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Controls on dyke injection at basaltic volcanoes from patterns of volcano-tectonic seismicity

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Flank eruptions at basaltic volcanoes are fed by dykes injected into the volcanic edifice from a magma reservoir at depth. To investigate the controls on dyke intrusion, we have analyzed volcano-tectonic (VT) seismicity associated with flank eruptions and intrusions at the frequently active basaltic volcanoes, Kilauea and Mauna Loa, Hawaii and Mt. Etna, Sicily. Approximately 40% of events are preceded periods of accelerating rates of VT seismicity exceeding 4 weeks in duration. Most clearly observed as accelerations in the cumulative number of earthquakes as a function of time, N(t), these sequences are well characterized by an exponential function, N(t) = k.exp((t-t_0)/τ), where τ and k are constants that vary for each sequence. The temporal and spatial patterns are consistent with models of progressive edifice deformation surrounding a pressurized magma reservoir, and parameter relations emerging from these models allow prediction of likely injection times. Although the remaining events are associated with limited precursory seismicity, for many, the onset and immediate aftermath are associated with increased rates of VT seismicity in the mobile flank of the volcano. The patterns of this mobile flank response are consistent with those recently observed following episodes of rapid aseismic flank slip at Kilauea. We propose that these "silent earthquakes" result in stress changes around the shallow magma reservoir and rift-zones that trigger the passive injection of magma. These observations provide the basis for (1) improved forecasts of eruptions and (2) identifying practical time-limits for initiating responses ($e.g.$, evacuations) to a volcanic emergency.