A COMMON PARENT FOR IIE IRON METEORITES AND H CHONDRITES. S. N. Teplyakova[1], M. Humayun[2], C. A. Lorenz[1], M. A. Ivanova[1], [1]Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, Kosygina st.19, 119991, Moscow, Russia (elga.meteorite@gmail.com), [2]National High Magnetic Field Laboratory and Department of Earth, Ocean & Atmospheric Science, Florida State University, 1800 E. Paul Dirac Drive, Tallahassee, FL 32310, USA (humayun@magnet.fsu.edu).

Introduction: Chemical and isotopic links between chondrites and differentiated meteorites are important for placing such meteorites into an asteroidal context. The IIE irons belong to a non-magmatic group of silicate-bearing iron meteorites [1-2] that have been linked by oxygen isotopes to H chondrites [3-4], and have been linked to the asteroid 6 Hebe by reflectance spectra that indicated the presence of metal sheets on Hebe [5]. The IIEs have Ni and Ge contents that span a larger range, while their Ir contents span a smaller range, than those of the magmatic iron groups [1-2]. These features are not consistent with fractional crystallization of a large metallic core. Thus, it has been concluded that metal of the IIE irons, like the IAB irons, were formed as a pool of impact-generated melt in a chondritic body [1, 2]. An alternative viewpoint argues for internal differentiation of IIEs based on slow metallographic cooling rates for unheated metal, and trends of $\delta^{18}O$ vs. Fs [6].

Silicate inclusions in the IIE irons vary in composition from chondritic in Netschaëvo and Watson to highly fractionated silica-, alkali-rich ones in Colomera, Miles and Elga [7-8]. A new high precision laser fluorination study of oxygen isotopic composition of the IIE silicates reveals almost complete overlap with the equilibrated H chondrites, with the exception of three outliers, Netschaëvo, Colomera and Miles [4]. The siderophile element composition of IIE metal is not identical to H chondrite metal, leading some workers to conclude that IIEs formed on a related but distinct asteroid from H chondrites [1-2, 6]. IIE irons also exhibit an enigmatic Ge isotope fractionation [9].

Here, we report new siderophile element abundances for the metal in the IIE irons - Watson, Tobychan, Elga, Verkhne Dnieprovsk and Miles - to examine the possible genetic relations between IIE metal and H chondritic precursors.

Samples and Analytical Methods: Analyses were performed on a New Wave UP193FX excimer laser ablation system coupled to a Thermo Element XR™ ICP-MS at the Plasma Analytical Facility, NHMFL [10]. Nine polished slabs of Watson, Tobychan, Elga, Verkhne Dnieprovsk and Miles from the meteorite collection of Russian Academy of Sciences were analyzed. Rasters with 100 µm spot size scanned at 25-50 µm/s were performed on areas ranging from 0.5-4 mm to average over the Widmanstätten structure.

Results: The new siderophile element data are shown on a Fe-, CI-normalized plot in Fig. 1, together with bulk H chondrite metal [20]. Two separate pieces of Elga metal were analyzed about 6 months apart [11]. The two analyses agree within 2% for Fe, Ni, Ga, Ru, Rh, Pd, Re, Os, Ir, and Pt, and within 10% for Co, Cu, Ge, W and Au, but Sb differed by 40% between the two measurements. The $(Au/As)_{CI}$ ratio was 1.44 vs. 1.65, a little lower for the earlier measurement indicating a higher taenite content in the earlier measurement. The abundances of Ni, Co, Cu, Ga, Ge and Au in our bulk composition of Elga metal, are within 10% of those previously reported for Elga by NAA [1-2], the abundances of W and As are within 15% of [1], and Re and Ir are 20-40% higher in our data than those of [1, 12]. Two separate metal fragments of Tobychan were analyzed which are indistinguishable on Fig. 1. Our abundances of Ir and Re are ~20% higher and Ni ~8% lower than previously reported for Tobychan [1].

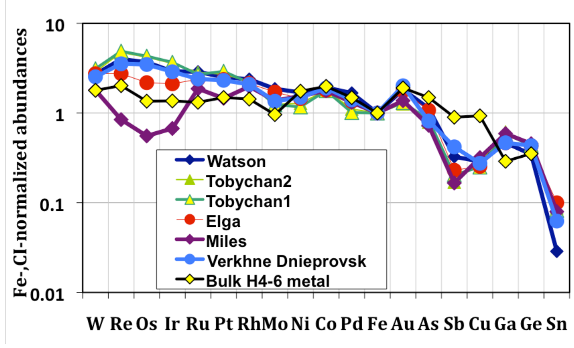

Fig. 1. IIE metal composition normalized to CI-chondrite and Fe, compared with bulk H metal [20].

Our data for Miles are in good agreement (better than 10%, except Rh, Pd, Au better than 20%) with NAA data [1-2, 13] with the exception of As (30-40% lower), and Ru, Re and Ir (50-70% higher). Our Os abundance (1.29) agrees with the Os (1.24 ppm) of [13], and their Pt abundance (7.06 ppm) is confirmed here (6.92 ppm). However, we obtain Sb (0.11 ppm) similar to [1-2], but a factor of 4 lower than the Sb of [13]. The higher $(Au/As)_{CI}$ ratio in our analysis of Miles (1.9) indicates that we have sampled a higher proportion of taenite than kamacite in our analysis compared with the NAA data (1.3 [13], 1.6 [1]). The Verkhne Dnieprovsk sample was only a few mm in diameter, and the available metal area rastered was an order of magnitude lower than for the other IIEs in this study. Three spot analyses were also taken on the metal. Abundances for the spot shown (Fig. 1) for Verkhne Dnieprovsk agree nicely with the NAA data, except for As which is 60% lower than by NAA [1]. These differences do not affect our interpretations.

Discussion: First, we describe a model for melting of bulk H chondrite. Then we apply this model to address two significant issues with the new IIE data.

Melting model for an H chondrite: We calculated a bulk siderophile element composition of H chondrites [14-18]. A metallic liquid derived by complete reduction and melting of bulk H chondrite is shown in Fig. 2 as the black line. Batch equilibrium liquids formed by partial melting of the H chondrite composition are given as green lines, calculated at 10% melting intervals using partition coefficients that tracked the sulfur content of the liquid using the formalism of [19]. The minimum melt has F_L~26%. The partial melts are all enriched in the incompatible elements, Pd, Au, As, Sb, Cu, and Sn, and depleted in compatible elements, W, Re, Os, Ir, Pt, Ru, relative to the starting composition. The complementary effect is noted in solid metal that is in equilibrium with each of these partial melts.

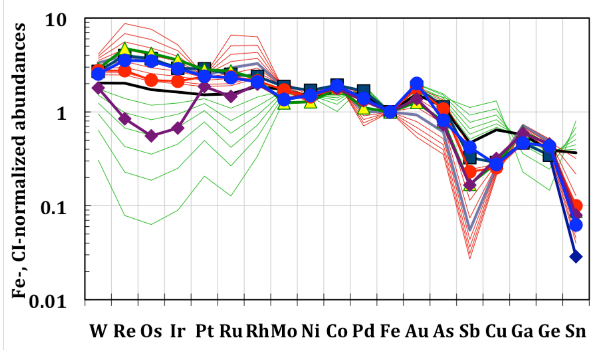

Fig. 2. Calculated compositions of liquid metal (green curves) and solid metal (red curves) formed by crystallization from H chondrite liquid metal (black line) compared with IIE irons (see Fig. 1 for legend).

Relationship to H chondrites: Our siderophile element data compare nicely with bulk H chondrite metal [20] for those elements that have $D^{\text{solid metal-liquid metal}}$ near unity: Co and Ge are essentially identical, but Ni is lower and Ga is higher in IIE metal relative to H chondrite metal. The depletion of Ga from metamorphosed H chondrite metal is a well known feature, where it is partitioned into silicates [20]. The Ga abundances of IIE metal are consistent with a completely reduced H chondrite composition. Thus, the partial melts that formed IIE metal were more reduced than the observed redox state of H chondrites, consistent with [1-2]. The issue is then whether one wishes to invoke a higher reduction of H chondrite, or to invoke a distinct ordinary chondrite end-member, HH chondrites [1-2], which is both more reduced and has higher Fe (and siderophile element) contents than H chondrites, such as invoked for Netschaëvo [21].

Differentiation of IIE metal: both the compatible and incompatible siderophile elements provide useful genetic information on the differentiation processes that formed IIE irons. Fig. 2 shows that the metal compositions of Tobychan, Elga, Watson and Verkhne Dnieprovsk plot above the bulk H metallic liquid composition in compatible siderophile elements, which requires that these metal compositions had to form as solids precipitated from a metallic liquid of H chondrite composition. Further, the incompatible elements, Pd, Au, As, and particularly Sb, Cu and Sn, are depleted in IIE metal (including Miles) relative to the H chondrite metallic liquid indicating that all of the IIEs studied here formed as solid metal precipitated from such a metallic liquid. Thus, even metal from Miles, the most fractionated siderophile element pattern for a IIE, has a composition consistent with precipitation from a parental liquid that had already experienced ~70% crystallization of solid metal. None of the IIE metal compositions obtained in this study are consistent with a metallic liquid that quenched within cooler silicate clasts during an impact [2], which may support an internal differentiation model [6]. The residual liquid has drained away, and was not sampled within the IIEs studied here. We conclude that the siderophile abundances of IIE metal are consistent with solid metal crystallized from a reduced, molten H-chondrite precursor, consistent with the oxygen isotope evidence.

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