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INTERPRETATION OF AEROMAGNETIC DATA OVER THE MAUNGAONGAONGA GEOTHERMAL PROSPECT

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Abstract

The Maungaongaonga area is located about 15 km SE of Rotorua, North Island, New Zealand. It is located inside a large thermal zone covering the Waiotapu, Waimangu, Waikite geothermal fields which has the largest total area of surface thermal activity in the Taupo Volcanic Zone (TVZ). The Maungaongaonga area was covered by a low-level (760 m a.s.l.) conducted in 1993. 3-D topographic modelling of the residual aeromagnetic anomalies suggest that most of the rocks forming the Maungaongaonga dome have been affected by hydrothermal demagnetization. The residual anomalies also indicate the presence of concealed non magnetic bodies (hydrothermally demagnetized rocks) below the base of the dome.

1. Introduction

The Maungaongaonga area is located about 15 km southeast of Rotorua, North Island, New Zealand. The study area lies within the NZ Map grid coordinates 2798500 to 2807000 (Easting) and 6311000 to 6319000 (Northing) and included in the NZMS 1:50,000 series sheets U-16 Rotorua and U-17 Wairakei. It covers an area of about 68 km^2. Geomorphology of this area is generally characterized by a rather steep terrain (medium to high relief). The highest peak is that of Mt. Maungaongaonga which is about 825 m above sea level (a.s.l.) The area surrounding Mt. Maungaongaonga has a mean elevation of 500 m (a.s.l) (see Figure 3). The study area is situated within a large thermal region covering the Waiotapu, Waimangu and Waikite geothermal fields on the eastern side of Taupo Volcanic Zone (Figure 1). This thermal region is associated with an elongated resistivity low extending in the NE-SW direction, where a wide variety of surface thermal phenomena are more or less enclosed by 30 Ω-m contour of Schlumberger AB/2 = 1000 m apparent resistivity (Bibby, et. al, 1994) (Figure 2).

The purpose of this magnetic study is to interpret airborne magnetic anomalies in terms of topographic effect and thermal alteration of rocks in the vicinity of Maungaongaonga dacite dome. The interpretation of the airborne magnetic anomalies (topographic modelling and 3-D modelling of concealed hydrothermally demagnetised bodies) was conducted along three S-N profiles over Mt. Maunga-ongaonga as shown in Figures 2 to 11.

2. Airborne Magnetic Survey of Maungaongaonga Geothermal Prospect

2.1. Review of Airborne Magnetic Methods Used in Geothermal Exploration

Airborne magnetic method has been applied as an exploration tool to investigate the structure of a number of geothermal prospects in New Zealand and elsewhere. The target of magnetic surveys for geothermal study is hydrothermally altered rocks at upper

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level of geothermal reservoir forming a demagnetized zone which normally has a significant magnetisation contrast with respect to the surrounding unaltered volcanic rocks.

Over the Taupo Volcanic Zone (TVZ) the airborne magnetic data show an association between most of geothermal fields and magnetic lows (Soengkono and Hochstein, 1996). This phenomenon can be explained by a reduction in the intensity of magnetization of reservoir rocks by the action of hydrothermal fluid (i.e. hydrothermal demagnetization) which alters the primary minerals such as magnetite, titanomagnetite and other ferrimagnetite minerals to non-magnetic minerals such as hematite, pyrite, leucoxene and sphene causing the reservoir rock to become partially or totally demagnetized (Browne, 1982). The demag-netization causes a contrast in magnetic properties between rock within a geothermal reservoir and the surrounding unaltered volcanic rocks. This phenomena was observed, for example, over Mokai and Orakeikorako geothermal fields (Soengkono, 1985, 1993), Broadlands-Ohaaki field (Henrys and Van Dijck, 1987) and also at Rotokawa (Risk, 1985).

Airborne magnetic surveys can be used to quickly investigate a large prospect area with access problem. Therefore, it is one of the cheapest geophysical methods in term of areal coverage (Hochstein, 1982). The geology condition of the area studied and some other existing scientific data which include the magnetization, magnetic declination and inclination need to be considered in the interpretation.

2.2. Interpretation of Aeromagnetic Data Over the Maungaongaonga Geothermal Prospect

Maungaongaonga area which is located within the Waiotapu-Waimangu geothermal area was included in an aero-magnetic survey conducted in 1993 (Soeng-kono and Hochstein, 1996) at a nominal flight altitute of 760 m (a.s.l). For this study, the aeromagnetic data were gridded at 500 metres spacing for contouring. Figure 2 shows the contour map of the residual magnetic anomalies over the study area. There is a low negative anomaly (anomaly A) located at the center of study area surrounded by some positive anomalies and negative anomalies. Others strong negative anomalies (anomalies B, C and D with values lower than -200 nT) also occur in the NW, SW and SE parts of the study area.

2.2.1. Magnetic Modelling of Topography

Theoretical 3-D magnetic topo-graphic effect of Maungaongonga area was computed by using MAGTOPO program (written by Soengkono in 1987) based on magnetic modelling algorithm of Barnett (1976). The topographic model of the sudy area was constructed by digitizing NZ's topographical map sheets U-16 and U-17 (1:50,000 scale) using a grid spacing of 500 m (re-contoured in Figure 3). The theoretical topographic effects were computed by using a constant mag-netization of 1.7 A/m which is the average magnetisation of normally magnetised volcanic rocks in the TVZ (Soengkono, 1990); it has a declinations of 0^0 and inclinations of -62.5^0; i.e. the same as the mean direction of magnetization of the volcanic rocks formed during the Brunches normal polarity epoch in the Taupo Volcanic Zone (Cox, 1971).

2.2.2. Interpretation of Topographic Effect

Figure 4 shows the contour map of theoretical magnetic effect of topography over the study area (at 760 m a.s.l) computed at 500 m spacing. A comparison between the computed topographic effects (Figure 4) and the observed residual data (Figure 2) shows that positive theoretical topographic effect of the Maungaongaonga dacite dome were not observed. This indicates that the dacite dome is non magnetic, ie. it has been affected by thermal demagnetisation. The presence of negative residual anomalies in the vicinity of

Maungaongonga (anomalies A, B, C and D in Figure 2) suggest that non magnetic rocks also occur at deeper levels.

The lack of correlation between theoretical topographic effect and the observed data can be seen more clearly along three profiles shown in Figures 6,8 and 10. It can be seen in these three figures that the amplitude of the observed data and that of the computed anomalies over the Maunga-ongaonga are in opposite sign, indicating that there are hydrothermally demagnetised rocks (altered rocks) beneath this area.

2.2.3. Interpretation of Concealed Magnetic Bodies

Quantitative interpretation of concealed anomalous bodies was made using a trial and error approach. A set of simple 3-D models was constructed with various lateral extents and shapes in order to obtain the best fit between the computed magnetic effects and the observed residual anomalies. The computation of magnetic effects of the 3-D bodies were also made using the 3-D magnetic modelling algorithm of Barnett (1976). The 3-D body was represented by polyhedrons composed of triangular facets. The body is characterized by a top, a bottom and a number of slices.

The computation was performed on the IBM compatible PC using the MAGPLH program (written by Soengkono in 1987). The same magnetization value of 1.7 A/m (with declination of -62.5^0 and inclination of 0^0) as that used for the topographic modelling (see Section 2.2.1) was also used for the average magnetisation of the unaltered volcanic rocks outside demagnetized rocks. All anomaly values were computed at actual flight height.

2.3. Result and Discussion

Because of time constraint, detailed modelling was only made along three flight lines (lines 1, 2 and 3 in Figure 2). Therefore, the lateral extent of the models to the west of line 3 and to the east of line 1 is not very well controlled by the quantitative interpretation.

The best fit magnetic model is shown in Figure 5. It consists of two bodies of demagnetized rocks together with two highly magnetised bodies. One demagnetizes body and one highly magnetised body lie outside the resistivity boundary to the NW direction.

The observed and the best fit computed anomalies along lines 1, 2 and 3 together with sections of 3-D models are shown in Figures 7, 9 and 11. These figures also show theprofiles of theoretical topographic effects. It can be seen that the fit between observed and computed anomalies for bodies 2 and 3 are slightly better than that for bodies 1 and 4.

The concealed magnetic body (Body 1 with 2.5 A/m) in the north that produce a positive anomaly (> 200 nT), has a maximum thickness in its center of about 370 m is inffered as a burried of rhyolite dome.

The hydrothermally demagnetized rocks (magnetisation: 0A/m) beneath the Maungaongonga dome are indicated by body 2 and body 3. Body 1 is located inside resistivity low with thickness varying from 50 m to 500 m and dipping relatively to the west. A large part of body 2 lies outside the resistivity low. The highly magnetized body 4 (3.2 A/m) in the south is located inside the resistivity low and extending down to more than 500 m depth. This body needed to be modelled in order to obtain a reasonable fit between the computed magnetic effect and the observed residual magnetic anomalies in the south (see Figure 11). This interpretation result indicates that within the southern part of resistivity low, some rocks are still magnetic.

3. Conclusions

Magnetic modelling of topography over Mt. Maungaongaonga indicates that a positive residual total force magnetic anomaly should have been observed if the rock forming this volcanic cone are still fresh and, therefore, magnetic. (Maximum anomaly of 350 nT at 760 m (a.s.l) if the average total magnetisation of the rocks is 1.7 A/m). However, no such a positive anomaly is shown in the residual airborne magnetic data (measured at 760 m a.s.l.) over the volcanic cone, indicating that the rocks have been affected by hydrothermal demagnetization.

The weak negative residual anomalies observed over Mt. Maungaonga-onga indicate that the demagnetization also occurs at deeper level beneath the base of the volcano. 3-D modelling suggests that there are two bodies with low magnetization. One body lies inside the resistivity low (Bibby et.al, 1994) and therefore it is likely to represent hydrothermally demagnetized rocks. The other body lies mostly outside the resistivity low. Hence, it may represent concealed, reversely magnetized rocks as has been suggested by Soengkono and Hochstein (1996).

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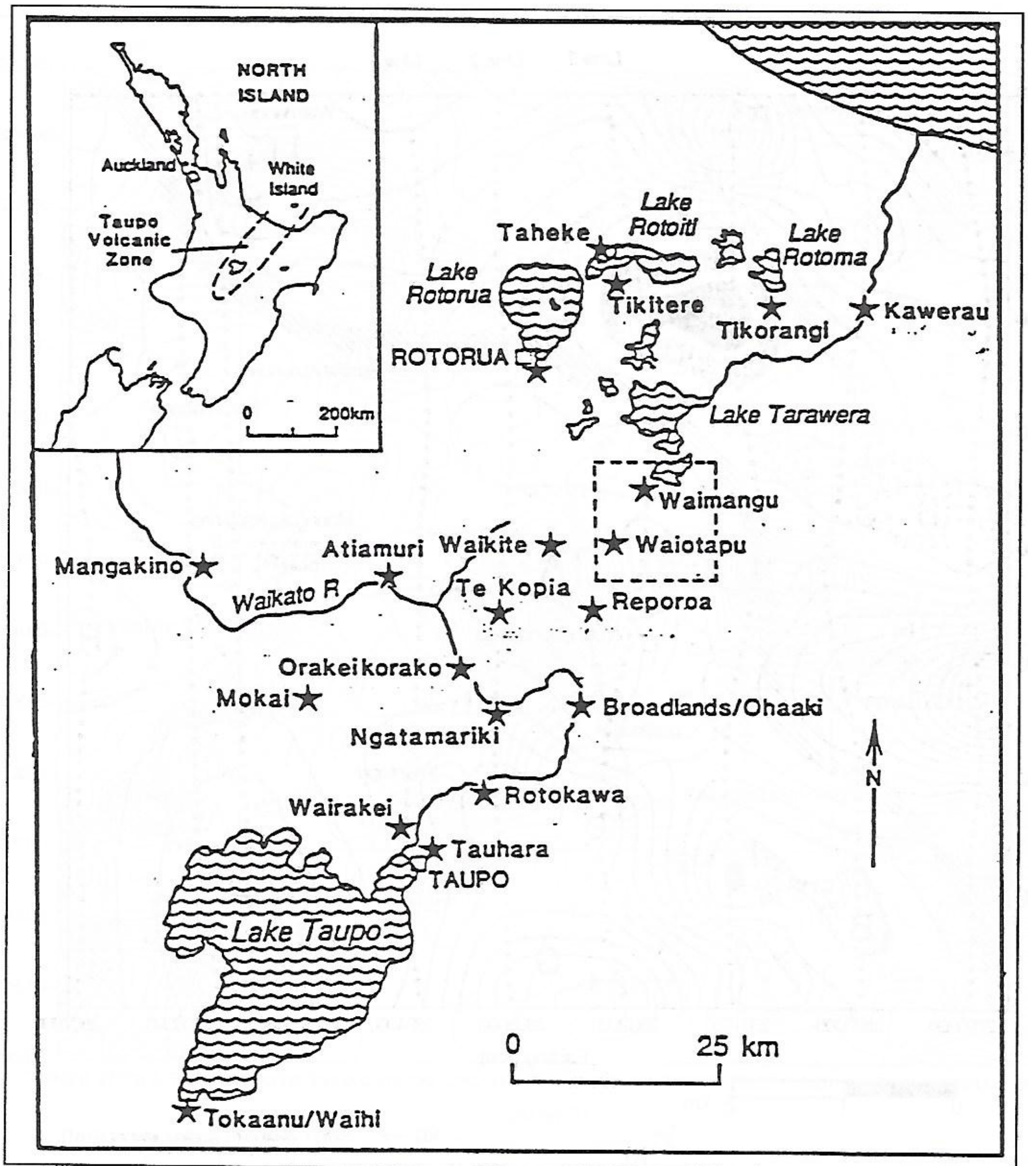

Figure 1 : The Taupo Volcanic Zone showing the approximate distribution of geothermal system (shown by stars). Thea area of this study is outlined (from Bibby et.al, 1994).

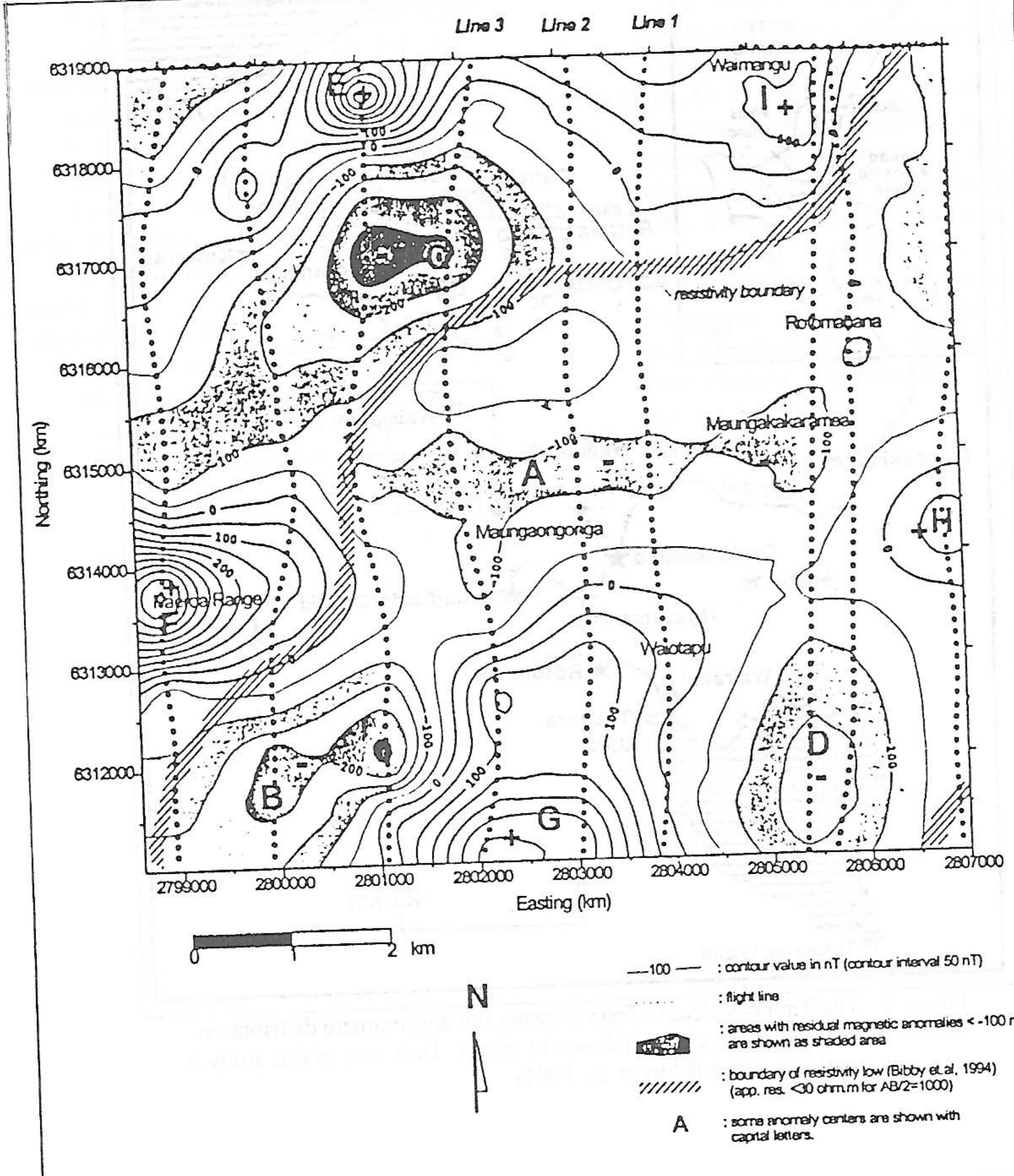

Figure 2: Observed total force magnetic anomalies (ΔF) of Waimangu-Waiotapu region at 760 m (asl).

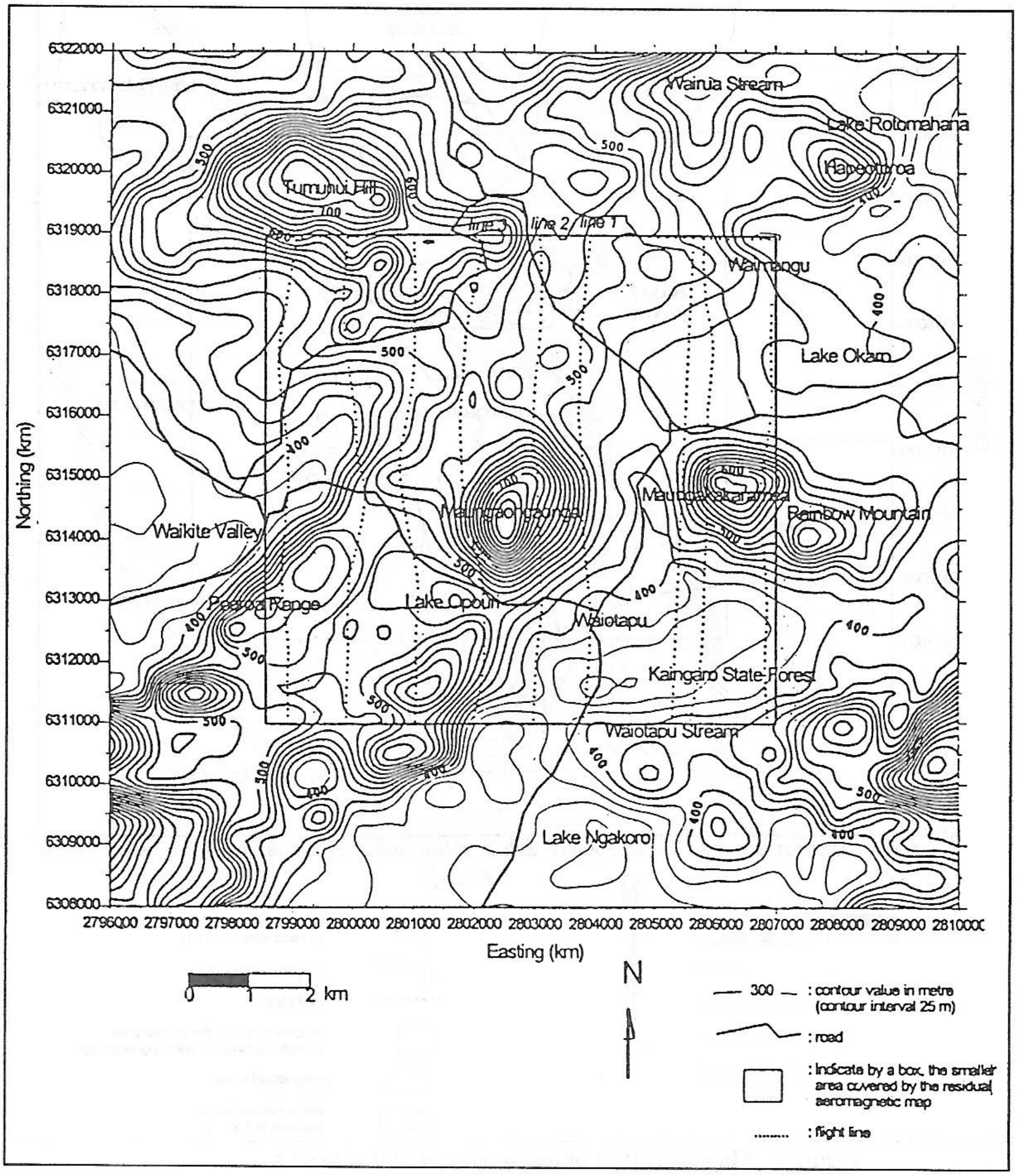

Figure 3: Digitized topography of the Waimangu-Waiotapu Geothermal Area

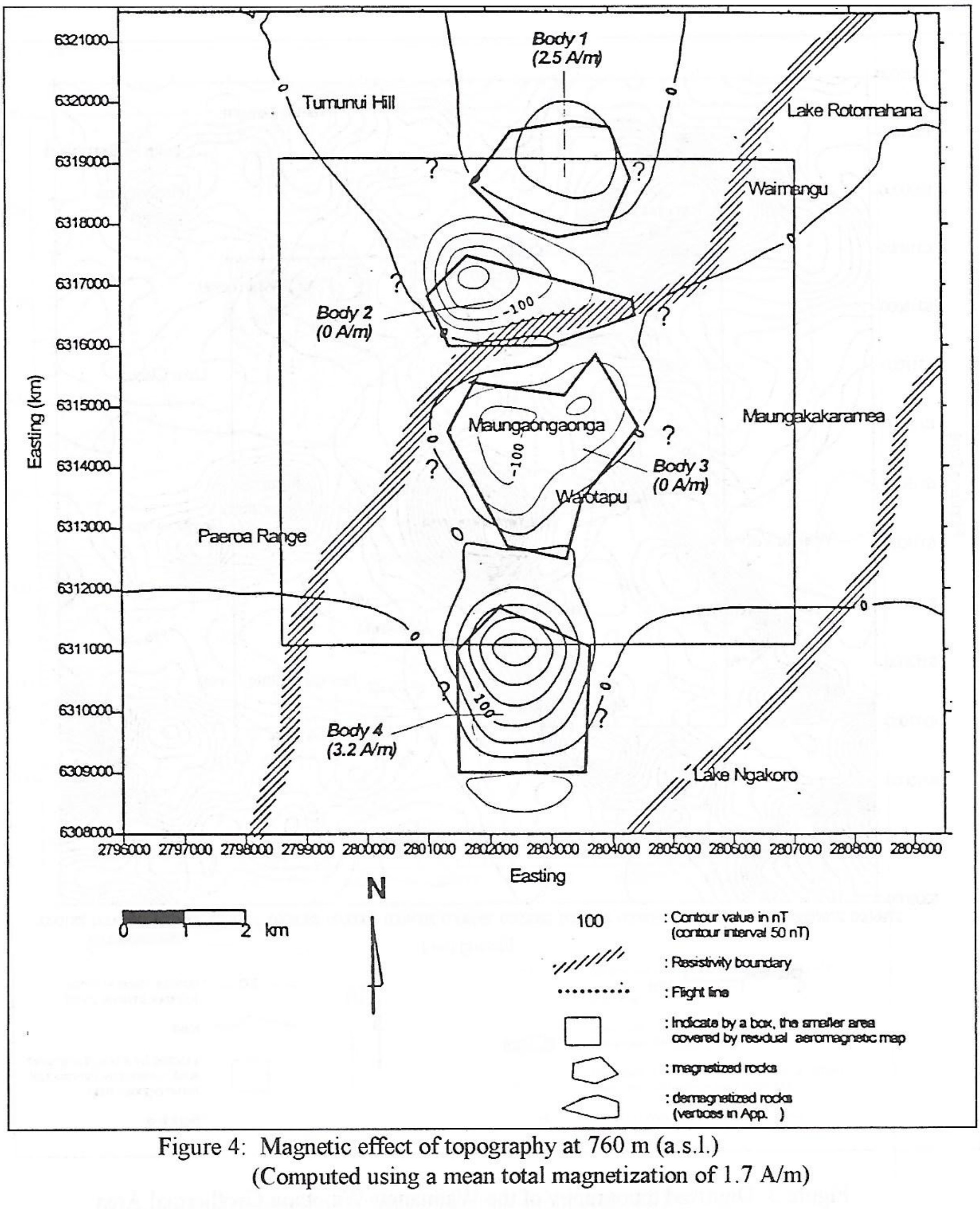

Figure 4: Magnetic effect of topography at 760 m (a.s.l.)
(Computed using a mean total magnetization of 1.7 A/m)

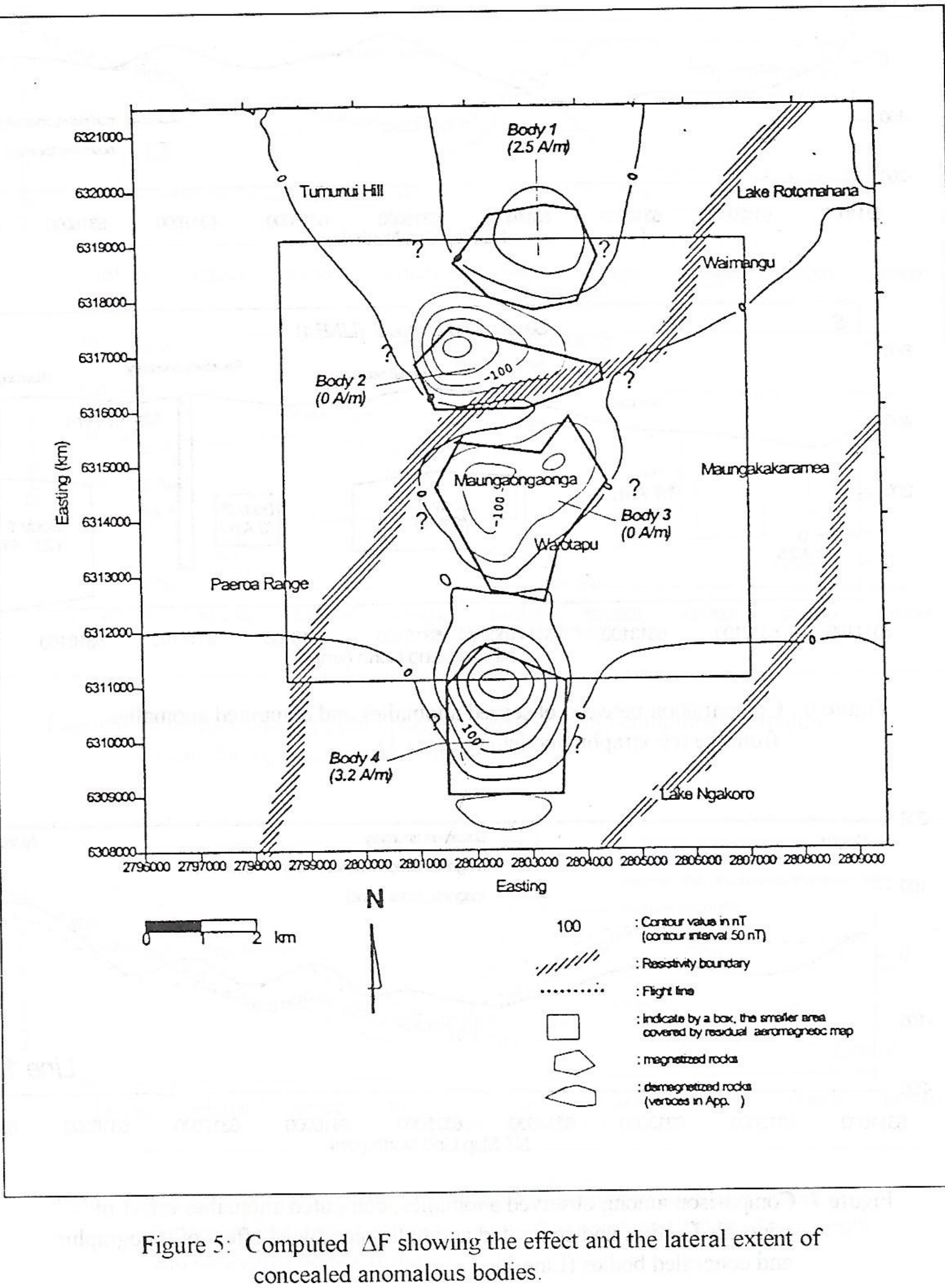

Figure 5: Computed ΔF showing the effect and the lateral extent of concealed anomalous bodies.

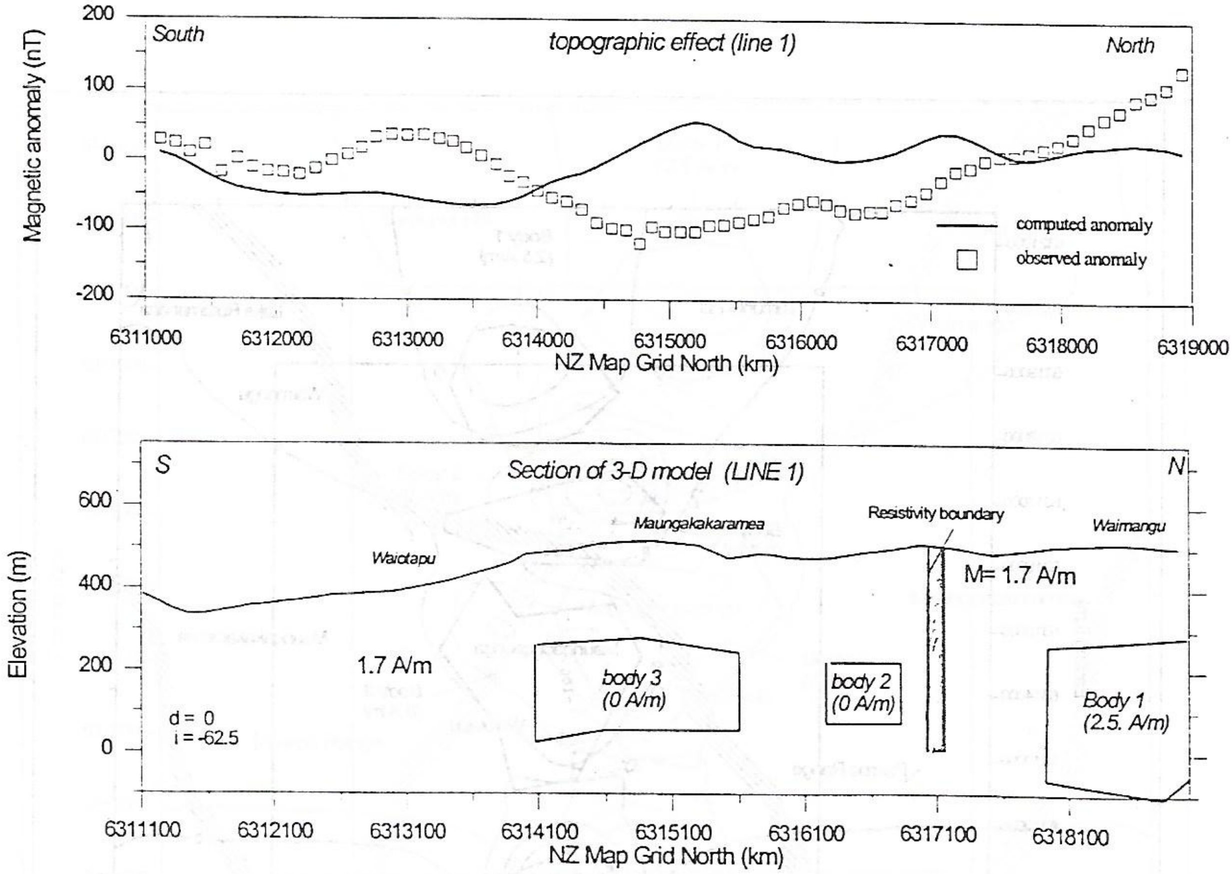

Figure 6: Comparasion between observed anomalies and computed anomalies from the topographic modelling (Line 1).

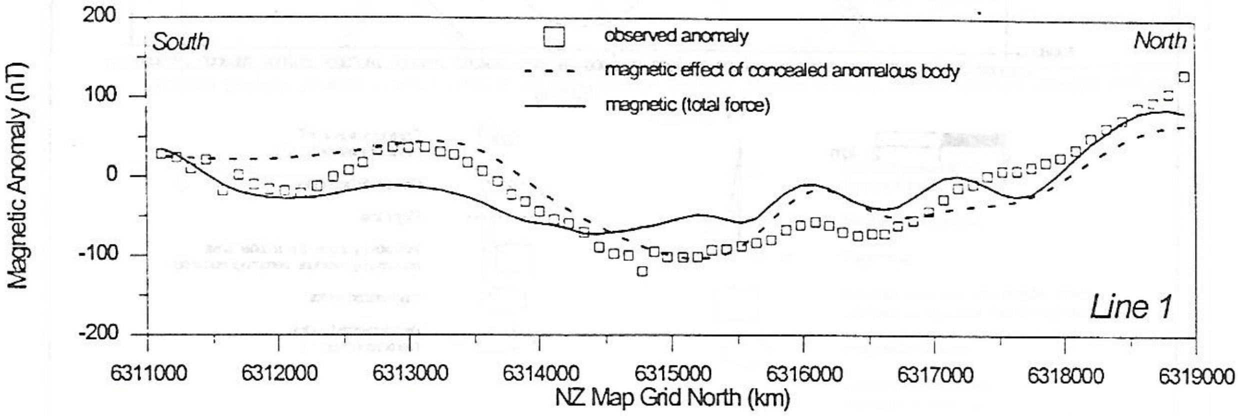

Figure 7: Comparison among observed anomalies, computed anomalies effect of concealed bodies and computed anomalies combined effect of topographic and concealed bodies (Line 1).

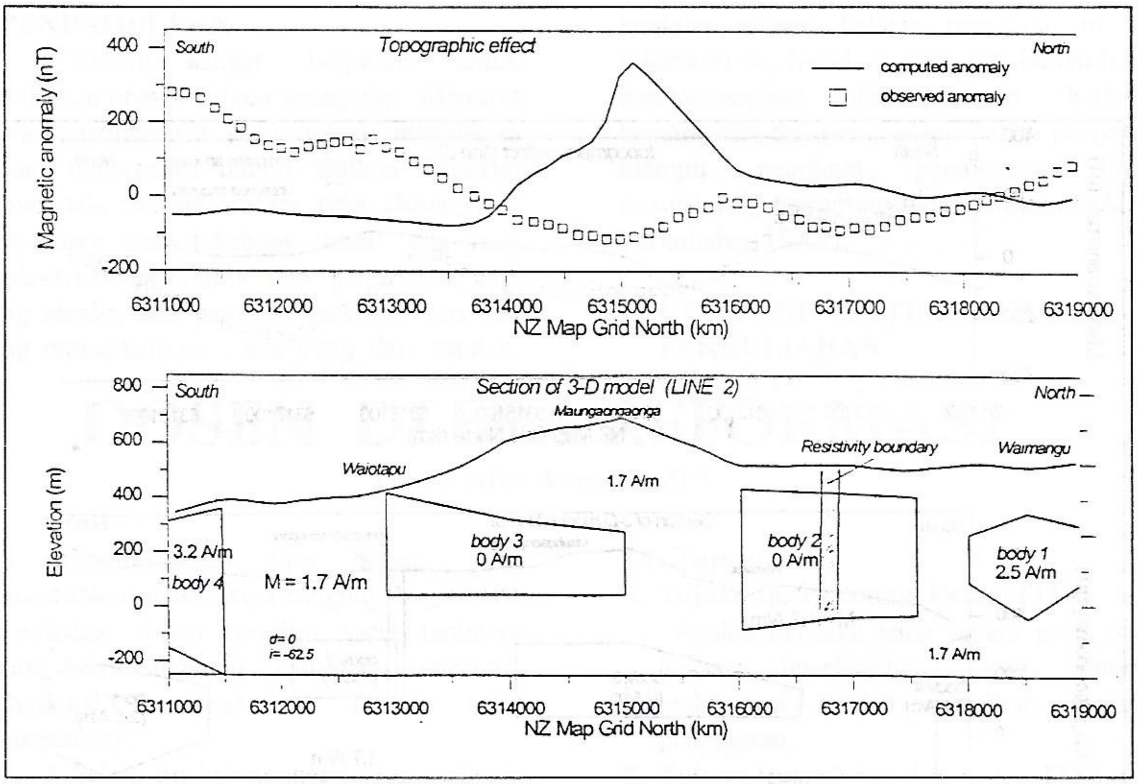

Figure 8: Comparasion between observed anomalies and computed anomalies from the topographic modelling (Line 2).

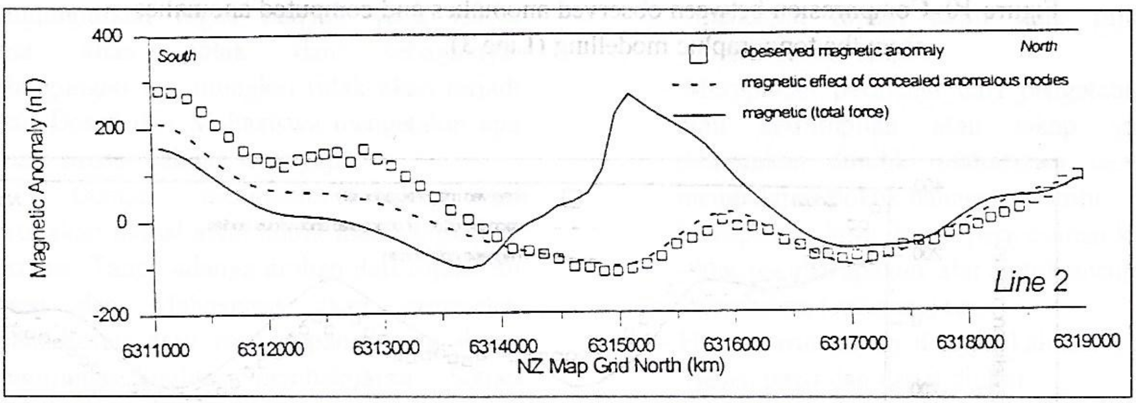

Figure 9: Comparison among observed anomalies, computed anomalies effect of concealed bodies and computed anomalies combined effect of topographic and concealed bodies (Line 2).

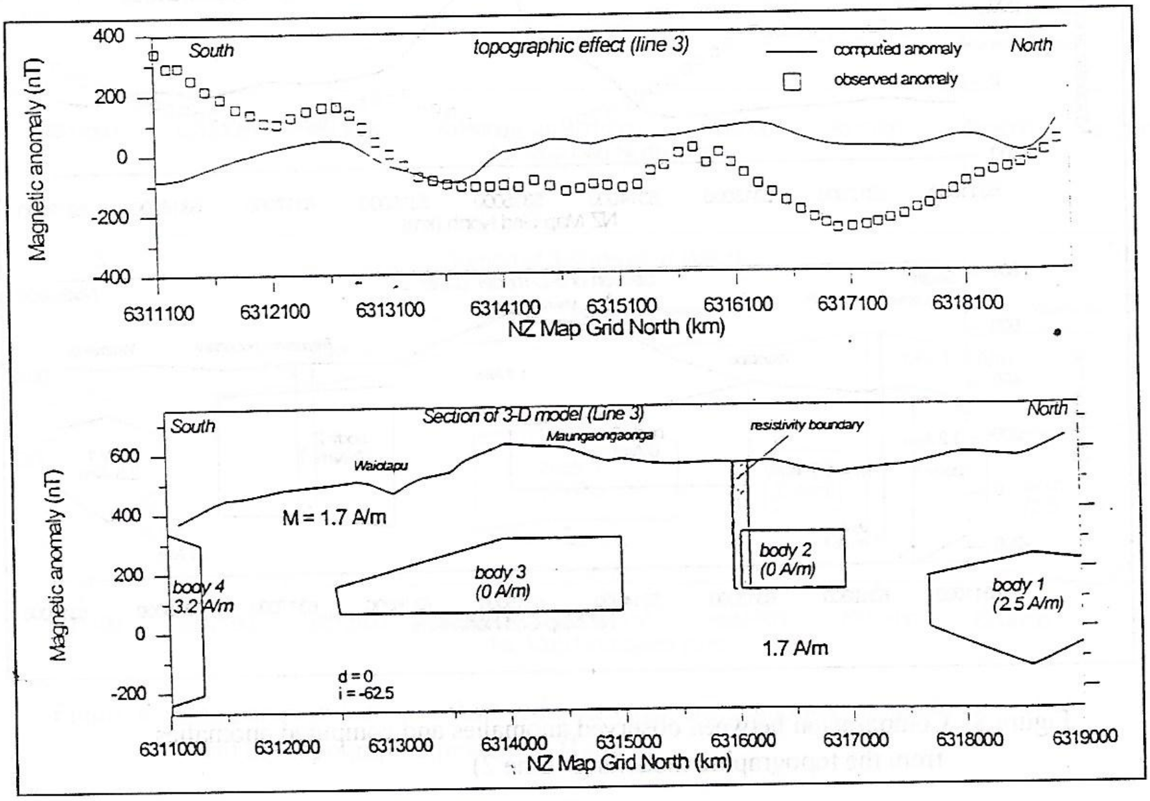

Figure 10: Comparasion between observed anomalies and computed anomalies from the topographic modelling (Line 3).

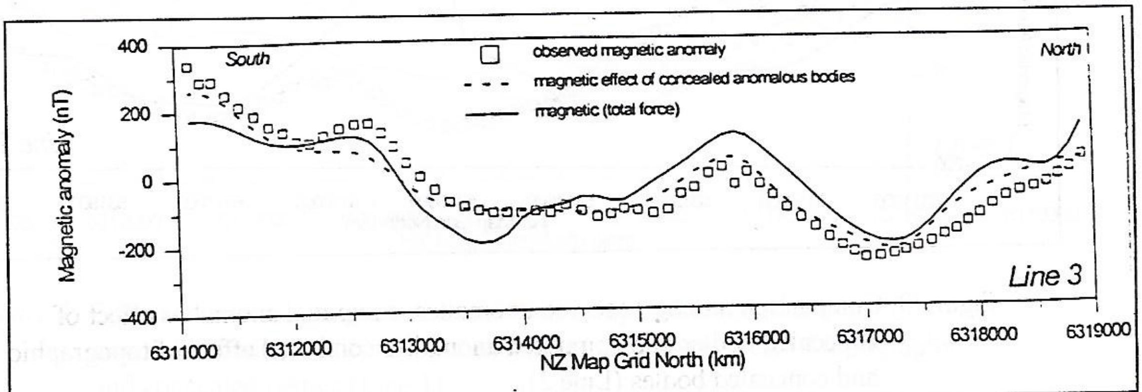

Figure 11: Comparison among observed anomalies, computed anomalies effect of concealed bodies and computed anomalies combined effect of topographic and concealed bodies (Line 3)