ORIGIN OF THE IVB IRONS IN A HIT-AND-RUN COLLISION. J. T. Williams[1] and M. Humayun[1], [1]Dept. of Earth, Ocean & Atmospheric Science, and National High Magnetic Field Laboratory, Florida State University, Tallahassee, FL 32310, USA (jtw11@my.fsu.edu).

Introduction: The IVB irons are the most refractory siderophile element enriched and volatile siderophile element depleted of any iron meteorites [1-3]. Asphaug et al. [4] proposed that some iron meteorite parent bodies may originate in hit-and-run collisions between protoplanets, where fragments of the core become separated as new, smaller, and more numerous bodies. On the basis of rapid cooling rates correlated with Ni contents, Yang et. al. [5] inferred that the IVB irons may be the product of a collisional event of two massive bodies. From this collisional event the IVBs represent the mantle-less ejected core. The S content involved in the IVBs crystallization has been reported as being very low: ~1-3 wt% [3, 6], consistent with the volatile element depletion. However, certain aspects of IVB composition are poorly understood, like the large Cu depletions, the W depletion, and how the refractory elements were so enriched in a protoplanet.

Here, we report new higher precision siderophile element abundances for a larger set of elements, and for 12 of the 14 known IVBs than [2]. We re-examine the origin of the IVBs in the light of hypothesis proposed [4-5] to demonstrate that IVBs really do require a hit-and-run collision for their origin. Further, new Cu isotope data on IVBs [7] require precise Ni/Cu ratios which we report here.

Analytical Methods: 2-5 mm pieces of 12 of the 14 known IVB irons were mounted and polished: Cape of Good Hope, Iquique, Kokomo, Tlacotepec, Dumont, Hoba, Santa Clara, Tinnie, Weaver Mountains, Tawallah Valley, Skookum, and Warburton Range. The samples were analyzed using a UP193FX excimer laser ablation system coupled to a Thermo Element XR™ at the Plasma Analytical Facility (NHMFL, FSU). To minimize Cu contamination, each sample was pre-ablated using a 150 µm spot, 1s dwell at 100 Hz. A 20s washout cycle was allowed prior to the main ablation of a 150µm spot, 10s dwell at 100hz. Five spots were taken on each sample and averaged. Peaks for ^{29}Si, ^{31}P, ^{34}S, ^{51}V, ^{53}Cr, ^{55}Mn ^{57}Fe, ^{59}Co, ^{60}Ni, ^{63}Cu, ^{66}Zn, ^{69}Ga, ^{74}Ge, ^{75}As, ^{77}Se, ^{95}Mo, ^{102}Ru, ^{103}Rh, ^{106}Pd, ^{107}Ag, ^{120}Sn, ^{121}Sb, ^{125}Te, ^{184}W, ^{185}Re, ^{192}Os, ^{193}Ir, ^{195}Pt, ^{197}Au, ^{208}Pb, and ^{209}Bi were acquired in low resolution mode with triple mode detector. Standards used were Hoba IVB iron (Fe, Co, Ni, Ru, Rh, Pd, Re, Os, Ir, Pt), North Chile (Filomena) IIA iron (Fe, Co, Cu, Ga, Ge, As, W, Au), NIST SRM 1263a steel (V, Cr, Mn, Fe, Co, Ni, Cu, Mo, Sn, Sb) and NIST SRM 610 glass (Si, P, S, V, Cr, Mn, Fe, Cu, Zn, Ga, Ge, As, Se, Mo, Ag, Sn, Sb, Te, W, Au, Pb, Bi).

Results: Each average analysis was precise to better than ±1% for refractory siderophile elements. New measurements of Ir and Os correlate in exactly the same ratio as isotope dilution measurements of the IVBs [3] (Fig. 3). Partly, this dataset uses Hoba [8] as the refractory siderophile element standard (in contrast to [2]), although a separate chip of Hoba was analyzed from the standard piece.

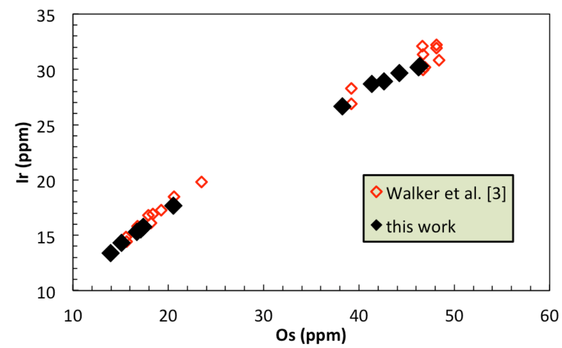

Fig. 1: Ir vs. Os for IVBs [this study] compared with isotope dilution abundances [8].

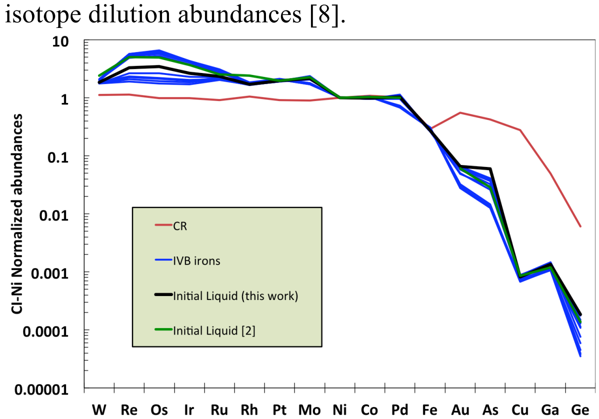

Fig. 2: CI/Ni normalized values for the 12 IVB irons, original liquid composition (this study, [2]) and protolith composition used (see text for discussion).

Many previous works have noticed a bi-modal distribution of Ni within the IVBs [1]. This data clearly shows a bi-modal distribution, especially in a Ni vs. Cu plot (Fig. 3). Cu has been a notoriously difficult element to measure due to surface contamination; using the pre-ablation technique we were able to produce a noticeably better precision than previous attempts [2,3]. The new data summarized in Table 1 shows that there is much less range in both the Cu and Ni values for each of the modes than previously obtained (Fig. 3).

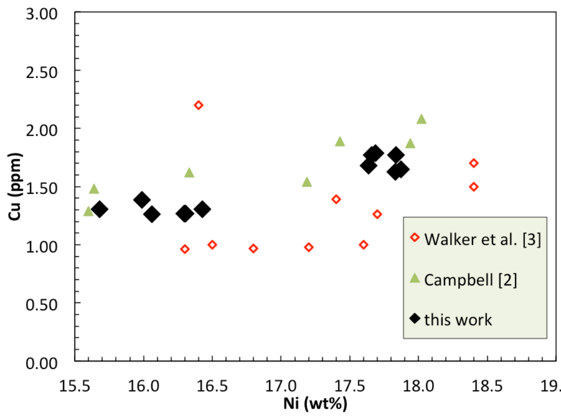

Fig. 3. Cu (ppm) vs. Ni (wt%) for IVB irons.

Table 1: Average (and standard deviations, in %) for the two IVB modes.

IVBs	Ni (wt%)	Cu (ppm)
High-Ni (average)	17.75 (±1%)	1.71 (±4%)
Low-Ni (average)	16.13 (±2%)	1.30 (±4%)

Discussion: Using the methods described by [2], D values for each element were calculated. In contrast to [2], D(Au) was fixed to 0.4. Initial liquid concentrations were then calculated from log-log plots of element vs. Au and are shown on Fig. 4. Compared to [2] (green), this data (black) yields plots lower for the refractory siderophile elements and slightly higher in some of the volatile siderophile elements, but both patterns exhibit a strong enhancement of the compatible siderophile elements. This is a direct consequence of the low sulfur content of the parental (original) liquid from which the IVBs formed by crystal fractionation, and cannot be modified by changing the choice of partition coefficients or sulfur content of the parental liquid. Incidentally, this parental liquid is not truly enriched in refractory elements, which should form a smooth pattern relative to chondritic abundances. Further, it strongly resembles the cumulate (solid) portion of a fractionating magmatic iron core.

Sulfur is known to have a great effect on the crystallization of Fe-Ni liquids [2, 8, 9]. A model for this effect of crystallization of a metallic liquid of CR chondritic composition –chosen as a protolith for its relative depletion in the volatile elements- was made using the method described by [8-9]. The goal of this model was to obtain a cumulate solid which shared a siderophile pattern similar to the IVB initial liquid shown in Figure 4. The D_0 used were the values described above. The model then calculated D values for each element at 1% increments of F_L with changing sulfur contents. Fig. 4 shows the model at 6 wt% S. Increasing the S content by 1% creates a noticeable change, and more than 7% S yields a pattern with too strong a compatible element enrichment.

The model creates a pattern that is very similar to the initial IVB liquid, especially for the compatible elements W-Fe. The volatile elements do not follow as closely. However, it does show the depletion in Cu relative to Ga and Ge. Using a protolith that is more volatile depleted would yield a closer volatile composition for the IVB irons. An indication of this can be seen by the little change in Ga and Ge throughout the fractional crystallization process. Therefore, Ga and Ge record their initial concentrations in the melt. A weakness of this model is the lack of enrichment of Mo. This model clearly shows that the IVB siderophile pattern can be formed as an early cumulate from an iron liquid with a significant amount of S and near CI initial concentrations of refractory siderophile elements. The progenitor of the IVB parent body did not have to be enriched in refractory elements contrary to previous proposals [2]. The S-rich progenitor liquid was stripped from the IVB parent body during a hit-and-run collision consistent with proposals by [4-5].

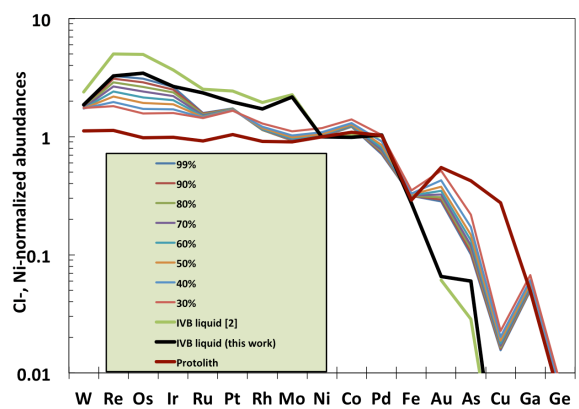

Fig. 4. Model cumulate solid metal with 6 wt% S; F_L (%) depicted together with IVB parental liquid compositions ([2], this study).

References:

[1] Rasmussen K. L. et al. (1984) *GCA 48*, 805-813. [2] Campbell A. J. and Humayun M. (2005) *GCA 69*, 4733-4744. [3] Walker R. J. et al. (2008) *GCA 72*, 2198-2216. [4] Asphaug E. et al. (2006) *Nature 439*, 155-160. [5] Yang J. et al. (2010) *GCA 74*, 4493-4506. [6] Goldstein J. I. et al. (2009) *Chemie der Erde 69*, 293-325. [7] Chen H. et al. (2013) *LPS XLIV*, this volume. [8] Chabot N. L. et al. (2009) *M&PS 44*, 505-519; [9] Chabot N. L. and Jones J. H. (2003) *M&PS 38*, 1425-1436.