

**GENETICS, AGE, AND CRYSTALLIZATION SEQUENCE OF THE SOUTH BYRON TRIO AND THE POTENTIAL RELATION TO THE MILTON PALLASITE.** C.D. Hilton<sup>1</sup>, K.R. Bermingham<sup>1</sup>, R.D. Ash<sup>1</sup>, R.J. Walker<sup>1</sup>, and T.J. McCoy<sup>2</sup> <sup>1</sup>Department of Geology, University of Maryland, College Park, Maryland, 20742, USA ([chilton@umd.edu](mailto:chilton@umd.edu)) <sup>2</sup>Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, DC, 20560, USA

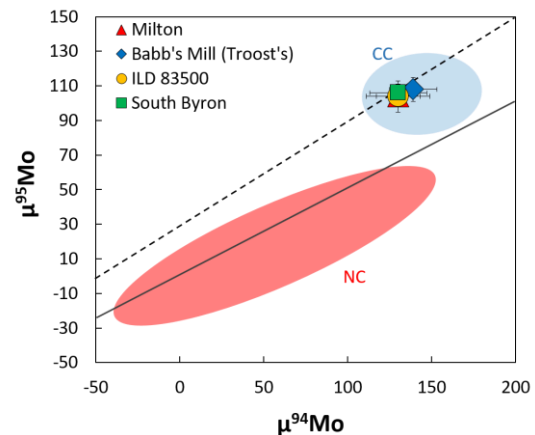
**Introduction:** Several studies have suggested that the ungrouped magmatic iron meteorites, Babb's Mill (Troost's Iron), Inland Forts 83500 (ILD 83500), and South Byron, represent metal from the same parent body [1-3]. Members of this iron meteorite grouplet, termed the South Byron Trio (SBT), are characterized by similar structures, chemical compositions, and oxygen isotopic compositions. These characteristics are also shared with the metal in the ungrouped pallasite, Milton [2-4]. The relationship between irons and pallasites remains uncertain, so if the SBT and Milton originated from the same parent body, these meteorites may provide insights into pallasite formation. In order to further test the potential genetic relationship between the SBT and Milton, we report Mo, Ru and W isotopic data. In addition, the abundances of siderophile elements in the SBT and Milton are discussed, as well as potential crystallization models, which investigate how they may be related.

**Methods:** Samples of the SBT and Milton were obtained from the Smithsonian Institution, Department of Mineral Sciences, National Museum of Natural History. Isotopic measurements of Mo, Ru, W, and Os were made at the University of Maryland (UMd) using a *Thermo-Fisher Triton* thermal ionization mass spectrometer (TIMS). Osmium was measured to monitor and correct for cosmic ray exposure (CRE) effects [5]. Siderophile element concentrations were obtained by laser-ablation using a *Thermo Finnigan Element 2* inductively coupled plasma mass spectrometer (LA-ICP-MS) at UMD. Highly siderophile element (HSE; Re, Os, Ir, Ru, Pt, Pd) data were also obtained by isotope dilution [5]. For this, Os concentrations and <sup>187</sup>Os/<sup>188</sup>Os ratios were determined using TIMS, and the other HSEs were measured using solution ICP-MS. Fractional crystallization models for HSE were explored using the parameterization method for determining HSE solid metal-liquid metal partition coefficients in the presence of variable concentrations of S, P, and C [6-9].

**Results:** The samples of Milton, Babb's Mill (Troost's), ILD 83500 and South Byron do not show resolvable effects of CRE in Os isotopic compositions. The SBT have Mo, Ru and W isotopic compositions that are identical within uncertainties, and the Mo isotopic composition of Milton matches the SBT within uncertainties.  $\mu^{182}\text{W}$  ( $\mu = 10^6 * [^{182}\text{R}_{\text{sample}}/^{182}\text{R}_{\text{standard}} - 1]$ ) values were corrected for nucleosynthetic variations using the correction method reported by [10]. The av-

erage  $\mu^{182}\text{W}$  and  $\mu^{183}\text{W}$  values for the SBT are  $-327 (\pm 7 \text{ 2SE})$ , which corresponds to a  $\Delta T_{\text{CAI}}$  age of  $1.9 \pm 0.7 \text{ Myr}$ , and  $+10 (\pm 5 \text{ 2SE})$ , respectively. The average Mo and Ru isotopic composition of the SBT are  $\mu^{94}\text{Mo} = +133 (\pm 6 \text{ 2SE})$ ,  $\mu^{95}\text{Mo} = +106 (\pm 2 \text{ 2SE})$ ,  $\mu^{97}\text{Mo} = +49 (\pm 3 \text{ 2SE})$ , and  $\mu^{100}\text{Ru} = -107 (\pm 5 \text{ 2SE})$ .

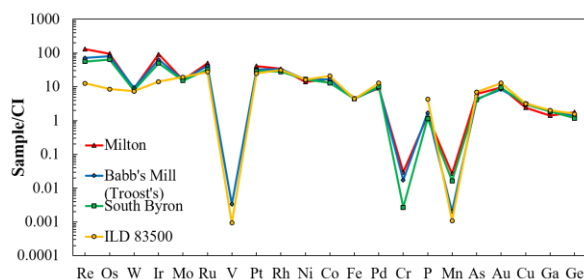
**Discussion:** The uniform Mo, Ru and W isotopic compositions of the SBT meteorites are consistent with them originating from the same parent body. Based on Mo, Ru, and W isotopic compositions defined by [11-13], the SBT should be grouped as carbonaceous (CC) iron meteorites (e.g., Mo; Fig. 1).



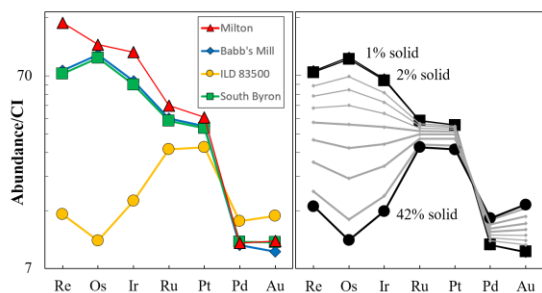
**Figure 1.**  $\mu^{94}\text{Mo}$  vs.  $\mu^{95}\text{Mo}$ . The red area represents the range of noncarbonaceous (NC) iron meteorite compositions and the blue area represents the range of carbonaceous (CC) iron meteorite compositions from [11]. The solid line represents theoretical mixing of pure *s*-process deficit and excess components, and the dashed line represents a linear regression through Murchison leachate data [11, 14].

The siderophile element concentrations of the SBT (Fig. 2-3) suggest that Babb's Mill (Troost's) crystallized from a primitive melt, followed soon afterward by South Byron. ILD 83500 crystallized later in the sequence from a more evolved melt. The HSE patterns of these meteorites can be reproduced by a fractional crystallization model, in which Babb's Mill (Troost's) represents the first 1 % of solid to crystallize. South Byron can be modeled as the solid composition after 2 % crystallization and ILD 83500 represents the solid composition at 42 % crystallization (Fig. 3). This model requires an initial melt composition of 7 wt. % S, 1 wt. % P, and 0.02 wt. % C.

The relative abundances of the HSE calculated for the initial melt by reversely modeling fractional crystallization are generally chondritic, e.g., with Re/Os and Pt/Os ratios of 0.082 and 1.7, respectively (Fig. 4). The modeled absolute concentrations of the HSE in the SBT parental core suggest that the core comprised about 10 % the mass of the body, assuming the upper range of HSE concentrations observed in chondrites as a starting parental melt composition [15]. This suggests that the SBT parent body was oxidized, which is also consistent with the high average nickel content for the SBT (17-18 wt. % Ni) and depletion in redox sensitive elements, like W, Mo, V, Fe, Cr, Mn, and P (Fig. 2). This conclusion is similar to those drawn for the IVA and IVB irons [16-17].



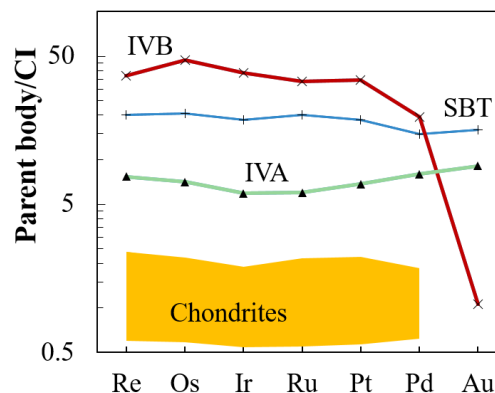
**Figure 2.** Siderophile element concentrations normalized to CI. Elements are listed in order of decreasing 50% condensation temperatures from left to right. The SBT and Milton metal have similar patterns, with depletions in redox sensitive elements. This suggests that the SBT and Milton formed on an oxidized parent body.



**Figure 3.** CI-normalized HSE content of Milton and the SBT (left) and HSE abundance results of a fractional crystallization model (right). Babb's Mill (Troost's), South Byron, and ILD 83500 match 1 %, 2 %, and 42 % metal crystallization in this model, respectively. Gray lines represent 5 % increments.

Milton has an identical Mo isotopic composition to the SBT (Fig. 1), within uncertainties, providing permissive evidence of being from the same parent body. This is consistent with having broadly similar siderophile element abundance patterns to the SBT (Fig. 2 and 3). The HSE content of Milton, however, cannot be related to the SBT through pure fractional

crystallization. Milton has a CI-normalized Pt/Os ratio characteristic of a primitive melt, however a Re/Os ratio characteristic of an evolved melt. If Milton and the SBT are related, the HSE content of Milton was likely set by multiple processes, perhaps including fractional crystallization, equilibrium crystallization and solid-liquid mixing.



**Figure 4.** Calculated HSE parental melt composition of the SBT, assuming 7 wt. % S, 1 wt. % P, and 0.02 wt. % C, normalized to CI. Also shown are calculated parental melt compositions for the IVA irons [16], IVB irons [17], and a range of HSE concentrations observed in chondrites [15], for reference.

**Conclusion:** Molybdenum, Ru, and W isotopic data are consistent with the SBT representing a single CC group parent body. The HSE content of the SBT can also be related through fractional crystallization of a chondritic parental melt. Milton has a similar Mo isotopic composition to the SBT, consistent with it being from the same parent body. The HSE content of Milton, however, cannot be related to the SBT through pure fractional crystallization, which suggests that Milton requires a more complex formation mechanism.

**References:** [1] Wasson et al. (1989) *Geochim. Cosmochim. Acta* **53**, 735-744. [2] Reynolds et al. (2006) *MCM LXIX*, Abstract #5233. [3] McCoy et al. (2017) *LPS XLVIII*, Abstract #2241. [4] Jones et al. (2003) *LPS XXXIV*, Abstract #1683. [5] Walker (2012) *EPSL* **351-352**, 36-44. [6] Worsham et al. (2016) *Geochim. Cosmochim. Acta* **188**, 261-283. [7] Jones and Malvin (1990) *Metall. Mater. Trans. B* **21B**, 697-706. [8] Chabot and Jones (2003) *Meteorit. Planet. Sci.* **38**, 1425-1436. [9] Chabot et al. (2014) *LPS XLV*, Abstract #1165. [10] Kruijer et al. (2014) *EPSL* **403**, 317-327. [11] Worsham et al. (2017) *EPSL* **467**, 157-166. [12] Birmingham et al. *EPSL (In revision)* [13] Kruijer et al. (2017) *PNAS* **114**, 6712-6716. [14] Burkhardt et al. (2012) *EPSL* **357**, 298-307. [15] Horan et al. (2003) *Chem. Geol.* **196**, 5-20. [16] McCoy et al. (2011) *Geochim. Cosmochim. Acta* **75**, 6821-6843. [17] Walker et al. (2008) *Geochim. Cosmochim. Acta* **72**, 2198-2216.