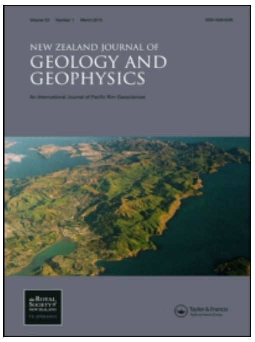

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GARNET-BEARING SANDS FROM THE EAST COAST, NORTH ISLAND, NEW ZEALAND

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Abstract

Garnets occur sporadically on most beaches of the east coast of New Zealand's North Island, south of Hawke Bay, and at Kairakau co-exist with barite, zircon, magnetite, ilmenite and hypersthene.

Garnets from this locality, analysed by electron microprobe, show three chemical groupings:

(a) Low spessartine garnets which were probably initially derived from gneisses and associated igneous and metamorphic rocks.
(b) High spessartine–low grossularite garnets, possibly derived from granitic or rhyolitic rocks.
(c) High spessartine–high grossularite garnets similar to those commonly found in greenschist facies pelitic schists.

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Introduction

Although garnets are common constituents of beach sands of the South Island and also occur in ironsands on the west coast of the North Island (Hutton 1945), they have only been briefly reported in sands on the east coast of the North Island by Challis (1962) and Kingma (1971). However, garnet is abundant in thin lenses of ironsand in several beaches south of Hawke Bay where local concentrations may reach 22%. Occasional grains also occur in present day river and stream deposits several miles inland.

In this study the compositions of garnets in sands from Kairakau Beach were used to investigate the possibility that they came from either volcanic rocks or basement complexes.

Occurrence

Garnet occurs in the heavy mineral fractions of sediments from several localities in the Central Hawke's Bay region and is known in both Cretaceous and Tertiary rocks (G. J. van der Lingen pers. comm.). It is also a common heavy mineral in the Lower Mesozoic sandstones that form the Ruahine Ranges at the western edge of the Makara Basin. Rare garnets have also been found in Upper Miocene rhyolitic tuffs in the Makara Basin sediments exposed in cuttings along the Kairakau Road (N141/305847)* and Atua Road (N141/227835).

*Grid reference based on the national thousand-yard grid of the 1:63,360 topographical map series (NZMS 1).

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At present, garnets are carried to the coast by rivers which drain this region, and were found in sediments of the Tukituki (N141/150883) and the Mangakuri Rivers (N41/320829). They are most abundant, however, in beach sands, and are irregularly distributed along Ocean, Waimarama, Kairakau, Mangakuri and Porangahau beaches and have been found as far south as Castlepoint (Fig. 1).

The greatest concentrations were found on Kairakau beach, where garnets occur together with ilmenite, magnetite, hypersthene, barite, and zircon in cusp-shaped lenses several metres wide and up to 20 cm thick at high tide level. The relative abundances of these minerals in the lenses varies greatly depending on the degree of wave sorting, but columns 1 and 2 of Table 1 are typical of the richest garnet-bearing horizons.

The heavy minerals in these lenses are immediately derived from a large (15 m high, 300 m long), shrub-covered dune directly behind the beach from which they are concentrated by rain, spray, and wave action. The mineral content of this dune sand (Table 1) shows that the garnets can be concentrated more than tenfold between dune and lenses.

Typically, the garnets are about 0·5 mm in diameter and are mainly angular to subangular though some grains have crystal faces preserved and rare examples are euhedral rhombic dodecahedra. The colour varies from pale pink to red though euhedral crystals are usually colourless.

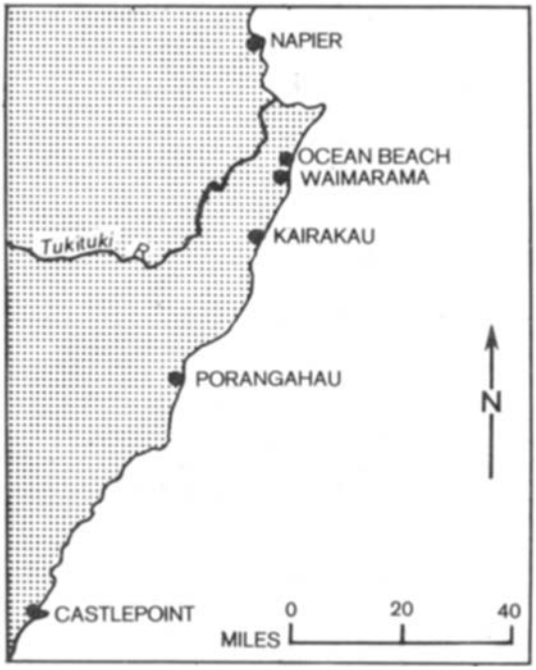

FIG. 1—Map of southern East Coast of the North Island showing location of garnetiferous beach sands.

TABLE 1—Modal analyses of sand from Kairakau Beach

	1	2	3
Ilmenite-magnetite	55·2	28·1	2·2
Garnet	21·1	21·4	1·8
Hypersthene	8·6	26·9	4·1
Barite	4·2	1·9	—
Quartz and feldspar	8·2	20·7	91·9
Zircon	2·7	1·0	—

1 From top 3 cm of a garnet-bearing beach concentrate (30 cm thick)
2 From 25 cm below surface of the garnet-bearing beach concentrate
3 From dune sand at rear of beach

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ANALYTICAL PROCEDURE

Garnet compositions were determined on polished grain mounts using an AEI/SEM 2A model electron microprobe. Chemically analysed garnets were used as standards and no matrix corrections applied. A relative accuracy of about 5% is estimated for Al, Fe, Mn, Mg, Ca and Ti. Glass compositions were determined by reference to quartz, orthoclase and obsidian standards and matrix corrections were made.

The total iron contents were estimated as FeO and the garnet end-member compositions calculated from the bivalent cation content so that all iron is combined as almandine and Ti as hypothetical Ti-andradite. A theoretical Al_2O_3 content has been back calculated from the end-member composition as a check against possible high Fe_2O_3 content. If the Al_2O_3 content is considerably less than the theoretical value then much of the iron could be in a trivalent state. Although this does not appear to be so, all published analyses used for comparison have been recalculated in the same way, to ensure that comparisons are valid.

RESULTS

Garnet Compositions

Ten partial analyses of garnets from Kairakau Beach are given in Table 2 and another 23 are plotted on Fig. 2 and 3. The garnets all have high iron content but the Al_2O_3 content is high and close to the theoretical value in every case. This indicates that almandine and grossularite probably account for most of the iron and calcium and the andradite content is correspondlingly low.

The garnets are divided into three distinct groups. The largest group, comprising 85–90% of the beach-sand garnets, is characterised by low spessartine and variable pyrope, almandine and grossularite. Some 10% belong to a high spessartine-low grossularite group while the smallest group, high spessartine–high grossularite, accounts for only 1 to 2% of the total.

TABLE 2—Composition of garnets of the Low Spessartine Group (1–7), the High Spessartine–Low Grossularite Group (8, 9), and the High Spessartine–High Grossularite Group (10), from Kairakau Beach sand

	1	2	3	4	5	6	7	8	9	10
Al_2O_3	19·2	17·7	18·6	21·0	20·6	21·0	20·5	20·0	18·8	20·7
FeO	37·2	37·1	35·1	35·5	34·4	33·2	27·5	36·8	24·6	21·4
MnO	0·4	0·2	0·8	1·1	0·6	0·7	1·0	3·3	18·8	9·8
MgO	0·1	0·4	1·1	1·8	2·9	6·1	8·5	2·5	1·3	0·6
CaO	6·5	5·6	5·4	5·3	4·6	2·4	1·3	0·8	0·5	11·1
TiO_2	0·2	0·2	0·1	0·2	0·1	0·1	0·1	0·1	0·1	0·4
Almandine	80·5	82·0	78·3	76·0	74·6	69·2	60·7	80·6	52·7	45·7
Spessartine	0·9	0·5	1·8	2·4	1·3	1·5	2·1	7·3	40·8	21·2
Pyrope	0·4	1·6	4·4	6·9	11·2	22·6	33·4	9·6	5·0	2·3
Grossularite	17·4	15·4	15·1	14·0	12·5	6·4	3·3	1·9	1·1	29·2
Ti-Andradite	0·6	0·4	0·3	0·6	0·3	0·3	0·3	0·3	0·3	1·2
Al_2O_3 (calculated)	21·7	21·3	21·1	21·9	21·7	22·6	21·4	21·5	21·9	21·8

Low Spessartine Group

The spessartine content of this group is less than 4% and the main variation is an increase in pyrope at the expense of almandine and grossularite. This trend (Fig. 2 and 3) clearly distinguishes them from the CaO and MnO rich garnets found in pelitic schists in New Zealand. Their closest-known equivalents in New Zealand are the pyralspites in garnet-biotite gneisses south of Hokitika, which according to Hattori (1967) formed under low pressure, intermediate metamorphic conditions. However, garnets of this composition usually occur in gneisses with high-grade mineral assemblage typical of the granulite facies of metamorphism. For example, garnets which compare closely with the more magnesian members of the low spessartine group occur in granulite facies gneisses of Ontario (Wynne-Edwards and Hay 1963), Minnesota (Himmelberg and Phinney 1967), and Finland (Parras 1958).

A close similarity between published analyses of garnets from gneisses and the low spessartine group applies only to the more MgO-rich (MgO $>$ 3%) garnets with a pyrope content above 12%. Most of the low spessartine garnets contain less than 3% MgO, and partial analyses of 70 garnets gave an average composition of MgO 2·4% and FeO 36·3%. Some of the beach-sand garnets, however, have less than 1% MgO and very high FeO. Published analyses of garnets with this composition are few. The closest comparison is with garnets in Norwegian iron-rich monzonites that were intruded under medium pressure granulite facies conditions (Griffin and Heier 1969). Thus, the overall impression is that the low spessartine group of beach sand garnets was derived originally from a varied series of gneisses and associated igneous and metamorphic rocks that were products of granulite facies metamorphism.

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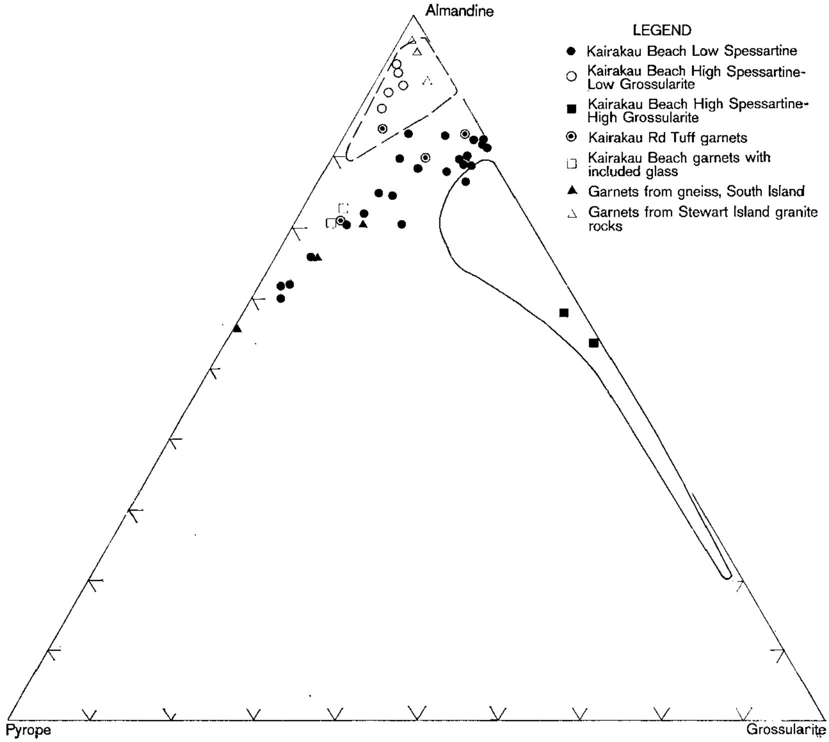

FIG. 2—Ternary diagram Almandine–Pyrope–Grossularite. Solid line encloses field of garnets from N.Z. schists; dashed line garnets from granites, granite pegmatites and rhyolite druses (references: Brown 1967, 1969; Hattori 1967; Mason 1962; Myashiro 1955; Pabst 1938; Reed 1958; Troger 1959; Williams 1934).

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High Spessartine–Low Grossularite Group

The garnets in this group are almandine-spessartine with low to moderate pyrope and low grossularite contents. Marked chemical variation within this group is shown by the inverse relationship between FeO and MnO, e.g., Table 2 Analysis 8 has the lowest, and 9 the highest MnO contents.

Garnets of the high spessartine–low grossularite group are clearly separated from the low spessartine group (Fig. 2 and 3) whilst the low grossularite content distinguishes them from the New Zealand pelitic schist garnets (Fig. 2). Low grossularite garnets of this composition are known in schists (e.g., Modell 1936) but are extremely rare and it is unlikely that the Kairakau Beach garnets came from such rocks. A more likely provenance is suggested by the fact that all these analyses plot within the field of the spessartine-almandine garnets that occur in granites, granite pegmatites and druses in rhyolites (Fig. 2 and 3). Garnetiferous granitic rocks occur in Stewart Island (Williams 1934), Fiordland (Turner 1937) and

Nelson (A. Wodzicki pers. comm.) though the only published analyses are of garnets from Stewart Island (Fig. 2 and 3).

Garnets occurring in rhyolite druses are usually clear and have perfect crystal forms (Pabst 1938). It may be relevant, therefore, that all of eight clear, euhedral garnets from Kairakau Beach sand are of high spessartine–low grossularite composition. However, garnets of this type are unknown in New Zealand volcanic rocks, suggesting that they were derived from granites and retain their euhedral form because of their small size (0·5 mm) and resistance to fragmentation.

High Spessartine–High Grossularite Group

Garnets with low MgO but high MnO, CaO and FeO contents typically occur in greenschist facies pelitic schists. Analyses of this small beach-sand group plot well within compositional field of garnets from regionally metamorphosed pelitic schists in New Zealand (Fig. 2 and 3). Presumably these garnets were derived from either now buried schist of the North Island or were transported from the South Island.

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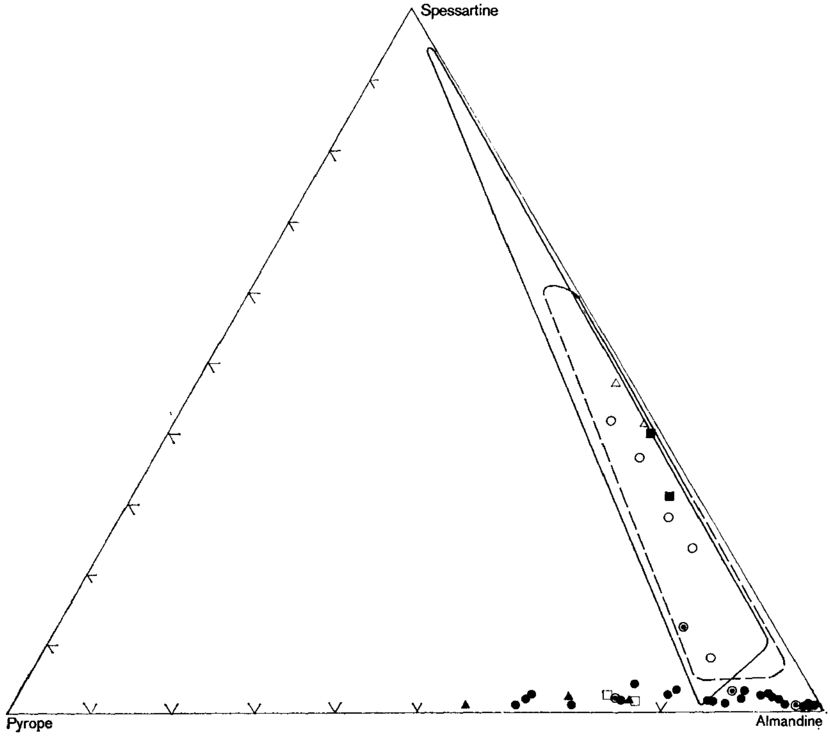

FIG. 3—Ternary diagram Almandine–Pyrope–Spessartine. Symbols as in Fig. 2.

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Kairakau Road Tuff

The Kairakau Road tuff has been described by Van der Lingen (1968). Angular fragments of garnet occur mainly in thin layers in which biotite is abundant and zircon, tourmaline, pyroxene and opaque oxides co-exist.

Analyses of four garnets are given in Table 3 and plotted on Fig. 2 and 3. Garnets 11, 12, and 13 belong to the low spessartine group whilst 14 is a high spessartine–low grossularite type. If these garnets had a volcanic origin and were genetically related to the host tuff, they would be expected to have a uniform composition (Green and Ringwood 1968), as they do not, they were more probably derived from pre-existing rocks and mechanically admixed with the tuff. This means that the tuffs of the Makara Basin are possibly a significant local source of the beach-sand garnets, but are not the primary one.

Glass Inclusions in Garnet

Many of the Kairakau Beach sand garnets are inclusion-free though rods and blebs of ilmenite are common in some whilst orthoclase and biotite are rare. Electron microprobe examination showed that occasional garnet grains contain flecks of a silica-rich material which, in two garnets, were large enough (30 μm) to analyse (Table 4). These inclusions were shown optically to be brown glass and are of similar composition to the silicic glass in the Taupo pumice and the Kairakau Road Tuff. Similar glass inclusions also occur in both hypersthene and ilmenite found with the garnets but these are less silicic.

The two host garnets have similar compositions and are magnesian members of the low spessartine group (Table 3, garnets 15 and 16). A possible explanation of this garnet-glass association is that the garnets were derived from gneiss and are xenocrysts from rock which either fused to form a rhyolitic magma or formed xenoliths in a pre-existing melt. Alternatively, they may be igneous garnets which crystallised in a magma.

TABLE 3—Composition of garnets from the Kairakau Road tuff (11–14) and garnets with included glass from Kairakau Beach (15, 16)

	11	12	13	14	15	16
Al_2O_3	19·1	19·1	20·9	20·0	20·0	21·1
FeO	37·1	34·1	31·2	35·0	32·1	30·0
MnO	0·3	1·1	0·8	5·3	0·7	1·1
MgO	0·6	2·1	5·8	2·8	5·5	5·9
CaO	5·3	3·9	2·0	1·3	1·9	1·5
TiO_2	0·2	0·1	0·1	0·1	0·2	0·1
Almandine	81·7	77·4	69·3	74·4	71·2	68·8
Spessartine	0·7	2·6	1·9	11·4	1·5	2·6
Pyrope	2·4	8·5	23·0	10·6	21·7	24·1
Grossularite	14·2	11·0	5·4	3·3	4·8	4·1
Ti-Andradite	0·7	0·3	0·3	0·3	0·6	0·3
Al_2O_3 (calculated)	21·3	20·7	21·2	22·2	21·2	20·5

TABLE 4—Comparative glass compositions

	1	2	3	4
SiO_2	71·3	72·0	70·4	69·8
Al_2O_3	13·0	12·6	13·0	15·1
FeO*	1·8	1·0	1·6	7·5
CaO	1·3	1·3	1·5	3·9
K_2O	2·9	2·9	2·5	1·8

*Total iron as FeO

1 Average residual glass of Taupo pumic (data from Ewart 1963)
2 Glass shards in Kairakau Road Tuff
3 Average of glass inclusions in garnets 15 and 16 (Table 3)
4 Glass included in hypersthene from Kairakau Beach sand

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In New Zealand, almandine garnet phenocrysts occur only in Cenozoic quartz andesite dykes at Whangarei Heads (Ferrar 1925) and in Cretaceous dacites and rhyolites of the Malvern Hills and Mt Somers provinces (Speight 1928, 1938). Garnets 15 and 16 (Table 3) are not of comparable composition to garnets from either of these localities. Those from Whangarei Heads have a higher pyrope and grossularite content whilst those from Malvern Hills and Mt Somers have a lower pyrope but higher grossularite content (C. P. Wood in prep.). However, the beach-sand garnets are similar to those found in Paleozoic calc-alkaline igneous rocks of Victoria (Green and Ringwood 1968) which suggests that an igneous origin is possible, but the source rock is not now exposed.

Co-existing Heavy Minerals in Beach-sand Lenses

Barite

The barite grains are derived from barite-bearing concretions common in Cretaceous rocks of the area (Lillie 1953).

Zircon

Zircon crystals generally have well preserved euhedral shapes suggesting that they have not been subject to much abrasion. As there are no obvious local plutonic sources, a volcanic origin is possible. Van der Lingen (1968) described small idiomorphic zircon crystals in the Kairakau Road Tuff and they are also common accessories of ignimbrites and ashes of the Taupo Volcanic Zone and Loisels pumice at Waimarama Beach (Challis 1962). It therefore seems probable that at least some of the beach-sand zircons were derived from volcanic rocks.

Magnetite and Ilmenite

Both magnetite and ilmenite are common constituents of volcanic rocks of the Taupo Volcanic Zone and both occur in the Kairakau Road Tuff. Further, some of the ilmenite grains from Kairakau Beach contain occluded glass and this clearly indicates that they were derived from volcanic rocks.

Hypersthene

Hypersthene usually occurs as subhedral or euhedral crystals and since these are susceptible to physical and chemical weathering it is unlikely that they could have been transported great distances or have been through more than one sedimentary cycle. Hypersthene is a common volcanic mineral and occurs in the Makara Basin tuffs, the Loisels pumice (Challis 1962) and many of the volcanic rocks of the Taupo Volcanic Zone. Several hypersthene crystals from Kairakau Beach have included glass comparable in composition to iron-rich rhyodacite (Table 4).

CONCLUSIONS

Most of the garnets on the eastern beaches south of Hawke Bay appear to have been derived originally from the plutonic igneous and metamorphic rocks of intermediate to silicic composition thought to comprise much of the North Island basement. Reed (1957) considered the Lower Mesozoic Wellington greywackes and argillites indicated a provenance from granite and gneiss but not Otago-type schists. Further evidence on the nature of the North Island basement is the occurrence of gneiss and granite pebbles in Triassic and Jurassic conglomerates of the North Island (Bartrum 1935; Marwick 1946).

However, the presence of glass inclusions in some of the beach-sand garnets complicates this interpretation. It is unlikely that garnets with these inclusions would survive as remnant minerals in a rhyolite magma generated by fusion of crustal greywacke, since spessartine is the stable garnet phase in low-pressure silicic melts. This low-spesartine, almandine-pyrope garnet would stand more chance of preservation if it was derived from gneissic rocks under high pressure granulite facies conditions.

Though the included glass has a similar composition to the Kairakau Road tuff glass, it has been earlier shown that these garnets were unlikely to have crystallised in the magma which produced the tuff. However, the coincidence is striking and it is possible that this magma came from, or passed through, disrupted gneiss. Alternatively, as suggested above, now unexposed rhyolite with primary igneous garnet may have been the source for these garnets.

The extent of this plutonic terrain is unknown and the immediate conclusion is that it lies beneath sediments west of the present shore line. However, Kingma (1957) suggested that a now submerged granitic landmass lay east of the North Island in late Mesozoic and early Tertiary times and Van der Lingen (1968) considers eastern off-shore volcanoes to be the source of the Miocene Makara Basin tuffs.

A detailed study of garnets in Mesozoic and Tertiary sediments might allow correlation between the incoming of a garnet type and the age of deposition. This would date the exposure and may point to the ultimate location of the original source rocks.

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