

Heavy Mineral Sands in Vietnam 2004

Fieldwork 2004 and status 2002 - 2004

Henrik Stendal

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF THE ENVIRONMENT



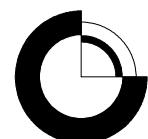
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Abstract

The fieldwork in 2004 was carried out in the Hué and Ha Tinh regions in the middle to northern part of Vietnam. Eight placer deposits were collected. The heavy mineral content in the sands varies a lot within the areas. The heavy mineral occurrences occur both in aeolian sand dunes and in beach sands.

The fieldwork carried out in Vietnam from 2002 to 2004 has outlined three potential areas with high-grade ilmenite.

1. The Ham Tan area, which covers parts of the provinces Binh Thuan and Vung Tau – Ba Ria in southern Vietnam. The most promising area for heavy mineral resources is the area between Chum Gang and Tan Thang with high-grade ilmenite varying between 56 - 60% TiO₂.
2. The Ky Khang and Cam Son deposits in the Ha Tinh province have high-grade ilmenite but the Cam Son deposit is already mined out. The CCSEM analyses of the raw samples from the region yielded high-grade TiO₂ from 60 - 65%. The Cam Thang deposit in the same region has 59% including rutile.
3. The third interesting area is the Hué region with high-grade ilmenite around 60% (one deposit has 72.5%) including rutile. The total amount of heavy minerals in that region is just below 1 million tonnes of heavy minerals. The zircon content is up to 8 wt%.



Figure 1. *The sampling team 2004. From left to right: Mr. Le Duc Luc geologist from DoNRE & Thua Thien-Hué, the driver, Mr. Pham Duc Chung Vice Director of DoNRE, Mr. Nguyen Xuan Hop geologist from DGMV. Photo taken by a sampling worker.*

Introduction

The joint venture heavy mineral sampling programme between the Department of Geology and Minerals of Vietnam (DGMV), the Geological Survey of Denmark and Greenland (GEUS) and DuPont continued the work from 2002 and 2003 (Stendal 2003 & 2004) in 2004. GEUS requested DGMV, Mr. Nguyen Xuan Hop, Vice-Director of the International Cooperation Division to carry out the fieldwork in 2004. DGMV accepted and did all the paperwork for permissions to collect samples from the MONRE.

A team from DGMV with the Vice-Director of International Cooperation Division, DGMV, Mr. Hop as sampling leader carried out the sampling tour in 2004 (Fig. 1). The results of the black sands are reported below together with a status of the main results of three years sampling in Vietnam.

The fieldwork was carried out in the period from June 9 to June 19 including travel time (Fig. 1). The main focus of the field-sampling programme was the Hué region together with follow-up in the Ha Tinh regions (Fig. 2). Sampling during the field campaigns in 2002 and 2003 did not cover the Hué area. The description of the field areas below is modified from the field diary of Mr. Hop.

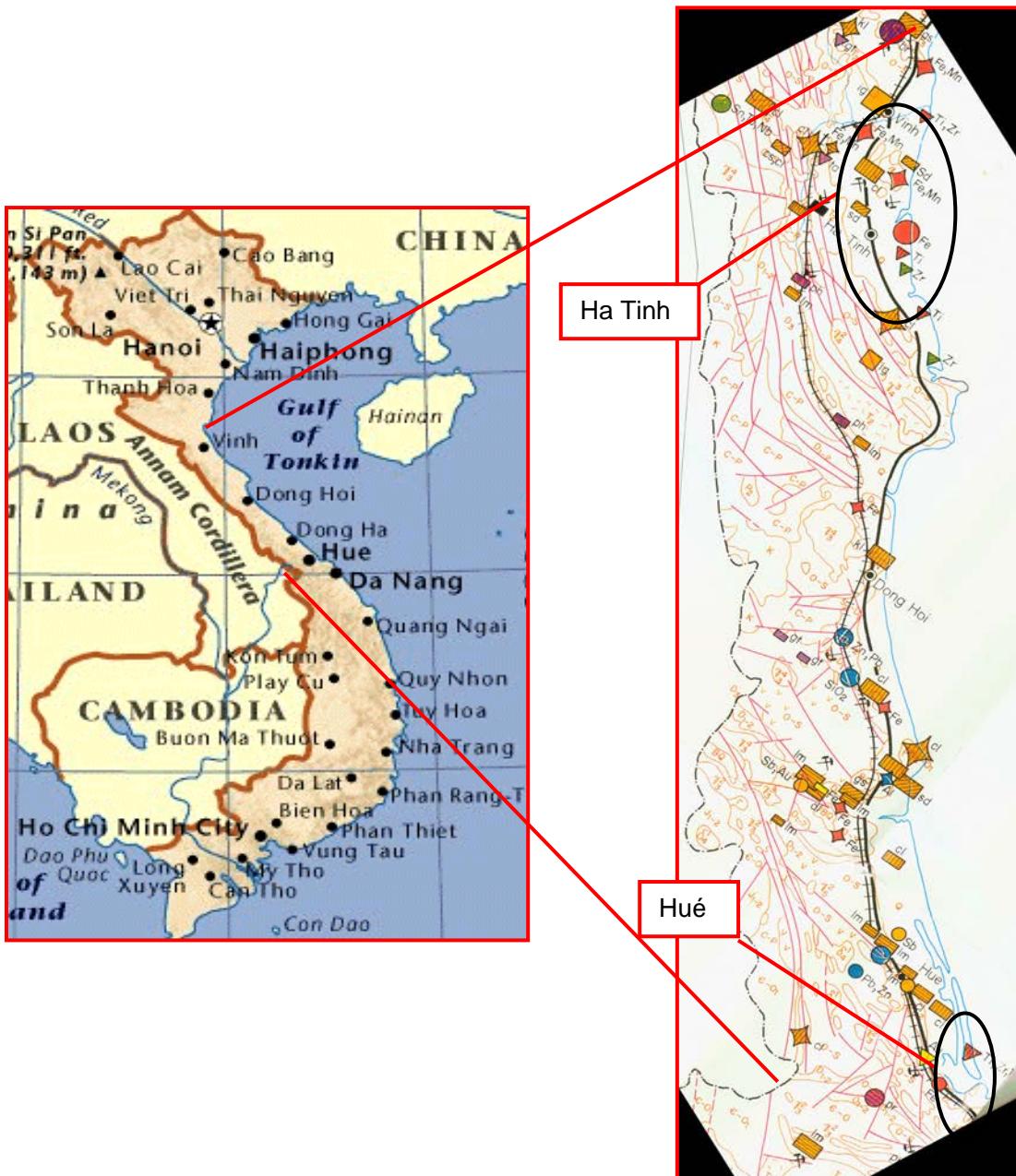


Figure 2. ***Sampling areas (ellipsoids) in the Hué and Ha Tinh regions.***

Background

During the meetings with different organisations in Vietnam in 2003 it turned out that there should be high-grade ilmenite in the Hué region. The Marine and Mineral Resources Centre gave us this information about the new high-grade ilmenite placer deposits. After digging into the information DGMV provided us with the following data about the Hué region. There are four deposits in the Ke Sung - Vinh My area, which are Ke Sung, Quang Ngan, Vinh My and Vinh Phong. The North central Geological Division under the DGMV has only preliminarily assessed those deposits with following details.

1. The Ke Sung ilmenite deposit:

The ore body is situated along the seashore with its length of 5,000 m, average width of 250 m and thickness of 1-9.5 m (average 5.49 m). The ore contents (kg/m^3) are for ilmenite 21-43 (average 28.5), leucoxene 0.1-2.97 (average 1.38), rutile 0.27-9.73 (average 1.6) and zircon 0.22-10.02 (average 5.73).

2. The Quang Ngan ilmenite deposit:

The ore body is 14,000 m long, 126 m wide (average) and 1-4.5 m thick (average 2 m). The ore contents (kg/m^3) are for ilmenite 13-267 (average 72.38), leucoxene 0.61-8.15 (average 3.45), rutile 0.29-22.9 (average 3.92) and monazite-xenotime 0.26-5.64 (average 0.87).

3. The Vinh My ilmenite deposit:

The ore body is 7,370 m long, 142 m wide (average) and 0.6-5.1 m thick (average 3.1 m). The deposit is covered by a sand layer up to 0.8 m. The ore contents (kg/m^3) are ilmenite averaging 44.5, rutile 1.81-10.56 (average 3.08), zircon 0.73-34.18 (average 8.88), monazite-xenotime 0.26-0.98 (average 0.51) and leucoxene 0.09-1.99 (average 0.69).

4. The Vinh Phong ilmenite deposit. Four ore bodies have been identified:

Orebody No.1: 1,000-1,100 m long, 200-500m wide and 4.2 m thick

Orebody No. 2: Consists of two lenses 2a and 2b

- 2a: 2,000 m long, 200 m wide, 2.8 m thick
- 2b: 200 m long, 60 m wide, and 4.6 m thick

Orebody No. 3: Consists of two lenses: 3a and 3b

- 3a: 300 m long, 20-50 m wide and 1.5 m thick
- 3b: 1,000-2,000 m long, 30-80 m wide and 0.3-1.5 m thick

Orebody No. 4: 2,000-2,200 m long, 50-250 m wide, 3.24 m thick.

The total probable reserves of the four deposits in the Hué region are just below 1 mill tonnes. The visits in the Hué region went to Vinh Xuan, Vinh My and Ke Sung.

The Ha Tinh region was visited in both 2002 and 2003 (Stendal 2003 & 2004). In 2004 it was revisited to collect a few more deposits. The visits in 2004 went to Pho Thinh, Cuong Gian, Cam Thang, and Cam Son.

Sampling procedure

The samples are taken in profiles (1-3 m) after digging into the dune or where steep section of the dune showed cross bedding. The sample is scraped along the wall in the hole/section with a small stainless shovel. The size of the sample is between 500-1000 g. All samples are representative for the site as described in the sample description. One sample (H1 – 2000779) is taken from a spiral pre-concentrating plant (Table 1).

Access to the Hué region (Thua Thien-Hue province) was permitted through the Department of Natural Resources and Environment (DoNRE). The Vice Director Mr. Pham Duc Chung and Mr. Le Duc Luc, principal expert was informed by our sampling program and the latter, who knew the locations well joined the sampling party.

In the Ha Tinh Province Mr. Nguyen Van Thanh from the Department of Natural Resources and Environment accompanied and helped to get the right permissions from the People's Committee of Ha Tinh Province for the sampling.

Deposit	HM-% of raw sand	Sand % <0.045 mm	Sample #	GEUS #	Type
Vinh Xuan	95.09	0.85	H1	2000779	Pre-concentrate
Vinh Xuan	4.73	0.72	H2	2000780	Raw sand, dune
Vinh Xuan	8.13	0.24	H3	2000781	Raw sand, dune
Vinh My	37.03	0.18	H4	2000782	Raw sand, dune
Vinh My	4.26	0.08	H5	2000783	Raw sand, dune
Pho Thing	4.56	1.67	H6	2000784	Raw sand, beach
Cuong Gian	13.82	1.64	H7	2000785	Raw sand, dune
Cam Thang	16.13	0.53	H8	2000786	Raw sand, beach

Table 1. Deposit name, contents of heavy minerals (HM) and fine fraction, sample numbers and type of sands.



Figure 3. *The Vinh Xuan Workshop No. 3 with spiral concentrators.*



Figure 4. *Sand dune with heavy mineral layers, Vinh Xuan Workshop No. 1.*

Field areas and results

Hué region

In the Hué region the following deposits were visited: Vinh My, Vinh Xuan and Ke Sung. The heavy mineral (HM) content of the raw sand samples varies from 4 to 37 wt% and the pre-concentrated sample had 95 wt% (Tables 1 and 2). The grain size of the samples varies from 100-300 µm (see appendix with the CCSEM results). The content of different heavy minerals based on the CCSEM analyses are shown in Table 2.

Lab. #	Field #	%	TiO ₂ %	TiO ₂ %	%	%	%	%	%	%	%
		HM of total	excl. Rutile	incl. Rutile	Ilmenite of total HM	Rutile of total HM	Leucoxene of total HM	Ti-magnetite of total HM	Zircon of total HM	Garnet of total HM	
2000779	H1	95.09	56.5	59.2	47.7	4.1	3.8	2.0	8.7	1.8	
2000780	H2	4.73	56.5	59.7	46.6	4.8	4.8	3.5	8.1	3.2	
2000781	H3	8.13	57.4	60.8	42.5	4.9	5.9	1.3	6.5	1.6	
2000782	H4	37.03	56.7	59.0	49.4	3.7	5.4	2.8	7.3	2.8	
2000783	H5	4.26	64.2	72.5	7.2	5.4	6.4	1.1	0.2	5.5	
2000784	H6	4.56	56.4	60.4	18.4	3.9	7.3	5.8	2.9	13.5	
2000785	H7	13.82	52.9	55.1	59.7	3.9	4.3	4.5	8.2	1.1	
2000786	H8	16.13	54.8	58.9	47.9	2.8	3.1	2.3	8.5	2.1	

Table 2. Main result of the CCSEM analyses. See detailed analyses in Appendix 1.

Vinh Xuan

Field

The Vinh Xuan deposit is located about 40 km west of Hué City. The placer deposit is deposited in sand dunes along the coast about 1,000 m long and 300 wide. The Minerals Company of Thua Thien-Hué mine this deposit. The Company has 3 Workshops, which are Vinh Xuan Workshops Nos. 1-3. The present mining production of the Company is 1,000 tons/year (by Spiral Gravity Separation, the content of heavy minerals in the pre-concentrated sand is ~72%). Most of the HM is extracted from the Holocene aeolian formation to about 15-m depth.

Sample No. H1 (2000779): The sample was taken from the mining site of Vinh Xuan Workshop No.3. The sample has been pre-concentrated by a spiral concentrator (Fig. 3).

Sample No. H2 (2000780): The sample was taken from the mining site of Vinh Xuan Workshop No.1 (Fig. 4).

Sample No. H3 (2000781): The sample was collected from the mining site of Vinh Xuan Workshop No.3.

It was not possible to visit or take any samples from Vinh Xuan Workshop No.2 due to the mine was not in operation that day.

Analyses

The TiO_2 content in ilmenite averaged 54.5% (Appendix 1) and including altered ilmenite e.g. leucoxene the TiO_2 percentage increases to 56.5-57.4%. If rutile is included the TiO_2 content increases to ~60%. The rutile content varies from 4.1-4.9%, leucoxene 3.8-5.9% and a rather high zircon content range from 6.5-8.7% (Table 2).



Figure 5. *Heavy mineral bands in a sand dune from Vinh My deposit (Sample H4 (2000782)).*

Vinh My

Field

The Vinh My deposit is located about 70-km west-northwest of Hué City. The prospect is about 1,000 m long, 300 wide and strikes along the coast. At present the deposit has not yet been licensed to any enterprise. According to the guide Mr. Le Duc Luc the contents of heavy minerals are fairly high, about $>45 \text{ kg/m}^3$. The deposit comprises of sand dunes about 5-7m high compared with the sea level but the dunes are covered with bushes. Two samples were collected from this deposit (No. H4 (2000782) and H5 (2000883)) were taken from the sand dunes along the coast (Fig. 5).

Analyses

The sample H4 (2000882) is comparable with the results from the Vinh Xuan deposit but sample H5 (2000883) differs by having high-grade ilmenite with a TiO_2 content as high as 64.2 (excl. rutile) and 72.5% including rutile. The high-grade ilmenite is due to a high proportion of leucoxene compared to ilmenite. However, the overall ilmenite content is rather low (7.2%) as well as the zircon content (Table 2).

Ke Sung

The Ke Sung deposit is located in Phu Dien District, about 50 km west-southwest of Hué City. The deposit covers an area of about 70 hectares. The thickness of the ore bodies average 10 m. The average content of heavy minerals yields $> 40 \text{ kg/m}^3$. The deposit is hosted in sand dunes. The Minerals Company of Thua Thien-Hué has already mined out the sand dunes along the coast and the mining site has been rehabilitated and Ke Sung has ceased its mining. The People's Committee of Phu Dien District did not allow the sampling team to take samples.

Ha Tinh region

Pho Thinh

Field

The Pho Thinh deposit (Fig. 6) is 9 km long, 200 m wide, and 2 m thick (average thickness). One sample was collected from a hole of 2-m depth - sample No. H6 (2000884). A wide sand beach hosts the deposit. The sand beach is elevated about 3-5 m over the sea level.

Analysis

The TiO_2 content in the ilmenite excluding is 56.4% and inclusive rutile 60.4%. The sample has higher garnet content than the other analysed samples (13.5% - Table 2).

Cuong Gian

Field

Cuong Gian deposit (Fig. 6) is 800 m long, 100 m wide and 1,9 m thick (average thickness) and belongs to the northern group of HM deposits of the Ha Tinh Province. Sample No. H7 (2000785) was collected from a sand dune about 5 m higher than the sea level close to the Dong Gian River.

Analysis

This deposit has the lowest content of TiO_2 of the titanium minerals exclusive rutile (52.9%) and including rutile 55.1% (Table 2). The zircon content of the heavy minerals is high (8.2%).

Northern group in the Ha Tinh Province

Other deposits, such as Xuan Son, Van Son and Song Nam are all located in the Northern Group of Deposits of Ha Tinh Province (Fig. 6). They mostly lie at the depth of 4 m and have low grade of heavy minerals as determined by the former AUSTINH Joint Venture Company between Ha Tinh Province and Westralian Sands Ltd. At present no company/enterprise has mining licence in this region. Local people exploit the sands as building

materials. The sampling task became impossible due to the black sand layer was not reached in 4 m depth.

Cam Thang

Field

The Cam Thang deposit (Fig. 6) - sample No. H8 (2000786) was collected from top to 2,75 m depth. The Cam Thang deposit is about 4,8 km long, 120 m wide and 1,7 m thick (average thickness). The average content of heavy minerals looks high in the field. This deposit is a fairly flat sand beach. Local people have their residences on top of the beach forming a small town called Cam Xuyen Townlet. The Ha Tinh Minerals – Trading Corporation has applied for the mining licence over this deposit but it has not yet been approved. The reason that the Corporation has not been licensed is that it is very difficult to move the local people to other places.

Analysis

The sample has ~16% heavy minerals and the TiO₂ content is rather low (54.8%) but including rutile it nearly reach 59% (Table 2). The zircon content yields 8.5%.

Cam Son

The Cam Son deposit (Fig. 6) is 1.4-km long, 110-m wide and 1,5 m thick. The deposit delivered in 2003 high-grade ilmenite, which was mixed with heavy mineral sands of the Ky Kang deposit and the concentrate, was sold to DuPont (Stendal 2004). The Ha Tinh Minerals – Trading Corporation has exhausted the mine and the area has been rehabilitated and planted. The CCSEM data from Cam Son show high grade of TiO₂ with more than 60% (Stendal 2004) and a grain size distribution from 100-200 µm.



Figure 6. Heavy mineral deposits in the Ha Tinh Province.

Status of ilmenite in Vietnam

Most of the collected samples from the Vietnam project are collected from aeolian sand dunes, which are striking parallel to the coastline. The total heavy mineral content varies a lot in the raw sand sample. This status comprises all samples from the field campaigns from 2002-2004.

Southern Vietnam (Binh Thuan)

The sampling area in the southern Vietnam is characterised by uniform distribution of the heavy minerals containing 50-60% ilmenite with a TiO_2 content from 56-60% and 1-3% lower with rutile excluded of the calculation. The most promising area for heavy mineral resources looks like to be the area between Chum Gang and Tan Thang (Fig. 7). These areas have the largest potential in tonnage and are not planned for other purposes such as industrialisation or urbanisation. The TiO_2 content in all Ti-minerals is around 59%, which is found in Chum Gang, Bau Doi A and Go Dinh 2. TiO_2 content around 58% is proven in Van Ké, Tan Thang, Son My and Go Dinh 1 (for details see Stendal 2004). The most valuable mineral after the ilmenite in the HM samples is zircon, which has considerable amounts from 6-15% of the total HM content. The leucoxene amounts from 3 to 8% except for one sample with 13%.

Middle Vietnam (Binh Dinh)

The aeolian sand dunes of the Binh Dinh Province (Fig. 7) comprise both Miocene and Quaternary dunes. In general, this region has low-grade ilmenite with TiO_2 contents between 52 - 53% (Stendal 2003).

Middle to northern Vietnam (Hué)

The sampling area in the Hué is characterised by uniform distribution of the heavy minerals containing 40-50% ilmenite (except one sample, Table 2, H1-H5). The TiO_2 content of the Ti-minerals is ~60% (one sample 72.5%) and 2-3% lower when rutile is excluded in the calculation. The Hué region is a good potential area for high-grade ilmenite (Fig. 7). The present reserves of heavy minerals are estimated to be just below 1 million tonnes (data from DGMV).

Southern part of northern Vietnam (Ha Tinh)

The Ha Tinh region has a great potential for heavy minerals with high-grade ilmenite (Fig. 7). However, the grade of TiO_2 of the Ti-minerals varies a lot. The northern part of the region has low-grade contents (54-57%) but areas around Ky Khang, Cam Son (60-65%) and Cam Thang (59%) have high-grade ilmenite calculated as average for all the Ti-minerals (Fig. 7).

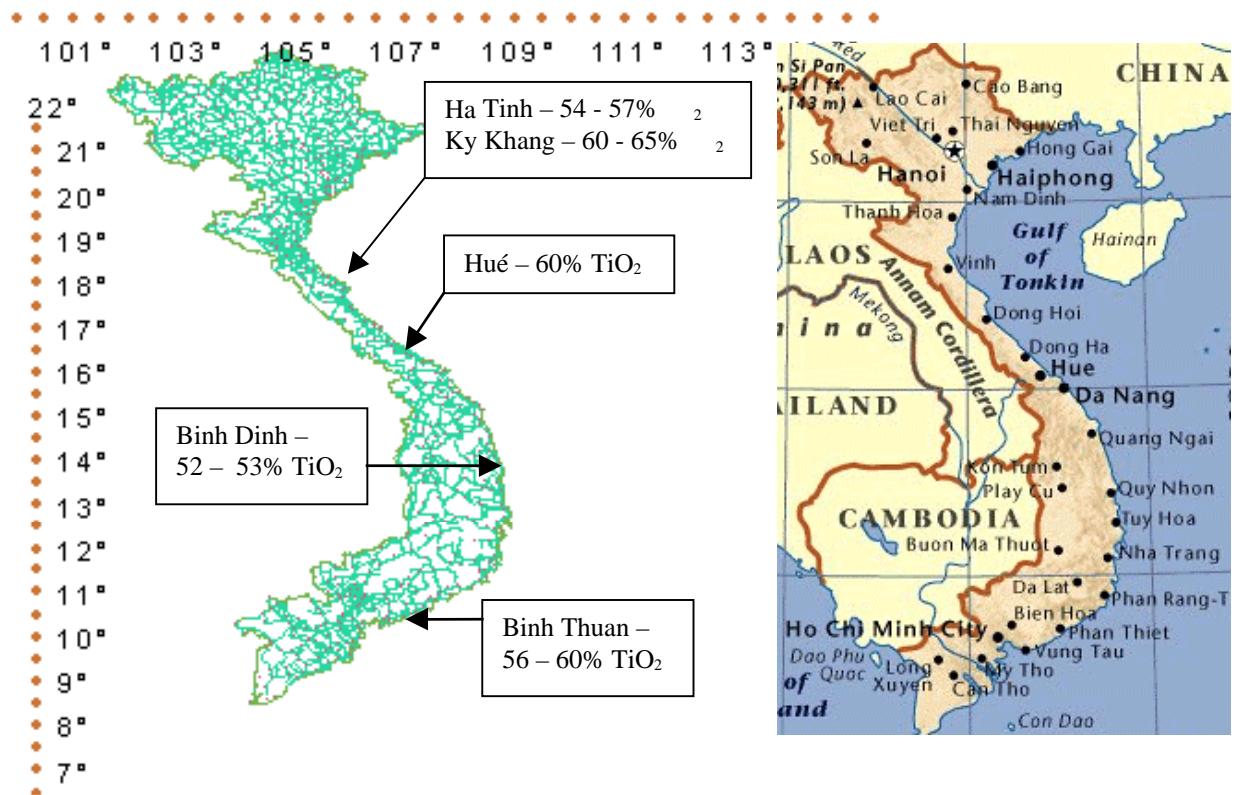


Figure 7. Map of Vietnam showing the grade of TiO_2 ilmenite minerals including rutile in different regions.

Conclusions

The fieldwork carried out in Vietnam 2002-2004 has outlined three potential areas with high-grade ilmenite (Fig. 7).

1. The Ham Tan area, which covers parts of the provinces Binh Thuan and Vung Tau – Ba Ria in southern Vietnam. The most promising area for heavy mineral resources is the area between Chum Gang and Tan Thang with TiO_2 content in ilmenite up to 59%, but general content varies between 56 – 60%. The zircon content of the area is relatively high (7-15%).
2. The Ky Khang and Cam Son deposits in the Ha Tinh province but the Cam Son mine is already empty. The CCSEM analyses of the raw samples from the area yielded high-grade TiO_2 from 60 - 65%. The Cam Thang deposit in the same region has 59% TiO_2 including rutile in the calculations. However, the area just north of the high-grade ilmenite terrain contains lower grade ilmenite.
3. The third interesting area is the Hué region with high-grade ilmenite around 60% (one deposit has 72.5%) including rutile. The total amount of heavy minerals in that region is just below 1 million tonnes of heavy minerals. The zircon content is up to 8 wt%.

Acknowledgement

GEUS would like to acknowledge the General Director Mr. Tran Xuan Huong and his staff from the DGMV for a great help in the planning and for carrying out the fieldwork in 2004 and for a good and fruitful co-operation during this joint project (2002-2004). Especially thanks go to the Deputy Director for 'Division for International Co-operation' Nguyen Xuan Hop and Ms. Bui Thi Huyen, International Co-operation Expert (interpreter) for all the administrative work and getting the permissions from the authorities to make the 2004 sampling tour possible. The latter persons are also acknowledged for all their efforts during the last three years within this joint project.

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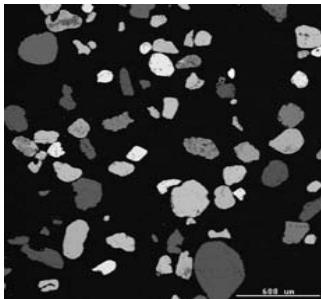
Appendix

CCSEM analytical results # 2000779 – 2000786.



Geological Survey of Denmark and Greenland
Øster Voldgade 10, DK-1350 Copenhagen K
Ph.: +45 38142000, Fax: +45 38142050

Sample Name:	2000779	No. of frames analysed	24
Lab. Name:	779	No. of particles analysed	675
Date:	10/25/2004	Heavy minerals in raw sand (%)	0.00
Submitter:	Henrik Stendal	Comments:	
Country:	Vietnam		
Analyzed by:	JK		
Acc. Voltage/Magnification:	17kV/40x		
Guard region:	350 µm		
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	54.8	37.9	2.6	0.1	1.5	1.1	0.2	0.2	0.3	98.6
Leucoxene	74.5	13.4	1.4	0.1	4.4	3.9	0.2	0.1	0.2	98.3
Rutile	93.4	1.3	0.2	0.1	1.9	0.8	0.1	0.2	0.2	98.3
Ti magnetite	38.4	27.5	2.0	0.3	11.2	6.5	0.4	0.5	4.0	90.9
Magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromite	0.3	32.3	0.9	47.7	0.7	11.4	4.7	0.3	0.0	98.4
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	18.6	0.4	0.0	0.0	5.9	3.7	0.1	1.2	7.3	37.3
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	9.5	8.9	0.4	0.0	38.0	22.0	0.9	18.6	0.0	98.3
Kya/Sill	0.1	0.7	0.1	0.1	43.1	53.0	0.0	0.3	0.1	97.6
Staurolite	0.5	13.1	0.3	0.2	33.9	47.7	1.4	0.3	0.3	97.7
Zircon	0.2	0.3	0.1	0.1	29.1	0.1	0.1	64.0	94.3	
Silicate	1.4	6.4	0.1	0.2	47.3	37.3	3.1	1.0	0.2	97.1
Unclassified	11.0	10.7	1.0	1.0	10.1	22.6	4.9	3.2	10.0	74.5

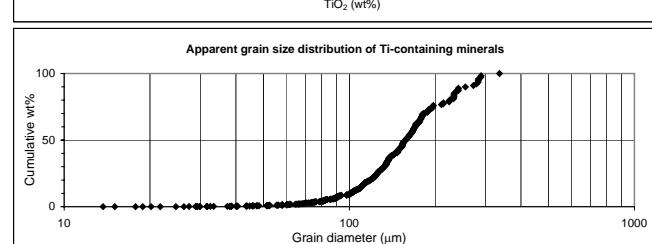
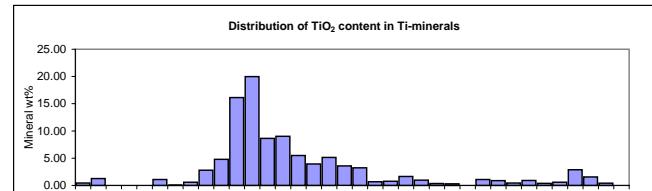
Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	68.8	5.4	5.9	2.8	2.6	12.6	0.7	1.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	55.5	75.8	95.1	42.3
Fe ₂ O ₃ wt%	38.4	13.7	1.3	30.3
MnO wt%	2.6	1.4	0.2	2.2
Cr ₂ O ₃ wt%	0.1	0.1	0.1	0.4
SiO ₂ wt%	1.5	4.5	2.0	12.4
Al ₂ O ₃ wt%	1.1	4.0	0.8	7.1
MgO wt%	0.2	0.2	0.1	0.4
CaO wt%	0.2	0.1	0.2	0.5
ZrO ₂ wt%	0.3	0.2	0.2	4.4
Total	100.0	100.0	100.0	100.0

Average TiO ₂ content of all the TiO ₂ minerals:	59.2
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	56.5
Valuable heavy minerals in raw sand:	0.00

Geological Survey of Denmark and Greenland
Øster Voldgade 10, DK-1350 Copenhagen K
Ph.: +45 38142000, Fax: +45 38142050

Lab. Name:	779	Analyzed by:	JK
Submitter:	Henrik Stendal	Acc. Voltage	17kV
Date:	10/25/2004		



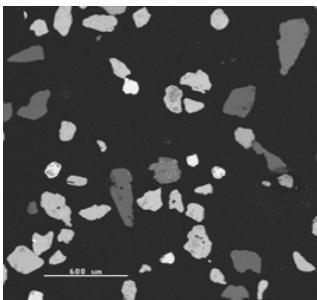
Average grain parameters					
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)
Ilmenite	1.6	1.7	503	188	13618
Leucoxene	1.5	1.7	503	187	13750
Rutile	1.4	1.6	439	157	12099
Ti magnetite	1.4	2.7	861	378	24220
Magnetite	0.0	0.0	0	0	0
Chromite	1.4	1.7	510	186	14049
Pyrite	0.0	0.0	0	0	0
Phosphate	0.0	0.0	0	0	0
Monazite	1.8	1.8	371	150	7210
Y-phosphate	0.0	0.0	0	0	0
Sphene	0.0	0.0	0	0	0
Garnet	1.6	2.4	1041	436	37748
Kya/Sill	2.1	2.2	866	355	32852
Staurolite	1.6	2.0	509	204	10652
Zircon	1.4	1.5	397	141	9625
Silicate	1.6	1.9	720	284	25908
Unclassified	1.4	2.0	546	229	15028



Geological Survey of Denmark and Greenland
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GEUS

Sample Name:	2000780	No. of frames analysed	39
Lab. Name:	780	No. of particles analysed:	870
Date:	10/25/2004	Heavy minerals in raw	
Submitter:	Henrik Stendal	sand (%):	0.00
Country:	Vietnam	Comments:	
Analyzed by:	JK		
Acc. Voltage/Magnification:	17kV/40x		
Guard region:	350 µm		
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	54.3	38.2	3.1	0.1	1.4	0.9	0.2	0.1	0.2	98.5
Leucoxene	78.6	10.0	1.2	0.2	4.6	2.3	0.2	0.2	0.8	98.0
Rutile	94.6	0.9	0.1	0.1	1.0	0.8	0.1	0.1	0.3	98.0
Ti magnetite	41.1	39.3	3.4	1.5	5.1	3.3	0.8	0.2	3.4	97.9
Magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromite	0.4	26.3	0.6	50.4	0.7	13.3	6.0	0.2	0.3	98.4
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	0.2	0.0	0.0	6.2	3.2	1.4	1.4	7.2	19.6
Y-phosphate	0.0	0.0	0.4	0.0	0.0	1.2	0.0	0.3	7.3	9.3
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.4	14.1	0.4	0.1	39.6	22.0	1.6	17.7	2.8	98.6
Kya/Sill	0.3	0.7	0.0	0.1	43.0	53.2	0.1	0.0	0.5	98.0
Staurolite	2.6	11.2	0.3	0.0	38.6	43.8	0.9	0.2	0.2	97.9
Zircon	0.2	0.4	0.2	0.2	28.9	0.1	0.1	64.1	94.7	
Silicate	0.7	7.7	0.2	0.2	48.0	35.6	3.2	1.4	0.3	97.2
Unclassified	6.4	7.9	0.5	2.0	13.1	33.5	6.1	1.7	15.0	86.2

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	63.2	6.5	6.6	4.8	4.3	11.0	0.6	3.2	100.0

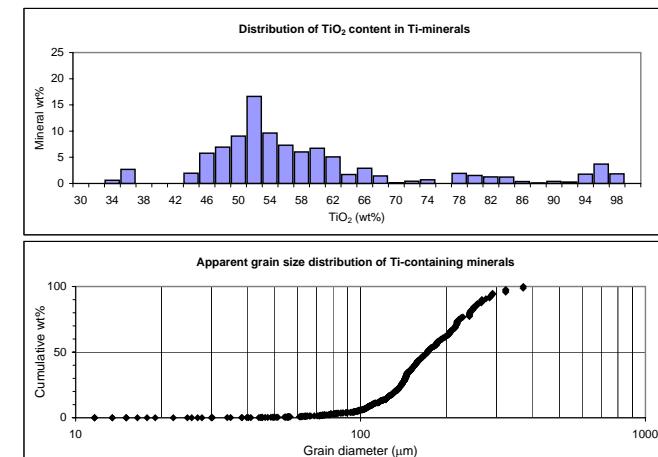
Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	55.1	80.2	96.5	41.9
Fe ₂ O ₃ wt%	38.8	10.2	1.0	40.1
MnO wt%	3.1	1.2	0.1	3.5
Cr ₂ O ₃ wt%	0.1	0.2	0.1	1.5
SiO ₂ wt%	1.4	4.7	1.0	5.2
Al ₂ O ₃ wt%	0.9	2.3	0.8	3.3
MgO wt%	0.2	0.2	0.1	0.8
CaO wt%	0.1	0.2	0.1	0.2
ZrO ₂ wt%	0.2	0.8	0.3	3.4
Total	100.0	100.0	100.0	100.0

Average TiO ₂ content of all the TiO ₂ minerals:	59.7
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	56.5
Valuable heavy minerals in raw sand:	0.00

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Lab. Name:	780	Analyzed by:	JK
Submitter:	Henrik Stendal	Acc. Voltage	17kV
Date:	10/25/2004		

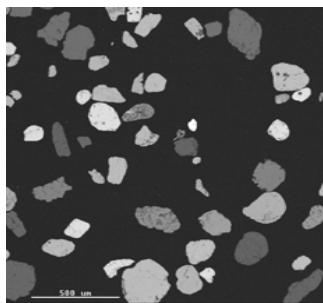


Average grain parameters					
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)
Ilmenite	1.5	1.7	548	207	15638
Leucoxene	1.4	1.9	862	337	34075
Rutile	1.3	1.7	611	229	20773
Ti magnetite	1.6	2.3	801	336	23730
Magnetite	0.0	0.0	0	0	0
Chromite	1.4	1.5	520	181	14114
Pyrite	0.0	0.0	0	0	0
Phosphate	0.0	0.0	0	0	0
Monazite	1.7	1.4	401	153	12618
Y-phosphate	1.5	1.3	411	122	10579
Sphene	0.0	0.0	0	0	0
Garnet	1.5	2.4	1180	499	46608
Kya/Sill	1.5	2.0	632	254	18198
Staurolite	1.5	2.3	1024	416	39845
Zircon	1.4	1.5	469	163	12226
Silicate	1.6	2.1	896	361	37651
Unclassified	1.6	2.2	849	351	32140



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Sample Name:	200781	No. of frames analysed	24
Lab. Name:	781	No. of particles analysed:	751
Date:	10/20/2004	Heavy minerals in raw	
Submitter:	Henrik Stendal	sand (%):	0.00
Country:	Vietnam	Comments:	
Analyzed by:	JK		
Acc. Voltage/Magnification:	17kV/50x		
Guard region:	275 µm		
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	54.5	37.7	2.7	0.1	1.8	1.2	0.2	0.1	0.2	98.5
Leucoxene	73.8	12.9	1.3	0.1	5.6	3.9	0.3	0.3	0.3	98.3
Rutile	93.2	1.2	0.1	0.1	2.0	0.8	0.1	0.2	0.2	97.9
Ti magnetite	40.8	33.8	2.6	0.1	6.1	0.6	0.4	0.7	7.0	92.1
Magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromite	0.3	28.4	1.5	48.5	1.0	12.8	5.8	0.5	0.1	98.9
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	1.9	0.0	0.0	9.2	8.7	0.5	0.0	7.4	27.7
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	0.6	12.8	0.5	0.0	39.4	21.9	0.1	22.9	0.2	98.4
Kya/Sill	0.3	0.4	0.1	0.1	42.8	53.7	0.1	0.4	0.1	97.9
Staurolite	1.3	12.4	0.3	0.1	34.1	47.9	1.7	0.4	0.2	98.4
Zircon	0.3	0.3	0.1	0.1	29.1	0.1	0.1	64.3	94.7	
Silicate	1.2	7.6	0.2	0.2	46.6	36.5	3.4	1.1	0.2	97.0
Unclassified	6.1	6.2	2.2	2.0	11.8	12.0	4.0	2.5	10.5	57.2

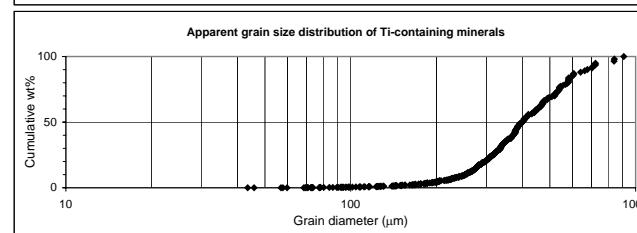
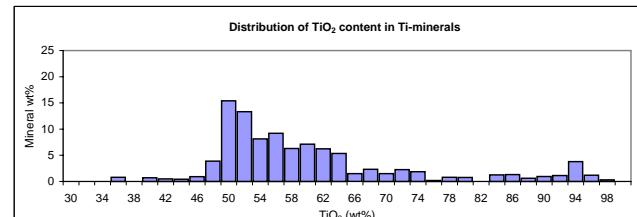
Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	64.6	9.0	7.5	2.0	2.4	9.9	2.5	2.1	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	55.3	75.0	95.2	44.3
Fe ₂ O ₃ wt%	38.3	13.1	1.2	36.7
MnO wt%	2.7	1.3	0.1	2.9
Cr ₂ O ₃ wt%	0.1	0.1	0.1	0.1
SiO ₂ wt%	1.8	5.7	2.1	6.6
Al ₂ O ₃ wt%	1.2	3.9	0.8	0.7
MgO wt%	0.2	0.3	0.1	0.4
CaO wt%	0.1	0.3	0.2	0.7
ZrO ₂ wt%	0.2	0.3	0.2	7.5
Total	100.0	100.0	100.0	100.0

Average TiO ₂ content of all the TiO ₂ minerals:	60.8
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	57.4
Valuable heavy minerals in raw sand:	0.00

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Lab. Name: 781 Analyzed by: JK
Submitter: Henrik Stendal Acc. Voltage: 17kV
Date: 10/20/2004



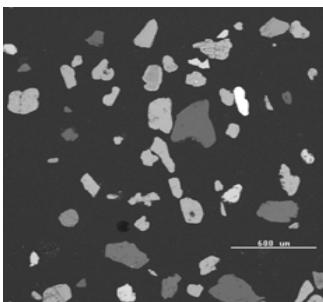
Category	Average grain parameters				
	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)
Ilmenite	1.5	1.8	1271	486	84182
Leucoxene	1.6	1.8	1540	600	119456
Rutile	1.5	1.7	1045	390	72560
Ti magnetite	1.4	2.2	1720	699	126430
Magnetite	0.0	0.0	0	0	0
Chromite	1.2	1.5	1274	431	104893
Pyrite	0.0	0.0	0	0	0
Phosphate	0.0	0.0	0	0	0
Monazite	1.7	1.6	482	173	11783
Y-phosphate	0.0	0.0	0	0	0
Sphene	0.0	0.0	0	0	0
Garnet	1.4	2.3	1996	839	158300
Kya/Sill	1.8	2.3	2202	919	203541
Staurolite	1.5	2.2	1559	639	92250
Zircon	1.4	1.6	1007	358	57936
Silicate	1.5	1.9	1756	690	148771
Unclassified	1.4	1.9	1444	570	111305
Total					100



Geological Survey of Denmark and Greenland
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GEUS

Sample Name:	2000782	No. of frames analysed	35
Lab. Name:	782	No. of particles analysed:	861
Date:	10/20/2004		
Submitter:	Henrik Stendal	Heavy minerals in raw sand (%):	0.00
Country:	Vietnam	Comments:	
Analyzed by:	JK		
Acc. Voltage/Magnification:	17kV/40x		
Guard region:	300 µm		
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	54.2	38.7	3.1	0.1	1.2	0.8	0.2	0.1	0.2	98.6
Leucoxene	78.9	10.3	1.0	0.1	4.0	2.2	0.3	0.3	1.4	98.6
Rutile	94.3	0.8	0.2	0.1	1.5	1.0	0.1	0.1	0.2	98.4
Ti magnetite	41.7	41.4	3.3	2.3	3.0	3.4	1.1	0.1	2.1	98.4
Magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromite	0.4	25.7	0.6	50.8	0.8	12.9	6.1	0.5	0.2	98.1
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	3.8	1.2	0.0	7.9	3.9	0.4	3.1	6.6	27.0
Y-phosphate	0.4	0.1	0.0	0.0	0.2	1.2	0.0	0.3	6.7	8.9
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.2	12.4	5.2	0.1	38.6	21.3	3.0	9.1	7.8	97.8
Kya/Sill	0.2	0.4	0.5	0.0	43.1	53.3	0.0	0.2	0.4	98.0
Staurolite	1.1	13.4	0.4	0.2	35.2	46.1	1.3	0.2	0.3	98.2
Zircon	0.2	0.3	0.2	0.2	28.9	0.1	0.1	64.2	94.6	
Silicate	0.7	7.1	0.2	0.1	49.0	35.2	3.2	1.4	0.2	96.9
Unclassified	7.0	7.1	1.2	0.7	10.4	44.1	5.3	1.3	9.3	86.4

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	66.0	7.2	4.9	3.8	3.7	9.8	0.4	4.3	100.0

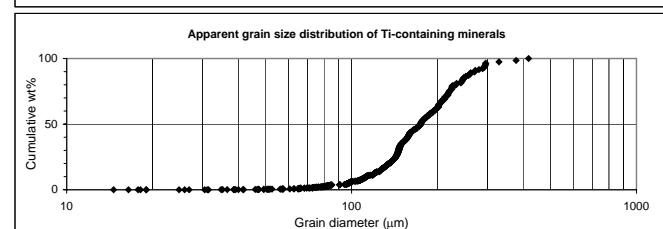
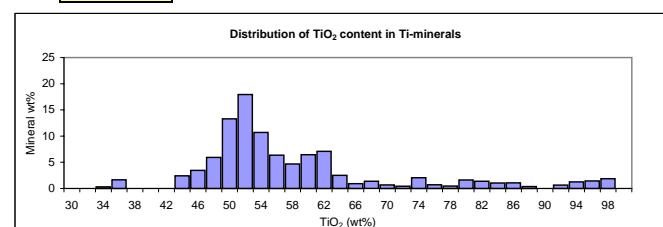
Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	54.9	80.1	95.9	42.4
Fe ₂ O ₃ wt%	39.2	10.5	0.8	42.1
MnO wt%	3.1	1.0	0.2	3.3
Cr ₂ O ₃ wt%	0.1	0.1	0.1	2.3
SiO ₂ wt%	1.2	4.1	1.5	3.0
Al ₂ O ₃ wt%	0.8	2.2	1.0	3.5
MgO wt%	0.2	0.3	0.1	1.1
CaO wt%	0.1	0.3	0.1	0.2
ZrO ₂ wt%	0.2	1.4	0.2	2.1
Total	100.0	100.0	100.0	100.0

Average TiO ₂ content of all the TiO ₂ minerals:	59.0
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	56.7
Valuable heavy minerals in raw sand:	0.00

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Lab. Name:	782	Analyzed by:	JK
Submitter:	Henrik Stendal	Acc. Voltage:	17kV
Date:	10/20/2004		

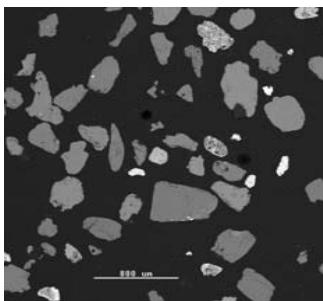


Average grain parameters					
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)
Ilmenite	1.5	1.7	568	215	16482
Leucoxene	1.6	2.1	930	373	35719
Rutile	1.3	1.8	587	223	18008
Ti magnetite	1.6	2.3	892	371	28345
Magnetite	0.0	0.0	0	0	0
Chromite	1.4	1.6	522	185	14239
Pyrite	0.0	0.0	0	0	0
Phosphate	0.0	0.0	0	0	0
Monazite	1.7	2.1	815	329	25947
Y-phosphate	1.5	1.8	507	190	11946
Sphene	0.0	0.0	0	0	0
Garnet	1.4	2.5	1115	471	44887
Kya/Sill	1.6	1.7	777	288	29767
Staurolite	1.5	2.0	807	321	31751
Zircon	1.5	1.6	482	170	12922
Silicate	1.6	2.0	885	354	37025
Unclassified	1.7	2.3	821	346	28801



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Sample Name:	200783	No. of frames analysed	23
Lab. Name:	783	No. of particles analysed:	696
Date:	10/26/2004	Heavy minerals in raw	
Submitter:	Henrik Stendal	sand (%):	0.00
Country:	Vietnam	Comments:	
Analyzed by:	JK		
Acc. Voltage/Magnification:	17kV/30x		
Guard region:	400 µm		
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	55.9	34.6	2.7	0.1	2.9	1.5	0.2	0.1	0.5	98.6
Leucoxene	75.6	4.8	0.5	0.1	14.4	2.6	0.3	0.2	0.2	98.5
Rutile	93.7	1.3	0.1	0.1	1.7	1.2	0.1	0.1	0.1	98.4
Ti magnetite	38.5	32.3	3.8	0.1	18.0	1.4	3.2	0.2	0.9	98.4
Magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
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	0.0	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	1.1	15.2	0.8	0.2	38.9	21.7	0.5	19.6	0.1	98.1
Kya/Sill	0.1	0.9	0.1	0.1	42.9	53.8	0.0	0.1	0.2	98.2
Staurolite	0.6	14.3	0.5	0.1	35.1	45.5	1.4	0.1	0.3	98.0
Zircon	0.2	0.2	0.2	0.2	28.5	0.0	0.1	64.3	0.0	93.7
Silicate	1.2	9.2	0.2	0.1	45.6	36.5	3.0	1.0	0.2	96.9
Unclassified	16.4	10.5	1.2	0.5	16.9	34.7	8.6	0.8	2.2	91.9

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	20.5	18.2	15.4	3.1	15.7	0.6	8.0	18.4	100.0

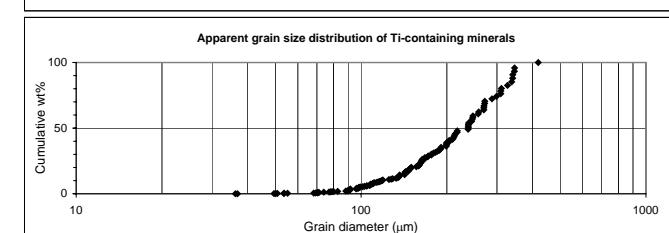
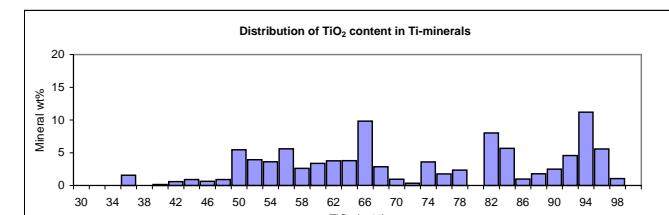
Normalised average contents of the valuable Ti-containing minerals:					
Average content	Category	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	56.8	76.8	95.2	39.2	
Fe ₂ O ₃ wt%	35.1	4.9	1.3	32.8	
MnO wt%	2.8	0.5	0.1	3.8	
Cr ₂ O ₃ wt%	0.1	0.1	0.1	0.1	
SiO ₂ wt%	2.9	14.6	1.7	18.3	
Al ₂ O ₃ wt%	1.5	2.6	1.2	1.4	
MgO wt%	0.2	0.3	0.1	3.2	
CaO wt%	0.1	0.2	0.1	0.2	
ZrO ₂ wt%	0.5	0.2	0.1	0.9	
Total	100.0	100.0	100.0	100.0	

Average TiO ₂ content of all the TiO ₂ minerals:	72.5
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	64.2
Valuable heavy minerals in raw sand:	0.00

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Lab. Name: 783 Analyzed by: JK
Submitter: Henrik Stendal Acc. Voltage: 17kV
Date: 10/26/2004

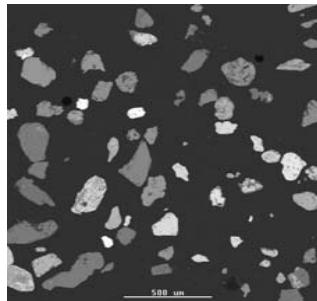


Category	Average grain parameters				
	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)
Ilmenite	1.5	1.7	549	204	15698
Leucoxene	1.5	1.7	880	330	40489
Rutile	1.5	1.8	843	327	37252
Ti magnetite	1.5	1.9	691	273	23750
Magnetite	0.0	0.0	0	0	0
Chromite	0.0	0.0	0	0	0
Pyrite	0.0	0.0	0	0	0
Phosphate	0.0	0.0	0	0	0
Monazite	0.0	0.0	0	0	0
Y-phosphate	0.0	0.0	0	0	0
Sphene	0.0	0.0	0	0	0
Garnet	1.5	2.0	895	357	37926
Kya/Sill	1.9	2.2	1136	464	54773
Staurolite	1.5	2.3	1017	435	42522
Zircon	1.4	1.4	328	109	6748
Silicate	1.6	2.0	960	379	43722
Unclassified	1.5	1.9	755	314	30246



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Sample Name:	2000784	No. of frames analysed	32
Lab. Name:	784	No. of particles analysed:	951
Date:	10/26/2004	Heavy minerals in raw	
Submitter:	Henrik Stendal	sand (%):	0.00
Country:	Vietnam	Comments:	
Analyzed by:	Jk		
Acc. Voltage/Magnification:	17kV/50x		
Guard region:	300 µm		
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	53.0	34.8	2.4	0.1	5.7	1.8	0.2	0.1	0.2	98.4
Leucoxene	73.5	4.4	0.2	0.2	15.2	3.7	0.3	0.1	0.3	97.9
Rutile	91.3	2.0	0.2	0.1	2.9	1.5	0.2	0.1	0.2	98.5
Ti magnetite	39.2	37.1	1.8	0.1	12.6	4.4	0.4	0.8	0.4	96.9
Magnetite	2.5	75.7	0.2	0.2	10.7	7.3	0.4	0.1	0.3	97.4
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	35.0	1.3	0.2	0.0	28.5	3.3	0.2	27.4	0.0	95.9
Garnet	0.8	13.1	0.5	0.1	40.6	21.0	1.2	20.2	0.1	97.7
Kya/Sill	0.1	1.0	0.0	0.0	42.7	53.6	0.0	0.2	0.6	98.2
Staurolite	0.9	15.7	0.4	0.2	32.4	47.6	0.9	0.1	0.1	98.3
Zircon	0.2	0.6	0.1	0.1	29.0	0.3	0.1	63.7	94.4	
Silicate	3.4	11.1	0.2	0.1	55.3	17.8	3.8	4.2	0.2	96.0
Unclassified	15.9	14.7	1.2	0.3	26.1	14.3	2.3	2.0	9.3	85.9

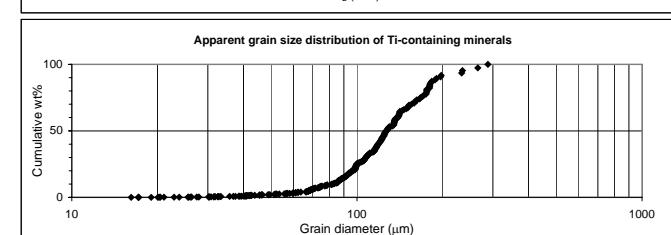
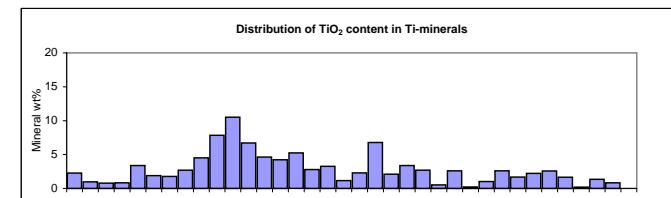
Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	33.9	13.5	7.1	10.3	24.9	5.4	0.5	4.3	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO ₂ wt%	53.8	75.1	92.7	40.5
Fe ₂ O ₃ wt%	35.4	4.5	2.0	38.3
MnO wt%	2.5	0.3	0.2	1.9
Cr ₂ O ₃ wt%	0.1	0.2	0.1	0.1
SiO ₂ wt%	5.8	15.5	2.9	13.0
Al ₂ O ₃ wt%	1.8	3.8	1.5	4.5
MgO wt%	0.2	0.3	0.2	0.4
CaO wt%	0.1	0.1	0.1	0.8
ZrO ₂ wt%	0.3	0.3	0.2	0.4
Total	100.0	100.0	100.0	100.0

Average TiO ₂ content of all the TiO ₂ minerals:	60.4
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	56.4
Valuable heavy minerals in raw sand:	0.00

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Lab. Name:	784	Analyzed by:	Jk
Submitter:	Henrik Stendal	Acc. Voltage:	17kV
Date:	10/26/2004		



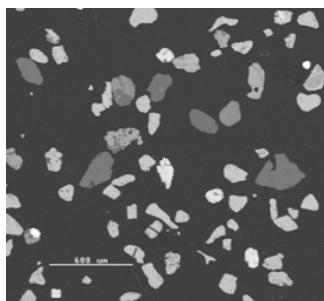
Category	Average grain parameters				
	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)
Ilmenite	1.6	1.7	383	145	7871
Leucoxene	1.6	1.7	443	169	10372
Rutile	1.5	1.7	394	145	8964
Ti magnetite	1.5	1.9	456	183	10649
Magnetite	1.5	1.8	442	168	10579
Chromite	0.0	0.0	0	0	0
Pyrite	0.0	0.0	0	0	0
Phosphate	0.0	0.0	0	0	0
Monazite	0.0	0.0	0	0	0
Y-phosphate	0.0	0.0	0	0	0
Sphene	2.0	2.2	380	157	5246
Garnet	1.5	1.8	389	151	7888
Kya/Sill	1.6	2.3	923	386	29039
Staurolite	1.7	2.3	566	236	12860
Zircon	1.7	1.6	355	129	6838
Silicate	1.6	1.8	462	182	11780
Unclassified	1.5	1.9	468	191	11835



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GEUS

Sample Name:	2000785	No. of frames analysed	38
Lab. Name:	785	No. of particles analysed:	1274
Date:	10/27/2004		
Submitter:	Henrik Stendal		
Country:	Vietnam		
Analyzed by:	JK		
Acc. Voltage/Magnification:	17kV/40x		
Guard region:	275 µm		
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	51.3	40.4	3.0	0.1	2.3	1.0	0.1	0.1	0.2	98.6
Leucoxene	75.4	5.2	0.6	0.1	13.3	2.8	0.1	0.1	0.4	98.0
Rutile	92.0	1.2	0.1	0.1	3.0	1.5	0.0	0.1	0.2	98.2
Ti magnetite	40.0	38.9	2.2	0.2	11.1	2.5	0.2	0.7	1.3	97.1
Magnetite	0.7	71.6	0.7	0.2	11.1	9.8	1.1	0.2	0.7	96.0
Chromite	0.4	17.7	0.6	37.8	0.7	28.3	13.0	0.1	0.0	98.6
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	1.1	0.0	0.0	23.4	3.7	0.6	0.4	6.9	36.0
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	0.3	23.2	0.5	0.1	38.6	19.7	0.6	14.2	0.1	97.4
Kya/Sill	0.3	0.3	0.3	0.3	42.8	53.6	0.0	0.0	0.0	97.6
Staurolite	0.8	16.0	0.5	0.1	31.1	47.9	1.2	0.1	0.4	98.2
Zircon	0.3	0.5	0.2	0.1	29.3	0.3	0.1	0.2	63.4	94.3
Silicate	3.0	9.9	0.2	0.1	50.6	28.5	2.7	0.9	0.3	96.3
Unclassified	10.8	11.3	1.0	0.3	16.4	10.3	1.5	2.3	17.0	70.8

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	72.8	5.2	4.8	5.5	1.3	10.0	0.1	0.3	100.0

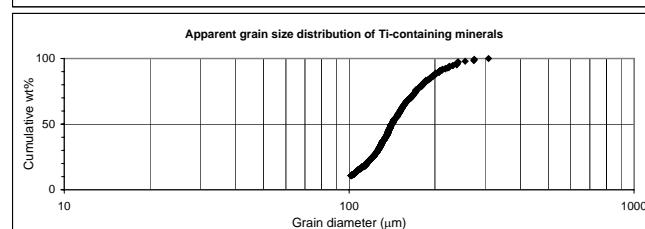
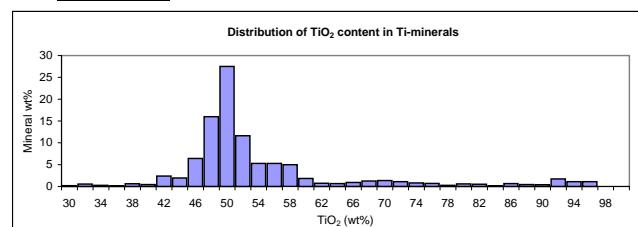
Normalised average contents of the valuable Ti-containing minerals:			
Average content	Category	Ilmenite	Leucoxene
TiO ₂ wt%	Ilmenite	52.1	77.0
Fe ₂ O ₃ wt%	Leucoxene	41.0	5.3
MnO wt%	Rutile	3.0	0.6
Cr ₂ O ₃ wt%	Ti magnetite	0.1	0.1
SiO ₂ wt%	Garnet	2.4	13.6
Al ₂ O ₃ wt%	Zircon	1.0	3.0
MgO wt%	Chromite	0.1	2.2
CaO wt%	Pyrite	0.1	0.2
ZrO ₂ wt%	Phosphate	0.2	0.7
Total	Monazite	100.0	100.0
	Y-phosphate		
	Sphene		
	Garnet		
	Kya/Sill		
	Staurolite		
	Zircon		
	Silicate		
	Unclassified		

Average TiO ₂ content of all the TiO ₂ minerals:	55.1
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	52.9
Valuable heavy minerals in raw sand:	0.00

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Lab. Name:	785	Analyzed by:	JK
Submitter:	Henrik Stendal	Acc. Voltage	17kV
Date:	10/27/2004		



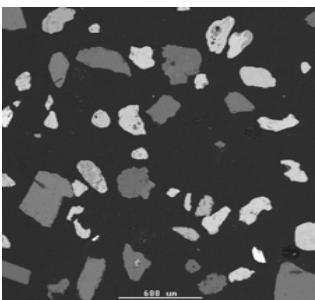
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	Total grains
Ilmenite	1.5	1.7	482	179	12248	804
Leucoxene	1.5	1.9	564	220	15098	47
Rutile	1.6	1.8	530	201	13221	44
Ti magnetite	1.6	1.7	452	176	11105	63
Magnetite	1.4	1.6	692	260	35280	18
Chromite	1.8	1.7	667	251	20650	1
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.3	1.6	285	102	4400	5
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.5	2.1	971	377	39692	5
Kya/Sill	1.4	1.8	765	297	25373	1
Staurolite	1.8	1.8	436	177	8707	5
Zircon	1.4	1.5	408	141	9647	135
Silicate	1.5	1.9	764	299	28466	98
Unclassified	1.5	1.6	490	186	18941	48



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G E U S

Sample Name:	2000786	No. of frames analysed	28
Lab. Name:	786	No. of particles analysed:	735
Date:	10/29/2004	Heavy minerals in raw	
Submitter:	Henrik Stendal	sand (%):	0.00
Country:	Vietnam	Comments:	
Analyzed by:	JK		
Acc. Voltage/Magnification:	17kV/40x		
Guard region:	300 µm		
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	53.4	39.5	3.2	0.1	1.2	0.7	0.2	0.1	0.3	98.7
Leucoxene	75.4	13.4	1.1	0.1	5.1	2.2	0.3	0.1	0.2	98.1
Rutile	94.4	1.3	0.2	0.1	1.0	0.8	0.1	0.1	0.1	98.3
Ti magnetite	38.1	36.3	3.1	0.2	11.4	4.6	0.9	0.4	0.8	95.8
Magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromite	0.3	28.5	0.5	50.0	1.2	11.9	5.7	0.1	0.3	98.5
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	0.7	0.0	0.0	7.5	0.8	0.3	1.9	7.7	18.8
Y-phosphate	0.2	0.0	0.0	0.0	0.0	0.9	0.0	1.1	6.1	8.3
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.3	16.0	0.6	0.2	38.0	21.0	0.6	20.4	0.2	97.3
Kya/Sill	0.4	0.4	0.1	0.1	42.8	53.2	0.0	0.1	0.3	97.4
Staurolite	0.8	13.8	0.4	0.1	34.7	46.3	1.3	0.4	0.3	98.1
Zircon	0.2	0.3	0.2	0.1	29.0	0.1	0.1	64.1	94.4	
Silicate	1.0	8.5	0.2	0.2	45.1	38.1	2.9	0.8	0.2	
Unclassified	1.8	3.7	0.6	0.1	8.9	28.9	4.0	4.4	10.4	62.8

Valuable heavy minerals									
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	68.1	4.4	4.0	3.3	3.0	12.1	0.1	4.9	100.0

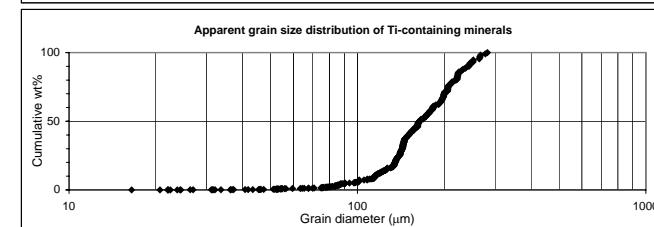
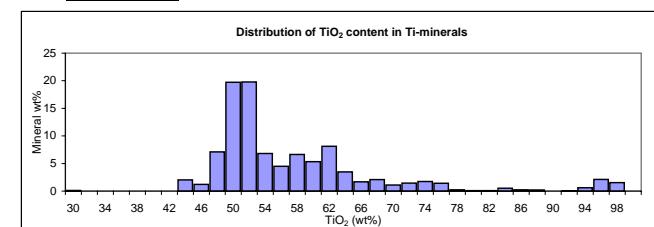
Normalised average contents of the valuable Ti-containing minerals:			
Average content	Ilmenite	Leucoxene	Category
TiO ₂ wt%	54.1	76.9	96.1
Fe ₂ O ₃ wt%	40.0	13.7	1.3
MnO wt%	3.2	1.1	0.2
Cr ₂ O ₃ wt%	0.1	0.1	0.1
SiO ₂ wt%	1.2	5.2	1.0
Al ₂ O ₃ wt%	0.7	2.3	0.8
MgO wt%	0.2	0.3	0.1
CaO wt%	0.1	0.1	0.1
ZrO ₂ wt%	0.3	0.3	0.1
Total	100.0	100.0	100.0

Average TiO ₂ content of all the TiO ₂ minerals:	56.9
Average TiO ₂ content of all the TiO ₂ minerals excl. rutile:	54.8
Valuable heavy minerals in raw sand:	0.00

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Lab. Name:	786	Analyzed by:	JK
Submitter:	Henrik Stendal	Acc. Voltage	17kV
Date:	10/29/2004		



Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm ²)	Total grains
Ilmenite	1.6	1.7	555	208	16253	338
Leucoxene	1.7	1.8	604	222	19744	18
Rutile	1.5	1.8	521	201	13269	22
Ti magnetite	1.5	2.0	709	295	22592	11
Magnetite	0.0	0.0	0	0	0	0
Chromite	1.4	1.8	659	242	19645	5
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.5	1.5	408	136	8903	3
Y-phosphate	1.4	1.6	444	162	9670	1
Sphene	0.0	0.0	0	0	0	0
Garnet	1.5	2.1	604	249	17109	16
Kya/Sill	1.9	1.7	394	150	7209	2
Staurolite	1.7	1.9	605	237	19529	24
Zircon	1.4	1.5	441	158	10852	87
Silicate	1.6	2.0	761	304	28332	171
Unclassified	1.5	1.9	602	242	17655	37