Growth and evolution of the western Galápagos volcanoes: insights from space-geodetic observations.

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Current understanding of the construction and evolution of basaltic shield volcanoes is largely based on studies of Hawai'i, however, the Hawaiian conceptual model is not sufficiently representative of basaltic shields elsewhere on Earth and other planets. For example, the volcanoes of the western Galápagos Islands generally lack well-developed rift zones, and eruptions occur from fissures oriented circumferentially to the summit on the upper portions of the volcanoes and radially on the flanks. The cause of the great difference between paths of magma transport or patterns of eruptive fissures at Hawaiian volcanoes and those of the western Galápagos Islands has long been a source of speculation, especially given the similar intra-plate hotspot origin for the two archipelagos. The application of space-geodetic techniques over the past 20 years has provided an unprecedented opportunity to study the sub-surface structure of the Galápagos volcanoes.

We use interferometric synthetic aperture radar (InSAR) measurements of surface displacements associated with eruptive activity as well as episodes of volcanic inflation and deflation that occurred between eruptions at Fernandina, the youngest and most active volcano in the Galápagos archipelago. The volcano is characterized by at least two hydraulically connected magma reservoirs, at $\sim$1 km and $\sim$5 km depth beneath the summit caldera. The deeper reservoir appears to be the source of large sill-like intrusions in 2006 and 2007 that are indicated by broad patterns of flank deformation, while the shallower reservoir feeds summit and flank eruptions. Displacements associated with eruptions in 1995, 2005, and 2009 are particularly instructive with regard to the origin of the pattern of eruptive fissures, since both radial (1995 and 2009) and circumferential (2005) fissure eruptions have been spanned by radar images acquired by multiple satellites. We show that magma transport at Fernandina is by means of subhorizontal intrusions, since both types of eruptions are initiated as subhorizontal sills, and not as subvertical dikes as would be expected by analogy with Hawai'i. A radar image acquired only two hours prior to the start of a radial fissure eruption in 2009 captures one of these intrusions in the midst of its emplacement.

The characteristic pattern of radial and circumferential fissures is best shown at Fernandina but is evident to varying degrees at all volcanoes in the western Galápagos, suggesting that the processes controlling intrusive and eruptive dynamics are common to all the edifices. These results suggest an alternative model for the internal growth of basaltic volcanoes that is contrary to the Hawaiian example. Furthermore, models of stress changes generated by sill intrusions at Fernandina suggest that it is possible to forecast the location and style of future eruptions based on deformation associated with previous events.