***IN SITU* DETERMINATION OF SIDEROPHILE TRACE ELEMENTS IN EL3 METEORITES.** D. van Niekerk[1], M. Humayun[2], and K. Keil[1], [1]Hawai'i Institute of Geophysics and Planetology, University of Hawai'i at Manoa, Honolulu, HI 96822, USA, dionysos@higp.hawaii.edu. [2]National High Magnetic Field Laboratory and Dept. of Geological Sciences, Florida State University, Tallahassee, FL 32310, USA.

Introduction: Weisberg et al. [1] first described intergrowths of enstatite and kamacite in meteorites classified as unequilibrated enstatite chondrites. These intergrowths are often spherical and consist mostly of metal (kamacite) with euhedral enstatite crystals protruding into it or wholly enclosed within. The apparent absence of impact melt features led them to prefer a petrogenetic hypothesis involving either nebular flash heating, or vapor-growth. Van Niekerk et al. [2] further described such "objects" – later terming them Metal/Sulfide - Euhedral Silicate/Graphite assemblages (MSSG's), reflecting their varied mineralogy – and found that all seven of the EL3's they studied contained them, whereas EH3's do not. They also later presented examples of MSSG's which are not spherical objects and appear to have an igneous relationship to surrounding chondrules, fragments, and interchondrule regions, which argue in favor of them being post accretional products [2]. They hypothesized that these intergrowths are similar to those found (more extensively) in EH- and EL impact melt breccias [e.g. 3] and thus indicative of parent body thermal processing (as opposed to nebular processing), possibly involving complex impact melting scenarios, which would make the EL3's impact-melt breccias (IMB's). Although little is known about the chemical composition of impact-melt derived metal, siderophile elements can provide important petrogenetic clues to the nebular [e.g., 4] or parent-body [e.g., 5] origins of metal. In this abstract, we present the first results of *in situ* siderophile trace element measurements in metal of EL meteorites by laser ablation ICP-MS (LA-ICP-MS) to constrain their petrogenetic histories. We also present results on Ilafegh 009, an IMB related to EL chondrites [6].

Samples and Methods: Siderophile trace elements predominantly in kamacite, but also sulfides, schreibersite, and perryite, were measured in polished thin sections of three EL3 meteorites documented by [2] (QUE 94594; PCA 91020; MAC 88136) and one EL impact melt (Ilafegh 009). Although the EL3 kamacite is predominantly present in MSSG-type intergrowths, some assemblages exist that have no silicate crystals (kamacite or kamacite-sulfide). We analyzed kamacite in all these textural settings and the grains were documented (prior to LA-ICP-MS analysis) by x-ray mapping, BSE-imaging, and EDS analyses using a JEOL 5900LV SEM at the University of Hawaii, Manoa. Trace element analyses were performed using a New Wave UP213 laser ablation system coupled to a Finnigan Element ICP-MS at Florida State University. Metal grains were analyzed with a spot mode using 15-40 µm spot sizes, 10 Hz repetition rate, 75% power output (0.3 mJ). The peaks ^{57}Fe, ^{59}Co, ^{60}Ni, ^{63}Cu, ^{69}Ga, ^{74}Ge, ^{75}As, ^{102}Ru, ^{103}Rh, ^{106}Pd, ^{184}W, ^{185}Re, ^{192}Os, ^{193}Ir, ^{195}Pt, and ^{197}Au, were acquired for metals, while sulfides were analyzed with a routine that also included ^{25}Mg, ^{29}Si, ^{31}P, ^{34}S, ^{43}Ca, ^{49}Ti, ^{51}V, ^{53}Cr, ^{55}Mn, ^{66}Zn, ^{82}Se, ^{88}Sr, ^{93}Nb, ^{97}Mo, ^{120}Sn, and ^{121}Sb, all in low resolution mode. Standards used included North Chile (Filomena) IIA iron meteorite, Hoba IVB iron meteorite, NIST SRM 1263a steel, NIST SRM 612 and MPI-DING silicate glasses. Abundances for standards are from [7], except for Hoba [8]. Our datasets for PCA 91020 and Ilafegh 009 are the most robustly processed of the four meteorites at the time of writing and we include these results below.

Results: Traverse analyses taken across metal grains in the EL3's and Ilafegh 009 do not show evidence for chemical zoning. The siderophile element pattern for Ilafegh 009 is shown in Fig. 1, where it is compared with bulk EL metal [9]. The only notable difference is the low W/Re ratio, indicating that some melt may have been lost from the system. Otherwise, Ilafegh 009 metal composition is consistent with whole-scale impact melting of an EL chondrite.

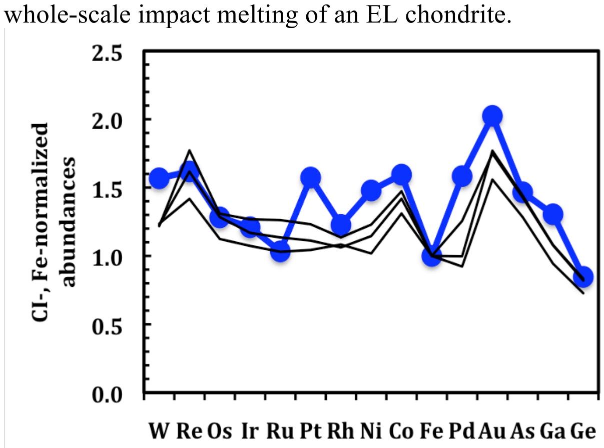

Fig. 1: CI-, Fe-normalized siderophile element pattern for Ilafegh 009 metal, compared with bulk EL metal (blue circles) [9].

Siderophile element patterns of 12 kamacite grains in the EL3 chondrite, PCA 91020, are shown in Fig. 2, compared with the bulk metal separate composition from PCA 91020 [9]. Many metal grains exhibit large depletions in the compatible elements Re, Os, Ir, and Pt. Superposed on Fig. 2 are the siderophile element patterns of (a) a eutectic C-rich metallic liquid, and (b) a S-rich (15 wt%) metallic liquid, calculated to be in equilibrium with bulk EL metal.

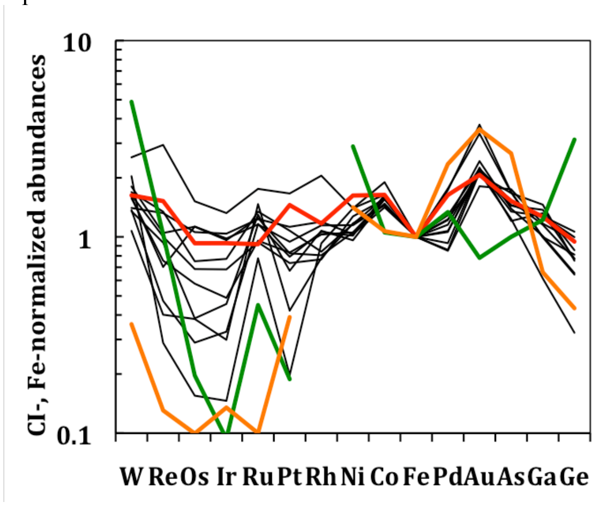

Fig. 2: CI-, Fe-normalized siderophile element pattern for kamacite from PCA 91020 (black), compared with bulk PCA 91020 metal (red) [9], and C-rich (green) and S-rich (orange) metallic liquids.

Certain features of the siderophile element pattern are best captured by the S-rich melt, but the W and Ru abundances require a role for C-rich metallic liquids. This is not surprising in view of the presence of graphite in the MMSG assemblages [2], and the abundance of both C and S in the parental EL3 chondrites. A possible role for Si also exists, but no experimental data are available to evaluate this aspect of the EL3 kamacites. One surprising aspect of the PCA 91020 kamacite data is that there are a lot of patterns featuring a depletion in the compatible siderophile elements relative to the bulk composition, but the complementary Re-Os-Ir-rich residual metal is not observed. Analyses of sulfides, schreibersite and perryite have also not yielded a complementary siderophile element pattern.

Schreibersite in metal is depleted in Re, Os, Ir, and Pt relative to Ru, Au, Pd and W. These results are consistent with equilibrium partitioning in the solid state between metal and schreibersite as schreibersite exolves during crystallization, a feature of schreibersite partitioning previously observed in opaque assemblages from Efremovka CAIs [10].

Discussion: A nebular condensate formed under very reducing conditions from a gas of solar composition should have a flat siderophile element pattern for the most refractory elements: W-Rh [10]. The EL-like siderophile element pattern, with characteristic fractionations of the refractory siderophile elements: superchondritic W/Ir, Re/Os, chondritic Ge/Ni, and the net depletion of Os, Ir and Pt, relative to Fe-Ni, argue against volatility-controlled (nebular) processes previously invoked to explain these assemblages [1]. The depletion of compatible Re, Os, Ir, and Pt, in PCA 91020 kamacite indicates a role for liquid metal-solid metal fractionation of planetary processes, consistent with impact melting [2]. Based on the partitioning experiments of [5, 11], the high W/Ir, Re/Os and Ru/Pt ratios in kamacite from PCA 91020, indicate that this kamacite crystallized from a carbon-bearing metallic liquid, supported by the presence of graphite in the MSSG assemblages [2]. The origin of the MSSG's is thus unlikely to be related to nebular processes such as condensation and evaporation. Rather, the abundance patterns (Fig. 2) appear to reflect injection of liquid metal, which is consistent with impact melting processes. These relative abundance patterns thus reflect metal grains which were partial melts (probably in the Fe-C-S system) which may have quenched or fractionally crystallized. The absence of any metal grains in the EL3's – regardless of textural/morphological setting – with a complementary partitioning pattern that would represent either an unmelted relict or an early solid that crystallized from a chondritic-flat source, implies that the observed metal is extraneous to the rock on the scale of the thin section. Thus quenching of a partial melt is unlikely, and fractional crystallization of a permeating melt is more likely. A porous regolith may offer one means to accommodate this movement of melt, while a dynamic regolith may have destroyed extensive metal veins if they were present.

The current analytical data are consistent with one of the explanations that [2] offers for MSSG petrogenesis, namely, that the source of the metal/sulfide is impact melt that infiltrated into a porous regolith and that the silicate intergrowths must represent an accompanying silicate melt or *in situ* thermo-physically disaggregated chondrules. Our work strengthens the emerging view that we may not be able to consider the EL3's as "unequilibrated" or "petrologic type 3" in the conventional sense of the definition.

References: [1] Weisberg et al. (1997) *LPSC, XXVIII,* 1768. [2] Van Niekerk et al. (2008) *LPSC, XXXIX,* 2296. [3] Rubin A. and Scott E. R. D. (1997) *GCA, 61,* 425–435. [4] Campbell et al. (2001) *GCA 65*, 163-180. [5] Chabot et al. (2006) *GCA 70*, 1322-1335. [6] McCoy et al. (1995) *GCA, 59,* 161-175. [7] Campbell et al. (2002) *GCA, 66*, 647-660. [8] Walker et al. (2008) *GCA, 72*, 2198-2216. [9] Kong et al. (1997) *GCA, 61*, 4895-4914. [10] Campbell et al. (2003) *GCA 67*, 3119-3134. [11] Chabot et al. (2003) *MAPS, 38*, 181-196.