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A geophysical reconnaissance survey of Great Barrier Island, North Island, New Zealand

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Abstract Results of a gravity and an airborne magnetic survey of Great Barrier Island are described. The interpretation of residual Bouguer gravity anomalies shows that a sequence of Miocene andesites up to 2 km thick (Coromandel Group volcanics) has been deposited in the elongated, northwest-trending Great Barrier Depression which extends offshore to the west and northwest of the island. Late Miocene rhyolites (Whitianga Group volcanics) erupted from the Mt Hobson caldera, a 2 km deep depression within the Miocene volcanics, and at Rakitu Island and Okupu.

Contemporaneous geothermal activity produced widespread alteration of near-surface volcanics, mineral deposition, and partial demagnetisation which is reflected in the low-amplitude pattern of magnetic anomalies over the central part of the island.

Keywords gravity anomalies; magnetic anomalies; Miocene; volcanic rocks; Great Barrier Depression; Mt Hobson caldera; geothermal systems; Great Barrier Island

INTRODUCTION

Great Barrier Island and the Coromandel Peninsula most likely are remnants of the eastern shoulder of the Hauraki Rift (Hochstein & Nixon 1979) and are separated by the Colville Channel (Fig. 1). Great Barrier Island and the Coromandel Peninsula are covered extensively by volcanics of Miocene - Early Pliocene age (Thompson 1960; Schofield 1967).

Published gravity data are restricted to stations along the Great Barrier Island coast (Woodward & Reilly 1972). When a regional gravity field, described later in this study, is used, these data can be expressed in terms of residual gravity anomalies which reach values of about −17 mgal (−170 μN/kg) near Port Fitzroy. Although these values point to a thick sequence of volcanic rocks, no significant magnetic anomalies are indicated in high-level airborne magnetic data (Hunt & Syms 1977). Recently, marine gravity anomalies have become available (Rawson 1983) which outline the Jurassic basement structure to the west and southwest of the island (Fig. 1).

A geophysical reconnaissance survey of Great Barrier Island was undertaken during 1980–81, to determine the thickness of the Miocene volcanics with respect to the underlying greywacke rocks, and to outline gross structural features within the volcanics.

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GEOPHYSICAL AND GEOLOGICAL SETTING

The geological setting of Great Barrier Island has been affected by the tectonic processes which led to the formation of the Hauraki Rift (Hochstein & Nixon 1979). Geophysical studies have shown that this rift extends over a distance of about 300 km from Whangarei to the Taupo Volcanic Zone and that it consists of a series of NNW-trending fault-angle depressions and concealed basement horsts (Hochstein 1978; Ferguson et al. 1980; Tearney 1980; Davidge 1982; Rawson 1983). The rift has been filled by unconsolidated Pleistocene sediments which are underlain in some parts by older volcanic rocks (Hochstein et al. in press).

The basement on Great Barrier Island consists of indurated, folded sediments, slates, and lithic sandstones, commonly described as greywackes, which have been correlated with the Late Jurassic Manaia Hill Group (Skinner 1967, 1976). These rocks crop out in the northern part and also along the eastern coast at Overtons Beach (Fig. 2).

A thick sequence of easterly dipping Tertiary andesitic flows and pyroclastics unconformably overlies the basement. Similar rocks on Coromandel Peninsula have been classified as Coromandel Group (Skinner 1976). The term Coromandel Group is here extended to include those rocks on Great Barrier Island, mapped originally as Beesons Island Volcanics by Thompson (1960), which typ-

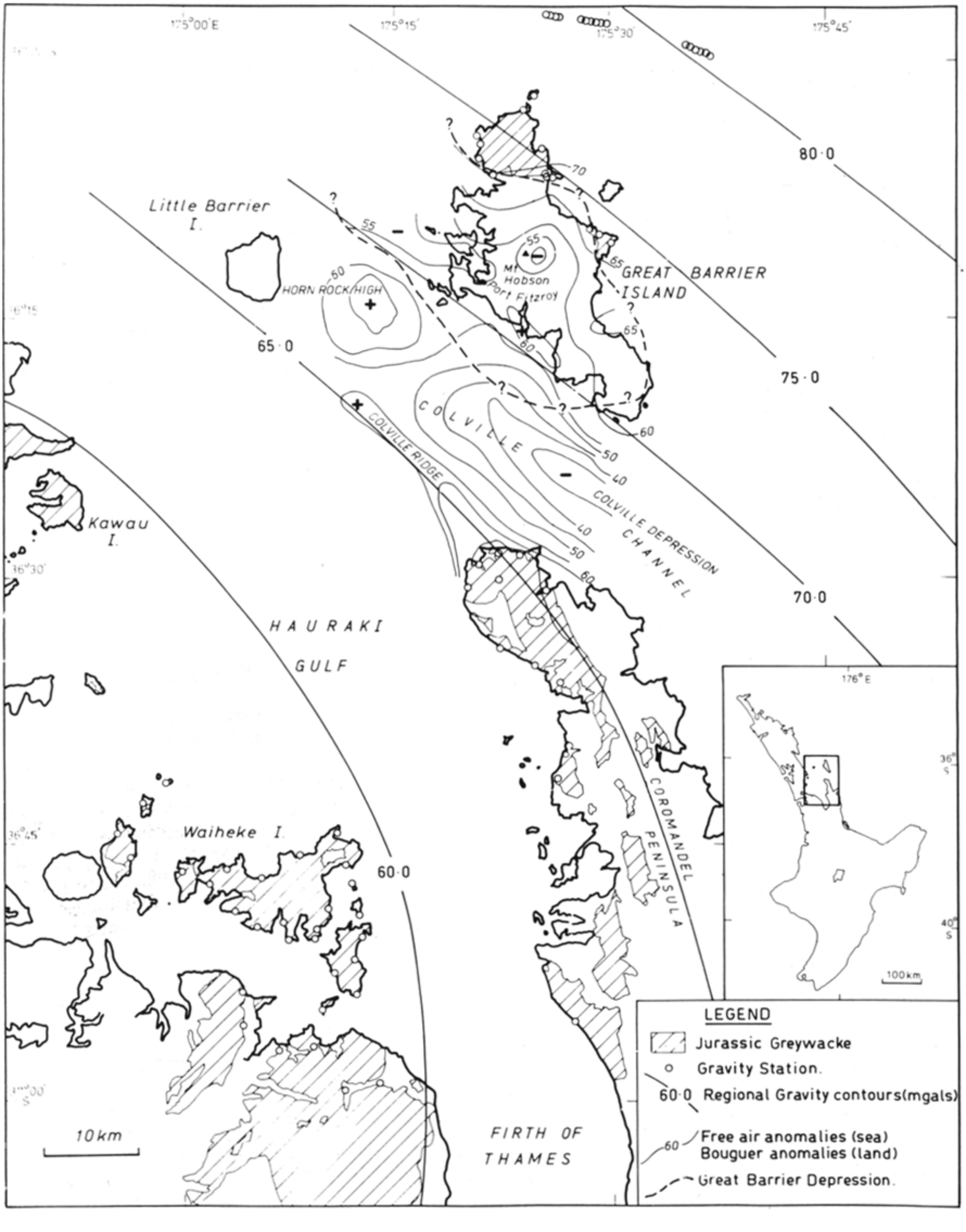


Fig. 1 Map of the Hauraki Gulf showing smoothed gravity anomalies over and around Great Barrier Island together with the regional gravity field. The dashed line around Great Barrier Island outlines the approximate extent of the Great Barrier Depression which has been filled with Miocene volcanic rocks.

ically consist of poorly bedded volcanic breccias and lava flows of marginally subaqueous mode of deposition (Ramsay 1971; Hayward 1973). These rocks have not been dated yet, but Pliocene lignite lenses interbedded with Coromandel Group breccias near Medlands Stream contain leaf impressions of late Mangapanian - Hautawan age (Henrys 1982). Radiometric ages for the Coromandel Group volcanics on the Coromandel Peninsula range from 16.2 to 2.54 Ma (Robertson 1983), but the northernmost andesites conformably overlie (?)Otaian marine beds of the Colville Formation.

The Coromandel Group volcanics are unconformably overlain by rhyolitic volcanics in the central part of Great Barrier Island (i.e., around Mt Hobson), which are very similar to rocks of the Whitianga Group on Coromandel Peninsula (Thompson 1960, 1961). Similar rocks can also be found further north on the Mokohinau Islands, Fanal Islands, and the Poor Knights Islands (Wodzicki & Bowen 1979). Lithologies of the Whitianga Group rocks on Great Barrier include crystal-free, flow-banded rhyolites, breccias of perlitic and vitric rhyolites, ignimbrites and pyroclastic flows, as well as rhyolitic domes. A remnant of a presumably more extensive pyroclastic flow sheet forms a 230 m high plateau at Mt Te Ahumata (Fig. 2) which, according to Erceg (1981), originated from a vent in the Mt Hobson area or from the Okupu Rhyolite Dome. Fission track dating of Whitianga Group rhyolites from Great Barrier Island and the Coromandel Peninsula gave ages between 8.9 ± 1.3 Ma and 2.3 ± 0.2 Ma (Rutherford 1978; Leach et al. 1981). Obsidian fragments near Awana, Mt Young, and Mt Te Ahumata gave dates of 8.9 ± 1.3, 8.3 ± 0.6, and 4.6 ± 0.9 Ma respectively (Rutherford 1978; Leach et al. 1981).

Faults in the basement rocks trend NW–NNW (Bartrum 1921; Hayter 1954); intrusive dikes, dated at 18.1 Ma, in the northern part of the island, follow this trend but also strike NNE, parallel to a minor fold direction (Thompson 1960).

Coromandel Group volcanics also strike NNW–NW with dips of up to 30° to the east (Ramsay 1971). Faults in these volcanics strike NNW and ENE, that is, similar to those observed in Coromandel Group rocks further south on Coromandel Peninsula (Skinner 1976). In the younger rhyolites, a pattern of NNW-striking normal faults has been observed over the Te Ahumata Plateau (Erceg 1981); the same direction was also found for lithoidal rhyolitic dikes near Mt Hobson, although ENE trends were also observed for lineaments in the same area (Henrys 1982). Analysis of Landsat imagery (reflective spectrum enhanced) has shown that there is a large ring structure in the Mt Hobson area which can also be traced by drainage patterns (Henrys 1982).

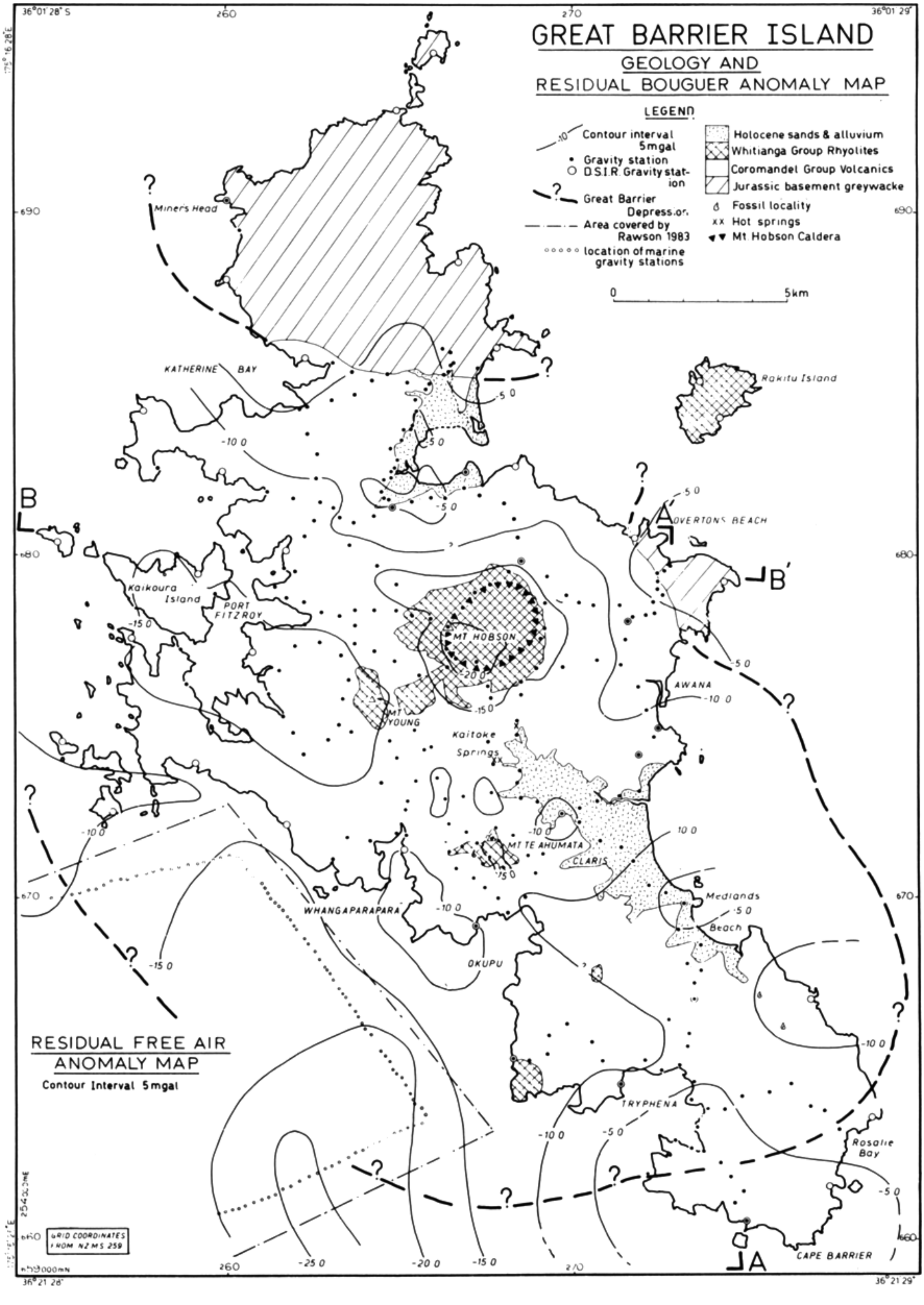
GRAVITY AND MAGNETIC SURVEYS

During the summer of 1980–81, 242 gravity stations (Fig. 2) were established in addition to the existing 70 DSIR stations. The measurements were made with Worden Pioneer meters (Nos 240 and 697). Stations were located along roads and tracks, forming closed nets. Grid co-ordinates were obtained within an error of ± 100 m from airphotos and 1:50 000 topographic maps (NZMS 259) and draft copies of recently compiled 1:25 000 maps (NZMS 270). Co-ordinates and elevations of 26 stations were determined by tacheometry. Heights of all the remaining stations were determined by barometry using two Paulin altimeters according to the single altimeter method of Hodgson (1970). Gravity measurements and altimeter readings were repeated at 4 h intervals at intermediate base stations. Drift-corrected data indicate mean closure errors of about ± 0.2 mgal for gravity and about ± 3 m for altimeter data except for the Mt Hobson net (± 5 m). The gravity and elevation data were tied into the DSIR base station at Port Fitzroy. All gravity data have been deposited with DSIR, Geophysics Division (station numbers 02/782–1013).

In computing Bouguer anomalies, the terrain effects (density of 2.67×10^3 kg/m^3) of Hammer Zones E–M were obtained by using a digitised terrain model of Great Barrier Island (Henrys 1982). The validity of the digitised terrain model was checked by determining separately the terrain effect of 20 widely spaced stations using Hammer Zone graticules. The rms difference in the terrain effect using the two procedures was found to be about ± 0.4 mgal for most of the island, although in the steeply dissected terrain around Mt Hobson, errors up to ± 1.5 mgal might occur. The resulting mean error of the Bouguer anomaly was estimated to be ± 1.4 mgal for all other stations.

The effect of deeper-seated crustal masses was reduced by constructing a regional field for the Hauraki Rift, which was obtained from a second-order polynomial fit of data from 79 stations located on greywacke in the area shown in Fig. 1. This regional field was removed from the computed Bouguer anomalies, and a residual Bouguer anomaly map was obtained which reflects only the effects of masses above the greywacke basement (Fig. 2).

A low-level aeromagnetic survey of Great Barrier Island was undertaken late in 1981 using a total force proton precession magnetometer. The total length of the profiles was 130 km. Two profiles (FL2 and 3 in Fig. 3) were flown at an altitude of 520 ± 20 m, and the other seven profiles were flown at 610 ± 20 m. The data of FL2 and 3 were later reduced to an elevation of 610 m using upward continuation (Rogan 1980). The flight lines were


GREAT BARRIER ISLAND
GEOLOGY AND
RESIDUAL BOUGUER ANOMALY MAP
LEGEND
Contour interval 5mgal
Gravity station
D.S.I.R. Gravity station
Great Barrier Depression
Area covered by Rawson 1983
location of marine gravity stations
Holocene sands & alluvium
Whitianga Group Rhyolites
Coromandel Group Volcanics
Jurassic basement greywacke
Fossil locality
Hot springs
Mt. Hobson Caldera
5km
Miners Head
KATHERINE BAY
Rakitu Island
OVERTONS BEACH
Kaikoura Island
PORT FITZROY
MT HOBSON
MT YOUNG
AWANA
Kaitoke Springs
MT TE AHUMATA
CLARIS
Medlands Beach
WHANGAPARAPARA
OKUPU
TRYPHENA
Rosalie Bay
CAPE BARRIER
RESIDUAL FREE AIR ANOMALY MAP
Contour Interval 5mgal
GRID COORDINATES FROM NZMS 259

selected on the basis of known residual gravity anomaly patterns. The horizontal position of the aircraft was determined within an error of ± 100 m by means of vertical airphotos taken every 30 s during the flight.

The raw magnetic data were processed and filtered by using computer programs developed by Bulte (1982). After subtraction of a suitable regional magnetic field, which produced zero anomalies over the nonmagnetic outcropping greywacke rocks, total force (ΔF) magnetic anomalies were obtained (Fig. 3). It was found that ΔF values at flight-line intersections agree within ± 10 nT.

DISCUSSION OF RESIDUAL GRAVITY AND MAGNETIC ANOMALY PATTERNS

The residual gravity anomalies shown in Fig. 2 mainly reflect the gravitational effect of less-dense volcanic rocks. The overall pattern of these anomalies is dominated by a few gravity lows of magnitude < -17 mgal, with wavelengths of > 5 km, which occur on the western side of the island (e.g., near Port Fitzroy and southwest of Okupu Bay). The marine gravity data shown in Fig. 2 were taken from Rawson (1983); these are residual free-air gravity anomalies which, for shallow water, agree closely (to ± 4 mgal) with the residual Bouguer anomalies at the coast. Assuming that there are no low-density sediments beneath the Coromandel Group volcanics, these gravity lows outline centres where the volcanic rocks reach their maximum thickness. An almost circular gravity low occurs over the rhyolites of Mt Hobson, where large horizontal gravity gradients ($\geqslant 5$ mgal/km) can also be found, suggesting a steeply dipping depression. Near the exposed greywacke/volcanic contacts, the horizontal gradients are smaller, indicating that these contacts are not related to steeply dipping faults. The data suggest that basement occurs at shallow depths at the southern tip of the island.

The main features in the residual ΔF magnetic anomaly map (Fig. 3) are the low-amplitude anomalies in the central part of the island indicative of rocks with rather low magnetisation. Since significant magnetic anomalies with amplitudes of -50 to $+120$ nT have been observed elsewhere over the Coromandel Group rocks, it can be inferred that these rocks, in the central part of Great Barrier Island, have lost part of their original magnetisation. Indeed, thermally altered and demagnetised Coromandel Group rocks were found on the surface between Port Fitzroy and the Mt Hobson area (Henrys 1982). The sign of most anomalies suggests normally magnetised rocks, although reversely magnetised rocks are indicated also by the anomaly pattern over the island and in marine data southwest of Okupu (Rawson 1983). The marine data also indicate the presence of thick volcanics offshore, thus providing evidence that these rocks are an extension of the volcanic rocks beneath the western coast of Great Barrier Island. The short wavelength magnetic anomalies offshore terminate rather abruptly to the west of the marine profiles shown in Fig. 3.

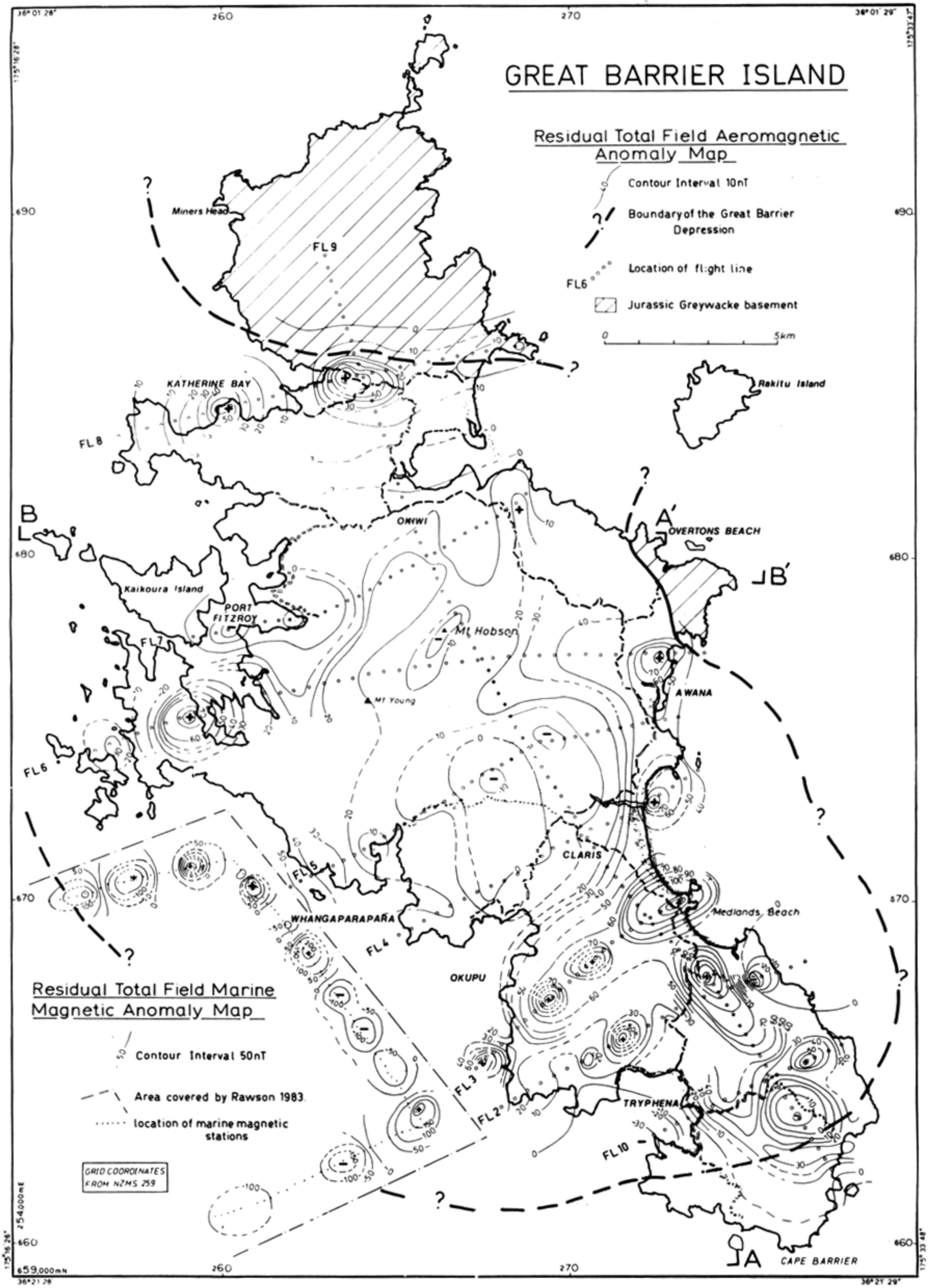
A more detailed interpretation of the data shown in Fig. 2 and 3 requires representative mean values of density and magnetisation for the volcanic rocks.

DENSITY AND MAGNETISATION

Representative mean densities of the volcanics were obtained from weighted means of mostly unweathered and unaltered surface samples (n = 58) and cores (n = 14) from one 160 m drillhole (see Fig. 6) at Mt Te Ahumata (Erceg 1981). A mean wet density of $(2.47 \pm 0.06) \times 10^3$ kg/m^3 was obtained for the Coromandel Group rocks from mean wet densities of 2.63, 2.40, and 2.28 $\times 10^3$ kg/m^3 for solid lava flows, tuffaceous breccias, and andesitic breccias weighted in proportion to their thickness in the stratigraphic columns of Ramsay (1971) and Hayward (1973). An indirect density determination using the observed topographic effects along three gravity profiles gave a mean of $(2.36 \pm 0.07) \times 10^3$ kg/m^3 for the upper 100 m of Coromandel Group rocks using the methods of Siegert (1942) and Jung (1953) and an algorithm described by Beattie (1975).

For Whitianga Group rocks, a mean wet density of $(2.28 \pm 0.06) \times 10^3$ kg/m^3 was derived from weighted means of samples, whereas the indirect method gave a mean density of $(2.22 \pm 0.08) \times 10^3$ kg/m^3 for the 150 m thick pyroclastics forming Mt Te Ahumata. Because of the large thickness of both Coromandel Group and Whitianga Group rocks, the effect of the slightly lower densities of the surface rocks in the upper 100 m was neglected. Lower densities were also observed for thermally altered volcanics around Mt Hobson (altered andesites: $(2.30 \pm 0.07) \times 10^3$ kg/m^3). Because of the unknown thickness of these rocks, their effect was also neglected in the interpretation.

Fig. 2 *(opposite)* Map of the general geology of Great Barrier Island (from Thompson 1960; Erceg 1981) upon which residual gravity anomalies are imposed (contour interval is 5 mgal).


GREAT BARRIER ISLAND
Residual Total Field Aeromagnetic Anomaly Map
Contour Interval 10nT
Boundary of the Great Barrier Depression
Location of flight line
Jurassic Greywacke basement
0
5km
Residual Total Field Marine Magnetic Anomaly Map
Contour Interval 50nT
Area covered by Rawson 1983
location of marine magnetic stations
GRID COORDINATES FROM NZMS 259
Miners Head
KATHERINE BAY
Rakitu Island
OKIWI
OVERTONS BEACH
Kaikoura Island
PORT FITZROY
Mt Hobson
Mt Young
AWANA
CLARIS
Medlands Beach
WHANGAPARAPARA
OKUPU
TRYPHENA
CAPE BARRIER
A
A'
B
B'
FL2
FL3
FL4
FL5
FL6
FL7
FL8
FL9
FL10
260
270
690
680
670
660
659,000mN
2540000mE

Representative mean magnetisations* were obtained indirectly by computing the magnetic effect of the terrain using an algorithm by Talwani & Heirtzler (1964). For this it was assumed that the direction of the magnetisation of these rocks is close to that of the present earth's magnetic field; this is a valid assumption since Robertson (1983) found that the thermal remanent magnetisation of most Miocene volcanic rocks belonging to the Coromandel Group has been overprinted by viscous magnetisation whose direction is similar to that of the present earth's magnetic field. An analysis of five profiles showed that the magnitude of the mean magnetisation of mainly unaltered Coromandel Group rocks is about 1.4 $\pm$ 0.4 A/m whereas that of thermally altered rock was found to be about 0.35 A/m (one profile only, near Mt Hobson). No significant magnetic topographic effects were found over the rhyolites of Mt Hobson, thus pointing to a magnetisation of < 0.35 A/m for these rocks. No direct measurements of magnetisation were made, but the cited mean magnetisation of unaltered Coromandel Group rocks on Great Barrier Island is similar to directly determined values of similar rocks on Coromandel Peninsula, for which a mean value of 1.0 A/m has been reported (Robertson 1983).

*The term "magnetisation" is used throughout to describe the magnitude (intensity) of the vector sum of induced and remanent magnetisation of magnetic rocks.

Using the mean wet density and magnetisation for greywacke rocks of 2.67×10^3 kg/m^3 and 0 A/m respectively (Whiteford & Lumb 1975), the densities, density contrasts, and magnetisations as listed in Table 1 are obtained.

For a quantitative interpretation of the residual gravity anomalies shown in Fig. 2, it was assumed initially that the mean density of the volcanics as listed in Table 1 does not change significantly below 100–150 m depth, and that mass inhomogeneities causing the anomalies can be approximated by two-dimensional structures. Using a trial and error method and restrictions imposed by the surface geology and the data in Table 1, best fit models were computed for six sections, two of which are shown in Fig. 4 and 5. The best fit theoretical anomalies were computed by using the method of Talwani et al. (1959).

Profile A–A′ (Fig. 4) extends from Cape Barrier to Overtons Beach. Since greywacke basement crops out at Overtons Beach, and was inferred to be shallow near Cape Barrier, the whole section was modelled in terms of a thick sequence (up to 1.5 km) of Coromandel Group volcanics which have been intruded near Medlands Beach by an inferred dense, magnetic body. The wavelengths of the Bouguer anomaly (Fig. 4) and of the magnetic anomaly (Fig. 3) associated with the intrusion indicate that its mass and dipole centre respectively lie within the Coromandel Group volcanics. Assuming that the intrusion lies entirely within the sequence of

Table 1 Density and magnetisation of rocks from Great Barrier Island.

Rock unit	Mean density (10^3 kg/m^3)	Density contrast with respect to basement (10^3 kg/m^3)	Mean magnetisation (A/m)
Greywacke basement	2.67	0	0
Coromandel Group volcanics:			
(Upper 100 m)	2.37 ± 0.07	(−0.30)	1.4 ± 0.4
(Below 100 m)	2.47 ± 0.06	−0.20	n.d.
Whitianga Group volcanics:			
(Upper 150 m)	2.22 ± 0.08	(−0.45)	≤ 0.35
(Below 150 m)	2.28 ± 0.06	−0.39	n.d.

Fig. 3 *(opposite)* Contour map of residual total force magnetic anomalies over Great Barrier Island. The contour interval for the aeromagnetic data (reduced to an elevation of 610 m) is 10 nT. Marine magnetic anomalies (Rawson 1983) taken at sea level are contoured at the 50 nT interval. The thick dashed line shows the approximate extent of the Great Barrier Depression.

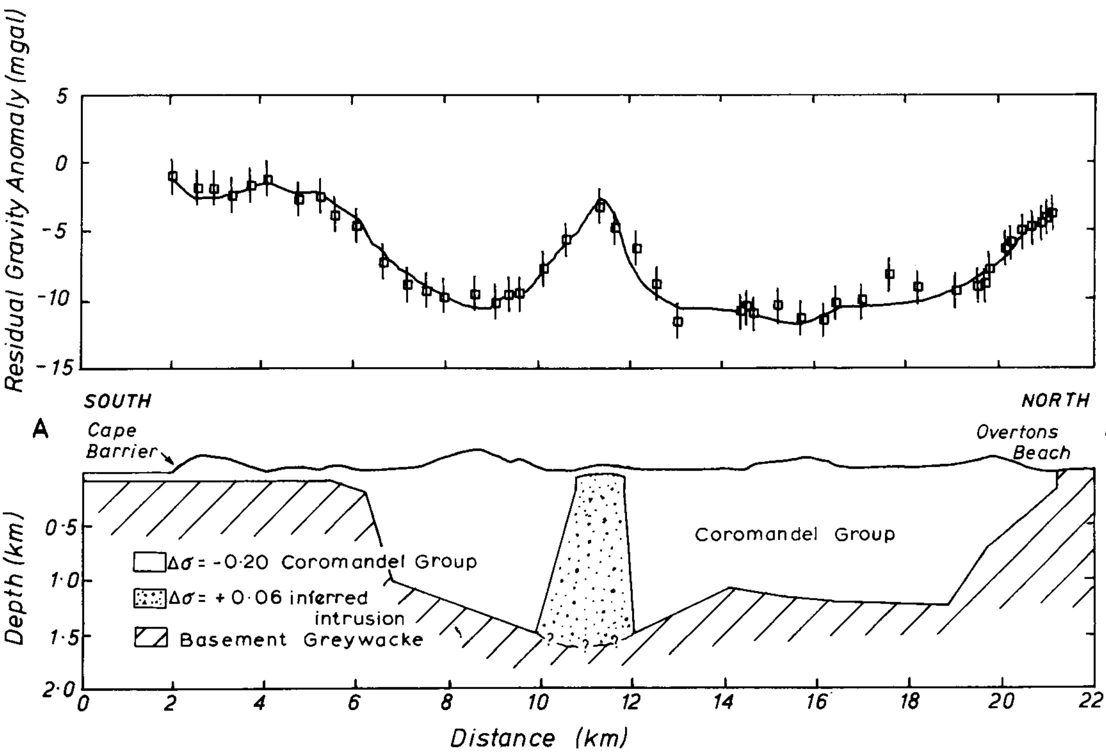


Fig. 4 Observed, computed Bouguer anomalies, and interpreted two-dimensional section across Great Barrier Island along profile A–A′; the location of the profile is shown in Fig. 2. Observed gravity anomalies are shown by open boxes with error bars. The solid line is the computed Bouguer anomaly (at station height) of the model shown in the section. Figures in the section denote the density contrast (in 10^3 kg/m^3) of Coromandel and Whitianga Group volcanics with respect to greywacke basement.

Coromandel Group rocks, and that it does not reach the surface, a density of 2.73×10^3 kg/m^3 (cf. $+0.06 \times 10^3$ kg/m^3 with respect to basement) is indicated for this body by the best fit model shown in Fig. 4. It is possible that this intrusion is a dacite body because andesitic-dacitic bodies occur within Coromandel Group rocks in the Coromandel area (Skinner 1976). There is no evidence for similar shallow intrusions elsewhere in the data shown in Fig. 2.

Profile B–B′ (Fig. 5) extends from Kaikoura Island to Overtons Beach and runs across the central gravity low around Mt Hobson. Although boundaries of the Whitianga Group rocks are not well known around the Mt Hobson area (Thompson 1960), the position of a deep-reaching depression infilled with less-dense rhyolites is clearly indicated in the gravity profile of Fig. 5. This gravity low can be interpreted either in terms of a 1 km deep depression within Coromandel Group volcanics, and filled with rhyolites of constant density of 2.28×10^3 kg/m^3, or by an even deeper caldera structure if allowance is made for slightly denser perlitic rhyolites which crop out along a track leading from Mt Hobson to the Kaitoke Springs (Henrys 1982).

Since the model in Fig. 5 indicates a steeply dipping ($\simeq 45°$) boundary structure, and because the thickness of three-dimensional structures is always underestimated if modelled by two-dimensional structures, a three-dimensional model of the Mt Hobson caldera was constructed; theoretical best fit anomalies were computed using the method of Talwani & Ewing (1960) and an iterative technique described by Cordell & Henderson (1968). To allow for the effects of the sloping basement, the model was finally extended to cover the basement beneath the whole island. Results of the best fit model are shown in Fig. 6 in terms of a basement level map which approximates an isopach map of the volcanics if one allows for likely errors in the density structure. The model fits the observed residual anomaly elsewhere on the island with an error of $< \pm 2$ mgal. The three-dimensional modelling

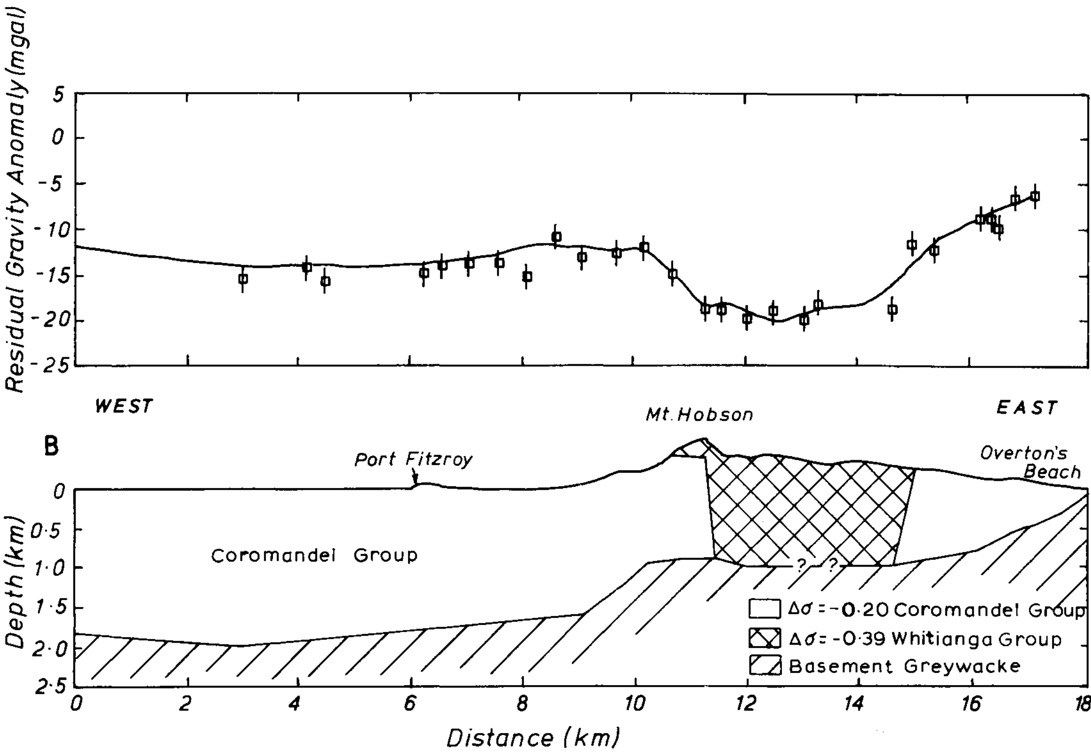


Fig. 5 Observed, computed Bouguer anomalies, and two-dimensional section across Great Barrier Island along profile B–B′ (Fig. 2) (details as for Fig. 4).

showed that the Mt Hobson caldera is a structure > 2 km deep, and that the inward dip of the caldera walls may be as steep as 70° in the southwestern part. Independent evidence for a caldera structure was found in Landsat images which show a well-defined ring structure almost coinciding with the margin of the caldera inferred from gravity data. Depths to basement of about 2 km are also indicated by long-wavelength gravity lows near Port Fitzroy and offshore southwest of Okupu. Rawson (1983) used a slightly different density structure, based on marine seismic velocities, and obtained a thickness of about 2 km for the low-density volcanic rocks southwest of Okupu.

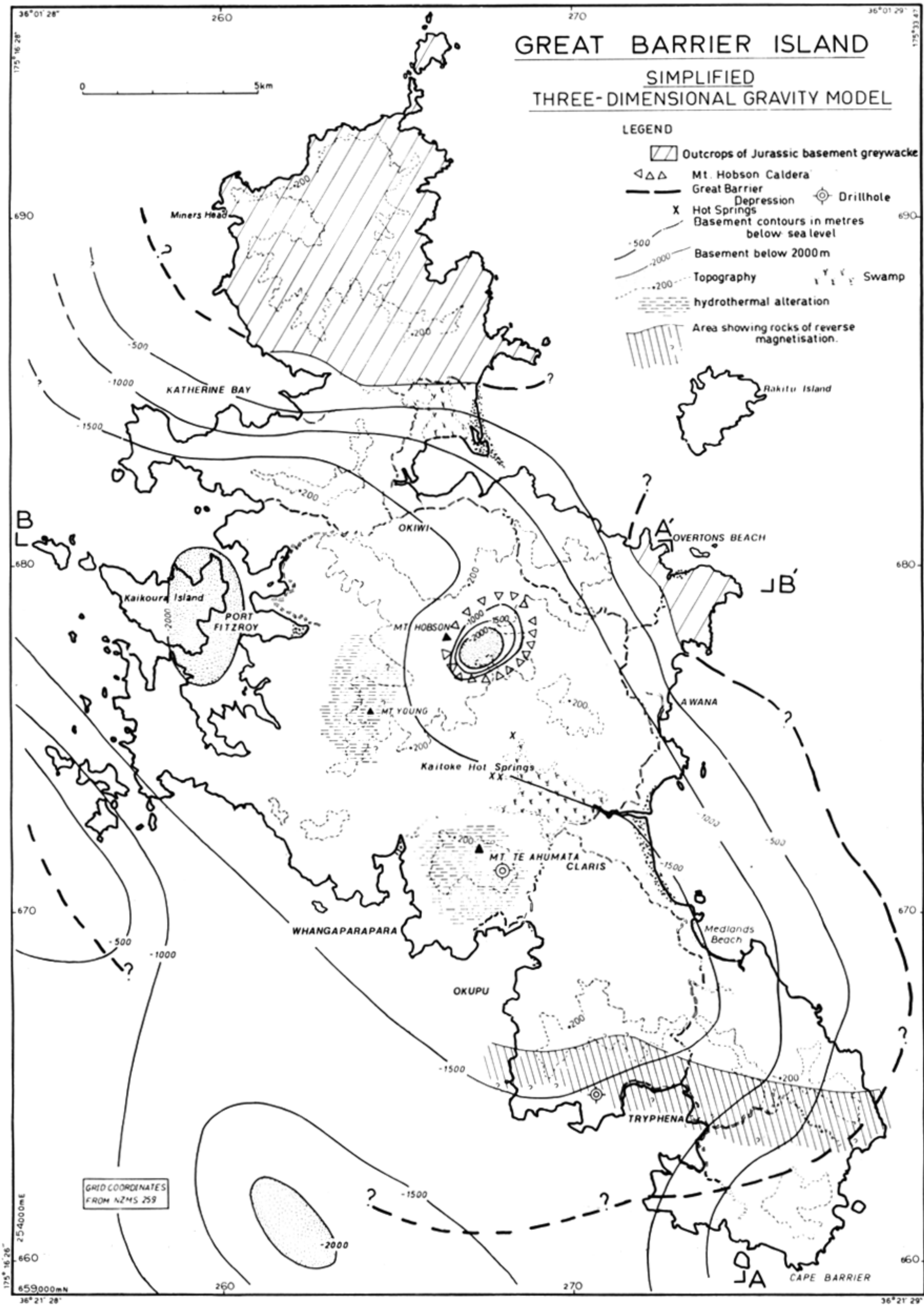
Modelling of gravity anomalies near basement–volcanic surface contacts on the island showed that most contacts dip at < 30°.

As the very low magnetisation (< 0.35 A/m, see Table 1) obtained for the volcanics in the central part of the island is associated with extensive surface alteration (Fig. 6), it was inferred that these rocks have lost most of their magnetisation because of thermal alteration. Aeromagnetic anomalies south of Claris showed that a coherent strip of Coromandel Group and Whitianga Group volcanics in the Tryphena area is reversely magnetised (see also Fig. 7). Reversely magnetised rocks belonging to the Coromandel Group also may occur between Mt Young and Port Fitzroy.

The results shown in Fig. 7 also indicate that the low-level aeromagnetic data contain little information related to the magnetic effect of deeper volcanics. To enhance this effect, filtering of the short-wavelength topographic anomalies is required. However, the large spacing between adjacent magnetic profiles precludes such analysis. The problem whether most of the low-density material producing the residual gravity anomalies over Great Barrier Island is composed of magnetic rocks with a magnetisation similar to that of the surface volcanics remains unsolved.

DISCUSSION OF RESULTS

The interpretation of residual gravity anomalies over Great Barrier Island has shown that a thick


GREAT BARRIER ISLAND
SIMPLIFIED
THREE-DIMENSIONAL GRAVITY MODEL
LEGEND
Outcrops of Jurassic basement greywacke
Mt. Hobson Caldera
Great Barrier Depression
Drillhole
Hot Springs
Basement contours in metres below sea level
Basement below 2000 m
Topography
Swamp
hydrothermal alteration
Area showing rocks of reverse magnetisation.
Miners Head
KATHERINE BAY
Rakitu Island
OKIWI
OVERTONS BEACH
Kaikoura Island
PORT FITZROY
MT. HOBSON
MT YOUNG
AWANA
Kaitoke Hot Springs
MT TE AHUMATA
CLARIS
Medlands Beach
WHANGAPARAPARA
OKUPU
TRYPHENA
CAPE BARRIER
GRID COORDINATES FROM NZMS 259
0
5km
B
B′
A′
A
260
270
690
680
670
660
659000mN
2540000mE
36°01′28″
36°01′29″
36°21′28″
36°21′29″
175°16′28″
175°33′47″
175°16′26″
175°33′48″

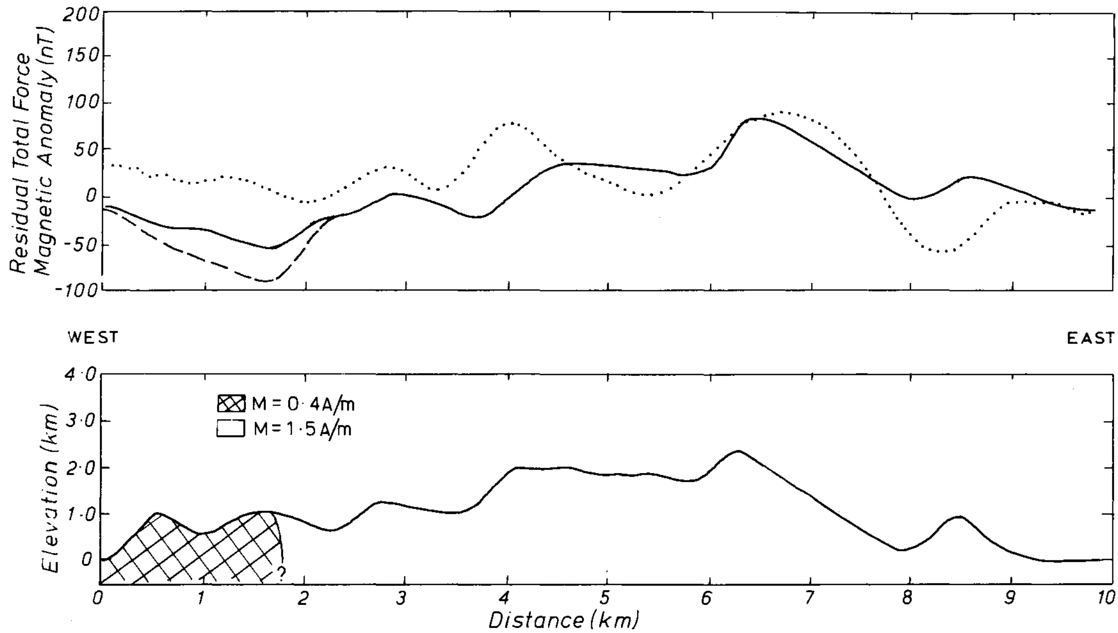


Fig. 7 Observed and computed total force magnetic anomalies (at 610 m elevation) and interpreted section along flight line FL2 (for location see Fig. 3). The observed residual magnetic anomaly is shown by dots. The solid line is the computed total force anomaly if the effect of Whitianga Group volcanics shown in the hatched pattern is computed with a reversed magnetic field; the dashed line represents the total force anomaly computed for Whitianga Group volcanics with a normal magnetic field. Coromandel Group rocks are normally magnetised.

sequence of Miocene volcanics (Coromandel Group) has been deposited in an elongated northwest-trending depression. These volcanics reach a maximum thickness of about 2 km onland near Port Fitzroy and offshore to the southwest of Whangaparapara. A sequence of low-density magnetic rocks of similar thickness occurs offshore about 15 km northwest of Katherine Bay (Rawson 1983), probably associated with the volcanic rocks exposed on the island. A spectral analysis of marine magnetic data (Hochstein et al. in press) has shown that thick volcanic rocks are probably absent to the west of the dashed line shown in Fig. 1, which outlines the depression in which thick (> 0.5 km) volcanic rocks were deposited (referred to here as the Great Barrier Depression). Because of the gravitational effect of low-density sediments in the Colville Depression (see Fig. 1), the southwestern boundary of the Great Barrier Depression cannot be recognised in the marine gravity anomalies. Sparse magnetic and seismic data (Tearney 1980) indicate that the Colville Depression is a young sedimentary basin which contains few magnetic rocks; it probably subsided after volcanism ceased on Great Barrier Island.

No significant geophysical structure can be recognised within the Miocene volcanics on Great Barrier Island apart from an intrusive body near Medlands Beach and a coherent sequence of outcropping, reversely magnetised rocks near Okupu–Tryphena (Fig. 6). A dominantly reversed paleomagnetic field in the Miocene occurred 10–11.6 Ma ago (Foster & Opdyke 1970).

The total thickness of the Miocene volcanics was much greater than 2 km and has been reduced by later erosion. Periods of rhyolitic volcanism took place at least 8–10 Ma ago. Most of the Whitianga Group volcanics on the island presumably originated from the Mt Hobson caldera, which, from gravity data, is a 2 km deep, 3–4 km wide conical depression in the Coromandel Group volcanics and,

Fig. 6 *(opposite)* Simplified three-dimensional gravity model of the volcanic rocks of Great Barrier Island presented in the form of a contour map showing the depth to basement below sea level. The open teeth indicate the boundary of the Mt Hobson caldera delineated by this study. The stipple-patterned areas are regions where the basement reaches depths greater than 2 km. The horizontally dashed lines outline areas with visible hydrothermal alteration. South of Claris, an area with inferred reversely magnetised rocks is shown by oblique solid lines.

in the greywacke basement, is filled with less-dense rhyolites and probably pyroclastics. Pyroclastic flows from this centre could have covered most of the island but have since been eroded and reduced to a few outcrops; the most impressive relict of these is the plateau structure forming Mt Te Ahumata. Other centres of rhyolitic volcanics are Rakitu Island, which was not studied, and a relict dome at Okupu. The youngest volcanic products from the Mt Hobson caldera are glassy flow-banded rhyolites and perlitic rhyolite breccias which can be found in the vicinity of the Mt Hobson caldera itself.

The Mt Hobson volcanism was also associated with an ancient, large geothermal system which probably occurred beneath most of the central part of the island, as manifested by the thermal alteration of outcropping Coromandel Group and Whitianga Group volcanics. The area with alteration at shallow depths is well defined by the area with low-amplitude magnetic anomalies, caused by partially demagnetised rocks. No outcrops of thermally altered rocks occur outside this area. Mineral deposition associated with the ancient Great Barrier geothermal system presumably led to the well-known base metal - silver mineralisation in the pyroclastic flows at Mt Te Ahumata (Erceg 1981) and probably also elsewhere around the Mt Hobson caldera. However, flow-banded and perlitic rhyolites which cover the Mt Hobson caldera are unaltered.

Present-day hot springs south of Mt Hobson at Kaitoke probably are not associated with any recent or rejuvenated intrusion. Model studies (Norton & Knight 1977) have shown that the anomalous heat of such intrusion can be dissipated by convective heat transfer through geothermal systems during a period of < 0.5 Ma. There is no evidence of volcanism younger than 4.6 ± 0.9 Ma on Great Barrier Island, if the identification of late Mangapanian - Hautawan palynofloras in andesite is discounted. Anomalous ground-water temperatures have been observed further south at Tryphena in a 226 m deep drillhole (see Fig. 6) which encountered Coromandel Group volcanics (Wilson et al. 1973). An anomalously high heat flux most likely occurs beneath the whole Hauraki Rift and beneath the rift shoulders (Hochstein 1978), and it is likely that this heat flux is the heat source for all thermal waters discharged today on Great Barrier Island (Henrys & Hochstein 1982).

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