Fluid flow, detachment kinematics, and core complex formation in the extensional Basin and Range Province

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Metamorphic core complexes (MCCs) are crustal-scale structural features in the North American Cordillera that result from exhumation of middle crust through large extensional detachment systems. They contribute to thermal and mechanical re-equilibrium of the orogenic crust after and during the Cenozoic extensional collapse of the Cordilleran orogen and thus, record the kinematic boundary conditions during the late stage(s) of orogenic evolution of western North America. The interplay among various parameters such as strain localization, fluid-rock interaction, and surface processes dominates the evolution of these detachment systems. In particular, localized synextensional interaction of fault zone rocks with surface-derived fluids appears to be a common feature that directly impacts the conditions of crustal flow, mineral recrystallization, elemental and isotopic exchange, and temperature gradients of actively extending crust.

To resolve the temporal and kinematical relationship between core complex formation and fluid flow from the Earth`s surface to the actively extending middle crust, we used a multi-disciplinary approach, including (1) observation of microstructures, (2) $^{40}Ar/^{39}Ar$ thermochronology, and (3) oxygen isotope thermometry ($D\delta^{18}O$), and (4) hydrogen isotope analyses (δD) of syntectonic hydrous minerals. The hydrogen isotopic composition of recrystallized hydrous minerals allows us to track the infiltration of meteoric water into brittle fault zones (e.g. clay gouges) and strongly localized fluid flow down to the brittle-ductile transition (e.g. mica-bearing mylonites) at mid-crustal levels.

One key example to resolve the structural evolution and multiphase synkinematic fluid-rock interaction of a detachment system is the Raft River MCC (Utah, USA). Combined microstructural, $^{40}Ar/^{39}Ar$ geochronological, and stable isotopic evidence from exhumed mylonitic footwall rocks of the Raft River MCC suggest that very low-δD surface-derived fluids penetrated through brittle faults in the upper crust down to the brittle-ductile transition as early as the mid-Eocene during a first phase of exhumation. Thus, Eocene extension within the Cordilleran hinterland not only occurred at more northerly latitudes, but most likely also characterized regions of the northeastern Basin and Range Province. In the eastern part of the core complex, prominent top-to-the-east ductile shearing, mid-Miocene $^{40}Ar/^{39}Ar$ ages, and higher δD values of recrystallized white mica, indicate Miocene structural and isotopic overprinting of Eocene fabrics. Miocene shearing in the western Raft River MCC seems to be a reactivation and/or continuation of an Eocene top-to-the-east shear zone with accompanied localized rather than pervasive fluid flow. Moreover, a significant component of cooling of the core complex might be due to fluid-induced refrigeration rather than exclusively to rock uplift and circulating fluids appear to have actively influenced the kinematic of the detachment and as a consequence the exhumation history of the core complex.

Collectively, combined geochronological and stable isotope geochemical studies in MCCs along strike of the North American Cordillera document that meteoric fluid flow was an integral component of crustal extension and surface-derived water was able to penetrate extending upper crust down to the

brittle-ductile transition. We therefore argue that meteoric fluid flow in extensional fault and detachment systems may be more common than previously assumed which permits to export this approach to extensional settings in other orogens.

Keywords: meteoric fluid infiltration, hydrogen isotopes, metamorphic core complex formation

