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MAGNETITE BEACH-SANDS OF BOUGAINVILLE ISLAND TERRITORY OF PAPUA AND NEW GUINEA

by

J.E. Thompson

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SUMMARY

Magnetite with combined titanium dioxide, the predominant heavy mineral of the Bougainville beach-sands, is derived from the unconsolidated pyroclastic and alluvial aprons of recently active andesitic volcanoes principally Mt. Balbi in the north, Mt. Bagana in the centre and Mt. Taroka in the south.

The spectacular high concentrations of magnetite on the eastern coast are probably too small for consideration as iron ore deposits.

Magnetite sand concentrations of economic importance may exist in the large areas of coastal plain, particularly on the western side of the island, which are obviously made up of a succession of old strands. Magnetic survey methods may be of value in delineating zones of magnetite concentration in these areas.

INTRODUCTION

Over a long period, several small parcels of magnetite beach-sand have been submitted for identification to the Geological office, Port Moresby by residents of, and travellers on, Bougainville Island. Except in the case of a specimen submitted in August, 1959, by Mr. G. Graham of the T.P. & N.G. Administration Department of Agriculture, neither the sand deposits nor the method of sampling were adequately described. As small accumulations of magnetite beach-sand are common throughout the Territory, particularly near Recent volcanic centres, little significance was attached to the earlier specimens.

Mr. Graham's specimen, which contained 87% titaniferous magnetite, was collected during soil investigations on the northern end of Bougainville's western coast from *"a depth of three feet about five chains inland from the present-day beach, near low, forested, parallel dune structures". This description suggested the possibility of magnetite sand deposits of economic importance and, in March, 1960, after an investigation of copper deposits in central Bougainville had been completed, opportunity was taken to briefly examine parts of the coastline around the southern half of the island.

Bougainville Island, the northern-most and largest island of the north-westerly aligned Solomon Chain, is roughly oval; approximately 127 miles long and has a maximum width of 50 miles. It is not included in the British Solomon Islands Protectorate but is, with Buka Island, an Administrative District of the Territory of Papua and New Guinea with administrative headquarters at Sohano, a small island between Bougainville and Buka Island.

* Personal communication.

Access to Bougainville is either by boat or by air from Rabaul. A fortnightly air service from Rabaul to Honiara (Administrative centre for the British Solomon Islands Protectorate) lands at Buka, near Sohano. On alternate weeks an air service from Rabaul visits Sohano, then Wakunai and Kieta on the eastern coast, and Buin at the southern end of the Island.

Bougainville has an extremely mountainous core, the principal peaks of which are active or recently active volcanoes. The eastern coastline is endowed with several small, protected harbours and supports many large, prosperous mixed copra and cocoa plantations. The products of these plantations are collected regularly by medium-sized coastal boats and every six weeks an overseas vessel from Australia calls at Kieta which, though an excellent large natural harbour, has only limited wharf facilities. A discontinuous barrier reef and many small fringing reefs extend along this coastline. In contrast, the western coastline has no good harbours, no reef protection and is exposed to heavy seas. Native population on the western coast is sparsely distributed and the only two plantations are at the northern end.

GENERAL GEOLOGY

The geology of the Island is dominated by three major centres of Recent volcanic activity; Mt. Bagana * (6,560 ft.) in the centre is currently active, Mt. Balbi (9,000 ft.) in the north and the Mt. Taroka group (7,385 ft.) in the south are dormant, with areas of residual solfataric activity. Loosely compacted, andesitic, pyroclastic and alluvial apron deposits extend from these centres to cover most of the island. These deposits are being rapidly eroded by many consequent streams which form a finely textured radial drainage pattern. These streams transport a heavy load of sediment and rapid alluviation has produced large flat coastal plains composed of a succession of old strands.

The rugged Crown Prince Range which extends south-east from Mt. Balbi is composed of older rocks, and has peaks to 5,000 ft. and saddles around 3,000 ft.. In the central portion of the island, it forms the divide between easterly and westerly drainage, and southwards it passes around the northern side of the Mt. Taroka volcanic complex. The geology of the Crown Prince Range is not known in detail but poorly bedded volcanic agglomerates and conglomerates dip regionally northwards at a low angle and appear to unconformably overlie folded, marine, argillaceous and calcareous sediments which are intruded by quartz porphyries (Fisher, 1936) and medium-acid plutonic rocks. Coarse-grained hornblendite and other basic igneous rocks are represented in the gravels of streams draining from the southern portion of this range; they were not seen in situ. Gold and copper mineralization is associated with intrusive quartz porphyries at Kupei on the northern fall, and at Pumkuna on the southern fall of the Range, respectively 8 miles and 10 miles south-west of Kieta. Small quantities of alluvial gold have been won from the headwaters of streams draining both sides of the Crown Prince Range in the Kupei-Pumkuna area and farther north near Atamo and Karato villages. Lode gold deposits, mined pre-war on a small scale at Kupei and Pumkuna, were visited and described by N.H. Fisher in 1936.

* Pronounced "Bugena"

The Emperor Range, north of Mt. Balbi and the Deuro Range south of Mt. Taroka were not visited but distant observations suggest that they are composed of old volcanic rocks possibly belonging to the same volcanic phase as the basaltic agglomerate and conglomerate on the Crown Prince Range and along the coast near Kieta.

The northern tip of the Island for about 15 miles south from Sohano consists of limestone raised about 150 ft. above sea-level to form steep cliffs on the seaboard and undulating karst topography inland. This limestone does not appear to be folded and may be of Pliocene or Pleistocene age.

THE MAGNETITE BEACH-SANDS.

General

This investigation was of a broad reconnaissance nature and the observations, which are widely scattered geographically, refer only, in a qualitative way, to superficial magnetite concentrations on present-day beaches. The only boring equipment available was a 4 inch "post-hole" type auger. This proved unsuitable for the recovery of sand samples below the water-table whidh, on the beaches and adjoining lowlands, was commonly within 4 feet of the surface. Sands without high magnetite content were reduced for visual estimation by panning.

As time was short and transport facilities poor, the northern half of the western coast from which Mr. Graham's specimen was taken, was not seen. On the eastern coast, beaches south from Kieta to Toimanapu were visited, and beaches north of Kieta were scanned from a low-flying plane. The southern beaches between Toimanapu and Buin were seen from a launch travelling about a mile off-shore. On the western coast, the southern half of Empress Augusta Bay, the Motupena Point area and the beaches near Buin were examined.

Magnetic and heavy liquid separation and grain-count analysis by W.R. Morgan* on Mr. G.Graham's sample from the northern end of the western coast indicated the following mineral components :-

Magnetite	87.0%
Plagioclase	3.1
Hematite	2.5
Clinopyroxene	2.4
Hornblende	2.3
Carbonate	2.0
Orthopyroxene	0.7
Ilmenite, Leucoxene, Zircon, Quartz	trace

A. McClure* determined by chemical analysis that the magnetite in this specimen contained 8.18% titanium dioxide. As the magnetite content of all the beaches appears to have been derived principally from the younger volcanic products, it is assumed that all the magnetite contains combined titanium approximately to the above analysis. Accordingly, all reference to "magnetite" in this report implies titaniferous magnetite.

One specimen from a beach concentrate near Kaukauwiriai, between Kieta and the Aropa airstrip examined by *G.M. Gregory contained discrete magnetite and discrete ilmenite in the ratio 16.8 to 1. This relatively high ilmenite content was probably derived from ultrabasic rocks in the Crown Prince Range.

* Geological laboratory, B.M.R. Canberra.

A magnetic fraction extracted by passing a small hand magnet closely over, but not in contact with, the specimen comprised 98% of the whole. This fraction which was magnetite with rare compound grains of magnetite and ilmenite and very rare discrete ilmenite contained 3.97% TiO_2 by X-ray spectro-chemical analysis. Details of this investigation are included in Appendix I.

The Bougainville beach-sands generally show mass colour gradation from mid-grey to mid-brown; in detail they have a "salt and pepper" appearance. Exceptions are the lighter coloured sands which contain coral fragments from adjoining contemporary reefs and the glistening, blue-black concentrations of magnetite formed under optimum conditions of sorting and preservation. The principal dark components of the average sand are ferromagnesian minerals, particularly hornblende. The light coloured minerals are essentially plagioclases of undetermined composition; quartz is rare. This association reflects the composition of the pyroclastic aprons and ash fans of andesitic material from which the sands are derived. The primary magnetite content of the pyroclastics is probably not abnormally high but it is readily released from the loosely aggregated parent material to become available for stream and beach concentration.

<u>Concentrating Processes</u>

The loosely aggregated pyroclastics, which include a great deal of pumiceous andesite and ash, are readily reduced to their component minerals, including widely dispersed magnetite crystals, by the abrasive action of steeply graded streams under prevailing high rainfall conditions.

The heavy load of sediments which is continually transported seawards is distributed along the coastline by wave and longshore current action. From the time the magnetite is freed as discrete grains from the pyroclastic fragments, it tends to concentrate because of its relatively high specific gravity. In all watercourses, from major rivers to rivulets, magnetite is being concentrated and transported coastwards. Even in road cuttings and on tracks after rain, magnetite "tails" are evident.

Stream concentrations of magnetite are small and probably not of economic importance.

On arrival at the seaboard, stream-borne sediments have their clay content dispersed and carried towards the ocean depths by current action. The component minerals of the sand fraction of these sediments are then subjected to the continuous winnowing action of waves and currents in shallow water.

Final concentration is effected on the shoreline where sand deposited at the top of the beaches by waves is sorted during each backwash down the beach slope leaving the heavy minerals at the upper limit of wave-action. Further concentration by wind action is negligible on Bougainville, because lush rain-forest or swamp growth extends to the limit of wave-action.

The formation of heavy mineral concentrates by wave-action is a cumulative process and the chances of preservation of these deposits is enhanced by a consistent recession of the limit of wave action. This may result from eustatic lowering of sea-level, emergence of land areas or from rapid alluviation along the coast. On Bougainville rapid alluviation is the principal factor causing seaward advance of the shoreline and expansion of the coastal plain; emergence may be a contributing factor. The effects of eustatic sea-level changes on beach growth are, in this case, probably overshadowed by alluviation and emergence.

Waves which strike the shore obliquely are more effective in sorting beach sands than waves which approach normal to the shoreline. In addition to sorting, they induce longshore currents which cause lateral migration of sands and accumulation of heavy minerals against rocky headlands.

Bougainville Island, with a north-westerly axis, is subjected to heavy seas from the east and south-east resulting in persistent strong north-moving currents and northerly migration of beach-sands. This trend is well illustrated on the western coast where sand moving northwards from the front of Mt. Taroka apron has formed Motupena Point, a low sandy spit; similarly on the east coast, heavy minerals are concentrated on beaches immediately north of major river mouths and against the southern sides of headlands.

On both coastlines high magnetite concentrations are commonly thin and vertically they grade abruptly into sands without conspicuous magnetite, so that superficial sampling could give quite misleading results.

The Eastern Coast Deposits.

This coast is well populated and extensively planted as far south as Toimanapu, so that detailed investigation or exploitation of sand embayments would be hampered. Discontinuous barrier and fringing reefs protect most of the eastern coast from heavy seas and many rocky headlands separate small crescent-shaped beaches. The central part of the coast is separated from the youngest volcanic centres, which are the main source of the beach magnetite, by the Crown Prince Range and thus the principal magnetite concentrations are in the north and south. Some ilmenite may be shed from ultrabasic rocks in the Crown Prince Range, which have been seen as pebbles in streams draining the southern end of the range.

Towards the northern end of the island, magnetite is shed from the Mt. Balbi volcanic complex but, as current and wave-action is restricted by offshore reefs, only small beach concentrations of magnetite occur. These can be seen from the air immediately north of the Wakunai River mouth and on the northern shore of Tinputz Harbour. A specimen from Deos near Tinputz Harbour examined by J. Ward, Bureau of Mineral Resources, in 1952 contained 91.5% magnetite, 3.8% ilmenite, 4.0% pyroxene and traces of brown hornblende, olivine, coral fragments, plagioclase, quartz and topaz. This specimen came from a small natural beach concentration but it may not be representative.

Toward the southern end of the island, glistening blue-black magnetite sands may be seen from an aircraft approaching the Aropa airstrip after passing over Kieta Harbour. These black sands are particularly impressive on the four-mile stretch of coastline north of the Aropa River mouth where basaltic headlands terminate several small beaches. The magnetite is concentrated as a surface layer just beyond the limit of normal wave action, particularly at the northern ends of the beaches against the headlands. One small, high grade deposit near Pt. Saucepan (Kaukauwiriai) has a maximum thickness of two feet, but passes abruptly downwards into grey sand without obvious magnetite. In plan this deposit is a lens, 200-300 feet long, and about 20 feet across with its long axis along the beach; it would contain about 100 tons of almost pure magnetite sand. In this area the beaches are narrow and close to the foothills so that, although individual magnetite concentrations are of high grade, the possibility of major deposits is precluded. The magnetite of these beaches has probably been derived from the Mt. Taroka pyroclastic apron by way of the Aropa, the Luluai and other rivers draining its south-eastern flank.

Beaches in the extreme south, between Toimanapu plantation and Orava village, and the large delta area behind them, may contain a large quantity of disseminated magnetite but only a thin veneer at the top of the present beach was seen. The magnetite in the Luluai delta may be concentrated along narrow zones parallel to former strands but this could only be proved by close drilling and sampling.

The Western Coast Deposits.

Observations along this coastline were limited to the southern portion of Empress Augusta Bay, Motupena Point and Buin where only very small magnetite concentrations, commonly less than half an inch in thickness, were seen on the present-day beaches.

Most of the western coastline is pounded by heavy seas throughout the year. Sand derived from the ash fans and coarser pyroclastic deposits from Recent volcanic activity is being rapidly deposited and sorted by the combined action of waves and consistent northerly currents. The abundant supply and rapid distribution of sand is expanding the coastal plain by accretion of successive strands before sorting reaches an advanced stage. This may not always have been the case, and heavy mineral concentrates may be associated with earlier strands now preserved in the coastal lowlands. It seems likely that Mr. Graham's sample (see page 3) from between Kunua and Soraken in the north was taken from one such concentration.

A specimen of the average, unconcentrated sand from the southern end of Empress Augusta Bay was examined by G.M. Gregory who reported thus :- "This specimen consists of 33% plagioclase grains, 28% rock fragments, 22% pyroxene grains, 6% brown hornblende grains, 6% green hornblende grains and 5% iron oxide grains.

Rock fragments range from fresh basalt and andesite composed of the above minerals to rounded and altered pieces containing epidote, limonite, and other secondary minerals.

The iron oxide is mainly magnetite, sometimes showing fine exsolution lamellae, and very subordinate hematite and limonite."

Examination of wartime aerial photography reveals wide zones of former strands in the coastal plain behind the northern half of Empress Augusta Bay, in the Motupena Point area and, farther north, between Cape Moltke and Soraken. Future investigations might well be directed towards these areas. Magnetic geophysical methods may be applicable as a preliminary method of search for magnetite-rich zones. Ground magnetic investigations in these areas may not be practicable because of the operational and technical difficulties of working heavily overgrown and trackless swamps. Low-flying aerial magnetometric methods may be of reconnaissance value.

CONCLUSIONS

Although this investigation has been of a purely qualitative and reconnaissance nature, the conclusion has been reached that the spectacular high concentrations of beach magnetite along the northern and southern portions of the eastern coast are individually too small for consideration as iron ore deposits.

A large quantity of magnetite will be contained in the coastal plains of western Bougainville and possibly in the Luluai River Delta, concentrated in zones paralleling former strand lines; further investigation should be directed to the coastal plain behind Empress Augusta Bay, the Motupena Point area and the lowlands between Cape Moltke and Soraken where aerial photographs show large tracts of preserved strands.

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FISHER, N.H., 1936 - Geological report on the Kupei Goldfield, Territory of New Guinea. (unpublished.)

DEPT.NAT.DEVELOPMENT, 1951 - The Resources of the Territory of Papua and New Guinea.

APPENDIX I

EXAMINATION OF MAGNETITE SAND FROM PT. SAUCEPAN BOUGAINVILLE ISLAND, NEW GUINEA

by

G.J.G. Greaves

Following is a description of a beach sand (p.431) from Pt. Saucepan, Bougainville Island submitted by J.E. Thompson.

The sand was separated into fractions based on specific gravity and magnetic susceptibility using heavy liquids and a hand magnet and will be described under the following fractions.

Specific Gravity (S.G.)	Magnetic Susceptibility	Percentage Weight
(i) < 2.85	non magnetic	0.3%
(ii) $> 2.85 < 3.26$	non magnetic	0.4%
(iii) > 3.26	non magnetic	0.1%
(iv) > 3.26	strongly magnetic	98%
(v) > 3.26	less strongly magnetic	1.2%

MINERALOGY

All the fractions have a grainsize from 0.1 mm. to 0.4 mm. in diameter.

(i) Non magnetic fraction with S.G. < 2.85

A sample was treated with boiling 5% oxalic acid to remove iron oxide staining. Examination in thin section showed that feldspar and quartz form the bulk of this fraction and are present in about equal amounts. Most of the feldspar grains show some evidence of abrasion, the composition ranges from minor sericitized orthoclase, mixtures of oligoclase and andesine, and both andesine and oligoclase. The plagioclase in places has altered to kaolin or sericite; some grains are partially altered to epidote and may be termed saussurite; others are strongly zoned. Quartz forms angular grains commonly coated with hydrated iron oxides. Some of these grains have a well-developed undulose extinction and some have equidimensional or acicular colourless inclusions which could not be identified.

A small quantity of hornblende and epidote are present and there is some contamination from other fractions.

(ii) Non magnetic fraction with S.G. $> 2.85 < 3.26$

In this fraction the principal constituents are: diopside 70%, hornblende 20%, hypersthene 5%, epidote and zircon less than 5%.

Diopside forms small slightly rounded elongate crystals which are pleochroic from pale green to green and the extinction angle $Z \wedge C$ has a maximum value of 45° to the cleavage. The surface is pitted and small rounded opaque inclusions are present.

Hornblende, which is more rounded than diopside is pleochroic from brownish green to dark green, showing a maximum extinction angle of 25° to the cleavage.

Hypersthene forms small slightly rounded elongate crystals which are strongly pleochroic from bluish green to orange red. The extinction is parallel to a well developed cleavage.

Pink zircon forms perfectly developed, doubly terminated crystals, up to 0.3 mm. long, which contain minute inclusions.

Epidote forms very minor elongate grains, pleochroic from yellowish green to green and show parallel extinction.

(iii) Non magnetic fraction with S.G. > 3.26

This fraction consists predominantly of ilmenite with minor contaminants from fraction (ii) (for a description of the ilmenite see the description of fraction (v)).

(iv) Strongly magnetic fraction with S.G. > 3.26

In polished section the grains are well rounded, pitted, and have a maximum diameter of 0.4 mm. This fraction consists almost entirely of magnetite with minor haematite hydrated iron oxide and rare ilmenite. Haematite has formed along the (111) directions of the magnetite, some grains of which are entirely altered to haematite. Ilmenite forms composite grains with magnetite, exsolution lamellae along the (111) directions giving a grid-like intergrowth, and very rarely as free grains.

The percentage of titanium determined X-ray spectrochemically, by W.M.B. Roberts, in this fraction is 2.38% which is equal to 3.97% TiO_2.

(v) Less strongly magnetic fraction with S.G. > 3.26

The principal constituents are roughly; ilmenite 60%, magnetite 20%, haematite 10%, haematite-magnetite intergrowths 5%, and non opaques 5%. The ilmenite is much more angular than the magnetite and has a maximum length of 0.3 mm.

CONCLUSIONS. The percentage ilmenite as free grains in the sand is roughly 1%; the percentage of magnetite is about 95% and the percentage TiO_2 in the magnetite is 3.97%. In addition TiO_2 from free ilmenite grains in the less magnetic fraction would increase the TiO_2 percentage by about 0.4% TiO_2.

The quartz in the light non magnetic fraction appears to be mainly derived from vein quartz and metamorphosed rocks containing quartz. It must be borne in mind that quartz forms only about 0.1% and that the bulk of the non opaque minerals suggests the heavy minerals were derived from basic igneous rocks.

(G. GREAVES)

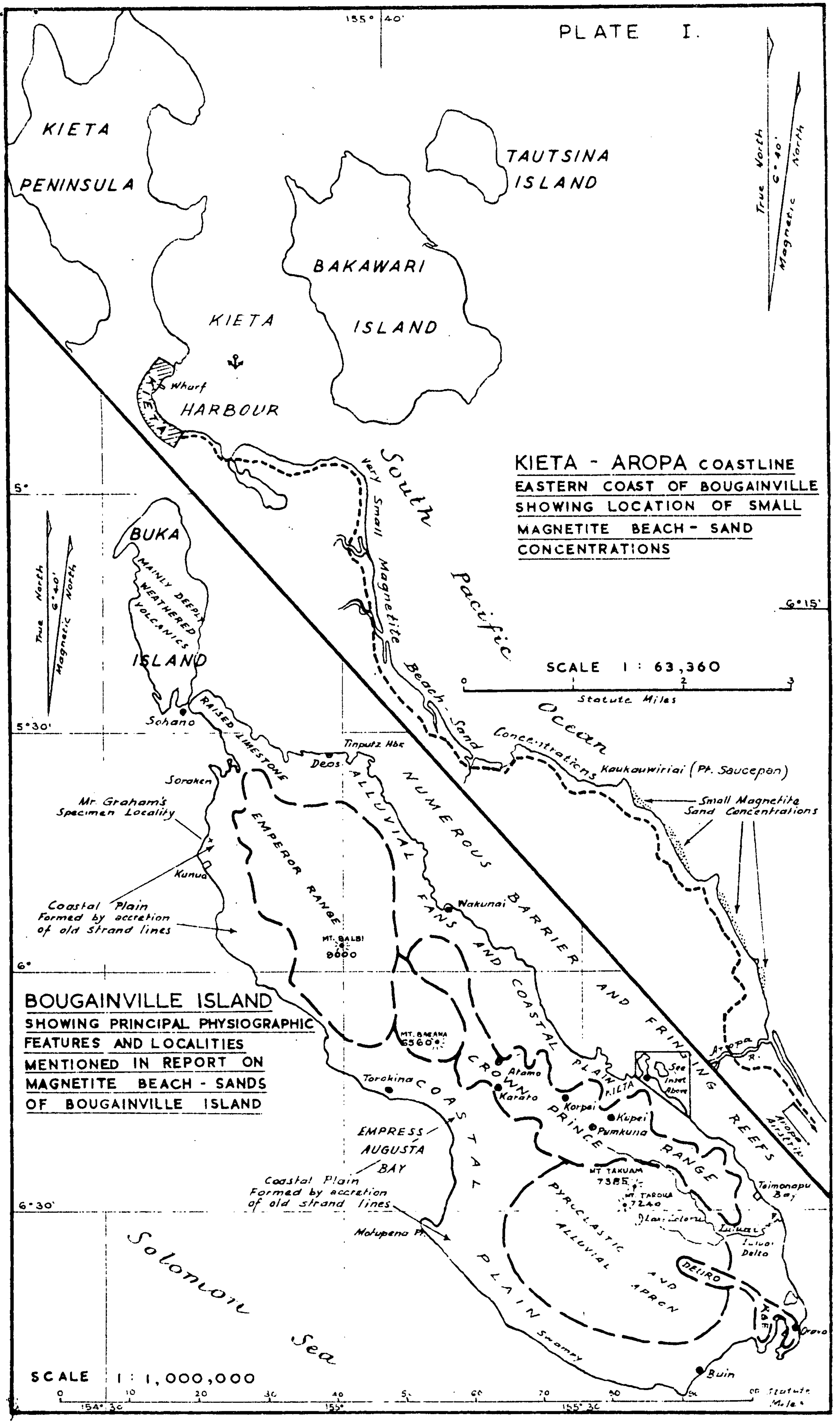
PLATE I.
KIETA - AROPA COASTLINE
EASTERN COAST OF BOUGAINVILLE
SHOWING LOCATION OF SMALL
MAGNETITE BEACH - SAND
CONCENTRATIONS
KIETA PENINSULA
TAUTSINA ISLAND
BAKAWARI ISLAND
KIETA HARBOUR
Wharf
KIETA
South Pacific Ocean
Very Small Magnetite Beach - Sand Concentrations
Kaukauwiriai (Pt. Saucepan)
Small Magnetite Sand Concentrations
Aropa
Aropa Airstrip
SCALE 1 : 63,360
0
1
2
3
Statute Miles
True North
6°40'
Magnetic North
155° 40'
6°15'
BOUGAINVILLE ISLAND
SHOWING PRINCIPAL PHYSIOGRAPHIC
FEATURES AND LOCALITIES
MENTIONED IN REPORT ON
MAGNETITE BEACH - SANDS
OF BOUGAINVILLE ISLAND
BUKA ISLAND
MAINLY DEEPLY WEATHERED VOLCANICS
Sohano
RAISED LIMESTONE
Soraken
Mr. Graham's Specimen Locality
Kunua
Coastal Plain Formed by accretion of old strand lines
Tinputz Hbr.
Deos
EMPEROR RANGE
MT. BALBI 8600
ALLUVIAL FANS AND COASTAL PLAIN
NUMEROUS BARRIER AND FRINGING REEFS
Wakunai
MT. BAGANA 6560
CROWN PRINCE RANGE
Atamo
Karato
Korpei
Kupei
Pumkuna
KIETA
See Inset Above
Torokina
COASTAL PLAIN
EMPRESS AUGUSTA BAY
Coastal Plain Formed by accretion of old strand lines
Motupena Pt.
MT. TAKUAM 7385
MT. TAROUA 7240
PYROCLASTIC ALLUVIAL APRON
Luluai
Luluai Delta
Toimonapu Bay
DEURO
RAF
Orava
Buin
Swampy
Solomon Sea
True North
6°40'
Magnetic North
5°
5°30'
6°
6°30'
SCALE 1 : 1,000,000
0
10
20
30
40
50
60
70
80
90
Statute Miles
154° 30'
155°
155° 30'