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Statistical properties of volcanic earthquakes

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The spatial and temporal patterns of volcano-tectonic earthquakes can provide insight into the properties and development of the percolating fracture network associated with failure and magma injection. Here we present examples of this from the basaltic volcanoes on the island of Hawaii. The network is created by the growth of fractures, either actively through poro-elastic stressing, and/or more passively through creep to failure mechanisms at relatively constant stress. Competing models for these processes however predict very similar outcomes – a constant loading-rate percolation model and extrapolations of rheology from sub-critical crack growth and creep tests all imply inverse power-law acceleration in the rate of rate of earthquakes prior to failure. For the latter two, exponential accelerations are also possible for very specific values of the critical exponents involved, in which case the failure time cannot be defined uniquely. Seismic event rate data for Kilauea volcano between 1959 and 2000 confirm that although some eruptions are preceded by such accelerations to failure, this is not always the case, and many increases in event rate do not lead to eruption, implying a significant forecast failure rate and number of false alarms for any forecasting of individual eruptions. However, a mean field accelerating behaviour 10–15 days before eruption is observed in data for many eruptions when stacked in phase with the eruption time. In terms of forecasting power, only a short-term forecast can be achieved with at most a few days warning, using a linear fit to inverse rate. We also investigate inter-event times Δt and inter-hypocentral distances Δr between subsequent events in comparison with a surrogate catalogue where time correlation is deliberately destroyed as null hypothesis. The characteristic length scale of interaction is $\sim$ 20km, on the same order of magnitude as to the seismogenic depth. For the inter event times we observe a slow power law decay with exponent $\sim$ – 0.25 which extend up to $\Delta t \sim$ 3 years where an exponential decay dominates. These observations are comparable to

those found in tectonic earthquake populations.