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Sub-lithospheric small scale convection - a process for continental collision magmatism

Lars Kaislaniemi, Jeroen van Hunen, Mark B. Allen, and Iain Neill
Durham University, Department of Earth Sciences, Durham, United Kingdom (l.m.kaislaniemi@durham.ac.uk)

We use combined geodynamic-petrological models to study the role of sub-lithospheric small scale convection for the generation of continental collision magmatism.

The active Arabia-Eurasia collision has produced a number of volcanic centres on the Turkish-Iranian plateau since the Miocene. These volcanic rocks have a highly variable geochemical signature, but commonly point to an Sr-Nd isotopically depleted mantle source. Major and trace element characteristics span the range from OIB-like, to calc-alkali, shoshonitic and even ultrapotassic.

We suggest these spatially, chemically and chronologically infrequent patterns of volcanism are caused by sub-lithospheric small scale convection (SSC). SSC is driven by a Rayleigh-Taylor instability, enhanced by the 1-2 orders of magnitude lower viscosity than the ambient asthenosphere, which is caused by an increased amount of water in the mantle (both the overlying lithosphere and the mantle wedge), which is in turn due to the subduction prior to the collision and/or continental subduction during collision.

SSC is modelled using the mantle convection code CitCom with an added parameterized melting model. We relate the water content in the mantle to the solidus temperature, and assume that water behaves as a highly incompatible element during melting. Viscosity is taken as a function of water and melt content and depletion. For SSC to take place under realistic conditions, a dislocation creep mechanism, or a diffusion creep mechanism with lowered activation energy, is needed.

Results show that SSC is able to produce small degrees (0-2 %) of melting of the mantle through dripping lithosphere, which results in a hot upwelling return flow, which leads, in turn, to decompression melting, erosion in to the overlying lithosphere, and advection of hot material into contact with the cold lithosphere. Partially molten mantle pools in the lithospheric pockets eroded by SSC, and leaves behind a depleted and more viscous mantle, low in water content, once the melt has exceeded a critical amount and is extracted to the surface. Assuming that these melts percolate instantanously to the surface, basaltic layers with thickness on the order of 100 metres are formed.

By its random nature, SSC can explain why the continental collision magmatism on the Turkish-Iranian plateau does not seem to have clearly recognisable spatial or temporal patterns. The potential of the SSC to effectively mix the asthenosphere-lithosphere close to their boundary appears to offer an explanation for the geochemical heterogeneity of the observed volcanism.