NEW INSIGHTS TO THE FORMATION AND CRYSTALLIZATION HISTORY OF GROUP IC IRON METEORITES. H.A.Tornabene, R.D. Ash, and R.J. Walker; Department of Geology, University of Maryland, College Park, Maryland, 20742, USA (hopet@umd.edu)

Introduction: The IC magmatic iron meteorite group consists of thirteen members, of which we have examined eleven. Early studies of the group characterized it as having moderate Ni and high volatile siderophile element abundances, compared with other magmatic irons [1]. Unlike most iron meteorite groups, the IC group is characterized by a diverse range of textures. Recent studies of genetic isotopes, based on nucleosynthetic variations of certain siderophile elements (e.g., Mo, W), have shown that the group is of the non-carbonaceous chondrite (NC) genetic type [2]. Further, the IC irons that have been examined are characterized by cosmic ray exposure corrected $^{182}W/^{184}W$ ratios that overlap within uncertainty of the initial $^{182}W/^{184}W$ ratio determined for calcium aluminum rich inclusions (CAI) [2], suggesting that parent body accretion and differentiation occurred simultaneous with or shortly after CAI formation. The IC group therefore, may sample the earliest formed differentiated body in our collections, making the chemical composition of the parent body particularly important to characterize.

Samples: The IC group consists of: Arispe, Bendego, Chihuahua City, Etosha, Mount Dooling, Murnpeowie, Nocoleche, NWA 2743, NWA 11404, Santa Rosa, St. Francois County, Union County, and Winburg. We obtained pieces of Arispe, Chihuahua City, Mount Dooling, Murnpeowie, Nocoleche, St. Francois County, Santa Rosa, Union County, and Winburg from the Smithsonian Institution, National Museum of Natural History, USA. NWA 2743 was obtained from Arizona Skies Meteorites, Flagstaff, Arizona and Bendego was obtained from the Museu Nacional/UFRJ, Brazil. We have also obtained a piece of Etosha from the UCLA Meteorite Collection which we are currently processing.

Methods: Bulk siderophile element concentrations for IC irons were obtained by laser-ablation using a *New Wave* UP213 ultraviolet laser coupled to a *Thermo Finnigan Element 2* inductively coupled plasma mass spectrometer (ICPMS) at UMd. To do this, each meteorite was ablated along several 1 mm long tracks, and concentrations were averaged. High precision highly siderophile element (HSE; Re, Os, Ir, Ru, Pt, Pd) concentration and Re-Os isotopic data for 0.05 to 0.2 g of bulk samples were also obtained by complete digestion, coupled with isotope dilution and standard separation and mass spectrometric techniques [e.g., 3]. For this, Os concentrations and $^{187}Os/^{188}Os$ ratios were determined using a *Thermo-Fisher Triton* thermal ionization mass spectrometry, and the other HSE were measured using a *Thermo-Fisher Neptune Plus* multi-collector ICP-MS.

Results: The Re-Os isotopic data for most IC meteorites plot on or near a 4.57 Ga reference isochron. This indicates minimal open system behavior for siderophile elements in this group. Chihuahua City and Mount Dooling plot beyond analytical uncertainties of the reference isochron, which indicates these meteorites underwent some modest open system behavior.

A plot of CI chondrite normalized HSE concentrations (**Fig. 1**) reveals varying degrees of fractionation for Re, Os and Ir. Although Ru and Pt concentrations vary by nearly a factor of 5, all IC irons are characterized by Ru/Pt ratios that are little fractionated compared to chondrites. As common in many magmatic iron groups, there is limited variation in Pd concentrations. There is also little crossing of patterns for most of the group, consistent with these meteorites being related by modest crystal-liquid fractionation from the same melt. The two exceptions to this are Nocoleche and Murnpeowie whose flat patterns are problematic to relate to other IC irons by crystal-liquid fractionation processes. These two meteorites have been previously classified as "anomalous", so our new results are consistent with this designation. Genetic isotope measurements that are underway will be used to assess whether or not these two meteorites are genetically related to the *bona fide* IC irons. For reasons discussed below, the remaining IC samples are categorized into two subgroups characterized by "high" and "low" Re, Os and Ir abundances.

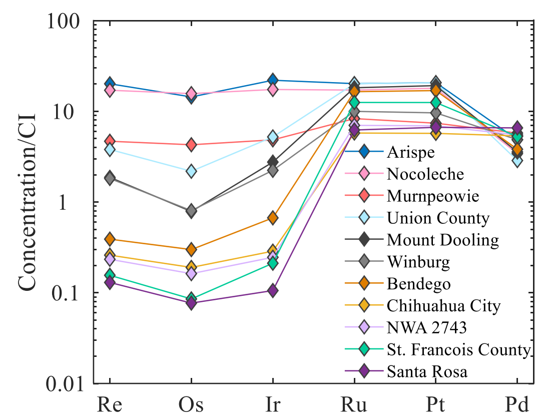

Figure 1. CI-normalized [from 4] highly siderophile element data for IC irons. Elements are arranged from left to right in order of decreasing 50% condensation temperature.

Discussion: Unlike most other major magmatic iron groups, variations in the HSE abundances among the members of the IC group (excluding Murnpeowie and Nocoleche) cannot be wholly accounted for by a simple fractional crystallization model. The HSE patterns for the IC irons instead suggest the IC irons may be comprised of two subgroups with high and low Re Os and Ir abundances. The high abundance group consists of Arispe, Union County, Mount Dooling and Winburg (**Fig. 2**). The low abundance group consists of Bendego, Chihuahua City, NWA 2743, St. Francois County and Santa Rosa. Initial attempts at modeling fractional crystallization, assuming initial S, P and C concentrations of 16, 0.1 and <0.5 wt. %, respectively, can account for all high abundance IC irons as mixtures of contemporaneous solids and liquids. The model traces an evolution path where Arispe represents an early crystallized solid after 10 % fractional crystallization (**Fig. 2**). Although Re, Os and Ir concentrations of the low abundance group can be accounted for as a result of extensive crystal-liquid fractionation, the limited fractionation in Ru/Pt abundances are not consistent with this type of model. Instead, the low Re, Os and Ir subgroup is best modeled as mixtures of early-formed solids and relatively evolved liquids. This is illustrated on the plot of Re vs. Re/Os. The low abundance group plots well to the left of the liquid track and cannot be accounted for by simple fractional crystallization model. They can be accounted for via mixing of an early-formed solid and a liquid present after 20 % fractional crystallization.

Scott [1] proposed that the IC parent body experienced a collision that disrupted the core causing recrystallization by deformation, consistent with some of the IC irons having recrystallized, anomalous textures. One possible scenario consistent with our new data is that evolved liquids were injected into collision-induced fractures in the evolving core. For this scenario, Santa Rosa and Chihuahua City would represent mixtures of liquids after 20 % crystallization and solids formed after 1 % crystallization assuming approximately >99 % of these meteorites would be composed of the evolved liquid. This is consistent with the conclusions of [1] that Santa Rosa and Chihuahua City have different mineral textures from the other IC irons. A collision to the IC parent body, followed by mixing could account for the two sub-groups of IC irons as well as their different mineral textures, although not all samples from each of the two sub-groups show similar structures.

The initial melt concentration of HSE calculated from our fractional crystallization model is also plotted in **Figure 2**. The estimated composition of the parent core is approximately four times that of the enstatite chondrite average indicating the core was likely ~25 % the mass of the IC parent body, assuming all HSE were extracted into the core. This is similar to other NC cores [3].

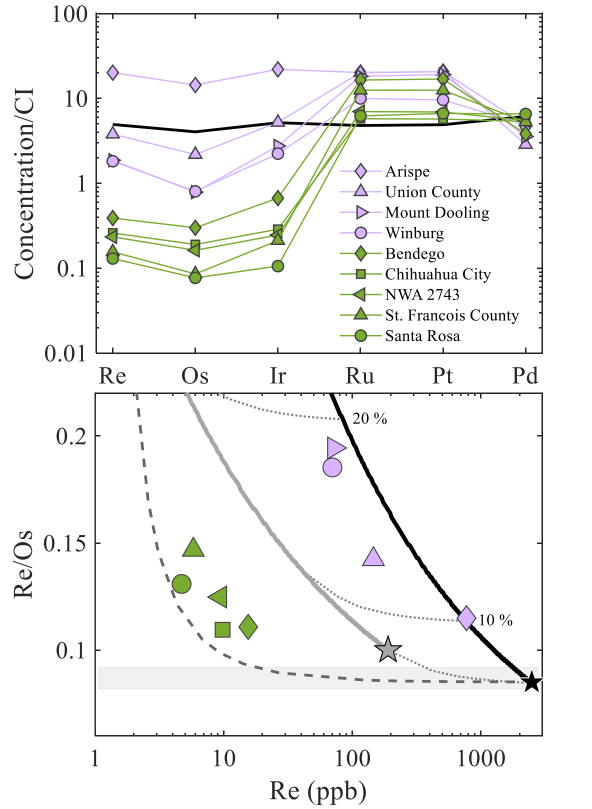

Figure 2. Top: CI normalized highly siderophile element data for IC irons highlighting the two sub-groups. The black solid line is the calculated initial melt concentration of HSE, normalized to the enstatite chondrite average [4]. Bottom: Fractional crystallization model of Re (ppb) versus Re/Os defined by 16 wt. % S, 0.1 wt. % P, and <0.05 wt. % C. The grey area is the range of chondrites [5]. The colored symbols are the same as the top figure. The black solid line represents the solid track and the grey solid line represents the liquid track. The dotted grey lines show mixing curves connecting the equilibrium solid and liquid tracks at 1, 10 and 20 % crystallization. The grey dashed line shows a mixing curve for an early formed solid generated following 1 % fractional crystallization and an evolved liquid after 20 % fractional crystallization. The grey star is the initial liquid composition and the black star is the composition of the first solid to form.

References: [1] Scott. E.R (1977) *Geochim. Cosmochim. Acta* **33**, 859-876. [2] Kruijer T.S. et al. (2017) *PNAS* **114**, 6712–6716. [3] McCoy et al. (2011) *Geochim. Cosmochim. Acta* **75**, 6821-6843. [4] Horan et al. (2003) *Chem. Geol.* **196**, 27-42 [5] Walker et al. (2002) *Geochim. Cosmochim. Acta* **66**, 4187-4201.