Available online at www.sciencedirect.com
SCIENCE DIRECT®

Journal of Volcanology and Geothermal Research 149 (2006) 312–328

Journal of volcanology and geothermal research

www.elsevier.com/locate/jvolgeores

The role of regional-scale faults in controlling a trapdoor caldera, Coromandel Peninsula, New Zealand

N. Smith [a,*], J. Cassidy [a], C.A. Locke [a], J.L. Mauk [a], A.B. Christie [b]

[a] *Department of Geology, University of Auckland, Private Bag 92019, Auckland, New Zealand*
[b] *Institute of Geological and Nuclear Sciences, PO Box 31-312, Lower Hutt, New Zealand*

Received 2 December 2004; received in revised form 15 July 2005; accepted 18 September 2005

Abstract

Regional gravity data from an eroded Miocene to Pliocene volcanic arc exposed in the Coromandel Peninsula, New Zealand, delineate a circular −26-mGal, 15-km-diameter gravity anomaly. This anomaly, which has steep gradients on its northern and western margins but shallow gradients elsewhere, correlates with relatively young volcanic and volcaniclastic rocks within a broad topographic depression. Gravity modelling, using an exponentially decreasing density contrast with depth profile, requires very low-density rocks (ca. 2280 kg m^{-3}) in the near-surface to account for the observed anomaly, giving a total depth of ca. 2.8 km for these rocks. The northern and western margins of this body dip steeply inward at 70°, whereas the southern and eastern margins have shallow inward dips (20–30°). The western margin coincides with the regional-scale Mangakino Fault, but the northern margin, recognizable only in the geophysical data (and named here the Ohinemuri Fault), is partially buried under younger volcanic rocks. We interpret these deep and steeply bounded, low-density volcanics in terms of a trapdoor caldera, faulted on its northern and western margins, with its hinge on the southern and eastern margins. Epithermal deposits are spatially associated with the Mangakino and Ohinemuri Faults, suggesting that both structures may have influenced hydrothermal fluid flow. These deposits pre-date caldera fill, indicating that caldera development followed pre-existing regional faults. These results delineate the subsurface geometry of a trapdoor caldera and highlight the role of pre-existing, regional-scale faults in controlling such caldera location and collapse.

Keywords: trapdoor caldera; gravity model; volcanism; density; Waihi; Coromandel

1. Introduction

Reconstructing the relations between volcanic history, tectonism and fluid flow in the Earth's crust requires the recognition and delineation of large-scale volcanic features and structures. However, in regions of dense vegetation cover, few outcrops and extensive overburden, this can be problematic. Geophysical techniques, particularly gravity and magnetic methods, can be very effective for investigating structures in such volcanic terranes, particularly calderas (e.g., Cordell et al., 1985; Carle, 1988; Hallinan, 1993; Ferguson et al., 1994; McKee et al., 1999; Malengreau et al., 2000). The subsurface structural geometry of calderas, which is key evidence for their style of evolution, is often only apparent from geophysical data. Calderas enclosed by ring faults are common, but those that are bounded by polygonal faults are rare (Lipman, 1997). Active vol-

* Corresponding author. Fax: +64 9 373 7435.
E-mail address: n.smith@auckland.ac.nz (N. Smith).

0377-0273/$ - see front matter
doi:10.1016/j.jvolgeores.2005.09.005

canic settings also commonly contain geothermal systems, which may form epithermal Au–Ag deposits (e.g., White, 1955; Henley and Ellis, 1983; Hedenquist and Lowenstern, 1994), localised by regional faults and calderas (e.g., Sibson, 1987; Sillitoe, 2000).

In this paper, we use new and existing gravity data to develop a model of a trapdoor caldera in the Waihi area of the Coromandel Peninsula, New Zealand. Trapdoor calderas result from asymmetrical collapse of caldera floors, resulting in steep-dipping margins on one side, and shallow-dipping margins on the other (Lipman, 1997; Cole et al., 2005). Several trapdoor calderas have been identified in the nearby Taupo Volcanic Zone (Wilson et al., 1984; Beresford and Cole, 2000; Milner et al., 2002), and similar structures occur worldwide (e.g., Rytuba and McKee, 1984; Seager and McCurry, 1988; Ferguson et al., 1994). Our gravity model allows the delineation of regional-scale faults and investigation of their role in controlling the location and nature of the Waihi caldera, as well as the possible relationship between these faults and former subaerial geothermal systems that formed epithermal Au–Ag deposits in the region.

2. Geological setting

2.1. Regional geology of the Coromandel Peninsula

The Coromandel Peninsula, located in North Island, New Zealand, is a Miocene to Quaternary volcanic province built on Mesozoic greywacke basement of the Manaia Hill Group (Skinner, 1972; Skinner, 1986). It is bounded to the west by the Hauraki Rift, a large graben filled with Quaternary and Tertiary sediments (Hochstein and Nixon, 1979; Hochstein and Ballance, 1993). To the south, the Coromandel Peninsula overlaps the presently active Taupo Volcanic Zone (TVZ). The Waihi area, which is the subject of the present study, is located at the southern end of the Coromandel Peninsula (Fig. 1).

The greywacke basement of the peninsula is divided into sub-rectangular fault blocks with NNW–SSE and WSW–ENE trends (Sporli, 1987; Gadsby and Sporli, 1989). These fault blocks are downthrown to the south, such that the volcanic cover becomes progressively thicker towards the southern end of the peninsula (Skinner, 1986). Volcanic activity began in the north at approximately 18 Ma and progressed gradually southward during the Miocene and Pliocene (Skinner, 1986; Adams et al., 1994). Early phases of volcanism were andesitic and dacitic in nature (Coromandel Group), with volcanism becoming more felsic with time (Whitianga Group), this trend continuing southward along the peninsula. Active volcanism in the Coromandel ended at approximately 1.5 Ma, at which time volcanism transferred to the TVZ without obvious breaks in activity (Adams et al., 1994; Carter et al., 2003).

A gravity study of the northern Coromandel Peninsula by Malengreau et al. (2000) revealed the presence of several large, circular negative anomalies, 10–25 km in diameter, with maximum anomalies of -26 to -34 mGal and gradients of about 2–3 mGal/km, which were attributed to calderas.

2.2. Geology of the Waihi area

In the Waihi area, the greywacke basement is thought to be directly overlain by units of the andesitic/dacitic Coromandel Group (Brathwaite and Christie, 1996), of which the two most important subgroups for this study are the Waiwawa (6.3–7.9 Ma) and Kaimai (3.5–5.6 Ma) (Fig. 1). The Waiwawa Subgroup chiefly crops out to the west and north of the Mangakino and Waihi faults, respectively, whereas the area to the east and south of these faults is dominated by the Uretara Formation of the Kaimai Subgroup. The Mangakino Fault marks a clear boundary between these units; however, the location of the contact along the Waihi Fault is obscured by sheets of younger ignimbrites of the Whitianga Group (Brathwaite and Christie, 1996). The Owharoa and Scotia faults have a similar orientation to the Mangakino Fault and align approximately with its northern extrapolation, forming a structural corridor of N–NNE-trending faults (Brathwaite and Christie, 1996).

Several large epithermal mineral deposits occur in the Waihi area, the largest of which are the Au–Ag deposits at Waihi (Martha), Karangahake and Golden Cross, the Zn–Pb–Cu deposit at Tui (Brathwaite et al., 1989), and the newly defined Favona Au–Ag deposit (Simpson et al., 2002) (Fig. 1). Together, these deposits have produced over 85% of the Au–Ag bullion from the Hauraki Goldfields (Brathwaite and Pirajno, 1993). They are chiefly hosted in the Waipupu Formation andesites of the Waiwawa Subgroup and are associated with extensive areas of hydrothermal alteration (Brathwaite and Christie, 1996). There is little evidence of hydrothermal alteration in the younger Omahine and Kaimai subgroups, and no significant epithermal deposits have been found in these units (Brathwaite and Christie, 1996). Thus, the largest (Martha, Waihi) and third largest (Karangahake) epithermal Au–Ag deposits in the Hauraki Goldfields, as well as several other