MAGNETIC ANOMALIES OF THE NEW ZEALAND BASEMENT

B Davy
Institute of Geological and Nuclear Sciences

Abstract

Prominent aeromagnetic and marine magnetic anomalies, including those of the Stokes Magnetic Anomaly System, are traced through the southern and western New Zealand region from Southland to the New Caledonia Basin. The continuity of several of the magnetic anomaly bands provides information on the location of major basement terranes and boundaries such as the Median Tectonic Line and the Dun Mountain Ophiolite Belt. High amplitude linear magnetic anomalies associated with the formation of the New Caledonia Basin are identified.

Introduction

Magnetic anomalies in southern and western New Zealand form prominent linear features. The most well known of these features is the Stokes Anomaly System (Hatherton 1975, Hunt 1978) of positive magnetic anomalies. The Junction Magnetic Anomaly (JMA), the short wavelength (~20 km) northeasternmost part of the Stokes System, is the most readily recognised and can be traced the length of New Zealand. Such characteristic magnetic anomalies provide diagnostic information about the nature of the basement rocks and/or about basement intrusions along lines of tectonic activity. A knowledge (or "roadmap") of the magnetic anomaly pattern through New Zealand as well as the likely source rocks for the anomalies provides important information on the basement terrane distribution and crustal structure. For petroleum exploration purposes knowledge of the rocktype distribution within and around a basin provides important information on tectonic evolution, thermal history and heatflow, density information crucial for gravity modelling, and sedimentary provenance.

Background

Magnetic observations by Gerard and Lawrie (1955) of anomalies, later identified as part of the Stokes System, were used by Wellman (1959) to trace upper Paleozoic igneous rocks between Nelson and the Waikato River. Hatherton (1966) identified and modelled northwest to southeast trending bands of positive magnetic anomaly within the Southland Syncline. Hatherton (1967) noted the similarities of magnetic anomalies in the Cook Strait region with anomalies observed in the Southland Syncline. He suggested that a strong positive magnetic anomaly belt in the Golden Downs–Tasman Bay area extended across to the Wanganui Bight and onshore at Patea and was probably sourced in ultramafics of the Dun Mountain Belt. Hatherton (1969), and Hatherton and Sibson (1970) identified the JMA extending from the Waikato River along the west coast of theAuckland and Northland Provinces and offshore near Kaitaia. Wellman (1973) identified the JMA as one of a paired set of positive magnetic anomaly belts running from the top of Northland as far south as Wanganui, with a single and disturbed positive anomaly belt extending further south to the Alpine Fault in the northern South Island. He argued that this strong magnetic anomaly in the eastern part of the Moutere Depression, Nelson, was due to the presence rocks of the Rotoroa Igneous complex.

Magnetic anomalies in the Marlborough, Nelson, Wanganui and Taranaki regions were mapped by Reilly (1971) and by Hunt and Syms (1975, 1976, 1977). The Wanganui and Marlborough aeromagnetic contour maps (Hunt and Syms 1976, Reilly 1971) indicate that the continuity of the JMA stops at ~40.4° with discrete ~8 km diameter, ~8 km spaced, high amplitude (~400 nT) anomalies continuing through to D'Urville Island. Transcurrent faulting associated with the Marlborough Shear Belt has probably disrupted the once continuous JMA in this region. The Taranaki and Wanganui magnetic anomaly maps of Hunt and Syms (1975, 1976) show a strong north-south orientated magnetic anomaly extending from the south Taranaki Bight through Mt Taranaki. Further south, work by Woodward (1975) and Woodward and Hatherton (1975) further defined the Stokes Anomaly System structure in the Southland and Nelson regions. The magnetic anomaly map of Hunt (1978) shows the continuous nature of the JMA between Patea and Kaitaia.

The work of earlier authors was well summarised by Hunt (1978) who identified two major belts within the Stokes Magnetic Anomaly System:

(i) a narrow (<10 km wide) 'Eastern Belt' of 100-200 nT positive magnetic anomalies. These anomalies are generally associated with rocks of the Dun Mountain Ophiolite Belt (JMA of Hatherton 1969 and other authors); and

(ii) a less well defined 10-100 km wide 'Western Belt' of 200-2000 nT positive anomalies situated 20-50 km west/southwest of the JMA. These anomalies are associated with basic igneous rocks of the Rotoroa Igneous Complex or their mafic-ultramafic intrusive equivalents (e.g. Longwood Complex, Anglem Complex).

The JMA in onshore Southland can be traced offshore to the southern member of an interpreted symmetric set of linear magnetic anomalies mapped by Davy (1989) in the Bounty Trough/Great South Basin area.

The Taranaki magnetic map (Hunt and Syms 1975) and the Cook oceanic series magnetic anomaly map (Davey and Robinson 1978) show that immmediately north of New Plymouth the anomaly trend extending into the New Caledonia Basin is north-northeast. Van der Linden (1967) and Hochstein (1967) showed that west of 170° E magnetic anomalies of a similar trend followed the West Norfolk Ridge and could be successfully modelled in terms of a basalt topography similar to the observed ridge topography. Seismic reflection profiles reported by Davey (1977) and Uruski and Wood (1991) trace the West Norfolk Ridge as far east as ~172° E. At this eastern limit it lies beneath ~ 1 km of sediment with little seafloor topographic expression. Further east it is not recognisable on seismic sections. The magnetic anomaly map of Davey and Robinson (1978) indicates however that the positive magnetic anomaly belt, modelled as sourced in the Norfolk Ridge further west, extends to the southeast as far as the continental shelf off the Waikato River mouth. A large (> 300 nT) positive magnetic anomaly follows the southwestern New Caledonia Basin floor, and terminates to the southeast against the continental shelf.

Anomalies immediately west of the North Island coast and north of 38.5° appear more discrete. These anomalies have been modelled by Hatherton *et al.* (1979) as being caused by large volcanic piles 5-6 km thick. Hatherton *et al.* noted that while the gravity/magnetic anomalies to the north of the Waikato River mouth (37.3° S) could be modelled satisfactorily by such volcanic piles, the high amplitude, broad magnetic anomalies to the south appeared to be sourced at much greater depth (>~ 5 km below sea level).

This paper will re-analyse the pattern of magnetic anomalies in the Nelson-Taranaki-Northland-New Caledonia Basin and Southland areas, particularly in the light of recently acquired offshore data in the Nelson-Taranaki-New Caledonia Basin area.

Data and Interpretation

Southland

Aeromagnetic data collected at a flight altitude of 3030 m along the flight lines shown in Figure 1 (Woodward 1975) are plotted in Figure 2 after subtracting the IGRF85 field (Barraclough 1988) from the measured total field.

The tracing of anomaly belts is necessarily a somewhat subjective process and use is made of a combination of continuity of anomaly strike, characteristic anomaly signature and anomaly strength. The positive anomalies shaded in Figure 2 are between the points of maximum anomaly gradient on either side of the identified anomaly belt.

Particular features of Figures 1 and 2 to note are:

(i) The magnetically quiet area north of the JMA. The JMA is close to the southern boundary of the Haast Schist.

(ii) The short wavelength of the JMA suggesting a source at shallow depth.

(iii) The JMA splits into two anomalies west of 168.5° E. The southern anomaly is noticeably the broader.

(iv) A strong anomaly, labelled as 'R' (Figure 1), associated with gabbro of the Longwood Range (Riddolls 1987).

(v) The anomaly intermediate between 'R' and the JMA can be traced with confidence from the southeast coast as far west as 168.5° E and only tentatively further west.

The shallow source for the JMA is supported by modelling (Figure 3) using the Werner deconvolution technique (Hsu and Tilbury 1977) along line AA' Figure 1. The technique models the observed magnetic field using a spectrum of either thin sheet source bodies or magnetic source interfaces within a specified depth range. Possible solution vertices are plotted as squares in Figure 3. The results indicate the source position is approximately at ground-level and corresponds to the exposed Dun Mountain Ophiolite Belt (Coombs *et al.* 1976) oceanic crust.

The southern boundary of anomaly 'R' coincides closely with that of the Median Tectonic Line (MTL) (Figure 4, Coombs *et al.* 1976). The MTL divides Lower Paleozoic Western Province rocks from the largely clastic/volcanoclastic Late Paleozoic-Mesozoic Eastern Province rocks. The Eastern Province rocks include Permian Brook Street volcanic arc and Permian Dun Mountain Ophiolite Belt oceanic crust (MacKinnon 1983). Mortimer (1990) has proposed relocating the MTL (northern line Figure 4) based upon the position of intrusions (largely Late Jurassic - Early Cretaceous Rotoroa Complex) which are not observed in Eastern Province rocks. Anomaly 'R' straddles this interpretation of the MTL.

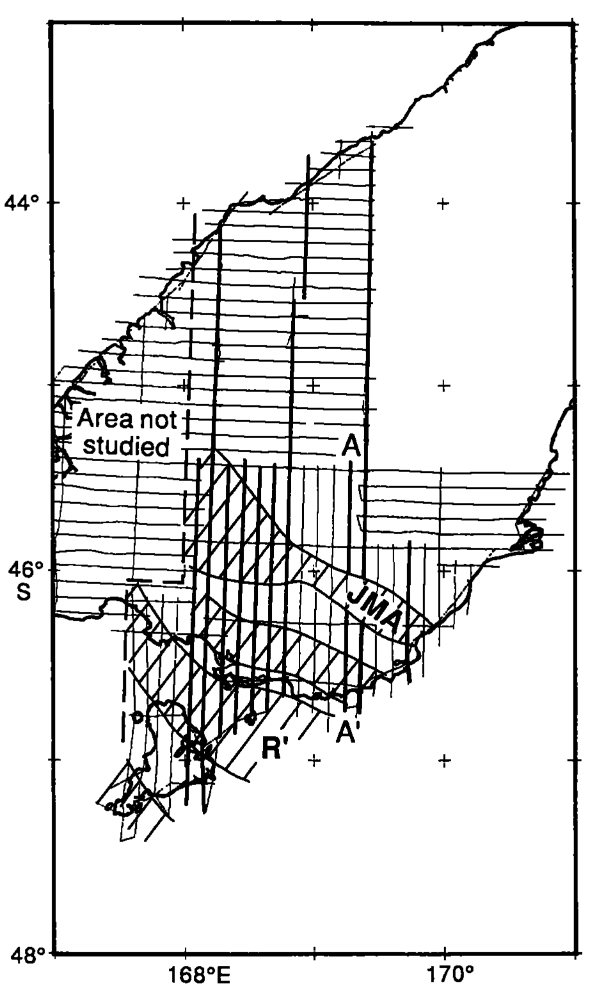

Figure 1: Aeromagnetic tracks and positive magnetic anomaly belts within the Southland region. Aeromagnetic data were collected at an altitude of 3030 m. Profiles west of the dashed line were not examined in this study. The Junction Magnetic Anomaly, JMA, and the high amplitude anomaly through Foveaux Strait, 'R', have been marked.

Nelson–Wanganui–Taranaki –Northland

The coverage of regional magnetic anomaly profiles over northern South Island and western North Island are shown in Figure 5. The magnetic anomaly profiles (Figure 6) are either aeromagnetic profiles overland, flown at 3030 m, or over sea, mostly marine data collected at sea level. The greater separation of the aeromagnetic measurements from the source rocks results in a loss of short wavelength information and lowers the resolution of the anomaly belt. This loss of resolution is particularly apparent in Nelson where several belts of anomalies have been tentatively identified although the merged nature of the anomalies on the aeromagnetic records makes the identification difficult.

Prominent positive magnetic anomaly belts, identified in a similar manner to those in Southland, have been traced (Figure 7). Several features are obvious in Figures 6 and 7.

(i) The lack of significant anomalies east of the interpreted JMA, apart from anomalies caused by the Ruapehu-Tongariro volcanic centre (lines FF' and HH') and the extinct arc volcanics of the Coramandel Peninsula (line BB'). These extinct volcanic arc derived magnetic anomalies occur in an otherwise magnetically quiet zone east of the JMA. This magnetically quiet zone correlates with schist or greywacke basement.

(ii) The short wavelength JMA can only be followed with confidence north of ~40.4° S (line EE' Figure 5). South towards D'Urville Island numerous short wavelength (<10 km) magnetic anomaly spikes are observable (e.g. P on Figure 6) but are not obviously JMA correlatives. A strong (>~200 nT) anomaly (marked by & in Figure 6), possibly caused by the Dun Mountain Ophiolite, occurs on the eastern flank of anomaly 'R' in the Nelson region. This possible JMA correlative occurs on most aeromagnetic lines in the Nelson region (Figure 6).

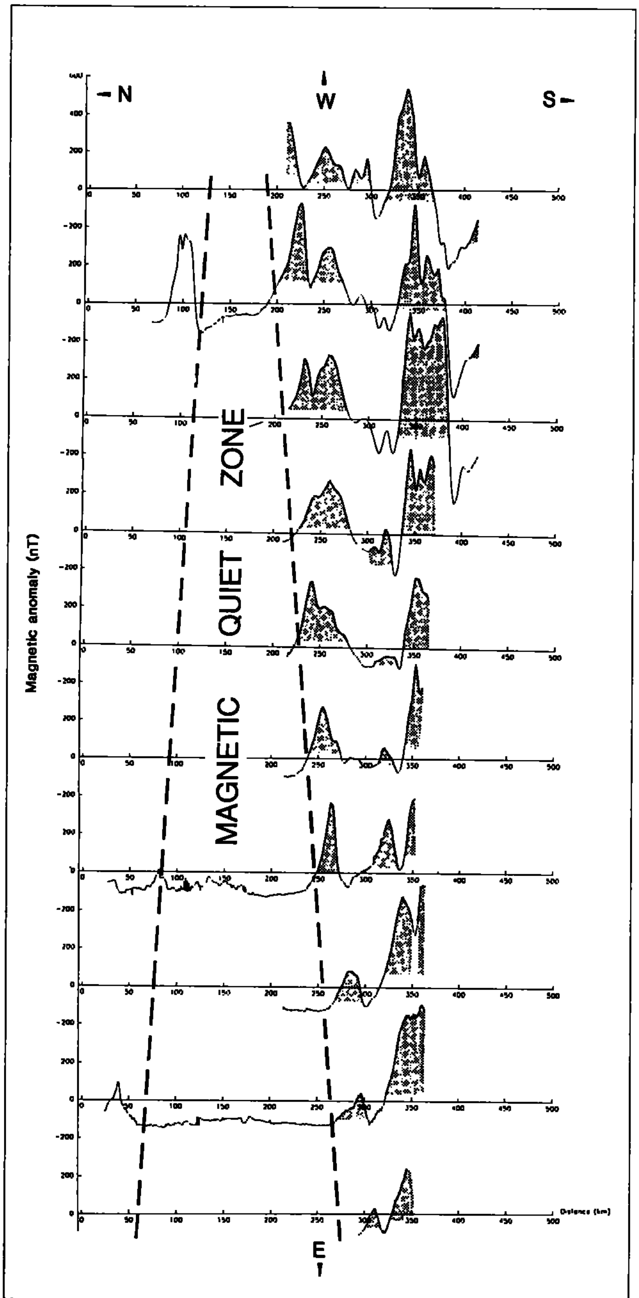

Figure 2: Total field magnetic anomaly profiles along tracks plotted in Figure 1. The areas of positive anomaly traced on Figure 1 have been shaded. The region of quiet magnetic anomaly (<~10nT) apparent from data, including profiles plotted, is indicated.

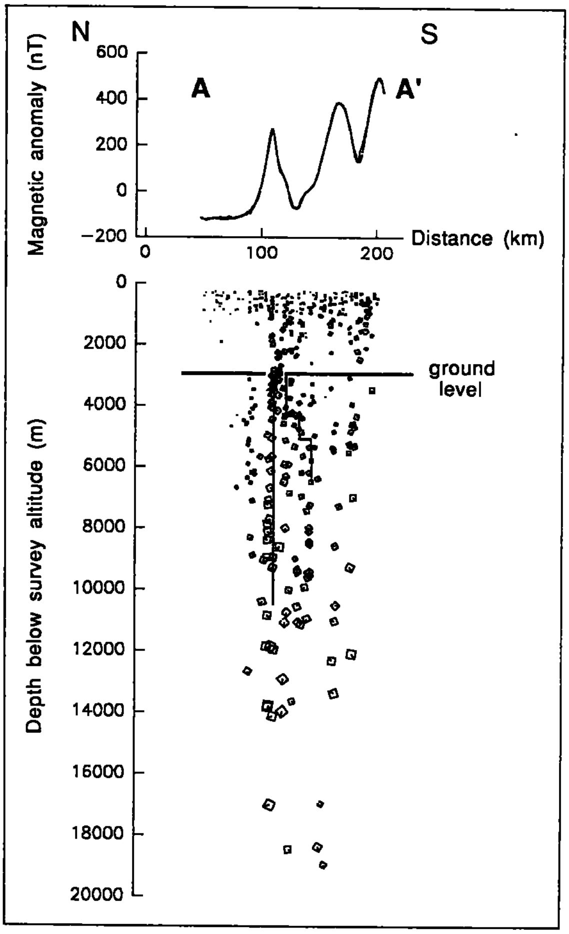

Figure 3: Werner deconvolution solution along profile AA', Figure 1, for line interface models producing the indicated magnetic anomaly. The solutions are derived using the techniques of Hsu and Tilbury (1977). The symbol size is proportional to the magnetisation of the solution and the clusters of symbols the location of magnetic body vertices in the solution. The degree of symbol clustering is a measure of the confidence in that solution.

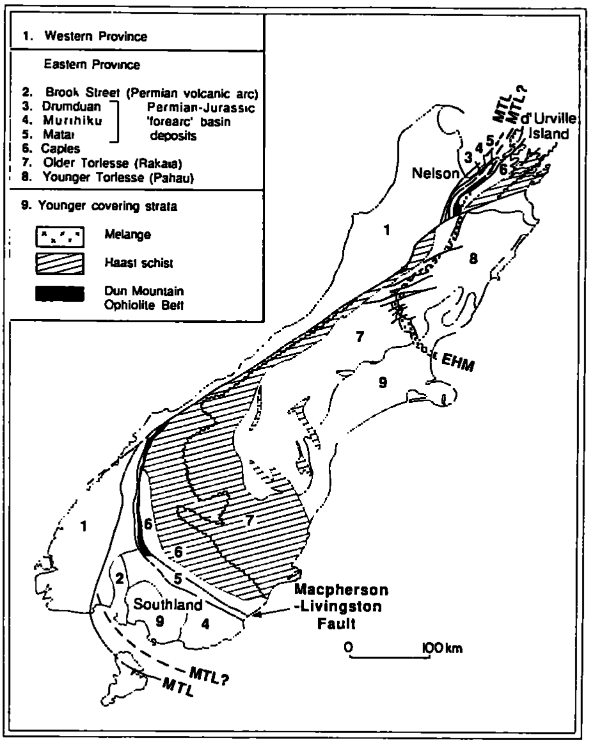

Figure 4: Geological map of the South Island modified from Bishopet al (1985) showing mapped terranes. The Median Tectonic Line (MTL) separates the Western Province rocks from the Eastern Province rocks. The uncertainty in the position of the MTL is indicated by the dashed alternative. The dark shaded area is the Dun Mountain Ophiolite Belt (Permian oceanic crust).

(iii) The anomaly pattern between Nelson and New Plymouth is dominated by the strong positive magnetic anomaly 'R', Figure 6, which passes from west of D'Urville Island to beneath Mt Taranaki. This anomaly is particularly strong north of 40.4° S(line EE', Figure 7) where it increases from ~200 nT to ~400 nT and it and adjacent anomalies appear to be right laterally shifted north of line AA'. A short wavelength (~20 km wide) 800 nT anomaly is attributable to the exposed Mt Taranaki volcano (line NN") and sits on top of the broader north-south tending 'R' anomaly.

(iv) Anomalies west of anomaly 'R' can be traced as far north as the dashed line DD' of Figure 7 where they are reduced in amplitude and similar north-south trending anomalies can be tentatively traced northwards to CC' (Figure 7). Between CC' (39°S) and 38.5° S there is insufficient data to trace anomalies with any confidence.

(v) Short wavelength (<~ 1 km), low amplitude (~10 nT) anomalies only occur on the shallow water eastern third of lines JJ', KK' and LL' and appear to increase in amplitude towards Mt. Taranaki, consistent with the magnetic anomaly source material in the shallow sedimentary section being at least partly volcanic derived.

Correspondence of magnetic anomalies and basement structure

Figure 8 shows the association of mapped magnetic anomalies, onshore geological terranes (Riddolls 1987) and petroleum well basement stratigraphy (Mortimer *et al.* 1991). The correspondence between the mapped magnetic anomalies and the basement terranesis poor. In onshore Nelson (at ~ 41.8°S), anomaly 'R' appears to overly the Rotoroa Igneous Complex. At the Tasman Bay coast and in Maui-2 the interpreted Rotoroa Igneous Complex basement lies within the magnetic anomaly to the west of 'R'. Similarly petroleum wells penetrating interpreted Separation Point Granite terrane do not appear spatially correlated with the anomaly pattern, with occurences ranging from the western edge of anomaly 'R' to 100 km west of anomaly 'R'. In the onshore North Island the JMA is interpreted as coincident with the Dun Mountain/Maitai Terrane, separating the magnetically quiet Torlesse greywackes and schist from the Murihiku group rocks. In the Nelson region much of the mapped onshore Dun Mountain Ophiolite falls within the range of the high amplitude 'R' anomaly. As mentioned earlier a distinct JMA may however be indistinguishable from anomaly 'R' due to the resolution of the aeromagnetics.

The similarity in strength and position (with respect to the JMA) of anomaly 'R' in Southland (Figure 1) and anomaly 'R' through Taranaki suggests that the Median Tectonic Line lies immediately west of anomaly 'R' in Taranaki—i.e. aligned north-south close to Cape Egmont. Such positioning is consistent with a Median Tectonic Line identified on the basis of the boundary between the largely Paleozoic sedimentary rocks of the Western Province and the Permian–Mesozoic sedimentary rocks of the Eastern Province. There is however an absence of exposed Paleozoic–Mesozoic sedimentary rocks within the Moutere Depression and locating the Median Tectonic line east of observed Rotoroa Complex rocks (Mortimer 1990) would locate the MTL within anomaly 'R', along the eastern Tasman Bay coast and immediately east of Mt Taranaki further north.

The pattern of anomalies in the Taranaki area has a moderate degree of correspondence with the pattern of faulting within the basement (Figure 9 Thrasher and Cahill (1990)) suggesting that some of the anomaly signature may be due more to topographic structure on the magnetic basement than any spatial variation in basement magnetisation. Magnetic modelling (Figure 10) along profile XX' (Figure 5) using a point source Werner deconvolution solution indicates that the large anomaly sources appear to be within the interpreted basement (Thrasher and Cahill (1990)) - many of them with upper surfaces within ~ 1 km of the basement surface. The solutions and magnetic modelling (Figure 11) also indicate that magnetic anomaly, H', is due principally to magnetic basement high H'. The ~4 km throw on the Taranaki Fault however does not appear to produce any correlatable magnetic anomaly signature corresponding to any similar shallowing of the magnetic basement. Shallow low amplitude point source solutions on the eastern third of XX' (Figure 10) correspond to the shallow volcanic flows from Mt Taranaki mentioned earlier.

Simple 2-dimensional magnetic modelling (Figure 11) using uniformly magnetised basement morphology (Thrasher and Cahill (1990)) provides a poor correlation with the observed magnetic anomaly, although basement high H can be modelled reasonably well with a magnetisation of 2.0 A/m. The JMA can be modelled reasonably by an intrabasement magnetised body also of 2.0 A/m as shown in Figure 11. A wide variety of bodies can be chosen which would equally well model the observed anomaly and the Werner deconvolution solution, Figure 10, suggests two bodies with magnetisation of 4.5 and 3.7 A/m, close to the

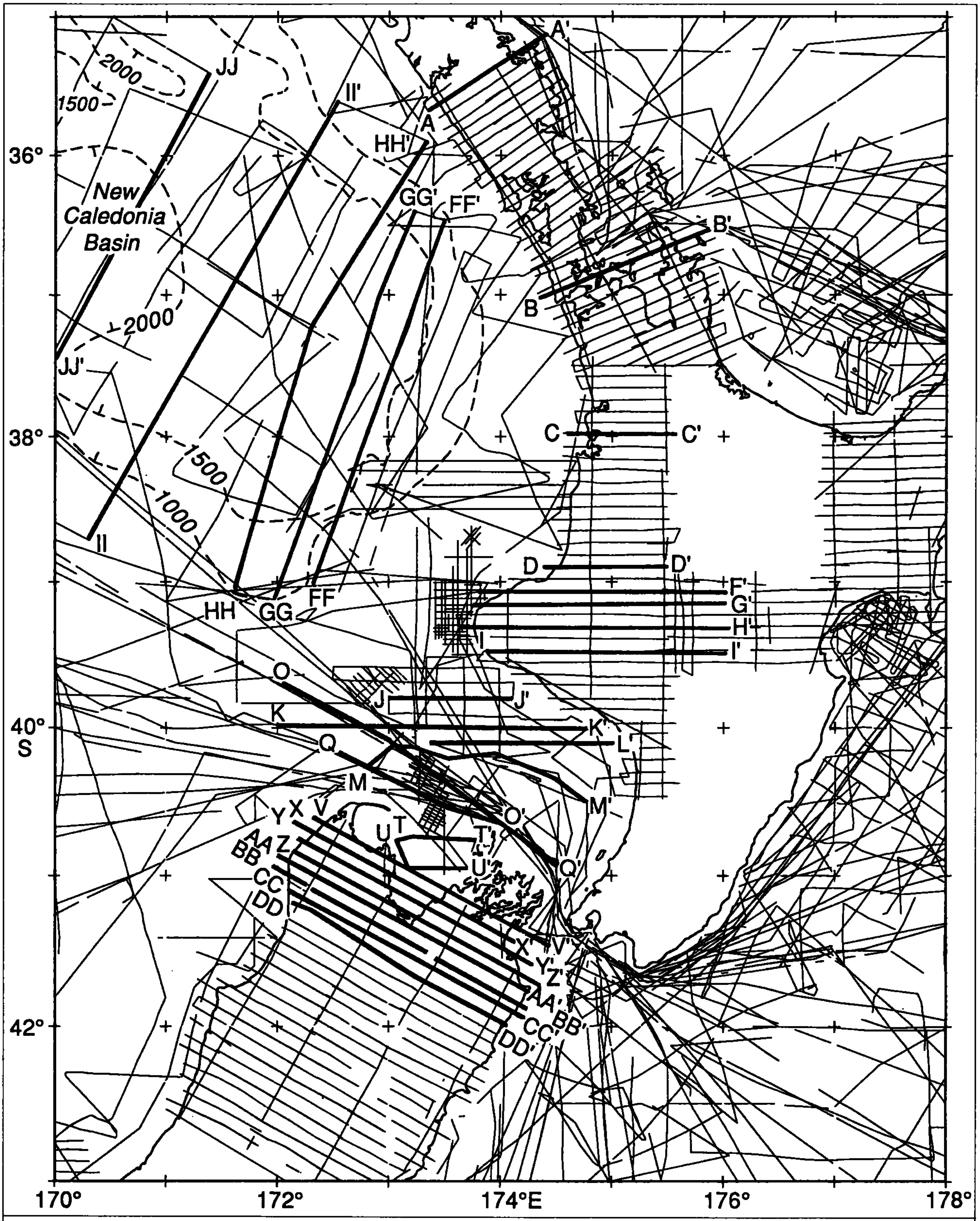

Figure 5: Magnetic anomaly tracks examined in this study. Magnetic profiles between Nelson and Northland along the highlighted tracks are shown in Figure 6. Tracks over land are aeromagnetic data collected at an altitude of 3030 m. The remaining tracks are marine magnetic data.

basement surface, which model well the large 'R' magnetic anomaly. These high magnetisation values indicate that source rocks for the strong magnetic anomaly are gabbro (or possibly diorite) of the Rotoroa Igneous Complex or ultramafic peridotite or serpentine rocks of the Dun Mountain Ophiolite Belt (Table 1, Mumme 1985).

The magnetic anomaly belt between the JMA and anomaly 'R' in the Taranaki - Waikato area corresponds approximately with the Patea-Tongapurutu High basement horst. Two dimensional magnetic models using uniformly magnetised basement topography inferred from the gravity models of Mills (1991) produce a poor match with the observed anomaly, Figure 12. Basement beneath the JMA was modelled as an uplifted block to tie with the uplifted block

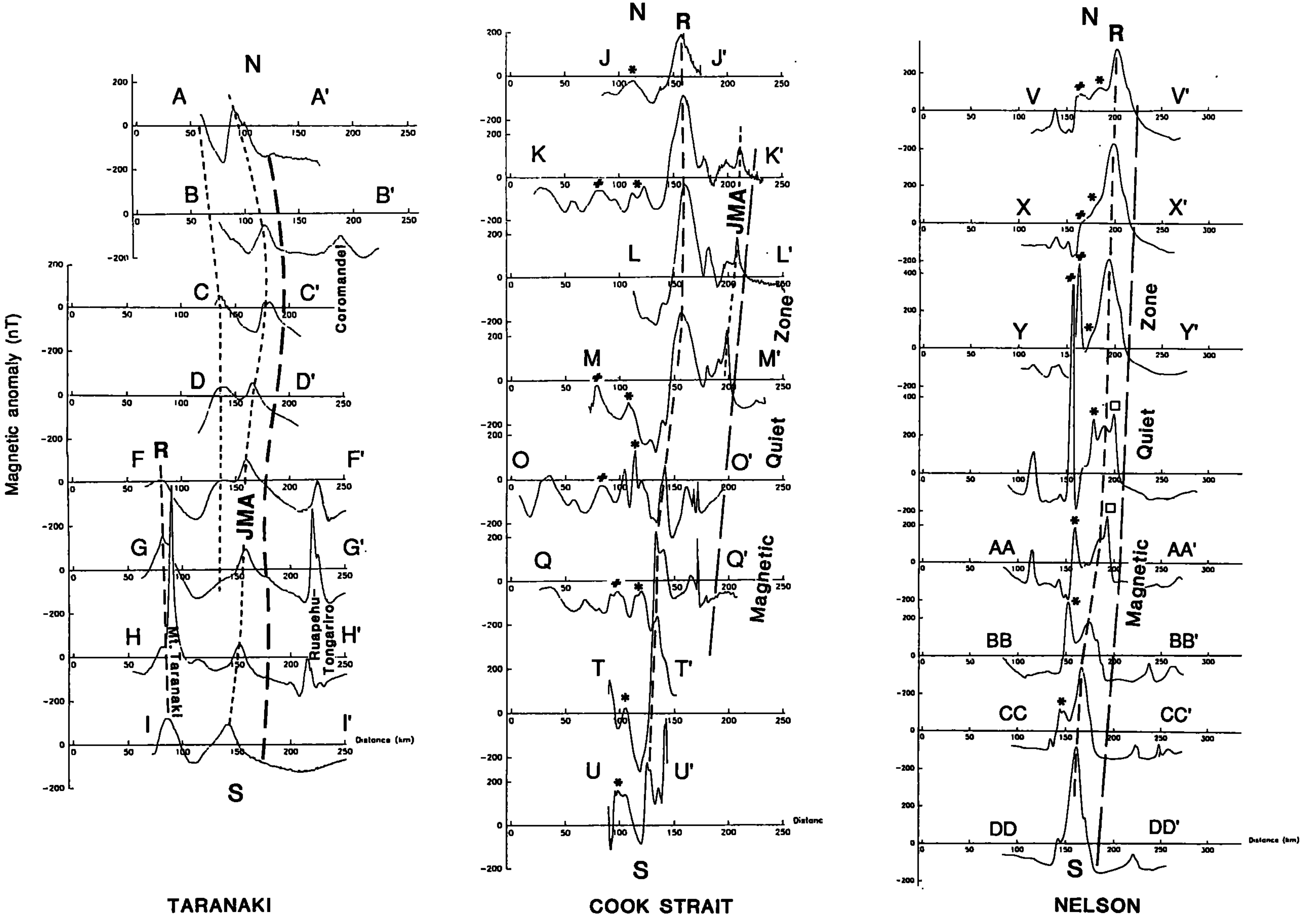

Figure 6: Magnetic anomaly profiles along tracks highlighted in Figure 5. The strong anomaly 'R' and the JMA have been highlighted. Additional anomaly belts have been tentatively identified and labelled as #, *, and 0. The region of quiet magnetic anomaly (<~10nT) apparent from data, including profiles plotted, is indicated.

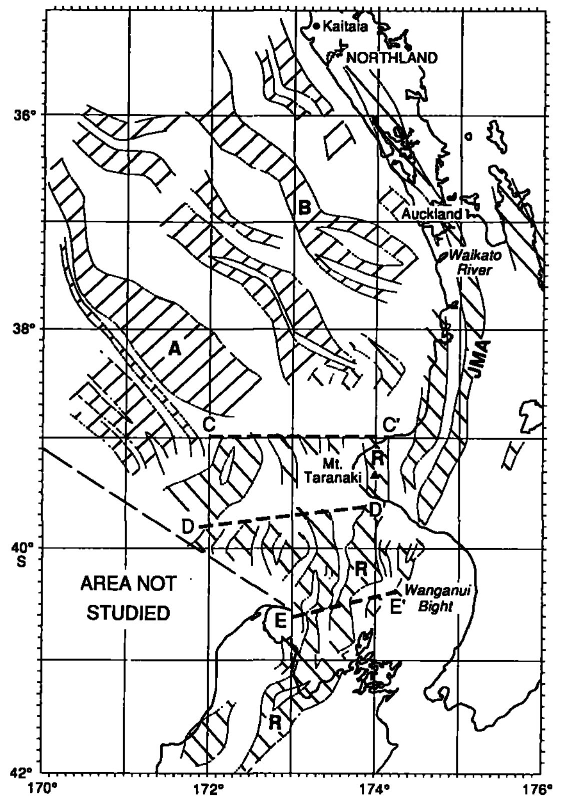

Figure 7: Positive magnetic anomaly belts traced from the data in Figure 5. The offshore area southeast of the dashed line was not examined in this study.

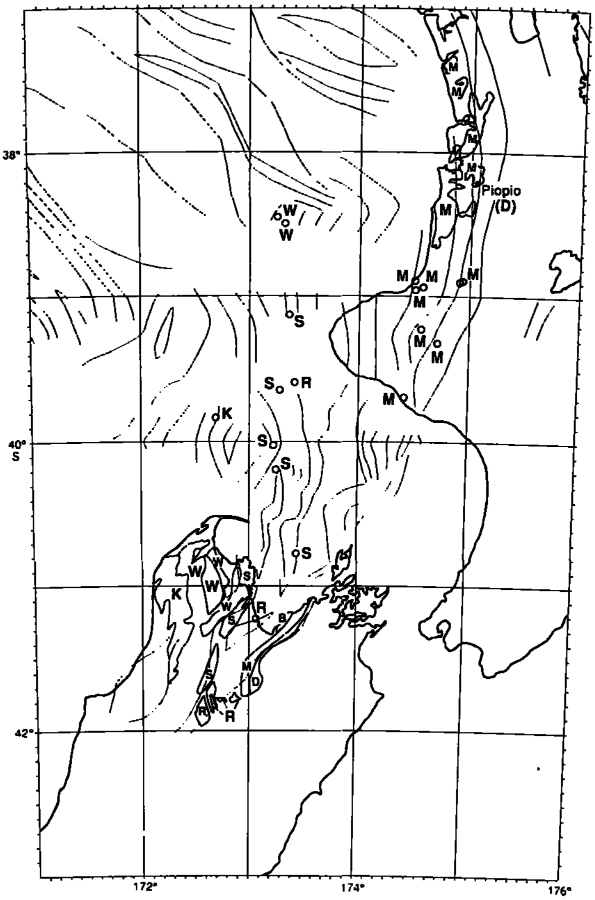

Figure 8: Magnetic anomaly pattern and basement terranes. The magnetic anomaly boundaries are marked similarly to Figure 7. Circles mark petroleum wells with the interpreted basement typelabelled beside each well. Basement Terranes are; Karamea Granite - K, Western Province sedimentary - W, Separation Point Granite - S, Rotoroa Igneous Complex - R, Brook Street Volcanics - B, Dun Mountain Ophiolite Belt - D, Murihiku Terrane - M (Johnston 1990).

suggested by the gravity model (Mills 1991) and in recognition of the surface exposure of Dun Mountain Ophiolite Belt rocks (a probable serpentine diapir) at Piopio (Figure 8) and in Nelson and Southland. The Patea-Tongaporutu High shows no particular correlation with the magnetic anomaly signature. By choosing an even more finely divided shallow magnetic source rock structure a better fit could be obtained. Figure 13 illustrates, however, that a good fit can be obtained using three comparatively simple structures located somewhat deeper. The comparative simplicity of such a model favours it over the required complexity of shallower structures. The magnetisation of ~3.0 A/m required by the deeper model suggests from Table 1 that the source rocks are either gabbro or ultramafic rocks. All of the models presented have involved magnetisation parallel to the Earth's present magnetic field as would be characteristic of induced magnetised bodies. Most of the highly magnetic minerals (Table 1) proposed as source rocks for the observed anomalies have large remanent magnetisation and the observed anomalies can be equally well modelled by a mixture of normal and reversely magnetised bodies of similar dimensions to those presented above.

New Caledonia Basin

Magnetic anomalies collected across the New Caledonia Basin are shown in Figure 14. Two belts of high amplitude (~200 and ~400 nT) magnetic anomalies, labelled 'A' and 'B' are traceable for ~250 km parallel to the axis of the New Caledonia Basin (Figure 7). The magnetic anomaly signature is very distinct throughout this distance. Parallel trending anomalies are observed between 'A' and 'B' but are not as continuous and are more tentatively identified and traced. Magnetic anomalies 'A' and 'B' occur on the slopes either side of the New Caledonia Basin. Modelling indicates, however, that the anomalies are not simply edge effects from magnetic sheets either side of the New Caledonia Basin. The northern 'B' set of anomalies are an eastward extension of the magnetic anomalies modelled as sourcedin the Norfolk Ridge by Hochstein (1967). Although the Norfolk Ridge is not apparent on seismic sections east of 172° E the anomalies are most likely sourced in an eastward continuation of this ridge buried beneath at least 2 km of sediment.

Uruski and Wood (1991) favoured a model of New Caledonia Basin development as an intra-continental rift with no evidence of sea-floor spreading. Their best estimate for the period of development was Cretaceous. The evidence of the magnetic anomalies presented here, by their trend clearly associated with New Caledonia Basin development, suggests that rifting reached a more advanced stage than envisaged by Uruski and Wood. Although there is no unambiguous evidence of symmetric anomalies in the New Caledonia Basin the anomalies intermediate between 'A'

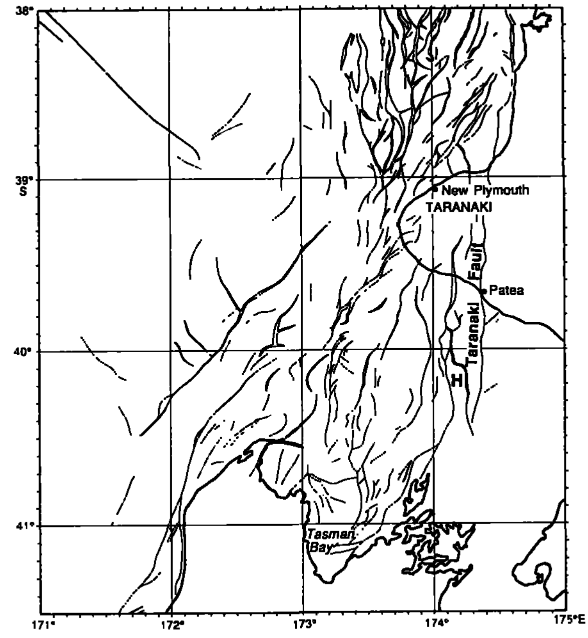

Figure 9: Basement fault pattern in the Taranaki region, from Thrasher and Cahill (1990). 'H' marks a fault-bounded basement high examined later.

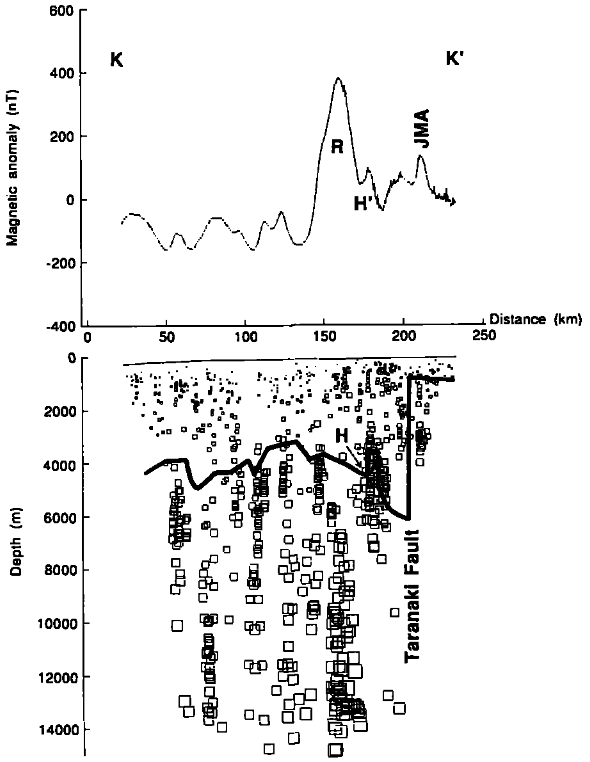

Figure 10: Werner deconvolution solution for point source models producing the indicated magnetic anomaly along line KK' Figure 5. The solutions are derived using the techniques of Hsu and Tilbury (1977). Basement depths from Thrasher and Cahill (1990) have been marked on the cross-section.

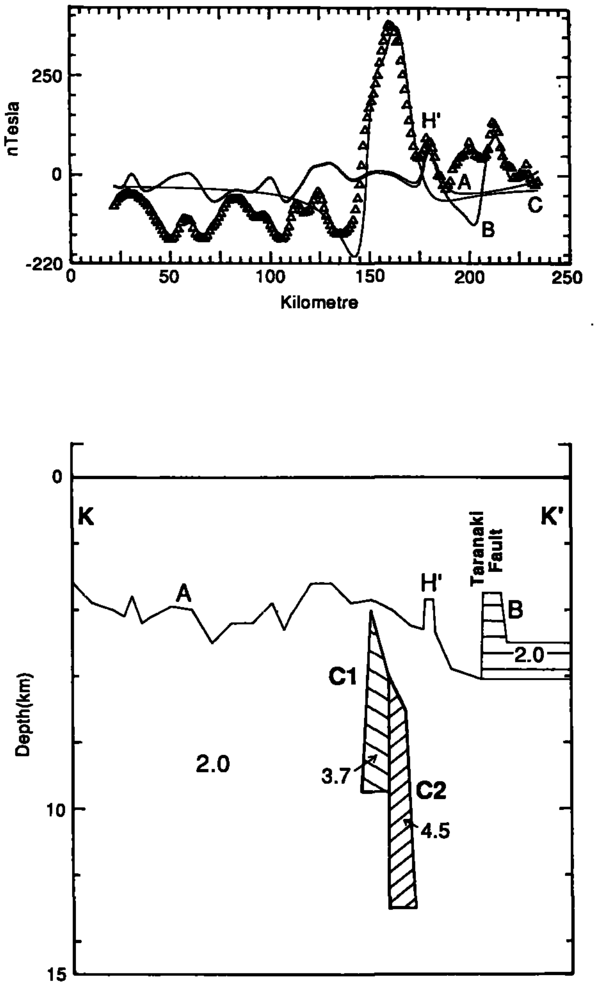

Figure 11: Two dimensional magnetic anomaly models along line KK' Figure 5. All modelled magnetisation is parallel to the Earth's field with the amplitude of magnetisation as labelled. Model A comprises a magnetic body with an upper surface which follows the mapped basement of Thrasher and Cahill (1990) except to the east of the Taranaki Fault (TF) where the modelled body remains 6km below sealevel. Model B is identical to model A only incorporating the shaded basement high east of the Taranaki Fault. Model C calculates the anomaly due to bodies C1 and C2 alone. Triangles indicate measured anomaly values and the solidline the computed model anomaly.

	Remnant	Induced
Andesite (Takitimu)	0.2-1.0	~3.0
Granite (Separation Point)	1.0-2.0	0.1-0.3
Diorite (Darran Diorite)	0.3-1.5	0.1-4.0
Diorite (Rotoroa Complex)	0.1-2.0	0.01-2.0
Gabbro (Darran Diorite)	1.5-115.0	2.0-3.0
Gabbro (Rotoroa Complex)	0.5-5.0	0.2-10.0
Basalt (Brook Street)	0.7-2.0	0.1-3.0
Peridotite (Red Mountain)	0.1-6.0	0.1-2.0
Serpentine (Red Mtn, Dun Mtn)	0.1-4.0	0.5-9.0

Table 1: Rock magnetisation (A/m).

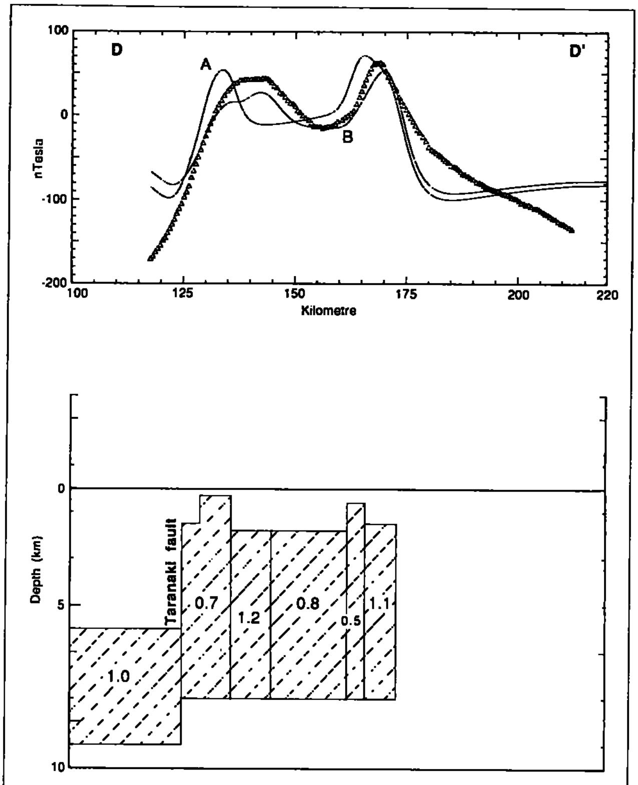

Figure 12: Two dimensional magnetic models along line DD', Figure 5. Model A: the basement, within the area shaded, has been modelled as uniformly magnetised parallel to the Earth's field with 1.0 A/m magnetisation. Model B: the intensity of magnetisation has been varied as indicated. Basement taken from Mills' (1991) model. Triangles indicate measured anomaly values and the solid line the computed model anomaly.

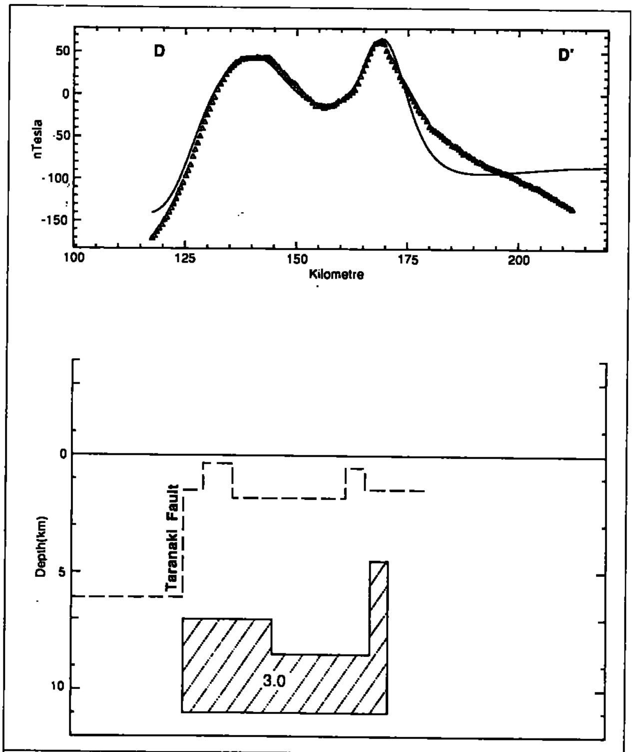

Figure 13: A two dimensional magnetic model along line DD', Figure 5, with a magnetisation of 3.0 A/m parallel to the Earth's field in the body shown. The basement surface is shown dashed.

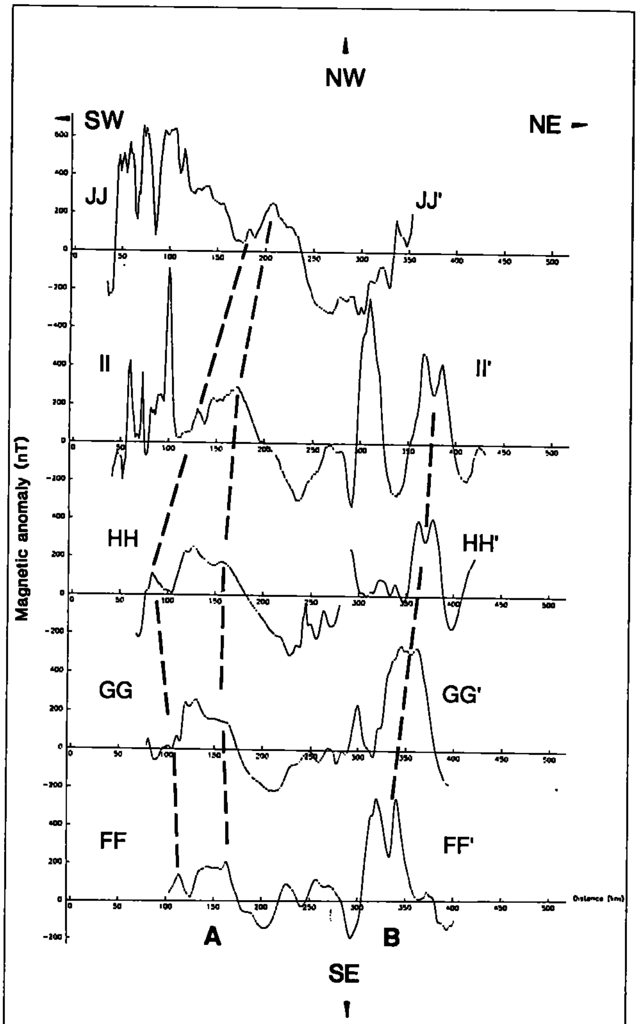

Figure 14: Magnetic anomaly profiles across the New Caledonia Basin along the tracks highlighted by heavy lines in Figure 5. Prominent traceable magnetic anomalies are indicated.

and 'B' may be the initial anomalies in such a seafloor spreading anomaly set. Anomaly belt 'A' is suggested to correspond to marginal oceanic rift anomalies similar to those observed at the Atlantic rifted margins (e.g. the East Coast Magnetic Anomaly, Grow and Sheridan 1981). Further detailed magnetic and gravity surveying in this region promises considerable resolution of the nature of New Caledonia Basin development.

Conclusions

The continuity of magnetic anomalies within the New Zealand region is greater than previously documented. The mapping of these anomalies, particularly the more characteristic, and easily traceable anomalies (JMA, 'R', 'A' and 'B') provides an important framework within which the tectonic development models must fit. Anomaly 'R' provides some constraint on the Median Tectonic Line position, anomalies 'A' and 'B' constrain developmental models of the New Caledonia Basin, and the JMA constrains the position of the up-faulted block of oceanic crust (the Dun Mountain Ophiolite Belt). Modelling of most of the above anomalies suggests they are sourced in highly magnetised rocks (> 3.0 A/m) such as Rotoroa Complex gabbro or ultramafic rocks.

References

BARRACLOUGH, D. R. 1988: Special Report on the International Geomagnetic Reference Field Revision 1987, IAGA Division I, Working Group 1. Geophysics 576.

BISHOP, D. G., BRADSHAW, J. D. & LANDIS, C. A. 1985: Provisional terrane map of the South Island, New Zealand. In - Howell, D. G., Tectonostratigraphic terranes of the Circum-Pacific region. Circum Pacific Council for Minerals and Energy, Houston, Texas. 515-512.

COOMBS, D. S., LANDIS, C. A., NORRIS, R. J., SINTON, J. M., BORNS, D.J. & CRAW, D. 1976: The Dun Mountain Ophiolite Belt, New Zealand : Its tectonic setting, constitution and origin with special reference to the southern portion. American Journal of Science. 276: 561-603.

DAVEY, F. J. 1977: Marine seismic measurements in the New Zealand region. New Zealand Journal of Geology and Geophysics 20:719-777.

DAVEY F. J. & ROBINSON, A. G. 1978: Cook (1st Ed.) 'Magnetic Total Force Anomaly Map, Oceanic Series, 1:1000000'. Department of Scientific and Industrial Research, Wellington, New Zealand.

DAVY, B. W. 1989: Magnetic anomalies of the New Zealand region. New Zealand Geology and Geophysics conference 1989- Programme and abstracts.

GERARD, V. B. & LAWRIE, J. A. 1955: Aeromagnetic surveys in New Zealand 1949-1952. New Zealand Department of Scientific and Industrial Research Geophysical Memoir 3.

GROW, J. A & SHERIDAN, R. E. 1981: Deep structure and evolution of the continental margin off the eastern United States. in Geology of Continental Margins, Oceanologica Acta.

HATHERTON, T. 1966: A geophysical study of the Southland Syncline. New Zealand Department of Scientific and Industrial Research Bulletin 168.

HATHERTON, T. 1967: A geophysical study of the Nelson-Cook Strait region. New Zealand Journal of Geology and Geophysics 10: 1330-1347.

HATHERTON, T. 1969: Geophysical anomalies over eu- and miogeosynclinal systems of California and New Zealand. Geological Society of America Bulletin 80: 213-230.

HATHERTON T. 1975: Stokes Magnetic Anomaly - Magnetic System orMagnetic Supergroup? New Zealand Journal of Geology and Geophysics 18:519-521.

HATHERTON, T., SIBSON, R. H 1970: Junction Magnetic Anomaly north of Waikato River. New Zealand Journal of Geology and Geophysics 18: 519-521.

HATHERTON, T., DAVEY, F. J. & T. M. HUNT 1979: Geophysical anomalies and igneous bodies off the West Coast, North Island. Journal of the Royal Society of New Zealand 9:13-28.

HOCHSTEIN, M. P. 1967: Interpretation of magnetic anomalies across Norfolk Ridge. New Zealand Journal of Geology and Geophysics. 10:1302-8.

HSU, H. D. & TILBURY, L. A. 1977: A magnetic Interpretation Program based on Werner Deconvolution. 1977/50, Bureau of Mineral Resources, Geology and Geophysics, Department of National Resources, Australia.

HUNT T. 1978: Stokes Magnetic Anomaly System. New Zealand Journal of Geology and Geophysics 21: 595-606.

HUNT, T. M. & SYMS, M. C. 1975,1976 and 1977: Sheets 7 Taranaki, 4 Hamilton, 10 Wanganui, 2 Whangarei, 3 Auckland. "Magnetic Map of New Zealand, 1:250,000". New Zealand Department of Scientific and Industrial Research, Wellington.

JOHNSTON, M. R. 1990: Sheet N29 - St Arnaud. Geological map of New Zealand 1: 50 000. Map (1 sheet). Wellington, New Zealand, Department of Scientific and Industrial Research.

MACKINNON, T. C. 1983: Origin of the Torlesse terrane and coeval rocks, South Island, New Zealand. Geological Society of America Bulletin 94: 967-985.

MILLS, C. 1991. Gravity Expression of the Patea-Tongaporutu High and subsequent model for the Taranaki Basin Margin. Proceedings of the 1989 New Zealand Oil Exploration Conference.

MORTIMER, N. 1990: A quick look at the basement. Petroleum Exploration in New Zealand Newsletter, September 1990.

MORTIMER, N., BEGGS, J. M., DAVY, B. W., TULLOCH, A. J. & G. THRASHER 1991: Geometry of basement terranes beneath Taranaki and Wanganui Basins. New Zealand Geological Society Conference 1991.

MUMME, T. C. 1985: A catalogue of physical properties of rocks. Supplementary Volume 3. Catalogue Numbers 7401-9794. Geophysics Division, DSIR, Wellington.

REILLY, W. I. 1971: Sheet 14 Marlborough Sounds. "Magnetic Map of New Zealand, 1:250,000, Total Force Anomalies". New Zealand Department of Scientific and Industrial Research, Wellington.

RIDDOLLS, P., M. 1987: New Zealand geology. Geological map of New Zealand, 1:2 000 000. Wellington, New Zealand. Department of Scientific and Industrial Research.

THRASHER, G. P. & CAHILL, J. P. 1990: Subsurface maps of the Taranaki Basin, New Zealand 1: 500 000. New Zealand Geological Survey Report G-142, NZ DSIR, Wellington.

URUSKI, C. & WOOD, R. 1991:,Structure and Stratigraphy of the New Caledonia Basin. Exploration Geophysics 22, 411-418.

WELLMAN, H. W. 1959: Geological interpretation of airborne magnetometer observations from Nelson to Waikato River, New Zealand. Geological Magazine, London. 94:118-124.

WELLMAN, H. W. 1973: The Stokes Magnetic Anomaly. Geological Magazine, London. 110: 419-429.

WOODWARD, D. J. 1975: Sheets 19 Haast, 22 Wakatipu, 24 Invercargill, 25 Dunedin , 26 Stewart Island, 27 Fiordland. "Magnetic Map of New Zealand, 1:250,000". New Zealand Department of Scientific and Industrial Research, Wellington.

WOODWARD, D. J. & HATHERTON, T. 1975: Magnetic anomalies over southern New Zealand. New Zealand Journal of Geology and Geophysics 18: 65-82.

Author

BRYAN DAVY is a marine geophysicist with the DSIR Geology and Geophysics. He has a Ph.D in geophysics from Newcastle upon Tyne.

Bryan is involved in most aspects of regional marine, inshore and freshwater geophysics from equipment design and construction to data acquisition, processing and interpretation. He has frequently acted as Project Leader in the many scientific and commercial investigations he has undertaken.