STABLE ISOTOPE CONSTRAINTS ON THE FORMATION OF MOON. T. Magna[1], N. Dauphas[2], K. Righter[3] and R. Canup[4]. [1]Czech Geological Survey, Prague, Czech Republic (tomas.magna@geology.cz), [2]Origins Lab, Department of the Geophysical Sciences and Enrico Fermi Institute, The University of Chicago, USA (dauphas@uchicago.edu), [3]Astromaterials Research & Exploration Science, NASA, Houston TX, USA (Kevin.righter-1@nasa.gov), [4]Space Science & Engineering Division, Southwest Research Institute, Boulder, Colorado, USA (robin@boulder.swri.edu).

Summary: The development of high-precision techniques to measure stable isotope compositions of a number of elements which, in the past, were considered homogeneous, implicated a new fresh look at the origin of Moon. Prior to 2004, only limited stable isotope information was available that mainly focused on oxygen isotopes in Apollo samples and lunar meteorites [1,2]. These studies have shown, to a high degree of confidence, that O isotope similarity (or identity) of Earth and Moon is a unique feature among bodies of the Solar System. More recent investigations [3,4] have re-assessed these earlier conclusions to an unprecedented precision of a few ppm. While the nature of this striking O isotope uniformity remains elusive, it either reflects effective homogenization of pre-collisional isotope disparity or indicates a broad isotope homogeneity of early Solar System planetesimals [5,6]. In general, the information and constraints on lunar origin derived from stable isotope systems are manifold as briefly outlined here.

It is notable that some other refractory elements show a similar degree of isotope identity between Earth and Moon. The highly refractory nature of W makes it an ideal candidate for tracing the earliest stage of Earth–Moon evolution. Advanced measurements of selected lunar materials have shown a slight excess of ^{182}W compared to Earth [7] but these authors were able to derive a pre-impact ε^{182}W which is identical for Earth and Moon [also 8]. Several models were discussed to account for W isotope homogeneity between Earth and Moon prior to the Giant impact. Given the refractory nature of W, a post-collisional exchange in hot atmosphere [5] may require substantial revisions.

Nucleosynthetic Ti anomalies were reported for a number of meteorite classes, including chondrites and achondrites, with the entire range of ε^{50}Ti values spanning nearly six ε units. Yet, lunar samples and their mineral constituents do not show any resolved departure from Bulk Silicate Earth value at ε^{50}Ti ~0 [9,10]. Zhang et al. [10] suggested that most lunar Ti should have a terrestrial origin, which appears to be in agreement with recent dynamic models [11]. Indeed, similar conclusions have been made for Cr [12] but given the still limited data set for stable Cr isotope compositions, further analyses are required because it could place constraints on the lunar core formation. In this respect, Si isotope analyses of lunar samples may provide further tests for core formation in the Moon. Silicon isotope homogeneity between Earth and Moon [13] requires that formation of a small metallic lunar core was incapable of sequestering a significant fraction of Si, a process thought to have occurred for Earth [14]. In this respect, [15] predicted isotopically heavy Si for Moon (~0.14‰ in δ^{30}Si) provided there had been a vapor-mediated exchange between Earth and Moon. The lack of any shift for current data set represents an argument against the equilibration model [5].

Stable isotope compositions of more volatile elements were rather rarely analyzed due to technical limitations. The early measurements of potassium isotope compositions in lunar rocks [16] have shown δ^{41}K values identical to those of Earth within contemporaneous analytical errors. The recent imporovements have allowed to distinguish between Earth and Moon at the δ^{41}K scale of ~0.2‰ [17]. Although the latter result is highly significant in itself as it requires high pressures and temperatures in the mantle atmosphere disc, the detailed implications for lunar origin are yet to be evaluated with the relevant experimental data.

References:

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