CHEMICAL COMPOSITION AND FRACTIONAL CRYSTALLIZATION OF IIIF IRON METEORITES.

Bidong Zhang[1] (bdzhang@ucla.edu), Nancy L. Chabot[2], Alan E. Rubin[1], Munir Humayun[3], Joseph S. Boesenberg[4], John T. Wasson[1], Deon van Niekerk[5] [1]University of California, Los Angeles, CA 90095-1567, USA. [2]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA. [3]Florida State University, Tallahassee, FL 32310, USA. [4]Brown University, Providence, RI 02912, USA. [5]Rhodes University, Makhanda 6140, South Africa.

Introduction: The IIIF iron meteorites comprise a magmatic group currently with nine members (Binya, Cerro del Inca, Clark County, Fitzwater Pass, Klamath Falls, Moonbi, Nelson County, Oakley (iron), St. Genevieve County). Group IIIF was defined based on its narrow ranges of Ga and Ge concentrations [1]. The group has inter-element (elements vs. Ni) correlations similar to other magmatic groups [2], so it was assumed to have formed by fractional crystallization of a metallic core. Recently, metals of two ungrouped pallasites (Zinder and Northwest Africa 1911) were reported to have elemental concentrations similar to Group IIIF, indicating possible derivation from the IIIF parent body [3, 4]. However, no studies to date have modeled the crystallization of the IIIF core to investigate its genetic relationship to these two pallasites.

In this study, we report new elemental concentrations of IIIF irons from instrumental neutron activation analysis (INAA) and include laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) data [4] to undertake modeling to test if fractional crystallization can explain the inter-element trends of IIIF irons. Elemental data for Zinder and NWA 1911 are also included to further test their possible link to the mantle of the IIIF parent body.

Analytical Methods and Results: We analyzed 15 elements in eight IIIF irons (excluding Fitzwater Pass) by INAA at UCLA and include data for 23 elements in seven IIIF irons (excluding Binya) and two pallasites by LA-ICP-MS at FSU [3, 4]. The elemental data from the two analytical techniques are consistent in the CI-chondrite-normalized diagram (Fig. 1), except for a divergence of W in Cerro del Inca. The IIIF irons show possible subgroupings or pairings (distinguished by green, red and yellow legends and lines), best demonstrated by the As concentrations (Fig. 1). The high Ga and Ge abundances measured by LA-ICP-MS showed that Fitzwater Pass is more compatible with IAB than IIIF [4]. We, therefore, exclude Fitzwater Pass from further discussion. Because the two analytical methods yield consistent results, but the INAA samples were larger, the elemental concentrations from INAA are shown, with LA-ICP-MS measurements extending the interpretation to more elements.

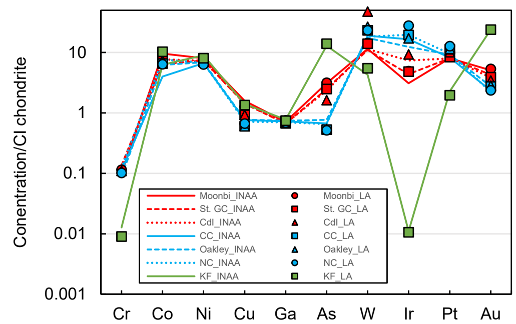

***Figure 1**. Comparison between INAA and LA-ICP-MS data. St. GC for St. Genevieve County, CdI for Cerro del Inca, CC for Clark County, NC for Nelson County, KF for Klamath Falls.*

Crystallization Modeling: The simple fractional crystallization modeling is based on previous methods [5], updated to use the latest experimentally determined partition coefficients [6]. Sulfur and P are the primary factors affecting the partition coefficients of siderophile elements. This study first compares the S-only model and the S + P model. For the S-only model, we tested various initial S contents (0 wt%, 2 wt%, 5 wt%, 10 wt%, 20 wt%) to find the best fit for the Co-, Ga-, Ir-, and Au-As plots (Fig. 2). Because the P model track is tightly constrained by P concentrations (measured by LA-ICP-MS), a trial-and-error method was used for the S + P model to find a S content that best fits all chosen elements. As a result, the S + P model with initial concentrations of ~2.0 wt% S and ~1.3 wt% P was selected as the best fit for the inter-element trends. Because IIIF irons contain P, the S + P model was chosen to best represent the crystallization of this group and was applied to 20 elements measured in this study.

Discussion and Conclusions: Overall, there are many aspects of the IIIF irons that are generally consistent with our chosen S + P fractional crystallization model, but the fits are far from perfect. One notable exception is Binya. The Co and Ga concentrations in Binya are significantly higher than the model tracks compared with those in other IIIF members (Fig. 2). We suggest that Binya may be an anomalous IIIF iron that has been affected by processes occurring after fractional crystallization, and we do not discuss it further.

The trends for some elements, in particular Ga, Co (Fig. 2), and Mo, do not fit the model well. The inconsistency of Ga concentrations between the model and analytical data is notable as the classification of

IIIFs is based on their similar Ga abundances. The Co variation in IIIF irons is wider than what the model predicts. With these Ga and Co anomalies, the question arises as to whether IIIF irons constitute a real group.

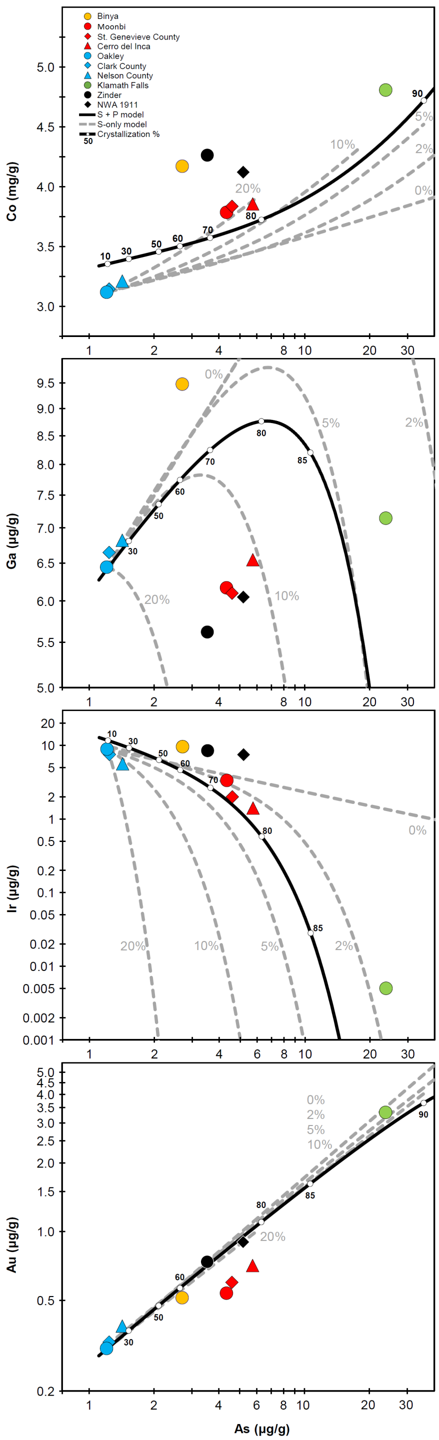

Figure 2. *S-only model (dashed lines; various initial wt% S) and S + P model (solid black lines; initial 2.0 wt% S and 1.3 wt% P) for Co-, Ga-, Ir-, and Au-As plots.*

However, the good correspondence between the modeling and the analyses of other elements indicates that IIIF irons are generally consistent with being formed by fractional crystallization, though additional processes may be needed to fully explain the Ga and Co trends.

Using the simple fractional-crystallization model, we can estimate the initial composition of the IIIF metallic core (Fig. 3). The bulk IIIF initial core composition has higher abundances of highly siderophile elements (HSE) than CI. The classification of IIIF irons as a carbonaceous-chondrite (CC) iron group [7] is consistent with HSE enrichments predicted for CC irons [8]. The IIIF group also displays a pattern consistent with some volatile depletion prior to core crystallization, although to a lesser extent than the IVB group [9].

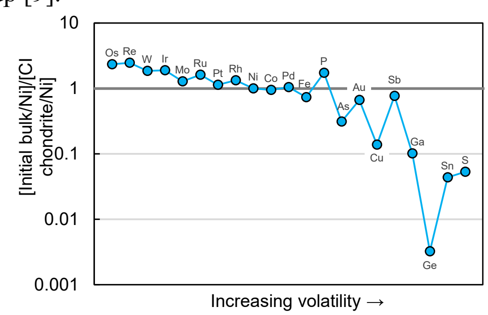

Figure 3. Initial elemental composition/Ni of the IIIF metallic core normalized to that of CI chondrites.

Elemental concentrations in the NWA 1911 and Zinder pallasites (Fig. 2) are close to those in Cerro del Inca, Moonbi, and St. Genevieve County. These two pallasites have similar petrographic characteristics and have been proposed previously to have been derived from the base of the mantle of the IIIF parent body [3]. The analyses of more elements and our fractional crystallization modeling show that most of the elements in these pallasites fit the simple fractional crystallization model as well as the IIIF irons. It is plausible that NWA 1911 and Zinder originated within the IIIF parent body. Yet, the pallasites do not appear at either end of the crystallization path, so their relationship with Group IIIF requires further consideration of the evolution of the parent body.

References: [1] Scott E.R. and Wasson J.T. (1976) *GCA*, 40, 103-115. [2] Kracher A. et al. (1980) *GCA*, 44, 773-787. [3] Boesenberg J. et al. (2017) *LPI*, abstract #2319. [4] Humayun M. et al. (2018) *LPI*, abstract #1461. [5] Chabot N.L. (2004) *GCA*, 68, 3607-3618. [6] Chabot N.L. et al. (2017), *Meteoritics & Planet. Sci.*, 52, 1133-1145. [7]. Kruijer T.S. et al. (2019) *Nat. Astron.*, 1-9. [8] Rubin A.E. (2018) *Meteoritics & Planet. Sci.*, 53, 2357-2371. [9] Campbell A.J. and Humayun M. (2005) *GCA,* 59, 4733-4744.