The challenge in quantifying magma input and output to active volcanoes—an example from Kilauea

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Two of the most fundamental parameters governing volcanic activity are magma supply to and effusion from the volcanic edifice. Both are especially relevant at persistently active volcanoes, where an imbalance in the two can result in changes in eruptive activity. Kilauea Volcano, in Hawai'i—one of the best–studied volcanoes in the world—provides an excellent example of the challenges in quantifying magma supply and effusion rates.

Magma supply to the volcano has been calculated by combining the volume of effusion with the volume of storage as determined from deformation modeling, but that approach assumes all magma storage areas are known and that models of surface deformation provide accurate volume change estimates. Simple elastic models of deformation, however, fail to account for magma compressibility, which can bias volume calculations by up to an order of magnitude. Carbon dioxide emissions provide a means of gauging changes in supply but are only useful in a relative sense because the CO_2 content of the hotspot supplied magma currently remains an estimate.

Numerous techniques have been employed to gauge lava effusion rates, including SO_2 emissions based on a known SO_2 content of the magma, lava tube cross-section and flux, topographic change due to lava emplacement, and thermal measurements. Extensive lava flow fields, however, confound efforts to image thermal and topographic change, since airborne measurements often lack sufficient areal coverage and satellite monitoring may not have adequate temporal resolution. In addition, lava that enters the ocean cannot be satisfactorily accounted for by measuring changes in subaerial topography. If no observable lava tubes are present, geophysical methods of determining flux through tubes are not possible. Finally, equating the rates of lava effusion to SO_2 emission assumes that all magma that degasses SO_2 also erupts. This assumption does not account for pre-eruptive degassing—a process that has been occurring since the start of Kilauea's summit eruption in 2008. Moreover, some magma may degas but not erupt, instead sinking to deeper levels after it has lost its volatiles.

Improved spatial and temporal resolution of satellite measurements can address the effusion rate question. This technique is best for flows that remain on land and do not enter the ocean. We are currently testing the TanDEM-X topographic mission as a means of mapping the volume change of Kilauea's Pu'u 'O'o flow field. Absolute determinations of magma supply, however, will continue to involve numerous assumptions until better understanding of primary melt composition and magma storage are available. For now, magma supply rate measurements remain most useful in a relative sense.