

OSMIUM ISOTOPE ANOMALIES IN ACID RESIDUES FROM ENSTATITE CHONDRITES. T. Yokoyama¹, C. M. O'D. Alexander² and R. J. Walker³, ¹Dpt. of Earth and Planetary Sciences, Tokyo Institute of Technology, Tokyo 152-8551, Japan (tetsuya.yoko@geo.titech.ac.jp) ²Dpt. of Terrestrial Magnetism, Carnegie Institution of Washington, DC 20015, USA, ³Dpt. of Geology, Univ. of Maryland, College Park, MD 20742, USA

Introduction: Isotopic anomalies in bulk chondrites and their components have been extensively investigated in the past 30 years. The discovery of presolar grains in primitive chondrites and IDPs [1-2], assisted by precise isotope analyses of individual grains, has dramatically improved our knowledge regarding stellar nucleosynthesis, as well as the origin of the solar system. The majority of previous presolar grain studies have focused on carbonaceous chondrites (CCs) and ordinary chondrites (OCs), yet there has been relatively little work done on presolar grains from enstatite chondrites (ECs) [3-6]. EC parent bodies formed under extremely reducing conditions in the early solar system. Thus, they might have sampled or preserved a different population of presolar grains compared to CC and OC. A closer look at the presolar grains from ECs can, therefore, provide useful information regarding material distribution and transport mechanisms in the solar nebula.

Acid residues of bulk chondrites are concentrated in presolar grains such as SiC, graphite and nanodiamond. The residues from some CCs and one OC are enriched in Os isotopes produced by s-process, whereas complementary acid leachates are enriched in r-process nuclides [7-9]. In contrast, bulk CCs, OCs and ECs have a uniform Os isotope composition [8]. This argues against the isotope heterogeneity in early solar system bulk materials that is suggested for some other elements (e.g. Cr, Ti, Mo, Ru and Ba) [10-12]. In this study, we carried out a preliminary investigation of the Os isotope anomalies in EC acid residues. A residue from an unmetamorphosed CM1/2 chondrite was analyzed as well. This is a part of our comprehensive study using precise isotope analysis of heavy elements in chondrites and their acid residues, which is aimed to better understand stellar nucleosynthesis and subsequent material injection/mixing processes that occurred in the early solar system.

Experimental: Acid residues analyzed in this study were prepared from three ECs (MAC02837, EL3; EET87746, EH3; Indarch, EH4) and one primitive CC (ALH83100, CM1/2) by employing a CsF/HF leaching technique [13]. The details of sample digestion and isotope analysis are described in [8]. In brief, the samples (2-5 mg) were first combusted at 1000°C in quartz Carius tubes, and then digested with a 1:2 mixture of concentrated HCl and HNO₃. The Os was extracted by CCl₄ and purified by a microdistillation technique.

Osmium isotope analyses were carried out by a TIMS (*Thermo-TRITON*) at the Univ. of Maryland. The Os isotope ratios, normalized to ¹⁸⁹Os, are reported in ϵ Os units ($\epsilon^{184}\text{Os}$, $\epsilon^{186}\text{Os}^i$, $\epsilon^{188}\text{Os}$ and $\epsilon^{190}\text{Os}$) which represent relative deviation (parts per 10⁴) from the average of bulk chondrite analyses ('solar values') [8]. The $^{186}\text{Os}/^{189}\text{Os}$ ratio has been time-corrected for ¹⁹⁰Pt decay over 4.56 Ga. Here, in contrast to our prior work, we attempted precise determination of $^{184}\text{Os}/^{189}\text{Os}$ ratios in the samples. Osmium-184 is a pure p-process nuclide of which the abundance is extremely low in chondrites (~0.02% of total Os). To do this, we monitored and corrected for the potential mass interferences from Pt and W by using an electron multiplier at the beginning of every block in individual isotope runs (1 run = 20 ratios/block \times 18 blocks).

Results and Discussion: Osmium isotope data for the acid residues are plotted on $\epsilon^{186}\text{Os}^i$ - $\epsilon^{188}\text{Os}$ and $\epsilon^{190}\text{Os}$ - $\epsilon^{188}\text{Os}$ diagrams (Fig. 1) along with those from the other CCs and OCs measured in [8]. The four residues, excluding one datum, are characterized by positive $\epsilon^{186}\text{Os}^i$, $\epsilon^{188}\text{Os}$ and $\epsilon^{190}\text{Os}$ values resolvable from the solar (= terrestrial) component, which are suggestive of the enrichment of Os isotopes produced by the s-process. Anomalies for $\epsilon^{184}\text{Os}$ were not obvious at the current level of analytical precision ($\pm \sim 50\epsilon$). The magnitude of positive Os isotope anomalies in the residue of the CC ALH83100 ($\epsilon^{186}\text{Os}^i = +16.6$, $\epsilon^{188}\text{Os} = +3.0$, $\epsilon^{190}\text{Os} = +2.1$) is nearly twice as large as are present in residues from the CM2 chondrite, Murchison ($\epsilon^{186}\text{Os}^i = +8.0$, $\epsilon^{188}\text{Os} = +1.7$, $\epsilon^{190}\text{Os} = +1.0$). This is the first direct comparison of Os isotope anomalies in residues from a single chondrite group with different petrologic types. Because Os concentrations in these residues are nearly identical (~10 ppm), the difference in Os isotope anomalies cannot be attributed to a dilution effect in Murchison residues by components with a solar Os isotope composition (e.g., oxides from CAIs). Rather, it is clearly due to the lower abundance of s-process-enriched presolar grains in Murchison residues compared with ALH83100, presumably caused by their different parent body histories. This is consistent with our previous observation that the extent of positive ϵ Os values in the residues from CC and OC is in the order of petrologic grade of the host meteorites (type 1 > type 2 > type 3).

In comparison, the residues from ECs do not conform to this ordering. First, the ϵ Os values in the residues

due for EET87746 (EH3) are fairly large ($\epsilon^{186}\text{Os}^i = +10.9$, $\epsilon^{188}\text{Os} = +2.2$, $\epsilon^{190}\text{Os} = +1.6$), which are at the upper end of those in residues from type 2 CC. Note that all the residues from type 3 CC and OC have only marginal positive anomalies ($\epsilon^{188}\text{Os} < 0.5$). Second, the residue from Indarch (EH4) possesses positive ϵOs anomalies ($\epsilon^{186}\text{Os}^i = +0.39$, $\epsilon^{188}\text{Os} = +0.18$, $\epsilon^{190}\text{Os} = +0.24$) that are identical to those present in a residue from the OC QUE97008 (L3.05). It should be also noted that a residue from Allende, of which the petrologic grade is >3.6 [14], shows minimal Os isotope anomalies in all residues we have analyzed ($\epsilon^{186}\text{Os}^i = -1.0$, $\epsilon^{188}\text{Os} = +0.10$, $\epsilon^{190}\text{Os} = +0.03$).

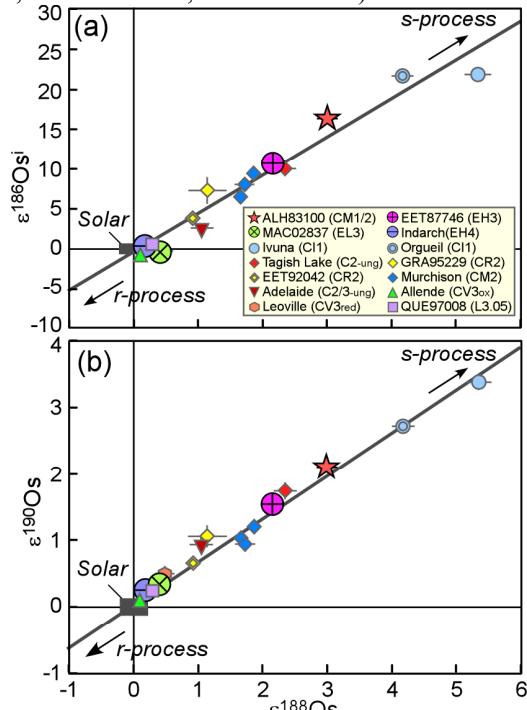


Fig. 1. (a) $\epsilon^{186}\text{Os}^i$ - $\epsilon^{188}\text{Os}$ and (b) $\epsilon^{190}\text{Os}$ - $\epsilon^{188}\text{Os}$ plots for acid residues from CC, OC and EC. Bold lines are regression lines for acid residues and bulk chondrites determined in [8].

It has been reported that the relative abundances of various presolar grain types in ECs are different from those in CCs [4-6], which may suggest a radially heterogeneous distribution of presolar grains in the solar nebula. For example, in Qingshen (EH3) and Indarch, presolar Si_3N_4 appears to be more abundant, but oxide grains less abundant than in CCs [4-5]. Most presolar Si_3N_4 grains are thought to have originated from supernova ejecta, where r-process nuclides are produced, while most oxide grains likely formed in the stellar outflow of asymptotic giant branch stars where s-process nuclides formed. Since Si_3N_4 and oxide grains are resistant to the CsF/HF digestion technique, they both are likely present in our residues. This conflicts with our observation that the residue from EET87746

is more enriched in s-process Os than residues from Murchison. Thus, although some level of heterogeneity should exist, the relative enrichment of presolar Si_3N_4 and depletion of presolar oxide grains in ECs must be masked by s-process-enriched phases that dominate the Os isotope anomalies in acid residues. These phases are, most likely, mainstream presolar SiC. Of note, bulk CCs, OCs and ECs have uniform “solar” Os isotope composition when dissolved by an alkali fusion, total digestion method [7-8]. This remains consistent with an interpretation of homogeneous distribution of presolar components in the early solar system, at least for Os isotopes, at the current level of precision.

Alternately, nebular or parent body processes might have acted differently on presolar phases located in regions of the early solar system characterized by different redox conditions. For example, selective destruction/metamorphism of r-process-enriched presolar phases under highly reduced conditions (ECs) could have led to s-process enrichments in the acid residues. Conversely, destruction of s-process-enriched phases under oxidizing conditions (CCs and OCs) could also account for the differences. Presolar phase that carry r-process Os could be X-type SiC grains, Si_3N_4 , and some graphite [1], all of which are presumed to be stable under reduced conditions. We therefore infer that the relative enrichment of s-process Os in the acid residues from ECs is the result of selective loss of s-process-enriched presolar phases (e.g. graphite or SiC) that occurred under oxidized conditions in CC/OC parent bodies or their formation locations. It is conceivable that during such nebular or parent body processing, the s-process-enriched Os was incorporated into a new, acid leachable phase(s) which was not lost, resulting in the uniform Os isotope composition observed in all types of bulk chondrites.

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Acknowledgments: This work was supported by JSPS grant to TY (21740388) and NASA grant to RJW (NNX07AM29G).