Data Repository item 2003066: Minerals in carbonate cement of Yucca Mountain

There have been reports of hydrothermal zircon and sphene in carbonate cements filling faults in and around Yucca Mountain (Dublyansky et al., 1998; Chepizhko et al., 1996), in particular in well-studied Trench 14. The existence of hydrothermally-precipitated zircons and sphenes would have implications for our use of zircon chemistry to study magmatic evolution and also for the Yucca Mountain Repository. Trench 14 traverses the Bow Ridge Fault which is a normal fault with a near-vertical displacement of 190 meters separating exposures of Rainier Mesa and Tiva Canyon tuffs (Report, 1993). Proving the hydrothermal origin of sphene and zircon in carbonate cement would indicate a relatively high temperature of hydrothermal solution that is pertinent to the risk assessment at Yucca Mountain. If hydrothermal, these zircons and sphenes can be used for successful U-Pb dating Single crystal SIMS or TIMS), and thus the age of last hydrothermal activity could be determined. We dissolved 5kg of carbonate-cemented fault gorge material from Trench 14 in HCl. Dr. Jerry Szymanski assisted in sampling from Trench 14 to ensure that our material was the same as that studied by Dublyansky et al. 1998) and Chepizhko et al. (1996). Extracted silicate fragments are represented by vesicular pumice clasts (>50wt% of the total mass), and individual minerals preserving igneous morphology.

Analyses of zircon, sphene, quartz, sanidine, pyroxene, amphibole, magnetite, and glass extracted from the carbonate cement of Trench 14 were performed individually or in bulk (Table 2). The oxygen isotope ratios of analyzed minerals, and the small mineral-mineral fractionations are consistent with high magmatic temperatures. The $\delta^{18}O$ of extracted zircons is +6.35‰ consistent with mixture of igneous zircons from the Rainier Mesa (+6.54 to 6.61‰) and Tiva Canyon tuffs (+5.68 to 5.93‰) (Fig. A2). The $\delta^{18}O$ value of sphene is 4.03‰, close to that of Tiva Canyon tuff (+4.74 to 4.76‰). Magnetite is 2.62‰, similar to RM (+2.5 to 3‰) and TC (+2.16 to 3.56‰), a piece of brown glass is 8.03‰, and 1 individual sanidine crystal is 7.90‰ similar to that in RM (San = +8‰), green clinopyroxene is 5.65‰, black amphibole is 5.00‰, also similar to TC or RM.

If any of the analyzed silicate minerals were precipitated from hydrothermal fluid, then they should be related to the δ^{18}O values of the fluid at respective temperatures of exchange (Fig. A2). For example, mineral-water oxygen isotope fractionation (Zheng, 1993) at >25 ^{0}C with δ^{18}O(water) = -10‰, -14‰, -18‰ consistent with equilibrium with: calcite cement, present-day groundwater, and Pleistocene groundwater respectively (Rumble, 1992) would generate lower δ^{18}O values of hydrothermally-precipitated zircon, sphene, and other minerals, than is observed in Trench 14. For example, at 50° C hydrothermal zircons will have δ^{18}O<0‰, and negative values at higher T. In addition, the fractionation between different minerals would be larger than observed.

We conclude that analyzed silicate and oxide minerals and glass from the carbonate cement Trench 14 are magmatic in origin and that fluids responsible for deposition of carbonate did not exchange oxygen with silicate material. Extracted minerals and glass represent tectonically-crushed and variably ground Rainier Mesa and Tiva Canyon tuffs, to the level of individual phenocrysts. These results do not support previous reports of hydrothermally precipitated zircon and sphene in Trench 14, and they support our conclusion that zircons faithfully preserve magmatic composition.

Fig. A2 Captions:

Fig. A2 A: Comparison of δ^{18}O values of minerals in carbonate cement of Trench 14 through Bow Ridge fault of Yucca Mountain and those in Tiva Canyon and Rainier Mesa tuffs, that form lower and upper shoulders of the fault. Notice that mineralogy and δ^{18}O of crystals within carbonate cement can be explained by mechanical mixture of tuffs adjacent to fault.

B-C: Calculated values of δ^{18}O(Zrc), A2B, and δ^{18}O(Sphene), A2C, in equilibrium with water of different δ^{18}O values and temperatures. Zircon and Sphene-water fractionations are calculated using experimental quartz-water (Friedman and O'Neil, 1977) and empirical quartz-sphene (King et al., 2001) and quartz-zircon (Valley et al. 2003).

Appendix 2 additional references.

Friedman, I., O'Neil, J.R., 1977, Compilation of stable isotope fractionation factors of geochemical interest: U.S. Geological Survey Professional Paper 440-KK.

Zheng, Y.F., 1993, Calculation of oxygen isotope fractionation in anhydrous silicate minerals, Geochimica et Cosmochimica Acta, v. 57, p. 1079-1091.

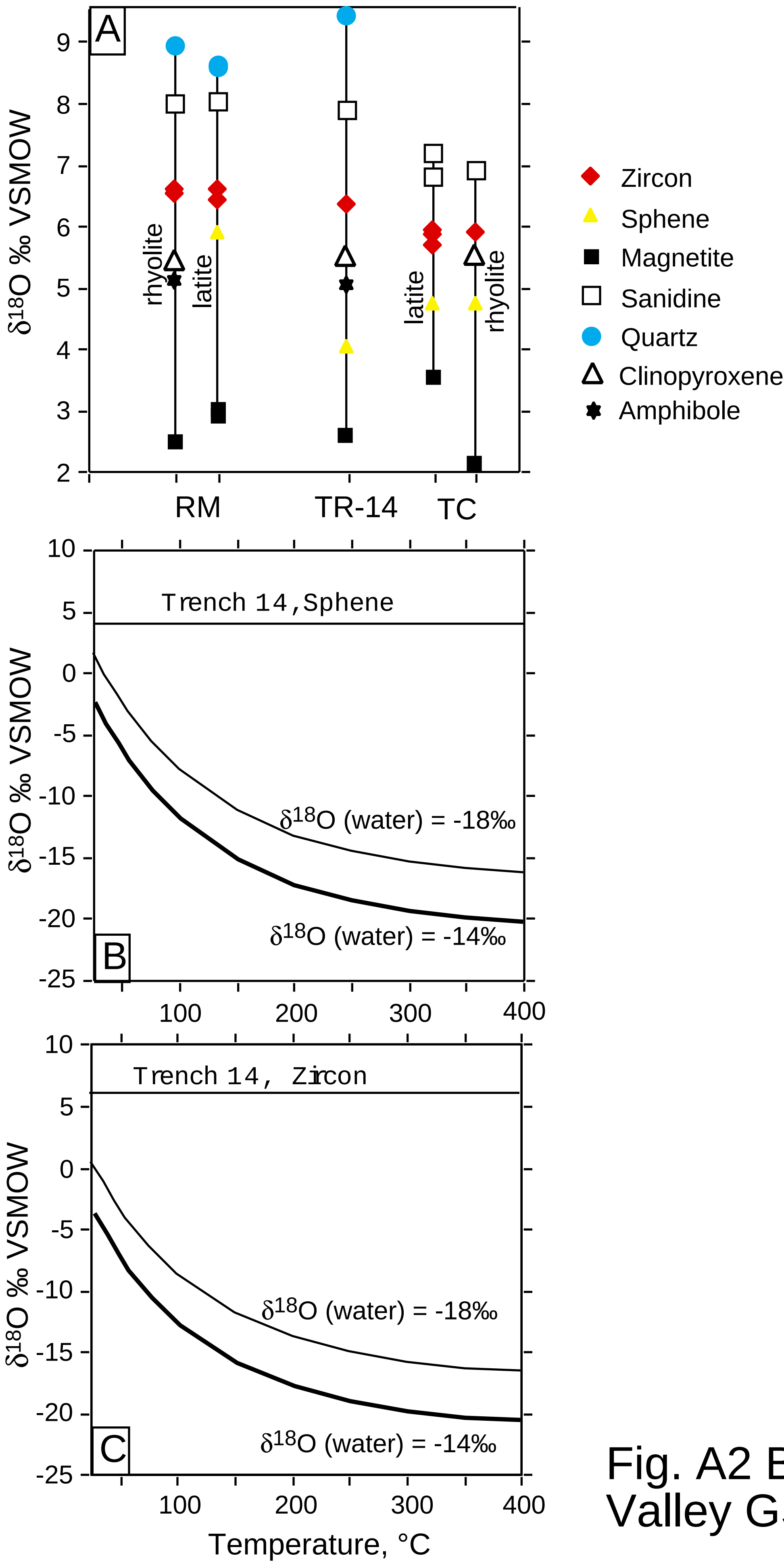

Fig. A2 Bindeman and Valley GSA Bulletin