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Post-seismic deformation of the Chilean volcanic arc (32°S-38°S): field and numerical studies

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Eruptive rates in volcanic arcs increase significantly after subduction zone mega-thrust earthquakes. Over short time periods the response of the arc is attributed to the passage of seismic waves and to the elastic deformation of the upper plate. A second peak of volcanic activity, however, occurs decades to centuries latter. A kinematic mechanism that controls such a long term response has yet to be proposed and verified.

In 2010 the M8.8 Maule earthquake struck in Central Chile causing normal stress reductions in the arc as high as 1MPa (from about 32°S to about 38°S) on optimally oriented faults. In such regions the shallow (i.e. less than 30 km deep) post-seismic intra-arc seismic activity increased remarkably in the post-seismic period. We combine classical geological methods with numerical models of seismic cycles calibrated for the Central Chile subduction zone to investigate the key processes driving the deformation of the volcanic arc and the reactivation of volcanic systems over long timescales (e.g. decades to centuries).

First, we undertook a geological field survey around and across the Nevados de Chillan volcanic complex, (∼36.5°S). We mapped the distribution and orientation of faults and dikes to better describe the long-term deformation occurring in the this part of the volcanic arc. We concentrated in this region as the volcano was affected by the Maule earthquake and its aftershocks. In addition, the volcanic complex is elongated along a NW-SE direction, which is sub-parallel to the orientation of basement lineaments that are thought to be reactivated by supra-lithostatic fluid and magmatic pressures occurring during the post-seismic period. Second, we run 2D numerical simulations of several seismic cycles with a viscous-elasto-plastic seismo-thermo-mechanical code that accounts for a realistic geometry and rheology of the compressive margin. The code includes spontaneously developing faults and the morphology of the volcanic arc, which affects the lithostatic load at shallow depths and therefore the local distribution of the stresses below the arc. Our field observations indicate that magmatic activity is strongly affected by the overall tectonic state of the upper crust. This is in agreement with our numerical experiments pointing out that upwelling of deep magmas may be controlled by a reduction of the normal effective stress acting in the shallow crust during the post-seismic periods. In other words, mega-thrust earthquakes accelerate natural processes (i.e. volcanic activity and the deformation of the upper crust) that would otherwise occur over far longer timescales.