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Fluid flow in extensional detachments determined from stable isotope analyses: Application to Kettle dome detachment, Washington, USA

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In detachment systems that border metamorphic core complexes fluids convect from the surface to the detachment along faults and fractures in the brittle crust that serve as zones of recharge and discharge. This buoyancy-driven fluid flow is controlled by a high heat flow at the base of the system, beneath the detachment, where heat is advected by crustal thinning and magma intrusions. This hydrothermal convective flow is focused in the detachment for the duration of activity of the detachment and at relatively high temperature (300-500°C), resulting in very significant fluid-rock interaction and isotopic exchange. Studies of detachments in the North American Cordilleran core complexes suggest that meteoric fluids permeate detachment zones, as recorded by the deuterium composition of hydrous phases such as white mica, biotite, and amphibole. Quantifying fluid flux in detachments is a challenge because permeability of ductilely deforming rocks is poorly understood. The approach we are using focuses on oxygen and hydrogen isotopes in quartzite (+ minor mica) sections of detachments, complemented by high-precision chemical analyses of mica to understand their growth history and recrystallization process. The initial fluid isotopic composition is approximated using the deuterium composition of mica at a particular temperature that is given by oxygen isotopes in quartz-mica pairs. The more fluid interact with the quartzite, the larger the expected shift in oxygen isotope value.

The Eocene Kettle Dome detachment in the North American Cordillera provides a continuous section of 2̃00 m thick quartzite mylonite where this methodology is applied. High-resolution sampling (up to 5 m) complements the initial sampling that was performed every 10 m in this section (Mulch et al., 2006, Tectonics, TC4001). Based on mica deuterium values, the fluid that participated in mica crystallization was meteoric in origin (1̃10 per mil). Interaction of this fluid with the quartz mylonite results in large drops in quartz oxygen isotopic values from +12 per mil to +5 per mil locally. In these isotopically depleted zones, mica isotopic values are also dramatically lowered from 9 per mil to below 5 per mil. The absence of vein networks in the depletion zones argues for pervasive fluid flow being at the origin of the isotopic shift, which suggests higher fluid-rock interaction due to higher permeability in these zones. This work provides geologic data for numerical models that address the permeability of rocks deforming in the ductile regime and the thermal and mechanical consequences of fluid flow.

Key words: metamorphic core complex, detachment, fluid flow, thermomechanical behavior, stable isotope, muscovite fish, microprobe analysis.