

Dust chemistry and accumulation rate in a long-term full-scale heater test at Yucca Mountain, Nevada, USA

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Yucca Mountain, an eastward-tilted fault block of Miocene-age volcanic rock in southwest Nevada, is the proposed site for storage of high-level radioactive waste in the USA. The repository would be built within a ~300-meter (m)-thick welded tuff about 200 m above the water table. A full-scale heater test was conducted in a sealed 47.5-m-long, 5-m-diameter drift with concrete invert and partial concrete liner. Steel canister heaters within the drift and borehole heaters on the sides of the drift maintained an in-drift temperature of approximately 200°C for more than 2 years. After 4.2 years of cooling, samples of dust were collected from the upper surfaces of the canister heaters. The amount and composition of the dust, especially the water-soluble fraction, are important factors in understanding the chemistry of the near-field environment in the proposed repository.

Fine dust (<63 micrometers) accumulated on the canister heaters at rates from 0.8 to 4.3 milligrams/square centimeter/year. The major dust components were derived from the host rock (rhyolite), concrete, and oxidized steel. Calcite from limestone aggregate in the concrete constitutes as much as 18 percent. Iron oxides (6 to 9 percent) are derived from *in situ* oxidation of the canisters and from visible accumulations beneath partially oxidized steel rock bolts. Water-soluble salts constitute 1.0 to 1.8 weight percent of the dust samples and are enriched in Na⁺, K⁺, Ca²⁺, Cl⁻, SO₄²⁻, F⁻, and Br⁻, and strongly depleted in Mg²⁺, and NO₃⁻ relative to dust from ventilated tunnels at Yucca Mountain. The low NO₃⁻ in the soluble salts may indicate lack of dust supply to the heated drift via ventilation or may indicate consumption of NO₃⁻ through redox reactions that occurred on the canisters or within the wall rock or liner prior to dust fall.

Six of the dust leachates also were analyzed for strontium isotope composition. The samples from canisters beneath the concrete liner have ⁸⁷Sr/⁸⁶Sr ratios of 0.70930 and 0.70963, indicating derivation of Sr from the liner materials, rather than from the host rock (average ⁸⁷Sr/⁸⁶Sr = 0.71715). The four samples under areas with no liner have larger ⁸⁷Sr/⁸⁶Sr than the other two, but still lower than the host rock, indicating limited mixing of dust within the heated drift over the 8.3-year isolation period.

This study indicates that dust in the underground environment isolated from ventilation is derived locally from both the host rock and introduced materials. Chemical differences between these dust samples and dust from ventilated areas may be due to isolation of the drift and (or) chemical reactions during the heater test.

REE and HFSE mobility from eclogite to amphibolite metamorphism (Vårdalsneset, Norwegian Caledonides)

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Hf and REE mobility during chemical diffusion and recrystallization controls the resetting of Sm-Nd and Lu-Hf geochronometers during metamorphism. It is therefore interesting to characterize HFSE and REE mobility at different scales - intergranular to outcrop scale - according to pressure, temperature and fluid circulation.

Hf and REE mobility is here exemplified by the retrogression of an eclogitic sample (16 kbars, 670 ± 40°C) into an amphibolitic sample (7.5 kbars, 640 ± 20°C) of identical protolith during Caledonian metamorphism, in the Vårdalsneset area (Western Gneiss Region, Norway). The initial eclogitic paragenesis (garnet, omphacite and rutile) is transformed in the amphibolite into a second paragenesis (amphibole, oligoclase, titanite and ilmenite), where garnets are partially resorbed and rutiles are present as relicts.

Elemental data allow to discuss chemical mass balances in each sample and during amphibolitization. In eclogite, more than 40 % of Hf but only 10 to 15 % of LREE are within paragenetic minerals. The remainder lies within accessory minerals (zircon). In the amphibolite, accessory minerals (zircon and epidote) concentrate not only LREE but also Hf (85 %). Thus, mass balance indicates mobility of Hf from cardinal minerals in the eclogite to accessory minerals in the amphibolite. Moreover, the increase in LREE contents (+ 20 %) from eclogite to amphibolite indicates the contribution of fluids during retromorphism, and reopening of the Sm-Nd system. By contrast, the HFSE content decreases only slightly (*ca.* 5%). However, isotopic data show significant difference for Hf between eclogitic isotopic ratio (¹⁷⁶Hf/¹⁷⁷Hf = 0.282804 ± 6) and amphibolitic ratio (¹⁷⁶Hf/¹⁷⁷Hf = 0.282620 ± 4). At the outcrop scale, whole rock isotopic ratios scatter from 0.2824 to 0.2828. This may be due either to limited reopening of the system during amphibolitization or to the isotopic heterogeneity of the protolith.

Four garnet fractions (three from the eclogite and one from the amphibolite) show a large variability in both ¹⁷⁶Lu/¹⁷⁷Hf and ¹⁷⁶Hf/¹⁷⁷Hf ratios and plot along a straight line. This line can be interpreted either as a mixing line between pure garnet and inclusions (e.g. zircons), or as a record of the reopening of Lu – Hf system. In this case, this alignment describes the reequilibration of Hf in garnet after eclogitic metamorphism, probably due to fluid circulation.