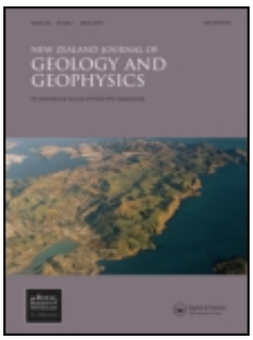

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HEAVY MINERAL CONTENT AND RADIOACTIVITY COUNTS OF BEACH SANDS WEST OF ORETI RIVER MOUTH TO BLUE CLIFFS, SOUTHLAND, NEW ZEALAND

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Summary

Beach and dune deposits on the south coast of Southland were sampled and the minerals of specific gravity greater than 2.9 were extracted, magnetically separated and counted for radioactivity; the percentages of heavy minerals are estimated and the predominant minerals noted. Total quantities of beach sands west of Orepuki are estimated. The predominant heavy mineral throughout is a green amphibole. No commercially attractive quantities of ore minerals are indicated.

INTRODUCTION

In 1956 extensive beaches on the southern coast of the South Island of New Zealand were examined, from the mouth of the Oreti River west of Bluff to a point 11 miles west of the Waiau River (Fig. 1) where the precipitous coast of Fiordland begins, as part of a plan for comprehensive examination of New Zealand beach and dune sands deposits for the occurrence of titaniferous or iron ore minerals.

Spot samples were taken as it has been found that, when the average content of heavy opaque ore minerals in any large sand deposit is sufficient to be of commercial interest, say 5%, their presence will be detected in practically any sample that can be taken from such an area. The heavy mineral content of samples taken from relatively shallow holes on an active beach, so that both rich and lean layers are included, can be surprisingly close to the average figure obtained for a deposit after extensive sampling.

The prime purpose of this work was investigation of the opaque ore minerals. However, as other heavy minerals were concentrated and separated while obtaining relatively pure specimens of the opaques, the nature and abundance of the former have been briefly examined.

Previous work (up to 1956) on the heavy minerals of the southern coasts or the water sheds of the main rivers discharging there, had not included descriptions of the beach sands. Hutton and Turner (1936) examined heavy minerals in rocks at Clifden in the middle Waiau valley and Coombs (1954) studied the mineralogy and petrography of rocks in the Taringatura hills forming a water shed between the Aparima and Oreti rivers south of Mossburn.

Wood (pers. comm.) reports an investigation of the heavy minerals on the beaches immediately adjacent to Orepuki township. Brothers (1959) has studied the heavy minerals in Permian-Jurassic sediments in Southland. Most

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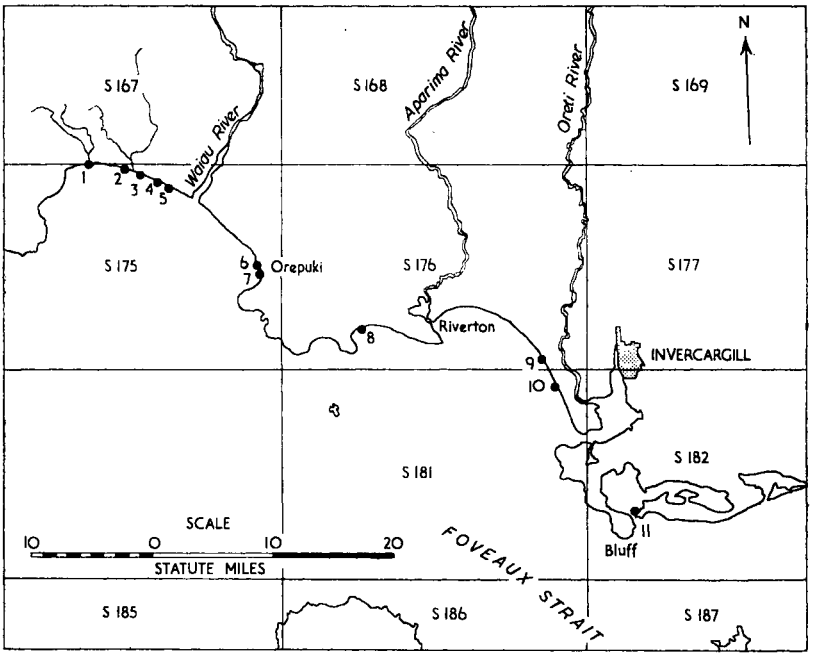

FIG. 1—Map showing coastline from west of Waiau River to Bluff.

of his samples are from the watersheds of the Mataura River but his S. 159 series is from sedimentary rocks to the west of the Taringatura country studied by Coombs and which drain into the Aparima River.

EXPERIMENTAL PROCEDURE

Some twenty-three samples, of about 50 lb each, were taken: seven from west of the Waiau and nine east of the Waiau in Te Wae Wae Bay; one in each of Colac and Taramea Bays; and four from the sands that stretch continuously between the mouths of the Aparima and Oreti Rivers. When it became apparent that there was little heavy mineral content of importance in any extensive deposit of sand, only eleven samples, listed in table 1, were fully examined.

In the laboratory the samples were thoroughly washed, dried, sieved through a 10 mesh screen, quartered down to about 300–400 g and stored. A rough preliminary examination for rutile, after crude bromoform separation, was made on smaller amounts. Subsequently, approximately 100-g portions of the stored samples were taken by means of a sample splitter, sieved through a 60 mesh B.S. screen and the fractions of + 60 and — 60 weighed.

Each — 60 fraction was passed once through the senior author's heavy liquid (bromoform) separator to extract the greater than S.G. 2·9 minerals. Both fractions were weighed and all "heavies" were examined under the petrological microscope for opaque and other minerals.

When a considerable proportion of opaque grains was found in a "heavy" fraction or if a radioactivity check indicated a significant count, the fraction was further separated in the senior author's high intensity modification of Officer's (1947) separator. Before separation, ferrimagnetic material was removed by hand methods, using successively magnets with field strengths of 200 and 700 oersteds.

The percentage of opaque grains in a fraction was established by counting 100–200 grains. Fractions containing significant quantities of opaque minerals were chemically analysed to ascertain the total iron, the titanium and, if practicable, the ferrous iron contents of the opaque minerals.

Products of the final separation of each particular sample and the "lighter than bromoform" fractions were checked for radioactivity.

The counting was performed in a 1½ in. thick lead walled castle manufactured by ERD Engineering Company, by spreading a thin layer of sample (several grains deep) over an aluminium tray 6 cm × 6·8 cm, at a fixed distance of 2·6 cm below the horizontal 25 mm dia. window of a 20th Century Type Ew3N, 1·5–2·5 mg/cm² mica end window, halogen filled counter tube. The counting circuitry comprised Philips PW 4022, PW 4032, PW 4052 equipment. Counts of 100 were taken in duplicate to derive the counting rate, in c.p.m. (counts per minute) for samples and single counts of 100 between pairs of sample counts, to obtain background counts which were averaged to give the background count, c.p.m. over each counting session.

For statistical considerations the number of counts was never less than 200 giving a standard deviation of $\sqrt{200} = 14{\cdot}14 = 7{\cdot}1\%$. The background times for 200 counts were around 12½–14½ minutes giving a counting rate of approximately 15–16 c.p.m. The standard deviation hence being $\frac{14{\cdot}14}{12{\cdot}5\text{–}14{\cdot}5}$ 0·97 to 1·13 c.p.m. For a difference between a sample and background count to be significant the difference must exceed the root of the sum of the squares of the errors of both background and sample count (Taylor, 1951). The standard deviation of a just significant sample count can be roughly taken as that of the background count 1·13 c.p.m. Hence it was considered that any difference exceeding the combined standard deviation $= \sqrt{2} \times 1{\cdot}13 = 1{\cdot}6$ rounded off to 2·0 was probably (79%) significant and any exceeding $1{\cdot}6 \times 1{\cdot}64 = 2{\cdot}6$ rounded off to 3·0 was reliably so, to the 94% confidence limit, and justified further separation in an endeavour to trace the source of the activity. In actual fact as the finally used background count was established over 1,000 or more counts during a counting session these count differences standards taken as indicating radioactivity were conservative.

All final "heavy mineral" fractions were examined under the petrological microscope. As these deposits appeared to contain no significant quantity of any mineral of commercial value it was considered that they did not justify any careful identification and quantitative estimation of the constituent minerals.

At the time of sampling, before it was known that the rutile and ore mineral content was uneconomic, field data was obtained to make a rough estimate of quantities of sands in the major deposits. The most doubtful

factor in estimating the quantities was as usual the average depth of a deposit. The figures taken were based on the experience of Mr J. H. Sorenson, of Orepuki, for some years manager of the Round Hill Gold Dredging Company until it recently ceased operations, who had spent a lifetime in the area prospecting and mining for gold. Mr Sorenson kindly accompanied Messrs Mitchell and Martin when samples were collected and freely made available much factual information about depths of sand at various places along the beaches, where during the years he had driven cased holes down to 20 ft prospecting for gold.

RESULTS

Table 1 gives the location and description of the samples.

In Tables 2, 3, and 4 are set out the results of the investigations carried out on samples listed in Table 1. From this table the following points will be noted:

(1) The relative weight % in the samples taken, of sand of greater or less size than 60 B.S. mesh (·01 in. = ·25 mm aperture);

(2) The proportions by weight of the samples recovered as material heavier than S.G. 2·9 in the continuous heavy liquid separator;

(3) Estimates of the total percentage of minerals heavier than S.G. 2·9 in the — 60 B.S. mesh fractions of the samples based on performance of that separator tested to three extractions on similar samples;

(4) The measure of radioactivity of the fractions separated above, as given by the difference in counts per minute between the fractions and the background counting rate of the equipment;

(5) For cases where significant proportions of opaque or radioactive minerals were detected, the weight proportions of subdivision of the "heavies" in the high intensity magnetic separator together with radioactivity counts for the subdivided fractions.

In table 3 is given a rough identification by inspection of the more plentiful minerals found in the products listed in table 2.

From table 4 it will be seen that in the two cases where the opaque ore mineral content was considered to be significant and to be representative of deposits in an area, the chemical analyses of the opaque ore minerals for iron and titanium are shown, together with an indication of the proportion of opaque grains in the fractions analysed and the nature of the gangue minerals in the undissolved residues after chemical solution of the ore minerals.

Table 4 also sets out the percentage by weight of total Fe and of TiO_2 in the acid or fused pyrosulphate soluble part of the opaque fraction analysed; where possible, the FeO and Fe_2O_3 contents; the percentage by weight insoluble residue; and the calculated Fe/Ti and Fe^{3+}/Fe^{2+} ratios.

Where iron oxides and TiO_2 fail to account for a major part of the soluble weight, Table 4 also gives an indication of the other elements which spectrographic analysis suggests contribute significantly.

TABLE 1—Catalogue of Samples Taken. Exact Localities in Terms of Immediate Local Geography and Description of the Sampling Method

Sample No.	Geographical Locality	Approximate Location*	Lab. No.	Date of Samplings
1	West of Waiau River Sample from 15 in. deep wet hole on active beach just west of the Waikoua river. This was deepest practicable hole that could be dug without casing.	S 175–570.300	MM5	11/10/56
2	West of Waiau River Sample from shallow wet hole in wide expanse of beach west of Rowallan Burn.	S 175–620.295	MM7	11/10/56
3	West of Waiau River Sample slice from 2 ft hole in damp sand on beach above normal high tide mark under cliff about 100 yd east of Rowallan Burn.	S 175–638.282	MM9	11/10/56
4	West of Waiau River Sample from active beach from a wet hole about 1 ft deep some 20 yd beyond tide line. About where coarse debris, shingle and drift wood from river was tapering off into plain sand beach.	S 175–275.671	MM10	11/10/56
5	West of Waiau River Dune sand seaward of drift wood some 100 yd east of small creek known locally as Breakfast Creek, probably Cameron's Creek on map. Dry surface sand scraped away and a slice of damp sand removed from toe to top of low dune.	S 175–266.691	MM11	11/10/56
6	Orepuki Beach From hole 2 ft deep vertical slice just above high water mark being an average sand sample for the beach between Sandy Creek and Taunoa Creek. There is a small accumulation of dune sand fairly rich in heavy minerals above the active beach in this area.	S 175–819.159	MM13	11/10/56
7	Orepuki Beach Average sand from 1 ft deep hole on wet beach about 40 ft out from cliffs where road comes down to the beach at Falls Creek.	S 175–823.147	MM14	11/10/56
8	Taramea Bay, Riverton From a hole 10 in. deep at high-water level about the middle of the wet beach.	S 176–965.062	MM18	11/10/56
9	Oreti Beach, Invercargill From 9-in.-deep hole on active beach 2½ miles west of road entrance from Invercargill to beach. The wet sand was very mobile and precluded a deeper hole.	S 176–230.020	MM20	12/10/56
10	Oreti Beach Dunes Composite of dune sand on south-east side of the main road cutting leading to the beach from Invercargill. Taken from some 20 ft of exposed damp dune face.	S 181–253.978	MM22	12/10/56
11	Bluff Harbour An average specimen of sand dredged from the harbour provided by the Bluff Harbour Board engineer as typical of harbour bottom material.		MM23	Date of taking uncertain but during 1956

*On N.Z. 1 mile/in. Topographical Maps giving: Map No. – West to East grid reference; South to North grid reference.

TABLE 2—Size Analyses and Percentages by Weight of Fractions Separated From — 60 Mesh Material by Bromoform Sink-Float and High Intensity Magnetic Methods Together With Radioactivity Counts, on all Fractions for Samples Listed in Table 1

Sample No.	In automatic heavy liquid separator†									Further separation of the — 60 "heavy" fraction by magnetic means																	
	Mechanical Analysis with B.S. sieves % total sample wt.		"Lights" S.G. < 2·9		"Heavy" fraction S.G. > 2·9					Strongly ferrimagnetic attracted by magnet, 200 oe. field.	Weakly ferrimagnetic attracted by magnet of 700 oersted field			In high intensity separation † triangular poles, 7/32 in. @ 12°; deflection throws for stated entrance fields													
			Radioactivity c.p.m.		"Heavies" recovered @ single pass Wt. % of — 60 mesh	Adjusting factor	Estimated "heavies" in — 60 mesh. Wt. %	Radioactivity c.p.m.						V. high susceptibility Throw > 5·7 cm @ 4650 oe field			High susceptibility Throw 2·5–5·7 cm @ 4650 oe. field			Inter. susceptibility Throw 2·7–3·9 cm @ 5500 oe. field			Low susceptibility Throw 1·0–2·7 cm @ 5300 oe. field			Very low susceptibility Throw < 1·0 cm @ 5300 oe. field		
	— 20 + 60	— 60	Background	Sample minus background				Background	Sample minus background		Wt. % of — 60 "heavies"	Radioactivity c.p.m.		Wt. % of — 60 "heavies"	Radioactivity c.p.m.		Wt. % of — 60 "heavies"	Radioactivity c.p.m.		Wt. % of — 60 "heavies"	Radioactivity c.p.m.		Wt. % of — 60 "heavies"	Radioactivity c.p.m.		Wt. % of — 60 "heavies"	Radioactivity c.p.m.	
												Background	Sample minus background		Background	Sample minus background		Background	Sample minus background		Background	Sample minus background		Background	Sample minus Background		Background	Sample minus Background
			A		B					C	D			E			F			G			H			I	
1	26.7	73.3	13.8	2.1	3.9	1.6	6.3	14.9	2.1																		
2	neg.	all	13.6	1.2	1.1	1.6	1.8	15.1	2.0																		
3	neg.	all	13.8	2.1	13.8	1.6	22.1	15.1	2.4																		
4	15.5	84.5	13.8	4.1 / 4.2	3.7	1.6	6.0	15.1 / 13.8	1.9 / 2.1																		
5	37.0	63.0	13.6	2.1	16.2	1.6	26.0	n.d.		4.1	10.5	15.1	0	nil			neg.			21.8	15.1	0.6	63.6	15.1	2.9	Not further separated		
6	33.5	66.5	13.8	2.5	93.0	1.0	93.0	14.9	7.0	4.9	24.0	n.d.		32.1	n.d.		14.5	14.5	1.0	7.6	14.5	3.7	12.0	14.5	13.6	2.7* 14.1 29.2 — 100 mesh		
7	2.7	97.3	13.8	2.0	43.0	1.0	43.0	n.d.		2.1	9.7	14.9	0.2	17.2	14.9	0.9	7.6	14.9	0.6	8.2	14.9	3.7	55.3	14.9	7.4	2.2* 13.8 12.9 + mesh Not further separated		
8	2.6	97.4	13.8	1.5	9.4	1.6	15.0	14.9	1.8																		
9	neg.	all	13.8	2.9	2.2	1.6	3.5	14.9	0.4																		
10	neg.	all	13.8	1.8	1.8	1.6	2.9	14.9	1.4																		
11	38.0	62.0	14.5	2.1	3.5	1.6	5.6	14.9*	4.6								20* Inc. 7·6% opaques	14.6	0	30* Inc. 5% opaques	13.8	3.5	50* Inc. 9% opaques	13.8	3.9			

*Indicates that fraction was too small to cover counting tray.
†Machines used were designed by the senior author and will be described in subsequent papers.
n.d. = not determined.

A count difference > 2 indicates probably significant radioactivity in sample tested.

A count difference > 3 indicates fairly certain significant radioactivity in sample tested.

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TABLE 3.—Showing % Opaque Grains Content of Individual Fractions by Grain Counting (not Adjusted for Relative sizes or Densities) and Rough Identification of Transparent Minerals, by Inspection in Clove Oil in the Heavy Mineral Fractions as Separated and Displayed in Table 2. The Sample Numbers and Columns Correspond to Table 2. p = predominant. a = abundant. m = minor.

Sample No.	"Heavy mineral" fraction as separated in bromoform B		High susceptibility F		Intermediate Susceptibiliy G		Low susceptibility H		Very low susceptibility I	
1.	Amphibole	p								
	Garnet	a								
	Biotite	m								
	Opaques	15%								
2.	Amphibole	p								
	Biotite	a								
	Garnet	m								
	Opaques	10%								
3.	Amphibole	p								
	Epidote	a								
	Zircon	m								
	Opaques	9%								
4.	Amphibole	p								
	Biotite	a								
	Garnet	m								
	Opaques	3%								
5					Amphibole	p	Unidentifiable "smoky" grains	p		
					Pyroxene	a	Epidote	a		
					Epidote	m	Amphibole	m		
					Garnet	m	Opaques	2%		
					Apatite	m				
					Opaques	30%				
6.			Opaques	85%	Opaques	60%	Amphibole	a	— 100 mesh	+ 100 mesh
			Garnet	a	Garnet	a	Epidote	a	Zircon a	Zircon a
					Amphibole	a	Zircon	m	Rutile a	Rutile m
					Pyroxene	a	Rutile	m		Epidote m
							Opaques	m		Monazite? m
7.			Opaques	40%	Amphibole	a	Amphibole	a		
			Garnet	a	Garnet	a	Zircon	a		
			Amphibole	a	Pyroxene	a	Epidote	a		
			Pyroxene	a	Opaques	15%	Rutile	m		
							Garnet	m		
							Opaques	m		
8.	Amphibole	a								
	Epidote	a								
	Kyanite	a								
	Opaques	6%								
9	Amphibole	p								
	Biotite	a								
	Epidote	a								
	Garnet	m								
	Zircon (big)	m								
	Opaques	3%								
10.	Amphibole	p								
	Biotite	a								
	Topaz?	m								
	Rutile	m								
	Opaques	< 1%								
11.			Amphibole	p	Amphibole	a	Zircon	p		
			Garnet	a	Pyroxene	a	Amphibole	a		
			Pyroxene	m	Zircon	m	Epidote	m		
			Epidote	m	Garnet	m	Biotite	m		
			Opaques	35%	Opaques	15%	Opaques	15%		

Most of the amphibole is dark green hornblende. Overall this is the predominant transparent heavy mineral.

"Smoky" grains. Many grains occur which contain inclusions which prevent their ready identification. They range from a "current bun" appearance with many small inclusions to the extreme where innumerable micro inclusions give even the edges of grains a smoky translucent appearance.

Most of the pyroxene appears to be distinctly pleochroic hypersthene.

TABLE 4—Chemical Analyses for Iron and Titanium of "Opaque Fractions" of Samples 5 and 7 listed in Table 2.

Sample No.	Columns corresponding to Table 2	Macroparity of fractions by grain-counting: No. of ore grains × 100 / Total No. of grains	Appearance of opaque grains	Wt. % of "heavies" examined	Solution effected by	Insoluble residue Wt. % of fractions	Chemical analysis of the soluble portion % of soluble wt.							Spectrographic analyses suggests "unaccounted for weight" comprised†:						
							Total Fe	FeO	Fe_2O_3	TiO_2	Unaccounted for	Fe / Ti	Feii / Feiii	CaO	MgO	Al_2O_3	SiO_2	Cr_2O_3	MnO	V_2O_5
5.	C. Strongly Ferrimagnetic	90% Some composite grains	n.d.	4.1	HCl plus H_2SO_4	26.7 Neg. undissolved opaque	58.4	23.9	56.9	7.0	12.2	13.91	2.11							
5.	D. Weakly Ferrimagnetic	45% Rest mainly "smoky"* grains some biotite & amphibole.	Dull, small, and angular.	10.5	HCl plus H_2SO_4	67.6 Neg. undissolved opaque	31.4	15.7	27.5	11.7	45.1	4.49	1.57	17	12	13	2	0.04	0.5	0.4
5.	G. Intermed. Suscept.	30% Few composites, rest amphibole, hypersthene, epidote, biotite.	Dull, small, angular and rounded.	21.8	Fused $KHSO_4$	80.2 Neg. undissolved opaque	29.8	If all 38.4	If all 42.7	19.2	38.1 or 42.4	2.59	n.a.	20	4	15	0.5	1	1	0.3
7.	C. Strongly Ferrimagnetic	90% Rest mainly composites.	Dull, small, and angular.	2.1	HCl plus H_2SO_4	13.4 Neg. undissolved opaque	64.6	26.5	63.1	4.9	5.5	22.06	2.14							
7.	D. Weakly Ferrimagnetic	90% Rest mainly "smoky"* grains.	Bright, very black, small, angular.	9.7	HCl plus H_2SO_4	40.0 Much undissolved opaque	45.0	29.0	52.0	32.1	6.9	2.32	1.00							
7.	E. Very High Suscept.	95% Rest mainly "smoky"* grains.	Bright black. Mixed sizes rounded and angular.	17.2	HCl plus H_2SO_4	60.5% original wt. Much undissolved opaque	55.0	21.6	54.7	22.6	1.1	4.05	2.28							
	$KHSO_4$ solution of insoluble opaque from acid solution 7E, above				Fused $KHSO_4$	7.2% Ins. residue Neg. undissolved opaque	40.9	If all 52.6	If all 58.4	41.4	0.2 or 6.0	1.64	n.a.							
7.	F. High Suscept.	40% Few composites. Rest garnet, hypersthene & epidote.	Bright black mixed sizes angular grains with rounded corners.	7.6	Fused $KHSO_4$	65.3 Neg. undissolved opaque	42.2	If all 53.9	If all 60.6	29.2	10.4 or 16.9	2.42	n.a.	7	0.5	2	1	3	1	0.3
7.	G. Intermed. Suscept.	15% Most opaque in composites amphibole, hypersthene, biotite, garnet.	Any pure grains, small and angular.	8.2	Fused $KHSO_4$	90.0 Neg. undissolved opaque	24.3	If all 31.3	If all 34.7	10.1	55.2 or 58.6	4.01	n.a.	17	3.5	13	3.5	16	0.5	0.2

*Smoky grains, see Note 2, Table 1. †No uncommon elements indicated. n.a. = not applicable. n.d. = not determined. neg. = negligible.

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Table 5 sets out the estimates made of the quantities of sand on the beaches at and west of Orepuki; it is probable that, west of the Waiau mouth, the quantities of sand greatly exceed those listed.

DISCUSSION OF RESULTS

Commercially Valuable Minerals

Taken together the results set out in tables 1–5 indicate that no commercially significant quantities of ore minerals are likely to be found in the beach sand deposits west of Bluff from the Oreti River Mouth to Blue Cliffs at the west end of Te Wae Wae Bay.

Radioactivity

Significant radioactivity was found in two areas; in the small beach area immediately around Orepuki township, in agreement with Nicholson's (1955) results, and, unexpectedly, in the sample from the Bluff Harbour.

Nicholson (Table 2, p. 381, Samples Nos. 227–228), shows significant radioactivity for two samples from the same general locality as present samples 6 and 7.

Tables 2 and 3 indicate that the radioactivity is associated mainly with zircon and principally with − 100 B.S. mesh material. Monazite is suspected in minor amounts in the + 100 mesh fraction and may make a small contribution to the activity.

Again the activity in the Bluff Harbour sediments appears to be associated with zircon. It is noted that the count differences for the fractions recorded in columns G and H are less than for column B. This is no doubt due to the smallness of the divided fractions which did not cover the counting tray.

Attention is drawn to the apparently significant radioactivity counts for the "lights" for samples 4 and 9, particularly as the "heavy" fractions of these showed no evidence of activity. In the case of 4 as the difference was 4·1 and clearly significant, both the "lights" and "heavies" were rechecked to ensure that no accidental event had given high or low counts; the original values were confirmed for both fractions. No attempt was made to further concentrate or seek the source of the activity in these "lights" as it was outside the scope of the work. If it shows nothing else, the finding of significant radioactivity associated with "lights" indicates that in any thorough examination for radioactivity, low density material should be checked even when passing 60 mesh. The somewhat higher than "probably significant" count for sample 6 "lights", is presumably due to incomplete separation of the definitely radioactive mineral that concentrated in the "heavies".

Rutile

In all the samples listed, rutile if present, was a minor constituent and in no case were commercially interesting concentrations indicated. In the preliminary rough investigation for rutile of the whole 23 samples originally taken several per cent was found for a small dune deposit on a small flat between the mouth of the Waimeamea River and the Taunoa Stream at Orepuki. This is regarded as a local concentration in a small pocket of sand

TABLE 5—Estimate of Order of Quantities of Sand on Beaches at and West of Orepuki

Locality	Length of deposit yd	Average width from foot of cliffs to low water yd	Estimated width accessible beyond low tide yd	Width taken for calculations yd	Known depth under foot of cliffs ft	Depth taken for estimates yd	Volume cu. yd. $\times 10^6$	Tonnage $\times 10^6$ at 1.5 tons per cu. yd.	Sample No. representative of the deposit
Blue Cliffs to Waikoau River	3,400	50	50	100	20	6.5	2.2	3.3	1
Waikoau River to Rowallan Burn	6,300	120	80	200	20	6.5	8.2	12.3	2
Rowallan Burn to Grove Burn	1,700	100	80	180	20	6.5	2.0	3.0	3
Grove Burn to Waiau River	Narrow or very stony beaches too small or not practicable for pumping of sand.								
Waimeamea River to Monkey Island	3,400	50	50	100	2 to 12	2.0	0.68	1.0	6 and 7

and not representative of the average of the sand accumulation around Orepuki, which is practically confined to the active beach.

"Heavy" Minerals

Green hornblende appears to be the predominant "heavy" mineral throughout the area. The occurrence of other "heavy" minerals is noted in table 3. These were only roughly identified by inspection in clove oil; no quantitative measurements of diagnostic constants were made. Only in the case of the opaque grains was the proportion estimated by grain counting.

Sample 8 in accordance with the darker appearance of the Taramea Beach, Riverton, indicates a higher than average concentration of heavy mineral; the opaque mineral content is rather low at 6% of the "heavy mineral" concentrate.

Opaque Minerals

The figures shown in table 3 for the opaque mineral content of various fractions are of low accuracy as they are based on grain counts of 100–200 grains of varying sizes and densities. The deposits did not warrant the extensive work necessary to give a higher accuracy. The results do show, however, the pattern of distribution of the opaques.

The chemical work is inherently of higher accuracy. It gives the overall figures for the total Fe and TiO_2 in whatever minerals dissolved. In the case of acid soluble opaques it was possible to estimate the ferrous iron contribution to the total iron. In cases where fused pyrosulphate was necessary to give preferential solution of the opaque mineral without solution of gangue impurities, it was not readily possible to estimate the ferrous iron. The usual method of HF/H_2SO_4 solution of the sample would also have attacked the iron containing gangue silicates. Only iron and titanium oxides were chemically estimated and the unaccounted for percentage weight is quoted. It gives an indication of the degree to which other elements have replaced these major elements or occur as other minerals. To assist in the inter comparison of probable titaniferous minerals present, the ratios Fe/Ti and Fe^{3+}/Fe^{2+} have been calculated.

These figures indicate that only for fraction 7E is the proportion of unaccounted for weight low; indicating little replacement of the main iron and titanium oxides. 5D, 5G, and 7G fractions show very large proportions of unaccounted for weight; this is considered to be too great to be largely lattice replacement and to indicate solubility of other than primarily titaniferous iron minerals. The proportion of unaccounted for weight in fractions 5C, 7C, 7D, and 7F can be explained as due to lattice replacement.

Spectrographic analyses of portions of the solutions containing fractions 5D, 5G, 7F, and 7G suggest that the "unaccounted for weight" is mainly due to the common oxides CaO, MgO, Al_2O_3, SiO_2. It is surprising that such quantities were taken into solution. From table 4 it will be noted that the principal minerals that contaminated the opaque fractions analysed, are in general highly insoluble; moreover the undissolved residues examined under the microscope showed no evidence of chemical attack on their surfaces. It thus appears that the fractions concerned held considerable amounts

of these oxides either free, or more probably as minerals, in such finely divided form that they were soluble under the conditions.

No attempts were made to mount specimens and examine either thin slices or polished surfaces metallographically to ascertain whether the chromium reported for samples 7F and 7G was present as free grains of chromite or as a constituent element of the average mineral of these particular fractions. From a practical point of view performance through the magnetic separator indicates that, while the other fractions can be produced chromium free, fractions 7F and 7G if not homongeneous, will not be separable by magnetic methods.

The negligible commercial significance of these minerals does not appear to justify the large amount of work that would be necessary to elucidate accurately the composition and structure of the various opaque mineral species present.

Some of the opaque minerals are of considerable academic interest and it is hoped that they will be further investigated and reported upon in a paper dealing with the nature of a large series of opaque iron titanium minerals occurring on New Zealand beaches.

The general impressions are that the strongly ferrimagnetic titanomagnetite 5C which is a principal opaque mineral west of the Waiau River persists as a minor opaque, c.f. 7C, at Orepuki; the higher total iron and lower TiO_2, hence the higher Fe/Ti ratio, for 7C can be explained by assuming the presence of a little free magnetite which would appear in this fraction. Such would exert little effect on a ferric/ferrous ratio of around 2. Otherwise it appears that the suite of opaque minerals around Orepuki is complicated and not directly related to the other two occurring west of the Waiau; and that all the opaque minerals are titaniferous.

Orepuki Area

The general sand accumulations on the beaches immediately around Orepuki, see samples 6 and 7, have a high heavy mineral content which is predominantly opaque minerals. Zircon with which radioactivity is associated, occurs to the extent of several per cent of the heavy mineral content. Rutile is a minor constituent. The relatively low TiO_2 content in the ilmenites and the associated chromium, as compared with the Westland or Auckland ilmenites render them unattractive for commercial development even if they did occur in economic quantities. They constitute a very small deposit that, with no protection from the open sea, would be difficult to mine.

Wood (1959) reports an investigation made of beach sands adjacent to Orepuki between Taunoa and Kenney's creeks. The heavy minerals were examined by Dr J. J. Reed, petrologist of the Geological Survey. The results are in general agreement with the relevant sections of this paper.

General

The heavy mineral suite on the beaches in Te Wae Wae Bay is probably largely derived from the sediments carried by the Waiau River with smaller contributions near Orepuki from the streams draining the Longwood Range. The nature of the heavy minerals found in the relevant samples does not appear to be in conflict with a considerable contribution from rocks of the type studied by Hutton and Turner at Clifden.

Sand derived from this major drainage waterway and carried by the littoral drift out of the Bay to the east, under present conditions, is probably sufficient to swamp the contribution of any distinctive heavy minerals carried down the estuarine Aparima and Oreti rivers to the beaches between them.

All separated products of samples listed are lodged in the Geology Department, Victoria University of Wellington.

CONCLUSIONS

The results indicate that no commercially attractive quantities of minerals valuable today are likely to be won from these deposits.

High concentrations of rutile, ilmenite, and zircon occur in favourable locations but the total quantities are small.

The black opaque minerals in the Orepuki area are different from those west of the Waiau; all are titaniferous.

Dark green amphibole, apparently hornblende, is the predominant heavy mineral throughout.

Slight radioactivity and an opaque ore mineral content greater than one per cent in the sample of Bluff Harbour sediments would appear to warrant further investigation.

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