POTASSIUM ISOTOPIC COMPOSITIONS OF ENSTATITE CHONDRITES AND AUBRITES.

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Introduction: Enstatite meteorites, which include undifferentiated chondrites and differentiated achondrites (known as aubrites), have received much attention due to their isotopic similarities with the Earth, in both mass-independent isotope systems such as O, Ca, Ti, Cr, Ni, Mo, and Ru [1–11], and mass-dependent isotope systems such as Mg, Ca, Fe, Zn, and Rb [12–16]. However, due to the previous analytical challenges associated with measuring high-precision K isotopes, the K isotopic compositions of enstatite meteorites, and whether they have the same K isotopic composition as the Earth, remained uncertain.

The K isotopic analyses by MC-ICP-MS have significantly improved the analytical precision [17–21]. Here, we use this method to analyze enstatite chondrites and aubrites and compare our results to high-precision K isotopic compositions of the Earth and other types of meteorites. The K isotopic signatures can help us understand the volatile evolutionary history and genetic relationships.

Samples and Method: We studied twelve bulk enstatite meteorite samples from various chemical groups (EH, EL and main-group aubrite), petrological types (3-6), shock degrees (S1-S4) and terrestrial weathering conditions. All samples are *finds* from Antarctica. A previous study has compared Antarctic *finds* with meteorite *falls*, which indicated that the K isotopic compositions of Antarctic meteorites have not been altered when compared to meteorites falls [22]. Our samples include three EH3 (LAR 12252, LAR 06252 and MIL 07028), one EH4/5 (EET 96135), one EL3 (MAC 88136), one EL4 (MAC 02747) and two EL6 (ALHA 81021 and LON 94100). Four main-group aubrite samples were analyzed (ALHA 78113, ALH 84009, MIL 13004 and LAR 04316).

Samples were crushed into fine powders (>100mg) and dissolved in Parr digestion vessels in concentrated HF/HNO_3 acid. Potassium was purified by cation-exchange chromatography (AG50W-X8) using the procedures described in [21]. The K yields were > 99% and all yields were monitored with pre-cuts and post-cuts collected before and after the K-cuts. Purified samples were then analyzed with a Thermo Scientific Neptune *Plus* MC-ICP-MS at Washington University in St. Louis. Instrumental mass bias was corrected by using sample-standard bracketing technique. The K isotopic compositions are reported in the delta notation relative to the NIST SRM 3141a, where $\delta^{41}K = ([(^{41}K/^{39}K)_{sample}/(^{41}K/^{39}K)_{NIST3141a} - 1] \times 1000)$. One geostandard (BHVO-2) was always analyzed in the same session as an external standard for quality control. The internal (within-run) reproducibility was typically ~0.05 ‰ (95% Confidence Interval; C.I.). The long-term (~20 months) reproducibility of this method has been evaluated as 0.11‰ (2SD; [21]).

Results: The reproducibility of the results were tested by analyzing replicates of six enstatite chondrite powders. In addition, different chips of the same aubrite were analyzed to check for sample heterogeneities because many aubrites are breccias. All replicated samples went through the full procedure from sample digestion, to column purification, to MC-ICP-MS analysis. **Fig. 1** shows that different analyses of the replicate chondrite samples agree well with each other within 95% C.I. Two of the aubrites appear to be homogeneous in K isotopic compositions, but the aubrite LAR 04316 is more variable (**Fig. 1**),

Enstatite chondrites. As shown in **Fig. 2**, the K isotopic compositions of enstatite chondrites scatter around the Bulk Silicate Earth (BSE) value (−0.48±0.03‰; [17]) and range from −0.76±0.02‰ (EL4 MAC 02747) to −0.18±0.03‰ (EL6 LON 94100). The error-weighted average of all enstatite chondrites is −0.47±0.57‰ (2SD, n=8), which is indistinguishable from the BSE value.

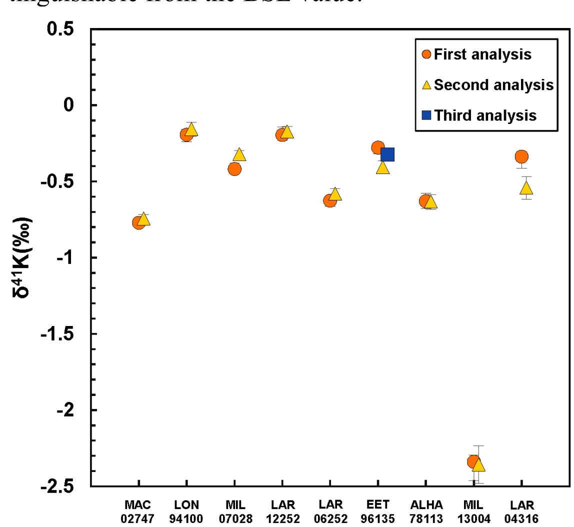

***Fig. 1**. Comparison of data of the same samples from different analyses. Error bars are 95% C.I.*

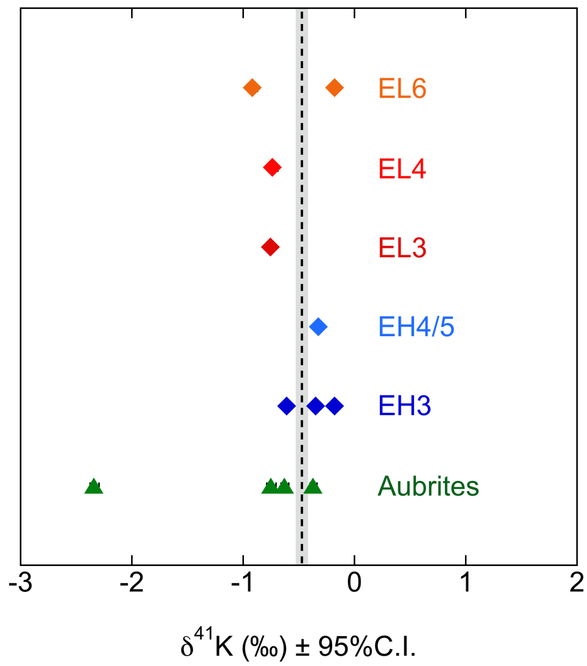

***Fig. 2**. Potassium isotope compositions of enstatite meteorites. Error bars (95% C.I.) are shown and are typically smaller than the symbol sizes. The dashed line shows the average of all enstatite chondrites (−0.47‰). The shaded area represents the BSE value (−0.48 ± 0.03‰).*

Aubrites. As shown in **Fig. 2**, the K isotopic compositions of aubrites display a large range (−2.34‰ < δ^{41}K < −0.37‰). Except MIL 13004, the average value of aubrites is −0.55±0.39‰ (2SD, n=3), which is indistinguishable from the average value of all enstatite chondrites (−0.47±0.57‰) and the BSE value.

Discussion: One previous study found no resolvable difference (within ~0.5‰) between enstatite chondrites and the Earth based on one EH4 chondrite, Indarch [23]. In this study, we analyzed 8 samples covering nearly all petrological and chemical types of enstatite chondrites. With improved analytical precision (~0.05‰), for the first time we are able to resolve any K isotopic differences between the Earth and individual enstatite chondrites (varying from −0.76 to −0.18‰). Interestingly, the mean of all eight enstatite chondrites is identical with the BSE value (−0.47±0.57‰ vs. −0.48±0.03‰). Among all undifferentiated (carbonaceous, ordinary and enstatite chondrites) and differentiated meteorites (Moon, Vesta, Mars, and aubrites) that have been analyzed so far [22, 24–26], enstatite chondrites are the only group of meteorites that have the same average K isotopic composition as the Earth. These high-precision K isotope results for enstatite chondrites are consistent with similarities seen in other isotopes systems, which overall could suggest a kinship of the matter that accreted to form both the Earth and enstatite chondrites.

We observed the lightest K isotopic composition (−2.34±0.04‰) seen among all meteorites in one aubrite sample MIL 13004. We did a repeat measurement of a new chip of the same sample; however the result was the same (−2.36±0.12‰ vs. −2.34±0.04‰; **Fig. 1**). The only viable explanation for such extremely large K isotopic fractionation in MIL 13004 is the inter-mineral K isotopic fractionation between K-bearing silicates and sulfides. The *ab initio* calculation study in [27] suggests that the characteristic K sulfide mineral in aubrites, djerfisherite, is enriched in lighter K isotopes. Heterogeneous distribution of this accessory mineral djerfisherite may account for the extreme light K isotopes in this fragment of MIL 13004.

The individual enstatite chondrites analyzed here have significant δ^{41}K variation (−0.77 to −0.16‰). We did not observe any obvious correlations with petrologic types (**Fig. 2**), shock degrees (S1-S4) or terrestrial weathering. We consider three major possibilities for explaining the variations among enstatite chondrites and achondrites although other processes may exist: 1) parent-body thermal processing; 2) impact vaporization; 3) spallogenic and cosmogenic effects. We plan to discuss these processes at the conference.

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