

NEW INSIGHTS TO THE GENETICS, 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 ten. 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 $^{182}\text{W}/^{184}\text{W}$ ratios that overlap within uncertainty of the initial $^{182}\text{W}/^{184}\text{W}$ 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, 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.

Methods: 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 $^{187}\text{Os}/^{188}\text{Os}$ 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. For this study, Mo and W isotopic data were determined using thermal ionization mass spectrometry and Pt isotopic data were determined 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 sider-

ophile 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 exception to this is Nocoleche whose flat pattern is problematic to relate to other IC irons by crystal-liquid fractionation processes. This meteorite has been previously classified as “anomalous”, so our new results are consistent with this designation. Winburg has also been classified as an “anomalous” IC iron. For reasons discussed below, we conclude Nocoleche and Winburg are not group IC iron meteorites and the remaining IC samples are categorized into two sub-groups characterized by “high” and “low” Re, Os and Ir abundances.

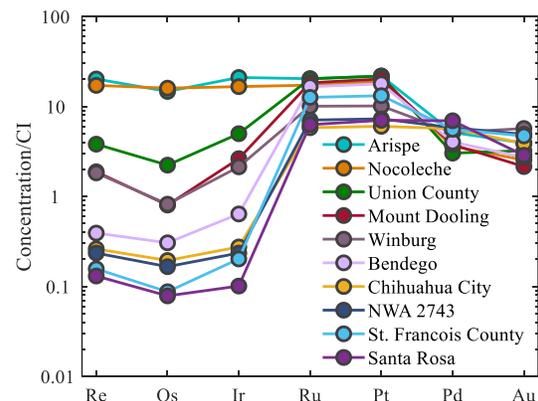


Figure 1. CI-normalized [from 4] highly siderophile element data for IC irons. Elements are arranged from left to right in order of decreasing 50% condensation temperature.

New $\mu^{182}\text{W}$ values for Arispe, Bendego, Chihuahua City and NWA 2743 were determined and corrected for cosmic ray exposure effects (CRE) using Pt isotopes as the neutron dosimeter. The four are characterized by an average preexposure value of -340 ± 8 , con-

sistent with the value of -345 ± 4 reported by [2]. The new ^{182}W isotopic data for the anomalous IC irons, Nocolche and Winburg, are characterized by resolutely higher preexposure $\mu^{182}\text{W}$ values of -246 ± 5 and -274 ± 5 , respectively.

Arispe, Bendego, Chihuahua City and NWA 2743 exhibit uniform CRE corrected $\mu^{94,95,97}\text{Mo}$ values and are in good agreement with the data reported by [2, 5, 6, 7]. The Mo isotopic data for Nocolche and Winburg are distinctly higher for $\mu^{94}\text{Mo}$ and $\mu^{95}\text{Mo}$ and lower for $\mu^{97}\text{Mo}$, again consistent with different genetics from the *bona fide* IC irons.

Discussion: The resolutely different $\mu^{94,95,97}\text{Mo}$ and $\mu^{182}\text{W}$ values for Nocolche and Winburg strongly suggest that they are not IC irons and should be henceforth considered ungrouped.

Unlike most other major magmatic iron groups, variations in the HSE abundances among the *bona fide* members of the IC group cannot be wholly accounted for by a simple fractional crystallization model. The HSE patterns for the IC irons instead suggest they may be comprised of two subgroups with high and low Re/Os and Ir abundances. The high abundance group consists of Arispe, Union County and Mount Dooling (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 19, 0.1 and <0.1 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 $\sim 7\%$ 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 $\sim 13\%$ 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, Bendego, Chihuahua City, NWA 2743, St. Francois

County and Santa Rosa would represent mixtures of liquids before $\sim 20\%$ crystallization and solids formed after 1% crystallization assuming approximately $>99\%$ of these meteorites would be composed of the evolved liquid. A collision with the IC parent body, followed by mixing could account for the two subgroups 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 approximately four times that of the enstatite chondrite average indicating the core was likely $\sim 25\%$ the mass of the IC parent body, assuming all HSE were extracted into the core. This is similar to other NC cores [3].

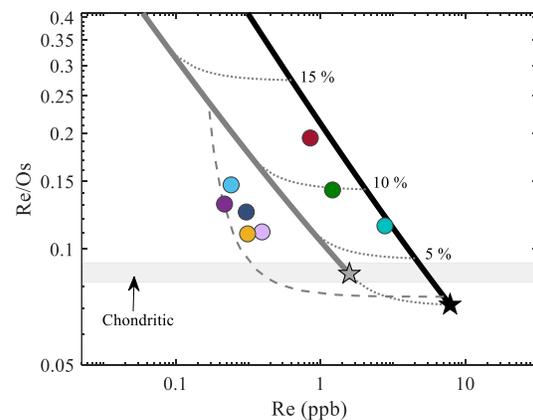


Figure 2. Fractional crystallization model of Re (ppb) versus Re/Os defined by 19 wt. % S, 0.1 wt. % P, and <0.1 wt. % C. The grey area is the range of chondrites [8]. The colored symbols are the same as Fig. 1. The black solid line represents the solid track and the grey solid line represents the liquid track. The dotted grey lines show mixing curves connecting the equilibrium solid and liquid tracks at 1, 5, 10 and 15 % crystallization. The grey dashed line shows a mixing curve for an early formed solid generated following 1 % fractional crystallization and an evolved liquid after $\sim 15\%$ 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] Burkhardt et al. (2011) *EPSL* **312**, 390-400. [6] Poole et al. (2017) *EPSL* **473**, 215-226. [7] Worsham et al. (2019) *EPSL* **521**, 103-112. [8] Walker et al. (2002) *Geochim. Cosmochim. Acta* **66**, 4187-4201.