DIRECT RELATIONSHIPS BETWEEN GEOLOGY AND AIRBORNE MAGNETIC DATA OVER THE TAUPO VOLCANIC ZONE (TVZ), NEW ZEALAND

Supri Soengkono

GNS Science, Wairakei Research Centre

114 Karetoto Road, Wairakei

New Zealand

s.soengkono@gns.cri.nz

Keywords: *Airborne magnetic survey, rock magnetisation, rhyolite dome, ignimbrite, geothermal field.*

ABSTRACT

The surface geology of the Taupo Volcanic Zone (TVZ) has been known very well as the results of surface geological mapping since early 1940s by geologists from the NZ Geological Survey, GNS Science and the New Zealand universities. Airborne magnetic data are available over the TVZ at three sets of different flight elevations: (1) detailed measurements at 60m above ground surface (AGS), (2) less detailed measurements at 760 m reduced level (RL) (draped at about 100m where ground elevations are higher than 650m RL) and (3) regional measurements at 1,500 m RL. A simple comparison between these three sets of airborne magnetic data shows that these data are highly consistent with each other.

Detailed interpretations and 3-D quantitative modelling of the data measured at 60 m above ground and at 760 mRL had been carried out over almost all geothermal fields in the TVZ. These interpretations were capable to delineate the lateral extents of the high temperature geothermal reservoirs in the TVZ and in providing depth estimates to where the volcanic rocks have been affected by hydrothermal alterations process.

There is more information than can be extracted from these airborne magnetic data. These data also directly correlate with the surface geology of the area covered by the surveys. Some geological information are directly shown by the airborne magnetic data. Maps of the airborne magnetic anomalies can be used to draw lithological boundaries beneath the survey area. This paper demonstrates how to extract such geological information without complex interpretations and quantitative modelling of the magnetic anomalies.

1 AIRBORNE MAGNETIC DATA OVER TVZ

Several airborne magnetic surveys have been carried out over the Taupo Volcanic Zone of New Zealand. The first set of surveys was conducted by the Department of Scientific and Industrial Research (DSIR) New Zealand between 1949 and 1952 (Gerard and Lawrie (1955). More recently, between 1983 and 1996, the author together with Prof M.P. Hochstein, when both of us were academic staff of the Geothermal Institute, University of Auckland, carried out a series of airborne magnetic surveys over geothermal fields in the Taupo Volcanic Zone (Hochstein and Soengkono, 1997). These surveys were carried out at 760m above sea level, often called *reduced level* (RL), with nominal flight line spacing of about 1 km, guided manually with the help of a GPS receiver not linked to the magnetometer. Between 1995 and 2005 some mineral exploration companies (such as BP Mineral Ltd, Glass Earth NZ Ltd) conducted detailed surveys over various parts of TVZ, with 100-300m flight line spacing, draped 60m above topography, for gold exploration. The survey with largest areal coverage was conducted by the Glass Earth NZ Ltd. in 2005. All the data have now become NZ public domain data.

Figure 1 shows the airborne magnetic maps over TVZ obtained from the 1949-1952 surveys by the DSIR, the 1980s-1990s surveys by the Geothermal Institute and the 2005 survey by the Glass Earth NZ Ltd. All airborne magnetic maps in Figure 1 are shown using the same color ranges.

It can be seen in Figure 1 that the three airborne magnetic maps, measured in different years using different technology, are highly consistent with each other. The maps differ only in the detail of the features. As expected, magnetic values measured at greater elevations above the ground surface are showing less details that those measured at lower elevations.

These consistent results clearly show that airborne magnetic survey is robust. Data quality is almost independent of the technology used to collect them.

1.1 Geology of TVZ

The geology of the TVZ are known very well from various surface geological mapping that have been carried out since before 1940 by geologists from the NZ Geological Survey, GNS Science and the New Zealand Universities. TVZ area is almost entirely covered by Quaternary volcanic rocks of rhyolitic compositions.

A simplified geological map of the TVZ drawn based on various geological maps available in the GNS library is shown in Figure 2. The map shows that older ignimbrites (age ≥500 ka, or ≥500 thousand years) are exposed in the northwest part of TVZ.

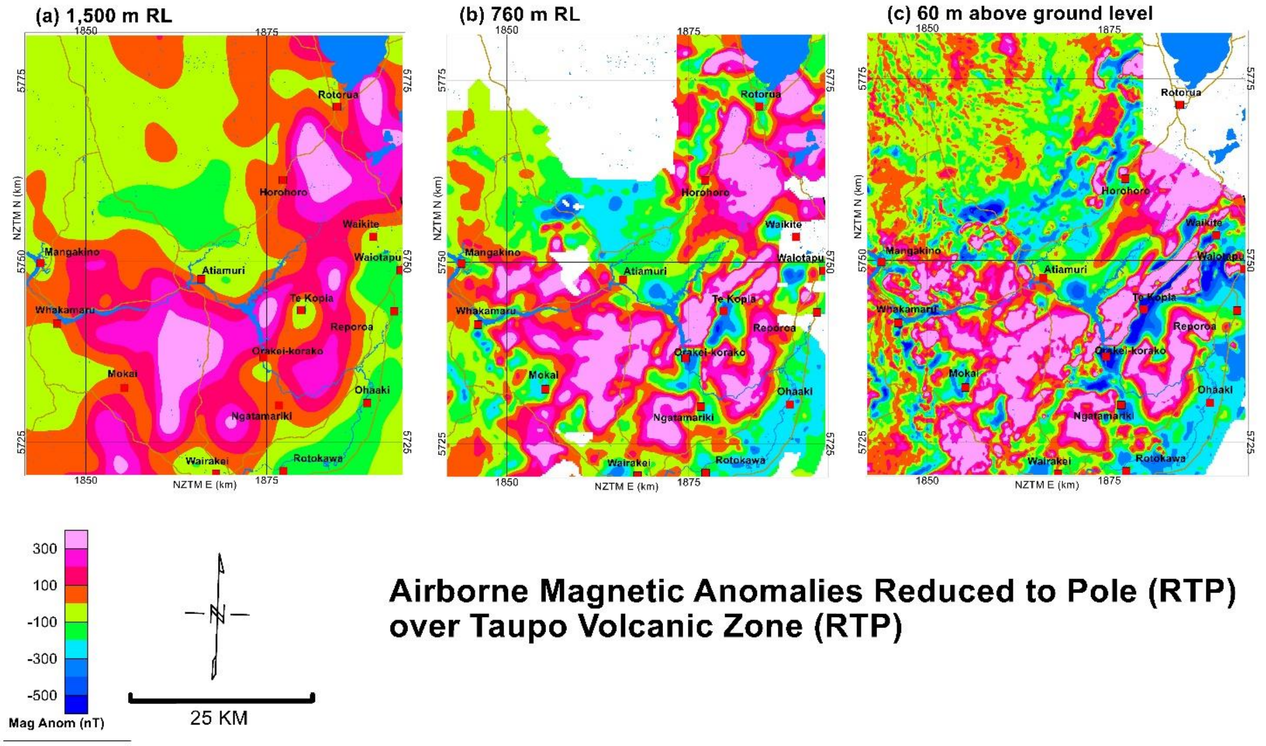

Figure 1 Airborne magnetic anomalies reduced to pole (RTP) over Central TVZ area: (a) at 1,500 m RL, (b) at 760 m RL, (c) draped at 60 m above ground surface.

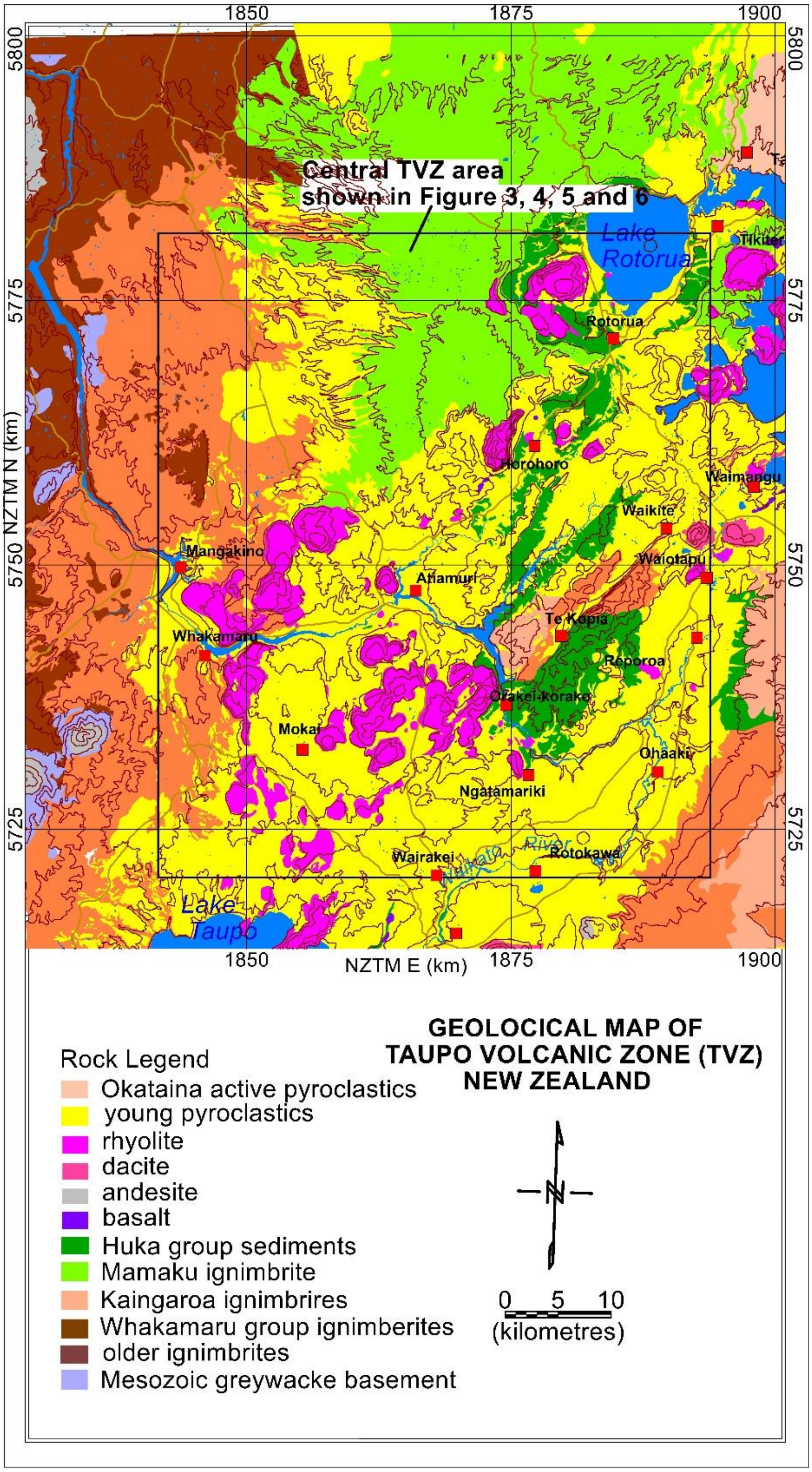

Figure 2: Geology of the Taupo Volcanic Zone (TVZ), New Zealand. Brown contour lines represent topography (contour interval 100 m). Location of named high temperature geothermal fields are shown by small red square.

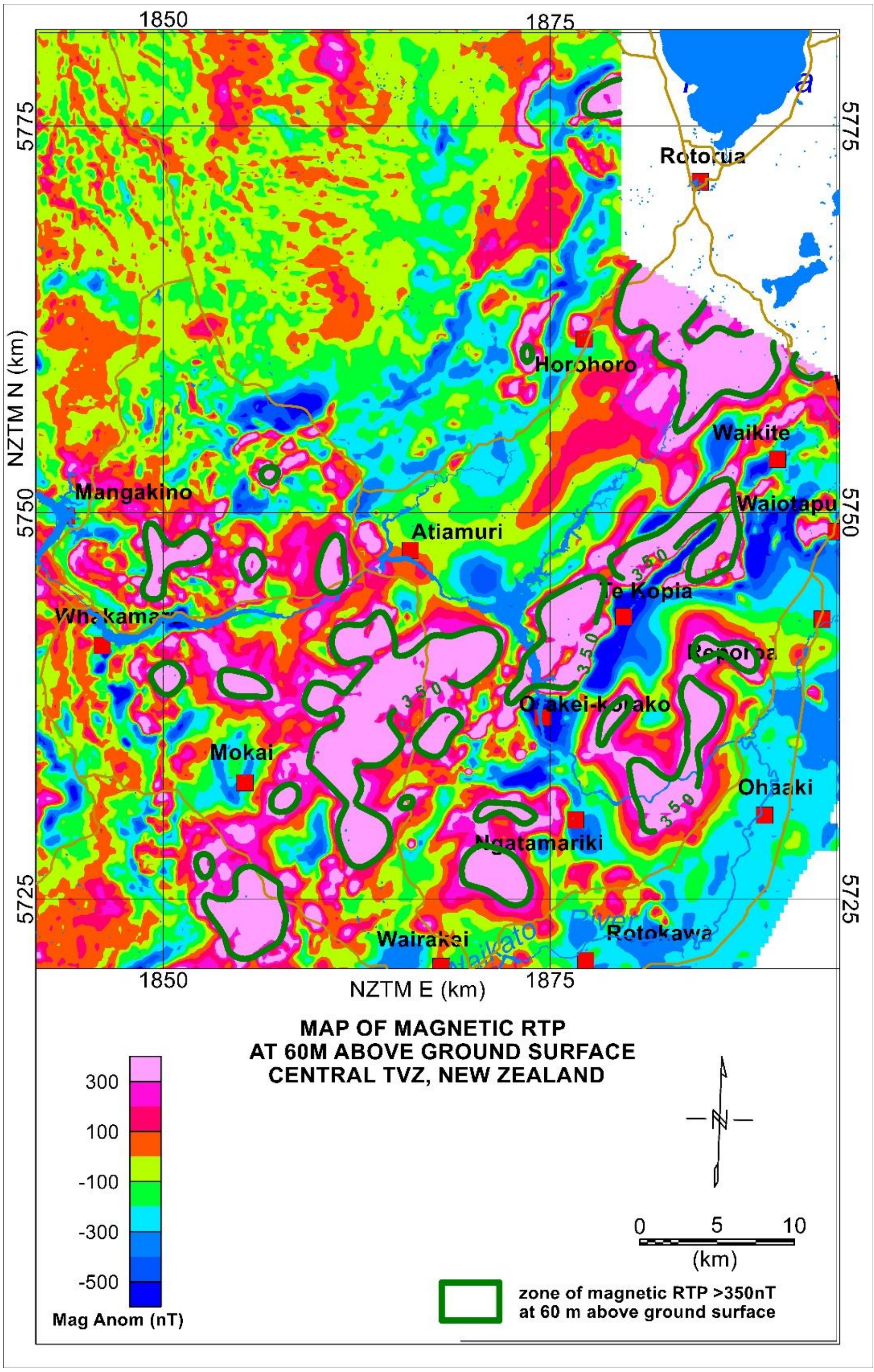

Figure 3: Airborne magnetic anomalies reduced to pole (RTP) at 60 m above ground over Central TVZ area. Zones of high RTP (>350 nT) are shown.

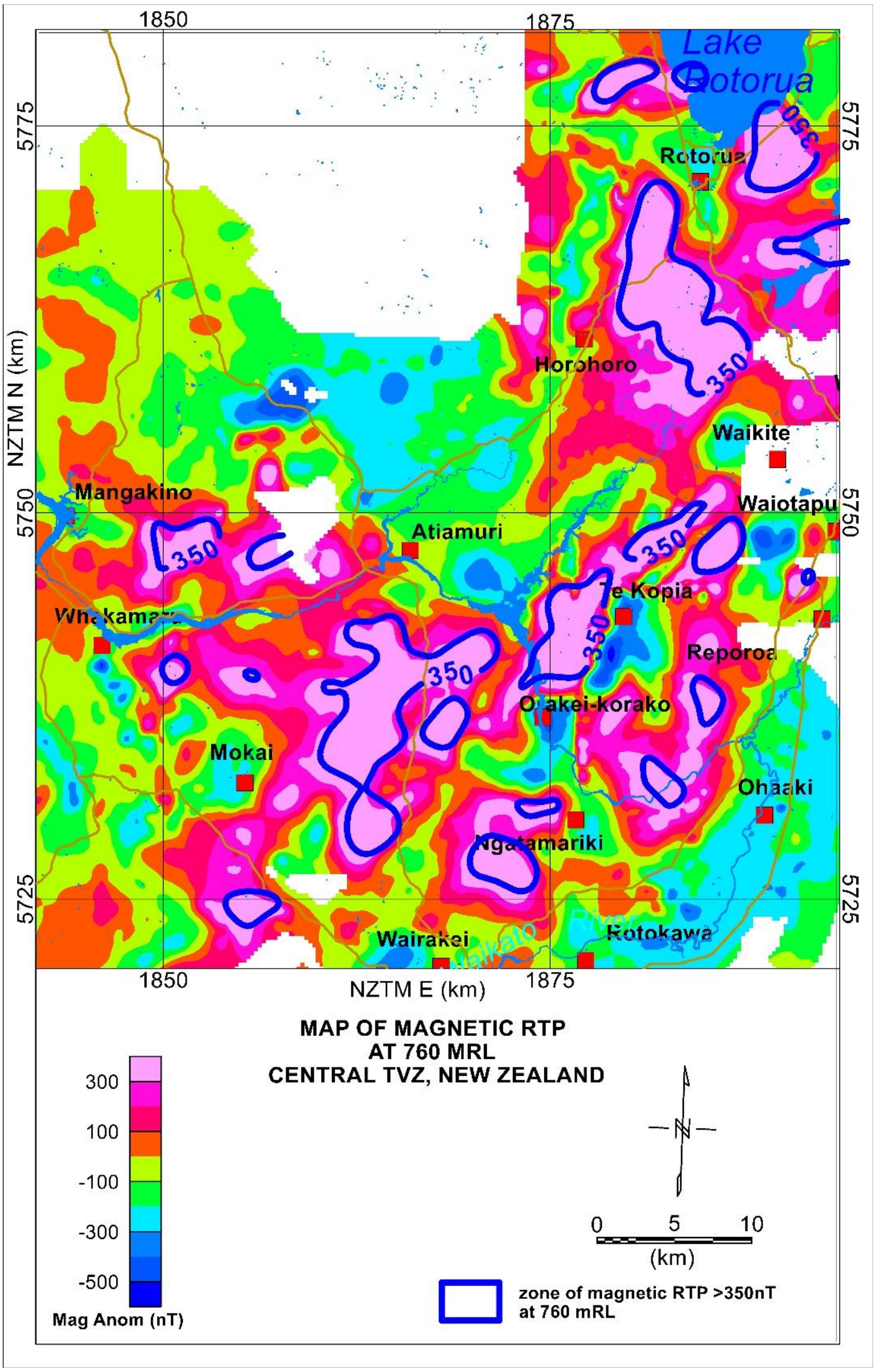

Figure 4: Airborne magnetic anomalies reduced to pole (RTP) at 760 m RL over Central TVZ area. Zones of high RTP (>350 nT) are shown.

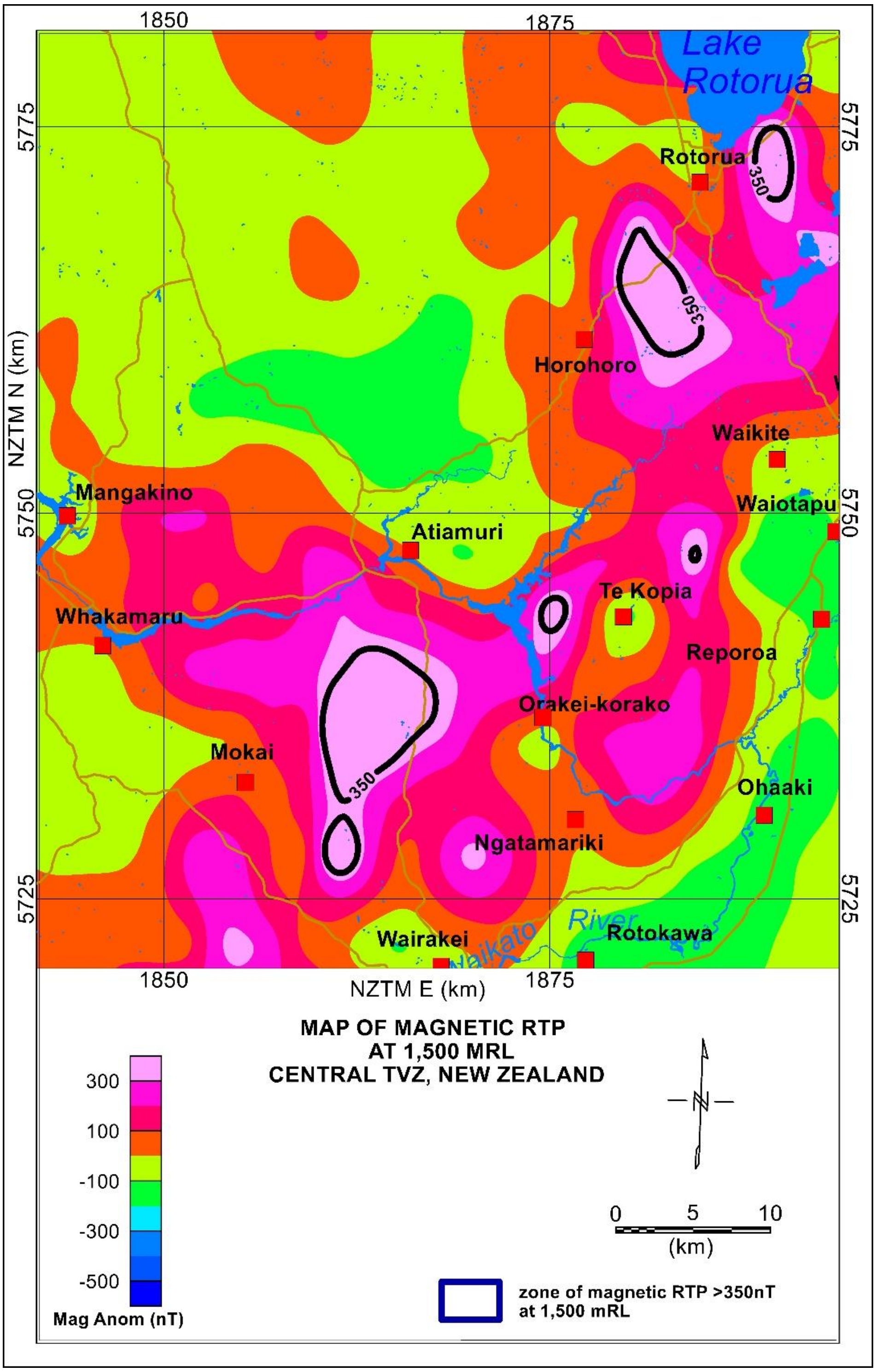

Figure 5: Airborne magnetic anomalies reduced to pole (RTP) at 1,5000 m RL over Central TVZ area. Zones of high RTP (>350 nT) are shown.

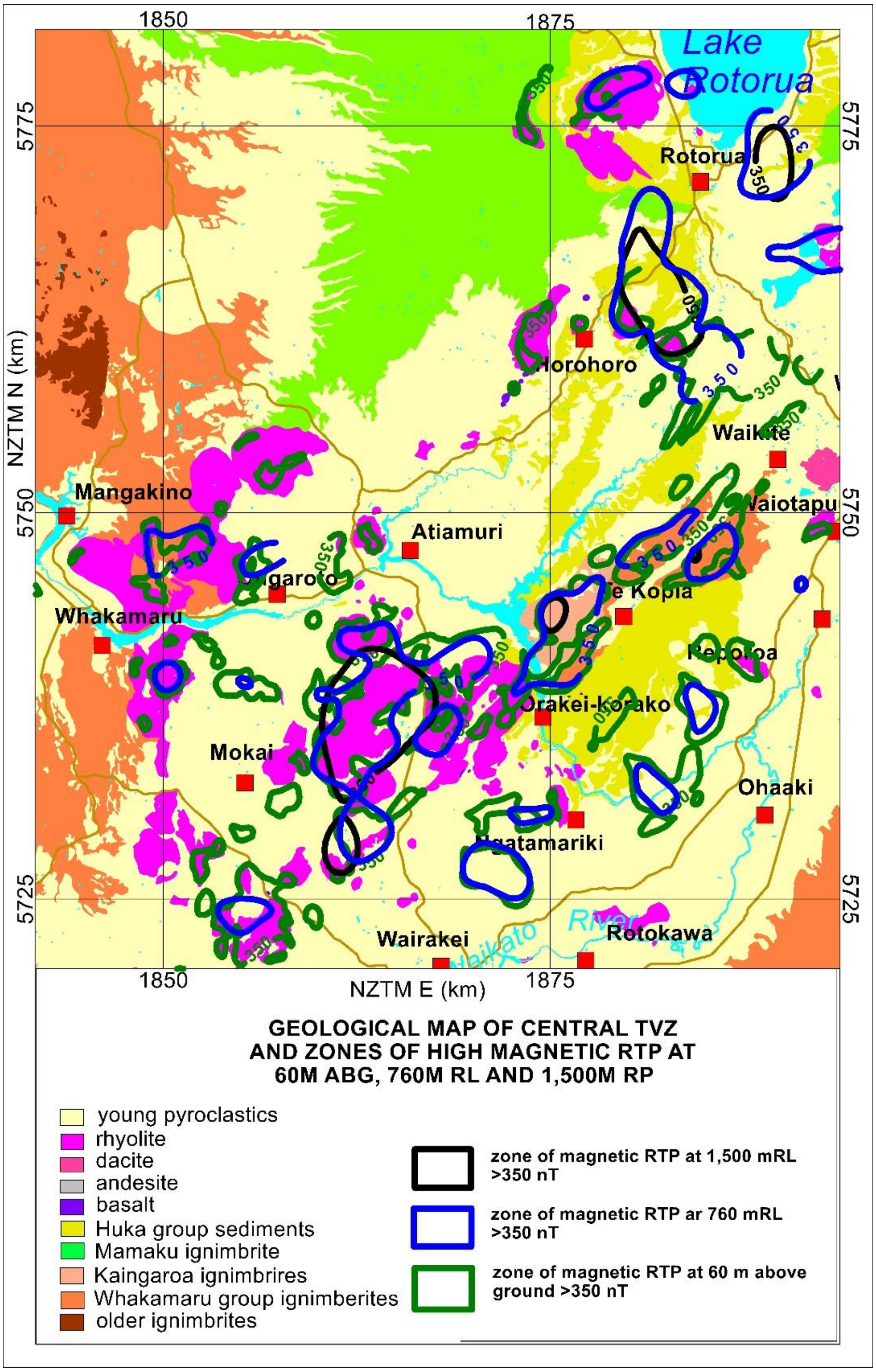

Figure 6: Geological map of Central TVZ area and zones of high magnetic RTP at 60 m above ground, at 760 m RL and at 1,500 m RL. Location of named high temperature geothermal fields are shown by small red square.

2. AIRBORNE MAGNETIC ANOMALIES OVER CENTRAL TVZ

Figures 3, 4 and 5 show the airborne magnetic anomalies over the central TVZ area observed at 60 m above ground surface, at 760 m RL and at 1,500 m RL, respectivelly. The magnetic anomalies have been reduced to pole (RTP), a filtering process that make magnetic anomalies to be nearly centered over their respective causative bodies (Dobrin and Savit, 1988).

Zones of high RTP values are also shown in Figures 3, 4 and 5. These are magnetic RTP ≥350 nT at 60 m above ground surface by green polygons (Figure 3), at 760m RL by blue polygons (Figure 4) and at 1,500 m RL by black polygons (Figure 5).

These old ignimbrites are overlain by the Whakamaru group ignimbrites of 330 – 230 ka. The Whakamaru group ignimbrites are also exposed in the central and southeast parts of TVZ, underlain in parts by younger Kaingaroa ignimbrites. Figure 2 also shows that rhyolite lavas, mostly exposed as rhyolite domes, are very prominent over the central TVZ area. In the central region in Figure 2, these rhyolite domes are surrounded by young, 1.8 - 26.5 ka pyroclastic deposits, whereas in the western region the west sides of the rhyolite domes are close to the exposed Whakamaru group ignimbrites.

3. DIRECT RELATIONSHIPS BETWEEN GEOLOGY AND AIRBORNE MAGNETI DATA

Figure 6 shows the geological map of the central TVZ area overlain by zones of high (≥350 nT) magnetic RTP anomalies shown in Figures 3, 4 and 5.

The rocks units in Figure 6 that are likely to have strong magnetisations are the rhyolite and dacite lavas, the welded old ignimbrite units in the western TVZ, and the Whakamaru group and the Kaingaroa ignimbrites. However, rocks with a strong magnetisation would not create magnetic anomalies if they form horizontal sheets. (The magnetic effects of magnetised horizontal sheet is zero ; Soengkono (2006)). In Figure 6, this is the case with the old ignimbrites in the western/northwestern TVZ and the Whakamaru and Kaingaroa ignimbrites in the eastern/southeastern TVZ. However, to the south and to the northeast of the Te Kopia geothermal fields, both the Whakamaru group ignimbrites and the Kaingaroa ignimbrite are clearly marked by high magnetic anomalies at all levels (60 m above ground surface, 760 m RL and 1,500 m R). The reason for this is that here the exposed of both Whakamaru Group ignimbrites and the Kaingaroa ignimbrite form a rugged topography related to a major faulting (the Pureroa fault system).

As expected, most exposed rhyolite domes in Figure 6 are marked by high magnetic anomalies. However, there are also exposed rhyolite and dacite lavas which are not marked by strong magnetic anomalies. This occurs with the rhyolite lavas around geothermal fields of Mokai, Mangakino, Rotokawa, Ngatamariki, Orakei-korako, Te Kopia, and the dacite lavas to the north of Waiotapu. This indicates that these lavas have probably been afffected by *hydrothermal demagnetisation* by the nearby geothermal fields. Hydrothermal demagnetisation is a term used for where a contact with geothermal fluid changes the magnetic minerals *magnetite* in the lava into a non-magnetic mineral *pyrite*.

There are also zones of strong RTP anomalies that are not marked by exposed rhyolite or dacite lavas. These zones indicate the presence of burried rhyolite (or dacite) domes but not flat lying welded ignimbrites. This information cannot be otained from surface geological mapping. This is an important advantage of a proper direct interpretation of airborne magnetic data.

4. SUMMARY AND CONCLUSION

This paper demonstrates that airborne magnetic survey is a robust survey. It is also the cheapest exploration method to cover a large area such as the TVZ region in New Zealand quickly. Transformation of the airborne magnetic data into their reduced to pole (RTP) format is an important and necessary step to obtain geological information directly, including in the area where geological maps are not available. Thus, a software capable of RTP processing, such as the *Oasis Montaj* or *Emapper*, is absolutely necessary. Such software can be purchased online.

Other necessary item for this type of work is a suitable set of topography data. Nowadays good and suitable digital topographic data for almost all regions of the earth can also be obtained/purchased online.

High value of magnetic RTP over area with rugged topography tell us that the rocks exposed as the rugged topography are significantly magnetic. In a volcanic region such as the TVZ, it is likely that these rocks are either lavas or welded ignimbrites

REFERENCES

Gerard, V.B. and Lawrie, J.A.: Aeromagnetic Surveys in New Zealand, 1949-1952. *Geophysical Memoirs 3*. Department of Scientific and Industrial Research, Wellington, New Zealand. (1955).

Dobrin, M.B and Savit, C.H.: Introduction to Geophysical Prospecting, 4th edition, *McGraw-Hill International*, 867 pages. (1988).

Hochstein, M.P.; Soengkono, S.: Magnetic anomalies associated with high temperature reservoirs in the Taupo Volcanic Zone (New Zealand). *Geothermics*, 26(1): 1-24. (1997).

Soengkono, S. Introduction to Geothermal Geophysics, Chapter 5, Magnetic Method, *Unpublished Lecture Notes, available from GNS Science, 114 Karetoto Road Wairakei, Taupo, New Zealand*, Email: s.soengkono@gns.cri.nz (2006)