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Fracture-controlled fluid flow in the Farnham Dome anticline: Insights from combined fluid-inclusion analysis and clumped-isotope thermometry of carbonate veins

P. Benjamin Luetkemeyer (1), David L. Kirschner (2), and Katharine W. Huntington (3)

(1) Department of Earth and Atmospheric Science, Saint Louis University, Saint Louis, United States (luetkepb@slu.edu), (2) Formerly Department of Earth and Atmospheric Science, Saint Louis University, Saint Louis, United States (dkirschn@gmail.com), (3) Department of Earth and Space Sciences, University of Washington, Seattle, United States (kate1@uw)

This study presents clumped-isotope, stable-isotope, and fluid-inclusion analyses of carbonate veins in the context of their structural and stratigraphic positions in order to characterize the fracture-controlled fluid flow system in the Farnham Dome anticline, east-central, Utah. Four sets of open- and shear-mode fractures and veins are recognized throughout the fold and are represented in the shale-sandstone-shale sequence at outcrop scale.

Samples were selected from each vein set in different structural and stratigraphic positions. There is no correlation between the isotopic values of the veins and inclusion fluids with vein type, but there is a correlation with structural stratigraphic position. δ13C values of calcite veins within the footwall and fold hinge units (Cedar Mountain Shale and Dakota Sandstone) fall within the range of about -3 to -8 ‰ (VPDB), while calcite veins located within the hangingwall (Tununk Member of the Mancos Shale) have δ13C values that fall within a narrow range of -0.3 to -0.8 ‰ (VPDB). δ18O values of calcite veins from the Cedar Mountain and Tununk shales cluster between +17 to +20 ‰ (VSMOW), consistent with syn-fold faulting that creates structural fluid pathways and separates portions of the fold into fluid compartments. δ13C and δ18O values of veins tend to be lower than those of their host rocks consistent with fluid-dominated or fluid-buffered system, likely related to significant fluid flow through discrete planes of fractures. Homogenization temperatures (Th) and salinities of sparse two-phase inclusions were measured on selected samples. Salinities for all units are between 0 to 3.5 wt% NaCl equivalent and Th values between 80 to 130 °C. The Th and salinities differ slightly among host rocks. Salinities are systematically higher with lower Th values in both shale units. Th and salinity do not vary systematically in the Dakota sandstone. These results are consistent with higher hydraulic connectivity in stratigraphically lower units during folding and uplift. Temperatures obtained from clumped-isotope thermometry on a subset of veins, including veins with Th data, range from 79 to 136 °C with one sample recording a temperature of 165 °C. Calculated δ18O values of fluids vary from -1 to +4 ‰ (VSMOW) consistent with fluids undergoing some degree of isotopic exchange with silicates. Temperatures do not vary systematically with structural and stratigraphic position, consistent with fracture reactivation during burial, folding and uplift though the relative timing of vein filling and cementation are not well constrained. δ13C values of veins decrease and δ18O values of veins remain relatively constant as temperatures increase, consistent with changing fluid chemistry during burial and vein formation possibly due to the onset of hydrocarbon production.

We interpret some veins formed early during burial or syntectonic loading and the fluid was stratigraphically bounded. Later veins developed in a structurally compartmentalized system characterized by strike-parallel fluid flow through highly fractured structural domains associated with thrust faults and fold hinges. Future work will consist of Raman spectroscopy in order to determine if CO_2 or hydrocarbons are present in the inclusions and field work to better constrain the relative timing of fracture formation.