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Magma ascent during thrusting: insights from Tromen volcano (Argentina) and laboratory experiments

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At convergent plate boundaries such as subduction zones, volcanoes obviously indicate that magma ascend in a global convergent tectonic context. Nevertheless in such settings, localized extension is often invoked to explain how magma reaches the surface. Probably this stands for mechanical reasons: compression is known to inhibit magma ascent. However, it has been rarely demonstrated from field examples that volcanism is synchronous with compression or extension. Consequently, to know if magma can ascend during compression or not remains an open question. Subsidiary, how does magma ascend through a shortening crust and does reach the surface?

Detailed fieldwork and geochronological study (40Ar-39Ar) show that the back-arc Tromen volcano (Neuquén basin, Argentina) was active during regional tectonic shortening. Tromen lies above an uplifted sedimentary basement. Although the basement is more deformed than the thin volcanic cover, both recorded a significant amount of E-W shortening. On maps, folds and faults broadly trend N-S, following arcuate trends around the foot of the volcano. Felsic domes within the volcano align E-W. N-S thrusts crosscut mafic feeder dykes. N-S folds affect some mafic lava flows. Blocks of conglomerates containing volcanic pebbles are involved in tectonic melange zones. A known historical eruption and dating on volcanic rocks reveal that the activity has been almost continuous since ca 2 Ma and that a part of the shortening is younger than ca 1Ma. Thus Tromen constitutes one of the first documented examples where magma reaches the surface in a compressional setting.

To study how magma ascends during compression, we performed laboratory experiments to model intrusions of low viscosity magmas within a shortening brittle crust.

Molten vegetable oil (η=0.02 Pa s) which is solid at room temperature and compacted fine-grained silica powder (cohesion C$\approx$300 Pa) represent, respectively, the magma and the crust. The set up consists in a rectangular box filled with the powder and equipped with a laterally moving piston. It ensures during an experiment the independent control of the shortening rate and of the flow rate at which the molten oil is injected punctually at the base of the powder (see also Galland et al., this session). After each experiment, the model is cut into longitudinal cross sections. The results of a series of experiments in which shortening and injection were coeval show that (1) compression favours emplacement of oil within horizontal intrusions, (2) oil propagates upward along thrusts, (3) an oil intrusion represents a localized décollement level which induces the formation of arcuate thrusts around the foot of a poorly deformed uplifted plateau. Those features illustrate some of the strong mechanical interactions one can expect between compressional tectonics and coeval magmatic intrusions.

Our experiments were not performed to reproduce the structure of Tromen. However, when attempting a comparison between experiments and field observations some similarities highlight possible consequences of coeval magma emplacement and shortening. The arcuate shape of the thrusts around the foot of Tromen uplifted basement can result from a décollement at depth within a partly molten sill-like intrusion. In addition, a significant ascent of the magma at depth might have been possible along thrusts. Contrasting with classic representations, it is therefore possible that the deep plumbing system forming the main roots of the volcano have to be looked for laterally at depth and not to a vertical below the volcano.