OXYGEN ISOTOPES OF CHROMITE IN IVB IRON METEORITES: RELATIONSHIPS TO OTHER METEORITE GROUPS AND IMPLICATIONS FOR FORMATION. C. M. Corrigan[1], T. J. McCoy[1] K. Nagashima[2]. [1]Department of Mineral Sciences, Smithsonian Institution, National Museum of Natural History, 10th St. and Constitution Ave. NW, Washington, DC, USA. [2]HIGP, University of Hawaii, Honolulu, HI, USA. Email: corriganc@si.edu.

Introduction: In this study, we revisit the relationships between iron meteorites, particularly those for which oxidation produced high-Ni iron compositions, including the ungrouped Tishomingo [1]. Numerous geochemical features of Tishomingo suggest a history similar to that of the IVB irons [2], though likely on a separate parent body. These include siderophile element, particularly HSE, and P abundances [1,3].

When we last left the high-Ni (32.5 wt.%) iron Tishomingo [1], we noted that, in addition to IVB irons, it shares similarities with other meteorite groups. Its oxygen isotopic composition is similar to aubrites, enstatite chondrites, HEDs, IIIAB irons, and pallasites, although these groups differ in degree of oxidation or volatile depletion. Groups IAB and IVA irons are known to contain stishovite, as does Tishomingo, but differ in $\Delta^{17}O$ and volatile siderophile element depletion.

Tishomingo [1] and the IVB irons [4] likely formed from a volatile-depleted precursor followed by an oxidation event. Campbell and Humayun [4] suggested that the angrites may be a complimentary silicate to the IVB irons. We also discussed the possibility of meteorites in the CR/CB/CH meteorite clan as being related, based on siderophile element concentrations (despite the marked difference in Ni concentrations [5]) [1].

To test these possible genetic relationships, we have measured the oxygen isotopic composition of IVB irons. The IVB irons Santa Clara and Warburton Range were noted by [6] to have SiO_2 and chromite, respectively. Our examination of Santa Clara failed to reveal oxygen bearing phases, but we did two grains in the IVB iron Warburton Range (Figure 1). We also identified a mm-sized chromite grain in Hoba. As suggested by [1], oxygen isotope measurements of IVBs were necessary to compare with Tishomingo not only to establish parent body relationships, but also to help determine conditions of formation. Until very recently, standards for the analysis of oxygen isotopes in chromite have been unavailable. Caplan et al. [7] recently developed such standards to analyze chromites from fossil meteorites in sedimentary formations in Scandinavia. After almost a decade, the development of this standard has allowed us to obtain the first oxygen isotope measurements for IVB irons, and to discuss the relationships between Tishomingo, IVB irons, and other possibly related meteorite groups.

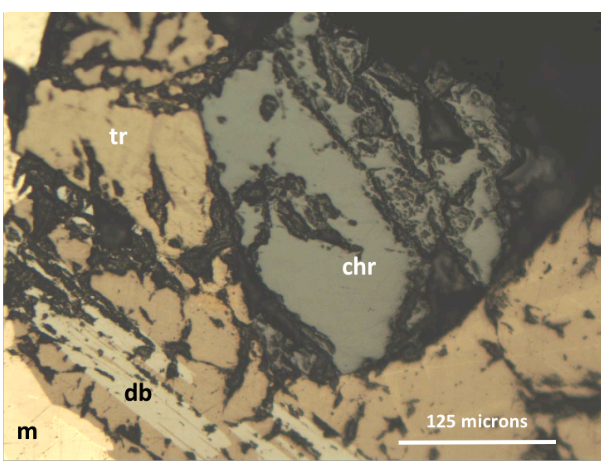

Figure 1. Chromite (chr) grain in Warburton Range in a matrix of troilite (tr), daubréelite (db) and metal (m).

Methods: Chromites were analyzed in the meteorites Hoba (section USNM 2618b from the Smithsonian Institution) and Warburton Range (section ASU 923.C.1 from Arizona State University). Oxygen isotopic compositions of chromite were measured with the ims-1280 SIMS at Hawai'i. We used ~3-5 nA Cs^+ primary beam and 3 Faraday cups for simultaneous detection of ^{16}O, ^{17}O, and ^{18}O. Standards used were chromite grains (Cr#~0.63, Fe#~0.58) from the Stillwater complex [7] developed for the Scandinavian fossil meteorites.

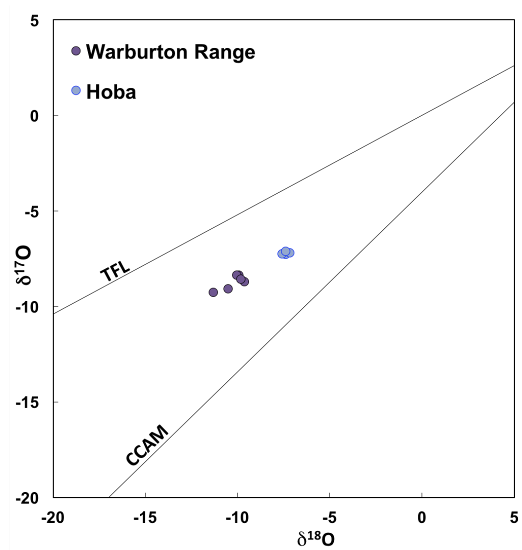

Figure 2. Oxygen isotope analyses of chromite grains in the IVB irons Hoba and Warburton Range.

Results: Multiple measurements were made on each chromite grain analyzed, with four analyses made in one large grain in Hoba and a total of six analyses in three grains in Warburton Range. These replicate analyses (Figure 2) yielded average values of $\delta^{17}O$ = -7.2 ‰ (2SD = ±0.1), $\delta^{18}O$ = -7.4 ‰ (2SD = ±0.3) and $\Delta^{17}O$ of -3.4 ‰ (2SD = ±0.2) for Hoba and $\delta^{17}O$ = -8.7 ‰ (2SD = ±0.8), $\delta^{18}O$ = -10.2 ‰ (2SD = ±1.2) and $\Delta^{17}O$ of -3.4 ‰ (2SD = ±0.4) for Warburton Range, where $\Delta^{17}O$ = $\delta^{17}O$ x 0.52($\delta^{18}O$). The spread in $\delta^{18}O$ as well as large offsets from CCAM line could be due to matrix effect.

Discussion: First, we point out that the oxygen isotope measurements of stishovite in Tishomingo ($\delta^{17}O$ = 3.06, $\delta^{18}O$ = 6.06, $\Delta^{17}O$ = -0.15 [1]) would preclude Tishomingo as being from the same parent asteroid as the IVB irons. However, the siderophile element abundances are similar [1], and it is likely that Tishomingo formed by similar mechanisms as the IVBs.

These new measurements of oxygen isotopes in IVB irons can help us rule out relationships between other meteorite types discussed in [1]. Examination of Figure 3, which shows the range of $\Delta^{17}O$ values for a number of groups of meteorites allows us to make these comparisons (y-axis is the number of meteorites per bin).

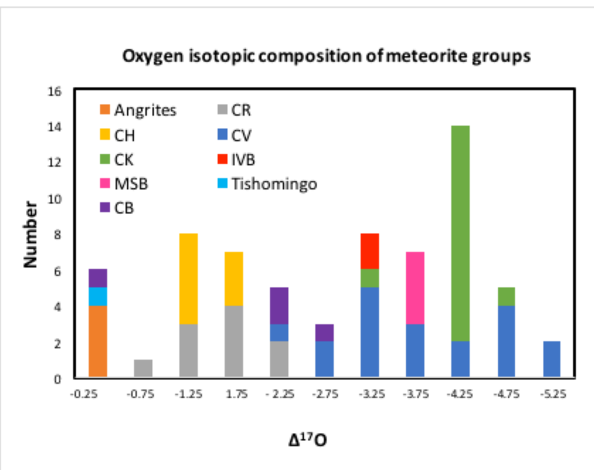

Figure 3. $\Delta^{17}O$ values in 0.5‰ bins with the central value shown of various meteoritic groups showing their relationship to IVB irons (red) and the Milton-South Byron trio (MSB, pink) and Tishomingo (turquoise). $\Delta^{17}O$ values are from this work as well as from [1, 8-11].

Despite suggestions of [1,4] of a possible relationship between IVB irons and angrites, the oxygen isotopic composition of IVB irons ($\Delta^{17}O$ ~ -3.4‰) precludes a common parent body with the angrites ($\Delta^{17}O$ = -0.10 to -0.23‰ [10]). We reiterate, however, that the oxygen isotopic similarity between Tishomingo and the angrites would allow a common parent body.

Other anomalous irons Bocaiuva ($\Delta^{17}O$ of -4.39‰), Deep Springs ($\Delta^{17}O$ of -3.1‰), and Mbosi (analysis from a chromite, $\Delta^{17}O$ of -3.07‰) are similar in oxygen isotopic composition [11]. Among these ungrouped irons, however, none are similar in bulk chemical composition to IVB irons.

The CR chondrites are inconsistent with the IVB oxygen isotopic composition, despite sharing similar high-Ni concentrations, with >1‰ difference between them, as are the CH and most CB chondrites [11].

Some of the more interesting results encountered from the analyses of chromites in the IVBs come from their comparison with the South Byron trio high-Ni irons and the Milton pallasite (see work submitted to this conference by McCoy et al. [8]). While providing a link between this pallasite-iron grouplet in oxygen isotopic composition, we noted that the $\Delta^{17}O$ of these meteorites ($\Delta^{17}O$ ~ -3.6 ± 0.6‰ (2SD)) was within error of both Hoba and Warburton Range (Figure 2). As discussed by McCoy et al. [8], these meteorites share similar degrees of parent body oxidation (despite the mineralogy of IVB irons, including daubréelite, indicating late-stage reducing conditions [6], Figure 1). They are also similar, though not identical, in refractory siderophile element abundances [7,12], although they differ dramatically in the abundance of volatile siderophiles. Further work will be necessary to examine the links between these meteorite groups, though they seem to represent similar degrees of oxidation but dramatic differences in volatilization.

When comparing IVB irons and Milton-South Byron grouplet with chondritic groups, CK and CV chondrites (most of the latter from the oxidized group, including Allende, Axtell, and Kaba, as well as Acfer 082 and 086 [10]) exhibit a broad range of $\Delta^{17}O$ that overlaps with both the IVB irons and Milton-South Byron subgroup. While this overlap could be fortuitous, CV and CK chondrites as well as these iron groups show a common feature of extensive oxidation. Metal in CV chondrites includes kamacite, taenite, and awaruite (Ni_3Fe) [13]. Although the relationship, if any, between these groups is uncertain, it is interesting to note that the model of [14] to explain magnetization in CV chondrites posits an extensively molten interior with an Fe,Ni core.

References: [1] Corrigan et al. (2005) *LPSC* #2062. [2] Rasmussen et al., (1984) *GCA* 48, 805. [3] Honesto et al. (2006) *LPSC* #1374. [4] Campbell and Humayun (2005) *GCA* 69, 4733. [5] Haack and McCoy (2003) *Treatise on Geochemistry*. [6] Teshima and Larimer (1983) *Meteoritics* 18, 406-407. [7] Caplan et al. (2015) *LPSC* #2794. [8] McCoy et al. (2017) *this volume.* [9] Clayton and Mayeda (1996) *GCA* 60, 1999. [10] Clayton and Mayeda (1999) *GCA* 63, 2089. [11] Weisberg et al. (2001) *MAPS* 36, 401. [12] Walker et al. (2008) *GCA* 72, 2198. [13] Brearley and Jones (1998) *Planetary Materials*. [14] Elkins-Tanton et al. (2011) *EPSL* 305, 1.