RECENT TERRESTRIAL DISTURBANCE OF THE ^{176}LU-^{176}HF SYSTEMATICS IN METEORITES

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Introduction: Time contraints for early solar system processes are largely based on short-lived radioisotope systems that provide precise but only relative ages. Anchoring these ages to the absolute timescale requires accurate and precise long-lived chronometers. With the exception of Pb-Pb, such chronometers are based on the measured proportion of a radioactive isotope to its decay product (e.g., ^{176}Lu-^{176}Hf, ^{147}Sm-^{143}Nd, or ^{87}Rb-^{87}Sr). A large range in parent-daughter ratios among minerals and a high closure temperature are attributes of a potentially precise and robust chronometer. The ^{176}Lu-^{176}Hf system is promising in this regard, but several meteorite "isochrons" exhibit excessive scatter and yield dates up to 300 Myr older than the solar system [1-5]. To determine the cause of this discrepancy, we have collected Lu-Hf mineral isochron data for 6 achondrites: the monomict basaltic eucrites Millbillillie and Piplia Kalan, the plutonic angrites NWA 4590 and NWA 4801, the quenched angrite D'Orbigny, and the ureilitic trachyandesite ALM-A [6] from the Almahata Sitta meteorite.

Results and discussion: For all samples, regressions of all respective bulk and mineral fractions result in errorchrons with MSWD values > 4. The corresponding Lu-Hf dates are mostly too old, and the y-axis intercepts (i.e., initial ^{176}Hf/^{177}Hf) vary. Low-Hf phases such as plagioclase, and, if present, olivine are most displaced from the regression lines. This pattern of scatter is observed in both eucrites and angrites from this study and also by [7-9]. Different splits of the same meteorite, however, yield contradictory results (e.g., the angrite data from this study vs. [9]). These observations are difficult to explain by irradiation events [10-11] or diffusion processes [12-15] in the early solar system. Instead, we infer that 1) recent parent-daughter fractionation caused by terrestrial weathering and 2) terrestrial contamination are more plausible disturbance mechanisms.

Terrestrial weathering: The Lu-Hf system is particularly susceptible to weathering because phosphate minerals, which can host significant amounts of Lu (and thus, with time radiogenic ^{176}Hf), are soluble in weak acids [16]. For precise and accurate Lu-Hf chronology, it is therefore crucial to identify and avoid weathered portions of a sample. We have investigated a sample of the Almahata Sitta meteorite, an observed fall from the year 2008 that was recovered within a year. The purest hand-picked plagioclase and pyroxene fractions and selectively digested phosphate minerals of ALM-A yield a Lu-Hf age of 4569 ±24 Ma (MSWD = 1.3, n = 13) using the accepted ^{176}Lu decay constant 1.867×10^{-11} yr^{-1} [17-19] and an initial ^{176}Hf/^{177}Hf of 0.279796 ±0.000011.

Contamination: The bulk (i.e., whole rock and fine) and impure mineral fractions of ALM-A, however, contain various amounts of excess ^{176}Hf. Regressions result in either steepened isochrons with low initial ^{176}Hf/^{177}Hf, or errorchrons with high MSWDs. We argue that terrestrial contamination is the source of the unsupported ^{176}Hf.

Conclusion: Terrestrial weathering and contamination can significantly disturb the ^{176}Lu-^{176}Hf systematics in meteorites and generate the observed scatter and steepened isochrons. However, high-purity, hand-picked mineral fractions of fresh meteorite falls such as Almahata Sitta yield a reasonable Lu-Hf age and an initial ^{176}Hf/^{177}Hf that is in good agreement with the Hf isotope composition measured in eucrite zircon [20] and the CHUR parameters of [21] calculated back to the beginning of the solar system.

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