

Garnet sand in Greenland: Examples from Tuttoqqortoog, Tasiilaq area and Sisimiut area

Jan Bernth Sørensen and Per Kalvig



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1. Summary

A number of localities within Upernavik Municipality, Sisimiut Municipality and Ammasalik Municipality having elevated garnet content are visited by GEUS during the 2001 field season. This activity has been part of the work conducted for Greenland Resources, aiming at evaluating the possibilities for establishing small-scale mining activities in Greenland.

Tuttoqqortoog

The garnet rich sand occurrence in Upernavik Municipality, Tuttoqqortoog was sampled, 25 samples are analysed for the content of heavy minerals (mean 17 %). 5 samples were analysed for content of different heavy mineral species as well as the shape, size and chemical composition of the different heavy minerals.

The results indicate that garnet is the dominating heavy mineral in the beach (mean of the 5 samples is 73.5 %). The composition is an almandine rich garnet characterised by angular grain shape. However, the estimated total tonnage of garnet in the beach is very limited and in the order of magnitude of 2000 ton. Considering the price for garnet and the cost of investment, this volume is too small to justify further investigations.

Isortuarsuk

The garnet rich sand occurrence at Isortuarsuk, Sisimiut Municipality, was visited and four grab samples taken. Garnet enriched sand occur in the active beach and shoreface, in a spit and on top of uplifted marine terraces. The sand in the active beach contains very high contents of heavy minerals (up to 80 %) and high relative contents of garnet (approx. 50%); almandine is the dominating garnet mineral. However, the active beach constitutes a very limited and economically insignificant volume. The spit was not visited during the very brief visit. Based on this very brief visit, the largest volume of garnet at this locality seems to be tied to the top of the uplifted marine terraces. However, the garnet content in this is approx. 5 %, which may be too low to be economical.

The composition of the garnet at this locality differs from that of Tuttoqqortoog in that there are two populations of garnet, indicating multiple sources for the garnet.

Provided further investigations are to be made here, it is recommended that the area with possible mineralised sand is measured based on aerial photographs, that representative sampling in grid be conducted, possibly backed by measuring the thickness of the sand layer using georadar. This to evaluate the garnet potential of the area. The quality of the garnets can initially be evaluated based on CCSEM data.

Ammasalik Municipality

Four sites were sampled, of which two contained elevated contents of garnet (Umivik and Kulusuk). However, the size of the occurrences are insignificant and considered non-economic.

Both of these Umivik and Kulusuk sands contain almandine (Fe) rich garnet, whereas the other localities (Ikerteq and Siaraq Dal) contain garnets with elevated contents of other components such as Ca and Mn.

CCSEM

During the present study, a new analytical scheme for analysing garnet composition and grain-size distribution was developed using Computer Controlled Scanning Electron Microscopy (CCSEM). This scheme proved to be very efficient in evaluating the mineralogical composition of the heavy mineral fraction as well as the chemical composition of the garnet, the grain size distribution and the grain shape parameters. It is recommended, that this procedure be used in further investigations. It was found that the elevated garnet content in beach sand in Greenland is tied to the presence of high-grade metamorphic supracrustal rocks in the bedrock in the area.

If further exploration for garnet rich sands, it is recommended, that this is based on evaluation of aerial photographs combined with studies of geological maps of the bedrock.

2. Introduction

The investigations mentioned in this report are carried out for Greenland Resources. The report contains a short description of garnet as an industrial mineral and a brief market analysis for garnet sand. The main focus of the report is to describe the occurrence of garnet sand on selected localities in Greenland.

The investigated localities are (fig. 1):

Tuttoqqortoq in the Upernavik district, Northwest Greenland was chosen based on observations made during a reconnaissance expedition by Greenland Resources in year 2000. The fieldwork was carried out in the period July 27th to August 4th 2001 by Jan Bernth Sørensen and Inger Seierstad.

Occurrences of garnet sand was earlier reported by Martin Ghisler in the municipality of Tasiilaq (fi, East Greenland. Four beaches and a river were sampled. The fieldwork was carried out in combination with the ornamental stone/quartzite expedition by Per Kalvig and Thomas Rasmussen.

An occurrence, Isortuarsuk, in the vicinity of Sisimiut (fig. 1) was sampled by Christian Knudsen in combination with GEUS' West Greenland 66°-70°15'N project in 2001. (A.H.Clark and Associates has recently given up an exploration licence to this deposit.)

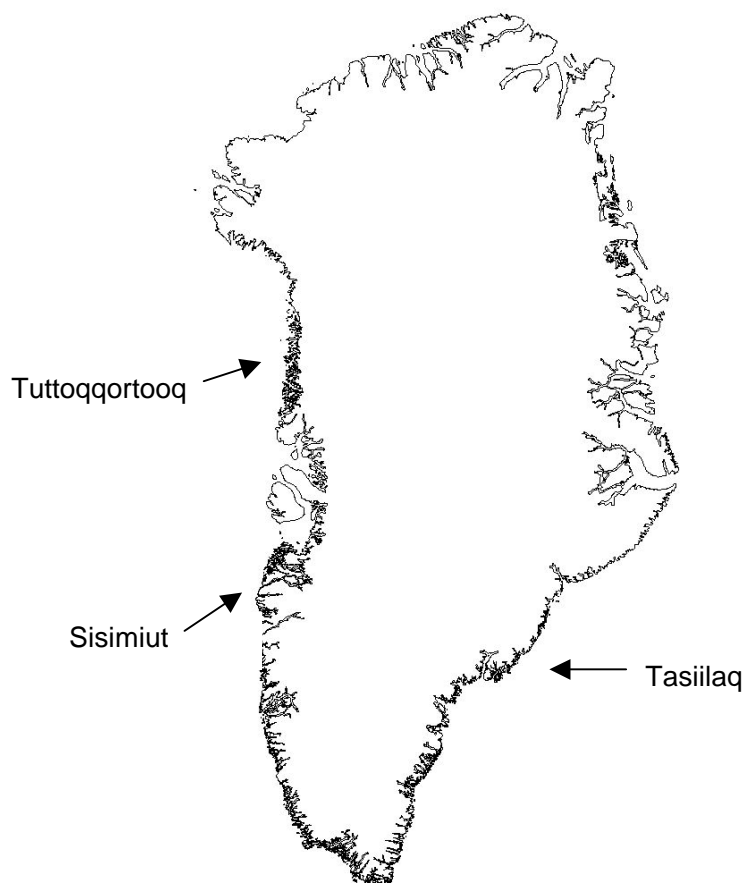


Fig. 1 Map of Greenland with selected garnet localities pointed out.

3. Properties and uses

Garnet is as an industrial mineral used for several purposes depending on the quality: The high quality garnet is used in the water jet cutting industry, whereas the lower quality garnet is used as abrasives in sandblasting and sandpaper or as a filter agent in water purification.

Abrasive water jet cutting does not produce heat that could alter the structure of the material being cut, and thus has many applications in the tool steel industry. Woodworking is another application for abrasive water jet cutting. Since wood is a softer material compared to steel, almost all wood can be cut, and the abrasive particles sand the surface, leaving a smooth finish that does not require sanding .

In the air/water blasting industry and as abrasive powders, garnet is increasingly substituting quartz sand, since quartz is known to cause severe health problems for the workers.

In water filtration garnet is used for "Rapid sand filtration". Rapid sand filtration is the flow of water through a bed of granular media, normally following settling basins in conventional water treatment trains. A rapid sand filter can operate up to 40 times faster than a slow conventional sand filter.

Three criteria are decisive for garnet to be of water jet cutting quality:

1. Hardness:
 - The abrasive must be harder than the material to be cut
 - The abrasive nozzle is subjected to greater wear by harder abrasives.
2. Grain size:
 - The grain size must be less than the nozzle diameter (generally between 0.8 and 1.2 mm).
 - Finer abrasives produce a finer smooth cut zone.
 - A finer grain size requires lower cutting force.
 - The grain size 125 μ yields good cutting results in virtually all materials.
3. Surface:
 - The abrasive particles must be of sharp crystalline structure since the cutting process here is equivalent to a micro-chipping abrasion process.

Other parameters determining the quality of garnet:

- Grains of higher specific gravity require lower cutting force.
- The tenacity (resistance to break) determines how many times the abrasives can be recycled.

Hardness, specific gravity and tenacity are dependent on the type of garnet. The preferred type of garnet in the Water jet cutting industry is almandine. The hardness of almandine is 7-7.5 and specific gravity 4.1-4.3 and almandine is relatively tenacious compared to other garnet types. The CCSEM datasheets (appendix B) have indications of all the relevant criteria. The ternary diagrams give an indication of the type of garnets; the grain size can be

seen on the grain size curve; and the values for aspect ratio and circularity give an indication of the sharpness of the mineral grains.

4. The garnet market

The cost of transportation is the crucial competitive factor in the garnet industry. The major competitors, with respect to a production in Greenland, are based in Australia, India and USA. The distance from Australia to Europe is > 8,000 nautical miles, from India > 5,000 nautical miles, and from New York and Greenland > 2,000 miles.

A new player on the European market is the Ukrainian producer Black Sea Minerals, Inc. On their homepage - www.blackseaminerals.com - they claim that they will be the first significant garnet producer in Europe. Because the quarry and processing plant are located in Ukraine, Black Sea Minerals, Inc. has access to both low cost production and low cost transportation.

In 1998 the world demand of industrial garnet was 240,000 t - 300,000 t garnet. Of which 20-25% was consumed in the United States. Before 1998 the garnet consumed in the United States has been used as follows: air/water blasting media, 45%; water filtration, 15%; abrasive powders, 15%; and abrasive water jet cutting, 7%.

Although the market is expected to increase, the pricing within the U.S. garnet industry is very competitive. A lot of the garnet that is produced, is stockpiled at the moment (table 1 and fig. 2). Hence it is not clear if the garnet producing companies are expecting the demand to increase significantly or if they are simply forced to continue production.

Year	Crude production			Sold or used			Prod - Sold	Prod - Sold acc.	Profit margin
	Quantity (metric tons)	Value in 1000\$	Price \$/per ton	Quantity (metric tons)	Value in 1000\$	Price \$/per ton	Quantity (metric tons)	Quantity (metric tons)	\$/per ton
1994	44700	3430	77	41100	10700	260	3600	3600	184
1995	46300	3850	83	39900	10100	253	6400	10000	170
1996	60900	5630	92	46200	11200	242	14700	24700	150
1997	64900	6050	93	53600	12500	233	11300	36000	140
1998	74000	7070	96	51900	12600	243	22100	58100	147
1999	60700	6170	102	43900	11600	264	16800	74900	163
2000	60200	7060	117	51300	14000	273	8900	83800	156

Table 1. Salient U.S. Industrial garnet statistics (based on Olson, 2000).

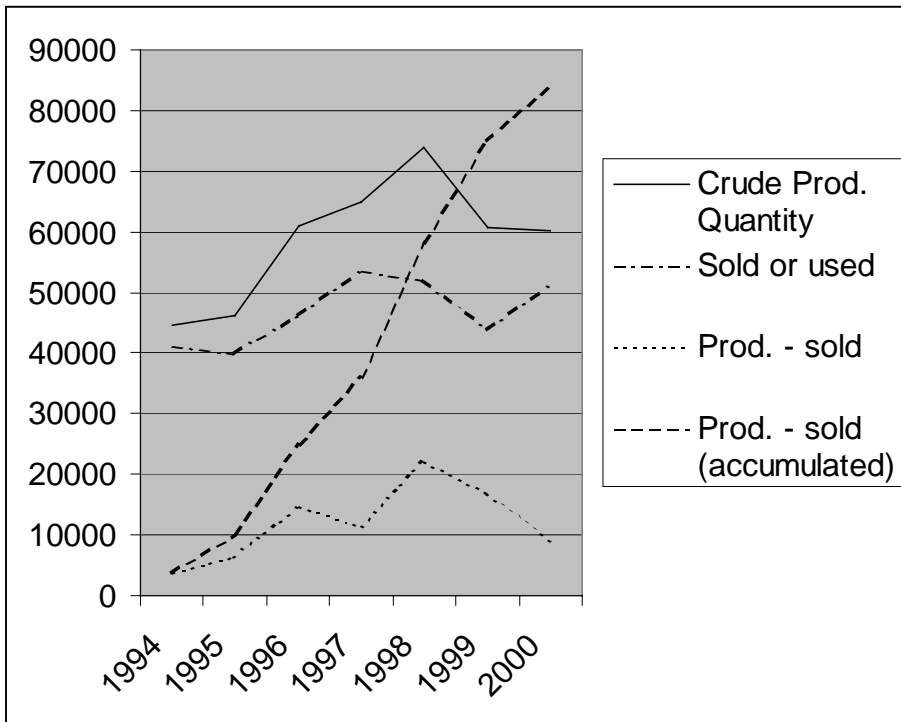


Fig 2. Plot of table 1 showing the trend in production compared to demand for garnet.

5. Tuttoqqortoq

The investigated beach on the north coast of the island Tuttoqqortoq is located approximately 100 km north of Upernavik, North-West Greenland at (73°40N 56°37W) (fig. 3).

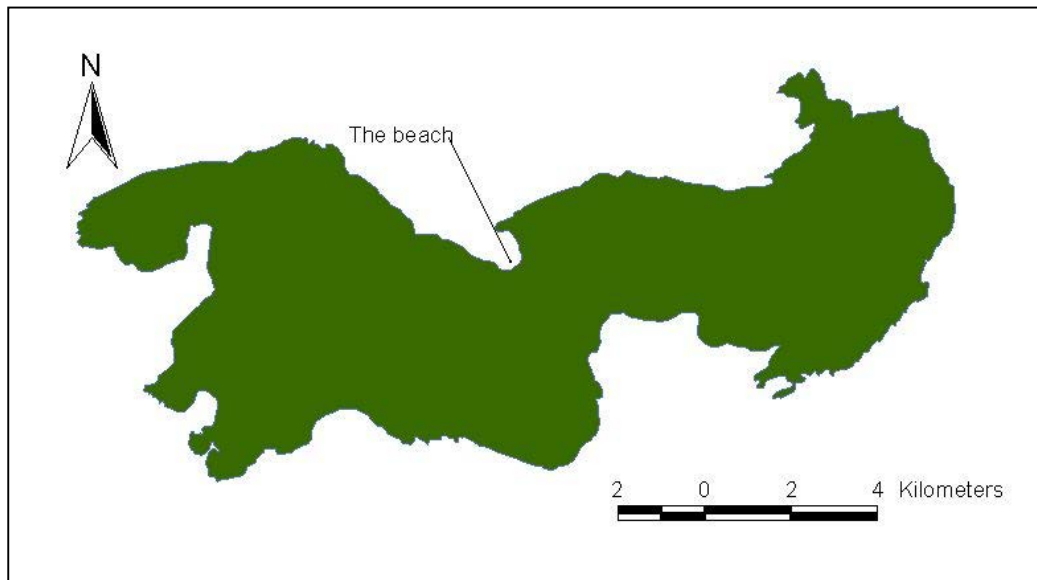


Fig. 3 Tuttoqqortoq

The island Tuttoqqortoq belongs geologically to the Karrat Group, part of the Rinkian mobile belt of West Greenland. In the Tuttoqqortoq area, the Karrat Group forms a thick sequence of Proterozoic, granulite facies metasediments (mainly) (Escher and Pulvertaft, 1976).

The Tuttoqqortoq garnet (almandine) sand beach, situated in a bay on the north side of Tuttoqqortoq facing Giesecke Isfjord, is about 500 m long and up to 50 m wide (figs. 4 and 5). The beach is divided in two by a stream. The stream drains a valley extending to the southern coast of Tuttoqqortoq. Erosion of the garnet rich Karrat Group is the source of the sand. This garnet rich sand is further sorted by wave action on the active shoreface in the swash-backwash zone giving rise to the garnet placer on the beach (fig. 6).



Fig. 4 Overview of the beach.

The observations made during the Greenland Resources expedition in 2000 suggest presence of garnet of good quality. This study attempts to give an estimate of the tonnage of the garnet deposit in order to evaluate the possibility of a small-scale operation.

5.1 Sampling methods

A tidal channel is cutting the beach almost in halves. To the west of the tidal channel a beach ridge consisting of boulder size rocks is dominating the beach (fig. 4). The active shoreface is poor in garnet. Behind the beach is a tidal lagoon. The sand in and around the lagoon is fine grained and relatively poor in garnet. Thus, the mineralised beach is the beach between the sea and the tidal lagoon on the eastern side of the tidal channel. The mineralised beach is about 200 m long and varying from 10 to 40 m wide (fig. 5).

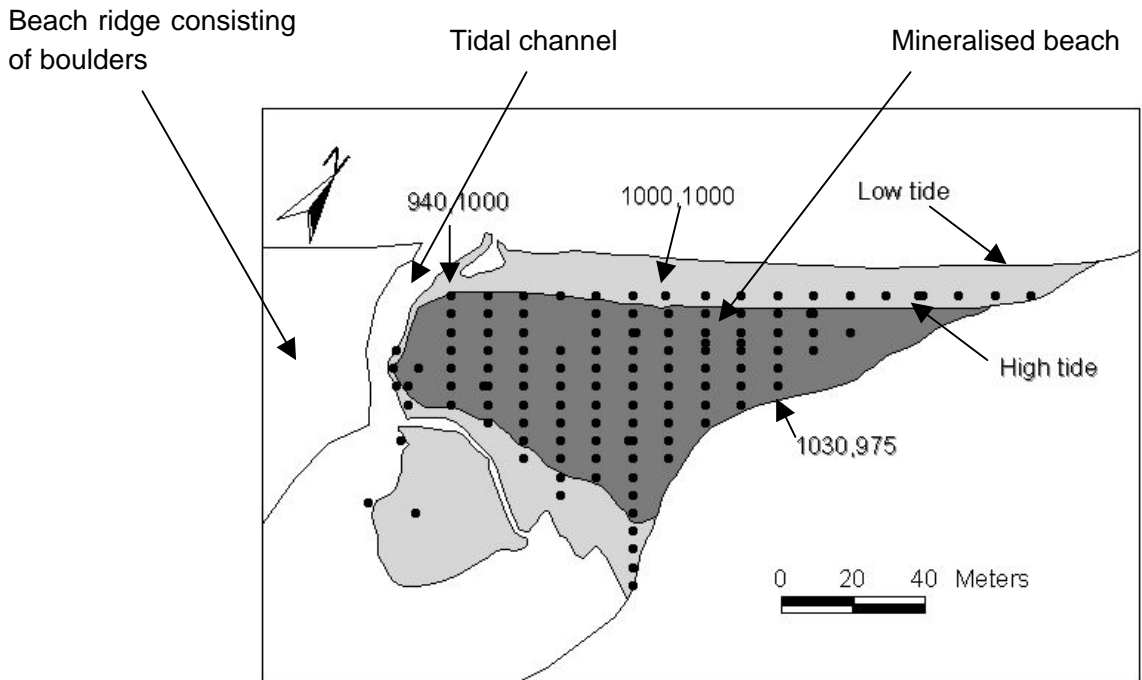


Fig. 5 Sketch of the mineralised beach to the east of the tidal channel. Sample points and a few coordinate pairs are marked. The dark grey is supra-tidal and the light grey is inter-tidal.



Fig. 6 The active shoreface on the mineralised part of the beach. The garnet is concentrated in the swash-backwash zone and covers the beach as a thin (mm-scale) veneer after high tide.

It is possible that the garnet deposit extends down below the permafrost or extends out in the bay. No uplifted beaches could be found in the hinterland.

The beach was sampled in a grid with a spacing of 5 m across the beach and 10 m along the beach (appendix A). Each sample represents the upper 20 cm. Five 1x1m holes were dug to a depth about 120 cm (fig. 7), where the permafrost inhibited further digging. Each of the 1x1m holes was sampled with 20 cm spacing (0 - -20cm, -20 - -40cm and so on).

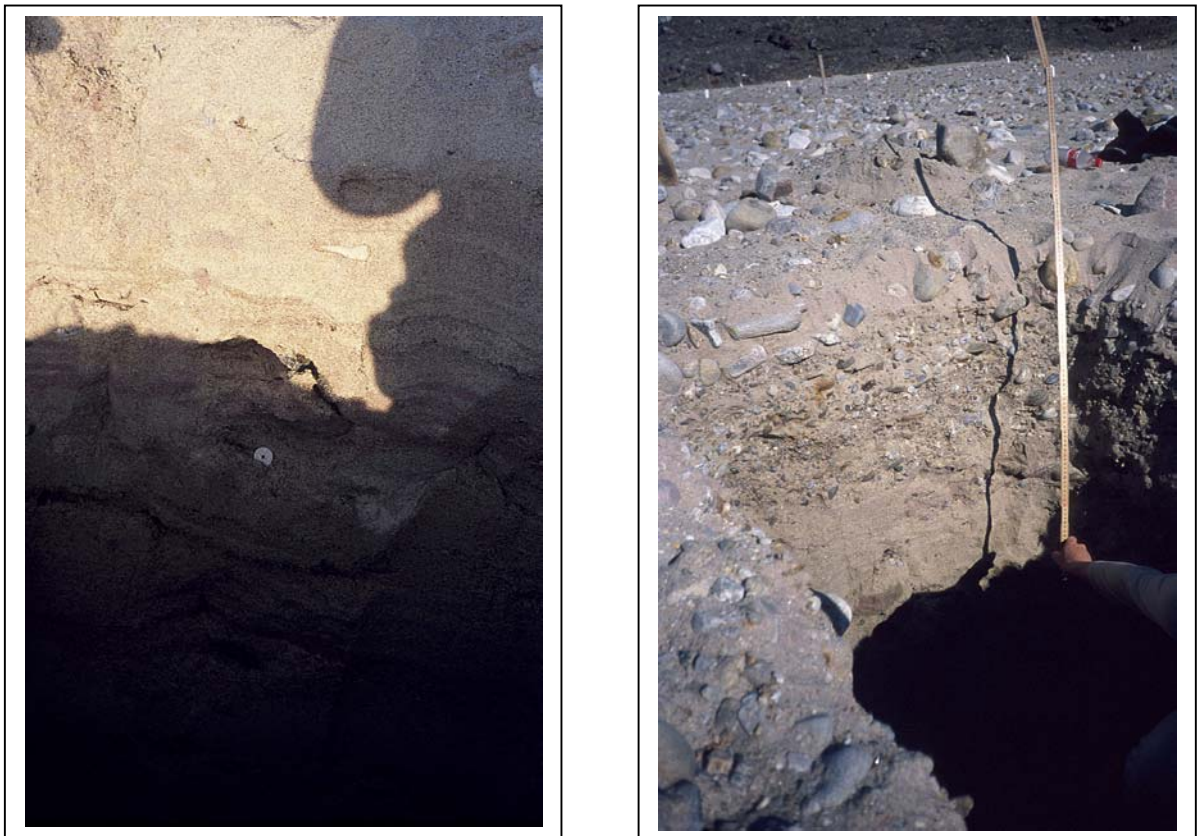


Fig. 7 Two of the 1x1 m holes. 1039,995 on the left and 949,975 on the right. The variability in gravel content is clearly seen on the photos. In general the gravel content is increasing to the west.

The sand on Tuttoqqortoq has a very varying gravel content ranging from 0 to ~80% and a size range from pebbles to boulders (fig. 7). Very large samples would be needed to ensure representative samples. The only realistic way was to visually estimate the gravel percentage in the field.

Horizons of garnet (1 – 5 cm thick) can be seen in all five large holes from top to bottom. It was in the field not possible to see a trend of increasing or decreasing garnet content with depth. In the hole 1039,995 a piece of seaweed was found near the permafrost, indicating

that the beach is very young. It is likely that the beach is washed away every spring and is building up the following summer.

Two large samples were collected in the case that processing experiments was considered relevant. The large samples were collected by scraping off the sides of the holes with a shovel, one representing 0 - -50cm and the other -50 - -120cm.

5.2 Analytical methods

In heavy liquid separation the washed and dried sand is poured in a liquid with a specific gravity of 2.8 g/cm³. The particles with a specific gravity greater than 2.8 g/cm³ will fall to the bottom and the rest will remain floating. The product of this operation is a heavy minerals (HM) concentrate.

The heavy mineral assemblages can be quantified using CCSEM (Computer Controlled Scanning Electron Microprobe). The CCSEM counts the relative abundance of HM as well as the average mineral composition of the individual HMs. The individual garnet grain compositions are tested against microprobe data in ternary diagrams.

5.3 Results

The percentage of heavy minerals in the sand was found using heavy liquid (2.8 g/cm³) separation of 25 samples. The HM% values are corrected for the gravel% (Table 2).

Five representative samples were selected for Microprobe and CCSEM analysis (appendix B).

Sample	Gravel %	Heavy minerals%	Garnet% in HM	Garnet% in raw sand	Median grain size (μ)	Aspect ratio	Circularity
472701	60	5,65	62,5	3,5	270	1,6	1,8
472702	60	8,60	67,1	5,7	250	1,6	2,0
472704	5	34,69	84,4	29,3	325	1,6	1,8
472705	5	19,49	74,8	14,6	325	1,7	2,0
472706	0	29,07	78,7	22,9	310	1,6	1,9
472710	0	11,14					
472711	0	6,32					
472712	0	27,83					
472713	0	43,23					
472714	30	13,21					
472715	60	8,51					
472716	20	18,20					
472717	5	16,59					
472718	10	16,03					

472719	10	24,28					
472720	0	2,42					
472721	0	2,58					
472722	0	5,45					
472723	10	20,93					
472724	5	5,03					
472725	5	35,22					
472726	0	17,55					
472727	5	24,65					
472728	30	13,82					
472729	20	14,43					
mean	14	17,00	73,5	12,5	296	1,6	1,9

Table 2 Heavy minerals concentration in raw sand, Tuttoqqortoq. The heavy mineral values are corrected for gravel content. 472701 – 472706 were analysed with CCSEM. The mean garnet wt% in raw sand is based on mean HM% and mean garnet% of HM.

The average garnet content in raw sand of the samples is 12,5 weight%. The mineralogy of the garnets is fairly uniform with about 80% almandine (Fe) component and 13% pyrope (Mg) component. The remaining 7% consists of other components (Ca, Mn etc.). The mineralogical composition of the garnets derived from CCSEM and microprobe are plotted in ternary diagrams (appendix B).

In microscope it can be seen that the grains are blocky shaped, angular to very angular and have low to medium sphericity. Indications from the CCSEM datasheets of the same parameters are aspect ratio, which on average is 1.6 and circularity, which is 1.8 (appendix A).

5.4 Discussion

No water jet cutting tests have been made on the Tuttoqqortoq garnets to determine the viability as an industrial mineral. However, the results of the CCSEM analyses (primarily blocky shaped almandine) suggest that the garnet is of good water jet cutting quality.

The access to Tuttoqqortoq can be difficult, and the sea is navigable for about 2-3 months only. It is possible to land heavy machinery on the beach using a barge. The company Lasø in Upernavik (the largest contractor in the district) can supply some machinery and a barge.

A volume of 7600 m³ beach sand with significant content of garnet is identified on Tuttoqqortoq. With a porosity of the sand of about 30% the bulk density is in the order of 2 tonnes/ m³. The average garnet wt% in raw sand is 12,5%, which amounts to 0.25 tonnes garnet/ m³. In total the garnet resource is approx. 2.000 tonnes. Although the deposit may extend below the permafrost, the total amount will not reach a volume that could make the deposit profitable.

The value of crude garnet is strongly dependent on the quality, ranging between US\$ 53 to US\$254. The garnet in Tuttoqqortoq is expected to be of a quality suitable for water jet cutting. Thus, a crude price/ton in the range \$200 to \$225 appears possible. Hence an overall in-situ (in Upernavik) value is in the range of US\$ 0.4 Mio. only.

6. The Tasiilaq municipality

Possible garnet sand deposits from within the Tasiilaq municipality were reported by Martin Ghisler; and some observations of possible garnet sand deposits are made by local inhabitants. Thus the reconnaissance was planned on this.

The area around Tasiilaq Ø is in general dominated by garnetiferous gneisses and schists that given the right topographic conditions could be the source of garnet placers. However, the area is dominated by steep mountain slopes with only very little foreland and substantial submarine slopes; such conditions do not facilitate concentration and deposition of garnet placers.

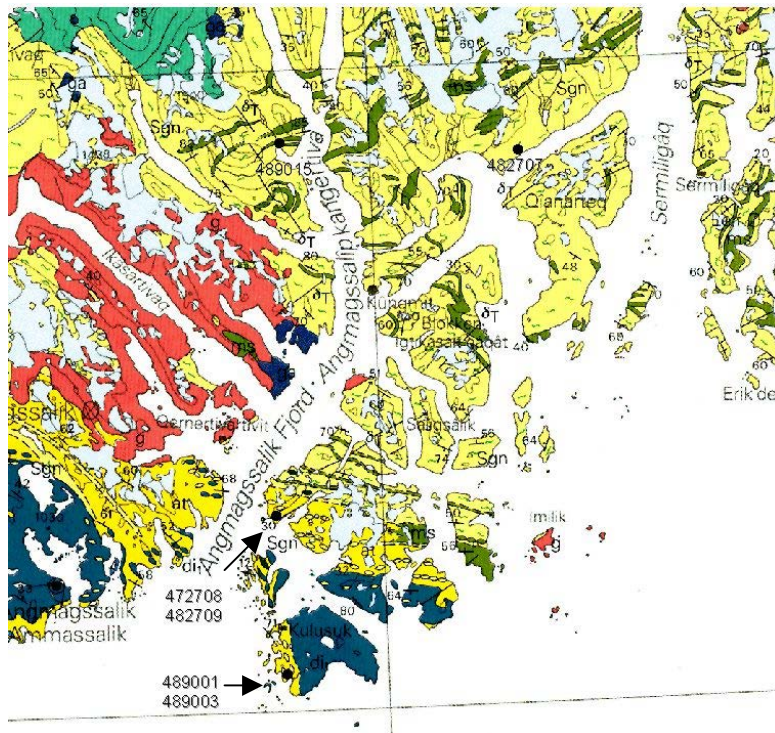


Fig. 8 Map of the Tasiilaq municipality with sample sites indicated.

The following localities have been investigated:

6.1 Locality 2b, Kulusuk Ø, West

A very small deposit was observed on the Western part of Kulusuk Ø (fig. 8). The active beach plane is only about 15 x 10 m (fig. 9). The material is derived from a moraine in the hinterland. The medium grained (max. ca. 1 mm) garnet sand is covering a beach plane consisting of 5 to 20 cm boulders. The deposit is not interesting from an economic point of view.

Sample	% Heavy minerals In raw sand	Garnet% in HM	Median grain size (μ)	Aspect ratio	Circularity
489001	19,86	30,2	225	1,6	1,9
489003	39,02	52,2	250	1,6	2,0

Table 3: Heavy minerals concentration in two samples from Kulusuk Ø



Fig. 9 The beach at Kulusuk with streaks of garnet sand.

6.2 The localities: Umivik, Tuno and Ikateq

None of the beaches visited on reconnaissance trip to Umivik, Tuno and Ikateq (fig. 8) showed sign of significant garnet deposits. Two samples were taken from small occurrences ($\sim 1 \text{ m}^2$) of sand (fig. 10).

Sample	Locality	% Heavy minerals In raw sand	Garnet% in HM	Median grain size (μ)	Aspect ratio	Circularity
472707	Ikerteq	4,37	1,3	200	1,3	1,5
472708	Umivik	53,57	64,5	210	1,7	2,0
472709	Umivik	20,76	70,4	325	1,6	2,0

Table 4: Heavy minerals concentration in samples from Ikerteq and Umivik.



Fig 10 Small finding of garnet sand on Umivik.

6.3 Siaraq Dal

One sample was taken in a river in Siaraq Dal (fig. 11). The sample was taken to give an idea of the composition of the sand before the sand was sorted by wave action (Appendix B).

Sample	% Heavy minerals In raw sand	Garnet% in HM	Median grain size (μ)	Aspect ratio	Circularity
489015	26,46	2,1	90	1,7	2,0

Table 5: Heavy minerals concentration in two samples from Siaraq Dal

Only 2.1% of the heavy minerals in the raw sand is garnet.



Fig 11 Siaraq Dal where sample 489015 was taken.

7. Isortuarsuk

The shores of Isortuarsuk (fig. 12) were briefly visited on July 25th (evening). The bay is characterised by uplifted marine terraces (fig. 13), which can be followed along the southern shore. The terraces consist mainly of poorly sorted, but predominantly fine-grained, silty sediments. However, on the top of the terraces, a sandy layer is seen with a thickness of approx. 1 to 3 meters where examined. Three samples were collected from this layer (464701, 02 and 03) at two different localities. The sand has an elevated content of heavy minerals (10 to 20 %). Of this approx. 20 to 40 % consist of garnet (appendix B). Apart from this, which may represent fossil shoreface sands, there are very high contents of garnet in the present day beach (Sample 464704, fig. 14). However, this probably represents a fairly limited volume. The heavy mineral rich sands in the easternmost part of the bay were not visited during the short visit.

The bedrock geology in the area is characterised by high-grade metamorphic supracrustal rocks, which probably is the source of the garnets.

Sample	% Heavy minerals In raw sand	Garnet% in HM	Median grain size (μ)	Aspect ratio	Circularity
464701	13,57	24,3	200	1,7	2,0
464702	19,96	39,7	250	1,7	1,9
464703	12,67	24,7	150	1,6	1,8
464704	81,22	53,8	125	1,6	1,9

Table 6: Heavy minerals concentration in samples from Isortuarsuk.

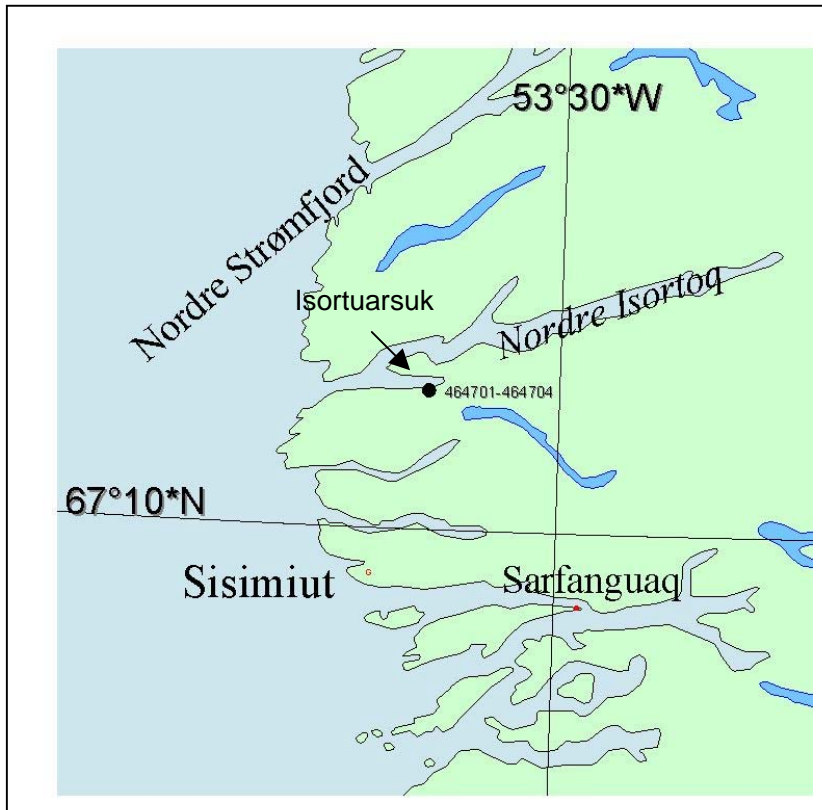


Fig. 12 Map of the Sisimiut area with sample numbers indicated.

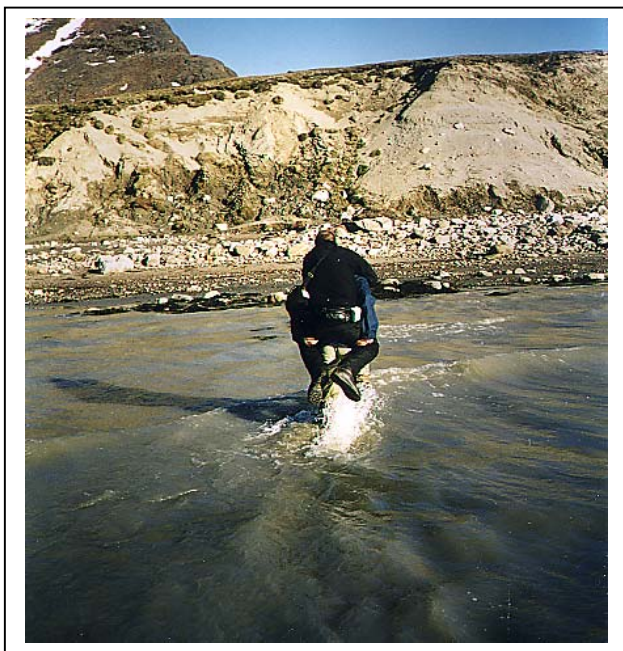


Fig. 13 The shore of Isortuarsuk. Note the uplifted marine terrace.



Fig. 14 The present day beach at the shore of Isortuarsuk.

8. Comparison of localities

The mineral chemistry of garnets can be used to characterise the garnets from different source areas. The garnets in Tuttoqqortoq show a very uniform distribution in ternary diagrams (appendix C), indicating that there is only one source area for the garnet in Tuttoqqortoq. The garnets in Isortuarsuk clearly fall in two groups, which indicates that the garnets have two different source areas. The garnets in Kulusuk and Umivik also have a uniform distribution, whereas the picture is less clear in Ikerteq and Siaraq Dal.

The slope of the curve is a measurement of the sorting of the garnets which reflects the sedimentary environment. 472708 (Umivik), 489001 (Kulusuk) and 464704 (Isortuarsuk) with relatively steep slopes (appendix D) on the grain size distribution curve are sampled on the active present day foreshore. 472709 (Umivik) and 489003 (Kulusuk) with less steep slope are sampled on the beach ridge and 464701, 464702 and 464703 (Isortuarsuk) are sampled on the uplifted terraces. In Tuttoqqortoq the grain size distribution curves also fall in two groups: 472702 and 472706 are relatively steep and 472701, 472704 and 472705 are less steep. 472701 and 472702 are from the same lateral coordinate – 928,970. 472701 represents the interval –40 - -60 and 472702 represents –100 - -120. 472702 is similar to the active foreshore samples from other localities and 472701 is similar to beach ridge samples. This indicates that the beach prograding.

9. Conclusions

On the basis of the small size of the deposit it is not recommended to carry on with further investigations of the Tuttoqqortoq particular deposit.

In Tasiilaq municipality samples with relatively high garnet content could be achieved but no deposits of economic interest was identified during this programme.

The uplifted marine terraces in the Sisimiut area could contain deposits of an economically interesting size. If further studies should be made, it is recommended to carry on with investigations in two phases:

- An estimation of the spatial distribution of the present day beach sand and the uplifted terraces based on aerial photographs.
- The spatial distribution should be evaluated in the field using georadar. The grade of the deposit should be evaluated by sampling in a grid much the same way as was done in Tuttoqqortoq.

On the basis of the then available information a draft for a flowsheet can be made.

It can be concluded that the CCSEM analysis has proved to give useful information on the composition of the HM phase (content of garnet), the compositional variation of the garnet as well as the grain-size and -shape parameters, information that form the basis of whether further tests are relevant.

The three areas visited yielded sand with high garnet contents. All three areas are characterised by having high metamorphic meta-sediments in the bedrock – with high contents of garnet.

If further exploration for garnet should be conducted possible garnet sand prospects may be found using aerial photographs and geologic maps/reports. In such an investigation the morphology of the terrestrial and marine environments should be taken into account, and attention given to logistic conditions involved with potential extraction.

10. References

- Escher & Pulvertaft in Escher & Watt (1976) Geology of Greenland
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Olson, Donald W. (2000) Industrial Garnet, www.minerals.usgs.gov
www.blackseaminerals.com

Appendix A

Samples from Tuttoqortoq

X-koo5d	y-koo5d	z-koo5d	gravel-pct	HM%	qqunr
880	1015	0	80		
890	1010	0	30		
890	1015	0	80		
910	1010	0	0		
917	943	0	0	24.65	472722
920	1000	0	0		
924	980	0	20		
924	980	-50	50		
925	975	0	20		
925	975	-100	60		
925	985	0	5		
926	960	0	5		
928	970	-40	60	5.65	472701
928	970	-100	60	8.60	472702
928	975	0	10		
928	975	-50	10		
930	940	0	0		
931	980	0	40		
931	980	-50	40		
940	970	0	5		
940	975	0	30		
940	980	0	20		
940	985	0	60		
940	990	0	60		
940	995	0	5	5.03	472724
940	1000	0	70		
949	975	0	40		
949	975	0	0		
949	975	0	30	13.21	472714
949	975	-20	60	8.51	472715
949	975	-40	20	18.20	472716
949	975	-60	5	16.59	472717
949	975	-80	10	16.03	472718
949	975	-100	10		
950	965	0	30		
950	970	0	10		
950	975	0	20		
950	980	0	40		
950	985	0	60		
950	990	0	20		
950	995	0	40		
950	1000	0	30		
960	955	0	50		
960	960	0	0		
960	965	0	10		
960	970	0	40		
960	975	0	60		
960	980	0	70		
960	985	0	70		
960	990	0	10		
960	995	0	60		
960	1000	0	60		
970	945	0	0		
970	950	0	0		
970	955	0	5		
970	960	0	10		
970	965	0	10	20.93	472723
970	970	0	5		
970	975	0	10		
970	980	0	50		
970	980	0	20		
970	985	0	70		
970	1000	0	5		
980	950	0	5		
980	955	0	5		
980	960	0	5		
980	965	0	10		
980	970	0	70		
980	975	0	30		
980	980	0	70		
980	985	0	20		
980	990	0	15		
980	995	0	5	35.22	472725
980	1000	0	10		
989	960	0	5		
989	960	-20	0		
989	960	-40	0		
989	960	-60	2		
989	960	-80	2		
990	920	0	10		
990	925	0	0		
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990	935	0	5		
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990	945	0	5		
990	950	0	10		

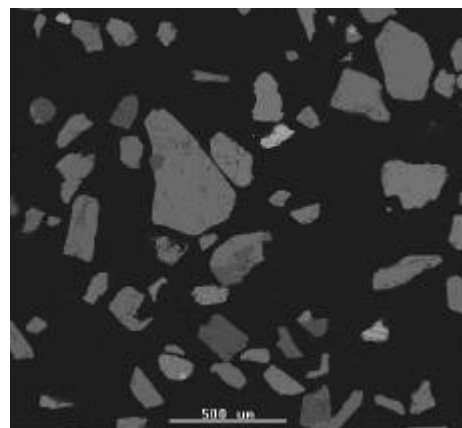
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990	960	0	30		
990	965	0	30		
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990	980	0	40		
990	985	0	0		
990	990	0	0	17.55	472726
990	995	0	2		
990	1000	0	20		
991	990	0	2		
991	990	0	0		
991	990	0	2		
991	990	-20	0		
991	990	-25	0		
991	990	-40	0		
991	990	-45	2		
991	990	-60	0		
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991	990	-80	0		
991	990	-85	5		
991	990	-100	0		
991	990	-105	10		
999	1000	0	10		
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1000	960	0	5		
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1000	970	0	10		
1000	975	0	25		
1000	980	0	50		
1000	985	0	5	34.69	472704
1000	990	0	0		
1000	995	0	50		
1010	965	0	5		
1010	970	0	5		
1010	975	0	5	24.65	472727
1010	980	0	10		
1010	985	0	5		
1010	987	0	0		
1010	990	0	2		
1010	995	0	40		
1010	1000	0	30		
1010	1000	-0.5	25		
1020	970	0	0		
1020	975	0	10		
1020	980	0	30	13.82	472728
1020	985	0	5		
1020	987	0	20		
1020	990	0	5		
1020	995	0	15		
1020	1000	0	20		
1030	975	0	5	19.49	472705
1030	980	0	20	14.43	472729
1030	985	0	2		
1030	990	0	0		
1030	995	0	20		
1030	1000	0	10		
1039	995	60-120	5		
1039	995	0-60	30		
1039	995	0	0	11.14	472710
1039	995	-20	0	6.32	472711
1039	995	-40	0	27.83	472712
1039	995	-60	0	43.23	472713
1039	995	-80	0	29.07	472706
1039	995	-100	0		
1040	985	0	10	24.28	472719
1040	990	0	10		
1040	995	0	5		
1040	1000	0	2		
1050	990	0	5		
1050	1000	0	2		
1060	1000	0	2		
1069	1000	-45	50		
1070	1000	0	0	2.42	472720
1070	1000	0	0		
1080	1000	0	0	2.58	472721
1090	1000	0	0		
1100	1000	0	0		

Appendix B

CCSEM and Micro Probe datasheets



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Sample Name: 464701	No. of frames analysed: 43
Lab. Name: 464701	No. of particles analysed: 896
Date: 16-01-02	Heavy minerals in raw
Submitter: GEUS	sand (%): 13,57
Country: Greenland	Comments:
Analyzed by: BV	
Acc. Voltage/Magnification: 17kV/100x	
Guard region: 375µm	
Sieve: 100 µm ²	

Category	Average content									
	TiO ₂ wt%	Fe ₂ O ₃ wt%	MnO wt%	Cr ₂ O ₃ wt%	SiO ₂ wt%	Al ₂ O ₃ wt%	MgO wt%	CaO wt%	ZrO ₂ wt%	Total
Ilmenite	48,5	43,6	0,4	0,2	3,6	1,2	0,6	0,1	0,1	98,4
Leucoxene	76,7	6,4	0,0	0,6	9,7	3,1	0,6	0,3	0,6	98,0
Rutile	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Ti magnetite	35,6	56,3	0,4	0,1	2,9	1,3	0,9	0,3	0,2	98,1
Magnetite	1,4	85,6	0,1	0,3	4,3	3,1	0,9	0,3	0,4	96,5
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	0,1	0,8	0,3	0,1	1,5	0,2	0,1	55,2	0,2	58,4
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	39,2	0,5	0,3	0,2	29,4	1,3	0,0	27,2	0,0	98,2
Garnet	0,2	27,7	0,6	0,1	38,9	19,9	7,7	2,5	0,3	98,0
Kya/Sill	0,0	0,5	0,2	0,2	43,1	53,7	0,1	0,2	0,3	98,2
Staurolite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Zircon	0,4	0,6	0,0	0,0	30,6	0,0	0,3	0,4	61,8	94,2
Silicate	1,0	18,4	0,4	0,1	47,2	9,3	9,9	9,7	0,3	96,1
Unclassified	5,8	16,4	0,1	0,2	20,5	6,8	1,9	21,5	6,3	79,5

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	6,8	0,3	0,0	12,6	75,4	0,4	4,5	0,0	100,0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	49,3	78,3	0	36,3
Fe ₂ O ₃ wt%	44,3	6,6	0	57,4
MnO wt%	0,4	0,0	0	0,4
Cr ₂ O ₃ wt%	0,2	0,6	0	0,1
SiO ₂ wt%	3,7	9,9	0	2,9
Al ₂ O ₃ wt%	1,2	3,1	0	1,3
MgO wt%	0,6	0,6	0	0,9
CaO wt%	0,1	0,3	0	0,3
ZrO ₂ wt%	0,1	0,6	0	0,2
Total	100,0	100,0	0	100,0

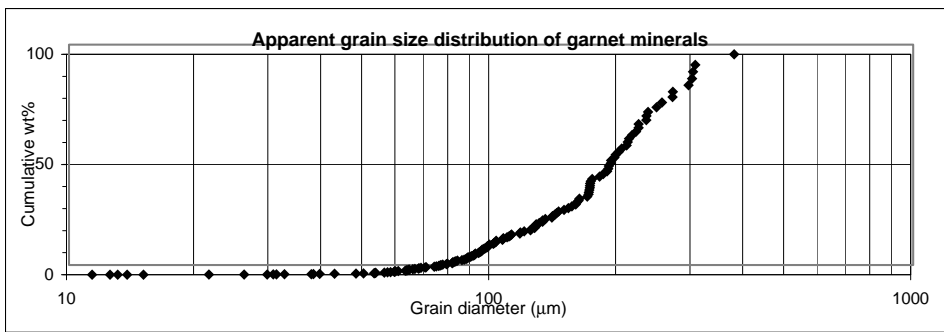
Average TiO ₂ content of all the TiO ₂ minerals:	41,5
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	41,5
Valuable heavy minerals in raw sand:	4,48

Weight percent on a mineral basis:		
Category	Heavy mineral	
	concentrate	Raw sand
	wt %	wt %
Ilmenite	2,2	0,3
Leucoxene	0,1	0,0
Rutile	0,0	0,0
Ti magnetite	4,0	0,6
Magnetite	1,2	0,2
Chromite	0,0	0,0
Pyrite	0,0	0,0
Phosphate	1,0	0,1
Monazite	0,0	0,0
Y-phosphate	0,0	0,0
Sphene	0,3	0,0
Garnet	24,3	3,4
Kya/Sill	1,5	0,2
Staurolite	0,0	0,0
Zircon	0,1	0,0
Silicate	65,1	95,1
Unclassified	0,2	0,0
Total	100,0	100,0

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Lab. Name: 464701 Analyzed by: BV
 Submitter: GEUS Acc. Voltage: 17kV
 Date: 16-01-02

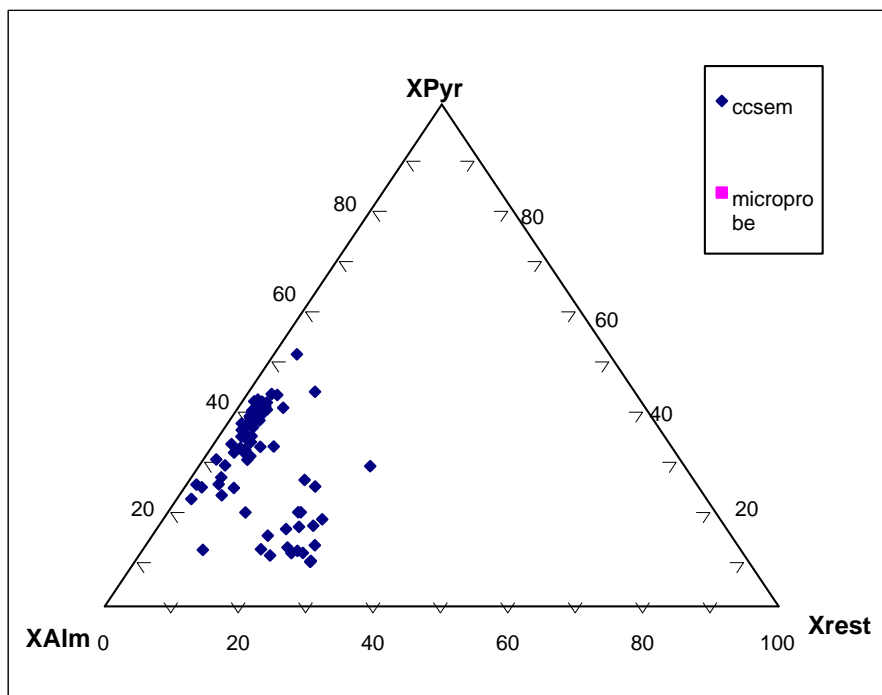


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	Total grains
Ilmenite	1,5	1,7	481	178	12818	15
Leucoxene	1,8	1,9	451	177	8564	1
Rutile	0,0	0,0	0	0	0	0
Ti magnetite	1,6	1,7	439	167	10716	31
Magnetite	1,5	1,6	341	128	6889	13
Chromite	0,0	0,0	0	0	0	0
Pyrite	0,0	0,0	0	0	0	0
Phosphate	1,6	1,6	422	153	10126	8
Monazite	0,0	0,0	0	0	0	0
Y-phosphate	0,0	0,0	0	0	0	0
Sphene	1,5	1,7	545	201	14047	2
Garnet	1,7	2,0	554	223	15483	154
Kya/Sill	1,6	2,3	1088	457	43974	4
Staurolite	0,0	0,0	0	0	0	0
Zircon	1,2	1,3	417	117	10706	1
Silicate	1,6	1,8	512	198	14963	645
Unclassified	1,3	1,4	219	84	3664	9

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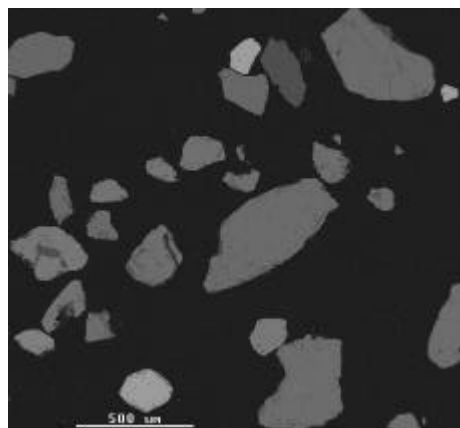


Lab. Name:	464701	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage:	17kV
Date:	16-01-02		





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Sample Name:	464702	No. of frames analysed:	74
Lab. Name:	464702	No. of particles analysed:	927
Date:	16-01-02	Heavy minerals in raw	
Submitter:	GEUS	sand (%):	19,96
Country:	Greenland	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/100x		
Guard region:	375µm		
Sieve:	100 µm ²		

Category	Average content									
	TiO ₂ wt%	Fe ₂ O ₃ wt%	MnO wt%	Cr ₂ O ₃ wt%	SiO ₂ wt%	Al ₂ O ₃ wt%	MgO wt%	CaO wt%	ZrO ₂ wt%	Total
Ilmenite	48,0	43,9	0,7	0,2	2,8	1,1	0,8	0,2	0,2	98,0
Leucoxene	76,9	13,0	0,0	1,0	2,7	2,5	0,0	0,0	0,3	96,4
Rutile	95,5	0,6	0,1	0,4	0,8	0,4	0,1	0,1	0,5	98,5
Ti magnetite	35,8	56,3	0,5	0,1	3,1	1,2	0,8	0,3	0,2	98,2
Magnetite	0,2	86,3	0,3	0,4	5,3	2,9	0,4	0,2	0,7	96,8
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	0,9	0,2	0,0	1,1	0,0	0,1	55,5	0,5	58,3
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	37,1	1,4	0,2	0,1	29,5	2,2	0,1	27,0	0,2	97,9
Garnet	0,1	26,9	0,6	0,1	39,3	20,2	8,3	2,2	0,3	98,1
Kya/Sill	0,2	0,7	0,2	0,1	43,0	53,3	0,0	0,1	0,3	98,1
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	0,8	18,6	0,4	0,1	47,8	9,4	9,9	8,7	0,3	96,1
Unclassified	3,2	18,2	1,1	0,5	32,4	9,8	3,6	7,0	4,4	80,3

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	1,4	0,2	2,0	9,1	86,5	0,0	0,9	0,0	100,0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	49,0	79,8	97,0	36,4
Fe ₂ O ₃ wt%	44,8	13,5	0,7	57,3
MnO wt%	0,7	0,0	0,1	0,5
Cr ₂ O ₃ wt%	0,2	1,0	0,4	0,1
SiO ₂ wt%	2,9	2,8	0,8	3,1
Al ₂ O ₃ wt%	1,2	2,6	0,4	1,2
MgO wt%	0,8	0,0	0,1	0,8
CaO wt%	0,2	0,0	0,1	0,3
ZrO ₂ wt%	0,2	0,3	0,6	0,2
Total	100,0	100,0	100,0	100,0

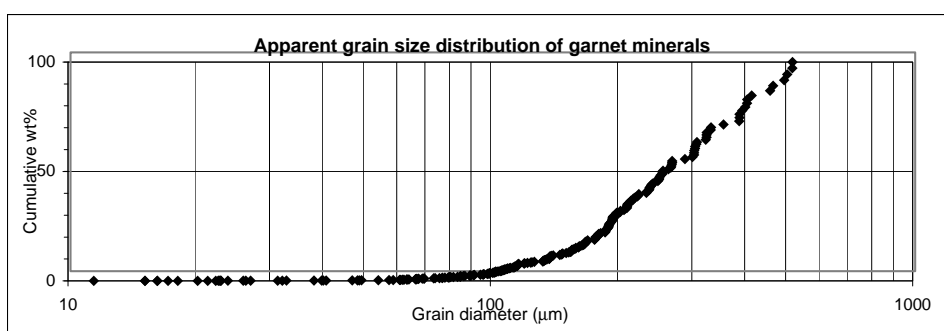
Weight percent on a mineral basis:		
Category	Heavy mineral concentrate	
	wt %	Raw sand wt %
Ilmenite	0,6	0,0
Leucoxene	0,1	0,0
Rutile	0,9	0,0
Ti magnetite	4,2	0,0
Magnetite	1,0	0,0
Chromite	0,0	0,0
Pyrite	0,0	0,0
Phosphate	0,1	0,0
Monazite	0,0	0,0
Y-phosphate	0,0	0,0
Sphene	0,3	0,0
Garnet	39,7	0,0
Kya/Sill	0,4	0,0
Staurolite	0,0	0,0
Zircon	0,0	0,0
Silicate	52,6	100,0
Unclassified	0,2	0,0
Total	100,0	100,0

Average TiO ₂ content of all the TiO ₂ minerals:	47,8
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	38,7
Valuable heavy minerals in raw sand:	0,00

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Lab. Name: 464702 Analyzed by: BV
 Submitter: GEUS Acc. Voltage: 17kV
 Date: 16-01-02

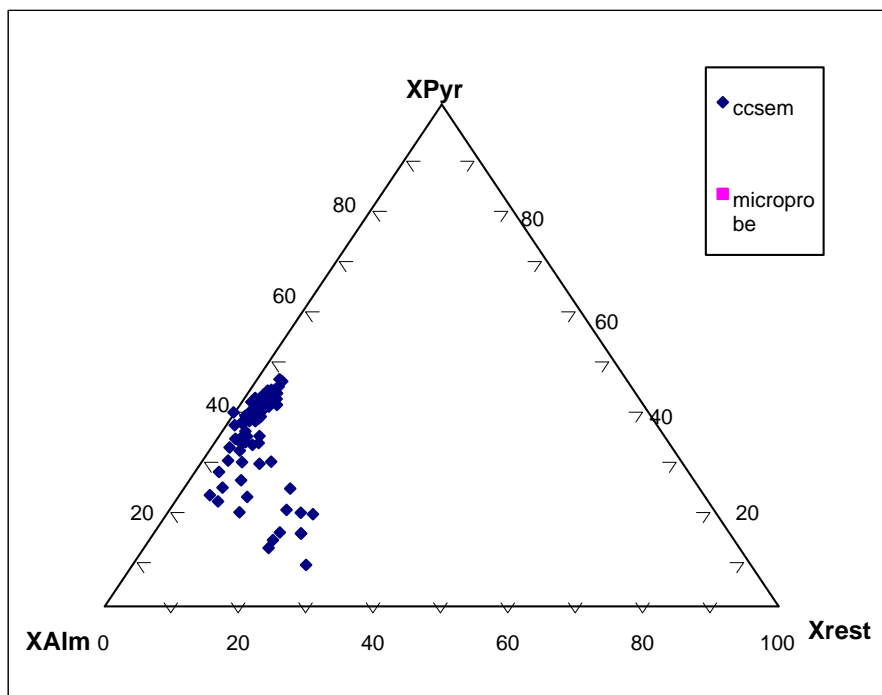


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	Total grains
Ilmenite	1,7	1,8	450	171	10922	10
Leucoxene	1,7	2,2	580	240	11946	1
Rutile	1,2	1,6	941	344	45553	3
Ti magnetite	1,5	1,9	614	241	20097	33
Magnetite	1,6	1,9	539	218	15909	9
Chromite	0,0	0,0	0	0	0	0
Pyrite	0,0	0,0	0	0	0	0
Phosphate	1,3	1,4	297	96	4985	2
Monazite	0,0	0,0	0	0	0	0
Y-phosphate	0,0	0,0	0	0	0	0
Sphene	1,4	1,6	421	148	9473	7
Garnet	1,7	1,9	724	289	28574	264
Kya/Sill	1,5	2,0	761	303	23174	4
Staurolite	0,0	0,0	0	0	0	0
Zircon	0,0	0,0	0	0	0	0
Silicate	1,6	1,8	684	267	26493	569
Unclassified	1,4	1,4	167	64	2496	25

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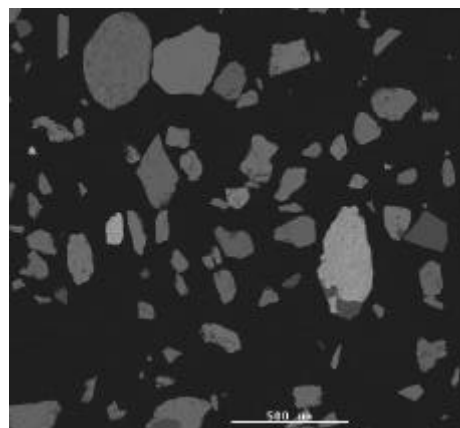


Lab. Name:	464702	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage:	17kV
Date:	16-01-02		





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Sample Name: 464703	No. of frames analysed: 60
Lab. Name: 464703	No. of particles analysed: 1484
Date: 16-01-02	Heavy minerals in raw sand (%)
Submitter: GEUS	12,67
Country: Greenland	Comments:
Analyzed by: BV	
Acc. Voltage/Magnification: 17kV/100x	
Guard region: 375µm	
Sieve: 100 µm ²	

Category	Average content									
	TiO ₂ wt%	Fe ₂ O ₃ wt%	MnO wt%	Cr ₂ O ₃ wt%	SiO ₂ wt%	Al ₂ O ₃ wt%	MgO wt%	CaO wt%	ZrO ₂ wt%	Total
Ilmenite	49,3	38,6	1,2	0,2	4,5	1,4	1,0	1,6	0,2	97,9
Leucoxene	83,7	2,2	0,3	0,9	6,4	1,9	0,0	0,0	0,4	95,7
Rutile	94,4	0,7	0,4	0,2	1,5	0,5	0,3	0,2	0,6	98,7
Ti magnetite	39,1	52,3	0,7	0,1	3,0	0,9	0,7	0,6	0,3	97,6
Magnetite	0,4	88,7	0,4	0,2	4,5	1,7	0,5	0,5	0,3	97,2
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	0,7	0,2	0,2	1,3	0,1	0,1	55,5	0,2	58,3
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	37,2	1,2	0,3	0,2	28,7	1,6	0,0	27,2	0,3	96,8
Garnet	0,2	27,8	0,8	0,1	38,8	19,6	7,2	3,0	0,3	97,8
Kya/Sill	0,1	0,6	0,3	0,4	43,0	53,8	0,1	0,1	0,4	98,7
Staurolite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Zircon	0,0	1,1	0,0	0,0	30,5	0,0	0,0	0,1	61,6	93,4
Silicate	0,9	17,6	0,4	0,2	47,8	9,6	9,8	9,3	0,3	95,9
Unclassified	2,2	17,7	1,3	0,9	23,3	9,2	3,9	17,2	2,0	77,8

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	5,8	0,0	3,1	7,6	82,5	0,2	0,8	0,0	100,0

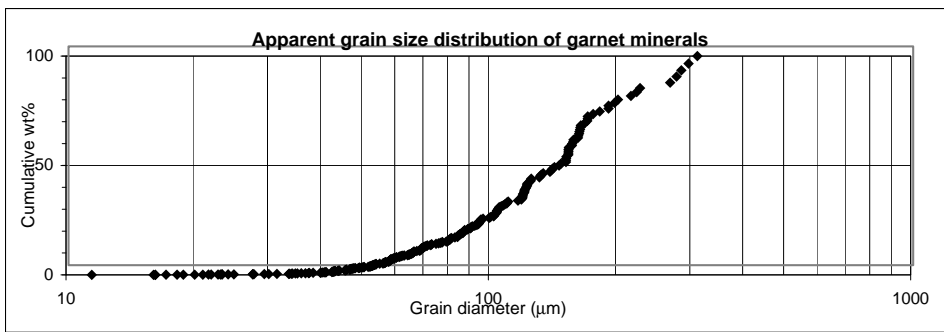
Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	50,4	87,5	95,6	40,1
Fe ₂ O ₃ wt%	39,4	2,3	0,7	53,5
MnO wt%	1,2	0,3	0,4	0,7
Cr ₂ O ₃ wt%	0,2	0,9	0,2	0,1
SiO ₂ wt%	4,5	6,7	1,5	3,0
Al ₂ O ₃ wt%	1,4	1,9	0,5	0,9
MgO wt%	1,0	0,0	0,3	0,7
CaO wt%	1,6	0,0	0,2	0,7
ZrO ₂ wt%	0,2	0,4	0,6	0,3
Total	100,0	100,0	100,0	100,0

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate	
	wt %	Raw sand
Ilmenite	1,7	0,0
Leucoxene	0,0	0,0
Rutile	0,9	0,0
Ti magnetite	2,3	0,0
Magnetite	3,2	0,0
Chromite	0,0	0,0
Pyrite	0,0	0,0
Phosphate	0,6	0,0
Monazite	0,0	0,0
Y-phosphate	0,0	0,0
Sphene	0,7	0,0
Garnet	24,7	0,0
Kya/Sill	0,2	0,0
Staurolite	0,0	0,0
Zircon	0,0	0,0
Silicate	63,8	100,0
Unclassified	1,7	0,0
Total	100,0	100,0

Average TiO ₂ content of all the TiO ₂ minerals:	54,3
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	44,6
Valuable heavy minerals in raw sand:	0,00



Lab. Name: 464703 Analyzed by: BV
 Submitter: GEUS Acc. Voltage: 17kV
 Date: 16-01-02

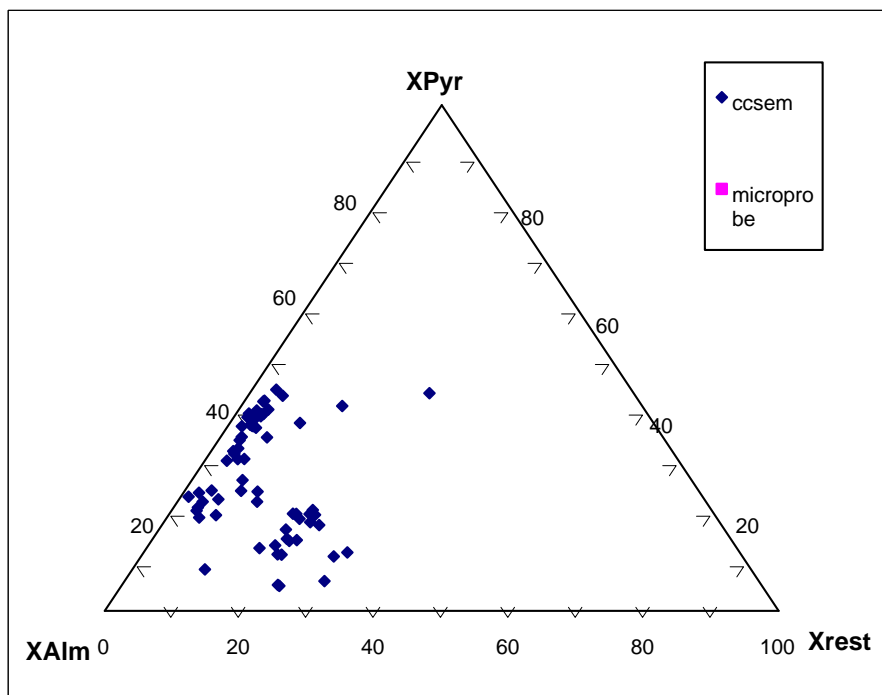


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	Total grains
Ilmenite	1,5	1,9	441	171	8776	16
Leucoxene	1,8	1,8	127	48	731	1
Rutile	2,0	1,9	431	164	9730	7
Ti magnetite	1,4	1,6	323	116	6155	28
Magnetite	1,4	1,6	311	119	6458	35
Chromite	0,0	0,0	0	0	0	0
Pyrite	0,0	0,0	0	0	0	0
Phosphate	1,6	1,6	261	97	3839	11
Monazite	0,0	0,0	0	0	0	0
Y-phosphate	0,0	0,0	0	0	0	0
Sphene	1,4	1,6	448	163	11034	7
Garnet	1,6	1,8	376	146	8025	280
Kya/Sill	1,5	1,6	332	121	5461	5
Staurolite	0,0	0,0	0	0	0	0
Zircon	1,1	1,5	260	88	3723	1
Silicate	1,6	1,7	371	142	8421	1041
Unclassified	1,4	1,5	228	89	4408	52

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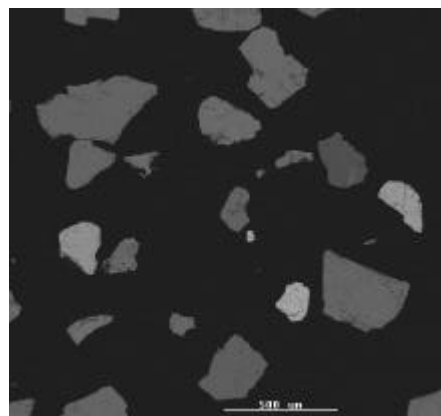


Lab. Name:	464703	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage:	17kV
Date:	16-01-02		





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Sample Name:	464704	No. of frames analysed:	94
Lab. Name:	464704	No. of particles analysed:	1001
Date:	1/16/02	Heavy minerals in raw sand (%):	82.10
Submitter:	GEUS	Comments:	
Country:	Greenland		
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/100x		
Guard region:	375μm		
Sieve:	100 μm ²		

Category	Average content									
	TiO ₂ wt%	Fe ₂ O ₃ wt%	MnO wt%	Cr ₂ O ₃ wt%	SiO ₂ wt%	Al ₂ O ₃ wt%	MgO wt%	CaO wt%	ZrO ₂ wt%	Total
Ilmenite	48.4	46.7	0.6	0.1	0.9	0.4	0.9	0.1	0.2	98.4
Leucoxene	83.6	4.1	0.0	0.2	1.4	0.0	0.0	0.6	0.1	90.1
Rutile	96.0	0.7	0.1	0.1	0.4	0.2	0.1	0.0	0.5	98.2
Ti magnetite	37.1	55.5	0.6	0.1	2.7	0.9	1.1	0.2	0.2	98.4
Magnetite	1.1	89.9	0.3	0.3	3.5	1.9	0.5	0.4	0.4	98.2
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	0.4	0.1	0.0	0.6	0.0	0.0	55.8	0.1	57.2
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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.1	27.4	0.6	0.1	39.2	20.2	8.5	2.0	0.2	98.3
Kya/Sill	0.1	0.5	0.1	0.3	42.7	53.7	0.1	0.1	0.0	97.6
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.1	0.8	0.0	0.1	29.9	0.0	0.1	0.2	63.2	94.6
Silicate	1.0	20.0	0.6	0.1	47.3	9.7	9.5	8.0	0.2	96.6
Unclassified	7.7	26.7	0.5	0.6	28.1	7.4	3.9	3.4	1.8	80.0

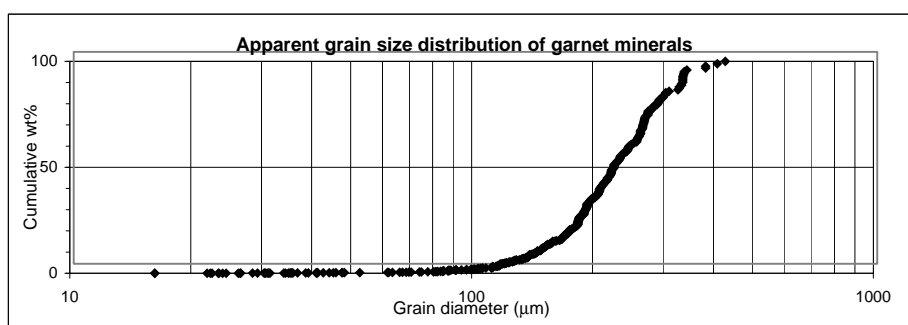
Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	7.1	0.0	3.0	11.5	76.7	1.1	0.6	0.0	100.0

Average content	Normalised average contents of the valuable Ti-containing minerals:			
	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	49.2	92.9	97.8	37.7
Fe ₂ O ₃ wt%	47.5	4.6	0.7	56.4
MnO wt%	0.6	0.0	0.1	0.6
Cr ₂ O ₃ wt%	0.1	0.2	0.1	0.1
SiO ₂ wt%	0.9	1.5	0.4	2.8
Al ₂ O ₃ wt%	0.4	0.0	0.2	0.9
MgO wt%	0.9	0.0	0.1	1.1
CaO wt%	0.1	0.6	0.0	0.2
ZrO ₂ wt%	0.2	0.1	0.5	0.2
Total	100.0	100.0	100.0	100.0

Category	Weight percent on a mineral basis:	
	Heavy mineral concentrate	Raw sand
	wt %	wt %
Ilmenite	5.0	4.1
Leucoxene	0.0	0.0
Rutile	2.1	1.7
Ti magnetite	8.0	6.6
Magnetite	5.3	4.3
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.6	0.5
Monazite	0.0	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	53.8	44.1
Kya/Sill	0.4	0.3
Staurolite	0.0	0.0
Zircon	0.8	0.6
Silicate	23.6	37.3
Unclassified	0.4	0.4
Total	100.0	100.0

Average TiO ₂ content of all the TiO ₂ minerals:	49.8
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	42.1
Valuable heavy minerals in raw sand:	57.53

Lab. Name: 464704 Analyzed by: BV
 Submitter: GEUS Acc. Voltage: 17kV
 Date: 1/16/02

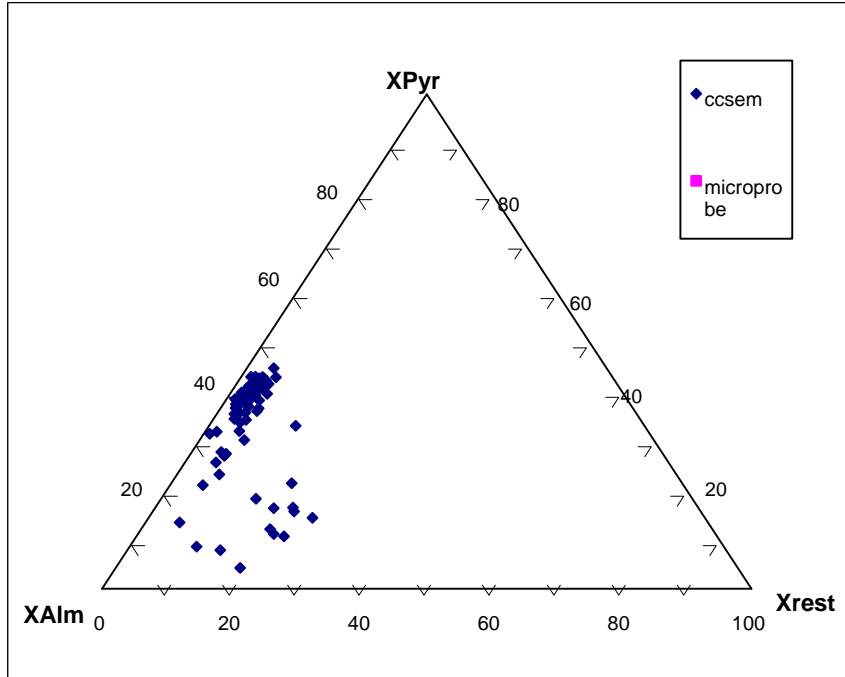


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	Total grains
Ilmenite	1.7	1.9	728	285	25200	40
Leucoxene	1.1	0.9	51	20	219	1
Rutile	1.5	1.9	704	277	23867	16
Ti magnetite	1.6	1.9	671	263	22328	69
Magnetite	1.6	1.9	585	228	18927	49
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	1.4	1.5	596	207	21895	5
Monazite	0.0	0.0	0	0	0	0
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.6	1.9	760	300	28222	436
Kya/Sill	1.3	1.7	788	291	29993	4
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.5	2.0	978	391	38467	4
Silicate	1.6	1.9	673	263	23179	352
Unclassified	1.5	1.2	172	64	6024	25

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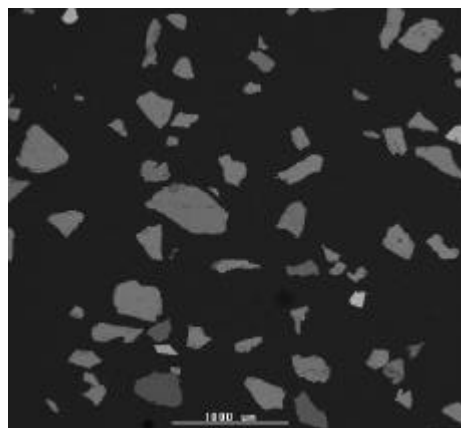


Lab. Name:	464704	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage:	17kV
Date:	1/16/02		





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Sample Name: 472701	No. of frames analysed: 43
Lab. Name: 472701	No. of particles analysed: 1498
Date: 16-01-02	Heavy minerals in raw sand (%)
Submitter: GEUS	5,65
Country: Greenland	Comments:
Analyzed by: BV	
Acc. Voltage/Magnification: 17kV/100x	
Guard region: 375µm	
Sieve: 100 µm ²	

Category	Average content									
	TiO ₂ wt%	Fe ₂ O ₃ wt%	MnO wt%	Cr ₂ O ₃ wt%	SiO ₂ wt%	Al ₂ O ₃ wt%	MgO wt%	CaO wt%	ZrO ₂ wt%	Total
Ilmenite	48,5	44,4	1,1	0,1	2,9	0,9	0,3	0,1	0,2	98,5
Leucoxene	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Rutile	88,4	2,3	0,2	0,1	3,5	0,0	0,0	0,0	0,0	94,5
Ti magnetite	33,4	49,5	0,4	0,2	10,1	2,5	0,8	0,1	0,5	97,4
Magnetite	2,4	86,0	0,3	0,3	4,2	3,3	1,0	0,4	0,3	98,3
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	0,0	56,7	1,1	58,8
Monazite	0,0	4,2	0,0	0,0	2,8	1,0	0,6	2,9	3,8	15,1
Y-phosphate	0,0	0,0	0,0	0,0	1,8	0,3	0,0	2,4	5,2	9,7
Sphene	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Garnet	0,1	33,2	1,2	0,1	37,5	19,7	5,2	1,0	0,2	98,2
Kya/Sill	0,2	2,2	0,0	0,2	42,7	53,1	0,0	0,0	0,0	98,3
Staurolite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Zircon	0,2	0,5	0,5	0,2	29,5	0,5	0,2	0,7	63,3	95,5
Silicate	1,5	17,9	0,4	0,2	47,4	15,2	7,6	3,4	0,3	93,9
Unclassified	1,5	17,6	1,1	2,1	17,4	8,3	3,7	1,3	6,2	59,1

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	1,1	0,0	0,0	2,2	96,1	0,5	0,1	0,0	100,0

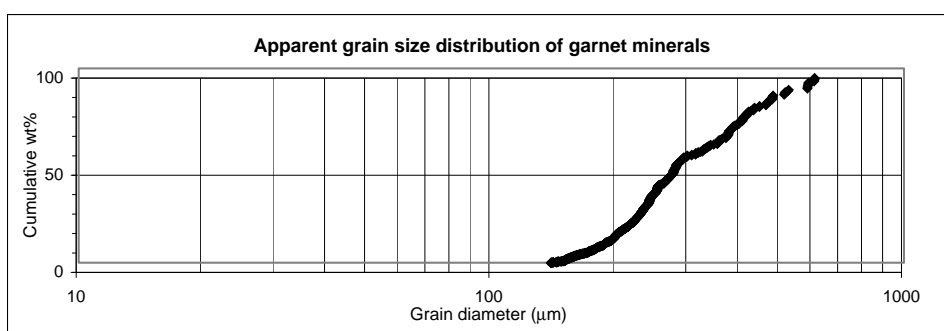
Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	49,2	0	93,5	34,3
Fe ₂ O ₃ wt%	45,1	0	2,4	50,8
MnO wt%	1,2	0	0,2	0,4
Cr ₂ O ₃ wt%	0,1	0	0,1	0,2
SiO ₂ wt%	3,0	0	3,7	10,3
Al ₂ O ₃ wt%	0,9	0	0,0	2,5
MgO wt%	0,3	0	0,0	0,8
CaO wt%	0,1	0	0,0	0,1
ZrO ₂ wt%	0,2	0	0,0	0,5
Total	100,0	0	100,0	100,0

Weight percent on a mineral basis:		
Category	Heavy mineral	
	concentrate	Raw sand
	wt %	wt %
Ilmenite	0,7	0,0
Leucoxene	0,0	0,0
Rutile	0,0	0,0
Ti magnetite	1,4	0,1
Magnetite	3,6	0,2
Chromite	0,0	0,0
Pyrite	0,0	0,0
Phosphate	0,3	0,0
Monazite	0,0	0,0
Y-phosphate	0,0	0,0
Sphene	0,0	0,0
Garnet	62,5	3,5
Kya/Sill	0,1	0,0
Staurolite	0,0	0,0
Zircon	0,3	0,0
Silicate	30,9	96,1
Unclassified	0,1	0,0
Total	100,0	100,0

Average TiO ₂ content of all the TiO ₂ minerals:	39,2
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	39,2
Valuable heavy minerals in raw sand:	3,67



Lab. Name: 472701 Analyzed by: BV
 Submitter: GEUS Acc. Voltage: 17kV
 Date: 16-01-02

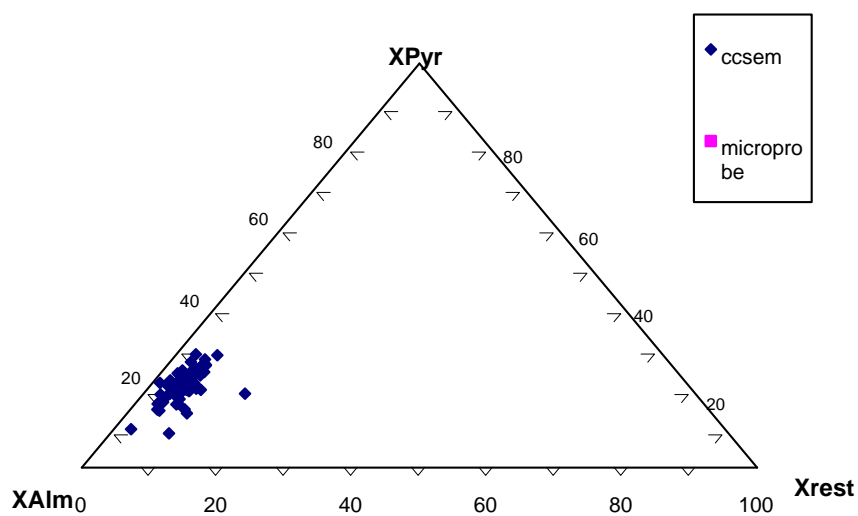


Category	Average grain parameters					Total grains
	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	
Ilmenite	1,8	1,8	828	318	36783	8
Leucoxene	0,0	0,0	0	0	0	0
Rutile	1,4	1,4	89	28	460	1
Ti magnetite	1,5	1,6	842	315	47978	15
Magnetite	1,7	1,9	967	379	45536	35
Chromite	0,0	0,0	0	0	0	0
Pyrite	0,0	0,0	0	0	0	0
Phosphate	1,2	1,4	850	276	40982	4
Monazite	1,4	1,2	298	94	7315	2
Y-phosphate	1,5	1,3	529	154	16987	1
Sphene	0,0	0,0	0	0	0	0
Garnet	1,6	1,8	906	352	42705	813
Kya/Sill	1,4	1,8	1140	437	58237	1
Staurolite	0,0	0,0	0	0	0	0
Zircon	1,4	1,8	971	372	42174	3
Silicate	2,0	2,0	1065	428	56627	447
Unclassified	1,4	1,2	135	51	1687	29

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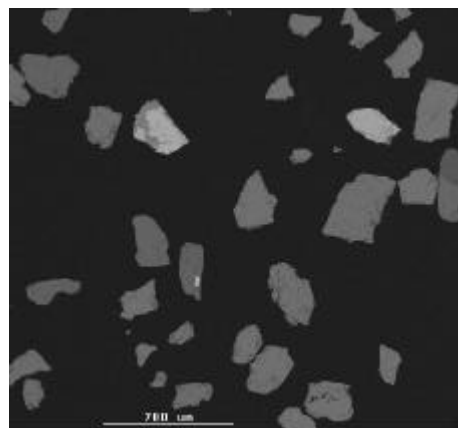


Lab. Name:	472701	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage:	17kV
Date:	16-01-02		





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Sample Name:	472702	No. of frames analysed:	80
Lab. Name:	472702	No. of particles analysed:	1089
Date:	16-01-02	Heavy minerals in raw sand (%)	8,60
Submitter:	GEUS	Country:	Greenland
Analyzed by:	BV	Comments:	
Acc. Voltage/Magnification:	17kV/100x		
Guard region:	375µm		
Sieve:	100 µm ²		

Category	Average content									
	TiO ₂ wt%	Fe ₂ O ₃ wt%	MnO wt%	Cr ₂ O ₃ wt%	SiO ₂ wt%	Al ₂ O ₃ wt%	MgO wt%	CaO wt%	ZrO ₂ wt%	Total
Ilmenite	47,9	47,6	1,5	0,0	0,5	0,3	0,4	0,1	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	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Ti magnetite	25,6	63,9	1,2	0,2	2,8	2,8	0,9	0,3	0,2	97,9
Magnetite	0,7	84,7	1,1	0,1	5,3	4,2	0,4	0,2	0,4	97,0
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	0,5	0,2	0,1	0,4	0,0	0,1	57,1	1,4	59,9
Monazite	0,0	2,3	0,0	0,0	7,7	4,4	0,5	2,7	2,6	20,3
Y-phosphate	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sphene	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Garnet	0,1	33,4	1,3	0,1	37,4	19,7	5,1	1,0	0,3	98,3
Kya/Sill	0,0	0,1	0,6	0,0	43,2	54,3	0,0	0,0	0,0	98,3
Staurolite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Zircon	0,0	1,2	1,0	0,0	28,4	0,0	0,0	0,5	59,8	90,7
Silicate	1,5	18,1	0,5	0,1	49,3	12,4	7,9	4,4	0,3	94,5
Unclassified	1,3	24,6	2,7	1,3	21,1	8,7	4,2	4,3	4,2	72,4

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	0,8	0,0	0,0	1,0	98,1	0,0	0,0	0,0	100,0

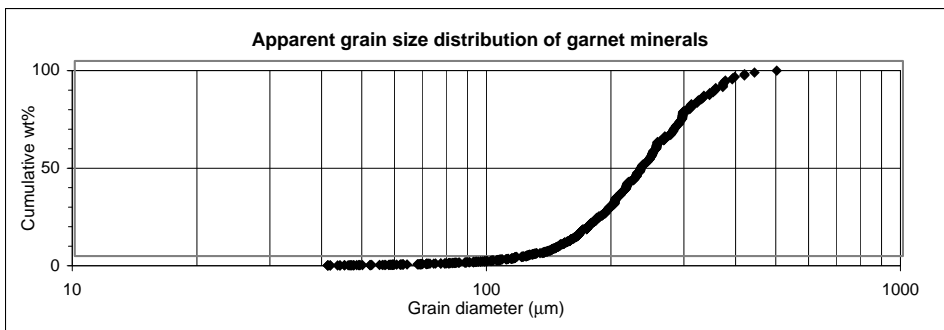
Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	48,6	0	0	26,2
Fe ₂ O ₃ wt%	48,3	0	0	65,2
MnO wt%	1,5	0	0	1,2
Cr ₂ O ₃ wt%	0,0	0	0	0,2
SiO ₂ wt%	0,5	0	0	2,9
Al ₂ O ₃ wt%	0,3	0	0	2,9
MgO wt%	0,4	0	0	1,0
CaO wt%	0,1	0	0	0,3
ZrO ₂ wt%	0,3	0	0	0,2
Total	100,0	0	0	100,0

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate	
	wt %	Raw sand wt %
Ilmenite	0,6	0,0
Leucoxene	0,0	0,0
Rutile	0,0	0,0
Ti magnetite	0,7	0,1
Magnetite	4,9	0,4
Chromite	0,0	0,0
Pyrite	0,0	0,0
Phosphate	0,5	0,0
Monazite	0,1	0,0
Y-phosphate	0,0	0,0
Sphene	0,0	0,0
Garnet	67,1	5,8
Kya/Sill	0,0	0,0
Staurolite	0,0	0,0
Zircon	0,0	0,0
Silicate	25,2	93,6
Unclassified	0,9	0,1
Total	100,0	100,0

Average TiO ₂ content of all the TiO ₂ minerals:	36,2
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	36,2
Valuable heavy minerals in raw sand:	5,89



Lab. Name: 472702 Analyzed by: BV
 Submitter: GEUS Acc. Voltage: 17kV
 Date: 16-01-02

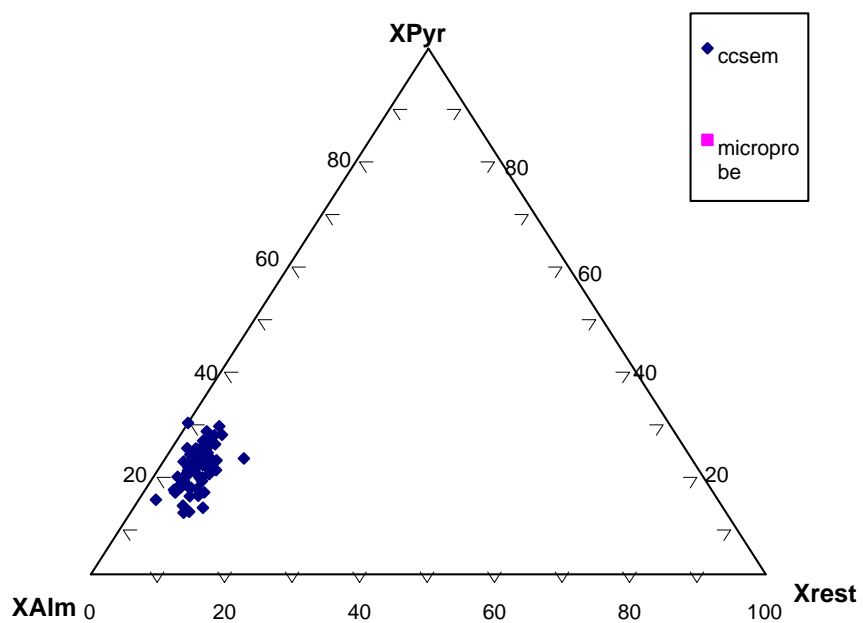


Category	Average grain parameters					Total grains
	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	
Ilmenite	1,3	1,5	616	213	21212	7
Leucoxene	0,0	0,0	0	0	0	0
Rutile	0,0	0,0	0	0	0	0
Ti magnetite	2,0	2,3	744	307	21674	8
Magnetite	1,6	2,2	748	305	24701	45
Chromite	0,0	0,0	0	0	0	0
Pyrite	0,0	0,0	0	0	0	0
Phosphate	1,3	1,7	683	258	29929	4
Monazite	1,0	1,6	382	140	7166	2
Y-phosphate	0,0	0,0	0	0	0	0
Sphene	0,0	0,0	0	0	0	0
Garnet	1,6	2,0	761	304	28355	696
Kya/Sill	1,1	1,4	456	150	11722	1
Staurolite	0,0	0,0	0	0	0	0
Zircon	1,3	1,4	139	45	1102	1
Silicate	1,9	2,3	920	378	38429	291
Unclassified	1,5	1,4	322	125	11362	34

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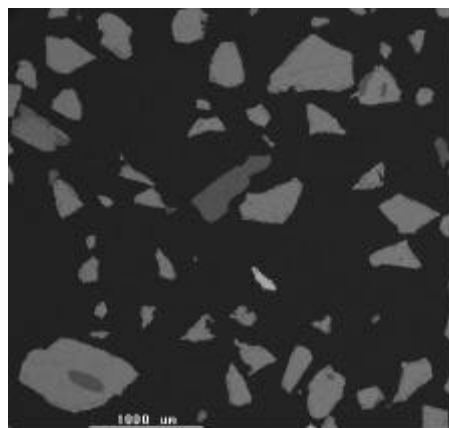


Lab. Name:	472702	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage:	17kV
Date:	16-01-02		





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Sample Name:	472704	No. of frames analysed:	48
Lab. Name:	472704	No. of particles analysed:	1483
Date:	1/16/02	Heavy minerals in raw sand (%):	34.69
Submitter:	GEUS	Country:	Greenland
Country:	Greenland	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/100x		
Guard region:	375µm		
Sieve:	100 µm ²		

Category	Average content									
	TiO ₂ wt%	Fe ₂ O ₃ wt%	MnO wt%	Cr ₂ O ₃ wt%	SiO ₂ wt%	Al ₂ O ₃ wt%	MgO wt%	CaO wt%	ZrO ₂ wt%	Total
Ilmenite	48.5	45.3	0.7	0.1	0.7	0.1	0.2	0.2	0.6	96.4
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	39.0	44.8	1.6	0.3	5.0	3.0	1.2	0.3	0.5	95.7
Magnetite	1.4	93.7	0.3	0.2	0.8	0.7	0.2	0.1	0.3	97.8
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	0.3	0.4	0.1	0.1	1.2	0.0	0.1	55.1	1.0	58.3
Monazite	0.0	0.7	0.0	0.0	2.1	0.5	0.1	1.6	2.1	7.1
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.1	33.3	1.2	0.1	37.5	19.7	5.1	1.0	0.3	98.2
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	20.8	0.6	0.1	48.7	13.1	7.4	3.3	0.3	95.4
Unclassified	1.3	27.4	1.2	1.1	23.8	13.5	5.3	2.4	3.3	79.3

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	0.4	0.0	0.0	0.7	98.9	0.0	0.0	0.0	100.0

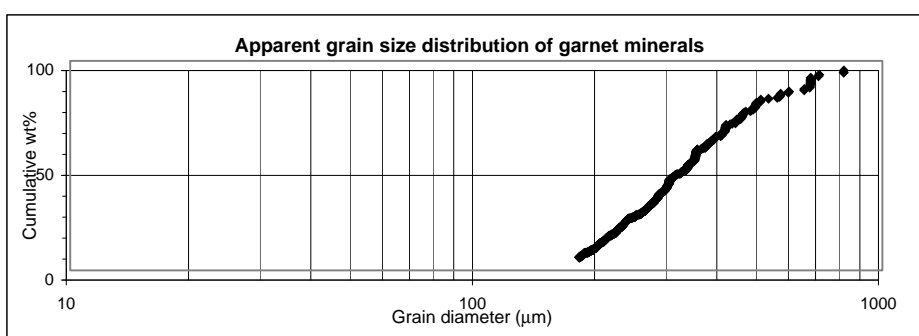
Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	50.3	0	0	40.7
Fe ₂ O ₃ wt%	47.0	0	0	46.8
MnO wt%	0.7	0	0	1.7
Cr ₂ O ₃ wt%	0.1	0	0	0.3
SiO ₂ wt%	0.7	0	0	5.2
Al ₂ O ₃ wt%	0.2	0	0	3.1
MgO wt%	0.2	0	0	1.2
CaO wt%	0.2	0	0	0.4
ZrO ₂ wt%	0.6	0	0	0.5
Total	100.0	0	0	100.0

Weight percent on a mineral basis:		
Category	Heavy mineral	
	concentrate wt %	Raw sand wt %
Ilmenite	0.3	0.1
Leucoxene	0.0	0.0
Rutile	0.0	0.0
Ti magnetite	0.6	0.2
Magnetite	5.6	1.9
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.2	0.1
Monazite	0.1	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	84.4	29.3
Kya/Sill	0.0	0.0
Staurolite	0.0	0.0
Zircon	0.0	0.0
Silicate	8.7	68.3
Unclassified	0.2	0.1
Total	100.0	100.0

Average TiO ₂ content of all the TiO ₂ minerals:	44.0
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	44.0
Valuable heavy minerals in raw sand:	29.57



Lab. Name: 472704 Analyzed by: BV
 Submitter: GEUS Acc. Voltage: 17kV
 Date: 1/16/02

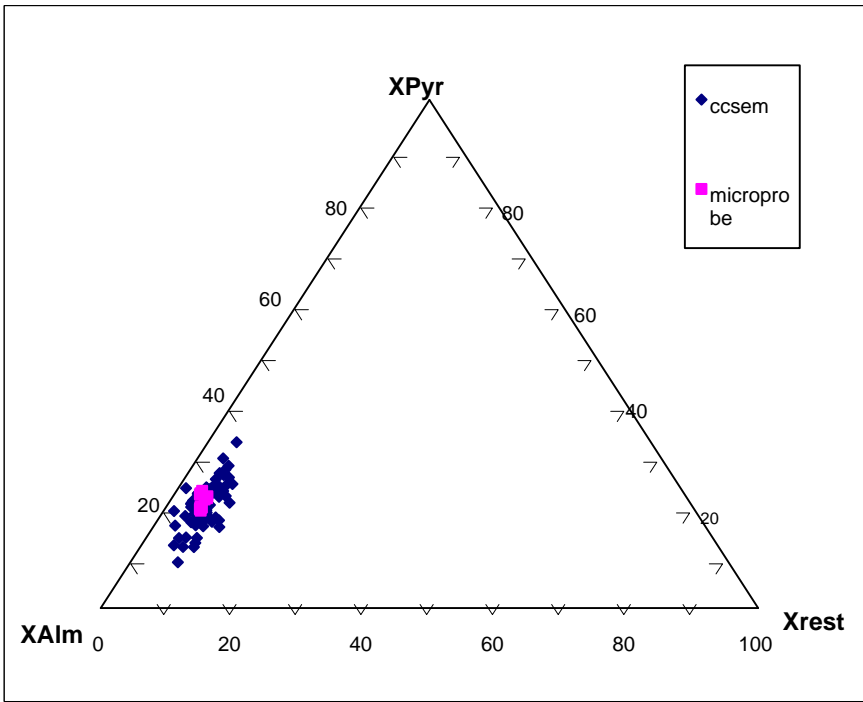


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm ²)	Total grains
Ilmenite	1.6	1.4	517	184	17740	10
Leucoxene	0.0	0.0	0	0	0	0
Rutile	0.0	0.0	0	0	0	0
Ti magnetite	1.7	1.9	725	291	26427	12
Magnetite	1.6	1.6	667	245	26568	104
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	1.3	1.4	476	160	12911	6
Monazite	1.3	1.5	451	155	10963	3
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.6	1.8	943	368	48256	1123
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	1.9	1.9	943	373	45300	187
Unclassified	1.3	1.2	216	79	5183	38

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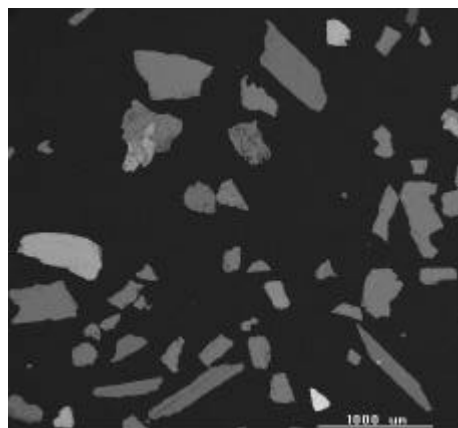


Lab. Name:	472704	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	1/16/02		





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Sample Name:	472705	No. of frames analysed:	33
Lab. Name:	472705	No. of particles analysed:	876
Date:	16-01-02	Heavy minerals in raw sand (%)	19,49
Submitter:	GEUS	Country:	Greenland
Analyzed by:	BV	Comments:	
Acc. Voltage/Magnification:	17kV/100x		
Guard region:	375µm		
Sieve:	100 µm ²		

Category	Average content									
	TiO ₂ wt%	Fe ₂ O ₃ wt%	MnO wt%	Cr ₂ O ₃ wt%	SiO ₂ wt%	Al ₂ O ₃ wt%	MgO wt%	CaO wt%	ZrO ₂ wt%	Total
Ilmenite	57,4	37,7	0,5	0,0	0,7	0,4	0,1	0,2	0,2	97,1
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	28,5	56,2	1,4	0,2	5,8	4,1	1,1	0,1	0,5	97,9
Magnetite	1,5	90,3	0,2	0,2	2,5	2,0	0,6	0,1	0,3	97,7
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	0,5	0,1	0,0	0,4	0,0	0,1	55,8	1,5	58,5
Monazite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Y-phosphate	0,5	1,6	0,2	0,0	0,0	1,8	0,0	0,0	1,5	5,6
Sphene	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Garnet	0,1	33,1	1,2	0,1	37,4	19,7	5,2	1,0	0,3	98,1
Kya/Sill	0,0	0,9	0,0	0,5	42,6	53,0	0,0	0,0	0,5	97,5
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	1,7	20,1	0,4	0,1	44,8	14,2	7,7	4,3	0,3	93,7
Unclassified	0,3	33,6	1,4	0,5	27,9	10,7	5,5	1,4	3,1	84,4

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	0,2	0,0	0,0	0,6	99,0	0,0	0,2	0,0	100,0

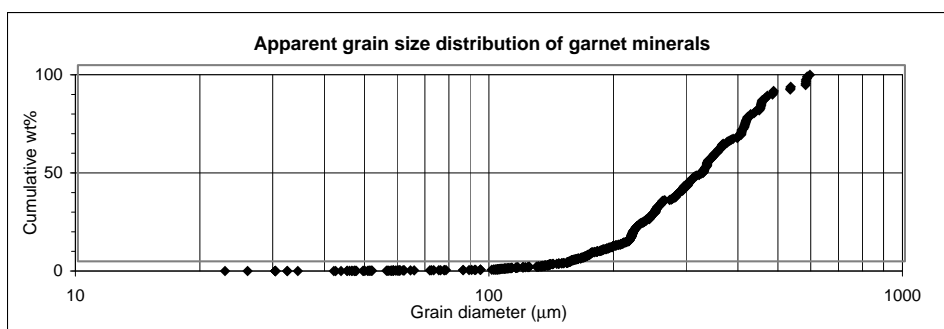
Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	59,1	0	0	29,1
Fe ₂ O ₃ wt%	38,8	0	0	57,4
MnO wt%	0,5	0	0	1,4
Cr ₂ O ₃ wt%	0,0	0	0	0,2
SiO ₂ wt%	0,7	0	0	6,0
Al ₂ O ₃ wt%	0,4	0	0	4,1
MgO wt%	0,1	0	0	1,1
CaO wt%	0,2	0	0	0,1
ZrO ₂ wt%	0,2	0	0	0,5
Total	100,0	0	0	100,0

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate	
	wt %	Raw sand wt %
Ilmenite	0,1	0,0
Leucoxene	0,0	0,0
Rutile	0,0	0,0
Ti magnetite	0,5	0,1
Magnetite	3,7	0,7
Chromite	0,0	0,0
Pyrite	0,0	0,0
Phosphate	0,2	0,0
Monazite	0,0	0,0
Y-phosphate	0,1	0,0
Sphene	0,0	0,0
Garnet	74,8	14,6
Kya/Sill	0,1	0,0
Staurolite	0,0	0,0
Zircon	0,0	0,0
Silicate	20,0	84,4
Unclassified	0,5	0,1
Total	100,0	100,0

Average TiO ₂ content of all the TiO ₂ minerals:	36,0
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	36,0
Valuable heavy minerals in raw sand:	14,72



Lab. Name: 472705 Analyzed by: BV
 Submitter: GEUS Acc. Voltage: 17kV
 Date: 16-01-02

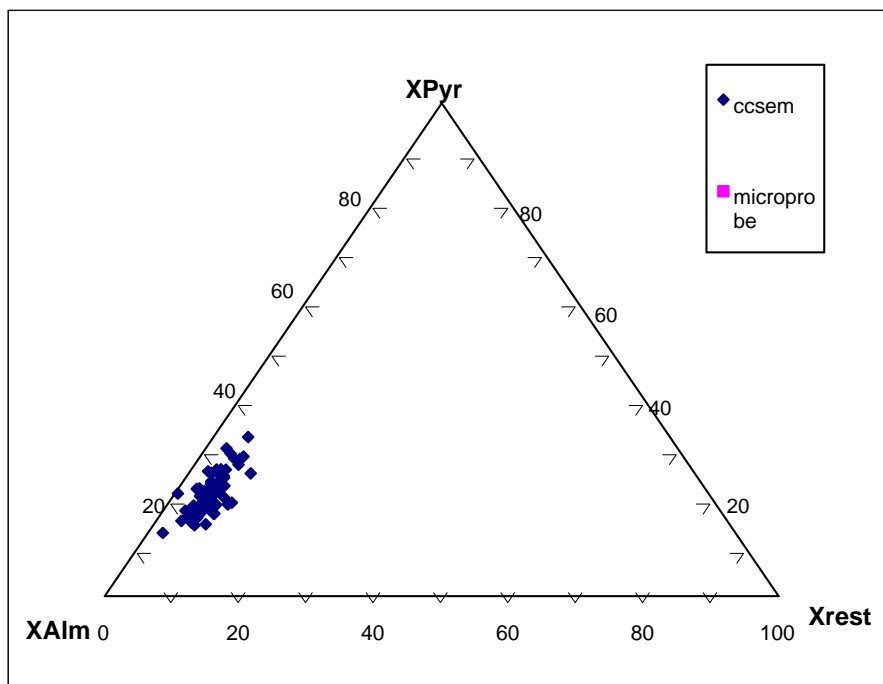


Category	Average grain parameters					Total grains
	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	
Ilmenite	1,4	1,9	794	310	26958	2
Leucoxene	0,0	0,0	0	0	0	0
Rutile	0,0	0,0	0	0	0	0
Ti magnetite	1,5	1,9	889	348	33962	5
Magnetite	1,5	1,7	742	277	32221	37
Chromite	0,0	0,0	0	0	0	0
Pyrite	0,0	0,0	0	0	0	0
Phosphate	1,3	1,8	628	245	17009	4
Monazite	0,0	0,0	0	0	0	0
Y-phosphate	1,5	1,7	746	279	26163	1
Sphene	0,0	0,0	0	0	0	0
Garnet	1,7	2,0	1011	401	50412	617
Kya/Sill	1,2	1,8	1172	447	62127	1
Staurolite	0,0	0,0	0	0	0	0
Zircon	0,0	0,0	0	0	0	0
Silicate	1,8	2,0	1138	459	68087	184
Unclassified	1,4	1,5	422	172	12271	25

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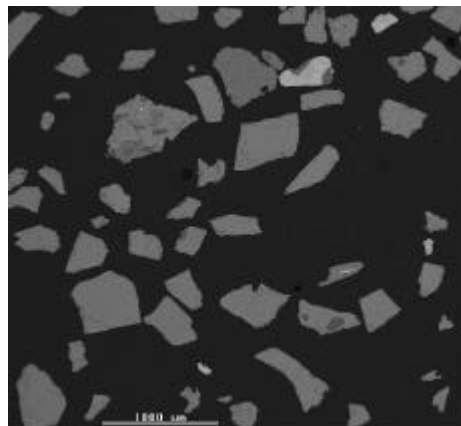


Lab. Name:	472705	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage:	17kV
Date:	16-01-02		





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Sample Name:	472706	No. of frames analysed:	56
Lab. Name:	472706	No. of particles analysed:	1465
Date:	16-01-02	Heavy minerals in raw	
Submitter:	GEUS	sand (%):	29,07
Country:	Greenland	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/100x		
Guard region:	375μm		
Sieve:	100 μm ²		

Category	Average content									
	TiO ₂ wt%	Fe ₂ O ₃ wt%	MnO wt%	Cr ₂ O ₃ wt%	SiO ₂ wt%	Al ₂ O ₃ wt%	MgO wt%	CaO wt%	ZrO ₂ wt%	Total
Ilmenite	50,6	31,5	1,6	0,1	12,8	1,0	0,7	0,1	0,2	98,4
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	32,3	61,3	1,6	0,2	0,9	1,7	0,6	0,1	0,2	98,8
Magnetite	1,9	90,3	0,1	0,1	3,8	1,3	0,3	0,1	0,2	98,2
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	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	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Garnet	0,1	33,4	1,3	0,1	37,4	19,6	5,1	1,0	0,3	98,2
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	20,7	0,6	0,1	46,5	13,5	7,4	5,4	0,3	95,6
Unclassified	1,7	21,9	1,3	1,7	20,9	11,3	3,8	1,8	4,9	69,3

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	1,8	0,0	0,0	0,8	97,4	0,0	0,0	0,0	100,0

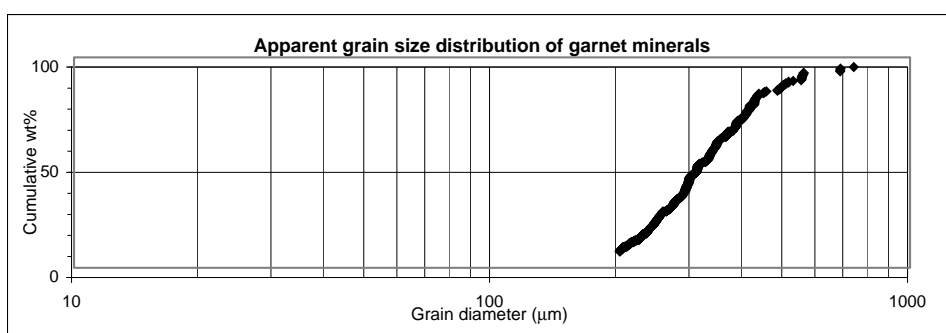
Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	51,4	0	0	32,6
Fe ₂ O ₃ wt%	32,0	0	0	62,0
MnO wt%	1,6	0	0	1,7
Cr ₂ O ₃ wt%	0,1	0	0	0,2
SiO ₂ wt%	13,0	0	0	0,9
Al ₂ O ₃ wt%	1,0	0	0	1,7
MgO wt%	0,7	0	0	0,6
CaO wt%	0,1	0	0	0,1
ZrO ₂ wt%	0,2	0	0	0,2
Total	100,0	0	0	100,0

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate	
	wt %	Raw sand
Ilmenite	1,5	0,4
Leucoxene	0,0	0,0
Rutile	0,0	0,0
Ti magnetite	0,6	0,2
Magnetite	2,1	0,6
Chromite	0,0	0,0
Pyrite	0,0	0,0
Phosphate	0,0	0,0
Monazite	0,0	0,0
Y-phosphate	0,0	0,0
Sphene	0,0	0,0
Garnet	78,7	22,9
Kya/Sill	0,0	0,0
Staurolite	0,0	0,0
Zircon	0,0	0,0
Silicate	16,7	75,8
Unclassified	0,4	0,1
Total	100,0	100,0

Average TiO ₂ content of all the TiO ₂ minerals:	45,7
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	45,7
Valuable heavy minerals in raw sand:	23,50



Lab. Name: 472706 Analyzed by: BV
 Submitter: GEUS Acc. Voltage: 17kV
 Date: 16-01-02

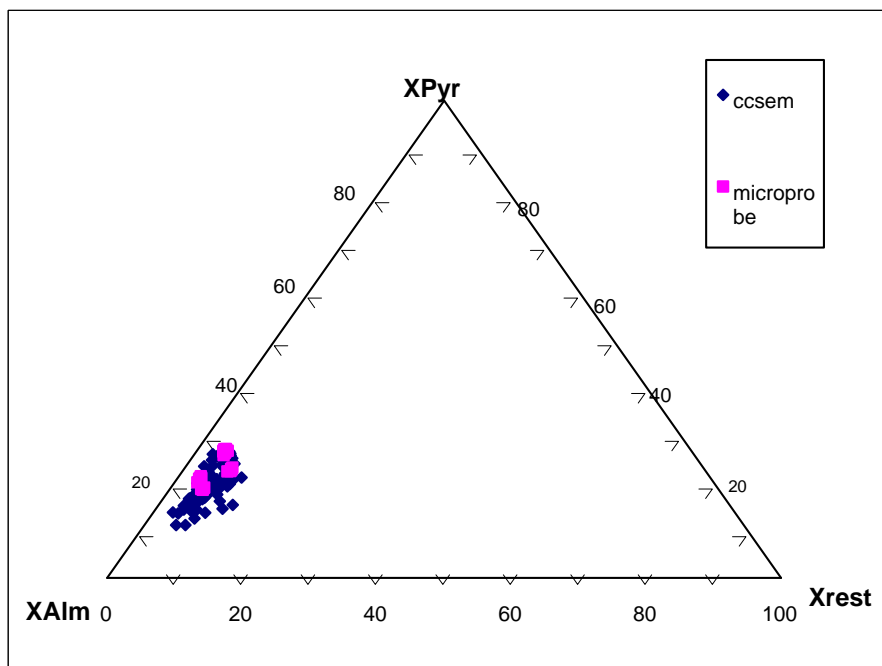


Category	Average grain parameters					Total grains
	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	
Ilmenite	1,9	1,9	1216	475	72679	13
Leucoxene	0,0	0,0	0	0	0	0
Rutile	0,0	0,0	0	0	0	0
Ti magnetite	1,6	1,8	920	348	43003	9
Magnetite	1,5	1,7	917	341	43559	27
Chromite	0,0	0,0	0	0	0	0
Pyrite	0,0	0,0	0	0	0	0
Phosphate	0,0	0,0	0	0	0	0
Monazite	0,0	0,0	0	0	0	0
Y-phosphate	0,0	0,0	0	0	0	0
Sphene	0,0	0,0	0	0	0	0
Garnet	1,6	1,9	1013	393	52262	1088
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	1,8	1,9	1081	430	60366	301
Unclassified	1,4	1,2	291	112	14894	27

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Lab. Name:	472706	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage:	17kV
Date:	16-01-02		

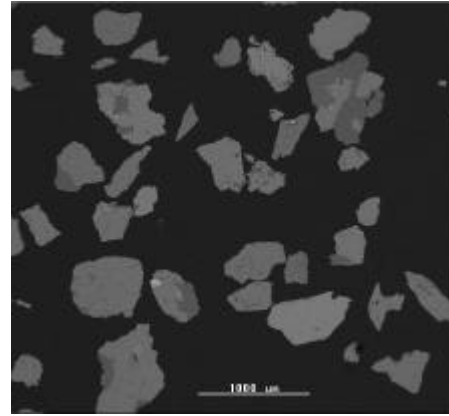




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GEUS

Sample Name:	472707	No. of frames analysed:	66
Lab. Name:	472707	No. of particles analysed:	1278
Date:	1/16/02	Heavy minerals in raw sand (%):	11.60
Submitter:	GEUS	Comments:	
Country:	Greenland		
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/100x		
Guard region:	375µm		
Sieve:	100 µm ²		



Category	Average content									
	TiO ₂ wt%	Fe ₂ O ₃ wt%	MnO wt%	Cr ₂ O ₃ wt%	SiO ₂ wt%	Al ₂ O ₃ wt%	MgO wt%	CaO wt%	ZrO ₂ wt%	Total
Ilmenite	61.2	18.2	0.4	0.3	10.1	2.5	0.4	1.5	0.6	95.3
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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Magnetite	0.4	75.5	0.5	0.1	9.3	4.2	1.2	1.3	0.3	92.7
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	0.4	0.2	0.1	0.3	0.0	0.1	57.3	1.8	60.3
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	38.0	1.0	0.2	0.1	29.3	1.6	0.2	27.5	0.2	98.0
Garnet	0.1	30.0	2.6	0.1	38.2	18.6	3.2	4.5	0.3	97.7
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	1.2	16.9	0.4	0.2	45.4	11.3	8.7	10.6	0.3	94.9
Unclassified	2.5	28.1	2.4	0.9	30.7	9.5	5.3	4.3	2.8	86.5

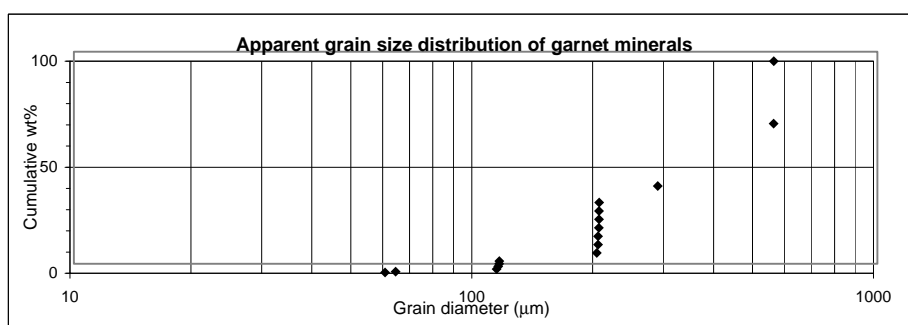
Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	3.7	0.0	0.0	0.0	96.3	0.0	0.0	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	64.2	0	0	0
Fe ₂ O ₃ wt%	19.1	0	0	0
MnO wt%	0.4	0	0	0
Cr ₂ O ₃ wt%	0.4	0	0	0
SiO ₂ wt%	10.6	0	0	0
Al ₂ O ₃ wt%	2.6	0	0	0
MgO wt%	0.5	0	0	0
CaO wt%	1.5	0	0	0
ZrO ₂ wt%	0.6	0	0	0
Total	100.0	0	0	0

Weight percent on a mineral basis:		
Category	Heavy mineral	
	concentrate	Raw sand
	wt %	wt %
Ilmenite	0.0	0.0
Leucoxene	0.0	0.0
Rutile	0.0	0.0
Ti magnetite	0.0	0.0
Magnetite	0.4	0.1
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.5	0.1
Monazite	0.0	0.0
Y-phosphate	0.0	0.0
Sphene	1.2	0.1
Garnet	1.3	0.1
Kya/Sill	0.0	0.0
Staurolite	0.0	0.0
Zircon	0.0	0.0
Silicate	96.0	99.5
Unclassified	0.6	0.1
Total	100.0	100.0

Average TiO ₂ content of all the TiO ₂ minerals:	64.2
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	64.2
Valuable heavy minerals in raw sand:	0.15

Lab. Name:	472707	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	1/16/02		

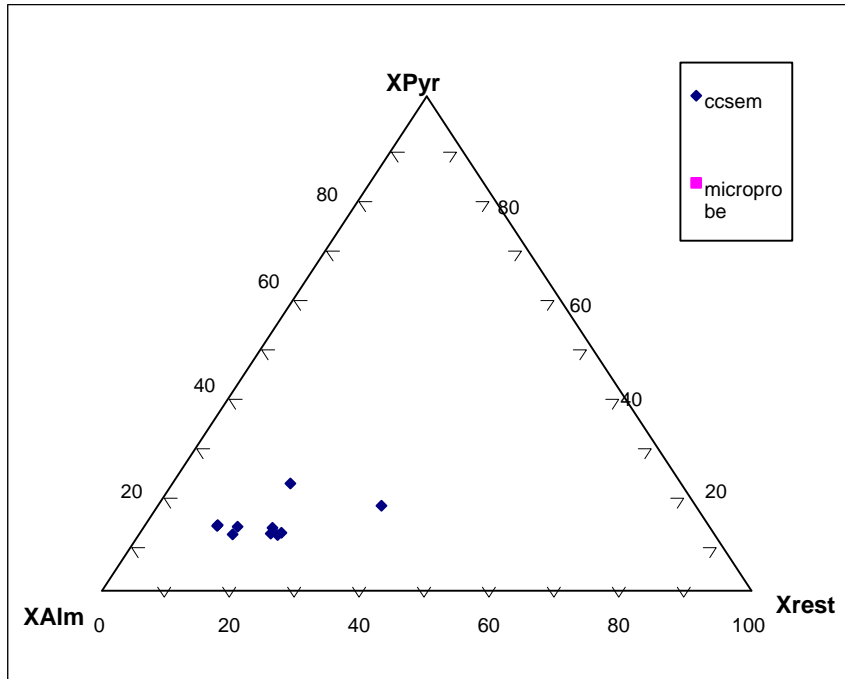


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	Total grains
Ilmenite	1.3	1.4	356	115	7335	4
Leucoxene	0.0	0.0	0	0	0	0
Rutile	0.0	0.0	0	0	0	0
Ti magnetite	0.0	0.0	0	0	0	0
Magnetite	1.5	1.4	409	155	16185	14
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	1.4	2.2	1334	547	65383	4
Monazite	0.0	0.0	0	0	0	0
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	1.6	2.0	1168	460	56277	17
Garnet	1.3	1.5	848	302	53162	16
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	1.7	1.9	1244	495	82513	1180
Unclassified	1.5	1.3	321	126	12761	43

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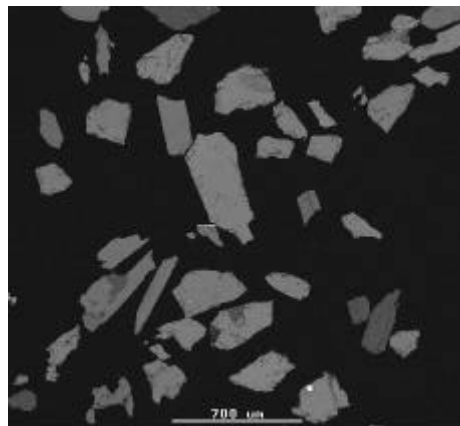


Lab. Name:	472707	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage:	17kV
Date:	1/16/02		





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Sample Name:	472708	No. of frames analysed:	83
Lab. Name:	472708	No. of particles analysed:	1484
Date:	16-01-02	Heavy minerals in raw	
Submitter:	GEUS	sand (%):	53,57
Country:	Greenland	Comments: Umivik	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/100x		
Guard region:	375μm		
Sieve:	100 μm ²		

Category	Average content									
	TiO ₂ wt%	Fe ₂ O ₃ wt%	MnO wt%	Cr ₂ O ₃ wt%	SiO ₂ wt%	Al ₂ O ₃ wt%	MgO wt%	CaO wt%	ZrO ₂ wt%	Total
Ilmenite	51,9	43,2	0,3	0,1	1,3	0,9	0,5	0,1	0,1	98,4
Leucoxene	71,8	9,7	0,0	0,1	8,5	5,9	0,5	0,6	0,0	97,0
Rutile	94,6	0,4	0,0	0,1	1,8	0,8	0,1	0,0	0,4	98,2
Ti magnetite	33,2	45,5	1,1	0,2	9,7	4,3	1,3	0,7	0,3	96,3
Magnetite	0,3	72,3	0,6	0,2	14,1	5,5	1,4	0,1	0,4	94,9
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	0,4	0,6	0,0	0,0	0,4	0,0	0,0	55,7	1,2	58,4
Monazite	0,0	4,8	0,0	0,0	4,3	3,3	0,8	1,8	5,2	20,2
Y-phosphate	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sphene	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Garnet	0,1	31,5	0,7	0,1	37,9	20,0	6,5	1,1	0,2	98,2
Kya/Sill	0,1	1,0	0,1	0,2	42,8	53,7	0,0	0,1	0,2	98,1
Staurolite	0,0	14,4	0,4	0,0	35,7	45,5	0,1	0,2	0,8	97,1
Zircon	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Silicate	1,7	16,2	0,3	0,1	43,6	22,9	7,2	2,2	0,3	94,6
Unclassified	1,8	25,4	1,1	1,3	26,2	13,3	3,5	2,4	4,4	79,4

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	0,7	0,3	0,9	0,4	96,1	0,0	1,3	0,3	100,0

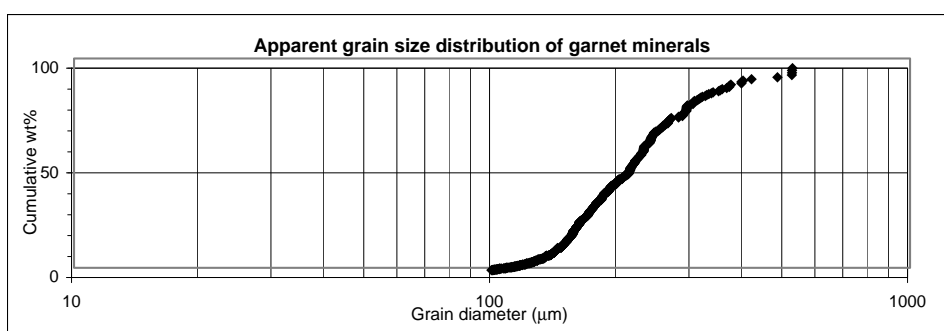
Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	52,8	74,0	96,3	34,5
Fe ₂ O ₃ wt%	43,9	10,0	0,4	47,3
MnO wt%	0,3	0,0	0,0	1,1
Cr ₂ O ₃ wt%	0,1	0,1	0,1	0,2
SiO ₂ wt%	1,3	8,8	1,8	10,1
Al ₂ O ₃ wt%	0,9	6,1	0,8	4,4
MgO wt%	0,5	0,5	0,1	1,3
CaO wt%	0,1	0,6	0,0	0,8
ZrO ₂ wt%	0,1	0,0	0,4	0,3
Total	100,0	100,0	100,0	100,0

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate	
	wt %	Raw sand wt %
Ilmenite	0,5	0,0
Leucoxene	0,2	0,0
Rutile	0,6	0,0
Ti magnetite	0,3	0,0
Magnetite	1,2	10,1
Chromite	0,0	0,0
Pyrite	0,0	0,0
Phosphate	0,1	0,0
Monazite	0,1	0,0
Y-phosphate	0,0	0,0
Sphene	0,0	0,0
Garnet	64,5	0,0
Kya/Sill	0,9	0,0
Staurolite	0,2	0,0
Zircon	0,0	0,0
Silicate	31,1	100,0
Unclassified	0,4	0,0
Total	100,0	100,0

Average TiO ₂ content of all the TiO ₂ minerals:	69,9
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	52,6
Valuable heavy minerals in raw sand:	0,00



Lab. Name: 472708 Analyzed by: BV
 Submitter: GEUS Acc. Voltage: 17kV
 Date: 16-01-02

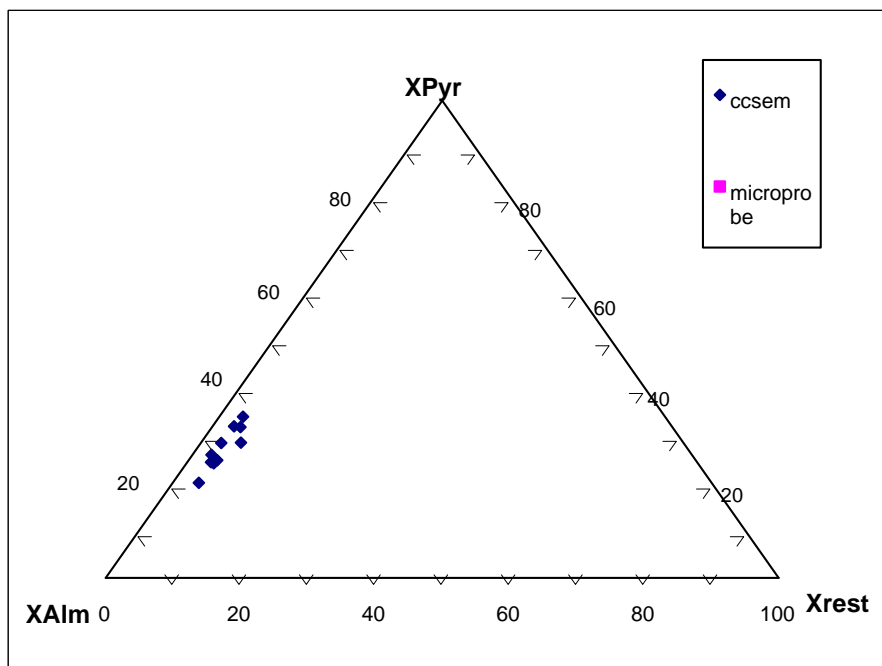


Category	Average grain parameters					Total grains
	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	
Ilmenite	1,3	1,8	741	286	25133	5
Leucoxene	1,4	2,5	908	397	30231	2
Rutile	2,0	2,1	817	332	30603	5
Ti magnetite	1,5	1,8	562	217	17054	4
Magnetite	1,6	1,9	531	220	15348	19
Chromite	0,0	0,0	0	0	0	0
Pyrite	0,0	0,0	0	0	0	0
Phosphate	1,4	1,4	271	93	6355	3
Monazite	1,8	1,7	560	207	15040	1
Y-phosphate	0,0	0,0	0	0	0	0
Sphene	0,0	0,0	0	0	0	0
Garnet	1,7	2,0	702	283	23467	862
Kya/Sill	1,7	1,9	844	332	33509	10
Staurolite	1,4	3,5	1102	478	37554	2
Zircon	0,0	0,0	0	0	0	0
Silicate	2,0	2,2	796	332	28168	522
Unclassified	1,5	1,3	179	72	4235	49

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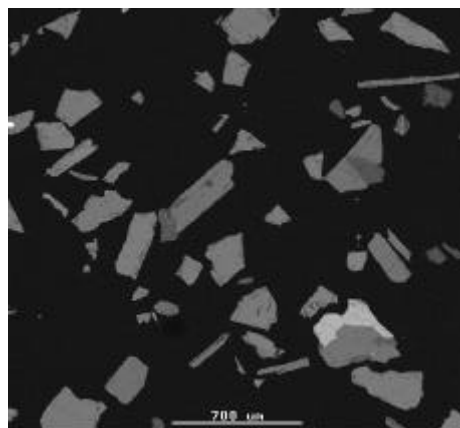


Lab. Name:	472708	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage:	17kV
Date:	16-01-02		





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Sample Name:	472709	No. of frames analysed:	64
Lab. Name:	472709	No. of particles analysed:	1269
Date:	16-01-02	Heavy minerals in raw	
Submitter:	GEUS	sand (%):	20,76
Country:	Greenland	Comments:Umivik	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/100x		
Guard region:	375μm		
Sieve:	100 μm ²		

Category	Average content									
	TiO ₂ wt%	Fe ₂ O ₃ wt%	MnO wt%	Cr ₂ O ₃ wt%	SiO ₂ wt%	Al ₂ O ₃ wt%	MgO wt%	CaO wt%	ZrO ₂ wt%	Total
Ilmenite	48,7	45,3	0,4	0,1	1,7	0,6	1,1	0,1	0,2	98,2
Leucoxene	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Rutile	91,6	1,1	0,2	0,0	2,7	1,1	0,1	0,2	0,3	97,3
Ti magnetite	27,7	32,6	0,9	0,1	24,9	8,2	3,1	1,2	0,2	99,0
Magnetite	1,0	74,6	0,4	0,3	10,1	3,5	0,5	0,4	0,9	91,6
Chromite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Pyrite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Phosphate	0,0	0,4	0,1	0,1	0,3	0,0	0,0	56,5	1,3	58,7
Monazite	0,0	1,3	0,0	0,0	1,8	1,7	0,2	1,6	1,1	7,8
Y-phosphate	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Sphene	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Garnet	0,1	31,4	0,8	0,1	37,7	19,9	6,4	1,5	0,3	98,1
Kya/Sill	0,1	0,6	0,0	0,0	42,5	54,5	0,0	0,1	0,4	98,2
Staurolite	0,2	13,0	0,1	0,1	39,6	42,1	2,2	0,5	0,6	98,4
Zircon	0,1	1,9	0,1	0,6	28,4	0,5	0,3	0,4	59,0	91,3
Silicate	2,1	15,6	0,2	0,2	44,3	19,4	9,4	0,8	0,4	92,4
Unclassified	3,5	18,5	1,6	1,4	26,6	18,0	3,6	0,6	4,3	78,1

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	5,6	0,0	0,1	1,6	92,3	0,0	0,1	0,2	100,0

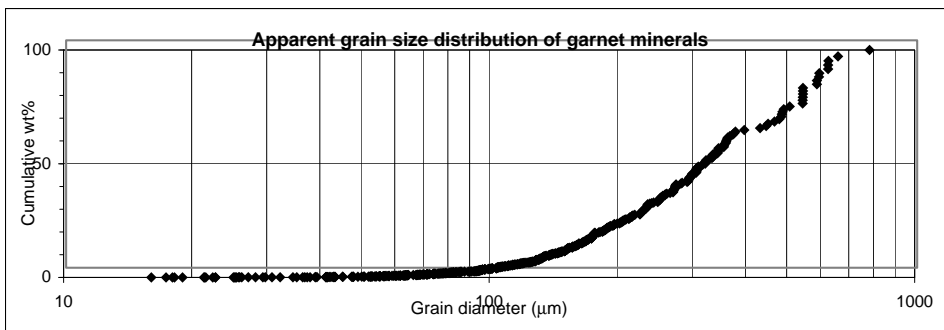
Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	49,6	0	94,1	28,0
Fe ₂ O ₃ wt%	46,1	0	1,1	32,9
MnO wt%	0,4	0	0,2	0,9
Cr ₂ O ₃ wt%	0,1	0	0,0	0,1
SiO ₂ wt%	1,7	0	2,8	25,1
Al ₂ O ₃ wt%	0,6	0	1,1	8,2
MgO wt%	1,1	0	0,1	3,2
CaO wt%	0,1	0	0,2	1,2
ZrO ₂ wt%	0,3	0	0,3	0,2
Total	100,0	0	100,0	100,0

Weight percent on a mineral basis:		
Category	Heavy mineral	
	concentrate	Raw sand
	wt %	wt %
Ilmenite	4,3	0,0
Leucoxene	0,0	0,0
Rutile	0,1	0,0
Ti magnetite	1,2	0,0
Magnetite	0,9	0,0
Chromite	0,0	0,0
Pyrite	0,0	0,0
Phosphate	1,2	0,0
Monazite	0,1	0,0
Y-phosphate	0,0	0,0
Sphene	0,0	0,0
Garnet	70,4	0,0
Kya/Sill	0,1	0,0
Staurolite	0,2	0,0
Zircon	0,0	0,0
Silicate	21,2	100,0
Unclassified	0,2	0,0
Total	100,0	100,0

Average TiO ₂ content of all the TiO ₂ minerals:	45,7
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	44,8
Valuable heavy minerals in raw sand:	0,00



Lab. Name: 472709 Analyzed by: BV
 Submitter: GEUS Acc. Voltage: 17kV
 Date: 16-01-02

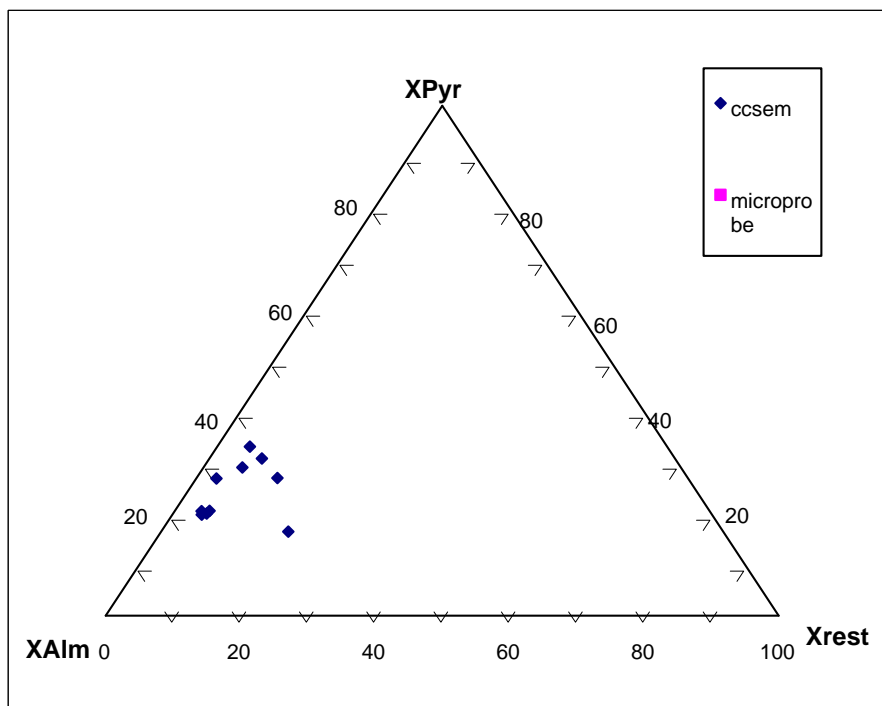


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	Total grains
Ilmenite	1,7	1,9	773	311	34253	27
Leucoxene	0,0	0,0	0	0	0	0
Rutile	1,3	1,5	279	103	4823	4
Ti magnetite	1,1	1,9	1088	428	62230	4
Magnetite	1,9	1,8	323	127	9760	17
Chromite	0,0	0,0	0	0	0	0
Pyrite	0,0	0,0	0	0	0	0
Phosphate	1,2	1,5	1063	376	58154	4
Monazite	1,5	1,6	427	154	9114	3
Y-phosphate	0,0	0,0	0	0	0	0
Sphene	0,0	0,0	0	0	0	0
Garnet	1,6	2,0	750	303	32831	522
Kya/Sill	1,4	1,7	379	151	8138	4
Staurolite	1,7	3,4	924	413	20266	2
Zircon	1,2	1,2	188	55	2280	1
Silicate	2,5	2,2	481	202	12238	637
Unclassified	1,4	1,3	136	55	2001	44

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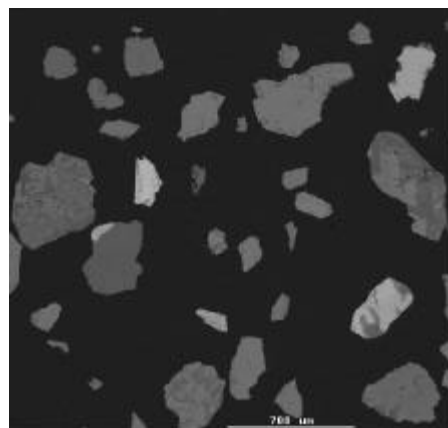
Lab. Name:	472709	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	16-01-02		





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Sample Name:	489001	No. of frames analysed:	88
Lab. Name:	489001	No. of particles analysed:	1479
Date:	1/16/02	Heavy minerals in raw sand (%):	19.86
Submitter:	GEUS	Comments:	
Country:	Greenland		
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/100x		
Guard region:	375µm		
Sieve:	100 µm ²		



Category	Average content									Total
	TiO ₂ wt%	Fe ₂ O ₃ wt%	MnO wt%	Cr ₂ O ₃ wt%	SiO ₂ wt%	Al ₂ O ₃ wt%	MgO wt%	CaO wt%	ZrO ₂ wt%	
Ilmenite	50.5	42.7	1.1	0.2	2.0	1.1	0.6	0.1	0.2	98.4
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	32.6	58.8	0.7	0.2	2.2	0.9	0.9	1.1	0.2	97.6
Magnetite	0.8	89.7	0.3	0.3	3.2	1.2	0.9	0.3	0.3	97.0
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	33.5	0.1	0.0	0.7	0.1	0.1	1.7	0.2	36.5
Phosphate	0.1	0.4	0.2	0.1	0.6	0.1	0.0	56.6	1.5	59.6
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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.1	29.3	0.6	0.1	38.6	20.1	7.9	1.3	0.3	98.2
Kya/Sill	0.0	1.2	0.0	0.5	42.5	53.4	0.0	0.0	1.2	98.8
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.1	0.7	0.3	0.0	29.6	0.0	0.2	0.0	66.4	97.3
Silicate	0.5	15.5	0.3	0.2	51.5	4.7	15.1	9.0	0.2	97.1
Unclassified	5.5	24.5	0.8	0.4	23.5	7.1	5.1	10.3	1.2	78.5

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	2.5	0.0	0.0	11.4	85.8	0.2	0.1	0.0	100.0

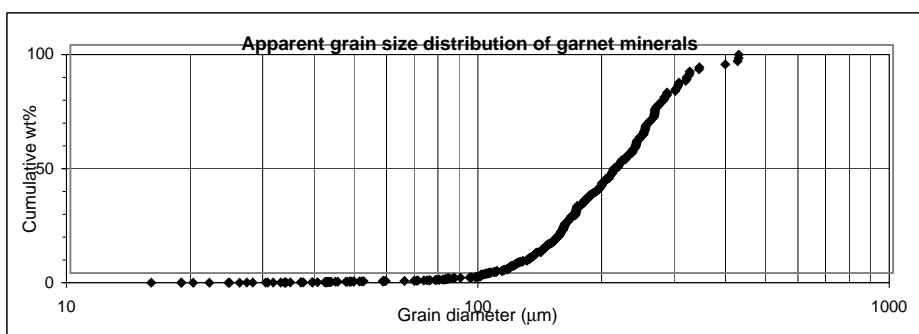
Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	51.4	0	0	33.5
Fe ₂ O ₃ wt%	43.4	0	0	60.3
MnO wt%	1.1	0	0	0.7
Cr ₂ O ₃ wt%	0.2	0	0	0.2
SiO ₂ wt%	2.0	0	0	2.2
Al ₂ O ₃ wt%	1.1	0	0	0.9
MgO wt%	0.6	0	0	0.9
CaO wt%	0.1	0	0	1.1
ZrO ₂ wt%	0.2	0	0	0.3
Total	100.0	0	0	100.0

Weight percent on a mineral basis:		
Category	Heavy mineral	
	concentrate wt %	Raw sand wt %
Ilmenite	0.9	0.0
Leucoxene	0.0	0.0
Rutile	0.0	0.0
Ti magnetite	4.0	0.0
Magnetite	0.6	0.0
Chromite	0.0	0.0
Pyrite	0.7	0.0
Phosphate	0.5	0.0
Monazite	0.0	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	30.2	0.0
Kya/Sill	0.0	0.0
Staurolite	0.0	0.0
Zircon	0.1	0.0
Silicate	62.0	100.0
Unclassified	0.9	0.0
Total	100.0	100.0

Average TiO ₂ content of all the TiO ₂ minerals:	36.7
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	36.7
Valuable heavy minerals in raw sand:	0.00



Lab. Name: 489001 Analyzed by: BV
 Submitter: GEUS Acc. Voltage: 17kV
 Date: 1/16/02

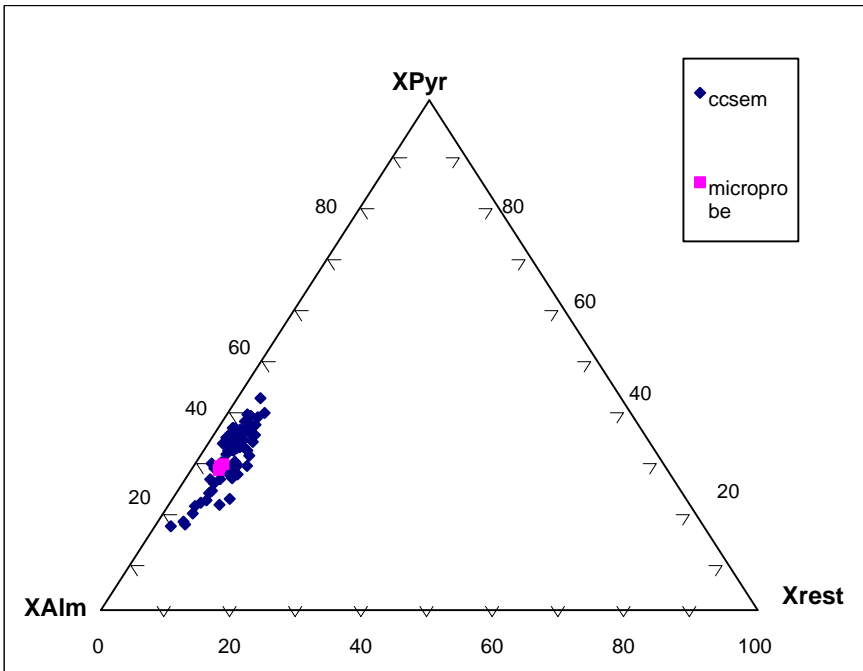


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	Total grains
Ilmenite	1.9	1.8	541	214	16643	16
Leucoxene	0.0	0.0	0	0	0	0
Rutile	0.0	0.0	0	0	0	0
Ti magnetite	1.7	1.9	726	284	26785	42
Magnetite	1.5	1.5	333	128	9847	17
Chromite	0.0	0.0	0	0	0	0
Pyrite	1.5	2.3	1014	429	39854	5
Phosphate	1.4	1.7	834	308	33507	4
Monazite	0.0	0.0	0	0	0	0
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.6	1.9	680	265	23663	428
Kya/Sill	1.7	2.1	486	197	9089	1
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.1	1.7	649	244	19715	1
Silicate	1.5	1.9	805	319	33567	936
Unclassified	1.5	1.8	469	202	15744	29

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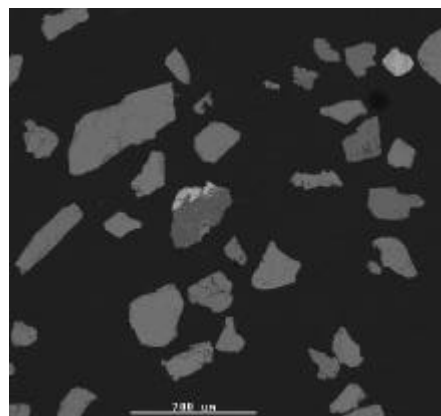


Lab. Name:	489001	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	1/16/02		





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Sample Name:	489003	No. of frames analysed:	100
Lab. Name:	489003	No. of particles analysed:	1350
Date:	1/16/02	Heavy minerals in raw sand (%):	39.51
Submitter:	GEUS	Comments:	Ikerteq
Country:	Greenland		
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/100x		
Guard region:	375μm		
Sieve:	100 μm ²		

Category	Average content									
	TiO ₂ wt%	Fe ₂ O ₃ wt%	MnO wt%	Cr ₂ O ₃ wt%	SiO ₂ wt%	Al ₂ O ₃ wt%	MgO wt%	CaO wt%	ZrO ₂ wt%	Total
Ilmenite	50.1	39.1	0.7	0.2	4.2	0.9	0.6	2.7	0.2	98.6
Leucoxene	84.0	3.3	0.1	0.5	4.6	4.4	0.3	0.1	0.3	97.6
Rutile	97.2	0.4	0.1	0.0	0.2	0.1	0.1	0.0	0.3	98.4
Ti magnetite	30.9	62.1	0.6	0.3	2.0	0.9	0.8	0.3	0.3	98.2
Magnetite	2.1	84.9	0.4	0.2	1.1	0.6	0.2	0.3	0.4	90.2
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.1	31.6	0.1	0.0	0.3	0.0	0.1	0.2	0.3	32.7
Phosphate	0.1	0.3	0.1	0.1	0.5	0.0	0.1	56.2	1.0	58.5
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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.1	29.5	0.6	0.1	38.3	20.0	7.9	1.3	0.3	98.1
Kya/Sill	0.1	0.8	0.1	0.5	43.0	54.0	0.1	0.0	0.0	98.5
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.1	0.2	0.0	0.0	29.6	0.0	0.0	0.1	64.5	94.4
Silicate	0.7	16.6	0.4	0.2	49.9	6.0	14.3	8.4	0.3	96.7
Unclassified	6.9	19.8	1.5	1.1	21.6	5.7	3.5	4.8	4.5	69.5

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	2.5	0.4	3.7	12.8	80.4	0.2	0.0	0.0	100.0

Average content	Normalised average contents of the valuable Ti-containing minerals:			
	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	50.8	86.1	98.7	31.4
Fe ₂ O ₃ wt%	39.6	3.4	0.4	63.2
MnO wt%	0.7	0.1	0.1	0.6
Cr ₂ O ₃ wt%	0.2	0.5	0.0	0.3
SiO ₂ wt%	4.2	4.7	0.3	2.1
Al ₂ O ₃ wt%	1.0	4.5	0.1	0.9
MgO wt%	0.6	0.3	0.1	0.8
CaO wt%	2.7	0.1	0.0	0.3
ZrO ₂ wt%	0.2	0.3	0.3	0.3
Total	100.0	100.0	100.0	100.0

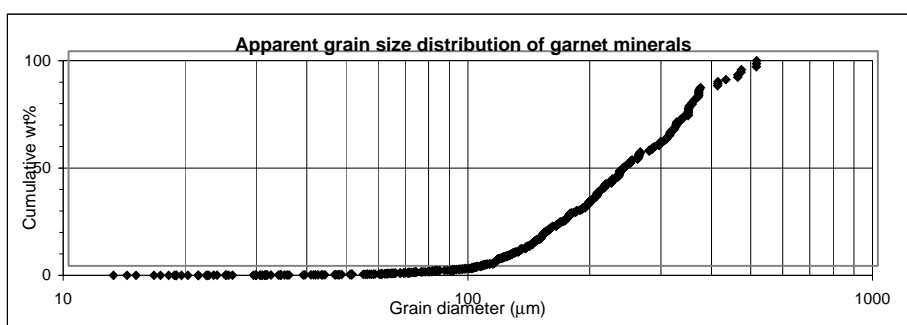
Category	Weight percent on a mineral basis:	
	Heavy mineral concentrate	Raw sand
	wt %	wt %
Ilmenite	1.6	0.7
Leucoxene	0.2	0.1
Rutile	2.4	0.9
Ti magnetite	8.3	3.3
Magnetite	0.7	0.3
Chromite	0.0	0.0
Pyrite	0.1	0.0
Phosphate	1.8	0.7
Monazite	0.0	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	52.2	20.6
Kya/Sill	0.0	0.0
Staurolite	0.0	0.0
Zircon	0.1	0.0
Silicate	31.8	73.1
Unclassified	0.6	0.3
Total	100.0	100.0

Average TiO ₂ content of all the TiO ₂ minerals:	47.8
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	35.9
Valuable heavy minerals in raw sand:	25.66

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Lab. Name:	489003	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	1/16/02		

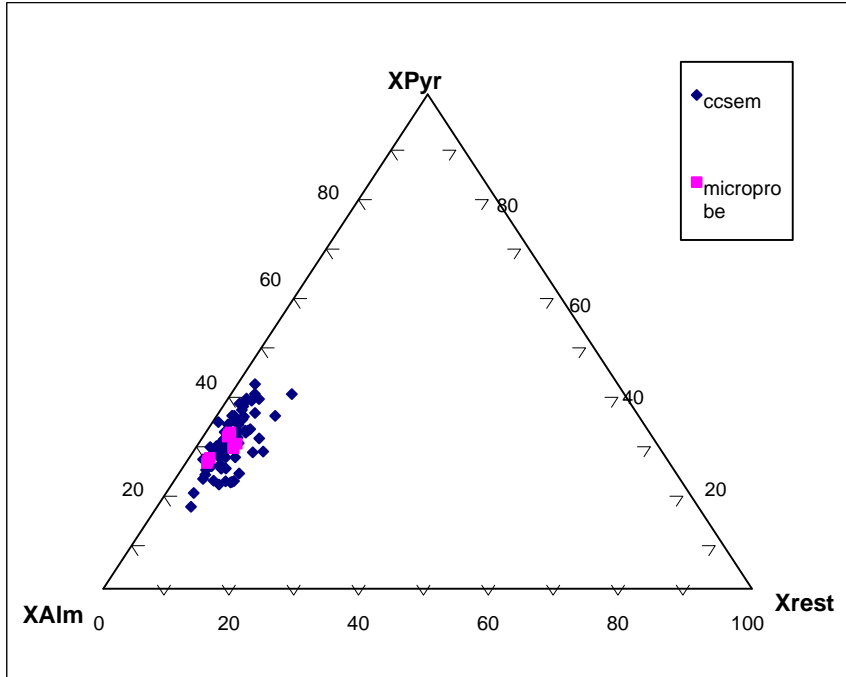


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	Total grains
Ilmenite	1.6	1.9	638	250	18261	23
Leucoxene	1.4	2.0	896	362	31153	2
Rutile	1.3	1.9	1099	441	68624	8
Ti magnetite	1.5	1.8	655	255	24915	80
Magnetite	1.5	1.8	428	163	10274	16
Chromite	0.0	0.0	0	0	0	0
Pyrite	1.3	2.2	683	282	16769	1
Phosphate	1.5	1.8	790	297	31707	13
Monazite	0.0	0.0	0	0	0	0
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.6	2.0	702	281	25748	582
Kya/Sill	1.3	1.7	341	128	5412	1
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.6	1.6	520	189	13819	2
Silicate	1.6	1.9	679	269	23112	596
Unclassified	1.3	1.3	274	107	10417	26

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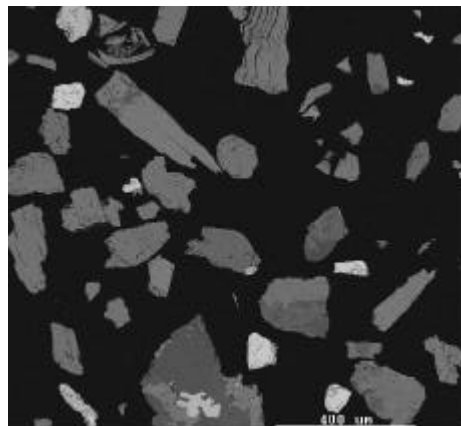


Lab. Name:	489003	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage:	17kV
Date:	1/16/02		





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Sample Name:	489015	No. of frames analysed:	64
Lab. Name:	489015	No. of particles analysed:	971
Date:	16-01-02	Heavy minerals in raw	
Submitter:	GEUS	sand (%):	26,46
Country:	Greenland	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/100x		
Guard region:	375µm		
Sieve:	100 µm ²		

Category	Average content									
	TiO ₂ wt%	Fe ₂ O ₃ wt%	MnO wt%	Cr ₂ O ₃ wt%	SiO ₂ wt%	Al ₂ O ₃ wt%	MgO wt%	CaO wt%	ZrO ₂ wt%	Total
Ilmenite	47,8	42,2	3,3	0,2	2,2	0,7	0,2	1,1	0,3	98,2
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	38,7	42,2	1,6	0,1	8,4	2,5	1,0	2,9	0,1	97,7
Magnetite	0,6	91,9	0,2	0,1	2,4	0,9	0,6	0,5	0,4	97,6
Chromite	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Pyrite	0,1	35,8	0,0	0,1	0,6	0,2	0,0	0,1	0,1	37,1
Phosphate	0,1	0,4	0,2	0,1	0,6	0,0	0,1	56,5	1,1	59,1
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	36,6	2,0	0,3	0,0	29,6	1,7	0,1	26,8	0,1	97,3
Garnet	0,1	30,6	1,7	0,1	37,3	19,5	4,0	4,8	0,3	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	0,1	0,9	0,2	0,1	29,5	0,0	0,1	0,1	63,9	94,9
Silicate	1,4	15,8	0,4	0,2	46,4	9,4	11,0	11,2	0,2	95,9
Unclassified	2,2	19,3	1,4	0,2	24,1	6,8	2,3	20,0	5,6	81,9

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	14,1	0,0	0,0	37,1	41,8	7,0	0,0	0,0	100,0

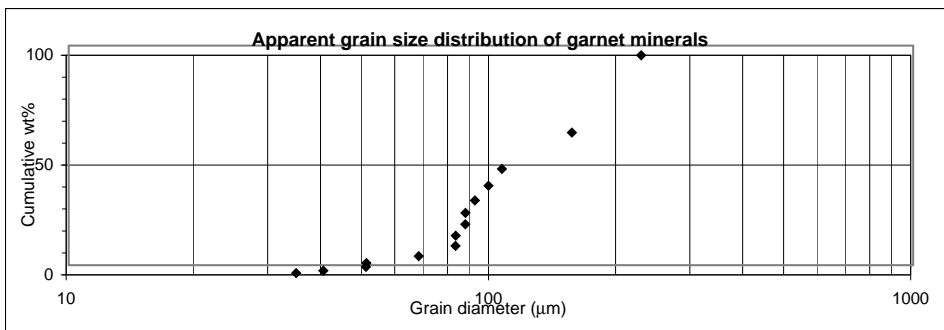
Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	48,7	0	0	39,7
Fe ₂ O ₃ wt%	43,0	0	0	43,2
MnO wt%	3,3	0	0	1,6
Cr ₂ O ₃ wt%	0,2	0	0	0,1
SiO ₂ wt%	2,3	0	0	8,6
Al ₂ O ₃ wt%	0,7	0	0	2,6
MgO wt%	0,2	0	0	1,0
CaO wt%	1,1	0	0	3,0
ZrO ₂ wt%	0,3	0	0	0,1
Total	100,0	0	0	100,0

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate	
	wt %	Raw sand wt %
Ilmenite	0,7	0,0
Leucoxene	0,0	0,0
Rutile	0,0	0,0
Ti magnetite	1,9	0,0
Magnetite	15,0	0,0
Chromite	0,0	0,0
Pyrite	0,2	0,0
Phosphate	2,9	0,0
Monazite	0,0	0,0
Y-phosphate	0,0	0,0
Sphene	2,0	0,0
Garnet	2,1	0,0
Kya/Sill	0,0	0,0
Staurolite	0,0	0,0
Zircon	0,4	0,0
Silicate	74,4	100,0
Unclassified	0,4	0,0
Total	100,0	100,0

Average TiO ₂ content of all the TiO ₂ minerals:	42,2
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	42,2
Valuable heavy minerals in raw sand:	0,00



Lab. Name: 489015 Analyzed by: BV
 Submitter: GEUS Acc. Voltage: 17kV
 Date: 16-01-02

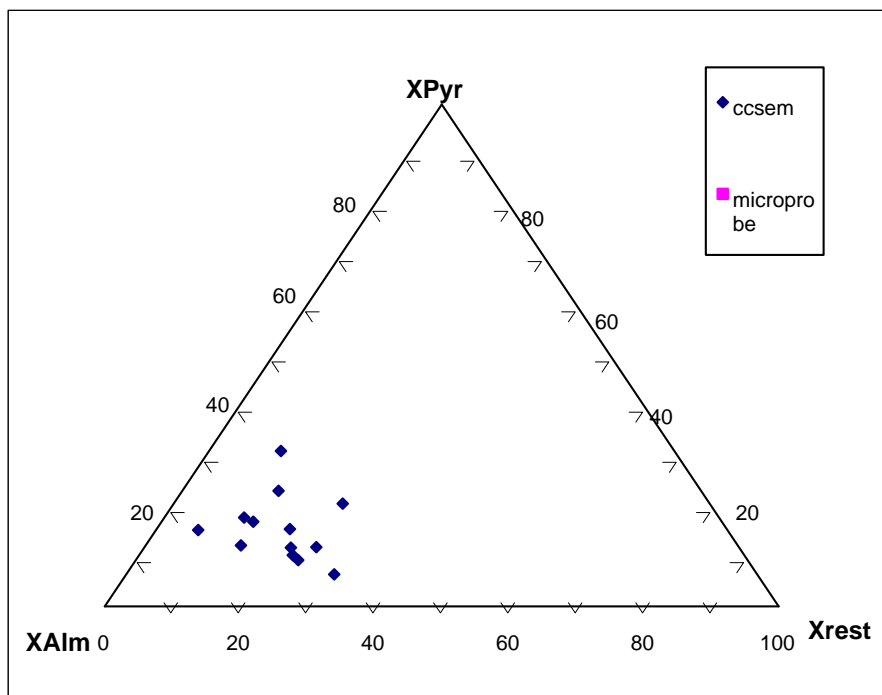


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	Total grains
Ilmenite	1,7	1,9	261	102	3208	11
Leucoxene	0,0	0,0	0	0	0	0
Rutile	0,0	0,0	0	0	0	0
Ti magnetite	1,5	1,7	303	114	4873	18
Magnetite	1,5	1,9	313	122	4806	134
Chromite	0,0	0,0	0	0	0	0
Pyrite	1,3	1,5	306	109	5223	2
Phosphate	1,5	1,8	381	147	7075	18
Monazite	0,0	0,0	0	0	0	0
Y-phosphate	0,0	0,0	0	0	0	0
Sphene	1,6	1,9	357	140	6161	21
Garnet	1,7	2,0	418	169	8436	14
Kya/Sill	0,0	0,0	0	0	0	0
Staurolite	0,0	0,0	0	0	0	0
Zircon	1,7	1,8	241	91	2838	6
Silicate	1,7	2,0	400	161	8603	729
Unclassified	1,6	1,6	204	79	2655	14

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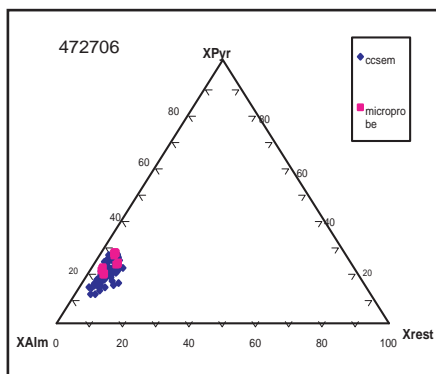
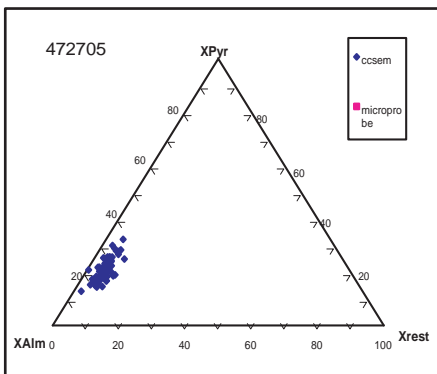
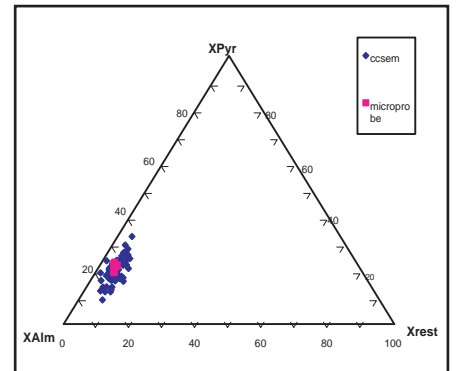
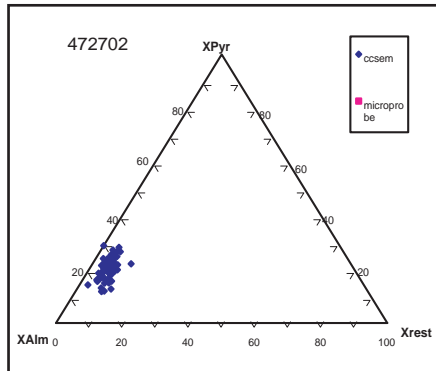
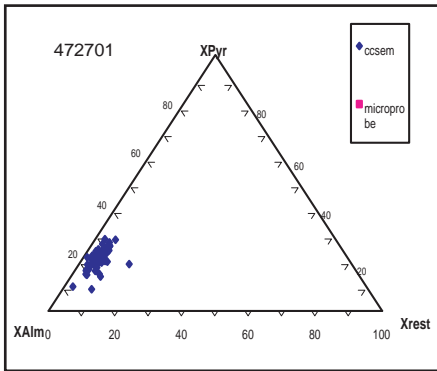
Lab. Name:	489015	Analyzed by:	BV
Submitter:	GEUS	Acc. Voltage	17kV
Date:	16-01-02		



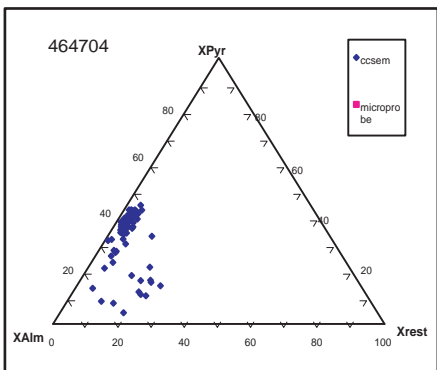
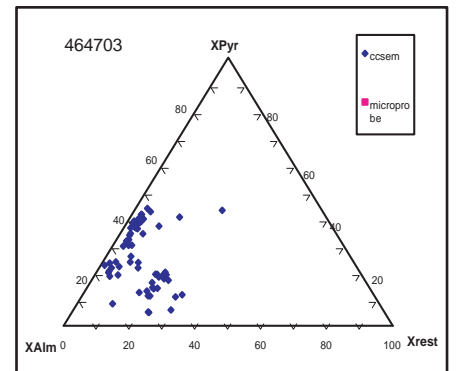
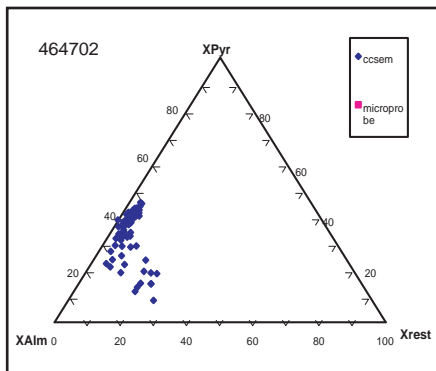
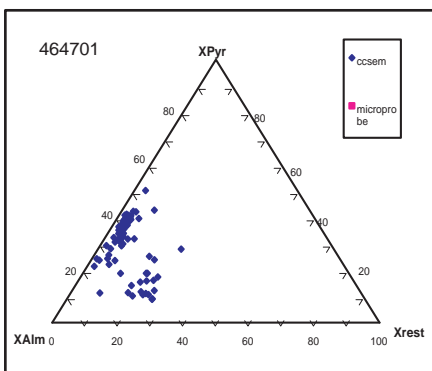
Appendix C

Ternary diagrams

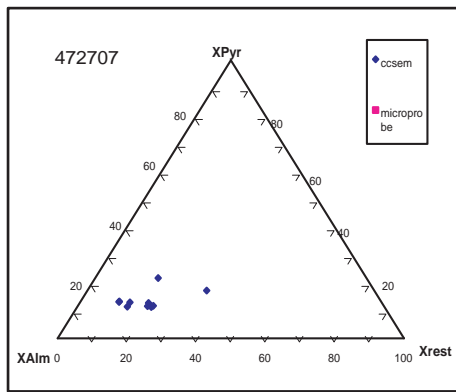
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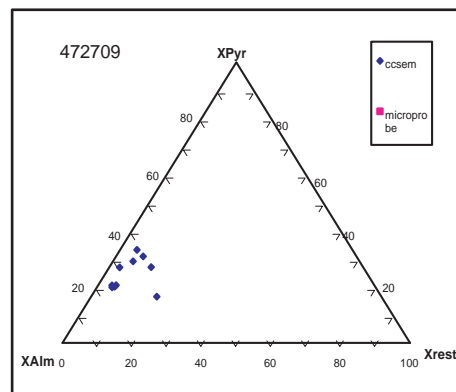
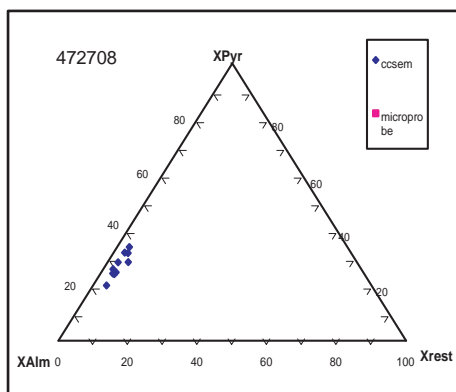
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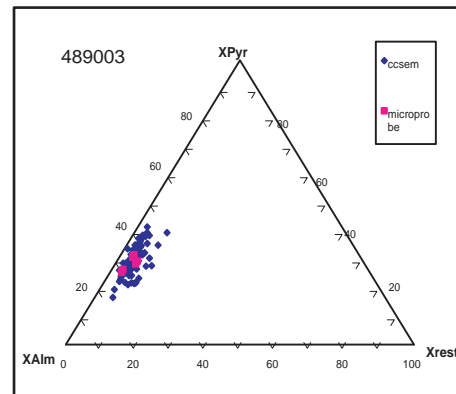
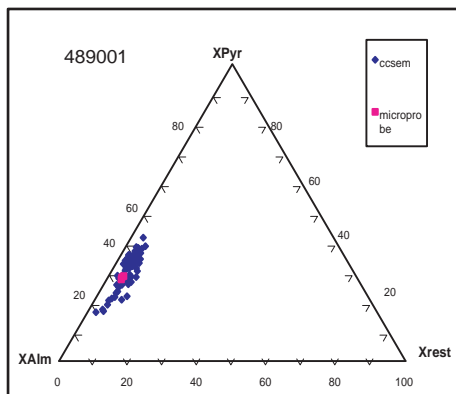
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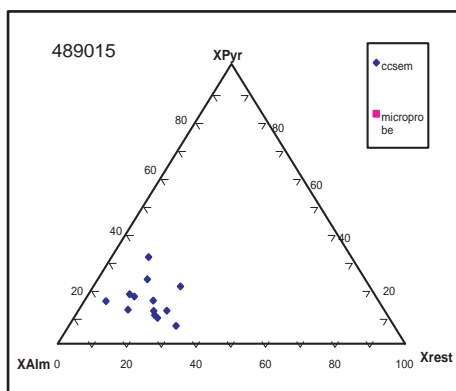
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Kulusuk



Siarq Dal

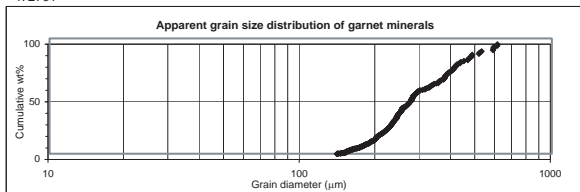


Appendix D

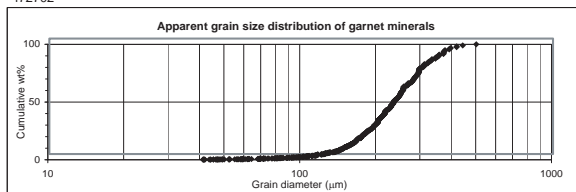
Grain size distribution

Tuttoqqortoq

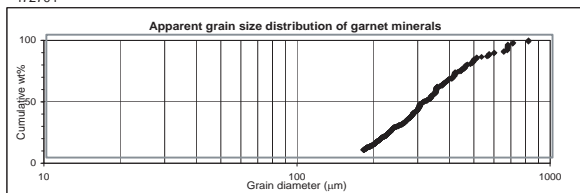
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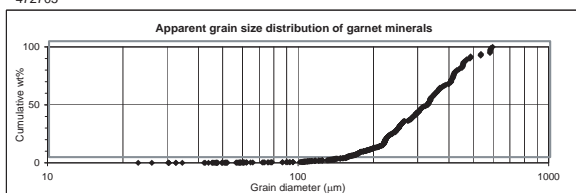
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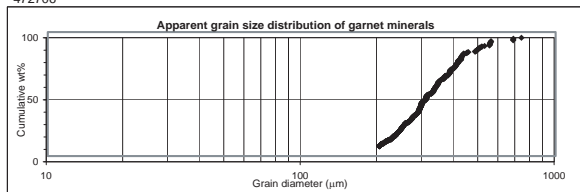
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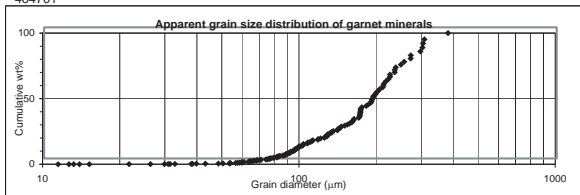


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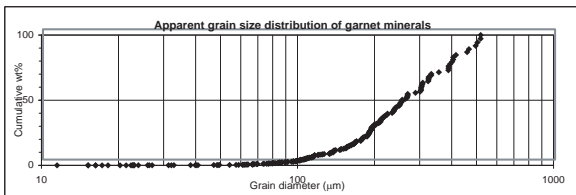


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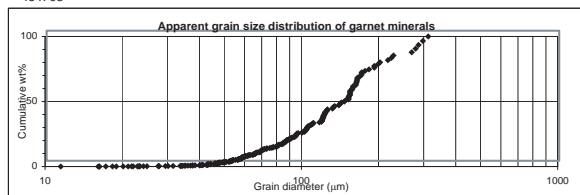
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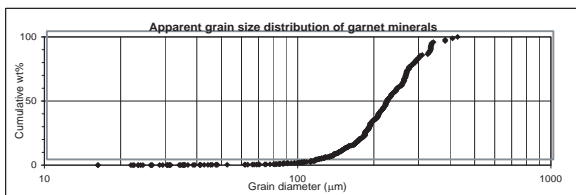
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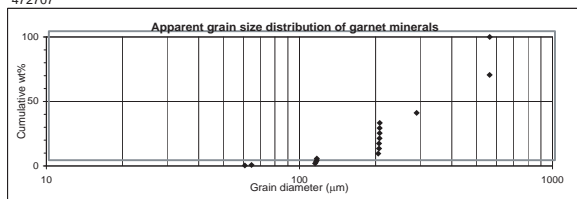


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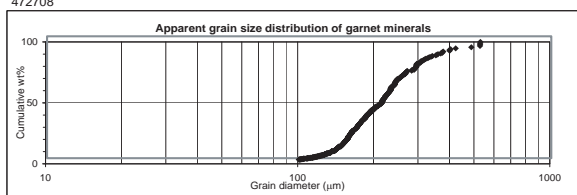
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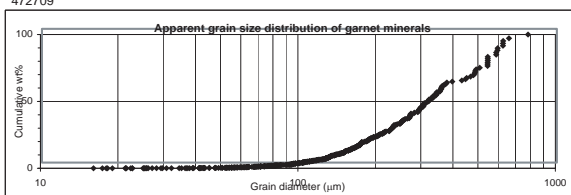


Umivik

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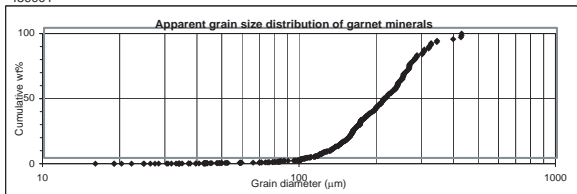


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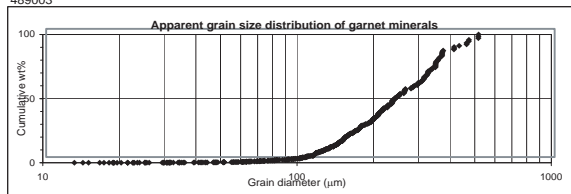


Kulusuk

489001



489003



Siarq Dal

489015

