COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1971/42

Preliminary Report
A Reconnaissance of Mineral Sands in South Viet Nam

by

L.C. Noakes

PRELIMINARY REPORT

A RECONNAISSANCE OF MINERAL SANDS IN SOUTH VIET NAM

BY

L.C. NOAKES

Record 1971/42

INTRODUCTION

Delegates to the Committee for Coordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas from the Republic of Viet Nam recorded their interest in mineral sands in 1969 and arrangements were made for the writer to discuss prospects and problems with members of the Geological Survey of South Viet Nam and to carry out a reconnaissance of promising areas following the meeting of CCOP in Saigon in May 1970.

Mineral sands in Viet Nam include deposits of glass sand, which are currently exploited in the Cam Ranh area, and prospective deposits of detrital heavy minerals - principally ilmenite, zircon, rutile and monazite - at a number of localities along the beaches bordering the South China Sea. Priority was given to the investigation of heavy mineral deposits because glass sand projects had been established whereas little was known of the prospects for exploiting detrital heavy minerals.

Data recently collected by the Vietnamese Geological Survey provided an obvious starting point for a reconnaissance of mineral sand deposits. Following interest aroused by CCOP in 1968 and 1969, the Survey collected shallow samples from a number of beaches along the eastern coast and arranged for these to be analysed by the Geological Survey of Malaysia. The most encouraging of these samples, containing ilmenite, rutile and zircon, came from Eagle Beach near Hue; although the grade of this shallow sample appeared marginally, the very extensive beaches of the Hue area warranted investigation.

A field team consisting of Mr V. Van An, Mr Nguyan Tan Thi and Father H. Fontaine of the Geological Survey and the writer spent a week in the Hue area toward the end of May 1970 and, thanks to the cooperation of Colonel Chism of CORD at Hue, who assisted greatly in transport by scout car and helicopter, it was possible in the time to carry out a reconnaissance of about 60 kilometres of coastline and to complete some reconnaissance drilling and sampling of the best prospect found at Vinh My.

Samples taken during the reconnaissance, including those from traverse lines at Vinh My, were subsequently analysed semi-quantitatively by Australian Mineral Development Laboratories in Adelaide whose report is included as Appendix 1. Unfortunately, auger equipment in Saigon was not suitable for this exercise, but equipment capable of recovering a sand core about two centimetres in diameter to a maximum depth of two metres was found to provide small but representative samples; however, the extension rod failed during the drilling of the deposit at Vinh My so that only a few of the holes could penetrate below a depth of one metre. This had little effect on reconnaissance beyond Vinh My, but it needs to be emphasised that reconnaissance drilling at Vinh My could only be shallow and in most holes could not explore values down to or below the water table. Moreover, no theodolite was available at the time and surveying at Vinh My was carried out by the writer using a quick-set level with a turning circle and stadia rod (marked in feet) kindly loaned by Australian Army Engineers; however, a base line and two traverse lines were established with reasonable accuracy and tied into a tomb for permanent identification so that future workers can readily re-establish these survey lines although the wooden pegs themselves are likely to disappear.

This report deals principally with reconnaissance results at the Vinh My deposit which certainly appears sufficiently attractive to warrant more detailed investigation. The results of reconnaissance sampling at other localities in the Hue area are also discussed and some data previously recorded on mineral sands elsewhere in Viet Nam are also included.

The writer wishes to thank his colleagues in the Geological Survey of Viet Nam for their interest and hospitality during the investigations, Colonel Chism and Lieutenant Frederickson of CORD for whole-hearted cooperation and Australian Army Engineers for their assistance in providing survey equipment.

CLIMATE AND ACCESS

South Viet Nam lies wholly in the tropics and is subject to the monsoonal climatic changes of South East Asia. The winter period, approximately October to February, is relatively dry under the influence of the south-west monsoon, but the summer period, about May to October, is the rainy season associated with the north-eastern monsoon. This period may include typhoons particularly late in the summer and the incidence of the storms will be of particular significance to beach mining.

The writer has found little information on longshore currents along the Viet Nam coast, but location and configuration of sand spits in relation to river mouths and headlands observed on maps and from aerial reconnaissance strongly suggests that the principal direction of longshore current movement is from north to south*. As mentioned later, concentration of heavy minerals along the coast near Hue indicate southerly longshore movement of sand, at least in that area. On the other hand, some features of both heavy mineral concentration and of coastal morphology suggests the influence of a reversal of sand movement offshore at times; but these matters require more data and consideration.

Security and the state of hostilities along the Vietnamese coast are not dealt with in this report. However, the Hue area, although the scene of the major TET offensive of 1968, was notably stabilized in 1970 with no apparent security hazards in beach sand mining in the areas visited. Access for prospecting or mining plant and supply of ground water should present no real difficulties, but matters of possible mining tenure were not investigated during the reconnaissance. One matter likely to affect mining in some parts of this area is the occurrence of tombs and burial grounds along dunes and sandhills, some of which may prove of mining potential. Little difficulty is expected at the Vinh My deposit where there are few tombs and none in the area drilled, but burial grounds could present difficulties in other areas and the problem needs to be kept in mind in prospecting for mineral sands.

* The writer gratefully acknowledges helpful discussions with Dr K.O. Emery on this point.

HEAVY MINERAL SAND PROSPECTS

General

The mineral constitution of heavy mineral sands appears to be remarkably uniform along the whole eastern coastline of South Viet Nam from the de-militarized zone in the north to the Mekong Delta as shown by the data from recorded samples shown in Plate 1. All samples recorded ilmenite and zircon as the dominant valuable heavy minerals along the coast followed by rutile and monazite in that order toward the northerly and southerly limits, but with monazite exceeding rutile in the central sector around Cam Ranh.

This uniform mineral constitution of the heavies predicates fairly uniform provenance for these minerals in South Viet Nam although no detailed work has apparently been done on the source for heavy minerals. Isnard (1957, 1962) refers these heavy minerals to intrusive and metamorphic rocks known along the coast and immediate hinterland. Prospects for viable deposits of these heavy minerals along the coast, other than in the Hue area, will be dealt with later, but it might be noted at this stage that available sampling data along the coast, although establishing mineral content, do not indicate likely grades of mineral sand deposits.

In the Hue area, the recent reconnaissance by scout car and helicopter was designed to indicate the best concentrations of heavy mineral concentrations for more detailed investigations. Localities and heavy mineral content of the samples are shown in Plate 2. The procedure at each locality was to sample by auger to a depth of about one metre about ten metres above high tide level on the beach. One auger sample was bagged for analysis in Australia and another sample from an adjacent hole was panned on the spot and results in terms of heavy minerals noted. In most localities samples of sand from dunes behind the beach were also panned.

This method gave a fairly clear indication of the relative amount of heavy minerals present and was confirmed by the results of sample analysis in Australia (see Plate 2). Aerial inspection alone provides some indication of the presence of heavy minerals, but particularly where average heavy mineral content is relatively low (less than 10 per cent) ground sampling is required to identify worthwhile concentrations. Inspection of panned concentrates by hand lens provided no precise information, but previous analyses from samples from Eagle Beach by the Malaysian Geological Survey provided a guide to heavy mineral content and a predominance of black iron oxides with grains of zircon and rarer grains of rutile and monazite could be recognised.

Samples from helicopter at HC3 (see Plate 2) near Vinh My provided the best tail of heavies in the pan from samples from both beach and dunes and accordingly arrangements were made for access by scout car to carry out reconnaissance drilling at this locality. Concentrations near Vinh My fit in well with the apparent major southerly moving longshore current, concentrating heavies against the subdued headland of Linh Thai Hill.

It is convenient to first describe the deposit at Vinh My, where most detail is available, before dealing with occurrences elsewhere in the Hue area and in other parts of Viet Nam.

Deposit at Vinh My

The deposit at Vinh My, where drilled, consisted of a wide beach and a subdued foredune behind which lay a shallow depression leading up to a dune reaching about 30 metres above sea level. Behind this dune the yellow-brown beach sand containing heavy minerals fairly abruptly gave way to the fine whitish-grey sand which is characteristic of the areas behind the dunes along this section of the coast (see sections Plate 3).

Two traverse lines were drilled from high tide mark across the beach, foredune and dune to the sand plain; the traverse lines were 320 metres apart and location of both traverse lines and drill holes were designed as part of a reconnaissance grid as indicated in the Manual on Beach Mining Practice (Macdonald 1968); such a grid can be extended and filled in during the course of more detailed investigations. Details of the grid are shown in Plate 3.

The base line, traverse lines and drill holes were surveyed and all stations levelled using an assumed datum at station 0-0 on the base line. Pegs will no doubt be removed by local fishermen, but the base line, which follows the crest of the main dune, was tied into a prominent tomb and can readily be re-established by a surveyor. The full grid calls for traverse lines at 40 metre intervals normally to the beach and for drill holes at 10 metre intervals along the traverse lines; in reconnaissance only every fourth hole was drilled along the traverse lines except on the upper part of the beach itself where the interval was closed to ten metres to provide some detail. Auger samples were taken normally at one metre intervals down the hole and because the auger was of small diameter the entire sample was bagged for analysis; logs of each hole are held by the Geological Survey of South Viet Nam.

Although these procedures would normally provide satisfactory reconnaissance data it must be emphasised that this reconnaissance at Vinh My had a number of shortcomings partly due to lack of time, but mostly due to lack of appropriate equipment. A theodolite rather than a quick-set level with turning circle would have been preferred for the surveying, but the major shortcoming was lack of augering equipment capable of sampling at depth and below the water table.

Semi-quantitative analyses of samples were carried out by AMDEL in Australia and the report is included as Appendix 1. A check sample was included; sample R6 was in fact a duplicate of O-O and considering the method of semi-quantitative analysis used, the check is satisfactory. Sample R5 should be deleted. The sample results should provide a good guide to grade and are adequate for the purpose particularly since the samples taken from Vinh My are generally well above marginal grade.

The results show a very uniform mineral constitution of heavy minerals in all samples throughout the deposit. The highest grade samples in both traverse lines, showing about 10 per cent heavy minerals, were taken from the beach well above sea level and reflect the occurrence of 5 to 10 centimetre seams of heavy minerals; however, the heavy mineral content of the dunes, at least to one metre depth, is also encouraging.

It should be noted that although grain counts were carried out on every sample on this occasion to provide detail on mineral constitution, grain counting can be restricted to a composite sample per traverse line in further work at Vinh My in which individual samples would be analysed only for total heavy mineral content.

Weighted averages of heavy mineral content for each hole are shown on Plate 3. The weighted heavy mineral content for all samples on traverse line O-O, excluding hole W8, is 6.9 per cent with an average mineral content (not weighted) as follows:- ilmenite (both types) 53.8 per cent, zircon 26 per cent, rutile 2.8 per cent, monazite 2.5 per cent. The weighted average heavy mineral content along line N8 is lower at 4.3 per cent with a comparable average mineral content of ilmenite 53 per cent, zircon 24 per cent, rutile 3.1 per cent and monazite 2.1 per cent.

Such a reconnaissance cannot of course establish reserves, but the data given above for the two traverse lines can be used to indicate likely grades of the sand drilled. Assuming the following prices in U.S. dollars f.o.b., which seem reasonable for production a year or so ahead, (ilmenite $13 per ton, zircon $40, rutile $134 and monazite $170) and 85 per cent recovery, average grades for both traverse lines appear as follows:-

Average Grade, Cents Per Cubic Metre*

	Zircon	Ilmenite	Rutile	Monazite	Total
Line O-O	103	70	37	42	252
Line N8	59	43	26	22	150

* Assuming 1.7 tons per cubic metre.

However, these preliminary calculations assume recovery of clean concentrates all of which could be sold; in this connection a number of queries should be noted for further investigations. In reference to ilmenite, a composite sample of both types of ilmenite identified by AMDEL was analysed by that laboratory to check on the content of titania and of trace elements with the following result:-

$TiO2$	51.9 per cent
Cr_2O_3	0.70 per cent
Va_2O_8	0.20 per cent.
FeO	26.3 per cent
Fe_2O_3	17.5 per cent

The titania content and the iron ratio are satisfactory; the vanadium content is within acceptable limits, but the chrome content of this sample is beyond the usual tolerance of 0.1 per cent. However, grains of chromite were found in most of the samples analysed by AMDEL and it is a fair assumption that the content of 0.7 per cent chromium oxide in the sample analysed could be reduced by exclusion of chromite grains; more detailed investigation of the ilmenite and of the problems of separation in treatment will need to be carried out. Again there appears to be no obvious problem in the separation and sale of the rutile and monazite, but the occurrence of abundant inclusions, mainly of magnetite and ilmenite, in the zircon will need to be investigated in terms of treatment and recovery. Such inclusions are not likely to affect the quality of the zircon in its main fields of use in foundry work, but by imparting some degree of magnetism, the inclusions could complicate the recovery of clean concentrates.

In general and despite the limitations of the reconnaissance, sampling at Vinh My indicates a mineral sand deposit well worthy of more detailed investigation. Panning along the beach north of Vinh My indicated that a significant heavy mineral content probably extends for at least three kilometres in that direction. No reconnaissance was carried out to the immediate south, but as the more southerly of the two traverse lines shows better values and since the main longshore current apparently moves in a southerly direction, further investigation might commence with some panning and reconnaissance southward and the possible extension of the drilling grid in that direction.

Heavy Minerals in the Hue Area

Procedures followed in sampling mineral sands in the Hue area have already been mentioned and the results in terms of heavy mineral content are shown on Plate 2. The results in terms of ilmenite, rutile, zircon and monazite content of the heavy minerals, shown in Appendix I, generally support southward movement of heavy minerals along the coast as the most northerly sampling point, HC3, returned markedly lower concentrations of these valuable heavy minerals than did all sampling points to the south although the concentration of these minerals relative to each other was little changed.

The next best concentration of heavies to that near Vinh My was recorded immediately south of the headland of Linh Thai Hill where heavies recorded from samples R2-4 ranged from 0.30 per cent to 1.99 per cent with the best values coming from a depth of 1 to 2 metres high on the beach. It is not clear whether this concentration is due to southerly migration around the headland of Linh Thai or whether it represents some concentration by northerly longshore currents against the headland, perhaps during the less effective south-western monsoon.

In considering the results of the samples taken to date it is useful to relate heavy mineral content to approximate grade per cubic metre. Using the assumption of prices and recovery listed in the last section and taking the average mineral content of the heavies south of Eagle Beach as the same as that established at Vinh My, one per cent heavy minerals approximates 35 cents per cubic metre. Although such a grade might be considered of interest where large reserves and economies of large-scale operations were possible, the writer suggests that at this stage of investigation a grade of 60 to 70 cents or above would be realistic, requiring an average heavy mineral content of the order of 2 per cent.

On this basis, the results of the recent reconnaissance of the Hue area provide no encouragement immediately north of Eagle Beach and little encouragement north of the Vinh My area. Apart from Vinh My, concentrations found immediately south of Linh Thai Hill and possible southerly extensions of these concentrations along the beach warrant further investigation; further concentrations may have built up against headlands south of Linh Thai Hill.

Mineral Sands Elsewhere in Viet Nam

Some information on mineral sands in a number of localities along the Vietnamese coast have been recorded by P. Isnard (1957, 1962) and details of mineral constitution of sand samples are reproduced in Table 2; localities are shown in Plate 2.

From the text and from the analyses themselves it is apparent that samples referred to by Isnard were taken from heavy mineral seams occurring on or within the beaches and thus do not indicate the average grade of beach sand in those localities; such an exercise would require reconnaissance investigations along the lines of that recorded in this report. Although the relative proportions of heavy minerals in Isnard's samples are different from the average content in sands at Vinh My, the suite of valuable heavy minerals is the same, indicating notable uniformity along the Vietnamese coast. Although samples from individual heavy mineral seams give no indication of the average grade of beach sands, the occurrence of prominent seams is itself an indication of the concentration of heavies and would suggest that further investigation of these localities would be warranted.

The location of more recent samples collected by the Geological Surveys is also shown on Plate 2 and some details of mineral content are reproduced in Table 3. These more recent samples were more in the nature of shallow random samples from the beaches and would appear to have little significance in regard to overall grade.

Information available at this stage certainly suggests that the coast from Hue to the Mekong Delta is a mineral sand province supplied with ilmenite, zircon, rutile and monazite and that deposits of these minerals of significant grade are likely to occur where longshore currents, wave action and coastal morphology have combined to trap heavy mineral sands. The recent reconnaissance near Hue has indicated one such deposit and the earlier work of Isnard suggests other localities worthy of more adequate prospecting.

CONCLUSIONS

The South Viet Nam coast from Hue to the Mekong is a mineral sand province containing ilmenite, zircon, rutile and monazite with some encouraging possibilities for commercial deposits where longshore current movement, wave action and coastal morphology have combined to trap and concentrate heavy minerals. Early sampling, although not indicating average grades, suggests a number of localities worthy of prospecting and the recent reconnaissance of the Hue area clearly indicates one deposit at Vinh My where some detailed investigation is well warranted.

Assistance, already arranged by Australia, in furthering field investigation at Vinh My and in associated laboratory work should establish techniques and equipment within the Geological Survey which can be used in due course to extend the investigation of mineral sand deposits along this promising coast.

REFERENCES

ISNARD P., 1957 - 'Etude de Sables Titanes du Viet Nam Meridional' Archives Geologiques du Viet Nam No. 4 Service Geologique du Viet Nam, Saigon, 1957.

1962 - 'Sables Titanes du Centre Viet Nam' Travaux de Geologique No. 1, Faculte des Sciences de Hue, 1962.

MACDONALD E.H., 1968 - 'Manual of Beach Mining Practice - Exploration and Evaluation'. Department of External Affairs, Canberra.

TABLE 1

SAMPLES FROM BEACHES IN SOUTH VIET NAM*

	CAM-RANH Weight - 112g		PORT DAYOT Weight - 192g		CAP SAINT JACQUES Weight - 97g		Lagune d'Hoi Loc, Qui-Nhon weight 76.65 gr	Bai-Bang Qui-Nhon weight 723 gr	Bo-Ngua Sông-Cau weight 616 gr
MINERALS SEPARATED	% in the sample	Remarks	% in the sample	Remarks	% in the sample	Remarks	% in the sample	% in the sample	% in the sample
Ilmenite	78%		85%		92%		94.00%	46.50%	72.50%
Magnetite	1.5%		0.1%		1.5%		0.03%	0.07%	0.90%
Monazite	3%		2%		0.25%		0.40%	0.10%	0.50%
Zircon	4%		7%		3%		2.40%	2.20%	2.00%
Rutile	0.5%	quite rare	0.5%		0.5%	quite rare	2.00%	1.00%	1.50%
Quartz	12%	dominant	4.5%		2%	dominant	0.55%	49.50%	19.50%
Calcite		rare		nil		rare			
Kyanite		very rare		nil		very rare	rare	very rare	very rare
Hematite brown		rare		very rare		rare	very rare		rare
Hematite red		-		-		very rare	very rare	very rare	very rare
Biotite		-		-		very rare			
Hornblende, green	0.3%	-	0.5%	-		rare			
Diopside				very rare		very rare	rare		
Ouwarowite		rare		rare		very rare			
Epidote		-		very rare		rare	very rare	very rare	also rare
Staurotile		very rare		rare		very rare	very rare	very rare	very rare
Tourmaline		quite rare		quite rare		rare	quite rare	0.10%	1.00%
Sillimanite	0.7%	rare	0.4%	rare	0.25%	very rare	0.40%	0.30%	0.90%
Andalousite		very rare		very rare		very rare		rare	very rare

Continued

TABLE 1 (Continued)

	CAM-RANH Weight - 112g		PORT DAYOT Weight - 192g		CAP SAINT JACQUES Weight - 97g		Lagune d'Hoi Loc, Qui-Nhon weight 76.65	Bai-Bang Qui-Nhon weight 723 gr	Bo-Ngua Sông-Cau weight 616 gr
MINERALS SEPARATED	% in the sample	Remarks	% in the sample	Remarks	% in the sample	Remarks	% in the sample	% in the sample	% in the sample
Muscovite									
Spinelle							very rare	rare	rare
Corundum								rare	rare
Titanite							rare		
Garnet							very rare	very rare	rare
Apatite								very rare	

* Compiled from tables given Isnard (1957, 1962).

<u>TABLE 2</u>

Heavy mineral contents of beach sands in the Republic of Viet-Nam*

Name of beach and sample no.		Value per cubic metre in US cents[1]	Heavy mineral contents in original sands (g/m^3)		
			Zircon	Rutile	Ilmenite
Thuan-An[(1)]	1	45	1823	3199	15537
	2	46	1641	3692	13537
	3	09	1145	327	2943
	4	21	2377	648	7566
	5	06	346	461	1615
	6	12	1707	142	4410
Da-Nang	1	-	-	48	478
	2	-	50	-	301
	3	-	50	-	198
	4	-	-	-	189
Son-Tra		-	-	-	-
Nam-O		-	24	60	192
Nha-Trang		03	138	138	1240
Thuy-Trieu	1	-	10	10	296
	2	-	35	20	151
Vung-Tau		-	-	-	32
Long-Hai	1	02	90	75	993
	2	05	230	184	2625
	3	03	290	75	1831

- : indicates nil or negligible content.

1 Value based on assumption of 85 per cent recovery of heavy mineral content and selling prices for zircon, rutile and ilmenite at US$44, $88 and $11 per ton, respectively.

* Taken from Committee for The Co-ordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas - Report of the Sixth Session, Bangkok 1969.

(1) Also called 'Eagle Beach'.

Appendix I

A SEMI-QUANTITATIVE MINERALOGICAL STUDY OF THIRTY THREE BEACH SAND SAMPLES FROM SOUTH VIETNAM *

1. INTRODUCTION

Thirty three samples of beach sand were submitted for heavy mineral separation and subsequent mineralogical examination of the heavy constituents to determine species present and their relative abundances.

The samples were obtained during reconnaissance investigations of a number of beaches in South Vietnam, and the majority are from reconnaissance borings of one deposit; the remainder, prefixed R or HC, denote samples from other localities.

2. METHODS

Initially the wet sand samples were washed to remove residual salt and oven-dried. The dry samples were then riffled to obtain representative samples suitable for separation, and heavy mineral separations were carried out, using tetrabromoethane (S.G. 2.96) as the separating medium. Results are shown in Table 1 expressed as weight percentages.

Representative portions of each of the Heavy fractions were obtained by riffling and examined in transmitted light by means of standard refractive index oil mounts to identify the non-opague phases present. A further portion of each was mounted as a polished briquette and examined optically using reflected light techniques, in order to identify the abundant opaques present.

Semi-quantitative grain counts were carried out on a minimum of 300 grains in each case, and the relative proportions of the constituent minerals are shown in Table 2. The accuracy of these values may be taken as ± 10% relative.

3. MINERALOGICAL NOTES

All heavy fractions examined are quite similar mineralogically and contain zircon and opaques as the dominant constituents and in most cases also contain identical suites of accessory minerals, even the samples from different localities.

---

*Investigation and Report by : M.J.W. Larrett.

Separations by : D. Campbell.

Officer in Charge, Mineralogy-Petrology Section : Dr K.J. Henley.

It should be noted that discrete grains of partially oxidised magnetite were observed in trace amounts in only a few of the heavy fractions and were not present as major constituents of the samples as had been intimated in your letter, Reference 70/609. The near presence of a hand-magnet was found to evoke very little response from any of the heavy fractions.

The samples all contain ilmenite as the dominant constituent and this has been arbitrarily subdivided into three groups, namely: "Ilmenite 1", which consists of fresh to partially altered material; "Ilmenite 2", which consists of partially to extensively altered Material (amorphous iron/titanium oxides), and "Leucoxene" which represents the final stage in the weathering of ilmenite.

The progressive alteration of ilmenite is accompanied by a change in its magnetic susceptibility and thus the values given for these three groupings may be of use, should these sands be considered for treatment by magnetic separation. One grain of gold was noted in PS 14125 and, in addition to ilmenite, some silicates contain inclusions of sulphides, probably pyrrhotite and/or chalcopyrite.

4. DESCRIPTIONS OF MINERALS

4.1 Zircon

Zircon occurs as subrounded to subhedral (and more rarely euhedral) grains, the majority of which are colourless and contain abundant inclusions. A few purplish grains are present in most of the heavy fractions and they are generally of a larger grain size than the colourless variety. Many of the inclusions are opaque and these are mainly magnetite and ilmenite.

4.2 Rutile

This occurs as red to red-brown subrounded to ovoid grains sometimes containing opaque inclusions. In some of the grains the colour is so dark as to render the grains almost opaque.

4.3 Monazite

This mineral is present in all the heavy fractions in very minor amounts, as very pale yellow, well rounded and ovoid grains, which in most cases can be distinguished by their peculiar 'pocked' or 'frosted' appearance.

4.4 Ilmenite 1

This consists of discrete, homogeneous, pinkish brown, subangular to subrounded grains, of relatively fresh to partially altered ilmenite. The majority of grains are strongly anisotropic and some contain minor oriented exsolution lamellae of hematite whilst oxidation to hematite and alteration to leucoxene is common at edges of grains and along fractures and cleavage planes.

4.4 Ilmenite 2

This type of ilmenite consists of discrete, subrounded to well-rounded grains with a rather porous texture and weak anisotropism, grading into brownish porous, amorphous iron/titanium oxides.

4.6 Leucoxene

Leucoxene, the end product of the weathering of ilmenite, occurs as discrete well rounded grains of a creamy white to orange brown colour, with a 'sugary' texture and a resinous lustre. Some grains appear to have recrystallised to fine-grained rutile, and others contain isolated ilmenite residuals.

4.7 Chromite

Chromite is present in most samples, in very minor amounts, as discrete, isotropic, greyish brown grains, generally subrounded but sometimes octahedral. A few grains show oxidation rims of magnetite.

Table 1: Heavy Mineral Contents Of The Samples

Sample No.	Depth Metres	Weight % Heavy Minerals (S.G. 2.96)
0-0	0 - 0.9	6.64
0-E4	0 - 0.7	5.23
0-E8	0 - 0.75	6.49
0-E10	0 - 1.0	6.81
0-E10	1 - 1.8	8.95
0-E12	0 - 1.0	11.76
0-E12	1 - 1.8	6.73
0-E13	0 - 1.0	10.57
0-E13	1 - 1.8	5.48
0-E14	0 - 1.0	3.54
0-E14	0.5 - 1.5	3.88
0-W4	0 - 0.7	3.70
0-W8	0 - 0.9	0.12
N8-0-0	0 - 0.8	6.03
N8-0-E4	0 - 0.7	3.52
N8-0-E8	0 - 0.7	5.54
N8-0-E10	0 - 0.8	6.99
N8-0-E11	0 - 0.8	1.23
N8-0-E12	0 - 0.7	10.37
N8-0-E13	0 - 0.75	4.55
N8-0-E14	0 - 0.75	2.61
N8-0-E15	0 - 0.6	1.65
N8-W4	0 - 0.8	1.12
R1	-	0.14
R2	1 - 1.5	0.31
R3	0 - 3 }	1.70
R3 (Foredune)	3 - 6 }	1.99
R4	0 - 3	0.30
R6	-	6.66
HC-1	1 - 3	3.76
HC-2	3"	0.38
HC-3	2' 9"	0.71

Table 2: Mineralogical Composition of the Heavy Fractions

Sample No.	Depth Metres	P.S. No.	Zircon %	Rutile %	Monazite %	Ilmenite 1 %	Ilmenite 2 %	Leucoxene %	Chromite %	"Others" %
0-0	0-0.9	14098	27	4	3	38	18	3	3	4
0-E4	0-0.7	14099	35	4	3	29	20	3	2	4
0-E8	0-0.75	14100	32	3	4	27	24	4	2	4
0-E10	0-1.0	14101	32	2	4	25	26	4	2	5
0-E10	1-1.8	14102	26	3	2	30	27	2	3	7
0-E12	0-1.0	14103	19	2	1	33	31	3	1	10
0-E12	1-1.8	14104	28	3	5	19	32	4	2	7
0-E13	0-1.0	14105	18	2	2	28	37	4	1	8
0-E13	1-1.8	14106	27	5	2	25	31	3	1	6
0-E14	0-1.0	14107	15	2	2	26	30	6	1	18
0-E14	0.5-1.5	14108	21	2	1	30	20	4	1	21
0-W4	0-0.7	14109	33	2	2	30	19	2	Tr	12
0-W8	0-0.9	14110	20	3	1	20	25	7	2	22
N8-0-0	0-0.8	14111	30	3	2	28	22	2	1	12
N8-0-E4	0-0.7	14112	27	2	2	31	14	2	1	21
N8-0-E8	0-0.7	14113	28	4	2	34	22	3	1	6
N8-0-E10	0-0.8	14114	34	4	3	30	18	4	1	6
N8-0-E11	0-0.8	14115	9	2	Tr	39	24	4	1	21
N8-0-E12	0-0.7	14116	20	3	3	26	29	11	-	8
N8-0-E13	0-0.75	14117	32	3	4	27	24	3	1	6
N8-0-E14	0-0.75	14118	13	3	1	37	30	5	4	7
N8-0-E15	0-0.6	14119	22	3	3	26	22	3	1	20
N8-W4	0-0.8	14120	21	4	1	26	24	4	1	19
R1	-	14121	16	1	1	29	28	4	-	21
R2	0-3	14122	27	3	3	24	17	8	1	17
R3	0-3	14123	12	1	1	43	23	2	1	17
R3 (Foredune)	3-6	14124	12	2	1	38	23	4	2	18
R4	1-1.5	14125	16	1	1	24	26	9	1	22
R6	-	14127	34	2	3	26	22	3	1	9

Continued

Table 2 (Continued)

Sample No.	Depth Metres	P.S. No.	Zircon %	Rutile %	Monazite %	Ilmenite 1 %	Ilmenite 2 %	Leucoxene %	Chromite %	"Others" %
HC-1	1-3	14128	23	1	1	25	23	5	1	21
HC-2	3"	14129	26	3	2	23	21	7	1	17
HC-3	2' -9"	14130	9	1	Tr	15	13	4	1	57

N.B. Leucoxene 1 = Fresh to partially altered leucoxene

Leucoxene 2 = Partially to extensively altered leucoxene

Tr = Trace

"Others" consists of accessory to trace amounts of goethite, oxidised magnetite, hematite, tourmaline, kyanite, staurolite, epidote, green and brown spinel, pyroxene, garnet, sphene, ?xenotime, sillimanite, andalusite, and green amphibole, but all are not necessarily present in any one heavy fraction.

Appendix II

ILMENITE CONCENTRATE*

A request was received for the preparation and subsequent analysis of an ilmenite concentrate from a series of heavy mineral concentrates obtained from beach sands from South Vietnam (previously reported in Report MP 193/71).

The heavy mineral concentrates from samples prefixed O and N (23 samples) were halved by means of a microsplitter, and one half of each was combined to give a composite sample. This composite of the 23 heavy fractions was then magnetically separated, using a Frantz Isodynamic Separator at a setting of 0.2 amps, to produce an ilmenite concentrate. The purity of the concentrate was checked by means of a polished briquette, and it was then submitted for chemical analysis.

The ilmenite concentrate was analysed for titanium, chromium, vanadium and ferric and ferrous iron; the results are shown in Table 1.

On the whole, the results indicate a good quality ilmenite although the value for chromium is anomalous. This high chromium value is probably attritutable to the presence of rare chromite in the concentrate, and may be difficult to remove due to the similar magnetic properties of ilmenite and chromite. As can be seen from Table 1, the analyses total 96.60%, indicating that certain other elements such as magnesium and/or manganese may be present.

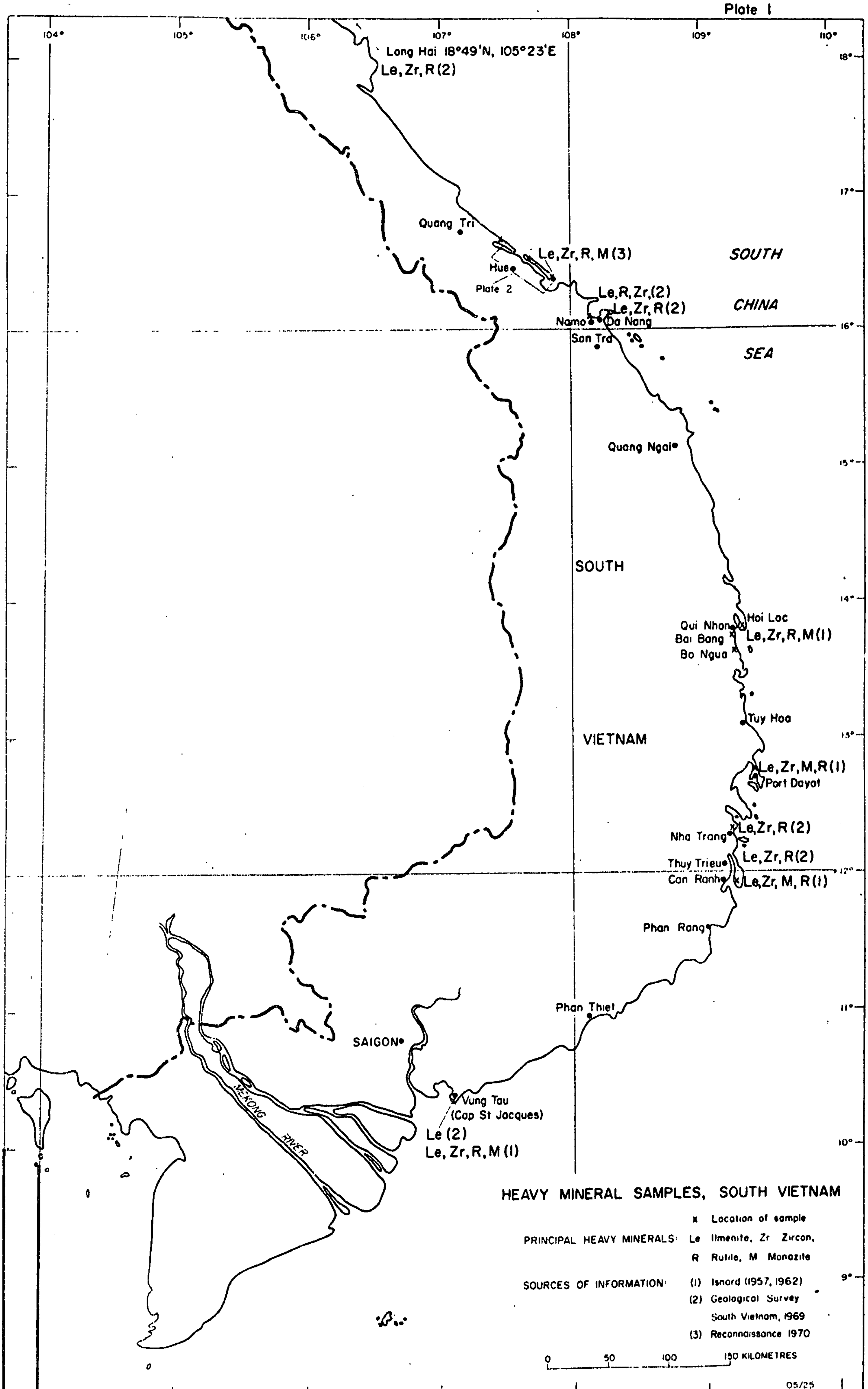
An important point in the utilization of ilmenite is that ilmenite is soluble in sulphuric acid, and that stronger acid is needed to attack those ilmenites higher in TiO_2 and lower in ferrous oxide.

Conventional methods would probably suit this material and this entails the removal of quartz etc., by wet gravity methods and magnetic separation of the ilmenite from the mixture of heavy minerals produced by High Tension separators.

* Investigation and Report by M.J.W. Larrett, Australian Mineral Development Laboratories, Adelaide.

TABLE 1: ANALYTICAL RESULTS

Sample No.	TiO_2 %	V_2O_5 %	Cr_2O_3 %	Fe_2O_3 %	FeO %	Total %
"B.M.R. Composite"	51.9	0.20	0.70	17.5	26.3	96.6



HEAVY MINERAL SAMPLES, SOUTH VIETNAM

x Location of sample

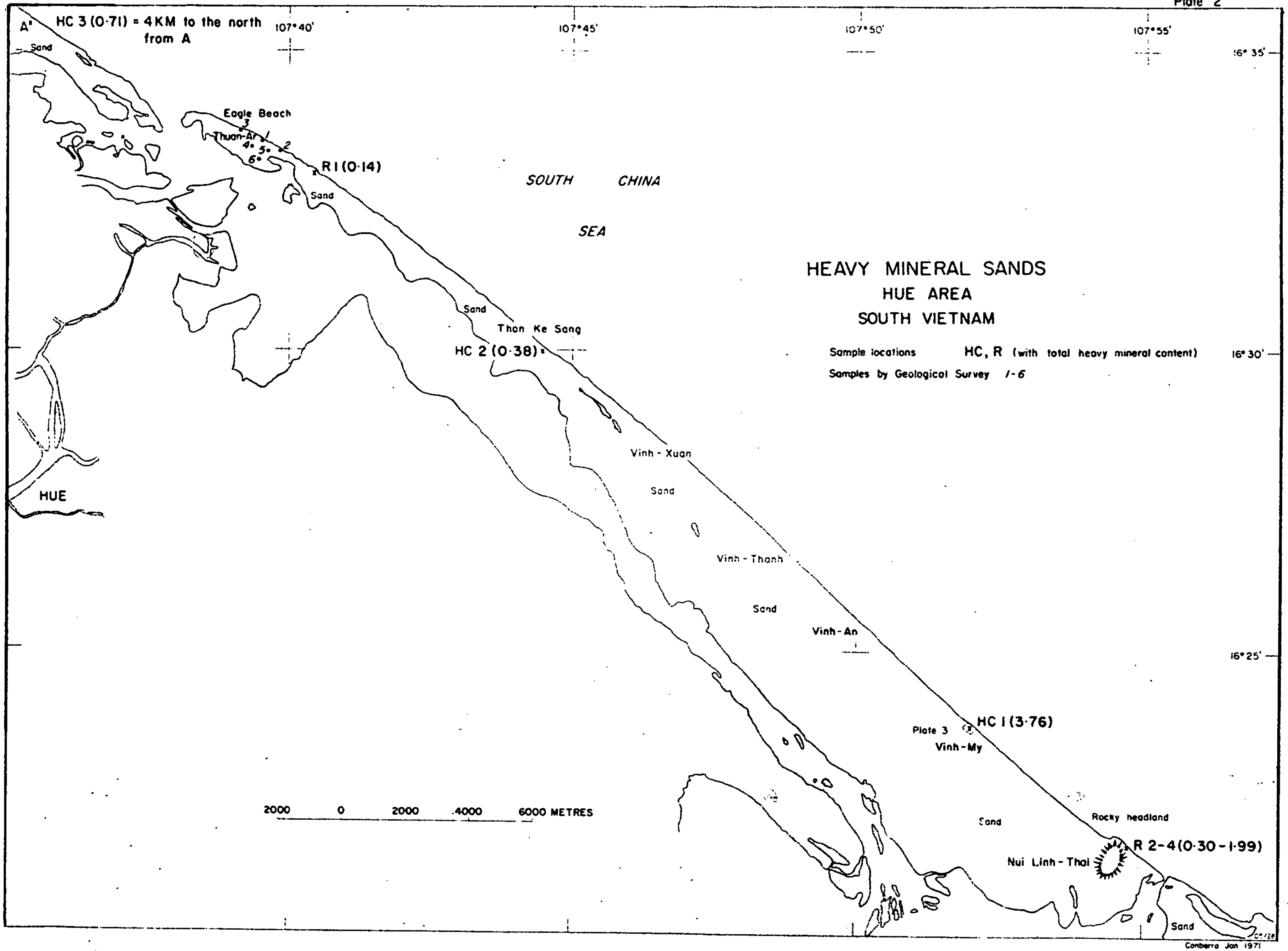
PRINCIPAL HEAVY MINERALS: Le Ilmenite, Zr Zircon, R Rutile, M Monazite

SOURCES OF INFORMATION: (1) Isnard (1957, 1962) (2) Geological Survey South Vietnam, 1969 (3) Reconnaissance 1970

0 50 100 150 KILOMETRES

05/25

Canberra Jan. 1971



HEAVY MINERAL SANDS
HUE AREA
SOUTH VIETNAM

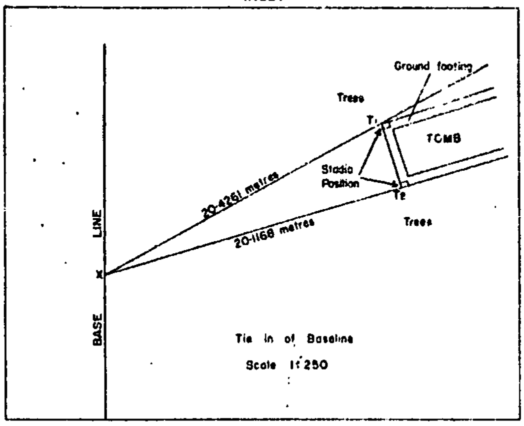
Sample locations HC, R (with total heavy mineral content)
Samples by Geological Survey 1-6

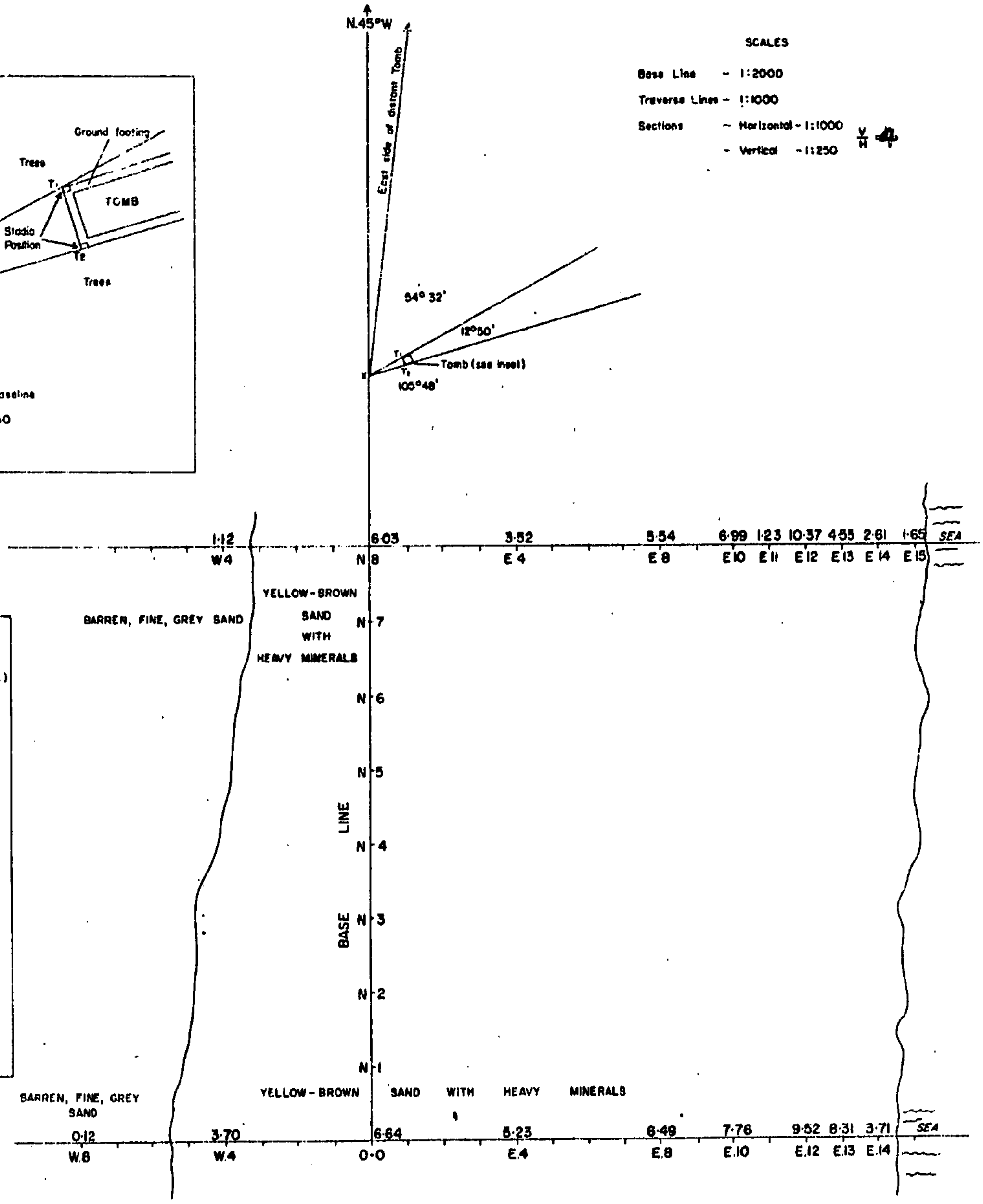
PLATE 3

MINERAL SANDS AT VINH MY
SOUTH VIETNAM

RECONNAISSANCE DRILLING RESULTS

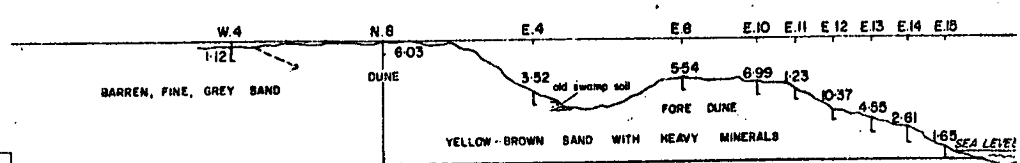
INSET





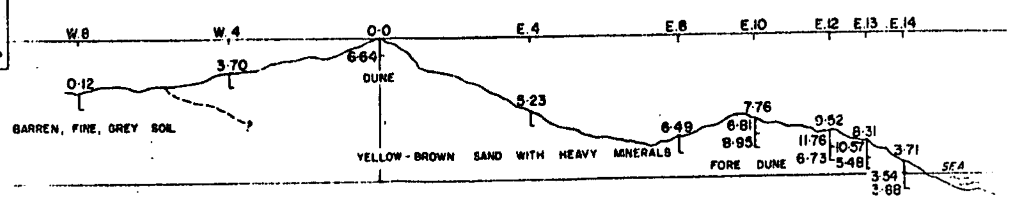
LEVELS			
ASSUMED R.L. AT PEG 0-0: 34·49 METRES (100 FT.)			
LINE 0-0		LINE N.8	
0-0	30·49	N.8	28·28
W.4	28·03	W.4	28·95
W.8	27·06	E.4	25·75
E.4	25·83	E.8	26·82
E.8	23·88	E.10	26·51
E.10	25·08	E.11	26·29
E.12	24·14	E.12	24·78
E.13	23·50	E.13	23·98
E.14	22·23	E.14	23·35
		E.15	22·22
Sea Level, 1200 hrs, 21·52 26-5-70		Sea Level, 1200 hrs, 21·65 27-5-70	

SECTION ALONG TRAVERSE LINE N.8



AVERAGE HEAVY MINERAL CONTENT					
Traverse Line	Weighted Heavy Mineral Content	Average Content of Heavy Minerals			
		Le	Zr	Rut	Mon
N.8	4·3%	53%	24%	3·1%	2·1%
0-0	6·9%	54%	26%	2·8%	2·5%

SECTION ALONG TRAVERSE LINE 0-0



6·49 — Heavy mineral content (Weighted where appropriate)
E.8 — Hole No.
7·76 — Weighted average heavy mineral content
6·81 / 8·95 — Sample interval and heavy mineral content

U5/24