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Magma Transport and Storage at Kilauea Volcano

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Modeling of ground deformation data, and the occurrence of low seismicity between 4 and 7 km beneath Kilaueas summit defines olivine-controlled magma storage, the source of eruptions and intrusions at Kilaueas summit and rift zones. H-f earthquake swarms beneath the rift zones define a brittle region above 5 km depth. A weakly seismic zone extends from 5 km down to the decollement at 10-12 km depth along which the south flank of Kilauea is sliding seaward. Parts of this region sustain aseismic magma transport. Small storage sites in the rift zone, just beneath the brittle cap, are defined by ground deformation surveys and contain differentiated magma. Olivine-controlled magma moving from summit storage to eruption on the rift zone mixes with differentiated magma to produce hybrid lava chemistry.

Clusters of l-f earthquakes deeper than 40 km lie offshore of Kilaueas south coast, directly above a segmented hotspot magma source in the asthenosphere. The easternmost l-f cluster is displaced more than 20 km to the south of the well-defined shallow plumbing. We propose a horizontal component of magma transport to explain the displacement of the deep (40-55 km) from the shallow (7-15 km) l-f earthquakes. The region of mantle between the deep and shallow l-f earthquakes coincides with the aftershock zone of the 2/1/94 earthquake (M 5.2, depth=35 km), suggesting a weakened zone capable of faulting. The 2/1/94 earthquake and other deep mainshocks within the same zone produce more aftershocks than other mainshocks at similar depths, and have a high aftershock decay rate. These observations are consistent with a greater crack density, presence of faults that remain close to failure, and rapid stress decay in a region of elevated temperature. Thus the seismic data are consistent with the existence of a deep magma transport path connecting the two sets of l-f earthquakes.

We conclude that Kilauea has been fed from the eastern end of the zone of deep l-f earthquakes, nearly due south of Kilaueas summit. Magma movement is inferred to be vertical below about 30 km, then sub-horizontal at 25-35 km, perhaps following the boundary between plagioclase and spinel peridotite in the oceanic mantle. Above 25 km the transport path is again near-vertical to meet the well-defined magma transport path beneath Kilaueas summit.

To extend Kilaueas history back in time, we consider the dynamics of the moving Pacific plate and the underlying thermal plume in the aesthenosphere. Kilaueas shallow plumbing moves with the plate. The deep l-f earthquakes also lie within the Pacific plate, but track the location of the thermal plume in the asthenosphere beneath the plate.

The last 10 years of motion of the Pacific plate, as defined by global GPS surveys, is about 7 cm/yr, azimuth 290deg, in agreement with the long-term plate motion of 7.8 cm/yr, azimuth 292deg inferred from the volcano propagation rate along the island chain northwest of the island of Hawaii. The volcanoes on the island of Hawaii are grouped on two locus lines, azimuth 325deg, volcano propagation rate about 13 cm/yr. The change of orientation requires either a change of plate motion, or a clockwise migration of the thermal plume rising from the hotspot.

On the assumption of constant plate motion, the WSW vector connecting Kilaueas original position to the present location of deep, long-period earthquakes is consistent with a longer-term clockwise migration of the plume. Assumed ages of 0.4-0.5 my for Kilauea are consistent with this model and with ages inferred from direct measurement or from geological considerations. Identification of a broad, segmented hot spot combined with migration of the plume can explain (1) the long-term geochemical separation of Kilauea from neighboring volcanoes Mauna Loa and Loihi, and (2) the short-term changes in trace-element and isotope signatures within Kilauea.