DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2003/12

Heavy Mineral Sands in Vietnam 2002

Henrik Stendal

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF THE ENVIRONMENT

GEUS

DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2003/12

Heavy Mineral Sands in Vietnam 2002

Henrik Stendal

Released 01.04.2005

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF THE ENVIRONMENT

GEUS

Contents

Abstract

The fieldwork was carried out in three chosen areas in the provinces of Ha Tinh (#23 on Fig. 1), Binh Dinh (#30 on Fig. 1) and Binh Thuan (#39 on Fig. 1). The samples are of different types such as raw sand, pre-concentrated ilmenite, and separates of ilmenite, rutile, zircon and monazite. The average grain-size is between 100-200 μm.

With respect to information given on the tour, it was anticipated that the chance for getting high-grade ilmenite was best in the Binh-Dinh province where the clean ilmenite separate should contain 54-56 TiO_2. The analytical results obtained give another story and pin point the Ha Tinh province especially the Ky Khang area as the most promising area with high-grade ilmentie with total TiO_2% above 60 %. A second area of possible interest would be the Bin Thuan province with TiO_2 grade up to 58%. The latter area is a big province and the fieldwork had only visited a small part of the potential HM deposits.

It is recommended to do more work in the Binh Thuan region, where we only have a few samples and our fieldwork was very sporadic. However, in this region there are possibilities for large deposits and this study show promising results concerning the possibility for high-grade ilmenite. In the Ha Tinh province, especially the Ky Khang area, where the highest TiO_2% is obtained, it is recommended to get more precise figures of deposit size and tonnage's of the heavy minerals.

Figure 1. ***From O'Driscoll 1996.***

Introduction

In the international “scouting” program for high-grade ilmenite deposits outside Denmark, Vietnam had long been one of the countries we wanted to have a closer look at the black sands. We decided to make contact to the authorities in Vietnam and got an excellent joint project together with the Department of Geology and Minerals of Vietnam (DGMV) in Ha-noi. The results of the joint project are reported here in the following pages.

The joint venture heavy mineral sampling tour between the Department of Geology and Minerals of Vietnam (DGMV) and the Geological Survey of Denmark and Greenland (GEUS) took place from February 24 to March 13 (travel included). The study was carried out for I.E. du Pont de Nemours & Co. The fieldwork was carried out during an 11 day’s period, the tour was nearly 4,200 km long and three main areas was visited and sampled. The plan for the tour and the itinerary was as follows:

February 24 – departure Denmark
February 25 – arrival Hanoi, Vietnam via a transit in Bangkok
February 26 – meetings at DGMV
February 27 – fieldtrip start – Ha Tinh – 375 km
February 28 – fieldwork in the Cam Xuyen area – 160 km
March 1st – fieldwork in the Ky Anh area – 136 km
March 2nd – Ha Tinh to Da nang – 456 km
March 3rd – Da nang to Quy Nhon – 360 km
March 4 – preparation for fieldwork in Cat Khanh area – 140 km
March 5 – fieldwork in the Cat Khang area – 260 km
March 6 – Quy Nhon – Phan Thiet – 503 km
March 7 – fieldwork in Ham Tan area and drive to Nha Trang – 443 km
Mach. 8 – Nha Trang – Danang – 559 km
March 9 – Danang – Thanh Hoa – 625 km
March 10 – Thanh Hoa – Hanoi –176 km. - meeting at DGMV.
March 11 – meetings at DGMV
Mach. 8 – Nha Trang – Danang – 559 km
March 9 – Danang – Thanh Hoa – 625 km
March 10 – Thanh Hoa – Hanoi –176 km. - meeting at DGMV.
March 11 – meetings at DGMV
March 12 – departure from Hanoi to Bangkok
March 13 – Bangkok to Denmark.

The field party consisted of Deputy Director Mr. Hop from DGMV and Mr. Trinh from the International Co-operation Department, DGMV was the interpreter on the field trip (Figure 2). The driver, Mr. Tinh, of the Toyota four-wheel vehicle was the third Vietnamese com-panion on the tour. The sample list is given in Table 1 and sample locations in Figure 3.

Figure 2. *The field party at Cam Hoa # 1. From left to right: The chief of the miners groups in Cam Hoa # 1 Mr. Chat, the guide from the Ha Tinh Minerals Office Mr. Nam, Deputy Director Mr. Hop from DGMV and Interpreter Mr. Trinh from DGMV. In the background the spiral concentrators can be seen with the pre-concentrated black sands in front.*

Objective

The main objectives of the heavy mineral joint project in Vietnam are:

To locate an ilmenite deposit with approximately 3 % ilmenite (TiO_2 > 58 %), rutile, leucoxene and zircon combined and heavy mineral (HM) grain-size > 100 micron. The volume should be approximately 100 mill t raw ore and overburden < 15 m.
To fulfil this aim samples from selected deposits in Vietnam were collected and the grade of the ilmenite determined as well as the HM paragenesis.

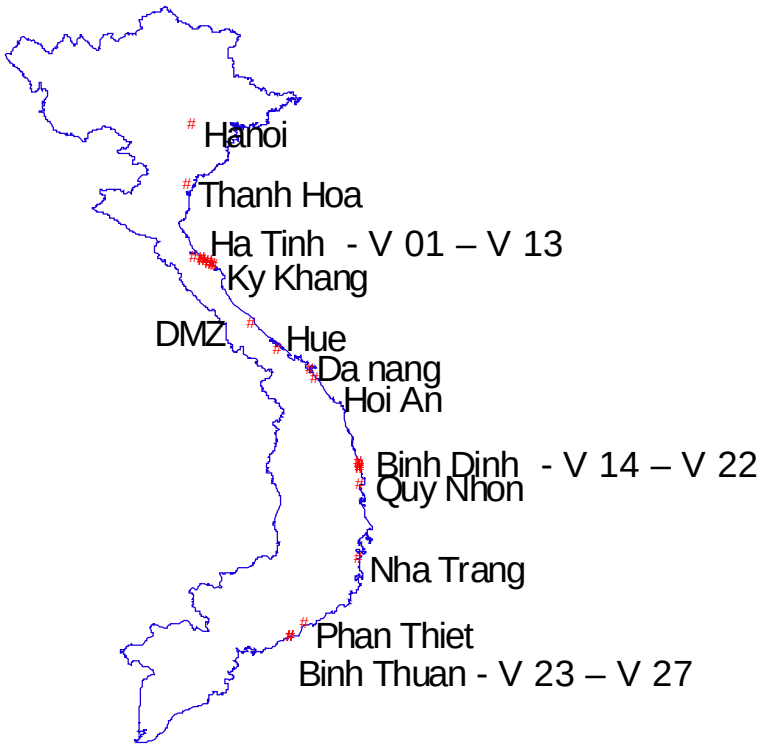


Figure 3. *Sample localities*

Sample #	Lab.no.	Latitude	Longitude	Date	Sample type
V 01	2000181	18.3261556	106.0293906	28-Feb-02	Raw sand
V 02	2000182	18.3261556	106.0293906	01-Mar-02	Pre-concentrated HM sand
V 03	2000183	18.3041024	106.0486972	28-Feb-02	Pre-concentrated HM sand
V 04	2000184	18.3039254	106.0495287	28-Feb-02	Raw sand
V 05	2000185	18.2811910	106.0827505	28-Feb-02	Pre-concentrated HM sand
V 06	2000186	18.2814914	106.0845637	28-Feb-02	Raw sand
V 07	2000187	18.2456088	106.1916428	28-Feb-02	Raw sand
V 08	2000188	18.2456088	106.1916428	28-Feb-02	Ilmenite 99% concentrate
V 09	2000189	18.2270426	106.2179392	28-Feb-02	Raw sand
V 10	2000190	18.2264096	106.2181055	28-Feb-02	Pre-concentrated HM sand
V 11	2000191	18.1699974	106.2840396	01-Mar-02	Pre-concentrated HM sand
V 12	2000192	18.1711507	106.2832081	01-Mar-02	Raw sand
V 13	2000193	18.1711507	106.2832081	02-Mar-02	Ilmenite 99% concentrate
V 14	2000194	14.2119474	109.1800260	05-Mar-02	Raw sand
V 15	2000195	14.2123604	109.1812437	05-Mar-02	Raw sand
V 16	2000196	14.0939731	109.2066174	05-Mar-02	Raw sand
V 17	2000197	14.0962261	109.2068749	05-Mar-02	Pre-concentrated HM sand
V 18	2000198	14.1242552	109.2042249	05-Mar-02	Ilmenite 99% concentrate (B-clean)
V 19	2000199	14.1242552	109.2042249	06-Mar-02	Ilmenite 99% concentrate (A-clean)
V 20	2000200	14.1242552	109.2042249	07-Mar-02	Rutile separate
V 21	2000201	14.1242552	109.2042249	08-Mar-02	Monazite separate
V 22	2000202	14.1242552	109.2042249	09-Mar-02	Zircon separate
V 23	2000203	10.7048089	107.8229302	07-Mar-02	Raw sand
V 24	2000204	10.7009626	107.8176408	07-Mar-02	Raw sand
V 25	2000205	10.7009626	107.8176408	08-Mar-02	Ilmenite 99% concentrate
V 26	2000206	10.7009626	107.8176408	09-Mar-02	Rutile separate - 80-82%
V 27	2000207	10.7009626	107.8176408	10-Mar-02	Zircon separate - 57%
DMZ		17.0050925	107.0509368	02-Mar-02	Visit
HANOI		21.0224033	105.8601701	25-Feb-02	Overnight. DGMV.
HA TINH		18.3382416	105.8953177	27-Feb-02	Overnight
HOI AN		15.8763278	108.3286231	03-Mar-02	Visit
HUE		16.4672131	107.5796216	02-Mar-02	Visit
NHA TRANG		12.2651035	109.1955023	06-Mar-02	Overnight
PHAN THIET		10.9406823	108.1028616	07-Mar-02	Overnight
QUYNH'N		13.7564224	109.2187678	04-Mar-02	Overnight
THANH HOA		19.7974921	105.7761526	09-Mar-02	Overnight
Thinh Cam		18.2794100	106.0952120	28-Feb-02	Visit

Table 1. *Sample and locality list with geographical co-ordinates in decimal grades.*

Previous investigations

In the magazine Industrial Minerals an article by O'Driscoll (1996) focussed on minerals in Vietnam with the subtitle 'Sands' future black & white'. The article mentioned that 40 heavy mineral deposits occurred in Vietnam (Fig. 1). Proven reserves are estimated to total some 11 million tonnes of titanium minerals and 0.5 million tonnes zircon. The principal titanium mineral is ilmenite accounting for approximately 10 million tonnes, while some rutile and leucoxene are also of value. In addition, zircon, monazite, and xenotime also count for some value.

The deposits are described as coastal placer deposits (O'Driscoll 1996) distributed along the coast and are hosted in Quarternary sediments. In most placer deposits, fine-grained fractions (0.05-0.15 mm) are dominant and occupy around 80%. Some figures on the different HM deposits are given in the UN ESCAP report from 1990 (Loan 1990).

Another source used in this report is facts deduced from senior expert Dr. Nguyen Van Quy, DGMV who outlined the heavy mineral deposits of Vietnam in a lecture at DGMV. Dr. Nguyen Van Quy told about the three major areas that we were going to visit during the fieldtrip. The three areas are (1) Ha Tinh Province, (2) the Binh Dinh Province, and (3) the Binh Thuan Province. Figures concerning tonnes, sizes and grades in this report are referred from this lecture, from local guides and from different not published DGMV notes.

Analytical methods

The analysis by Computer Controlled Scanning Microscopy (CCSEM) is described in detail in Knudsen and Appel (2000). Layout of data sheet can be seen in Appendix 1 where the results of the individual samples are given. The average grain parameters are shown within each mineral category. The grain curve is only based on the Ti-containing minerals – this means that only grains which fall within the categories Ti-magnetite, ilmenite, leucoxene or rutile are contained in the grain curve. The analytical result of each mineral is given in an table as well as tables yielding normalised average contents of the valuable Ti-containing minerals and the weight percentage based on the individual minerals. The concentration limits of the cations in weight % are given below.

Ilmenite: Fe + Ti >= 60; Ti >= 42.3; Ti < 66.8
Leucoxene: Fe + Ti >= 60; Ti >= 66.8; Ti < 85.8
Rutile: Fe + Ti >= 65; Ti >= 85.8
Ti magnetite: Fe + Ti >= 60; Ti < 42.3; Ti > 15
Magnetite: Fe > 60; Ti <= 15; Cr <= 10; S < 40
Chromite: Fe + Cr > 60; Cr > 10
Pyrite: S > 40; Fe >= 20; Fe + S >= 60
Phosphate: P > 25; Zr < 3.5; Y < 10
Monazite: P > 10; Ce > 20; Zr < 10
Y-phosphate: P > 22; Y > 10; Zr < 10
Sphene: Ca + Si + Ti >= 90; Ca >= 25; Ti >= 25
Garnet: Si / Al > 1.5; Si / Al < 1.8; Si > 25; Si < 42; Al > 15; Al < 28; Ca < 10
Sillimanite: Al > 55; Si < 40; Si > 30; Fe < 5
Staurolite: Al + Si > 70; Fe > 10; Fe < 30; Al > 40; Al < 60
Zircon: Si > 18; Zr > 65
Silicate: Na + Mg + Al + Si + K + Ca > 50; Zr < 3.5; Si > 20

Analytical control

As analytical control five ilmenite concentrates were analysed by both XRF and CCSEM. In Figure 4 and Table 2 the results are shown together with results from the raw samples which make the basis for the concentrate samples.

Sample no. Concentrate	Lab. no. Concentrate	Concentrate XRF TiO_2 %	Concentrate CCSEM TiO_2 %	Raw sample CCSEM TiO_2 %	Sample no. Raw sample
V 08	2000188	53.1	52.6	54.5	**V 06**
V 13	2000193	56.9	58.4	59.9	**V 11**
V 18	2000198	56.2	60.3	52.1	**V 15**
V 19	2000199	50.5	52.3	52.5	**V 17**
V 25	2000205	52.8	53.5	55.0	**V 24**

Table 2. *CCSEM results of ilmenite concentrates and raw samples compared to XRF analyses of the ilmenite concentrates.*

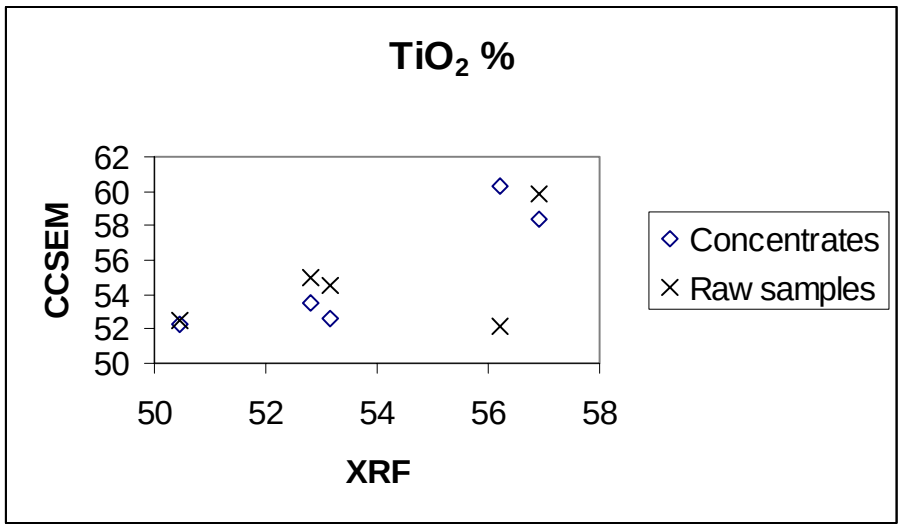


Figure 4. *CCSEM results of ilmenite concentrates and raw samples compared to XRF analyses of the ilmenite concentrates.*

The results in Table 2 show that the TiO_2 values of the CCSEM are slightly higher than the XRF analyses. The raw samples V 15 and V 17 deviate from the concentrate samples by given much lower values. The concentrate samples V 18 and V 19 are samples from the same deposit and should be equivalent in content to the raw samples V 15 and V 17. The two concentrate samples (V 18 and V 19) are given to us by Mr. Doan at the concentrator plant and explained as A and B cleaned ilmenite concentrate. The reason for the controversy in the results between V 18 and V 19 is not completely clear. It is not an analytical failure due to duplicate analyses of the samples and the duplicates gave the same results. Polished sections of sample V18 and V 19 did not show a great difference between the two samples. They have ilmenite and in addition up to 5% rutile, some zircon and monazite. Sample V 18 yields the high TiO_2 content and the XRF analytical results have higher Cr, Y, Nb, Zr, La and Ce than sample V 19 (Appendix 2). However, this high TiO_2 value is not the typical content of the deposit compared to the results of the raw sample (V 15 and V 17) and the other concentrated sample (V 19). It is concluded that the average content for this particular deposit is close to 52 TiO_2 % (see description of the sample locality from the Binh Dinh area).

Results

Ha Tinh Province

The heavy mineral sand of the Ha Tinh region is all of the aeolian type found in sand dunes. The ilmenite content of the regions is estimated to be 6-7 million tonnes (Table 4). Associated minerals are rutile, leucoxene, zircon and monazite, which also are exploited. The zircon content of the area is estimated to be more than 250,000 t.
The mines in the area belong to the Ha Tinh Minerals and Trading Company, which con-

Figure 5. *Cam Hoa # 1 open pit. The black sand layer is close to the water table.*

centrate and separate the heavy minerals locally. Vietnam does not have their own processing plant, thus all products are sold. The ilmenite concentrates goes to Japan and only a smaller part go to South Korea and Malaysia. Zircon and monazite are sold to China.

Sampling

Together with a guide, Mr. Nam, from the local Minerals Office in Ha Tinh we visited five operating heavy mineral mines. The three first belongs to the Cam Hoa deposit, which is up to 18 km long and approximately one km wide in the Cam Xuyen area. The Cam Hoa belongs to the Ha Tinh Minerals and Trading Company. The Cam Hoa mines have1-5m overburden of sand before you reach the 1-5 m thick heavy mineral layer (Fig. 5). It looks like that the content of heavy minerals is highest in the northern part of the area and lowest in the southern part. The HM sands are deposited in sand dunes inland some km from the coast. From all three Cam Hoa mines a spiral centrifuge pre-concentrates the sand to a heavy mineral content of 80-85% (Figs. 2 and 5). The landscape is restored after the mining by planting of trees.

Cam Hoa # 1

The chief of the miners group, Mr. Chat, showed the mine to us (Fig. 5). The HM layer is here in average 1,5 m thick (max. 3m). The mining company only licence in a 500-m belt but the orebody is here one km wide.
Sample V 01 – 2000181 – Raw sand sample.
Sample V 02 – 2000182 – Pre-concentrated HM sand with 80-85% HM.

Cam Hoa # 2

The chief of the miners group, Mr. Ky, showed the mine to us. The heavy mineral bed is 1-5 m thick and average 3-m (Fig. 6). The content of HM is lower than in Cam Hoa # 1 but the ilmenite content is very erratic from 1-70% of the raw sand.
Sample V 03 – 2000183 – Pre-concentrated HM sands.
Sample V 04 – 2000184 – Raw sand sample of dune.

Figure 6. *Cam Hoa # 2 open pit. The grey layer in the middle of the profile is the heavy mineral bed. From left to right: The chief of the miners groups in Cam Hoa # 2 Mr. Ky, the Interpreter Mr. Trinh from DGMV, the guide from the Ha Tinh Minerals Office Mr. Nam, Deputy Director Mr. Hop from DGMV.*

Cam Hoa # 3

The director of the mine enterprise, Mr. Dinh, showed the mine to us. This mine has a rather low HM content with 1-2%. The cut-off grade is one- % ilmenite. The concentrator is here more modern and automatic than the two first mines. It was an Australian concentrator with a capacity of 120 t/h.

Sample V 05 – 2000185 – Pre--concentrated HM sands.
Sample V 06 – 2000186 – Raw sand sample from the mine but with relatively low HM content.

Heavy minerals (black sands) in the beach sand in the Cam Hoa area are nearly absent.

Kyxuan # 1

This mine belongs to Company No. 4 under the Vietnam National Minerals Corporation, Ministry of Industry. The director of Company No. 4 showed us the mine. The orebody is 1.5 km long and 200 m wide with a thickness of 3-5 m. It is a sand dune (Fig. 7) one km from the coast with very high contents of heavy minerals. The Company 4 has its own plant for concentration and separation and delivers 99% pure ilmenite concentrate. The production is 15-20,000 t/year of ilmenite concentrate.
Sample V 07 – 2000187 – Raw sand sample – rich in HM.
Sample V 08 – 2000188 – 99% ilmenite separate.

Figure 7. *Left: Sand dunes with heavy minerals, Kyxuan # 1. Right: Pre-concentrated black sand, Kyxuan # 2.*

Kyxuan # 2

This mine is 1.3 km long and 100 m wide with heavy minerals in a thickness of 6-9 m. The mine produce 9,000 t/year. The sand is pre-concentrated by washing at site and gives a concentrate with 54% ilmenite (Fig. 7).
Sample V 09 – 2000189 – Raw sand sample.
Sample V 10 – 2000190 – Pre-concentrated HM sand with 54% ilmenite.

Figure 8. *Ky Khang Heavy mineral deposit. The deposit is hosted in a layered (cm-dm dark layering) sand dune.*

Ky Khang

Ky Khang is located 50 km south of Ha Tinh. The deposit also belongs to the Ha Tinh Minerals and Trading Company and is the largest deposit in the Ha Tinh region. The Ky Khang deposit is 7.2 km long, 1-km wide and the HM bed is 7 m thick and contains up to 15% HM with 3 million t of HM. The deposit is hosted in a layered (cm-dm layering) sand dune (Fig. 8). The heavy minerals are ilmenite, leucoxene, rutile, zircon and monazite but in general fine-grained. The fine-grained sand sometimes causes problems in the separation process. Zircon and monazite are sold to China and most of the ilmenite concentrates goes to Japan and only a smaller part go to South Korea and Malaysia. The separation of the minerals is done on site in the Ky Anh ilmenite concentration plant, which has the ISO 9001 Standard certificate.
Sample V 11 – 2000191 – Pre-concentrated HM sands.
Sample V 12 – 2000192 – Raw sample from top of the HM bed.
Sample V 13 - plant site – 2000193 - Ilmenite separate.

Analytical results

The TiO_2 content of the ilmenite is especially interesting in the Ky Khang area, where the TiO_2 content of the ilmenite concentrate varies from 54 to 56% and the overall TiO_2% is over 60 (Tables 3 and 4). In the areas outside Ky Khang TiO_2 is lower around 54%. The heavy minerals are ilmenite, leucoxene, rutile, zircon and monazite but in general fine-grained. The fine-grained sand sometimes causes problems in the separation process. The XRF values in Table 2 are from an ilmenite concentrate. The detailed results from the

CCSEM analyses can bee seen in Appendix 1 and Table 7 (V01-V13) and XRF results in Appendix 2 (Sample V 13).

The grain size of the samples from the region range normally from 100-200µ. In Figure 9 the grain size distribution is given from Ky Khang where the grain size is a little bit more fine-grained than the average from the area. The TiO_2 analytical results from CCSEM and XRF yielded similar figures.

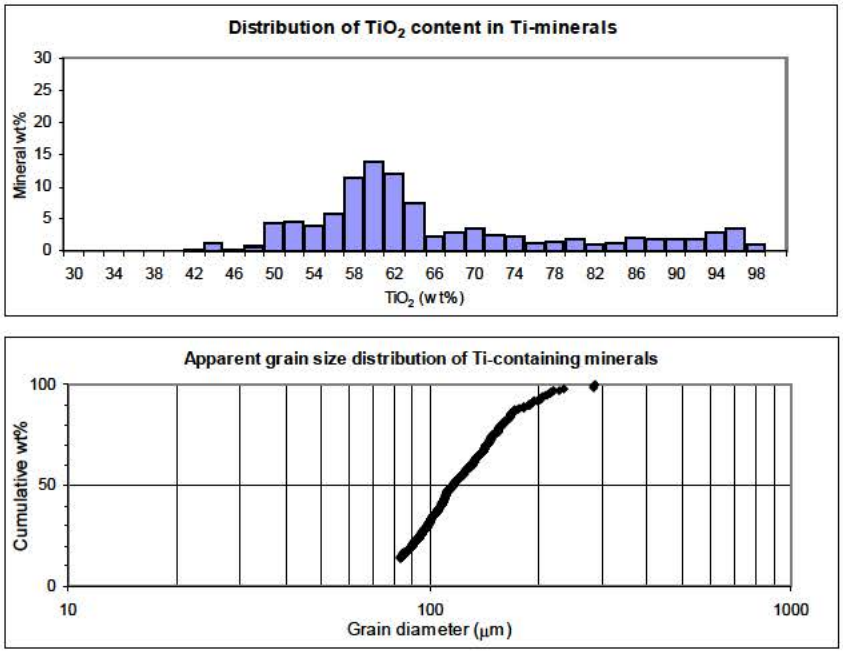


Figure 9. *Grain size distribution of sample V11, Ky Khang.*

Normalised average contents of the valuable Ti-containing minerals:						Weight percent on a mineral basis:		
							Heavy mineral concentrate	Raw sand
Average content	Category Ilmenite	Leucoxene	Rutile	Ti magnetite		Category	wt %	wt %
TiO_2 wt%	59.9	77.7	94.7	42.1		Ilmenite	56.9	35.9
Fe_2O_3 wt%	34.3	12.6	1.6	35.3		Leucoxene	11.8	7.4
MnO wt%	2.7	0.8	0.2	2.2		Rutile	11.9	7.5
Cr_2O_3 wt%	0.1	0.2	0.2	0.8		Ti magnetite	0.7	0.5
SiO_2 wt%	1.5	6.1	2.0	10.2		Magnetite	0.0	0.0
Al_2O_3 wt%	0.9	2.0	0.8	4.4		Chromite	0.3	0.2
MgO wt%	0.1	0.1	0.1	0.6		Pyrite	0.0	0.0
CaO wt%	0.1	0.1	0.1	0.1		Phosphate	0.0	0.0
ZrO_2 wt%	0.4	0.4	0.3	4.4		Monazite	0.6	0.3
Total	100.0	100.0	100.0	100.0		Y-phosphate	0.0	0.0
						Sphene	0.0	0.0
						Garnet	0.0	0.0
						Kya/Sill	0.4	0.2
Average TiO_2 content of all the TiO_2 minerals:				67.4		Staurolite	1.0	0.6
						Zircon	10.8	6.8
Average TiO_2 content of all the TiO_2 minerals excl. rutile				62.8		Silicate	4.6	39.8
						Unclassified	1.0	0.7
Valuable heavy minerals in raw sand:				58.98		Total	100.0	100.0

Table 3. *Results from the sample V 011, Ky Khang.*

Deposit name	**Length (km) x width (m)**	**Thickness of HM bed (m)**	**Ilmenite (mill.t)**	**Zircon (t)**	**TiO_2 % of ilmenite**	**TiO_2 % of CCSEM (ilm. + leucoxene)**	**Type of HM deposit**	**Comments**
Cam Hoa (1-3)	18 x (500-1000)	1 -5	2.3	84,000	53.3	55-56	Aeolian	Three deposits – 6 samples
Kyxuan 1	1.5 x 200	3-5	0.6	-	53.5 (XRF)		Aeolian	Rich in HM – 2 samples
Ky Khang	7.2 x 1000	7	3	150,000	54-56 57.6 (XRF)	60-63	Aeolian	15% HM, fine-grained – 3 samples
Ky Ninh	7 x 500	0.6-1.1	0.2	35,000	-		Aeolian	Not sampled

Table 4. *Heavy mineral deposits in the Ha Tinh region. The numbers are partly from published figures (Loan 1990), Dr. Quy, DGMV, Hanoi (personal communication) and from the information given by the mining companies during the fieldtrip.*

Binh Dinh Province

The heavy mineral sand of the Binh Dinh region is all of the aeolian type found in sand dunes but the age differs probably with both Miocene and Quaternary dunes. The ilmenite content of the regions is estimated to be 2.5 million tonnes (Table 5). Associated minerals are rutile, leucoxene, zircon and monazite, which also are exploited. The zircon content of the area is estimated to be more than 250,000 t. The mines in the area belongs to Bimal Minerals Co. Ltd., which concentrate and separate the heavy minerals locally. A few other heavy mineral deposits occur in the region namely Dong Xuan and Xuong Ly (Loan 1990; see Table 5).

Sampling

In Quy Nhon we picked up our guide of the day, Mr. Choung from the local Minerals Office. The deposit was investigated by the Geological Division no. 5 in Corporation with the Malaysian Geological Survey. At My Tho it was claimed that the overburden down to the Miocene sand should be 1.2 m but we dig down to approximately to 2-m without reaching any heavy mineral horizon. Instead we took sample of the Quaternary dunes, which obviously carry heavy minerals with one sample in the middle of the dunes where testing basins had been exploited and one in a coastal dune profile with mm bands of heavy minerals.

Sample V 14 – 2000194 – Raw sand samples from the middle of Quaternary dune.
Sample V 15 – 2000195 – Raw sand sample from the Quaternary coastal dune.

De Gi and Cat Khang

The De Gi and Cat Khanh deposits are physically the same orebody. Mr. Ly from the Bimal Minerals Co. Ltd. showed us the mining site and gave us kindly some information about the orebody. The deposit was investigated by the Geological Division no. 5 in co-operation with the Malaysian Geological Survey. It is at least 5-km long and 100-1000 m wide and the thickness of the heavy mineral sands varies from 1-6 m and average 5.6% heavy minerals. The deposit is Miocene sand dunes with a distinct heavy mineral banding (mm-cm bands). At the site the heavy mineral sands are pre-concentrated and in the nearby separation plant the heavy minerals are separated into ilmenite with A and B quality, rutile, monazite, and zircon concentrates. Mr. Doan at the separation plant provided us kindly with samples of the different mineral separates.

Sample V 16 – 2000196 – Raw sand sample of Miocene dune.
Sample V 17 – 2000197 – Pre-concentrated 85-90% ilmenite.
Sample V 18 – 2000198 – Ilmenite separate B-clean – 99% ilmenite.
Sample V 19 – 2000199 – Ilmenite separate A-clean – 99% ilmenite.
Sample V 20 – 2000200 – Rutile separate.
Sample V 21 – 2000201 – Monazite separate.
Sample V 22 – 2000202 – Zircon separate.

Analytical results

The area has low content of TiO_2 (around 52%) except for one XRF analysis of an ilmenite concentrate, which yields 56.5%. The grain size varies between 100-200μ. The individual CCSEM results are given in Appendix 1 and Table 7 (V14 - V19). This province was beforehand mentioned to be one of the high-grade regions, which turned not to be the case. The controversy between the TiO_2 contents in the ilmenite concentrate samples is discussed in the chapter about the analytical methods. It is concluded that the average content for the deposits in the area are close to 52 TiO_2 %.

Deposit name	**Length (km) x width (m)**	**Thickness of HM bed (m)**	**Ilmenite (mill.t)**	**Zircon (t)**	**TiO_2 % of CCSEM (ilm + leucoxene)**	**Type of HM deposit**	**Comments**
My Tho	7 x 1000	1.6 - 4	0.8	55,000	51-53	Miocene Aeolian	3 ore bodies – 2 samples
Cat Khanh	5 x (100-1000)	1-6	1.6	32,000	52 51-56.5 (XRF)	Miocene Aeolian	Av. 5.6% HM – 7 samples
Xuong Ly	-	-	0.02	-		-	Not sampled
Dong Xuan	-	-	0.1	2,400		-	Not sampled

Table 5. *Heavy mineral deposits in the Binh Dinh Province. The numbers are partly from published figures (Loan 1990), Dr. Quy, DGMV, Hanoi (personal communication) and from the information given by the mining company during the fieldtrip.*

Binh Thuan region

From the information given on the fieldtrip the heavy mineral sand deposits in the Ham Tan area are of the dune type and young Quaternary deposits. The ilmenite potential is huge with nearly 2 million tonnes of ilmenite. In Table 6 data from the overall area is recorded.

Figure 10. *Sand dune in the Ham Cam area. The black 'statues' in the upper part of the sand dune are spiral concentrators.*

Sampling

From the Department of Industry the Vice Director Mr. Hung accompanied us to the heavy mineral fields in the Ham Tan area. In Ham Tan we were guided by Mr. Tan from the 'Ilmenite Exploiting Enterprise' – a company under the Vietnam National Mineral Corporation, which has the mineral rights in the area.

Ham Tan

The heavy minerals are in coast parallel sand dunes (Fig. 10). The dunes at the visited site are 10-15 m high and 30-100 wide and continue along the coast. The heavy mineral content is 4-5% and the TiO_2 % in ilmenite is c. 52%. The heavy mineral sand is preconcentrated at the site and the mineral separation takes place in Ham Tan at the 'Enterprise of CIDISACO (Mineral Development Corp., HCM City), which belongs to the Vietnam National Mineral Corporation. The production of ilmenite is more than 10,000 t/year.

Sample V 23 – 2000203 – Raw sand sample of Quaternary dune.
Sample V 24 – 2000204 – Raw sand sample of Quaternary dune.
Sample V 25 – 2000205 – Ilmenite – 99% ilmenite.
Sample V 26 – 2000206 – Rutile separate – 80-82%.
Sample V 27 – 2000207 – Zircon separate – 57%.

Analytical results

The grade of the TiO_2 content is moderate to high (55%). If rutile is taken into account the TiO_2 percentage is between 57-58% (V23 - V25 in Appendix 1 and Table 7).

Deposit name	**Length (km) x width (m)**	**Thick-ness of HM bed (m)**	**Ilme-nite (mill.t)**	**Zircon (t)**	**TiO_2 % of il-menite**	**TiO_2 % of CCSEM (ilm + leu-coxene)**	**Type of HM de-posit**	**Comments**
Ham Tan	2.3 x (400-600)	Av. 4.2	1.9	442,000	53.2	55-56 53.2 (XRF)	Aeolian	Three de-posits – 5 samples
Ham Tan stanard. South	7 x (200-300)	0.6-1.4	0.112	22,000	-		Aeolian	Not sampled
Long Hai	-	-	0.072	10,500	-		Aeolian	Not sampled
Trum Gang	4.5 x (15-450)	0.9-7.5	0.152	23,000			Aeolian	Not sampled
Thien Ai	1.5 x 250	3.5	0.054	15,000			Aeolian	Not sampled
Mui Ne	15 x 1800	2-11	0.46	60,000	50.0		Aeolian	Not sampled

Table 6. *Heavy mineral deposits in the Ha Tinh region. The numbers are partly from published figures (Loan 1990) and from Dr. Quy, DGMV, Hanoi (personal communication).*

Conclusions

The fieldwork was carried out in three chosen areas in the provinces Ha Tinh, Binh Dinh and Binh Thuan was a success and the anticipated sampling program turned out to be satisfactorily. The sample list is given in Table 1 and altogether 27 samples were collected. The samples are of different types such as raw sand, pre-concentrated ilmenite, and separates of ilmenite, rutile, zircon and monazite. The average grain-size is between 100-200 μm. A summary of the CCSEM analytical results is given in Table 7.

The impression from the fieldwork and information given on the tour, it was anticipated that the chance for getting high-grade ilmenite was best in the Binh-Dinh province where the clean ilmenite separate should contain 54-56 TiO_2. The analytical results obtained give another story and pin point the Ha Tinh province especially the Ky Khang area as the most promising area with high-grade ilmenite with total TiO_2% above 60 %. A second area of possible interest would be the Bin Thuan province with TiO_2 contents up to 58%. The latter area is a big province and the fieldwork had only visited a small part of the potential HM deposits.

It is recommended to do more work in the Binh Thuan region, where we only have a few samples and our fieldwork was very sporadic. However, in this region there are possibilities for large deposits and this study show promising results concerning the possibility for high-grade ilmenite. In the Ha Tinh province, especially the Ky Khang area, where the highest TiO_2% is obtained, it is recommended to get more precise figures of the deposit size and tonnage's of the heavy minerals.

Locality	Field no.	% HM in raw sand	% TiO_2 in Ilmenite	% TiO_2 in all Ti minerals
Cam Hoa #1, Ha Tinh	V01	16,9	54,3	55,7
Cam Hoa #1, Ha Tinh	V02	74,65	54,3	57,6
Cam Hoa #2, Ha Tinh	V04	78,53	53,9	57,4
Cam Hoa #3, Ha Tinh	V06	2,74	54,5	61,2
Cam Hoa	V08	HM concentrate	52,6	52,8
Kyxuan #2, Ha Tinh	V09	21,38	52,9	53,4
Kyxuan #2, Ha Tinh	V10	67,96	53,1	53,7
Ky Khang; Ha Tinh	V11	63,1	59,9	67,4
Ky Khang, Ha Tinh	V12	42,43	56,8	64,4
Ky Khang, Ha Tinh	V13	HM concentrate	58,4	59,7
My Tho, Bin Dinh	V14	7,18	52,3	51,6
My Tho, Bin Dinh	V15	13,05	52,1	53,3
Cat Khang, Bin Dinh	V16	16,29	52,0	52,4
Cat Khang, Bin Dinh	V17	92,07	52,5	52,5
Cat Khang, Bin Dinh	V18	HM concentrate (B)	60,3	62,5
Cat Khang, Bin Dinh	V19	HM concentrate (A)	52,3	51,6
Ham Tan, Binh Thuan	V23	7,95	55,0	57,2
Ham Tan, Bin Thuan	V24	24,67	55,0	57,4
Ham Tan, Bin Thuan	V25	HM concentrate	53,5	53,2

Table 7. *Summary of the CCSEM analyses*

References

Knudsen, C. and Appel, C. C. 2000: Heavy mineral exploration in Denmark 1999. GEUS report **2000/6**, pp 31 + appendixes.

Loan, N.M. 1990: Titanium and heavy mineral sands. In: Atlas of Mineral Resources of the ESCAP region, Viet Nam, Explantory Brochure. United Nations, Economic and social commission for Asia and the Pacific in Co-operation with the General Department of Mines and Geology of Viet Nam, 86-101.

O'Driscoll, M. 1996: Minerals of Vietnam. Sands' future black and white. Industrial Minerals **350**, 72-93.

Acknowledgements

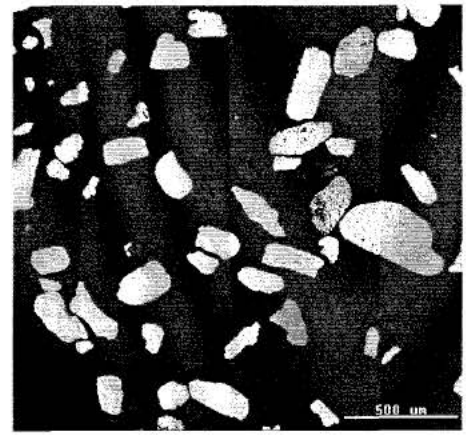
I would like to acknowledge the General Director Mr. Tran Xuan Huong and his staff from the DGMV for a great help in the planning of this joint project. Especially thanks go to the Deputy Director for ‘Division for International Co-operation’ Nguyen Xuan Hop and Ms. Bui Thi Huyen, International Co-operation Expert (interpreter) for all the administrative work and getting the permissions from the authorities to make this tour possible. My field companions Deputy Director Mr. Hop from DGMV, the interpreter Mr. Trinh from the International Co-operation Department, DGMV and the ever talking and hard working driver, Mr. Tinh are thanked for their always-good humour and good company, which make the tour very enjoyable. The help from local field guides and various people during the fieldwork were highly appreciated.

Appendix 1

CCSEM analytical results

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

G E U S



Sample Name:	V 02	No. of frames analysed:	31
Lab. Name:	2000182	No. of particles analysed:	808
Date:	23/05/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	74.65
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/50x			
Guard region:	250 µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	53.3	39.5	3.4	0.1	0.9	0.6	0.1	0.1	0.3	98.2
Leucoxene	77.0	7.6	0.5	0.2	8.3	2.8	0.1	0.1	0.3	96.9
Rutile	92.5	1.5	0.1	0.1	2.3	1.2	0.1	0.1	0.2	98.1
Ti magnetite	40.5	36.3	2.4	0.0	10.9	2.5	0.3	0.1	3.3	96.4
Magnetite	0.5	81.0	0.2	0.2	5.4	8.0	0.2	0.1	0.4	96.1
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	3.0	0.0	0.0	0.0	5.6	11.4	5.7	1.7	0.0	27.4
Y-phosphate	0.4	3.1	0.0	0.0	2.1	1.9	0.4	2.2	0.5	10.5
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	1.0	26.5	0.4	0.1	38.8	20.8	1.5	1.5	0.2	90.7
Kya/Sill	0.8	1.4	0.0	0.0	42.0	53.2	0.0	0.0	0.1	97.5
Staurolite	1.0	16.6	0.2	0.2	31.4	46.9	1.2	0.1	0.4	97.9
Zircon	0.3	0.6	0.1	0.1	29.6	0.1	0.1	0.1	61.4	92.5
Silicate	3.3	6.8	0.2	0.1	62.0	20.8	2.0	0.4	0.3	96.0
Unclassified	14.3	9.7	0.9	0.4	20.9	1.6	0.5	0.4	33.3	82.0

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	81.6	6.4	4.4	1.7	0.0	4.1	1.1	0.7	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	54.3	79.5	94.3	42.0
Fe_2O_3 wt%	40.2	7.8	1.5	37.7
MnO wt%	3.4	0.5	0.1	2.5
Cr_2O_3 wt%	0.1	0.2	0.1	0.0
SiO_2 wt%	1.0	8.5	2.3	11.3
Al_2O_3 wt%	0.6	2.9	1.2	2.6
MgO wt%	0.1	0.1	0.1	0.3
CaO wt%	0.1	0.1	0.1	0.1
ZrO_2 wt%	0.3	0.4	0.2	3.4
Total	100.0	100.0	100.0	100.0

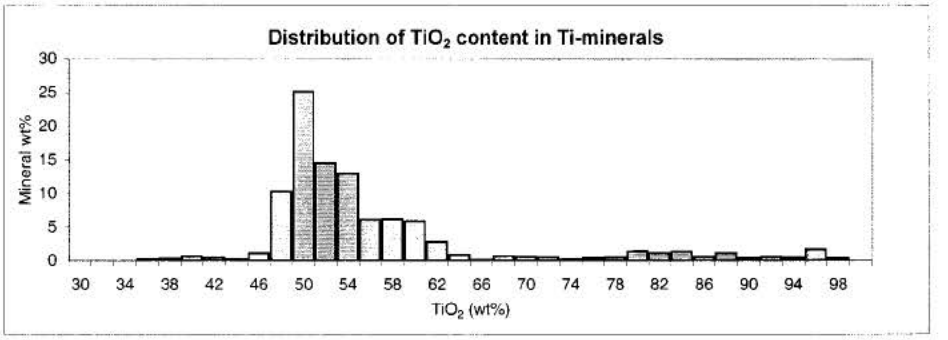
Average TiO_2 content of all the TiO_2 minerals:	57.6
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	55.8
Valuable heavy minerals in raw sand:	69.59

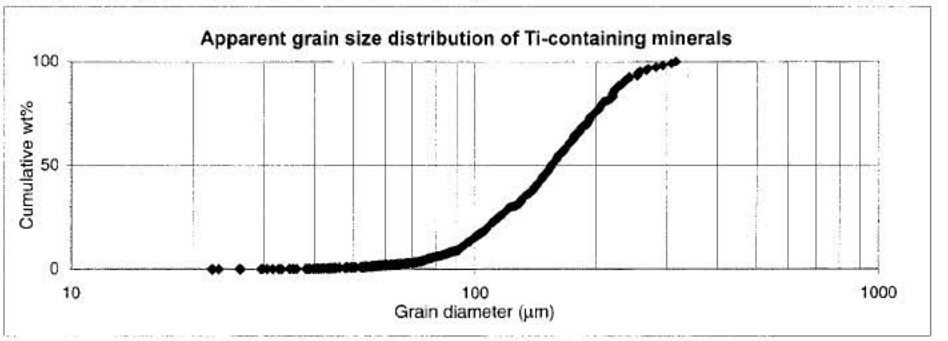
Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	76.0	56.8
Leucoxene	5.9	4.4
Rutile	4.1	3.1
Ti magnetite	1.6	1.2
Magnetite	0.8	0.6
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.0	0.0
Y-phosphate	0.1	0.1
Sphene	0.0	0.0
Garnet	0.0	0.0
Kya/Sill	1.0	0.7
Staurolite	0.7	0.5
Zircon	3.8	2.8
Silicate	4.8	28.9
Unclassified	1.1	0.8
Total	100.0	100.0

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

GEUS

Lab. Name:	2000182	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	23/05/02		

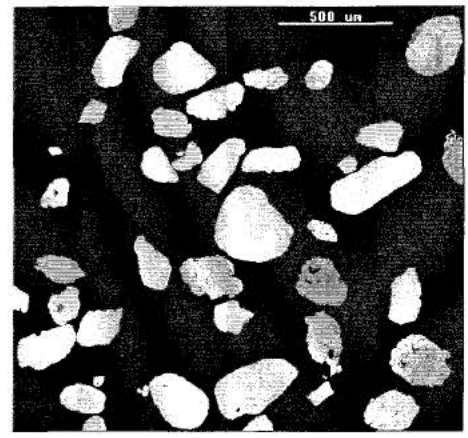




Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.8	498	192	12481	568
Leucoxene	1.6	1.9	548	216	14172	39
Rutile	1.6	1.8	458	172	10794	32
Ti magnetite	1.6	2.1	533	219	12703	11
Magnetite	1.5	1.7	447	165	10853	6
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.6	1.2	59	18	226	1
Y-phosphate	1.3	1.4	226	79	3404	2
Sphene	0.0	0.0	0	0	0	0
Garnet	1.3	1.4	135	47	1148	4
Kya/Sill	2.3	3.7	2459	1114	128675	1
Staurolite	1.3	2.1	710	291	19256	4
Zircon	1.4	1.6	325	114	6017	57
Silicate	1.5	1.8	489	191	12217	62
Unclassified	1.4	1.7	351	144	8152	21

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

G E U S



Sample Name:	V 04	No. of frames analysed:	60
Lab. Name:	2000184	No. of particles analysed:	1000
Date:	29/05/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	78.53
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/50x		
Guard region:	300 µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	52.9	39.5	3.4	0.1	1.1	0.7	0.1	0.1	0.2	98.1
Leucoxene	76.8	8.2	0.5	0.1	9.0	2.4	0.1	0.1	0.3	97.6
Rutile	90.7	2.6	0.2	0.1	2.6	1.3	0.1	0.1	0.2	97.9
Ti magnetite	41.0	37.7	2.7	0.3	10.4	3.5	0.3	0.3	0.4	96.6
Magnetite	0.3	73.9	0.2	0.1	10.3	11.2	0.4	0.1	0.4	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	1.3	0.0	0.0	7.4	3.8	0.0	1.6	1.0	15.1
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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kya/Sill	0.2	0.6	0.1	0.0	42.8	53.9	0.0	0.1	0.2	97.9
Staurolite	0.9	15.2	0.3	0.1	32.3	47.3	1.3	0.1	0.4	97.9
Zircon	0.2	0.3	0.2	0.1	30.0	0.1	0.0	0.1	62.8	93.8
Silicate	1.0	8.3	0.1	0.1	48.9	32.9	3.7	1.0	0.3	96.5
Unclassified	17.9	14.0	1.3	0.6	19.4	19.8	4.4	0.4	12.1	89.9

	Valuable heavy minerals							
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	82.3	9.0	3.5	1.9	0.0	1.7	0.3	1.1	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	53.9	78.7	92.6	42.4
Fe_2O_3 wt%	40.2	8.4	2.6	39.0
MnO wt%	3.5	0.5	0.2	2.8
Cr_2O_3 wt%	0.1	0.1	0.1	0.3
SiO_2 wt%	1.2	9.2	2.6	10.8
Al_2O_3 wt%	0.7	2.5	1.4	3.6
MgO wt%	0.1	0.1	0.1	0.3
CaO wt%	0.1	0.1	0.1	0.3
ZrO_2 wt%	0.2	0.3	0.2	0.4
Total	100.0	100.0	100.0	100.0

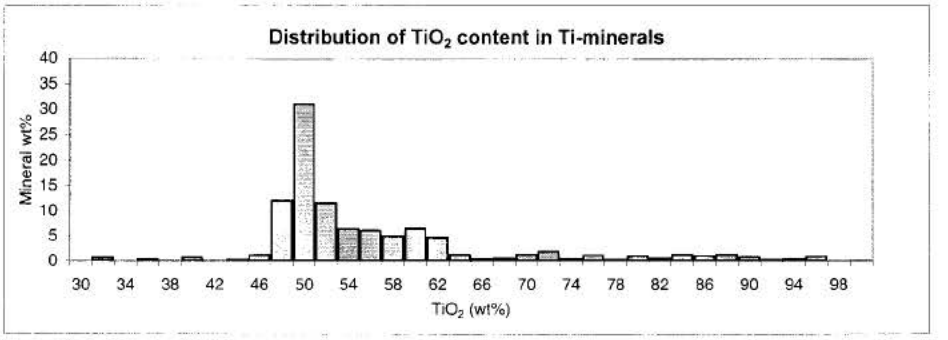
Average TiO_2 content of all the TiO_2 minerals:	57.4
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	56.1
Valuable heavy minerals in raw sand:	71.31

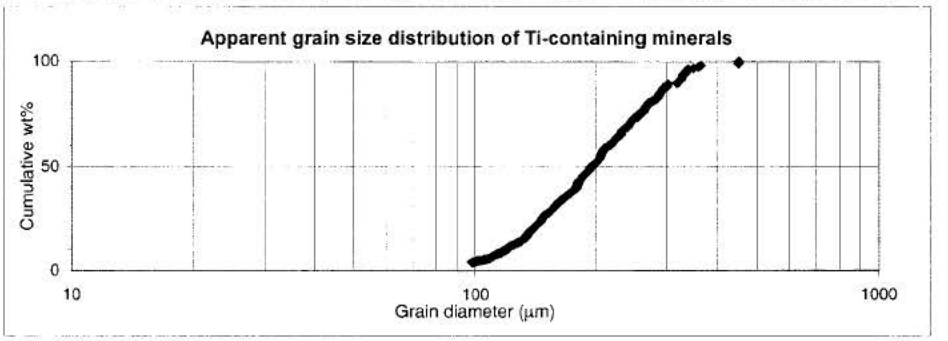
Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	74.8	58.7
Leucoxene	8.2	6.4
Rutile	3.2	2.5
Ti magnetite	1.7	1.4
Magnetite	2.5	2.0
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.0	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	0.0	0.0
Kya/Sill	0.3	0.2
Staurolite	1.0	0.8
Zircon	1.6	1.2
Silicate	5.0	25.4
Unclassified	1.6	1.3
Total	100.0	100.0

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

GEUS

Lab. Name:	2000184	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	29/05/02		

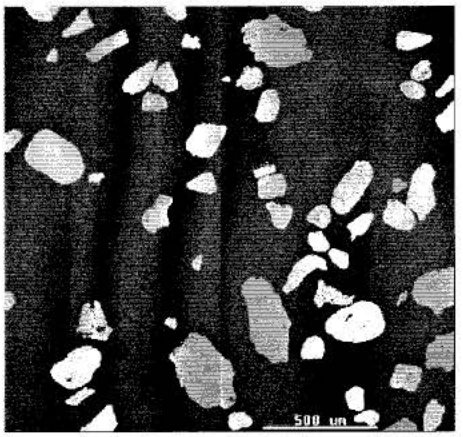




Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.8	624	241	19890	723
Leucoxene	1.5	1.7	610	232	21607	73
Rutile	1.4	1.7	528	199	16340	34
Ti magnetite	1.6	2.0	658	278	22415	14
Magnetite	1.3	1.7	1303	463	104760	4
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.4	1.5	215	76	2420	3
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	0.0	0.0	0	0	0	0
Kya/Sill	1.8	2.1	694	279	20441	4
Staurolite	1.6	2.1	601	241	16298	14
Zircon	1.5	1.6	416	147	9509	31
Silicate	1.6	2.0	670	273	21855	75
Unclassified	1.4	2.1	652	277	20682	25

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

G E U S



Sample Name:	V 06	No. of frames analysed:	41
Lab. Name:	2000186	No. of particles analysed:	1078
Date:	30/05/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	2.74
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/50x			
Guard region:	275 µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	53.3	37.9	3.3	0.1	1.9	0.9	0.2	0.1	0.3	97.9
Leucoxene	75.6	7.2	0.4	0.2	10.4	3.2	0.1	0.1	0.3	97.5
Rutile	91.6	2.0	0.2	0.2	2.2	1.4	0.1	0.1	0.3	97.9
Ti magnetite	39.3	36.8	2.1	0.3	8.1	3.4	0.3	0.7	2.2	93.2
Magnetite	0.8	68.8	0.2	0.2	12.3	13.1	0.5	0.1	0.4	96.3
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	0.0	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	1.7	0.7	0.0	2.1	0.0	4.5
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	1.2	33.5	0.0	0.1	37.6	18.9	2.4	0.0	0.6	94.4
Kya/Sill	0.9	2.1	0.2	0.3	39.5	53.8	0.0	0.4	0.3	97.6
Staurolite	1.6	13.9	0.4	0.2	31.9	48.2	1.1	0.0	0.5	97.9
Zircon	0.3	0.7	0.2	0.3	29.2	0.1	0.1	0.1	62.1	93.0
Silicate	3.1	9.5	0.2	0.1	48.3	29.9	3.4	1.2	0.3	96.0
Unclassified	26.7	9.1	0.8	0.5	26.4	17.8	4.7	0.3	5.2	91.5

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	70.7	16.4	6.9	1.0	1.2	2.6	0.0	1.1	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	54.5	77.5	93.5	42.1
Fe_2O_3 wt%	38.7	7.4	2.0	39.5
MnO wt%	3.3	0.4	0.2	2.2
Cr_2O_3 wt%	0.1	0.2	0.2	0.3
SiO_2 wt%	1.9	10.6	2.2	8.7
Al_2O_3 wt%	0.9	3.3	1.4	3.6
MgO wt%	0.2	0.2	0.1	0.3
CaO wt%	0.1	0.1	0.1	0.7
ZrO_2 wt%	0.3	0.3	0.3	2.4
Total	100.0	100.0	100.0	100.0

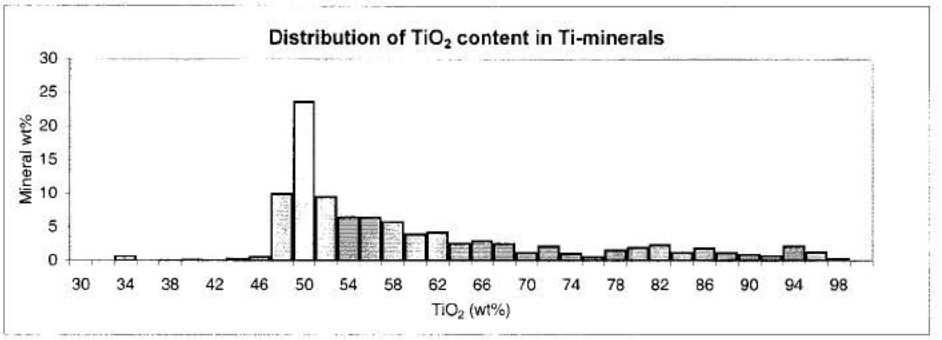
Average TiO_2 content of all the TiO_2 minerals:	61.2
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	58.6
Valuable heavy minerals in raw sand:	2.06

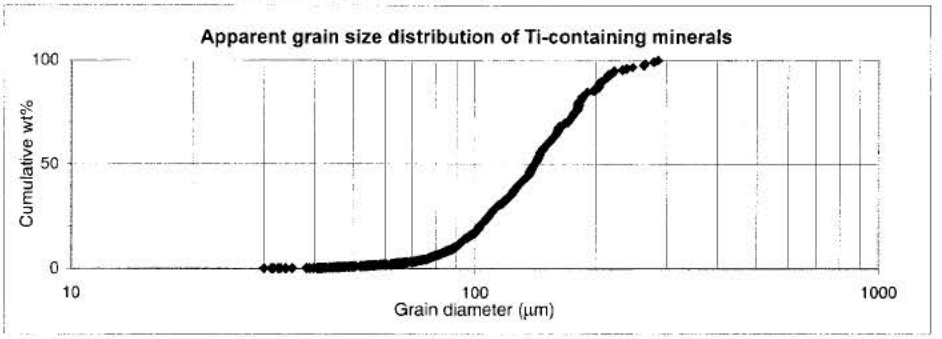
Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	53.1	1.5
Leucoxene	12.3	0.3
Rutile	5.2	0.1
Ti magnetite	0.8	0.0
Magnetite	5.1	0.1
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.1	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	0.9	0.0
Kya/Sill	0.0	0.0
Staurolite	0.8	0.0
Zircon	2.0	0.1
Silicate	16.3	97.7
Unclassified	3.5	0.1
Total	100.0	100.0

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

GEUS

Lab. Name:	2000186	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	30/05/02		



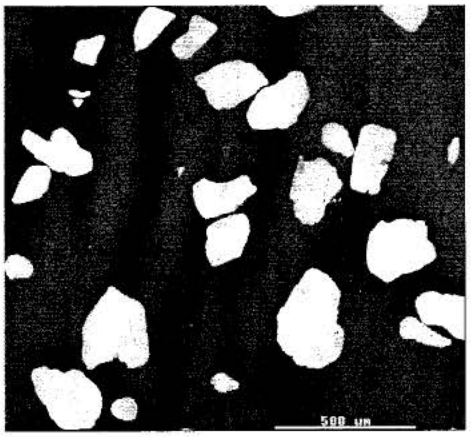


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.8	456	176	10368	529
Leucoxene	1.7	2.0	537	214	13236	96
Rutile	1.5	1.7	432	163	10292	47
Ti magnetite	1.5	1.8	282	118	4870	15
Magnetite	1.5	2.0	575	232	15572	29
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.7	1.7	359	136	5913	1
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	2.1	1.9	896	349	34838	3
Kya/Sill	1.3	1.3	118	39	1058	2
Staurolite	1.5	1.9	404	164	7876	13
Zircon	1.4	1.5	296	105	5069	39
Silicate	1.5	1.9	490	194	12978	220
Unclassified	1.4	1.9	454	183	11691	51

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

G E U S

Sample Name:	V 08	No. of frames analysed	64
Lab. Name:	2000188	No. of particles analysed:	478
Date:	28/10/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	0.00
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/60x			
Guard region:	225 µm		
Sieve:	100 µm²		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	51.9	41.8	3.6	0.1	0.4	0.4	0.1	0.1	0.2	98.6
Leucoxene	74.1	18.0	1.2	0.1	2.1	2.5	0.3	0.1	0.3	98.6
Rutile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ti magnetite	44.0	38.8	2.9	0.1	5.7	2.3	0.3	0.1	1.8	96.0
Magnetite	1.3	56.4	0.0	0.2	19.7	20.1	0.1	0.0	0.0	97.9
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	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kya/Sill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Silicate	1.4	5.9	0.3	0.1	78.8	6.2	0.4	0.2	0.8	94.1
Unclassified	0.4	17.1	0.2	0.2	9.6	69.4	0.3	0.2	0.3	97.5

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	98.4	0.9	0.0	0.7	0.0	0.0	0.0	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	52.6	75.1	0	45.8
Fe_2O_3 wt%	42.4	18.3	0	40.4
MnO wt%	3.7	1.2	0	3.1
Cr_2O_3 wt%	0.1	0.1	0	0.1
SiO_2 wt%	0.4	2.1	0	5.9
Al_2O_3 wt%	0.4	2.5	0	2.4
MgO wt%	0.1	0.3	0	0.3
CaO wt%	0.1	0.1	0	0.1
ZrO_2 wt%	0.2	0.3	0	1.8
Total	100.0	100.0	0	100.0

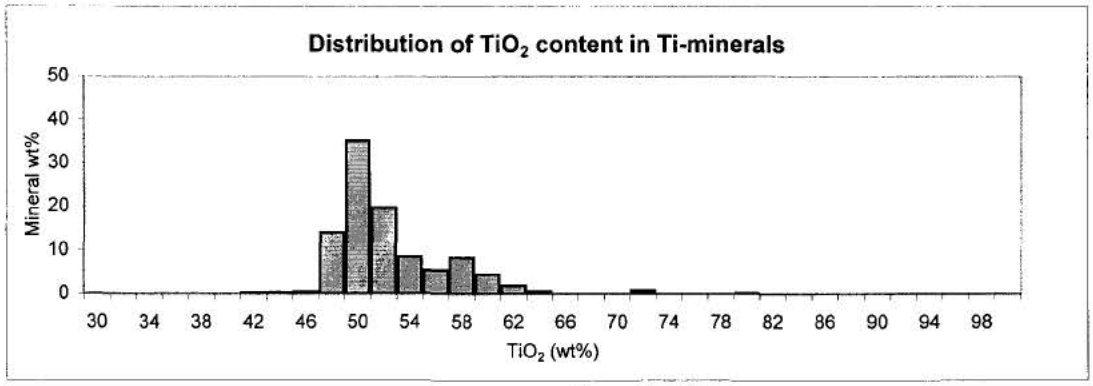
Average TiO_2 content of all the TiO_2 minerals:	52.8
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	52.8
Valuable heavy minerals in raw sand:	0.00

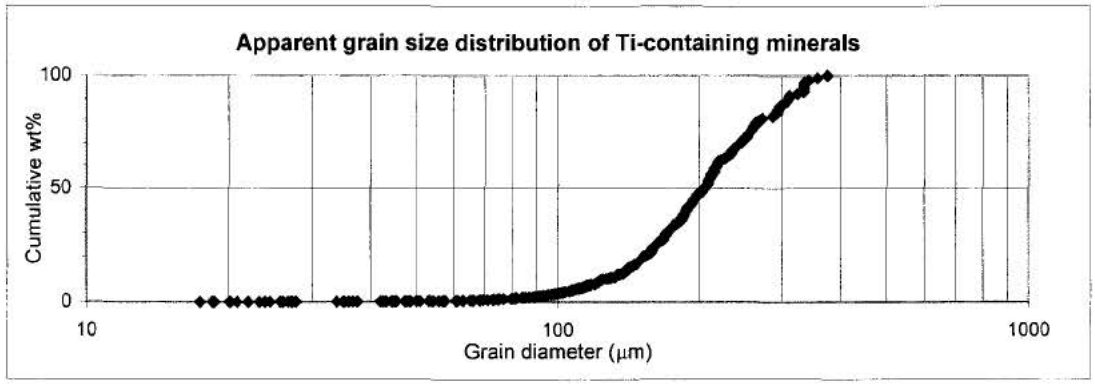
Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	98.1	
Leucoxene	0.9	
Rutile	0.0	
Ti magnetite	0.7	
Magnetite	0.2	
Chromite	0.0	
Pyrite	0.0	
Phosphate	0.0	
Monazite	0.0	
Y-phosphate	0.0	
Sphene	0.0	
Garnet	0.0	
Kya/Sill	0.0	
Staurolite	0.0	
Zircon	0.0	
Silicate	0.0	
Unclassified	0.1	
Total	100.0	

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

GEUS

Lab. Name:	2000188	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	28/10/02		



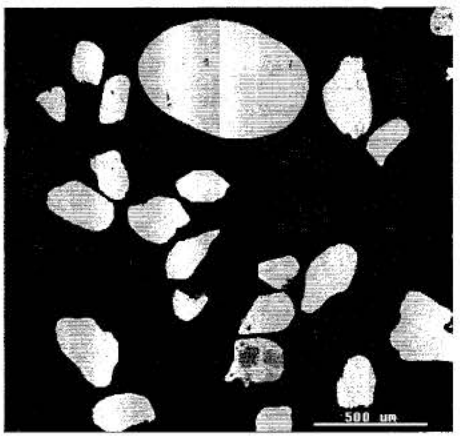


	Average grain parameters					
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.8	650	246	22575	455
Leucoxene	1.4	2.2	774	322	22980	4
Rutile	0.0	0.0	0	0	0	0
Ti magnetite	1.5	1.4	314	119	8478	8
Magnetite	1.2	1.5	558	193	16651	1
Chromite	0.0	0.0	0	0	0	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	0.0	0.0	0	0	0	0
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	1.5	1.3	94	31	577	7
Unclassified	1.3	1.8	307	112	5163	3

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

G E U S

Sample Name:	V 09	No. of frames analysed:	81
Lab. Name:	2000189	No. of particles analysed:	551
Date:	14/06/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	21.38
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/50x		
Guard region:	350 µm		
Sieve:	100 µm²		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	52.1	41.1	3.3	0.1	0.7	0.7	0.1	0.1	0.2	98.4
Leucoxene	81.0	8.8	0.7	0.2	2.8	3.9	0.1	0.2	0.2	97.9
Rutile	89.3	0.9	0.2	0.2	3.6	3.0	0.2	0.0	0.5	97.8
Ti magnetite	41.3	36.2	3.3	0.4	8.7	2.6	0.8	0.2	0.4	93.9
Magnetite	0.1	77.3	0.5	0.1	7.9	8.2	2.4	0.1	0.8	97.5
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	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	1.6	17.8	1.0	0.1	42.9	23.6	1.6	0.2	1.3	90.1
Kya/Sill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurolite	0.7	13.3	0.0	0.1	38.5	42.5	1.4	0.1	0.0	96.5
Zircon	0.2	0.4	0.0	0.2	29.8	0.1	0.1	0.1	64.1	95.0
Silicate	4.2	15.2	1.0	0.1	55.6	18.0	1.9	0.5	0.3	96.6
Unclassified	9.3	17.6	1.3	0.5	27.9	37.5	0.7	0.0	1.0	95.6

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	95.9	1.4	0.2	0.6	0.3	1.2	0.0	0.4	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	52.9	82.7	91.3	44.0
Fe_2O_3 wt%	41.8	9.0	1.0	38.6
MnO wt%	3.4	0.8	0.2	3.5
Cr_2O_3 wt%	0.1	0.2	0.2	0.4
SiO_2 wt%	0.7	2.9	3.6	9.3
Al_2O_3 wt%	0.7	4.0	3.0	2.7
MgO wt%	0.1	0.1	0.2	0.8
CaO wt%	0.1	0.2	0.0	0.2
ZrO_2 wt%	0.2	0.2	0.5	0.4
Total	100.0	100.0	100.0	100.0

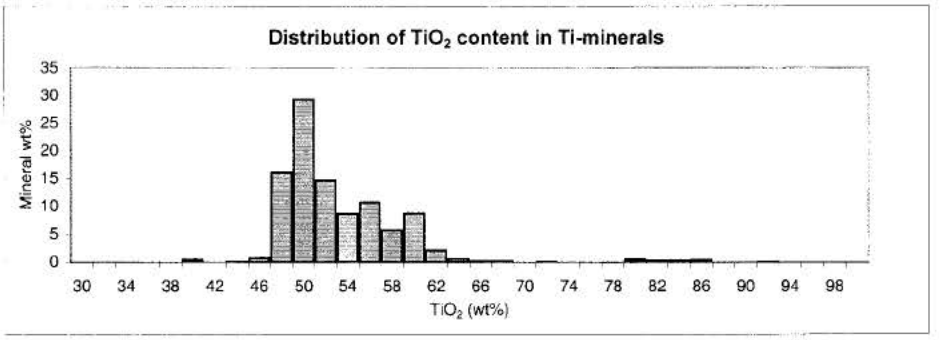
Average TiO_2 content of all the TiO_2 minerals:	53.4
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	53.3
Valuable heavy minerals in raw sand:	19.28

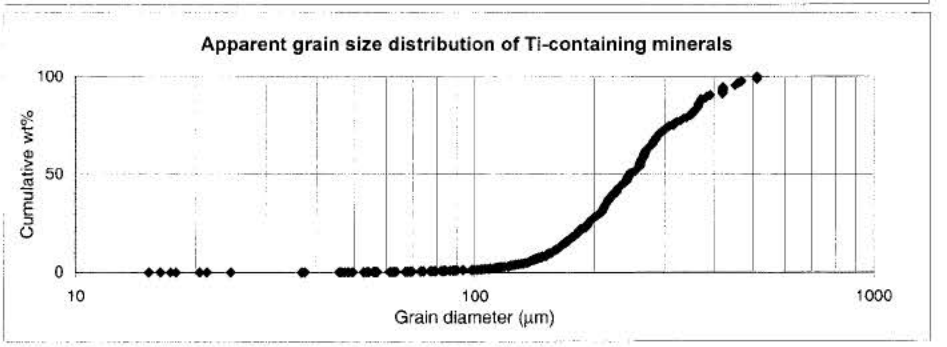
Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	86.5	18.5
Leucoxene	1.3	0.3
Rutile	0.2	0.0
Ti magnetite	0.6	0.1
Magnetite	6.8	1.5
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.0	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	0.3	0.1
Kya/Sill	0.0	0.0
Staurolite	0.3	0.1
Zircon	1.1	0.2
Silicate	2.3	79.1
Unclassified	0.7	0.1
Total	100.0	100.0

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

GEUS

Lab. Name:	2000189	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	14/06/02		

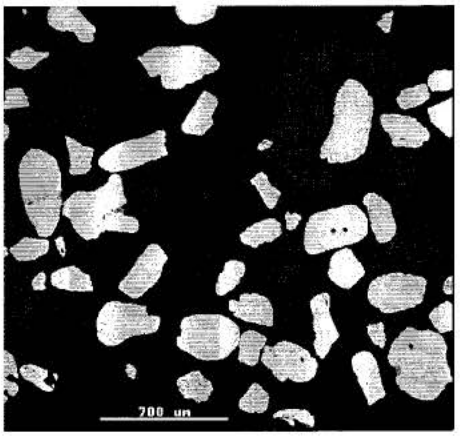




Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.5	1.8	805	304	34315	485
Leucoxene	1.5	1.7	735	278	27039	9
Rutile	1.6	1.6	602	216	18685	2
Ti magnetite	1.5	1.7	336	135	9094	11
Magnetite	1.2	1.4	1488	467	141868	8
Chromite	0.0	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	1.4	1.2	271	91	12695	5
Kya/Sill	0.0	0.0	0	0	0	0
Staurolite	1.3	1.9	1338	530	73527	1
Zircon	1.6	1.6	651	240	21950	9
Silicate	1.5	1.9	986	378	50808	15
Unclassified	1.5	2.0	909	367	36797	6

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

G E U S



Sample Name:	V 10	No. of frames analysed:	64
Lab. Name:	2000190	No. of particles analysed:	945
Date:	14/06/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	67.96
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/40x		
Guard region:	325 µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	52.2	41.3	3.3	0.1	0.6	0.4	0.1	0.1	0.2	98.3
Leucoxene	76.2	12.6	0.7	0.1	4.2	3.2	0.3	0.2	0.3	97.8
Rutile	90.9	3.7	0.2	0.0	1.9	1.4	0.2	0.1	0.0	98.4
Ti magnetite	41.1	36.3	3.0	0.4	5.4	2.0	0.5	0.2	0.7	89.6
Magnetite	0.4	69.5	0.3	0.5	11.0	5.6	1.0	0.6	0.4	89.2
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	0.1	0.8	0.0	0.0	0.1	0.9	0.0	0.2	0.0	2.1
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kya/Sill	0.0	0.1	0.0	0.0	43.0	53.1	0.0	0.1	0.0	96.2
Staurolite	0.8	15.9	0.0	0.3	32.0	47.6	1.4	0.1	0.5	98.5
Zircon	0.8	0.7	0.0	0.0	29.2	0.0	0.0	0.5	65.8	97.0
Silicate	7.3	6.0	0.2	0.2	70.0	11.3	1.4	0.5	0.3	97.2
Unclassified	13.7	13.5	2.4	13.5	6.1	15.4	7.5	0.9	3.0	75.9

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	97.0	2.0	0.2	0.5	0.0	0.1	0.1	0.2	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	53.1	77.9	92.3	45.8
Fe_2O_3 wt%	42.0	12.9	3.8	40.5
MnO wt%	3.4	0.7	0.2	3.3
Cr_2O_3 wt%	0.1	0.1	0.0	0.5
SiO_2 wt%	0.6	4.3	1.9	6.1
Al_2O_3 wt%	0.4	3.3	1.5	2.3
MgO wt%	0.2	0.3	0.2	0.5
CaO wt%	0.1	0.2	0.1	0.2
ZrO_2 wt%	0.2	0.3	0.0	0.8
Total	100.0	100.0	100.0	100.0

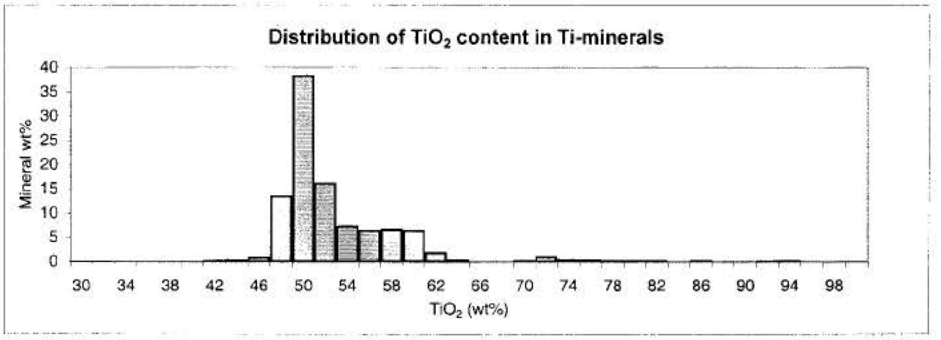
Average TiO_2 content of all the TiO_2 minerals:	53.7
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	53.6
Valuable heavy minerals in raw sand:	64.71

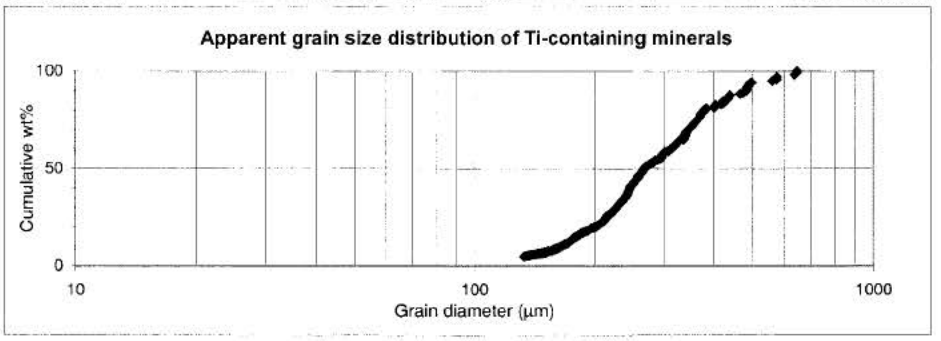
Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	92.3	62.8
Leucoxene	1.9	1.3
Rutile	0.2	0.1
Ti magnetite	0.4	0.3
Magnetite	3.2	2.1
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.0	0.0
Y-phosphate	0.1	0.1
Sphene	0.0	0.0
Garnet	0.0	0.0
Kya/Sill	0.1	0.1
Staurolite	0.2	0.1
Zircon	0.1	0.0
Silicate	1.4	33.0
Unclassified	0.1	0.1
Total	100.0	100.0

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

GEUS

Lab. Name:	2000190	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	14/06/02		



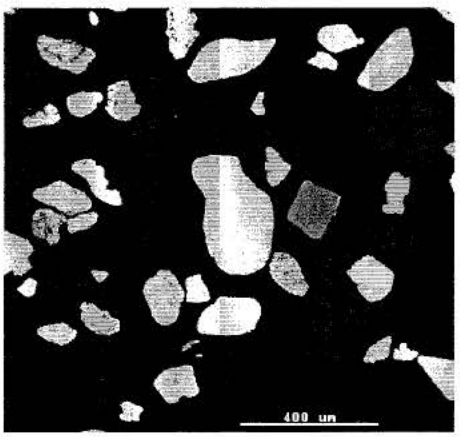


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.9	874	341	38895	863
Leucoxene	1.7	1.9	925	364	43735	16
Rutile	1.4	1.8	618	239	16977	3
Ti magnetite	1.3	1.6	400	154	13758	11
Magnetite	1.4	1.8	1073	416	66099	15
Chromite	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	1.5	1.3	567	168	19382	2
Sphene	0.0	0.0	0	0	0	0
Garnet	0.0	0.0	0	0	0	0
Kya/Sill	2.0	2.3	1083	449	41484	1
Staurolite	1.7	2.4	906	377	27988	3
Zircon	1.3	1.4	622	202	22000	1
Silicate	1.5	2.0	816	330	34094	25
Unclassified	1.5	1.4	456	187	16548	5

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

G E U S

Sample Name:	V 11	No. of frames analysed:	83
Lab. Name:	2000191	No. of particles analysed:	1484
Date:	11/06/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	63.10
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/75x			
Guard region:	200 µm		
Sieve:	100 µm^2		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	58.8	33.7	2.6	0.1	1.5	0.8	0.1	0.1	0.4	98.2
Leucoxene	75.9	12.3	0.8	0.1	5.9	2.0	0.1	0.1	0.4	97.7
Rutile	92.7	1.6	0.2	0.2	2.0	0.8	0.1	0.1	0.3	97.9
Ti magnetite	40.1	33.7	2.1	0.7	9.8	4.2	0.5	0.1	4.2	95.5
Magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromite	0.8	20.0	0.6	49.1	0.2	18.7	9.3	0.0	0.3	99.0
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	2.0	0.4	0.0	0.0	3.8	1.2	0.3	1.4	0.7	9.9
Y-phosphate	0.0	1.1	0.0	0.0	2.8	2.4	0.1	2.6	2.4	11.5
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	4.9	11.5	0.0	0.0	47.6	27.2	3.6	0.4	0.2	95.3
Kya/Sili	0.1	0.8	0.1	0.1	42.4	53.8	0.1	0.1	0.5	98.1
Staurolite	1.1	14.1	0.4	0.2	31.7	48.7	1.1	0.1	0.4	97.7
Zircon	0.4	0.4	0.2	0.2	29.6	0.1	0.1	0.1	62.5	93.6
Silicate	1.9	8.4	0.1	0.2	51.6	29.4	3.5	0.7	0.4	96.2
Unclassified	13.8	4.0	0.8	1.4	18.3	23.1	5.4	0.5	19.4	86.7

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	60.9	12.6	12.7	0.8	0.0	11.6	0.4	1.1	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	59.9	77.7	94.7	42.1
Fe_2O_3 wt%	34.3	12.6	1.6	35.3
MnO wt%	2.7	0.8	0.2	2.2
Cr_2O_3 wt%	0.1	0.2	0.2	0.8
SiO_2 wt%	1.5	6.1	2.0	10.2
Al_2O_3 wt%	0.9	2.0	0.8	4.4
MgO wt%	0.1	0.1	0.1	0.6
CaO wt%	0.1	0.1	0.1	0.1
ZrO_2 wt%	0.4	0.4	0.3	4.4
Total	100.0	100.0	100.0	100.0

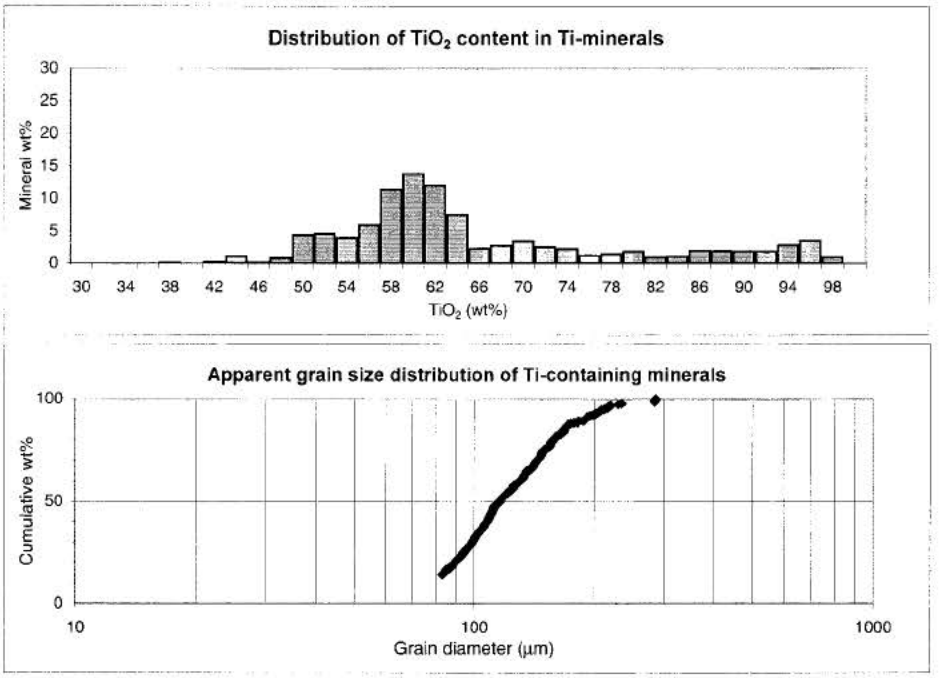
Average TiO_2 content of all the TiO_2 minerals:	67.4
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	62.8
Valuable heavy minerals in raw sand:	58.98

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	56.9	35.9
Leucoxene	11.8	7.4
Rutile	11.9	7.5
Ti magnetite	0.7	0.5
Magnetite	0.0	0.0
Chromite	0.3	0.2
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.6	0.3
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	0.0	0.0
Kya/Sill	0.4	0.2
Staurolite	1.0	0.6
Zircon	10.8	6.8
Silicate	4.6	39.8
Unclassified	1.0	0.7
Total	100.0	100.0

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

GEUS

Lab. Name:	2000191	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	11/06/02		

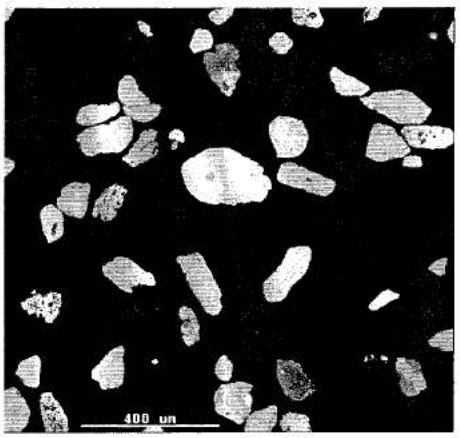


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.9	409	160	8064	760
Leucoxene	1.6	1.9	392	154	7461	170
Rutile	1.5	1.9	389	153	7334	157
Ti magnetite	1.6	2.6	616	263	12116	6
Magnetite	0.0	0.0	0	0	0	0
Chromite	1.3	1.8	431	164	8957	3
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.9	2.2	399	164	6569	8
Y-phosphate	1.4	1.6	230	83	2653	1
Sphene	0.0	0.0	0	0	0	0
Garnet	1.2	1.1	42	15	134	1
Kya/Sill	1.2	3.9	702	311	13697	4
Staurolite	1.4	2.0	357	148	6442	20
Zircon	1.4	1.7	327	124	5489	205
Silicate	1.5	2.2	417	173	7767	109
Unclassified	1.5	1.8	277	114	4639	40

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

G E U S

Sample Name:	V 12	No. of frames analysed:	31
Lab. Name:	2000192	No. of particles analysed:	558
Date:	12/06/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	42.43
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/75x		
Guard region:	175 µm		
Sieve:	100 µm^2		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	55.8	35.9	2.8	0.1	2.2	0.9	0.1	0.1	0.3	98.3
Leucoxene	76.7	10.0	0.8	0.2	7.4	2.5	0.1	0.1	0.3	98.0
Rutile	90.9	2.0	0.1	0.1	3.7	1.1	0.1	0.1	0.3	98.4
Ti magnetite	40.0	39.5	2.9	0.5	5.6	5.2	1.6	0.1	0.5	95.8
Magnetite	8.2	81.5	0.0	0.6	2.5	2.2	0.4	3.5	0.0	98.9
Chromite	0.5	27.2	0.0	54.6	0.3	9.6	6.5	0.1	0.0	98.7
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	0.3	0.0	0.0	4.0	0.0	0.0	1.7	0.0	6.0
Y-phosphate	0.1	0.7	0.0	0.0	2.1	0.2	0.2	1.3	3.1	7.8
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kya/Sill	0.3	0.5	0.1	0.2	43.0	53.5	0.0	0.0	0.0	97.6
Staurolite	0.7	14.1	0.1	0.2	32.6	48.6	1.2	0.0	0.4	98.1
Zircon	0.3	0.5	0.1	0.1	29.5	0.1	0.1	0.1	63.1	93.9
Silicate	2.5	7.5	0.2	0.1	51.9	31.0	1.9	1.9	0.3	97.3
Unclassified	14.8	9.5	1.9	2.2	11.7	10.4	2.5	1.3	14.9	69.1

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	61.5	13.3	11.7	2.2	0.0	10.2	0.4	0.7	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	56.8	78.3	92.4	41.7
Fe_2O_3 wt%	36.6	10.2	2.0	41.3
MnO wt%	2.8	0.8	0.1	3.0
Cr_2O_3 wt%	0.1	0.2	0.1	0.5
SiO_2 wt%	2.2	7.6	3.7	5.9
Al_2O_3 wt%	0.9	2.6	1.1	5.4
MgO wt%	0.1	0.1	0.1	1.7
CaO wt%	0.1	0.1	0.1	0.1
ZrO_2 wt%	0.3	0.3	0.4	0.5
Total	100.0	100.0	100.0	100.0

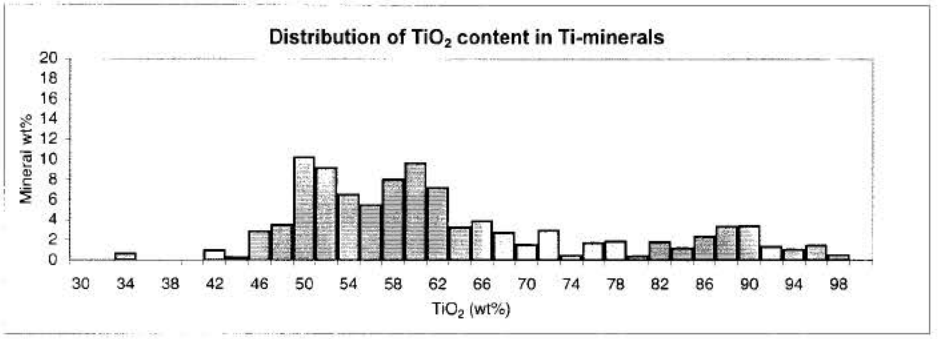
Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	55.6	23.6
Leucoxene	12.0	5.1
Rutile	10.6	4.5
Ti magnetite	2.0	0.8
Magnetite	0.0	0.0
Chromite	0.2	0.1
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.2	0.1
Y-phosphate	0.3	0.1
Sphene	0.0	0.0
Garnet	0.0	0.0
Kya/Sill	0.4	0.2
Staurolite	0.6	0.3
Zircon	9.2	3.9
Silicate	4.3	59.4
Unclassified	4.7	2.0
Total	100.0	100.0

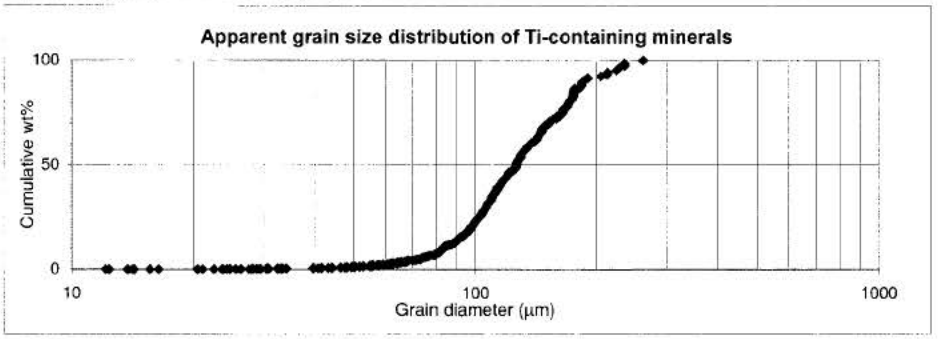
Average TiO_2 content of all the TiO_2 minerals:	64.4
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	60.1
Valuable heavy minerals in raw sand:	38.33

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

GEUS

Lab. Name:	2000192	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	12/06/02		



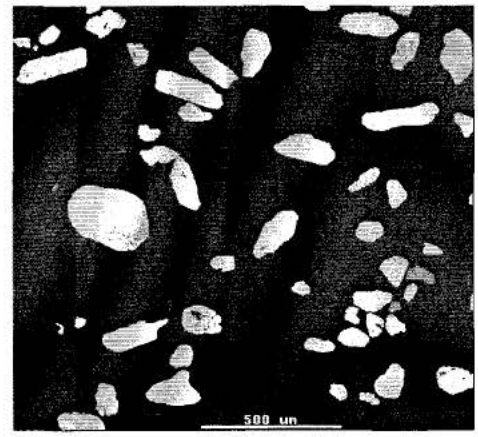


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.8	425	164	8913	294
Leucoxene	1.5	2.1	510	209	11092	51
Rutile	1.7	1.9	449	174	9337	48
Ti magnetite	1.6	2.3	531	224	10976	8
Magnetite	1.7	1.5	75	26	299	1
Chromite	1.1	1.8	436	169	8350	1
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.5	1.7	434	163	8761	1
Y-phosphate	1.8	2.1	356	142	5383	2
Sphene	0.0	0.0	0	0	0	0
Garnet	0.0	0.0	0	0	0	0
Kya/Sill	1.5	1.8	339	132	5958	4
Staurolite	1.9	2.6	421	181	5833	6
Zircon	1.4	1.7	363	136	7122	59
Silicate	1.6	1.9	419	166	8703	40
Unclassified	1.6	2.0	444	179	8505	43

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

G E U S

Sample Name:	V 13	No. of frames analysed	49
Lab. Name:	2000193	No. of particles analysed:	1133
Date:	28/10/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	0.00
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/60x		
Guard region:	175 µm		
Sieve:	100 µm^2		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	57.4	35.7	2.8	0.1	1.0	0.9	0.1	0.1	0.2	98.4
Leucoxene	75.2	18.2	1.4	0.1	1.0	1.8	0.1	0.1	0.3	98.3
Rutile	93.2	1.7	0.1	0.2	1.8	1.2	0.1	0.0	0.3	98.6
Ti magnetite	40.9	33.5	1.9	0.1	16.8	3.7	1.3	0.0	0.1	98.4
Magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromite	0.5	26.8	0.5	44.4	4.1	18.5	2.3	0.1	0.0	97.2
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	0.9	0.0	0.0	4.7	1.2	0.4	1.1	1.4	9.7
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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kya/Sill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurolite	0.8	15.2	0.3	0.0	31.3	48.9	1.3	0.1	0.3	98.2
Zircon	0.5	0.3	0.2	0.4	30.2	0.1	0.1	0.1	62.0	93.9
Silicate	3.4	5.1	0.1	0.1	70.0	15.0	1.9	0.3	0.4	96.4
Unclassified	4.1	5.1	0.4	2.3	0.9	72.8	3.0	8.0	0.5	97.0

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	90.8	7.3	0.3	0.9	0.0	0.0	0.0	0.5	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	58.4	76.6	94.5	41.6
Fe_2O_3 wt%	36.3	18.5	1.7	34.1
MnO wt%	2.9	1.4	0.1	1.9
Cr_2O_3 wt%	0.1	0.2	0.2	0.1
SiO_2 wt%	1.0	1.1	1.8	17.1
Al_2O_3 wt%	0.9	1.9	1.2	3.8
MgO wt%	0.1	0.1	0.1	1.3
CaO wt%	0.1	0.1	0.0	0.0
ZrO_2 wt%	0.2	0.3	0.3	0.1
Total	100.0	100.0	100.0	100.0

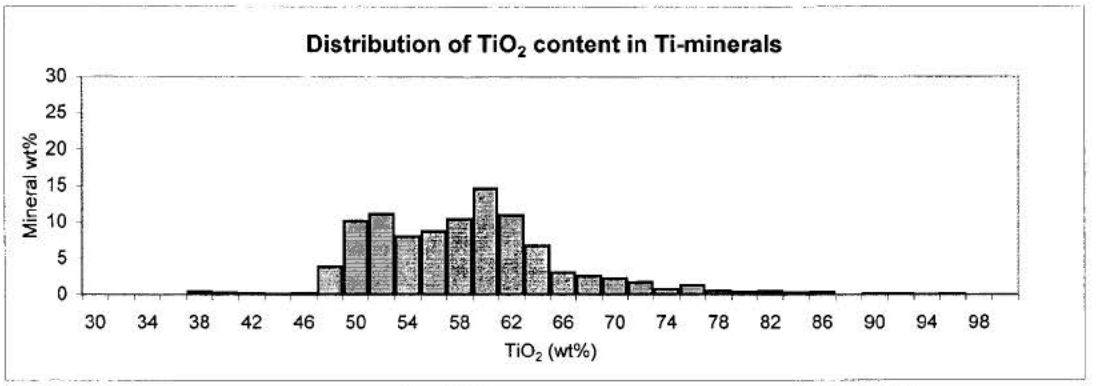
Average TiO_2 content of all the TiO_2 minerals:	59.7
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	59.5
Valuable heavy minerals in raw sand:	0.00

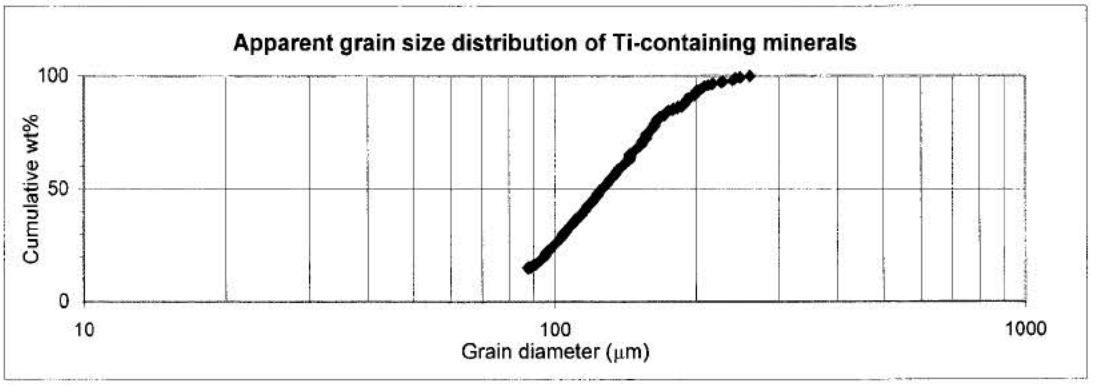
Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	85.0	
Leucoxene	6.9	
Rutile	0.3	
Ti magnetite	0.8	
Magnetite	0.0	
Chromite	0.3	
Pyrite	0.0	
Phosphate	0.0	
Monazite	0.1	
Y-phosphate	0.0	
Sphene	0.0	
Garnet	0.0	
Kya/Sill	0.0	
Staurolite	0.5	
Zircon	0.0	
Silicate	1.1	
Unclassified	4.9	
Total	100.0	

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

GEUS

Lab. Name:	2000193	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	28/10/02		



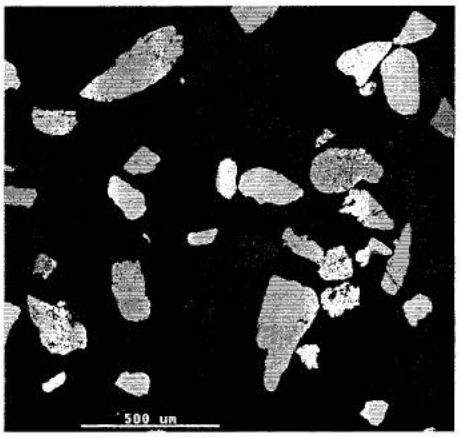


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm²)	Total grains
Ilmenite	1.7	1.8	421	160	9062	994
Leucoxene	1.6	1.8	432	164	9712	75
Rutile	1.7	1.8	297	111	4315	7
Ti magnetite	1.6	2.0	457	185	9386	9
Magnetite	0.0	0.0	0	0	0	0
Chromite	1.5	1.6	425	156	10746	3
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.3	1.8	269	103	3227	3
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	0.0	0.0	0	0	0	0
Kya/Sill	0.0	0.0	0	0	0	0
Staurolite	1.8	2.4	563	236	10679	6
Zircon	1.4	1.4	162	61	1534	2
Silicate	1.5	1.9	405	159	8003	24
Unclassified	1.5	2.0	958	410	86060	10

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

G E U S

Sample Name:	V 14	No. of frames analysed:	64
Lab. Name:	2000194	No. of particles analysed:	884
Date:	19/06/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	7.18
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/60x			
Guard region:	275 µm		
Sieve:	100 µm^2		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	51.5	41.7	2.3	0.1	1.3	0.9	0.2	0.1	0.2	98.3
Leucoxene	78.4	9.5	1.1	0.2	3.7	3.6	0.5	0.1	0.4	97.5
Rutile	89.3	1.7	0.1	0.1	4.0	2.2	0.3	0.2	0.2	98.0
Ti magnetite	33.9	52.6	1.8	0.1	5.7	1.8	0.9	0.7	0.3	97.9
Magnetite	1.5	92.2	0.2	0.2	1.6	1.9	0.2	0.1	0.3	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	0.4	0.1	0.2	0.5	0.4	0.0	57.1	1.6	60.2
Monazite	0.0	1.1	0.0	0.0	3.0	1.2	0.4	1.9	3.3	10.8
Y-phosphate	0.3	1.6	0.6	0.0	2.0	4.0	0.5	0.0	3.4	12.4
Sphene	38.0	1.6	0.2	0.1	28.4	1.8	0.1	26.6	0.4	97.2
Garnet	0.1	33.9	1.4	0.1	36.4	19.4	4.4	1.1	0.3	97.3
Kya/Sill	0.1	0.4	0.0	0.5	42.9	53.7	0.0	0.1	0.0	97.7
Staurolite	0.3	12.3	0.2	0.1	35.8	48.9	0.5	0.0	0.0	98.1
Zircon	0.1	0.8	0.2	0.1	29.8	0.2	0.1	0.0	63.9	95.3
Silicate	1.2	15.0	0.4	0.1	47.2	12.7	8.7	10.6	0.3	96.1
Unclassified	11.9	17.7	0.8	0.2	28.6	11.5	3.1	6.6	7.2	87.6

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	80.6	1.6	1.3	9.5	3.7	2.2	0.4	0.9	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	52.3	80.5	91.1	34.7
Fe_2O_3 wt%	42.4	9.7	1.7	53.8
MnO wt%	2.4	1.2	0.1	1.9
Cr_2O_3 wt%	0.1	0.2	0.1	0.1
SiO_2 wt%	1.3	3.8	4.1	5.8
Al_2O_3 wt%	0.9	3.7	2.2	1.8
MgO wt%	0.2	0.5	0.3	0.9
CaO wt%	0.1	0.1	0.2	0.7
ZrO_2 wt%	0.2	0.4	0.2	0.3
Total	100.0	100.0	100.0	100.0

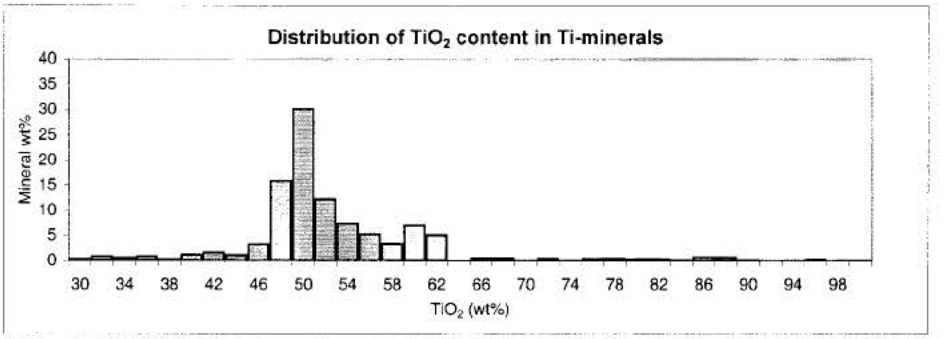
Average TiO_2 content of all the TiO_2 minerals:	51.6
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	51.0
Valuable heavy minerals in raw sand:	3.43

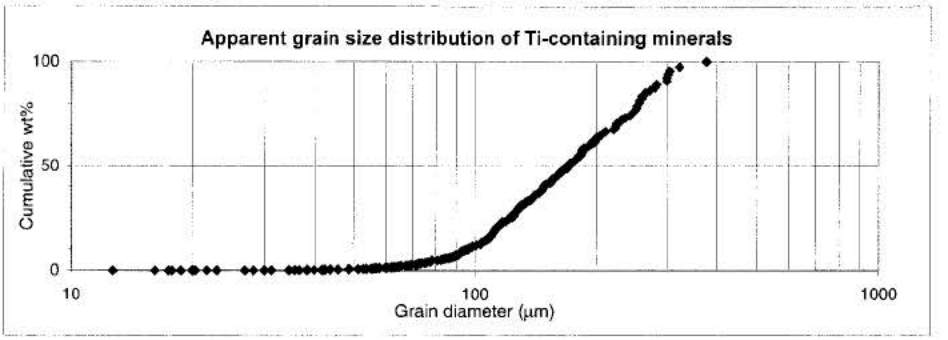
Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	38.5	2.8
Leucoxene	0.8	0.1
Rutile	0.6	0.0
Ti magnetite	4.5	0.3
Magnetite	2.0	0.1
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.2	0.0
Monazite	0.7	0.1
Y-phosphate	0.1	0.0
Sphene	0.7	0.1
Garnet	1.8	0.1
Kya/Sill	0.2	0.0
Staurolite	0.4	0.0
Zircon	1.1	0.1
Silicate	46.5	96.2
Unclassified	2.1	0.2
Total	100.0	100.0

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

GEUS

Lab. Name:	2000194	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	19/06/02		

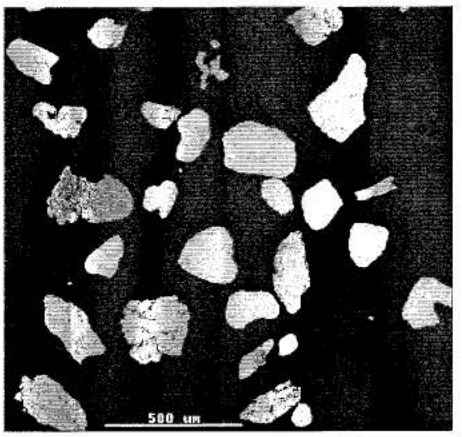




Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.8	512	198	14230	267
Leucoxene	1.9	2.7	591	255	10629	7
Rutile	1.4	1.7	415	159	10988	5
Ti magnetite	1.6	2.3	613	255	14994	28
Magnetite	1.5	1.7	367	137	7275	23
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	1.7	3.2	822	365	16805	1
Monazite	1.7	1.6	416	152	9240	7
Y-phosphate	1.4	1.6	366	133	6700	1
Sphene	2.6	2.3	582	238	12719	7
Garnet	1.7	2.0	326	132	5142	38
Kya/Sill	2.0	2.5	610	260	11699	2
Staurolite	1.2	1.8	661	263	23974	2
Zircon	1.3	1.7	430	158	10049	10
Silicate	1.6	2.1	619	255	17149	454
Unclassified	1.6	2.1	531	229	13888	25

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

G E U S



Sample Name:	V 15	No. of frames analysed:	81
Lab. Name:	2000195	No. of particles analysed:	753
Date:	19/06/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	13.05
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/60x		
Guard region:	300 µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	51.3	42.8	2.4	0.1	0.8	0.5	0.2	0.1	0.3	98.4
Leucoxene	71.4	6.5	0.5	0.1	17.1	2.2	0.1	0.1	0.1	98.2
Rutile	95.0	0.6	0.2	0.2	1.0	0.5	0.1	0.0	0.2	98.0
Ti magnetite	33.9	54.9	2.5	0.1	3.2	1.7	0.4	0.8	0.2	97.8
Magnetite	0.8	90.4	0.2	0.2	3.1	2.9	0.2	0.1	0.2	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	3.0	2.8	0.0	0.0	3.0	0.8	0.3	2.0	1.9	13.8
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	39.3	2.6	0.0	0.2	27.5	1.4	0.0	25.8	0.7	97.6
Garnet	0.1	32.5	1.8	0.1	37.2	19.8	4.9	1.6	0.2	98.3
Kya/Sill	0.2	0.0	0.1	0.4	42.6	53.4	0.0	0.1	0.4	97.2
Staurolite	1.1	15.4	0.3	0.3	31.4	47.3	1.1	0.0	0.0	96.8
Zircon	0.3	0.6	0.2	0.1	29.6	0.1	0.1	0.1	63.6	94.8
Silicate	1.6	14.6	0.4	0.1	46.7	12.7	7.7	12.4	0.2	96.4
Unclassified	14.2	15.7	0.8	0.1	21.2	20.0	4.2	5.8	10.6	92.6

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	77.4	2.4	3.3	5.0	6.3	4.7	0.4	0.4	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	52.1	72.7	97.0	34.7
Fe_2O_3 wt%	43.5	6.6	0.6	56.1
MnO wt%	2.5	0.5	0.3	2.6
Cr_2O_3 wt%	0.1	0.1	0.2	0.1
SiO_2 wt%	0.8	17.4	1.1	3.3
Al_2O_3 wt%	0.5	2.2	0.5	1.7
MgO wt%	0.2	0.1	0.1	0.4
CaO wt%	0.1	0.1	0.0	0.8
ZrO_2 wt%	0.3	0.1	0.2	0.2
Total	100.0	100.0	100.0	100.0

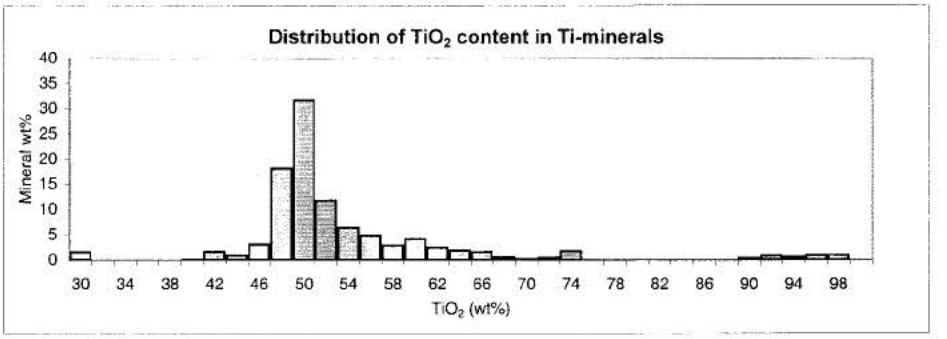
Average TiO_2 content of all the TiO_2 minerals:	53.3
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	51.6
Valuable heavy minerals in raw sand:	7.60

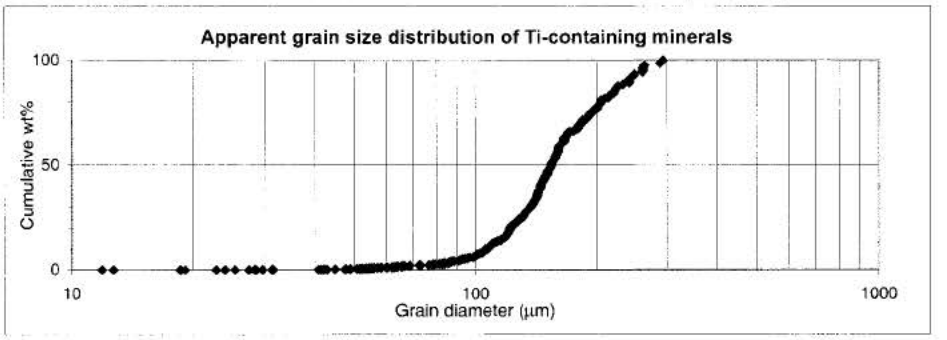
Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	45.0	5.9
Leucoxene	1.4	0.2
Rutile	1.9	0.3
Ti magnetite	2.9	0.4
Magnetite	5.0	0.6
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.8	0.1
Y-phosphate	0.0	0.0
Sphene	0.2	0.0
Garnet	3.7	0.5
Kya/Sill	0.3	0.0
Staurolite	0.2	0.0
Zircon	2.7	0.4
Silicate	34.2	91.4
Unclassified	1.6	0.2
Total	100.0	100.0

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

GEUS

Lab. Name:	2000195	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	19/06/02		



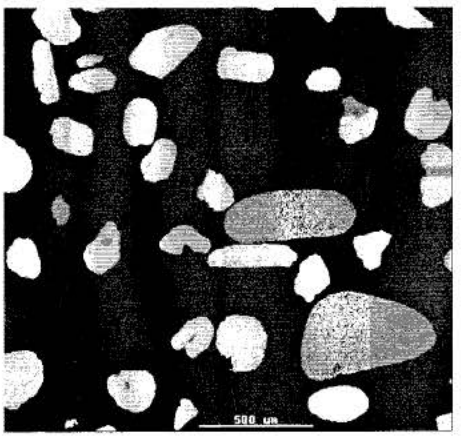


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.5	1.8	538	206	14477	336
Leucoxene	1.9	1.9	609	241	19146	8
Rutile	1.4	1.8	570	217	15644	12
Ti magnetite	1.4	2.0	587	239	15676	19
Magnetite	1.4	1.8	522	202	13612	34
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.6	2.1	525	211	11397	7
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	1.2	2.0	539	215	13048	2
Garnet	1.9	2.2	610	248	14887	30
Kya/Sill	1.8	2.2	732	301	19374	2
Staurolite	1.7	2.4	930	393	28349	1
Zircon	1.4	1.6	496	184	13629	21
Silicate	1.7	2.2	753	312	23853	263
Unclassified	1.8	2.3	639	276	16313	18

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

G E U S

Sample Name:	V 16	No. of frames analysed:	81
Lab. Name:	2000196	No. of particles analysed:	731
Date:	17/06/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	16.29
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/50x			
Guard region:	400 µm		
Sieve:	100 µm^2		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	51.1	43.2	2.2	0.1	0.7	0.6	0.2	0.1	0.2	98.3
Leucoxene	75.6	8.6	0.6	0.1	8.5	4.1	0.1	0.1	0.1	97.8
Rutile	96.5	0.7	0.1	0.3	0.3	0.3	0.0	0.1	0.1	98.6
Ti magnetite	36.0	52.6	2.2	0.4	1.9	1.6	0.3	0.1	0.6	95.6
Magnetite	4.6	87.0	0.4	0.2	2.4	2.7	0.2	0.1	0.1	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	0.0	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	1.5	0.7	1.0	1.6	4.6	9.3
Y-phosphate	0.0	0.2	0.0	0.0	3.2	1.2	0.9	2.0	0.0	7.6
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.0	37.3	1.1	0.0	35.5	19.7	3.7	1.7	0.0	99.0
Kya/Sill	0.1	1.0	0.1	0.1	43.1	53.9	0.0	0.2	0.2	98.7
Staurolite	0.6	14.6	0.4	0.1	31.3	49.1	1.4	0.0	0.0	97.6
Zircon	0.2	0.3	0.2	0.1	30.1	0.3	0.1	0.1	64.4	95.7
Silicate	1.6	11.0	0.3	0.2	44.8	22.5	7.0	8.1	0.3	95.9
Unclassified	4.2	16.7	2.0	0.6	5.2	42.4	6.5	0.5	3.3	81.4

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	85.7	1.1	2.0	5.4	0.5	2.0	2.4	0.9	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	52.0	77.3	97.9	37.6
Fe_2O_3 wt%	43.9	8.8	0.7	55.0
MnO wt%	2.2	0.7	0.1	2.3
Cr_2O_3 wt%	0.1	0.1	0.3	0.4
SiO_2 wt%	0.7	8.7	0.4	1.9
Al_2O_3 wt%	0.6	4.2	0.3	1.6
MgO wt%	0.2	0.1	0.0	0.3
CaO wt%	0.1	0.1	0.1	0.1
ZrO_2 wt%	0.2	0.1	0.1	0.7
Total	100.0	100.0	100.0	100.0

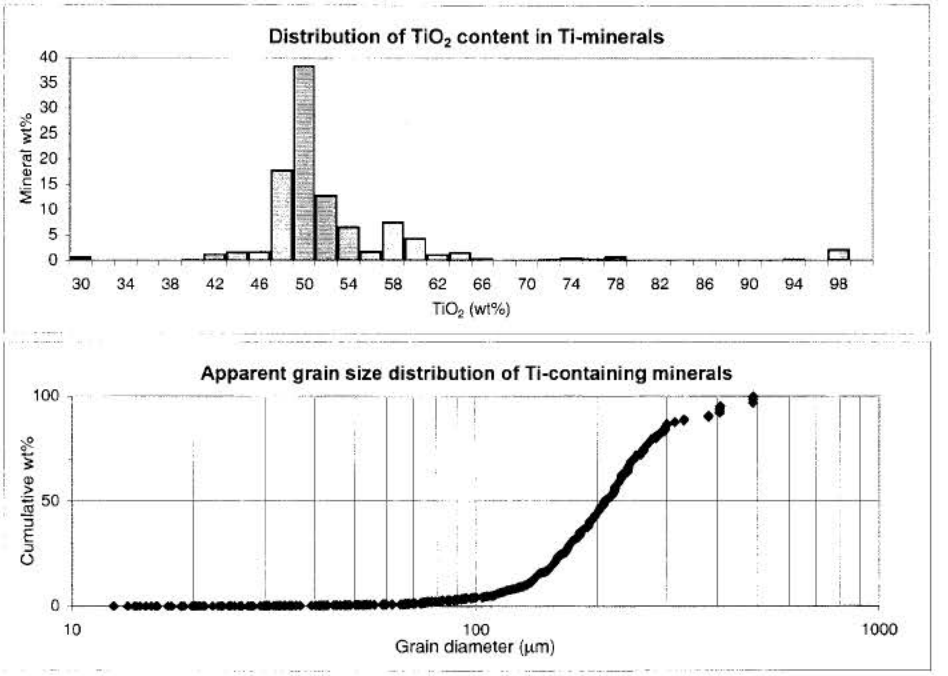
Average TiO_2 content of all the TiO_2 minerals:	52.4
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	51.4
Valuable heavy minerals in raw sand:	12.94

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	68.1	11.1
Leucoxene	0.9	0.1
Rutile	1.6	0.3
Ti magnetite	4.3	0.7
Magnetite	7.3	1.2
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.1	0.0
Y-phosphate	0.5	0.1
Sphene	0.0	0.0
Garnet	0.4	0.1
Kya/Sill	1.9	0.3
Staurolite	0.7	0.1
Zircon	1.6	0.3
Silicate	11.3	85.6
Unclassified	1.3	0.2
Total	100.0	100.0

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

GEUS

Lab. Name:	2000196	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	17/06/02		

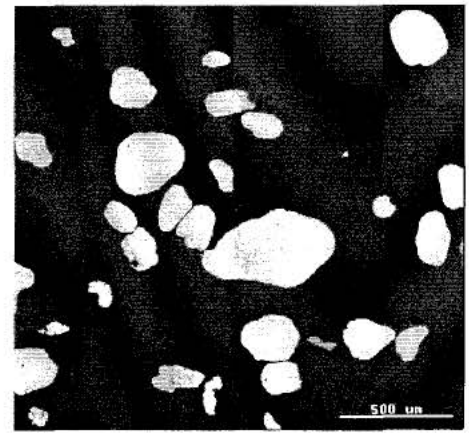


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.5	1.8	625	239	21542	505
Leucoxene	1.5	2.2	730	285	23631	6
Rutile	1.2	1.5	1001	341	58276	4
Ti magnetite	1.4	1.6	437	167	15034	43
Magnetite	1.5	1.8	754	300	40632	25
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.2	1.3	392	115	9280	1
Y-phosphate	1.7	1.5	825	282	36728	2
Sphene	0.0	0.0	0	0	0	0
Garnet	1.3	1.5	780	269	32433	2
Kya/Sill	1.4	1.9	1405	553	107317	4
Staurolite	1.5	3.3	1365	579	65124	2
Zircon	1.4	1.6	619	226	20689	12
Silicate	1.6	1.8	688	271	34220	90
Unclassified	1.3	1.4	287	115	9669	35

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

G E U S

Sample Name:	V 17	No. of frames analysed:	74
Lab. Name:	2000197	No. of particles analysed:	832
Date:	19/06/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	92.07
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/50x			
Guard region:	300 µm		
Sieve:	100 µm²		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	51.7	42.8	2.3	0.1	0.6	0.5	0.1	0.1	0.2	98.5
Leucoxene	79.4	14.0	0.5	0.2	2.2	1.1	0.1	0.1	0.2	97.9
Rutile	94.1	1.0	0.1	0.1	2.1	0.6	0.0	0.0	0.1	98.3
Ti magnetite	36.9	51.0	2.0	0.3	4.4	1.4	0.2	0.1	0.5	96.7
Magnetite	7.4	84.6	0.4	0.4	2.0	1.7	0.3	0.1	0.3	97.1
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	1.6	1.7	0.0	0.0	5.1	0.6	0.2	1.6	2.0	12.8
Y-phosphate	0.0	0.0	0.0	0.0	2.8	0.8	0.0	2.6	4.0	10.3
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.8	27.3	2.5	0.0	36.5	19.8	8.4	2.0	0.1	97.4
Kya/Sill	0.3	1.1	0.0	0.4	42.9	53.7	0.1	0.1	0.0	98.6
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.2	0.4	0.2	0.1	30.0	0.1	0.1	0.1	64.3	95.3
Silicate	1.8	15.5	0.4	0.1	43.9	15.7	7.3	10.6	0.4	95.6
Unclassified	13.8	18.9	5.3	0.4	11.8	4.2	1.9	1.1	3.3	60.8

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	87.4	0.7	2.0	7.7	0.3	1.7	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%	52.5	81.2	95.7	38.2
Fe_2O_3 wt%	43.5	14.3	1.0	52.7
MnO wt%	2.4	0.6	0.2	2.1
Cr_2O_3 wt%	0.1	0.2	0.1	0.3
SiO_2 wt%	0.6	2.2	2.2	4.5
Al_2O_3 wt%	0.5	1.2	0.6	1.4
MgO wt%	0.1	0.1	0.0	0.2
CaO wt%	0.1	0.1	0.0	0.1
ZrO_2 wt%	0.2	0.2	0.1	0.5
Total	100.0	100.0	100.0	100.0

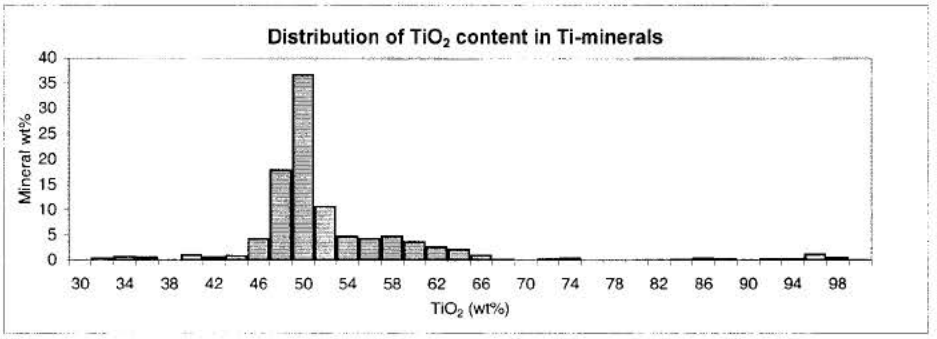
Average TiO_2 content of all the TiO_2 minerals:	52.5
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	51.6
Valuable heavy minerals in raw sand:	88.39

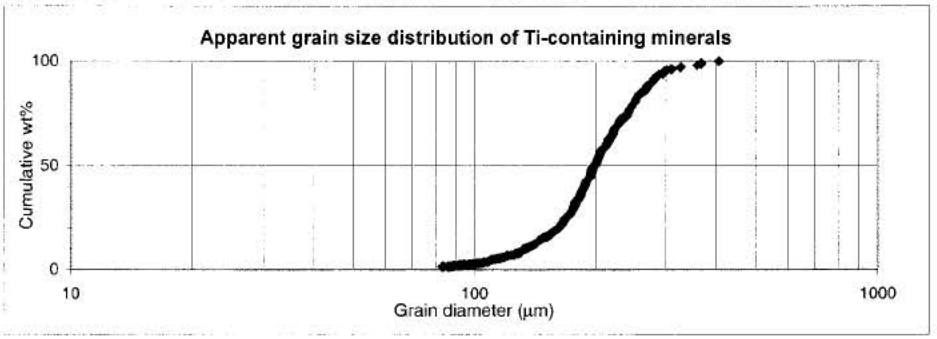
Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	83.9	77.2
Leucoxene	0.7	0.7
Rutile	1.9	1.8
Ti magnetite	7.4	6.8
Magnetite	1.8	1.6
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.9	0.8
Y-phosphate	0.2	0.2
Sphene	0.0	0.0
Garnet	0.3	0.3
Kya/Sill	0.2	0.2
Staurolite	0.0	0.0
Zircon	1.6	1.5
Silicate	1.1	8.9
Unclassified	0.0	0.0
Total	100.0	100.0

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

GEUS

Lab. Name:	2000197	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	19/06/02		



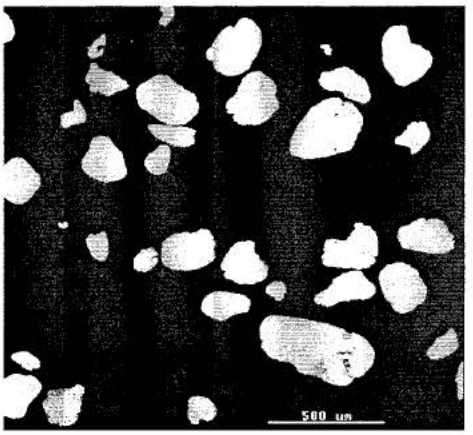


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.5	1.7	655	243	23067	671
Leucoxene	1.5	1.7	676	254	21885	6
Rutile	1.5	1.8	642	245	21217	15
Ti magnetite	1.4	1.7	649	249	24179	53
Magnetite	1.4	1.6	578	211	20152	14
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.3	1.6	602	216	18934	8
Y-phosphate	1.8	1.7	903	335	38904	1
Sphene	0.0	0.0	0	0	0	0
Garnet	1.5	1.7	415	159	9250	7
Kya/Sill	1.1	1.7	720	274	24021	2
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.5	1.8	623	237	19092	15
Silicate	1.5	1.6	412	149	10547	32
Unclassified	1.3	1.1	61	21	285	8

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

G E U S

Sample Name:	V 18	No. of frames analysed	64
Lab. Name:	2000198	No. of particles analysed:	780
Date:	13/11/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	0.00
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/50x		
Guard region:	250 µm		
Sieve:	100 µm²		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	59.3	35.0	2.2	0.1	0.7	0.8	0.2	0.1	0.2	98.4
Leucoxene	78.6	13.8	0.8	0.1	1.9	1.8	0.2	0.1	0.2	97.6
Rutile	94.4	1.6	0.2	0.2	0.6	0.5	0.1	0.0	0.3	97.8
Ti magnetite	37.2	19.5	1.0	0.6	37.2	1.9	0.1	0.1	0.0	97.4
Magnetite	14.3	58.3	0.8	0.1	13.4	11.1	0.0	0.1	0.4	98.5
Chromite	0.3	20.3	0.4	43.5	0.2	22.6	11.4	0.1	0.1	99.0
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	1.6	1.8	0.0	0.0	4.8	1.8	0.4	1.4	2.4	14.2
Y-phosphate	0.1	0.5	0.0	0.0	1.3	1.0	0.4	0.7	1.9	5.8
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.1	18.9	6.9	0.0	44.0	13.2	0.4	15.0	0.0	98.6
Kya/Sill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurolite	1.1	15.6	0.5	0.3	35.4	42.9	1.1	0.1	0.7	97.7
Zircon	0.2	0.4	0.1	0.1	29.7	0.1	0.1	0.1	64.5	95.4
Silicate	1.0	4.6	0.2	0.4	69.5	2.5	13.6	2.6	0.5	94.8
Unclassified	4.3	16.0	0.6	7.5	3.7	42.1	8.2	0.3	4.9	87.6

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	91.3	2.1	5.0	0.3	0.0	1.2	0.0	0.1	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	60.3	80.6	96.5	38.2
Fe_2O_3 wt%	35.5	14.1	1.6	20.0
MnO wt%	2.2	0.8	0.2	1.0
Cr_2O_3 wt%	0.1	0.1	0.2	0.6
SiO_2 wt%	0.7	2.0	0.7	38.2
Al_2O_3 wt%	0.8	1.9	0.5	1.9
MgO wt%	0.2	0.2	0.1	0.1
CaO wt%	0.1	0.1	0.0	0.1
ZrO_2 wt%	0.2	0.2	0.3	0.0
Total	100.0	100.0	100.0	100.0

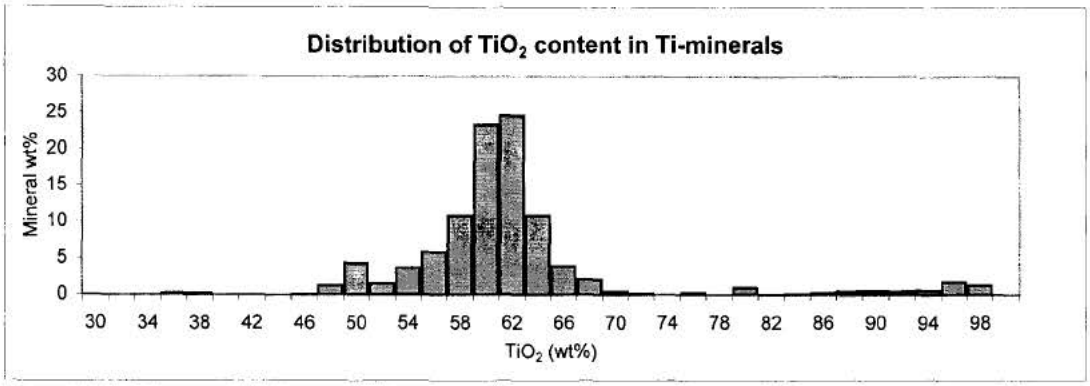
Average TiO_2 content of all the TiO_2 minerals:	62.5
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	60.6
Valuable heavy minerals in raw sand:	0.00

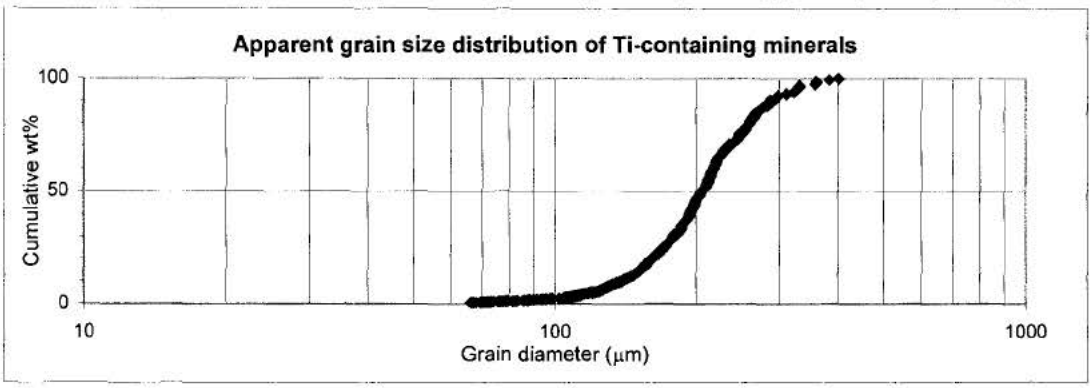
Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	87.0	
Leucoxene	2.0	
Rutile	4.8	
Ti magnetite	0.3	
Magnetite	0.1	
Chromite	1.1	
Pyrite	0.0	
Phosphate	0.0	
Monazite	1.4	
Y-phosphate	0.4	
Sphene	0.0	
Garnet	0.0	
Kya/Sill	0.0	
Staurolite	0.1	
Zircon	1.1	
Silicate	0.1	
Unclassified	1.5	
Total	100.0	

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

GEUS

Lab. Name:	2000198	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	13/11/02		



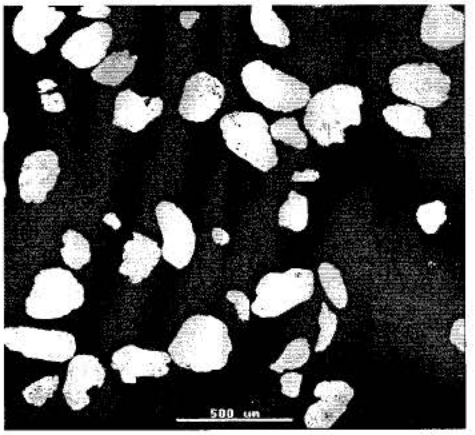


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.5	1.7	687	256	24938	644
Leucoxene	1.6	1.9	627	246	19249	19
Rutile	1.5	1.9	763	301	26496	30
Ti magnetite	1.4	1.7	794	302	28727	2
Magnetite	1.4	2.0	722	287	21297	1
Chromite	1.3	1.6	829	291	35067	5
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.6	1.8	631	239	18161	13
Y-phosphate	1.6	1.8	537	199	13319	5
Sphene	0.0	0.0	0	0	0	0
Garnet	1.8	1.9	299	117	3850	1
Kya/Sill	0.0	0.0	0	0	0	0
Staurolite	1.4	2.1	733	299	20050	1
Zircon	1.4	1.6	505	182	16330	12
Silicate	1.6	1.5	215	84	3187	9
Unclassified	1.5	1.7	467	181	14408	33

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

G E U S

Sample Name:	V 19	No. of frames analysed	64
Lab. Name:	2000199	No. of particles analysed:	564
Date:	13/11/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	0.00
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/50x			
Guard region:	225 µm		
Sieve:	100 µm²		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	51.6	43.3	2.2	0.1	0.5	0.5	0.2	0.1	0.2	98.6
Leucoxene	78.4	13.5	1.4	0.1	1.7	1.6	0.0	0.1	0.3	97.0
Rutile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ti magnetite	33.9	58.7	2.0	0.2	1.8	1.3	0.3	0.0	0.2	98.4
Magnetite	7.9	82.8	0.2	0.1	4.9	1.8	0.2	0.1	0.3	98.2
Chromite	0.3	22.4	0.1	34.2	5.5	24.9	11.3	0.0	0.4	99.0
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	0.4	33.5	2.4	0.1	36.7	19.6	4.2	1.3	0.1	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	1.8	17.4	0.4	0.1	48.3	8.6	8.4	9.8	0.2	95.0
Unclassified	19.8	23.2	1.7	0.2	27.3	10.2	1.2	0.9	5.8	90.3

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	93.8	0.4	0.0	5.0	0.8	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%	52.3	80.8	0	34.4
Fe_2O_3 wt%	43.9	13.9	0	59.7
MnO wt%	2.2	1.4	0	2.0
Cr_2O_3 wt%	0.1	0.1	0	0.2
SiO_2 wt%	0.5	1.7	0	1.9
Al_2O_3 wt%	0.5	1.6	0	1.3
MgO wt%	0.2	0.0	0	0.3
CaO wt%	0.1	0.1	0	0.1
ZrO_2 wt%	0.2	0.3	0	0.2
Total	100.0	100.0	0	100.0

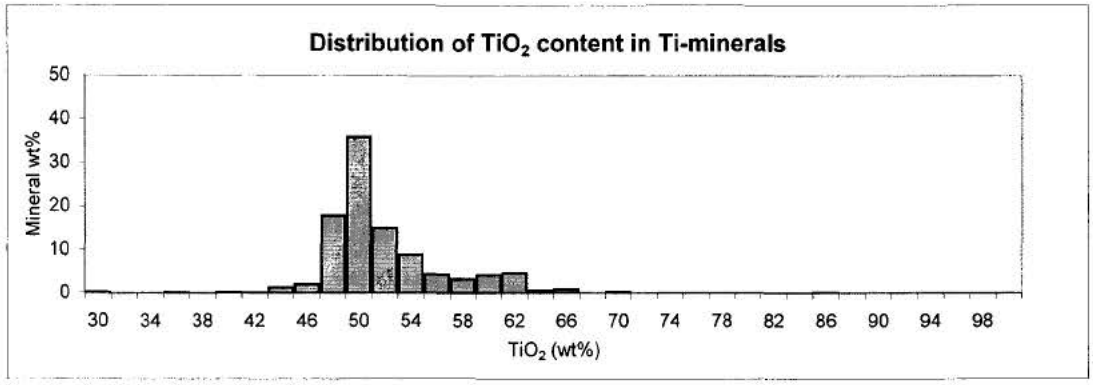
Average TiO_2 content of all the TiO_2 minerals:	51.6
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	51.6
Valuable heavy minerals in raw sand:	0.00

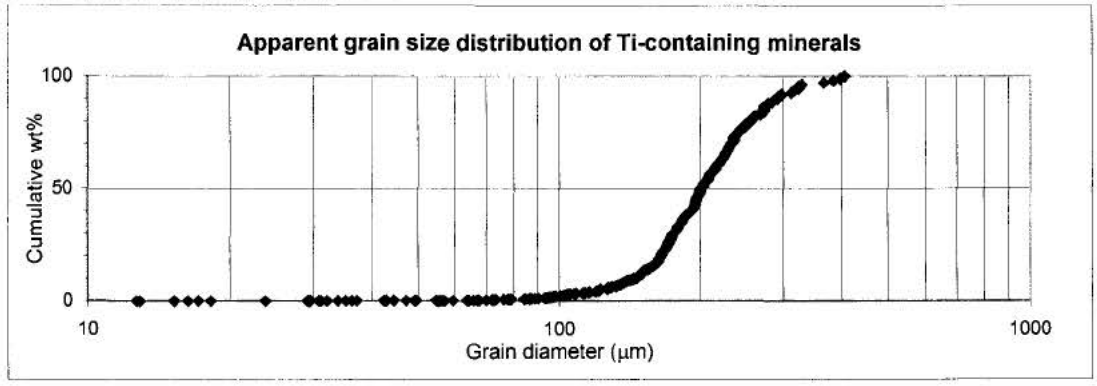
Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	87.8	
Leucoxene	0.4	
Rutile	0.0	
Ti magnetite	4.7	
Magnetite	2.6	
Chromite	0.2	
Pyrite	0.0	
Phosphate	0.0	
Monazite	0.0	
Y-phosphate	0.0	
Sphene	0.0	
Garnet	0.7	
Kya/Sill	0.0	
Staurolite	0.0	
Zircon	0.0	
Silicate	0.9	
Unclassified	2.6	
Total	100.0	

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

GEUS

Lab. Name:	2000199	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	13/11/02		



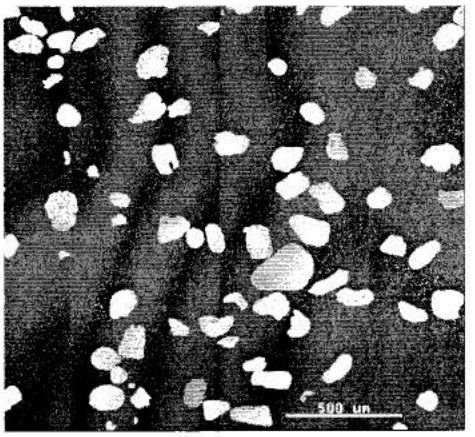


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm²)	Total grains
Ilmenite	1.6	1.8	702	265	25243	496
Leucoxene	1.2	1.9	779	308	26451	2
Rutile	0.0	0.0	0	0	0	0
Ti magnetite	1.6	2.0	788	316	27358	23
Magnetite	1.6	1.7	644	237	25051	13
Chromite	1.1	1.7	734	272	25922	1
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	1.3	2.7	1099	467	38781	3
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	1.5	1.8	527	207	13690	16
Unclassified	1.4	1.8	905	385	62417	10

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

G E U S

Sample Name:	V 23	No. of frames analysed:	28
Lab. Name:	2000203	No. of particles analysed:	770
Date:	20/06/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	7.95
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/50x			
Guard region:	255 µm		
Sieve:	100 µm^2		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	54.1	37.7	3.4	0.1	1.4	1.0	0.2	0.1	0.3	98.3
Leucoxene	75.2	8.2	0.7	0.2	9.7	3.4	0.3	0.1	0.3	98.0
Rutile	92.0	1.4	0.1	0.2	3.0	1.3	0.1	0.1	0.2	98.4
Ti magnetite	42.1	37.6	3.0	0.1	10.5	2.5	0.4	0.1	1.7	98.1
Magnetite	12.7	72.7	0.4	0.2	7.8	3.5	0.2	0.1	1.0	98.5
Chromite	0.4	22.1	1.0	52.1	6.7	12.5	1.8	0.2	0.0	96.7
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	0.4	0.0	0.0	7.8	1.4	0.0	1.5	2.2	13.2
Y-phosphate	0.0	0.0	0.0	0.0	4.4	0.1	0.0	1.7	1.6	7.7
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	2.7	20.3	0.0	0.0	40.6	23.2	6.8	3.1	0.0	96.8
Kya/Sill	0.4	0.4	0.1	0.2	41.1	53.2	0.0	0.0	0.0	95.5
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	0.2	0.2	29.6	0.2	0.1	0.1	63.8	94.9
Silicate	2.1	8.8	0.2	0.1	50.6	26.7	2.0	5.6	0.4	96.6
Unclassified	15.8	18.3	2.5	1.3	22.7	1.1	0.2	0.4	29.5	91.9

	Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	69.6	4.1	3.8	4.9	0.3	17.0	0.3	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	55.0	76.8	93.5	42.9
Fe_2O_3 wt%	38.4	8.3	1.4	38.4
MnO wt%	3.4	0.7	0.1	3.1
Cr_2O_3 wt%	0.1	0.2	0.2	0.1
SiO_2 wt%	1.4	9.9	3.1	10.7
Al_2O_3 wt%	1.0	3.5	1.3	2.5
MgO wt%	0.2	0.3	0.1	0.4
CaO wt%	0.1	0.1	0.1	0.1
ZrO_2 wt%	0.3	0.3	0.2	1.8
Total	100.0	100.0	100.0	100.0

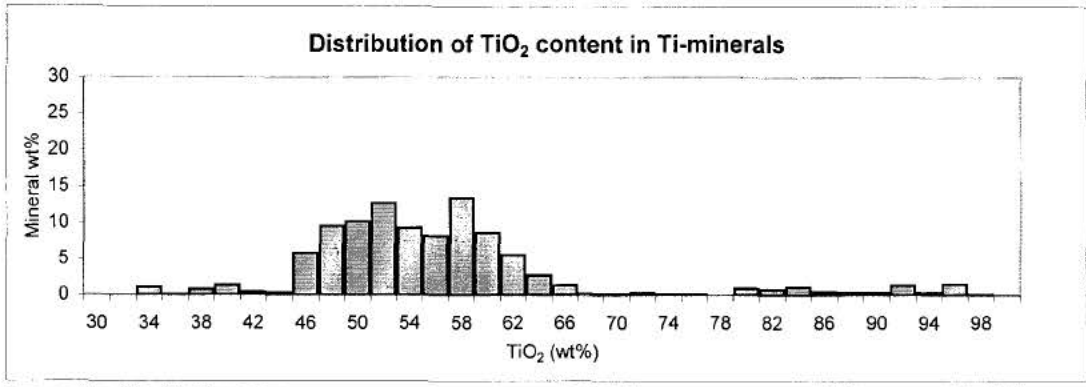
Average TiO_2 content of all the TiO_2 minerals:	57.2
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	55.4
Valuable heavy minerals in raw sand:	7.30

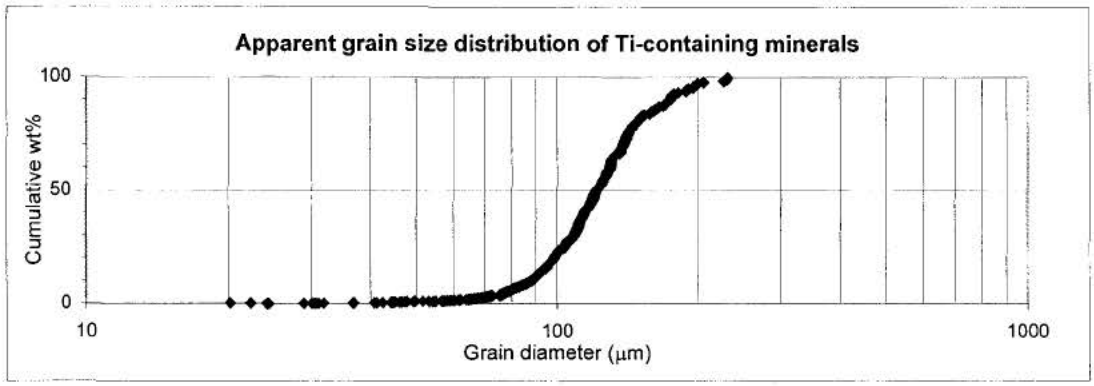
Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	63.9	5.1
Leucoxene	3.8	0.3
Rutile	3.5	0.3
Ti magnetite	4.5	0.4
Magnetite	0.4	0.0
Chromite	0.1	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.3	0.0
Y-phosphate	0.1	0.0
Sphene	0.0	0.0
Garnet	0.3	0.0
Kya/Sill	0.3	0.0
Staurolite	0.0	0.0
Zircon	15.6	1.2
Silicate	5.4	92.5
Unclassified	1.9	0.2
Total	100.0	100.0

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

GEUS

Lab. Name:	2000203	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	20/06/02		



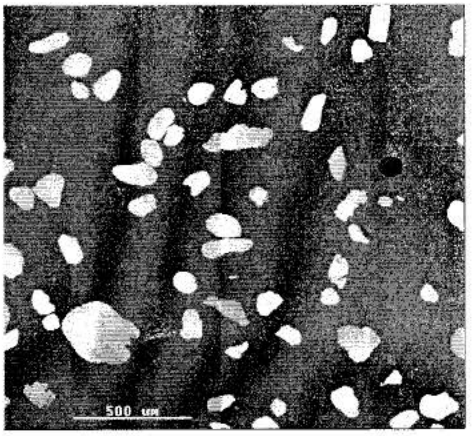


	Average grain parameters					
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.5	1.7	430	159	9437	479
Leucoxene	1.5	1.9	583	225	15661	17
Rutile	1.5	1.6	446	162	10149	22
Ti magnetite	1.8	2.0	496	198	10324	29
Magnetite	1.9	2.3	429	184	7607	3
Chromite	1.6	1.8	288	112	3571	1
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.3	1.5	361	126	6861	3
Y-phosphate	1.1	1.4	259	87	3694	1
Sphene	0.0	0.0	0	0	0	0
Garnet	1.8	1.9	752	295	23832	1
Kya/Sill	3.1	2.5	899	383	25555	1
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.4	1.5	367	129	7592	141
Silicate	1.5	1.9	508	197	12656	51
Unclassified	1.5	2.3	614	259	14196	16

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

G E U S

Sample Name:	V 24	No. of frames analysed:	19
Lab. Name:	2000204	No. of particles analysed:	681
Date:	20/06/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	24.67
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/50x			
Guard region:	225 µm		
Sieve:	100 µm^2		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	54.0	37.2	3.6	0.1	1.8	0.9	0.2	0.1	0.2	98.1
Leucoxene	75.8	12.6	1.2	0.2	5.2	2.5	0.1	0.1	0.2	97.9
Rutile	93.8	1.1	0.2	0.2	1.4	0.8	0.1	0.1	0.2	97.9
Ti magnetite	43.6	45.1	3.3	0.1	3.0	0.8	0.4	0.1	1.8	98.2
Magnetite	15.8	57.9	0.4	8.1	2.1	8.5	5.2	0.2	0.0	98.1
Chromite	0.8	30.2	0.0	33.8	0.7	22.9	9.7	0.0	0.0	98.2
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	0.9	0.0	0.0	14.3	1.8	0.5	0.7	2.2	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	2.5	19.3	0.2	0.4	40.8	23.6	6.5	2.4	0.0	95.6
Kya/Sill	0.3	0.4	0.1	0.6	42.8	53.7	0.1	0.1	0.2	98.3
Staurolite	1.0	17.1	0.7	0.1	31.8	46.8	1.2	0.0	1.1	99.8
Zircon	0.3	0.5	0.1	0.2	29.6	0.2	0.1	0.1	63.4	94.6
Silicate	1.3	10.6	0.2	0.2	46.3	26.7	2.2	8.3	0.3	96.2
Unclassified	19.5	9.3	1.4	2.7	20.1	17.8	1.7	0.1	16.2	88.8

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	74.3	2.8	4.5	4.1	0.3	13.3	0.6	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	55.0	77.4	95.8	44.4
Fe_2O_3 wt%	37.9	12.9	1.1	45.9
MnO wt%	3.6	1.2	0.2	3.3
Cr_2O_3 wt%	0.1	0.2	0.2	0.1
SiO_2 wt%	1.8	5.3	1.5	3.1
Al_2O_3 wt%	1.0	2.5	0.8	0.8
MgO wt%	0.2	0.1	0.1	0.4
CaO wt%	0.1	0.1	0.1	0.1
ZrO_2 wt%	0.2	0.2	0.3	1.8
Total	100.0	100.0	100.0	100.0

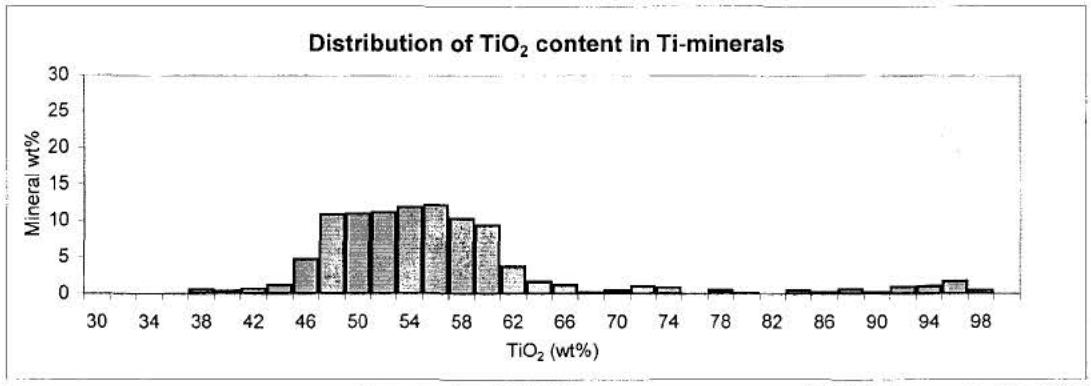
Average TiO_2 content of all the TiO_2 minerals:	57.4
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	55.3
Valuable heavy minerals in raw sand:	22.96

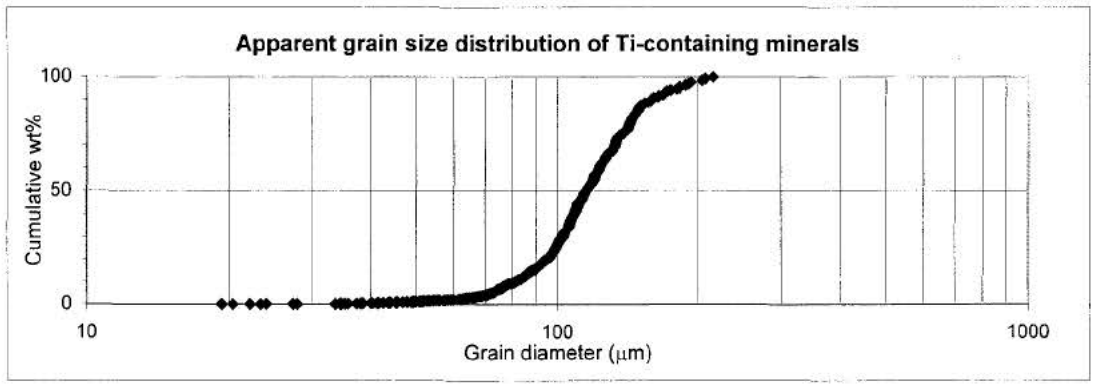
Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	69.2	17.1
Leucoxene	2.6	0.6
Rutile	4.2	1.0
Ti magnetite	3.8	0.9
Magnetite	0.1	0.0
Chromite	0.3	0.1
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.4	0.1
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	0.3	0.1
Kya/Sill	0.5	0.1
Staurolite	0.0	0.0
Zircon	12.4	3.1
Silicate	4.2	76.4
Unclassified	1.9	0.5
Total	100.0	100.0

Geological Survey of Denmark and Greenland
Thoravej 8, DK-2400 Copenhagen NV
Ph.: +45 38142000, Fax: +45 38142050

GEUS

Lab. Name:	2000204	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	20/06/02		



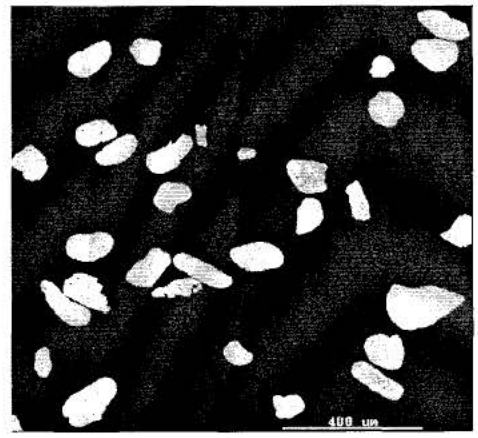


Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm²)	Total grains
Ilmenite	1.6	1.7	409	151	8564	464
Leucoxene	1.6	1.8	474	180	10788	14
Rutile	1.5	1.6	416	151	9065	24
Ti magnetite	1.4	1.6	393	143	8161	25
Magnetite	1.4	1.6	322	116	5212	1
Chromite	1.2	1.4	495	160	13984	1
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	2.1	2.1	551	224	11595	2
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.7	2.1	715	292	19255	1
Kya/Sill	1.6	1.7	535	197	14382	3
Staurolite	1.4	1.5	195	66	2079	1
Zircon	1.4	1.5	357	125	7100	97
Silicate	1.4	1.7	479	184	12531	33
Unclassified	1.5	1.9	489	197	11888	15

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

GEUS

Sample Name:	V 25	No. of frames analysed	59
Lab. Name:	2000205	No. of particles analysed:	798
Date:	11/11/02	Heavy minerals in raw sand (%):	0.00
Submitter:	DuPont/GEUS		
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/75x			
Guard region:	150 µm		
Sieve:	100 µm²		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	52.6	39.8	3.7	0.1	0.9	0.7	0.2	0.1	0.2	98.3
Leucoxene	72.8	18.3	3.1	0.2	1.7	1.7	0.1	0.1	0.3	98.4
Rutile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ti magnetite	44.4	45.7	4.0	0.1	2.6	0.9	0.2	0.1	0.2	98.0
Magnetite	8.5	86.6	0.3	0.7	0.7	0.9	0.1	0.0	0.1	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	1.4	0.0	0.0	0.8	0.0	0.2	1.6	0.0	3.9
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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kya/Sill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.2	0.5	0.2	0.1	30.1	0.0	0.0	0.2	63.8	95.3
Silicate	5.5	20.9	0.0	0.5	68.9	0.4	0.9	0.7	0.0	97.8
Unclassified	21.7	14.8	0.9	0.1	34.0	13.5	0.8	0.3	6.2	92.5

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	94.2	0.4	0.0	4.3	0.0	1.1	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%	53.5	73.9	0	45.3
Fe_2O_3 wt%	40.5	18.6	0	46.6
MnO wt%	3.8	3.2	0	4.0
Cr_2O_3 wt%	0.1	0.2	0	0.1
SiO_2 wt%	1.0	1.8	0	2.6
Al_2O_3 wt%	0.7	1.8	0	0.9
MgO wt%	0.2	0.1	0	0.2
CaO wt%	0.1	0.1	0	0.1
ZrO_2 wt%	0.2	0.3	0	0.2
Total	100.0	100.0	0	100.0

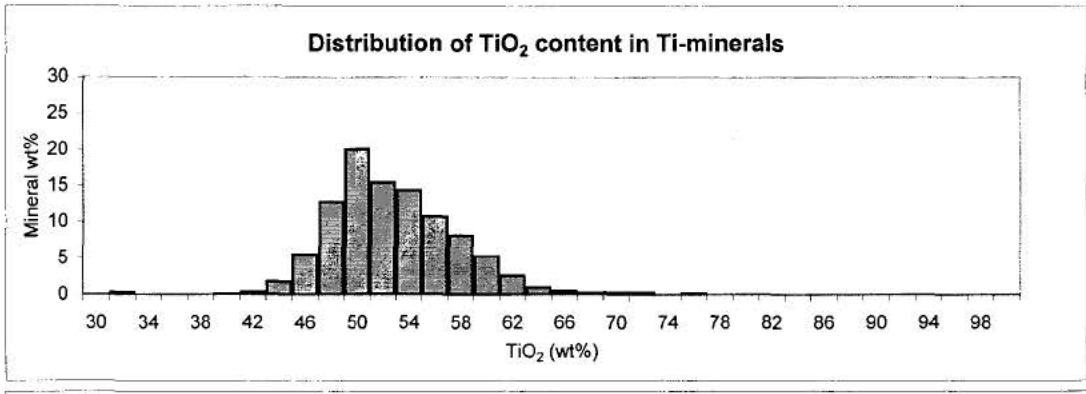
Average TiO_2 content of all the TiO_2 minerals:	53.2
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	53.2
Valuable heavy minerals in raw sand:	0.00

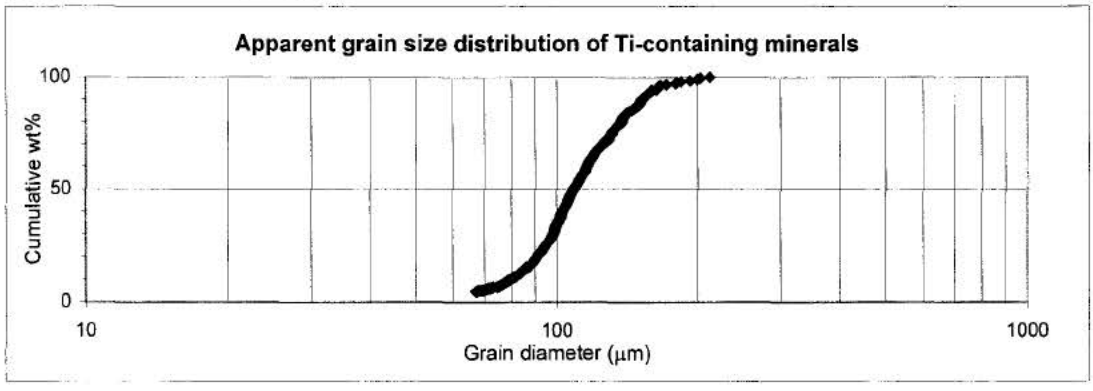
Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	93.9	
Leucoxene	0.4	
Rutile	0.0	
Ti magnetite	4.3	
Magnetite	0.2	
Chromite	0.0	
Pyrite	0.0	
Phosphate	0.0	
Monazite	0.1	
Y-phosphate	0.0	
Sphene	0.0	
Garnet	0.0	
Kya/Sill	0.0	
Staurolite	0.0	
Zircon	1.1	
Silicate	0.0	
Unclassified	0.0	
Total	100.0	

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

GEUS

Lab. Name:	2000205	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	11/11/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.5	1.7	395	149	7786	749
Leucoxene	1.3	1.5	311	112	5942	4
Rutile	0.0	0.0	0	0	0	0
Ti magnetite	1.6	1.9	409	161	7586	33
Magnetite	1.5	1.7	349	129	5675	2
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.1	1.5	257	88	3562	1
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	0.0	0.0	0	0	0	0
Kya/Sill	0.0	0.0	0	0	0	0
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.5	1.8	550	208	13580	5
Silicate	1.3	1.5	136	48	965	1
Unclassified	1.2	1.0	38	14	114	3

Appendix 2

XRF analytical results

Danmarks og Grønlands Geologiske Undersøgelse
Laboratoriet for bjergartsanalyse

Analyseresultater beregnet 6-maj-2002
Rekvireret af Henrik Stendal

	2000188 V08	2000193 V13	2000198 V18	2000199 V19	2000205 V25
Hovedelementer i procent					
SiO2	0.000	0.711	0.084	0.075	0.000
TiO2	53.483	57.561	56.509	51.190	53.175
Al2O3	0.467	1.163	3.172	0.788	0.718
Fe2O3	45.059	36.507	32.544	48.292	42.426
FeO	0.000	0.000	0.000	0.000	0.000
MnO	2.993	2.361	1.601	1.996	3.084
MgO	0.221	0.292	1.179	0.394	0.382
CaO	0.000	0.000	0.000	0.007	0.000
Na2O	0.000	0.000	0.000	0.000	0.000
K2O	0.000	0.000	0.003	0.000	0.000
P2O5	0.023	0.102	0.299	0.031	0.031
Volat	-2.930	-0.290	0.780	-3.170	-1.500
Sum,maj.	99.316	98.407	96.171	99.603	98.316
Sporelementer i ppm					
V	258	633	884	896	857
Cr	0	372	5972	121	0
Ni	52	48	137	68	55
Cu	0	0	0	0	0
Zn	0	0	272	0	0
Rb	323	295	252	332	306
Sr	439	418	395	442	427
Y	561	788	1142	623	558
Zr	1081	2650	4970	1091	3076
Nb	1192	1405	1364	914	1142
Mo	0	0	0	0	0
Sn	0	0	0	0	0
Ba	2445	2962	2848	2248	2509
La	187	198	978	245	105
Ce	252	441	1960	322	267
Sum,min.	6790	10210	21174	7302	9302
Total %	99.995	99.428	98.288	100.333	99.246

Værdier for Mo, Sn, La og Ce er kun orienterende

Reference : Geology of Greenland Survey Bulletin 184, 59-62(1999)

udtag fra Hannes prøver