DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2001/26

Heavy mineral exploration in 2000

Summary report

Henrik Stendal, Christian Knudsen, Charlotte Appel,
Tine Jørgensen, Torben Fischer, Christian Abildtrup
and Thomas Rasmussen

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MINISTRY OF ENVIRONMENT AND ENERGY

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Summary

The present report is a summary of the results obtained by GEUS in the exploration for high grade ilmenite deposits in Denmark and in other countries. The report will be divided into separate reports dealing with the different topics.

The main objective is 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. Overburden < 15 m. The main area of interest in the past year has been Denmark, but scouting for high grade ilmenite deposits outside Denmark was initiated during the year.

Denmark

A number of objectives have been put forward in Denmark. The primary objectives has been: Prospecting for new deposits in the Miocene sands, definition of the size, shape and grade of the Vorslunde deposit (barrier island play) and the Skjern deposit (marine play). Secondary objectives has been to develop exploration methods such as GPR localisation and definition of HM deposits, X-met logging of drillcore in sand, wireline logging for description of in situ grade, CCSEM analysis of mineralogy and mineral chemistry and zircon dating for provenance of HM deposits.

No new prospects were found during the regional exploration. No further exploration for new deposits in Denmark is recommended.

The minimum size, shape and grade of the Vorslunde and Skjern deposits were tested. However, the deposits are still open, and further drilling is planned in 2001.

International scouting

The first contacts were made in Europe, and consequently the majority of results are generated here. Good contacts were established with German, Polish, Lithuanian and Dutch surveys. Further contacts to surveys in Hungary, Romania, Ukraine, Belarus, Spain and France are in progress.

Samples has been collected or received from Sweden, Germany, Holland, Poland and Lithuania. The main results are, that the picture from Denmark, with low grade ilmenites in the Quaternary sediments, whereas the ilmenite in the pre Quaternary is generally high.

The German results from **Sleswig Holstein** indicate that the Neogene sediments here are fine-grained marine, and as the Danish marine play, characterised by low grade ilmenite. In **Sweden**, the Ti minerals are high grade, but the grade in ground too low.

No samples from **Poland** has been analysed yet, but Polish data indicate, that the relative content of economic minerals in the HM fraction is generally low in the Quaternary sediments as is the HM grade in ground. The focus here is the Neogene sediments, which is likely to contain high-grade ilmenite. HM grade in ground in **Lithuania** is low, as is the grade of the ilmenite in the Quaternary sands. However, ilmenite grade in Miocene and Devonian sands is high. At present the most interesting target is Miocene/Pliocene sediment from **Holland**. Here grade of ilmenite is high and the content of rutile and zircon in the HM fraction is high. Data concerning location and grade of HM deposits in **Ukraine** has been received from a local contact.

In Australia both the Australian Geological Survey Organisation (AGSO) and the individual district Surveys have been contacted. However, samples are not easy to get, but some information concerning the grade of ilmenite has been received for a few localities. In Asia correspondence has been forwarded to India, Malaysia, Papua New Guinea, Sri Lanka, Thailand, and Vietnam. In Africa the following countries has been contacted Ghana, Kenya, Mozambique, Namibia, Senegal, South Africa, and Tanzania. The most interesting response has been from Vietnam, Ghana, Mozambique, and Namibia, and it is the intention is to visit these areas during spring 2001

Methods

The GPR method was further developed into a routine method. The X-met method was calibrated against other method, proved very useful. The CCSEM analysis method was also further developed on Danish as well as other samples, and used extensively. All of these methods will be used in future exploration in Denmark and abroad. The logging methods were tested as proved also to be useful. Further work will be conducted in connection to Tines M.Sc. thesis. The new zircon method was tested and proved to be a useful tool in discriminating source for heavy minerals. Further work is necessary to understand the implications of the patterns. The method will be tested in other countries.

Summary 2

Denmark 2
International scouting 2
Methods 3

Introduction 5

Methods 6

CCSEM analyses 6
X-MET 21
LA-ICPMS on zircons, a new fingerprint method 22

Denmark 26

Screening of old samples 26
Georadar (GPR) 26
Prospecting for new deposits in Denmark 27
The Vorslunde area 28
The Skjern deposit 39

International work 43

Europe 43
Australia 50
Asia 53
Africa 56
Americas and Greenland 64
References 65

Recommendations 67

Denmark 67
International scouting 67
Methods 68

Appendices 69

Introduction

The present report is a summary of the results obtained by GEUS in the exploration for high grade ilmenite deposits in Denmark and in other countries. The report will be divided into chapters dealing with the different topics.

The main objective is 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.

The main area of interest in the past year has been Denmark, but scouting for high grade ilmenite deposits outside Denmark was initiated during the year. It is the attempt to generate a database covering the heavy mineral sand deposits in the world. The database will not only focus on deposits being mined, but also deposits that may attract interest as exploration targets. To obtain this, we have started trying to get information about heavy mineral deposits as well as representative samples (one from each deposit). The strategy in this approach letters has been sent to Geological Surveys in Australia, Asia and Africa. In Appendix 1 the Geological Surveys to whom the letters are mailed, replies and received materials are listed.

At present target areas for further investigation is in progress in Europe. Countries chosen and contacts made outside Europe concerns especially Vietnam, Ghana, Kenya, Mozambique, Namibia, and Tanzania. The intention is to visit some of these areas during spring 2001. The international part of this report will give a short summary of the possibilities for heavy minerals in the individual countries we have been in contact with. In Australia both the Australian Geological Survey Organisation (AGSO) and the individual district Surveys have replied to our request. In Asia correspondence has been forwarded to India, Malaysia, Papua New Guinea, Sri Lanka, Thailand, and Vietnam. In Africa the following countries has been contacted Ghana, Kenya, Mozambique, Namibia, Senegal, South Africa, and Tanzania.

The individual contributors to the present report are:

CCSEM – Charlotte Appel
X-MET – Tine Jørgensen
LA-ICPMS – Thomas Rasmussen and Christian Knudsen
Denmark – Christian Abildtrup, Torben Fischer, Tine Jørgensen and Christian Knudsen
International work – Henrik Stendal and Christian Knudsen
Recommendations – Christian Knudsen and Henrik Stendal

The figures and Tables are numbered within each chapter.

Methods

CCSEM analyses

By Charlotte Appel

The analysis by Computer Controlled Scanning Microscopy (CCSEM) is described in detail in Knudsen and Appel (2000). Some modification of the datasheets were made during autumn 2000. The modifications are the following:

- The calculations are made automatically – this will minimise the risk of mistakes during calculations.
- Layout of data sheet was changed at the same time as the automation – it is thus easy to see whether the CCSEM calculation have been made before or after the modifications of the data sheets.
- The average area of the grains within each mineral category has been added.
- 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 mineral categories have been changed – "other Ti-oxides" is no longer a category instead limits for Ti-magnetite have been made, magnetite and chromite has been included. 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

The last modification of the data sheet was made in November 2000.

It is important to note that, because of the change in calculation of the CCSEM analyses, there are differences in the ways some of the values in the summary below are obtained.

Reproducibility of CCSEM analyses

Several samples have been analysed twice as mentioned in Abildtrup et al. (2000). The results of the double analyses are also shown in Abildtrup et al. (2000). The reproducibility of the results is shown by two analyses of V62 1-13. One analysis was made 13th July 00 and the other one 7th August (see CCSEM appendix). The average TiO_2 content of ilmenite in the two analyses is 60.6 and 60.1, respectively, and the average TiO_2 content of all the TiO_2 minerals is 62.6 and 63.3. This shows a good reproducibility of the analyses at the same SEM and with the same operator.

The heavy part of the HM fraction of SK99/1 17-27 (SK99/1 17-27 heavy) was analysed on another SEM by another operator, by Henning Sund Sørensen at Danfoss. The result of the Danfoss CCSEM analysis is also given in the CCSEM appendix. The result is very similar to the results obtained at GEUS. However, the measured grain curve shows a significantly smaller grain size in the Danfoss analysis compared with the GEUS analysis; the median grain size obtained in the Danfoss analysis is 54 μm whereas it is 69 μm in the GEUS analysis. This is most probably due to the way of set up of contrast on the images for the CCSEM analysis and therefore the grain size determination depends on the operator.

Denmark

From Denmark 64 HM samples have been analysed by CCSEM during 2000 and beginning of 2001 (Table 1). Most of the samples are from the Skjern and Vorslunde areas. The samples were analysed during various periods. Table 1 shows during which periods the samples were analysed; this may be important to know because during the acquisition of CCSEM in October-November 2000 the data sheet was changed as described above. In the report Abildtrup et al. (2000) it is noted for which analyses made in October-November 2000 was calculated in the new data sheet.

Vorslunde

A large amount of samples (27) from Vorslunde were analysed by CCSEM. The CCSEM results have been given in earlier reports and the results are summarised in Table 2. The Vorslunde samples generally are rather coarse grained with median grain sizes > 150 μm; however, 3 Vorslunde samples have median grain sizes below 100 μm (V31 12-23m, V32 22-27m and V47 19-23 m); this indicates that these three samples are from marine type deposits.

Analysed					Analysed
2000					2001
March	July-September		October-November		January
V22 11-20m	V53 6-11m	Sk0007 11-26m	E 1 11-16m	SK0015 18m	M2A00.01 23-24m
V23 1-9m	V53 12-23m	SK0009 21-22m	E1 18-23m	SK0015 22m	
V31 12-23m	V62 1-13m	Sk0009 23-29m	E2 15-26m	SK0015 25m	
V32 22-27m	V62 15-23m	SK0010 21-24m	F1 15-22m	SK0029 14-22m	
V36 1-11m	V89 21-22m	SK0010 28-30m	V62 6m	SK0030 18-24m	
V36 1-11m	V89 23-24m	SK0011 13-28m	V62 14m	SK0030 25-32m	
V37 1-12m	V89 5-18m	SK0012 16-30m	V62 23m	SK0033 14-22m	
V41 12-23m	V83 16-23m	Sk0015 15-27m	V92 9-13m	SL10001 19-25m	
V42 14-20m	V83 9-14m	SK0016 12-25m	V92 17-26m		
V44 22-26m	LM1 12-12m	SK0017 18-32m	V101 3-17m		
V47 19-23m	LM2 7-8m	SK0019 14-26m	V101 21-26m		
	LM2 18-22m	SK0021-15-29m	V1A002 9-18m		
	HP2 17-26m	SK0022 12-25m			
	HP3 12-21m	SK0035 14-18m			
	FM1 20-21m	SK0035 19-21m			
	SK0006 9-24m	SK0035-22-32m			

Table 1: Periods during which the Danish HM-samples were analysed by CCSEM.

The CCSEM analyses from each locality will be described separately and some of the characteristic numbers obtained from CCSEM are compiled in Tables 2 to 4.

From some of the drill holes CCSEM analyses have been made on HM-concentrates from various depth levels. Although some of the HM-concentrates cover a large depth interval there seems to be a general tendency of a lower average TiO_2 content of the TiO_2 minerals and a lower TiO_2 content in the ilmenite with increasing depth (see V42, V53, V62, V92 and V101; Table 2). However, V83 and V89 show the opposite tendency.

The amount of valuable heavy minerals in the raw sand varies between 0.5 and 4.2 weight %, but for most of the samples it is between 1 and 2 weight %. The amount of valuable heavy minerals in the HM fraction is high commonly above 80 weight %. For the high marine type samples in the HM fraction has considerably lower Ti content, 41-68.4 weight %. In several of the Vorslunde samples more than 5 weight % of the heavy minerals are zircon.

Skjern

24 samples from Skjern were analysed during 2000. The CCSEM results have been given in earlier reports and the results are summarised in Table 3. The Skjern samples generally are fine grained with median grain sizes < 130 μm; Most of the samples have median grain sizes less that 100 μm.

The amount of valuable heavy minerals in the raw sand varies between 0.9 and 8.0 weight %. However, the content of valuable heavy minerals in the HM fraction is considerably lower, 22.7-49.7 weight %, than in the coarse grained Vorslunde samples.

Some of the Skjern samples have a very high amount (> 10 weight %) of unidentified minerals. The unidentified minerals are observed to have a high average content of CaO and in some of the samples fragments of shells were seen; therefore relatively large amounts of calcite may be present and calcite will fall within the category unclassified minerals. The high amount of unclassified material is seen in the samples: SK0009 21-22m, SK0010 28-30m, SK0035 19-21m and SK0035 22-32m.

Fjaldene

Only one sample was analysed by CCSEM from Fjaldene. The result is seen in Abildtrup et al. (2000). A summary is seen in Table 4. The average TiO_2 content in all TiO_2 minerals in F1 15-22m is relatively high (64.5 weight%) although the TiO_2 content in the ilmenite is low (56.7 weight %). But the contents of leucoxene and rutile are high, respectively,10.5 and 8.2 weight %.

Eg

3 samples were analysed by CCSEM from Eg. The results are seen in Abildtrup et al. (2000). A summary is seen in Table 4.

Two of the samples from Eg (E1 18-23m and E2 15-26m) have a high amount of unclassified material, respectively 7 and 10 weight %. The average composition of the unclassified phase is not similar in the two samples. On the SEM image from E1 18-23m layered minerals are observed; no layered silicates are classified and therefore they may fall in the unclassified category. The average content of CaO in the unclassified category in E2 15-26m is high and therefore calcite may also be present, thus giving rise to the high amount of unclassified grains.

Filskov Mark

Only one sample was analysed by CCSEM from Filskov Mark. The result is seen in Abildtrup et al. (2000). A summary is seen in Table 4. This sample does not have any obvious characteristics which makes it easy to distinguish from the other samples.

Hastrup Plantage

Two samples were analysed by CCSEM from Hastrup Plantage. The results are seen in Abildtrup et al. (2000). A summary is seen in Table 4. These two analyses are similar to the one from Filskov Mark although the content of valuable heavy minerals in the raw sand is lower in the samples from Hastrup Plantage than in the one from Filskov Mark.

Lindbjerg Mark

Three samples were analysed by CCSEM from Lindbjerg Mark. The results are seen in Abildtrup et al. (2000). Grains composed of several minerals is a dominant feature in the samples; this is seen in the images of LM2 7-8m and LM2 18-22m. In LM2 7-8m the amount of unclassified material is 11.5 weight % and this large value may be caused by a large amount of composite grains. The average TiO_2 content of the TiO_2 minerals is extremely low in LM2 7-8m; the reason is a large content of 'other Ti-oxides' with a low Ti-content. Therefore LM2 7-8m was recalculated in the new data sheet which classifies Ti-magnetite and not 'other Ti-oxides' (see results in CCSEM Appendix 2). The recalculation changes the average TiO_2 content of the TiO_2 minerals from 39.7 to 59.4 and the curve showing the apparent grain size distribution of the TiO_2 containing minerals does not show the large grains because they are not classified as TiO_2 containing minerals. A summary of the CCSEM results, including the new calculation of LM2 7-8m is seen in Table 4.

Sønder Felding

Only one sample was analysed by CCSEM from Sønder Felding. The result is seen in Abildtrup et al. (2000). A summary is seen in Table 4. The CCSEM analysis of SL10001 19-25m may contain some artefacts because the grains are very close to each other in certain areas; therefore several grains may not be separated during the analysis; this is also seen on the image supplied with the data. The average TiO_2 content of all the TiO_2 minerals is below 60 weight % and there is 1.9 weight % valuable heavy minerals in the raw sand.

Vemb

Only one sample was analysed by CCSEM from Vemb. The result is seen in Abildtrup et al. (2000). A summary is seen in Table 4. The amount of grains in the sample is very low, within 100 images it was only possible to analyse 218 grains, therefore the statistics in the analysis are poor. The amount of valuable heavy minerals in the raw sand is only 0.1 weight %.

Møborg

Only one sample was analysed by CCSEM from Møborg. The result is seen in the CCSEM appendix. A summary is seen in Table 4. M2A00.01 23-24m has 69.5 weight % in average TiO_2 in all TiO_2 minerals this is the highest measured TiO_2 content in the Danish samples. The TiO_2 content in the ilmenite is relatively high, 59.6 weight % and the weight % of leucoxene in the HM-fraction is as high as 15.2 weight %. But the amount of valuable heavy minerals in the raw sand is low, 0.5 weight %.

Comparison of the CCSEM results on samples from Danish localities

The CCSEM results from the Danish localities have been plotted in various diagrams to be able to determine the characteristics of the various deposits. From the summary Tables it is already clear that the median grain size is larger in the Vorslunde and Vemb samples than in the samples from the other localities (in the new data sheet the median grain size only cover the TiO_2 containing minerals). The 3 fine grained high marine type Vorslunde samples are easily distinguished on plots showing median grain size on one axis (Fig. 1). The lowest average TiO_2 contents in all TiO_2 minerals are measured in the fine grained Skjern samples, but some of the Skjern samples and the fine grained sample from Vemb also have high average TiO_2 contents in all TiO_2 minerals (Fig. 1).

When the amount of valuable heavy minerals (ilmenite, leucoxene, rutile, Ti-magnetite/other Ti-oxides, garnet, zircon and sillimanite) are plotted against the median grain size (Fig. 2), it is clearly seen that the coarse grained Vorslunde samples have the highest content of valuable minerals in the HM-concentrate.

The TiO_2 content in ilmenite in the coarse grained Vorslunde samples and in the Vemb sample is higher than in the fine grained samples whereas the opposite is the case with the TiO_2 content in the leucoxene (Fig. 3). The fine grained sample from Møborg plots together with the coarse grained Vorslunde samples, and one coarse grained Vorslunde sample (V62 23m) plots among the high marine type samples (Fig. 3). The variation in the TiO_2 content in the leucoxene may illustrate a higher degree of alteration in the fine-grained samples.

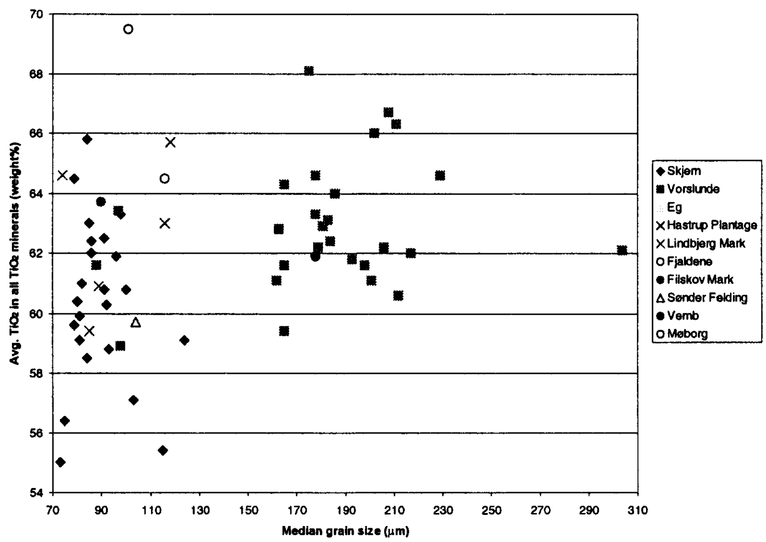

Figure 1: The median grain size (only the median grain size of the TiO_2 minerals for some of the samples) plotted against the average TiO_2 content in all TiO_2 minerals.

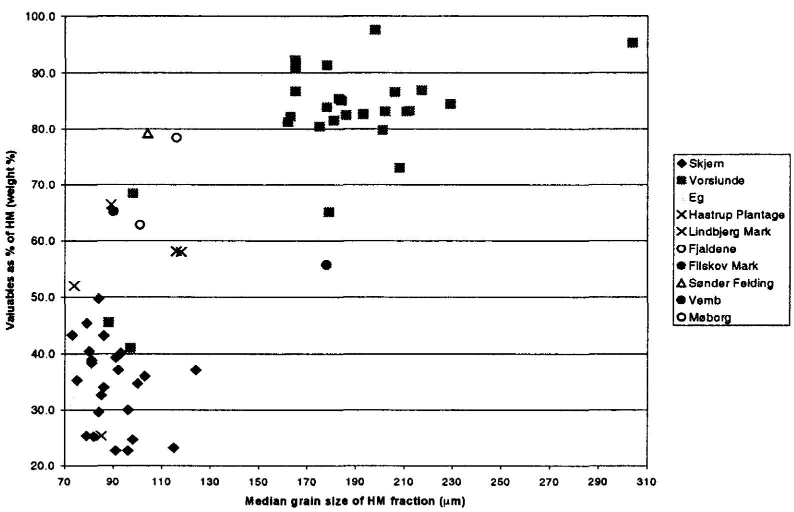

Figure 2: The median grain size (only the median grain size of the TiO_2 minerals for some of the samples) plotted against the amount of valuable heavy minerals in the HM-concentrate.

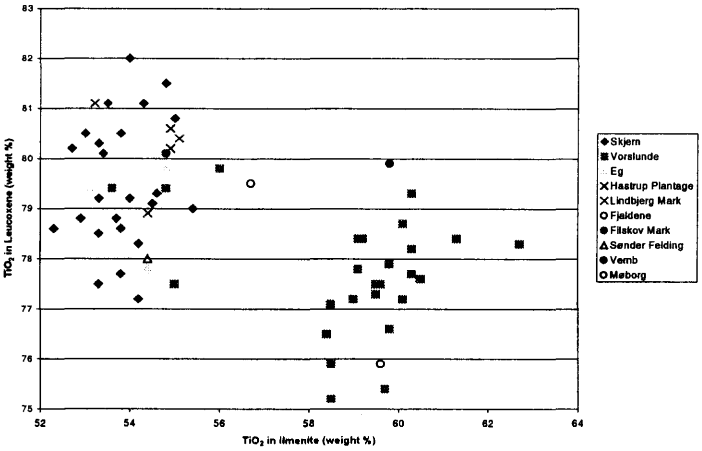

Figure 3: The average TiO_2 content in ilmenite plotted against the average TiO_2 content in leucoxene.

Chemistry of the ilmenite

On the basis of the provenance studies on a Vorslunde sample (Hough, 2000) a similar discrimination of groups was tried by using the CCSEM data. This was not successful because the analysis time used for the CCSEM is only 10 seconds and the ratio between peak and background for the minor elements does not reach a value, which makes it significant.

A typical Vorslunde (V62 6m) and Skjern sample (SK15 18m) have been chosen for a more detailed examination of the ilmenite chemistry. The lower content of TiO_2 and higher content of Fe_2O_3 in the Skjern ilmenite compared to the Vorslunde ilmenite is seen in Fig. 4. A larger scatter is seen in both the TiO_2 and the Fe_2O_3 content in the ilmenite from

Skjern than in the one from Vorslunde. The ilmenites from the two localities form the same trend in the diagram (Fig. 4).

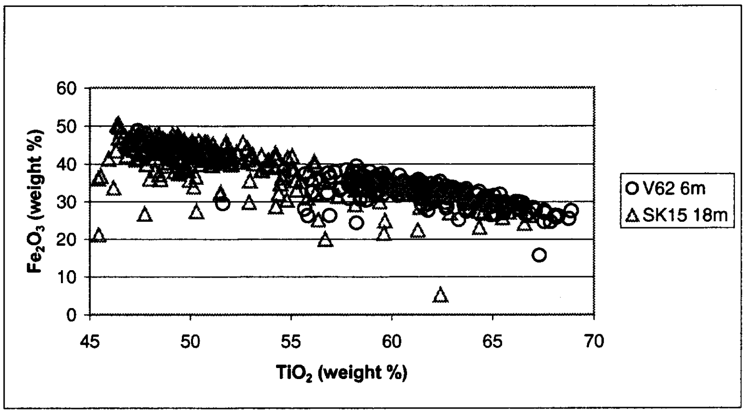

Figure 4: The TiO_2 content in ilmenites from V62 6m and SK15 18m plotted against the Fe_2O_3 content in the ilmenites.

The variation in the SiO_2 content in ilmenite in the two samples (V62 6m and SK15 18m) is seen in Fig. 5. The largest scatter in SiO_2 content is seen in the ilmenites with the lowest TiO_2 content; most of the ilmenite in V62 6m has a SiO_2 content below 1 weight %. This may indicate that inclusions of silicates in the ilmenites may to some degree be responsible for the lower TiO_2 content in the Skjern ilmenites as observed in Fig. 3; but since the TiO_2/Fe_2O_3-ratio (this is possible to see from fig. 4) is lower for the Skjern ilmenites than for the Vorslunde ones the pure Skjern ilmenite has a lower TiO_2-content.

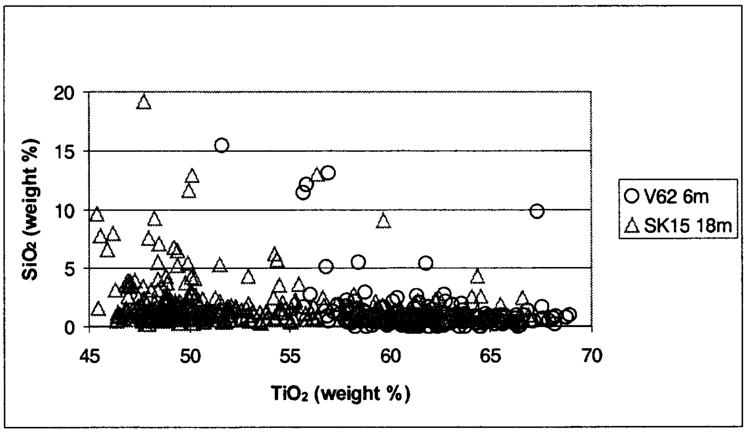

Figure 5: The TiO_2 content in ilmenites from V62 6m and SK15 18m plotted against the SiO_2 content in the ilmenites.

Sweden

Four samples from Eriksdal were analysed. As already described in Abildtrup et al. (2000) the average TiO_2 content in all the TiO_2 minerals is very high 73 to 78 weight %. This is caused by a high content of TiO_2 in the ilmenite and a high content of leucoxene in the HM-concentrate; but the amount of heavy minerals in the raw sand is lower than 0.5 weight %.

Sample no	Avg. TiO_2 in all TiO_2 minerals	Avg. TiO_2 in all TiO_2 minerals ex. Rutile	TiO_2 in Ilmenite	TiO_2 in Leucoxene	TiO_2 in Rutile	Ilmenite as % of all HM	Leucoxene as % of all HM	Rutile as % of all HM	Zircon as % of all HM	Garnet as % of all HM	Sillimanite as % of all HM	Other TiO_2 oxides (artifact)	Valuables as % of HM	Median grain-size of HM fraction
V22 11-20m	61.8	58.9	58.5	75.2	95.1	60.0	3.5	5.7	7.0	4.3	0.2	1.9	82.6	193
V23 1-9m	62.8	61.0	59.7	75.4	94.9	63.6	7.6	4.2	3.7	1.7	0.8	0.6	82.2	163
V31 12-23m	58.9	56.0	54.8	79.4	94.4	40.9	5.6	4.4	7.2	3.3	0.3	6.7	68.4	98
V32 22-27m	61.6	57.5	53.6	79.4	95.4	23.7	6.7	4.1	3.6	3.7	0.0	3.7	45.5	88
V36 1-11m	59.4	57.4	59.1	78.4	94.7	62.9	3.7	4.3	7.8	1.2	2.3	8.5	90.7	165
V37 1-12m	62.2	60.8	59.8	76.6	95.0	66.2	8.6	3.3	3.1	1.5	1.3	2.5	86.5	206
V41 12-23m	66.0	62.5	60.1	78.7	96.1	59.9	9.5	8.1	4.1	1.0	0.1	0.4	83.1	202
V42 3-11m	62.9	60.6	59.8	77.9	95.8	65.1	3.5	4.8	5.4	1.2	1.4	0.1	81.5	181
V42 14-20m	61.6	59.9	58.5	75.9	96.9	73.6	6.5	3.8	9.4	1.9	2.1	0.2	97.5	198
V44 22-26m	62.0	60.9	59.5	77.3	96.1	63.2	7.3	2.4	5.2	6.1	1.6	1.1	86.9	217
V47 19-23m	63.4	60.3	55.0	77.5	94.2	22.0	8.5	3.2	1.8	3.5	0.4	1.6	41.0	97
V53 6-11m	62.4	60.0	59.6	77.5	96.6	67.2	3.1	5.0	4.7	1.0	3.1	1.0	85.1	184
V53 12-23m	60.6	59.3	58.4	76.5	96.5	65.9	3.6	2.4	4.9	3.7	2.6	0.1	83.2	212
V62 6m	68.1	65.4	62.7	78.3	95.8	56.6	11.6	6.6	3.6	0.4	1.6	0.0	80.4	175
V62 1-13m	63.3	61.9	60.1	77.2	95.2	68.4	7.9	3.4	7.9	1.4	2.2	0.1	91.3	178
V62 14m a	64.3	62.4	61.3	78.4	97.1	73.9	5.1	4.6	4.1	0.6	3.8	0.1	92.2	165
V62 15-23m	63.1	61.2	59.2	78.4	96.1	62.1	8.2	4.1	4.0	4.1	2.1	0.8	85.4	183
V62 23m	61.1	59.5	56.0	79.8	96.3	55.2	11.0	3.2	1.7	5.9	2.3	1.9	81.2	162
V83 9-14m	61.6	59.6	59.1	77.8	95.2	63.7	6.1	4.2	5.2	3.2	1.4	2.9	86.7	165
V83 16-23m	64.6	62.0	60.3	79.3	95.7	61.3	5.2	5.5	5.0	5.7	1.2	0.5	84.4	229
V89 5-18m	64.0	61.5	60.3	78.2	94.5	63.5	6.5	5.7	2.0	0.9	2.4	1.4	82.4	186
V89 21-22m	66.7	62.7	60.3	77.7	95.5	47.9	8.3	7.7	3.1	2.0	3.6	0.4	73.0	208
V89 23-24m	66.3	62.9	60.5	77.6	95.7	59.9	9.8	8.1	3.5	1.1	0.7	0.0	83.1	211
V92 8-13 m	62.2	60.9	59.5	77.5	95.1	52.3	6.1	2.5	2.0	0.2	0.5	1.5	65.1	179
V92 17-26m	61.1	59.6	58.5	77.1	96.2	64.0	4.0	3.0	5.6	0.5	2.6	0.1	79.8	201
V101 3-17m	64.6	62.4	60.3	77.7	96.1	60.8	8.6	5.0	5.7	2.4	1.1	0.3	83.9	178
V101 21-26m	62.1	60.3	59.0	77.2	96.3	71.9	6.9	4.0	5.8	4.6	1.1	0.9	95.2	304
average	62.9	60.6	59.0	77.7	95.6	59.1	6.8	4.6	4.7	2.5	1.6	1.5	80.7	183

Table 2. Summary of the CCSEM analyses made in 2000 of samples from Vorslunde.

Sample no	Avg. TiO_2 in all TiO_2 minerals	Avg. TiO_2 in all TiO_2 minerals ex. Rutile	TiO_2 in Ilmenite	TiO_2 in Leucoxene	TiO_2 in Rutile	Ilmenite as % of all HM	Leucoxene as % of all HM	Rutile as % of all HM	Zircon as % of all HM	Garnet as % of all HM	Sillimanite as % of all HM	Other TiO_2 oxides (artifact)	Valuables as % of HM	Median grain-size of HM fraction
SK0006 9-24m	62.4	57.6	54.2	78.3	95.5	16.8	5.3	3.5	0.9	5.6	0.0	1.9	34.0	86
SK0007 11-26m	59.1	54.6	53.8	78.6	96.7	20.9	3.4	3.4	1.8	4.2	0.2	4.5	38.4	81
SK0009 21-22m	59.1	54.6	53.3	79.2	95.6	19.8	2.1	3.0	2.9	6.8	0.4	2.1	37.1	124
SK0009 23-29m	60.3	57.1	55.4	79.0	94.5	21.7	4.1	2.7	3.3	2.7	0.0	2.6	37.1	92
SK0010 21-24m	62.0	57.2	53.8	77.7	96.7	21.6	5.3	4.0	7.1	2.8	0.2	2.2	43.2	86
SK0010 28-30m	61.9	55.1	54.6	79.3	94.8	7.6	4.3	3.3	1.2	1.8	0.3	4.2	22.7	96
SK0011 13-28m	63.3	59.7	55.0	80.8	95.7	13.7	4.5	2.2	0.8	1.5	0.2	1.8	24.7	98
SK0012 16-30m	61.9	56.7	54.8	81.5	95.4	9.8	7.1	3.5	0.8	3.2	0.4	5.2	30.0	96
SK0015 15-27m	59.9	56.5	53.4	80.1	95.4	21.9	4.7	2.8	4.9	1.8	0.1	2.7	38.9	81
SK0015 18m	58.5	53.8	52.7	80.2	94.2	29.7	2.4	4.6	5.4	3.5	1.1	3.0	49.7	84
SK0015 22m	56.4	52.2	52.3	78.6	94.6	18.6	2.5	3.0	2.6	1.9	0.0	6.7	35.3	75
SK0015 25m	61.0	56.0	54.5	79.1	94.7	11.4	3.1	2.7	0.9	3.1	0.1	4	25.3	82
SK0016 12-25m	60.8	57.4	54.3	81.1	94.4	10.5	4.0	1.6	0.7	3.5	0.6	1.8	22.7	91
SK0017 18-32m	60.8	57.1	54.0	79.2	95.6	16.6	6.0	2.9	2.0	1.9	0.4	4.9	34.7	100
SK0019 14-26m	65.8	62.4	54.0	82.0	94.3	13.1	7.4	2.6	1.6	3.2	0.2	1.5	29.6	84
SK0021 15-29m	62.5	57.5	53.7	78.8	94.5	18.2	6.8	4.5	3.9	1.6	0.2	4.1	39.3	91
SK0022 12-25m	63.0	55.8	53.8	80.5	92.9	16.1	3.1	5.2	1.9	3.7	0.0	2.6	32.6	85
SK29 14-22m	60.4	56.8	52.9	78.8	93.9	19.3	5.7	3.1	4.0	4.6	0.3	3.4	40.4	80
SK30 18-24m	59.6	54.4	53.0	80.5	95.3	26.1	3.1	4.7	6.1	1.6	0.0	3.8	45.4	79
SK30 25-32m	64.5	57.7	54.2	77.2	95.1	12.0	3.9	4.0	1.6	1.5	0.1	2.3	25.4	79
SK33 14-22m	58.8	56.7	53.3	80.3	94.5	21.9	6.1	1.9	2.8	3.0	0.0	4.4	40.1	93
SK0035 14-18m	55.0	50.7	53.3	78.5	94.5	20.4	4.9	3.5	4.5	2.5	0.4	7.1	43.3	73
SK0035 19-21m	57.1	50.8	53.3	77.5	95.2	15.1	4.3	4.1	4.3	2.7	0.2	5.3	36.0	103
SK0035 22-32m	55.4	52.6	53.5	81.1	95.1	12.5	1.5	1.2	2.8	1.4	0.4	3.4	23.2	115
average	60.4	55.9	53.8	79.5	95.0	17.3	4.4	3.3	2.9	2.9	0.2	3.6	34.5	90

Table 3. Summary of the CCSEM analyses made in 2000 of samples from Skjern

Sample no	Avg. TiO_2 in all TiO_2 minerals	Avg. TiO_2 in all TiO_2 minerals ex Rutile	TiO_2 in Ilmenite	TiO_2 in Leucoxene	TiO_2 in Rutile	Ilmenite as % of all HM	Leucoxene as % of all HM	Rutile as % of all HM	Zircon as % of all HM	Garnet as % of all HM	Sillimanite as % of all HM	Other TiO_2 oxides (artifact)	Valuables as % of HM	Median grain-size of HM fraction
Fjaldene *marine*														
F1 15-22m	64.5	60.2	56.7	79.5	94.6	43.3	10.5	8.2	5.0	5.1	3.4	2.9	78.4	116
Eg *marine*														
E1 11-16m	62.8	59.0	54.8	79.8	95.2	18.1	5.1	2.9	2.4	0.9	0.2	1.8	31.4	78
E1 18-23m	62.9	59.0	53.1	79.4	93.8	14.8	6.1	2.9	3.8	2.0	0.0	2.1	31.7	74
E2 15-26m	63.0	57.8	54.4	77.8	94.6	16.9	4.0	3.6	4.1	0.9	0.3	1.4	31.2	61
average	62.9	58.6	54.1	79.0	94.5	16.6	5.1	3.1	3.4	1.3	0.2	1.8	31.4	71
Filskov Mark *marine*														
FM1 20-21m	63.7	60.7	54.8	80.1	94.5	34.6	13.5	5.0	3.0	4.3	1.4	3.4	65.2	90
Hastrup Plantage *marine*														
HP2 17-26m	65.7	63.1	54.9	80.6	94.5	24.0	16.4	4.0	2.2	5.1	2.2	4.1	58.0	118
HP3 12-21m	63.0	60.0	54.9	80.2	94.7	35.9	10.3	4.4	2.6	4.0	0.0	0.9	58.1	116
average	64.4	61.6	54.9	80.4	94.6	30.0	13.4	4.2	2.4	4.6	1.1	2.5	58.1	117
Lindbjerg Mark *marine*														
LM1 12-12m	60.9	56.4	53.2	81.1	95.7	36.5	7.4	6.1	9.2	2.5	0.6	4.1	66.5	89
LM2 7-8	59.4	55.3	54.4	78.9	95.0	14.2	2.6	2.3	1.9	0.5	0.2	3.7	25.4	85
LM2 18-22m	64.6	60.2	55.1	80.4	94.7	26.4	9.2	5.8	5.0	2.0	0.3	3.3	52.0	74
average	61.6	57.3	54.2	80.1	95.1	25.7	6.4	4.7	5.4	1.7	0.4	3.7	48.0	83
Sønder Felding *marine*														
SL100.01 19-25	59.7	57.3	54.4	78.0	93.9	44.1	11.1	4.3	5.0	7.3	0.8	6.6	79.2	104
Vemb *barriere*														
V1A0002 9-18m	61.9	61.8	59.8	79.9	92.2	40.1	5.7	0.1	1.8	5.2	1.1	1.7	55.7	178
Møborg *barriere*														
M2A00.01 23-24m	69.5	65.9	59.6	75.9	91.7	30.0	15.2	7.0	4.6	3.3	0.4	2.3	62.8	101

Table 4. Summary of the CCSEM analyses made in 2000 of samples from Fjaldene, Eg, Filskov Mark, Hastrup Plantage, Lindbjerg Mark, Sønder Felding, Vemb og Møborg

Sample no	Avg. TiO_2 in all TiO_2 minerals	Avg. TiO_2 in all TiO_2 minerals ex. Rutile	TiO_2 in Ilmenite	TiO_2 in Leucoxene	TiO_2 in Rutile	Ilmenite as % of all HM	Leucoxene as % of all HM	Rutile as % of all HM	Zircon as % of all HM	Garnet as % of all HM	Sillimanite as % of all HM	Other TiO_2 oxides (artefact)	Valuables as % of HM	Median grain-size of HM fraction
Limburg 5	74.1	64.6	62.0	77.7	94.6	38.0	7.6	21.2	12.6	1.2	0.2	0.0	80.8	110
KW21 27-28m	75.4	63.2	58.6	78.3	94.5	21.4	9.8	21.2	20.6	1.3	0.1	2.3	76.7	92
KW24 16-17m	76.6	67.7	58.2	79.0	94.4	20.7	19.0	20.0	20.3	0.9	0.0	0.7	81.6	86
KW24 21-21.8m	68.9	61.1	57.4	77.2	95.3	17.2	8.7	8.5	23.8	1.3	0.0	3.0	62.5	95
KW25 9-10m	70.6	62.5	58.0	77.9	94.1	26.2	10.7	13.6	22.1	1.5	0.4	2.1	76.6	103
KW26 11-12m	70.3	66.0	60.3	78.9	93.9	3.7	3.4	1.5	3.0	0.1	0.0	0.9	12.6	106
average	72.7	64.2	59.1	78.2	94.5	21.2	9.9	14.3	17.1	1.1	0.1	1.5	65.1	99

Table 5. Summary of the CCSEM analyses made in 2000 and 2001 of samples from Holland.

Sample no	Avg. TiO_2 in all TiO_2 minerals	Avg. TiO_2 in all TiO_2 minerals ex. Rutile	TiO_2 in Ilmenite	TiO_2 in Leucoxene	TiO_2 in Rutile	Ilmenite as % of all HM	Leucoxene as % of all HM	Rutile as % of all HM	Zircon as % of all HM	Garnet as % of all HM	Sillimanite as % of all HM	Other TiO_2 oxides (artefact)	Valuables as % of HM	Median grain-size of HM fraction
HL5 321-324	54.2	52.1	52.9	79.7	96.4	29.3	3.7	2.1	1.7	1.8	1.5	8.7	48.8	150
HL16 489-495	55.7	51.8	53.3	80.1	95.8	14.3	0.8	1.8	3.4	0.4	0.7	3.5	24.9	85
SL1 90-114	64.3	59.9	54.5	78.9	95.4	17.6	6.0	3.5	3.9	1.2	0.3	1.1	33.6	74
SL1 240-257	61.8	54.9	54.3	80.5	94.6	14.2	1.5	3.8	3.6	1.7	0.8	2.2	27.8	81
AB11 90-95	61.6	57.6	55.3	81.0	95.0	23.1	4.1	3.6	1.3	1.5	2.5	3.1	39.2	114
BH15 102-117	58.4	53.5	53.4	79.8	93.9	8.7	1.3	1.7	1.0	0.7	0.6	2.2	16.2	81
BH17 276-282	60.8	56.4	53.5	77.3	94.6	20.8	4.5	3.5	4.7	1.1	0.4	2.2	37.2	87

Table 6. Summary of the CCSEM analyses made in 2000 of samples from Germany.

Sample no	Avg. TiO_2 in all TiO_2 minerals	Avg. TiO_2 in all TiO_2 minerals ex. Rutile	TiO_2 in Ilmenite	TiO_2 in Leucoxene	TiO_2 in Rutile	Ilmenite as % of all HM	Leucoxene as % of all HM	Rutile as % of all HM	Zircon as % of all HM	Garnet as % of all HM	Sillimanite as % of all HM	Other TiO_2 oxides (artefact)	Valuables as % of HM	Median grain-size of HM fraction
Quarternary:														
5 Tauragnai Q3bl	38.0	38.0	53.5	0.0	0.0	0.6	0.0	0.0	0.4	17.2	0.0	4.0	22.2	
1 Didziasalis Q3bl	41.3	41.0	54.4	72.1	96.4	4.0	0.0	0.1	0.3	16.2	0.1	6.0	26.7	
Miocene:														
6 Vetygala Q1vl upper part	70.3	66.0	62.0	78.6	93.2	42.3	18.0	12.1	4.6	0.6	1.0	2.5	81.1	104
2 Vetygala Q1vl	60.7	59.7	59.3	75.4	95.5	57.3	2.6	1.7	10.2	6.6	0.4	1.1	79.9	147
7 Vetygala D3sv	64.2	60.5	58.2	77.2	97.7	27.3	4.8	4.3	4.9	0.6	1.2	0.9	44.0	86
Devonian:														
4 Anykschchiai-7middle part	75.7	68.5	64.8	79.5	94.6	33.6	14.2	18.9	4.4	0.0	1.9	1.7	74.7	136
3 Anykschchiai-delta layer	78.4	71.0	64.5	79.0	94.3	26.6	21.5	22.4	13.2	0.0	0.6	0.0	84.3	89
8 Anykschchiai-7	76.6	69.2	64.3	77.7	95.1	28.8	16.8	18.3	17.2	0.0	0.8	0.0	81.9	129

Table 7. Summary of the CCSEM analyses made in 2001 of samples from Lithuania.

Holland

The CCSEM analysis of one Dutch sample (Limburg 5) was already reported in Abildtrup et al. (2000). In the CCSEM Appendix 2 five other analyses are reported and a summary of all 6 samples is given in Table 5.

The Dutch samples have a very high average TiO_2 content in all the TiO_2 minerals; this is mainly caused by a high content of leucoxene and rutile. The zircon content is also high; 4 of the samples have more than 20 weight % zircon. The amount of valuable heavy minerals in the raw sand is low (below 0.5 weight %).

Two of the samples from Holland (KW24 21-21.8m and KW26 11-12m) had some relatively large grains composed of several minerals; these composite grains are visible on the image supplied with the analyses. The composite grains case a relatively large amount of unclassified grains in the samples.

Germany

The analyses of the samples from Germany have been described in Abildtrup et al. (2000). A summary of the analyses is given in Table 6.

Lithuania

8 samples from Lithuania were analysed by CCSEM. Two of the samples have a very low content of TiO_2 minerals whereas the amount of magnetite and garnet is relatively high. In the 6 other samples the average TiO_2 content in all the TiO_2 minerals is higher than 60 weight % and it even goes up to 78.4 weight %. Some of the samples also have a high content of zircon. The content of valuable heavy minerals in the raw sand is generally low; in one sample this value is 1.5 weight %, in the rest of the samples it is 0.5 weight %. A summary of the CCSEM analyses is seen in Table 7.

References

Abildtrup C., Appel, C. C., Andersen, G., Jørgensen, T. G. and Knudsen, C. 2000: Heavy mineral exploration in Denmark: Factual report January to October 2000. GEUS report **2000/80**, pp 22 + appendixes.

Hough, F. E. 2000: Provenance analysis for ilmenite populations in Danish Miocene sand and Spanish (Galician) sand; tested against Spanish (Galician) ilmenite populations of known provenance. **Report for DuPont**, Oct. 18th 2000, pp 14 + Tables.

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X-MET

By Tine Jørgensen

X-MET results have been calculated in proportion to XRF data (Fig. 1) to get realistic contents of TiO_2. As it is seen on Fig. 1 the relationship between X-MET and XRF results varies and different algorithms should be used to translate X-MET to real TiO_2 numbers in the two play types.

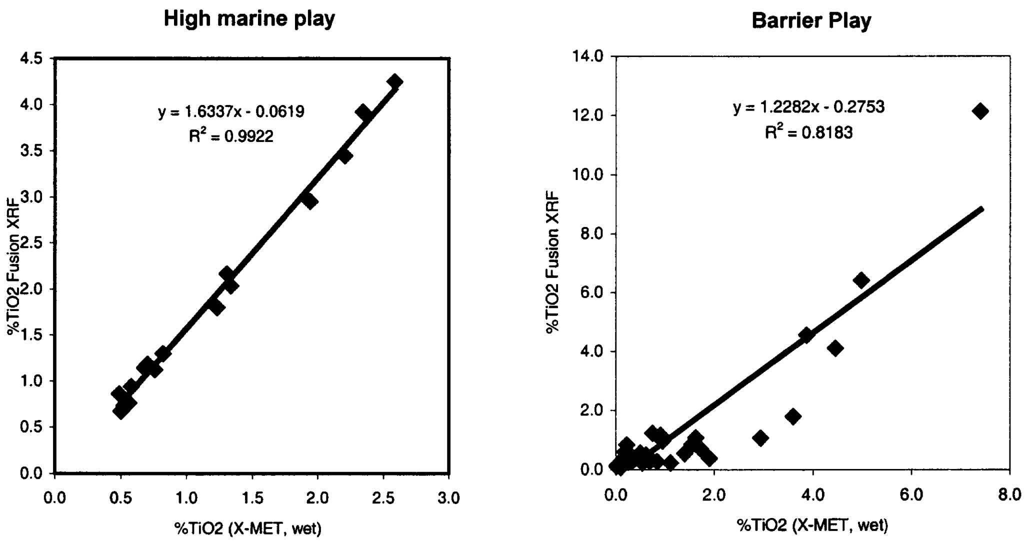


Figure 1: X-MET results measured on calibration model 3 (eclogite) compared with fusion XRF data. The High marine Play is based on analysis from drill hole Sk00.15 and the Barrier Play is based on analysis from drill hole V4, V42 and V62.

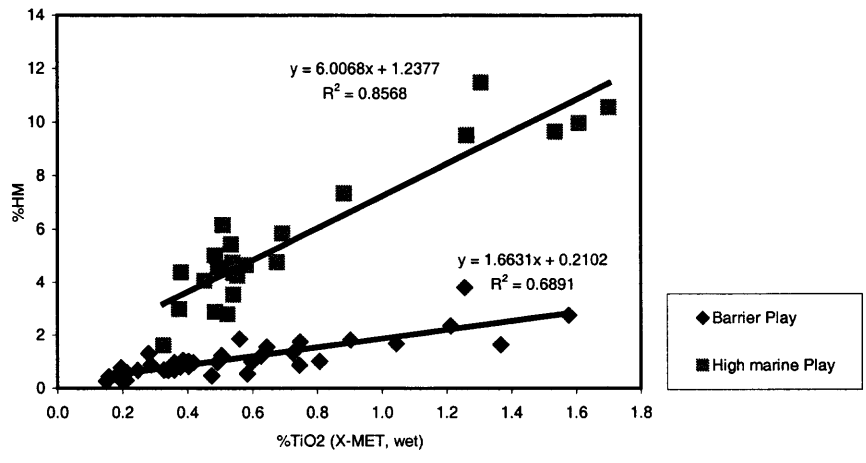


Figure 2: HM laboratory analysis compared with X-met results.

As can be seen on Fig. 2, the relationship between the X-MET values and the content of heavy minerals can be established in the two play types, and the algorithms to be used can be taken from this figure.

LA-ICPMS on zircons, a new fingerprint method

By Thomas Rasmussen and Christian Knudsen

The method used is Laser Ablation coupled with the Inductively Coupled Plasma Mass Spectrometer (LA-ICPMS).

The LA-ICPMS method works by burning with a laser c. 5 µm into zircon grains with diameter of c. 10 µm. Constant flow argon parses through the laser chamber and brings the evaporated zircon martial in to the ICPMS. In the ICPMS the argon gas are first in the plasma chamber inductively heated to c. 7000° and from there it goes to the mass spectrometer. The setup of the ICPMS is set to measure the $^{206}Pb/^{207}Pb$ ratios and the amount of ^{208}Pb. The $^{206}Pb/^{207}Pb$ ratios are used to calculate the age. The amounts of ^{208}Pb are used as a control of whether it is a zircon or a monazite. Monazite tends to have a very high ratio of ^{208}Pb because Th substitutes P in the monazite lattice, whereas the amount of ^{208}Pb in zircons is limited compared to monazite.

The precision of the ages in Fig. 1 measured by the LA-ICPMS is ± 15 ma. calculated from the variation by running the standard (NIST 610) 150 times.

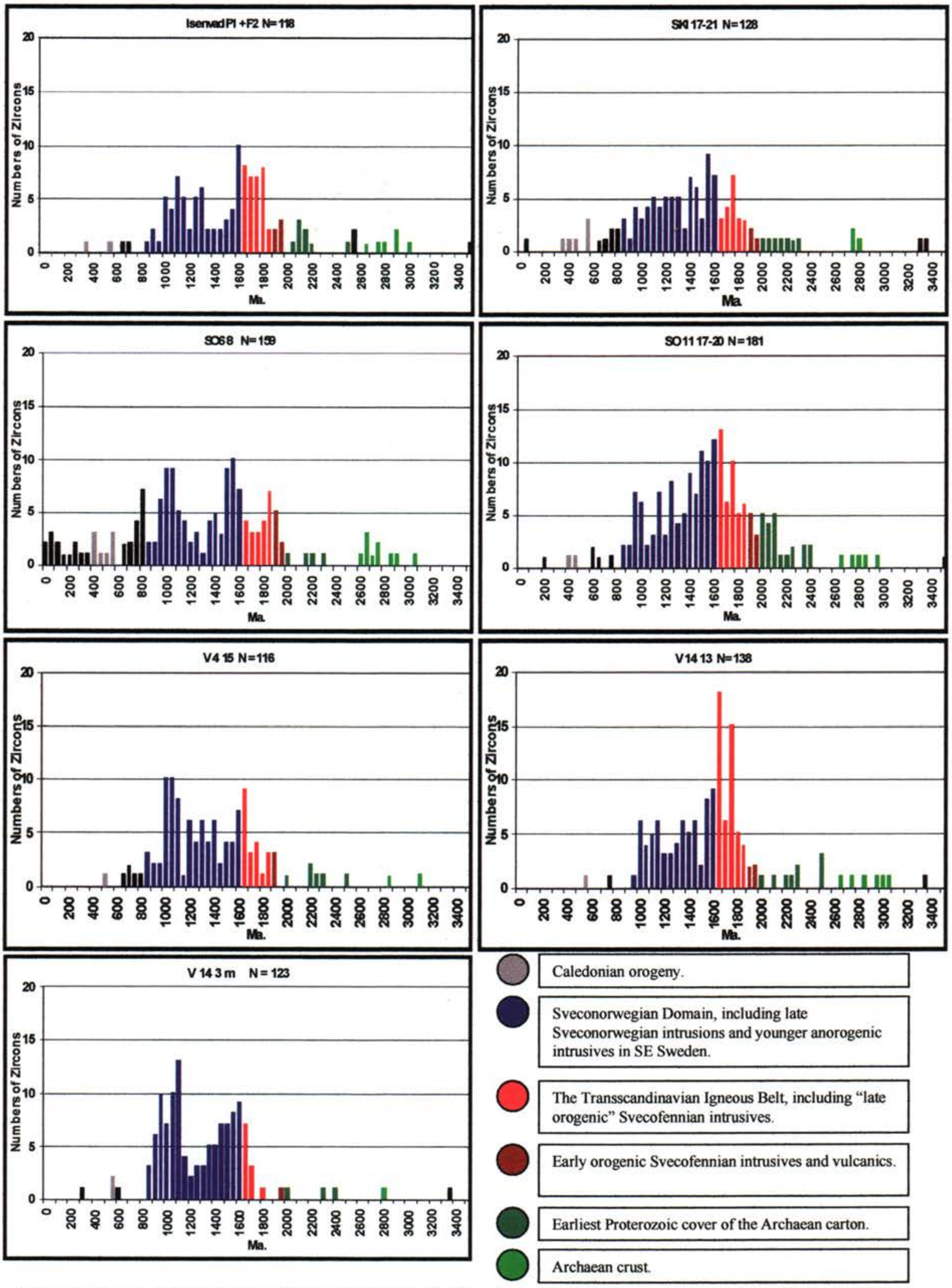
963 zircon grains were analysed from the following localities:
Isenvad (Barrier)
Sønder Omme (Barrier): SO 6, 8 m (Odderup Fm.), SO 11, 17-20 m (Arnum Fm.),
Vorslunde (Barrier): V14, 3 m (above clay/lign.), V 14, 13 m, (below clay/lign.) and V4, 15 m (below clay/lign.).
Skjern (Marine): SK 1 17-21 m.

On Fig. 1 it is seen, that the main source rock for the sedimentary deposits is the southern part of the Fennoscandian Shield in Sweden and Norway (Fig. 2).

The source rocks consist primarily of rocks evolved during the Gothian orogeny (1500 – 1750 ma.) partly overprinted by the Sveconorwegian orogeny (850 – 1250 ma.) and again partly overprinted by the Caledonian orogeny (350-550 ma.). Zircons from the Hallandian orogeny (1350-1400 ma.) are found in all the samples in small amounts. These zircons are interpreted to originate from granite intrusions in southern Sweden (Fig. 2). A significant input of zircons from the middle area of Sweden (Fig. 2) developed during the Svecofennian orogeny (1750 – 2000 ma.) are seen in all the sits except V 14 3 m, V 4 15 m and partly in SK 1 7-21 m (Fig. 1).

The same is the case for the representation zircons from the Archaean crust (2600 – 3100 Ma). In Isenvad, SO 6, 8 m., SO 11, 17-20 m. and V 14, 13 m. zircons from the Archaean crust are fairly represented. In SK 1 17-21 m., V 4, 15 m. and V 14, 3 m are the zircons from the Archaean crust (Figure 2) only sporadic represented (Fig. 1).
Figure 1: The age distribution of the zircons in the samples.

Figure 1: The age distribution of the zircons in the samples.



The ages intervals are from Gaál and Gorbatschev (1987).

The black pillar in the histograms (Figure 1) are interpreted as mix ages, because some of the zircons are presumably zoned with a older core surrounded by one ore more younger rims created during later episodes. When the laser burns in the zircon it can hit one or more rims/episodes and the result will be a mix age. A second implication in working with transported possibly zoned zircons, is that rims can be missing due to the transport grinding. That will cause a missing input of the youngest age from the source area. In this case the Caledonia orogeny.

Ages younger than 400 ma. (Fig. 1) are likely to be erroneous.

In relation to play types, the samples from the barrier play (Isenvad; SO 6, 8m; V 4, 15 m; V14, 3 m; V 14; 13 m), seems to be characterised by a bimodal distribution, with peaks in the Sveconorwegian (850 – 1250 Ma) and the Gothian (1500 – 1750 Ma) orogenies. The samples from the marine play (SK 1, 17-21m and SO 11, 17-20m) seems to be characterised by skew distribution with higher representation of older zircons. This may be interpreted as a change of the source, where the marine play get more material from the east (central Fennoscandian shield in Sweden and Finland) whereas the barrier play get its clastic input from north and north-east.

Jotnian sedimentary rocks, <1.50, >1.26 Ga.
Late Sveconorwegian intrusions, c 1.00-0.85 Ga.
The Fennoscandian rapakivi complexes, c. 1.65-1.50 Ga.
Younger anorogenic intrusives in SE Sweden, c. 1.40-1.35 Ga.
The Transscandinavian Igneous Belt, 1.85-1.65 Ga.
The Lapland Granulite Belt, c.2.0-1.9 Ga.
The Sveconorwegian Domain, 1,76-0,90 Ga.
"Late orogenic" Svecofennian intrusives, 1.84-1.77 Ga.
Early orogenic Svecofennian intrusives, c.1.95-1.86 Ga.
Early Svecofennian sedimentary supracrustals, pre-1.86 Ga.
Early Svecofennian volcanics, c. 1.90-1.87 Ga.
Archaean greenstone belts and basins, c. 2.9-2.7 Ga.
Earliest Proterozoic cover of the Archaean carton, c2.5-2.0 Ga. Archaean crust, c. 3.1-2.6 Ga.

Reference

Gaàl, G. and Gorbatchev, R., 1987. An outline of the Baltic Shield. Precambrian Research, **35**: 15-52.

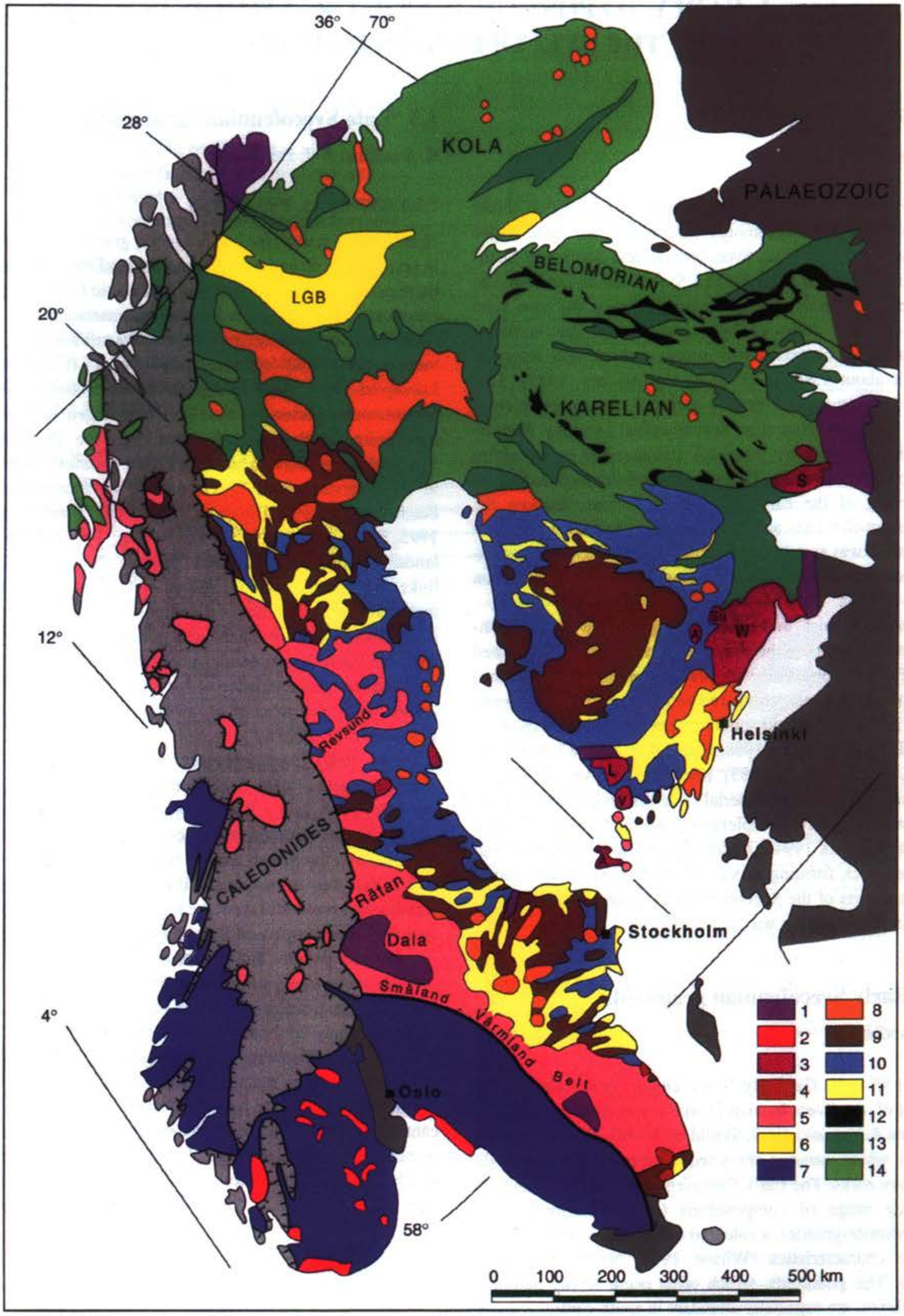


Figure 2: Lithological subdivision of the Fennoscandian shield (modified after Gaál & Gorbatschev (1987).

Denmark

By Christian Abildtrup, Torben Fischer, Tine Jørgensen and Christian Knudsen.

Three main lines of work was followed in Denmark:
1. Exploration for new barrier island type deposits in Miocene sand, Denmark
2. Size, shape and grade of the Vorslunde deposit.
3. Size, shape and grade of the Skjern deposit.

The main findings will be described.

During the work a number of field methods and procedures were tested such as
- GPR as a tool for locating fossil barrier islands
- Geophysical well logging as a tool for measuring Ti in the formation
- Dating of zircon for locating the provenance of the heavy mineral fraction
- X-MET logging of wet samples

A brief evaluation of the results of this will be given.

Screening of old samples

Samples from GEUS archives were screened using the X-MET. High titanium contents were found in fine-grained mica sand (Lindbjerg Mark).

Georadar (GPR)

A large number of localities have been surveyed with GPR, where information from water-wells indicates shallow overburden over Miocene sands. A total of 20 areas were investigated. A list of the localities surveyed using GPR in the regional prospecting is given in Abildtrup et al. (2000, Table 4.2.1) together with maps showing the position of lines as well as drill holes made based on the structures identified (Appendix 6.1.3). The GPR lines made in the Vorslunde area in 2000 is shown on Figure 3 in the present report about Denmark (Abildtrup et al. 2001, red and orange lines).

A number of structures were identified in the regional activity, based on the dip of the foresets and the general geology known from waterwells. However, no new HM rich deposits were found. In the Vorslunde area, the GPR work was of good use in defining the volume and shape of the barrier type deposits as well as the position of the clay/lignite layer in the deposit.

Prospecting for new deposits in Denmark

Fourteen of the areas investigated by GPR had structures, which may indicate barrier island deposits and a total of 57 drill holes were made testing these structures.

No new titanium-rich barrier island deposits were located during this programme. A few localities with medium grained sand (ilmenite > 100 micron) with elevated but not high ilmenite content (F1, HP2 & 3, SL1) and not high grade.

Table 1 Regional prospecting

Drillhole	Depth	Ilmenite	All Ti min	Gr. size	% VHM
		% TiO_2	% TiO_2	Micron	Raw sand
E1	11-16	54,8	62,8	78	1,1
E1	18-23	53,1	62,9	73	0,9
E2	15-26	54,4	63	60	1,5
F1	15-22	56,7	64,5	120	0,7
FM1	20-21	54,8	63,7	90	2,5
HP2	17-26	54,9	65,7	120	0,8
HP3	12-21	54,9	63	120	1
LM1	12	53,2	60,1	90	2,3
LM2	7-8	54,4			6,9
LM2	18-22	55,1	64,6	72	1,2
SL1	19-25	54,4	59,7	100	1,9

High marine deposits with high titanium content were located SW and approximately on strike with the Skjern deposit (TiO_2 values based on X-Met results calibrated to real TiO_2):
Eg (E2): avg. of 1.5 %TiO_2 over 12 m was found at a depth of 12 m.
Lindbjerg mark (LM2): avg. 3.2 %TiO_2 over 2 m was found at a depth of 6 m. Grain-size obscured by pyrite overgrowth.
Skovlund (SL1): avg. 1,7 %TiO_2 over 4 m was found at a depth of 18 m.
Sandet (SK1 00.03): avg. 1.6 %TiO_2 over 4 m was found at a depth of 11 m and avg. 1 %TiO2 over 5 m was found at a depth of 17 m.
All these were found in fine-grained mica sand (High marine play)

This indicates that further resources of high marine play type can be located. The average depth to the top of enriched layer is 13,5 m, Grain-size is generally low (<100 micron), ilmenite grade is low (54,6 % TiO_2), as well as zircon content (0,15 % in raw sand). The grade of heavy minerals in ground was locally rather high, and if further exploration on the high marine play type is needed, these findings can be useful.

At a few locations grain-size exceeding 100 micron was found, but the HM grade in ground was low as well as the grade of the ilmenite.

No further work on these findings is recommended for 2001.

The Vorslunde area

The geology in the area is characterised by an approximately 10 m thick coarsening upward sequence of quartz sand overlying the mica clay and mica silt of the Arnum Formation. The uppermost 2 m of this sequence is often enriched in ilmenite and probably representing the swash backwash environment in a prograding barrier. Overlying this, an approximately ½ to 1 m thick layer of clay and lignite is found, probably representing lagoonal, back-barrier environment. On top of this, quartz sand with steeply NE dipping foresets is found, probably representing a fossil dune.

GPR work was conducted in the period, and structures were found during this work and drilled (Drill holes V 49 to V 101). Fig. 3 shows the sample baselines.

Geological map of the pre-Quaternary surface

The regional geology of the area around Store Vorslunde has been displayed in a pre Quaternary surface map (Fig. 4) and as top of pre-Quaternary (Fig. 5). The maps were made from an existing well map (Geologisk basisdatakort 1214 III Brande, Danmarks Geologiske Undersøgelse 1980). The thickness of the Quaternary is given in Fig. 6.

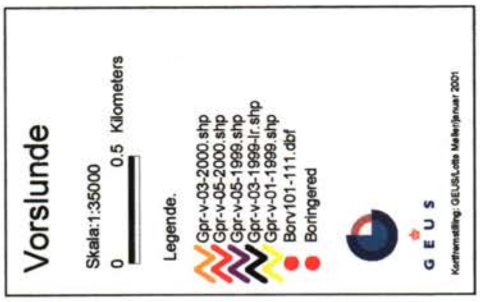
The lithology in every single well has been viewed and divided in to 3 zones; Red > 15 m quaternary, green < 15 m quaternary (on top of Miocene clay), yellow < 15 m quaternary (on top of Miocene sand). These zones was set, as the overall objective is to locate an ilmenite sand deposit with overburden < 15 m (Fig. 4).

The pre-Quaternary map shows that the Store Vorslunde area is located in an yellow zone of thin Quaternary sediments and with a minor red zone of thicker Quaternary northwest of the main exploration site in the township of Store Vorslunde.

According to (Andersen, 1996) seismic profiles reveals a line of elongated synclinals in a WNW-ESE belt from Nissum Fjord at the west coast of Jutland to Horsens Fjord at Store Bælt at the east coast of Jutland. These depressions are typically 5-10 km wide and 20-30 km long. Store Vorslunde is located west of the southern end of the Give-Brande-Herning synclinal. Trending more N-S the southern branch is also referred to as the Give synclinal. The Give synclinal is almost symmetric and bounded by relatively steep sides, which has been accentuated by parallel normal faulting at Basis Zechstein. North of Store Vorslunde the wider Brande synclinal trends WNW-ESE. The Brande synclinal is approximately 100 m deeper than the Give synclinal and very asymmetric with steepest bounding to the south (Andersen, 1996).

From the pre Quaternary map it can be seen that the distribution of the late Miocene marine clay of the Gram Fm is controlled by the tectonic development in the area throughout the Tertiary. It is clearly seen that the Gram Fm is restricted to the Give-Brande depression, which has existed as a depocenter in late Miocene.

Figure 3: Sample baselines in Vorslunde area.



Geological map of the prequaternary surface.

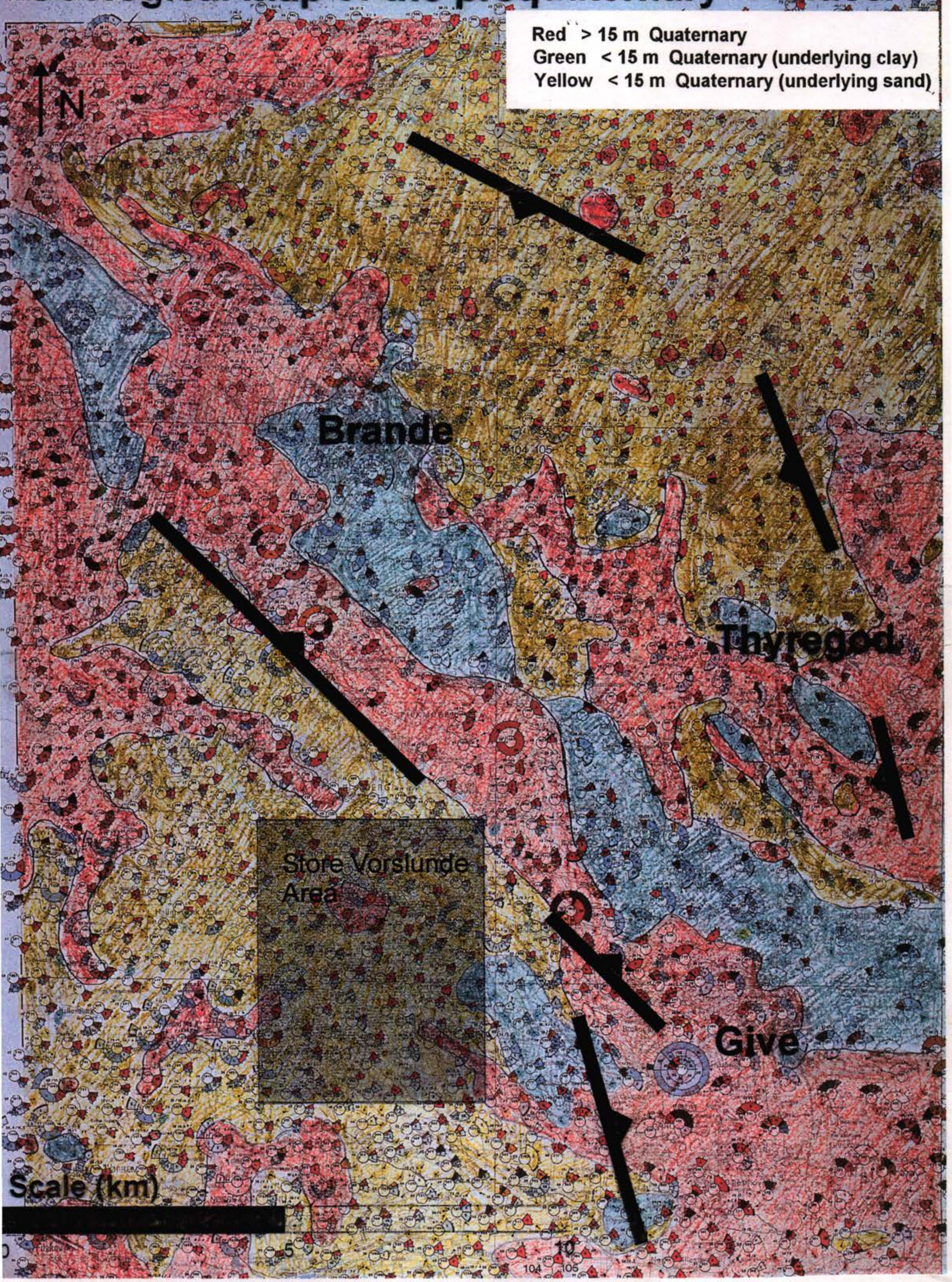


Figure 4

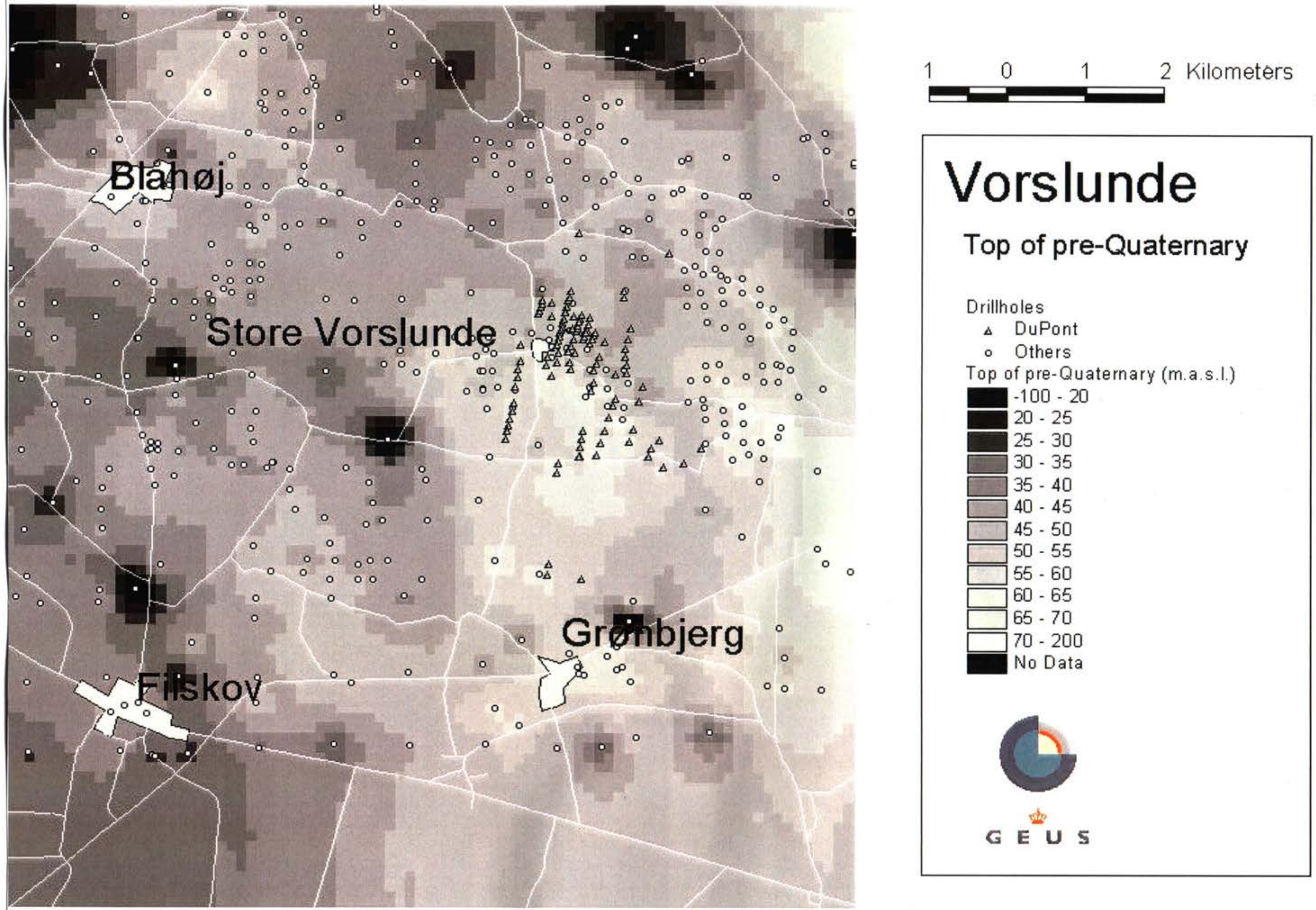
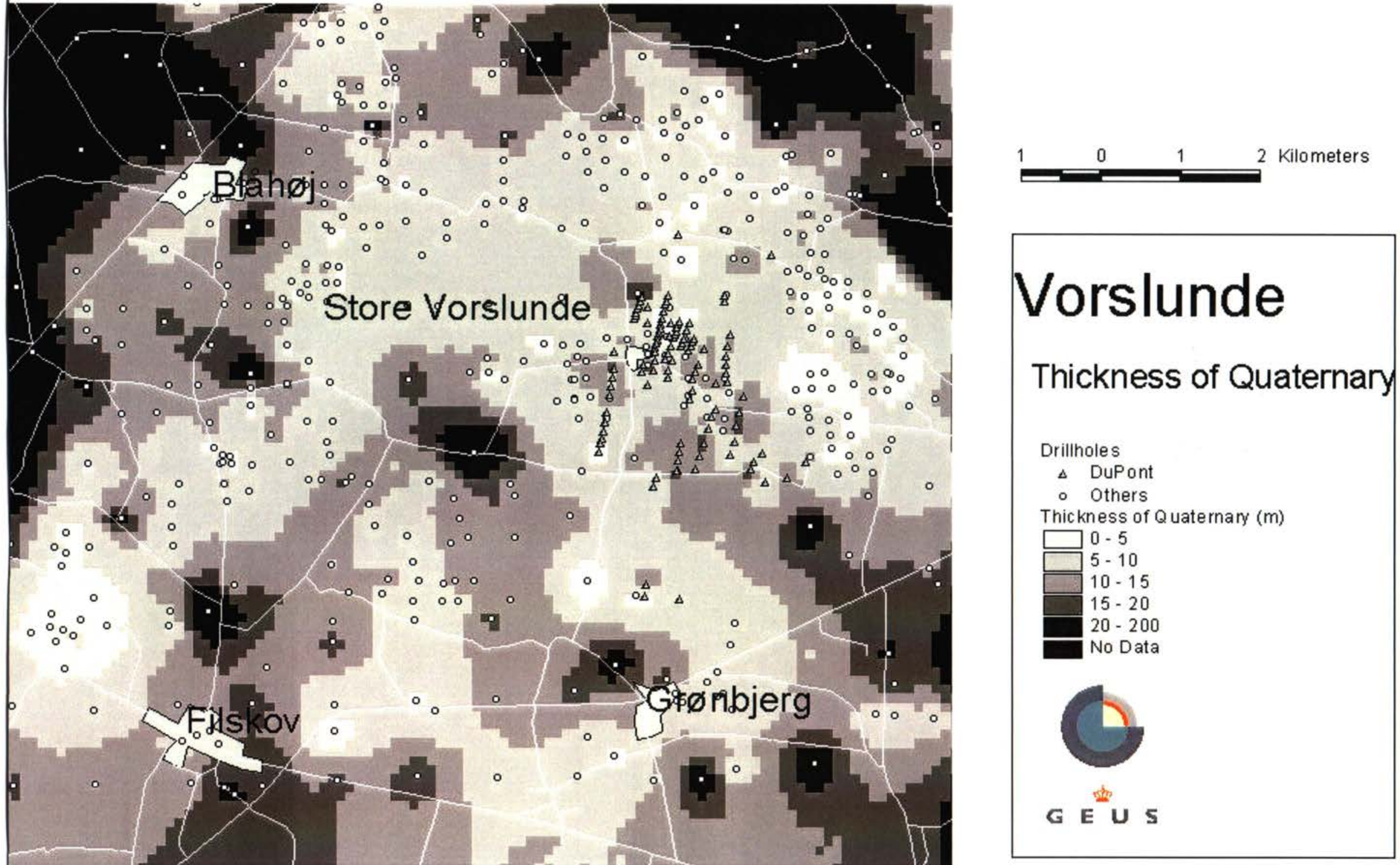

Blåhøj
Store Vorslunde
Grønbjerg
Filskov
1 0 1 2 Kilometers
Vorslunde
Top of pre-Quaternary
Drillholes
DuPont
Others
Top of pre-Quaternary (m.a.s.l.)
-100 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
50 - 55
55 - 60
60 - 65
65 - 70
70 - 200
No Data
GEUS

Figure 5:

Figure 6:


Blåhøj
Store Vorslunde
Filskov
Grønbjerg
1 0 1 2 Kilometers
Vorslunde
Thickness of Quaternary
Drillholes
DuPont
Others
Thickness of Quaternary (m)
0 - 5
5 - 10
10 - 15
15 - 20
20 - 200
No Data
GEUS

Barrier type GPR images

As a part of the exploration strategy GPR profiling has been used as a preliminary geophysical reconnaissance method to locate beach/barrier structures in areas with thin Quaternary overburden. Based on prior drilling results a type GPR image could be connected with beach/barrier structures to be used to target the following drilling campaign.

Figs. 7 and 8 present sections of 3 GPR profiles. The shown sections of Vors 5 and Vors 6 are coincident with the major drilling site in the township of Store Vorslunde. They represent the core of the barrier structure. To comparison a section of a resent barrier named Holmlands Klit on the west coast of Jutland is shown.

The GPR profile of Holmlands Klit was conducted with the exact same equipment as used in Store Vorslunde. The Holmlands Klit profile has been topographically corrected to accentuate the erecting foredunes. The profiling was conducted perpendicular to the coastline from the Ringkøbing Fjord lagoon to the West Coast beach towards the North Sea.

By comparing the GPR profiles from Store Vorslunde and Holmlands Klit (Figs. 7 and 8) it becomes clear that there are matching radar facies. The radar images from both localities have sets of angular reflectors with a dip direction landwards (NE or E) and at the lower penetration boundary there is a strong reflector blocking the signal. At Store Vorslunde this reflector correlates with a ½ -1 m thick lagoonal mica silt/clay layer with lignite.

GPR investigations of coastal fore-dunes in Norfolk, UK conducted by Bristow (2000) have also determined the internal structure and stratification of coastal dunes and beach facies. According to Bristow (2000) swash bars form landward-dipping sets of cross-stratification (up to 4 m in thickness) within the beach sediments below the the water-Table. The dimensions of the large-scale foresets recorded in Store Vorslunde is not seen in Norfolk, but have been recorded in other coastal dunes.

The displayed GPR images by Bristow (2000) match the Holmlands Klit image. The type GPR image from Store Vorslunde included sets of large-scale foresets dipping landward with underlying lagoonal clay. As this seems to be a certain indication of barrier structures when compared to recent barrier systems, this image was used to make an isopach map of the barrier. The Quaternary/Miocene interface was used as the geo-morphological top limit and the lagoonal clay was used as the lower limit.

Type GPR images used to locate and map the Vorslunde barrier structure.

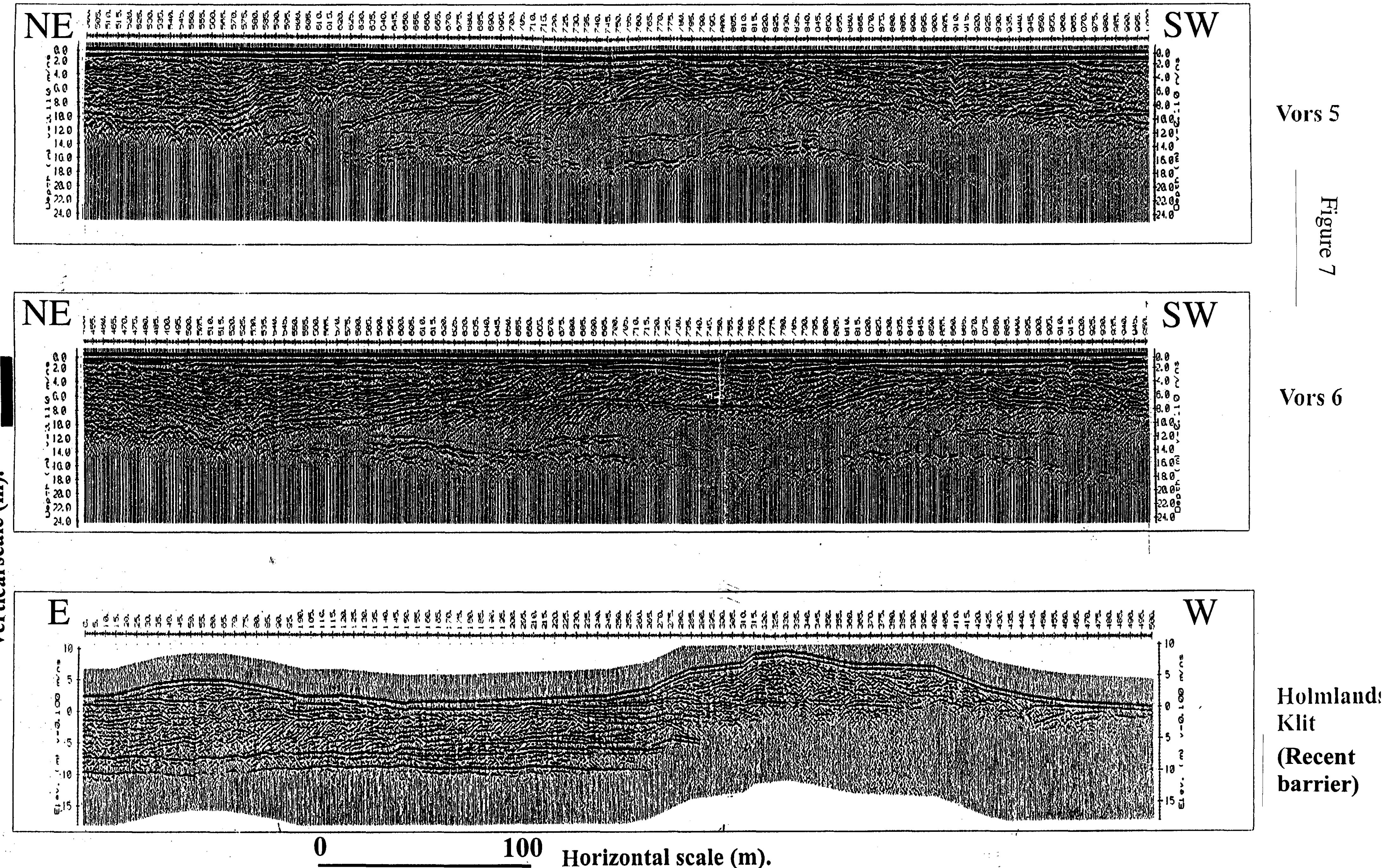
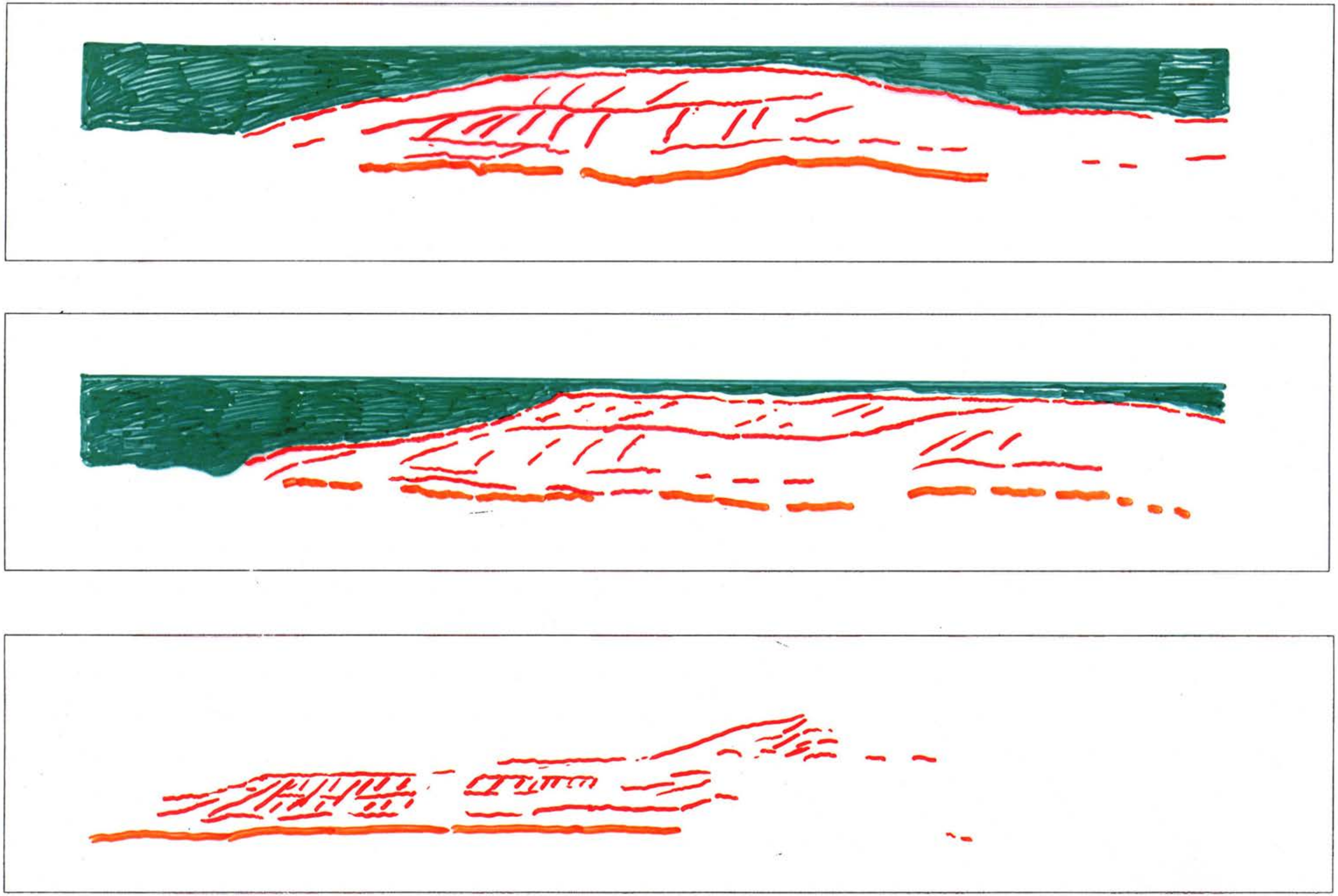


Figure 7

Interpretation

Type GPR images used to locate and map the Vorslunde barrier structure.



Vors 5

Vors 6

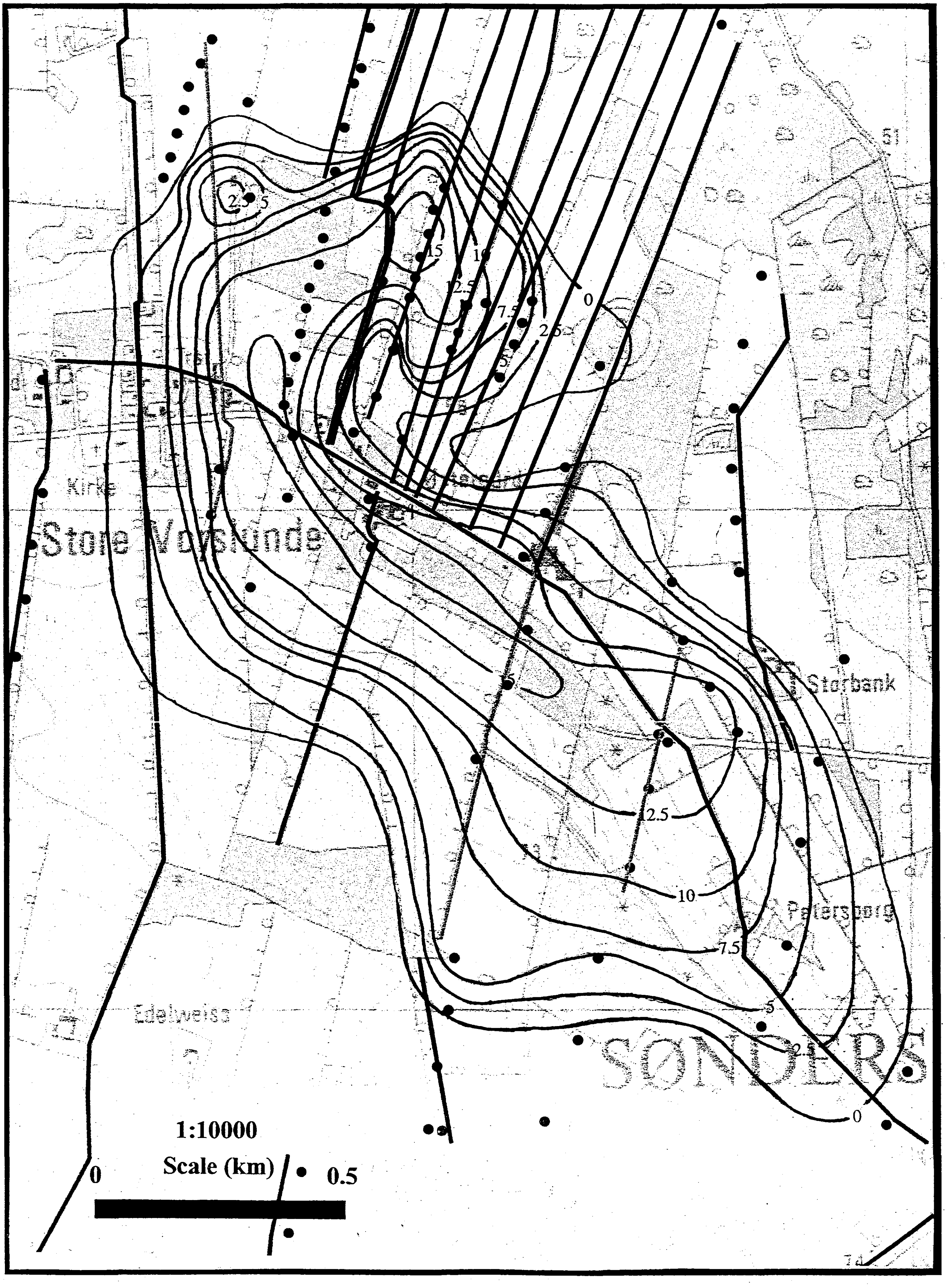
Holmlands Klit (Recent barrier)

Figure 8

■ Quaternary ■ Internal architecture of barrier structure ■ Lagoonal clay

Isopach map of type GPR image
Vorslunde barrier structure.

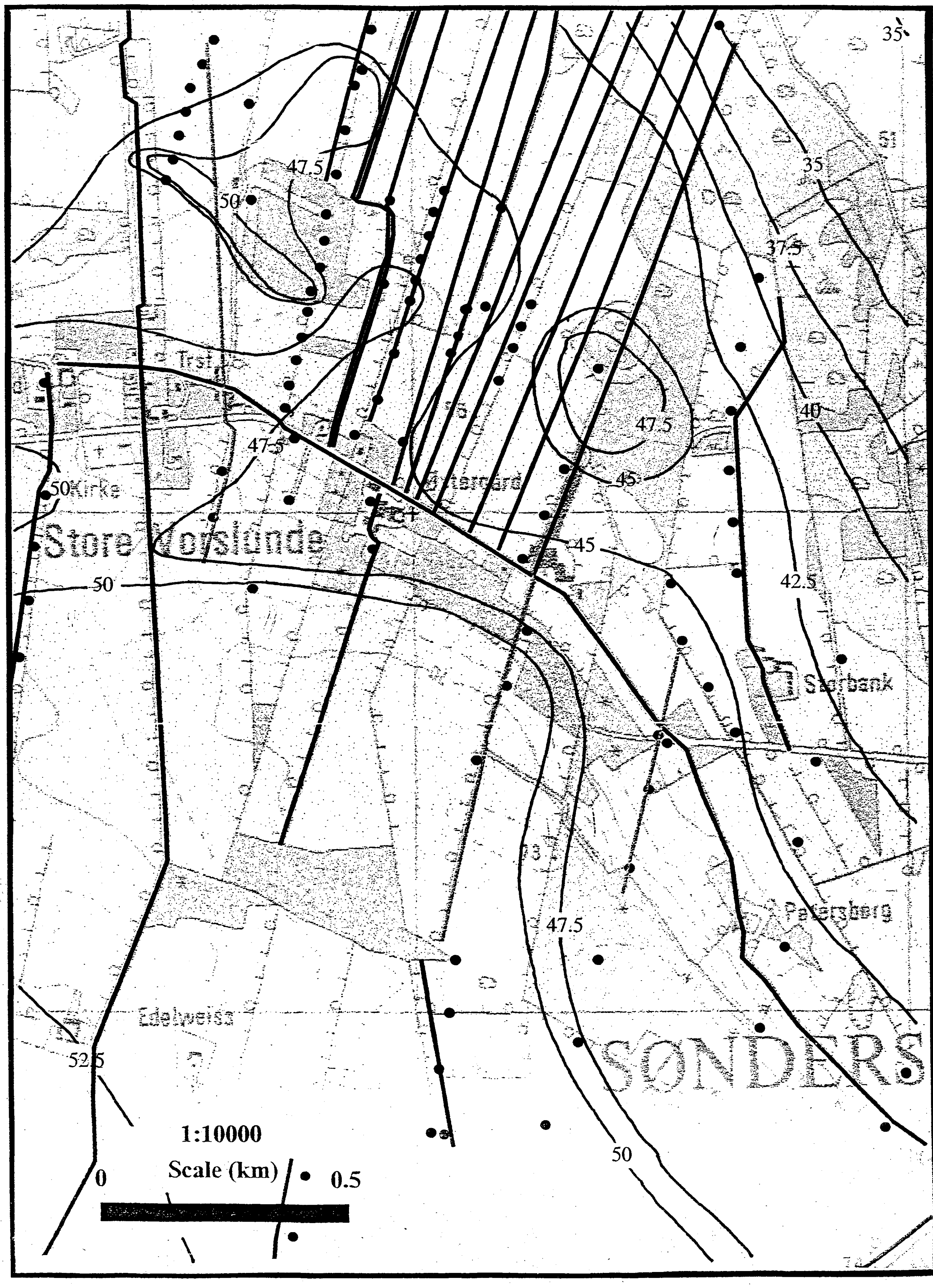
Figure 9:



Subsurface map of lagoonal clay

underlying the Vorslunde barrier structure.

Figure 10:



Isopach map of type GPR image

The scope of producing an isopach map of the type GPR image of the Store Vorslunde barrier structure is to map the known characteristics of the structure (Fig. 9).

By projecting the lithological logs from all the drilled wells onto the radargrams a precise depth conversion could be made and by correlating strong reflector with abrupt changes in lithology. From the analysis of the type GPR image the Quaternary/Miocene interface was used as the geo-morphological top limit and the lagoonal clay was used as the lower limit. The position and thickness of the barrier sequence was mapped. The bulk volume has been calculated to c. 12 mill. m^3 of the type GPR image. It is seen from the map that the bulk volume of the structure is elongated with a strike NV-SE. It is also seen that the structure is a complex of two sand bodies.

Subsurface map of lagoonal clay

The lagoonal silt/clay/coal can be followed as a marker both in the drill reports and on the GPR profiles. A subsurface map of the silt/clay/coal has been produced to establish the structural distribution of this marker (Fig. 10).

From the subsurface map it can be seen that the marker is almost flat with a weak 0.5 degree dip towards NE. The clay layer has local highs underneath the barrier structure.

The area of the HM has been extended from approximately one km^2 to about 4 km^2.

The character of the mineralisation is a lower zone below a clay/lignite layer, generally two-m thick, with variable and locally high ilmenite content. Above the clay/lignite layer, large-scale cross bedding is often seen on GPR. Elevated contents of ilmenite are often, but not always tied to these structures. We are trying to make a model of the distribution of high titanium in ground, based on the X-met values based on fence diagrams.

Size, shape and HM grade in ground

The purpose of the geological model construction is to map the extension of theTiO_2 enriched ore body represented in the Miocene sediments. Geological interpretations of the TiO_2 extension in three dimensions form the basis of a TiO_2 volume calculation. The TiO_2 mapping is based on data collected from the 47 drill holes in the Skjern area and 102 drill holes in the Vorslunde area drilled during the exploration campaign in 1999 and 2000.
The Volume calculation is based on systematic measurements of TiO_2 content in meter intervals with the X-MET field instrument.

The construction of the geological model for both investigated areas has been structured in the following steps:

- Drill holes are projected on parallel profile lines perpendicular to the TiO_2 occurrence.
- Lithology is correlated between drill holes in each profile.
- The X-met (X) values are multiplied by a factor of 1,23*X – 0,3 to get realistic contents of the amount of TiO_2 represented in the ore body

- Contouring of TiO_2 values in each profile is prepared in the light of a geological interpretation.
- Thickness contouring for different TiO_2 intervals across the profile lines to visualise the TiO_2 extension in 3-D.
- The acres for each thickness contour is measured and multiplied by the thickness.
- Volume calculation.

The horizontal and vertical variations of the TiO_2 content in the Miocene sediments are illustrated by contouring the TiO_2 values for each profile line in the model. The contouring is prepared in a geological kind of view, so that the contouring follows the lithology as good as possible. Following the interpretation of the horizontal and vertical extension of the TiO_2 enriched deposits an interpretation of the thickness of the ore body across the profile lines is possible. This third dimension visualises the TiO_2 interpretation in a 3-D view and makes the basis of a TiO_2 volume calculation. Thickness maps based on the profile contouring are constructed in different intervals of TiO_2 values and three intervals >1%, >2% and >3% (Skjern, >1%, >2%, >3% and >5%). The area of each thickness interval is measured either by a planiometer or by counting squares and then multiplied by the thickness of the calculated area. The sum of the calculated volumes for each thickness map is the total volume of the mapped TiO_2 interval. To comply the volume calculation the acreage difference between the TiO_2 intervals is calculated so that the volume greater than 1% is subtracted from the volume greater than 2%, 3% and 5% and so on to get an estimated volume in the interval from 1-2%, 2-3%, 3-5% and >5%. Based on a geological interpretation and prepared contour maps an estimation of the total volume of the TiO_2 ore body:

The total volume of TiO_2 from 1-2% = $8.1 * 10^6$ m^3.
The total volume of TiO_2 from 2-3% = $3.3 * 10^6 m^3$.
The total volume of TiO_2 > 3% = $0,6 * 10^6 m^3$.

The present can be calculated from these numbers as minimum amount of TiO_2. However, this is calculated without taking barren sand in between mineralised layers into account. Accordingly a grade in ground cannot be calculated from this. It is considered likely that the area with similar mineralisation can be found towards south as well as north by further drilling.

The Skjern deposit

GPR was not conducted in this area as a clay layer in most of the area shields the mineralised structure.

39 drill holes was made in the area. Apart from logging the samples using X-MET, the drill holes were logged using Spectral Natural Gamma (SNG) logging and Induction Conductivity logging. This because the Th and U gives good possibilities of measuring the grade in ground directly, and because the log-patterns give valuable information about the geology in the drill hole.

The mineralised mica sand is a lens shaped, irregular, elongated body trending northwest southeast. The orebody is zoned, with the richest parts in the core of the lens. The overburden consists of glacio-fluvial sand and gravel (approximately 10 m) and Miocene mica-silt and clay (approximately 5 m). The thickness of the Quternary is given in Fig. 11 and top of the pre-Quternary is illustrated in Fig. 12.

Figure 11:

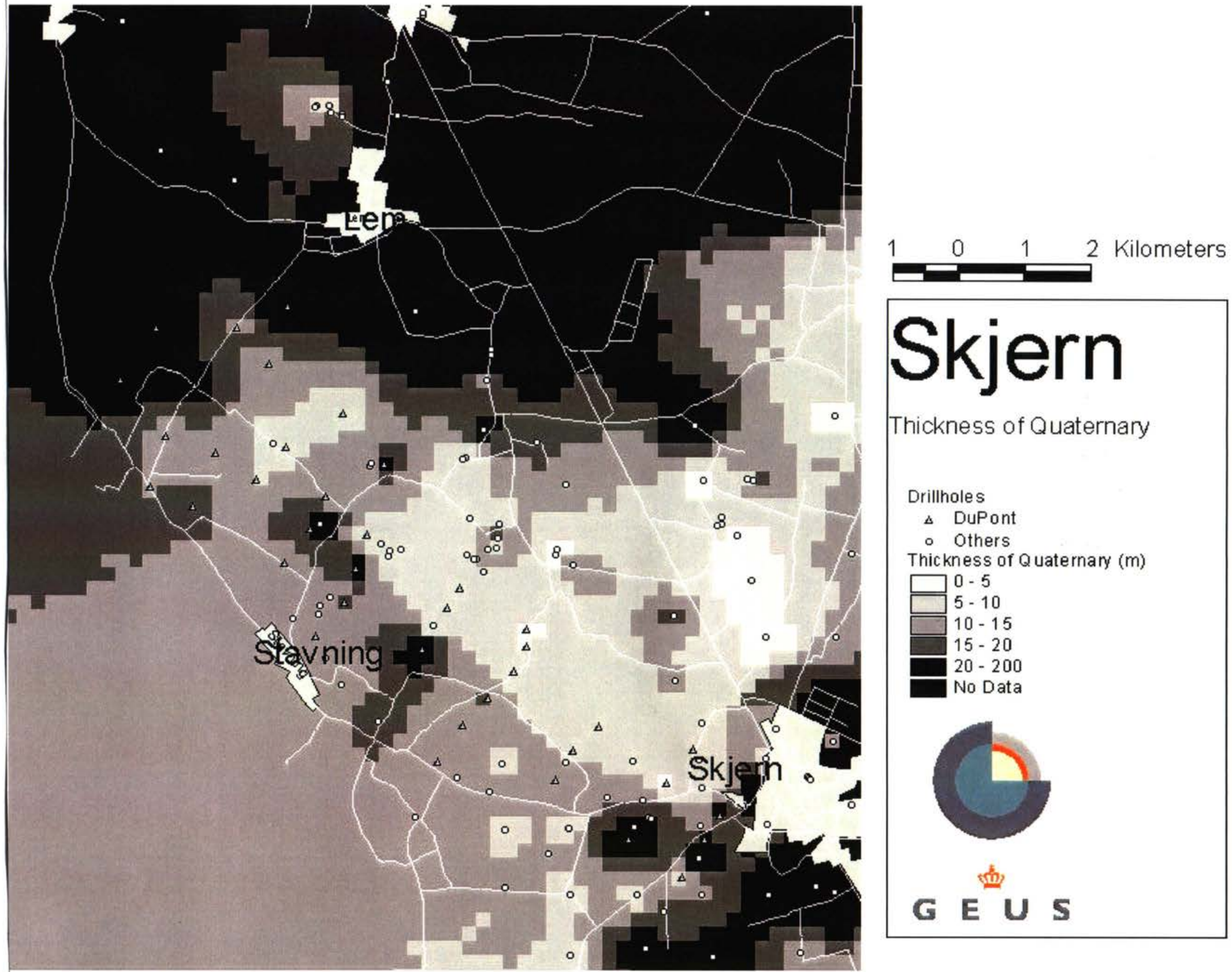
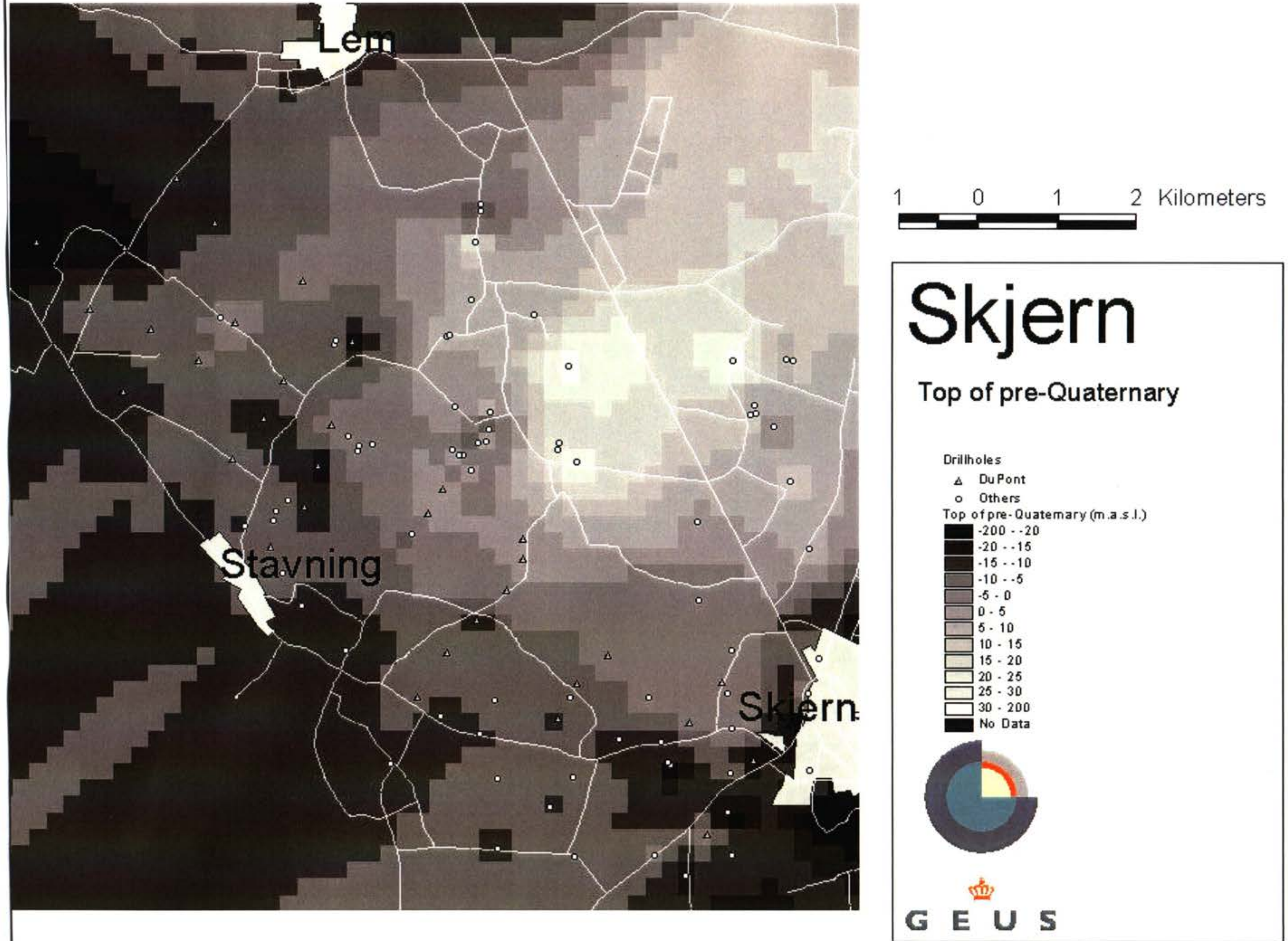

Lem
Stavning
Skjern
1 0 1 2 Kilometers
Skjern
Thickness of Quaternary
Drillholes
DuPont
Others
Thickness of Quaternary (m)
0 - 5
5 - 10
10 - 15
15 - 20
20 - 200
No Data
GEUS

Figure 12:


Lem
Stavning
Skjern
1 0 1 2 Kilometers
Skjern
Top of pre-Quaternary
Drillholes
Du Pont
Others
Top of pre-Quaternary (m.a.s.l.)
-200 - -20
-20 - -15
-15 - -10
-10 - -5
-5 - 0
0 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 200
No Data
GEUS

An approximately one ton composite sample representing mica sand from the Skjern deposit is available.

For next year's programme, it is recommended to map the overburden by using GPR. This will indicate the volume of glacio-fluvial deposits with valuable gravel and the depth to the Miocene. Further it is recommended, that a drilling programme (approximately 50 drill holes) to be conducted, focussed on the high-grade ore in the core of the deposit. During the 2000 programme, the content of gravel in the overburden was estimated. In next year's programme, the amount of gravel should be measured by screening of the overburden samples.

Evaluation of size, shape and grade

The object of the geological model construction is to map the extension of theTiO_2 enriched ore body. Geological interpretations of the TiO_2 extension in three dimensions form the basis of a TiO_2 volume calculation. The procedure used is the same as above.

The volume calculation is based on systematic measurements of TiO_2 content in meter intervals with the X-MET field instrument. The X-MET values are multiplied by a factor of 1.63 to get realistic contents of the amount of TiO_2 represented in the ore body.

Based on a geological interpretation and prepared contour maps an estimation of the total volume of the TiO_2 ore body in the investigated Skjern area has been measured for different TiO_2 content. The areas of the thickness intervals have been measured.

TiO_2 grade 1-2%	=	$221 * 10^6\ m^3$
TiO_2 grade 2-3%	=	$111 * 10^6\ m^3$
TiO_2 grade 3-5%	=	$52 * 10^6\ m^3$
TiO_2 grade >5%	=	$1 * 10^6\ m^3$

References

Andersen, H.L., Madirazza, I., & Sandersen, P.B.E. 1996: Tektonik og landskabsdannelse i Midtjylland. Dansk Geologisk Forenings nyheds- og informationsskrift **1996/3**, 1-33.

Bristow, C.S., Chronston, P.N., & Bailey, S.D. 2000: The structure and development of foredunes on a locally prograding coast: insights from ground-penetrating radar surveys, Norfolk, UK. Sedimentology **47**, 923-944.

International work

By Henrik Stendal and Christian Knudsen

In the international "scouting" for high-grade ilmenite deposits outside Denmark, the following approach was taken. The main problem in the existing literature and databases is that there is no mention of the grade (TiO_2) in the ilmenite. To overcome this problem we need to analyse samples from a large number of deposits. To get our hands on as many samples as possible, is was decided to make contact to selected Geological Surveys in Europe, Australia, Asia and Africa in an attempt to generate a database covering the heavy mineral sand deposits in the world. The database is not only focussed on deposits being mined, but also deposits that may attract interest as exploration targets.

Europe

Sweden

Visit was paid to a Jurassic quartz sand quarry (Eriksdal) and 4 samples analysed. The content of heavy minerals is low, but the grade showed a 65,8 % TiO_2 ilmenite, 76 % TiO_2 in all titanium minerals and 12.6 % zircon among the heavy minerals. The grade of heavy minerals in the sand is low (0.4 %), but median grain-size reasonable (136 micron). The grade is too low and the potential area too small, and there is no reason to proceed with prospecting here. The main purpose of the visit was to evaluate whether the Jurassic sand could be a source for the Miocene sands in Denmark due to Miocene uplift in the area, as indicated by the presence of reworked Jurassic micro fossils in Miocene sediments in Denmark. The grade of the ilmenite seems to in the high end for this to be the case, but this may be due to in situ leaching of the ilmenite at Eriksdal.

Holland

Good relations to the Dutch Geological Survey have been established.

A quartz sand quarry was visited (Limburg). CCSEM analysis of a sample from this showed a 62 % TiO_2 ilmenite, 74.1 % TiO_2 in all titanium minerals and 12.6 % zircon among the heavy minerals. The grade of heavy minerals in the sand is low (0.2 %), but chemical analysis of drillcore from Holland indicate that higher grades can be found in Neogene sands in Holland. Such drillcore is in the process at GEUS.

Relations to a very large quartz sand producer in the area (Sibelco) is being established via the Danish arm Dansand, with the aim of getting samples from a large number of quarries, with possible by-product ilmenite recovery in mind.

It is likely, that an exploration program with GPR and drilling can be established next year, in co-operation with the Dutch survey.

Germany

Only one state Schleswig-Holstein has been visited. Samples from drill holes with gamma logging anomalies have been analysed. The average depth of the samples is high (229 m), the average heavy mineral content is low (0.8 %), the average grade of the ilmenite is low (53.9 % TiO_2), the average grain-size is fairly low (100 micron). Accordingly there is no justification to proceed with exploration in this state.

Contacts to the geological surveys in Mecklenburg-Forpommern and Brandenburg have been made, but no visit paid yet.

In the states east of here: Mecklenburg-Forpommern, Brandenburg and Sachsen, there is sandy Neogene deposits, some of which is being mined for lignite. Dr. Kasinski (Poland) told, that marine/beach structures have been described from some of the quarries. This is worth while checking, and a trip to these states is planned in 2001.

Poland

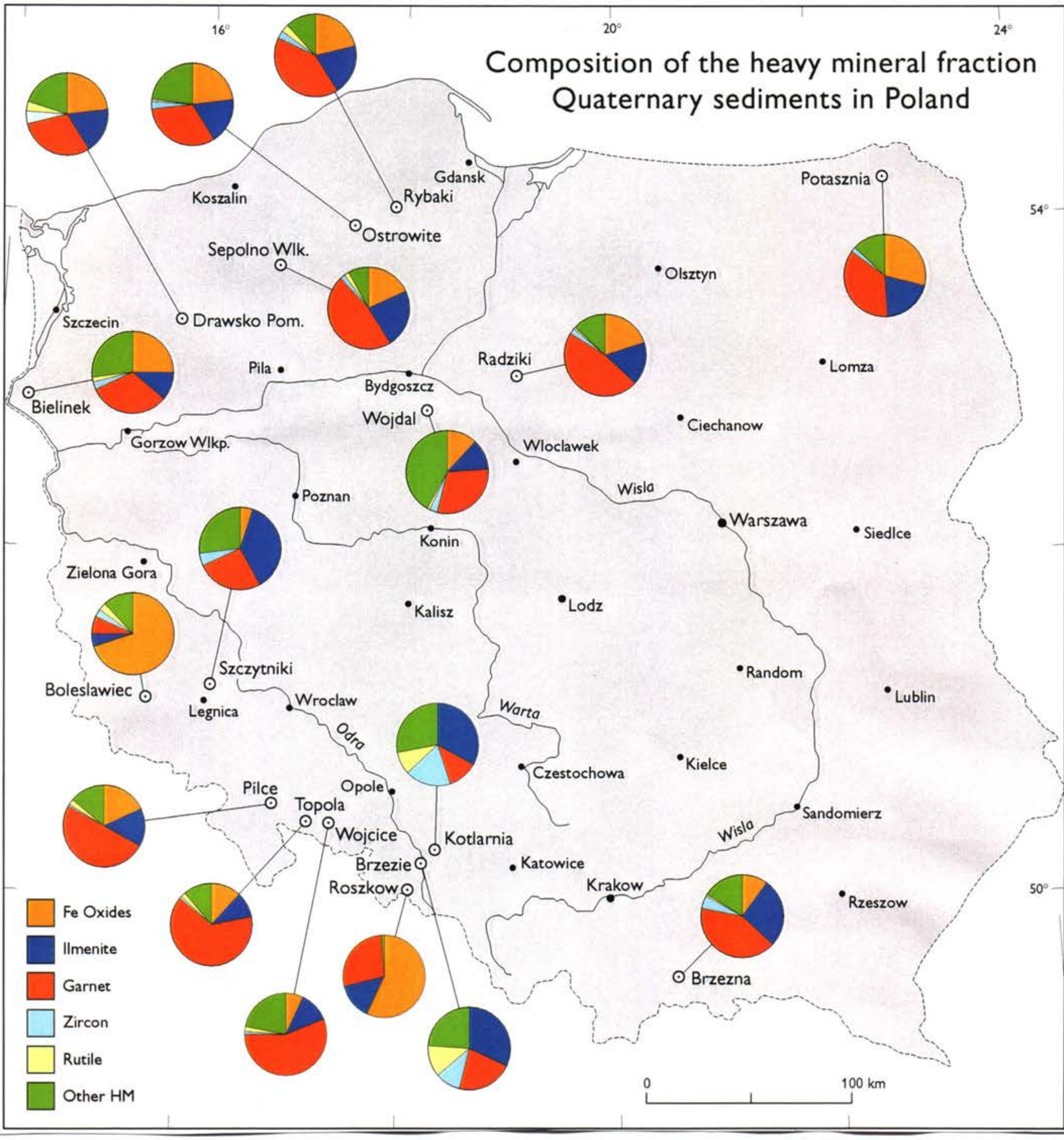
Contact has been established to the Polish Geological Institute (PGI) and a meeting been held.

Work concerning heavy mineral-rich Holocene marine sands on the Slupsk Bank in the Baltic was undertaken some 15 years ago, but it was not possible to locate the data and samples.

During extensive lignite mining in Neogene sediments large quantities of sand are removed. Possible by-production of heavy minerals justifies that samples from this are analysed.

The PGI has supplied us with some data on the composition of the heavy mineral fraction on some Quaternary sands, which we have compiled into the map shown on the (Fig. 1). Some samples from potential heavy mineral bearing sands have been delivered but not analysed yet.

Figure 1:



Composition of the heavy mineral fraction
Quaternary sediments in Poland
16°
20°
24°
54°
50°
Gdansk
Koszalin
Rybaki
Ostrowite
Sepolno Wlk.
Olsztyn
Potasznia
Szczecin
Drawsko Pom.
Radziki
Lomza
Pila
Bydgoszcz
Bielinek
Wojdal
Ciechanow
Gorzow Wlkp.
Wloclawek
Wisla
Poznan
Warszawa
Siedlce
Konin
Zielona Gora
Lodz
Kalisz
Szczytniki
Random
Boleslawiec
Legnica
Wroclaw
Lublin
Warta
Odra
Kielce
Czestochowa
Pilce
Opole
Topola
Wojcice
Kotlarnia
Sandomierz
Brzezie
Katowice
Roszkow
Krakow
Rzeszow
Brzezna
Fe Oxides
Ilmenite
Garnet
Zircon
Rutile
Other HM
0
100 km

Hungary

The Hungarian Geological Survey will send 5-10 samples of fluvial (Holocene) sands. When they arrive they will be analysed on the CCSEM and thereafter be interpreted.

Lithuania

Indication of high-grade ilmenite was found earlier on. Contact to the local survey and a local consultant has been established. An evaluation of the heavy mineral content in the Quaternary sands in Lithuania has been undertaken (mainly focussed on gold). The consultant is translating the report to English (Report just received and not commented here; Juozapavicius, 2000). The grades of heavy minerals are very low, and the proportion of valuable HM is low too.

Samples from Neogene and Devonian sands were received at a meeting, and are at present in the GEUS labs. Further samples from a large coastal dune complex at the Baltic coast as well as samples from dunes tied to a late glacial ice dammed lake is on the way to GEUS.

Belarus

J. Ginutis has agreed to make contact colleagues from Minsk to get some sand samples from Belarus. He has been asked to make a proposal for how we can get further in Belarus. This could be divided into different phases, where the first phase could be to make a five-page description of

- the geology
- current knowledge about titanium minerals in the country
- recommendations for further work

The next stage would be to get samples from whatever environments is recommended in phase 1.

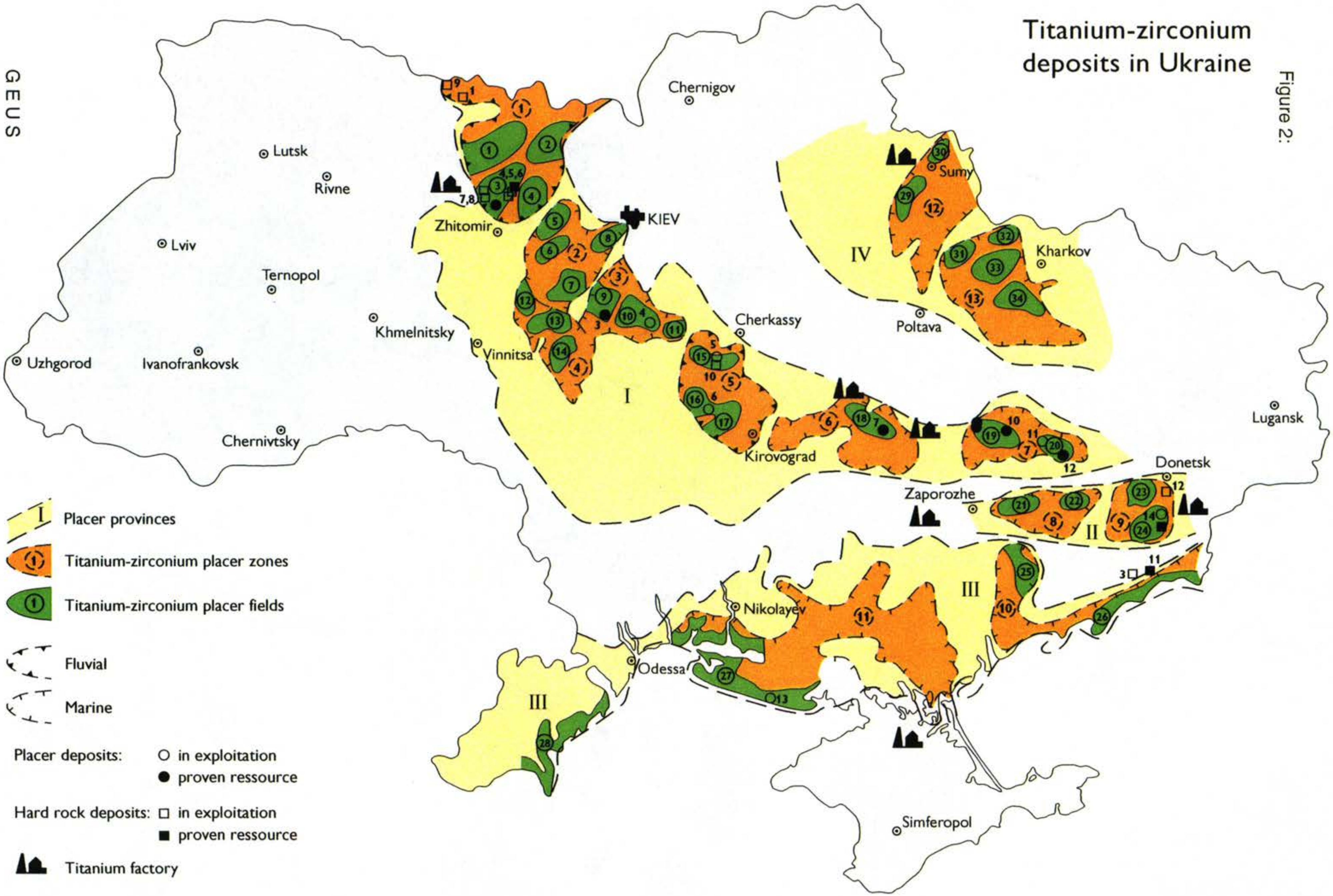
This proposal should contain a realistic time schedule and budget. Please remember that our focus is on ilmenite with elevated TiO_2 content of about 60 %. This means, that most Quaternary deposits are ruled out because of too low degree of alteration, and that our focus is in the pre Quaternary. In Ukraine there is mining of such ilmenite deposits but probably in Neogene sediments.

Ukraine

The available information indicates that there are large deposits of Neogene sands (Fig. 2). There is currently ilmenite production at two localities: Vilnohisk about 250 km southeast of Kiev with high-grade ilmenite (63 to 64 % TiO_2) and at Irshansk 120 km northwest of Kiev with med. Grade ilmenite (50 to 59 % TiO_2)(Industrial Minerals Oct. 1998). Several companies have been (and probably are) active in Ukraine, looking for heavy mineral business opportunities, but the political climate is currently difficult. Our contact has provided us with a list of deposits from Ukaine. There are two Tables, the first one is called native deposits and the second one placer deposits. Both Tables are given in Appendix 3.

Figure 2:

Titanium-zirconium deposits in Ukraine



Placer provinces

I – Near Dniper
II – Near Azov Sea
III – Azov + Near Black Sea
IV – Kharkov – Sumy

Titanium-zirconium placer zones

1. Volynskiy
2. Skvirskiy
3. Belotserkovskiy
4. Zelenoyarskiy
5. Novomirgorodskiy
6. Pravoberezhniy
7. Levoberezhniy
8. Gulyaypolskiy
9. Mokroyalynskiy
10. Tokmakskiy
11. Kahovskiy
12. Sumskiy (Soomskiy)
13. Kharkovskiy

Titanium-zirconium placer fields

1. Luginskoe (Looginskoe?)
2. Litvinovskoe
3. Irshanskoe
4. Kocherovskoe
5. Kozievskoe
6. Mar'yanovskoe
7. Golubiatinskoe
8. Vasilkovskoe
9. Tarasovskoe
10. Taraschanskoe
11. Steblikovskoe
12. Makarovskoe
13. Morozovskoe
14. Zelenoyarskoe
15. Gorodishchensko-Smolyanskoe
16. Novomirgorodskoe
17. Bolshevysokovskoe
18. Pridneprovskoe (Near Dnieper river)
19. Voskresenskoe
20. Volchanskoe
21. Kamyshevahskoe
22. Ternovatskoe
23. Uspenovskoe
24. Pavlovskoe
25. Tokmakskoe
26. Berdyanskoe (shelf of Azov sea)
27. Ochakovo-Dzharylgachskoe (shelf of Black sea)
28. Vilkovskoe
29. Lebedinskoe
30. Hotinskoe
31. Krasnokutskoe
32. Bogoduhovskoe (Bogodoohovskoe?)
33. Nurchinskoe
34. Novovodolazhskoe

Native hard rock deposits

1. Yastrubetskoye (Zr + rare metals)
2. Mazurovskoe
3. Azovskoe
4. Stremigorodkoe
5. Fedorovskoe
6. Vidiborzhskoe
7. Kropivenskoe
8. Paromovskoe
9. Yur'evskoe
10. Nosachevskoe
11. Mariupolskoe
12. Pokrovsko-Kireevskoe

Placer deposits of titanium-zirconium ores

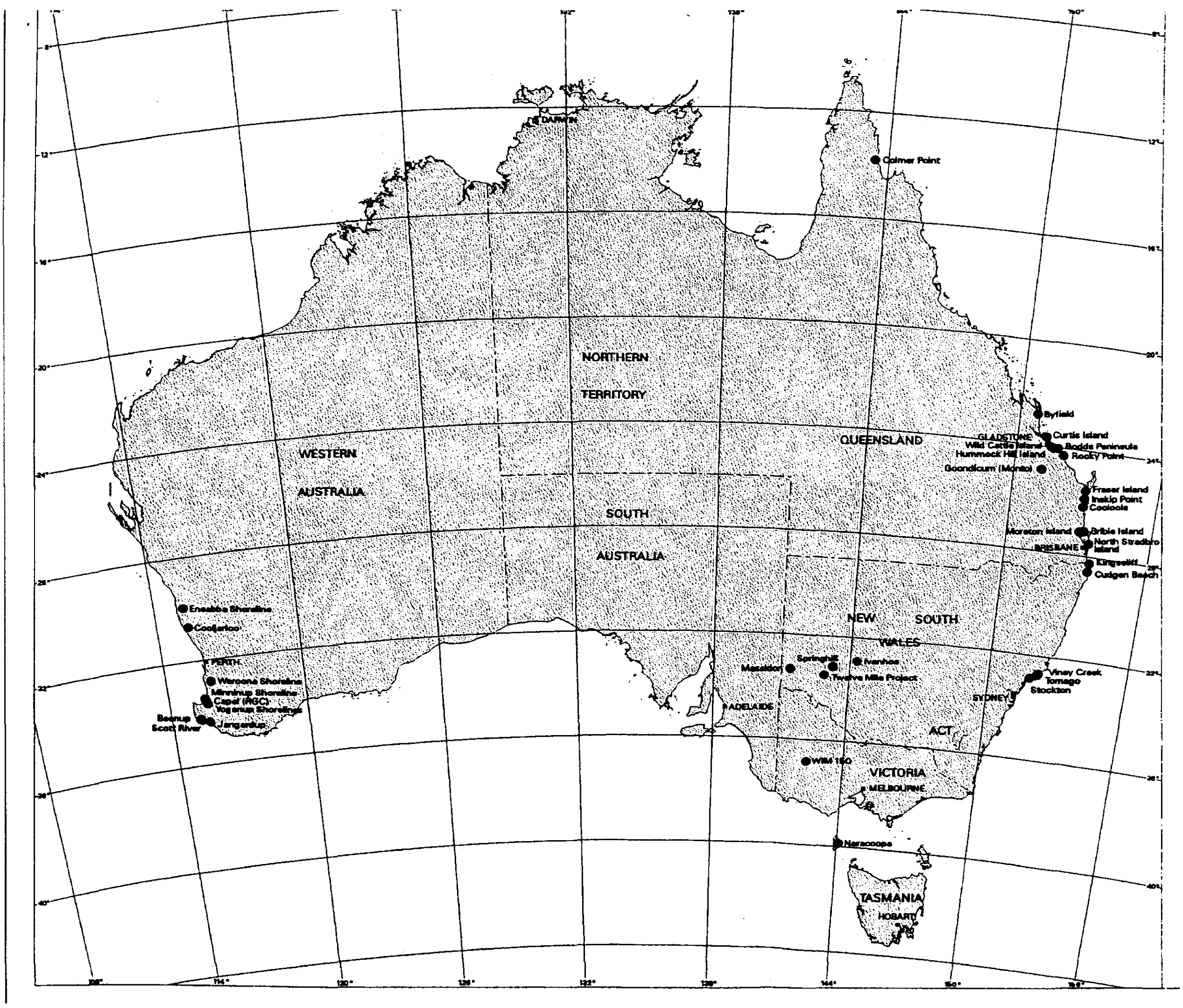
1. Irashanskoe (15 deposits-ore group)
2. Zelenoyarskoe
3. Tarasovskoe
4. Tarashchanskoe
5. Gorodishchensko-Smelyanskays gruppa (group – 4 sites)
6. Novomirgorodskoe (6 sites)
7. Malyshevskoe
8. Yuzhnoe (Southern)
9. Krasnokutskoe
10. Voskresenovskoe
11. Novonikolaevskoe
12. Volchanskoe
13. Dzharylgachskoe
14. Mokroyalynskoe (3 sites)

Contact was made to a geologist from the Geological Survey of Ukraine, through a GEUS project in Ukraine. He is preparing a report about sedimentary deposits of ilmenite in Ukraine for us. The Survey has supplied us with a map from a publication of the Ukrainian titanium and zircon deposits in which we have translated and redrafted.

Further action is to be decided on when we have the report.

Australia

A report produced in late 1996 by AGSO on heavy mineral sand deposits in Australia includes some of the information we are seeking (Towner et al. 1996). Dr. Greg Ewers commented that both current and past AGSO's program has not included any systematic study of heavy mineral sand deposits. Commodity specialists in AGSO in the course of visits to mining operation have collected some samples. However, this material is not necessarily representative of a given deposit and covers only a small number of the Australian deposits. Information from the district Geological Surveys is therefore more accurate. Fig. 3 (below) shows some of the HM deposits in Australia.



Queensland

Consolidated Rutile Limited (CRL) is Queensland's only mineral sands miner. CRL's sands production in 1998-99 is ilmenite (94578 t), rutile (79685 t), and zircon (57578 t). Senior geologist Fred Bruvel has provided us with a list of contact names and addresses (Australian Register of Mining 2000/2001) and articles by Wallis and Oakes (1990), Cooper (1990), a recent review on mineral sands by Smart (2000), and a ressource article in Queenland Minerals (2000).

Deposits

The North Stradbroke Island dune system is currently mined by CRL. Within the dune system several resources have been defined. These are the Herring Enterprise, Vance, Ibis, and Yarraman resources of which Ibis and Yarraman are being mined. In general no TiO_2 content of the ilmenite is given.

The Goondicum Crater (central Queensland) ilmenite prospect forms a resource where alluvial and eluvial placer deposits have been derived by erosion of the Goondicum Gabbro. The ilmenite is high in titanium and low in chromium, thorium and uranium. The ore resource is 156.5 Mm^3 ranging in grades from 3.6% to 5.3% including nearly 14 Mm^3 ilmenite.

The Eulogie deposit also in central Queensland consists of eluvial, alluvial ilmenite, and flood plain sands derived from the ilmenite bearing Eulogie Park Gabbro. Ore grades are not reported but 103 Mt of ore is estimated.

New South Wales

Director J.N. Cramsie, Geological Survey reports that exploration for heavy minerals is currently taking place in coastal deposits north of Newcastle, and in the Murray Basin, which is located in the south western part of the State. The Murray Basin in particular has been intensely explored in recent years, resulting in the discovery of numerous deposits of heavy minerals, many of which have commercial potential.

Contact person at the Geological Survey is geologist John Whitehouse (email: whitehoj@minerals.nsw.gov.au). The main companies exploring for heavy mineral deposits in New South Wales are Murray Basin Titanium Pty Ltd, Basin Minerals NL, BeMax Resources NL, Iluka Resources Ltd, Redfire Resources Ltd, RZM Pty Ltd, BHP Titanium Minerals, and Mineral Deposits (Operations) Pty Ltd.

Victoria

A summary of Mineral Sands in Victoria can be found in McHaffie and Buckley (1995). Heavy mineral sand deposits are widespread over southern margin of the Murray Basin. These deposits occur within the Parilla sands and to a lesser extent, within the underlying Bookpurnong Beds. The Parilla Sands were deposited in a littoral to nearshore, shallow water, low energy environment on the southwest margin of the Murray Basin during late Miocene to early Pliocene times. In 1988-90 Wimmera Industrial Minerals (WIM) announced the discovery of a series of heavy mineral sand deposits along the southern margin of the Murray Basin. The titanium resources in the WIM deposits double Australia's previously known resources. The Wim deposits also contain Australia's largest monazite and xenotime resources, which in turn represent about 35% of estimated total world yttrium resources. The largest of the WIM deposits is WIM 150.

Dougls Mineral Sands prospect is in its pre-feasibilty study and is operated by Basin Minerals Ltd. Other prospects are Wemen investigated by Sons of Gwalia Ltd, and Kulwin/Woornack studied by Iluka Resources Ltd.

South Australia

No heavy mineral deposits are recorded in South Australia and the district is even not mentioned in the AGSO report by Towner et al. (1996).

Northern Territory

There are no sand deposits, which are being mined for heavy minerals. However, there are a number of heavy mineral occurrences in the Northern Territory. A report published by the Northern Territory Geological Survey on heavy mineral sands has an enclosed microfiche including data sheets on 20 sand deposits (Eupene Exploration Enterprises Pty Ltd, 1989).

In general, the heavy mineral sand deposits are small and subeconomic.

Western Australia

Accumulations of heavy minerals are located on the Swan Coastal Plain which extends from Busselton 200 km south of Perth to Eneabba 300 km north og Perth, and on the Scott Coastal Plain, 160 km south of Busselton (Baxter 1997). All of the accummulations are associated with Quaternary and Tertiary strandlines. The bulk of the rutile and zircon resources currently being mined are located in the northern portion of the Swan Coastal Plain. In these northerly deposits the ilmenite has very high TiO_2 normally over 60%.

The information of heavy minerals in Western Australia is available in a number of databases and publications of the Geological Survey of Western Australia. The most important sources are MINEDEX (Townsend et al. 2000) and WAMIN databases and the Mineral Resources Bulletin 10 (Baxter 1977).

The MINEDEX database contains information on Western Australian mines and mineral deposits, including those of heavy minerals (Townsend et al. 2000) includes Tables in ACCESS format. MINEDEX provides a co-ordinated, project based enquiry system for textual information on mine and site locations (coordinates etc.), notice of intent to mine, mineral resources, mine production, mining inspection data, and environmental reports.

The WAMIN database contains information on prospects and occurrences of heavy minerals, including the larger deposits, but this database is still in the process of development, and does not cover the whole state. Director Griffin of the Geological Survey has kindly provided us with an extract from WAMIN (excel file) of the sand deposits with commodity, coordinates, locality name and in some instances a short description of genetic type and/or mode of occurrence.

In both databases information on analytical records are missing. These data are in the position of the mining companies. The major mineral sand producers, which own the majority of the heavy mineral deposits in the State are: Iluka Resources Ltd, TiWest Pty Ltd, Cable Sands (WA) Pty Ltd, and GMA Garnet Pty Ltd.

Tasmania

Heavy mineral sands occur on King Island as beach placers containing up to 60% heavy minerals. Rutile and zircon occur in about equal proportions. Australian Titanium Minerals Ltd own the deposits (Towner et al. 1996).

Asia

Figure 4

Indonesia

Indonesia (Fig. 4) is interesting due to many heavy mineral deposits but has not yet responded on our request. In Sumatra titaniferous sands have been reported at several localities (Skillen, 1996). Indonesia has especial many Ti-magnetite heavy mineral occurrences but at least one ilmenite placer looks interesting. This is Sondan, East Sumatra where a 14 km long beach, 20-50 m wide contains 4.1% heavy minerals composed of ilmenite and traces of zircon and monazite (Skillen, 1996). Ilmenite is also derived as a by-product of e.g. tin mining.

Malaysia

In Malaysia (Fig. 4), ilmenite is derived from two sources, from alluvial tin mining and another from a stand-alone mine. The total production of ilmenite in 1998 was 124,689 tonnes, of which 97,889 tonnes were derived as a by-product of tin mining (Malaysian Minerals Yearbook, 1998).

Malaysia is in the form of beneficiation of synthetic rutile and manufacture of TiO_2 pigments. Malaysian Titanium Sdn. Bhd., located in Ipoh, produces synthethic rutile. The ilmenite is obtained locally.

Rutile and anatase are also widely distributed along with other heavy minerals in the alluvium and very small quantities of them are recovered as by-products of tin mining.

Papua New Guinea

After a contact by Ioannis Abatzis (GEUS), it has been reported that there are some heavy mineral occurrences within the country that are kept at the Geological Survey of Papua New Guinea (Fig. 4) archives. We got a contact (fax), which we answered but got no further reply.

South Korea

South Korea has extensive possibilities for heavy mineral occurrences. In Industrial Minerals (January 1997) a world class titanium ore deposit was discovered to the south of the Korean peninsula. The deposit is estimated to contain 2 billion tonnes of titanium ore that is believed to have a TiO_2 content of 4-6.7%. The Director Hee Young Chun, Korea Institute of Geoscience and Mineral Resources (KIGAM), Geology Division has recently been contacted.

Vietnam

Exploration for heavy minerals has been conducted in Vietnam for a number of years, and according to O'Driscoll (1996) reserves containing 11 mill. t. of titanium minerals have been identified, in 40 deposits mainly along the long Vietnamese coastline (Fig. 5). Most deposits are located in four groups in the central part of the coastline. The heavy mineral deposits are primarily Quaternary beach/barrier deposits, but no detailed descriptions have been found yet. One deposit (Cay Cham, north of Hanoi) is located inland and is likely to have a different history (and might have higher ilmenite grade).

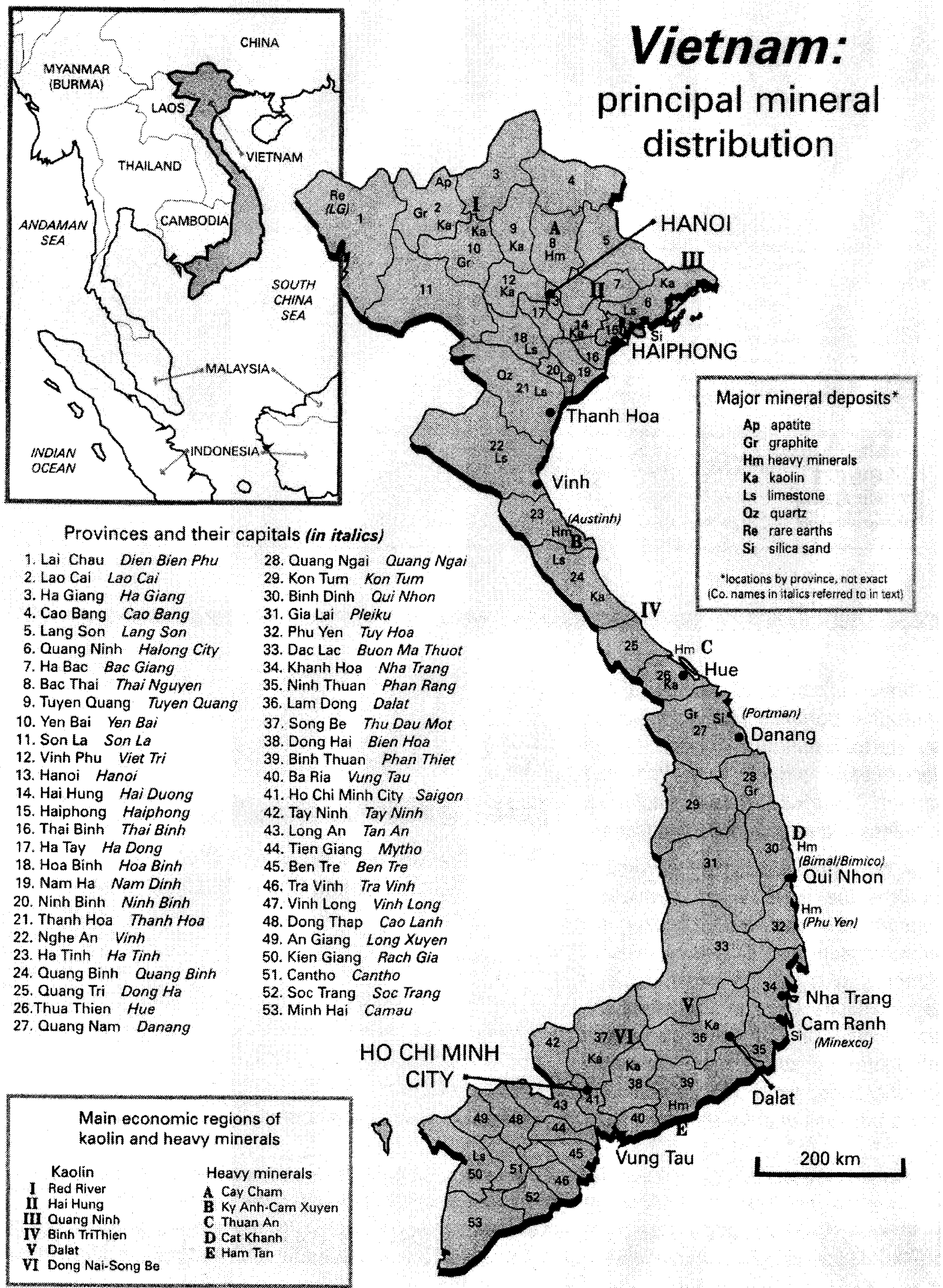


Figure 5 – From O'Driscoll (1996).

Contact was made to the local geological survey (GEUS has connections to Vietnam, as we are preparing another programme in Vietnam concerning oil). At present a correspondence is running with Prof. Dr. Tran Van Tri from the Geological Society of Vietnam. We got an offer from the survey to do sampling of the HM deposits in Vietnam. This offer is discussed at the moment.

Africa

Kenya

We got some information concerning heavy mineral deposits in Kenya. All the economical deposits are found along the Kenyan coastline, within the Quaternary Pliocene sands. Four deposits in this area are under exploration licences held by Tiomin Kenya Limited. However, grade of the ilmente is rather low (<55% TiO_2). Apart from the main deposits there are various other minor deposits within the Mozambique Belt, which not have been fully investigated.

The Commissioner of Mines and Geology L.K. Biwott explains that they not have samples ready. The collection of such samples will have some financial and logistical implications, which at the moment the Department is not in a position to cater for. It is therefore necessary to visit the appropriate deposits and collect samples. For this exercise the Department needs funding.

Mozambique

The country has a shoreline to the Indian Ocean, which is km 2600 long. Based on the heavy-mineral sand potential the coast can be divided into a southern, central and a northern part. Branco et al. (1997) rate the different coastal stretches with to the heavy-mineral potential as follows (Fig. 6):

- The southern part stretches from the South African border to Beira and its heavy-mineral potential is rated as moderate. Deposits are generally small.
- The central part covers the coastline from Beira to Nacala. It contains the economically more important deposits.
- The northern part from Nacala to the Tanzanian border is devoid of any heavy-mineral potential.

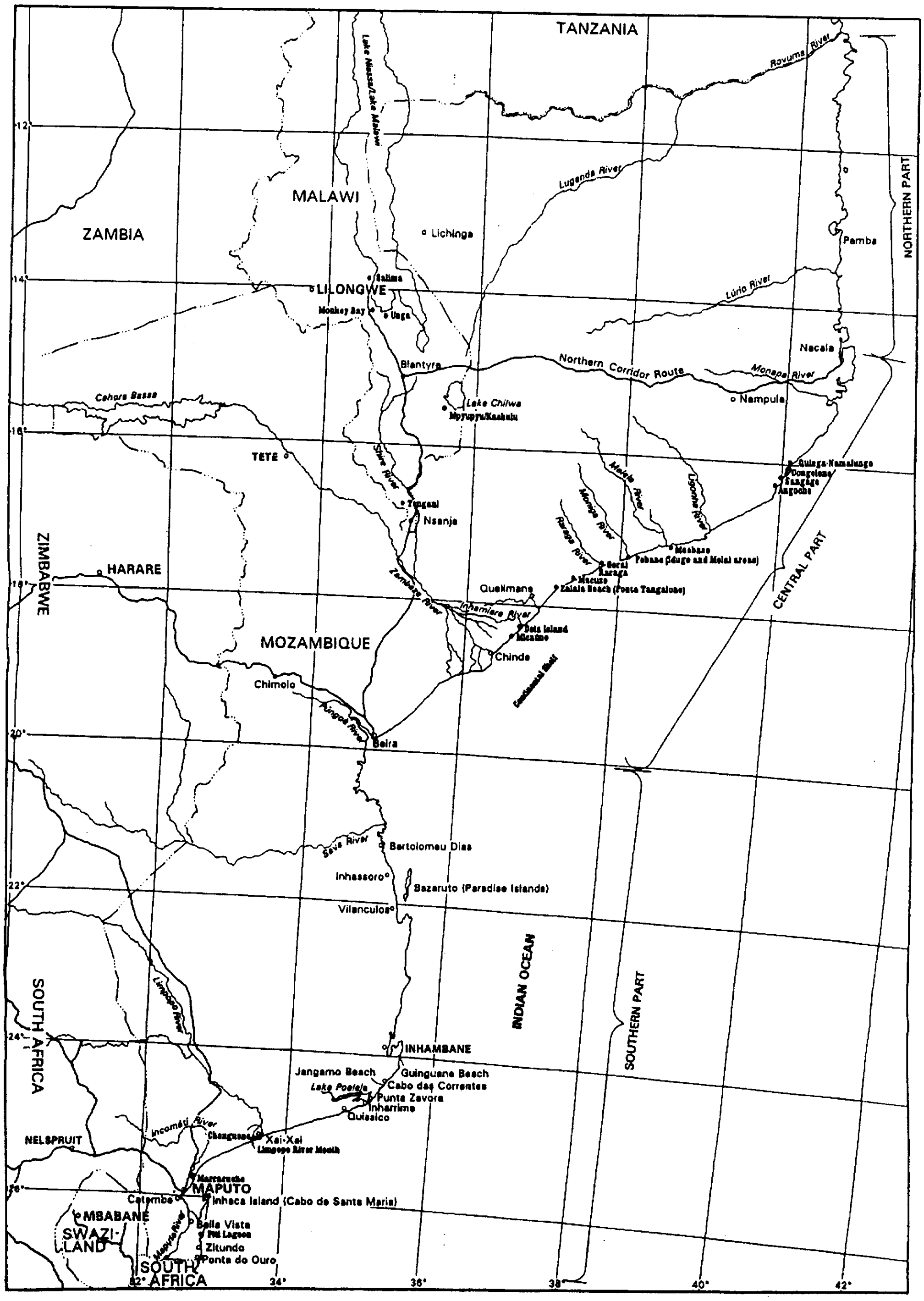


Figure 6 – From Branco et al. (1997).

The Direccao Nacional de Geologia, Republica de Mocambique (DNG, Geol. Survey of Mozambique) has kindly given us some information on some of the heavy-mineral deposits in the country. Heavy-mineral deposits occur both onshore and offshore. Some of them are related to Zambezi River delta – either present day beach ridges or fossil beach ridges, which got submerged. DNG also stresses that the central coast between Chinde to Angoche, strecthing over 600 km, are the most favourable places for accumulation of heavy-mineral sands.

From the Table given by DNG some examples are listed here:

- Idugo and Melai areas have TiO_2 contents from 56.9-51.7%. The ilmenite content of the heavy-minerals is c. 80%, rutile 2,7-5,9% and zircon 5.9-8.2%. The deposits are coastal dunes and no concession has been taken on the land at the moment.
- In the southern part not far from the capital Muputo Limpopo River has several prospects. Just outside Maputo the Marracuene deposit has 51.2% TiO_2 and the ilmenite proportion is 86,3% occurring in fossil and dune ridges.

It is not stated whether the TiO_2 content is calculated for the ilmenite mineral or the heavy mineral concentrate in the data from the Survey.

According to the Mining Annual Review 2000 Billitons' s heavy-mineral sands project at Moebase has not left the ground yet. However, Kenmare appears ready to press on with its mineral sand resource at Moma (I'm not sure of its location). Also on the positive site, Southern Mining's Corridor Sands titanium discovery inland near Xai-Xai has emerged as a world-class ressource, larger and richer than the Richards Bay deposit down the coast in South Africa.

It looks like that the heavy-mineral production in Mozambique has great potential – "elephant country". New exploration has recently commenced and new exploration data are being generated. The chemical data from the survey indicate that high-grade ilmenite may be found, and the possibilities should be tested.

Visit is planned to Mozambique in the second half of April 2001.

Namibia

Namibia has a number of heavy mineral occurrences (Fig. 7). They are elaborated in The Surveys Mineral Resource Series, which contains chapters on each and every mineral deposit.

The entire western part of Namibia is occupied by the Namib Desert which stretches from the Orange River in the south to Namibe in Angola app. 100 km north of the mouth of the Kunene River (Schneider, 1997). The provenance of heavy minerals comes from Proterozoic bedrocks. The heavy minerals are present in sand dunes and contain abundant ilmenite and rutile. A potential for dune-placer deposits exists along the entire coastal stretch of the Namib Sand Sea, where the dune sand is constantly reworked by the prevailing southwesterly winds. Beach-placer deposits also occur within the storm beach section, approximately 1,5 to 3 m above sea level, of the Namibian coast, carry layers of minerals composed of ilmenite, rutile, magnesite, garnet, staurolite, zircon, and monazite (Schneider, 1997). The ilmente contents of the beach sand are 8-9%, rutile below a half percent and zircon up to one percent.

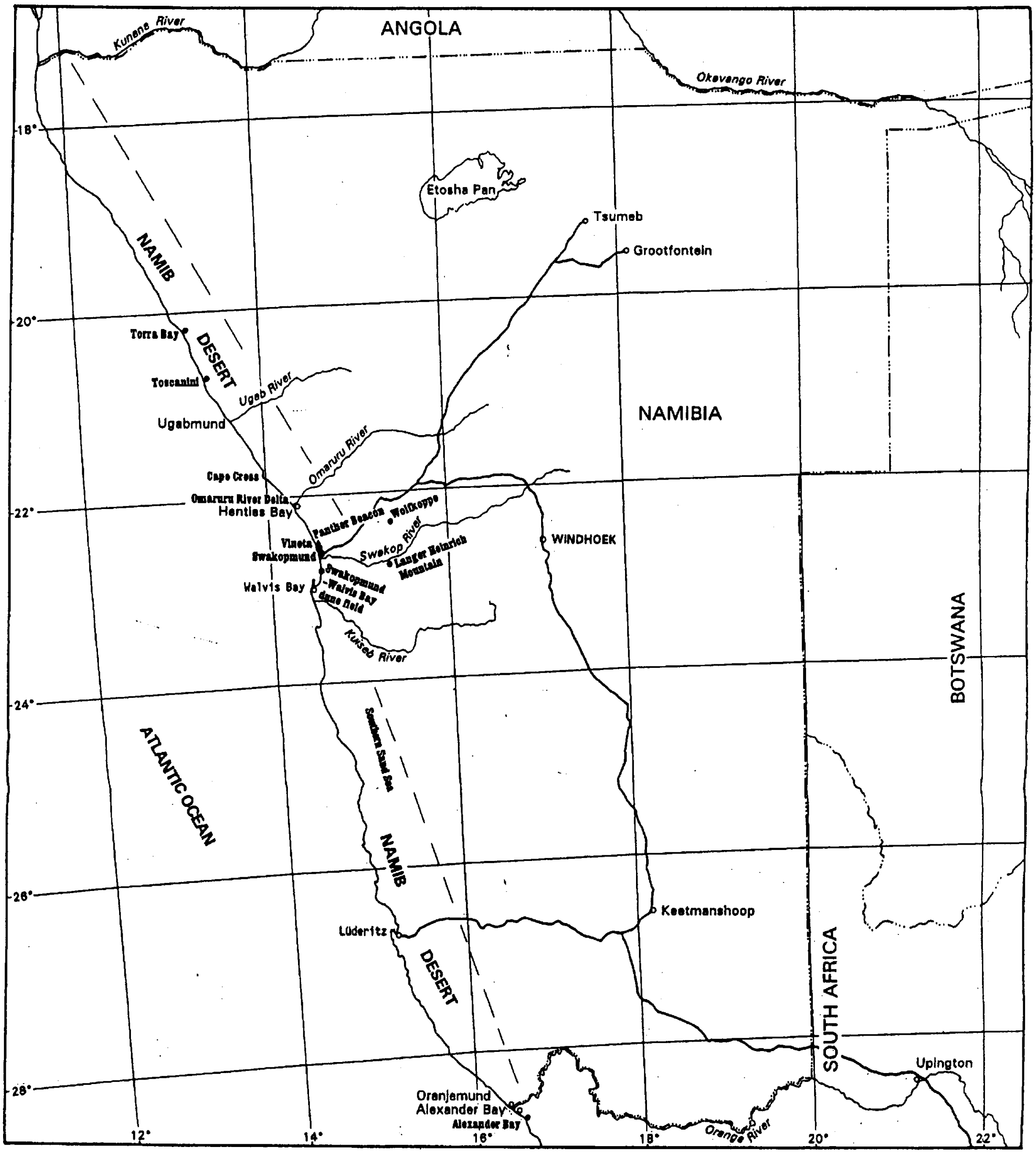


Figure 7 - From Schneider (1997).

Contact with the Ministry of Mines and Energy, Geological Survey is in progress at the moment. The Geological Survey welcomes us to visit Namibia, and they can facilitate the export formalities to Denmark. They also are willing to give us information about the licensing system. The Survey also wants to assist in the preparation of an excursion. Visit is planned to take place ultimo April/primo May 2001.

South Africa

The answer on our request to South Africa was as follows: We have a mineral database report for sale (3600 $) which include GIS locality maps. The contents of the 44-page report were also given. To this a lot question came up and these were mailed prime January 2001.

The South African primary titanium-ore production is based on shore-related placer-sand deposits (Fig. 8). They represents an important part of the demonstrated world resource of placer titanium (Wipplinger, 1997). Ilmenite is the most important mineral but associated with rutile. The TiO_2 content of ilmenite concentrates ranges between 48 and 52%. Rutile, though less abundant, is an important by-product. The South African area is divided into three provinces: (1) Province of Kwazulu/Natal, (2) Province of the Eastern Cape, and (3) Province of Northern Cape.

(1) Most of the deposits in the Province of KwaZulu/Natal are coastal Quaternary sand dunes. The ilmenite content ranges from 3-6%. The dunes of the Zululand titanium (Reserve No. 4) covers coast parallel dunes, which are of Quaternary age, may rise to 150 m above sea level (Wipplinger, 1997). The existence of heavy-mineral deposits on the continental shelf off the KwaZulu/Natal North Coast was confirmed in the early 1970s by a limited oceanographic survey. More recent investigations by the Marine Geoscience Unit in Durban (Ramsay 1996) showed that both transgressive and regressive events provide the opportunity for the preservation of beach/barrier sediments on the continental shelf.

(2) Placer deposits in the Province of the Eastern Cape occur as coast-parallel deposits, as accumulations along river mouths, as aeolian sand deposits, and as continental shelf deposits. The ilmenite content ranges from 3-6%.

(3) The West Coast deposits were already investigated in the mid-1950s by the Geological Survey of South Africa. The Namaqua Sands (Graauw Duinen) was proved economic on basis of re-evaluating airborne geophysical radiometric records. The proven reserves amount 530 million tonnes grading 9% total heavy minerals (Wipplinger, 1997). The possibility of exploiting heavy minerals from marine diamond placers has been investigated at Alexander Bay. The deposit was estimated but it was too small ore reserve and the ilmenite was too iron rich. Thus, the possibility of integrating the heavy mineral exploitation with diamond recoveries has not yet been established.

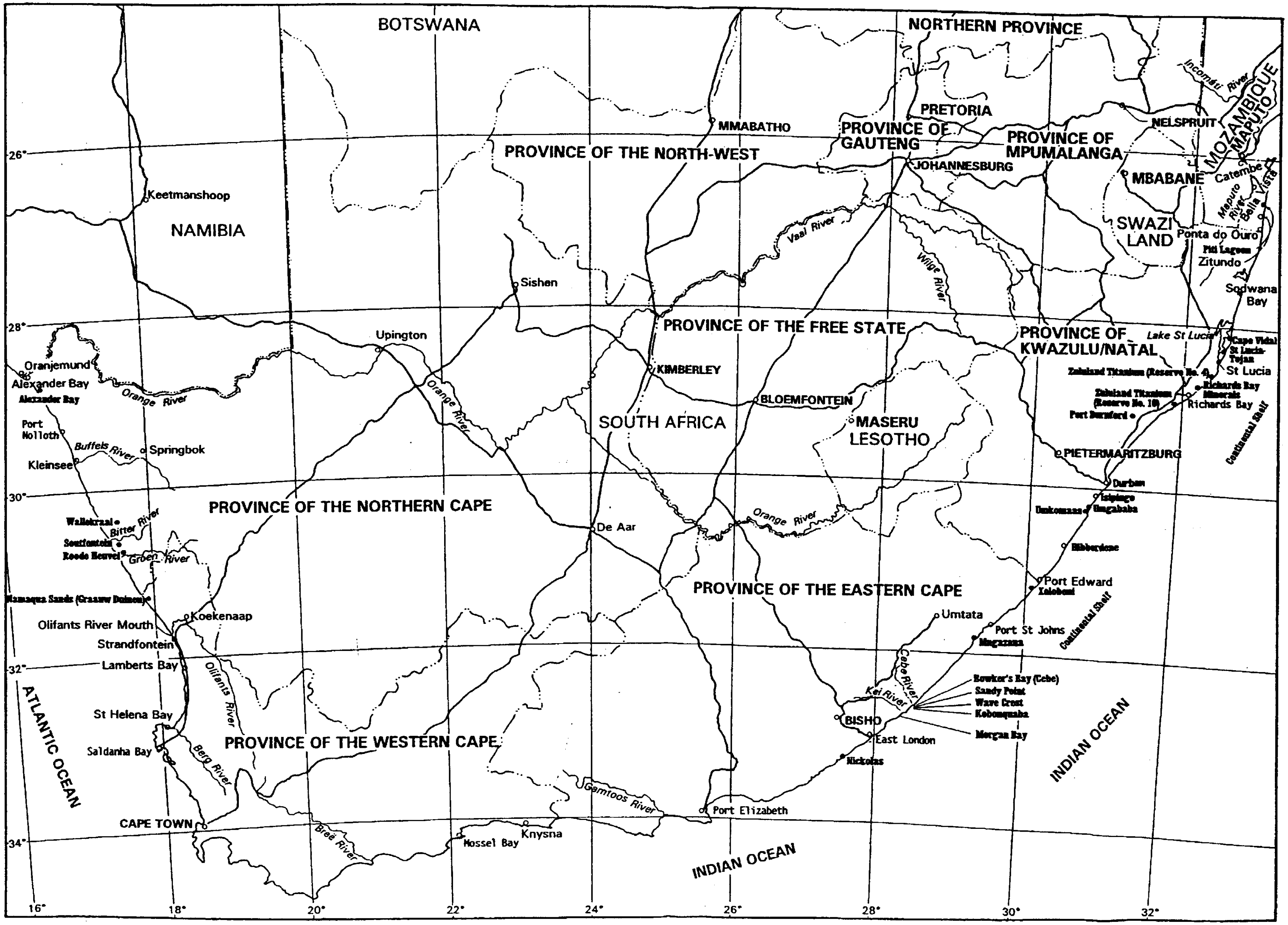


Figure 8 – From Wipplinger (1997).

Tanzania

The contact to Tanzania has both been in written and persoanally. In spite of that the Authorities has not replied officially. Harris (1981) reports that beach sands along the coast of Tanzania carry as much as 55 % ilmenite and from 5 to 15% rutile, e.g. south of Bagamoyo and in the Kunduchi and Mbweni areas near Dar es Salaam. Mbawala (1997) reports that many Tanzanian beaches appear suiTable for the large-scale exploitation of heavy minerals (Fig. 9). Provenance rocks containing heavy minerals are common in the Usagaran System (Palaeoproterozoic).

It is recommended (Mbawala, 1997) that the mainland coast of Tanzania, particularly the areas between Dar es Salaam and Bagamoyo and between Ras Luale and Mtwara and and Msimbati be investigated in more depth as far their heavy-mineral potential is concerned.

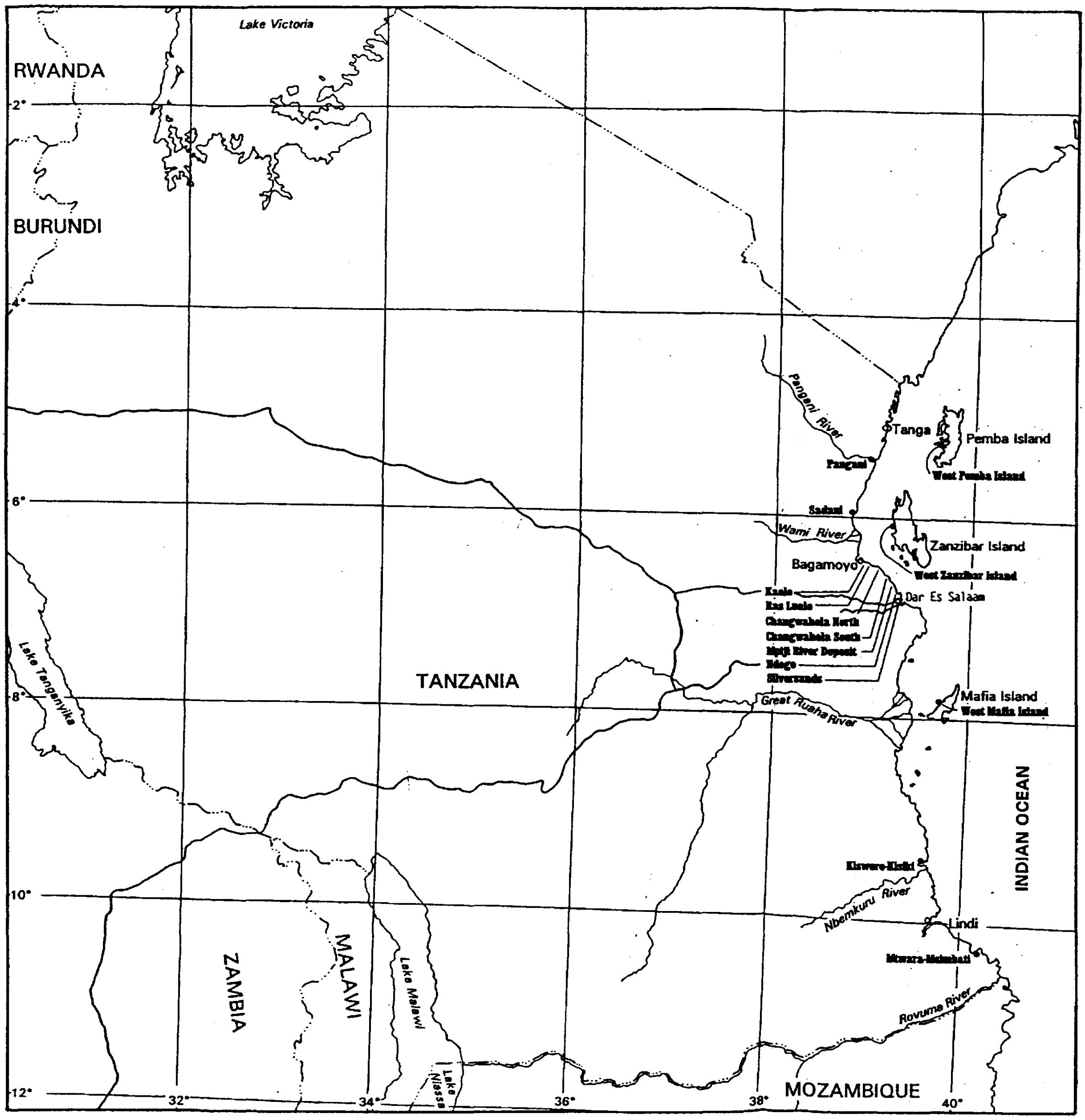


Figure 9 – From Mbawala (1997).

West Africa - Ghana

West Africa has long coastlines and one of the countries along this coastline is a major producer of ilmenite, rutile, and zircon from placer deposits namely Sierra Leone. But to approach this country has not been advisable for a long time due to civil war. An attempt to reach Senegal has been without success. An approach to looking for heavy minerals in Ghana is in progress at the moment. A visit to Ghana is planned to take place in the middle of March 2001 to get an impression of the possibilities for heavy mineral deposits in a country where the mining industry is an important part of the income.

Ilmenite and rutile are widespread occurrences known from alluvial deposits (Fig. 10; Information given by Prof. Asiedu, University of Ghana, Legon). In the Volta region, ilmenite and rutile appear to be particularly abundant in the streams draining the Dahomeyan gneiss in the Ho area. In the western Ghana high alluvial ilmenite content has been reported in some of the alluvial concentrates in the Berekum area.

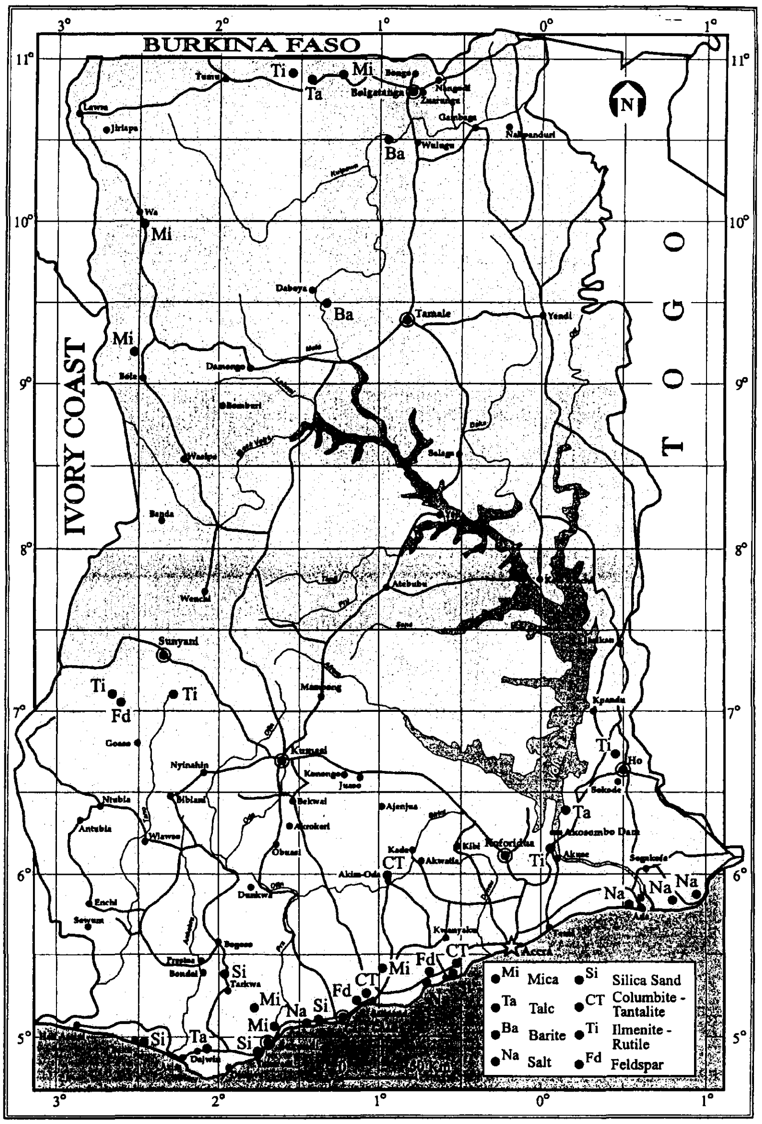


Figure 10.

Americas and Greenland

Manitoba, Canada

GPR profiling was conducted in the Swan River Valley, Manitoba during the period of the 16th to the 20th of Nov. 2000 by Tais Dahl and Torben Fischer from GEUS assisted by Richard Gunter from Industrial Mineral Consultant Inc. as the local consultant.

The target of the operation was to test the use of GPR as a possible preliminary geophysical exploration technique to locate the heavy mineral enriched sand deposits of the Swan River Fm.. Outcrops suggest that these sand deposits are located as infillings of paleochannels cut into the underlying shale of the Swan River Fm.

Swan River Formation

Middle Cretaceous age; the Swan River Formation unconformably overlies Devonian carbonate rocks and the formation is conformably overlain by a thick shale sequence of Cretaceous age.

Near shore and beach facies; the Swan River Formation contains discrete sand and kaolinitic clay units.

The western Swan River Valley the sand units appear to be restricted to three N10°E trending channels. The interchannel lithology is predominantly kaolinitic clay with minor sand and silt interbeds. The Main Channel outcrops in two separate river bank cuts, approximately 7 kilometers apart. The channel shows cut and fill structures with the clay-rich strata in each of the outcrops.

The western portion of the Swan River Valley is covered by a series of Pleistocene sand to fine gravel sheet deposits that result in an almost planar land surface, which makes the area perfect for GPR profiling.

The eastern Swan River Valley has significantly less data as it is not an agricultural area. The presence of white silica sand on the surface and the disappearance of surface drainage indicate that the clay rich units of the Swan River Formation are minor or absent.

The sand within the Swan River Formation has a tight grain size distribution and less than 1% clay minerals. The titanium minerals contained in the sand are highly weathered. The range from ilmenite to leucoxene with a large proportion converted to rutile.

The provenance of the Swan River Formation is The Superior Craton (granulite facies) of Archean age, towards the north and east.

Results

Due to winter conditions the survey was difficult and had to be cut to a minimum. Approximately 10 profiles were recorded and the method was proven to be very suiTable to locate these paleo-channels. Good relations to Richard Gunter have been made and preliminary plans concerning an extensive GPR campaign in spring 2001 has been discussed.

Greenland

Milne Land, East Greenland

The fossil placers in Milne Land are anomalous in zirconium, REE, titanium, and thorium, The fossil placer is Mesozoic in age representing a marine transgression over a deeply eroded part of the Caledonian Fold Belt (Harpøth et al. 1986). The sediments are conglomerates, intraformational breccias, and cross-bedded sandstones and commonly up to 25 m in thickness. The heavy mineral sands found in different levels, mainly unconsolidated, contains garnet, anatase, rutile, zircon and monazite, which interfinger with the arkosic sandstone. The heavy mineral sands occur as irregularly distributed 10-40 cm thick lenses. The resource is estimated to 3.7 million tonnes of sand with 2.6% anatase, 0.5% monazite, 1.1% zircon, 3.1% garnet, and 0.03% xenotime (Ross, 1992). A 15 tonnes bulk sample was shipped to Australia for metallurgical purposes. The results of this study were that the anatase has a complex nature and a very fine grain size. This means it did not appear to be possible to produce a substantial anatase product utilising conventional mineral sands processing techniques (Ross 1992). A monazite product was produced with relative ease from Kelsey Jig concentrate utilising a permroll magnet and a wet Table at +85% recovery.

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Wallis, D.S., & Oakes, G.M. 1990: Heavy mineral sands in Eastern Australia. In: Hughes, F. E. (ed.): Geology of mineral deposits of Australia and Papua New Guinea: Melbourne The Australian Institute of Mining and Metallurgy,1599-1608.

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Recommendations

By Christian Knudsen and Henrik Stendal

Denmark

- The preliminary results of the Danish deposits have not reached the goal of a 100 mill. m^3 deposit with 3% TiO_2 and high grade ilmenite of the right grain size.
- The Vorslunde deposit looks at present much smaller than the Skjern deposit. The estimated volume is approximately 12 mill. m^3 containing more than 1% TiO_2, but the grain size is here in general over 100 µm. The TiO_2% in the ilmenite averages 62.9%. The drilling profiles made so far in Vorslunde indicate possibilities for extension of the ore deposit. Thus, further drilling is recommended to define size, shape and grade of the deposits found.
- The Skjern deposit is the largest with an estimated volume of 150 mill. m^3 containing more than 2% TiO_2, but the grain size is generally below 100 µm and the TiO_2 content in the ilmenite averages 60.4%.
- It is recommended to collect bulk samples for processing work.

International scouting

The objective is to locate new HM deposits with an ilmenite grade > 60% TiO_2 and a medium grain-size of 100 µm.

- Investigate the possibilities for heavy-minerals in the respective countries
- Get samples from potential HM environments through the respective Geological Surveys
- Visit heavy-mineral occurrences if relevant
- Evaluate the HM potential
- Set up a program for a later sampling program and make a budget for such an activity
- Involving the local Department/Company in the activity

Australia

Australia is the world's dominant producer of rutile, ilmenite, and zircon, and extensive exploration is ongoing in Australia. As our first attempt to establishing contacts, get data and samples from the local geological surveys did not produce new targets Australia is low priority at the moment.

Africa

Many parts of Africa have the potential for ilmenite in placer deposits. Great possibilities are found within the SADC region. Promising heavy mineral sand deposits are known to exist in Malawi, Mozambique, South Africa, Tanzania, and Namibia (Wipplinger and Daudi, 1997). Interesting countries concerning heavy mineral deposits but not yet contacted might be Marocco, Liberia, and Madagascar. The first visit to a African country will be Ghana where contacts are established through the University of Ghana. Then follows visits to Mozambique and Namibia, where contacts have been established to the local surveys.

Asia

The possibilities for heavy minerals are great in many places of Asia where the countries contacted have long coastlines with huge placer deposits. The difficulties at least in the beginning are the communication and who to communicate with. India, Sri Lanka, and Thailand have also been contacted but the respective Ministries have not responded on our request so far. We will try new contacts. A project in Vietnam is being outlined at the moment together with the Geological Survey of Vietnam. Relevant letter was received from Papua New Gunea, which will be followed-up.

Europe

Holland is the most promising at the moment. More samples will come from the survey, and we will discuss how to prospect in more detail.
The German states of Mecklenburg-Vorpommern, Brandenburg and Sachsen will be visited. No further work in Schleswig-Holstein due to low grade of the ilmenite.
Samples from Hungary and Poland are in the pipeline.
Contacts to Romania, Belarus, Ukraine, France and Spain are taken and will be followed-up.

Methods

Further work on the methods:

1. Zircon dating method (samples from Denmark and the scouting programme)
2. Ilmenite types. Hard rock ilmenite of known origin and environment will be analysed using microprobe and LA ICPMS for trace elements. This to further trace provenance of ilmenites.
3. Logging methods. Further work on the data collected in 2000 (Tines M.Sc. thesis). The objective is to monitor bedrock content of ilmenite and zircon from wireline logging.

Appendices

Appendix 1

Overview over the correspondence carried out between GEUS and organisations from Australia, Asia and Africa

Appendix 2

CCSEM results

Appendix 3

Mineral deposits and placer deposits in Ukraine.

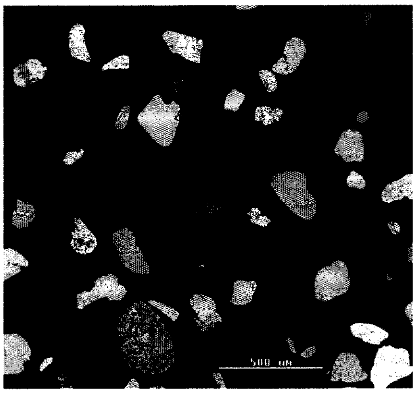
Appendix 1

Organisation	Contact	Country	Reply	Comments/ Contacts
Australian Geological Survey Organisation	Ewers, Greg	Australia	18-08-2000	Report
Department of Mines & Energy Northern Territory	Bajwah, Zia	Australia	25-08-2000	Report
Geological Survey of Victoria	Buckley, Roger	Australia	02-10-2000	Report
Geological Survey Western Australia	Abeysinghe, Dr. P.	Australia	09-10-2000	Report and diskette
Mineral Resources New South Wales	Cramsie, J N	Australia	11-09-2000	List of Explorers
Mineral Resources South Australia		Australia		
Mineral Resources Tasmania	Bacon, Carol	Australia		
Queensland Minerals and Energy Centre	Bruvel, Fred	Australia	12-09-2000	Reports
Geological Survey of Papua New Guinea	Kopi, Gwaibo	Papua New Guinea	09-11-2000	
Geological Survey of India		India		
Directorate of Mineral Resources		Indonesia		
Korea Institute of Geoscience and Mineral Resources	Chun, Hee Young	Korea		
Ministry of Science, Tecnology and the Environment	Akbar Mahbat, Mohamad	Malaysia	04-09-2000	CD-Rom received
National Science Foundation, Natural Resources	Amarasinghe, Amusha U.	Sri Lanka		
Department of Science Service		Thailand		
Geological Society of Vietnam	Tran Van Tri	Vietnam	16-11-2000	30.01.2001, negociatior
Ministry of Environment and Natural resources	Biwott, L.K.	Kenya	04-09-2000	
National Directorate of Geology	Daudi, Elias Xavier Felix	Mozambique	23-10-2000	Visit planned
Ministry of Mines and Energy, Geological Survey	Schneider, G.	Namibia	09/01/01	Visit planned
Department of Geological Sciences		Senegal		
Council of Geoscience	Ramsay, Peter	South Africa	04-10-2000	E-mail 19.01.2001
Ministry of Energy and Minerals	Kenyunko, P.M	Tanzania		
University of Ghana, Legon	Asiedu, Daniel	Ghana	17-01-2001	Visit planned
Danish Embassy, Accra	Klitten, Kurt	Ghana	27.01.2001	

Appendix 2

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

Sample Name:	V62 1-13
Date:	13/07/00
Submitter:	Dupont
Analyzed by:	CCA
Acc. Voltage	17 kV
Magnification	50x
Guard region	250 µm
Sieve	100 μm^2



Number of frames: 30

Number of valuable particles analyzed: 533

Heavy minerals in raw sand (%): 1.82

Average content	Category										
	ilmenite	leucoxene	pyrite	rutile	silicate	other Ti-ox	unclassified	zircon	garnet	sillimanite	staurolite
TiO_2 w/w	59.1	75.5	0.0	92.5	2.2	32.2	13.8	0.4	0.2	0.2	0.6
Fe_2O_3 w/w	33.1	11.5	27.7	1.2	6.5	50.4	13.1	0.3	24.2	0.8	12.0
MnO w/w	2.1	0.8	0.0	0.2	0.5	0.7	0.6	0.2	10.2	0.3	0.2
Cr_2O_3 w/w	0.1	0.2	0.1	0.2	0.1	0.9	10.2	0.2	0.2	0.1	0.2
SiO_2 w/w	1.5	4.7	14.9	1.8	48.0	4.5	14.3	29.5	37.0	43.0	33.9
Al_2O_3 w/w	0.9	2.6	0.0	0.7	31.8	0.6	2.4	0.1	19.4	53.9	46.6
MgO w /w	0.3	0.2	0.0	0.1	1.3	0.1	0.9	0.1	2.1	0.0	1.4
CaO w/w	0.1	0.2	0.6	0.2	6.3	0.0	1.7	0.2	4.8	0.1	0.0
ZrO_2 w/w	0.3	0.5	0.0	0.4	0.4	5.8	16.3	63.3	0.2	0.2	1.1
Total	97.6	96.2	43.3	97.3	97.3	95.2	73.2	94.4	98.3	98.5	96.1

Normalised average contents of the valuable Ti-containing minerals:

Average content	Category			
	ilmenite	leucoxene	rutile	other Ti-ox.
TiO_2 w/w	60.6	78.5	95.1	33.8
Fe_2O_3 w/w	33.9	11.9	1.2	52.9
MnO w/w	2.1	0.8	0.2	0.7
Cr_2O_3 w/w	0.1	0.2	0.2	0.9
SiO_2 w/w	1.6	4.9	1.9	4.7
Al_2O_3 w/w	0.9	2.7	0.7	0.7
MgO w/w	0.3	0.2	0.1	0.1
CaO w/w	0.1	0.2	0.2	0.0
ZrO_2 w/w	0.3	0.6	0.4	6.0
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals: 62.6

Average TiO_2 content of all the TiO_2 minerals excl. rutile: 61.3

Weight percent on a mineral basis:

the heavy mineral concentrate

Category	w/w
ilmenite	72.74
leucoxene	3.95
pyrite	0.02
rutile	3.15
silicate	6.34
sphene	0.00
otherTi-ox.	0.46
unclassified	0.58
zircon	6.49
garnet	2.18
monazite	0.00
phosphate	0.00
sillimanite	3.19
staurolite	0.91
Y-phosphate	0.00
Total	100.00

the raw sand

Category	w/w
ilmenite	1.32
leucoxene	0.07
pyrite	0.00
rutile	0.06
silicate	98.30
sphene	0.00
otherTi-ox.	0.01
unclassified	0.01
zircon	0.12
garnet	0.04
monazite	0.00
phosphate	0.00
sillimanite	0.06
staurolite	0.02
Y-phosphate	0.00
Total	100.00

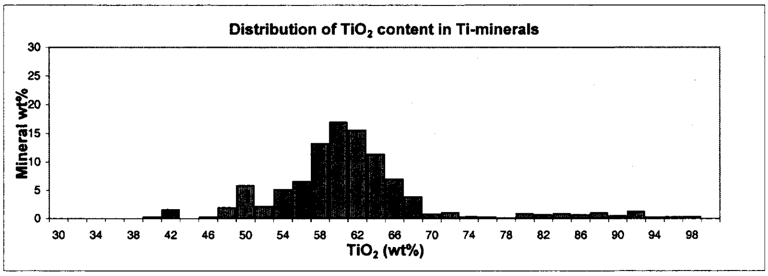
the valuable heavy minerals

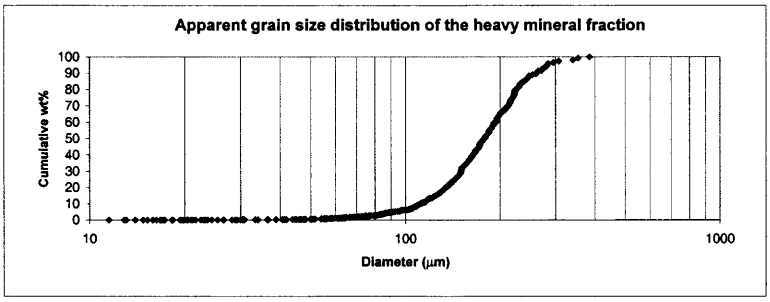
Category	w/w
ilmenite	78.93
leucoxene	4.29
rutile	3.42
otherTi-ox.	0.49
zircon	7.04
garnet	2.37
sillimanite	3.46
Total	100.00

Valuable heavy minerals in raw sand: 1.68

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

Sample Name:	V62 1-13	Date:	13/07/00
Submitter:	Dupont		
Analyzed by:	CCA		
Acc. Voltage	17kV		





Average grain parameters	Category										
	ilmenite	leucoxene	pyrite	rutile	silicate	other Ti-ox	unclassified	zircon	garnet	sillimanite	staurolite
Aspect ratio	1.56	1.57	1.31	1.49	1.60	1.35	1.40	1.40	1.46	1.94	1.32
Circularity	1.76	1.57	1.35	1.63	2.09	1.74	1.36	1.62	1.95	2.21	1.49
Perimeter (µm)	565.36	472.31	148.26	359.36	591.76	414.35	263.45	509.91	671.84	936.46	555.42
Length (µm)	214.45	171.61	45.91	138.40	239.47	165.65	102.59	182.51	264.34	388.69	212.65
Total grains	357	21	1	27	49	4	12	37	10	11	4

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Thoravej 8, DK-2400 Copenhagen NV
Ph: +45 38142000, Fax.: 38142050

Sample Name:	V62 1-13
Date:	07/08/00
Submitter:	Dupont
Analyzed by:	CCA
Acc. Voltage	17 kV
Magnification	50x
Guard region	250 μm
Sieve	100 μm^2

Number of frames: 36

Number of valuable particles analyzed: 626

Heavy minerals in raw sand (%): 1.82

Average content	Category										
	ilmenite	leucoxene	pyrite	rutile	silicate	other Ti-ox	unclassified	zircon	garnet	sillimanite	staurolite
TiO_2 w/w	58.7	75.3	0.0	93.9	1.1	19.1	18.4	0.4	0.6	0.3	0.7
Fe_2O_3 w/w	33.4	15.7	30.6	1.3	7.2	63.4	12.8	0.3	27.0	0.9	13.7
MnO w/w	2.0	1.4	0.0	0.1	0.7	0.5	0.2	0.2	7.5	0.1	0.3
Cr_2O_3 w/w	0.2	0.2	0.0	0.1	0.2	2.0	3.6	0.2	0.1	0.2	0.2
SiO_2 w/w	1.7	2.4	1.4	2.0	43.9	3.3	26.1	29.5	36.9	42.4	32.7
Al_2O_3 w/w	0.9	2.0	0.7	0.7	35.8	1.0	11.6	0.1	19.5	53.9	48.1
MgO w /w	0.3	0.2	0.0	0.1	0.9	0.5	1.7	0.1	1.9	0.1	1.7
CaO w/w	0.1	0.1	0.2	0.1	6.6	0.4	1.4	0.1	4.3	0.1	0.1
ZrO_2 w/w	0.3	0.3	0.4	0.3	0.3	0.1	15.9	64.1	0.2	0.2	0.3
Total	97.7	97.6	33.3	98.6	96.8	90.4	91.8	95.1	98.0	98.1	98.0

Normalised average contents of the valuable Ti-containing minerals:

Average content	Category			
	ilmenite	leucoxene	rutile	other Ti-ox.
TiO_2 w/w	60.1	77.2	95.2	21.1
Fe_2O_3 w/w	34.2	16.0	1.4	70.1
MnO w/w	2.0	1.4	0.1	0.6
Cr_2O_3 w/w	0.2	0.2	0.2	2.2
SiO_2 w/w	1.7	2.5	2.0	3.7
Al_2O_3 w/w	1.0	2.0	0.7	1.1
MgO w/w	0.3	0.2	0.1	0.6
CaO w/w	0.1	0.2	0.1	0.4
ZrO_2 w/w	0.3	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: 63.3

Average TiO_2 content of all the TiO_2 minerals excl. rutile: 61.9

Weight percent on a mineral basis:

the heavy mineral concentrate

Category	w/w
ilmenite	68.42
leucoxene	7.88
pyrite	0.03
rutile	3.42
silicate	5.84
sphene	0.00
otherTi-ox.	0.07
unclassified	1.64
zircon	7.93
garnet	1.39
monazite	0.00
phosphate	0.00
sillimanite	2.18
staurolite	1.19
Y-phosphate	0.00
Total	100.00

the raw sand

Category	w/w
ilmenite	1.25
leucoxene	0.14
pyrite	0.00
rutile	0.06
silicate	98.29
sphene	0.00
otherTi-ox.	0.00
unclassified	0.03
zircon	0.14
garnet	0.03
monazite	0.00
phosphate	0.00
sillimanite	0.04
staurolite	0.02
Y-phosphate	0.00
Total	100.00

the valuable heavy minerals

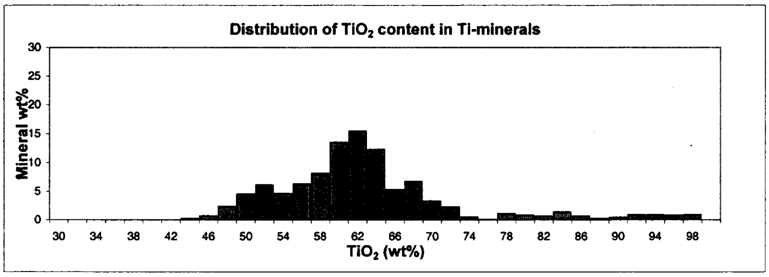
Category	w/w
ilmenite	74.94
leucoxene	8.64
rutile	3.75
otherTi-ox.	0.07
zircon	8.69
garnet	1.52
sillimanite	2.39
Total	100.00

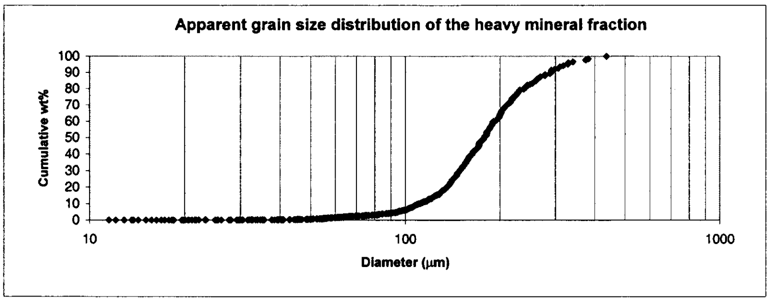
Valuable heavy minerals in raw sand: 1.66

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

Sample Name: V62 1-13   Date: 07/08/00

Submitter: Dupont
Analyzed by: CCA
Acc. Voltage 17kV





Average grain parameters	Category										
	ilmenite	leucoxene	pyrite	rutile	silicate	other Ti-ox	unclassified	zircon	garnet	sillimanite	staurolite
Aspect ratio	1.56	1.48	1.17	1.50	1.57	1.66	1.53	1.48	1.95	1.53	1.55
Circularity	1.75	1.60	1.46	1.86	1.73	1.40	1.73	1.67	1.87	1.87	2.17
Perimeter (μm)	554.02	617.60	211.86	576.73	463.56	156.43	553.84	498.76	384.72	654.38	670.68
Length (μm)	209.33	226.66	71.81	223.83	181.94	56.39	218.32	183.06	151.80	255.60	267.50
Total grains	397	32	1	19	67	4	15	54	16	14	7

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

GEUS

Sample Name:	SK99/1 17-27 heavy	No. of analysed frames:	35
Date:	07/03/00	No. analysed of particles	716
Submitter:	Dupont	Heavy minerals in raw sand (%):	0.00
Analyzed by:	CCA	comments: Same sample has been analysed by Henning Sund Sørensen, Danfoss	
Acc. Voltage	17 kV		
Magnification	100x		
Guard region	120 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	50.7	43.0	2.2	0.1	1.4	0.6	0.2	0.1	0.2	98.6
Leucoxene	77.4	15.1	0.7	0.1	2.2	1.4	0.1	0.1	0.2	97.3
Rutile	94.3	1.6	0.1	0.2	1.4	0.4	0.1	0.1	0.2	98.4
Ti magnetite	41.4	42.5	1.7	0.1	8.8	2.1	0.3	0.4	0.8	98.1
Magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromite	0.3	27.8	0.7	44.7	2.8	15.8	5.9	0.2	0.2	98.5
Pyrite	0.1	34.0	0.2	0.0	1.5	0.5	0.1	0.0	0.1	36.6
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	23.4	1.0	0.0	0.0	2.2	8.4	0.0	0.7	4.2	39.9
Y-phosphate	0.0	0.9	0.0	0.0	3.8	0.8	0.3	1.8	4.1	11.7
Sphene	37.7	1.2	0.2	0.1	29.3	1.4	0.0	28.1	0.1	98.1
Garnet	0.2	28.9	4.0	0.1	37.7	19.5	3.7	4.1	0.3	98.5
Sillimanite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurolite	1.0	13.4	0.0	0.2	31.9	48.9	1.2	0.1	0.2	97.0
Zircon	0.2	0.9	0.1	0.2	29.4	0.2	0.1	0.2	63.8	95.1
Silicate	0.8	11.4	0.3	0.1	43.4	20.6	1.2	19.7	0.1	97.7
Unclassified	10.0	18.1	0.6	0.1	22.6	6.5	0.2	5.4	18.9	82.5

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	52.5	3.4	9.9	7.5	3.3	23.3	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category: Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	51.5	79.5	95.9	42.2
Fe_2O_3 wt%	43.6	15.5	1.6	43.3
MnO wt%	2.3	0.7	0.1	1.7
Cr_2O_3 wt%	0.1	0.1	0.2	0.1
SiO_2 wt%	1.4	2.3	1.4	9.0
Al_2O_3 wt%	0.6	1.4	0.5	2.1
MgO wt%	0.2	0.1	0.1	0.4
CaO wt%	0.1	0.1	0.1	0.4
ZrO_2 wt%	0.2	0.2	0.2	0.9
Total	100.0	100.0	100.0	100.0

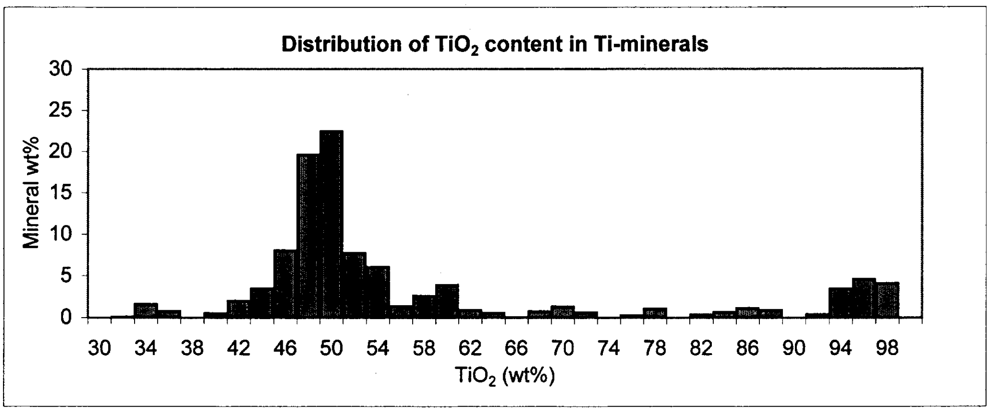
Average TiO_2 content of all the TiO_2 minerals:	57.8
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	51.9
Valuable heavy minerals in raw sand:	0.00

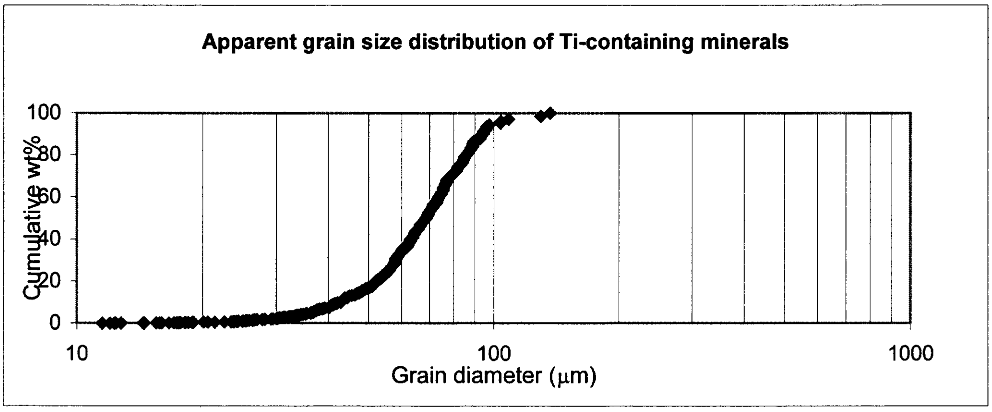
Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	37.1	0.0
Leucoxene	2.4	0.0
Rutile	7.0	0.0
Ti magnetite	5.3	0.0
Magnetite	0.0	0.0
Chromite	0.5	0.0
Pyrite	3.7	0.0
Phosphate	0.0	0.0
Monazite	0.1	0.0
Y-phosphate	0.4	0.0
Sphene	0.9	0.0
Garnet	2.3	0.0
Sillimanite	0.0	0.0
Staurolite	0.3	0.0
Zircon	16.5	0.0
Silicate	22.1	100.0
Unclassified	1.2	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

Sample Name:	SK99/1 17-27 heavy	Analyzed by:	CCA
Submitter:	Dupont	Acc. Voltage	17kV
Date:	07/03/00		





Average grain parameters					
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Total grains
Ilmenite	2	2	223	84	282
Leucoxene	1	2	267	102	13
Rutile	2	2	205	75	51
Ti magnetite	2	2	260	104	30
Magnetite	0	0	0	0	0
Chromite	2	2	251	97	3
Pyrite	1	2	259	102	12
Phosphate	0	0	0	0	0
Monazite	1	2	162	68	1
Y-phosphate	1	1	265	90	2
Sphene	2	2	304	120	6
Garnet	2	2	200	77	24
Sillimanite	0	0	0	0	0
Staurolite	2	2	311	124	2
Zircon	1	2	246	88	95
Silicate	2	2	278	107	188
Unclassified	1	2	373	154	7

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GEUS

Sample Name:	SK99/1 17-27 heavy	No. of analysed frames:	19
Date:		No. analysed of particles	514
Submitter:	Dupont	Heavy minerals in raw sand (%):	0.00
Analyzed by:	HSS		
Acc. Voltage	17 kV	comments: Analysed by Henning Sund , Sørensen, Danfoss	
Magnification	100x		
Guard region	120 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	50.7	43.5	2.2	0.1	1.0	0.4	0.3	0.1	0.2	98.4
Leucoxene	78.3	5.7	0.7	0.0	10.1	2.3	0.1	0.3	0.3	97.7
Rutile	95.1	1.5	0.1	0.1	0.7	0.3	0.1	0.1	0.1	98.0
Ti magnetite	44.0	47.6	1.7	0.2	2.5	1.1	0.4	0.1	0.5	98.1
Magnetite	0.0	81.6	0.2	0.1	1.7	1.1	0.6	2.0	0.4	87.6
Chromite	0.0	25.3	0.0	50.0	0.1	14.7	5.1	0.4	0.7	96.4
Pyrite	0.1	35.9	0.0	0.1	1.3	0.4	0.1	0.1	0.3	38.4
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	3.6	0.0	0.0	3.3	1.7	0.9	2.2	2.3	13.9
Y-phosphate	0.0	0.3	0.0	0.0	0.0	1.9	0.0	0.0	3.5	5.7
Sphene	39.5	1.6	0.1	0.0	26.9	1.3	0.1	27.5	0.4	97.5
Garnet	0.3	32.9	4.1	0.1	35.9	18.9	2.4	3.5	0.2	98.3
Sillimanite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurolite	0.7	16.8	0.0	0.3	32.6	44.8	1.7	0.1	0.0	97.0
Zircon	0.3	0.7	0.1	0.2	28.5	0.0	0.1	0.2	65.0	95.2
Silicate	0.7	13.5	0.6	0.1	41.2	19.5	1.3	20.4	0.2	97.5
Unclassified	39.2	11.3	0.5	0.0	42.9	2.9	0.4	0.0	0.4	97.6

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	57.4	1.7	7.5	8.8	4.2	20.4	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category: Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	51.5	80.1	97.0	44.9
Fe_2O_3 wt%	44.2	5.8	1.5	48.6
MnO wt%	2.2	0.7	0.1	1.7
Cr_2O_3 wt%	0.1	0.0	0.1	0.2
SiO_2 wt%	1.0	10.3	0.7	2.6
Al_2O_3 wt%	0.4	2.4	0.3	1.1
MgO wt%	0.3	0.1	0.1	0.4
CaO wt%	0.1	0.3	0.1	0.1
ZrO_2 wt%	0.2	0.3	0.1	0.5
Total	100.0	100.0	100.0	100.0

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	42.5	0.0
Leucoxene	1.3	0.0
Rutile	5.5	0.0
Ti magnetite	6.5	0.0
Magnetite	0.3	0.0
Chromite	0.3	0.0
Pyrite	3.9	0.0
Phosphate	0.0	0.0
Monazite	0.3	0.0
Y-phosphate	0.2	0.0
Sphene	0.3	0.0
Garnet	3.1	0.0
Sillimanite	0.0	0.0
Staurolite	0.3	0.0
Zircon	15.1	0.0
Silicate	20.3	100.0
Unclassified	0.1	0.0
Total	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	55.9
Average TiO_2 content of all the TiO_2 minerals excl. rutile	51.4
Valuable heavy minerals in raw sand:	0.00

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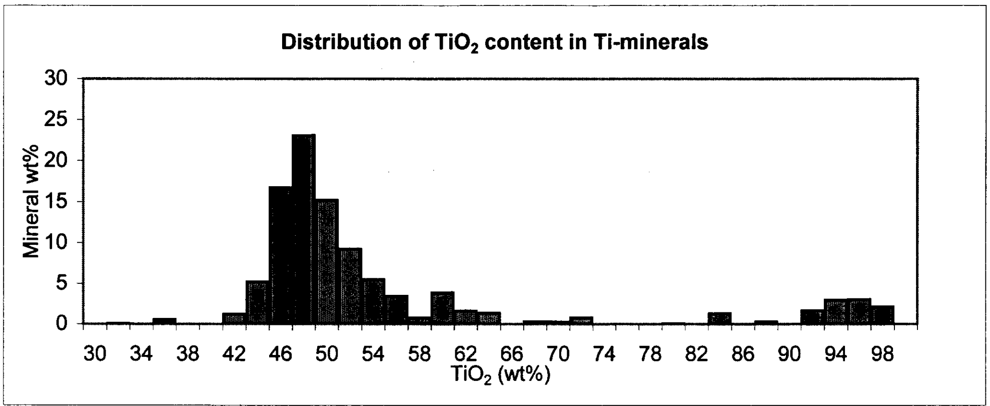
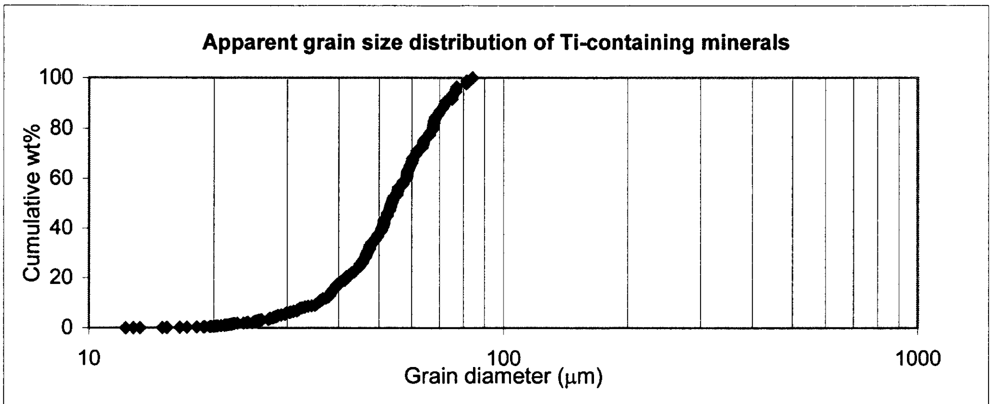
GEUS

Sample Name:	SK99/1 17-27 heavy	Analyzed by:	HSS
Submitter:	Dupont	Acc. Voltage	17kV
Date:	00/01/00		





Average grain parameters					
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Total grains
Ilmenite	2	2	192	74	203
Leucoxene	1	2	213	84	5
Rutile	1	2	165	64	33
Ti magnetite	2	2	208	82	26
Magnetite	1	2	183	76	2
Chromite	1	1	205	70	1
Pyrite	1	2	340	150	6
Phosphate	0	0	0	0	0
Monazite	1	1	136	47	2
Y-phosphate	2	2	197	78	1
Sphene	2	2	150	59	3
Garnet	2	2	180	71	20
Sillimanite	0	0	0	0	0
Staurolite	1	2	260	101	1
Zircon	1	2	184	67	68
Silicate	1	2	211	85	141
Unclassified	1	2	92	33	2

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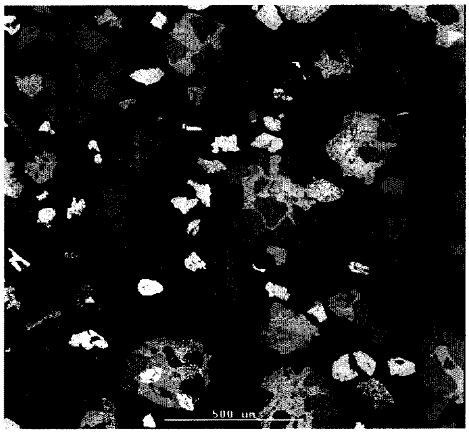
Sample Name:	LM2 7-8m
Date:	11/09/00
Country:	Denmark
Submitter:	Dupont
Analyzed by:	CCA
Acc. Voltage	17 kV
Magnification	60x
Guard region	150 µm
Sieve	100 μm^2

No. of analysed frames:	20
No. analysed of particles	793
Heavy minerals in raw sand (%):	16.46
comments: old analysis was calculated in new data sheet to be able to classify Ti-magnetite	



	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	53.0	37.8	2.0	0.1	2.6	1.1	0.3	0.2	0.4	97.5
Leucoxene	76.5	10.6	0.6	0.2	5.5	2.5	0.3	0.3	0.5	97.0
Rutile	92.8	1.4	0.2	0.2	1.6	1.0	0.1	0.1	0.3	97.7
Ti magnetite	38.8	39.5	1.6	0.1	7.6	2.0	0.3	0.8	1.2	91.8
Magnetite	0.8	70.1	0.5	0.1	13.3	4.2	0.3	5.8	0.6	95.8
Chromite	1.6	36.1	0.3	47.1	1.3	6.6	2.3	0.0	0.0	95.2
Pyrite	1.2	30.4	0.2	0.1	3.4	1.9	0.2	0.1	0.3	37.8
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	0.7	0.0	0.0	3.5	2.0	0.0	2.2	5.7	14.2
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.5	27.8	1.3	0.1	38.5	20.2	4.2	5.1	0.3	98.1
Sillimanite	0.4	1.2	0.2	0.2	42.9	53.5	0.1	0.1	0.2	98.9
Staurolite	1.0	11.8	0.2	0.1	35.9	46.8	1.3	0.1	0.6	97.9
Zircon	0.6	0.7	0.2	0.2	28.9	0.3	0.2	0.3	63.2	94.5
Silicate	1.2	6.8	0.2	0.2	72.7	8.2	0.3	5.2	0.5	95.2
Unclassified	10.1	21.7	1.0	0.5	37.0	4.3	0.4	2.6	10.4	88.2

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	55.9	10.4	9.2	14.4	2.0	7.4	0.9	100.0

Normalised average contents of the valuable Ti-containing minerals				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	54.4	78.9	95.0	42.2
Fe_2O_3 wt%	38.8	10.9	1.4	43.0
MnO wt%	2.1	0.6	0.2	1.7
Cr_2O_3 wt%	0.1	0.2	0.2	0.2
SiO_2 wt%	2.7	5.7	1.6	8.3
Al_2O_3 wt%	1.1	2.6	1.0	2.1
MgO wt%	0.3	0.3	0.1	0.3
CaO wt%	0.2	0.3	0.1	0.8
ZrO_2 wt%	0.4	0.5	0.3	1.3
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	59.4
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	55.3
Valuable heavy minerals in raw sand:	4.18

Weight percent on a mineral basis		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	14.2	2.3
Leucoxene	2.6	0.4
Rutile	2.3	0.4
Ti magnetite	3.7	0.6
Magnetite	15.5	2.5
Chromite	0.0	0.0
Pyrite	1.9	0.3
Phosphate	0.0	0.0
Monazite	0.2	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	0.5	0.1
Sillimanite	0.2	0.0
Staurolite	0.1	0.0
Zircon	1.9	0.3
Silicate	44.3	90.8
Unclassified	12.6	2.1
Total	100.0	100.0

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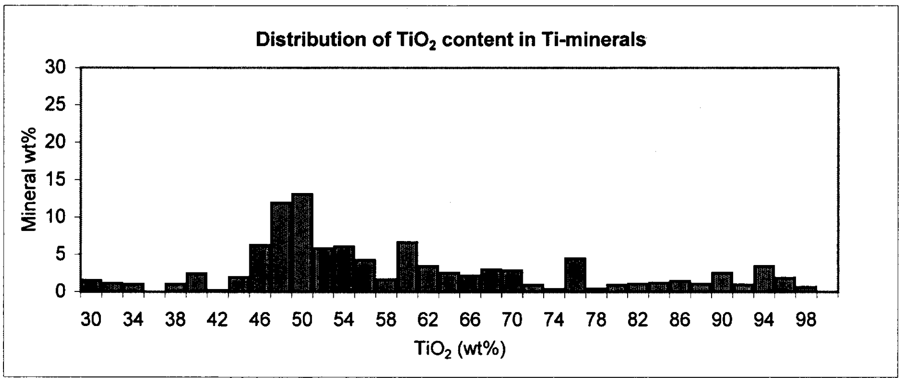
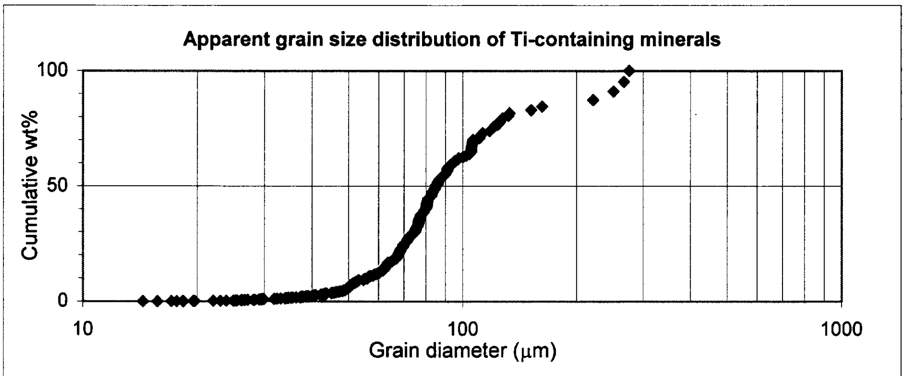
GEUS

Sample Name:	LM2 7-8m	Analyzed by:	CCA
Submitter:	Dupont	Acc. Voltage	17kV
Date:	11/09/00		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm^2)	Total grains
Ilmenite	1.6	1.9	308	122	4282	194
Leucoxene	1.6	1.8	349	132	7332	21
Rutile	1.7	1.7	251	93	3227	38
Ti magnetite	1.7	2.2	390	162	6715	30
Magnetite	1.3	2.1	625	259	19124	41
Chromite	1.4	1.4	131	42	978	2
Pyrite	1.5	2.0	358	149	6306	16
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.3	1.6	312	113	4879	2
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	2.1	2.1	298	121	3648	9
Sillimanite	2.0	2.1	342	137	4386	4
Staurolite	1.6	1.8	251	99	2998	3
Zircon	1.4	1.5	225	78	2965	36
Silicate	1.5	2.0	463	193	13165	335
Unclassified	1.4	2.7	718	315	19842	62

GEUS

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Sample Name:	M2A00.01 23-24m	No. of analysed frames:	40
Date:	12/01/01	No. analysed of particles	505
Country:	Denmark	Heavy minerals in raw sand (%):	0.86
Submitter:	Dupont		
Analyzed by:	CCA	comments:	
Acc. Voltage	17 kV		
Magnification	100x		
Guard region	120 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	59.6	30.5	2.0	0.1	3.5	1.1	0.2	0.2	0.2	97.5
Leucoxene	75.9	10.1	0.8	0.1	7.2	2.2	0.1	0.5	0.3	97.4
Rutile	91.7	1.9	0.2	0.1	2.3	0.9	0.1	0.3	0.4	97.9
Ti magnetite	33.5	32.2	0.5	0.1	2.5	1.0	0.1	0.1	0.4	70.4
Magnetite	0.5	74.3	4.5	0.8	10.9	3.3	0.0	3.8	0.0	98.2
Chromite	1.0	38.6	0.1	41.1	1.3	13.0	3.2	0.1	0.0	98.5
Pyrite	0.2	29.9	0.2	0.1	5.2	0.6	0.1	0.0	0.4	36.7
Phosphate	0.0	5.1	0.0	0.0	0.8	41.9	0.0	5.1	0.0	53.0
Monazite	0.0	7.1	0.0	0.0	4.7	1.5	0.0	2.1	0.0	15.4
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.3	29.3	3.5	0.1	37.0	19.4	2.5	4.4	0.4	97.0
Sillimanite	0.5	0.3	0.1	0.0	43.2	53.6	0.0	0.0	0.0	97.7
Staurolite	0.8	13.4	0.3	0.1	34.3	45.7	1.6	0.1	0.1	96.5
Zircon	0.4	0.5	0.1	0.2	29.4	0.2	0.1	0.4	63.6	95.1
Silicate	1.4	4.0	0.2	0.1	65.8	20.1	0.9	2.5	0.4	95.4
Unclassified	10.7	14.4	0.3	0.1	38.0	1.7	0.1	0.2	5.8	71.3

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	47.7	24.2	11.1	3.6	5.3	7.4	0.7	100.0

Normalised average contents of the valuable Ti-containing minerals				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	61.2	78.0	93.7	47.6
Fe_2O_3 wt%	31.3	10.4	1.9	45.7
MnO wt%	2.1	0.8	0.2	0.8
Cr_2O_3 wt%	0.1	0.1	0.1	0.1
SiO_2 wt%	3.6	7.4	2.4	3.5
Al_2O_3 wt%	1.1	2.3	1.0	1.5
MgO wt%	0.3	0.1	0.1	0.2
CaO wt%	0.2	0.5	0.3	0.1
ZrO_2 wt%	0.2	0.3	0.4	0.5
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	69.5
Average TiO_2 content of all the TiO_2 minerals excl. rutile	65.9
Valuable heavy minerals in raw sand:	0.54

Weight percent on a mineral basis		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	30.0	0.3
Leucoxene	15.2	0.1
Rutile	7.0	0.1
Ti magnetite	2.3	0.0
Magnetite	0.0	0.0
Chromite	0.1	0.0
Pyrite	9.4	0.1
Phosphate	0.0	0.0
Monazite	0.2	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	3.3	0.0
Sillimanite	0.4	0.0
Staurolite	0.9	0.0
Zircon	4.6	0.0
Silicate	25.4	99.4
Unclassified	1.1	0.0
Total	100.0	100.0

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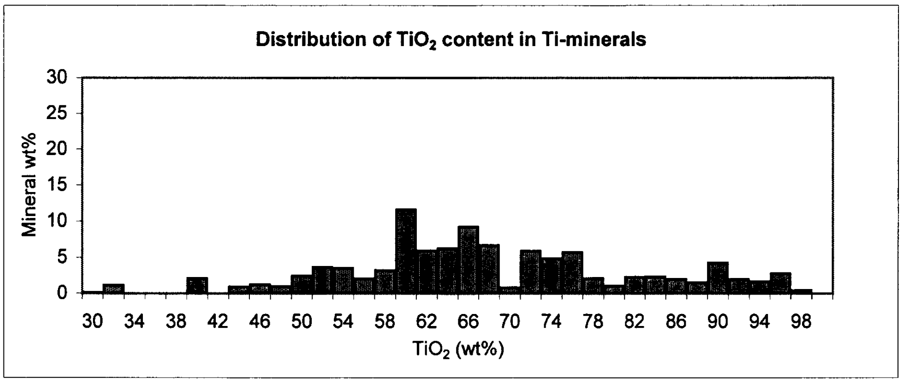
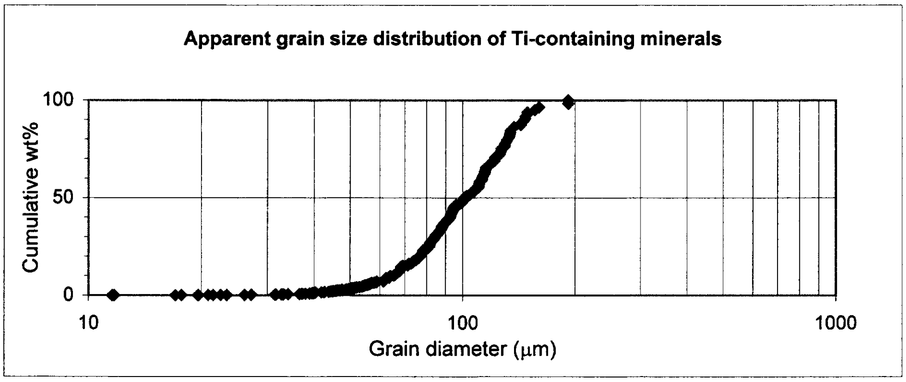
GEUS

Sample Name:	M2A00.01 23-24m	Analyzed by:	CCA
Submitter:	B9	Acc. Voltage	17kV
Date:	12/01/01		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (μm^2)	Total grains
Ilmenite	1.7	2.1	352	143	5193	167
Leucoxene	1.5	2.4	444	187	7594	58
Rutile	1.6	2.2	356	146	5043	36
Ti magnetite	2.1	3.1	669	296	12438	5
Magnetite	1.6	1.4	63	21	225	1
Chromite	1.8	1.8	152	59	1265	2
Pyrite	1.3	2.2	469	199	13537	18
Phosphate	1.4	1.6	149	53	1117	1
Monazite	1.3	2.7	402	174	4699	1
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	2.1	2.8	401	175	5162	21
Sillimanite	1.6	2.1	417	170	8790	2
Staurolite	1.5	2.9	424	186	5935	5
Zircon	1.4	1.8	346	130	5633	23
Silicate	1.8	2.5	451	193	8194	152
Unclassified	1.5	1.8	267	106	4179	13

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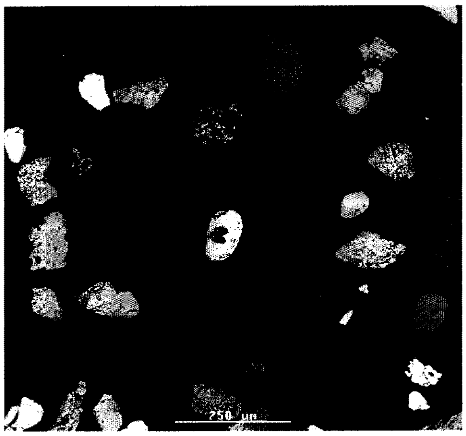
GEUS

Sample Name:	KW21 27-28m	No. of analysed frames:	58
Date:	12/01/01	No. analysed of particles	538
Submitter:	Dupont / Netherland	Heavy minerals in raw sand (%):	0.53
Analyzed by:	CCA	comments:	
Acc. Voltage	17 kV		
Magnification	100x		
Guard region	120 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	57.5	31.0	1.2	0.1	5.5	1.7	0.7	0.1	0.4	98.2
Leucoxene	76.4	6.4	0.2	0.2	11.3	2.5	0.2	0.1	0.3	97.6
Rutile	92.8	1.4	0.1	0.1	2.5	0.8	0.1	0.1	0.2	98.2
Ti magnetite	40.7	42.7	1.0	0.2	7.3	1.9	1.8	0.0	2.2	97.8
Magnetite	0.6	75.1	1.2	0.3	9.0	4.2	0.5	1.7	0.5	93.1
Chromite	0.2	20.1	0.6	49.0	2.2	16.4	9.1	0.1	0.1	97.9
Pyrite	0.2	32.4	0.3	0.0	1.3	0.4	0.3	0.1	0.5	35.6
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	2.8	0.0	0.0	10.3	3.0	0.3	1.1	2.9	20.4
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	3.1	26.5	1.2	0.1	37.7	20.0	3.2	1.8	0.5	94.2
Sillimanite	0.0	1.2	0.0	0.0	43.2	52.9	0.0	0.0	0.0	97.3
Staurolite	1.3	15.0	0.2	0.0	32.3	47.9	1.4	0.0	0.3	98.5
Zircon	0.2	0.8	0.1	0.1	29.8	0.2	0.1	0.2	63.6	95.2
Silicate	2.8	11.6	0.2	0.2	47.9	26.0	3.8	3.6	0.4	96.4
Unclassified	13.0	16.7	1.3	1.3	27.7	7.8	1.0	0.7	18.4	87.9

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	27.9	12.7	27.7	3.0	1.7	26.9	0.1	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	58.6	78.3	94.5	41.6
Fe_2O_3 wt%	31.6	6.5	1.4	43.7
MnO wt%	1.2	0.2	0.2	1.1
Cr_2O_3 wt%	0.1	0.2	0.1	0.2
SiO_2 wt%	5.6	11.6	2.6	7.4
Al_2O_3 wt%	1.7	2.5	0.8	1.9
MgO wt%	0.7	0.2	0.1	1.8
CaO wt%	0.1	0.1	0.1	0.1
ZrO_2 wt%	0.4	0.3	0.2	2.2
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	75.4
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	63.2
Valuable heavy minerals in raw sand:	0.41

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	21.4	0.1
Leucoxene	9.8	0.1
Rutile	21.2	0.1
Ti magnetite	2.3	0.0
Magnetite	5.6	0.0
Chromite	2.7	0.0
Pyrite	0.4	0.0
Phosphate	0.0	0.0
Monazite	1.0	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	1.3	0.0
Sillimanite	0.1	0.0
Staurolite	1.1	0.0
Zircon	20.6	0.1
Silicate	9.0	99.5
Unclassified	3.6	0.0
Total	100.0	100.0

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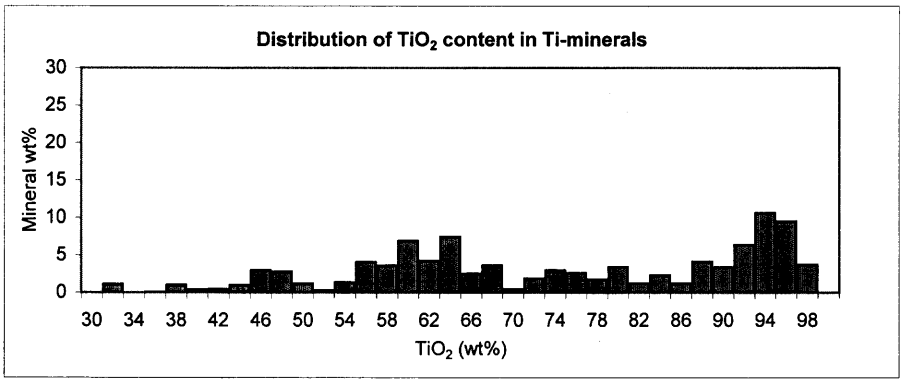
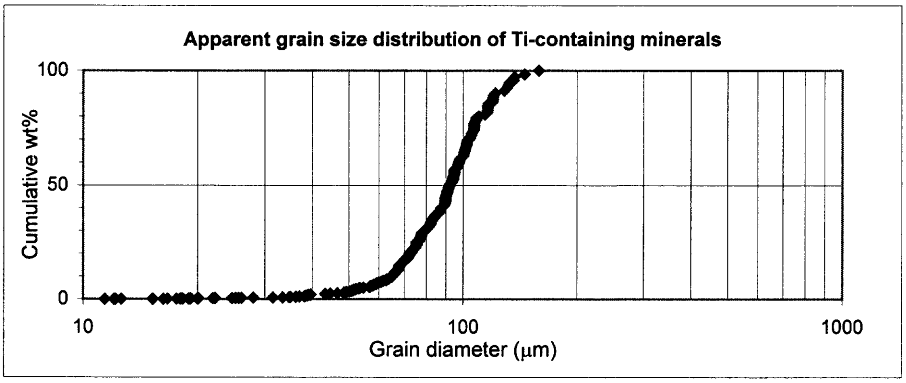
GEUS

Sample Name:	KW21 27-28m	Analyzed by:	CCA
Submitter:	Dupont / Netherland	Acc. Voltage	17kV
Date:	12/01/01		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm^2)	Total grains
Ilmenite	1.5	1.8	309	119	4740	103
Leucoxene	1.6	2.0	388	152	6550	34
Rutile	1.4	1.9	310	120	4688	93
Ti magnetite	1.4	1.7	246	97	3759	13
Magnetite	1.4	1.8	288	111	4606	24
Chromite	1.5	2.1	335	130	4913	11
Pyrite	1.9	2.6	251	107	2038	4
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.5	1.6	209	77	2443	8
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.6	1.7	190	73	2511	13
Sillimanite	1.2	2.3	254	106	2216	1
Staurolite	1.4	1.9	354	140	6086	5
Zircon	1.5	1.6	242	88	3373	135
Silicate	1.5	1.9	325	128	5256	66
Unclassified	1.5	2.1	315	130	4858	28

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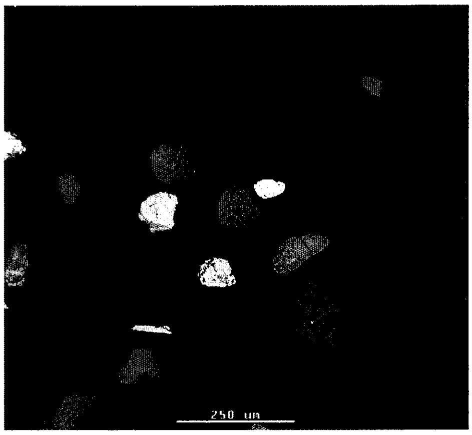

Sample Name:	KW24 16-17m
Date:	11/01/01
Submitter:	Dupont / Netherland
Analyzed by:	CCA
Acc. Voltage	17 kV
Magnification	100x
Guard region	120 μm
Sieve	100 μm^2

No. of analysed frames:	81
No. analysed of particles	563
Heavy minerals in raw sand (%):	0.56
comments:	

	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	57.2	29.7	1.3	0.1	6.9	1.8	0.7	0.1	0.5	98.3
Leucoxene	77.1	5.6	0.2	0.2	10.7	3.3	0.2	0.1	0.2	97.6
Rutile	92.5	1.0	0.1	0.1	2.7	1.1	0.1	0.1	0.2	98.0
Ti magnetite	40.8	40.7	2.0	0.1	7.3	4.0	2.4	0.1	0.4	97.8
Magnetite	0.8	93.0	0.0	0.6	0.4	1.8	0.0	0.0	1.4	98.1
Chromite	1.5	26.2	0.4	40.5	2.9	18.6	7.2	0.4	0.1	97.8
Pyrite	0.2	30.7	0.0	0.0	2.7	1.3	0.1	0.2	0.2	35.5
Phosphate	1.2	7.7	0.0	0.0	0.0	39.9	0.4	4.6	0.0	53.8
Monazite	0.4	0.8	0.0	0.0	16.7	3.2	0.2	0.9	3.6	25.7
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	0.3	25.8	6.7	0.1	37.6	19.4	3.4	4.6	0.2	98.1
Sillimanite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurolite	0.6	14.5	0.6	0.2	33.7	46.7	1.1	0.1	0.2	97.7
Zircon	0.3	0.5	0.2	0.1	30.1	0.4	0.1	0.2	63.6	95.4
Silicate	3.9	10.8	0.4	0.1	53.9	22.5	2.6	2.1	0.2	96.6
Unclassified	16.4	6.7	0.8	2.7	24.8	7.6	1.1	0.7	26.3	87.1

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	25.4	23.3	24.5	0.9	1.1	24.9	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	58.2	79.0	94.4	41.8
Fe_2O_3 wt%	30.2	5.7	1.0	41.7
MnO wt%	1.4	0.2	0.2	2.0
Cr_2O_3 wt%	0.1	0.2	0.1	0.1
SiO_2 wt%	7.0	10.9	2.8	7.4
Al_2O_3 wt%	1.8	3.3	1.1	4.0
MgO wt%	0.7	0.2	0.1	2.5
CaO wt%	0.1	0.1	0.1	0.1
ZrO_2 wt%	0.5	0.3	0.3	0.4
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	76.6
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	67.7
Valuable heavy minerals in raw sand:	0.45

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	20.7	0.1
Leucoxene	19.0	0.1
Rutile	20.0	0.1
Ti magnetite	0.7	0.0
Magnetite	0.0	0.0
Chromite	2.3	0.0
Pyrite	1.0	0.0
Phosphate	0.5	0.0
Monazite	1.9	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	0.9	0.0
Sillimanite	0.0	0.0
Staurolite	0.9	0.0
Zircon	20.3	0.1
Silicate	9.1	99.5
Unclassified	2.8	0.0
Total	100.0	100.0

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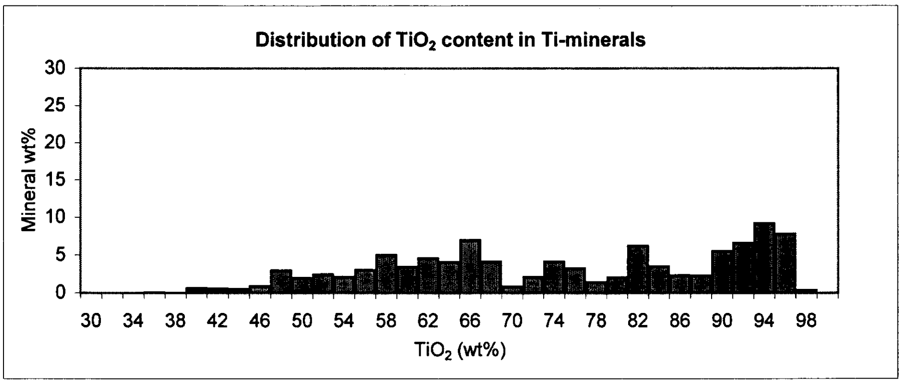
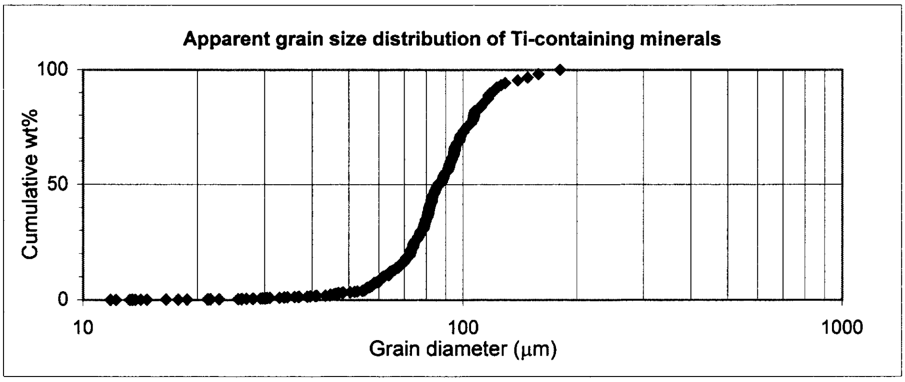
GEUS

Sample Name:	KW24 16-17m	Analyzed by:	CCA
Submitter:	Dupont / Netherland	Acc. Voltage	17kV
Date:	11/01/01		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm^2)	Total grains
Ilmenite	1.6	1.9	300	116	4326	107
Leucoxene	1.5	2.1	376	151	5901	72
Rutile	1.5	1.8	303	115	4520	89
Ti magnetite	1.8	1.8	170	65	1832	8
Magnetite	1.3	1.1	38	14	107	1
Chromite	1.4	1.7	264	99	3501	13
Pyrite	1.5	1.8	170	67	1623	13
Phosphate	1.3	1.4	397	125	9204	1
Monazite	1.5	1.9	310	121	4204	9
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.6	1.7	218	84	2566	9
Sillimanite	0.0	0.0	0	0	0	0
Staurolite	1.4	2.0	275	109	3433	7
Zircon	1.5	1.8	265	100	3483	126
Silicate	1.5	2.0	305	123	4537	76
Unclassified	1.6	2.0	252	102	3286	32

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GEUS

Sample Name:	KW24 21-21.8m	No. of analysed frames:	45
Date:	11/01/01	No. analysed of particles	578
Submitter:	Dupont / Netherland	Heavy minerals in raw sand (%):	0.55
Analyzed by:	CCA	comments:	
Acc. Voltage	17 kV		
Magnification	100x		
Guard region	120 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	56.1	31.5	1.6	0.1	5.7	1.7	0.7	0.1	0.4	97.9
Leucoxene	74.9	6.2	0.3	0.1	11.6	2.9	0.5	0.1	0.3	97.0
Rutile	93.6	1.2	0.1	0.1	2.1	0.5	0.1	0.1	0.2	98.2
Ti magnetite	34.7	42.0	1.2	0.1	12.6	3.7	1.5	0.2	1.1	96.9
Magnetite	0.9	84.6	0.6	0.1	6.3	2.4	0.6	1.2	0.3	97.0
Chromite	1.2	19.1	0.6	50.0	2.5	16.6	7.4	0.1	0.2	97.7
Pyrite	0.2	33.4	0.0	0.1	1.1	0.4	0.7	0.0	0.0	35.8
Phosphate	1.5	3.6	0.0	0.3	0.0	43.2	0.0	5.9	0.0	54.5
Monazite	0.0	0.9	0.0	0.0	7.2	1.4	0.2	1.5	2.3	13.5
Y-phosphate	0.0	2.1	0.0	0.0	0.5	1.6	0.0	0.4	0.0	4.6
Sphene	36.8	0.1	0.2	0.0	30.6	2.2	0.4	28.3	0.1	98.6
Garnet	0.6	30.5	2.8	0.2	38.1	19.9	2.6	2.7	0.3	97.6
Sillimanite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurolite	0.4	17.3	0.0	0.0	34.9	43.7	1.4	0.2	0.8	98.7
Zircon	0.2	0.7	0.2	0.1	30.2	0.2	0.1	0.1	63.6	95.5
Silicate	1.6	12.8	0.9	0.1	49.7	21.6	4.2	5.0	0.2	96.2
Unclassified	13.8	15.6	0.6	0.9	27.2	9.7	1.4	0.7	15.0	85.0

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	27.5	14.0	13.6	4.8	2.1	38.0	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	57.4	77.2	95.3	35.8
Fe_2O_3 wt%	32.2	6.4	1.3	43.3
MnO wt%	1.6	0.3	0.2	1.2
Cr_2O_3 wt%	0.1	0.1	0.2	0.1
SiO_2 wt%	5.8	12.0	2.1	13.0
Al_2O_3 wt%	1.7	3.0	0.5	3.8
MgO wt%	0.7	0.5	0.1	1.5
CaO wt%	0.1	0.1	0.1	0.2
ZrO_2 wt%	0.4	0.3	0.2	1.1
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	68.9
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	61.1
Valuable heavy minerals in raw sand:	0.34

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	17.2	0.1
Leucoxene	8.7	0.0
Rutile	8.5	0.0
Ti magnetite	3.0	0.0
Magnetite	8.2	0.0
Chromite	1.3	0.0
Pyrite	0.6	0.0
Phosphate	0.2	0.0
Monazite	3.2	0.0
Y-phosphate	0.2	0.0
Sphene	0.1	0.0
Garnet	1.3	0.0
Sillimanite	0.0	0.0
Staurolite	0.1	0.0
Zircon	23.8	0.1
Silicate	17.1	99.5
Unclassified	6.4	0.0
Total	100.0	100.0

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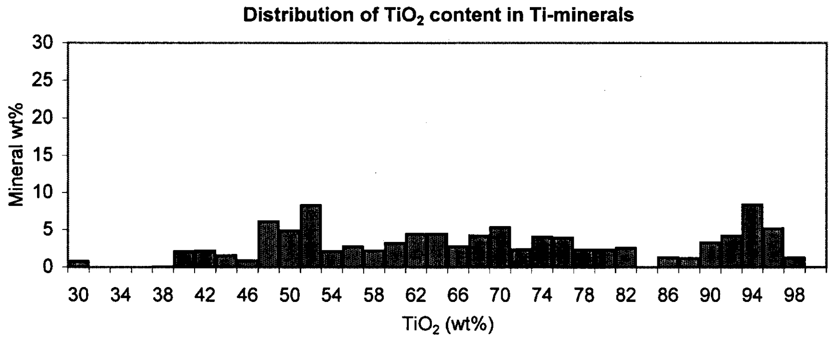
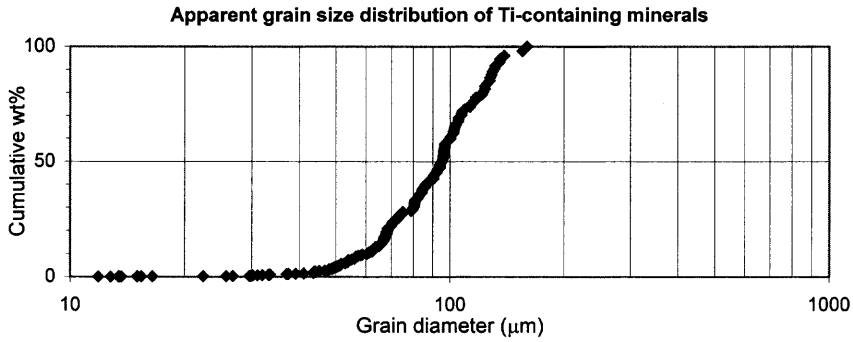
GEUS

Sample Name:	KW24 21-21.8m	Analyzed by:	CCA
Submitter:	Dupont / Netherland	Acc. Voltage	17kV
Date:	11/01/01		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm^2)	Total grains
Ilmenite	1.6	1.9	324	126	5014	93
Leucoxene	1.5	1.9	379	147	6771	35
Rutile	1.5	1.8	273	103	3767	55
Ti magnetite	1.7	1.9	298	117	4800	16
Magnetite	1.6	2.7	466	203	8785	22
Chromite	1.4	1.7	187	70	2270	14
Pyrite	1.7	2.9	501	221	7568	2
Phosphate	1.3	1.5	330	115	5772	1
Monazite	1.6	1.7	268	103	3899	20
Y-phosphate	1.7	2.0	268	109	2969	2
Sphene	2.5	2.0	233	93	2196	1
Garnet	1.6	1.8	227	92	3117	13
Sillimanite	0.0	0.0	0	0	0	0
Staurolite	1.3	1.9	255	100	2766	1
Zircon	1.5	1.8	281	107	3999	156
Silicate	1.6	2.2	399	161	7296	108
Unclassified	1.7	2.7	467	203	7398	39

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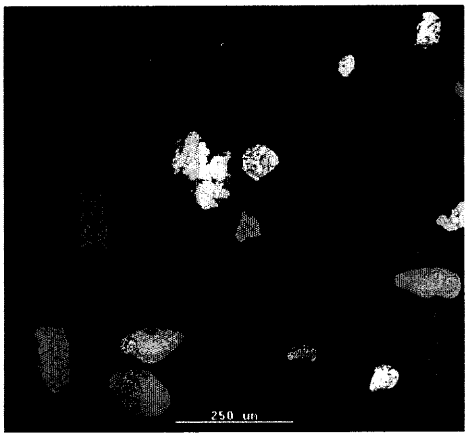
G E U S

Sample Name:	KW25 9-10 m
Date:	11/01/01
Submitter:	Dupont / Netherland
Analyzed by:	CCA
Acc. Voltage	17 kV
Magnification	100x
Guard region	120 μm
Sieve	100 μm^2

No. of analysed frames:	81
No. analysed of particles	522
Heavy minerals in raw sand (%):	0.38
comments:	



	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	56.8	31.5	1.6	0.1	5.4	1.5	0.6	0.1	0.3	97.9
Leucoxene	75.7	6.2	0.2	0.2	10.4	3.5	0.2	0.2	0.6	97.2
Rutile	91.9	1.3	0.1	0.2	2.7	1.1	0.1	0.1	0.2	97.7
Ti magnetite	39.1	42.6	0.5	0.2	7.5	2.6	2.3	0.1	2.7	97.7
Magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromite	1.3	28.3	0.9	41.8	1.9	17.4	5.9	0.1	0.4	98.0
Pyrite	0.1	31.1	0.1	0.1	3.0	1.2	0.2	0.1	0.3	36.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	1.0	0.0	0.0	6.3	3.0	0.2	2.1	3.1	15.6
Y-phosphate	1.0	3.5	0.2	1.4	6.0	3.3	0.4	0.6	3.0	19.4
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.1	29.6	2.0	0.3	38.2	19.6	3.2	3.4	0.4	96.8
Sillimanite	0.0	0.6	0.4	0.0	43.0	53.4	0.0	0.0	0.0	97.4
Staurolite	0.6	16.0	0.6	0.0	33.6	46.5	1.4	0.0	0.0	98.7
Zircon	0.2	0.5	0.2	0.2	30.0	0.3	0.1	0.1	63.7	95.3
Silicate	2.3	11.1	1.1	0.2	54.7	19.8	1.7	1.2	0.3	92.4
Unclassified	8.1	9.9	0.3	1.5	33.5	8.8	0.9	0.3	20.3	83.7

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	34.3	13.9	17.7	2.8	1.9	28.8	0.5	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	58.0	77.9	94.1	40.1
Fe_2O_3 wt%	32.1	6.4	1.3	43.6
MnO wt%	1.6	0.2	0.1	0.5
Cr_2O_3 wt%	0.1	0.2	0.2	0.2
SiO_2 wt%	5.5	10.8	2.7	7.7
Al_2O_3 wt%	1.5	3.6	1.1	2.7
MgO wt%	0.6	0.2	0.1	2.3
CaO wt%	0.1	0.2	0.1	0.1
ZrO_2 wt%	0.3	0.6	0.3	2.8
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	70.6
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	62.5
Valuable heavy minerals in raw sand:	0.29

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	26.2	0.1
Leucoxene	10.7	0.0
Rutile	13.6	0.1
Ti magnetite	2.1	0.0
Magnetite	0.0	0.0
Chromite	0.7	0.0
Pyrite	7.7	0.0
Phosphate	0.0	0.0
Monazite	0.7	0.0
Y-phosphate	0.3	0.0
Sphene	0.0	0.0
Garnet	1.5	0.0
Sillimanite	0.4	0.0
Staurolite	0.8	0.0
Zircon	22.1	0.1
Silicate	9.1	99.7
Unclassified	4.1	0.0
Total	100.0	100.0

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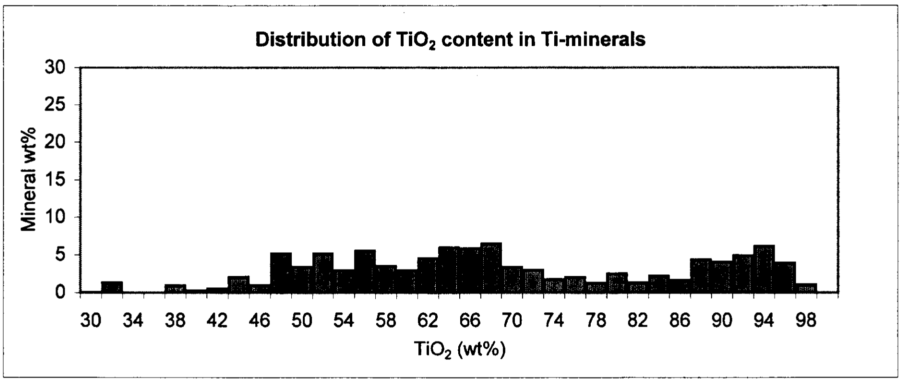
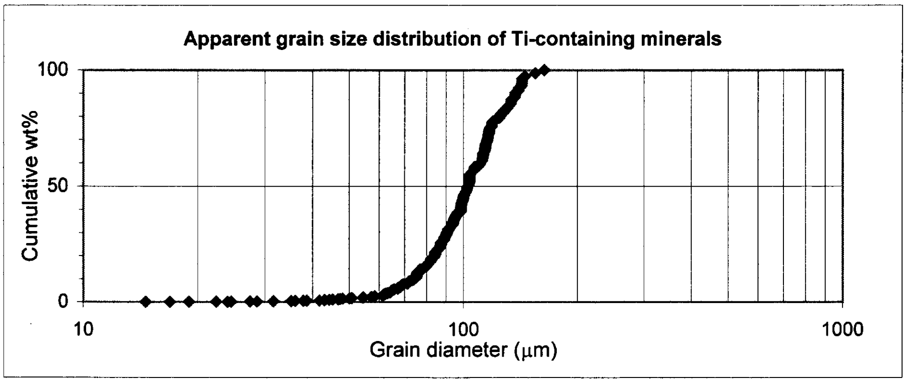
GEUS

Sample Name:	KW25 9-10 m	Analyzed by:	CCA
Submitter:	Dupont / Netherland	Acc. Voltage	17kV
Date:	11/01/01		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.9	400	155	7254	107
Leucoxene	1.6	1.9	396	155	7337	43
Rutile	1.5	1.8	344	133	5640	64
Ti magnetite	1.4	2.0	388	157	6610	9
Magnetite	0.0	0.0	0	0	0	0
Chromite	1.5	1.6	264	96	3753	5
Pyrite	1.5	2.2	367	153	7331	28
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.4	1.6	302	109	4651	4
Y-phosphate	1.4	1.7	267	101	3773	2
Sphene	0.0	0.0	0	0	0	0
Garnet	1.7	1.9	309	124	4456	11
Sillimanite	2.6	2.4	720	304	16895	1
Staurolite	2.0	2.5	630	268	13975	2
Zircon	1.4	1.6	297	109	4579	138
Silicate	1.5	1.9	287	114	5731	80
Unclassified	1.5	1.9	343	139	7289	28

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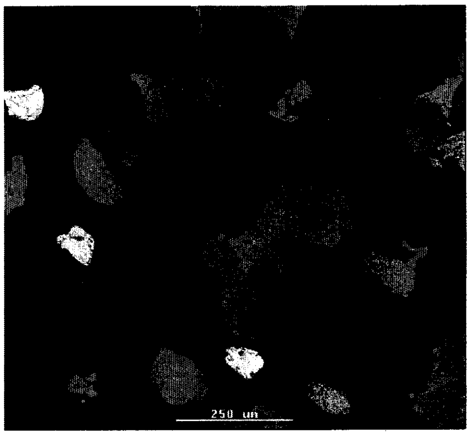

Sample Name:	KW26 11-12m
Date:	11/01/01
Submitter:	Dupont / Netherland
Analyzed by:	CCA
Acc. Voltage	17 kV
Magnification	100x
Guard region	120 μm
Sieve	100 μm^2

No. of analysed frames:	81
No. analysed of particles	647
Heavy minerals in raw sand (%):	1.07
comments:	Many large (>200 μm) composite grains

	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	58.6	26.6	1.8	0.1	6.9	1.9	0.8	0.2	0.2	97.3
Leucoxene	76.5	7.4	0.2	0.3	9.4	2.3	0.3	0.3	0.3	97.0
Rutile	92.5	1.8	0.2	0.2	2.5	0.8	0.2	0.1	0.2	98.5
Ti magnetite	41.6	48.5	0.8	0.1	2.4	1.0	1.4	1.0	0.6	97.4
Magnetite	0.2	78.4	0.7	0.2	6.5	2.6	0.5	5.7	0.5	95.4
Chromite	0.1	30.2	0.5	43.7	2.0	14.5	6.4	0.8	0.3	98.3
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	18.6	2.3	0.7	0.9	3.8	27.7
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.2	35.2	3.4	0.0	34.1	17.5	1.3	6.2	0.1	97.9
Sillimanite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurolite	0.6	15.9	1.2	0.2	31.2	47.7	1.5	0.2	0.3	98.8
Zircon	0.1	0.9	0.1	0.1	30.0	0.1	0.1	0.2	63.6	95.4
Silicate	1.0	11.1	0.2	0.1	75.8	4.6	1.0	1.2	0.5	95.4
Unclassified	6.2	26.3	0.9	0.8	28.8	5.2	1.1	3.9	2.8	76.0

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	29.4	26.6	11.6	7.5	1.2	23.8	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	60.3	78.9	93.9	42.7
Fe_2O_3 wt%	27.4	7.6	1.8	49.8
MnO wt%	1.9	0.2	0.2	0.8
Cr_2O_3 wt%	0.1	0.3	0.2	0.1
SiO_2 wt%	7.1	9.7	2.5	2.4
Al_2O_3 wt%	2.0	2.4	0.9	1.0
MgO wt%	0.8	0.3	0.2	1.5
CaO wt%	0.2	0.3	0.1	1.1
ZrO_2 wt%	0.3	0.3	0.2	0.6
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	70.3
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	66.0
Valuable heavy minerals in raw sand:	0.14

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	3.7	0.0
Leucoxene	3.4	0.0
Rutile	1.5	0.0
Ti magnetite	0.9	0.0
Magnetite	36.6	0.4
Chromite	0.8	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	0.1	0.0
Sillimanite	0.0	0.0
Staurolite	0.3	0.0
Zircon	3.0	0.0
Silicate	41.2	99.4
Unclassified	8.3	0.1
Total	100.0	100.0

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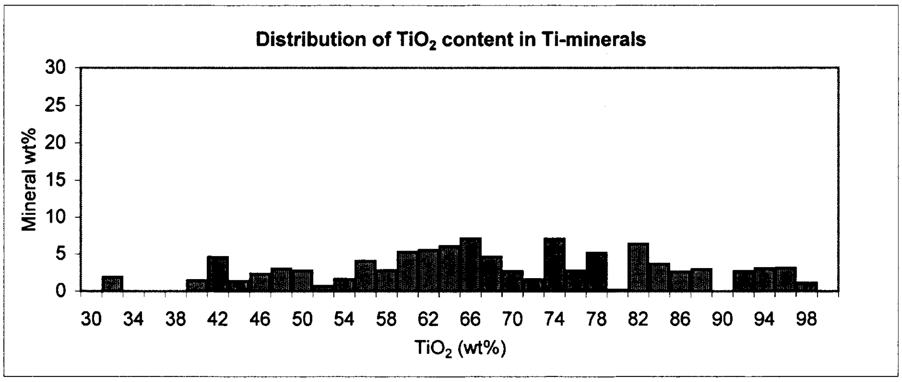
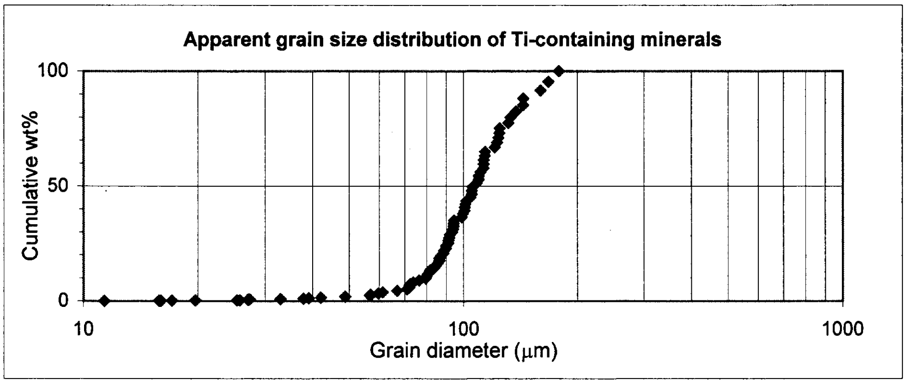
Sample Name:	KW26 11-12m	Analyzed by:	CCA
Submitter:	Dupont / Netherland	Acc. Voltage	17kV
Date:	11/01/01		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm^2)	Total grains
Ilmenite	1.7	2.1	420	169	7319	31
Leucoxene	1.6	2.0	403	158	7918	26
Rutile	1.5	2.0	307	122	4257	19
Ti magnetite	1.4	3.0	579	252	9039	6
Magnetite	1.6	2.6	360	157	5825	332
Chromite	1.4	2.3	461	189	7373	6
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.3	1.6	252	95	3716	2
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	2.3	3.1	423	183	5043	2
Sillimanite	0.0	0.0	0	0	0	0
Staurolite	1.8	2.2	505	209	9133	2
Zircon	1.3	1.6	291	103	4677	38
Silicate	1.5	2.8	877	382	31844	134
Unclassified	1.5	2.5	529	233	17318	49

GEUS
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Sample Name:	5 Tauragnai Q3bl	No. of analysed frames:	81
Date:	12/01/01	No. analysed of particles	948
Country:	Lituania	Heavy minerals in raw sand (%):	2.56
Submitter:	Dupont	comments:	
Analyzed by:	CCA		
Acc. Voltage	17 kV		
Magnification	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	52.3	34.2	2.1	0.1	6.3	1.7	0.4	0.4	0.4	97.9
Leucoxene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rutile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ti magnetite	34.4	46.0	2.0	0.2	8.2	2.2	1.0	2.1	0.6	96.7
Magnetite	1.1	81.6	0.5	0.2	8.0	2.7	1.1	1.7	0.2	97.2
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.1	0.6	0.4	0.2	1.3	0.2	0.3	55.6	1.1	59.8
Monazite	0.0	0.9	0.0	0.0	4.1	0.5	0.3	3.0	1.5	10.2
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.2	33.2	2.1	0.1	36.6	19.3	3.4	2.1	0.3	97.3
Sillimanite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurolite	0.8	15.5	1.1	0.2	31.8	45.9	2.1	0.2	0.3	97.9
Zircon	0.1	0.5	0.2	0.1	29.8	0.1	0.1	0.2	63.5	94.6
Silicate	1.2	17.1	0.5	0.2	48.7	11.9	6.4	8.8	0.3	95.1
Unclassified	1.2	12.2	1.8	0.4	14.4	3.9	16.7	33.9	1.6	86.2

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	2.9	0.0	0.0	17.8	77.3	2.0	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	0	0	35.5
Fe_2O_3 wt%	34.9	0	0	47.6
MnO wt%	2.1	0	0	2.1
Cr_2O_3 wt%	0.1	0	0	0.2
SiO_2 wt%	6.4	0	0	8.4
Al_2O_3 wt%	1.7	0	0	2.3
MgO wt%	0.4	0	0	1.1
CaO wt%	0.4	0	0	2.2
ZrO_2 wt%	0.5	0	0	0.7
Total	100.0	0	0	100.0

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	0.6	0.0
Leucoxene	0.0	0.0
Rutile	0.0	0.0
Ti magnetite	4.0	0.1
Magnetite	14.3	0.4
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.4	0.0
Monazite	1.1	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	17.2	0.4
Sillimanite	0.0	0.0
Staurolite	0.6	0.0
Zircon	0.4	0.0
Silicate	51.7	98.8
Unclassified	9.7	0.2
Total	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	38.0
Average TiO_2 content of all the TiO_2 minerals excl. rutile	38.0
Valuable heavy minerals in raw sand:	0.57

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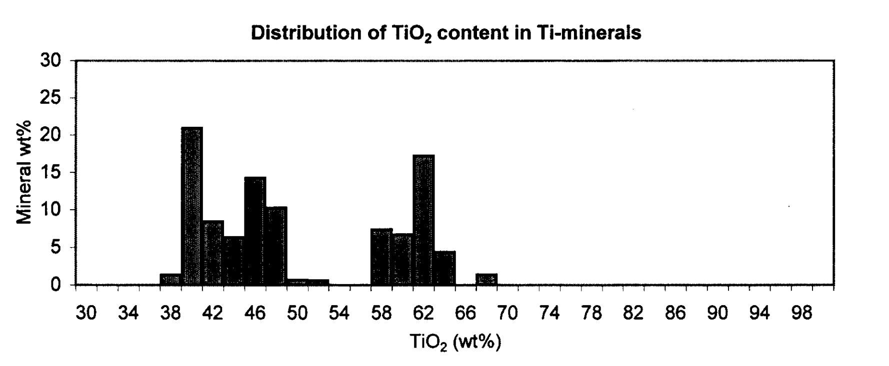
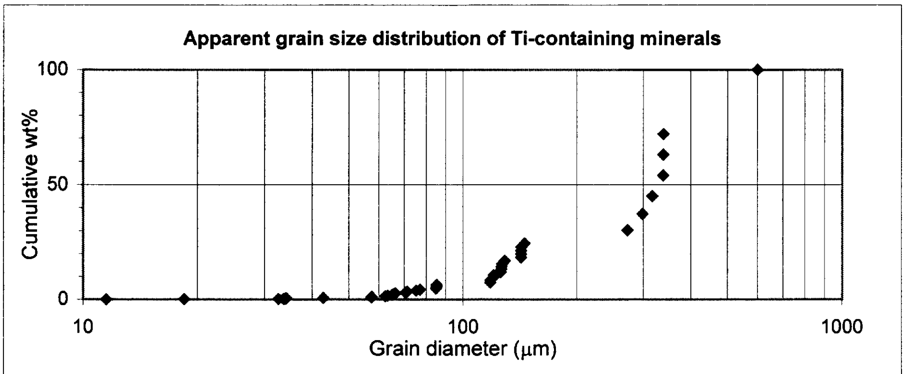
GEUS

Sample Name:	5 Tauragnai Q3bl	Analyzed by:	CCA
Submitter:	Dupont	Acc. Voltage	17kV
Date:	12/01/01		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm^2)	Total grains
Ilmenite	1.5	1.7	363	135	7150	21
Leucoxene	0.0	0.0	0	0	0	0
Rutile	0.0	0.0	0	0	0	0
Ti magnetite	1.5	1.8	731	290	37669	23
Magnetite	1.5	1.9	820	332	43515	66
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	1.5	1.7	439	163	12614	6
Monazite	2.0	1.6	1232	446	75825	3
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.6	2.3	869	363	40978	110
Sillimanite	0.0	0.0	0	0	0	0
Staurolite	1.4	2.3	1543	643	81798	2
Zircon	1.4	1.5	368	123	7720	13
Silicate	1.8	2.0	742	303	36105	565
Unclassified	1.5	1.8	521	207	27009	139

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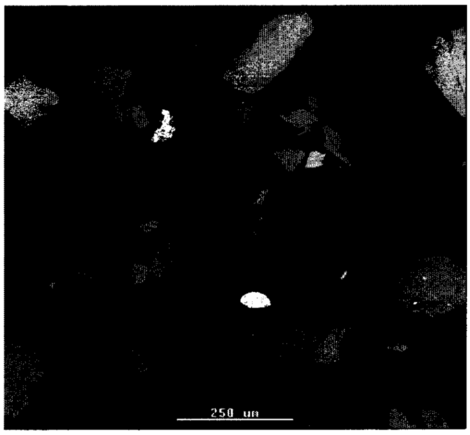
GEUS

Sample Name:	1 Didzasalias Q3bl	No. of analysed frames:	81
Date:	12/01/01	No. analysed of particles	872
Country:	Lituania	Heavy minerals in raw sand (%):	2.83
Submitter:	Dupont	comments:	
Analyzed by:	CCA		
Acc. Voltage	17 kV		
Magnification	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	53.4	37.8	2.1	0.1	3.0	0.8	0.4	0.2	0.3	98.1
Leucoxene	70.3	25.0	0.2	0.0	1.4	0.3	0.2	0.1	0.0	97.6
Rutile	94.3	1.4	0.5	0.3	0.8	0.4	0.1	0.0	0.0	97.8
Ti magnetite	31.0	57.0	1.3	0.4	3.9	2.2	0.6	1.1	0.3	97.7
Magnetite	1.7	78.3	0.6	0.2	9.4	3.4	1.1	1.0	0.4	96.0
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.1	0.6	0.1	0.7	4.0	1.5	0.6	52.6	1.0	61.3
Monazite	0.0	1.7	0.0	0.0	4.1	1.5	0.5	4.7	4.5	16.9
Y-phosphate	0.0	3.4	0.0	0.0	2.1	2.1	0.2	0.8	5.8	14.4
Sphene	35.1	1.2	0.0	0.2	30.3	1.7	0.3	27.7	0.6	97.0
Garnet	0.3	32.8	2.8	0.2	36.4	19.2	2.9	2.1	0.4	97.1
Sillimanite	0.6	1.4	0.9	0.0	41.1	53.8	0.0	0.0	1.5	99.4
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.2	1.0	0.3	0.2	30.0	0.2	0.1	0.1	62.9	95.0
Silicate	1.2	16.8	0.6	0.2	47.5	12.9	6.6	8.0	0.5	94.4
Unclassified	0.9	13.4	0.9	0.4	15.0	5.9	16.4	33.6	1.7	88.1

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	15.0	0.2	0.2	22.3	60.8	1.1	0.4	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	54.4	72.1	96.4	31.8
Fe_2O_3 wt%	38.5	25.6	1.4	58.3
MnO wt%	2.1	0.2	0.5	1.3
Cr_2O_3 wt%	0.1	0.0	0.3	0.4
SiO_2 wt%	3.1	1.4	0.9	4.0
Al_2O_3 wt%	0.9	0.3	0.4	2.2
MgO wt%	0.4	0.2	0.1	0.6
CaO wt%	0.2	0.1	0.0	1.2
ZrO_2 wt%	0.3	0.0	0.0	0.3
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	41.3
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	41.0
Valuable heavy minerals in raw sand:	0.75

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	4.0	0.1
Leucoxene	0.0	0.0
Rutile	0.1	0.0
Ti magnetite	6.0	0.2
Magnetite	26.0	0.7
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.1	0.0
Monazite	0.2	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	16.2	0.5
Sillimanite	0.1	0.0
Staurolite	0.0	0.0
Zircon	0.3	0.0
Silicate	34.5	98.1
Unclassified	12.5	0.4
Total	100.0	100.0

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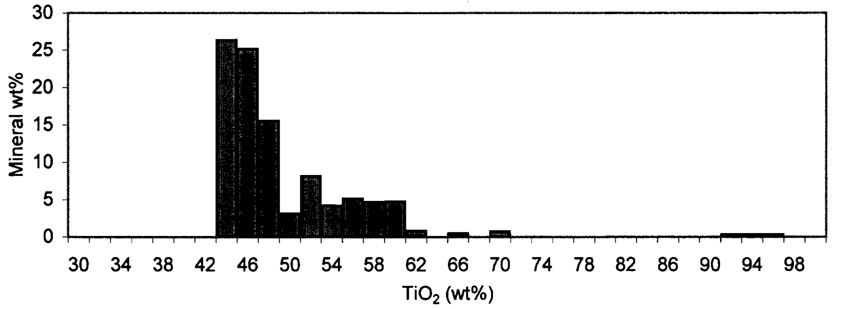
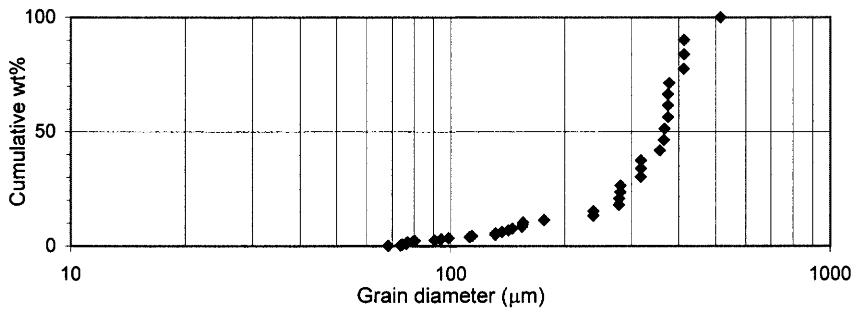
GEUS

Sample Name:	1 Didzasalias Q3bl	Analyzed by:	CCA
Submitter:	Dupont	Acc. Voltage	17kV
Date:	12/01/01		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (μm^2)	Total grains
Ilmenite	1.5	1.7	744	282	33279	27
Leucoxene	2.3	2.2	525	215	10171	1
Rutile	1.2	1.2	260	76	4309	3
Ti magnetite	1.4	1.7	1256	475	84259	15
Magnetite	1.5	2.0	838	337	42235	120
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	1.3	1.3	245	88	5315	3
Monazite	1.3	1.7	675	259	23043	2
Y-phosphate	1.2	1.5	378	129	7710	1
Sphene	1.6	1.7	201	76	1987	4
Garnet	1.6	2.0	704	286	34827	118
Sillimanite	1.5	2.0	893	361	30971	1
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.3	1.5	458	151	12845	5
Silicate	1.8	2.1	704	291	33502	394
Unclassified	1.5	1.7	475	190	26434	178

GEUS

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

Sample Name:	6 Vetygala Q1vl upper part	No. of analysed frames:	81
Date:	13/01/01	No. analysed of particles	638
Country:	Lituania	Heavy minerals in raw sand (%):	0.53
Submitter:	Dupont	comments:	
Analyzed by:	CCA		
Acc. Voltage	17 kV		
Magnification	100x		
Guard region	150 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	60.7	26.5	1.4	0.2	5.9	2.2	0.3	0.2	0.6	97.9
Leucoxene	76.5	9.5	0.3	0.2	6.9	3.2	0.2	0.2	0.4	97.4
Rutile	91.2	1.8	0.2	0.1	2.5	1.5	0.1	0.1	0.3	97.9
Ti magnetite	41.4	29.3	0.7	0.1	18.3	6.7	1.3	0.3	0.0	98.1
Magnetite	0.9	75.7	1.8	0.8	5.0	2.7	0.9	0.7	3.4	91.9
Chromite	1.3	35.7	0.4	31.8	3.7	21.2	4.1	0.0	0.5	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	0.0	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	2.0	24.5	1.4	0.2	39.0	20.8	3.5	3.5	0.5	95.6
Sillimanite	0.2	0.6	0.2	0.1	42.4	54.0	0.0	0.1	0.3	97.9
Staurolite	0.9	14.4	0.3	0.1	33.2	46.9	1.3	0.1	0.3	97.4
Zircon	0.4	0.5	0.1	0.2	29.9	0.8	0.1	0.2	63.5	95.6
Silicate	2.2	5.7	0.4	0.2	56.6	28.0	1.9	0.9	0.5	96.3
Unclassified	15.2	6.6	0.9	3.5	28.7	8.8	1.3	0.6	17.5	83.0

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	52.1	22.2	14.9	3.1	0.8	5.6	1.3	100.0

Normalised average contents of the valuable Ti-containing minerals				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	62.0	78.6	93.2	42.2
Fe_2O_3 wt%	27.1	9.7	1.8	29.9
MnO wt%	1.5	0.3	0.2	0.7
Cr_2O_3 wt%	0.2	0.2	0.1	0.1
SiO_2 wt%	6.1	7.0	2.6	18.6
Al_2O_3 wt%	2.3	3.3	1.5	6.8
MgO wt%	0.3	0.2	0.1	1.3
CaO wt%	0.2	0.3	0.1	0.3
ZrO_2 wt%	0.6	0.4	0.3	0.0
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	70.3
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	66.0
Valuable heavy minerals in raw sand:	0.43

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	42.3	0.2
Leucoxene	18.0	0.1
Rutile	12.1	0.1
Ti magnetite	2.5	0.0
Magnetite	0.6	0.0
Chromite	0.2	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	0.6	0.0
Sillimanite	1.0	0.0
Staurolite	2.3	0.0
Zircon	4.6	0.0
Silicate	12.5	99.5
Unclassified	3.2	0.0
Total	100.0	100.0

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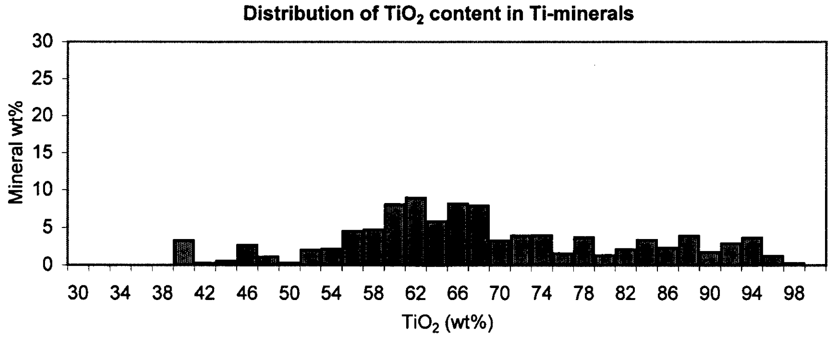
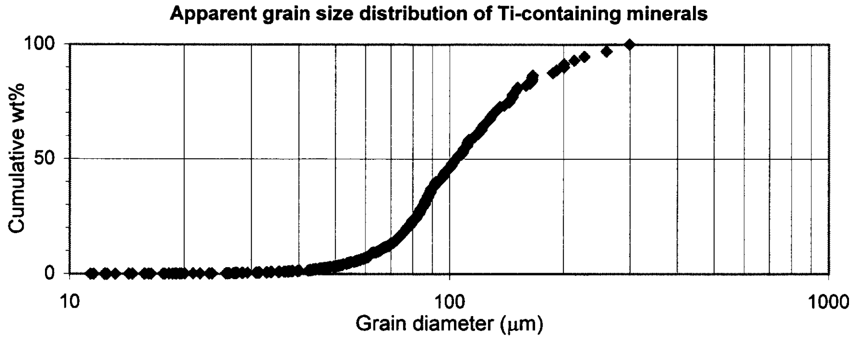
Sample Name:	6 Vetygala Q1vl upper part	Analyzed by:	CCA
Submitter:	Dupont	Acc. Voltage	17kV
Date:	13/01/01		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm^2)	Total grains
Ilmenite	1.6	2.0	368	148	6151	221
Leucoxene	1.6	2.0	356	142	5858	99
Rutile	1.8	2.0	337	134	5066	69
Ti magnetite	1.4	2.6	788	346	25668	3
Magnetite	1.6	2.2	348	150	5561	3
Chromite	1.8	2.0	345	139	4677	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	1.6	2.0	230	95	2894	8
Sillimanite	1.9	2.3	397	161	5799	8
Staurolite	1.5	1.9	252	101	3172	28
Zircon	1.5	1.7	257	95	3458	41
Silicate	1.7	2.1	324	132	5010	136
Unclassified	1.6	2.1	401	165	8167	21

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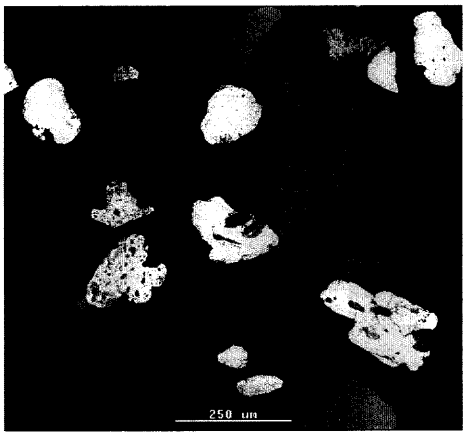
GEUS

Sample Name:	2 Vetygala Q1vl
Date:	13/01/01
Country:	Lituania
Submitter:	Dupont
Analyzed by:	CCA
Acc. Voltage	17 kV
Magnification	100x
Guard region	150 µm
Sieve	100 μm^2

No. of analysed frames:	81
No. analysed of particles	519
Heavy minerals in raw sand (%):	1.81
comments:	



	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	58.1	29.5	3.4	0.1	5.2	1.0	0.2	0.1	0.3	97.9
Leucoxene	73.7	12.0	1.1	0.1	8.5	1.5	0.2	0.2	0.3	97.8
Rutile	93.5	0.8	0.1	0.0	2.5	0.7	0.1	0.1	0.1	97.9
Ti magnetite	39.3	20.5	4.6	0.1	24.6	5.2	0.2	0.2	0.8	95.5
Magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromite	0.0	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	0.4	0.8	0.0	0.0	16.8	2.1	0.2	1.3	2.0	23.6
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.3	26.9	7.3	0.1	36.6	19.5	2.4	4.2	0.2	97.6
Sillimanite	0.4	0.9	0.0	0.1	42.2	54.3	0.0	0.0	0.2	98.2
Staurolite	1.0	15.9	0.4	0.1	32.2	47.0	1.4	0.1	0.2	98.2
Zircon	0.2	0.4	0.2	0.2	29.6	0.1	0.1	0.1	64.2	95.2
Silicate	1.2	7.5	1.0	0.2	64.7	19.3	1.3	1.4	0.4	96.9
Unclassified	9.1	11.7	1.8	0.2	33.9	8.7	0.9	0.9	26.3	93.4

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	71.8	3.3	2.1	1.4	8.2	12.7	0.5	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	59.3	75.4	95.5	41.2
Fe_2O_3 wt%	30.1	12.3	0.9	21.5
MnO wt%	3.5	1.2	0.1	4.8
Cr_2O_3 wt%	0.1	0.1	0.0	0.1
SiO_2 wt%	5.3	8.7	2.5	25.7
Al_2O_3 wt%	1.0	1.6	0.7	5.4
MgO wt%	0.3	0.2	0.1	0.2
CaO wt%	0.1	0.2	0.1	0.2
ZrO_2 wt%	0.3	0.3	0.1	0.8
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	60.7
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	59.7
Valuable heavy minerals in raw sand:	1.45

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	57.3	1.0
Leucoxene	2.6	0.0
Rutile	1.7	0.0
Ti magnetite	1.1	0.0
Magnetite	0.0	0.0
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.7	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	6.6	0.1
Sillimanite	0.4	0.0
Staurolite	4.5	0.1
Zircon	10.2	0.2
Silicate	13.9	98.4
Unclassified	1.1	0.0
Total	100.0	100.0

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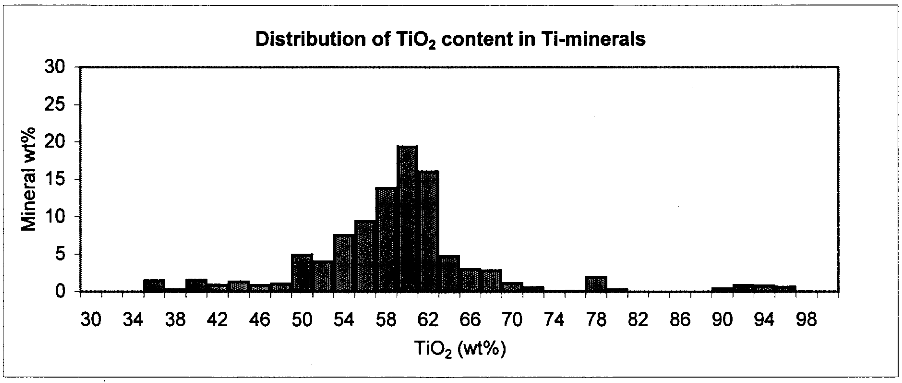
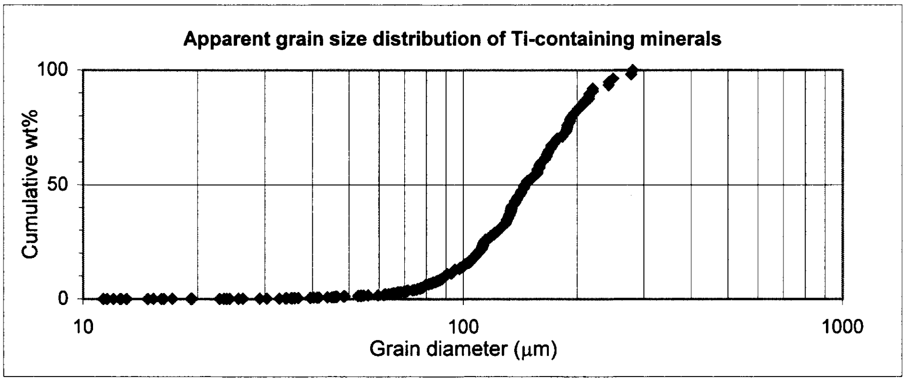
Sample Name:	2 Vetygala Q1vl	Analyzed by:	CCA
Submitter:	Dupont	Acc. Voltage	17kV
Date:	13/01/01		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm^2)	Total grains
Ilmenite	1.7	2.1	497	201	11310	266
Leucoxene	1.5	2.0	436	175	10563	13
Rutile	1.5	1.8	397	153	7969	10
Ti magnetite	1.7	2.0	582	243	18395	3
Magnetite	0.0	0.0	0	0	0	0
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	1.8	2.1	472	191	8697	4
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.7	2.4	619	261	17648	22
Sillimanite	1.6	2.4	376	171	6811	4
Staurolite	1.6	2.8	651	282	15702	18
Zircon	1.5	1.7	379	141	8201	63
Silicate	1.5	2.4	510	216	12751	97
Unclassified	1.8	2.2	292	119	4847	19

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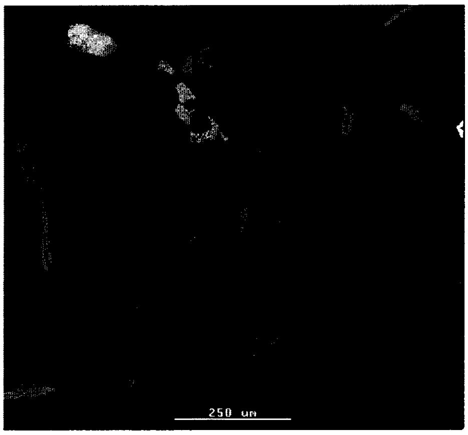
GEUS

Sample Name:	7 Vetygala D3sv	No. of analysed frames:	100
Date:	14/01/01	No. analysed of particles	596
Country:	Lituania	Heavy minerals in raw sand (%):	0.57
Submitter:	Dupont	comments:	
Analyzed by:	CCA		
Acc. Voltage	17 kV		
Magnification	100x		
Guard region	150 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	57.0	31.3	2.3	0.1	5.0	1.4	0.3	0.1	0.3	97.9
Leucoxene	75.3	9.2	0.5	0.1	9.5	2.2	0.1	0.2	0.3	97.5
Rutile	91.0	2.4	0.2	0.2	2.2	1.1	0.2	0.2	0.5	98.1
Ti magnetite	40.0	21.7	1.3	0.1	29.8	3.1	0.2	0.3	0.6	97.2
Magnetite	0.3	76.3	0.5	0.2	10.1	4.1	1.0	2.7	0.4	95.6
Chromite	0.3	23.0	1.3	53.5	0.8	13.7	5.3	0.2	0.0	98.1
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	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	20.6	2.8	0.2	41.6	21.6	1.3	3.4	0.6	92.6
Sillimanite	0.3	0.7	0.1	0.2	42.2	53.9	0.0	0.1	0.4	98.0
Staurolite	0.9	15.2	0.4	0.2	33.5	47.0	1.2	0.1	0.3	98.8
Zircon	0.2	0.6	0.3	0.1	29.9	0.1	0.1	0.3	63.2	94.8
Silicate	0.5	1.9	0.3	0.1	83.2	7.3	0.4	0.5	0.5	94.6
Unclassified	12.4	11.7	1.9	0.6	35.4	7.1	0.4	0.6	11.6	81.6

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	61.9	10.8	9.8	2.1	1.4	11.1	2.8	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	58.2	77.2	92.7	41.1
Fe_2O_3 wt%	32.0	9.4	2.5	22.3
MnO wt%	2.4	0.6	0.2	1.3
Cr_2O_3 wt%	0.2	0.1	0.2	0.2
SiO_2 wt%	5.1	9.8	2.3	30.7
Al_2O_3 wt%	1.5	2.2	1.1	3.2
MgO wt%	0.3	0.1	0.2	0.3
CaO wt%	0.1	0.2	0.2	0.3
ZrO_2 wt%	0.3	0.4	0.5	0.7
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	64.2
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	60.5
Valuable heavy minerals in raw sand:	0.25

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	27.3	0.2
Leucoxene	4.8	0.0
Rutile	4.3	0.0
Ti magnetite	0.9	0.0
Magnetite	7.6	0.0
Chromite	0.3	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	0.6	0.0
Sillimanite	1.2	0.0
Staurolite	0.9	0.0
Zircon	4.9	0.0
Silicate	44.2	99.7
Unclassified	2.9	0.0
Total	100.0	100.0

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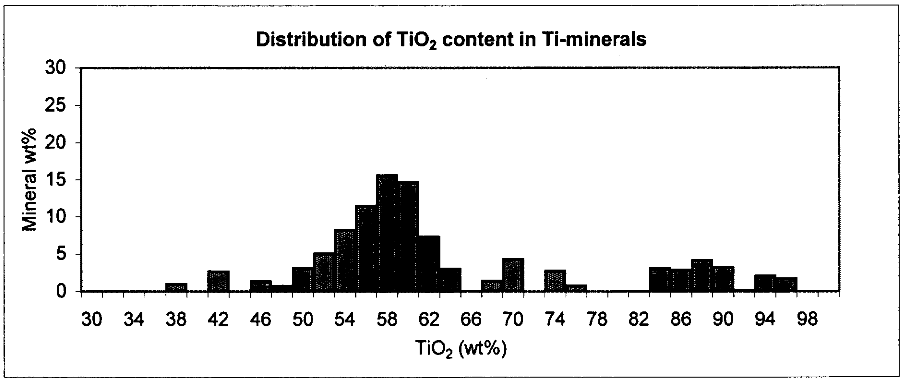
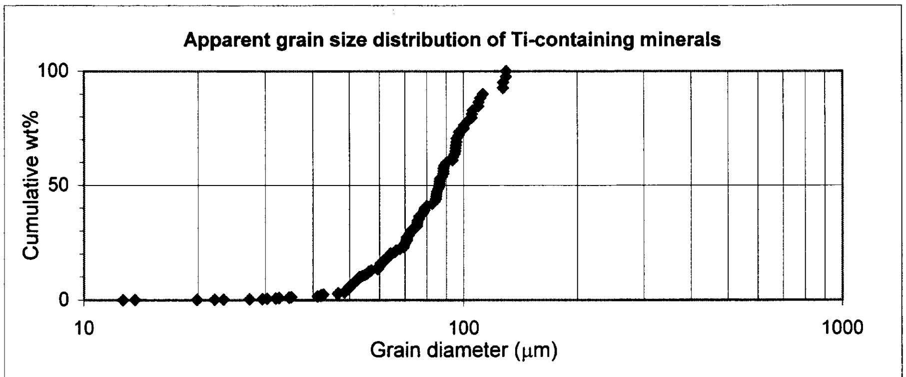
GEUS

Sample Name:	7 Vetygala D3sv	Analyzed by:	CCA
Submitter:	Dupont	Acc. Voltage	17kV
Date:	14/01/01		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (μm^2)	Total grains
Ilmenite	1.8	2.1	318	129	4240	92
Leucoxene	1.6	2.4	378	153	5685	12
Rutile	1.7	2.2	299	122	3723	15
Ti magnetite	1.3	2.1	324	131	4146	3
Magnetite	1.5	2.3	367	156	5850	16
Chromite	1.4	1.7	307	116	4334	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	1.6	1.5	142	49	1659	6
Sillimanite	1.5	2.2	341	142	4899	5
Staurolite	1.8	2.1	233	97	2494	6
Zircon	1.4	1.6	272	97	3982	17
Silicate	2.3	2.5	264	111	2661	403
Unclassified	1.7	2.3	262	110	3413	20

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Geological Survey of Denmark and Greenland
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Ph.: +45 38142000, Fax: +45 38142050

Sample Name:	4 Anykschchiai-7 middel part	No. of analysed frames:	81
Date:	14/01/01	No. analysed of particles	486
Country:	Lituania	Heavy minerals in raw sand (%):	0.43
Submitter:	Dupont	comments:	
Analyzed by:	CCA		
Acc. Voltage	17 kV		
Magnification	100x		
Guard region	150 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	63.5	26.9	1.5	0.2	4.1	1.0	0.3	0.2	0.3	98.1
Leucoxene	77.4	13.3	0.8	0.3	3.6	1.2	0.2	0.3	0.3	97.4
Rutile	92.5	1.6	0.2	0.2	1.9	0.8	0.1	0.1	0.3	97.8
Ti magnetite	45.5	24.6	23.0	0.0	0.7	0.4	0.0	0.0	0.0	94.2
Magnetite	1.9	90.8	0.8	0.1	2.6	1.4	0.3	0.1	0.3	98.4
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	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
Sillimanite	0.0	1.2	0.0	0.2	42.6	53.2	0.0	0.0	0.6	97.9
Staurolite	0.8	13.8	0.4	0.1	33.1	47.6	1.5	0.1	0.2	97.6
Zircon	0.3	0.4	0.3	0.1	29.6	0.4	0.1	0.1	64.3	95.6
Silicate	2.5	4.4	0.2	0.2	54.9	31.6	2.3	0.8	0.3	97.0
Unclassified	27.2	4.1	0.2	1.6	30.7	1.6	0.7	0.6	14.3	80.9

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	45.0	19.1	25.3	2.2	0.0	5.9	2.5	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	64.8	79.5	94.6	48.3
Fe_2O_3 wt%	27.4	13.7	1.6	26.1
MnO wt%	1.6	0.8	0.2	24.5
Cr_2O_3 wt%	0.2	0.3	0.2	0.0
SiO_2 wt%	4.2	3.7	1.9	0.7
Al_2O_3 wt%	1.0	1.2	0.8	0.4
MgO wt%	0.3	0.2	0.1	0.0
CaO wt%	0.2	0.3	0.1	0.0
ZrO_2 wt%	0.3	0.3	0.3	0.0
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	75.7
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	68.5
Valuable heavy minerals in raw sand:	0.32

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	33.6	0.1
Leucoxene	14.2	0.1
Rutile	18.9	0.1
Ti magnetite	1.7	0.0
Magnetite	4.0	0.0
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
Sillimanite	1.9	0.0
Staurolite	2.7	0.0
Zircon	4.4	0.0
Silicate	17.1	99.6
Unclassified	1.6	0.0
Total	100.0	100.0

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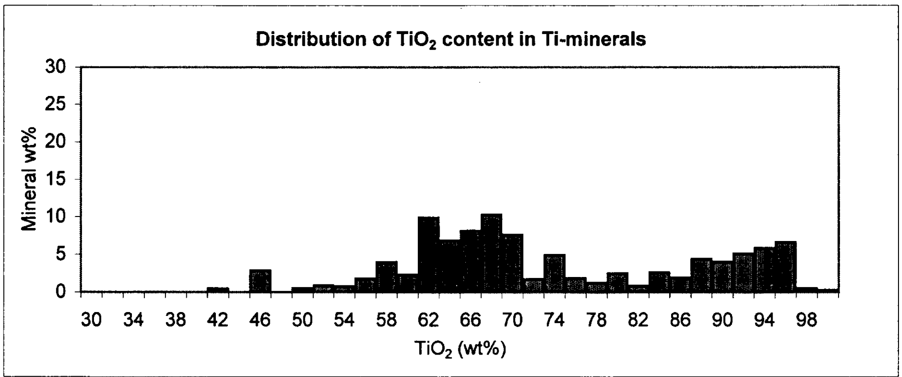
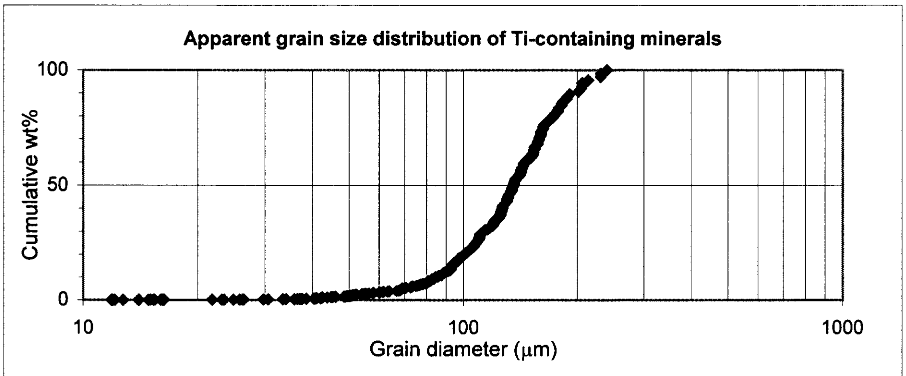
Sample Name:	4 Anykschchiai-7 middel part	Analyzed by:	CCA
Submitter:	Dupont	Acc. Voltage	17kV
Date:	14/01/01		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	2.1	473	191	10097	142
Leucoxene	1.5	2.0	425	171	8556	71
Rutile	1.7	2.3	451	185	8638	84
Ti magnetite	1.1	2.1	938	382	33327	2
Magnetite	1.6	2.0	466	184	9787	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	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
Sillimanite	2.1	2.4	742	312	27843	4
Staurolite	1.5	2.3	468	199	11307	12
Zircon	1.5	1.8	360	138	6451	28
Silicate	1.7	2.5	520	221	10713	116
Unclassified	1.7	2.2	481	201	9697	12

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Sample Name:	3 Anykschchiai - 7 delta layer	No. of analysed frames:	116
Date:	14/01/01	No. analysed of particles	558
Country:	Lituania	Heavy minerals in raw sand (%):	0.53
Submitter:	Dupont	comments:	
Analyzed by:	CCA		
Acc. Voltage	17 kV		
Magnification	100x		
Guard region	150 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	63.5	27.8	1.7	0.2	3.2	1.4	0.2	0.2	0.3	98.3
Leucoxene	77.1	11.9	0.6	0.3	5.3	1.6	0.2	0.3	0.3	97.7
Rutile	92.5	1.6	0.2	0.2	2.2	0.9	0.1	0.2	0.3	98.2
Ti magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Magnetite	2.9	73.9	0.7	0.2	5.9	0.7	0.0	11.9	0.7	96.9
Chromite	0.8	26.5	0.6	56.0	1.5	8.6	3.4	0.2	0.4	97.9
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	38.4	1.9	0.5	0.0	26.7	0.8	0.1	29.3	0.2	98.0
Garnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sillimanite	0.4	0.9	0.2	0.2	42.2	54.0	0.0	0.2	0.1	98.2
Staurolite	0.8	15.1	0.4	0.3	32.4	47.3	1.5	0.1	0.3	98.1
Zircon	0.3	0.3	0.2	0.2	30.0	0.3	0.1	0.2	64.1	95.7
Silicate	1.3	5.4	0.2	0.1	53.0	32.1	2.8	1.9	0.3	97.1
Unclassified	9.3	13.3	1.9	2.3	12.9	2.3	0.6	3.1	25.5	71.1

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	31.6	25.5	26.6	0.0	0.0	15.7	0.7	100.0

Normalised average contents of the valuable Ti-containing minerals				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	64.5	79.0	94.3	0
Fe_2O_3 wt%	28.2	12.2	1.6	0
MnO wt%	1.7	0.6	0.2	0
Cr_2O_3 wt%	0.2	0.3	0.2	0
SiO_2 wt%	3.3	5.5	2.3	0
Al_2O_3 wt%	1.4	1.6	0.9	0
MgO wt%	0.2	0.2	0.1	0
CaO wt%	0.2	0.3	0.2	0
ZrO_2 wt%	0.3	0.3	0.3	0
Total	100.0	100.0	100.0	0

Average TiO_2 content of all the TiO_2 minerals:	78.4
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	71.0
Valuable heavy minerals in raw sand:	0.44

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	26.6	0.1
Leucoxene	21.5	0.1
Rutile	22.4	0.1
Ti magnetite	0.0	0.0
Magnetite	0.4	0.0
Chromite	0.4	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
Sillimanite	0.6	0.0
Staurolite	3.8	0.0
Zircon	13.2	0.1
Silicate	10.3	99.5
Unclassified	0.8	0.0
Total	100.0	100.0

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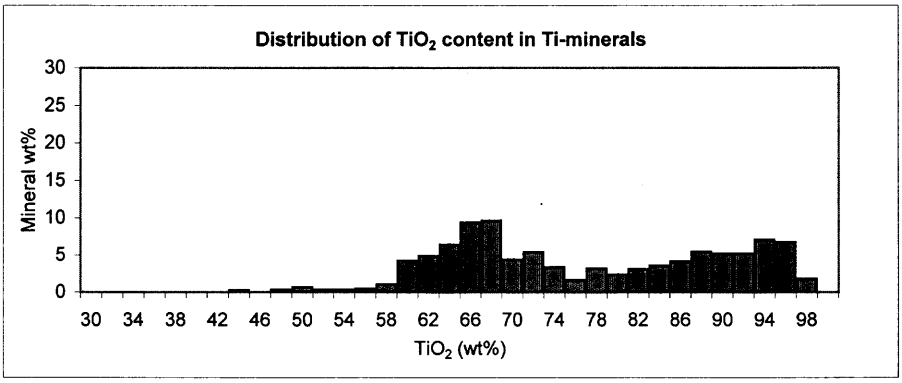
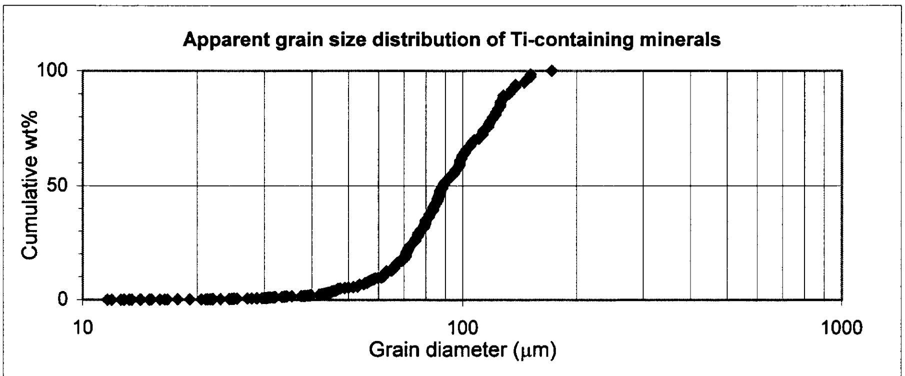
Sample Name:	3 Anykschchiai - 7 delta layer	Analyzed by:	CCA
Submitter:	Dupont	Acc. Voltage	17kV
Date:	14/01/01		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (μm^2)	Total grains
Ilmenite	1.6	1.8	300	116	4644	130
Leucoxene	1.6	2.0	325	128	5020	97
Rutile	1.6	2.0	305	121	4274	107
Ti magnetite	0.0	0.0	0	0	0	0
Magnetite	1.4	1.9	254	101	3442	2
Chromite	1.5	1.7	184	70	1744	5
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	1.7	1.9	178	70	1321	1
Garnet	0.0	0.0	0	0	0	0
Sillimanite	1.4	2.0	358	145	5822	3
Staurolite	2.0	2.5	352	149	5032	20
Zircon	1.5	1.7	263	98	3665	79
Silicate	1.7	2.1	306	124	4176	95
Unclassified	1.3	1.4	129	48	1561	19

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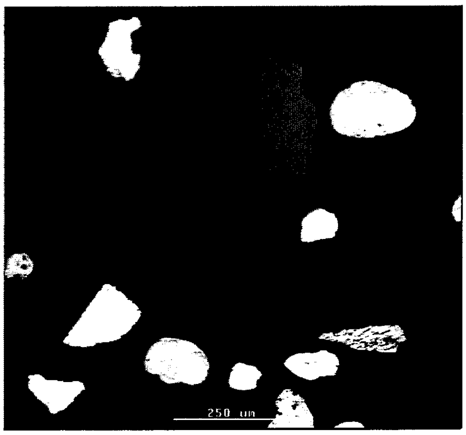

Sample Name:	8 Anykschchiai - 7	No. of analysed frames:	100
Date:	14/01/01	No. analysed of particles	381
Country:	Lituania	Heavy minerals in raw sand (%):	0.39
Submitter:	Dupont	comments:	
Analyzed by:	CCA		
Acc. Voltage	17 kV		
Magnification	100x		
Guard region	150 μm		
Sieve	100 μm^2		

	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	63.0	26.7	1.9	0.2	4.7	0.9	0.2	0.2	0.3	98.0
Leucoxene	75.6	12.1	0.8	0.3	6.5	1.3	0.2	0.3	0.3	97.4
Rutile	93.2	1.2	0.2	0.2	2.1	0.6	0.1	0.1	0.2	98.0
Ti magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Magnetite	4.0	65.6	0.0	0.3	10.6	8.4	0.3	0.0	0.0	89.2
Chromite	0.7	18.3	0.5	58.2	1.8	11.5	7.3	0.2	0.2	98.6
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	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
Sillimanite	0.0	0.5	0.0	0.3	42.8	53.7	0.1	0.1	0.5	98.0
Staurolite	0.6	14.8	0.3	0.1	34.1	46.4	1.3	0.1	0.2	98.0
Zircon	0.3	0.4	0.2	0.2	29.8	0.1	0.1	0.2	64.3	95.5
Silicate	0.7	3.7	0.2	0.2	65.7	23.9	1.2	0.7	0.4	96.7
Unclassified	18.4	1.6	0.2	0.1	65.5	0.8	0.0	0.1	8.6	95.3

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Sillimanite	Total
wt %	35.2	20.5	22.3	0.0	0.0	21.0	1.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	64.3	77.7	95.1	0
Fe_2O_3 wt%	27.2	12.4	1.2	0
MnO wt%	2.0	0.8	0.2	0
Cr_2O_3 wt%	0.2	0.3	0.2	0
SiO_2 wt%	4.8	6.7	2.2	0
Al_2O_3 wt%	0.9	1.4	0.6	0
MgO wt%	0.2	0.2	0.1	0
CaO wt%	0.2	0.3	0.1	0
ZrO_2 wt%	0.3	0.3	0.2	0
Total	100.0	100.0	100.0	0

Average TiO_2 content of all the TiO_2 minerals:	76.6
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	69.2
Valuable heavy minerals in raw sand:	0.32

Weight percent on a mineral basis:		
Category	Heavy mineral concentrate wt %	Raw sand wt %
Ilmenite	28.8	0.1
Leucoxene	16.8	0.1
Rutile	18.3	0.1
Ti magnetite	0.0	0.0
Magnetite	0.0	0.0
Chromite	1.3	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
Sillimanite	0.8	0.0
Staurolite	5.5	0.0
Zircon	17.2	0.1
Silicate	10.1	99.6
Unclassified	1.1	0.0
Total	100.0	100.0

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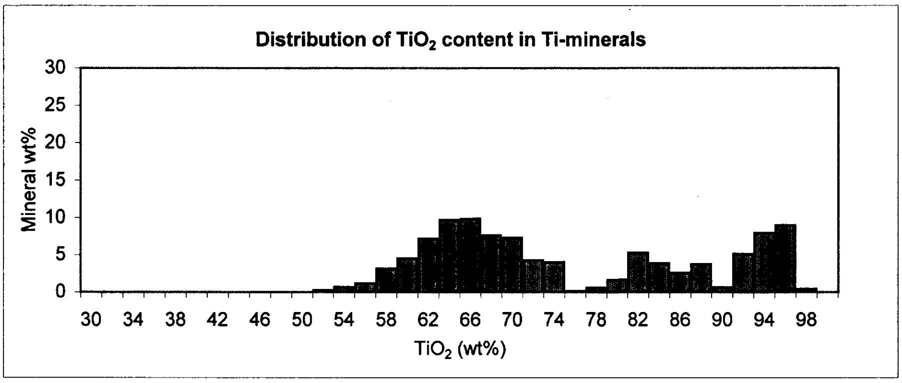
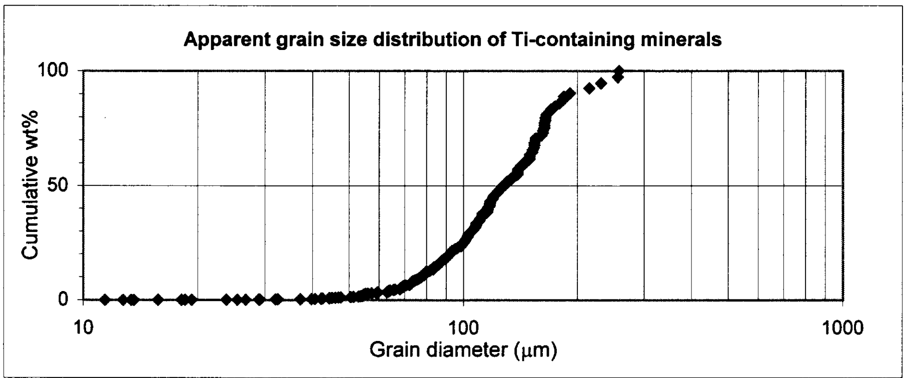
Sample Name:	8 Anykschchiai - 7	Analyzed by:	CCA
Submitter:	Dupont	Acc. Voltage	17kV
Date:	14/01/01		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.9	423	165	8798	98
Leucoxene	1.7	2.1	441	178	9300	54
Rutile	1.6	2.1	447	182	8501	58
Ti magnetite	0.0	0.0	0	0	0	0
Magnetite	1.9	1.9	71	28	213	1
Chromite	1.3	1.6	380	135	8669	4
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
Sillimanite	2.0	3.0	554	243	8301	4
Staurolite	1.6	2.5	565	239	13946	14
Zircon	1.5	1.8	391	148	7789	64
Silicate	1.7	2.2	370	153	6607	78
Unclassified	1.7	2.2	344	143	8945	6

Appendix 3

NATIVE DEPOSITS (HARD ROCK)

№	The name of deposits	location, (region, district)	Geographical position data (n.w., e.l.)	The index of geological age	Mineral fossil **main** secondary	Content	The data concerning ore body			The exploring
							middle thickness, m	area, thousands of m^2	middle thickness of cover, m	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	Yastrebetskoe	Zhitomirsk Olevsk	$51^0$24’ $27^0$53’	PR_1pž	zirconium Y- fluorite	ZrO_2- 0.42-1.07% F_2O_5-15-40%	4.1 5		0-25	
2	Mazurovskoe	Donetsk Volnovaxsk	$47^0$31’ $37^0$31’	PR_1vp	zirconium, titanium, niobium tantalum	ZrO_2- 0.5% TiO_2- 2% Nb_2O_5- 0.12-0.15%; Ta_2O_5-0.005-0.007	2.5-30		12-280	detailed exploration
3	Azovskoe	Donetsk Volodarsk	$47^0$13’ $36^0$17’	PR_1vp	zirconium, rare-earth	ZrO_2- 0.02-27.12, middle 1.5% Σ Tl_2O_5-1.5% (Ge-1.3; Y-0.2)	15.5		2.0-35.0	preliminary exploration
4	Stremigorodskoe	Zhitomirsk Korostensk	$50^0$52’ $28^0$49’	PR_1ks	titanium, phosphorus, scandium, vanadium	ilmenite - 60-150 кг/м^3, TiO_2- 8-10%, P_2O_5-2.5-9.1, middle 3% Sc-80 г/т, V_2O_5- 0.2 %	460-490		0-40.0	detailed exploration
5	Fedorovskoe	Zhitomirsk Volodarsk-Volinsk	$50^0$30’ $28^0$46’	PR_1ks	titanium phosphorus	TiO_2- 5.42-15.67%, P_2O_5- 2.3-6.7%	93.3		4.0-10.0	preliminary exploration
6	Vidiborskoe	Zhitomirsk Chernyaxovsk	$50^0$33’ $28^0$48’	PR_1ks	titanium phosphorus	TiO_2- 4.5-18.7%, P_2O_5- 2.3-6.7%	166.0		3.0-6.5	exploration
7	Paromovskoe	Zhitomirsk Volodarsk-Volinsk	$50^0$36’ $28^0$33’	PR_1ks	titanium phosphorus	TiO_2- 2.7-15.1%, P_2O_5- 2.0-6.4%	203.0		2.0-10.0	exploration

8	Yurovskoe	Zhitomirsk Olevsk	$51^0$21' $27^0$48'	$PR_2p\check{z}$	titanium	TiO_2- 0.2-14.86%	105.0		0-12.0	exploration
9	Mariupol'skoe (Zhdanovskoe)	Donetsk Volnovaxsk	$47^0$30' $37^0$26'	PR_1vp	zirconium, titanium, hafnium, niobium	ZrO_2- 0.41% TiO_2- 2.2%	2.5-30		12-280	detailed exploration
10	Pokrovo-Kereevskoe	Donetsk Starobeshevsk	$47^0$39' $38^0$13'	D	titanium vanadium	TiO_2- 7-19.7%% V_2O_5- 0.05-0.29 %	300.0		32-138	search

PLACER DEPOSITS

№	The name of deposits	location, (region, district)	Geographical position data (n.w., e.l.)	The index of geological age	Mineral fossil <u>main</u> secondary	Content	The data concerning ore body			The exploring
							middle thickness, m	area, thousands of m^2	middle thickness of cover, m	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	Irshansk groups	Zhitomir, Volodarsk-Volinsk	50^0 43' 28^0 42'	₽-K_1 ad IV	titanium	ilmenite 30-150 kg/m^3 middle 70-80 kg/m^3	10.0		5-6	detailed exploration
2	Tarasovskoe	Kiev, Belotserkovsk	49^0 32' 30^0 17'	N	zirconium titanium niobium hafnium	ZrO_2 3900 $г/м^3$ TiO^2 –17.9 kg/m^3	16.0		-	preliminary exploration
3	Novomirgorodsk group	Kirovogradsk, Novomirgorodsk	48^0 57' 31^0 45'	₽-K_1 ad IV	titanium	ilmenite 70-80 kg/m^3	10.0		5-6	
4	Malishevskoe	Dnepropetrovsk, Verxnednepropetrovsk	48^0 36' 34^0 16'	N	<u>zirconium</u> <u>titanium</u> staurolite	ZrO_2 5442 g/m^3 TiO^2 –135.9 g/m^3	2-20.0		on surface	detailed exploration
5	Krasnokutskoe	Kharkov, Krasnokutsk	50^0 05' 35^0 11'	N	titanium zirconium	TiO^2 –15 kg/m^3 ZrO_2 3600 g/m^3	2-20.0		on surface	preliminary exploration
6	Volchanskoe	Dnepropetrovsk, Vasil'evsk	40^0 11' 36^0 26'	N	titanium zirconium	TiO^2 –76.9 kg/m^3 ZrO_2 3980 g/m^3	0/2-18..0		on surface	detailed exploration