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Understanding volcanic plumbing systems using constrained 3D inversion of gravity and magnetic data; examples of maar volcanoes.

Teagan Blaikie, Jackson van den Hove, Laurent Ailleres, Peter Betts, and Ray Cas
Monash University, School of Earth, Atmosphere and Environment, Australia (teagan.blaikie@monash.edu)

We developed a technique to model volcanic plumbing systems using integrated analysis of geologic data and constrained three-dimensional gravity and magnetic inversions. Our modelling technique was applied to examine the structure of maar-diatreme volcanoes within the Newer Volcanics Province of south-eastern Australia.

High-resolution ground gravity and magnetic data was initially acquired across several maar volcanoes with dry crater lakes. Bouguer gravity lows were observed across the volcanic craters, and are interpreted to be caused by lower density lake sediments and pyroclastic debris infilling the underlying maar-diatremes. Short-wavelength positive gravity and magnetic anomalies identified within the centre of the craters suggest complex internal structures exist within the diatreme, including feeder vents filled with volcanic debris, dykes and ponded magma.

The geometry of the maar-diatremes and their internal structures were initially determined by 2.5D forward modelling of the gravity and magnetic response, and were constrained by geologic data (eg. crustal lithic fragments in ejecta rim and petrophysical data). These models were used as a skeleton to build a 3D geologic model, which was then subject to constrained 3D gravity and magnetic inversion to optimise the geometry and property distribution within the model. These models provided a greater understanding of the plumbing system, and eruptive history of these volcanoes.

The geophysical models suggest the maar-diatremes within the NVP have broad, ‘bowl-shaped’ morphologies with relatively shallow diatreme depths compared to their diameters. This geometry is interpreted to be predominantly related to the relatively shallow level of aquifers that fuel phreatomagmatic explosions, as well as the unconsolidated to weakly lithified state of the host rock. This allowed for easy explosive excavation of the diatremes and lateral migration of the explosive foci which lead to widening of the vent. Some models indicate dykes and magma ponds are present in the diatreme fill. This suggests a system not fully saturated with water, which allowed dykes to propagate through the diatreme fill, and resulted in the eruption style fluctuating between phreatomagmatic and magmatic. This is also observed in the deposits contained within the ejecta rim of these volcanoes.