AN ANALYSIS OF ANOMALOUS METEORITE ENON: CLASSIFICATION AND THERMAL HISTORY

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Introduction:

Enon was discovered in 1883 in Springfield, Ohio, and it is currently classified as an anomalous stony-iron meteorite. The purpose of this study is to understand Enon's formation history and to determine if the meteorite can be genetically linked to any other known meteorite group.

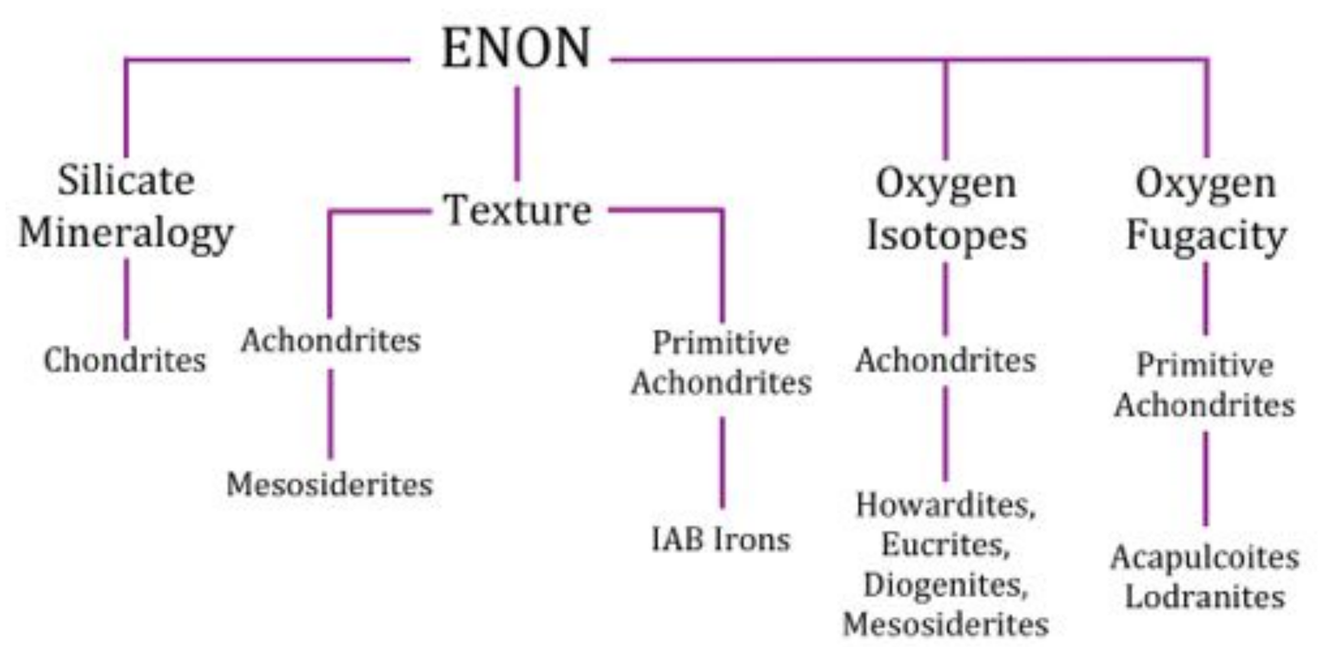

Figure 1: A flow-chart outlining Enon's similarities in mineralogy, texture, and oxygen isotope composition with other meteorites identified by past research. The results of this study also indicate similarities in oxygen fugacity values.

Classifying Enon is particularly difficult because texturally Enon appears to have an affinity with the mesosiderites and IAB irons [2,4]. However, Enon's silicate mineralogy varies dramatically from what is expected for mesosiderites and has mineral compositions similar to ordinary chondrites and IAB iron meteorites [1,2,4,5,6,7]. Furthermore, despite the differences in mineral chemistry, research has shown that Enon's oxygen isotope composition is similar to that of mesosiderites and the HEDs [1,3] For the above reasons, the data obtained for Enon in this study will be compared to ordinary chondrites, mesosiderites, and IAB iron meteorites to determine if Enon could be related to any of these meteorite groups.

Methodology:

A one-inch round thick-section of Enon was provided by the Smithsonian Institution's NMNH. Back-scattered electron (BSE) and x-ray images were obtained using the FEI NovaSEM 600 scanning electron microscope in the Mineral Sciences department at NMNH (Figure 2). Mineral chemistry was measured using the Cameca SX-50 electron microprobe analyzer at the University of Oklahoma.

Dr. Greenwood at the Open University performed oxygen isotope analyses for Enon. Fifty milligrams of olivine from Enon was powdered for analysis, and infrared laser-assisted fluorination was used to collect the oxygen isotope measurements from the powder [8].

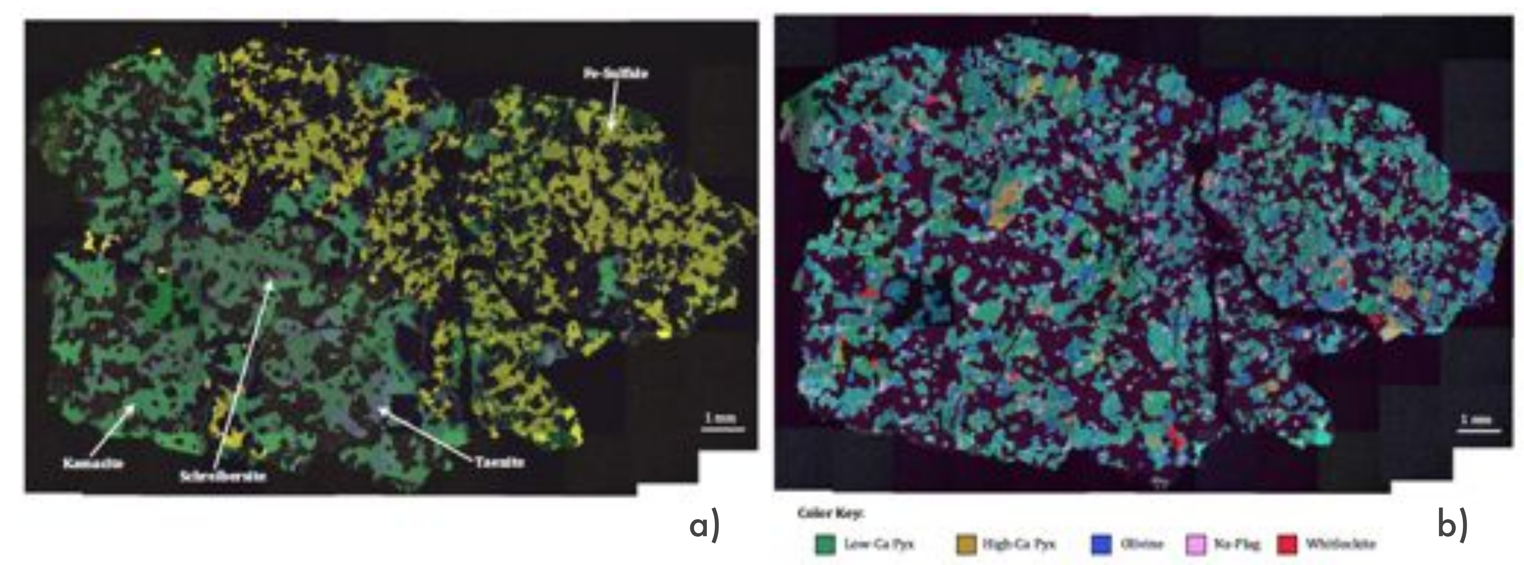

Figure 2: SEM maps showing phases present in the thick-section of Enon a) metallic phases b) silicate phases.

Enon's two-pyroxene closure temperature was calculated using QUILF [9], using a pressure of 1 bar [10,11]. These temperatures were used in the oxygen fugacity calculations. Examples of the methodology used in these calculations can be found in [10,11].

Thermal History:

Enon appears to record the earliest stage of igneous differentiation of its parent body.

The average two-pyroxene closure temperatures are similar to that of the Fe, Ni-FeS eutectic temperature, which lies at ~950^{0}C [15]. It has been proposed that melting at the eutectic may form veins due to overpressure [16] and Enon does contains micrometer-size Fe-Ni/FeS veins, which can be found both around and cross-cutting silicate grains (Figure 4). The Fe-Ni/FeS veins cross-cutting the silicate inclusions suggest that the silicates were solid during the migration of the Fe-Ni/FeS melt. This indicates that the temperature never reached the silicate melting point, which is supported by Enon's two-pyroxene closure temperatures. However, the homogeneity of the silicate compositions in Enon does

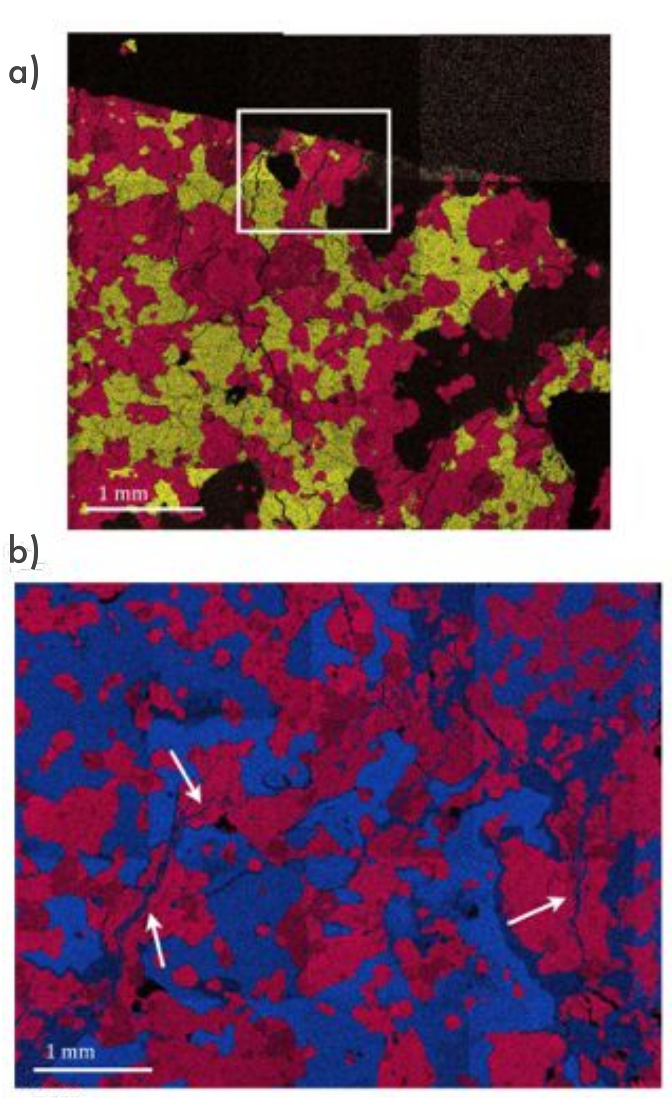

Figure 4: Images showing FeS and Fe-Ni veins cross-cutting silicate grains. The silicate minerals are shown in red, the FeS in yellow, and the Fe-Ni in blue. The square in (a) shows the area where an FeS vein (yellow) can be seen cross-cutting a silicate grain (red). The arrows in (b) point to examples of Fe-Ni (blue) veins cross-cutting silicate grains (red).

Results:

The sample of Enon used in this study contains nearly equal parts silicate, Fe-Ni metal, and troilite (Figure 2). Measured silicate compositions are homogenous throughout the sample, with averages as follows: plagioclase $Ab_{79}An_{15}Or_6$, high-Ca pyroxene $Wo_{44}En_{52}Fs_4$, low-Ca pyroxene $Wo_2En_{88}Fs_{10}$, olivine $Fo_{93}Fa_7$. The kamacite has an average Fe content of 92.1 wt% Fe and 7.2 wt% Ni. Taenite grains within the sample have a higher-Ni rim with a Ni content ranging from 25.0-32.9 wt% and Fe from 67.0-74.9%. In comparison, the lower-Ni taenite cores have a Ni content of 17.0-25.1% and Fe of 73.8-83.1%.

The oxygen isotope measurements yielded a $\delta^{17}O$% value of 1.56 and a $\delta^{18}O$% value of 3.41 (Figure 3). This differs slightly from the $\delta^{17}O$%composition of 1.66 and significantly from the $\delta^{18}O$% composition of 3.88 listed for Enon in older research [3,12,13] It is likely that this composition has changed because in the last decade there have been significant advances in oxygen isotope analyses.

Pyroxene closure temperatures ranged from 879-975 ^{0}C, and the fO_2 calculated using the QIFs system and the two-pyroxene temperature is IW-2 (Table 1).

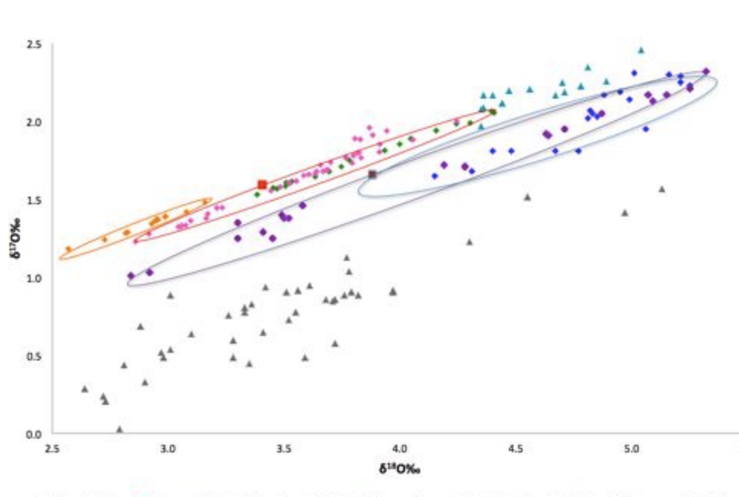

Figure 3: Graph comparing the oxygen isotope compositions for Enon, achondrites, and primitive achondrites

Table 1: Enon's oxygen fugacity as calculated from the Quartz-Iron-Ferrosilite system and two- pyroxene closure temperatures and its relationship to the iron-wustite (IW) buffer.

Two-pyroxene pairs	Two-pyroxene temperature (°C)	QIFs[a] log fO_2	ΔIW^b
Pair 1	879	-19.35	-2.20
Pair 2	947	-17.85	-2.01
Pair 3	947	-17.86	-2.02
Pair 4	975	-17.31	-1.98
Pair 5	989	-17.06	-1.97
Pair 6	975	-17.31	-1.98
Pair 7	871	-19.45	-2.13
Pair 8	975	-17.31	-1.98
Average	**958**	**-17.64**	**-2.01**

Comparing Enon to other meteorite groups:

Enon has a brecciated texture which is achondritic and similar to what is described for mesosiderites and IAB irons [2,4]. The sample of Enon analyzed in this study has nearly equal parts Fe-Ni metal, FeS, and silicates (Fig. 7). The silicate inclusions are encapsulated in an Fe-Ni/FeS matrix. However, Enon's silicate compositions are chondritic, showing similarities to both ordinary chondrites and IAB irons. The oxygen isotope composition measured in this study deviates from previous analyses [3,12,13], but still lies on the edge of the field defined by the HEDs and mesosiderites.

Most interestingly perhaps, is the new oxygen fugacity data collected by this study, a calculation that has not yet been performed for Enon. This value of IW-2 is similar to that of the acapulcoite and lodranite clan. Samples from both acapulcoites and lodranites contain micrometer-size metal/sulfide veins, and centimeter-size veins has been documented in the acapulcoite Monument Draw [14]. Acapulocoites and lodranites have mineral assemblages similar to that of ordinary chondrites although their chemistries and oxygen fugacity compositions differ. This adds yet another group that Enon is similar to, but not a member of, as it does not share a similar oxygen isotope composition to the acapulcoite-lodranite clan.

This study would suggest that Enon be classified as an anomalous primitive achondrite, not a stony iron as previously suggested

References:

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