DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2003/13

Heavy Mineral Sands in Kerala and Tamil Nadu, southern India

Henrik Stendal, Hanuma Prasad and
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GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF THE ENVIRONMENT

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Contents

Abstract

The presence of high-grade ilmenite in southern India has been described earlier, and in Vasudev *et al.* (2002) it was concluded that some areas in India i.e. the Kerala has high-grade ilmenite with TiO_2 at 62 – 64 %. Accordingly the aim of this study was to pinpoint the areas of interest, and as the focus the states Kerala and Tamil Nadu was chosen.

It was decided to sample beach placers along approx. 500 miles of coast, as well as sands from major rivers and backwaters. Further, representative bedrock samples were taken for provenance analysis and an attempt to investigate if certain rock types are the source for high-grade ilmenite.

The present study has yielded a wide variety of ilmenite grades with high-grade ilmenite (>60%) only at certain localities. The northern part of Kerala is characterized by low-grade ilmenite (K1 – K15, 50 - 53 % TiO_2). The most promising area is located along the south-western shore of Kerala over a stretch of 70-km. The highest ilmenite grades are found in the Chavra beach placer deposit (61.6 to 62.6 % TiO_2). Further high-grade ilmenite is found north of Kovalam Beach (60.2 % TiO_2). High-grade ilmenite seems to be tied to beach sand in Kerala, whereas the river sands in Kerala have low TiO_2 content in the ilmenite (~52%). This could indicate that the enrichment of TiO_2 in the ilmenite is tied to processes in the beach.

Close to the southern tip of India in the state of Tamil Nadu, elevated TiO_2 in ilmenite occurs in one beach sand sample (56,6%) and in the river sand of the Nambiar River (60,2%). The river only flows during the monsoon period and the sediments are coarse-grained. The changing wet and dry season might have something to do with the high-grade TiO_2 in ilmenite.

The Inland Teri sands of Tamil Nadu are red undulating dunes but probably original marine sands occupying higher elevations relative to the surrounding areas. The Teri Sands do not have high-grade ilmenite.

The main conclusion is that the presence of high-grade ilmenite in Kerala and Tamil Nadu is confirmed, but that the grade of the ilmenite varies significantly along the coast. Two beach placers with high-grade ilmenite were found, but due to the low sampling density other high-grade ilmenite deposits may be present.

Recommended further work:

- To approach local producers and get insight in mineral rights and possibilities for co-operation.
- Constrain the areas with high-grade TiO_2 in ilmenite. Sampling in a closer grid and analyzing the sand using powder XRF can do this.
- To continue the work with provenance, aiming at understanding the source of the high-grade ilmenite and understand the processes responsible for the enrichment of the ilmenite.
- Evaluate possibilities of locating offshore high-grade ilmenite deposits adjacent to on-shore deposits of high-grade ilmenite.

Introduction

Background

India has a vast coastline of more than 6000 km on the eastern and western margins of the peninsula. The high-grade metamorphic terrain's of the south (Precambrian) and Deccan trap basalt's in western margins of the north central (Mesozoic – Lower Tertiary) coupled with the tropical to sub-tropical climate, drainage systems and offshore forces have contributed heavy minerals for the rich beach placer resources on the coasts. India hosts some of the world's largest and richest shoreline placers. A combination of favourable factors like the hinterland geology, coastal geomorphology, sub-tropical to tropical climate and intricate network of drainage, aided by wind and coastal processes like waves and currents, have influenced the formation of beach and adjoining dune sands deposits. The heavy mineral assemblage varies widely from near mono-mineral to multi-mineral suites.

On basis of the review made by Vasudev *et al.* (2002) in five states, Orissa, Andhra Padesh, Tamil Nadu, Kerala and Maharashtra, it was concluded that further commitments should focus on the states of Kerala and Tamil Nadu. Here ilmenite with TiO_2 content of more than 60 % was indicated.

This report deals with the results of the analytical work of heavy mineral sand.

Samples of bedrock in the area have been taken thin sections made and microprobe work finalised. However, the provenance work and investigation of the rock samples is part of a M.Sc. thesis (Mads S. Christiansen), Geological Institute, University of Copenhagen, and the work is still in progress.

Objectives and plan

A project was defined with the following objectives:

- Heavy mineral sampling along the coast of Kerala and around the tip of India into the Tamil Nadu region where the travel connection goes to Sri Lanka. It is a long stretch and the plan was to collect 20-30 samples. Thus, the sample density is low. Further, the aim was to collect 2-3 samples of 3-4 river up-streams to follow the high-grade ilmenite both as transport in the rivers and along the beach and see if the ilmenite is uniform in composition in the whole region.
- Rock samples from the source areas to the sand. Sampling of approx. 15 representative rocks with ilmenite (e.g. charnockite and amphibolites). The purpose of rock samples was to analyse for the ilmenite composition using both microprobe and LA ICP/MS. And further to investigate if certain lithologies are more prone to alter to high-grade ilmenite

The fieldwork was conducted by our partners Prasad and Vasudev, and took place in April 2002. Prasad and Vasudev (Appendix 1) report the sampling programme and the geology of the sampling areas (Fig. 1).

Figure 1. *Area of interest is framed and represents the area shown in the Figures 2 and 4.*

Sampling programme

The heavy mineral sampling along the west and East Coast of Kerala and Tamil Nadu, South India, river placer sampling along selected river courses and provenance rock samples was completed around the 20 April. Unbiased but representative grab samples of river sand, beach sand and rock samples were collected. The locations are registered with the help of GARMIN GPS II and numbered K1 onwards. Photograph of every observation/ sampling point was taken. A total of 67 samples have been collected (Table 1 and Fig. 2). Samples of sands weigh between 5 to 10 kilograms depending on the content of ilmenite and garnet. The heavy mineral samples were split to about 2 kg each. Rock samples were on an average weigh ~3kg.

Waypoint	Longitude	Latitude	Sample_Type	Description	State
K1	75.7879	12.1103	Rock	Charnockite	Kerala
K2	75.7212	12.0664	Rock	Garnetiferous Gneiss	Kerala
K3	75.6187	11.9876	River Sand	~5% heavies; Iritty river	Kerala
K4	75.2852	11.9603	Beach Sand	~5% heavies	Kerala
K5	75.2711	11.9801	Beach Sand	~5% heavies	Kerala
K6	75.3549	11.9289	River Sand	Iritty river back waters	Kerala
K7	75.6932	12.0113	Rock	Granodioritic Gneiss	Kerala
K8	75.5106	11.728	Beach Sand	20-50% heavies	Kerala
K10	75.7143	11.3925	Rock	Gneiss (amphibolite grade)	Kerala
K11	76.0351	10.8491	Rock	Massive Charnockite	Kerala
K12	76.0259	10.839	River Sand	5% heavies; Bharat river	Kerala
K14	75.9702	10.6556	Beach Sand	20% heavies	Kerala
K15	76.0974	10.3834	Beach Sand	30% heavies	Kerala
K16	76.2184	10.6481	Rock	Charnockite	Kerala
K19	76.614	10.7873	Rock	Migmatitic gneiss	Kerala
K20	76.3814	10.575	Rock	Mafic granulite	Kerala
K23	76.5587	10.2866	Rock	Garnetiferous Gneiss	Kerala
K24	76.2802	9.77651	Beach Sand	~5% heavies	Kerala
K25	76.365	9.3516	Beach Sand	40-50% heavies: part of Chavra deposit	Kerala
K26	76.4083	9.25659	Beach Sand	40-50% heavies: part of Chavra deposit	Kerala
K27	76.4758	9.12181	Beach Sand	30-40% heavies; backwaters	Kerala
K28	76.5283	8.97085	Beach Sand	50% heavies; part of Chavra deposit	Kerala
K29	76.6671	8.78889	Beach Sand	30-40% heavies	Kerala
K30	76.7565	9.08631	River Sand	~5% heavies; Kallada river	Kerala
K31	76.7666	9.09782	Rock	Garnetiferous Gneiss; khondalite	Kerala
K32	76.9264	9.02628	River Sand	~5% heavies; Kallada river	Kerala
K33	76.9097	9.0366	Rock	Garnetiferous Gneiss; khondalite	Kerala
K34	77.0235	8.98424	River Sand	~5% heavies; Kallada river	Kerala
K36	76.9784	8.96487	Rock	Garnetiferous Gneiss; khondalite	Kerala
K37	76.8628	8.89689	Rock	Charnockite	Kerala
K38	76.7637	8.66151	Beach Sand	~10% heavies	Kerala
K39	76.9649	8.41468	Beach Sand	15-20% heavies; north of Kovalam Beach	Kerala
K40	76.9742	8.39551	Beach Sand	40% heavies; Kovalam Beach	Kerala
K41	77.0921	8.47165	Rock	Garnetiferous Gneiss; khondalite	Kerala
K42	77.2605	8.3971	River Sand	<5% heavies; Tributary to Martand river	TN
K43	77.3028	8.41061	Rock	Garnetiferous alkali granite	TN

K44	77.2479	8.39488	Rock	Charnockite	TN
K45	77.5458	8.07663	Beach Sand	~20% heavies	TN
K46	77.4898	8.08595	Beach Sand	~10% heavies	TN
K47	77.4238	8.09878	Beach Sand	~30% heavies	TN
K48	77.294	8.15023	Beach Sand	>50% heavies; Manavalakurichichi deposit	TN
K49	77.2451	8.17389	Beach Sand	~20 heavies	TN
K50	77.2083	8.20509	Beach Sand	30-40% heavies	TN
K51	77.18	8.2296	Rock	Garnetiferous Gneiss; khondalite	TN
K52	77.1722	8.23477	Beach Sand	~5% heavies	TN
K53	77.8038	8.25071	River Sand	~5% heavies; Nambiar river	TN
K54	77.8838	8.30317	Teri Sand	5-10% black heavies	TN
K55	77.642	8.44141	River Sand	5-10% black heavies	TN
K56	77.5527	8.2668	Rock	Garnetiferous Gneiss; khondalite	TN
K57	77.5774	8.325	Rock	Charnockite	TN
K59	77.6233	8.1512	Beach Sand	~5% heavies	TN
K61	77.7382	8.18061	Rock	Garnetiferous Gneiss; khondalite	TN
K62	77.746	8.17858	Teri Sand	~20% black heavies; Idindakari deposit	TN
K64	77.7599	8.18702	Beach Sand	~50% heavies; near to a Garnet deposit	TN
K65	77.775	8.21184	Teri Sand	~90% heavies, reworked teri sand; Idindakarai deposit	TN
K66	77.7567	8.4049	Rock	Garnetiferous Gneiss; khondalite	TN
K67	77.7215	8.44893	Rock	Garnetiferous Gneiss; khondalite	TN
K68	78.0863	8.77168	Teri Sand	~10% ilmenite	TN
K70	78.0464	8.54995	Teri Sand	~15% ilmenite; Kudraimoli deposit	TN
K72	77.9205	8.40966	Teri Sand	~10% ilmenite; Sattankulum deposit	TN
K74	77.8832	8.28184	Teri Sand	~15% ilmenite; Navaladi deposit	TN
K80	78.3664	9.07456	Beach Sand	~15% heavies; Vembar beach	TN
K81	78.3303	9.09953	Teri Sand	~15% heavies; Sevalampatti deposit	TN
K82	78.405	9.16713	Teri Sand	~15% heavies; Sevalampatti deposit	TN
K83	78.5593	9.20729	Teri Sand	~5% heavies	TN
K86	78.7369	9.22824	Teri Sand	~5% heavies	TN
K87	78.9231	9.26198	Beach Sand	~20% heavies	TN

Table 1. *Sampling information with geographical co-ordinates and short descriptions of the sampling sites.*

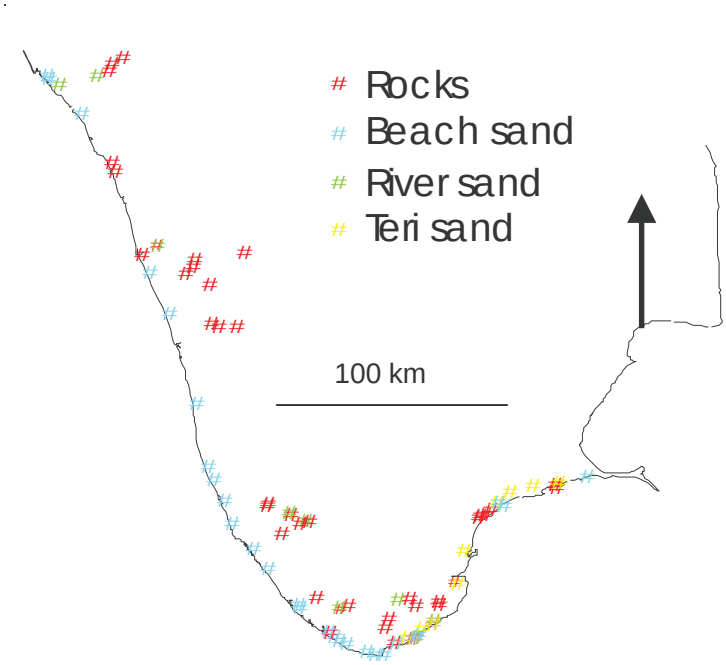

Figure 2. *Sampling localities in southern India divided into sample types.*

Results

Lab. no.	Sample no.	Sediment <0,045mm in % of total weight	Sediment >0,71 in % of total weight	% HM 0,045-0,71mm	% HM of total weight	% TiO_2 in ilmenite	% TiO_2 in all Ti - minerals	wt% ilmenite of HM	wt% zircon of HM
2000210	K3	3.09	7.22	19.15	17.17	50.0	45.4	5.8	1.5
2000211	K4	1.56	0.33	9.68	9.50				
2000212	K5	1.22	0.29	25.15	24.77	50.4	52.4	14.2	0.9
2000213	K6	1.79	27.59	14.11	9.97				
2000215	K8	0.51	2.96	79.76	76.99	53.0	58.9	26.1	12.6
2000218	K12	0.65	2.15	10.28	9.99	51.9	40.1	4.4	1.0
2000219	K14	1.39	5.08	37.46	35.04	50.2	41.1	11.1	3.6
2000220	K15	1.33	0.15	56.90	56.05				
2000225	K24	1.45	0.62	11.65	11.41				
2000226	K25	1.39	0.33	97.58	95.90	62.6	66.9	58.1	1.0
2000227	K26	0.81	0.12	98.63	97.72				
2000228	K27	1.14	1.82	87.59	85.00				
2000229	K28	0.46	0.27	96.17	95.47	61.2	66.9	46.9	21.8
2000230	K29	0.20	0.95	88.66	87.64				
2000231	K30	0.42	52.56	15.21	7.15	52.1	43.2	14.4	0.1
2000233	K32	0.43	21.51	18.25	14.24				
2000235	K34	0.39	75.17	36.88	9.01	51.4	45.7	11.1	0.0
2000238	K38	0.27	0.99	21.96	21.69				
2000239	K39	0.28	2.47	40.32	39.21	60.2	62.9	62.8	5.4
2000240	K40	0.71	0.16	87.72	86.96				
2000242	K42	0.29	31.97	11.49	7.78				
2000245	K45	0.42	5.64	74.82	70.29	52.9	51.8	44.4	2.0
2000246	K46	0.54	0.56	51.38	50.82				
2000247	K47	0.26	2.04	64.34	62.85				
2000248	K48	0.46	0.18	96.96	96.35	56.6	59.5	52.3	10.2
2000249	K49	0.57	6.58	22.62	21.00				
2000250	K50	0.63	1.34	94.48	92.61	55.2	55.1	65.0	4.7
2000252	K52	0.31	6.96	47.10	43.68				
2000253	K53	0.20	1.25	44.65	44.00	60.2	64.0	20.7	23.0
2000254	K54	2.19	11.65	6.93	5.97				
2000255	K55	0.58	37.20	44.12	27.44	52.6	55.9	12.5	0.2
2000258	K59	2.64	0.19	29.25	28.43				
2000260	K62	2.64	0.45	60.42	58.55				
2000261	K64	0.64	2.82	54.19	52.31				
2000262	K65	0.59	0.91	90.91	89.54	51.4	52.8	81.2	4.6
2000265	K68	1.85	0.37	6.39	6.25	53.5	54.2	24.2	1.3
2000266	K70	0.86	3.11	9.02	8.67				
2000267	K72	2.52	0.85	5.47	5.29	53.0	56.5	58.9	1.8
2000268	K74	4.40	3.16	8.07	7.46				
2000269	K80	0.70	0.58	74.47	73.52	50.5	48.6	26.6	1.0
2000270	K81	1.93	4.62	39.47	36.88	49.6	47.3	46.0	2.1
2000271	K82	4.22	2.82	4.27	3.97				
2000272	K83	18.96	12.55	2.72	1.86				
2000273	K86	8.56	7.52	12.80	10.74				
2000274	K87	0.18	0.63	79.49	78.85	50.3	48.6	47.7	2.4

Table 2. *Main results of the heavy liquid separation and the CCSEM analyses.*

The main results of the heavy mineral sand samples are given in Table 2 and the detailed CCSEM analyses are given in Appendix 3. From Table 2 it is clear that the investigated regions absolutely not represent high-grade TiO_2 in the whole area. The grain size of the samples varies in general between 100-400μm (see details of the individual samples in Appendix 3). In Appendix 2 a photo list from the fieldwork is given. The photos are available on a CD-ROM on request to H. Stendal.

Kerala

The Kerala river and beach sand samples (K1-K41) varies a lot in the TiO_2 contents from around 50% to more than 60% in the heavy mineral sand samples. The samples from the northern part of Kerala (K1-K15) have all around 50% TiO_2 content in the ilmenite and the total TiO_2 content goes down to 40% due to a high content of Ti-magnetite (Fig. 3).

Figure 3. *Black beach sand from the northern part of Kerala (Photo K15).*

The southern part of the Kerala region has TiO_2 content in the ilmenite over 60% in three of the analysed samples (K25, K28, and K39; Fig 4). The locality K28 represents the area close to the Chavra deposit. The coast consists of large sand bar with average width of the beach of more than 50m. However, villages are situated just few metres from the coast. Therefore the effective width of the exposed beach is about 10-20 m only. The thickness of the beach sand is >13-m as seen in the mine sections of Chavra deposit. In general, more than one terrace is noticed in the area. Near Chavra, there are two different terraces of the black sand. The upper terrace is about 1m in thickness and contains about 40-50% of black minerals. The village is just a meter away from the present shoreline on this terrace (Fig. 5).

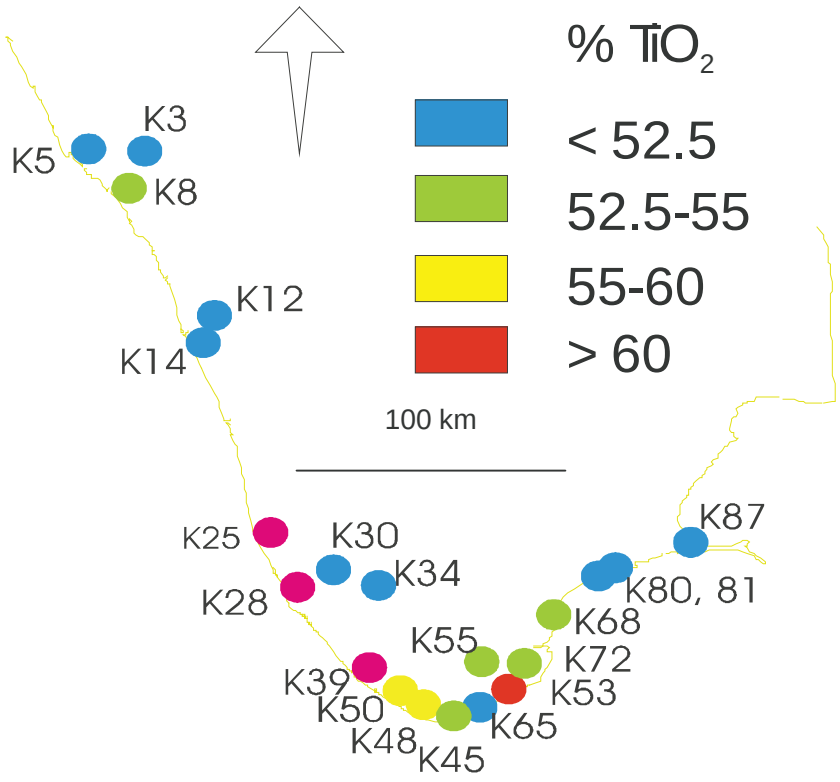

Figure 4. *TiO_2 contents in ilmenite in HM sands of the CCSEM analysed samples. See Index area in Figure 1.*

Figure 5. *Black sand near Chavra (Photo K28b)*

The present day depositional surface represents another terrace. In the adjoining Chavra, mine pits as deep as 9-m still expose black sand. The heavy mineral assemblage is dominated by ilmenite followed by sillimanite, garnet, zircon and rutile. Zircon makes up to 21.8 wt.% of the heavy mineral sample (K28).

The K39 area, the coastline is represented by small gulfs with rocky headlands. The length of these curvilinear bays vary from 30 m to 300 - 400 m. The effective width of the beach is small (< 3-m). The black sand (40% concentration, Fig. 6) occurs in two different terraces. Presence of several terraces and large thickness of the beach sediment clearly indicates a protracted event of deposition, reworking and concentration of heavy minerals in this tract. In all the above occurrences, ilmenite predominates over other heavy minerals. The thickness of the sand deposit thus formed varies from 6-m to 30-m, as is seen from the mine sections and wells. The black sand layers occur even at that depth. Thus, finding a deposit away from the coast cannot be ruled out in this sector.

Some important points from this region:

1. The width of the deposits can be more than the present due to many villages is situated on the sandbars, therefore the exact width could not be studied.
2. The depth of the deposits may also be more as is seen in the mine sections at Chavara and wells.
3. Offshore extensions exist, which is not explored.
4. Backwater lakes also contain sizeable deposits.
5. This is the only region in Kerala in this study, which have the high-grade ilmenite (over 60% TiO_2).

The beach sands with the high-grade TiO_2 in ilmenite are not the case for the river sands in the same area (K30, K34). The TiO_2 content in the ilmenite in the river sands is around 52%.

Figure 6. *Black sand from locality 39 (Photo K39).*

Tamil Nadu

The heavy mineral sand in Tamil Nadu has up to 60.2% TiO_2 in the ilmenite (K53). The sample represents river sand with 20-wt% ilmenite, 25-wt% garnet and 23-wt% zircon (Table 2; Appendix 2; Figs. 4 and 7).

Figure 7. *HM concentration in the riverbed of Nambiar river (Photo K53).*

There are several major rivers in this tract, which include Nambiar, Tamarparani and Vaigi. None of them are perennial rivers. Only during the monsoon these rivers flow. The rivers in the southern side, particularly Nambiar River, have a very short course to the sea. They flow through steep cliffs of the Western Ghats and suddenly debauch on to a flat lateritic country. In the northern part the rivers are big and matured. During the present study Nambiar River was sampled at two places. The river sand is distinctly coarse.

The beach consists of coastal sandbars and dunes up to a width of a few km. In sample K48 the TiO_2 grade is 56.6 in ilmenite and the total TiO_2 content of all Ti-minerals is close to 60% (sample K48; Fig. 4; Table 2). This locality is close to the Manavalakurichichi-Kolachel deposit, where IREL is carrying out excavation. The deposit occurs in a large bay and the concentration of heavy sands is 50 m in width. Here the sand is multicoloured, coarse-grained and contains about 60% heavy minerals. Ilmenite dominates with more than 50-wt.%, 10-wt% zircon, 2.8-wt.% monazite, and 15-wt.% garnet (Table 2, Appendix 2, and Fig. 8). Major part of the beach deposits is covered by IREL licence. The other beach sand samples (K50, K80, K87) have TiO_2 grade in ilmenite reaching 50% (K80 and 87 - northern part) and 55% (K50 - southern part; Fig. 4).

Figure 8. *Multicoloured heavy mineral sand, Manavalkurichi deposit (Photo K48c).*

Teri Sands

Vast stretches of TERI Sand deposits occur all along the coast in southern Tamil Nadu. They generally lie about ½ - 5 km away from the coast, though at places they are exposed few meters away from the present coastline. Towards the coast these Teri sand deposits are overlain by active beach sediment (see more in Vasudev *et al.* 2002). The thickness of the Teri Sands, as noticed in the wells and road cuttings, varies from 1,5-m to 7-m (Fig. 9).

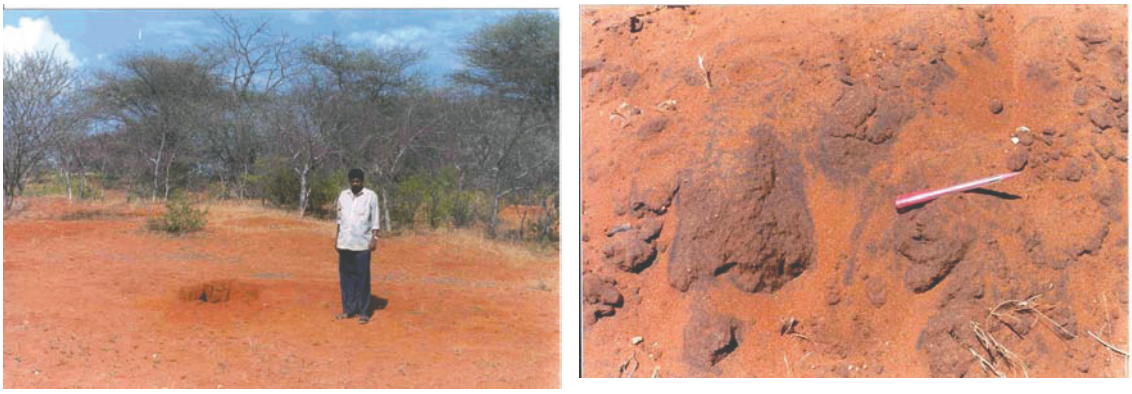

Figure 9. *Teri Sands (Photo 01). Ilmenite concentrations (right Photo K72) in Teri Sand - both photos are from the area of the Vijayaram deposit.*

The analysed Teri Sand samples (K65, K68, K72, K81; Fig. 4) vary in concentration of heavy minerals from place to place but is generally high with more than 40-wt.%. The TiO_2 grade of the ilmenite varies from 50-53% and a zircon content from 1 to 4,6-wt.%.

There are several factors, which make the Teri Sands unique. They are:

- Coexistence of quartz (lightest) and ilmenite (heaviest),
- Absence of garnet in the Teri Sands in contrast to its abundance in the provenance and in the present day beach
- Oxidised nature of the sands, which are presently located in an arid climate.
- Teri Sands are basically marine sediments, rarely fluvial, which are reworked by aeolian processes.

Conclusions

The high ilmenite grades (TiO_2 at 62 – 64 %) to be present in the Kerala, indicated by Vasudev *et al.* (2002) could be reproduced from the southwestern part of Kerala (Fig. 4). The TiO_2 content in all Ti-minerals range in that area from 63 to 67 %.

In the state of Kerala, the high-grade ilmenite samples are all of beach sands from the southern part of Kerala, whereas the northern part of Kerala is rather low in TiO_2 content (Fig. 4). The river sands have much lower TiO_2 in ilmenite (~52%). Accordingly, the up-grading process of TiO_2 in ilmenite is suggested to happen in the beach zone.

In the state of Tamil Nadu, a high concentration of heavy minerals occurs in the beaches. Close to southern tip of India high-grade TiO_2 in ilmenite occurs in one beach sand sample (56,6% in K48; Fig. 4) and in the river sand of the Nambiar River (60,2% K53; Fig. 4). The Nambiar River only flows during the monsoon period and the sediments are coarse-grained. The changing wet and dry season might have something to do with the high-grade TiO_2 in ilmenite.

The Inland Teri sands of Tamil Nadu are red undulating dunes but probably original marine sands occupying higher elevations relative to the surrounding areas. The Teri Sands do not have high-grade ilmenite.

The overall conclusion is that the high-grade ilmenite in this study is only found along the southwestern shores of Kerala and elevated TiO_2 values occur only in few places in Tamil Nadu (southern tip of India; Fig. 4).

Recommended further work in that region will be:

- To constrain the high-grade ilmenite deposits along the southwestern shores of Kerala. This constrains shall be used to estimate the potential sizes of the deposits.
- To involve local companies in this work, which might help in the process for eventually later exploitation activities and/or for buying the ilmenite products.
- To continue the work with provenance, aiming at understanding the source of the high-grade ilmenite and understand the processes responsible for the enrichment of the ilmenite.
- Evaluate possibilities of locating offshore high-grade ilmenite deposits adjacent to onshore deposits of high-grade ilmenite.

Reference

Vasudev, V.N., Jensen, J.B., Lomholt, S. and Stendal, H. 2002: Heavy mineral ressource potential of India: an overview. GEUS Report 2002/5.

Appendix 1

Report on the heavy mineral and provenance rocks sampling carried out in April 2002 in Kerala and Tamil Nadu, South India.

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Mineral Resources Consultants
Bangalore
Dt.18.5.02
INTRODUCTION

In continuation of the ongoing project on the "Heavy mineral resource potential of India", fieldwork was carried out in the states of Kerala and southern Tamil Nadu during April which is a summer month in south India. The purpose of the field study is as outlined by Dr. Henrik Stendal in his email dated 8th February 2002 communicated to Vasudev. The purpose is three fold Viz.,

1) to collect samples of the beach sand at certain interval both along the west and east coast of south India and Teri sands inland close the east coast in Tamil Nadu state;
2) to collect heavy mineral sands from few major rivers that carry heavy mineral sands to the beaches along both east and west coasts and,
3) to collect samples of dominant rock samples from the high grade metamorphic terrain that constituted the provenance for the heavy mineral sands. The map showing all the sample locations is enclosed here with (already sent by email).

The hinterland for the beach sand deposits is made up essentially of Precambrian granulite facies metamorphic rocks of volcanic and sedimentary parentage and, plutonic rocks. The terrain has undergone extensive reworking during the Neoproterozoic (~0.6Ga) and is traversed by several major ductile shear zones, which trend E-W, WNW and also ENE. Prominent among them are; a) WNW trending Moyar Shear Zone in the north located at the southwestern fringe of the *c*.2.6Ga Dharwar Craton, (b) NE trending Bhavani Shear Zone, (c) E-W trending Palaghat-Cauvery shear zone, (d) Periyar Fault Zone and (e) NW trending Achankovil Shear Zone in the south. These shear zones are 20 to 50km wide and characterised by amphibolite facies retrogression. These structures demarcate the boundaries of different lithotectonic blocks having diverse tectonometamorphic histories. Large linear bodies of mafic and ultramafic granulites, granitoid plutons and fine-banded bt-hnbl mylonitic gneisses constitute the Bhavani shear zone. The Palaghat-Cauvery shear zone is essentially composed of mylonitic and banded bt-hnbl gneisses and irregular bodies of charnockites and granitoid plutons. The terrain between (a) and (b) zones are composed dominantly of charnockites and gneisses; beween (b) and (c) is made up essentially of migmatitic gneisses and linear bodies of charnockites and south of (c) the terrain is composed of charnockites, gneisses charnockites. Similarly, the terrain between Periyar Fault and Achankovil shear zone is composed of massive charnockites, with few metasedimentary and metabasic granulites. The terrain south of Achankovil shear zone is composed of Neoproterozoic granulite belt known as TGB (Trivandrum Granulite Belt) or Kerala Khon

dalite Belt (KKB). It is composed of granulite grade metasediments with leptynites, charnockites and intrusive alkali granites.

All the major beach sand and Teri deposits are concentrated along the east and west coast line of the terrain south and east of Achankovil shear zone.

The subtle differences in the hinterland geology described above have brought about significant variation in the concentration of heavy minerals in the beach sand deposits. For example, the coast line southwest of the KKB is laden with several world class deposits as at Chavra, where as the terrain just north of it, i.e., the terrain between Periyar Fault and Achankovil Shear is devoid of any deposit. Further, the terrain between Periyar Fault and Plaghat shear zone is known to contain black sand deposits, but the proprtion of ilmenite is less than the pyriboles. Similar variations can be noted along the East Coast also.

A description of the sampling and related field observations are summarized under the following five headings;
1) The Block up to Palghat Shear zone,
2) The block between Palghat and Periyar Faults,
3) The Block between Achankovil Shear zone and Trivandrum,
4) The Block between Trivandrum and Kanyakumari and
5) The large tract between Kanyakumari and Rameshwaram along the East Coast.
It is to be noted that, though the classes 3 and 4 fall in the same geological block, i.e., KKB, subtle differences are noted in the concentration of heavy minerals. For example, in the block 3 ilmenite concentration is more, where as substantial amount of monazite is noted in the block 4. In each block, the lithological characters, river system and beach sand deposits / coastline is discussed presented.

Sampling Procedure
Unbiased but representative grab samples of river sand, beach sand and rock samples were collected. The locations are registered with the help of GARMIN GPS II and numbered K1 onwards. Photograph of every observation/sampling point was taken. About 5 kgs (some times, for the same volume of material the bag weighed 10 kgs due to higher content of ilmenite/garnet) of beach or river sand was collected. Rock samples weighed 3 to 5kgs.

SUMMARY OF THE BLOCK NORTH OF PALGHAT SHEAR ZONE

This block is bounded by Palghat - Cauvery shear zone in the south and a high grade schist complex fringing the Dharwar craton in the north. It is traversed by many rivers, amongst which Iritty river in the north and Beypore river in the south are prominent. Both are perennial rivers.

Lithology: The block is composed of garnetiferous gneisses, massive charnockites, and granites *s.l.* Gneisses represent the major lithounit of the block, followed by granites and charnockites. Garnetiferous gneisses, exposed near Iritty town about 60 km from the coast, are medium to coarse - grained and exhibit well-developed gneissic banding **(Photo K2).** Incipient granite melt structures are common in it. Garnet constitutes about 15% of the rock. They are metapelitic gneisses of upper amphibolite grade. In addition, near Iritty

town, orthogneisses of granodioritic composition are seen, which exhibit faintly developed banding defined mafic and felsic layers. They are made up of bt + amph + plag + qtz. Granoblastic texture, indicating high-temperature recrystallization, is common. These gneisses may be high - temperature solid-state deformation products of granodiorite protolith. Deformation took place in amphibolite to granulite grade. In addition, near Kappad beach are exposed migmatite gneisses, with amphibolite paleosome, granodioritic melanosomes and granitic leucosome. Stromatic and agmatic structures are common **(Photo K10).** The gneissic banding in this block trends 20°-40° E and dips 50° towards SE.

Charnockite in this block is massive, megacrystic and contain magacrysts of pyroxene. Charnockite is devoid of any deformational fabric but are cut by fine-grained granite sheets **(Photo K1).** They are exposed near Virajpet and Iritty towns. Apart from this, south of Iritty town, a large tract is represented by coarse-grained bt-bearing pink granites. They do not have any heavy minerals and also devoid of deformational fabric. Among the rocks in this block gneisses seem to be the source for the heavy minerals, by virtue of it being the dominant lithounit in the block.

River System: This block contains several major rivers, of which Iritty and Beypore are prominent. These rivers originate on the granulite terrain lying to the east and drain westerly towards the sea. They generally meet the sea at high angle, with large backwater lakes. However, several large coast-parallel sandbars of fluvio-marine origin, control the direction of the river course. Thus, some times the rivers are bent either to north or south, before meeting the sea. For example, Iritty River bends southerly and Beypore River swings northerly before reaching the sea. This phenomenon has been attributed to the faulting by some workers. During the present study, Iritty River is sampled for the stream sediment at two places. This being a Perennial river, sand is not exposed in the river bed anywhere (**Photo K3, photo of the river**). Thus, samples from the sand dumps were studied and collected. This river, as observed near Iritty town, drains through charnockites and gneisses. The sand collected near Iritty town is medium grained and contain about 5% of black minerals **(Photo K3, sand photo**). The black minerals are by ilmenite and / or pyriboles. Second sample is collected from the backwaters. Here the sand is coarse grained and contain <5% of the heavy minerals.

Beach: long, coast-parallel sandbars and small bays represent the coastline in this block protected by rocky headlands. The beach between north of Mattul and Quilandi belong to the first type, whereas the coastline between Quilandi and Ellattur belongs to the second category. Between Mattul and Quilandi the beach has gentle slope and made up of parallel sandbars, deposited by long-shore currents **(Photo K4**). The shoreline is receding as the deposition taking place. Here, the width of the beach varies 50 to 100 m. On the other hand, coastline between Quilandi and Calicut has steep slope towards the sea. The small bays between rocky headlands contain narrow beach, which is some times less than 1m. The amount of sediment deposition in these bays is very less. It is to be noted that the width of the beach is more in the northern part than in the south. However, the exposed width of the beach is controlled (!!) by the presence of villages, which sometimes stand right on the coast line (just a1m from the active sea line). However, at many places, like Mattul, it is wide. Concentration of black minerals in the beach sand is noticed sporadically between Mattul and Badagara **(Photo K5**). In general, the black minerals form about 5% - 10% of the beach sand. In some cases, like near Telicherry, they represent 50% of the

sand **(Photo K8).** Ilmenite and pyribole dominate the heavy minerals. They occur as small patches and streaks on the beach. Sometimes the concentration is more along the coastal bars. In the Telicherry, beach burrows show black sand subsurface. In some cases, the beach sediment is reworked due to seasonal fluctuations in the sea level. This leaves sea-cut terraces marked by laterite along the active beach **(Photo K10).**

SUMMARY OF THE AREA BETWEEN PALGHAT AND PERIYAR FAULTS

Palghat shear zone in the north and NW trending Periyar Fault in the south bound this block. It is traversed by number of rivers, of which Bharatpura in the north and Challakudi River in the south is prominent. Both join the sea with large backwater system.

Lithology: The rock types in this block are represented by massive charnockites, migmatitic gneisses, garnetiferous gneisses and mafic granulites. The charnockites are coarse-grained, greasy in appearance and traversed by number of carbonate veins **(Photo K11).** The charnockites cover a large, NW-SE trending tract between Valancheri in the west and Shornur in the east. The migmatitic gneisses are exposed to the east of the charnockite country. Good exposures of the migmatitic gneisses are seen between Ottapalem up to Palghat and further east. Near Palghat they are stromatic, agmatic to schleric in nature **(Photo K19).** The Palaeosomes are amphibolitic, melanosomes are dioritic to granodioritic and leucosomes are quartzo-feldspathic in composition. The gneissic banding in this block trends E-W to 280°. Thin sheets of granite are emplaced along banding. Similar polyphase gneisses are exposed all along the Challakudy River in the southern part of the block. In addition, near Atripally garnetiferous gneisses are exposed. Garnet is seen both in melanosomes and leucosomes **(Photo K23).** It is possible that the protolith for the garnetiferous gneisses is a pelitic rock. Few exposures of the mafic granulites are seen in the central part of the block. The mafic granulite exhibit granoblastic texture represented by the equant grains of pyroxene, plagioclase and quartz. The protolith could be a basic rock. In essence, this block is composed of pelitic and basic rocks, which were migmatised during granulite facies metamorphism. In turn, massive charnockites and granites intrude them.

River System: All the rivers in the block are fault controlled. For example Bharat river follows Palghat shear zone and Challakudy follows another E-W fault. Large backwater lakes are formed where the rivers meet the sea. Like in the previous block, the rivers meet the sea at high angle. However, large coastal bars control the course of the several smaller rivers, which flow parallel to the coast for some distance. Few interconnected lakes are seen along this river course. It is to be noted that both Bharat and Challkudy rivers bend southerly, before meeting the sea.

During the present study both Bharat and Challkudy rivers were studied for their river sediment. The Bharat River is examined at two places. Near Valancheri the river sand is made up of different fractions ranging from fine to coarse sand with rare pebbles **(Photo K12).** Few point bars with coarser size fraction are noticed. Heavy minerals are generally concentrated with the finer fractions of the sand (**Photo K12**; **close up of the sand**). The black minerals form about 5-10% of the stream sediment. The heavy minerals in the stream sediment are ilmenite, magnetite, pyribole, epidote, zircon and brown mica. Further, upstream near Shornur, the heavies are uniformly distributes in the sand and constitute <5%. They are represented by ilmenite / pyribole, zircon and garnet. There is an ap

parent enrichment in heavies from Shornur to Valancheri, along the downstream in the Bharat River. It is not clear whether this is true for all rivers or not. In the Challakudy river, the coarse sand fraction contain <3% of heavies - ilmenite / pyribole and garnet. Presence of garnet in the river sediment clearly suggests the garnetiferous gneisses as one of the major source component.

Beach: The coastal tract between Ponnani and Irinjalakkuda is covered by large coastal sand bars of fluvio-marine origin, which extends for a length of 50 km with an average width of 1 km. This signifies large-scale deposition and emergence of coast along this tract**. Villages leaving only few meters of beach 50 mts cover major part of the sand bar.** In some places the beach is reclaimed. The beach sediment was examined at three places i.e.near Ponnani, Kadikkal and Irinjalakkuda. Near Ponnani a 60cm thick terrace is seen, which spreads over a width of 20 m **(Photo K13).** The visual proportion of the black minerals is ~20% and they are uniformly distributed. The mineral assemblage is ilmenite + pyribole + garnet + zircon + epidote + fluorite ?

Near Kadikkal two different terraces, other than the present depositional surface, are seen **(Photo K14).** The upper terrace is about 30cm and the second one is about 1m thick. Both contain thin laminae of black heavy minerals. In the present day depositional surface the heavies occur both as <1 cm thick layers, as well as uniformly dispersed grains throughout the sand **(Photo K14).** In the first case the concentration of heavy minerals **is as high as 80%,** where as in the second case they constitute 20% of the sand. The heavy minerals include ilmenite + pyribole + garnet + zircon. **The exposed width of the beach is about 200 mts**. However, the thickness is not clear. Presence of different terraces, formed over a long period of time, suggest greater thickness of the beach sands. During the seasonal fluctuations, the earlier terraces are reworked, contributed to further winnowing and concentration of heavy minerals.

At the southern end, near Irinjalakkuda only one depositional surface is seen, which is the present day depositional surface. The width of the active beach is about 15-20 mts, which extends over few km **(Photo K15).** The slope along the beach is very gentle. Also the grain size of the beach sand is finer than the other two places. Visual estimation of the **black minerals is ~30%.** Other heavies include zircon and fluorite. Garnet content in the assemblage is very low to absent. It appears that where the grain size of the sand is more, the proportion of the garnet increases. On the other hand, **where grain size is finer, black mineral concentration is high** in the beach sediment.

On the whole this tract looks promising simply because of the extent of the area covered by the coastal sand bar. With in the tract, the southern portion is more promising. However, it depends a lot on the relative proportions of ilmenite and pyribole in the beach sand. At present no major exploration or moning activity is underway in this block.

BLOCK BETWEEN ACHANKOVIL SHEAR ZONE AND TRIVANDRUM

This block lies between Amblapulai in the north and Kovalam (near Trivandrum) in the south i.e. between Pamba - Achankovil river system in the north and Attingok river in the south. Lithologically the rocks of this block form part of Kerala Khondalite belt (KKB). This block is traversed by several rivers, namely Pamba, Achankovil, Pollikapal, Kallada and

Attingok. The famous ilmenite deposit at Chavra being mined by IREL is located in this block.

Lithology: The rocks in this block include garnetiferous gneisses, khondalites, leptynites & charnockites. All the rock types in this block contain garnets. Most abundant of the above rock types is garnetiferous gneisses and/or Khondalites. The garnetiferous gneiss contains garnet, plagioclase, biotite, quartz and heavy minerals like ilmenite and spinel **(Photo K31 near Punalur).** Garnet constitutes ~ 20% of the rock goes up to 30% in places. Garnets occur both as dispersed grains throughout the rock or as discrete bands **(Photo K36).** They are prophyroblastic and contain inclusion trails. Melt generation structures are evident. The khondalites are composed of garnet, plagioclase, biotite, quartz and sillimanite. Leptynites also contain garnet, biotite, plagioclase and quartz, and are characterized by distinct gneissic layering. The leucosomes in the leptynites are made up of quartz and feldspar where as 1-2 cm thick melanosomes contain garnet + biotite. Garnet in leucosomes is rare. At many places incipient charnockitization is seen along the gneissic banding **(Photo K36).** Both incipient and massive charnockites are seen in the area. The incipient charnockites contain garnet and cordierite apart from quartz, feldspar and pyroxene. It is greasy looking rock and fabric free, except for relict gneissic fabric at some places. Thegneissic fabric in the various rock types always trends 320°, which is the regional trend of the KKB. All the above rocks occur as interlayered sequences which together constitute the Kerala Khondalite Belt.

From the field observations and available literature it is evident that the protoliths for different types of gneisses are pelitic to semipilitic in composition. It is also clear that the heavy minerals like ilmenite, zircon, garnet and sillimanite are released from the Khondalite Group of rocks.

River System: As indicated earlier, several rivers flow from east to west and meet the sea in this block. Many of these rivers are fault controlled. For example Achankovil and Kallada rivers have absolutely straight NW-SE trending course, which is parallel to the Achankovil shear zone. Both take westerly swing and follow SW course to meet the sea. They also form large backwater lakes. River Kallada flows in to the “Ashtamudi Lake”.

Among the rivers, Kallada river was studied and sampled at three different places along its upstream. It is a perennial river and hence the sand dumps were studied and sample collected. Near Adur, the sand is coarse grained and contains about 5% of heavy minerals which include ilmenite, garnet and zircon **(Photo K32).** Among the heavy minerals, garnet is coarser in size, whereas ilmenite is finer. Ilmenite concentration is more in the finer size sand. Before Punnalur, the sand is medium- to coarse - grained and contains about 10% of heavy minerals. Here also garnets are coarse - grained than ilmenite. Further upstream, near Tenmalai, the river course is straight and run NW-SE. The riverbed deposit shows different size fractions, which can be classified as fine, medium and coarse-grained **(Photo K34).** All the fractions contain garnet and ilmenite. However, enrichment of ilmenite is noted in the finer fractions. Different sizefractions of garnets clearly suggest varying distance to Provenance. Further upstream, near Tenmali, a dam is built across the Kallada River. On the lee side of the dam crevices and potholes in the bedrock are filled with **almost 100% ilmenite of fine size fraction.** This location is about 70 km from the beach.

The above observations suggest that:

1. Ilmenite, garnet and other heavies are derived from Khondalites i.e. garnet bearing high grade metamorphosed aluminous sediments,
2. Their provenance extend up to >60 km from the HM deposits.
3. Garnets show wide variation in size depending on the distance to the provenance. However, ilmenite shows little variation in size. This is possibly a reflection of it's uniform size in the host rock.
4. Ilmenite concentration is more in the finer fraction of the sediment.
5. Down stream ilmenite survives more than garnet.

Beach: The entire stretch between Amblapulai and Kovalam shows anomalous concentration of heavy minerals. The coastline between Amblapulai and Anjengo is gently sloping, whereas near Kovalam, it is represented by a small bay with rocky headlands.
Near Varkala, steep lateritic cliffs are seen near the beach, which points to erosional coast. The wave direction at many places is oblique (NEly) to the coastline. A northerly directed long shore current direction is common.

The depositional coast between Amblapulai and Anjengo consists of large sand bar. The **average width** of the beach in this sector is more than **50m**. However, villages are situated just few metres from the coast. Therefore the effective width of the exposed beach is about 10-20 m only.

The thickness of the beach sand is >13m as seen in the mine sections of Chavra deposit. In general, more than one terrace is noticed in the area between Amblapulai and Anjengo. Near Chavra, there are two different terraces of the black sand **(Photo K28).** The upper terrace is about 1m in thickness and contains about 40-50% of black minerals **(Photo K28).** The village is just a meter away from the present shoreline on this terrace. The present day depositional surface represents another terrace. **In the adjoining Chavra, mine pits as deep as 9m still expose black sand.** The heavy mineral assemblage is dominated by ilmenite followed by sillimanite, garnet, zircon and rutile.

North of Varkali two terraces of 1ft thick, apart from the present day depositional surface are seen. Further south, near Anjengo different terraces are seen with uniformly distributed black sand. However, the concentration is ~10% **(Photo K38).**

Near Kovalam beach, the coastline is represented by small gulfs with rocky headlands. The length of these curvilinear bays vary from 30 m to 300 - 400 m. The effective width of the beach is very less (< 3 mts). The black sand (40% concentration) **(Photo K39)** occurs over two different terraces. Presence of several terraces and large thickness of the beach sediment clearly indicates a protracted event of deposition, reworking and concentration of heavy minerals in this tract. In all the above occurrences ilmenite predominates over other heavy minerals. The thickness of the sand deposit thus formed varies from 6m to 30m, as is seen from the mine sections and wells. The black sand layers occur even at that depth. Thus, finding a deposit away from the coast cannot be ruled out in this sector. In addition, near Haripad, GSI is carrying out offshore survey, which yielded good results**.** The backwaters of Ashtamudi lake and other smaller lakes contain about ~20-30% black minerals.

Important points:

1. The width of the deposits can be more. Many villages are situated on the sandbars, therefore the exact width could not be studied.
2. The depth of the deposits may also be more as is seen in the mine sections at Chavara and wells.
3. Offshore extensions exist; to be explored.
4. Backwater lakes also contain sizeable deposits.

BLOCK BETWEEN TRIVANDRUM AND KANYAKUMARI

This block is the continuation of the block described above and includes the famous Manavalakurichi deposit. The rocks in the provenance are the same as in the previous one. However, subtle differences in the mineralogical composition of the heavy mineral sands are observed between the two. The deposit in the Chavra is ilmenite - dominant, whereas, the Manavalakurichi deposit contains abundant Monazite and ilmenite. Few small rivers of which Martand River is a prominent one traverse this block.

Lithology: The major rock types in the provenance are garnet-biotite gneiss (khondalite), leptynites, charnockites, and garnet – bearing granites. The khondalites like elsewhere, contains garnet - plagioclase- biotite and quartz with or without sillimanite **(Photo 44).** The leucosomes in them are quartzo-feldspathic with bands and clusters of garnets. The charnockites are massive, structureless and contain garnets. Few relict patches of khondalites are seen in them. Granites are medium- to coarse grained and are distinctly alkaline. Garnets are homogenously distributed in them. Granites occupy a large area in the provenance. They appear to be anhydrous melts. The gneisses trend 320° and dip steep to shallow towards SW.

River System: There are several small rivers in this block, which flow either to SW or S to meet the sea. They have very short course compared to the rivers in the other blocks, and reach the sea in youth stage only. Few backwater lakes are seen. One of the major rivers, i.e. River Martanda, has been studied near Kaliyal. This river contributes sediment to the Manavalakurichi deposit. It is a perennial river and the river sand contains abundant garnets along with the other heavies. The sediment is coarse grained.

Beach: The coastal area between **Puvar (south of Trivandrum) and Kanyakumari** has been studied at several places. Several bays bounded by rocky headlands, and vast stretches of the sandbars characterise the coastline. In both the cases, seasonal variations in the sea level produced different terraces with variable thickness. At some places the previously deposited terraces were reworked. In general the slope of the beach is shallow and rarely steep.

Near **Kanyakumari,** several small bays contain narrow beaches (<20m). The sand in these beaches is coarse - grained, reddish brown and contains about 20% heavy minerals **(Photo K45**). The heavy minerals are garnet + monazite + ilmenite. They are spread in patches in which ilmenite dominates over other heavy minerals.

South of **Nagercoil** the beach is made up of several terraces and heavy mineral concentration is seen on all the terraces **(Photo K47).** The dark patches you see in the photo are

dominated by ilmenite, sometimes reaches up to 30%, followed by garnet and monazite. The heavy mineral sands occur as patches along a length of ½ km with an exposed width of 100 m. A village is situated on one of the terraces.

Near **Manavalakurichichi-Kolachel,** where IREL is carrying out excavation, the deposit occurs in a large bay and the concentration of heavy sands is spread over 50-m width **(Photo K48).** Here the sand is multicoloured, coarse-grained and contains about **60%** heavy minerals. Ilmenite dominates followed by monazite and garnet. Heavy mineral concentration is slightly less in the present day active beach sediment. It is learned from the local people that the beach is slowly submerging, with the **sea transgressing the land at a rate of 10m / year!!!** This indicates a possibility of finding a deposit on the shallow sea. Another important feature is that the Manavalakurichichi and Kolachel deposit contains well-developed Teri Sand away from the coast. These Teri Sands are reddish in colour and coarse - to grain. They contain ~5-10% of the heavy minerals. It is to be noted that these red sands also contribute heavy minerals to the beach placers. **In this block too, like in the other blocks, the beaches are thickly populated and villages are situated right on the beach**. Major part of the beach deposit is covered by IREL.

THE COASTAL TRACT BETWEEN KANYAKUMARI AND RAMESHWARAM

This tract covers a large area in the East Coast of India. It contains several known beach sand deposits, easpecailly garnet deposits. Several major rivers drain through this block, including Nambiar, Tamaraparani and Vaigi.

Lithology: The major rock types in this tract include, khondalites, mafic granulites, charnockites and granites. The rock units in the southern part, between Kanyakumari and the Tamaraparani River, belong to KKB. The rocks between Tamaraparani river and Rameshwaram form part of another Precambrian granulite terrain. The khondalites in this tract contain garnet-biotite-plagioclase-quartz **(Photo K66).** The gneissic fabric trends 320° paralleling the KKB trend. Both incipient and massive charnockites are present. Several phases of granites, majority of which contain garnet, are present in the area. All these rocks contributed garnets and other heavy minerals to the present day beach. Near the coast all the rocks are lateritized with the flat blanket of laterite lying almost at the present day sea level extending up to the Western Ghats (“Ghat”me ans Hill range) with the sea in the east. Western Ghats might have risen during a neotectonic regime in the Late Quarternary (Late Pleistocene to mid Holocene reactivation of the Precambrian faults: Valdiya K.S.2001). This neotectonic activity is thought by us as important in the formation of TERI sands; discussed later. The maximum thickness of the laterites is 10m.

River System: There are several major rivers in this tract, which include Nambiar, Tamarparani and Vaigi. None of them are perennial rivers. Since, this area, particularly between Kanyakumari and Tuticorin presently fall in the rain shadow zone, contribution from the minor streams to these rivers is also insignificant. Only during the monsoon these rivers flow. These rivers originate in the Western Ghats and flow SE and E to the sea. The rivers in the southern side, particularly Nambiar River, have a very short course to the sea. They flow through steep cliffs of the Western Ghats and suddenly debouch on to a flat lateritic country. In the northern part, i.e. between Tiruchendur and Rameshwaram, the rivers are big and matured. During the present study Nambiar River was sampled at two places. The

river sand is distinctly coarse and contains abundant garnets along with other heavy minerals **(Photo K55).** Other heavies include ilmenite and zircon.

Beach sands: The coastal tract between Kanyakumari and Rameshwaram is covered by vast stretches of coastal sandbars and dunes. The width of the beach sediment in such cases exceeds **few kms away from the coast**. However, at few places, particularly near Kanyakumari, the coastline is dotted with few bays with rocky headlands. Here the width of the beach is less (~300m). **Many villages are situated on these sandbars.** Several terraces are found in many of the beaches. Apart from the present day, active beach sediment, vast stretches of Teri sands are found along the East Coast. Both Teri Sand deposits and active beach sand deposits are discussed separately.

TERI SANDS (PALAEO BEACH?):

Vast stretches of TERI sand deposits occur all along and close to stern coast between Kanyakumari and Rameshwaram. They generally lie about ½ km away from the coast, though at places they are exposed few m away from the present coastline. Towards the coast these Teri sand deposits are overlain by active beach sediment. In the west, the Teri sands overlie the coast-level laterite referred to above. Well-developed Teri Sand deposits can be seen around Idindakarai, Ovari, Navaladi, Sttankulum-Surangudi, Kudiraimoli and Sevalmaptti-Vembar as illustrated in Vasudev et al., GEUS Report 2002/5. The width of the Teri sand deposits is variable, ranging from 500 m to 5 km. Similarly the thickness of the Terisands, as noticed in the wells and road cuttings, vary from 1,5m to 7m. Kudiraimoli Teri sand deposit is the largest followed by Sattankulum-Surangudi and Sevalampatti-Vembar. Presence of lateritic clay unit is seen underlying the Teri sand deposits in some of the well sections.

The Teri sand terrain is undulatory, appear reddish and devoid of any vegetation except for palm trees and thorny shrubs (see Photos K54, 58, 62, 65, 69, 70, 71, 72, 81, 82). As a result the area is poorly inhabited. The terrain bears the look of a desert. Soil Conservation department is making some efforts for better utilisation of the land. For most part of the year the streams draining through the Teri deposits remain dry.

Teri sand deposits vary in colour from pale to deep brownish red. They are composed of fine- to medium-sized sand grains of quartz and fine grained ilmenite, rutile and zircon (-80 +100 mesh size) dominated by ilmenite and rutile. Garnet is practically absent. The heavy mineral concentration varies from 5-20%. Grain size distribution is uniform through out the deposit, though at places dominance of one particular grain size is noticed. Individual grains are well rounded. Traces of bedding are preserved in many places (Photo). In some cases alternate fine and medium-grained units define the bedding. In general, Teri Sands are poorly cemented and hence are porous. Due to the high friability, they are easily stripped off by wind.

The concentration of heavy minerals varies from place to place. For example, very high concentration is noted near Idindakarai, Ovari-Navaladi, and Vembar. On the other hand, Teri Sands near Tutukudi are practically devoid of any heavy minerals. It is not clear whether the selective enrichment is a primary feature or is attributable to the secondary

processes. The color of the Teri Sand is directly proportional to concentration of ilmenite and rutile in it. High concentration imparts deep brownish red colour to the sand.

Enrichment of ilmenite and rutile appears to have been aided by aeolin process as noticed in an individual deposit. Wind action has resulted in patchy enrichment of ilmenite and rutile (Photo). Small streams and rivulets, at places contain almost 100% ilmenite, as noticed in Idindakari deposit (Photo).

A Note on the origin of Teri Sands:

There are several factors, which make these Teri sands unique. They are:

1) Coexistence of quartz (lightest) and ilmenite (heaviest),
2) Absence of garnet in the TERI sands in contrast to its abundance in the provenance and in the present day beach
3) Oxidised nature of the sands, which are presently located in an arid climate.

Any hypothesis should explain all the above features.

As pointed earlier, Teri Sands are highly mature sands. This coupled with their distribution parallel to the coast clearly suggests that they are originally beach sands. Occurrence of Teri Sands, as far as 5 km from the coast indicate that either the coast line has developed that much distance over a period of time, or the sands are transported by wind or some of them could be of fluvial origin.

Available literature suggests that these Teri Sands are basically marine sediments, rarely fluvial, which were reworked by aeolin process. Many workers attribute anomalous segregation of ilmenite in these sands to this process. However, this process could not explain the absence of garnets in the Teri Sands. Many workers attribute this to the aeolin processes subsequent to their deposition. However, we have serious doubts about this explanation. The wind action can not selectively enrich ilmenite and remove garnet from the sand.

We interpret that this bimodal nature of the Teri sands can be explained by invoking oxidation during lateritization of the original multi component beach bands. Oxidation and leaching of the beach sand deposit removes easily oxidisable iron bearing minerals such as magnetite and garnet. The exact timing of the enrichment of the Teri sands is not clear. It is to be noted that the Teri sands lie over low level laterites. But the age of lateritization has not been worked out so far.

Presently Teri areas fall in the rain shadow zone of the Western Ghats and receive little or no rain. That would automatically mean the laterites were formed prior to the formation of the present day topography. It is well known in the Indian literature that, upliftment of the Western Ghats took place during post-Cretaceous period, possibly during Late Quaternary Neotectonic movements. Thus, it is possible that these laterites were formed after the separation of the Gondwana continents but before the Quaternary Neotectonics. Lateritization brought about selective removal of garnet and other easily oxidizable minerals like magnetite.

Beach Sand Deposits

The present day beach between Kanyakumari and Rameshwaram along the east coast is characterized by wide stretches of sand deposits, which often extend few hundred meters inland. They are constituted of various terraces and coast-parallel sandbars. The sandbars control course of several small streams. The beach is gently sloping. Active beach sedimentation is going on. The beach sand was studied at few places, namely near Idindakarai, Vembar and south of Paniakulum. Several Indian private mining companies doing garnet mining, making it difficult to access cordon off the entire tract of the beach. In the places where studied, the beach sands are coarse- to medium-grained and are multicoloured **(Photo K48a, c)**. The proportion of heavy minerals range from 20-50%. Garnets, ilmenite, rutile, zircon and other heavies represent the heavy mineral assemblage. Among the above garnets are dominant followed by ilmenite. In fact, all the mining activity is concentrated towards garnet only. The width of the beach sand deposits varies from few meters to few tens of meters. The depth is not clearly known, but it is learned that it could be ~10m. Thickness should be more, as the East Coast is known to have prolonged history. The length of the individual deposits also varies widely. The concentration of heavies is generally more in the southern part, where as in the Ramanathapuram district it is very less. This can be attributed to the preponderance of garnetiferous rocks in the provenance in the southern part. The carrying the heavy minerals must have (we guess) originated in post Quaternary times after the neotectonic upliftment of the Western Ghats (hill ranges).

Mining Activity: Large-scale mining is going on here and there along both the coasts particularly along the east. As many as 6 companies (named above) are actively working mainly for garnets along the east coast of Tamil Nadu State. We understand that the entire coastal stretch is covered either by exploration and prospecting licences or Mining Leases for garnet. Nevertheless, interest in Ilmenite and rutile is shown by very few companies namely IREL, TATA the Indian giant, and the Australian Mineral Deposits Limited (MDL) in association with ISCOR (RSA).

Economic Potential of Teri Sand:

As described earlier, the Teri sand deposits cover large areas with ~5-20% ilmenite. Also, they persist at depth of up to 10 m. Since the terrain covered by Teri Sands is barren for most part, it is easy to exploit. Among the places visited during the present fieldwork, deposits around Ididndakarai, Ovari-Navaladi, Kudiraimoli, Sevalmaptti-Vembar appeared very promising.

There are few mining companies working the beach sands and that is mainly for garnets, namely VVM (Vetri Vel Minerals), BMC, TWG (Trans World Garnets), IOGS (Indian Ocean Garnets) and Manikam Minerals. No exploration activity is noticed along the Teri Sand deposits. However, it is learnt that Kudiraimoli, (370 million tonnes grading 8.9% total HM with Ilmenite at 23 milion tones), Sattankulam, Navladi, Periathalai deposits (610 million tones grading 11.3% total HM, with Ilmenite at 38 million tonnes) have been earmarked for exploitation by an Australian Company styled Mineral Deposits Limited (MDL) in association with Iscor Limited (RSA). It is not known whether these deposits have been leased to the Indian entities of these two majors or not. It is rumoured that a big processing plant is going to be established here. There is no sign of any construction activity in this region though these companies reported to have crystallized their agreements with the Indian companies. Needless to caution that Du Pont should hurry up to acquire exploration or

Mining Leases in India as the HM resources of India has already drawn enough attention of both national and International attention and competition to acquire lands has already set in.

ANNEXURES

(Source: MMR, June 2000, page.49)

Transworld Garnet India

Transworld Garnet India Private Limited (TGI), a wholly owned subsidiary of Western Garnet International (WGI), Canada has established a 100% EOU for processing of heavy mineral sands and recover the “almandite garnet” and upgrading the same before export. The plant with an installed capacity of 60,000 tonnes per annum, established at a total cost of about Rs. 22 crores near Tuticorin, Tamilnadu, has gone into commercial production during April, 1997.

Western Garnet International, Canada, one of the world’s largest producers of almandite garnet, has supplied the latest technological process, plant and machinery and other inputs to its subsidiary. TGI has secured its own captive resources for processing.

TGI has so far exported over 80,000 tonnes of garnet abrasive of 8/9 mesh sizes to 25 countries the world for a total value of Rs. 2510 lakhs during the past 3 years. TGI’s share in the export of Garnet sand from our country is around 40-42 per cent.

Appendix 2

Photo description

All photos are in the Archives at GEUS as 'jpg' files.

01	Sattankulam - Vijayapuram deposit
K2	Irritty, Kerala
K2a	Quarry face in Garnetiferous Gneiss near Iritty
K3	River Sand showing black ilmenite, Irritty Road
K3a	River sand with H.M concentration, Iritty River
K3b	Iritty River near Iritty
K4	Coast Parallel bars with patchy ilmenite concentration Mattol Beach
K5	Ilmenite rich beach sand, present day coast, Kerala
K5a	Streaks & Patches of Ilmenite along present day coast. K8 Ilmenite - rich black sand, Telichery.
K8	Ilmenite - rich black sand, Telichery.
K10a	A beach terrace with inter veining laterite bed: Kappad beach
K10b	Migmatitic banded gneiss Kappad beach
K11	Massive charnockite near Bharat River, Kerala Coast
K12	Ilmenite & other H.M bearing River sand, Bharat River, Kerala
K12a	Panoramic view of Bharat river
K13	60cm thick terrace of H.M sand, Ponnani beach
K14a	Different beach terraces of ilmenite-rich sand, Kerala coast
K14b	Close up of H.M. beach sands Kerala Coast at K-14
K15	Ilmenite-rich beach sand; Present day coast - Kerala
K19	Banded Multiphase (migmatitic) gneiss
K23	Garnetiferous gneiss
K25	H.M. & Ilmenite rich present day coast, Kerala
K26	H.M Sand
K28a	close up of Chavara beach sands. Note trace of bedding surfaces. Kerala
K28b	Northern extension of Chavara Ilmenite deposit, Kerala
K29	Different depositional surfaces, Kerala Coast
K31	Garnetiferous gneiss near Punalur
K32	Garnet, Ilmenite concentration (Pale brown) in Kallada River sand
K36	High strain garnetiferous gneiss, Velikkupura quarry
K38	Beach Sand with patchy concentration of ilmenite - bearing HM sand near Anjengo.
K39	Locality north of the famous Kovalam beach tourist resort, H.M. Sand
K44	Garnetiferous Charnockite with pelitic granulite
K45	Garnet + Ilmenite + Monazite bearing beach sand, Kanyakumari
K47	Different beach terraces (Levels) of H.M concentration
K48	Manavalakurichi deposit, Kerala
K48a	Closeup of multicoloured beach sand, Manavalakurichi deposit
K48b	Very rich Concentration of ilemenite + Monazite; Manavalakurichi working mine

	"Teri Sand"
K48c	Multicolloured Heavy Mineral Sand, working mine, Manavalakurichi
K50	1m thick
K50a	30 to 40% concentration of Ilmenite
K51	Garnet - plagioclase biotite gneiss NW of Manavalakurichi
K52	Heavy Mineral concentration in Beach Sand on a terrace; North of Manavala Kurichi
K53	H.M Concentration in the river bed of Nambiar river
K54	Teri Sand - Ilmenite concentration can be seen in Fine fraction near Tisaiyanvilai
K58	Teri Sand
K59	H.M Concentration in Beach Sand
K62	20% Ilmenite concentration in Teri Sand, Idandakarai
K62a	Teri Sand Idindikarai
K64	One m thick terrace with garnet + ilmenite sand; Idindakarai Beach
K64a	Closeup of Garnet + Ilmenite beach sand near Idandikarai
K65	Concentration of Ilmenite in a stream draining Teri Sand near Idandakarai
K66	West of Vijaya Narayanam Banded boudinagud garnetiferous gneiss
K66A	Banded Garnetiferous gneiss
K69	Kuduraimoli Teri Sand deposit; Tamil Nadu
K70	Teri Sand, Kuduraimoli Deposit, Tamil Nadu
K71	Teri Sand; Sattankulam
K72	Ilmenite concentration in the fine fraction of Teri Sand; Near Vijayaram Puram, Tamil Nadu
K80	Vembar Beach; Garnet + Ilmenite beach sand
K81	Ilmenite concentration due to wind action in Teri Sand, near Vembar
K82	Teri Sand with poor concentration of Ilmenite, near Sayalkudi
K87	Present day deposition of garnet + ilmenite sand. South of Pannaikkulam, Tamil Nadu

Appendix 3

CCSEM analyses of the heavy mineral sand

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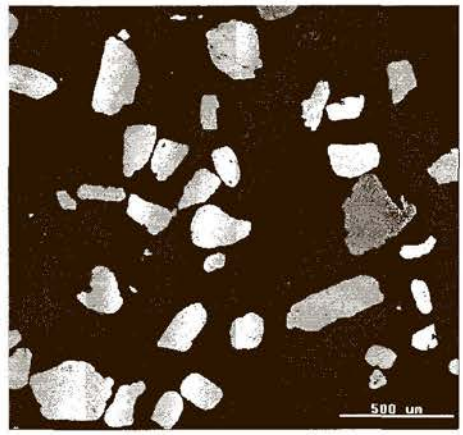
G E U S



Sample Name:	V 01	No. of frames analysed:	88
Lab. Name:	2000181	No. of particles analysed:	1487
Date:	22/05/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	0.00
Country:	Vietnam	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/50x			
Guard region:	230 µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	53.3	39.4	3.3	0.1	0.9	0.6	0.1	0.1	0.2	98.0
Leucoxene	77.0	9.3	0.7	0.2	7.9	2.0	0.1	0.1	0.3	97.6
Rutile	91.2	1.8	0.2	0.2	2.9	1.0	0.1	0.1	0.4	97.7
Ti magnetite	42.6	35.8	2.9	0.2	9.3	2.3	0.3	0.2	1.3	94.7
Magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Y-phosphate	0.0	0.0	0.0	0.0	3.9	0.6	0.0	2.5	0.0	7.0
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kya/Sill	0.0	1.1	0.0	0.1	43.2	53.9	0.0	0.0	0.0	98.3
Staurolite	0.7	14.4	0.4	0.1	33.7	47.2	1.2	0.1	0.2	97.9
Zircon	0.3	0.3	0.2	0.1	29.8	0.1	0.1	0.1	61.3	92.3
Silicate	0.8	7.0	0.2	0.2	58.5	24.7	3.0	1.2	0.4	96.0
Unclassified	14.2	8.7	1.2	1.6	13.6	28.5	3.2	0.4	9.1	80.4

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	92.9	2.4	2.0	0.9	0.0	1.2	0.1	0.4	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	54.3	78.9	93.3	44.9
Fe_2O_3 wt%	40.2	9.5	1.8	37.8
MnO wt%	3.4	0.7	0.2	3.1
Cr_2O_3 wt%	0.1	0.2	0.2	0.2
SiO_2 wt%	0.9	8.1	2.9	9.8
Al_2O_3 wt%	0.6	2.0	1.0	2.4
MgO wt%	0.1	0.1	0.1	0.3
CaO wt%	0.1	0.1	0.1	0.2
ZrO_2 wt%	0.3	0.3	0.4	1.3
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	55.7
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	54.9
Valuable heavy minerals in raw sand:	0.00

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	90.1	0.0
Leucoxene	2.3	0.0
Rutile	2.0	0.0
Ti magnetite	0.9	0.0
Magnetite	0.0	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
Kya/Sill	0.1	0.0
Staurolite	0.4	0.0
Zircon	1.2	0.0
Silicate	2.7	100.0
Unclassified	0.4	0.0
Total	100.0	100.0

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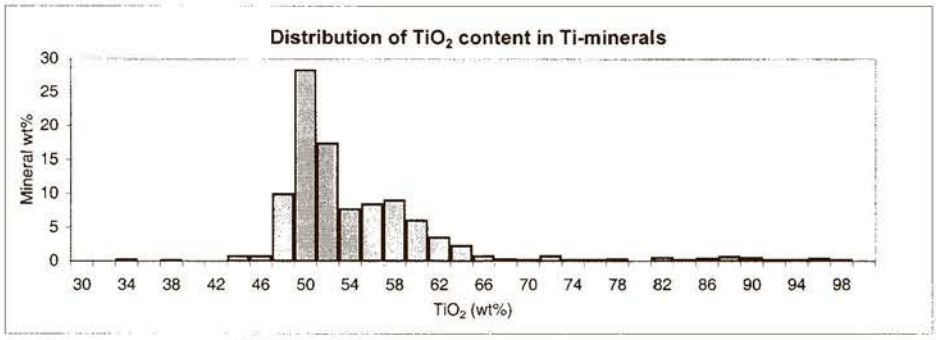
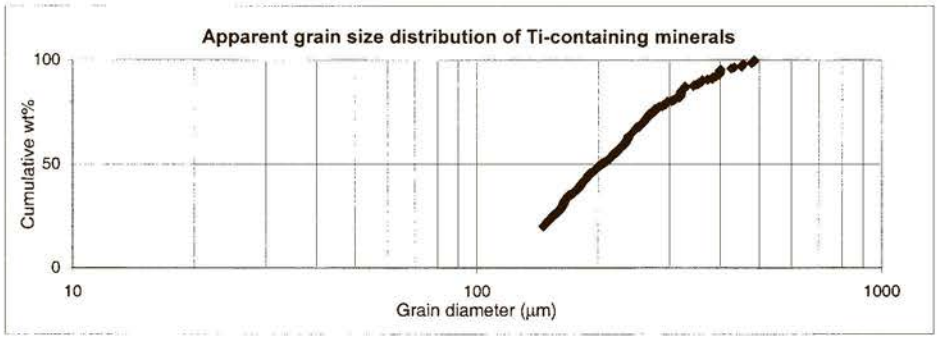
GEUS

Lab. Name:	2000181	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	22/05/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.8	652	251	22334	1263
Leucoxene	1.6	1.9	609	240	19179	38
Rutile	1.5	1.8	535	209	14707	38
Ti magnetite	1.3	1.7	558	219	21252	12
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	0.0	0.0	0	0	0	0
Y-phosphate	1.5	1.6	323	117	5160	1
Sphene	0.0	0.0	0	0	0	0
Garnet	0.0	0.0	0	0	0	0
Kya/Sill	1.1	1.8	755	293	24771	1
Staurolite	1.5	1.7	703	260	24615	6
Zircon	1.3	1.5	457	157	11751	31
Silicate	1.5	2.0	634	253	18325	77
Unclassified	1.3	1.6	397	164	11301	20

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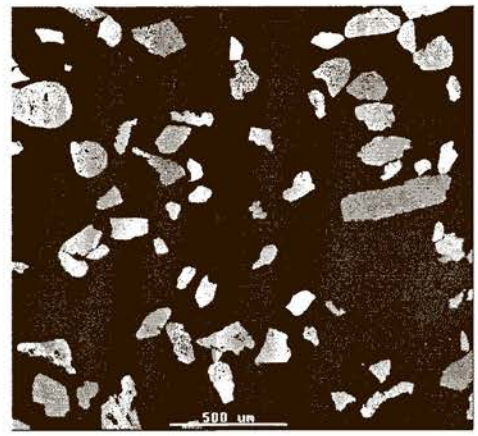
G E U S

Sample Name:	K 3	No. of frames analysed:	55
Lab. Name:	2000210	No. of particles analysed:	1486
Date:	24/09/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	17.17
Country:	India	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/50x			
Guard region:	375 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	49.2	43.9	1.1	0.1	1.6	1.8	0.4	0.1	0.2	98.3
Leucoxene	82.7	2.5	0.2	0.5	5.8	5.4	0.2	0.1	0.2	97.5
Rutile	93.5	2.1	0.0	0.5	0.4	0.2	0.0	0.1	0.1	96.8
Ti magnetite	38.1	49.4	1.0	0.2	4.7	3.2	0.6	0.2	0.3	97.9
Magnetite	0.7	69.5	0.2	0.4	10.0	15.2	0.5	0.2	0.6	97.3
Chromite	1.0	45.9	0.0	33.8	0.7	12.8	0.6	0.3	0.6	95.8
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	3.0	1.3	0.2	0.2	0.4	0.1	0.0	53.3	2.6	61.1
Monazite	0.0	0.9	0.0	0.0	2.2	3.4	1.2	1.3	1.7	10.6
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	38.7	1.7	0.1	0.2	28.8	2.0	0.0	25.6	0.0	97.3
Garnet	0.9	21.4	0.4	0.2	41.1	17.7	5.8	8.9	0.3	96.7
Kya/Sill	0.1	1.2	0.1	0.4	42.7	53.5	0.1	0.1	0.3	98.5
Staurolite	0.1	9.4	0.2	0.5	38.6	46.9	0.7	0.3	0.2	97.0
Zircon	0.2	0.8	0.1	0.1	29.5	0.4	0.1	0.1	64.1	95.4
Silicate	0.9	13.8	0.3	0.3	48.0	18.3	8.0	6.3	0.3	96.2
Unclassified	2.1	36.2	0.6	0.6	20.4	27.8	1.5	1.1	1.7	92.1

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	16.5	1.5	0.3	23.0	49.9	4.3	4.2	0.3	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	50.0	84.9	96.5	38.9
Fe_2O_3 wt%	44.6	2.6	2.1	50.5
MnO wt%	1.1	0.2	0.0	1.1
Cr_2O_3 wt%	0.1	0.5	0.5	0.2
SiO_2 wt%	1.6	6.0	0.4	4.8
Al_2O_3 wt%	1.8	5.5	0.3	3.3
MgO wt%	0.4	0.2	0.0	0.6
CaO wt%	0.1	0.1	0.1	0.2
ZrO_2 wt%	0.2	0.2	0.1	0.3
Total	100.0	100.0	100.0	100.0

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	5.8	1.0
Leucoxene	0.5	0.1
Rutile	0.1	0.0
Ti magnetite	8.1	1.4
Magnetite	11.0	1.9
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.1	0.0
Monazite	0.0	0.0
Y-phosphate	0.0	0.0
Sphene	0.6	0.1
Garnet	17.5	3.0
Kya/Sill	1.5	0.3
Staurolite	0.1	0.0
Zircon	1.5	0.3
Silicate	47.9	91.1
Unclassified	5.1	0.9
Total	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	45.4
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	45.1
Valuable heavy minerals in raw sand:	6.03

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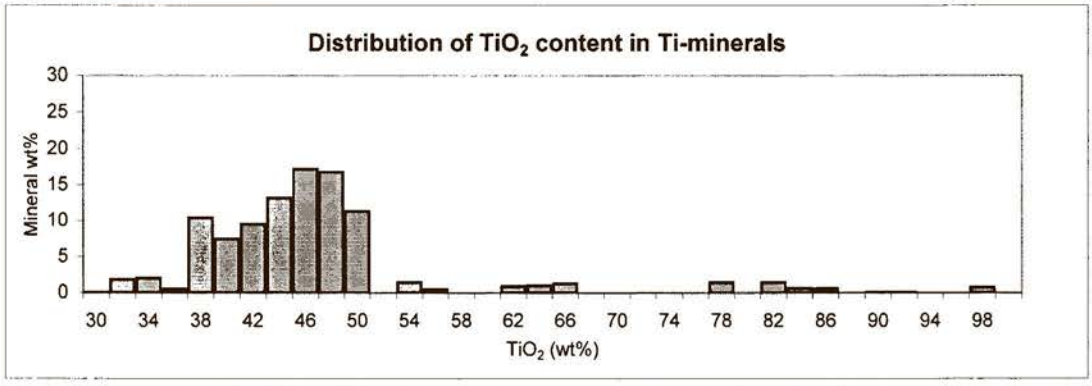
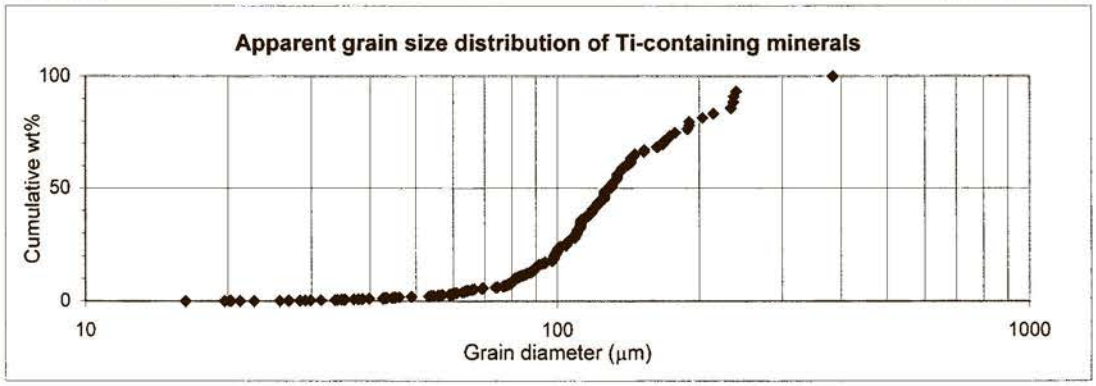
GEUS

Lab. Name:	2000210	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	24/09/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.7	1.8	382	146	7411	100
Leucoxene	1.9	3.0	695	306	13286	5
Rutile	1.5	1.3	216	75	4030	3
Ti magnetite	1.6	1.8	451	175	11313	86
Magnetite	1.8	2.1	567	231	19120	64
Chromite	2.8	2.0	248	99	2480	1
Pyrite	0.0	0.0	0	0	0	0
Phosphate	2.5	2.8	719	311	14919	1
Monazite	1.1	1.5	173	59	1637	1
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	2.0	3.3	1386	613	49693	2
Garnet	1.6	1.9	453	183	11059	228
Kya/Sill	1.5	1.9	496	195	13201	20
Staurolite	1.4	1.6	283	111	4318	4
Zircon	1.4	1.6	421	151	11012	17
Silicate	1.7	2.0	489	200	12078	863
Unclassified	1.5	1.9	420	173	12039	91

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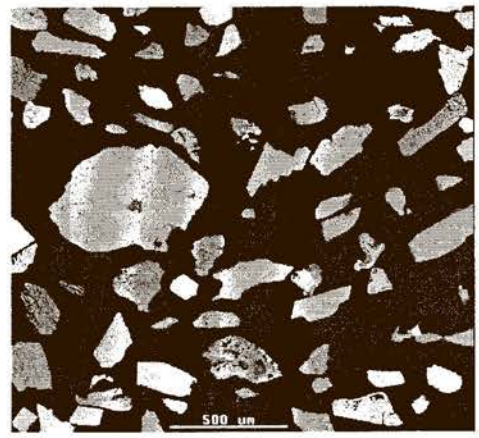

Sample Name:	K 5	No. of frames analysed:	23
Lab. Name:	2000212	No. of particles analysed:	772
Date:	24/09/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	24.77
Country:	India	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/50x			
Guard region:	300 µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	49.5	45.1	1.4	0.2	0.8	0.5	0.4	0.1	0.2	98.2
Leucoxene	77.8	11.4	0.0	0.0	5.6	1.9	1.1	0.2	0.1	98.1
Rutile	95.4	0.7	0.1	0.4	0.5	0.4	0.1	0.1	0.2	97.8
Ti magnetite	39.9	48.6	1.1	0.2	4.2	1.7	1.0	0.3	0.6	97.7
Magnetite	1.4	81.5	0.4	0.7	4.9	6.9	0.8	0.4	0.3	97.4
Chromite	0.0	41.1	0.7	39.0	0.7	13.2	4.6	0.0	0.0	99.3
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	1.2	0.5	0.4	0.5	0.2	0.3	57.5	2.1	62.6
Monazite	0.0	1.7	0.0	0.0	7.6	15.1	0.3	1.8	1.3	27.8
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.7	23.1	0.6	0.2	39.5	19.0	5.1	9.5	0.3	97.7
Kya/Sill	0.1	0.7	0.1	0.5	42.6	53.5	0.1	0.1	0.3	98.1
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.1	1.6	0.2	0.3	29.5	0.2	0.1	0.1	63.9	95.9
Silicate	0.8	12.2	0.3	0.2	47.5	20.3	8.3	6.8	0.3	96.7
Unclassified	8.8	23.1	0.3	0.9	12.9	34.0	5.1	5.9	1.1	92.2

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	30.8	0.3	4.7	13.7	39.9	1.9	8.7	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	50.4	79.3	97.5	40.9
Fe_2O_3 wt%	45.9	11.7	0.7	49.8
MnO wt%	1.4	0.0	0.1	1.1
Cr_2O_3 wt%	0.2	0.0	0.4	0.2
SiO_2 wt%	0.8	5.7	0.5	4.3
Al_2O_3 wt%	0.6	1.9	0.4	1.7
MgO wt%	0.4	1.1	0.1	1.0
CaO wt%	0.1	0.2	0.1	0.3
ZrO_2 wt%	0.2	0.1	0.2	0.7
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	52.4
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	47.7
Valuable heavy minerals in raw sand:	11.43

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	14.2	3.5
Leucoxene	0.2	0.0
Rutile	2.2	0.5
Ti magnetite	6.3	1.6
Magnetite	6.4	1.6
Chromite	0.1	0.0
Pyrite	0.0	0.0
Phosphate	0.1	0.0
Monazite	0.4	0.1
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	18.4	4.6
Kya/Sill	4.0	1.0
Staurolite	0.0	0.0
Zircon	0.9	0.2
Silicate	45.0	86.4
Unclassified	1.9	0.5
Total	100.0	100.0

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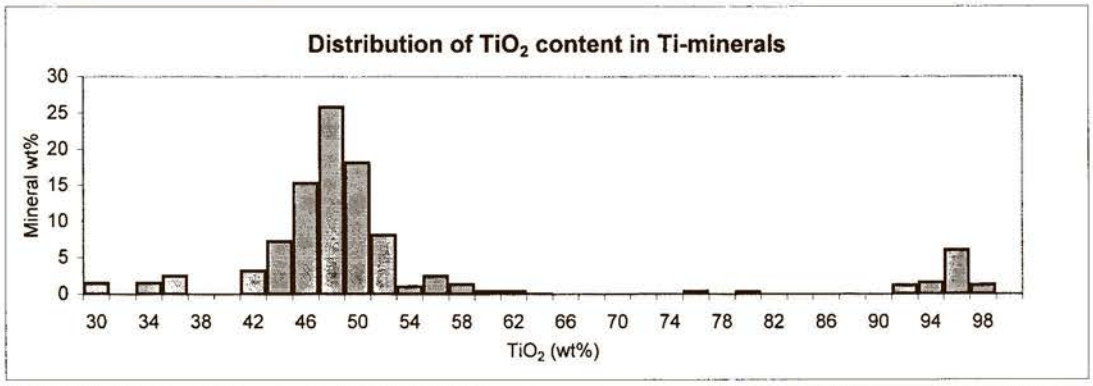
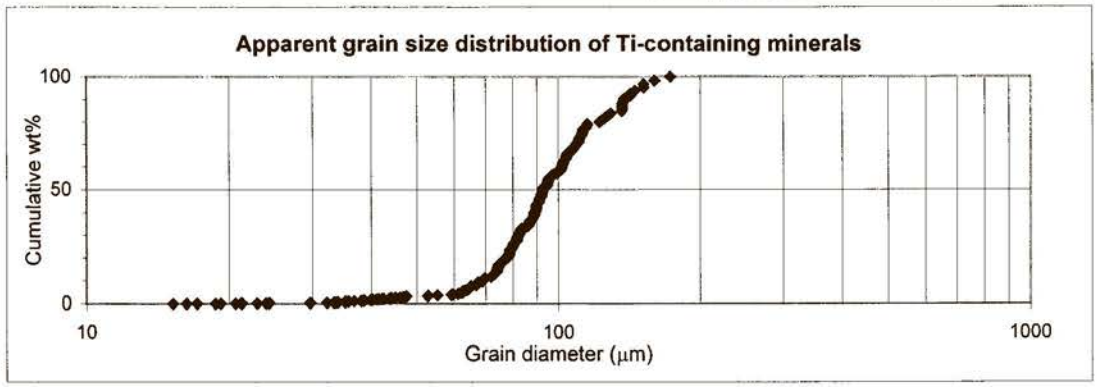
GEUS

Lab. Name:	2000212	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	24/09/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm^2)	Total grains
Ilmenite	1.7	1.8	327	125	5229	164
Leucoxene	2.0	2.7	392	168	4633	2
Rutile	1.6	1.8	353	135	6167	19
Ti magnetite	1.6	1.9	374	149	6419	56
Magnetite	1.4	1.9	471	188	12867	26
Chromite	1.2	1.9	323	127	4429	1
Pyrite	0.0	0.0	0	0	0	0
Phosphate	1.9	1.5	274	96	3946	1
Monazite	1.9	1.9	344	135	5237	4
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.6	2.0	448	182	9207	136
Kya/Sill	1.5	2.1	569	232	13455	25
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.4	1.5	326	115	5613	9
Silicate	1.7	2.1	578	236	14601	316
Unclassified	1.7	2.0	535	225	14934	13

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G E U S

Sample Name:	K 8	No. of frames analysed:	78
Lab. Name:	2000215	No. of particles analysed:	952
Date:	26/09/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	76.99
Country:	India	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/40x		
Guard region:	400 µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	52.1	42.9	1.0	0.2	0.5	0.7	0.5	0.1	0.2	98.2
Leucoxene	79.6	7.9	0.3	0.6	1.9	2.4	0.2	0.3	1.5	94.8
Rutile	95.7	1.1	0.2	0.3	0.3	0.2	0.1	0.1	0.2	98.1
Ti magnetite	41.5	51.9	0.8	0.2	1.1	0.8	0.9	0.2	0.4	97.7
Magnetite	2.7	87.8	0.2	0.2	2.6	3.5	0.3	0.1	0.3	97.8
Chromite	1.7	30.9	0.5	40.9	0.8	15.4	6.1	0.4	0.0	96.5
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	0.0	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	0.5	28.5	1.1	0.2	38.2	18.4	4.0	6.7	0.2	97.6
Kya/Sill	0.2	0.9	0.1	0.4	42.7	53.7	0.0	0.1	0.2	98.3
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.3	0.6	0.1	0.1	29.5	0.1	0.1	0.1	64.4	95.3
Silicate	0.5	8.7	0.3	0.3	53.7	23.0	5.8	4.7	0.2	97.2
Unclassified	5.8	12.4	1.0	0.3	18.1	13.7	0.7	17.9	19.8	89.9

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	35.6	0.5	13.9	20.8	5.0	17.2	7.0	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	53.0	84.0	97.5	42.5
Fe_2O_3 wt%	43.7	8.3	1.1	53.1
MnO wt%	1.0	0.3	0.2	0.8
Cr_2O_3 wt%	0.2	0.7	0.3	0.2
SiO_2 wt%	0.5	2.0	0.3	1.1
Al_2O_3 wt%	0.7	2.5	0.2	0.9
MgO wt%	0.6	0.2	0.1	0.9
CaO wt%	0.1	0.4	0.1	0.2
ZrO_2 wt%	0.2	1.6	0.2	0.4
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	58.9
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	49.4
Valuable heavy minerals in raw sand:	56.39

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	26.1	20.1
Leucoxene	0.4	0.3
Rutile	10.2	7.9
Ti magnetite	15.3	11.8
Magnetite	20.0	15.4
Chromite	1.0	0.8
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	3.6	2.8
Kya/Sill	5.1	3.9
Staurolite	0.0	0.0
Zircon	12.6	9.7
Silicate	4.1	26.2
Unclassified	1.7	1.3
Total	100.0	100.0

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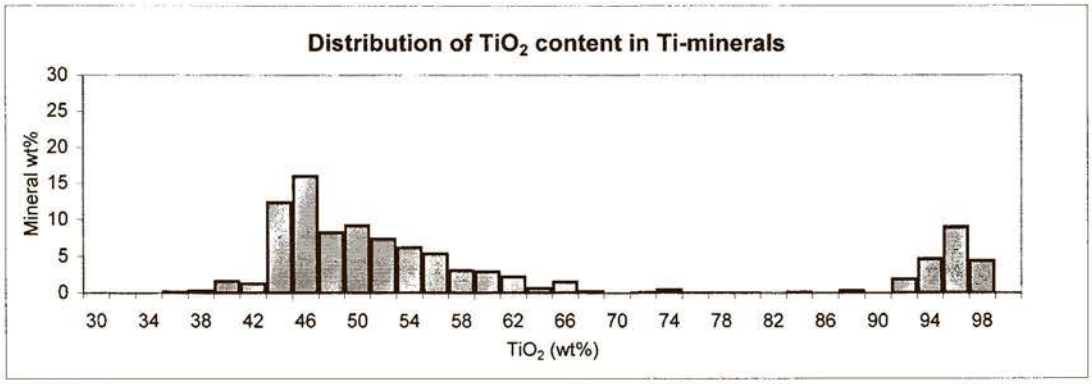
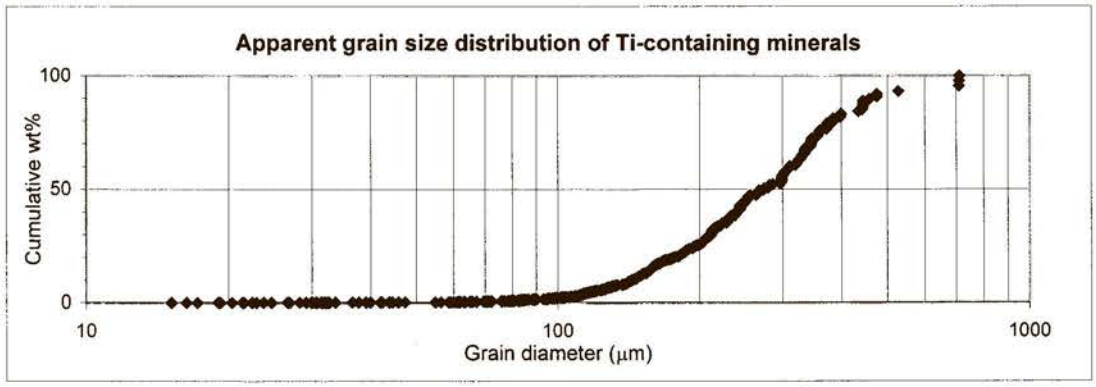
GEUS

Lab. Name:	2000215	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	26/09/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm^2)	Total grains
Ilmenite	1.5	1.7	710	268	27709	333
Leucoxene	1.5	1.4	366	133	13574	10
Rutile	1.4	1.6	1037	376	66335	49
Ti magnetite	1.5	1.7	711	275	32434	157
Magnetite	1.6	1.6	901	325	53203	115
Chromite	1.5	1.7	1163	437	63697	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	0.0	0.0	0	0	0	0
Garnet	1.7	2.1	890	365	33635	43
Kya/Sill	1.6	1.9	1462	578	124889	20
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.5	1.8	791	300	37292	116
Silicate	1.7	2.1	922	376	43519	57
Unclassified	1.6	1.8	651	275	25010	39

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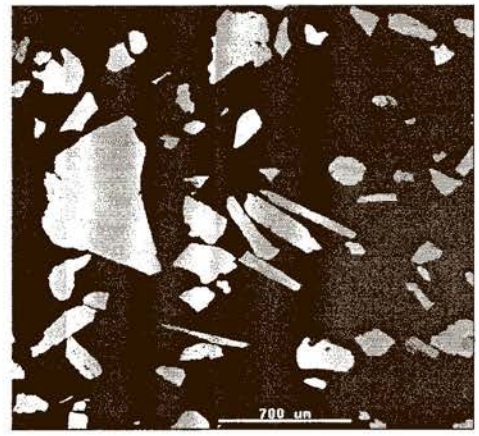

Sample Name:	K 12	No. of frames analysed:	26
Lab. Name:	2000218	No. of particles analysed:	685
Date:	26/09/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	9.99
Country:	India	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/40x		
Guard region:	400 µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	51.0	43.3	1.1	0.2	1.0	1.1	0.3	0.1	0.2	98.4
Leucoxene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rutile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ti magnetite	34.9	56.7	1.3	0.1	2.7	0.9	0.8	0.2	0.2	98.0
Magnetite	0.4	84.3	0.4	0.2	6.2	5.0	0.2	0.7	0.2	97.7
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.5	0.3	0.1	0.8	0.1	0.0	55.4	1.6	58.8
Monazite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.8	22.5	0.7	0.1	40.7	15.7	5.3	9.9	0.4	96.1
Kya/Sill	0.0	0.4	0.2	0.6	41.8	53.5	0.1	0.0	0.4	96.9
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.7	0.9	0.2	0.3	29.4	0.1	0.2	0.3	63.3	95.4
Silicate	1.1	17.1	0.4	0.2	46.7	9.9	10.3	9.5	0.2	95.5
Unclassified	4.0	25.7	0.9	0.8	25.0	11.4	4.6	7.0	2.9	82.2

	Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	17.7	0.0	0.0	46.2	31.7	4.0	0.3	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	51.9	0	0	35.6
Fe_2O_3 wt%	44.0	0	0	57.9
MnO wt%	1.1	0	0	1.3
Cr_2O_3 wt%	0.2	0	0	0.1
SiO_2 wt%	1.0	0	0	2.8
Al_2O_3 wt%	1.2	0	0	1.0
MgO wt%	0.3	0	0	0.8
CaO wt%	0.1	0	0	0.2
ZrO_2 wt%	0.2	0	0	0.2
Total	100.0	0	0	100.0

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	4.4	0.4
Leucoxene	0.0	0.0
Rutile	0.0	0.0
Ti magnetite	11.4	1.1
Magnetite	3.2	0.3
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	1.4	0.1
Monazite	0.0	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	7.8	0.8
Kya/Sill	0.1	0.0
Staurolite	0.0	0.0
Zircon	1.0	0.1
Silicate	66.8	96.7
Unclassified	3.9	0.4
Total	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	40.1
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	40.1
Valuable heavy minerals in raw sand:	2.47

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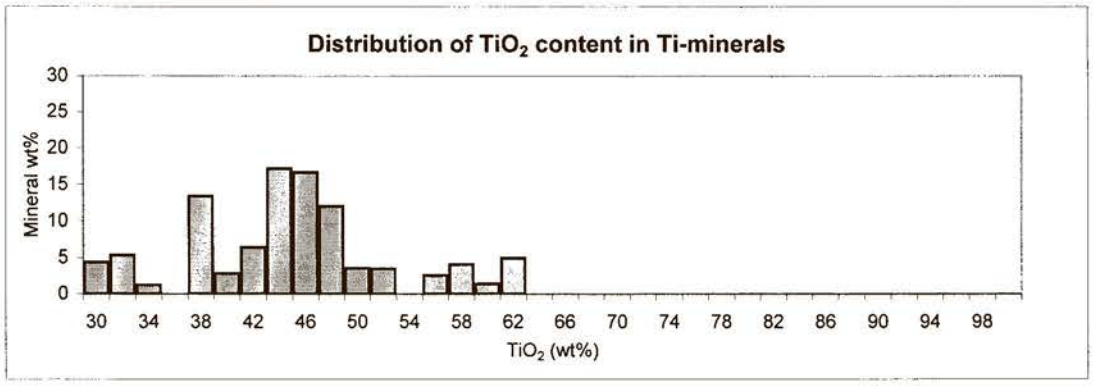
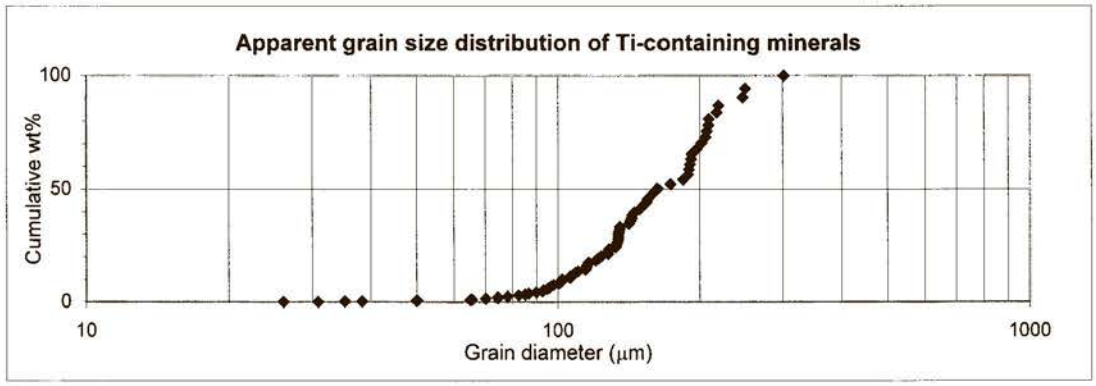
GEUS

Lab. Name:	2000218	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	26/09/02		





	Average grain parameters					
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm^2)	Total grains
Ilmenite	1.8	1.8	518	197	13671	27
Leucoxene	0.0	0.0	0	0	0	0
Rutile	0.0	0.0	0	0	0	0
Ti magnetite	1.6	1.8	575	220	16816	54
Magnetite	1.4	1.6	361	135	7481	31
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	1.6	1.9	796	315	27158	4
Monazite	0.0	0.0	0	0	0	0
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.6	1.7	502	195	18167	41
Kya/Sill	2.9	2.6	569	245	9768	1
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.6	1.6	422	155	10150	8
Silicate	1.8	2.0	619	250	19520	491
Unclassified	1.6	1.9	584	249	19386	28

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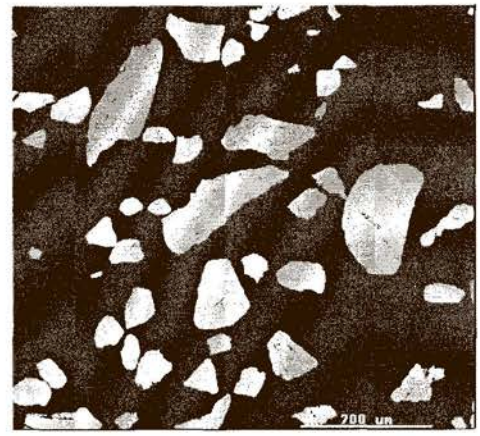
G E U S



Sample Name:	K 14	No. of frames analysed:	46
Lab. Name:	2000219	No. of particles analysed:	615
Date:	27/09/02	Heavy minerals in raw sand (%):	35.04
Submitter:	DuPont/GEUS		
Country:	India	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/50x		
Guard region:	350 µm		
Sieve:	100 µm²		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	49.4	45.3	1.6	0.1	0.6	0.5	0.5	0.1	0.2	98.3
Leucoxene	66.5	10.3	0.0	0.2	14.8	0.1	0.4	0.1	0.0	92.5
Rutile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ti magnetite	36.1	58.4	0.8	0.2	1.1	0.7	0.7	0.2	0.2	98.3
Magnetite	1.1	92.4	0.2	0.3	1.5	1.7	0.5	0.2	0.2	98.0
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.2	0.8	0.2	0.2	0.7	0.2	0.1	55.2	1.4	58.9
Monazite	0.0	0.5	0.0	0.0	2.5	0.4	0.3	2.2	2.4	8.3
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.2	28.5	1.1	0.2	38.2	17.9	5.4	6.0	0.3	97.8
Kya/Sill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.2	0.9	0.1	0.2	29.6	0.2	0.1	0.1	64.2	95.7
Silicate	1.3	16.3	0.4	0.2	48.4	8.5	10.7	10.0	0.2	96.1
Unclassified	3.7	19.9	0.4	1.5	22.9	5.3	3.3	9.0	16.5	82.4

	Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	22.2	0.0	0.0	46.3	24.3	7.2	0.0	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	50.2	71.9	0	36.7
Fe_2O_3 wt%	46.1	11.1	0	59.4
MnO wt%	1.6	0.0	0	0.9
Cr_2O_3 wt%	0.1	0.2	0	0.2
SiO_2 wt%	0.6	16.0	0	1.2
Al_2O_3 wt%	0.5	0.2	0	0.7
MgO wt%	0.5	0.4	0	0.7
CaO wt%	0.1	0.2	0	0.2
ZrO_2 wt%	0.2	0.0	0	0.2
Total	100.0	100.0	0	100.0

Average TiO_2 content of all the TiO_2 minerals:	41.1
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	41.1
Valuable heavy minerals in raw sand:	17.53

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	11.1	3.9
Leucoxene	0.0	0.0
Rutile	0.0	0.0
Ti magnetite	23.2	8.1
Magnetite	7.9	2.8
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.9	0.3
Monazite	0.3	0.1
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	12.1	4.3
Kya/Sill	0.0	0.0
Staurolite	0.0	0.0
Zircon	3.6	1.3
Silicate	39.6	78.8
Unclassified	1.2	0.4
Total	100.0	100.0

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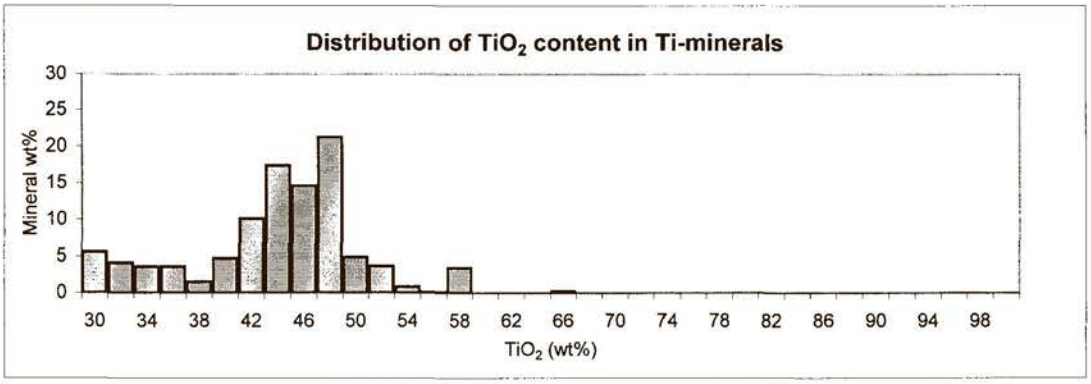
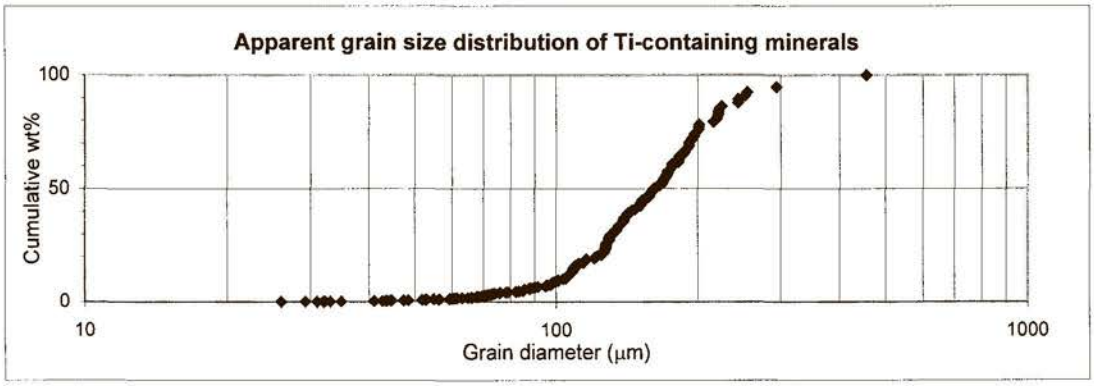
GEUS

Lab. Name:	2000219	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	27/09/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.7	1.8	508	195	13054	82
Leucoxene	1.2	1.0	83	31	531	1
Rutile	0.0	0.0	0	0	0	0
Ti magnetite	1.6	1.9	551	214	15249	138
Magnetite	1.6	1.9	456	178	10013	66
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	1.5	2.1	509	210	12565	6
Monazite	1.6	1.6	366	130	6835	4
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.7	2.1	690	284	25334	52
Kya/Sill	0.0	0.0	0	0	0	0
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.4	1.6	461	164	11272	30
Silicate	1.7	2.1	770	314	28970	224
Unclassified	1.4	2.3	596	263	16611	12

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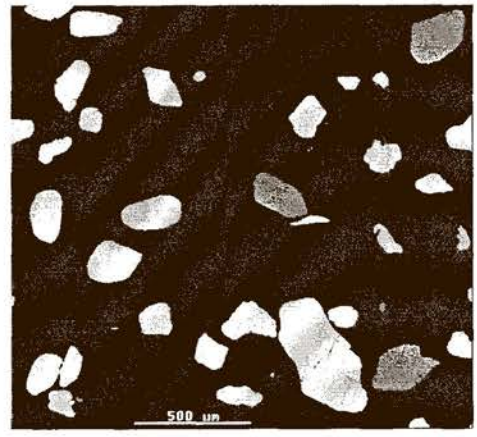
G E U S

Sample Name:	K 25	No. of frames analysed:	81
Lab. Name:	2000226	No. of particles analysed:	933
Date:	27/09/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	95.90
Country:	India	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/50x		
Guard region:	300 µm		
Sieve:	100 µm²		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	61.5	33.4	0.6	0.2	0.5	1.0	0.9	0.1	0.2	98.3
Leucoxene	74.5	19.3	0.3	0.4	0.9	1.9	0.8	0.2	0.2	98.3
Rutile	94.5	1.5	0.1	0.3	0.4	0.3	0.1	0.0	0.4	97.7
Ti magnetite	36.5	31.0	0.5	0.3	11.6	4.8	2.3	5.3	0.7	93.1
Magnetite	0.5	61.6	0.3	0.2	16.5	16.4	0.3	0.0	0.6	96.4
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	2.4	0.0	0.4	2.7	6.1	11.6
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	0.2	26.7	1.2	0.1	39.1	20.5	9.8	0.8	0.1	98.6
Kya/Sill	0.2	0.5	0.2	0.3	42.8	54.0	0.0	0.1	0.2	98.2
Staurolite	0.4	14.7	0.3	0.1	31.0	48.8	2.3	0.0	0.3	97.9
Zircon	0.2	0.4	0.1	0.1	29.6	0.0	0.1	0.1	65.3	96.0
Silicate	0.5	0.5	0.1	0.2	44.9	51.6	0.0	0.1	0.2	98.2
Unclassified	8.1	9.8	0.3	0.4	3.6	56.9	13.7	0.3	2.1	95.2

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	64.9	20.0	3.6	0.2	1.9	1.2	7.8	0.4	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	62.6	75.7	96.7	39.2
Fe_2O_3 wt%	34.0	19.6	1.5	33.3
MnO wt%	0.6	0.3	0.1	0.6
Cr_2O_3 wt%	0.2	0.4	0.3	0.3
SiO_2 wt%	0.5	0.9	0.5	12.4
Al_2O_3 wt%	1.0	1.9	0.3	5.2
MgO wt%	0.9	0.8	0.1	2.4
CaO wt%	0.1	0.2	0.0	5.7
ZrO_2 wt%	0.2	0.2	0.4	0.8
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	66.9
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	65.6
Valuable heavy minerals in raw sand:	85.89

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	58.1	55.8
Leucoxene	17.9	17.2
Rutile	3.2	3.1
Ti magnetite	0.2	0.1
Magnetite	0.5	0.5
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.0	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	1.7	1.7
Kya/Sill	7.0	6.7
Staurolite	0.4	0.3
Zircon	1.0	1.0
Silicate	9.0	12.7
Unclassified	0.9	0.9
Total	100.0	100.0

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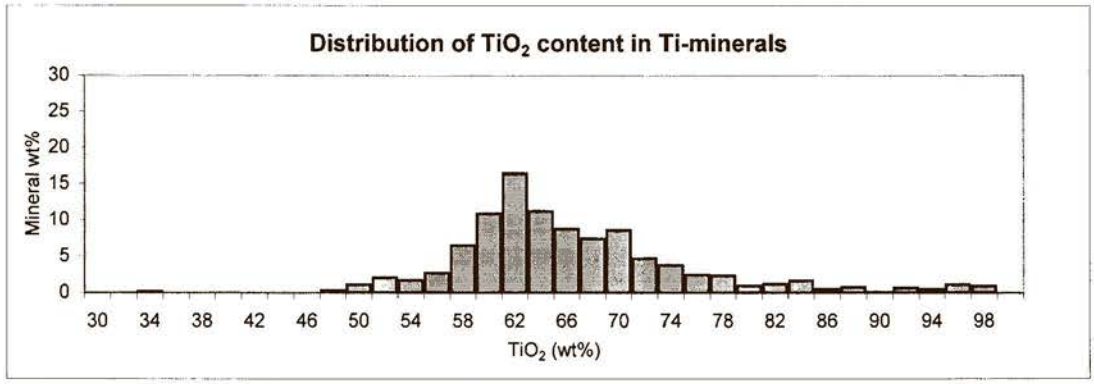
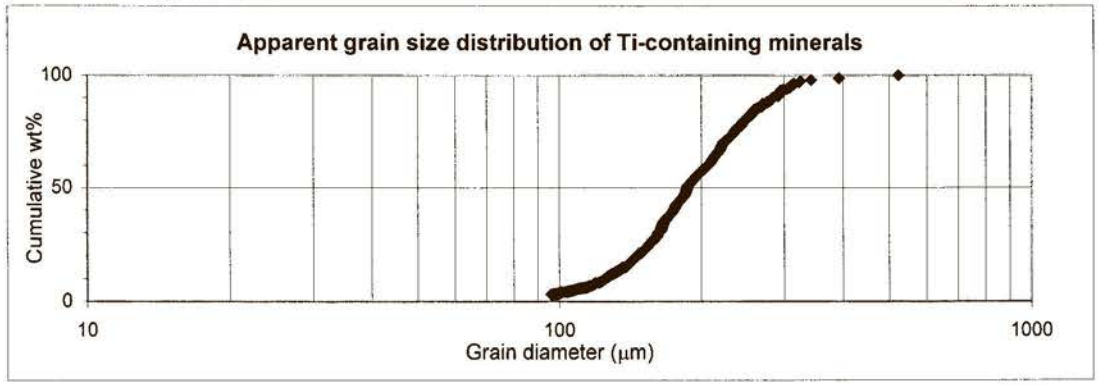
GEUS

Lab. Name:	2000226	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	27/09/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm²)	Total grains
Ilmenite	1.6	1.8	642	244	20612	590
Leucoxene	1.6	1.7	700	262	26021	144
Rutile	1.7	1.8	553	217	14778	41
Ti magnetite	1.3	1.5	470	190	15216	2
Magnetite	1.7	1.6	1327	477	88832	1
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.4	1.4	332	110	6136	1
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.8	2.0	1031	403	67637	6
Kya/Sill	1.6	2.1	1172	473	58000	35
Staurolite	2.1	2.2	764	312	22293	4
Zircon	1.5	1.7	444	164	10120	21
Silicate	1.6	2.2	1037	425	45499	70
Unclassified	1.7	1.9	616	248	18361	18

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GEUS

Sample Name:	K 28	No. of frames analysed:	63
Lab. Name:	2000229	No. of particles analysed:	1488
Date:	30/09/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	95.47
Country:	India	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/40x			
Guard region:	250 µm		
Sieve:	100 µm²		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	60.1	34.3	0.5	0.2	0.7	1.0	0.9	0.1	0.3	98.1
Leucoxene	75.1	17.8	0.2	0.4	1.3	2.1	0.6	0.1	0.2	97.9
Rutile	95.6	0.7	0.1	0.3	0.3	0.3	0.1	0.1	0.4	97.8
Ti magnetite	40.4	40.0	0.1	0.0	2.4	4.5	0.8	0.4	0.4	89.1
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	1.5	0.6	0.0	0.0	3.1	0.6	0.2	2.6	3.4	12.1
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.1	31.6	0.5	0.2	37.3	19.6	7.4	1.1	0.3	98.1
Kya/Sill	0.2	0.6	0.1	0.2	42.8	53.7	0.0	0.1	0.3	97.9
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.2	0.3	0.1	0.1	29.6	0.1	0.1	0.1	65.0	95.7
Silicate	0.8	1.1	0.1	0.2	50.8	44.6	0.2	0.1	0.3	98.2
Unclassified	8.4	11.3	0.5	0.5	9.7	24.1	4.8	1.0	15.4	75.8

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	53.9	6.8	8.2	0.5	0.8	25.1	4.7	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	61.2	76.7	97.8	45.4
Fe_2O_3 wt%	35.0	18.2	0.7	44.9
MnO wt%	0.5	0.3	0.1	0.2
Cr_2O_3 wt%	0.2	0.4	0.3	0.0
SiO_2 wt%	0.7	1.3	0.3	2.7
Al_2O_3 wt%	1.0	2.1	0.3	5.0
MgO wt%	0.9	0.6	0.1	0.9
CaO wt%	0.1	0.1	0.1	0.4
ZrO_2 wt%	0.3	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:	66.9
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	62.8
Valuable heavy minerals in raw sand:	83.07

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	46.9	44.8
Leucoxene	5.9	5.6
Rutile	7.1	6.8
Ti magnetite	0.5	0.4
Magnetite	0.0	0.0
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	4.6	4.4
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	0.7	0.6
Kya/Sill	4.1	3.9
Staurolite	0.0	0.0
Zircon	21.8	20.8
Silicate	6.6	10.8
Unclassified	1.8	1.7
Total	100.0	100.0

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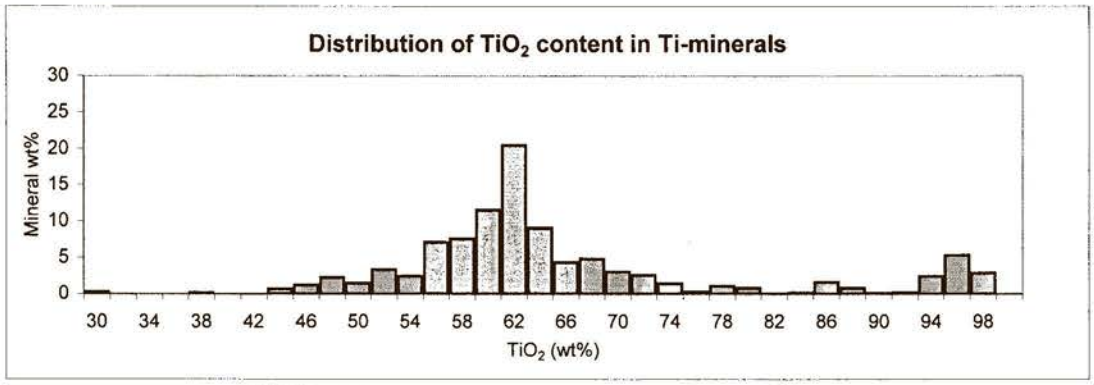
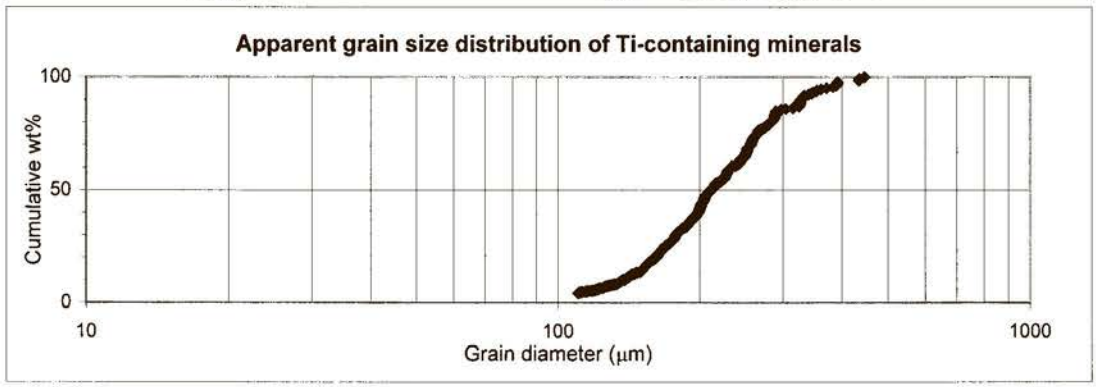
GEUS

Lab. Name:	2000229	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	30/09/02		





	Average grain parameters					
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm²)	Total grains
Ilmenite	1.5	1.7	707	265	26592	629
Leucoxene	1.5	1.7	708	262	26582	79
Rutile	1.5	1.7	597	224	19705	116
Ti magnetite	1.6	2.1	783	327	25951	6
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	1.6	1.6	524	193	15196	97
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.5	1.7	662	264	24730	11
Kya/Sill	1.5	2.0	977	392	44881	45
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.4	1.7	617	228	21620	348
Silicate	1.6	2.1	981	395	42566	94
Unclassified	1.6	2.1	702	297	23994	44

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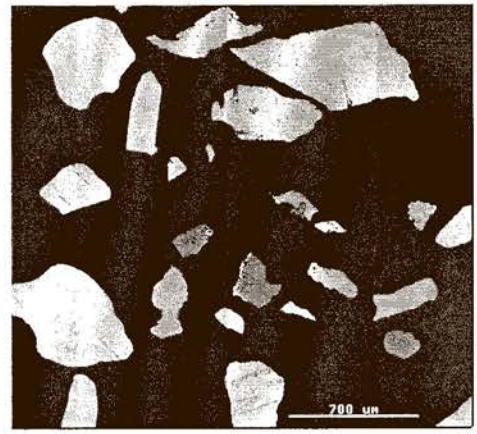
G E U S



Sample Name:	K 30	No. of frames analysed:	46
Lab. Name:	2000231	No. of particles analysed:	530
Date:	30/09/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	7.15
Country:	India	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/40x		
Guard region:	400 µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	51.3	41.8	0.5	0.1	1.7	2.0	0.8	0.0	0.2	98.5
Leucoxene	73.5	14.3	0.1	0.2	4.4	4.7	0.5	0.1	0.4	98.2
Rutile	93.1	0.7	0.2	0.2	1.6	1.6	0.1	0.1	0.7	98.3
Ti magnetite	36.2	57.0	0.6	0.1	1.4	1.5	0.8	0.1	0.2	98.0
Magnetite	1.5	68.6	0.6	0.3	9.0	12.3	0.8	0.8	0.8	94.7
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	0.6	0.1	0.1	2.4	1.0	0.4	3.0	2.6	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	0.3	31.0	0.9	0.2	37.9	19.8	6.9	1.0	0.3	98.1
Kya/Sill	0.2	0.8	0.1	0.3	42.7	53.3	0.0	0.1	0.4	97.8
Staurolite	0.2	12.6	0.0	0.4	27.8	53.6	0.2	0.0	0.4	95.3
Zircon	0.0	1.1	0.0	0.2	30.3	0.0	0.0	0.1	63.6	95.3
Silicate	1.0	12.0	0.4	0.2	47.5	28.3	5.8	0.8	0.3	96.2
Unclassified	3.5	30.1	1.4	1.5	17.2	31.2	2.7	0.7	2.2	90.4

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	15.9	3.1	0.1	39.0	39.6	0.1	2.1	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	52.1	74.9	94.7	36.9
Fe_2O_3 wt%	42.5	14.6	0.7	58.1
MnO wt%	0.5	0.1	0.2	0.6
Cr_2O_3 wt%	0.1	0.2	0.2	0.2
SiO_2 wt%	1.7	4.5	1.6	1.4
Al_2O_3 wt%	2.0	4.8	1.6	1.6
MgO wt%	0.8	0.5	0.1	0.9
CaO wt%	0.0	0.1	0.1	0.1
ZrO_2 wt%	0.2	0.4	0.8	0.2
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	43.2
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	43.1
Valuable heavy minerals in raw sand:	6.46

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	14.4	1.0
Leucoxene	2.8	0.2
Rutile	0.1	0.0
Ti magnetite	35.3	2.5
Magnetite	1.4	0.1
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	2.0	0.1
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	35.8	2.6
Kya/Sill	1.9	0.1
Staurolite	0.0	0.0
Zircon	0.1	0.0
Silicate	4.9	93.2
Unclassified	1.3	0.1
Total	100.0	100.0

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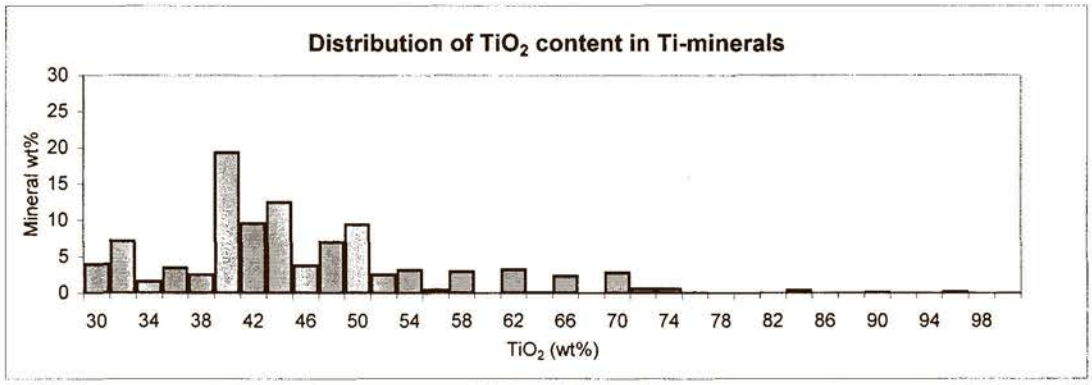
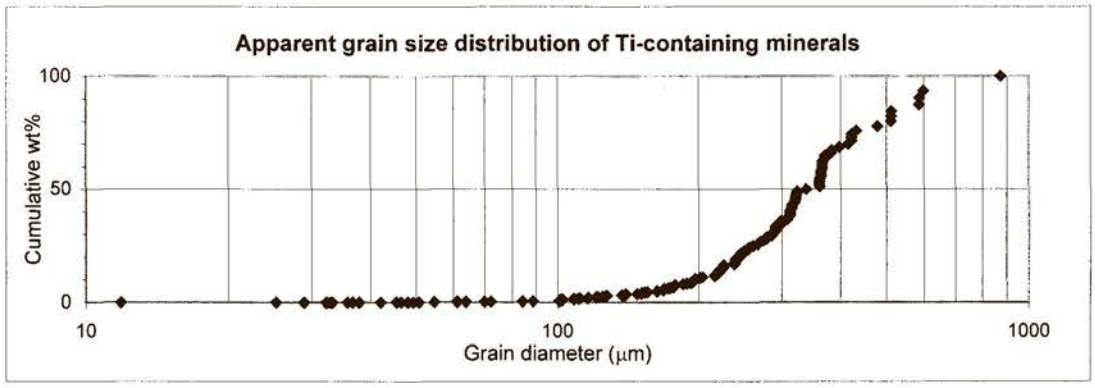
GEUS

Lab. Name:	2000231	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	30/09/02		





	Average grain parameters					
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.8	844	323	37643	71
Leucoxene	1.5	1.9	944	387	46925	11
Rutile	1.7	2.1	477	193	8799	2
Ti magnetite	1.5	1.9	1102	427	69190	89
Magnetite	1.6	1.5	316	125	10788	21
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.4	1.4	510	177	17587	19
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.7	2.1	895	374	43224	173
Kya/Sill	1.8	1.9	665	263	25726	19
Staurolite	1.3	1.6	181	67	1976	3
Zircon	1.8	2.2	569	236	11473	1
Silicate	1.8	1.9	553	218	16979	90
Unclassified	1.5	1.8	415	174	13275	31

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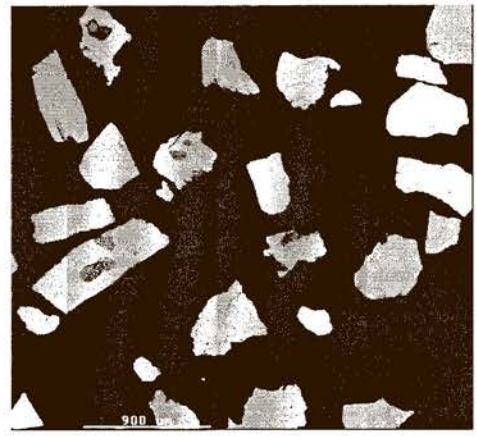

Sample Name:	K 34	No. of frames analysed:	81
Lab. Name:	2000235	No. of particles analysed:	838
Date:	27/09/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	9.01
Country:	India	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/30x		
Guard region:	500 µm		
Sieve:	100 µm^2		

	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	50.3	42.1	0.6	0.2	1.8	1.8	0.9	0.1	0.2	98.0
Leucoxene	74.4	8.2	0.9	0.2	7.7	6.2	0.2	0.2	0.2	98.1
Rutile	88.3	4.3	0.2	0.1	2.9	1.6	0.1	0.3	0.1	98.0
Ti magnetite	32.0	59.7	1.5	0.2	1.6	1.6	0.7	0.1	0.4	97.7
Magnetite	3.0	86.0	0.5	0.2	2.2	5.7	0.5	0.1	0.1	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	0.2	30.8	1.0	0.1	38.2	20.0	6.6	1.1	0.3	98.2
Kya/Sill	0.1	0.8	0.2	0.2	42.2	53.4	0.1	0.1	0.3	97.2
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Silicate	1.3	17.2	0.6	0.1	52.1	14.6	6.9	1.9	0.3	95.2
Unclassified	2.4	34.6	1.6	0.3	20.0	29.7	3.9	0.4	1.2	94.1

	Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	13.5	2.9	2.1	19.7	61.6	0.0	0.3	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	51.4	75.8	90.2	32.7
Fe_2O_3 wt%	43.0	8.4	4.4	61.1
MnO wt%	0.6	0.9	0.2	1.5
Cr_2O_3 wt%	0.2	0.2	0.1	0.2
SiO_2 wt%	1.9	7.8	2.9	1.7
Al_2O_3 wt%	1.8	6.3	1.6	1.7
MgO wt%	0.9	0.2	0.1	0.7
CaO wt%	0.1	0.2	0.3	0.1
ZrO_2 wt%	0.2	0.2	0.1	0.4
Total	100.0	100.0	100.0	100.0

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	11.1	1.0
Leucoxene	2.4	0.2
Rutile	1.7	0.2
Ti magnetite	16.2	1.5
Magnetite	6.0	0.5
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.0	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	50.6	4.6
Kya/Sill	0.2	0.0
Staurolite	0.0	0.0
Zircon	0.0	0.0
Silicate	8.3	91.7
Unclassified	3.5	0.3
Total	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	45.7
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	43.1
Valuable heavy minerals in raw sand:	7.41

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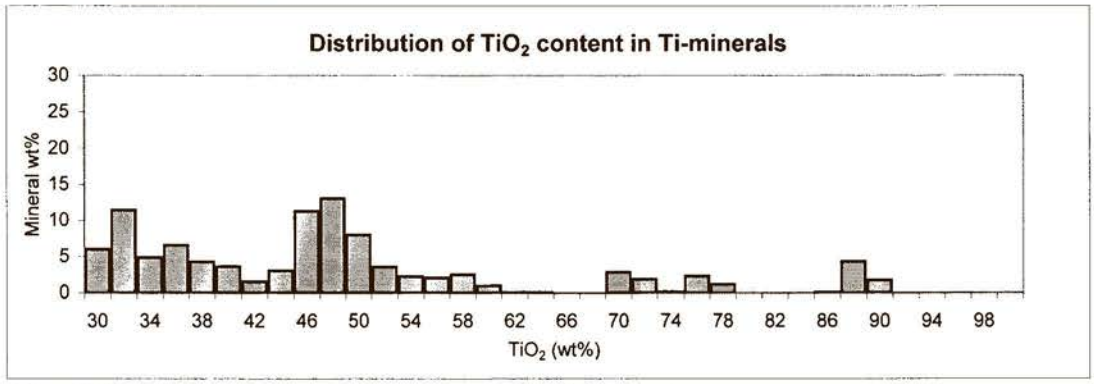
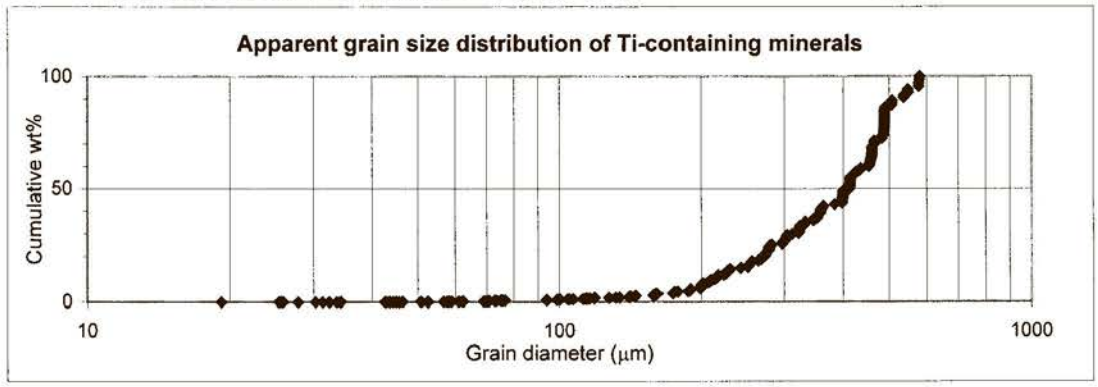
GEUS

Lab. Name:	2000235	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	27/09/02		





	Average grain parameters					
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.7	1005	371	60353	114
Leucoxene	1.3	1.9	1317	528	97197	15
Rutile	1.9	1.8	1438	557	105413	9
Ti magnetite	1.5	1.7	1018	397	60027	157
Magnetite	1.5	1.8	1355	524	86535	37
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	0.0	0.0	0	0	0	0
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.6	2.1	1445	587	99319	355
Kya/Sill	1.4	1.7	849	321	35602	6
Staurolite	0.0	0.0	0	0	0	0
Zircon	0.0	0.0	0	0	0	0
Silicate	1.8	2.2	1379	578	92698	94
Unclassified	1.7	2.0	1056	432	71237	51

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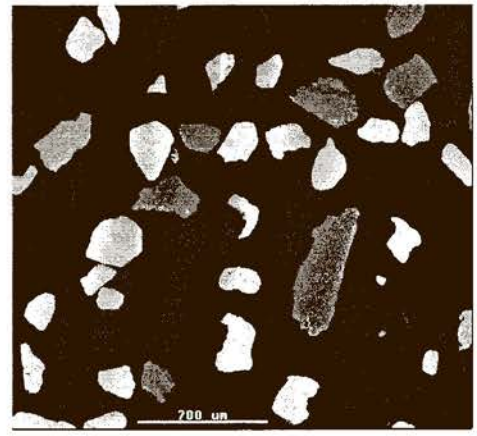

Sample Name:	K 39	No. of frames analysed:	40
Lab. Name:	2000239	No. of particles analysed:	694
Date:	02/10/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	39.21
Country:	India	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/40x		
Guard region:	400 µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	59.0	35.1	0.5	0.2	0.8	1.1	0.9	0.1	0.3	98.0
Leucoxene	75.7	16.1	0.2	0.4	1.9	2.6	0.6	0.2	0.3	98.0
Rutile	94.3	1.2	0.2	0.2	0.4	0.6	0.1	0.0	0.3	97.4
Ti magnetite	37.1	37.4	0.3	0.4	9.8	5.7	0.9	0.4	3.4	95.2
Magnetite	0.4	70.9	0.1	0.3	9.8	14.2	0.4	0.2	0.3	96.5
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	0.6	0.0	0.0	2.8	0.8	0.1	2.2	2.7	9.2
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.1	31.0	0.8	0.2	38.1	20.2	6.8	0.9	0.4	98.5
Kya/Sill	0.1	0.7	0.2	0.3	42.7	53.9	0.1	0.1	0.2	98.2
Staurolite	1.1	13.1	0.1	0.4	33.8	47.5	1.2	0.2	0.1	97.6
Zircon	0.4	0.5	0.1	0.3	29.6	0.1	0.1	0.1	64.7	95.8
Silicate	0.6	1.9	0.1	0.2	46.4	47.4	0.7	0.1	0.2	97.5
Unclassified	2.3	13.1	0.4	0.9	19.7	37.2	3.1	0.4	6.6	83.7

	Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	70.5	7.8	3.3	1.5	5.2	6.1	5.2	0.4	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	60.2	77.3	96.8	38.9
Fe_2O_3 wt%	35.8	16.5	1.3	39.3
MnO wt%	0.5	0.2	0.2	0.3
Cr_2O_3 wt%	0.2	0.4	0.2	0.4
SiO_2 wt%	0.8	1.9	0.4	10.2
Al_2O_3 wt%	1.1	2.6	0.6	6.0
MgO wt%	0.9	0.6	0.1	0.9
CaO wt%	0.1	0.2	0.0	0.4
ZrO_2 wt%	0.3	0.3	0.3	3.6
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	62.9
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	61.5
Valuable heavy minerals in raw sand:	34.89

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	62.8	24.6
Leucoxene	6.9	2.7
Rutile	2.9	1.2
Ti magnetite	1.4	0.5
Magnetite	2.7	1.1
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.9	0.4
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	4.6	1.8
Kya/Sill	4.6	1.8
Staurolite	0.3	0.1
Zircon	5.4	2.1
Silicate	6.8	63.5
Unclassified	0.6	0.2
Total	100.0	100.0

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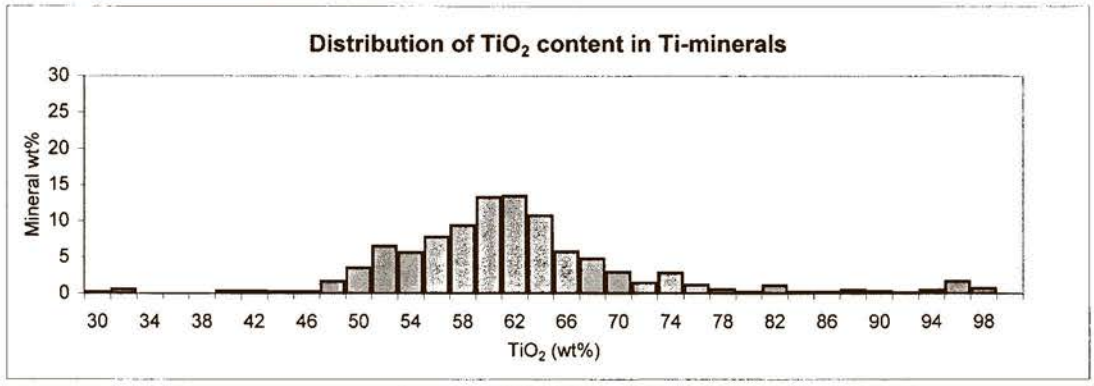
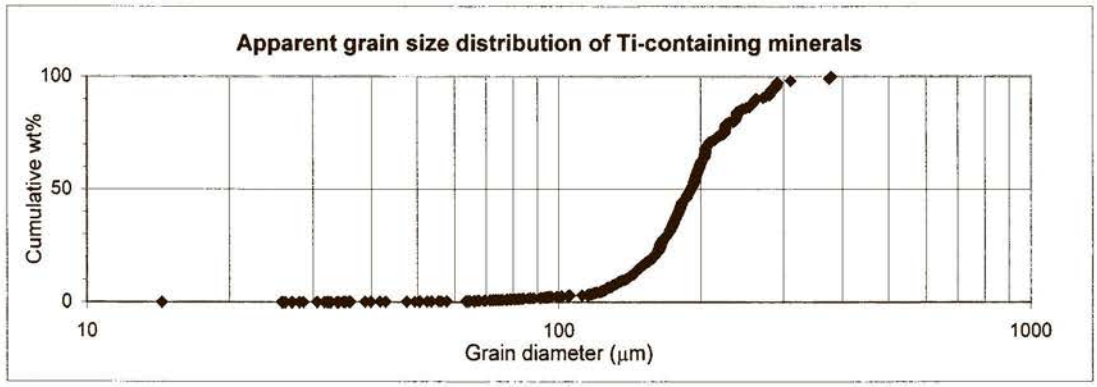
GEUS

Lab. Name:	2000239	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	02/10/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.5	1.6	654	240	22932	423
Leucoxene	1.6	1.7	656	240	22736	47
Rutile	1.7	1.8	598	225	17071	24
Ti magnetite	1.6	1.8	631	259	21952	9
Magnetite	1.6	2.2	945	377	40021	9
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	1.5	1.5	514	178	14088	9
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.9	2.6	894	377	27875	29
Kya/Sill	1.7	2.1	912	377	35456	28
Staurolite	1.7	1.8	591	237	19048	3
Zircon	1.4	1.6	609	224	20218	40
Silicate	1.7	2.0	756	302	28939	62
Unclassified	1.7	1.6	385	149	13340	11

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G E U S

Sample Name:	K 45	No. of frames analysed:	81
Lab. Name:	2000245	No. of particles analysed:	1135
Date:	02/10/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	70.29
Country:	India	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/30x			
Guard region:	450 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	52.1	44.0	0.4	0.1	0.5	0.4	0.7	0.1	0.2	98.5
Leucoxene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rutile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ti magnetite	40.1	46.0	0.5	0.2	5.9	3.5	1.6	0.1	0.5	98.3
Magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	0.4	0.0	0.0	2.8	0.2	0.2	3.2	2.8	9.6
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	0.2	32.6	0.7	0.1	37.7	19.6	5.7	1.4	0.2	98.4
Kya/Sill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.3	0.4	0.1	0.1	29.1	0.1	0.2	0.2	64.4	94.9
Silicate	0.2	13.3	0.3	0.2	63.7	16.2	1.0	1.8	0.2	96.9
Unclassified	0.7	2.1	0.7	0.4	3.3	14.4	4.8	62.0	2.9	91.2

	Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	47.4	0.0	0.0	5.0	45.5	2.2	0.0	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	52.9	0	0	40.8
Fe_2O_3 wt%	44.7	0	0	46.8
MnO wt%	0.5	0	0	0.5
Cr_2O_3 wt%	0.1	0	0	0.2
SiO_2 wt%	0.5	0	0	6.0
Al_2O_3 wt%	0.4	0	0	3.5
MgO wt%	0.7	0	0	1.7
CaO wt%	0.1	0	0	0.1
ZrO_2 wt%	0.2	0	0	0.5
Total	100.0	0	0	100.0

Average TiO_2 content of all the TiO_2 minerals:	51.8
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	51.8
Valuable heavy minerals in raw sand:	65.94

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	44.4	31.2
Leucoxene	0.0	0.0
Rutile	0.0	0.0
Ti magnetite	4.7	3.3
Magnetite	0.0	0.0
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.7	0.5
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	42.6	30.0
Kya/Sill	0.0	0.0
Staurolite	0.0	0.0
Zircon	2.0	1.4
Silicate	0.7	30.2
Unclassified	4.8	3.4
Total	100.0	100.0

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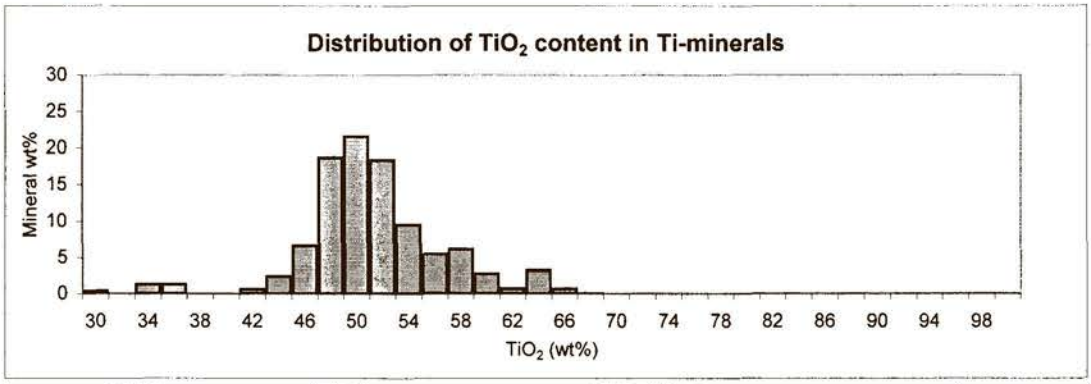
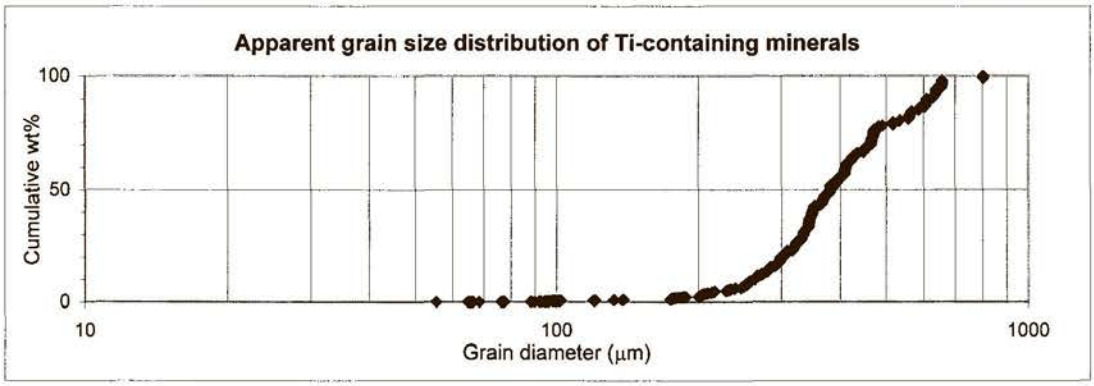
GEUS

Lab. Name:	2000245	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	02/10/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (μm)	Length (μm)	Area (μm^2)	Total grains
Ilmenite	1.5	1.7	1288	482	84934	565
Leucoxene	0.0	0.0	0	0	0	0
Rutile	0.0	0.0	0	0	0	0
Ti magnetite	1.4	2.3	2031	843	153655	31
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	1.5	1.3	903	272	58348	11
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.5	2.0	1589	639	113881	455
Kya/Sill	0.0	0.0	0	0	0	0
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.3	1.6	1144	449	106759	20
Silicate	1.9	2.7	2213	950	149457	9
Unclassified	1.6	2.0	2191	910	227147	38

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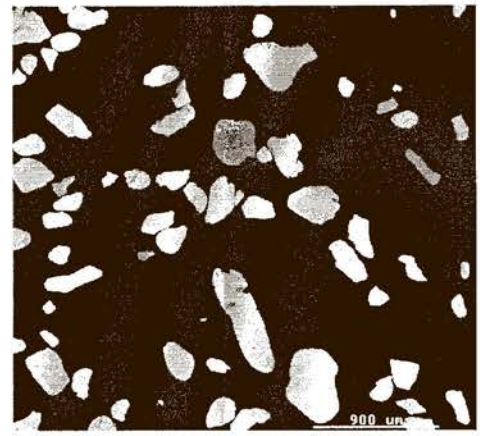

Sample Name:	K 48	No. of frames analysed:	21
Lab. Name:	2000248	No. of particles analysed:	729
Date:	02/10/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	96.35
Country:	India	Comments:	
Analyzed by:	JK		
Acc. Voltage/Magnification:	17kV/30x		
Guard region:	375 µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	55.5	39.4	0.5	0.2	0.7	0.7	0.8	0.1	0.3	98.2
Leucoxene	75.6	12.5	0.2	0.5	4.1	3.7	0.7	0.2	0.2	97.8
Rutile	94.8	0.9	0.1	0.3	0.3	0.5	0.1	0.0	0.6	97.7
Ti magnetite	36.1	37.5	0.3	0.1	10.4	5.5	2.3	0.3	2.2	94.9
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	1.4	1.0	0.0	0.0	3.2	1.1	0.4	2.5	2.6	12.2
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	0.3	32.1	0.6	0.1	37.6	19.8	6.4	1.1	0.2	98.3
Kya/Sill	0.2	0.5	0.1	0.3	42.5	53.6	0.0	0.1	0.2	97.7
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.3	0.5	0.2	0.2	29.3	0.2	0.1	0.1	64.8	95.6
Silicate	0.2	0.6	0.2	0.2	54.2	42.3	0.1	0.0	0.3	98.1
Unclassified	13.7	20.1	0.9	1.3	14.8	20.6	4.8	5.7	6.3	88.2

	Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	56.7	4.8	4.3	3.7	16.9	11.1	2.6	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	56.6	77.3	97.0	38.1
Fe_2O_3 wt%	40.1	12.8	1.0	39.6
MnO wt%	0.5	0.3	0.1	0.4
Cr_2O_3 wt%	0.2	0.6	0.3	0.1
SiO_2 wt%	0.7	4.2	0.4	11.0
Al_2O_3 wt%	0.8	3.7	0.5	5.8
MgO wt%	0.9	0.7	0.1	2.4
CaO wt%	0.1	0.2	0.0	0.4
ZrO_2 wt%	0.3	0.2	0.6	2.4
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	59.5
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	57.0
Valuable heavy minerals in raw sand:	88.91

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	52.3	50.4
Leucoxene	4.4	4.3
Rutile	3.9	3.8
Ti magnetite	3.5	3.3
Magnetite	0.0	0.0
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	2.8	2.7
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	15.5	15.0
Kya/Sill	2.4	2.3
Staurolite	0.0	0.0
Zircon	10.2	9.9
Silicate	2.3	5.9
Unclassified	2.6	2.5
Total	100.0	100.0

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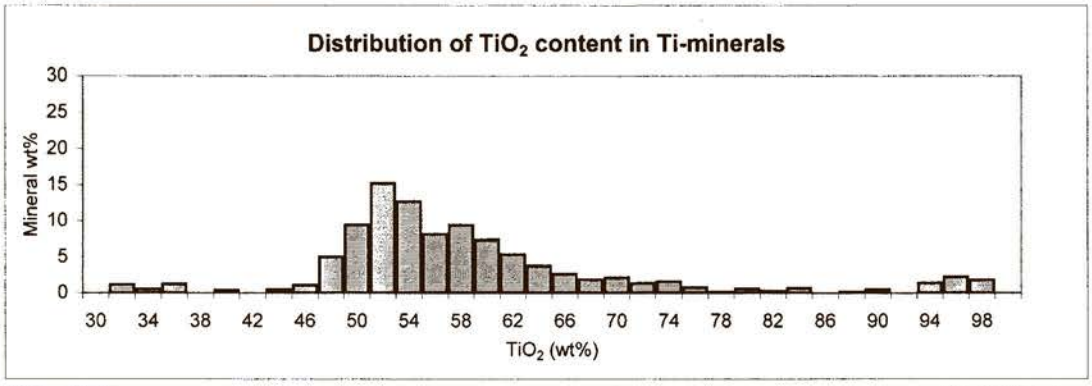
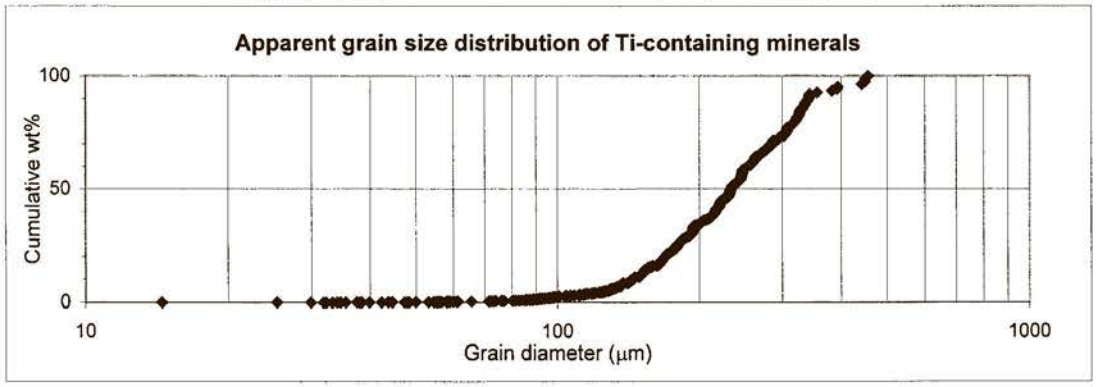
GEUS

Lab. Name:	2000248	Analyzed by:	JK
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	02/10/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.5	1.7	725	268	29001	392
Leucoxene	1.5	1.6	701	261	26678	36
Rutile	1.4	1.6	735	257	30812	25
Ti magnetite	1.6	2.6	1212	528	54346	13
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	1.6	1.5	579	202	19006	29
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.6	1.9	957	377	46966	81
Kya/Sill	1.6	1.7	822	312	34563	21
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.4	1.6	685	249	26934	80
Silicate	1.4	1.7	678	257	25269	34
Unclassified	1.6	2.3	1091	474	51906	18

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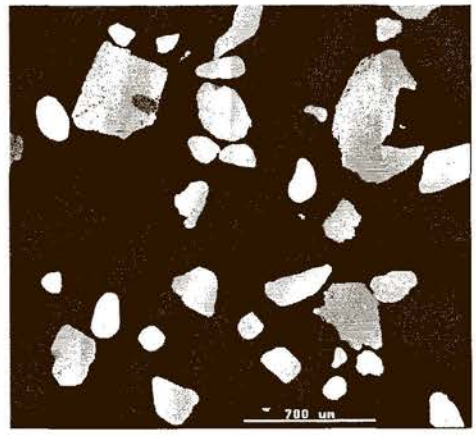

Sample Name:	K 50	No. of frames analysed:	49
Lab. Name:	2000250	No. of particles analysed:	570
Date:	02/10/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	92.61
Country:	India	Comments:	
Analyzed by:	JK		
Acc. Voltage/Magnification:	17kV/40x		
Guard region:	375 µm		
Sieve:	100 μm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	54.3	41.2	0.4	0.2	0.5	0.7	0.9	0.1	0.2	98.5
Leucoxene	75.7	11.9	0.3	0.2	4.6	4.1	0.7	0.2	1.0	98.5
Rutile	94.7	1.8	0.0	0.1	0.5	0.3	0.1	0.0	0.4	97.8
Ti magnetite	39.2	44.4	0.5	0.1	5.2	3.3	1.8	0.2	0.5	95.2
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	1.1	0.6	0.0	0.0	2.4	0.5	0.3	2.6	3.4	10.8
Y-phosphate	0.0	0.5	0.0	0.0	0.3	0.0	0.0	2.7	3.8	7.3
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.2	31.8	0.5	0.1	37.9	19.9	6.6	1.2	0.2	98.4
Kya/Sill	0.0	1.1	0.0	0.1	43.2	54.1	0.0	0.1	0.5	99.1
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.5	0.6	0.2	0.1	29.4	0.2	0.1	0.1	64.5	95.7
Silicate	0.7	9.2	0.3	0.8	39.5	36.7	4.2	0.3	0.4	92.1
Unclassified	8.9	16.3	0.6	0.0	17.8	14.3	2.9	0.6	22.2	83.6

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	71.9	0.6	0.7	3.4	18.1	5.2	0.2	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	55.2	76.8	96.8	41.2
Fe_2O_3 wt%	41.8	12.1	1.8	46.7
MnO wt%	0.4	0.3	0.0	0.5
Cr_2O_3 wt%	0.2	0.2	0.1	0.1
SiO_2 wt%	0.5	4.6	0.5	5.5
Al_2O_3 wt%	0.7	4.1	0.3	3.5
MgO wt%	0.9	0.7	0.1	1.9
CaO wt%	0.1	0.2	0.0	0.2
ZrO_2 wt%	0.2	1.0	0.4	0.5
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	55.1
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	54.7
Valuable heavy minerals in raw sand:	83.77

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	65.0	60.2
Leucoxene	0.5	0.5
Rutile	0.6	0.5
Ti magnetite	3.1	2.8
Magnetite	0.0	0.0
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	7.7	7.1
Y-phosphate	0.1	0.1
Sphene	0.0	0.0
Garnet	16.4	15.1
Kya/Sill	0.1	0.1
Staurolite	0.0	0.0
Zircon	4.7	4.4
Silicate	0.6	8.0
Unclassified	1.2	1.1
Total	100.0	100.0

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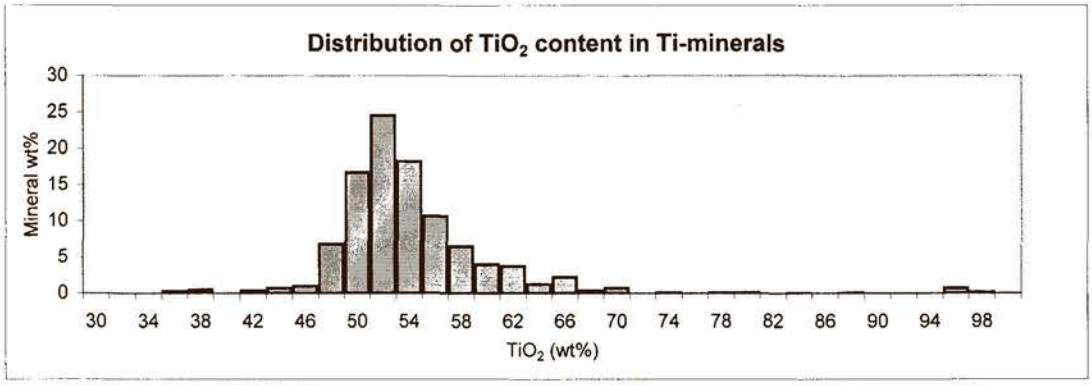
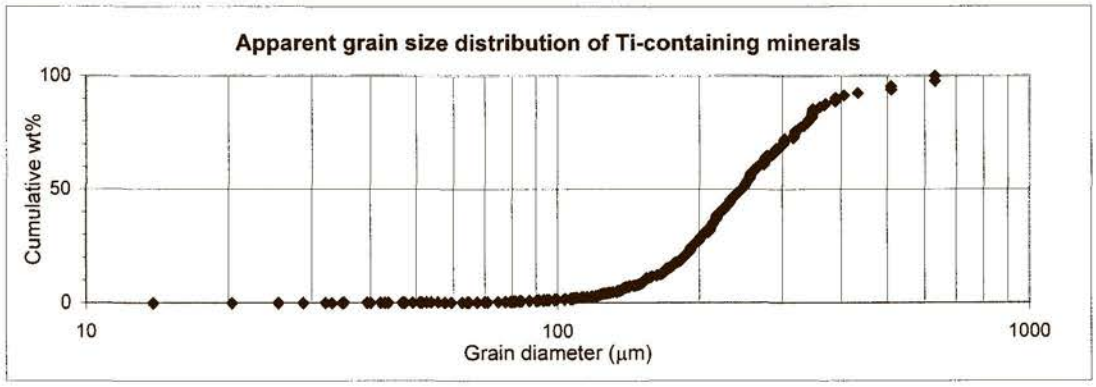
GEUS

Lab. Name:	2000250	Analyzed by:	JK
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	02/10/02		





	Average grain parameters					
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.5	1.7	794	298	33878	382
Leucoxene	1.6	1.6	555	198	18103	6
Rutile	1.4	1.6	631	230	21187	5
Ti magnetite	1.7	2.4	1262	526	57618	10
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	1.4	1.5	620	214	22493	61
Y-phosphate	1.2	1.6	611	222	18602	1
Sphene	0.0	0.0	0	0	0	0
Garnet	2.0	2.3	1290	539	76305	48
Kya/Sill	1.3	1.7	647	240	20150	2
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.4	1.7	729	272	28565	32
Silicate	1.2	2.1	915	383	35488	6
Unclassified	1.7	2.7	1170	511	47928	8

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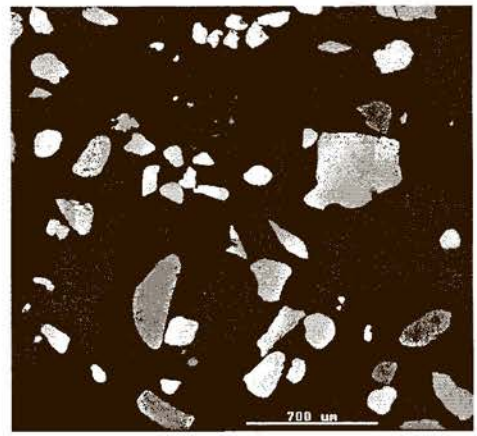

Sample Name:	K 53	No. of frames analysed:	39
Lab. Name:	2000253	No. of particles analysed:	782
Date:	02/10/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	44.00
Country:	India	Comments: High amount of unclassified.	
Analyzed by:	JK	Will be re-analysed.	
Acc. Voltage/Magnification: 17kV/40x			
Guard region:	400 µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	59.0	35.6	0.5	0.2	0.8	0.8	0.8	0.1	0.3	98.0
Leucoxene	76.6	12.9	0.2	0.3	3.5	1.9	0.7	0.2	0.5	96.8
Rutile	94.6	0.8	0.2	0.2	0.7	0.4	0.1	0.1	0.5	97.6
Ti magnetite	29.9	33.5	0.3	0.2	16.6	9.6	3.5	4.0	0.1	97.8
Magnetite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	0.4	0.0	0.0	3.2	0.4	0.2	2.0	3.0	9.3
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.3	32.2	0.6	0.1	37.7	19.4	5.8	1.9	0.4	98.3
Kya/Sill	0.3	0.5	0.2	0.2	42.8	53.7	0.1	0.1	0.3	98.0
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.2	0.4	0.2	0.1	29.6	0.1	0.1	0.1	64.9	95.7
Silicate	0.2	2.1	0.1	0.2	63.7	28.4	0.7	1.1	0.4	97.0
Unclassified	4.4	4.2	0.5	0.3	10.1	6.6	0.8	58.7	7.4	92.8

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	25.1	2.8	6.8	5.1	30.5	28.0	1.7	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	60.2	79.2	97.0	30.6
Fe_2O_3 wt%	36.4	13.3	0.8	34.2
MnO wt%	0.5	0.2	0.2	0.3
Cr_2O_3 wt%	0.2	0.3	0.2	0.2
SiO_2 wt%	0.8	3.6	0.7	17.0
Al_2O_3 wt%	0.8	2.0	0.4	9.9
MgO wt%	0.8	0.8	0.1	3.6
CaO wt%	0.1	0.2	0.1	4.1
ZrO_2 wt%	0.3	0.5	0.5	0.1
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	64.0
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	57.2
Valuable heavy minerals in raw sand:	36.16

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	20.7	9.1
Leucoxene	2.3	1.0
Rutile	5.6	2.5
Ti magnetite	4.2	1.8
Magnetite	0.0	0.0
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	4.7	2.1
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	25.1	11.0
Kya/Sill	1.4	0.6
Staurolite	0.0	0.0
Zircon	23.0	10.1
Silicate	4.1	57.8
Unclassified	9.1	4.0
Total	100.0	100.0

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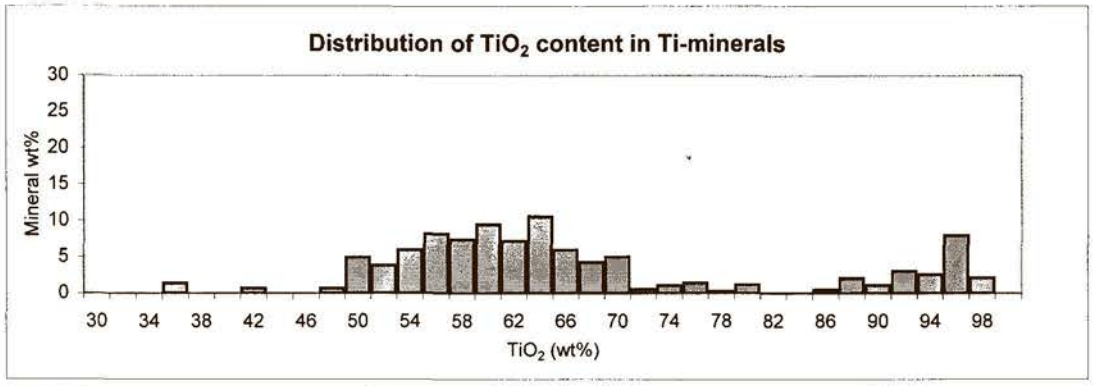
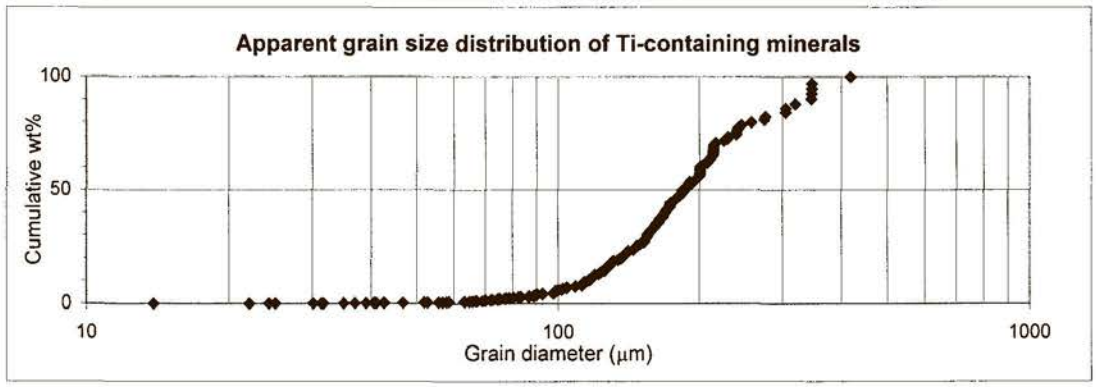
GEUS

Lab. Name:	2000253	Analyzed by:	JK
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	02/10/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.5	1.7	591	219	18482	153
Leucoxene	1.5	1.5	490	173	15551	20
Rutile	1.5	1.6	496	181	14043	49
Ti magnetite	1.7	4.4	2033	931	76879	7
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	1.4	1.5	483	172	13761	42
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.8	2.1	711	291	24263	159
Kya/Sill	1.6	2.0	597	235	16415	16
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.5	1.6	516	188	14457	211
Silicate	1.7	1.9	532	207	14555	65
Unclassified	1.8	2.1	859	360	34425	60

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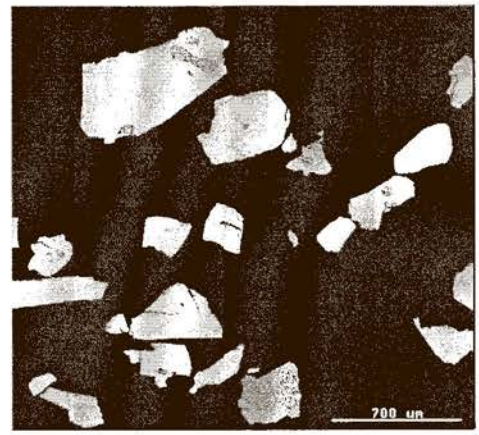

Sample Name:	K 55	No. of frames analysed:	79
Lab. Name:	2000255	No. of particles analysed:	669
Date:	03/10/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	27.44
Country:	India	Comments:	
Analyzed by:	JK		
Acc. Voltage/Magnification:	17kV/40x		
Guard region:	450 µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	51.7	42.5	0.3	0.1	1.8	1.1	0.7	0.1	0.1	98.4
Leucoxene	74.5	7.6	0.3	0.0	10.3	5.2	0.3	0.3	0.3	98.7
Rutile	93.7	1.4	0.1	0.3	1.0	0.6	0.3	0.1	0.9	98.2
Ti magnetite	44.4	50.5	0.4	0.0	1.2	0.8	0.8	0.1	0.6	98.8
Magnetite	0.6	68.1	0.2	0.2	14.6	11.8	0.5	0.6	0.6	97.3
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	0.4	0.0	0.0	7.0	0.2	0.2	2.0	2.6	12.4
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	0.1	31.3	0.6	0.1	38.2	19.9	6.3	1.1	0.3	98.1
Kya/Sill	0.1	0.8	0.1	0.2	42.6	53.7	0.0	0.1	0.4	98.0
Staurolite	1.2	14.7	0.4	0.3	38.2	41.2	2.5	0.1	0.0	98.7
Zircon	0.2	0.3	0.3	0.0	29.9	0.0	0.0	0.0	64.4	95.1
Silicate	0.3	9.1	0.3	0.1	48.7	36.0	1.8	0.8	0.3	97.4
Unclassified	0.3	27.3	0.4	0.4	22.6	13.7	3.8	2.5	1.9	73.0

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	13.2	1.2	0.5	0.0	82.7	0.2	2.0	0.3	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	52.6	75.4	95.4	45.0
Fe_2O_3 wt%	43.1	7.7	1.4	51.1
MnO wt%	0.3	0.3	0.1	0.4
Cr_2O_3 wt%	0.1	0.0	0.3	0.0
SiO_2 wt%	1.8	10.4	1.0	1.2
Al_2O_3 wt%	1.1	5.3	0.6	0.8
MgO wt%	0.7	0.3	0.3	0.8
CaO wt%	0.1	0.3	0.1	0.1
ZrO_2 wt%	0.1	0.3	0.9	0.6
Total	100.0	100.0	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:	54.4
Valuable heavy minerals in raw sand:	26.11

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	12.5	3.4
Leucoxene	1.1	0.3
Rutile	0.5	0.1
Ti magnetite	0.0	0.0
Magnetite	0.1	0.0
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.3	0.1
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	78.7	21.6
Kya/Sill	1.9	0.5
Staurolite	0.3	0.1
Zircon	0.2	0.0
Silicate	4.0	73.7
Unclassified	0.4	0.1
Total	100.0	100.0

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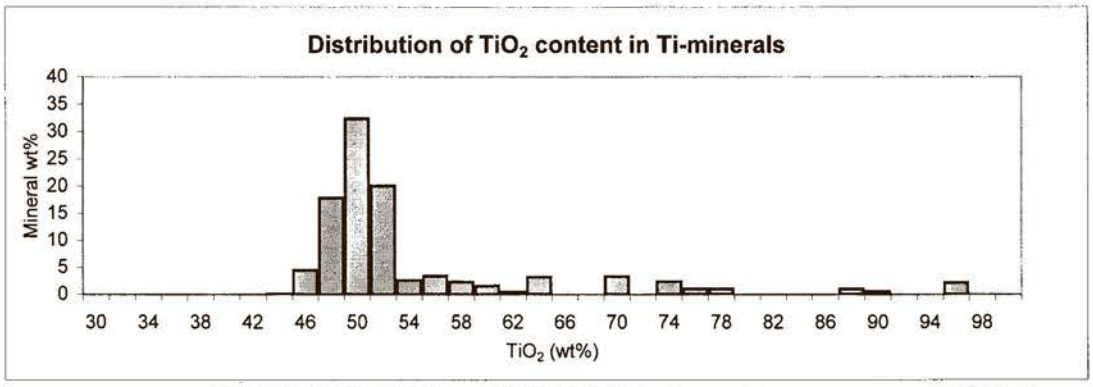
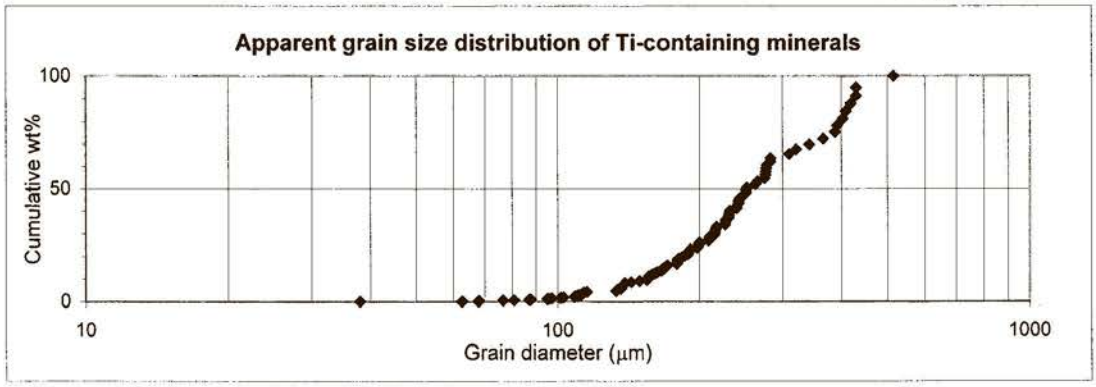
GEUS

Lab. Name:	2000255	Analyzed by:	JK
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	03/10/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.5	1.8	866	336	38076	95
Leucoxene	1.2	1.6	1135	419	63741	5
Rutile	1.4	1.7	544	207	15111	9
Ti magnetite	3.4	2.0	280	113	3073	2
Magnetite	1.8	1.5	219	83	3513	6
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.7	2.2	872	358	27996	3
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.7	2.2	1113	467	58097	440
Kya/Sill	1.7	2.5	1048	455	44402	17
Staurolite	1.5	6.6	2783	1321	93054	1
Zircon	1.2	1.7	966	359	44651	1
Silicate	1.6	2.2	706	296	25534	77
Unclassified	1.4	1.3	353	138	15525	13

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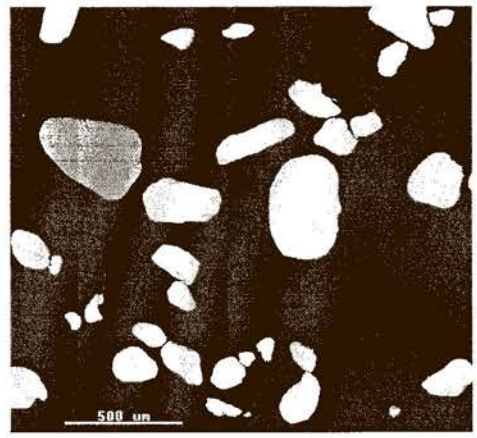

Sample Name:	K 65	No. of frames analysed:	54
Lab. Name:	2000262	No. of particles analysed:	709
Date:	07/10/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	89.50
Country:	India	Comments:	
Analyzed by:	JK		
Acc. Voltage/Magnification:	17kV/50x		
Guard region:	250 µm		
Sieve:	100 µm²		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	50.6	44.5	0.5	0.1	1.0	0.9	0.6	0.1	0.2	98.5
Leucoxene	75.3	16.9	0.2	0.3	2.0	1.5	0.3	0.2	0.5	97.2
Rutile	94.1	1.7	0.1	0.3	0.6	0.4	0.1	0.1	0.4	97.7
Ti magnetite	42.1	45.1	0.5	0.1	4.0	3.1	0.6	0.1	0.8	96.4
Magnetite	0.6	81.1	0.7	0.4	9.7	6.3	0.0	0.0	0.0	98.9
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	1.5	1.4	0.0	0.0	4.0	0.9	0.3	2.1	2.4	12.7
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	6.1	21.5	0.3	0.4	42.4	23.5	0.6	0.2	0.9	95.9
Kya/Sill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.2	0.7	0.2	0.1	29.8	0.3	0.1	0.1	64.1	95.6
Silicate	1.9	16.0	0.3	0.2	44.1	29.8	0.6	0.8	0.4	94.2
Unclassified	11.4	19.0	0.7	0.2	26.0	10.7	0.5	0.2	19.9	88.5

	Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	83.8	1.7	3.0	6.7	0.0	4.8	0.0	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	51.4	77.5	96.4	43.7
Fe_2O_3 wt%	45.2	17.4	1.7	46.7
MnO wt%	0.5	0.2	0.1	0.5
Cr_2O_3 wt%	0.1	0.3	0.3	0.1
SiO_2 wt%	1.0	2.0	0.6	4.2
Al_2O_3 wt%	0.9	1.6	0.4	3.2
MgO wt%	0.6	0.3	0.1	0.6
CaO wt%	0.1	0.2	0.1	0.1
ZrO_2 wt%	0.2	0.5	0.4	0.8
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	52.8
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	51.3
Valuable heavy minerals in raw sand:	86.67

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	81.2	72.6
Leucoxene	1.6	1.5
Rutile	2.9	2.6
Ti magnetite	6.5	5.8
Magnetite	0.0	0.0
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	2.4	2.2
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	0.0	0.0
Kya/Sill	0.0	0.0
Staurolite	0.0	0.0
Zircon	4.6	4.1
Silicate	0.2	10.7
Unclassified	0.5	0.4
Total	100.0	100.0

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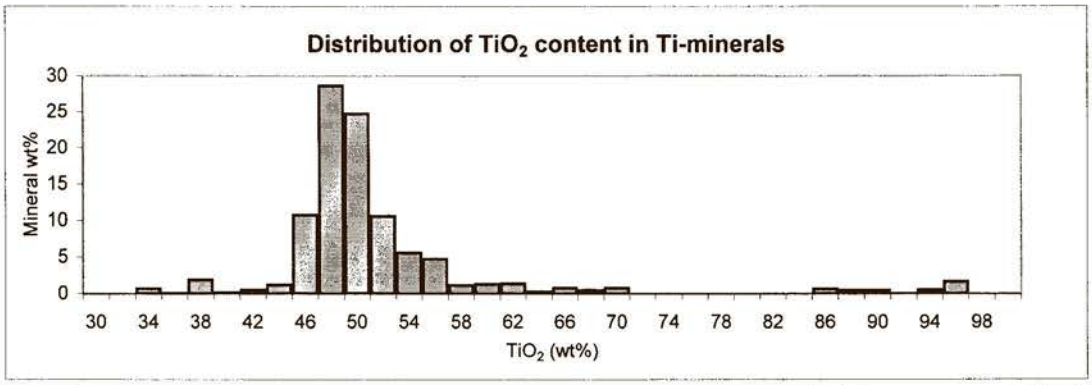
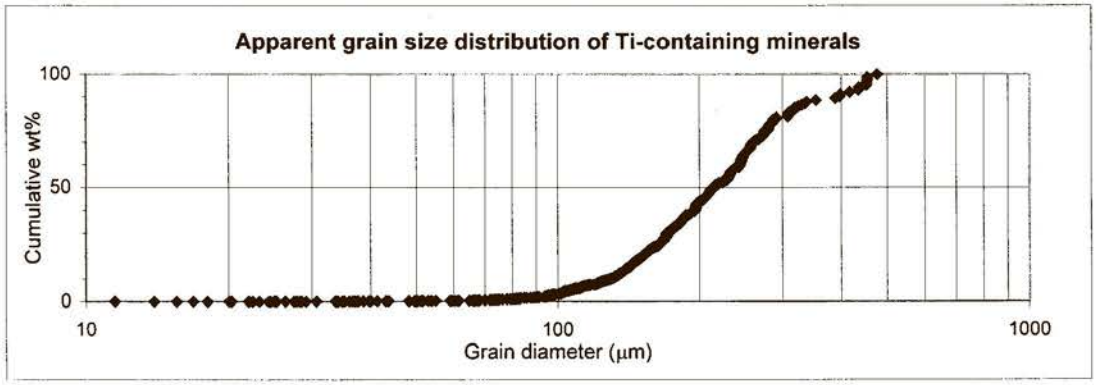
GEUS

Lab. Name:	2000262	Analyzed by:	JK
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	07/10/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.5	1.8	690	262	24546	506
Leucoxene	1.6	2.0	978	401	41477	6
Rutile	1.6	2.0	790	320	27066	15
Ti magnetite	1.5	1.8	485	190	14801	63
Magnetite	1.4	1.6	148	53	1117	1
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.6	1.7	531	196	15339	22
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.5	1.5	116	42	749	6
Kya/Sill	0.0	0.0	0	0	0	0
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.5	1.6	469	168	12645	54
Silicate	1.3	1.4	166	60	2518	22
Unclassified	1.4	1.4	301	124	9011	14

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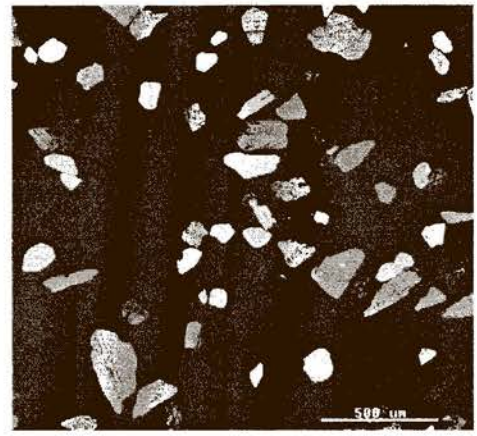
G E U S

Sample Name:	K 68	No. of frames analysed:	45
Lab. Name:	2000265	No. of particles analysed:	1408
Date:	03/10/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	6.30
Country:	India	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/50x		
Guard region:	275 µm		
Sieve:	100 µm²		



	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	52.6	39.7	0.8	0.2	2.1	1.8	0.8	0.1	0.2	98.3
Leucoxene	74.5	9.2	0.2	0.3	6.8	4.5	0.4	0.2	0.2	96.4
Rutile	93.0	0.9	0.1	0.2	1.6	1.3	0.1	0.1	0.5	97.7
Ti magnetite	40.9	47.8	0.9	0.2	3.7	3.3	0.9	0.1	0.2	98.0
Magnetite	3.5	71.9	1.1	0.2	8.6	6.2	0.4	0.6	0.7	93.2
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	1.7	0.0	0.0	0.8	0.1	0.0	4.9	1.3	8.7
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	1.8	20.1	0.5	0.5	42.8	21.6	3.6	1.0	1.9	93.7
Kya/Sill	0.2	0.7	0.1	0.2	42.7	53.6	0.0	0.1	0.3	97.9
Staurolite	4.4	9.0	0.2	0.3	36.1	47.3	0.4	0.2	0.2	98.0
Zircon	0.2	0.6	0.1	0.2	30.0	0.8	0.1	0.2	63.7	96.0
Silicate	0.7	4.6	0.2	0.2	45.6	44.2	0.5	0.4	0.4	96.7
Unclassified	8.1	23.1	0.4	0.6	27.2	25.0	2.0	1.8	2.9	91.2

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	42.2	1.1	5.4	17.7	3.0	2.3	26.6	1.6	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	53.5	77.3	95.2	41.8
Fe_2O_3 wt%	40.4	9.6	0.9	48.8
MnO wt%	0.8	0.2	0.1	0.9
Cr_2O_3 wt%	0.2	0.3	0.2	0.2
SiO_2 wt%	2.2	7.0	1.6	3.8
Al_2O_3 wt%	1.8	4.7	1.3	3.4
MgO wt%	0.8	0.4	0.1	0.9
CaO wt%	0.1	0.2	0.1	0.1
ZrO_2 wt%	0.2	0.2	0.5	0.3
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	54.2
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	50.6
Valuable heavy minerals in raw sand:	3.62

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	24.2	1.5
Leucoxene	0.6	0.0
Rutile	3.1	0.2
Ti magnetite	10.2	0.6
Magnetite	0.3	0.0
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.1	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	1.7	0.1
Kya/Sill	15.3	1.0
Staurolite	0.9	0.1
Zircon	1.3	0.1
Silicate	39.8	96.2
Unclassified	2.3	0.1
Total	100.0	100.0

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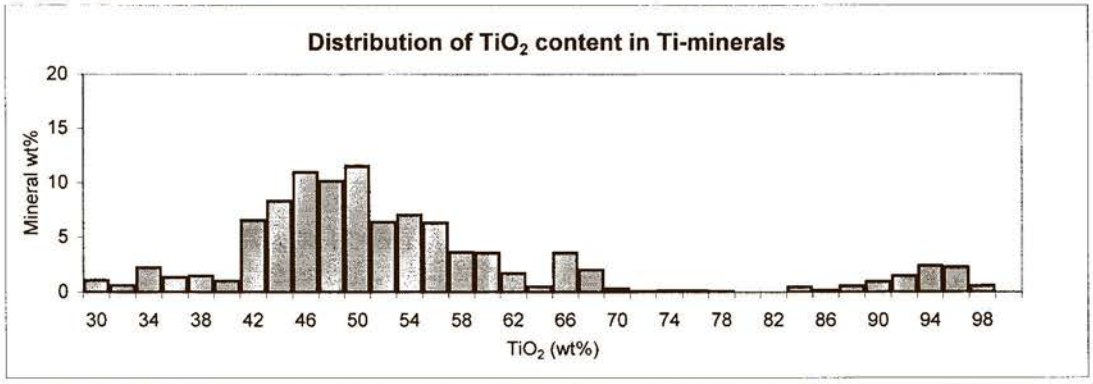
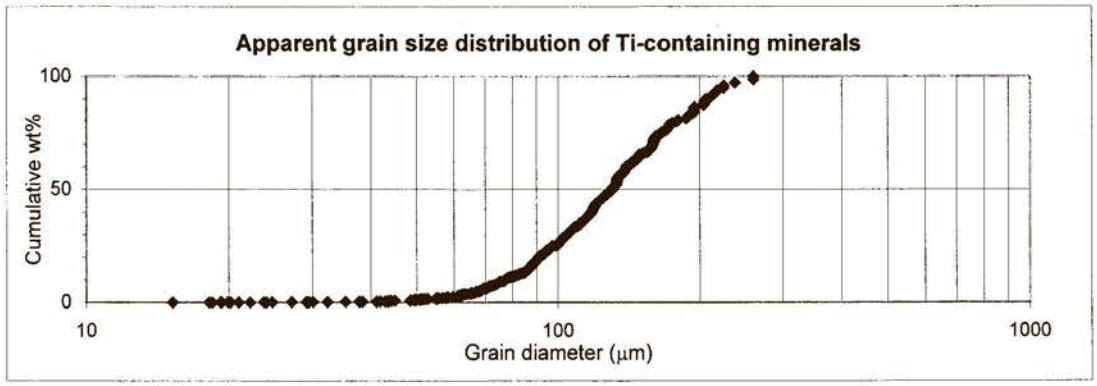
GEUS

Lab. Name:	2000265	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	03/10/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.5	1.7	422	155	9565	261
Leucoxene	1.7	1.6	299	110	5111	13
Rutile	1.4	1.6	394	141	9320	31
Ti magnetite	1.6	1.6	385	142	8737	113
Magnetite	1.4	1.2	162	55	2748	9
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.2	1.5	359	123	6934	2
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.6	1.5	202	80	3423	58
Kya/Sill	1.6	2.0	612	243	16373	133
Staurolite	1.8	2.5	634	276	14272	8
Zircon	1.6	1.5	352	127	7900	17
Silicate	1.6	1.8	420	167	9832	709
Unclassified	1.4	1.9	357	150	7859	50

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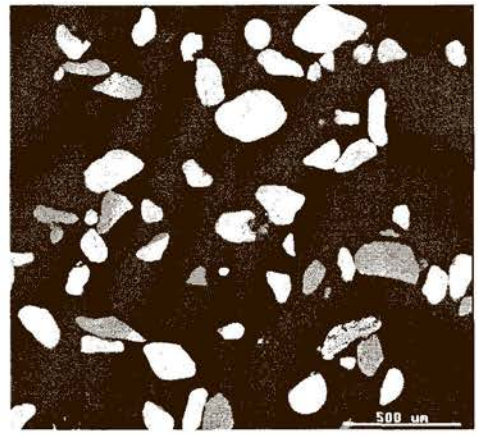
G E U S



Sample Name:	K 72	No. of frames analysed:	28
Lab. Name:	2000267	No. of particles analysed:	744
Date:	03/10/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	5.30
Country:	India	Comments:	
Analyzed by:	JK		
Acc. Voltage/Magnification:	17kV/50x		
Guard region:	250 µm		
Sieve:	100 µm²		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	52.0	41.7	0.5	0.2	1.4	1.5	0.6	0.1	0.2	98.2
Leucoxene	75.5	9.0	0.3	0.3	5.4	5.7	0.2	0.1	0.7	97.3
Rutile	93.9	1.0	0.1	0.1	1.2	1.0	0.1	0.1	0.5	97.9
Ti magnetite	36.8	40.9	0.7	0.2	9.0	8.5	0.4	0.1	0.5	97.1
Magnetite	1.4	65.8	0.7	1.2	9.9	10.2	0.1	0.3	0.7	90.3
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	0.0	0.0	0.0	1.7	0.6	0.0	1.2	2.3	5.6
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	1.3	26.5	0.9	0.1	39.4	21.3	3.6	0.9	0.7	94.8
Kya/Sill	0.2	0.9	0.2	0.3	42.8	53.5	0.0	0.1	0.2	98.1
Staurolite	4.9	10.1	0.2	0.5	36.2	44.9	0.3	0.1	0.6	97.7
Zircon	0.5	0.5	0.1	0.2	29.5	0.1	0.1	0.1	64.9	96.1
Silicate	0.8	6.3	0.2	0.2	44.9	43.5	0.3	0.1	0.4	96.9
Unclassified	7.9	19.3	0.9	0.5	23.2	25.1	1.7	0.2	5.1	84.0

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	74.5	3.6	7.1	4.8	0.4	2.2	6.0	1.4	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	53.0	77.6	95.9	37.9
Fe_2O_3 wt%	42.5	9.3	1.0	42.1
MnO wt%	0.5	0.3	0.1	0.7
Cr_2O_3 wt%	0.2	0.3	0.1	0.2
SiO_2 wt%	1.5	5.5	1.2	9.3
Al_2O_3 wt%	1.5	5.9	1.1	8.8
MgO wt%	0.6	0.2	0.1	0.4
CaO wt%	0.1	0.1	0.1	0.1
ZrO_2 wt%	0.2	0.8	0.5	0.6
Total	100.0	100.0	100.0	100.0

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	58.9	3.1
Leucoxene	2.9	0.2
Rutile	5.6	0.3
Ti magnetite	3.8	0.2
Magnetite	2.8	0.1
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.1	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	0.3	0.0
Kya/Sill	4.7	0.2
Staurolite	1.1	0.1
Zircon	1.8	0.1
Silicate	15.6	95.5
Unclassified	2.4	0.1
Total	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	56.5
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	53.2
Valuable heavy minerals in raw sand:	4.19

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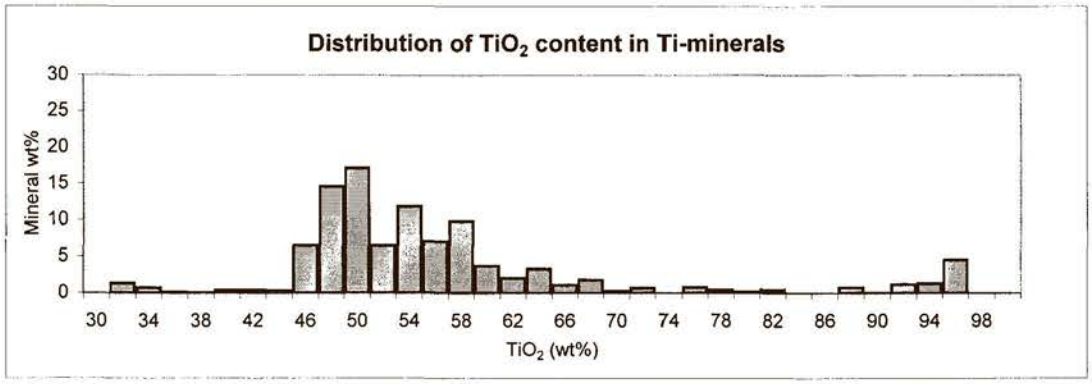
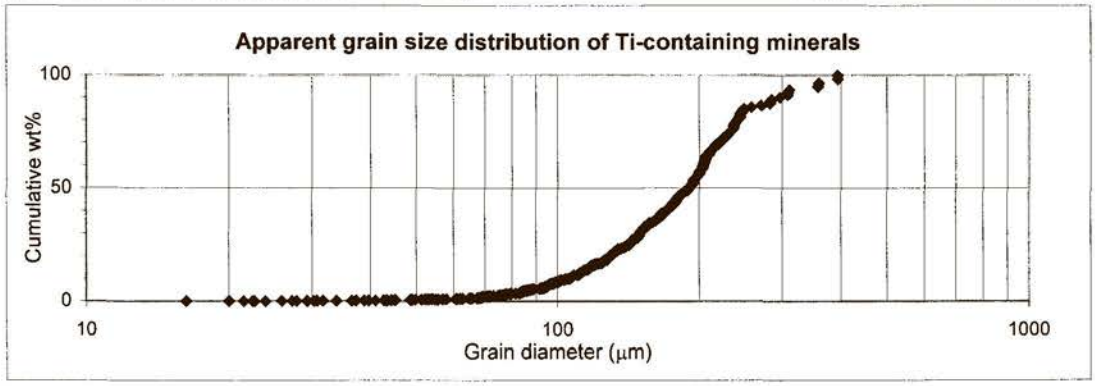
GEUS

Lab. Name:	2000267	Analyzed by:	JK
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	03/10/02		





	Average grain parameters					
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.7	577	217	17906	319
Leucoxene	1.5	1.8	563	214	17381	16
Rutile	1.5	1.6	494	177	14786	33
Ti magnetite	1.4	1.7	431	168	10443	33
Magnetite	1.6	1.6	538	218	21018	11
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.7	1.9	312	118	4455	2
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.5	1.5	246	91	4406	8
Kya/Sill	1.7	1.9	576	226	15815	40
Staurolite	1.6	2.0	579	241	18398	7
Zircon	1.4	1.6	490	173	13717	12
Silicate	1.6	1.8	422	166	11135	231
Unclassified	1.5	2.0	472	199	12336	32

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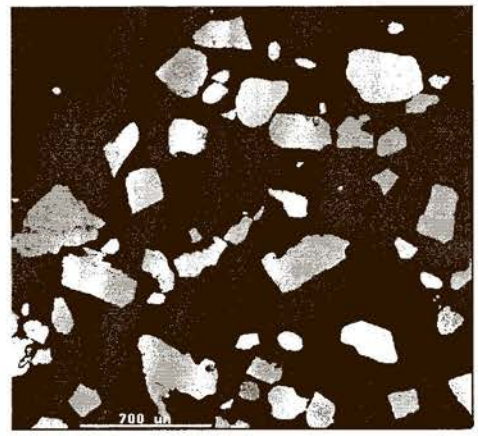
G E U S

Sample Name:	K 80	No. of frames analysed:	49
Lab. Name:	2000269	No. of particles analysed:	903
Date:	07/10/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	73.50
Country:	India	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification: 17kV/40x			
Guard region:	375 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	49.7	45.4	0.9	0.1	0.8	0.5	0.7	0.1	0.2	98.4
Leucoxene	73.7	13.2	1.0	0.2	5.3	3.1	1.0	0.4	0.3	98.1
Rutile	97.2	0.4	0.0	0.7	0.0	0.0	0.0	0.0	0.5	98.8
Ti magnetite	40.2	51.9	1.2	0.2	2.0	1.1	1.2	0.2	0.3	98.3
Magnetite	1.3	84.9	0.4	0.3	6.2	3.3	1.1	0.4	0.2	98.1
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.2	0.4	0.0	0.1	1.1	0.1	0.1	55.9	1.1	58.9
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	0.2	29.2	1.6	0.1	38.2	19.6	6.9	2.0	0.3	98.2
Kya/Sill	0.3	1.8	0.2	0.1	42.6	53.0	0.0	0.0	0.4	98.4
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.2	0.6	0.2	0.2	29.7	0.1	0.2	0.1	64.3	95.5
Silicate	1.2	18.7	0.4	0.2	49.1	8.0	10.7	7.6	0.3	96.1
Unclassified	7.9	22.9	0.8	0.6	18.6	9.3	5.0	14.6	3.5	83.2

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	31.0	1.7	0.1	14.3	51.7	1.2	0.1	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	50.5	75.1	98.4	40.9
Fe_2O_3 wt%	46.1	13.5	0.4	52.8
MnO wt%	0.9	1.0	0.0	1.2
Cr_2O_3 wt%	0.1	0.2	0.7	0.2
SiO_2 wt%	0.8	5.4	0.0	2.0
Al_2O_3 wt%	0.5	3.1	0.0	1.1
MgO wt%	0.8	1.0	0.0	1.2
CaO wt%	0.1	0.4	0.0	0.2
ZrO_2 wt%	0.2	0.3	0.5	0.3
Total	100.0	100.0	100.0	100.0

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	26.6	19.5
Leucoxene	1.4	1.1
Rutile	0.1	0.1
Ti magnetite	12.3	9.0
Magnetite	1.1	0.8
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.3	0.2
Monazite	0.0	0.0
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	44.3	32.6
Kya/Sill	0.0	0.0
Staurolite	0.0	0.0
Zircon	1.0	0.8
Silicate	9.9	33.8
Unclassified	2.9	2.2
Total	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	48.6
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	48.5
Valuable heavy minerals in raw sand:	63.06

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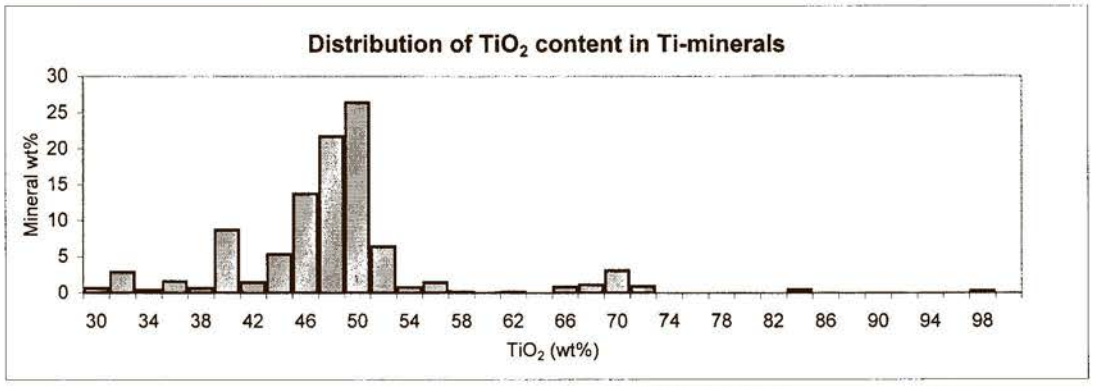
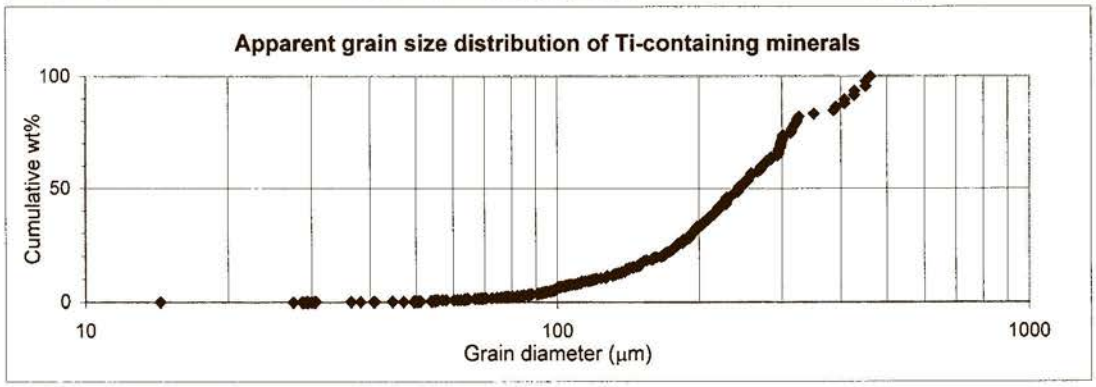
GEUS

Lab. Name:	2000269	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	07/10/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.7	635	243	23645	216
Leucoxene	1.7	2.0	1132	436	55168	5
Rutile	1.5	1.6	629	228	19791	1
Ti magnetite	1.6	1.9	682	271	24199	92
Magnetite	1.3	1.7	467	172	16292	11
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	1.4	1.7	400	149	8672	6
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	1.7	2.0	743	300	27478	349
Kya/Sill	1.6	1.6	348	122	6601	2
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.2	1.6	547	201	15834	12
Silicate	1.7	2.0	629	254	18272	177
Unclassified	1.6	2.3	800	347	29352	32

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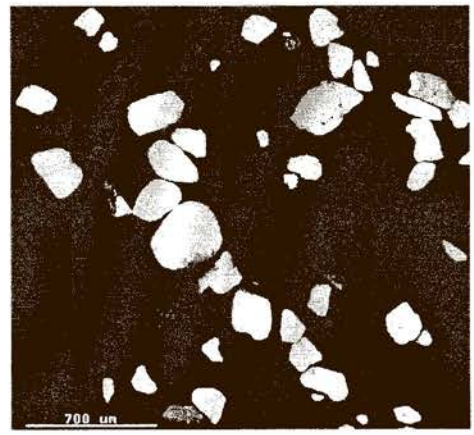
G E U S



Sample Name:	K 81	No. of frames analysed:	44
Lab. Name:	2000270	No. of particles analysed:	855
Date:	07/10/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	36.90
Country:	India	Comments:	
Analyzed by:	BV		
Acc. Voltage/Magnification:	17kV/40x		
Guard region:	350 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	48.8	45.3	0.9	0.1	1.5	0.9	0.6	0.1	0.2	98.5
Leucoxene	75.3	7.1	0.2	0.3	9.3	5.9	0.2	0.1	0.1	98.5
Rutile	95.7	0.7	0.1	0.2	0.6	0.4	0.1	0.0	0.5	98.3
Ti magnetite	40.0	52.6	0.7	0.2	2.1	1.4	0.8	0.1	0.4	98.2
Magnetite	2.7	82.1	0.2	0.2	6.6	4.5	0.2	0.3	0.3	97.1
Chromite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	2.9	3.6	0.0	0.0	3.0	0.5	0.2	3.2	2.7	16.1
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	36.5	2.3	0.0	0.1	29.5	2.2	0.0	27.6	0.3	98.4
Garnet	2.0	25.3	1.3	0.2	40.2	21.0	3.9	1.2	0.9	96.0
Kya/Sill	0.3	0.8	0.3	0.0	43.0	53.3	0.1	0.2	0.5	98.4
Staurolite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zircon	0.2	0.8	0.1	0.1	29.9	0.4	0.1	0.1	63.8	95.6
Silicate	1.7	7.9	0.4	0.2	54.2	28.4	0.4	0.4	0.3	93.9
Unclassified	10.0	23.7	0.8	0.7	25.7	18.8	2.0	0.4	6.6	88.7

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	48.9	0.9	2.4	39.6	5.7	2.2	0.3	0.0	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average	Category			
content	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	49.6	76.5	97.3	40.7
Fe_2O_3 wt%	46.0	7.2	0.7	53.5
MnO wt%	0.9	0.2	0.1	0.8
Cr_2O_3 wt%	0.1	0.3	0.2	0.2
SiO_2 wt%	1.5	9.4	0.6	2.1
Al_2O_3 wt%	1.0	6.0	0.4	1.5
MgO wt%	0.6	0.2	0.1	0.8
CaO wt%	0.1	0.1	0.0	0.1
ZrO_2 wt%	0.2	0.1	0.5	0.4
Total	100.0	100.0	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	47.3
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	45.9
Valuable heavy minerals in raw sand:	34.68

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	46.0	17.0
Leucoxene	0.8	0.3
Rutile	2.3	0.8
Ti magnetite	37.2	13.7
Magnetite	3.0	1.1
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	1.2	0.4
Y-phosphate	0.0	0.0
Sphene	0.2	0.1
Garnet	5.4	2.0
Kya/Sill	0.2	0.1
Staurolite	0.0	0.0
Zircon	2.1	0.8
Silicate	0.6	63.3
Unclassified	1.0	0.4
Total	100.0	100.0

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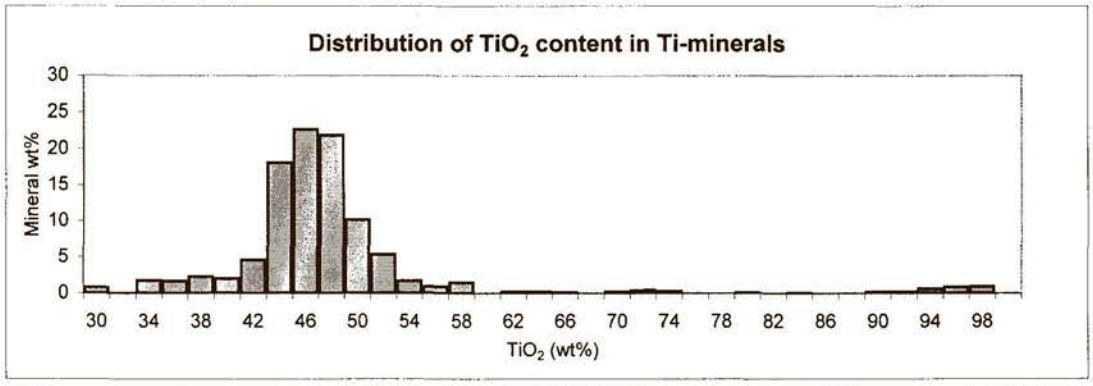
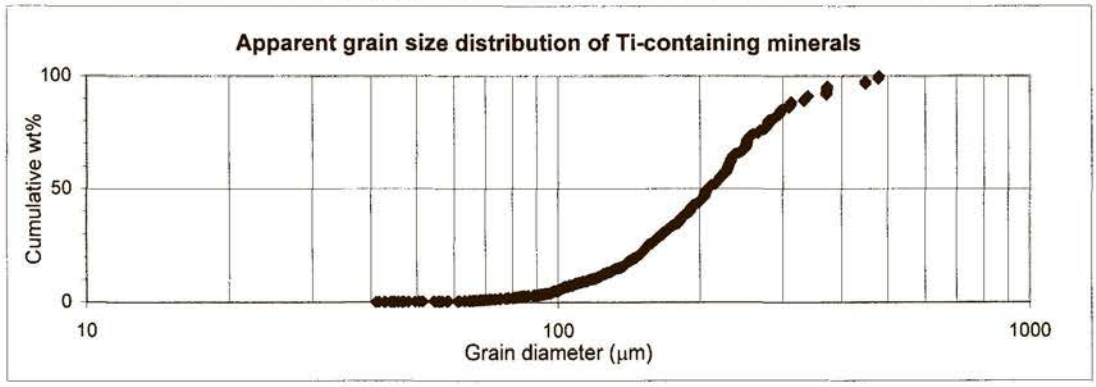
GEUS

Lab. Name:	2000270	Analyzed by:	BV
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	07/10/02		





Average grain parameters						
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.5	1.8	693	266	24300	327
Leucoxene	1.3	1.5	637	225	23949	6
Rutile	1.5	1.7	668	253	22084	16
Ti magnetite	1.6	1.7	587	220	19144	316
Magnetite	1.5	1.5	445	163	14666	31
Chromite	0.0	0.0	0	0	0	0
Pyrite	0.0	0.0	0	0	0	0
Phosphate	0.0	0.0	0	0	0	0
Monazite	1.4	1.6	693	242	26946	7
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	1.3	1.7	954	354	43496	1
Garnet	1.6	1.6	430	170	13754	76
Kya/Sill	1.7	1.9	520	202	11531	5
Staurolite	0.0	0.0	0	0	0	0
Zircon	1.5	1.5	527	183	16520	21
Silicate	1.4	1.3	248	92	6799	24
Unclassified	1.5	1.8	417	180	11728	25

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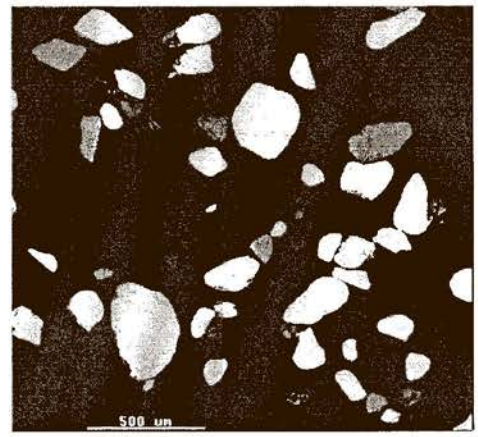
G E U S



Sample Name:	K 87	No. of frames analysed:	64
Lab. Name:	2000274	No. of particles analysed:	1066
Date:	07/10/02	Heavy minerals in raw	
Submitter:	DuPont/GEUS	sand (%):	78.90
Country:	India	Comments:	
Analyzed by:	JK		
Acc. Voltage/Magnification:	17kV/50x		
Guard region:	300 µm		
Sieve:	100 µm^2		

	Average content									
Category	TiO_2 wt%	Fe_2O_3 wt%	MnO wt%	Cr_2O_3 wt%	SiO_2 wt%	Al_2O_3 wt%	MgO wt%	CaO wt%	ZrO_2 wt%	Total
Ilmenite	49.5	43.4	0.9	0.1	2.1	1.5	0.6	0.1	0.2	98.4
Leucoxene	79.2	4.5	0.2	0.3	7.5	4.6	0.2	0.2	0.4	97.1
Rutile	93.7	1.3	0.1	0.2	1.3	1.0	0.1	0.1	0.3	98.1
Ti magnetite	40.7	46.8	0.8	0.2	4.8	3.6	0.7	0.1	0.4	98.0
Magnetite	2.1	80.2	0.4	0.3	7.2	4.8	0.3	0.4	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Monazite	0.0	2.9	0.0	0.0	15.1	3.5	0.0	2.5	4.8	28.8
Y-phosphate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Garnet	3.8	18.8	0.8	0.2	42.6	21.4	2.2	1.4	1.6	92.7
Kya/Sill	0.2	0.9	0.1	0.2	42.9	53.6	0.0	0.1	0.3	98.4
Staurolite	5.7	11.7	0.2	0.0	33.2	47.4	0.1	0.2	0.1	98.6
Zircon	0.3	0.9	0.1	0.1	30.1	0.8	0.1	0.1	63.1	95.5
Silicate	1.4	8.5	0.2	0.3	50.1	33.3	0.6	0.5	0.6	95.4
Unclassified	8.1	16.9	1.8	0.6	28.9	22.9	2.0	0.3	10.0	91.5

Valuable heavy minerals								
Category	Ilmenite	Leucoxene	Rutile	Ti magnetite	Garnet	Zircon	Kya/Sill	Staurolite	Total
wt %	55.3	0.4	2.7	33.2	1.1	2.8	4.0	0.5	100.0

Normalised average contents of the valuable Ti-containing minerals:				
Average content	Category			
	Ilmenite	Leucoxene	Rutile	Ti magnetite
TiO_2 wt%	50.3	81.6	95.5	41.6
Fe_2O_3 wt%	44.1	4.6	1.4	47.8
MnO wt%	0.9	0.2	0.1	0.8
Cr_2O_3 wt%	0.1	0.3	0.2	0.2
SiO_2 wt%	2.1	7.7	1.4	4.9
Al_2O_3 wt%	1.5	4.8	1.0	3.6
MgO wt%	0.7	0.2	0.1	0.7
CaO wt%	0.1	0.2	0.1	0.1
ZrO_2 wt%	0.2	0.5	0.3	0.4
Total	100.0	100.0	100.0	100.0

Weight percent on a mineral basis:		
	Heavy mineral concentrate	Raw sand
Category	wt %	wt %
Ilmenite	47.7	37.6
Leucoxene	0.3	0.2
Rutile	2.4	1.9
Ti magnetite	28.7	22.6
Magnetite	0.9	0.7
Chromite	0.0	0.0
Pyrite	0.0	0.0
Phosphate	0.0	0.0
Monazite	0.1	0.1
Y-phosphate	0.0	0.0
Sphene	0.0	0.0
Garnet	1.0	0.8
Kya/Sill	3.4	2.7
Staurolite	0.4	0.3
Zircon	2.4	1.9
Silicate	11.1	29.8
Unclassified	1.7	1.4
Total	100.0	100.0

Average TiO_2 content of all the TiO_2 minerals:	48.6
Average TiO_2 content of all the TiO_2 minerals excl. rutile:	47.2
Valuable heavy minerals in raw sand:	68.06

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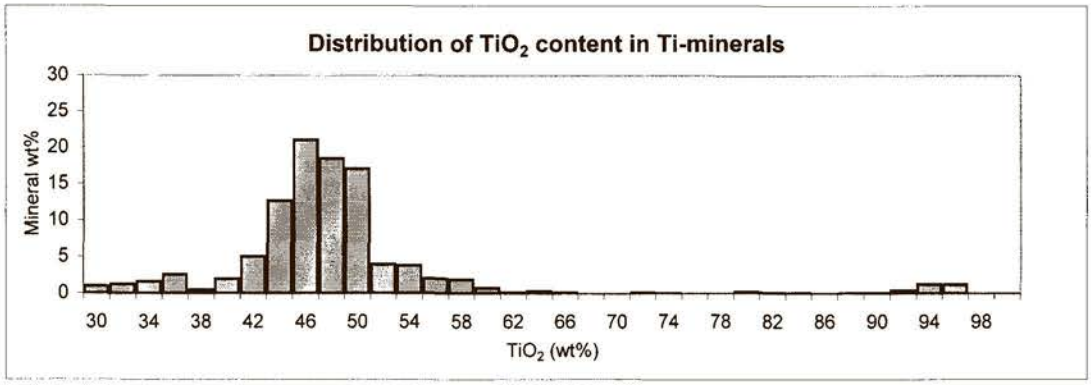
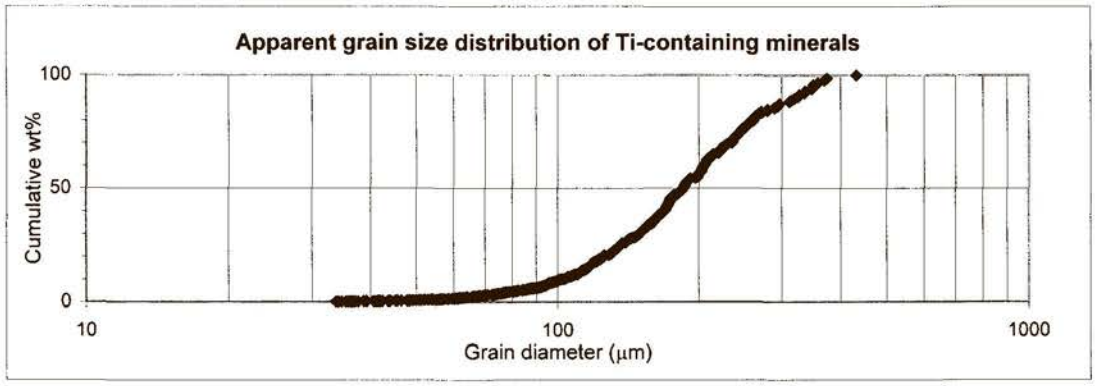
GEUS

Lab. Name:	2000274	Analyzed by:	JK
Submitter:	DuPont/GEUS	Acc. Voltage	17kV
Date:	07/10/02		





	Average grain parameters					
Category	Aspect ratio	Circularity	Perimeter (µm)	Length (µm)	Area (µm^2)	Total grains
Ilmenite	1.6	1.8	572	216	17646	374
Leucoxene	1.5	1.7	361	135	6978	6
Rutile	1.4	1.6	498	178	16289	18
Ti magnetite	1.6	1.8	497	191	13775	271
Magnetite	1.6	1.6	361	132	8589	12
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	2.3	1.6	312	114	5811	2
Y-phosphate	0.0	0.0	0	0	0	0
Sphene	0.0	0.0	0	0	0	0
Garnet	1.4	1.4	198	78	3471	43
Kya/Sill	1.7	2.1	873	356	32954	20
Staurolite	1.5	2.7	860	372	22819	3
Zircon	1.5	1.5	421	152	10541	31
Silicate	1.5	1.7	358	142	10569	246
Unclassified	1.6	1.8	392	166	9909	40