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Geodetic signature of 2015-16 unrest at Cotopaxi-Ecuador: modeling of GPS data, a deep magma source, synchronous seismic swarms and petrologic constraints

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Cotopaxi volcano's 2015-16 unrest resulted in GPS displacements, increased GPS velocities and reversal of vectors and positive tilt, coinciding with increased long period (LP) seismicity, high frequency tremor and accentuated accumulative seismic energy. Seismicity at Cotopaxi in late April-15 was typified by abundant LPs and VLPs, located 3-15 km below the crater. Onset of seismic activity and deformation was synchronous. The culmination were 5 phreatomagmatic outbursts on 14 August-15. Vigorous degassing and ash fallout were recorded until November, prior to cessation of horizontal GPS displacements. A seismic swarm began 10 September-15, registering ~14,883 volcano-tectonic earthquakes through March-16. The last ash emissions in November-15 expulsed abundant microcrystalline material, implying rheological stiffening at the top of the magma column and low rates magma of ascent.

The deformation patterns obtained from GPS are asymmetrical and showed stronger western GPS vectors and displacements, but weak E-NE vectors. To explain these patterns we used GeodMod for modeling a Mogi point source to the observed Cotopaxi GPS data, finding a match for volume, depth, GPS velocities and vectors. Our best fitting model for deformation at Cotopaxi is a Mogi inflationary point source below the SE flank at 24.2 km depth, with a volume increase of $41.8 \times 10^6 \pm 26 \times 10^6$ m^3. Rates of change for GPS displacements never exceeded 5 mm/month, total maximum horizontal GPS displacements were 15 mm and vertical offsets obtained 16 mm. Ash that fell during the unrest amounted to ~0.9Mm^3; ~50% was possibly juvenile and became progressively more microcrystalline. This volume is minor compared to the modeled volume; we classify the eruption as "failed", since little juvenile magma erupted. Understanding the causes, patterns and evolution of the deformation signals of this episode is important for interpreting future geodetic patterns displayed before new eruptions at Cotopaxi