

EVALUATION OF PARENT BODY PROCESSES ON PRESOLAR COMPONENTS IN CHONDRITES: OSMIUM ISOTOPES IN ACID RESIDUES FROM CM AND CR CHONDRITES. T. Yokoyama¹, C. M. O'D. Alexander² and R. J. Walker³, ¹Dept. of Earth and Planetary Sciences, Tokyo Institute of Technology, Tokyo 152-8551, Japan (tetsuya.yoko@geo.titech.ac.jp) ²Dept. of Terrestrial Magnetism, Carnegie Institution of Washington, DC 20015, USA, ³Dept. of Geology, Univ. of Maryland, College Park, MD 20742, USA

Introduction: 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) [1-3]. Differences in the degree of isotopic anomalies in bulk meteorites also exist not only across but also within chondrite classes, especially for carbonaceous chondrites. 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. In contrast, uniform, terrestrial isotopic compositions in bulk chondrites have been reported for some elements (e.g. Sr-Os) [4-5]. The contrasting isotopic characteristics of diverse elements may provide important clues to how Solar System precursor solids formed, were transported, and mixed in the nebula.

Processes that occur on parent bodies can also potentially affect the isotopic compositions of bulk chondrites and bear further investigation. For example, presolar SiC and graphite did not survive to higher degrees of thermal metamorphism on chondrite parent bodies [6]. Also, signs of aqueous alteration are widespread in carbonaceous chondrites. If aqueous fluid in a parent body preferentially dissolves some presolar phases and carries away their constituent elements, it can potentially lead to the formation of an isotopically heterogeneous parent body. In such a case, chondritic meteorites would not necessarily record the isotopic compositions of their source region or parent body.

For these reasons, it is important to understand how much secondary processes have modified the initial population of presolar phases in chondritic parent bodies. 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, more or less, control the isotopic composition of bulk chondrites. We have previously measured Os isotopes in acid residues from nine carbonaceous and one ordinary chondrites, and found that they were enriched in Os isotopes produced by the *s*-process, of which the extent of anomaly varied across chondrite groups (CI >Tagish Lake >CM >CR >Adelaide >CV ≈ OC) [5]. The observed variation was presumably created during parent body processing, however, it remains unclear how individual processes have acted on the modification of initial presolar grain populations. Here we present evidence recorded in the Os

isotope compositions of acid residues from CM and CR chondrites with a variety of petrologic grades, that aqueous alteration in the meteorite parent bodies has preferentially destroyed some presolar phases.

Experimental: We analyzed Os isotope compositions in acid residues from four CMs (MET 01070, CM1; ALH 83100, CM1/2; Murchison, CM2; QUE 97990, CM2.6) and three CRs (GRO 95577, CR1; EET 92042, CR2; GRA 95229). We followed a CsF/HF leaching technique [7] for the preparation of the acid residues. The residues were combusted at 1000°C in sealed quartz Carius tubes, and digested with a 1:2 mixture of conc. HCl + HNO₃. The Os was extracted by CCl₄ and purified by a microdistillation technique. Osmium concentrations were measured in aliquots of the initial solutions by N-TIMS using *Thermo-TRITON* at the Univ. of Maryland (UMd), and Re, Ir, Ru, Pt and Pd concentrations were measured using two ICP-MS (either *Thermo-ELEMENT2* at UMd or *Thermo-X series2* at Tokyo Tech). Osmium isotopes were also measured by N-TIMS. The Os isotope ratios, normalized to ¹⁸⁹Os and corrected for mass fractionation using ¹⁹²Os/¹⁸⁹Os = 2.527411, are reported in εOs units (ε¹⁸⁴Os, ε¹⁸⁶Os_i, ε¹⁸⁸Os and ε¹⁹⁰Os), which represent relative deviation (parts per 10⁴) from the average of bulk chondrite analyses ('solar values') reported in [5]. The ¹⁸⁶Os/¹⁸⁹Os ratio has been time-corrected for ¹⁹⁰Pt decay over 4.56 Ga, hence, the use of ε¹⁸⁶Os_i.

Results and Discussion: Osmium isotope data for the CM/CR-residues are shown in the ε¹⁹⁰Os-ε¹⁸⁸Os diagram (**Fig. 1**), along with data from other carbonaceous and ordinary chondrite residues reported in [5]. All the CM/CR-residues are characterized by positive ε¹⁸⁶Os_i (not shown), ε¹⁸⁸Os and ε¹⁹⁰Os values that are resolvable from the solar (= terrestrial) component, which are suggestive of the enrichment of Os isotopes produced by the *s*-process. There are significant variations in εOs values across CM-residues. The magnitude of the positive Os isotope anomalies in the residue of the CM1/2 chondrite, ALH 83100 (ε¹⁸⁸Os = +3.10) is nearly twice as large as those present in residues from the CM2 chondrite, Murchison (ε¹⁸⁸Os_{average} = +1.66). Consistent with this, the residue of MET 01070 (CM1) has εOs values (ε¹⁸⁸Os = +2.31) that are larger than those of the Murchison residues, whereas that from the CM2.6 chondrite (QUE 97990) has the smallest deviation in εOs values from zero among all CM chondrites

($\epsilon^{188}\text{Os} = +0.95$). Variations in the magnitude of the ϵOs values are also observed in residues from CR chondrites, where the residue from the CR1 chondrite (GRO 95577) showed the largest positive Os isotope anomalies ($\epsilon^{188}\text{Os} = +2.64$), and are comparable with CM1 chondrites.

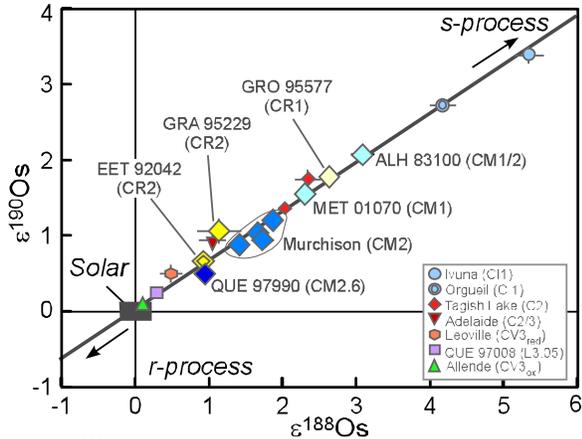


Fig. 1 $^{190}\text{Os} - \epsilon^{188}\text{Os}$ plots for acid residues from. Data are from [5] and this study. Bold line is the regression for acid residues from ten primitive chondrites obtained in [5], which represent mixing between the solar component and presumed *s*-process component.

We propose that the isotopic variation in **Fig. 1** 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 [8]. However, destruction of presolar phases during pre-accretionary alteration would result in the modification of Os isotopic compositions at the bulk meteorite scale, which is evidently not the case [5]. 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.

Presolar grains found in meteorites are generally strongly acid resistant, excluding silicates that are soluble in HF. However, low-Ca pyroxene is moderately resistant to HF at room temperature [9]. Thus, presolar enstatite grains, if present in the meteorites, may survive in the acid residues. On the other hand, petrological observation of CM chondrites shows that fine-grained anhydrous silicates in the matrices are highly susceptible to aqueous alteration and form secondary

phyllosilicates [10], which are then leachable with relatively mild acids. If this is the case, the ordering of ϵOs values in **Fig. 1** suggests that the abundance of enstatite grains from type II Supernovae (SNeII) in the residues, which may be enriched in the *r*-process nuclides, decreases as the degree of aqueous alteration on the parent body increases. However, it remains unknown whether Os is abundant in SNeII enstatite grains. A more likely candidate for the *r*-process Os carrier(s) would be some sort of reduced presolar phase(s), such as metal alloys, carbides and silicides which are unidentified in chondrites. Many of these grains must contain much Os, compared to silicates, and are thought to be susceptible to aqueous alteration, which tends to be quite oxidizing. In fact, the abundance of metallic Fe-Ni decreases during aqueous alteration as metal oxidizes [10]. This is further supported by the observation that the largest positive ϵOs values are found in CI-residues (**Fig. 1**), implying higher levels of aqueous alteration on the CI parent body than CM and CR.

Chondritic meteorite precursors have experienced various physical/chemical processes in the nebula and on their parent bodies. 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.

References: [1] Dauphas, N. et al. (2004) *EPSL* 226 465-475. [2] Carlson, R.W. et al. (2007) *Science* 316 1175-1178. [3] Trinquier, A. et al. (2009) *Science* 324 374-376. [4] Andreasen, R. et al. *ApJ* 665 874-883. [5] Yokoyama, T. et al. (2010) *EPSL* 291 48-59. [6] Huss, G.R. and Lewis, R.S. (1995) *GCA* 59 115-160. [7] Cody, G.D. et al. (2002) *GCA* 66 1851-1865. [8] Brearley, A.J. (2003) *Treatise Geochem.* 1 247-268. [9] Yokoyama, T. et al. (2002) *GCA* 66 1085-1093. [10] Rubin, A.E. et al. *GCA* 71 2361-2382.

Acknowledgments: This work was supported by JSPS grant to TY (21740388) and NASA grants (NNX08AH65G) and (NNX10AG94G) to CA and RJW, respectively.