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Morphometric evolution of volcanic edifices related to growth and deformation: insights from analogue models

Pablo Grosse (1), Daniel Yagupsky (2), and Diego Winocur (3)

(1) CONICET & Fundación Miguel Lillo, Tucumán, Argentina (pablogrosse@yahoo.com), (2) Laboratorio de Modelado Geológico, Universidad de Buenos Aires, Argentina, (3) Laboratorio de Tectónica Andina, Universidad de Buenos Aires, Argentina

In order to evaluate the effects of growth and deformation (both separately and jointly) on volcano shape evolution, we performed a set of analogue experiments simulating these processes. The models consist of an initial symmetrical cone of 3 to 6 cm height composed of a mixture of quartz sand and plaster (cohesion of 100 to 300 Pa). Deformation was simulated through the relative motion of two underlying plates, generating a dextral E-W transcurrent fault. Growth was simulated through sedimentation of loads of granular material. For experiments simulating a fixed emission point, sedimentation was done on the same central point, whereas for experiments simulating variable emission points, sedimentation was done at the location of extrusion of corn syrup (pure and water-diluted, viscosities of 2 to 20 Pa.s) injected at the cone base, modeling magma intrusion. The experiments were documented by photographs and topographic scans, from which digital elevation models were constructed and used to calculate morphometric parameters. Five types of experiments were performed:
-1. Deformation without growth (the initial cone is deformed by the E-W fault): the edifice elongates ENE-WSW, sub-perpendicular to $\sigma 1$; a large graben forms at the summit region; the height/width ratio (H/W) strongly decreases.
-2. Fixed-location growth without deformation (sedimentation on top of the initial cone): the edifice maintains its symmetrical, circular and regular shape, only size increases.
-3. Variable-location growth without deformation (cycles of injection and sedimentation at the extrusion location): location of extrusions are variable, both within and between experiments; edifices are strongly irregular; elongation values and directions vary; H/W is maintained or decreases slightly.
-4. Fixed-location growth with deformation (the initial cone is deformed by the fault and sedimentation is done on a central point): as with type (1) models, the cone elongates ENE-WSW and the central graben forms; however, sedimentations cover the graben and are distributed on a NW-SE belt, perpendicular to the elongation direction; edifices have similar elongation values and directions as type (1); H/W decreases, but less than in type (1) models.
-5. Variable-location growth with deformation (cycles of deformation by the fault alternate with injection and sedimentation at the extrusion location): extrusions occur on the fault trace or slightly south of it, sub-parallel to $\sigma 1$; edifices are elongated E-W or NW-SE, with higher elongation values than type (3) models; irregularity is also higher; H/W decreases, generally more than in type (3) models.
The models can be compared and related to the shapes and morphometric evolutions of real volcanoes. Type (1) models simulate an inactive volcano degraded by deformation. Type (2) models simulate an active volcano in an inactive tectonic zone, with enough magma pressure and/or a sufficiently resistant edifice to keep growing 'upwards' through the main conduit. In type (3) models the volcano lacks sufficient magma pressure and/or resistance and thus opens up new lateral pathways. Type (4) models simulate an active volcano in an active tectonic zone, where the main conduit is maintained despite the deformation. In type (5) models the deformation diminishes edifice resistance so that, as in type (3) models, new pathways are generated, but in this case the distribution of the new conduits is not random but is instead conditioned by the developing structures.