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Interpretation of gravity and magnetic anomalies at Lake Rotomahana: Geological and hydrothermal implications

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ABSTRACT

We investigate the geological and hydrothermal setting at Lake Rotomahana, using recently collected potential-field data, integrated with pre-existing regional gravity and aeromagnetic compilations. The lake is located on the southwest margin of the Okataina Volcanic Center (Haroharo caldera) and had well-known, pre-1886 Tarawera eruption hydrothermal manifestations (the famous Pink and White Terraces). Its present physiography was set by the caldera collapse during the 1886 eruption, together with the appearance of surface activities at the Waimangu Valley. Gravity models suggest that subsidence associated with the Haroharo caldera is wider than the previously mapped extent of the caldera margins. Magnetic anomalies closely correlate with heat-flux data and surface hydrothermal manifestations and indicate that the west and northwestern shore of Lake Rotomahana are characterized by a large, well-developed hydrothermal field. The field extends beyond the lake area with deep connections to the Waimangu area to the south. On the south, the contact between hydrothermally demagnetized and magnetized rocks strikes along a structural lineament with high heat-flux and bubble plumes which suggest hydrothermal activity occurring west of Patiti Island. The absence of a well-defined demagnetization anomaly at this location suggests a very young age for the underlying geothermal system which was likely generated by the 1886 Tarawera eruption. Locally confined intense magnetic anomalies on the north shore of Lake Rotomahana are interpreted as basalt dikes with high magnetization. Some appear to have been emplaced before the 1886 Tarawera eruption. A dike located in proximity of the southwest lake shore may be related to the structural lineament controlling the development of the Patiti geothermal system, and could have been originated from the 1886 Tarawera eruption.

1. Introduction

Lake Rotomahana (LR) is one of many volcanic lakes in the Rotorua District (Healy 1975a), within the Taupo Volcanic Zone (TVZ) on the North Island of New Zealand (Fig. 1). It is located approximately 1 km south of Lake Tarawera (LT) and 5 km southwest of Tarawera Volcanic Complex (TVC). The active Waimangu Valley (WV) is the southwest extension of Lake Rotomahana thermal area. On the 10th of June 1886, a devastating explosive eruption formed a 17 km long chain of craters, from Mt Tarawera through the former smaller Lake Rotomahana to the Waimangu Valley area (Fig. 1), which is known as the 1886 Tarawera Rift eruption. This eruption was a short, powerful basaltic fissure eruption that ended with a phreatomagmatic explosion at Rotomahana and Waimangu, where several craters in alignment with Tarawera fissure trend were formed independently of topography (e.g., Cole, 1970; Nairn, 1979; Nairn and Cole, 1981, Nairn, 1989, Nairn 2002).

Modern Lake Rotomahana currently lays within a series of deep interconnected craters (Nairn 1979) that were formed during the Tarawera Rift eruption. Before 1886, two smaller lakes (Lake Rotomahana and Lake Rotomakariri) were located in this area (Fig. 2). The pre-1886 smaller Lake Rotomahana had well-known hydrothermal activities, such as the Pink and White Terraces on the western side (Hochstetter, 1864). Following the landscape changing 1886 eruption water ponded in the craters and the level rose due to climate and rainfall (Healy 1975b), now covering an area of ~8 km^2 and a maximum depth of ~130 m (Keam, 1988).

The 1886 Tarawera Rift is part of the Okataina Volcanic Center (OVC), delimited by a major caldera, forming one of at least four major volcanic centres in the TVZ (Wilson et al., 1984). The lake area lays in a collapse embayment in the south western portion of the Okataina Volcanic Centre (OVC), where the Haroharo Caldera boundaries are poorly defined (Nairn 2002). Geothermal activity is widespread in the Lake Rotomahana area occurring along the northwestern

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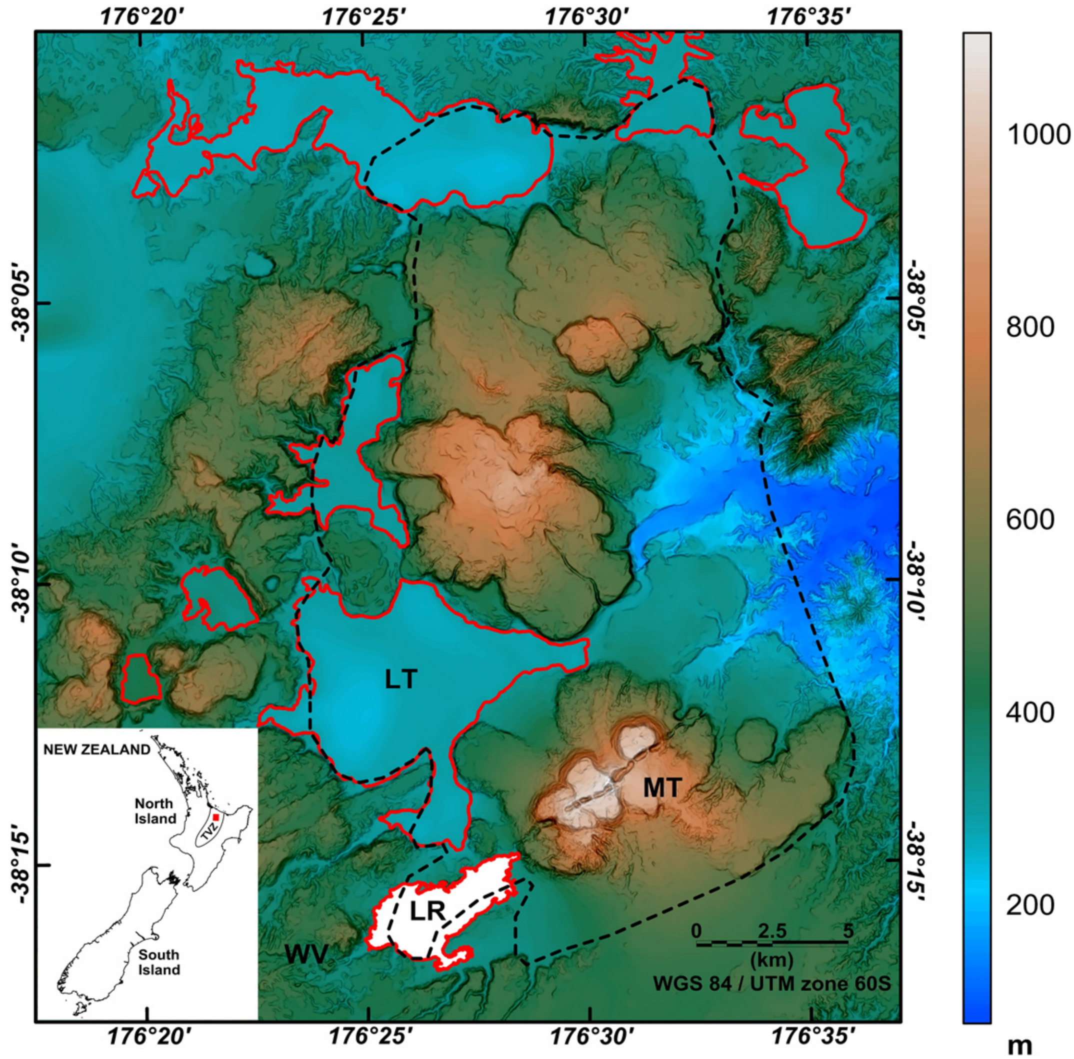

Fig. 1. Map showing the location of Lake Rotomahana (LR) relative to Haroharo Caldera (black dashed line) in the Okataina Volcanic Center. The 1886 Tarawera Rift along Mt Tarawera (MT) is clearly visible extending through Lake Rotomahana to the Waimangu Valley (WV). The red polygons mark the boundaries of the Rotorua Lakes; Lake Tarawera (LT) is located 1 km North of Lake Rotomahana (filled in white). The inset shows the location of the Rotorua Lakes area (red rectangle) within the Taupo Volcanic Zone (TVZ).

and southern lake shores, in the Waimangu Valley, north of the lake on the divide with Lake Tarawera and in the Haumi Stream to the south. Bubbles and plumes of hot water are also observed in the lake (Fig. 2). All these geothermal manifestations are part of the Waimangu–Rotomahana–Mt Tarawera Geothermal Field.

In this study, we will show the interpretation of new gravity and magnetic data collected at Lake Rotomahana in 2011 and integrated with pre-existing aeromagnetic data. We will analyse these data to identify the extent and subsurface distribution of hydrothermal alteration and investigate the distribution of volcanic rocks under the lake floor.

2. Geological and geothermal setting

Lake Rotomahana is located in a topographic low formed by the collapse of the southwestern edge of the Haroharo Caldera (Nairn, 1981; Rogan, 1982; Wilson et al., 1984; Nairn 2002). The Okataina Volcanic Centre is characterized by a major negative gravity anomaly (Rogan, 1982; Seebeck et al., 2010). Joint gravity and magnetic modelling suggest a depth to the greywacke basement up to 5 km under the Okataina Volcanic Centre (Haroharo caldera) with a shallow, 1–2 km thick layer of magnetized rocks (Rogan, 1982), suggesting the existence of a deep felsic magma body with temperature still above the Curie point. Basement rocks become shallower on all sides of the caldera and in the Rotomahana area (Fig. 2) the basement depth is shallower than 500 m (Rogan, 1982), almost outcropping under Lake Rotomahana and along the south shore of Lake Tarawera.

The erupted material around Lake Rotomahana and Mt Tarawera is mainly rhyolitic (Nairn and Cole, 1981; Wilson et al., 1984; Nairn, 2002) being part of four major eruptive episodes building the Tarawera Volcanic Complex since 17,000 years ago (Cole, 1970; Nairn, 1981; Nairn, 2002). There is evidence of basalt erupted during each of these rhyolite episodes (Nairn, 1992, 2002; Darragh et al., 2006; Shane et al., 2007) and it is believed that injections of basaltic magma played a key role in triggering the rhyolitic eruptions (Leonard et al., 2002; Villamor et al., 2007). Basalts predating the 1886 eruption (Nairn, 1979; Nairn and Cole, 1981) have been mapped along the South and North shore of Lake Rotomahana (Fig. 2). The rocks in the study area (Fig. 2) are normally magnetized lavas and ignimbrites younger than 0.3 Ma (Soengkono, 2001; Leonard et al., 2010).

The 1886 Tarawera Rift eruption was characterized by the intrusion of basaltic dikes along a 17 km long rift dissecting the original Tarawera rhyolite massif, forming a series of separate and coalescing explosion craters (Nairn, 1979; Nairn and Cole, 1981). Although Mt. Tarawera is a rhyolitic volcano, the 1886 eruption produced basaltic scoria and lavas. Basaltic dikes reaching the