

TUNGSTEN STABLE ISOTOPES IN ALTERED CHONDRITES.

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Introduction: Radiogenic tungsten (W) isotopes are commonly used to date and study early differentiation processes in the solar system. Until recently, however, tungsten stable isotopes have rarely been investigated mainly due to analytical issues. The ^{182}Hf - ^{182}W short-lived radiochronometer applied to CR2 metal-rich chondrites shows intriguing results: the isochron of the most altered sample, Renazzo, seems to be disturbed [1]. Given that non-traditional stable isotopes are potential tools to better apprehend the conditions and pathways of alteration processes [e.g. 2-4], we decided to study the mass dependent isotope fractionation of W in a variety of chondrites showing different degrees of alteration to test the explanation proposed for Renazzo.

Samples: Carbonaceous chondrites (petrographic types 1 to 3) have been analyzed with some emphasis on CV3 chondrites as they are known to present various degrees of alteration going along with variations in textures, matrix abundance and metal preservation. Altogether, seven carbonaceous chondrites have been selected including Orgueil (CI, fall), Murchison (CM2, fall), Allende (CV3 ox., fall), Axtell (CV3 ox., find), Vigarano (CV3 red., fall), and NWA 3118 (CV3 red., find). We also analyzed five L6 and two H5 ordinary chondrites previously studied for their Fe isotope composition [5] and known to have suffered from terrestrial weathering in deserts of Morocco and Algeria. The meteorite Mocs (L5-6), an observed fall, is considered as the least weathered sample.

Results and Discussion: All carbonaceous chondrites are enriched in heavy W isotopes relative to the NIST SRM 3163 standard. CV3 chondrites show large variations in their signatures while the W isotope compositions previously determined for 6 more or less severely metamorphosed H-chondrites (from H3 to H6) are homogeneous, suggesting that the effect of metamorphism on the fractionation of W stable isotopes is limited, if any. In CV3s, the tungsten isotope fractionation seems to be related to the degree of alteration, and so is the Hf/W ratio of the samples. Considering Vigarano as one of the most primitive chondrites, representative of the reduced starting material, we propose that the trend observed for Allende and Axtell is due to the progressive loss of W relative to Hf during increasing alteration processes on the parent body. The W-bearing solution resulting from the alteration is enriched in light W isotopes, and the remaining rock thus enriched in heavy isotopes as observed. Ordinary chondrites altered in terrestrial deserts also display some isotope variability, even if the spread is smaller. Once again, the isotope composition seems to be related to the degree of weathering as approximated by the S content of the meteorite.

Thus, the Hf/W ratio as well as the W isotope fractionation appear to be potential proxys for the extent of aqueous alteration in chondrites.

Laboratory experiments and thermodynamical modeling: In parallel to the analysis of natural samples, laboratory experiments were performed to study the relative mobility of Hf and W during fluid-rock interactions. For the first stage, three different rocks (basalt, dunite, lherzolite) chosen as analogues of the meteoritic silicate content were powdered and placed in a vessel with the solution. The initial pH of the weathering solution in meteorites is unknown. We therefore tested two different reaction pathways for the silicate weathering: an acidic one (starting pH=4) and a basic one (starting pH=8). Batch experiments conducted at a temperature of 110°C confirmed that W is much more mobile than Hf, resulting in a strong Hf/W fractionation during alteration processes. The dunite and lherzolite lixiviation results show that the mineral dissolution (mainly olivine and pyroxene) is incongruent concerning W and about the same order of magnitude for the two rocks. Last but not least, we compared our experimental results with modeling data. The aim of our numerical approach was to parametrize a simple model, so that it can be extrapolated to the geological scale. For this purpose, we used the PHREEQC program [6]. Both experiments and modeling indicate that the dissolution-precipitation equilibria are not controlled by the saturation in W of the solution but rather by adsorption and coprecipitation on/with secondary phases, as tungsten is a trace element in the minerals under consideration.

References:

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