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Testing the reliability of the Gutenberg-Richter b-value to aid volcanic eruption forecasting

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The distribution of earthquake magnitudes is an important additional attribute of a volcanic earthquake catalogue and analyses of properties of the "frequency-magnitude distribution" (FMD) underpins most studies of volcanic seismicity. The event rate and inter-event intervals are of primary interest as their changes can be a primary indicator of volcanic unrest. The classic model for the earthquake FMD is the Gutenberg-Richter (GR) relation (Gutenberg and Richter, 1954): log(N) = a - bM, where N is the cumulative number of earthquakes of magnitude equal to or greater than M, a is a measure of the total seismicity rate of the region and the b-value represents the relative proportion of large and small events in the catalogue. The b-value for tectonic earthquakes has been well studied with a global average of approximately 1. However, b-values in volcanic settings are often reported to be much higher, sometimes with values as high as 3. Spatial variations in the volcanic b-value have been used to map stress conditions and magma reservoirs, and it has been argued that temporal variations have the potential to forecast eruptive activity.

Here we assess different methodologies for analysing properties of the FMD, and re-evaluate what we know about the FMD of volcanic earthquakes. Using synthetic models we evaluate the reliability of methods for calculating the catalogue completeness magnitude where earthquake rates fluctuate rapidly in time to simulate pre-, syn- and post- earthquake swarm activity. We also evaluate to what extent volcanic FMDs are consistent with the GR model, using earthquake data from volcanoes including El Hierro, Canary Islands and Kilauea and Mauna Loa, Hawaii.

We suggest that much of the proposed variation in b-value can be attributed to uncertainty in the completeness magnitude, and FMDs not displaying GR properties. In the case where event rate is pulsing or swarming the b-value has a tendency not to stabilise with increasing completeness magnitude suggesting a GR model is not appropriate. High b-values can often be associated with high completeness magnitudes and incomplete catalogues; excluding these results we see find b-values fall more in line with typical values at tectonic settings.