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ENON AND PUENTE DEL ZACATE: A DUO OF PRIMITIVE-SILICATE-BEARING MAGMATIC IRONS. R. G. Mayne, T. J. McCoy[2], R. C. Greenwood[3], I. A. Franchi[3] and C. M. Corrigan[2] [1]Monnig Meteorite Collection and Gallery, School of Geology, Energy, and the Environment, Texas Christian University, TCU Box 298830, Fort Worth, TX 76109. (r.g.mayne@tcu.edu) [2]Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution 10th & Constitution NW, Washington, DC 20560-0119 [3]Planetary and Space Sciences, The Open University, Milton Keynes, MK7 6AA, United Kingdom.

Introduction: In a previous LPSC abstract [1], we presented new electron microprobe and oxygen isotopic analyses for Enon, which is currently classified as an ungrouped iron. We highlighted how its apparent affinities to multiple meteorite groups made its classification complex but concluded that its achondrite-like texture and the primitive-composition of its silicates were perhaps indicators that it was best described as a primitive achondrite. Here we reevaluate those analyses and those of previous authors and suggest that Enon is actually a IIIAB silicate-bearing iron, which would make it the second IIIAB that contains primitive silicate material [2].

Puente del Zacate: Puente del Zacate was classified as a member of the IIIAB iron meteorite group-based upon the composition of its metal [3]. The identification of a primitive silicate inclusion by [2] came as quite a surprise. They noted that the chondritic nature of the silicate minerals contrasted with the formation models for the magmatic (differentiated) IIIABs. However, their analyses of the whole-rock oxygen isotope composition of the silicate clast were consistent with other oxygen-bearing phases within IIIAB irons [2], supporting its initial classification. They admitted that it was hard to explain the formation of such primitive material embedded within a magmatic iron matrix.

Enon and the IIIABs: The suggestion that Enon is related to the IIIAB irons is not a new one, it was first put forward by [4], who recognized that his measured Ga/Ni and Ge/Ni ratios were similar to the IIIAB irons. [5] also noted that, if you compared the Ni-content in Enon's metal component with other meteorites, several of the rare earth elements (Ga, Ge, As, Au) were equivalent to that of a IIIAB iron. However, this idea was not seriously entertained because of the chondritic silicates it contains.

Enon is approximately equal parts silicate, sulfide, and metal. When examining textural relationships within Enon, combined with the high abundance of sulfide, it is reasonable to suggest that this small meteorite (763g total known weight) is sampling part of a larger sulfide nodule. These nodules are not uncommon in IIIAB irons, e.g. Cape York, and are suggested to form as droplets that segregated from the parent melt during metal crystallization. It is pertinent to note here that both the silicate clasts (PdZ, Enon) and the

SiO_2 grain (Cape York) identified in the IIIABs have a relationship with the sulfide nodules present in each sample [6]. However, the primitive-silicate clasts in Puente del Zacate and Enon are markedly different from the one pure silica grain found in Cape York [6].

The oxygen isotopes composition of chromites from 5 IIIAB meteorites were measured by [7] using high precision laser fluorination. They found that 4 of the 5 IIIABs have a mean linearized $\Delta^{17}O$ values of -0.18‰ with a 2 scatter of ±0.02‰ (2σ). Oxygen isotope analysis of a silicate fraction from Enon, also undertaken at the Open University, using the same procedures as [7], gave the following results: $\delta^{17}O = 1.60$‰; $\delta^{18}O = 3.41$‰; $\Delta^{17}O = -0.19$‰ (linearized). The $\Delta^{17}O$ value for Enon is within error of the mean IIIAB chromite value obtained by [7] and so lends weight to the suggestion that it is a IIIAB iron (Figure 1).
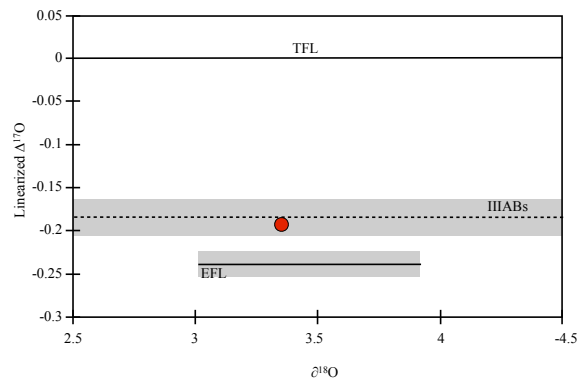

Figure 1: Oxygen isotope analysis of Enon compared to the IIIABs and the Eucrite Fractionation Line (EFL) [7]. The datum from this study is given in a bold red circle. The standard deviation for both IIIABs and the EFL is given by the limits of the grey box around each line. Recently collected data for the IIIABs is scarce, so the line defined by the initial studies of [7] has been extended to Enon's $\partial^{18}O$ space.

Iron Compositions: The IIIAB iron meteorite group, are considered to be the product of fractional crystallization of a large single body, although this model is acknowledged to be too simplified to explain all the geochemical trends observed [8 and references therein]. Based on previous analyses of the host metal, both Enon and Puente del Zacate appear to occupy the same part of the crystallization trend defined by the IIIAB iron group as a whole (Table 1). This indicates that

they formed at about the same time in the fractional crystallization history of the IIIAB core.

Table 1: Host Metal Composition

	Ni %	Ga ppm	Ge ppm	Ir ppm
Enon [4]	8.1	17.1	34.9	2.35
PdZ [3]	8.2	20.6	40.5	1.4

Origins: If both Enon and Puente del Zacate are IIIAB irons, it strongly suggests that primitive material was able to remain on the parent body even after core separation. There are several models that can be explored to explain their formation:

Metamorphosed chondrites: The silicates present in both silicate clasts (PdZ and Enon) are homogeneous and pyroxene geothermometry using QUILF yields closure temperatures either at the Fe, Ni-FeS eutectic (879-975°C Enon) or below it (852°C PdZ using data from [2]). If they were not embedded in IIIAB material, these clasts would likely would be classified as highly metamorphosed (type 6) chondritic material. The question then becomes how can you preserve fragments of primitive silicate material within a differentiating body?

Partial melt residues: One of the simplest ways to explain clasts of a primitive composition inside a magmatic (differentiated) iron meteorite is to say that they represent the residues of partial melting on the parent body. This would mean that both Enon and Puente del Zacate straddle the boundary directly between achondrites and primitive achondrites. However, their mineralogies and mineral chemistries do not support such a model for their formation. Residues should be depleted in the melts removed from them, yet both Enon and Puente del Zacate contain abundant plagioclase, suggesting that no silicate melt removal has occurred. Furthermore, pyroxene geothermometry of both samples indicate that the temperatures required for silicate melting were not met; you cannot have a residue without the formation of a partial melt. Therefore, these samples could not have formed by this method.

IAB models: It would be remiss to not consider existing models for other silicate-bearing iron groups as comparative models for the origin of the silicate-bearing IIIAB irons. The IABs meteorites are the most abundant silicate-bearing irons and they contain silicates that are chondritic in composition but with recrystallized textures, similar to the IIIABs studied here. The most recent model for their formation involves partial melting followed by collisional fragmentation, mixing upon reassembly, and additional fractional crystallization of remaining molten metal bodies [9]. It

has been suggested, as an explanation for the wide range in metallographic cooling rates, that the IIIAB parent body was also affected by an impact, which least partially exposed the core during some of its cooling history [10]. However, the host metal within the IAB iron follows a very different petrogenetic path than that seen within the IIIABs and, as a result, shows none of the fractionation trends that define the latter group. Therefore, a IAB-like model cannot adequately explain the metal compositions seen in PdZ or Enon and, therefore, how primitive material was preserved within it.

Intact primitive crust: A number of studies have suggested that a intact primitive crust could remain on the surface of an otherwise differentiated body. These models vary widely, from those that predict a thin veneer of primitive material [11], to those that advocate a single differentiated parent body with a thick crust containing chondritic material which is increasingly metamorphosed with depth [12]. If we take the general idea behind these studies – a remnant primitive crust - and combine it with the evidence for a core-exposing impact on the IIIAB parent body, it would appear possible to recombine some fragments of the primitive crust in the newly-exposed core.

Implications: We believe that Enon and Puente del Zacate are both silicate-bearing IIIAB irons. If correct, then the primitive silicates they contain are preserving the material from which the IIIAB body differentiated. This is important as we currently have no definitive crust or mantle samples that can be directly linked to the IIIAB parent body, but it has been suggested that similarities between the IIIABs and HEDs could argue for a common origin [13], and we can use the composition of these primitive clasts to directly test such theories.

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