Carbon, oxygen and strontium isotopic constraints on fluid flow in the Junggar Basin (NW China)

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As physical and chemical interactions between fluid and rock are evident in the Junggar Basin (NW China), reservoired fractures are extensively cemented with calcites. Some calcites host fluid/oil inclusions. Thus, calcite cements are resulted from leakage of basin fluids (and hydrocarbons).

Twenty-eight calcite cements with no zoned textures present were analyzed. Calcite has carbon isotopic composition between -21.5 and 5.2‰ (Peedee belemnite, PDB) and oxygen isotopic composition between -22.3 and -8.1‰ (PDB). In contrast, strontium isotopic ratios of these samples have a relatively narrow range from 0.703896 (±10) to 0.706423 (±10).

Previous studies reported that calcite cemented in lacustrine environment of eastern China has relatively heavy carbon isotopic values from 2.9 to 3.3‰. Near-zero $\delta^{13}C_{PDB}$ values measured in this study may reflect a process related to the presence of hydrocarbons. So far, we have suggested tentative carbon sources present in the fluids during calcite cementation, i.e., deep mixed formation water-thermogenic sources, suggesting deep carbonate sources during carbonate cementation.

Oxygen isotopic values are generally less than $\delta^{18}O_{PDB}$ measured in Dagang and Dongying depreesion of Bohaiwan Basin, eastern China (-13.33 ~ -7.89‰ and -9.2 ~ 0.4‰, respectively). As homogenization temperatures of fluid inclusion indicate hot fluid event happened commonly here, the negative $\delta^{18}O_{PDB}$ values appear to be most likely related to the elevated temperatures, which may further cause the depletion in $\delta^{18}O$ for early diagenetic carbonates. The high temperatures could make ^{18}O in cementing fluids deplete greatly, thus leading to the low $\delta^{18}O$ of calcite cements.

Strontium isotopic ratios are significantly less than modern seawater (0.7092). This may be ascribed to the rock environment that fluid passed by. The Carboniferous and Permian igneous rocks in the Junggar Basin consist mainly of mafic rocks. Initially, magma material, generated by partial melting of mantle rocks, was mostly mafic, and it usually had low $^{87}Sr/^{86}Sr$ ratios of about 0.7035. Then, as this hot deep fluid migrated upwards, it can be diluted by the primary formation water (with relatively high $^{87}Sr/^{86}Sr$ ratio). The mixing caused the $^{87}Sr/^{86}Sr$ ratio measured in this study locates between the $^{87}Sr/^{86}Sr$ ratios of primary formation water and deep-derived hot fluid.

In summary, the cemented fluid is most likely influenced by thermal fluid ascending up from depth. During the migration, this deep-sourced hot water is associated with hydrocarbons, with dilution by primary formation water.