Gravity and bathymetric constraints on volcanism and tectonics at the submarine Monowai cone and caldera (Kermadec arc)

M. Paulatto
A. B. Watts
C. Peirce
D. Bassett
J. Hunter
L. M. Kalnins
W. Stratford

1. The Monowai volcanic centre

The submarine Monowai volcanic centre lies in the northern Kermadec arc, at the point of collision with the Louisville ridge (Fig. 1). It consists of a 1500 m high stratovolcano (the Monowai cone), a 8x11 km caldera (the largest known mafic caldera) and several additional small cones (Fig. 2). Monowai cone is one of the most active in the Kermadec arc as demonstrated by observation of discouloured water, T-wave data and seafloor differences from repeat swath surveys [1]. The eruptive products are folicletic basalts. [2]

Monowai caldera shows signs of ongoing hydrothermal activity [3] but the time of the last eruption is unknown. The eruptive products range from basalt to andesite.

2. Gravity and geomorphology data and analysis

Here we present a combined analysis of new multibeam bathymetry data from a Kongsberg-Maritime EM 120 swath system and marine gravity data (from a LaCoste & Romberg Air-Sea gravimeter) collected on the RV Sonne in two phases of the cruise SO215 in May and June 2011 (Fig. 2).

3. Gravity inversion

The gravity data reveal a ~30 mgal Bouguer anomaly high coincident with Monowai caldera. Other features include Bouger anomaly lows corresponding with the highly faulted region to the NW of Monowai caldera and to the basin SW of Monowai cone and a modest Bouguer anomaly high at Monowai cone.

Inversion. The Bouger anomaly data were inverted using the inversion software GROWTHZ [3]. The inversion method is based on growing a subsurface density anomaly by aggregation of prisms. The least squares functional combines a misfit term with a regularization term. The relative contributions of the two terms are controlled by a regularization factor λ. The prisms are 2 km in side on average but are smaller close to the surface and larger at depth. The sensitivity is higher for cells of 2.5 km depth and lower for shallow, deep and peripheral cells.

4. Results

(i) The morphometric analysis allows detailed mapping of tectonic and volcanic features: the Monowai cone and two nested calderas, the several parasitic cones, and numerous faults bounding the volcanic centre to the west and east.

(ii) The gravity data reveals a Bouguer anomaly high at Monowai caldera, indicating the presence of a large buried high-density anomaly. The density anomaly is reconstructed by gravity inversion.

(iii) The main features of the density model are a large high-density body beneath Monowai caldera and low-density anomalies beneath the highly faulted region in the NW and the basin SW of Monowai cone. The high-density body is shifted about 2km to the SE with respect to the caldera and its NW side is aligned with the strike of the NW faults.

(iv) The high-density anomaly likely corresponds to a mafic pluton, probably the result of amalgamation of several smaller sheet intrusions plus a shallow feeder system.

(v) The absence of a significant density anomaly beneath Monowai cone may indicate that it is homogeneous and that it formed relatively quickly. At current eruption rates it would take only about 500 years to build the volcanic edifice.

5. Volcanism and tectonics

Volcanism and tectonics are closely linked at Monowai. The formation of the volcanic centre is believed to be related to tectonic and volcanic features: the Monowai cone and two nested calderas, the several parasitic cones, and numerous faults bounding the volcanic centre to the west and east.

Extensional faulting may have favoured upwelling of magma and influenced the shape and orientation of magma reservoirs, and would have also determined their ultimate fate as rapid extension may have caused the collapse of a proto-Monowai cone and the formation of Monowai caldera.

Monowai cone and caldera and some parasitic cones are aligned in an arc-parallel direction, suggesting that faulting also provides preferential pathways for magma migration and eruption.

Acknowledgements

We thank the captains and crew of the RV Sonne for their help at sea and to Malcom Clark and Geoffrey Lamarche (SNPF) who encouraged us to undertake a new survey of Monowai. The figures were compiled using GMT and Fledermaus. The project was funded by UK Natural Environment Research Council grant NE/F018551/1.

References

