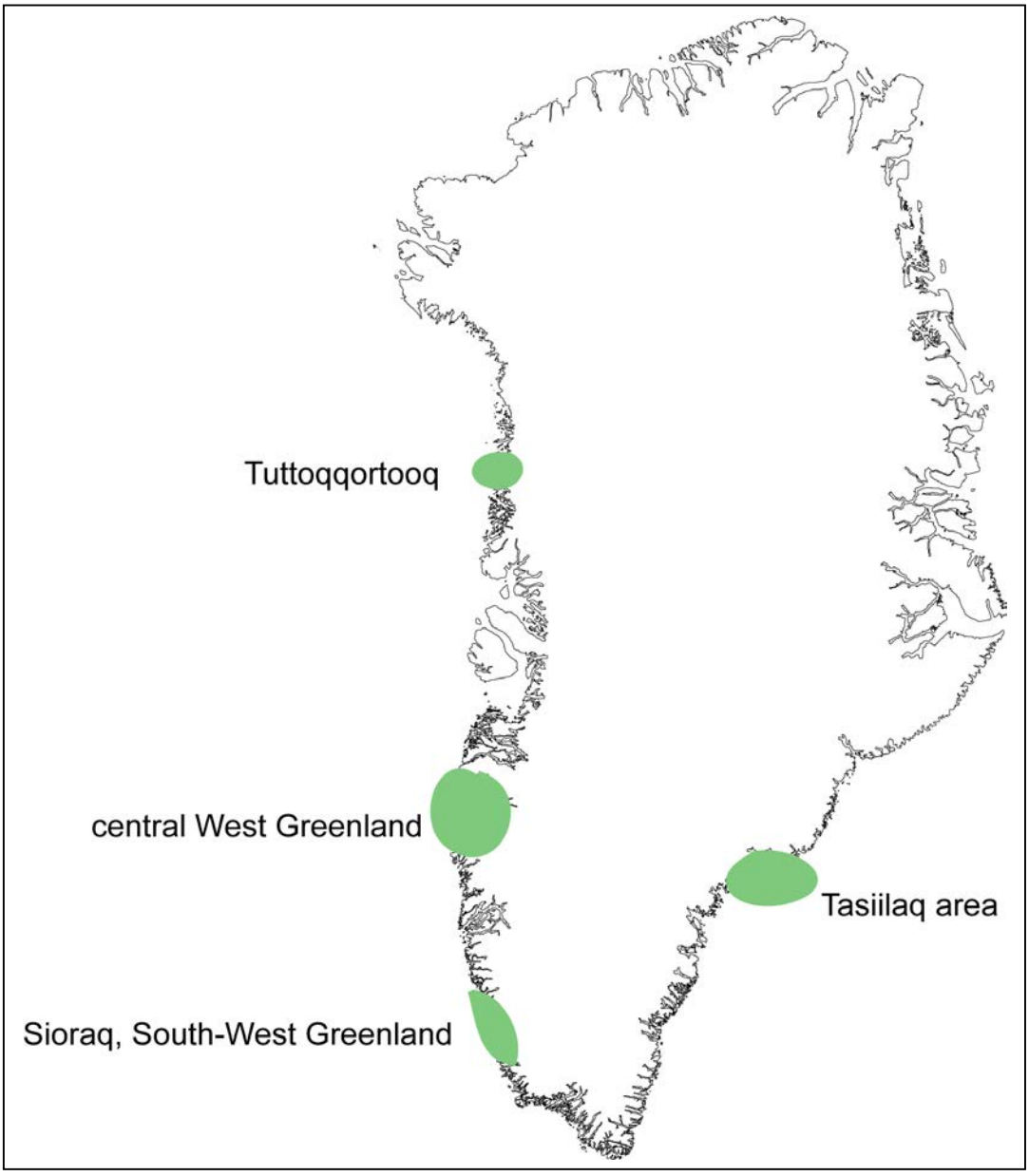

Fig. 18. Map of Greenland showing the regions in which garnet investigations have been conducted in 2001 and 2002.

5.1 Analytical results

The results of the heavy liquid separations are summarised in table 1.

The mineral chemistry of garnets can be used to characterise the garnets from different source areas and rock types (Sørensen & Kalvig, 2002). The garnets from Sioraq fall in two distinct populations (Appendix 1), which indicates that the garnets have two different source areas. The chemistry of these garnets is similar to the garnets from Isortuarsuk in central West Greenland (Sørensen & Voigt, 2002). These are Fe-Mg garnets from metasediments and more Ca-rich garnets from amphibolites. In Kangerlussuaq the garnets can also be divided in two populations similar to Isortuarsuk and Sioraq, though the distinction is less clear.

In Isortuarsuk the Fe-Mg garnets dominate over the more Ca-rich garnets, in Sioraq the distribution is almost fifty-fifty and in Kangerlussuaq the Ca-rich garnets dominate over the Fe-Mg garnets.

The physical parameters of the garnet grains are important for the industry. The preferred grain size for water jet cutting is around 125μ. The sharpness of a mineral grain is indicated by its aspect ratio and circularity. These parameters are summarised from the CCSEM analyses in Table 2. The values for Sioraq and Kangerlussuaq indicate that the mineral grains are angular to very angular and have low to medium sphericity.

Table 1. Administrative data and results of the heavy liquid analyses.

Sample	Latitude	Longitude	Material < 0.045mm i %. of total weight	Material >0.71mm i %. of total weight	HM% in mat<0.71mm >0,045mm	HM% of total weight	Location	Collector	Sampling method
472730	62°23'71"	50°09'58"	0.1	0.0	89.7	89.6	Sioraq	Jan Bernth Sørensen	Sampled selectively
472731	62°23'79"	50°12'04"	2.2	0.0	4.2	4.1	Sioraq	Jan Bernth Sørensen	mean upper 30 cm
472732	62°31'96"	50°16'77"	0.4	0.6	6.4	6.4	Sioraq	Jan Bernth Sørensen	averaged over 30 cm
472733	62°30'92"	50°17'81"	1.0	4.4	19.1	18.2	Sioraq	Jan Bernth Sørensen	mean upper 30 cm
472734	62°29'85"	50°18'25"	0.1	0.1	19.8	19.7	Sioraq	Jan Bernth Sørensen	mean upper 30 cm
472735	62°25'80"	50°12'70"	0.1	0.1	24.2	24.2	Sioraq	Jan Bernth Sørensen	mean upper 30 cm
472736	62°27'25"	50°14'37"	0.0	4.6	32.7	31.1	Sioraq	Jan Bernth Sørensen	Sampled selectively
472737	62°29'13"	50°18'47"	0.0	0.0	36.4	36.4	Sioraq	Jan Bernth Sørensen	Sampled selectively
472738	62°34'99"	50°16'15"	0.1	1.7	22.8	22.4	Sioraq	Jan Bernth Sørensen	Sampled selectively
472739	62°33'80"	50°16'48"	0.2	0.1	31.5	31.4	Sioraq	Jan Bernth Sørensen	Sampled selectively
472740	62°16'67"	49°52'14"	0.4	0.0	45.9	45.8	Sioraq	Jan Bernth Sørensen	Sampled selectively
472741	61°38'02"	48°34'22"	0.1	7.1	32.5	30.1	Neria Kujalleq	Jan Bernth Sørensen	Sampled selectively
500751	67°37'37"	-53°40'16"	0.1	0.0	89.7	89.6	Akuliaruseq	Henrik Stendal	mean upper 50 cm
500752	67°37'38"	-53°40'15"	2.2	0.0	4.2	4.1	Akuliaruseq	Henrik Stendal	mean upper 50 cm
500753	67°20'17"	-53°10'24"	0.4	0.6	6.4	6.4	Eqalussussuit	Henrik Stendal	mean upper 80 cm
500754	67°34'10"	-53°45'19"	1.0	4.4	19.1	18.2	Inussuk	Henrik Stendal	mean upper 150 cm
500755	67°34'10"	-53°45'17"	0.1	0.1	19.8	19.7	Inussuk	Henrik Stendal	mean upper 30 cm
500756	67°11'19"	-53°26'38"	0.1	0.1	24.2	24.2	Sisimiut Isortuat	Henrik Stendal	mean upper 50 cm
500757	67°11'05	-53°33'51"	0.0	4.6	32.7	31.1	Sisimiut Isortuat	Henrik Stendal	mean upper 100 cm
464617	66°55'24"	-53°04'10"	0.1	0.1	96.3	96.0	Utoqqaat	Karsten Secher	mean upper 20-30 cm
2000355	67°00'33"	-50°41'19"	1.6	0.1	26.2	25.8	Kangerlussuaq	Karsten Secher	Sampled selectively
2000356	67°00'33"	-50°41'19"	2.0	0.1	36.0	35.3	Kangerlussuaq	Christian Knudsen	Sampled selectively

HM is heavy minerals.

Table 2. Selected parameters from CCSEM sheets (Appendix 1). Percentages are weight percentage.

Sample	% Heavy minerals in raw sand	Garnet % In HM	Garnet % In raw sand	Apparent median grain size (μ)	Aspect ratio	Circularity
464617	96.00	36.4	34.9	275	1.5	1.9
472730	89.60	2.2	1.9	200	1.7	1.9
472734	19.70	9.3	1.8	170	1.5	1.8
472738	22.40	6.2	1.4	190	1.5	1.8
2000356	35.26	16.7	5.9	120	1.5	1.6

5.2 Size and shape of the deposits

The Sioraq deposit forms a huge body of sand, and due to its size is also a big reservoir of garnet. However, the analyses (Table 3) show that the content of garnet in the sand is very low (< 2%) and this is not a potential garnet deposit. Apart from Utoqqaat the amount of garnet contained in the other investigated beaches is small (< 3000 ton) and accordingly not potential garnet deposits.

Tuttoqqortooq has been investigated systematically to determine the amount of garnet at the locality (Sørensen & Kalvig, 2002). The tonnages at the other localities in Table 3 are only estimates - in most cases based on length and width of the beach, thickness of the garnet bearing zone and analysis of one or a few samples. The values in table 3 should be treated in accordance with this.

Table 3. Estimated tonnage and grade of garnet localities from the 2001 and 2002 investigations.

Region	Locality	Estimated tonnage of garnet	Garnet% in raw sand
North-West Greenland	Tuttoqqortooq	2,000	12-13
central West Greenland	Isortuarsuk	250	6-7
central West Greenland	Akuliaruseq	750	10-15
central West Greenland	Eqalussussuit	50	3-5
central West Greenland	Inussuk	500	15-20
central West Greenland	Utoqqaat	5,000	30-40
central West Greenland	Kangerlussuaq	?	15-18% garnets of HM
South-West Greenland	Sioraq	1000	<2
South-West Greenland	Neria Kujalleq	<100	<2
South-East Greenland	Kulusuk	<100	6
South-East Greenland	Umivik	<100	25
South-East Greenland	Tuno	<100	<2
South-East Greenland	Ikateq	<100	<2
South-East Greenland	Siaraq Dal	<100	<2

There is no representative sample from Kangerlussuaq.

6. Conclusions

All the small garnet deposits that have been registered during the garnet investigations in Greenland in 2001 (Sørensen & Kalvig, 2002; Sørensen & Voigt, 2002) and 2002 are from active geological environments - beaches and rivers.

The sand on some beaches may only reside on the beach a single or a few years (Sørensen & Kalvig, 2002). Thus, if the garnet sand resources are replenished with a certain frequency, it may be worth while to acquire more knowledge of the replenishment rate of sand on those beaches. The idea is to look at all the small deposits as one prospect, which can be mined with mobile equipment.

The garnet investigations in 2001 and 2002 have not resulted in the finding of a garnet deposit economical for large-scale mining. However, a small garnet deposit may still be economically viable if the costs of mining the garnet with small-scale mining is less than the value of the garnet. A small processing test of garnet sand from Greenland is currently being carried out. Based on this a simple flow sheet will be made and an estimate of the minimum investment in e.g. a village processing unit will be made. This study is still going on and will be reported in a separate report. Further recommendations will have to await that report.

7. References

Dawes, P. 1970a: Grønlandske granater som smykkesten. Grønland, Det Grønlandske Selskab. Charlottenlund, Danmark, vol. 4, 113-119.

Dawes, P. 1970b: Bedrock geology of the nunataks and semi-nunataks in Frederikshåb Isblink area of southern West Greenland. Rapport Grønlands Geologiske Undersøgelse, 29, 60 pp.

Sørensen, J.B. & Kalvig, P 2002: Garnet sand in Greenland: Examples from Tuttoqqortooq, Tasiilaq area and Sisimiut area. Danmarks og Grønlands Geologiske Undersøgelse Rapport 2002/12. 26 pp. + app.

Sørensen, J.B. & Voigt, B 2002: CCSEM analyses of garnet in sand from Isortuarsuk, Sisimiut. Danmarks og Grønlands Geologiske Undersøgelse Rapport 2002/46. 8 pp. + app.

Appendix 1

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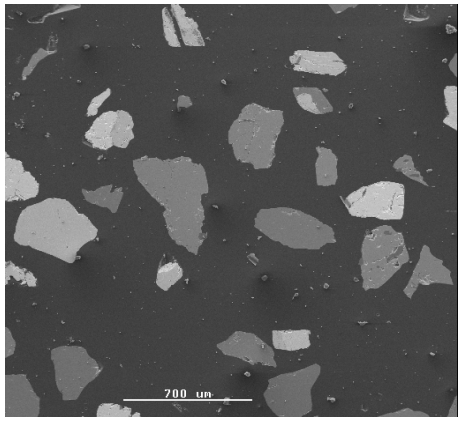

Sample Name:	464617	No. of frames analysed:	37
Lab. Name:	464617	No. of particles analysed:	696
Date:	05-03-02	Heavy minerals in raw	
Submitter:	GEUS	sand (%):	96.00
Country:	Greenland	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/100x			
Guard region:	375µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	47.8	48.6	0.8	0.1	0.4	0.3	0.6	0.1	0.2	98.9
Leucoxene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rutile	96.7	0.6	0.1	0.3	0.3	0.1	0.0	0.0	0.3	98.5
Ti magnetite	35.1	57.6	0.7	0.1	2.6	1.4	0.8	0.4	0.1	98.9
Magnetite	0.9	91.5	0.2	0.1	2.3	2.4	0.4	0.3	0.2	98.3
Chromite	0.2	40.3	1.0	37.8	0.0	15.5	3.8	0.1	0.0	98.8
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	1.6	0.0	0.0	11.9	4.5	0.4	2.3	4.1	24.7
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	39.1	0.6	0.1	0.3	29.3	1.6	0.3	27.4	0.0	98.6
Garnet	0.1	30.4	1.2	0.1	38.1	19.7	5.7	3.0	0.1	98.4
Kya/Sill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.2	0.1	0.0	0.0	30.0	0.0	0.0	0.0	69.3	99.6
Silicate	1.0	18.3	0.5	0.1	47.5	7.7	10.5	10.5	0.1	96.4
Unclassified	2.8	10.8	2.8	2.4	7.7	4.7	2.3	3.7	8.6	45.8

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	7.8	0.0	1.6	34.6	55.0	0.9	0.0	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	48.4	0	98.2	35.5
Fe_2O_3 wt%	49.1	0	0.7	58.3
MnO wt%	0.8	0	0.1	0.7
Cr_2O_3 wt%	0.1	0	0.3	0.1
SiO_2 wt%	0.5	0	0.3	2.6
Al_2O_3 wt%	0.3	0	0.1	1.4
MgO wt%	0.6	0	0.0	0.8
CaO wt%	0.1	0	0.0	0.4
ZrO_2 wt%	0.2	0	0.3	0.1
Total	100.0	0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	40.1
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	37.9
Valuable heavy minerals in raw sand:	63.50

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	5.2	5.0
Leucoxene	0.0	0.0
Rutile	1.1	1.0
Ti magnetite	22.9	22.0
Magnetite	11.2	10.8
Chromite	0.2	0.2
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	1.0	1.0
Y-phosphate	0.0	0.0
Sphene	0.4	0.4
Garnet	36.4	34.9
Kya/Sill	0.0	0.0
Staurolite	0.0	0.0
Zircon	0.6	0.6
Silicate	17.9	21.2
Unclassified	3.1	3.0
Total	100.0	100.0

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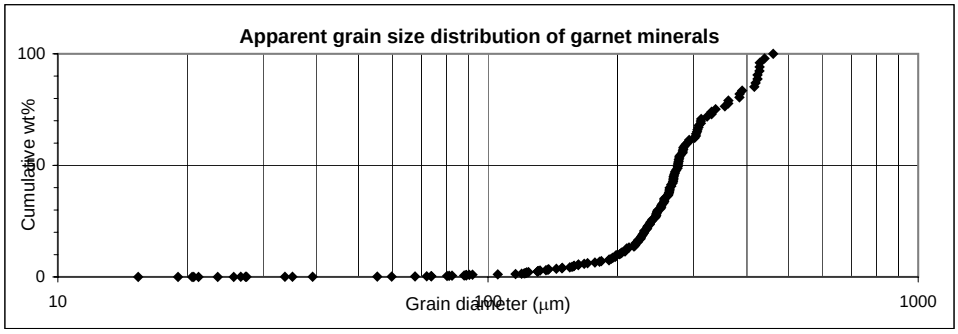
Lab. Name:	464617	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	05-03-02		



Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm^2)	Total grains
Ilmenite	1.5	1.7	795	301	33387	30
Leucoxene	0.0	0.0	0	0	0	0
Rutile	1.6	1.9	940	363	47221	4
Ti magnetite	1.5	2.0	1108	438	56136	74
Magnetite	1.6	1.8	844	324	37400	50
Chromite	1.3	2.3	1080	448	41234	1
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.3	1.8	949	363	43611	4
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	1.5	2.1	1579	642	94724	1
Garnet	1.5	1.9	944	369	45141	175
Kya/Sill	0.0	0.0	0	0	0	0
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.1	1.5	1472	515	113784	1
Silicate	1.7	1.9	1065	424	56920	103
Unclassified	1.4	1.4	177	68	4357	231

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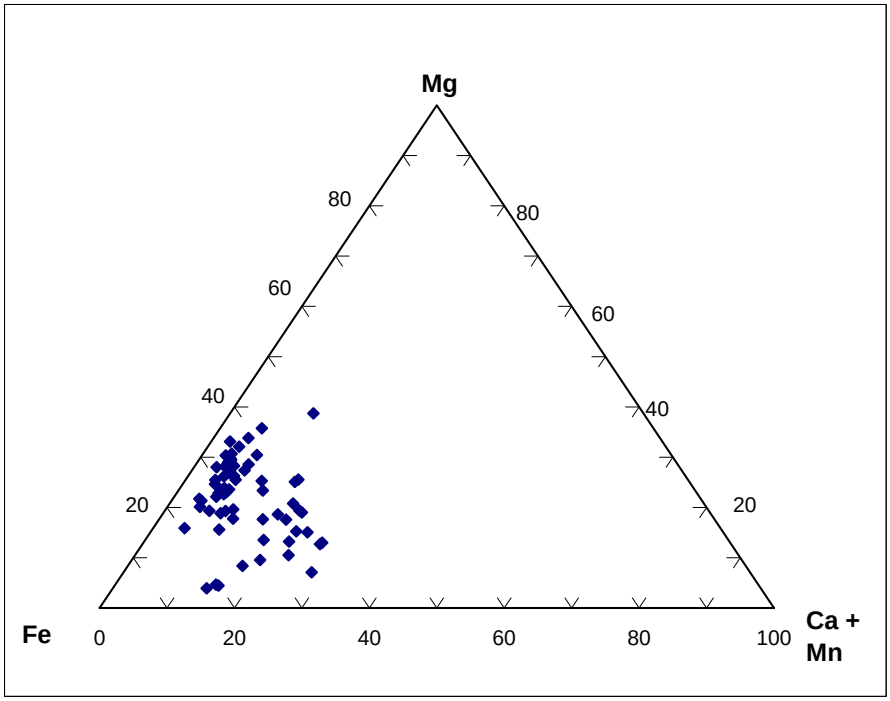
Lab. Name:	464617	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	05-03-02		



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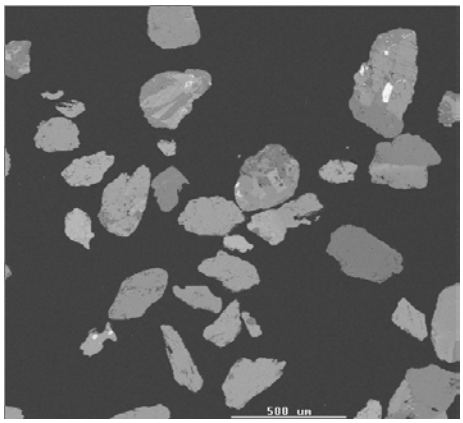

Sample Name:	472730	No. of frames analysed:	64
Lab. Name:	472730	No. of particles analysed:	998
Date:	05-03-02	Heavy minerals in raw	
Submitter:	GEUS	sand (%):	89,60
Country:	Greenland	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/100x			
Guard region:	375µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	48,8	37,2	0,5	0,1	8,1	1,3	0,9	1,9	0,3	99,0
Leucoxene	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Rutile	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Ti magnetite	27,6	54,9	1,2	0,1	9,2	1,7	2,6	1,4	0,4	99,0
Magnetite	0,9	87,9	0,5	0,5	4,1	1,4	1,8	0,8	0,2	98,1
Chromite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Pyrite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Phosphate	0,1	0,2	0,2	0,1	0,5	0,0	0,1	56,1	1,4	58,8
Monazite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Y-phosphate	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sphene	37,5	0,8	0,0	0,3	30,3	1,4	0,1	27,8	0,2	98,2
Garnet	0,5	26,9	1,0	0,1	38,7	19,9	7,5	3,5	0,2	98,3
Kya/Sill	0,2	0,8	0,0	0,1	42,2	53,2	0,1	0,2	0,3	97,2
Staurolite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Zircon	0,0	0,5	0,1	0,4	30,5	0,1	0,2	0,7	62,8	95,3
Silicate	0,8	13,8	0,3	0,2	50,3	10,3	8,8	11,7	0,2	96,4
Unclassified	8,7	25,4	0,7	0,5	26,4	6,7	3,5	13,8	2,0	87,7

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	19,6	0,0	0,0	22,1	54,6	1,3	2,3	0,0	100,0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	49,3	0	0	27,8
Fe_2O_3 wt%	37,6	0	0	55,5
MnO wt%	0,5	0	0	1,2
Cr_2O_3 wt%	0,1	0	0	0,1
SiO_2 wt%	8,2	0	0	9,3
Al_2O_3 wt%	1,3	0	0	1,7
MgO wt%	0,9	0	0	2,6
CaO wt%	1,9	0	0	1,5
ZrO_2 wt%	0,3	0	0	0,4
Total	100,0	0	0	100,0

Average TiO_2 content of all the TiO_2 minerals:	37,9
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	37,9
Valuable heavy minerals in raw sand:	3,56

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	0,8	0,7
Leucoxene	0,0	0,0
Rutile	0,0	0,0
Ti magnetite	0,9	0,8
Magnetite	1,3	1,2
Chromite	0,0	0,0
Pyrite	0,0	0,0
Phosphate	0,7	0,7
Monazite	0,0	0,0
Y-phosphate	0,0	0,0
Sphene	0,2	0,2
Garnet	2,2	1,9
Kya/Sill	0,1	0,1
Staurolite	0,0	0,0
Zircon	0,1	0,0
Silicate	92,5	93,3
Unclassified	1,3	1,2
Total	100,0	100,0

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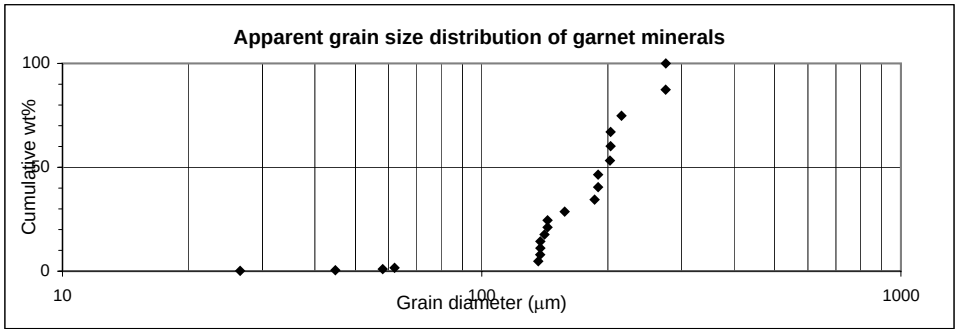
GEUS

Lab. Name:	472730	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	05-03-02		



Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1,6	2,0	718	290	25083	6
Leucoxene	0,0	0,0	0	0	0	0
Rutile	0,0	0,0	0	0	0	0
Ti magnetite	1,9	3,2	1233	552	39938	4
Magnetite	1,5	1,8	553	218	16854	13
Chromite	0,0	0,0	0	0	0	0
Pyrite	0,0	0,0	0	0	0	0
Phosphate	1,5	1,7	668	250	21171	6
Monazite	0,0	0,0	0	0	0	0
Y-phosphate	0,0	0,0	0	0	0	0
Sphene	1,6	1,9	539	213	12205	4
Garnet	1,7	1,9	676	264	22394	21
Kya/Sill	2,1	1,8	757	294	24734	1
Staurolite	0,0	0,0	0	0	0	0
Zircon	1,8	1,6	447	163	9848	1
Silicate	1,6	1,9	820	324	32892	921
Unclassified	1,4	1,8	697	282	28016	15

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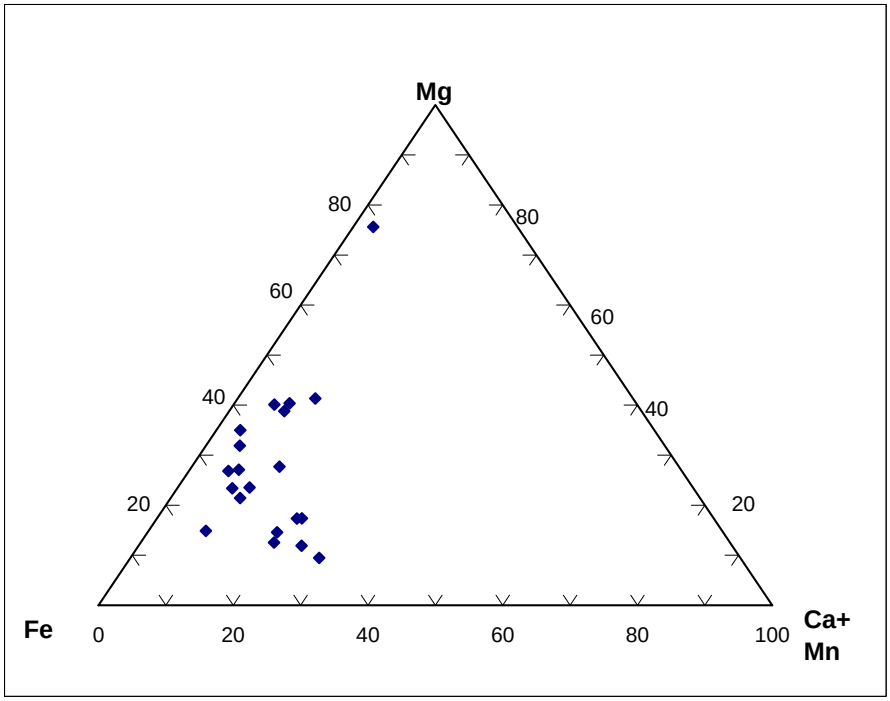
Lab. Name:	472730	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	05-03-02		



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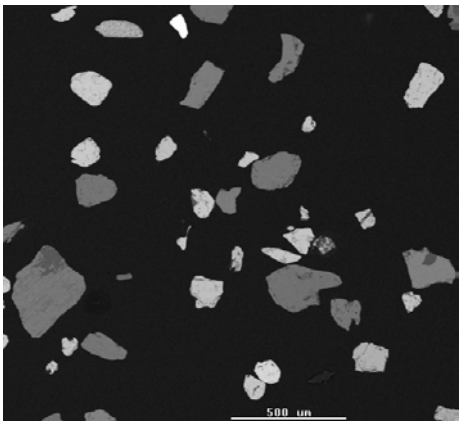
GEUS

Sample Name:	472734	No. of frames analysed:	21
Lab. Name:	472734	No. of particles analysed:	587
Date:	05-03-02	Heavy minerals in raw	
Submitter:	GEUS	sand (%):	19,70
Country:	Greenland	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/100x			
Guard region:	375µm		
Sieve:	100 µm^2		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	48,5	47,1	1,4	0,1	0,7	0,2	0,3	0,2	0,2	98,7
Leucoxene	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Rutile	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Ti magnetite	33,1	58,6	1,2	0,1	2,3	1,0	0,6	0,7	0,2	97,9
Magnetite	1,8	92,4	0,3	0,3	1,2	1,1	0,9	0,1	0,2	98,5
Chromite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Pyrite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Phosphate	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Monazite	11,1	0,0	0,0	0,0	0,0	0,0	0,0	0,8	0,0	11,9
Y-phosphate	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sphene	42,2	1,3	0,2	0,1	22,4	0,7	0,4	30,0	0,1	97,5
Garnet	0,1	29,0	1,9	0,1	38,4	19,9	4,9	3,9	0,2	98,5
Kya/Sill	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Staurolite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Zircon	0,2	0,7	0,1	0,2	29,9	0,0	0,2	0,1	64,7	96,1
Silicate	0,7	16,2	0,4	0,1	47,6	9,4	10,0	12,3	0,2	97,0
Unclassified	3,4	13,9	3,3	3,4	7,2	5,5	3,7	3,1	6,5	50,0

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	18,2	0,0	0,0	42,7	34,4	4,7	0,0	0,0	100,0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	49,2	0	0	33,8
Fe_2O_3 wt%	47,7	0	0	59,9
MnO wt%	1,4	0	0	1,2
Cr_2O_3 wt%	0,1	0	0	0,1
SiO_2 wt%	0,8	0	0	2,3
Al_2O_3 wt%	0,2	0	0	1,0
MgO wt%	0,3	0	0	0,6
CaO wt%	0,2	0	0	0,7
ZrO_2 wt%	0,2	0	0	0,2
Total	100,0	0	0	100,0

Average TiO_2 content of all the TiO_2 minerals:	38,4
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	38,4
Valuable heavy minerals in raw sand:	5,32

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	4,9	1,0
Leucoxene	0,0	0,0
Rutile	0,0	0,0
Ti magnetite	11,5	2,3
Magnetite	33,1	6,5
Chromite	0,0	0,0
Pyrite	0,0	0,0
Phosphate	0,0	0,0
Monazite	0,3	0,1
Y-phosphate	0,0	0,0
Sphene	0,6	0,1
Garnet	9,3	1,8
Kya/Sill	0,0	0,0
Staurolite	0,0	0,0
Zircon	1,3	0,2
Silicate	26,6	85,5
Unclassified	12,3	2,4
Total	100,0	100,0

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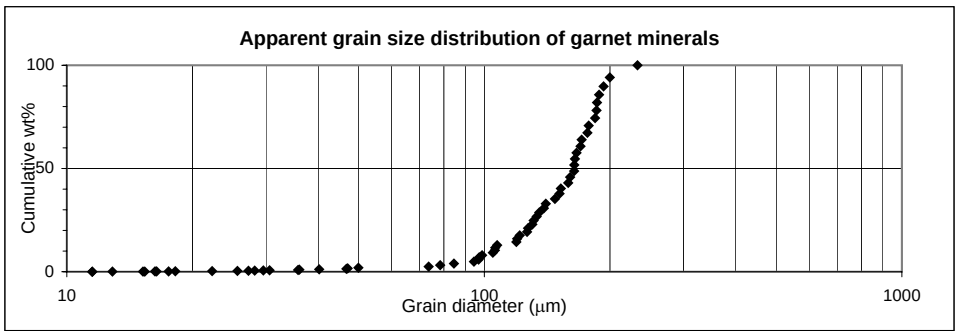
Lab. Name:	472734	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	05-03-02		



Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1,4	1,8	495	188	12638	27
Leucoxene	0,0	0,0	0	0	0	0
Rutile	0,0	0,0	0	0	0	0
Ti magnetite	1,5	1,7	465	175	11391	66
Magnetite	1,5	1,7	434	162	10327	192
Chromite	0,0	0,0	0	0	0	0
Pyrite	0,0	0,0	0	0	0	0
Phosphate	0,0	0,0	0	0	0	0
Monazite	1,2	1,4	591	193	19698	1
Y-phosphate	0,0	0,0	0	0	0	0
Sphene	1,5	2,0	591	239	14197	4
Garnet	1,5	1,8	456	180	11496	63
Kya/Sill	0,0	0,0	0	0	0	0
Staurolite	0,0	0,0	0	0	0	0
Zircon	1,5	1,6	556	201	16913	5
Silicate	1,5	1,9	452	184	11576	270
Unclassified	1,5	1,6	573	210	17997	79

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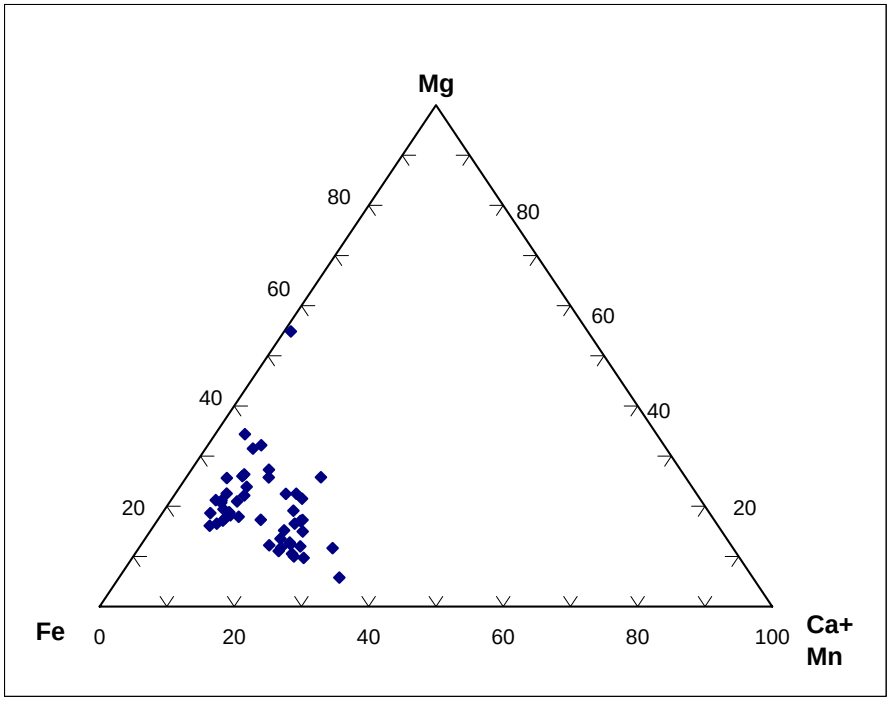
Lab. Name:	472734	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	05-03-02		



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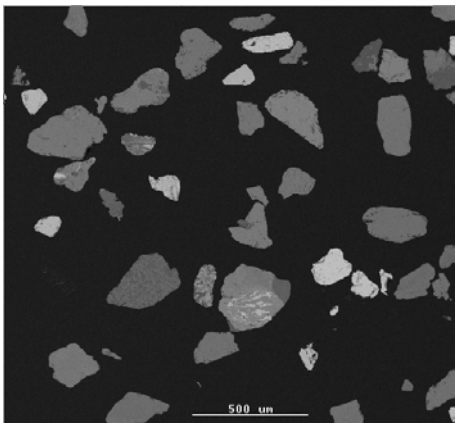
GEUS



Sample Name:	472738	No. of frames analysed:	34
Lab. Name:	472738	No. of particles analysed:	694
Date:	05-03-02	Heavy minerals in raw	
Submitter:	GEUS	sand (%):	22,40
Country:	Greenland	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/100x			
Guard region:	375µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	49,9	44,7	2,1	0,0	0,7	0,3	0,4	0,3	0,1	98,6
Leucoxene	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Rutile	90,3	3,4	0,1	0,1	1,6	0,4	0,9	0,1	0,3	97,2
Ti magnetite	26,3	58,5	1,0	0,1	6,6	2,9	1,7	1,1	0,2	98,4
Magnetite	1,6	90,5	0,3	0,2	2,2	1,6	1,3	0,2	0,3	98,0
Chromite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Pyrite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Phosphate	0,2	0,3	0,0	0,1	0,6	0,0	0,0	56,4	2,6	60,2
Monazite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Y-phosphate	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sphene	46,2	1,4	0,1	0,4	15,6	0,9	0,4	31,6	0,4	97,1
Garnet	0,2	27,3	1,2	0,1	39,3	19,6	6,4	4,3	0,2	98,5
Kya/Sill	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Staurolite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Zircon	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Silicate	1,0	14,6	0,3	0,1	49,7	9,7	9,6	11,3	0,1	96,5
Unclassified	6,0	21,6	0,9	0,5	32,6	4,3	9,0	11,3	1,9	88,1

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	3,9	0,0	10,0	25,2	61,0	0,0	0,0	0,0	100,0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	50,6	0	92,9	26,8
Fe_2O_3 wt%	45,3	0	3,4	59,4
MnO wt%	2,2	0	0,1	1,0
Cr_2O_3 wt%	0,0	0	0,1	0,1
SiO_2 wt%	0,8	0	1,7	6,7
Al_2O_3 wt%	0,3	0	0,5	2,9
MgO wt%	0,4	0	0,9	1,7
CaO wt%	0,3	0	0,1	1,1
ZrO_2 wt%	0,1	0	0,3	0,2
Total	100,0	0	100,0	100,0

Average TiO_2 content of all the TiO_2 minerals:	46,1
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	30,0
Valuable heavy minerals in raw sand:	2,26

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	0,4	0,1
Leucoxene	0,0	0,0
Rutile	1,0	0,2
Ti magnetite	2,5	0,6
Magnetite	3,6	0,8
Chromite	0,0	0,0
Pyrite	0,0	0,0
Phosphate	0,2	0,0
Monazite	0,0	0,0
Y-phosphate	0,0	0,0
Sphene	0,1	0,0
Garnet	6,2	1,4
Kya/Sill	0,0	0,0
Staurolite	0,0	0,0
Zircon	0,0	0,0
Silicate	85,1	96,7
Unclassified	0,8	0,2
Total	100,0	100,0

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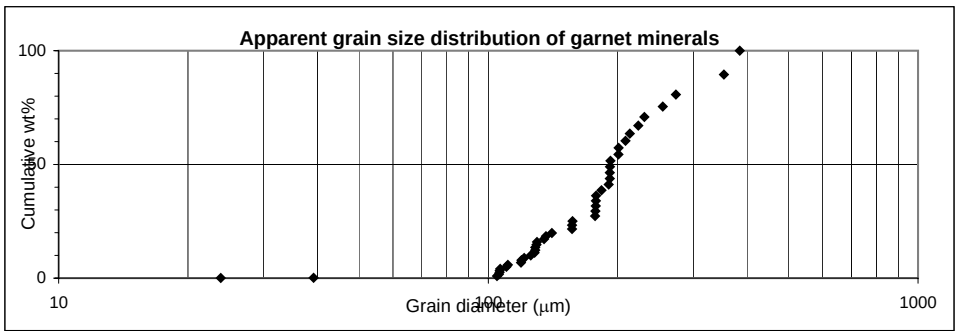
Lab. Name:	472738	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	05-03-02		



Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm^2)	Total grains
Ilmenite	1,4	1,3	338	105	8981	7
Leucoxene	0,0	0,0	0	0	0	0
Rutile	1,6	2,4	1483	625	72994	2
Ti magnetite	1,7	1,7	669	253	23998	16
Magnetite	1,6	2,1	632	260	16866	30
Chromite	0,0	0,0	0	0	0	0
Pyrite	0,0	0,0	0	0	0	0
Phosphate	1,4	2,0	877	352	30596	1
Monazite	0,0	0,0	0	0	0	0
Y-phosphate	0,0	0,0	0	0	0	0
Sphene	1,6	1,8	440	161	10554	2
Garnet	1,5	1,8	699	269	24702	45
Kya/Sill	0,0	0,0	0	0	0	0
Staurolite	0,0	0,0	0	0	0	0
Zircon	0,0	0,0	0	0	0	0
Silicate	1,6	1,9	867	338	40384	575
Unclassified	1,5	1,6	427	172	13521	16

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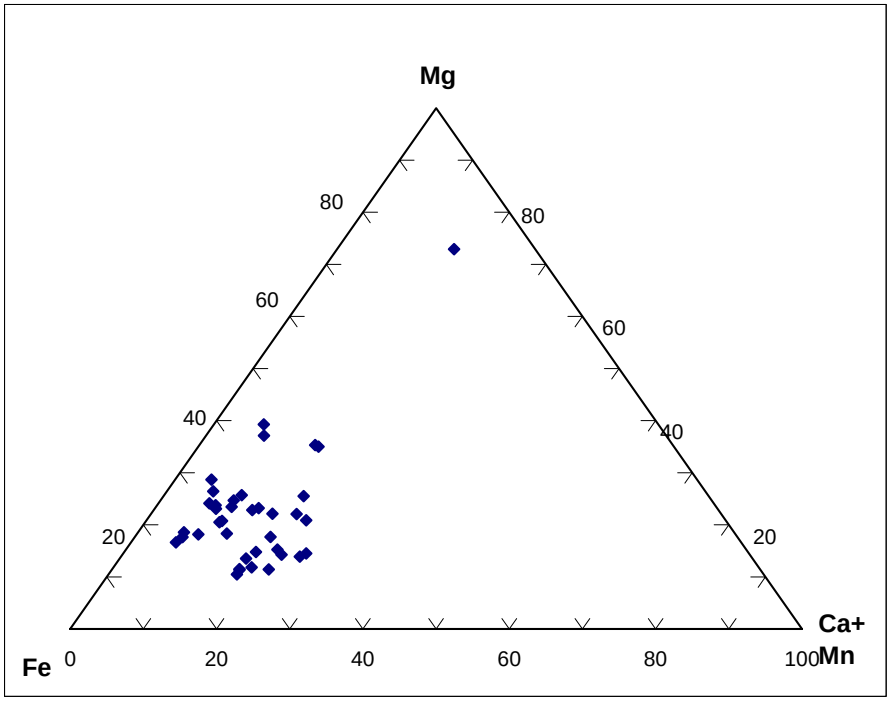
Lab. Name:	472738	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	05-03-02		



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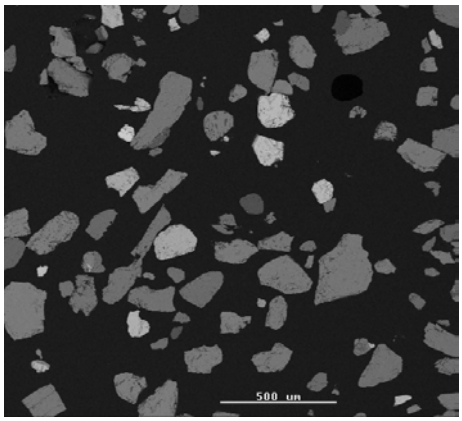

Sample Name:	2000356	No. of frames analysed:	39
Lab. Name:	2000356	No. of particles analysed:	3891
Date:	05-03-02	Heavy minerals in raw	
Submitter:	GEUS	sand (%):	35,26
Country:	Greenland	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/100x			
Guard region:	375µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	47,9	47,4	0,9	0,1	1,1	0,3	0,3	0,4	0,3	98,6
Leucoxene	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Rutile	95,2	0,3	0,2	0,5	1,4	0,1	0,0	0,9	0,2	98,9
Ti magnetite	36,4	55,6	0,7	0,2	2,6	0,8	0,6	0,5	0,3	97,8
Magnetite	1,1	92,1	0,2	0,2	1,8	1,1	0,5	0,3	0,3	97,6
Chromite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Pyrite	0,0	33,9	0,1	0,2	2,1	0,1	0,2	0,1	0,2	36,8
Phosphate	0,0	0,6	0,1	0,1	0,8	0,1	0,1	56,7	1,2	59,7
Monazite	0,0	0,0	0,0	0,0	3,1	0,0	1,2	3,8	4,2	12,4
Y-phosphate	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sphene	37,4	1,0	0,3	0,1	30,0	1,5	0,1	27,0	0,3	97,7
Garnet	0,2	29,3	1,3	0,1	38,3	18,7	3,8	6,1	0,2	98,0
Kya/Sill	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Staurolite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Zircon	0,5	1,4	0,1	0,2	29,2	0,1	0,1	0,2	63,4	95,3
Silicate	0,9	19,5	0,6	0,1	45,6	10,9	7,5	10,9	0,3	96,3
Unclassified	2,6	24,7	1,4	1,1	27,3	8,5	4,5	9,2	3,2	82,5

	Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	12,6	0,0	0,3	26,7	58,9	1,5	0,0	0,0	100,0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	48,5	0	96,3	37,3
Fe_2O_3 wt%	48,1	0	0,3	56,9
MnO wt%	0,9	0	0,2	0,8
Cr_2O_3 wt%	0,1	0	0,5	0,2
SiO_2 wt%	1,1	0	1,5	2,7
Al_2O_3 wt%	0,3	0	0,1	0,8
MgO wt%	0,3	0	0,0	0,6
CaO wt%	0,4	0	1,0	0,5
ZrO_2 wt%	0,3	0	0,2	0,4
Total	100,0	0	100,0	100,0

Average TiO_2 content of all the TiO_2 minerals:	41,3
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	40,9
Valuable heavy minerals in raw sand:	9,97

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	3,6	1,3
Leucoxene	0,0	0,0
Rutile	0,1	0,0
Ti magnetite	7,6	2,7
Magnetite	12,1	4,3
Chromite	0,0	0,0
Pyrite	0,4	0,1
Phosphate	0,5	0,2
Monazite	0,1	0,0
Y-phosphate	0,0	0,0
Sphene	1,5	0,5
Garnet	16,7	5,9
Kya/Sill	0,0	0,0
Staurolite	0,0	0,0
Zircon	0,4	0,2
Silicate	56,2	84,6
Unclassified	1,0	0,4
Total	100,0	100,0

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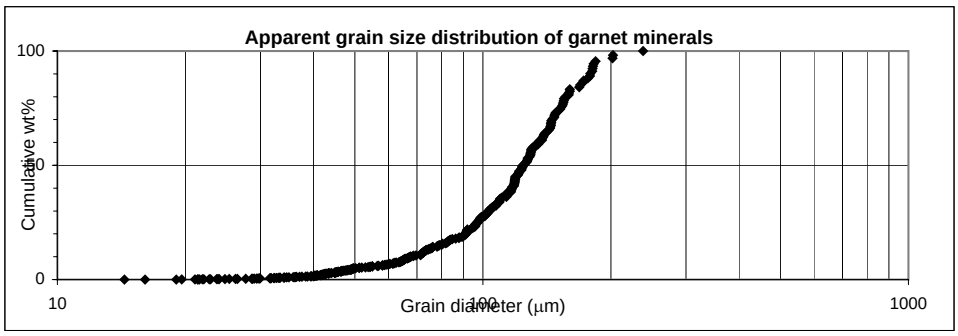
Lab. Name:	2000356	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	05-03-02		



Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1,6	1,6	344	125	6682	65
Leucoxene	0,0	0,0	0	0	0	0
Rutile	2,6	1,6	256	94	3171	3
Ti magnetite	1,5	1,5	338	123	6925	128
Magnetite	1,5	1,6	346	126	6832	187
Chromite	0,0	0,0	0	0	0	0
Pyrite	1,2	1,5	422	144	9560	4
Phosphate	1,3	1,4	320	112	7260	7
Monazite	1,2	1,4	523	173	15313	1
Y-phosphate	0,0	0,0	0	0	0	0
Sphene	1,7	1,7	441	165	10816	18
Garnet	1,5	1,6	343	126	7138	338
Kya/Sill	0,0	0,0	0	0	0	0
Staurolite	0,0	0,0	0	0	0	0
Zircon	1,4	1,4	246	85	4434	13
Silicate	1,5	1,7	418	157	10292	1182
Unclassified	1,4	1,5	282	111	6326	37

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Lab. Name:	2000356	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	05-03-02