CHEMICAL COMPOSITIONS OF THE GROUP IIIE IRON METEORITES.

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Introduction: The IIIE magmatic iron meteorite group currently officially consists of sixteen members. We have acquired and analyzed ten of these. The IIIE iron meteorites have been previously characterized as having moderate Ni and volatile siderophile element concentrations when compared to the other magmatic iron meteorite groups [1]. The IIIE irons are chemically similar to the larger IIIAB group, but are distinguished by their coarser kamacite bands, as well as by the presence of the C-rich minerals graphite and haxonite ($[Fe, Ni]_{23}C_6$). Textural characteristics of the group IIIE irons exhibit evidence of alteration due to shock-induced heating, indicating one or more impacts to the parent body [2]. Recent nucleosynthetic (genetic) isotope data (e.g. Mo, Ru, W) have indicated that the IIIE group belongs to the noncarbonaceous chondrite (NC) suite of meteorites [3-4]. The limited extent of chemical analyses of the IIIE irons means that little is known of the IIIE parent body core, and as such, further investigation of the chemical composition of the group IIIE irons is warranted.

Samples: We have obtained pieces of Coopertown (USNM 1003), Kokstad (USNM 488), Paloduro (USNM 6877), Rhine Villa (USNM 272), Staunton (USNM 2204), Tanokami Mountain (USNM 1456), and Willow Creek (USNM 900) from the Smithsonian Institution, National Museum of Natural History. Burlington (ASU #978) and Colonia Obrera (ASU #1032) were obtained from the Carlton B. Moore Meteorite Collection at Arizona State University. Aletai was commercially obtained from KD Meteorites, Kansas. This meteorite is currently classified as an anomalous IIIE due to its reportedly high Au and Ir concentrations [5].

Methods: Bulk siderophile element concentrations were obtained via laser ablation inductively coupled mass spectrometry (LA-ICP-MS) using a *New Wave UP213* ultraviolet laser coupled to a *Thermo Finnigan Element 2* ICP-MS. Multiple 1-2 mm long tracks were ablated along cut and polished pieces of each meteorite, and concentrations for each of 18 siderophile elements were averaged for the combined length of tracks. High precision highly siderophile element concentrations (HSE; Re, Os, Ir, Ru, Pt, Pd) and Re-Os isotopic data were obtained on 0.07-0.25 g chunks of bulk samples via isotope dilution [6]. Osmium concentrations and isotopic ratios were determined using a *Thermo Fisher Triton* thermal ionization mass spectrometer. The remaining HSE were measured using a *Thermo Neptune Plus* multi-collector ICP-MS.

Results: Highly siderophile element concentrations of the IIIE iron meteorites, normalized to the CI-chondrite Orgueil [7], are shown in **Figure 1**. There is minimal crossing of patterns, allowing that most of the meteorites are related through fractional crystallization of the same parent melt. The HSE concentrations are broadly similar to that of the more chemically evolved members of the IIIAB group. The HSE pattern for Aletai, however, is substantially different and will be discussed further below. The $^{187}Re/^{188}Os$ data for the meteorites relative to a 4.56 Ga reference isochron are shown in **Figure 2.** The IIIE irons are characterized by a moderate range of $^{187}Re/^{188}Os$ and $^{187}Os/^{188}Os$ ratios of 0.7542-1.0278 and 0.15678-0.17662, respectively. Willow Creek, Paloduro, and Tanokami Mountain do not plot within uncertainties of the reference isochron, suggesting minor open-system behavior within those meteorites, possibly related to the inferred impacts to the parent body. Normalized concentrations of the 18 siderophile elements obtained via LA-ICP-MS are provided in **Figure 3**. Here, Re concentrations were below detection limits for all samples except for Kokstad, Colonia Obrera, and Aletai.

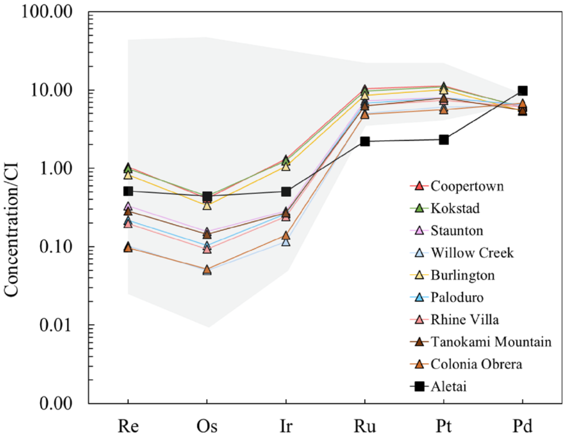

Figure 1. Bulk CI-chondrite normalized HSE abundances for nine IIIE irons and the anomalous IIIE Aletai are shown with the range of IIIAB HSE abundances in gray. Note that the pattern obtained for Aletai differs from that of the other IIIE irons.

Discussion: The IIIE irons exhibit depleted Re, Os, and Ir concentrations, relative to Ru, Pt, and Pd. This suggests that the samples analyzed are all strongly fractionated, as Re, Os, and Ir tend to be removed from a system early on during crystallization. The low concentrations of these elements indicate that all the IIIE samples are relatively late-forming in the crystallization sequence. All of the IIIE irons exhibit moderate depletions in the volatile siderophile elements Ga and Ge, consistent with their current group III classification.

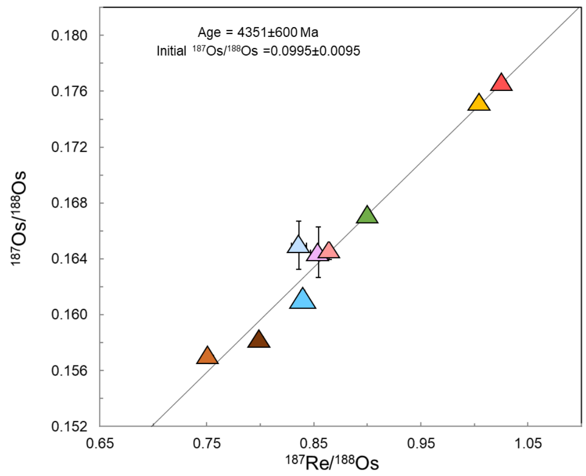

Figure 2. ^{187}Re/^{188}Os vs. ^{187}Os/^{188}Os isochron plot for the group IIIE meteorites. Symbols are the same as in Figure 1. Data are shown relative to a 4.56 Ga reference isochron.

Aletai has Ni, Ga, and Ge concentrations similar to that of the other group IIIE irons, which explains its original classification. However, the high Ir content reported in [5] relative to other IIIE irons is not apparent here, and the HSE concentrations obtained here do not fit the crystallization trend established by the other IIIE irons. As crystallization proceeds, Re, Os, Ir, Ru, and Pt concentrations are expected to decrease due to their compatible partitioning behaviors. The high Re and Os concentrations relative to the other IIIE irons would suggest that Aletai crystallized early on, but the relatively low Ru and Pt concentrations would conversely require it to be a later-crystallizing sample. These discrepancies suggest that Aletai is unlikely to sample the same crystal-liquid fractionation process as the other IIIE irons and may sample a different parent body. It should therefore be reclassified as ungrouped.

Conclusions: The group IIIE iron chemistry is consistent with their formation through the same crystal-liquid fractionation process. This relationship will be evaluated further through fractional crystallization modeling. Aletai is chemically distinct from the group IIIE iron meteorites, indicating that it should not be considered a IIIE iron and should be reclassified.

References: [1] Scott E. R. et al. (1973) *Geochim. Cosmochim. Acta,* 37, 1957-1983. [2] Breen J. P. et al. (2016) *Meteoritics & Planetary Sci., 52*, 1611-1631. [3] Worsham E. A. et al. (2019) *Earth Planet. Sci. Lett., 521,* 103-112. [4] Kruijer T. S. et al. (2017) *PNAS, 114,* 6712-6716. [5] Bouvier A. et al. (2017) *Meteoritics and Planetary Sci.,* 52. [6] Walker R. J. et al. (2008) *Geochim. Cosmochim. Acta, 72,* 2198-2216. [7] Horan M. F. et al. (2003) *Chem. Geol., 196*, 27-42.

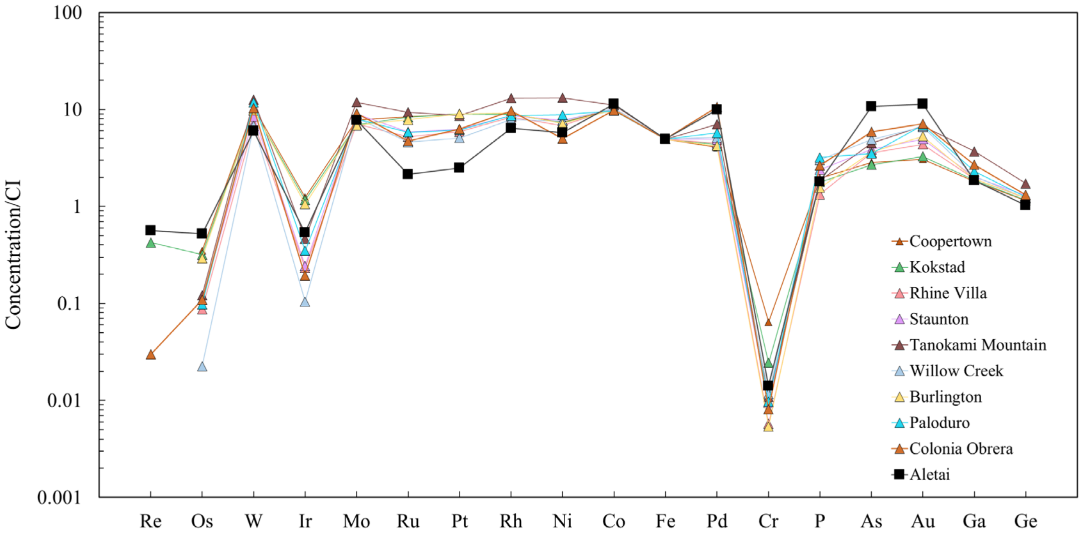

Figure 3. CI-chondrite normalized siderophile element abundances for nine group IIIE iron meteorites and Aletai obtained via laser ablation ICP-MS. Elements are listed in order of decreasing 50% condensation temperature from left to right.