The interplay of crustal stress and structure at Kilauea Volcano inferred from seismic anisotropy

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Using shear wave splitting analysis, we have examined volcano-tectonic earthquakes with M >2 at Kilauea Volcano, Hawaii, recorded between April 2007 and December 2011, for seismic anisotropy. We use an the automated algorithm, MFAST, to calculate shear wave splitting parameters. The algorithm uses a grid-search inversion over the azimuth of the fast polarization direction and delay time, for a given time window. It incorporates cluster analysis over a range of time windows to find the most stable result, calculates the optimum three filters to apply to the data on the basis of signal-to-noise ratios and then grades each measurement and marks any null measurements in which no splitting result is obtained. We assume that the polarization of the fast shear wave is parallel to the maximum horizontal compressive stress or the orientation of geologic structures.

Stations more than 5 km from Kilauea's summit eruptive vent record fast directions that are strongly aligned in a NE-SW direction (mean of $071.3 \pm 2.2°$), consistent with previous studies from the 1980s and 1990s and suggesting that regional stress is stable over decadal time periods. We also observe fast directions aligned with prominent faults trending obliquely to the NE-SW regional shear wave splitting direction when the stations are close (<1 km) to the fault, and fast directions tangential to the summit caldera (parallel to the caldera ring faults) at stations close to the caldera. Our observations suggest that highly fractured zones associated with faulting overprint the anisotropy from micro-cracks that are aligned with the regional stress. The exception to these trends is in 2008, when anisotropy fast directions at stations on the caldera floor (within the caldera-bounding faults) rotated to be perpendicular to the caldera bounding faults. These changes were roughly coincident in time with the onset of Kilauea's current summit eruption in March 2008. Interestingly, the eruption was not preceded by a dramatic change in the numbers of discrete earthquakes nor by the usual inflationary ground deformation, but SO_2 emissions and seismic tremor began to increase several months prior to March 2008. We interpret the changes in anisotropy to be due to an increase in the gas filled pore and crack pressure associated with increased SO_2 emissions preceding the start of the summit eruption–an interpretation that is supported by corresponding decreases in V_p/V_s ratio, calculated with the same dataset. Our result demonstrates that changing SWS should not solely be interpreted in terms of stress conditions.