

Tracing $\delta^{18}\text{O}$ – $\delta^2\text{H}$ isotopic evolution of ancient fracture fluids: A novel approach using Sr stable isotopes

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Fluids discharging from fractures deep in the Precambrian crust have $\delta^{18}\text{O}$ – $\delta^2\text{H}$ signatures displaced above the Global Meteoric Water Line (GMWL), indicative of pervasive water-rock interaction. For a series of saline fracture fluids from a mine in Timmins, Ontario at 2.4 km depth, noble gas-derived residence times of more than a billion years were determined [1]. We present $\delta^{18}\text{O}$ – $\delta^2\text{H}$ data for the same fluids and also for new fracture fluids from the deepest level of the mine (~3 km). $\delta^{18}\text{O}$ – $\delta^2\text{H}$ signatures from the 3 km level are the most elevated above the GMWL ever reported for free-flowing fluids, comparable only to large “vug” fluid-inclusions [2]. At two new sites in Sudbury, fluids have comparable signatures to those analysed by [1]. We examine the mechanisms of water-rock reaction that could have caused such elevated signatures and model the fluid evolution.

Significant variations in $\delta^{18}\text{O}$ with relatively little displacement in $\delta^2\text{H}$ are observed (e.g. $\delta^2\text{H}=-30.9\text{‰}$; $\delta^{18}\text{O}=-17.5\text{‰}$). Recent analytical advances enable the measurement of the stable isotopes of heavy elements such as Sr. We use high precision DS-TIMS and report variations in $\delta^{88}\text{Sr}$ from $+0.36 \pm 0.01\text{‰}$ to $+0.54 \pm 0.01\text{‰}$ for fracture fluids from all three sites, and a site-wide $\delta^{18}\text{O}$ – $\delta^{88}\text{Sr}$ trend. As the stable isotopes of Sr are strongly fractionated during carbonate precipitation (e.g. [3]), we pair $\delta^{18}\text{O}$ with $\delta^{88}\text{Sr}$ to show that the fluids are dominated primarily by secondary carbonate (calcite) precipitation. The lighter isotopes of Sr preferentially partition into calcite, driving the waters to isotopically heavier values during calcite precipitation. This shows that new developments in non-traditional stable isotopes can be paired with traditional analyses to better understand fluid-rock interactions and secondary mineral precipitation.

[1] Holland et al. (2013) *Nature* **497** (7449): 367-360 [2] Guha and Kanwar (1987) *Geological Association of Canada* **33** 95-101 [3] Fietzke & Eisenhauer (2006) *Geochem. Geophys. Geosyst.* **7**, Q08009.