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HEAVY BLACK SANDS FROM PHILLIP ISLAND, VICTORIA.

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Abstract.

An account is given of the distribution and extent of some heavy black beach sands on Phillip Island. The most extensive deposit lies on the southern coast just west of Cape Woolamai. The physical and mineralogical compositions of six samples of the bromoform-separated sand concentrates are described. They are composed chiefly of opaque particles, olivine, zircon, augite, rutile, tourmaline and garnet. A considerable proportion of the opaques, which make up more than 67 per cent. in all the samples, is limonite. No beach sands with a higher olivine content have been described from Australia. The physical and mineralogical compositions point to there being more than one source for the heavy constituents, and suggest that the immediate sources are chiefly rocks which outcrop nearby. The minerals are described, and the results of an inquiry into their origin are given. The black sand deposits are shown to have little economic value because of the low zircon and rutile contents and their restricted extent.

Introduction.

The submission to the Museum for examination of a sample of heavy black sand from Cat Bay, Phillip Island, led to an investigation of the occurrence and a search for other deposits on the island. The results of this work, and the study of the samples collected, form the substance of this paper.

Heavy mineral beach sands, commonly called "black sands" because of their dark colour, are naturally concentrated by wave and wind action, and form extensive deposits in various parts of the world. They are made up largely of minerals of high specific gravity which have withstood chemical and mechanical weathering. Large deposits, which are exploited for their zircon and rutile contents, occur along the coast of Northern New South Wales and Southern Queensland (Beasley, 1948; 1950). Zircon is an important refractory and opacifier, while rutile is used largely for coating electric welding rods and as a source of titanium metal.

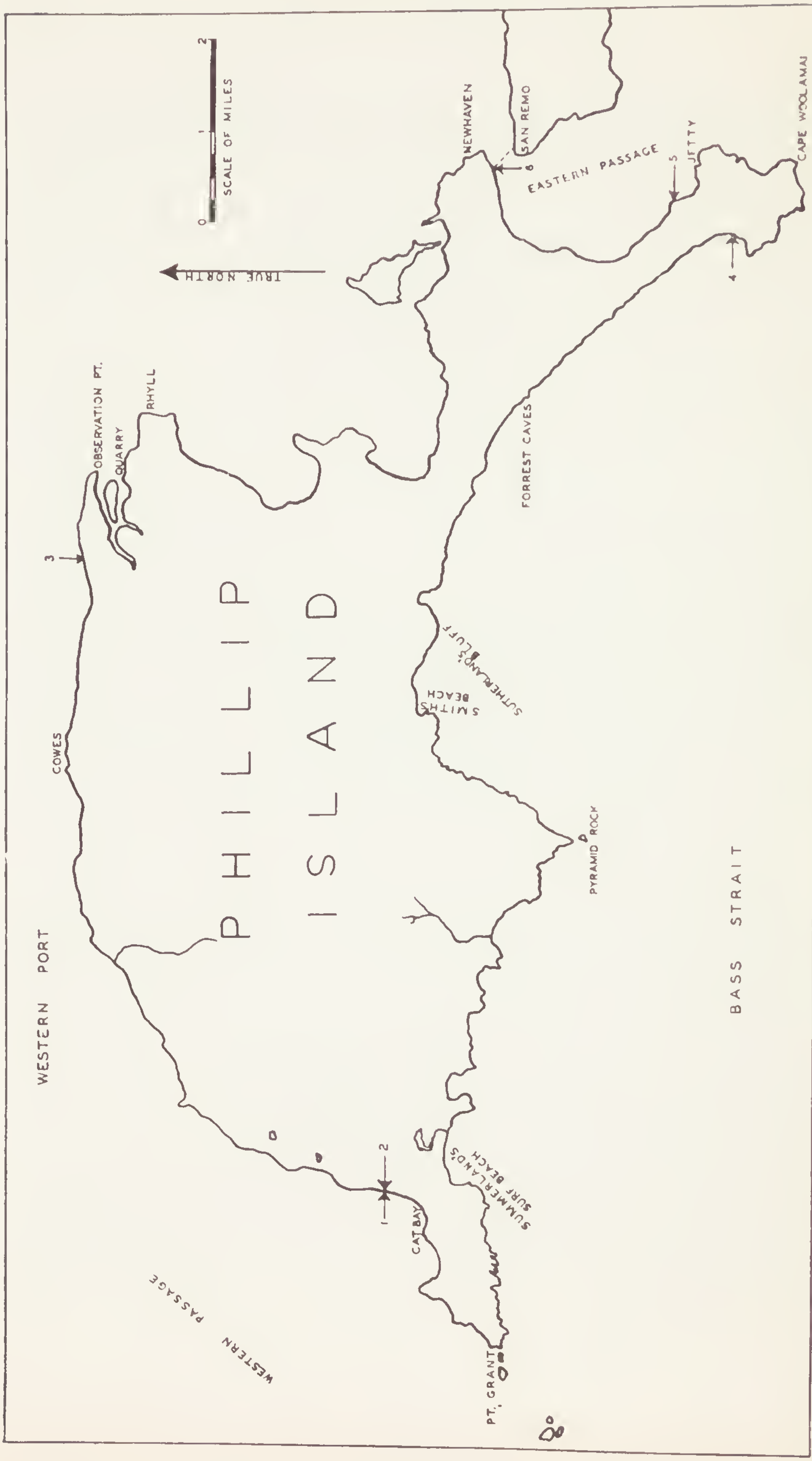

Fig. 1.—Map showing places of collection of Sand Samples.

Baker (1945, p. 12) has referred to the occurrence in patches "on some of the Phillip Island beaches in Western Port of dark-coloured beach deposits, where the dark colour is due entirely to an abundance of dark-brown to black grains of ironstone (limonite, &c.) derived from the weathering of altered basalt lavas and tuffs forming the cliffs in the immediate vicinity."

Distribution and Extent of Deposits.

The most extensive deposit located on the island was found on the southern coast just before reaching the first bluff (plate 1, fig. 1) on the western side of the Cape Woolamai headlands mass. This is some 1⅛ miles N.-W. of Cape Woolamai itself, which is the extreme easterly point of Phillip Island. The deposit occurs in the upper part of the beach and takes the form of lenticular layers or seams and surface "washings," the total thickness of black sand ranging up to 1 ft. 3 in. The deposit has a length of 1,400 feet, with a maximum width of 70 feet and an average width of 40 feet. Beneath 1 to 4 inches of heavy mineral surface " washings " (plate 1, fig. 2) and a layer of white (quartz) sand a well-defined black sand seam up to 6 inches thick (plate 1, fig. 3) was found. This is underlain by white sand resting on another layer of black sand about 4 inches thick. In some of the auger holes a third black sand seam of approximately the same thickness was passed through, but in none was any found below a depth of 5 feet. Borings at right angles to the strandline have shown that the seams gradually thin out seawards, and that their greatest thickness is located about 30 feet in front of the scarp base at the top of the beach. When traced parallel to the beach in a south-easterly direction towards the headland the lower two seams were found to unite, the amount of white sand between them gradually decreasing. The heavy sand grains have been fairly well concentrated by wave action, the weight percentage of heavies in the samples collected from this deposit ranging from 28 per cent. up to 84 per cent.

A smaller deposit was found on the eastern coast of the island in the vicinity of a small bluff approximately ½ mile N.-W. of the old Granite Quarry Jetty. It is a lenticular deposit occurring in the upper part of the beach, and consists of from 1 to 3 inches of surface " washings " and a black sand seam up to 4 inches thick beneath a layer of white sand (plate 1, fig. 4). The deposit measures some 300 feet in length and 40 feet in width.

The only deposit of any size on the northern coast of the island occurs near the eastern end of Cat Bay. It lies on both sides of the mouth of the small, spring-fed creek that enters the sea about ½ mile N.-E. of the old Cat Bay jetty. The deposit is approximately 300 feet long but the maximum width is only 30 feet and the total thickness of black sand does not exceed 9 inches. It occurs on and just below the surface in the upper part of the beach, the thickest individual layer measuring 5 inches.

Smaller accumulations of heavy black sand were found at a number of places on the island. At some, such as around the Newhaven end of the San Remo Bridge (plate 1, fig. 5), near Rhyll jetty, and near Observation Point, they are merely small patches of surface "washings" just above high-tide mark. Unless deposited during heavy gales or at times of exceptionally high tides, when the waves may reach far beyond normal high-water mark, their position usually does not remain fixed. Rather larger than these are several accumulations adjacent to basalt and tuff cliffs on the southern coast, as on Smith's Beach and Summerland's Surf Beach. At these places boring has revealed the presence of thin seams of black sand down to a depth of about 4 feet, as well as small patches on the surface. However, in none of the bores was more than 9 inches of black sand passed through, nor was the lateral extent of the layers found to be at all extensive.

Places of Collection of Sand Samples.

The localities of the black sand samples collected for study are given below. They are numbered consecutively from west to east, as shown in Figure 1.

1. Upper part of beach, 20 feet S.-W. of small creek mouth, Cat Bay.
2. Rills in eroding cliff face of Tertiary sediments and aeolian sand immediately behind locality 1 and approximately 12 feet above cliff base, Cat Bay.
3. Upper part of beach, surface "washings" 1 mile W. of Observation Point.
4. Seam from 6 inches to 10 inches in bore on beach 850 feet N.-W. of first bluff met on western side of Cape Woolamai headlands mass, and 16 feet seawards from cliff base.
5. Seam in bore in upper part of beach, ½ mile N.-W. of old Granite Quarry Jetty.
6. Surface "washings" immediately above high-water mark on beach, Newhaven end of San Remo Bridge.

Mechanical Composition of the Concentrates.

Sieve analysis of samples of the heavy mineral concentrate obtained from the natural concentrates by bromoform separation was carried out, as knowledge of their size distribution was required for purposes of comparison. Satisfactory comparisons cannot be made from the mechanical analysis of the natural concentrates, owing to the difference in grain size of the light and heavy constituents and the sometimes considerable local variations in the degree of natural heavy mineral concentration.

Phillip Island consists chiefly of Tertiary Older Volcanic basalts, tuffs and agglomerates. Jurassic and some Tertiary sediments, and Palaeozoic granites outcrop in smaller areas. Boring has shown that the volcanic and sedimentary rocks overlie Palaeozoic sediments. An account of the island's geology and physiography has been given by Edwards (1945).

Mechanical Analysis.

In the laboratory, the samples of natural concentrate, usually of the order of several hundred grams, were washed free of salt, seaweed, &c., dried, and then split by quartering to a bulk estimated to give approximately 40 grams of heavy minerals after bromoform separation. The samples of natural concentrate were then weighed, and heavy liquid separations were carried out with bromoform of specific gravity 2·88. The separated concentrate was weighed, and the weight percentage of heavy minerals in each sample of natural concentrate was determined (see Table II.). The bromoform-separated concentrates were shaken in a nest of sieves with a mechanical shaker for twenty minutes. The sieves used were numbers 30, 60, 72, 85, 100, 120, 150, and 240 of the British Standard Series. The resulting size fractions were then weighed, percentages calculated, and the results tabulated (Table I). Cumulative-frequency curves were constructed from this information, and the median (50 per cent.) diameter and the first and third quartile diameters were read off. From the latter figures the sorting coefficients of the heavy constituents were calculated. Where Q3 and Q1 are the third and first quartile diameters, respectively, the sorting coefficient is $\sqrt{Q3/Q1}$. It expresses the measure of the average quartile spread. Thus perfect sorting equals unity, and the larger the value the more poorly sorted is the sample. Comparison and description of the samples are made from the median diameters and sorting coefficients (Table II.).

TABLE I.—MECHANICAL ANALYSES OF THE BROMOFORM-SEPARATED, HEAVY BEACH SAND CONCENTRATES.

No.	Size of Openings in Millimetres.								
	> ·500	·500–·251	·251–·211	·211–·178	·178–·152	·152–·124	·124–·104	·104–·066	< ·066
	%	%	%	%	%	%	%	%	%
1 ..	1·5	31·0	17·9	13·9	6·6	20·9	7·4	0·9	..
2 ..	0·1	1·0	8·9	19·0	12·7	39·8	13·6	1·4	0·2
3 ..	0·1	2·6	11·9	24·2	9·0	31·9	15·0	5·2	0·1
4 ..	0·7	48·4	30·1	12·6	2·6	4·5	1·0	0·1	..
5 ..	0·4	24·7	21·5	13·6	11·0	17·1	8·0	0·8	..
6 ..	0·1	3·8	8·5	14·3	7·9	37·5	24·4	3·5	..

TABLE II.—MEDIAN DIAMETERS, SORTING COEFFICIENTS, AND WEIGHT PERCENTAGES OF THE HEAVY CONSTITUENTS.

No.	Median Diameter (in Millimetres).	Sorting Coefficient.	Weight Percentage Heavies.
	%	%	%
1..	0·21	1·30	29·0
2..	0·15	1·23	11·4
3..	0·15	1·23	43·5
4..	0·25	1·28	83·7
5..	0·21	1·29	40·0
6..	0·14	1·21	21·2

DISCUSSION OF RESULTS.

From Table I. it is apparent that the size distribution of the heavy constituents in certain of the samples is similar. In samples 1, 4, and 5 the dominant or maximum percentage is in the 0·500 to 0·251 mm. size class, and there is a secondary maximum in the 0·152 to 0·124 mm. size class. In samples 2, 3, and 6 the maximum percentage is in the 0·152 to 0·124 mm. size class, and there is a secondary maximum in the 0·211 to 0·178 mm. size class. The mechanical analysis of the latter samples shows that their average size is much less than that of samples 1, 4, and 5. The presence of a marked secondary maximum in each sample may suggest that there is more than one source for the heavy constituents.

From Table II. it is seen that the median diameter of the heavy constituents ranges from a minimum of 0·14 mm. to a maximum of 0·25 mm. The fact that samples 1, 4, and 5 have relatively high median values (respectively 0·21, 0·25, and 0·21 mm.) suggests close proximity to the chief source of the heavy constituents, and a relatively short detrital history for the bulk of them. The smaller median values of samples 2, 3, and 6 (respectively 0·15, 0·15 and 0·14 mm.) suggest a rather longer detrital history for these. Since sample 2 has a median diameter much less than that of sample 1, it seems clear that the Tertiary sediments and overlying aeolian sands of the Cat Bay cliff only provide some of the heavy constituents to the beach deposit there.

The heavy constituents of the samples are moderately well sorted, the coefficient of sorting ranging from 1·21 to 1·30. The less well-sorted ones are those with the higher median values (samples 1, 4, and 5). These black sands are from places near or adjacent to rock outcrops. The better sorted ones (samples 2, 3, and 6) are those with smaller median values. It is of interest to note that sample 2 is better sorted than sample 1.

Mineralogical Composition of the Concentrates.

To determine the mineralogical composition, the bromoform-separated heavy concentrates were split by quartering to a bulk of approximately 3 grams. Temporary mounts were made directly from these small samples without sieve division into two size fractions. Except where accurate tests for refractive index were made, liquid with a refractive index of 1·67 was used for the temporary mounts. The heavy particles were identified under the microscope, and the number percentage of the various species was determined on the basis of a count of about 350 grains. Because of the difficulty of distinguishing between ilmenite and magnetite under the microscope and deciding definitely between limonite grains and partly altered rock particles, the black and brownish-coloured opaque particles were counted together and the combined grain number percentage of them calculated. The results of the grain counts are given in Table III.; the symbol " * " is used to indicate that the mineral is present in an amount less than 1 per cent. Permanent mounts of the heavies were made in Canada balsam, and placed in the Museum collection (Nos. E.1662 to E.1667).

The weight percentage of heavy constituents in the samples ranges up to 83·7 per cent. (Table II.). The light constituents are mainly quartz and shell fragments.

The following abbreviations are used in Table III:—

Op-, opaques except leucoxene; Ol, olivine; Zir, zircon; Aug, augite; Ru, rutile; Leu, leucoxene; Tour, tourmaline; Gar, garnet; Hyp, hypersthene; Epi, epidote; Top, topaz; Mon, monazite; Sph, sphene; Spi, spinel; St, staurolite.

TABLE III.—MINERAL ANALYSES OF THE HEAVY SAND CONCENTRATES IN GRAIN NUMBER PERCENTAGES.

No.	1.	2.	3.	4.	5.	6.
	%	%	%	%	%	%
Op	65·3	76·4	70·4	78·9	78·3	79·5
Ol	10·4	1·0	9·4	5·7	3·9	3·2
Zir	6·2	10·9	1·0	1·1	6·1	11·0
Aug	7·6	1·0	6·4	2·8	1·2	0·6
Ru	3·9	5·1	1·2	2·1	1·1	1·2
Leu	2·0	1·1	1·0	1·0	2·2	1·4
Tour ..	3·2	*	3·6	2·4	1·7	1·8
Gar	*	*	*	1·9	1·5	1·0
Hyp ..	*	*	*	*	..	..
Epi	..	..	*	..	*	..
Top	*	*	*	*	..	*
Mon ..	..	..	*	*	..	*
Sph	..	..	..	*	..	..
Spi	*	*	..	..	*	*
St	*	*	..	*	..	*

The above Table shows that the heavy concentrates are composed chiefly of opaque particles, olivine, zircon, augite, rutile, and tourmaline. All the other minerals together make up less than 5 per cent. of the concentrates, garnet being the most abundant.

Opaques are the principal constituents of the concentrates. They comprise more than 67 per cent. in all the samples. Although a considerable proportion of them is made up of limonite grains, magnetic tests and optical examination have shown that particles of magnetite and ilmenite are fairly common. Magnetite was found to be more abundant in samples 4 and 5 than in the other samples. Leucoxene is present in amounts ranging from 1 per cent. in sample 4 (Cape Woolamai) to 4 per cent. in sample 3 (Observation Point), and many of the ilmenite grains show partial alteration to leucoxene. Some of the opaques were found to be small particles of weathered basalt.

Olivine is next in abundance to the opaques in one-half of the samples studied, zircon being next in abundance to the opaques in the other samples. Minerals such as hypersthene, epidote, topaz, monazite, sphene, spinel, and staurolite, where present, occur only in very small amounts; fewer than 4 and sometimes only 1 grain of some of these species were seen in the assemblages grain-counted.

There is a general similarity in the mineralogical composition of the samples. However, some of the changes in the percentages of various minerals are notable.

It will be seen that the olivine and augite contents are higher in sample 1 (Cat Bay) than in any of the other samples. This is apparently related to the larger occurrence of basic volcanic rocks in the vicinity as compared with the places of collection of the other samples. Sample 6 (Newhaven) has a zircon content higher than that of any of the others. This may be due to the fairly close proximity of Jurassic sediments and also of Devonian granite. The zircon and rutile contents of sample 2 are notable particularly as they are much greater than those of sample 1. This suggests that the Tertiary sediments of the cliff are not the sole contributor of heavy constituents to the beach deposit there.

Description of the Minerals.

Limonite.—The limonite particles appear yellowish-brown to reddish-brown and dark brownish-black under reflected light. They vary considerably in size, some being quite large. Usually they are irregular in shape, and few are well rounded. An appreciable number of the grains is strongly magnetic, but a larger percentage is not attracted by a horseshoe hand magnet.

Magnetite.—Many of the magnetite grains are irregular in shape, but some have quite regular outlines. The degree of roundness varies considerably, the smaller grains usually having the higher degree. Octahedral crystals are scarce and dodecahedral ones are very rare, but many of the grains show remnants of crystal faces. Faceting is clearly visible on the surface of some grains. Some partial alteration to limonite is often seen.

Ilmenite.—The ilmenite grains generally have a higher degree of roundness than the magnetite and limonite; many are rounded and some are well rounded. Commonly the grain shape is irregular. Partial alteration to leucoxene can been seen in some grains.

Leucoxene.—The leucoxene grains appear dull-white to yellowish-white in reflected light. Usually they are rounded or well rounded. In size they are generally much smaller than the limonite grains.

Olivine.—Most of the olivine grains are irregular in shape and their degree of roundness is not high. The particles vary considerably in size, some being quite large. The colour ranges from almost colourless to yellowish-green. Many of the grains appear quite fresh, but some show traces of decomposition and others are quite clouded. Minute inclusions are fairly common in some grains, many being iron-ores. Euhedral crystals are rare and subhedral ones scarce.

Zircon.—Almost all of the grains are colourless; yellow ones are rare. The number of rounded grains is slightly greater than the number of euhedral and subhedral ones in the samples. Inclusions are not very abundant; they are rarer in the rounded than in the euhedral and subhedral grains. This may be because the inclusions are points of weakness in the crystals, and abrasion liberates them. The grains are considerably smaller than most of the olivine grains.

Augite.—Most of the grains are shades of brown including pale purplish-brown, but some are greenish and greyish. The degree of roundness usually is not high, and the shape generally is irregular. Some of the grains are fairly large, and most are slightly pleochroic. Some grains are clouded from decomposition, and inclusions may be abundant.

Rutile.—Foxy-red coloured and yellow-coloured grains are present, and some are dark reddish-brown and almost black. The foxy-red variety is the most common type. The grains generally are rounded, although edges of prism faces often can be seen. Inclusions are rare, and pleochroism is weak. The grains are about the same size as the zircon.

Tourmaline.—The tourmaline grains commonly are brown, but some are grey and a few are blue. Some are well rounded, and have a high sphericity. Prismatic crystals showing only slight abrasion are also present.

Garnet.—Most of the garnet grains are pink, but there are some colourless and a few brown ones. Usually they are subangular and are irregular in shape. Some show surface etching, but this is much less common than in the garnet of Queensland heavy mineral beach sands described by Beasley (1950, p. 79). Most of the garnet is the variety almandine. It is moderately magnetic.

Hypersthene.—The rare grains of hypersthene occur as elongated prisms with rounded terminations and as irregularly-shaped particles which are pale brownish-green to greyish-green in colour. Inclusions are common, most being dark-coloured. The grains display the characteristic pleochroism, and are about the same size as the augite. The degree of roundness is not very high.

Epidote.—The epidote grains are greenish-yellow and subangular or subrounded. Pleochroism is distinct but weak.

Topaz.—The rare topaz occurs as colourless, irregularly-shaped grains which are subangular or subrounded.

Monazite.—The monazite grains are pale-yellow, and usually well rounded.

Sphene.—The grains of this mineral are pale-brown, subangular, and irregular in shape.

Spinel.—The spinel group mineral, ceylonite, occurs as bluish-green, rounded grains which usually show traces of the octahedral habit.

Staurolite.—The rare grains of staurolite are irregular in shape, brownish-yellow, and moderately pleochroic. Inclusions are fairly numerous.

Origin of the Heavy Minerals.

The physical and mineralogical composition of the concentrates suggests that in most cases the immediate sources of the heavy constituents are chiefly rocks which outcrop nearby.

It seems that most of the opaques, the olivine and the augite have been derived from the Tertiary volcanic rocks which are so abundant on the island. The often quite large grain size of these heavy sand constituents, their usually low degree of roundness and only moderate sorting suggest that their detrital history has not been very long. It is thought that many of these grains have probably not travelled far at all following their liberation from the volcanic rocks of the shore platforms, cliffs and hinterland. The presence of particles of quite fresh olivine and augite in the sands points to fairly recent liberation of such grains, since both of these minerals are not very stable (Smithson, 1950, p. 14) and fairly soon become clouded from decomposition. The Tertiary volcanic rocks have been described by Edwards, and their distribution is shown on his map (1945, p. 2). They consist of flows of Older Volcanic basalts intercalated with thick beds of tuff and agglomerate. The flows are olivine-basalts chiefly of Edwards' (1938) Flinders type. They contain olivine crystals up to 3 mm. in diameter and sometimes have quite large augite and magnetite and ilmenite grains. The tuffaceous material, as Edwards (1945, p. 13) has said, " is generally altered to red clay, red ochre, or laterite," and in places the basalts are also very altered. The soils derived from the weathering of these volcanic rocks contain ironstone gravel, the concretions ranging from 1 mm. to 1 cm. or so in diameter. Since this ironstone is physically and chemically resistant it often appears on the surface after erosion, and it seems likely that some of the opaque particles in the heavy black beach sands have come from this material.

The immediate source rocks of much of the zircon, rutile, tourmaline, garnet, epidote, topaz, monazite, spinel and sphene appear to be the Jurassic and Tertiary sediments of the island and the neighbouring mainland. Jurassic sediments consisting largely of friable arkose and felspathic grits outcrop to the west of Rhyll, and are described by Edwards (1945, p. 11). A sample of arkose from the quarry in the cliff face (see map) was found to contain 1 per cent. of heavy minerals, the suite containing grains of the above minerals very similar in general appearance to those found in the beach sands. Their size is approximately the same as in the black sands; it is much smaller than most of the olivine, augite, and opaques. There are the same colour-varieties of garnet, tourmaline, and rutile as are present in the beach sands, which points to the Jurassic sediments as source rocks for these minerals.

Tertiary sediments outcrop at certain places along the coast such as at the Cat Bay black sand locality. The ferruginous sediments which outcrop in the cliff at Cat Bay, overlying decomposed basalt, resemble the " Red Beds " above Older Volcanic basalts at Stony Point and at Corinella Point, on the western and eastern shores of Western Port. The heavy mineral assemblage of the Cat Bay material was found to contain the species present in the arkose, with the same colour-varieties and only slightly smaller grain size. Many of the grains show a fairly high degree of roundness and clearly resemble those in the beach sands. Although opaques are the most abundant of the heavy constituents in the assemblage, and limonite the most common, there is an absence of large particles of them and also of olivine and augite.

The Devonian granites which outcrop at Cape Woolamai and at Pyramid Rock contain zircon, rutile, tourmaline, and iron ores; and it seems that some of the grains of these minerals in the beach sands have come directly from the disintegration of these rocks. The granite and the rocks of its contact aureole appear to have provided most of the minerals in the Jurassic arkose. They are thus the primary source of the majority of the grains of this suite (zircon, rutile, tourmaline, garnet, &c.) of heavy minerals in the beach sands.

Although there are no outcrops of Palaeozoic sediments on the island to provide minerals by direct weathering to the beach sand, they have been found *in situ* in deep bores, as xenoliths in the granite outcrops and as pebbles on the ocean beaches. It is thought that they form the sea-bed at least between Pyramid Rock and Cape Woolamai. These rocks, which are believed to be Ordovician in age, contain zircon, tourmaline, rutile and iron ores; and it seems likely that some of the smaller and more rounded grains of these species in the arkose, the Tertiary sediments, and the beach sands have come from them. Since these heavy minerals are of a granitic nature, their primary source must be pre-Ordovician granite. Thus, some of the grains in the beach sands have probably passed through at least four cycles of erosion, transportation and deposition.

Conclusion.

The work carried out indicates that the deposits of heavy black sand on the island have little economic value. Unfortunately, the zircon and rutile contents are too low, and the extent of the deposits is too restricted to warrant exploitation, except perhaps on a very small scale.

The position of the most extensive deposit (on the southern coast just west of Cape Woolamai) is due largely to the configuration of the coastline, with exposure to the full violence of south-westerly gales, and the presence of a sandy beach stretching from near Forrest Caves to the beginning of the Cape Woolamai headlands. Particularly during south-westerly gales which last sometimes for several days, powerful waves strike the coast obliquely, and sand is moved eastward towards the headlands which act as a barrier and provide a place before them for the natural accumulation of the heavy minerals. There the heavy minerals have been well concentrated by wave action into seams, the rest of the beach being left impoverished. Because of its location, and its manner of formation by waves reaching far beyond normal high-water mark, the deposit has become fixed.

The Phillip Island heavy black sands are very different from the zircon-rutile-ilmenite sands of Eastern Australia (Beasley, 1950). No beach sands with a higher olivine content have been described from Australia. The physical composition of the sand concentrates and their mineralogical composition point to there being more than one source for the heavy constituents; and the inquiry into the origin indicates that weathering of the rocks of the island and neighbouring mainland has provided the various heavy ingredients of the black sands.

Acknowledgment.

I am indebted to Mr. H. A. B. West, of Cowes, for conducting me to the Cat Bay black sand locality, after sending a sample from it to the Museum. Mr. West also kindly conducted the author and Mr. E. D. Gill to the quarry in Jurassic rocks near Rhyll.

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EXPLANATION OF PLATE I.

Fig. 1.—Sandy beach south-east of Forrest Caves, looking towards Cape Woolamai. The black sand deposit lies just before the first bluff, near the centre of the left-hand edge of the photograph.

Fig. 2.—Surface " washings " at site of black sand deposit shown in photograph on left, on southern coast just west of Cape Woolamai.

Fig. 3.—Excavation showing black sand seam 6 inches thick in deposit on southern coast just west of Cape Woolamai.

Fig. 4.—Excavation showing 1 inch of black sand surface " washings " and a seam 3 inches thick in deposit approximately ½ mile north-west of old Granite Quarry Jetty.

Fig. 5.—Small patch of black sand surface " washings " around high-tide mark near Newhaven end of San Remo Bridge.

Fig. 6.—Storm-wave platform cut in granite near Cape Woolamai.

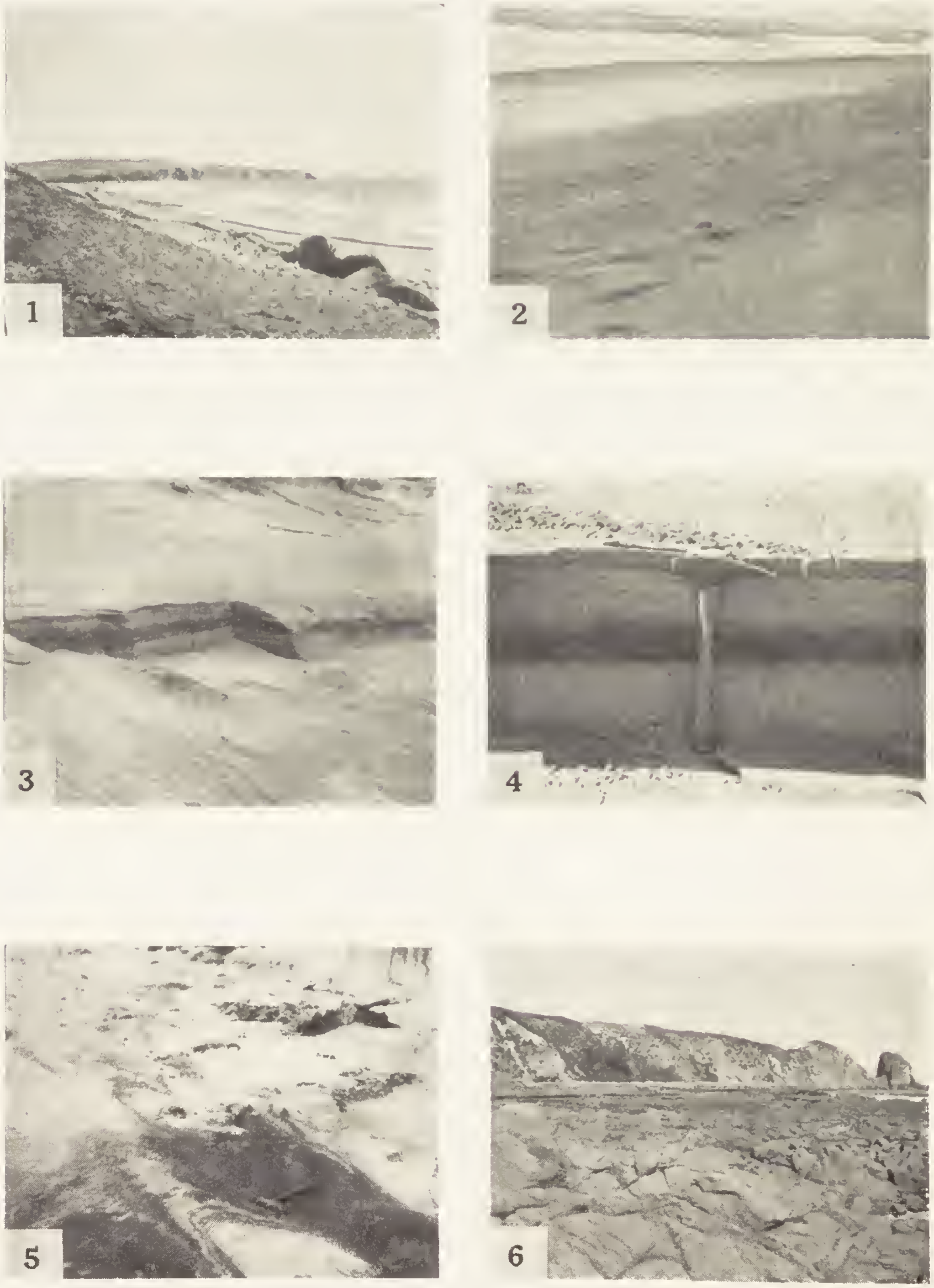

PLATE 1.