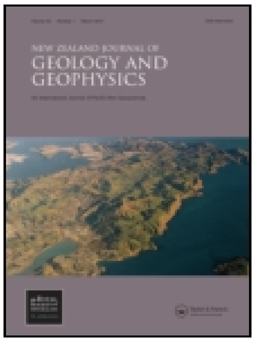

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# OPAQUE MINERAL CONCENTRATES FROM BEACHES ON BOTH SIDES OF FOVEAUX STRAIT

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ABSTRACT

Opaque minerals in one artificial and four natural beach sand concentrates from Southland and Stewart Island were examined by microscope, X-ray, and thermomagnetic techniques. In all the samples, magnetite, ilmenite, and hematite exhibit a variety of intergrowth textures. Chromite and rutile were found only in Southland concentrates.

There are sufficient differences in mineralogy of the assemblages to make it unlikely that any cross-channel transport was involved in formation of the beach sands.

Many features of the Southland beach sand concentrates are identical with those characterising opaque minerals in the basic/ultrabasic Bluff complex. A likely reason is that similar basic and ultrabasic rocks are widespread in the Longwood complex, from which these particular concentrates are in part derived.

Stewart Island concentrates are mainly derived from the granitic and/or high grade metamorphic rocks forming the island.

## INTRODUCTION

Previous studies of heavy minerals in beach sands of this region (Martin and Long, 1960; Williams and Mackie, 1959) were made from the standpoint of their economic potential. This communication summarises the results of a detailed mineralogical examination, carried out by the first author in partial fulfilment of the requirements for a B.Sc. honours degree in mineral technology at the University of Otago (Graham, 1966). A few observations have also been made on the non-opaque minerals, chiefly in so far as they relate to provenance of the detrital assemblages. Brief descriptions of the concentrates used for the study are set out in Table I. The collection localities are shown in Fig. 1

Seventy to eighty percent by weight of all the natural concentrates have a grain size range of 0.1–0.2 mm. Magnetic separation yielded magnetite-rich, ilmenite-rich, and non-opaque fractions from each sample. Magnetite constitutes about 80% of the opaque mineral content of Stewart Island samples, with ilmenite next in abundance, followed by subordinate amounts of hematite and other minerals. For the Southland samples, the ilmenite (*c.* 70%)-magnetite proportions are approximately reversed.

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TABLE 1 – Sample Descriptions

| Locality | Collector | Otago University Collection No. | Remarks |
|---|---|---|---|
| *Southland* | | | |
| Pahia Point | J. A. Templeton | 23178 | Artificially concentrated by collector to 60%–70% garnet, 5% opaques. |
| Orepuki Beach | W. F. Lindqvist | 20144 | Natural beach concentrate, 60% opaques. |
| *Stewart Island* | | | |
| Ringaringa Beach | R. Thompson | 20143 | Natural "black sand" concentrates, 90% opaques. |
| Leask Bay | W. F. Lindqvist | 20145 | |
| Lonnekers Bay | R. Thompson | 20146 | |

## MICROSCOPIC EXAMINATION

### *Magnetite*

Most of the magnetite in all samples is pale brown, homogeneous, and isotropic, but a significant proportion of grains exhibit a variety of intergrowths:

1. White oxidation lamellae of hematite (martite) are developed along {111} directions of some magnetite grains (Figs. 2, 3). They are more prominent in samples from Southland than from Stewart Island.

2. Lamellae of ilmenite and aluminous spinel (hercynite?) display slightly different habits characterising the two sample groups:

*Southland*: Thinly lensoid lamellae and irregular blebs of ilmenite are bordered by much smaller aluminous spinel lamellae, which also occur separately along {100} directions (Fig. 4).
*Stewart Island*: Ilmenite lamellae are more regular, with greater continuity throughout the grains (*cf.* hematite in Fig. 2). Transparent spinel is rare and never borders ilmenite.

3. Regular thin lamellae of rutile occur in rare magnetic grains from the Orepuki sand (Fig. 5).

A few magnetic grains in all samples contain inclusions of other minerals notably apatite, pyrite, pyrrhotite and chalcopyrite.

### *Ilmenite*

About half of the pinkish bireflectant ilmenite grains in all samples show varying degrees of {0001} hematite exsolution. Numerous other grains are partly or wholly altered to fine intergrowths of magnetite-rutile, hematite-rutile, or magnetite-hematite-rutile, perhaps as a result of hydrothermal activity in the parent rock. Rarer leucoxene is probably a weathering product.

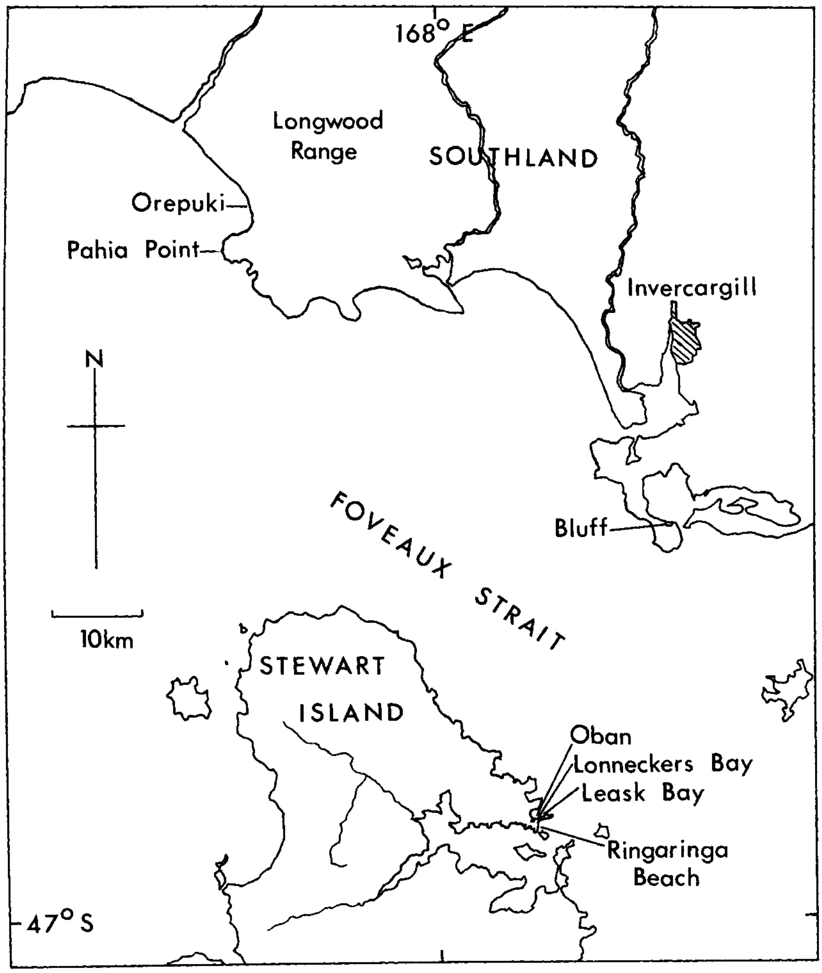


FIG. 1—Map of the southern tip of the South Island and the northern part of Stewart Island showing the locations from which beach sands were collected.

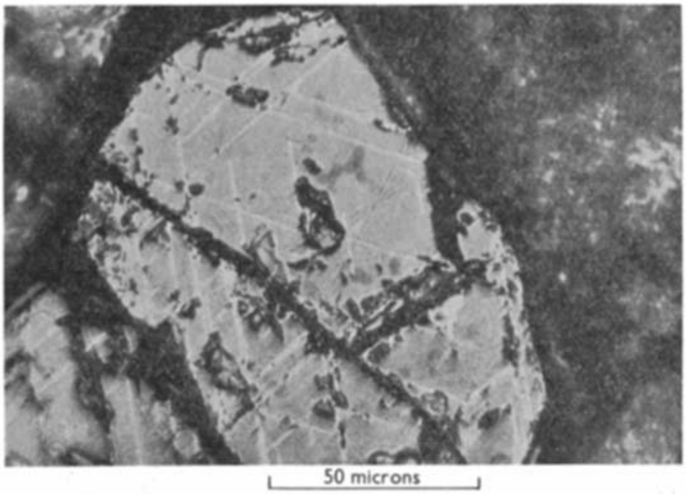


FIG. 2—Magnetite grain partly martitised to hematite along (111) directions. Pahia Point.

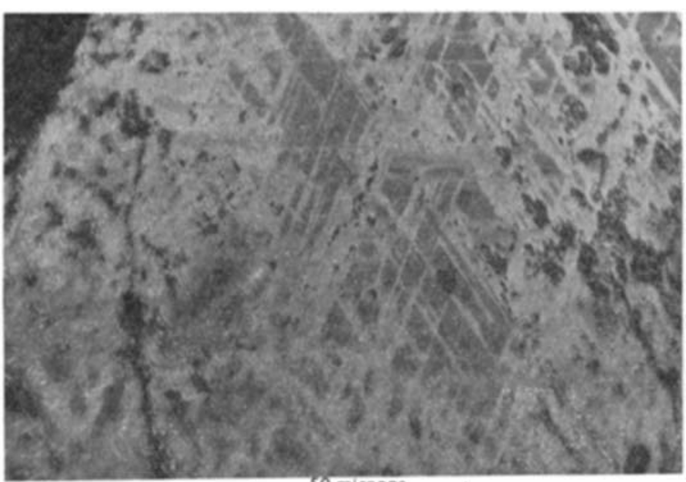


FIG. 3—Magnetite more extensively martitised. East-west lamellae demonstrate the bireflectant nature of the hematite. Pahia Point.

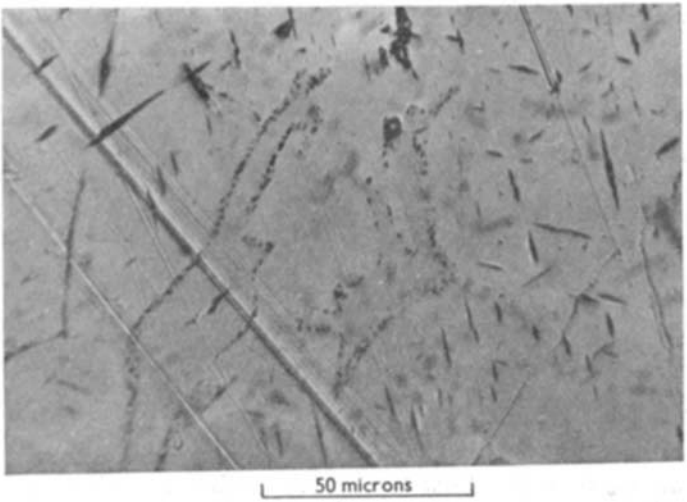


FIG. 4—Magnetite with regular black spinel exsolution along (100) and irregular growths of ilmenite (darker grey) bordered by spinels. Pahia Point.

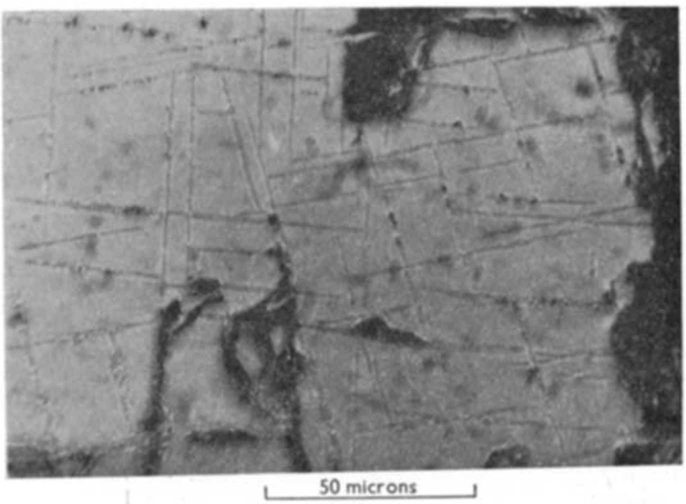


FIG. 5—Magnetite with internally reflecting rutile lamellae in four (octahedral?) directions. Orepuki.

Some differences were detected in ilmenite from each side of Foveaux Strait:

*Southland*: Twining is very rare. Hematite lamellae range in size from almost sub-microscopic to prominent sub-individual crystals with secondary exsolution (Fig. 6).

*Stewart Island*: Twinning is well developed in a small but significant proportion of ilmenite grains. Hematite lamellae are restricted to a much smaller size range than those in the Southland samples (Fig. 7).

### *Hematite*

*Southland*: Two varieties of detrital hematite were recognised:

(a) Somewhat spongy grains with patchy anisotropy showing relict octahedral texture (*cf.* Wright, 1964), probably the end product of martitisation.

(b) Grains believed to have crystallised as a distinct primary phase in metamorphic rocks, displaying regular exsolution of ilmenite and/or rutile (Fig 8). Practically all such hematite is found in Orepuki sand.

*Stewart Island*: Only the spongy variety, (a) above, was found in Stewart Island samples.

### *Rutile and chromite*

*Southland*: The non-magnetic fraction from Orepuki contains a few grains of rutile and chromite, amounting to less than 1%.

*Stewart Island*: No rutile or chromite grains were found in any of the black sand concentrates.

## X-RAY EXAMINATION

Cell parameters of magnetite, ilmenite, and hematite were determined from diffractometer patterns made with Mn-filtered iron radiation using quartz as an internal standard.

The relevant peaks were scanned several times at a speed of $\frac{1}{2}^{\circ}$ $2\theta$/min. Computed cell dimensions are given in Tables 2 and 3.

TABLE 2 – Cell Dimensions of Magnetite

| Specimen locality | Cell dimensions Å | |
|---|---|---|
| Pahia Point | 8·393 | ± ·001Å |
| Orepuki | 8·393 | |
| Ringaringa Beach | 8·396 | |
| Leask Bay | 8·396 | |
| Lonnekers Bay | 8·395 | |
| Basta (1957) | 8·3963 | ± ·0005Å |

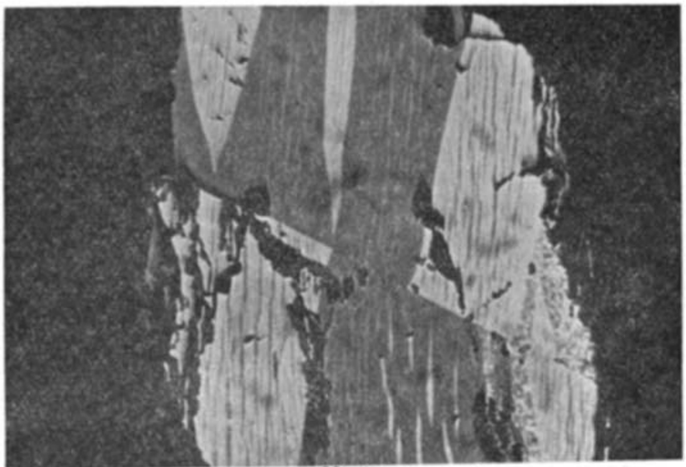


FIG. 6—Coarse ilmenite-hematite exsolution texture. The finely mottled material at the left of the grain is an intergrowth of rutile and hematite. Orepuki.

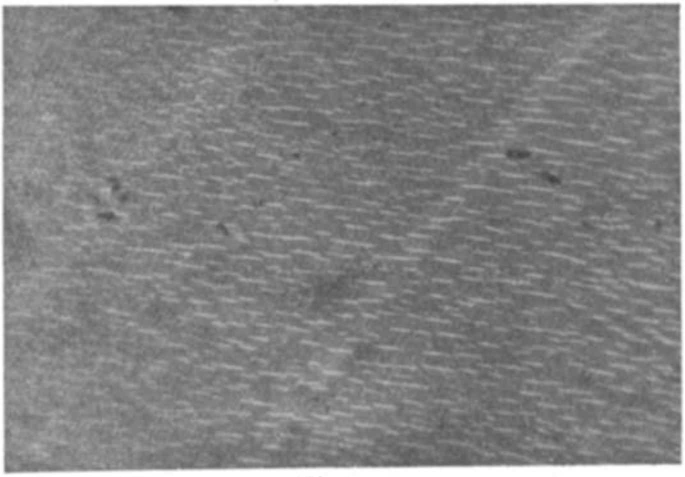


FIG. 7—Ilmenite with twins (NE–SW) and hematite lamellae (E–W) along the basal plane (0001) of the host ilmenite. Ringaringa Beach.

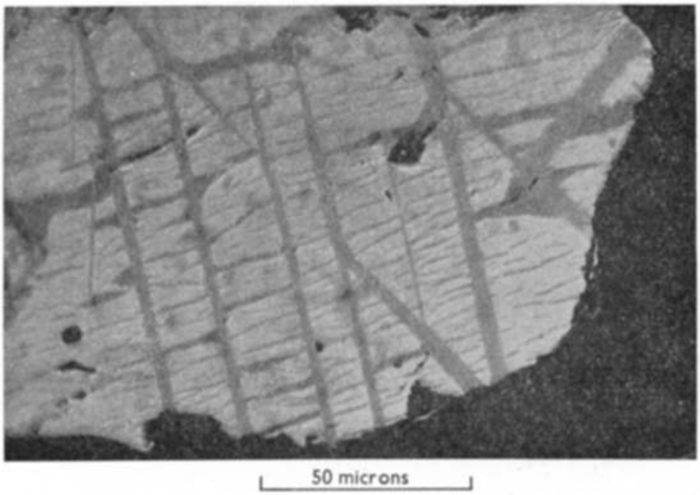


FIG. 8—Hematite with ilmenite and rutile which is developed along three presumably rhombohedral directions. Orepuki.

TABLE 3 – Cell Dimensions of Ilmenite and Hematite

| Specimen locality | Mineral | aÅ | | cÅ | | c/a |
|---|---|---|---|---|---|---|
| Orepuki | Ilmenite | 5·087 | | 14·05 | | 2·76 |
| | Hematite | 5·039 | ± ·005 | 13·77 | ± ·01 | 2·73 |
| Ringaringa Beach | Ilmenite | 5·082 | | 14·08 | | 2·77 |
| Lonnekers Bay | Ilmenite | 5·080 | | 14·08 | | 2·77 |
| Deer *et al.*, 1962 | Ilmenite | 5·089 | | 14·166 | | 2·78 |
| | Hematite | 5·035 | | 13·749 | | 2·73 |
| Basta (*in* Vincent *et al.*, 1957) | Ilmenite | 5·082 | | 14·04 | | 2·76 |
| | Hematite | 5·029 | | 13·70 | | 2·73 |

## THERMOMAGNETIC MEASUREMENT

Curie point curves were kindly determined by Mr A. E. Leopard of the Geophysics Division, Department of Scientific and Industrial Research, Wellington, on magnetite samples from Pahia Point and Lonnekers Bay, previously sealed *in vacuo* in small pyrex tubes. The curves show reasonably sharp Curie points (Fig. 9) indicating a rather narrow compositional range. Similar thermomagnetic curves can be expected for magnetite in the remaining samples, in view of the overall similarity in cell dimensions (Table 2).

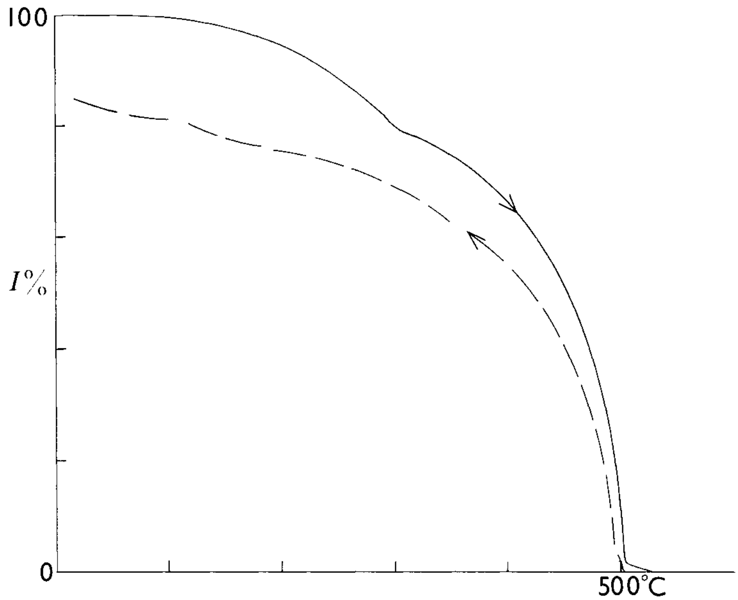


FIG. 9a—Thermomagnetic curve for magnetite from Pahia Point.

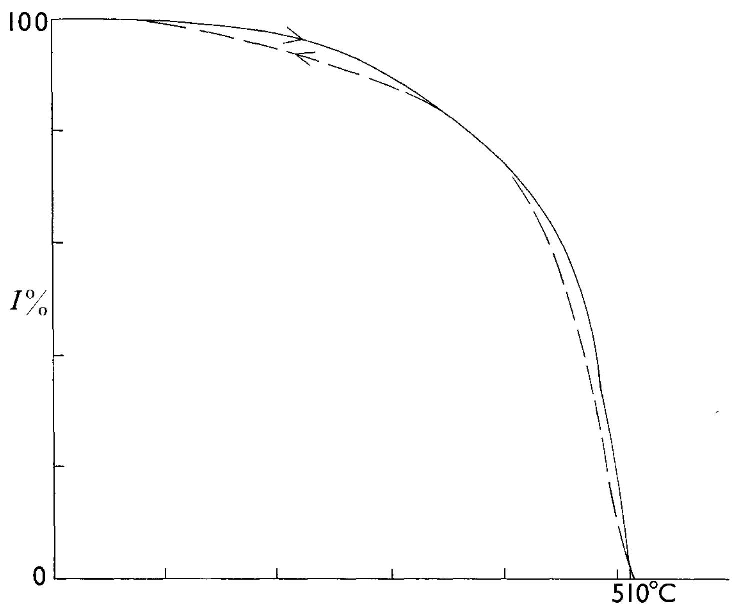


FIG. 9b—Thermomagnetic curve for magnetite from Lonnekers Bay.

## COMPOSITION OF THE OPAQUE MINERALS

Because the concentrates are derived from a variety of source rocks, estimates of mineral composition cannot have more than limited reliability. Nonetheless, sufficient data are available to permit some compositional limits to be indicated.

### *Magnetite*

#### *Southland*

Magnetite from Orepuki has been analysed spectrographically (Wood, 1969), and contains 2·5% Ti, which is equivalent to nearly 12% $Fe_2TiO_4$ (ulvöspinel). Other minor impurities (Mg, Mn, etc.) recalculated to plausible spinel molecules (Vincent *et al.,* 1957) give a total impurity of around 16%. The cell dimensions of these Southland magnetites (Table 2) are less than that for pure magnetite, suggesting an appreciable aluminous spinel component in solid solution, acting in opposition to ulvöspinel to reduce the cell edge and in combination with it to depress the Curie point (Wright, 1964). The latter indicates (Fig. 9a) a *minimum* impurity in the Pahia Point magnetite of 16%, using the curves of Chevalier (*in* Vincent *et al.,* 1957).

#### *Stewart Island*

Williams and Mackie (1959) reported that Ringaringa magnetite is almost pure, with a total iron content of 71·5% compared with the theoretical value of 72·5%. The other Stewart Island magnetites are almost certainly similar in composition, to judge from their cell dimensions. The Curie point for Lonnekers Bay magnetite, however (Fig. 9b), suggests a minimum impurity of 14%, but in the absence of further data no explanation is offered for this discrepancy.

### *Ilmenite and hematite*

#### *Southland*

From Table 3, Orepuki ilmenite and hematite would seem to be fairly pure, with mutual exsolution carried virtually to completion.

#### *Stewart Island*

Williams and Mackie (1959) quoted a 15.9% $Fe_2O_3$ content for Ringaringa ilmenite. The slightly lower cell dimensions of the Stewart Island ilmenites (Table 3) are consistent with the presence of some hematite still in solid solution, but they do not unequivocally demonstrate it. In any case, it is preferable to attribute the chemically analysed hematite impurity to the microscopically obvious lamellae and separate grains of hematite.

## NON-OPAQUE MINERALS

### *Southland*

The commonly euhedral (*c* 0·5 mm diameter) red brown garnet crystals which predominate in the Pahia Point concentrate have a refractive index of 1·812 to 1·820, cell edge of 11·588 ± 0·002Å, and specific gravity close to 4·03. Partial analysis (kindly determined by Dr A. Reay) showed 1·70% MnO, equivalent to a spessartite content of almost exactly 4%. Smaller and more fragmentary but otherwise similar garnet from Orepuki has $Cr_2O_3$ of 1·0% (Wood, 1969). If these values are valid for both localities, a possible approximate average composition for the detrital Southland garnets is $And_4Alm_{77}Gross_{15}Spess_4$ (curves from Winchell, 1958).

Other minerals found in the Southland sands are quartz, feldspar, augite, hypersthene, hornblende, biotite, epidote, zircon, and rare monazite.

### *Stewart Island*

All samples contain less than 10% transparent minerals, comprising quartz, feldspar, dark green hornblende, biotite, epidote, and zircon. Garnet and pyroxenes were not found.

## PROVENANCE

The main differences between detrital assemblages from each side of Foveaux Strait can be summarised as follows:

1. Southland magnetite contains rutile and a higher proportion of transparent spinel.
2. Southland magnetite has a lower cell edge (Table 2).
3. Hematite exsolution is commonly coarser in Southland ilmenite.
4. Pyroxene, garnet, chromite, rutile, and primary hematite are confined to the Southland sands.

These contrasts suggest that no cross-channel transport was involved in the development of beach sands along the shores of Foveaux Strait.

Many of the mineralogical and textural features characterising opaque minerals of the Southland beach sand samples can be closely matched in rocks of the basic/ultrabasic Bluff complex (Lindqvist, 1965). Similar ultrabasic rocks, norites, and gabbros are common in the Longwood Complex (Wood, 1966), from which the Orepuki and Pahia Point sands must in part be derived.

Available compositional data show that, as in the Bluff complex, the magnetite in Orepuki and Pahia Point sands is Ti-poor. Such magnetite is more characteristic of intermediate to acid igneous and high-grade metamorphic rocks than of *normal* gabbroic assemblages (Buddington *et al.,* 1963; Buddington and Lindsley, 1964). At Bluff this can be explained by the widespread occurrence of hornblende-gabbros (Service, 1937; Watters 1962), suggesting water-rich melts in which granular magnetite-ilmenite assemblages would be more stable than Ti-rich magnetite (Buddington and Lindsley, 1964). The occurrence of hornblende-gabbros at Pahia Point (Watters, 1962) suggests a similar paragenesis for some of the iron-titanium oxides in Orepuki and Pahia Point sands.

The Stewart Island magnetites are also Ti-poor, which is consistent with derivation from the granites and high-grade metamorphic rocks forming most of the island. The small isolated hornblende-gabbro of Cow and Calf Point (Watters, 1962) could also have contributed to these sands, but there is insufficient data on this point.

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