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A model to forecast magma chamber rupture

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An understanding of the amount of magma available to supply any given eruption is useful for determining the potential eruption magnitude and duration. Geodetic measurements and inversion techniques are often used to constrain volume changes within magma chambers, as well as constrain location and depth, but such models are incapable of calculating total magma storage. For example, during the 2012 unrest period at Santorini volcano, approximately 0.021 km̂3 of new magma entered a shallow chamber residing at around 4 km below the surface. This type of event is not unusual, and is in fact a necessary condition for the formation of a long-lived shallow chamber. The period of unrest ended without culminating in eruption, i.e the amount of magma which entered the chamber was insufficient to break the chamber and force magma further towards the surface. Using continuum-mechanics and fracture-mechanics principles, we present a model to calculate the amount of magma contained at shallow depth beneath active volcanoes. Here we discuss our model in the context of Santorini volcano, Greece. We demonstrate through structural analysis of dykes exposed within the Santorini caldera, previously published data on the volume of recent eruptions, and geodetic measurements of the 2011–2012 unrest period, that the measured 0.02% increase in volume of Santorini's shallow magma chamber was associated with magmatic excess pressure increase of around 1.1 MPa. This excess pressure was high enough to bring the chamber roof close to rupture and dyke injection. For volcanoes with known typical extrusion and intrusion (dyke) volumes, the new methodology presented here makes it possible to forecast the conditions for magma-chamber failure and dyke injection at any geodetically well-monitored volcano.