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Submarine Rift Systems in Hawaiian Volcanoes

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Hawaiian volcanoes are built by intrusions of magma into central magma storage reservoirs and subsequent channeling of that magma into intrusive dikes and sills and extrusion at surface vents. After variable lengths of residence time in a summit reservoir, magmas either erupt at the summit or travel laterally away from the summit into elongated dike systems known as rift zones. The surficial expression of rift zones in Hawaii is a relatively narrow (3-5 km wide) zone of constructional and extensional volcanic features. Rift zones are fundamental components of Hawaiian volcanoes. They are the principal conduits for subsurface magma transport and they form fundamental structural boundaries that control volcano stability and structural evolution, and they are loci of secondary eruptive vents along strike.

Rift zones on Hawaiian volcanoes can be very long, with much of their length extending below sea level. Numerous studies have focused on subaerial portions of rift zones, but few have looked in detail at the submarine portions. This study focuses on two pronounced and well-developed submarine rift zones: Puna Ridge, the submarine extension of the East Rift Zone (KERZ) of Kilauea volcano, Hawaii, and Hana Ridge, the submarine extension of the East Rift Zone (HERZ) of Haleakala volcano, Maui. The KERZ is 125 km in length from the Kilauea summit to the submarine tip of the Puna Ridge; the 75-km-long Puna Ridge is 60percent of the total length of the KERZ. The HERZ at 145 km is even longer than the KERZ. Its submarine portion, Hana Ridge, is 125 km long, or 86 percent of the total length of the HERZ. Therefore, because most of the length of these rift zones is below sea level, a thorough understanding of their formation and evolution requires detailed submarine investigations.

Submarine portions of rift zones in Hawaii have steeper along-axis slopes than do their subaerial portions. For example, the subaerial KERZ has a slope of 2.3 percent, whereas the submarine Puna Ridge has slopes of 5.1 in its upper half and 9.5 in its deepest section. This slope difference is thought to result from differences in the density contrast between magma-air and magma-water. In turn, the steeper slopes of submarine rift zones lead to excess magma pressure near the leading edge of the dike, resulting in increased dike height at the tip and preferential downrift eruptions. Thus, steeper slopes may provide a feedback mechanism wherein submarine portions of rift zones can grow by enhanced dike propagation.

Submarine rift zone morphology is dominated by primary constructional volcanism. This volcanism produces pointed cones, flat-topped cones, sheet flow fields, pillow mounds and ridges, and terraces. These features reflect variations in eruption rate, topographic slope, magma volatile content, and confining pressure of the overlying water column. Mass-wasting occurs on submarine rift zones, but generally not at the large scale seen in subaerial portions of the rift zone (e.g. Hilina Fault system on Kilauea; Nuuanu slide on Oahu). Features interpreted to be slump terraces, landslide amphitheaters, and slump scars are seen on both the Puna and Hana Ridges, but they are rather small in comparison to Hilina, Nuuanu, and other collapse features.

Subaerial rift zone eruptions are generally consistent with shallow (greater than 3 km) crystal fractionation of magmas. This implies that dikes feeding subaerial rift zone eruptions are rooted at these depths. However, uncertainty still exists regarding the vertical extent of submarine portions of rift zones. Elevated Al_2O_3 contents in volcanic glass rinds of pillow lavas are interpreted to signify higher pressures of fractionation in basalts erupted at the tip and on the flanks of the Puna Ridge. These results suggest that dikes at the steeply sloping, distal sections of the rift zone extend to greater depths.