HASSI el BIOD 002: A PYROXENE PALLASITE FROM THE MANTLE OF THE IIAB IRON PARENT BODY. J. S. Boesenberg[1], M. Humayun[2] and D. E. Ibarra[1], [1]Dept of Earth, Environmental and Planetary Sciences, Brown University, 324 Brook Street, Providence, RI 02920 (joseph_boesenberg@brown.edu). [2]National High Magnetic Field Laboratory, Florida State University, Tallahassee, FL 32310.

Introduction: Hassi el Biod 002 is a recently classified Algerian pallasite that was first reported on at the 2022 Meteoritical Society meeting [1]. It was thought to be similar to Main Group pallasites and the ungrouped pallasite, Milton, by having only olivine and no pyroxene, but containing more Mg-rich olivine. Recently, the authors of this abstract saw a photograph of the etched surface of Hassi el Biod 002 (HeB 002), and noted that this pallasite did not contain "swathing kamacite" surrounding the olivine grains, a very common feature in most pallasites, which piqued their interest in doing further analysis. Upon petrographic examination using the electron microprobe, it was determined that this pallasite contains about 1% pyroxene, and in fact, contains both orthopyroxene and diopside in roughly equal proportions, and thus is a new pyroxene pallasite. Further analysis of the trace element composition of the metal has revealed that it is nearly identical to that found in the IIAB iron meteorite, Negrillos. Hassi el Biod 002 is the first silicate-bearing metal sample found to be related to the IIAB irons. Discovery of silicate phases within metal of IIAB composition enables placing the IIABs within the context of other meteorite classes with oxygen isotopes, etc. This is similar to the relationship found between pyroxene pallasites, Zinder and NWA 1911, and the IIIF iron meteorite members, Moonbi, St. Genevieve County, and Cerro del Inca [2].

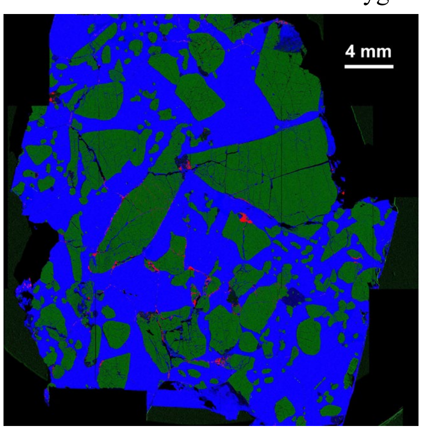

Figure 1. Ca-Mg-Fe (RGB) map of Hassi el Biod 002 showing pyroxene-rich regions in bright red.

Analysis: Microprobe analysis and sample characterization of Hassi el Biod 002 was performed at Brown University, and trace elemental data for the metal was gathered by laser ablation ICP-MS at Florida State University. Though oxygen isotopic analysis has been previously determined for this meteorite [1], there are plans to obtain confirmation analyses at the new Brown University oxygen isotope laser fluorination laboratory.

Table 1. All data in ppm.

	HeB002	Negrillos
Fe	939000	941000
Co	4470	4520
Ni	53000	52800
Cu	90	135
Ga	57.2	59.1
Ge	165	178
As	3.52	3.38
Mo	7.5	
Ru	24.7	30.6
Rh	2.29	2.68
Pd	1.39	1.8
Sn	0.29	0.14
W	4.43	3.90
Re	5.34	5.76
Os	80.5	74.8
Ir	54.2	56.42
Pt	36.3	45.6
Au	0.49	0.48

Results: Hassi el Biod 002 petrology (Fig. 1) contains fairly typical pallasite features. Some olivine grains are fragmented, some sub-angular, and most smaller olivine grains are sub-rounded to rounded. Most olivine compositions are Mg-rich ($Fa_{7.1\text{-}9.2}$, Fe/Mn = 20-28, 0.01-0.1 wt% Cr_2O_3) and are equilibrated. There are however, a few small olivine grains poikilitically enclosed by chromite which were found to have more Mg- and Cr-rich compositions ($Fa_{5.7\text{-}8.2}$, Fe/Mn = 19-26, 0.13-0.9 wt% Cr_2O_3) than the primary group. Hassi el Biod 002 contains two types of pyroxene. Both orthopyroxene ($Wo_{0.5}En_{90.5}$ to $Wo_{2.3}En_{90.4}$, Fe/Mn = 12-16, 0.12-0.4 wt% Cr_2O_3) and chrome diopside ($Wo_{46.4}En_{50.7}$ to $Wo_{44.0}En_{51.6}$, Fe/Mn = 8-13, 0.8-2.05 wt% Cr_2O_3) occur in complex troilite-orthopyroxene-diopside, coarse symplectite assemblages, which occur in many pyroxene pallasites. These are presumed to form on cooling by subsolidus reaction between metal and olivine [3]. Chromite [(Al/(Al+Cr)*100 = 1.6-3.7, Fe/(Fe+Mg)*100 = 55.1-62.5] in HeB 002 is noteworthy as the Al concentrations are among the lowest reported in all pallasites, while the Mg concentrations are among the highest, making it a near endmember of chromite among pallasites. Schreibersite (0.13-0.2 wt% Co) typically forms between kamacite and troilite (0.14-0.22 wt% Cr, 0.06-0.13 wt% Co). Kamacite is the only metal phase present, and is quite low in Ni (~5.3 wt%). No phosphates were found.

Laser ICP-MS trace element analysis results of the kamacite are presented in Table 1. Moderately volatile elements (Ga, Ge, Au and As) and Ni-Co abundances distinctive of iron meteorite groups unambiguously link the HeB 002 metal to IIAB irons. In the plot of Ga vs. Au (Fig. 2) HeB 002 can be seen to plot at the low-Au end of the IIABs. The metal in HeB 002 is typical of that seen in the primitive members of the IIAB irons and matches that of the IIAB member, Negrillos, extraordinarily well [4]. In the Ir vs. Au plot (Fig. 3), HeB 002 plots among the most Ir-rich members.

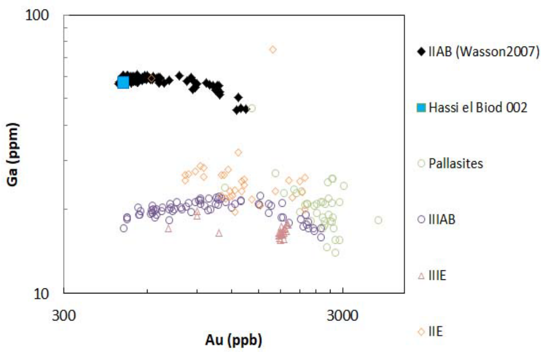

Figure 2. Ga vs Au plot showing Hassi el Biod 002 having metal consistent with the IIAB irons. IIAB iron data from [4].

Discussion: Hassi el Biod 002 contains the first known silicate sample of the IIAB iron parent body. It contains both Mg-rich (reduced?) silicate compositions and primitive metal. The IIABs are a large group of magmatic irons consisting of over 120 separate meteorites with perhaps the Russian fall, Sikhote-Alin, being the most famous member. Structurally, the IIAB iron meteorites are hexahedrites or coarsest octahedrites, and are among the most nickel-poor iron meteorites known. Most contain Neumann lines (schreibersite), and do not contain a Widmanstätten pattern, as the Ni content of the metal (~ 5 %) is within the kamacite stability phase field at all temperatures. IIAB irons are also related to the IIG irons. Chemically, the IIGs are products of liquid immiscibility from the IIABs in the phosphorus-sulfur system [5].

Given the trace element metal composition of HeB 002 and the extensive number of IIAB members with more fractionated metal, the metal in HeB 002 is consistent with being an early crystallized product from a high-sulfur melt. If we assume HeB 002 is likely a mantle sample, and place it within a concentrically crystallizing mantle-core, this would imply that the IIAB parent body core crystallized downward or inward, leaving the silicates in or near the mantle. If the IIG irons are also considered as taking part in the crystallization process, then perhaps a dendritically crystallizing core is more likely for this parent body. Much like Main Group pallasites, crystallization models for the core and mantle can be complex when silicates are involved, particularly if additional IIAB silicate-bearing samples, such as HeB 002, are discovered. Certainly, other models may be possible.

The chemical link between HeB 002 metal and the IIAB irons provides insight into the petrologic characteristics of this parent body. HeB 002 contains both opx and diopside, which would suggest that the meteorite derives from a parent body with a lower degree of partial melting than MG pallasites [6]. Meanwhile, the chromite is more magnesian, and has a lower Al content than chromites from Main Group pallasites.

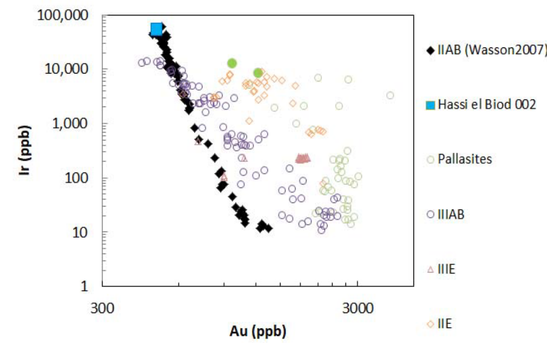

Figure 3. Ir vs Au plot showing Hassi el Biod 002 contains high Ir, consistent with having early crystallized metal. IIAB iron data from [4].

The oxygen isotopic composition of the silicate in HeB 002 was noted by [1] to be among the lodranite-acapulcoites. Several pyroxene pallasites plot in this region of the oxygen isotopic diagram (Choteau, Vermillion, and Yamato-8451). The relationship between HeB 002 and lodranites and acapulcoites, however, seems unlikely given this new metal data. Its placement in this part of the oxygen isotope diagram however is perhaps more indicative of the non-carbonaceous (NC) and carbonaceous (CC) isotopic reservoir relationships between the pallasite and irons. The location of HeB 002 in oxygen isotopic space would reflect a non-carbonaceous isotopic reservoir consistent with the IIAB and IIG members that have been measured and are part of the NC group [7]. Perhaps future Mo or Cr isotopic analyses on HeB 002 will bear this out.

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References: [1] C. B. Agee et al. (2022) *Meteoritics & Planet. Sci.* 57, S1, Abstract #6428. [2] B. Zhang et al. (2022) *GCA* 323, 202-219. [3] A. M. Davis and E. J. Olsen (1991) *Nature* 353, 637-640. [4] J. T. Wasson et al. (2007) *GCA* 71, 760-781. [5] J. T. Wasson and W-H. Choe (2009) *GCA* 73, 4879-4890. [6] J. M. Sunshine et al. (2007) *Meteoritics & Planet. Sci.,* 42, 155-170. [7] A. E. Rubin (2018) *Meteoritics & Planet. Sci.* 53, 2357-2371.