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Top–Down Precursory Volcanic Seismicity: Implications for 'Stealth' Magma Ascent and Long-Term Eruption Forecasting

Diana Roman (1) and Katharine Cashman (2)

(1) Carnegie Institution for Science, Department of Terrestrial Magnetism, (droman@carnegiescience.edu), (2) School of Earth Sciences, University of Bristol, Bristol, United Kingdom

Volcanic eruptions occur when a conduit forms to connect a crustal magma reservoir to Earth's surface. Conduit formation is generally assumed to be a 'bottom–up' process and a major driver of precursory volcanic seismicity, which is the most commonly monitored parameter at volcanoes worldwide. If both assumptions are true, initial precursory seismicity should coincide spatially with petrologically-estimated magma reservoir depths. A review of six well-constrained case studies of arc volcanoes that erupt after repose intervals of decades indicates that, to the contrary, initial precursory seismicity is consistently several kilometers shallower than the magma reservoir. We propose a model involving a three-phase process of unrest and eruption: initial (partial) conduit formation occurs during a 'staging' phase, either aseismically or long before the onset of the immediate precursory run-up to eruption. Staging may involve slow ascent rates and/or small volumes. A destabilization phase then coincides with the onset of precursory seismicity, leading to a 'tapping' phase that involves additional magma ascent from the magma reservoir. This model implies that, most critically, it may be possible to detect precursory magma ascent well before the onset of seismic activity by continuous monitoring of the state of stress in the mid to shallow crust.