GENEALOGY OF IVA IRON AND PALLASITE METEORITES: THE IMPLICATIONS FOR PLANETESIMAL DIFFERENTIATION PROCESSES IN THE EARLY SOLAR SYSTEM. M. E. Sanborn[1], Q.-Z. Yin[1], and K. Ziegler, [1]Department of Earth and Planetary Sciences, University of California-Davis, Davis, CA 95616 (E-mail: mesanborn@ucdavis.edu), [2]Institute of Meteoritics, University of New Mexico, Albuquerque, NM

Introduction: Melting and differentiation of asteroids in the emerging early Solar System are two of the key processes in the evolution of planetesimals into the planetary bodies we have today. Information into surface and near surface magmatic processes during differentiation are provided to us by stony achondrite meteorites. However, insight into differentiation processes at greater depths requires a different set of planetary materials, stony-iron and iron meteorites, provided through collisional breakup of differentiated planetesimals.

In most cases, the parent body bulk composition of stony-iron and iron meteorites are not known. Therefore, in order to fully understand differentiation processes occurring in the early Solar System, it is necessary to reconstruct the genealogy of the iron and stony-iron meteorites and their relationships and origins with other planetary materials in hand. By doing so, it is possible to link evidence of deep differentiation processes (core formation and cooling, mantle crystallization) with processes recorded in the crust of the same planetesimals. Alternatively, the stony-iron and iron meteorites may be originating from distinct geochemical reservoirs for which no stony meteorite counterparts are known. Distinguishing between these scenarios is important for their use in modelling and interpreting planetary differentiation and evolution.

Potential connections between at least some stony-iron and iron meteorite groups and stony meteorite counterparts have been proposed. Such potential connections include IVA iron meteorites with ordinary chondrites [1], the anomalous Eagle Station pallasite with CV chondrites [2], and IIIAB irons and main group pallasites (MPG) [3]. The connection of stony-iron and iron meteorites to chondritic counterparts has strong implications for planetesimal evolution. Their genetic relationship would provide support for various differentiation models, such as the "onion-shell" structure proposed for the ordinary chondrite parent bodies [4,5] or partially differentiated carbonaceous chondrite parent bodies [6].

Here, we focus on investigating what geochemical reservoir within the solar nebula generated the IVA iron meteorites and pallasites (main group pallasites - MGP and anomalous ones) using Cr isotopes. Using this information, we further look at the proposed petrogenetic linkages to stony meteorite counterparts and what implications this may have in how we view differentiation on planetesimals in the early Solar System.

Analytical Methods: Four meteorites were investigated in this study: two pallasites (Brenham and Milton) and two IVA iron meteorites (Steinbach and São João Nepomuceno). For the IVA iron meteorites and the pallasite Milton, silicate material was removed manually and then leached in 6N HCl to remove any adhered metal. After leaching, the silicate materials from each sample were placed in individual Parr bombs and heated in a 3:1 mixture of $HF:HNO_3$ at 190°C for 96 h. For Brenham, a single large chromite grain was isolated from the metal matrix. A subsample of this chromite was placed directly into a Parr bomb using the same procedure as the silicate fractions.

Chromium was separated from the dissolved samples using a 3-column chemistry procedure described by [7]. The Cr isotopic composition was measured using a Thermo *Triton Plus* thermal ionization mass spectrometer at the University of California, Davis. A total of 12 μg of Cr was analyzed for each sample by loading onto outgassed W filaments (3 μg per filament). Details on the mass spectrometry procedures can be found in [8]. Every sample was bracketed by measurement of the NIST SRM 979 Cr standard. All the Cr isotope ratios are reported as parts per 10,000 deviation (ε-notation) from the measured Cr standard.

Results and Discussion: The Cr isotopic composition of each of the four meteorites analyzed in this study are shown plotted in Figure 1 in Cr-O isotope space.

The anomalous pallasite Milton has a positive $\varepsilon^{54}Cr$, similar to the values seen among carbonaceous chondrite, specifically plotting near the CV-type chondrites. Milton is not an isolated achondrite in this region of Cr-O space with several stony meteorites: Northwest Africa (NWA) NWA 1839 (CO7, originally L7), NWA 3133 (CV7 achondrite), and NWA 10503 (CV metachondrite) having similar Cr and O [9,10]. As such, Milton could potentially be sampling the core-mantle boundary of a partially differentiated CV-type object for which these stony meteorites are shallower components. This parent body would be distinct from the one for Eagle Station based on their different Cr and O compositions. Eagle Station, which contrary to the suggestion as being similar to CV-type chondrites [2], actually plots closer to CK- and CO-type chondrites (Fig. 1). As with Milton, there is another example of a stony meteorite, NWA 8186 (CK7), that plots in the same region of Cr-O space as Eagle Station and the CO- and CK-type chondrites [11,12]. If Milton and Eagle Station were two distinct objects, then the complete disruption of these early differentiating bodies in the carbonaceous chondrite forming region of the nebula was not a rare occurrence.

In contrast to the anomalous pallasites, the MGP Brenham has a negative ε^{54}Cr, similar to the only other reported MGP, Krasnojarsk, and the howardites-eucrites-diogenites (HEDs) [13,14]. However, the Δ^{17}O for all MGP including Brenham plots >2σ above the normal HED mean [15, 16]. This may indicate the MGP originated from a Vesta-like object with similar Cr, yet distinct O isotopic composition to the normal HEDs points to separate parent body.

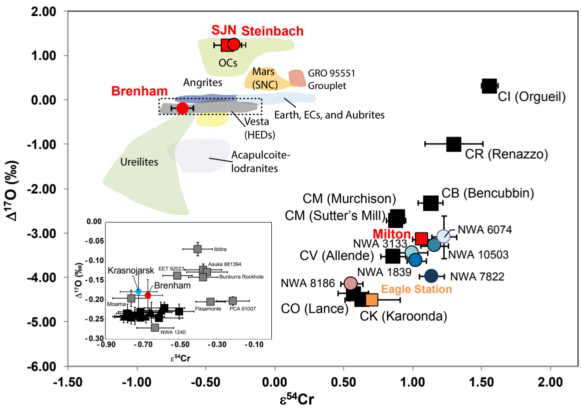

Fig. 1. Δ^{17}O-ε^{54}Cr diagram of Milton (anomalous pallasite), Brenham (MGP), São João Nepomuceno (SJN) and Steinbach (both IVA irons) with other meteorite groups. Inset shows a zoomed in view of the HED region with Brenham (red), Krasnojarsk (blue), normal eucrites (black squares), and anomalous eucrites (grey squares). Literature data are from [9,10,13,14,18] and references therein.

The previous suggestion for IVA irons being similar to ordinary chondrites was based on the similarity in their oxygen isotopic composition [1]. The ε^{54}Cr determined for the silicate inclusions from Steinbach and São Joao Nepomuceno plot within the range previously determined for ordinary chondrites as well. Thus, the two IVA iron silicates analyzed so far have strong isotopic similarities to ordinary chondrite in Cr-O space, plotting near the L and LL chondrites (Fig. 1), indicating IVA iron may originate from an L/LL chondrite parent body. Based on cooling rates, the IVA irons are believed to have cooled inwards meaning the crystallization occurred *in situ* on its parent body, as opposed to rapid crystallization during disruption of the parent body [19]. Such conditions are evidence for the "onion-shell" structure that has been previously proposed [5], except with much more aggressive heating, complete melting and differentiation in the interior as opposed to thermally metamorphosed type-6 chondrite comprising the interior. Recently, physical evidence for large scale break-up of the L-chondrite parent body has been reported based on massive meteorite fluxes during the Ordovician [20,21] and observed L chondrite fall with lower intercept isotopic disturbance at ~470 Ma [22]. This indicates that large scale planetesimal-wide disruption was occurring in the region of the nebula where the ordinary chondrite parent bodies formed. Such a breakup event could provide the mechanism to excavate the IVA irons from the interior.

The ubiquity of melting and differentiation of planetesimals in the early Solar System is evident from the chucks of basalts as a result of surface eruptions to the range of stony-iron and iron meteorites of deeper interiors. Now with the new Cr isotopic finger printing approach (cosmic forensics, so to speak), we can relate these diverse melt products to specific parent body composition that have been sampled by other primitive planetary materials in hand (revealing planetary genealogy), thus allowing us to begin to assemble a more robust, full picture of the geochemical evolution of asteroids after their initial accretion. As such, our view of planetary melting and differentiation processes can now be further expanded to both carbonaceous and non-carbonaceous regions of the solar nebula.

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