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The evolution of periodic seismicity, waveform similarity, and conduit processes during unrest episodes at Tungurahua volcano, Ecuador, in 2015

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Tungurahua is a large andesitic stratovolcano located in the Andes of Ecuador. The current eruptive phase at Tungurahua began in 1999, and has been characterised by episodes of vulcanian and strombolian activity, interspersed by periods of relative quiescence. Despite showing only modest eruptive activity in 2015, seismic data revealed a pronounced change in the behaviour of the magma-conduit system compared to the preceding 15 years of activity. The change is most notable in the periodicity of interevent-times of volcanic earthquakes. Previous seismicity at Tungurahua is characterised by interevent-time periodicities typical of a Poisson process, or modestly clustered, with slightly elevated (anti-clustered) periodicities observed only rarely during vulcanian episodes. However, activity in 2015 saw a series of unrest episodes characterised by highly-periodic interevent-times, and including several notable episodes of 'drumbeat' earthquakes. Here we report seismic and associated geophysical signals recorded at Tungurahua in 2015 by the monitoring network of the Instituto Geofisico of Ecuador, their relation to conduit processes, and implications for the origins of unrest and likely future activity.

Although the nature of the low-frequency seismic signals change both within and between unrest episodes, the underlying periodicity is more consistent and gradually evolving. Waveform similarity is high within phases, resulting from the repeated activation of persistent sources, but low between different episodes, suggesting the emergence of new sources and locations. The strength of periodicity is correlated with the average waveform similarity for all unrest episodes, with the relatively low waveform similarities observed for the highly periodic drumbeat earthquakes in April due to contamination from coexisting continuous tremor. Eruptive activity consisted of a few minor explosions and ash emission events. Notably, a short-lived episode of Strombolian activity in November with juvenile magma was quickly followed by a resumption of periodic low-frequency seismicity.

The changes in the seismicity of Tungurahua in 2015 suggest a significant change in the magma-conduit system. Elevated periodicity may indicate the presence of a slowly upward moving plug at a depth of 1-2km below the summit crater, likely associated with the unusually long repose period since the last major vulcanian episode in October 2014. Evolution in the periodicity and type of seismic signals within and between unrest episodes will be controlled by a combination of the gas flux and permeability, and a balance between thermo-mechanical plug degradation and time-dependent healing processes. These factors are also likely to determine the nature of future eruptive activity.