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Evaluation of parent body processes on presolar components in chondrites

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Chondrites and differentiated meteorites at the bulk meteorite scale commonly show small but resolvable mass-independent isotopic deviations from the terrestrial values in refractory elements (e.g., Cr, Ti, Mo, Ru, Ba, Sm). At least some of these anomalies are nucleosynthetic in origin, and have been interpreted to reflect incomplete mixing of isotopically diverse presolar materials in the protosolar nebula, although uniform, terrestrial isotopic compositions in bulk chondrites have been reported for some elements (e.g. Sr, Os). Processes that occur on parent bodies such as thermal metamorphism and aqueous alteration can also potentially affect the isotopic compositions of bulk chondrites. Isotopic investigation of acid residues from primitive chondrites may shed light on this problem. The residues are rich in a variety of isotopically anomalous presolar grains which can control the isotopic composition of bulk chondrites. In this study, we analyzed Os isotope compositions in acid residues from four CMs (MET 01070, ALH 83100, Murchison, QUE 97990) and three CRs (GRO 95577, EET 92042, GRA 95229).

All the CM/CR-residues are characterized by positive epsilon-Os (eOs) values that are resolvable from the solar (= terrestrial) component, suggesting the enrichment of Os isotopes produced by the s-process. There are significant variations in eOs values across CM-residues. The magnitude of the positive Os isotope anomalies in the residue of the ALH 83100 (CM1/2) (e188Os = +3.10) is nearly twice as large as those present in residues from Murchison (CM2) (e188Os = +1.66). The residue of MET 01070 (CM1) has eOs values (e188Os = +2.31) larger than those of Murchison, whereas that from QUE 97990 (CM2.6) has the smallest deviation in eOs values from zero among all CM chondrites (e188Os = +0.95). Variations in the magnitude of the eOs values are also observed in residues from CR chondrites, where the residue from GRO 95577 (CR1) showed the largest positive Os isotope anomalies (e188Os +2.64). We propose that the observed isotopic variation was caused by the destruction of presolar phases via progressive aqueous alteration on the CM/CR parent bodies, rather than any nebular processes creating heterogeneous distributions of presolar grains that predate the planetesimal formation. Some petrologic observations of CM chondrites point to the occurrence of aqueous alteration prior to parent body accretion. However, destruction of presolar phases during preaccretionary alteration would result in the modification of Os isotopic compositions at the bulk meteorite scale, which is evidently not the case. The enrichment of s-process Os isotopes in the residues from highly altered CM/CR chondrites implies that aqueous alteration on the parent body preferentially destroyed the r-process-Os carrier(s) and modified it into an acid leachable phase in the chondrite matrices, while acid resistant s-process-rich grains (SiC, graphite) survived. This process, however, did not disturb the Os isotopic composition at bulk meteorite scale. Even though bulk chondrites are isotopically homogeneous in Os, our new results suggest that parent body aqueous/metamorphic processes have acted on the distribution of Os among presolar phases. This suggests that isotopic anomalies reported for some other elements that have been interpreted as reflecting nebular heterogeneities, may partly or wholly be the result of parent body processing. Presolar phases that are enriched in certain nucleosynthetic components could release these components upon destruction of the hosting phases. If the element is more highly soluble than Os, fluid transport could lead to the formation of isotopically modified bulk samples whose isotopic compositions are not representative of the whole parent body. Thus, isotopic heterogeneities among bulk chondrites should not automatically be interpreted as evidence for nebular heterogeneity.

Keywords: chondrite, presolar grain, aqueous alteration, osmium isotope