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Meteoric water in metamorphic core complexes

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The trace of surface water has been found in all detachment shear zones that bound the Cordilleran metamorphic core complexes of North America. DeltaD values of mica fish in detachment mylonites demonstrate that these synkinematic minerals grew in the presence of meteoric water. Typically deltaD values are very negative (-120 to -160 per mil) corresponding to deltaD values of water that are < -100 per mil given the temperature of water-mica isotopic equilibration (300-500C). From British Columbia (Canada) to Nevada (USA) detachment systems bound a series of core complexes: the Thor-Odin, Valhalla, Kettle-Okanogan, Bitterroot -Anaconda, Pioneer, Raft River, Ruby Mountain, and Snake Range. The bounding shear zones range in thickness from ∼100 m to ∼1 km, and within the shear zones, meteoric water signature is recognized over 10s to 100s of meters beneath the detachment fault. The age of shearing ranges generally from Eocene in the N (∼50-45 Ma) to Oligo-Miocene in the S (25-15 Ma).

DeltaD water values derived from mica fish in shear zones are consistent with supradetachment basin records of the same age brackets and can be used for paleoaltimetry if coeval isotopic records from near sea level are available. Results show that a wave of topography (typically 4000-5000 m) developed from N to S along the Cordillera belt from Eocene to Miocene, accompanied by the propagation of extensional deformation and volcanic activity. In addition, each detachment system informs a particular extensional detachment process. For example, the thick Thor-Odin detachment shear zone provides sufficient age resolution to indicate the downward propagation of shearing and the progressive incorporation of footwall rocks into the hanging wall. The Kettle detachment provides a clear illustration of the dependence of fluid circulation on dynamic recrystallization processes. The Raft River system consists of a thick Eocene shear zone that was overprinted by Miocene shearing; channels of meteoric paleofluids can be traced into a zone of pervasive flow (in the direction of extension from W to E) in which a high transient geotherm is preserved. In the Snake Range the pattern of meteoric signature is consistent with the expected diachronous fluid-rock interaction that would be expected from a rolling-hinge detachment; in the arched section of the detachment meteoric fluid-rock interaction was cut-off early, while the long-lived portion of the E-dipping detachment continued to receive surface fluids.

In summary, the hydrology of extending crust involves circulation of surface fluids through the upper crust to the ductile detachment shear zones in the root system of normal faults. Synkinematic hydrous phases encapsulate the signature of meteoric fluids and indicate high-elevation catchment areas for the Cordillera, with development of topography from N to S over Cenozoic time. Meteoric fluids leave a distinct stable isotopic signature that tracks the spatial and temporal interaction among fluid, rock, and structures/ microstructures, and provides useful fingerprints of the inter-relationship between tectonics and crustal hydrology.