Physics-based modeling at Kīlauea Volcano, Hawai'i: Constraining magma supply and storage rates, primary melt volatile content, and reservoir volume

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Kīlauea Volcano has been intensively studied for more than a century, yet many of its fundamental properties remain poorly resolved, including the volume of magma storage beneath the summit (estimates vary from 0.08 to more than 200 km^3), the deep magma supply rate (0.06 to 0.19 km^3/yr), and the rate at which magma accumulates in the rift zones. These properties are often estimated using only a single type of observation to constrain a simple model which fixes other parameters to assumed values; this approach does not make use of all available data, does not account for uncertainties in assumed parameters, and produces results which are not always physically consistent with one another.

Physics-based models of volcanic systems can be used to relate a wide range of observations and physical properties to one another in a coherent system. Using such a model, an observation of ground deformation for instance might better inform not only an estimate of the magma reservoir location, but also of the volatile content of melt in that reservoir.

In this work we develop a physical model of magma supply, storage, and eruption at Kīlauea Volcano which is capable of predicting CO_2 and SO_2 emissions and ground deformation. We constrain the model using observations from different time periods in the ongoing Pu'u 'Ō'ō–Kupaianaha eruption to estimate magma supply rate, magma storage rate, and primary melt volatile content. We also look for changes associated with an inferred surge in magma supply to the volcano during 2003-2007. Inversions are performed using a Bayesian technique which yields probability distributions for all estimated parameters. When possible, we compare results to independent estimates from the literature. This work can be considered a first step towards the development of more realistic physics-based models of Kīlauea's magma plumbing system with which to better interpret and utilize the remarkable diversity and quantity of geological and geophysical observations available at the volcano.