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Mechanics of volcanic systems: Considerations of magma buoyancy and viscoelastic behaviour of host rock

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Improved understanding of processes leading to volcanic eruptions helps mitigate their influence. Volcano inflation associated with arrival of new magma in volcano roots is sometimes revealed by repeated geodetic measurements and the source of deformation inferred through modelling. Such observations can be used to infer the dynamics of volcanic systems. Most widely used models assume elastic behaviour of host rock and ignore density difference between magma and host rock. However, these assumptions are unjustified in many cases and lead to erroneous view of how volcanoes work. A large part of any given magmatic system lies below the brittle-ductile transition in the Earth (3-9 km depth in volcanic regions) where creep or visco-elastic deformation mechanisms dominate for the duration of magma accumulation. For volcanic systems in Iceland magma is as well boyant at these depths; less dense than host rock. These two effects combined, viscoelasticty and magma buoyancy, need to be considered for understanding how volcanic systems work. Viscoelastic effects allow the deeper parts of magmatic systems to gradually accommodate large volumes of magma with limited surface deformation rates, and without significant raise in host rock deviatoric stress. When such a source is drained by magma outflow, the buoyancy of its magma leads to the development of underpressure which contracts the source. Rates of magma outflow from deep sources is limited, typically to 1-10 m3/s, orders of magnitude less than from shallow sources in elastic host rock. Interplay between magma movements and storage in shallow elastic crust and at deeper ductile levels can thus explain eruptive and volcanic unrest episodes, with the episode duration dependent on the viscoelastic contraction of the underlying deep source feeding the episode.