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Where do migmatites in metamorphic core complexes really come from?

Christian Teyssier (1), Megan Korchinski (1), Donna L. Whitney (1), and Patrice F. Rey (2)

(1) Earth Science, University of Minnesota, Twin Cities, MN 55455, USA (teyssier@umn.edu), (2) Earthbyte Research Group, The University of Sydney, Sydney, NSW, Australia

Metamorphic core complexes (MCC) are commonly exhumed in the footwall of extensional detachment systems. Structural reconstructions typically place MCC rocks back in the mid-crust along a trajectory that follows the dip of the detachment. However, MCC are also commonly cored by migmatite domes, and although the migmatites represent partially molten crust that crystallized at low pressure (P< 0.5 GPa), they typically contain inclusions of refractory material that originated in the deep crust (P∼1.0-1.5 GPa). Therefore, rocks in migmatite-cored MCC record a wide variety of structures, conditions of deformation (partially molten versus solid-state), metamorphic record (particularly pressure), and geochronologic relations (cooling history) that raise questions about their provenance and path.

In order to approach this problem, we conducted a suite of 2D numerical experiments (Underworld-1). The starting configuration is a 60 km thick crust, with T-Moho ∼800°C, that is extended at the boundaries at a velocity of 2 cm/yr. After 10 My of extension deep crustal rocks have reached the near-surface, forming a MCC; at this point we study particles along horizontal cross sections across the MCC located at ∼5, 10, and 15 km depth, and interrogate them for their trajectories and P-T-t-D paths. In nature, these cross sections would be available at exposure levels after some erosion of the MCC has taken place. When the model deep crust has a relatively low viscosity, the particles at the center of the MCC can be traced to the deepest crust (40-55 km depth) and are overturned – the shallowest particles in the MCC originated at the deepest levels of the crust. Particles in the center of the MCC are also far traveled – they originated 100-150 km apart near the Moho and converged toward the center of the MCC by a combination of lateral and vertical flow. Particles at the edge of the MCC originate at shallower depth and record mostly vertical flow as they are exhumed under the detachment system. Overall, a model cross section of MCC contains particles that represent the whole column of ductile crust from 20 to 55 km depths. The orientation and magnitude of finite strain that are tracked in the models reveal intense deformation during exhumation, with the formation of shallowly dipping foliation during the latest stages of flow. Therefore, in models, rocks that start at very different structural levels and lateral position in the crust, end up forming a thin and structurally simple metamorphic terrain. These results help explain the complex record of natural rocks in MCC.