Understanding cyclic seismicity and ground deformation patterns at volcanoes: intriguing lessons from Tungurahua volcano, Ecuador

Supplementary online material

Jürgen W. Neuberg*[a], Amy S. D. Collinson[a], Patricia A. Mothes[b], Mario, C. Ruiz[b] and Santiago Aguaiza[b]

[a] School of Earth & Environment, The University of Leeds, Leeds, United Kingdom

[b] Instituto Geofisico, Escuela Politécnica Nacional, Quito, Ecuador

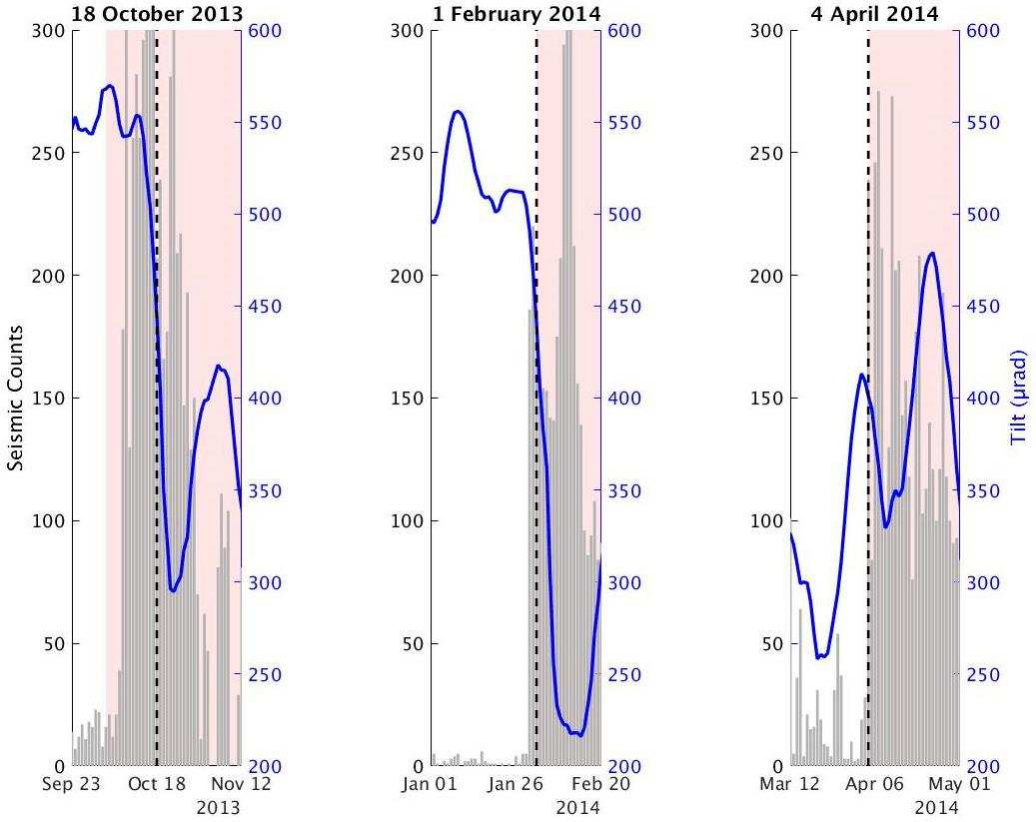

Figure S1: Zoomed view of the tilt and seismicity associated with the last three events in our study. Each Vulcanian explosion is preceded by the onset of increased seismicity and a decrease in tilt.

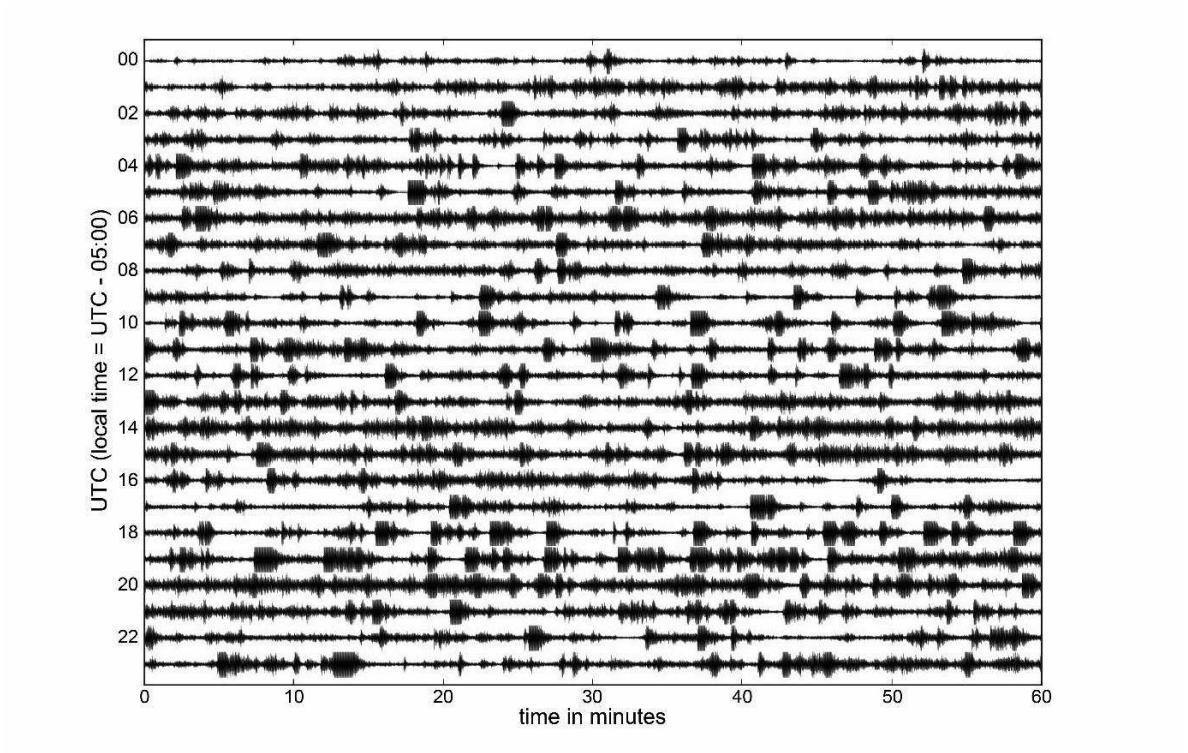

Figure S2: Seismic swarms recorded at RETU for 11 October 2013 – seven days prior to the explosive event on 18 October 2013.

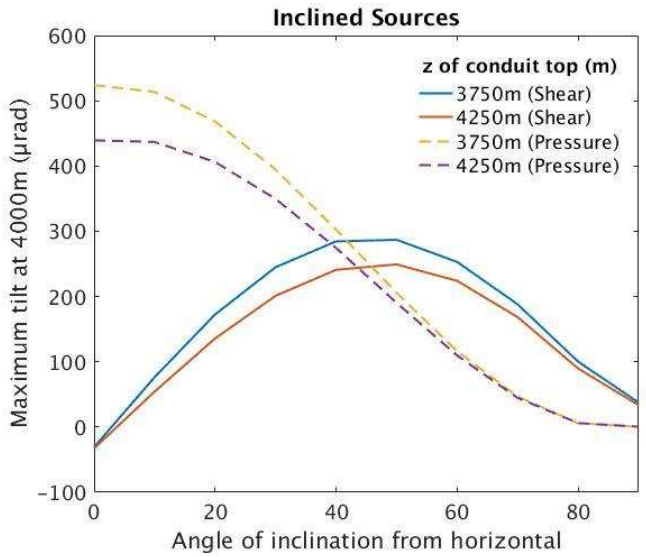

Figure S3: Maximum tilt recordable at RETU for inclined sources. Sources have a length of 250m at different angles of inclination from 0° (horizontal) to 90° (vertical). Two different locations of the top of the source are modelled for both shear stress and pressure.

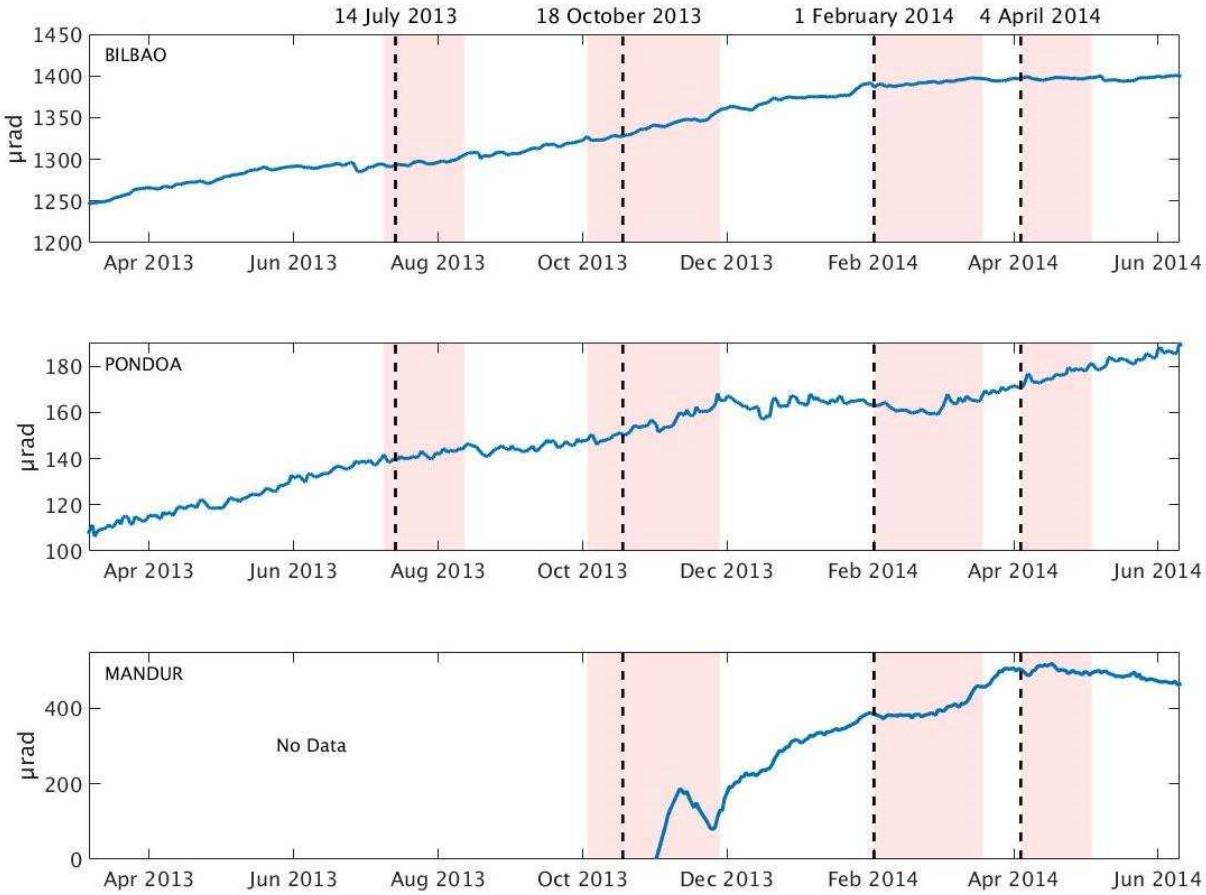

Figure S4: Maximum tilt for the three distal stations, BILBAO, PONDOA and MANDUR. The location of the four Vulcanian explosions of interest are marked (dashed lines) along with the duration of the eruptive phases (shaded).

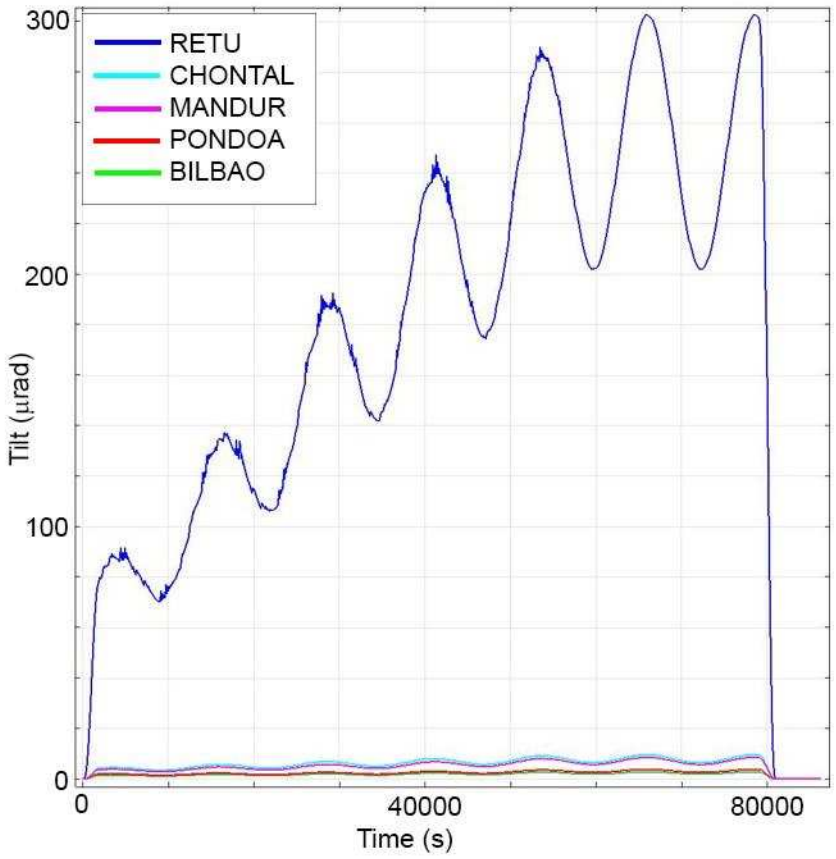

Figure S5: Example modelling results where the magnitude of shear stress and magma ascent velocity vary through time. The ascending magma is modelled between 2500-4500m elevation, where the magma ascent velocity increases linearly from 0.01 to 0.03 m/s and the shear stress by ±5MPa generating the undulations. Note the numerical noise due to fast changes in shear stress. Compared to the significant tilt signature for RETU, the model predicts near zero tilt for the more distal stations.

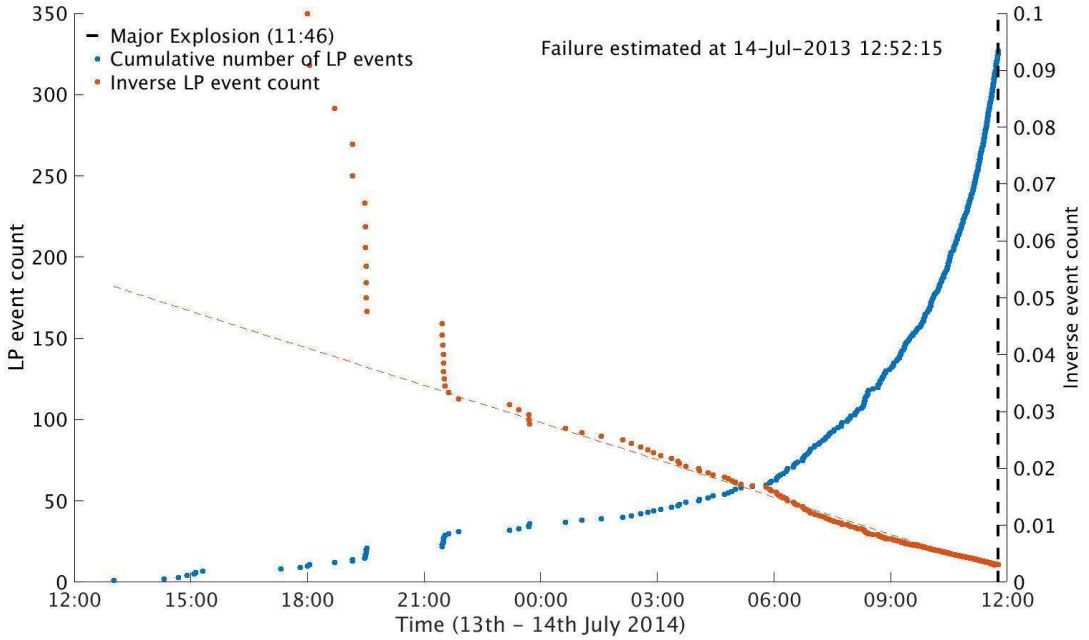

Figure S6: LP event count preceding the eruption on the 14 July 2013 (blue) plotted with the inverse of the LP event count (red). The inverse trend points to a "predicted" eruption time based upon the acceleration of seismicity. The time of the major explosion on the 14 July 2013 is marked by the vertical dashed line.

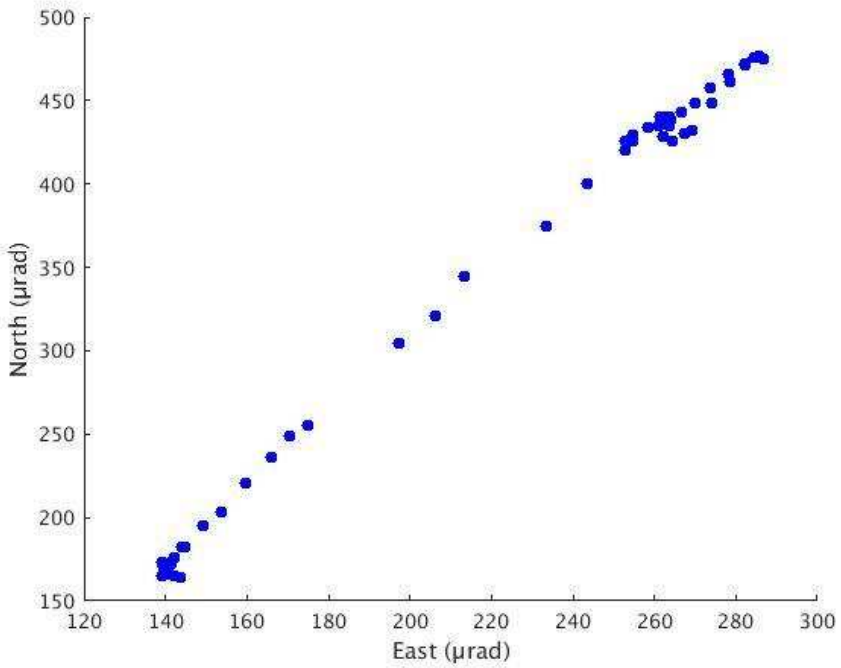

Figure S7: Tilt trajectory of the RETU tilt meter for January 1st through February 20th, 2014, see Figure S1 centre panel. Note, the linear trajectory indicates shear stress as a source process.