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Magma-controlled tectonics in compressional settings: insights from experimental modelling

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Magmatic activity tends to concentrate at tectonic plate boundaries. At rapidly convergent margins, such as the Andes, intense magmatic activity is coeval with strong tectonic shortening, and some volcanoes and magmatic intrusions have been emplaced near active compressional structures, usually major thrust faults. In such settings, as long as magma remains molten, it should be very much weaker than its country rock. We may therefore expect a body of magma to influence the pattern of tectonic deformation.

In order to study the mechanical interactions between compressional deformation and magmatic intrusion, we resorted to laboratory experiments, in which a brittle crust was shortened, while magma was intruding. Our model materials were (1) cohesive fine-grained silica powder, representing brittle crust, and (2) molten low-viscosity vegetable oil, representing magma. In general, horizontal shortening and injection were coeval but independent processes. In experiments, thrust faults accommodated the shortening, while overpressured oil formed hydraulic fractures. In those experiments where there was no injection, shortening resulted in a classical thrust wedge, in which thrusts had straight traces and were separated by about 5-6 cm; the apical angle of the wedge was about 15º. In the other experiments, where there was injection, oil formed a basal sill, and the structure of the wedge strongly differed. Once in place, the sill lubricated the base of the model, so that arcuate thrusts formed at the leading edge of the sill. The distance between thrusts increased, defining a non-deformed plateau. The apical angle of the wedge was smaller than 10º. Uplift of the plateau promoted further intrusion of oil at depth. In general, the pattern of deformation and intrusion depended on the kinematic ratio R between rates of shortening and injection. The lengths of the basal sill and plateau increased with decreasing R.

On the basis of these results, we have re-examined two natural examples of magmatic complexes, which were emplaced in compressional tectonic settings, Tromen volcano in Argentina and the Boulder Batholith of Montana. We conclude that magma can play an important role in the tectonic development of compressional margins.