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

Durham University

M. Paulatto[1] (e-mail: michelep@earth.ox.ac.uk), A. B. Watts[1], C. Peirce[2], D. Basset[1], J. Hunter[1], L. M. Kalnins[1], W. Stratford[2]

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 discoloured water, T-wave data and seafloor differences from repeat swath surveys [1]. The eruptive products are tholeitic basalts. [2]

Monowai caldera shows signs of ongoing hydrothermal activity [2] but the time of the last eruption is unknown. The eruptive products range from basalt to andesite.

Here we present a combined analysis of new multibeam bathymetric 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).

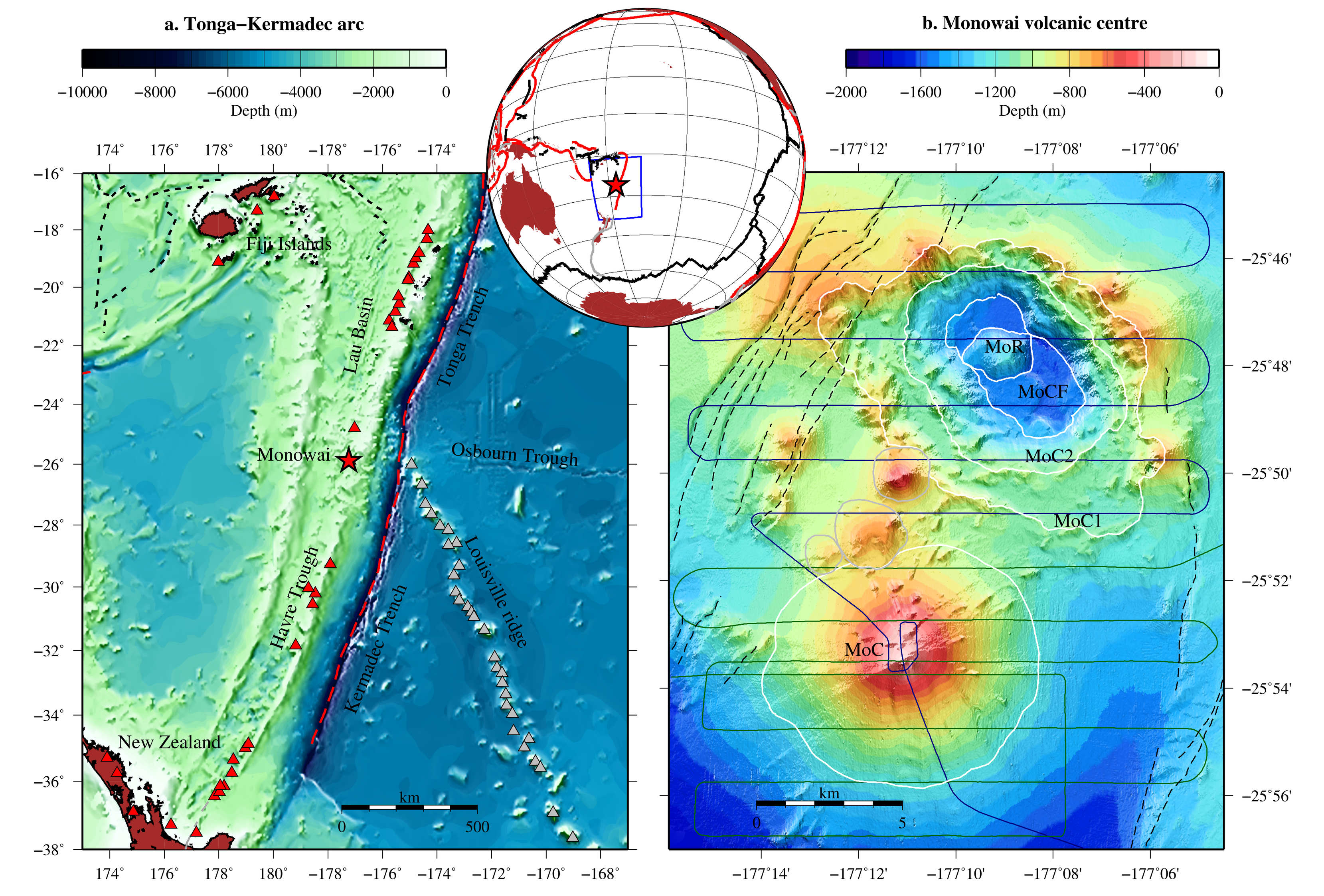

Figure 1. a. Tonga-Kermadec arc. Bathymetric map showing the location of Monowai volcanic centre. The red dashed line marks the subduction zone. The red triangles mark active volcanoes. **b. Monowai volcanic centre.** Bathymetric map with ship track (blue = May survey, green = June survey) and main morphological features (see Fig. 2).

2. Gravity and geomorphology data and analysis

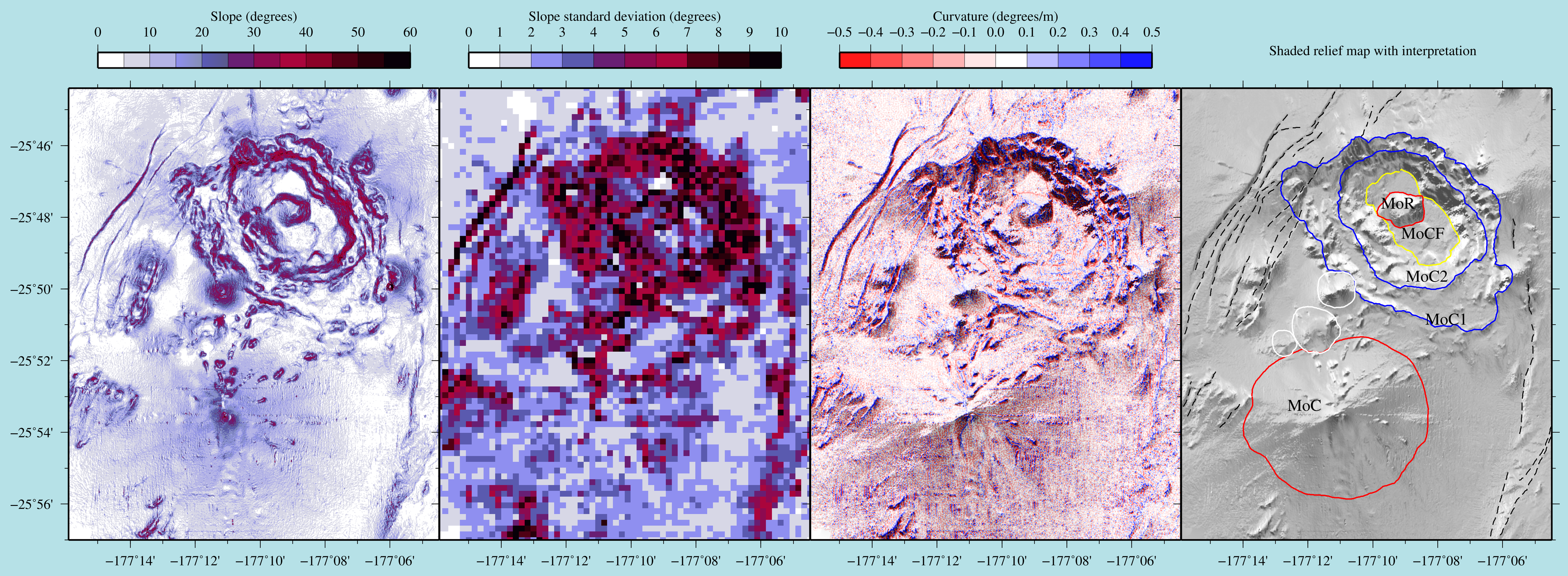

Figure 2. Geomorphology. Morphometric attributes have been calculated to aid the identification of tectonic, volcanic and erosional features. From left to right: slope gradient map, slope gradient standard deviation in 300 m bins, plan curvature, shaded relief map. MoC = Monowai cone, MoC1 = caldera outer rim, MoC2 = caldera inner rim, MoCF = caldera floor, MoR = resurgent dome. Faults marked with dashed lines.

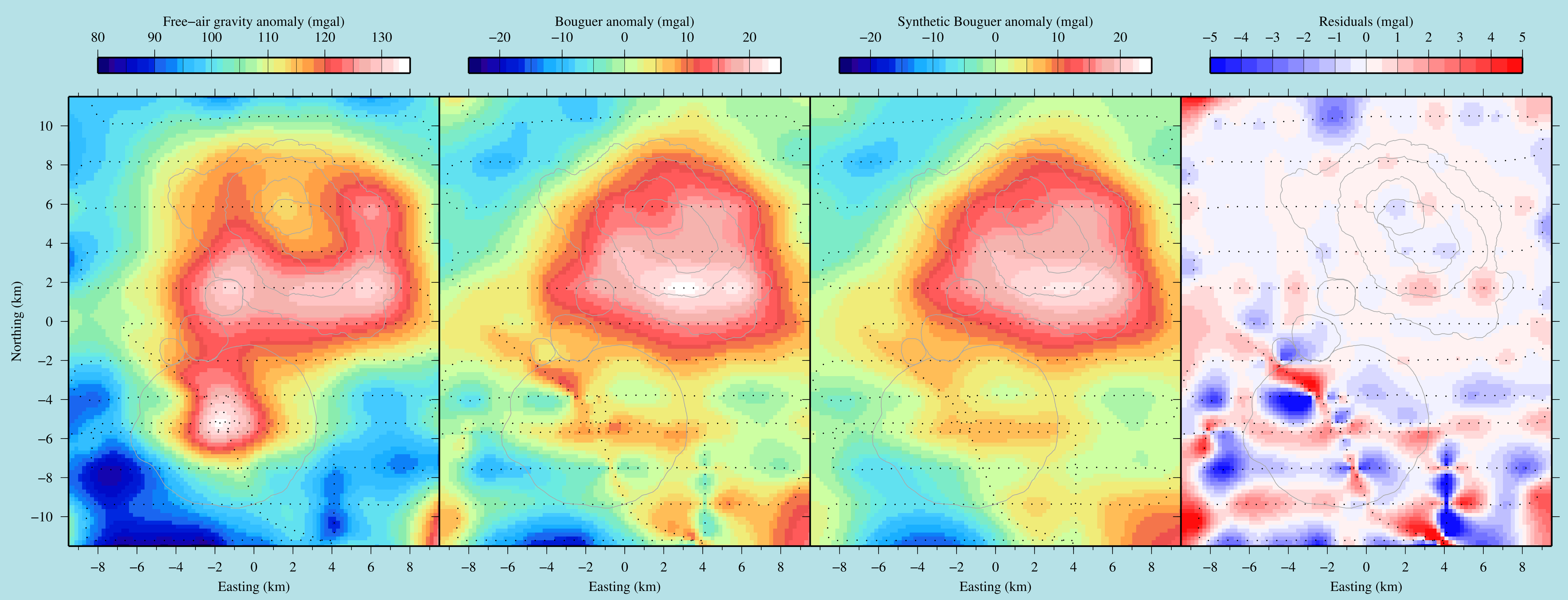

Figure 3. Gravity. The gravity data have been tied to global base stations in Auckland (NZ) and Townsville (AUS) and corrected for drift, cross-coupling error and Eotvos correction. From left to right: Free-air gravity anomaly, Bouguer gravity anomaly with regional trend and mean removed (terrain density = 2170 g/cm^3 determined by imposing lowest correlation with topography), synthetic gravity anomaly from density model, gravity anomaly residuals.

3. Gravity inversion

The gravity data reveal a ∼30 mgal Bouguer anomaly high coincident with Monowai caldera. Other features include Bouguer 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 Bouguer anomaly data were inverted using the inversion software GROWTH2.0 [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 minimum mass constraint. 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 at 2-5 km depth and lower for shallow, deep and peripheral cells.

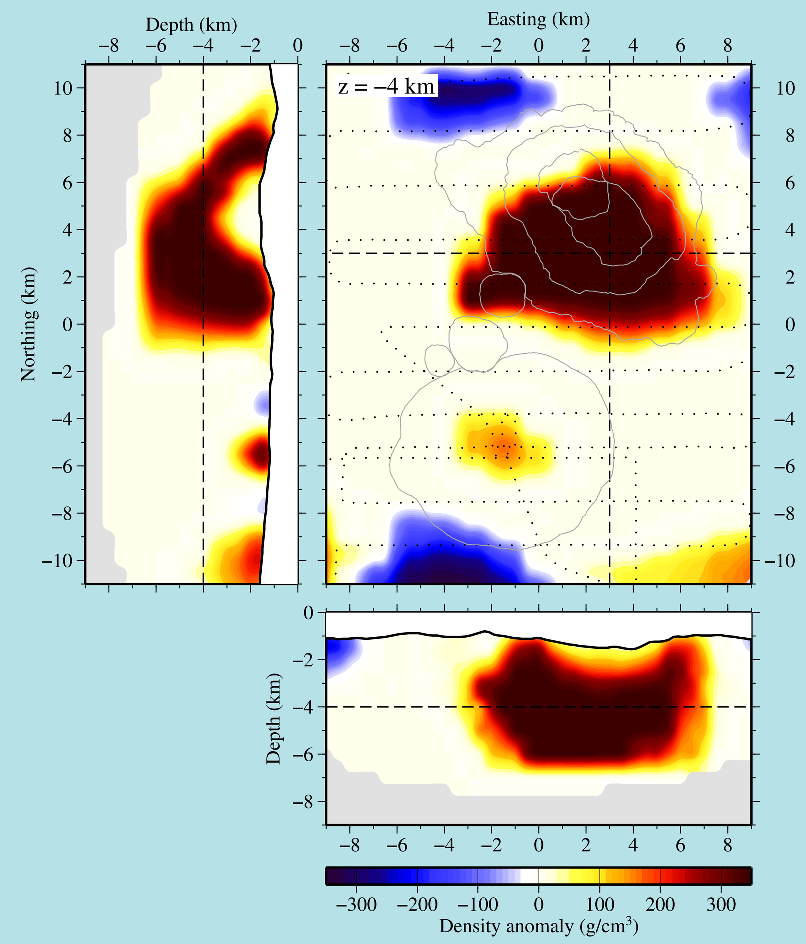

Figure 4. Sections through the density model. A maximum (negative or positive) density anomaly of 350 g/cm^3 was found to produce the best results. The method suffers from a tradeoff between size and strength of the anomaly. The regularization constant λ was kept relatively high to avoid fitting cross-line noise. The RMS residual is 2 mgal. The June data have larger residuals due to higher noise caused by bad weather (see Fig. 3).

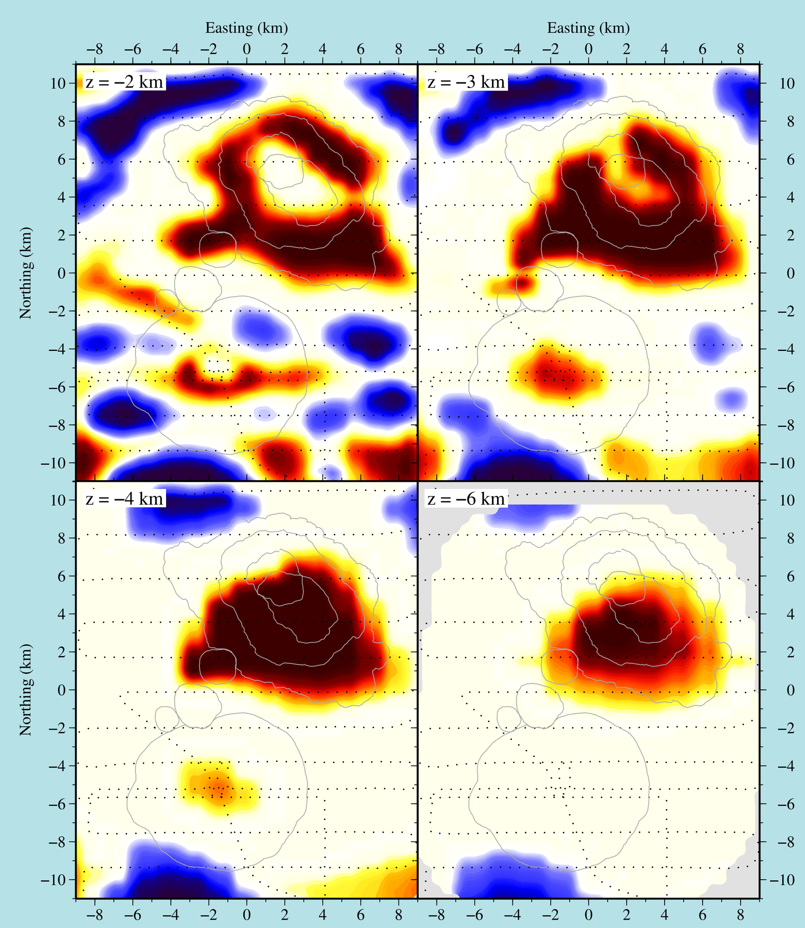

Figure 5. Horizontal sections at various depths through the model reveal a saucer-shaped high density body beneath Monowai caldera. This feature is stable during inversion and independent of the inversion parameters. The high density body has roughly triangular outline and a depressed top beneath the caldera floor, likely indicating the presence of soft sediments. A small positive density anomaly is found beneath the Monowai cone.

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 extension of the arc and opening of the Havre Trough [2]. Extension is likely to be relatively recent and may be still ongoing as suggested by outcropping normal faults mapped on the seabed.

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.

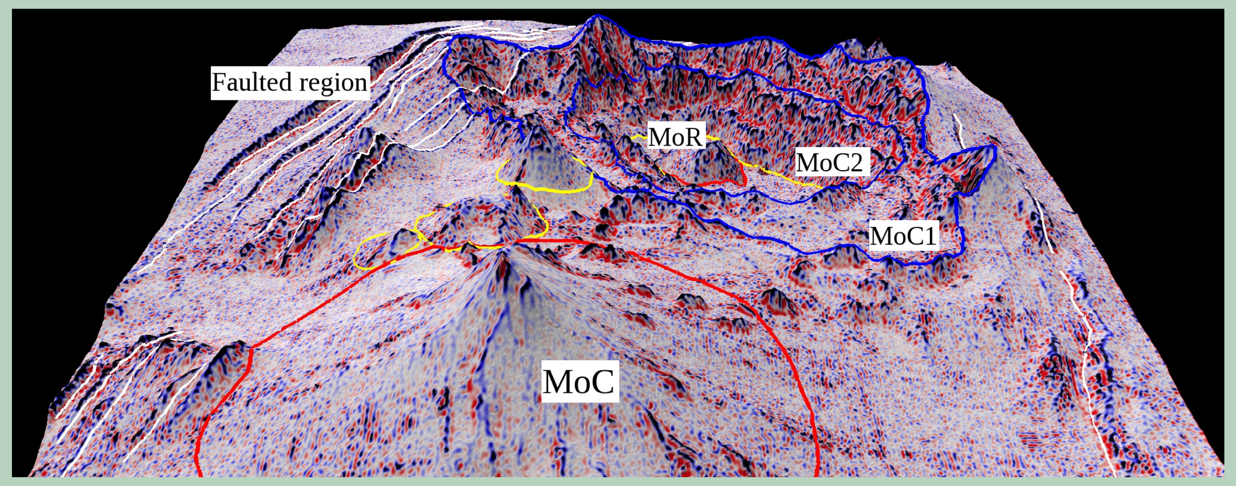

Figure 6. Perspective view of Monowai with curvature map draped over bathymetry and main morphological features. Vertical exaggeration 3:1.

Acknowledgements

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