Heavy isotope fractionation in the solar system – A volatile perspective

M Rehkämper[1,2], M Schönbächler[1,2], F Wombacher[3], RGA Baker[1,2], SG Nielsen[4] and HM Williams[4]

[1]Impact and Astromaterials Research Centre (IARC), Imperial College, London SW7 2AZ, UK
[2]The Natural History Museum, London SW7 5BD, UK
[3]Institut für Geologische Wissenschaften, FU Berlin, 12249 Berlin, Germany
[4]Dept. of Earth Science, Parks Road, Oxford OX1 3PR, UK

It is well recognized that most solar system bodies are significantly depleted in volatile constituents relative to primitive CI chondrites but the origin of this signature is only poorly understood. Stable isotope studies of volatile elements in meteorites are well suited for addressing this fundamental question. This conclusion is underlined by the observation that for chondritic meteorites, heavier but more volatile elements (such as Cd) typically display larger isotopic effects than lighter and less volatile constituents (e.g., Zn). This suggests that partial vaporization and condensation play an important role in generating stable isotope variations [1-3].

The isotope data acquired for a number of volatile elements indicates that stable isotope effects are generally much larger for ordinary than for carbonaceous chondrites. The large isotope variations determined for ordinary chondrites (e.g., ~25‰ for $^{114}Cd/^{110}Cd$) are thought to reflect redistribution of volatile constituents by thermal metamorphism on the meteorite parent bodies [1,2]. In contrast, most carbonaceous chondrites display only small or no resolvable isotope effects of ≤0.15‰/amu for Ag, Zn, Cd, and Tl [1-5]. This demonstrates that the variable volatile abundances of carbonaceous chondrites reflect either partial equilibrium condensation/evaporation or mixing processes.

Refractory (CAI- & chondrule-rich) separates from Allende display light Cd and Zn isotope compositions (of about -1‰/amu) relative to the bulk meteorite [2,3]. These signatures cannot reflect Rayleigh evaporation but are most readily explained by the interaction of refractory materials with a volatile-rich nebular gas. Such processes may also be responsible for the lack of nucleosynthetic isotope anomalies of volatile elements in CAI's.

The short-lived ^{107}Pd-^{107}Ag and ^{205}Pb-^{205}Tl decay systems are well suited for studying the time scales of volatile loss in the early solar system. Such studies must be carried out with care, as Ag and Tl have only two isotopes, such that radiogenic and stable isotope effects may not be readily discernable. One example are the troilite inclusions of IAB irons, which appear to have Ag and Tl isotope compositions that were fractionated (~1‰/amu) by diffusion [6,7].

References

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High-resolution geochemistry and lithology of laminated sediment in the Weddell Sea, Antarctica

L. Reichelt[1], M. E. Weber[2], G. Kuhn[3] and W. Ricken[4]

[1]Institute for Geology and Mineralogy, University of Cologne, Germany (LReichelt@gmx.de)
[2]Institute for Geology and Mineralogy, University of Cologne, Germany (michael.weber@uni-koeln.de)
[3]Alfred-Wegener-Institute, Bremerhaven, Germany (gerhard.kuhn@awi.de)
[4]Institute for Geology and Mineralogy, University of Cologne, Germany (wricken@uni-koeln.de)

Methods

Sediment sites PS1789 and PS1791 from the southeastern Weddell Sea (Antarctica), were investigated for geochemical and lithological variability. We used several non-destructive means to obtain information at ultrahigh resolution (mm to sub-mm scale). An x-ray-flourescence core scanner should reveal relative chemical composition of some selected elements. Magnetic susceptibility records were compared to counts of ice-rafted debris (IRD). We determined sediment color using both a photospectrometer, RGB readouts from a line scanner, and gray-scale images from x-radiographs. Stratigraphy relies on previously published AMS^{14}C dates.

Results

The glacial sediment sections reveal mostly laminated sediments and rarely intercalated fine-grained turbitdites. Bioturbated section occur at the top and are linked to Holocene or late-glacial times. Geochemical composition is relatively stable during the glacial; only bioturbated sediment shows elevated Fe and diminished Al and Si contents, whereas turbidites reveal the opposite.

In order to reveal wether or not the lamination is a result of an interannual (seasonal) variability, we developed tools for semi-automated layer counting of the gray-scale scans. First results indicate that the lamination is most likely an innerannual process, e.g., site PS1789 contains 4860 visually detectable layer between 199 and 1211 cm core depth, where AMS^{14}C dates indicate an age difference of 2430 years, i.e., more than 90 % of the expected layers encountered.

Future Work

More sites will have to be investigaed to corroborate the preliminary stratigraphic results. Geochemical investigation will focus on the differentation between the seasonal layers, i.e., is there a compositional difference between the darker and lighter layers documented in the gray-scale images or is the alteration caused by grain-size changes only.