

## Oxygen isotope ratios in mantle xenoliths (Mt. Carmel, Israel): Implications for thermometry and sources of alkaline mafic magmas

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A suite of rare mantle pyroxenite xenoliths occurs within Upper Cretaceous mafic pyroclastic sections at Mt. Carmel, northern coastal Israel. The suite solely includes clinopyroxenites with abundant garnet indicating crystallization at  $P > 2$  GPa [1].  $\delta^{18}\text{O}$  values of clinopyroxene (Cpx) and garnet (Grt,  $\text{Pyr}_{60}\text{Alm}_{30}\text{Grs}_{10}$ ) from 9 xenoliths range from 4.99 to 5.42‰ and 5.14 to 5.47‰, respectively. All laser fluorination analyses were duplicated with average duplication difference of 0.03‰ for Grt and 0.05‰ for Cpx;  $\delta^{18}\text{O}_{\text{Cpx}}$  values were corrected according to [2]. Isotope fractionations are  $\Delta^{18}\text{O}_{\text{Cpx-Grt}} = -0.22$  to  $0.07$ ‰, averaging  $-0.08 \pm 0.06$ ‰ (2SE). The Carmel negative Cpx-Grt fractionations (7 out of 9 xenoliths) are outside the overwhelmingly positive  $\Delta^{18}\text{O}_{\text{Cpx-Grt}}$  range of 0.0 to 0.6‰ measured in 62 worldwide 'eclogitic' mantle xenoliths [3]. The experimental calibration of diopside-grossular fractionations predicting  $\Delta_{\text{Di-Grs}} = 0.17$ ‰ at 1000°C is not applicable here due to the Mg-Fe composition of the garnet. However, calculations based on natural samples predict  $\Delta_{\text{Di-Ca-poor Grt}}$  (1000°C) to be  $-0.06$  [2] or  $-0.02$  [4]. If equilibrated, our results extend to  $T \approx 1100$ °C, further showing that for the vast majority of igneous and metamorphic rocks diopside-Ca-poor garnet equilibrium fractionation is  $\approx 0$ ‰ and insensitive of temperature. The 0.6‰ variability in  $\Delta^{18}\text{O}_{\text{Cpx-Grt}}$  measured in mantle eclogites [3] may stem from differences in chemical composition, late alteration and analytical precision. Garnet megacrysts (<10cm) that also occur within the pyroclastic sections have chemical composition and  $\delta^{18}\text{O}$  ( $5.43 \pm 0.06$ ‰) similar to the granoblastic garnet (3-4mm) in the xenoliths. This suggests that metamorphic recrystallization of the pyroxenites prior to uptake by magma did not involve metasomatism by exotic fluids.

[1] Mittlefehldt (1986) *CMP* **94**, 245–252. [2] Kohn & Valley (1998) *JMG* **16**, 625–639. [3] Matthey *et al.* (1994) *EPSL* **128**, 231–241. [4] Valley (2003) *Rev. Min. Geochem.* **53**, 343–385.

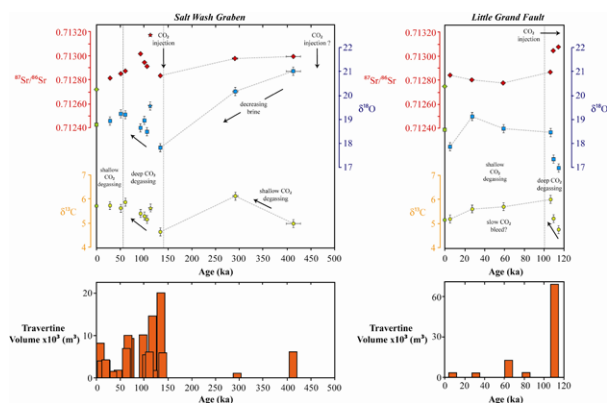
## Coupled CO<sub>2</sub>-leakage and *in situ* fluid-mineral reactions in a natural CO<sub>2</sub> reservoir, Green River, Utah

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Surface travertine deposits and carbonate veining within the footwall of Little Grand Fault and Salt Wash Graben, Utah, record a 413 ka history [1] of CO<sub>2</sub> leakage [2]. Isotopic analysis of U-series dated carbonate veins reveals a coupling between CO<sub>2</sub> injection into the host aquifer and the rates of surface leakage, CO<sub>2</sub>-promoted silicate mineral hydrolysis reactions within the reservoir [3] and carbonate deposition within fracture conduits through which CO<sub>2</sub>-charge fluids ascend to the surface (Fig. 1). Rapid carbonate precipitation rates, recorded in the kinetic fractionation of  $\delta^{13}\text{C}_{\text{HCO}_3}$  and  $\delta^{18}\text{O}_{\text{HCO}_3}$ , reflect an increase in *in situ*  $p\text{CO}_2$  which elevates concentrations of  $\text{Ca}^{2+}$  and  $\text{HCO}_3^-$ , lowering the point at which the ascending fluid reaches carbonate supersaturation due to CO<sub>2</sub> degassing. The spatial and temporal relationship of travertine deposition to CO<sub>2</sub> injection, suggests that rapid rates of carbonate deposition initially plug easily exploited leakage pathways causing leakage sites to propagate laterally, but that this blocking rate decreases with dissipation of the CO<sub>2</sub> charge. This has important implications for the prediction of leakage behaviour in storage sites and for modeling the coupling of subsurface geochemical processes to the evolution of surface leakage.



[1] Burnside *et al.* (2009) in *Faults & Top seals*, EAGE. Montpellier, France. [2] Dockrill *et al.* (2010) *J. Struct. Geol.* *in press* [3] Kampman *et al.* (2009) *Earth Planet. Sci. Lett.* **284**, 473–488.