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Nucleosynthetic zinc isotope anomaliesreveal the origin of Earth's volatiles

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The mode by which Earth and other terrestrial planets accreted their volatile constituents is a major unresolved problem in planetary science and of particular significance because water, as a key volatile, is required for the emergence of life and has a profound impact on the rheological properties of planetary mantles [e.g. 1]. Recently, new constraints on the heritage of Earth's building blocks were derived from the nucleosynthetic isotope anomalies of refractory metals in bulk meteorites relative to the silicate Earth [e.g. 2-5]. The implications of these results for Earth's volatile accretion history are unclear, however, due to the decoupled distribution of refractory and volatile elements in the protoplanetary disk and meteorites [1, 6].

Here, we show that silicate Earth records a mass independent isotope composition for the volatile element Zn, which differs from that observed in meteorites (Fig. 1). In detail, the results reveal complementary Zn isotope anomalies for carbonaceous and non-carbonaceous meteorites, which are in accord with nucleosynthetic production models that were invoked to account for the variable abundances of neutron-rich Ca, Ti and Cr isotopes in the Earth and meteorites [7].

As Zn does not strongly partition into the core, the intermediate Zn isotope composition of the silicate Earth implies that the bulk Earth inventory of Zn and other volatile elements was provided by an approximately equal mixture of material derived from the inner and outer Solar System. In the context of previous findings [8], these results imply that the bulk of the volatile rich outer Solar System material was most likely delivered late during terrestrial accretion, when Theia collided with Earth in the Moon-forming giant impact.

References

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Figure 1. Mass independent Zn isotope compositions of meteorites in $\varepsilon^{i}Zn$ notation.