Pervasive migration of magma through the crust

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The migration of magma through the crust from deeper, hotter levels affects the composition and temperature of the crust, and so understanding mechanisms of magma migration help us to understand crustal structure and evolution. Two different mechanisms have been extensively studied: dyking and diapirism. Pervasive migration is an alternative to these.

The mechanism by which magma migrates depends on the properties of the magmas and conditions in the crust. Large quantities of fluid magma can migrate quickly through cracks in brittle crust by dyking. Diapirism, where a large blob of magma squeezes upward through plastically deforming surroundings, is favoured when the magma is very viscous and the crust is ductile. In both dyking and diapirism magma transport is strongly localized into one or maybe several distinct pathways.

"Pervasive" migration is the motion of magma through an extensive network of channels. It involves an intimate contact and efficient heat transfer between the magma and the country rock, and therefore requires that the country rocks be at temperatures above the magma solidus. Granite magma injection complexes, which are common in hot crustal terranes, are thought to result from magma migrating pervasively through an interconnected network of blobs and sheets, of scales varying between millimetres and tens of metres. At least four mechanisms control pervasive magma migration: a) tectonic pumping; b) pervasive flow through hot, low viscosity country rocks; c) volatile-driven intrusion, where magma follows volatile-rich phases; and d) small-scale local dyking.

Although the high-temperature requirement may seem very restrictive, we envisage a feedback mechanism whereby heat advected with early magma batches will warm the crust, allowing later batches to reach shallower levels. We explored this idea with a simple conceptual and numerical model in order to judge its viability. We found that pervasive migration is an efficient way of heating the lower crust, which can result in a several kilometre thick injection complex formed by approximately 50-50 original crust and magma.