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Magma Reservoir Volumes and Eruption Forecasting

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The volume of a volcano's magma reservoir places a fundamental limit on the maximum size of an eruption (neglecting significant recharge), and also controls the temporal evolution of eruptive activity. The ability to estimate reservoir volume therefore critically informs eruption forecasts and hazard analyses. Geochemical residence times, the volumes of aseismic zones beneath volcanoes, and the volumes of past eruptive products may all be used to estimate reservoir volume, but most estimates are associated with a great deal of uncertainty and can vary by an order of magnitude or more for a single volcano.

A promising new technique for constraining properties of volcanic systems involves using physics-based eruption models in combination with diverse observations of volcanic activity. Simple eruption models which assume that eruption rate is proportional to the pressure in a deflating elastic reservoir suggest that the reservoir volume should be directly proportional to the erupted volume, to the magnitude of ground deformation around the volcano, and to the time constant (rate of change) of these observations during an eruption. To explicitly estimate reservoir volume with such a model we must be able to place constraints on reservoir pressure, properties of the conduit linking the reservoir to the surface, and the compressibility of the melt-reservoir system. The latter may be uniquely constrained using measurements of extrusive flux and ground deformation, but reservoir volume cannot in principle be constrained using only these data sets. Additional information, such as a constraint on reservoir pressure change, is required.

In this work we generate synthetic data and run Monte Carlo simulations to evaluate our ability to place limits on reservoir volume using a priori information about the volcanic system (i.e. the strength of the reservoir's host rock) and additional data sets (such as the heights of active lava lakes) in a Bayesian inverse approach. Finally, we examine the influence of reservoir volume on eruption forecasts. Probabilistic forecasts of erupted volume and duration may be obtained using the same Bayesian approach, in which we use observations to estimate the model's initial conditions (including reservoir volume), and from which future behavior may be forecast. In an actual eruption, simulations may be run whenever a new observation becomes available, thus updating and improving the forecasts.