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Subsurface magma pathways inferred from statistical analysis of volcanic vent distribution and numerical model of magma ascent

Aurelie Germa, Laura Connor, Chuck Connor, and Rocco Malservisi
University of South Florida, Department of Geology, Tampa, United States (agerma@usf.edu)

One challenge of volcanic hazard assessment in distributed volcanic fields (large number of small-volume basaltic volcanoes along with one or more silicic central volcanoes) is to constrain the location of future activity. Although the extent of the source of melts at depth can be known using geophysical methods or the location of past eruptive vents, the location of preferential pathways and zones of higher magma flux are still unobserved. How does the spatial distribution of eruptive vents at the surface reveal the location of magma sources or focusing? When this distribution is investigated, the location of central polygenetic edifices as well as clusters of monogenetic volcanoes denote zones of high magma flux and recurrence rate, whereas areas of dispersed monogenetic vents represent zones of lower flux. Additionally, central polygenetic edifices, acting as magma filters, prevent dense mafic magmas from reaching the surface close to their central silicic system. Subsequently, the spatial distribution of mafic monogenetic vents may provide clues to the subsurface structure of a volcanic field, such as the location of magma sources, preferential magma pathways, and flux distribution across the field. Gathering such data is of highly importance in improving the assessment of volcanic hazards.

We are developing a modeling framework that compares output of statistical models of vent distribution with outputs form numerical models of subsurface magma transport. Geologic data observed at the Earth's surface are used to develop statistical models of spatial intensity (vents per unit area), volume intensity (erupted volume per unit area) and volume-flux intensity (erupted volume per unit time and area). Outputs are in the form of probability density functions assumed to represent volcanic flow output at the surface. These are then compared to outputs from conceptual models of the subsurface processes of magma storage and transport. These models are using Darcy's law with variable conductivity dependent on flow rate and lithospheric stress to model the flow of a viscous fluid within a homogeneous porous medium.

Here, we apply the initial developments of this framework to the Lassen Segment (northern California), a distributed volcanic system. An investigation of the spatial density of eruptive vents has been processed separately for basaltic, andesitic and silicic vents. Results suggest that mafic and andesitic melt regions are related, widespread in space and time, with frequent eruptions distributed across the entire field. In contrast, silicic volcanism is spatially focused, and geochronological record suggest episodic activity. Additionally, we explore the influence of various physical parameters, such as crust porosity and the development of shallow reservoirs, into magma transport and flux by modeling it as the non-linear flow of a viscous fluid within a homogeneous porous medium. By comparing output data from numerical simulations to the flux revealed at the surface by our spatial density analysis, we gain insights into the subsurface processes controlling the location of mafic distributed volcanism.