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LiDAR observations of an Earth magmatic plumbing system as an analog for Venus and Mars distributed volcanism

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Clusters of tens to thousands of small volcanoes (diameters generally <30 km) are common features on the surface of Mars, Venus, and the Earth. These clusters may be described as distributed-style volcanism. Better characterizing the magmatic plumbing system of these clusters can constrain magma ascent processes as well as the regional magma production budget and heat flux beneath each cluster. Unfortunately, directly observing the plumbing systems of volcano clusters on Mars and Venus eludes our current geologic abilities. Because erosion exposes such systems at the Earth's surface, a better understanding of magmatic processes and migration can be achieved via field analysis.

The terrestrial plumbing system of an eroded volcanic field may be a valuable planetary analog for Venus and Mars clusters. The magmatic plumbing system of a Pliocene-aged monogenetic volcanic field, emplaced at 0.8 km depth, is currently exposed as a sill and dike swarm in the San Rafael Desert of Central Utah, USA. The mafic bodies in this region intruded into Mesozoic sedimentary units and now make up the most erosion resistant units as sills, dikes, and plug-like conduits.

Light Detection and Ranging (LiDAR) can identify volcanic units (sills, dikes, and conduits) at high resolution, both geomorphologically and with near infrared return intensity values. Two Terrestrial LiDAR Surveys and an Airborne LiDAR Survey have been carried out over the San Rafael volcanic swarm, producing a three dimensional point cloud over approximately 36 sq. km. From the point clouds of these surveys, 1-meter DEMs are produced and volcanic intrusions have been mapped.

Here we present reconstructions of the volcanic instrusions of the San Rafael Swarm. We create this reconstruction by extrapolating mapped intrustions from the LiDAR surveys into a 3D space around the current surface. We compare the estimated intrusive volume to the estimated conduit density and estimates of extrusive volume at volcano clusters of similar density. The extrapolated reconstruction and conduit mapping provide a first-order estimate of the final intrustive/extrusive volume ratio for the now eroded volcanic field.

Earth, Venus and Mars clusters are compared using Kernel Density Estimation (KDE) , which objectively compares cluster area, complexity, and vent density per sq. km. We show that Martian clusters are less dense than Venus clusters, which in turn are less dense than those on Earth. KDE and previous models of intrusive morphology for Mars and Venus are here used to calibrate the San Rafael plumbing system model to clusters on the two planets. The results from the calibrated Mars and Venus plumbing system models can be compared to previous estimates of magma budget and intrusive/extrusive ratios on Venus and Mars.