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Melt, extension rates, and metamorphic core complexes

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Numerical models show that two essential parameters - crustal viscosity and extension rate - control the thermo-mechanical evolution of metamorphic core complexes (MCC). Model predictions are compared to geologic observations in metamorphic core complexes. We classify MCCs in terms of the presence/absence of partially molten crust (migmatite) and the rate of exhumation (fast/slow) used as a proxy for the rate of extension, resulting in 4 broad groups of MCCs, including migmatite-cored (McMCC). The 4 groups are (1) fast McMCCs, which include the northern N American Cordillera (Thor-Odin, Valhalla, Okanogan, Bitterroots) and some Aegean/E Mediterranean MCCs (Naxos, central Menderes, Nigde) (2) slow McMCCs, which are rare in the Phanerozoic and may be restricted to crustal overturning typical of the Archean; (3) fast non-McMCCs, such as Arizona-style MCCs developed at fast extension rates under mostly subsolidus conditions; and (4) slow non-McMCCs, which may characterize zones of distributed (non-localized) extension such as wide rifts. The ubiquity of fast McMCCs indicates that localized thinning of upper crust and coupled ascent of partially molten crust are the main processes by which heat and mass are transferred towards the surface in young orogens. Rapid ascent of deep, hot crust is accommodated along km-thick detachment zones developed at high-T conditions. In non-McMCCs, the detachment zone is thinner and shows a range of mechanical behaviors from ductile to brittle. Numerical models indicate that the presence of a low viscosity lower crust (partial melt) has a profound effect on P-T paths, consistent with studies of MCCs. Near-isothermal decompression $>$500 MPa and cooling $>$600 $^{\circ}$C characterize McMCC evolution. In contrast, non-McMCCs record more gradual decompression accompanied by smaller deltaT. Disclaimers: Processes other than continental extension exhume domes; extension rates may vary from the regional to local

scale; some non-McMCCs locally contain abundant crystallized magma.