The source and paleofluid evolution of secondary minerals in low-permeability Ordovician limestones of the Michigan Basin

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Secondary vein minerals in low-permeability sedimentary rocks provide a unique opportunity to understand solute transport with deep basin fluids. Here we report on the source and evolution of fluids that contributed to secondary mineral formation in Ordovician limestones and Cambrian siliciclastics of the Michigan Basin.

Microthermometric measurements on fluid inclusions were used to identify three stages of fluid influx responsible for vein formation. Primary fluid inclusions from these stages have T_{trap} values of 88–128 °C (stage I – dolomite) and 54–78 °C (stages II and III – calcite and anhydrite/celestine, respectively), and salinities that indicate formation from halite-saturated brines (31 to 37 wt.%). Previous U-Pb model ages of 434 ± 5 Ma (LA-ICP-MS) and 451 ± 38 Ma (TIMS) on calcite provide constraints on the absolute timing of stage II fluid influx. Secondary stage IV fluid inclusions have minimum T_{trap} values of 57–106 °C and are interpreted to reflect fluid migration during a regional heating event.

Vein minerals from the Cambrian and the overlying Ordovician Shadow Lake Formation have $\delta^{13}C$ values of −6.1 to −2.5‰ (VPDB), $\delta^{18}O$ values of +14.6 to +24.2‰ (VSMOW) and $^{87}Sr/^{86}Sr$ of 0.70975 to 0.71043. With increasing distance upward into the Black River and Trenton groups, positive shifts in $\delta^{13}C$ (−1.0 to +1.9‰) and $\delta^{18}O$ (+18.9 to +28.1‰) and decreases in $^{87}Sr/^{86}Sr$ (0.70790 to 0.70990) are observed. The isotope data are suggestive of mixing between connate porewater and ascending hydrothermal fluids with a geochemical signature inherited from interaction with the underlying Precambrian shield, or shield-derived minerals in the Cambrian aquifer. Relatively uniform isotopic compositions in veins from the Trenton Group suggest formation from either connate fluids or hydrothermal fluids that experienced high degrees of fluid-rock interaction during transit through the underlying Black River Group.