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Far-field surface displacements resulting from magma-chamber failure and caldera formation

John Browning and Agust Gudmundsson

Royal Holloway, University of London, Department of Earth Sciences, Egham, United Kingdom
(john.browning.2012@live.rhul.ac.uk)

On certain rare occasions, the physical processes in a volcano encourage chamber-roof failure and vertical collapse along bounding ring-faults. The conditions which lead to caldera forming collapse are still poorly constrained. As there have only been four, possibly five well documented caldera forming events, the geodetic signals produced from chamber failure and collapse are not well understood. We present results from numerical models designed to simulate the failure and subsidence of a magma chamber roof. Our aim is to present the resultant surface deformation expected from such collapse events. All shallow magma chambers reside in crustal segments which to a first approximation can be considered to behave as a linear elastic material. The crustal response due to deflation and inflation cycles at caldera volcanoes is often considered using a point-pressure (Mogi) source; however, such models are not suitable for constraining magma chamber failure and collapse volumes. We consider roof displacement for a number of magma chamber depths, geometries, and sizes using the numerical Finite Element software, COMSOL. In addition, we investigate the role of crustal heterogeneities and anisotropies, as well as the surface cover (such as an ice sheet) on the results obtained. Initial models indicate significant vertical displacement (> 0.5 m), several tens of kilometres from the collapse area. Results are significantly affected by the mechanical properties of the host rock, the magma chamber geometry, and the collapse volume (the volume of the subsidence). The models can be used to estimate the amount of vertical and horizontal far-field surface displacements that would be expected to be recorded by geodetic monitoring networks for a given caldera subsidence. Such results may be useful for interpreting signals from ice-covered volcanoes, such as Bardarbunga and many other volcanoes in Iceland.