AUBRITE AND IMPACT MELT ENSTATITE CHONDRITE METEORITES AS POTENTIAL ANALOGS TO MERCURY.

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Introduction: The MESSENGER (MErcury Surface, Space ENvironment, GEochemistry and Ranging) orbiter measured the mercurian surface abundances of key rock-forming elements to help us better understand the planet's surface and bulk geochemistry [1-3]. A major discovery is that the mercurian surface and interior are characterized by an extremely low oxygen fugacity (fO_2; Iron-Wüstite (IW) -7.3 to IW-2.6 [4-6]. This is supported by low Fe and high S abundances on the surface [1-3,7]. This low fO_2 causes a different elemental partioning from what is observed on Earth [5, 8-10]. Using surface composition, it was shown that the mercurian surface mainly consists of normative plagioclase, pyroxene, olivine, and exotic sulfides, such as niningerite ((Mg,Mn, Fe)S) and oldhamite (CaS) [1, 6-7, 9-10, 12-13].

To better understand the elemental behavior and magmatic processes on Mercury we need samples of mercurian rocks. In the absence of such samples,. The aubrite and impact melt enstatite chondrite meteorites are the best candidate mercurian analogs because they are products of highly reduced formation conditions [14-15]. Aubrites are enstatite achondrites that formed from a differentiated body [14], whereas impact melt enstatite chondrites originate from impact-induced melting of undifferentiated bodies [14-17].

Here we present a comprehensive study of aubrites, which include a wide range of brecciation, and impact melt enstatite chondrites. By conducting textural and mineral elemental analyses of these rocks, including samples that have not been previously studied, we aim to better understand the magmatic processes occurring on Mercury.

Samples: The aubrites included in this study are: Bishopville, Cumberland Falls, Khor Temiki, Miller Range (MIL) 13004, Mount Egerton Enstatite, Norton County, Peña Blanca Springs, and Shallowater. Miller Range has not been studied previously. The impact melt enstatite chondrites in this study are: Northwest Africa (NWA) 4799, NWA 7214, NWA 7809, and NWA 11071. With the exception of NWA 4799, these samples have not been previously investigated. It is important to address that the aforementioned impact melt enstatite chondrites were previously classified as aubrites, but here we show that these samples are actually impact melt enstatite chondrites.

Methods: We conducted textural analyses using a petrographic microscope to interpret petrogenetic relationships of minerals within the samples. X-ray maps displaying elemental abundances were created using the electron microprobe (EMP) *JEOL JXA-8900* at the University of Nevada, Las Vegas (UNLV) for Mg-S-Fe-Ca-Na-Ti-Al-Si. Additional maps of Cr-Ni-P were made for the aubrites, with the exception of Bishopville and Mt. Egerton. Modal abundances of minerals were calculated using *Image J* point counting software. We analyzed major element compositions of our samples using the UNLV *JEOL JXA-8900* EMP.

Results:

Textural and mineral analyses:

NWA 4799: The sample is heavily terrestrially-weathered. It is composed of fractured, euhedral-subhedral enstatite ($En_{98.3}Fs_{1.3}Wo_{0.4}$, 41.3 mod.%) grains up to 1.1 mm in length with interstitial albitic plagioclase ($An_{4.3}Ab_{85.4}Or_{10.3}$, 9.8 mod.%), and Si-rich (SiO_2 63 wt%) impact melt. NWA 4799 also consists of angular daubréelite ($FeCr_2S_4$) grains measuring up to 1.5 mm in length. Fe-rich weathering veins up to 1.1 mm in width surround the silicates and sulfides.

NWA 11071: This sample is moderately weathered. Enstatite grains ($En_{99.3}Fs_{0.2}Wo_{0.5}$, 50.9 mod.%) are subhedral and measure up to 2 mm. Interstitial albite ($An_{4.7}Ab_{90.6}Or_{4.6}$, 8.8 mod.%), and Si-rich impact melt are observed. We observed troilite, kamacite, schreibersite ($(Fe,Ni)_3P$) as inclusions within metal grains, and daubréelite.

NWA 7809: The sample is moderately weathered and non-brecciated. It is composed of elongated; euhedral-subhedral enstatite grains ($En_{98.9}Fs_{0.6}Wo_{0.4}$, 51.4 mod.%), sometimes striated, that measure up to 4.3 mm, and interstitial plagioclase ($An_{3.1}Ab_{92.1}Or_{4.7}$, 13.1 mod.%), and impact melt. Striated enstatites indicate fast cooling. Kamacite grains are observed, and are associated with rounded graphite and with schreibersite. Troilite forms in association with metal, and daubréelite exsolved from the troilite grains.

NWA 7214: The sample is moderately weathered and non-brecciated (see Fig. 1). Enstatite ($En_{99.4}Fs_{0.1}Wo_{0.5}$, 63 mod.%) grains are fine (200 μm) to coarse (4.5 mm) and rounded. The enstatite grains are surrounded by interstitial albite ($An_{5.5}Ab_{89.8}Or_{4.7}$, 9.5 mod.%) and Si-rich melt. The sample is kamacite-rich (8.1 mod.%). Schreibersite is found within the metal grains. Large oldhamite (0.7 mm) and troilite grains are present, and daubreelite and niningerite are observed in association with troilite. Caswellsilverite ($NaCrS_2$) occurs as a replacement phase of other sulfides. Djerfisherite ($K_3(Na,Cu)(Fe,Ni)_{12}S_{14}$) is observed on the edges of other sulfides.

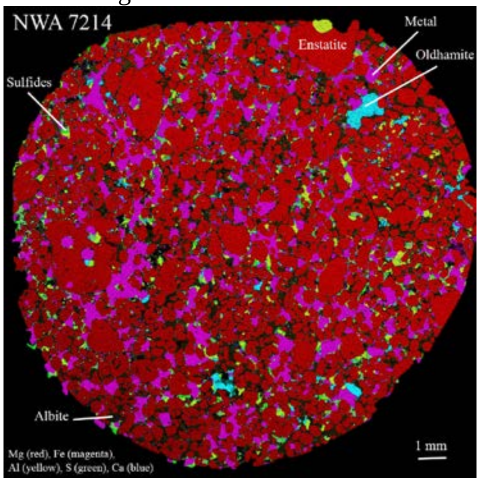

Fig. 1: X-ray map composite of NWA 7214 (Mg: Red; Fe:Magenta; Al: Yellow; S: Green; and Ca: Blue).

MIL 13004: This aubrite is brecciated, and is composed of angular enstatite ($En_{98.8}Fs_{0.5}Wo_{0.7}$, 65 mod.%) in a matrix of smaller enstatite grains. Olivines ($Fo_{99.97}$, 5.2 mod.%) up to 800 µm are rounded, and some are enclosed within enstatite grains. Albitic plagioclase ($An_{99.8}$, 4.4 mod.%) and diopside ($En_{53}Wo_{47}$, 2.6 mod.%) are present. Troilite is observed in association with oldhamite. Ferroan alabandite ((Mn,Fe)S) and caswellsilverite are in association. Schollhornite ($Na_{0.3}(H_2O)CrS_2$) is an alteration phase, and heidite ($FeTi_2S_4$) is present in fractures. Sulfides compose 3.2 mod.% of phases in this sample.

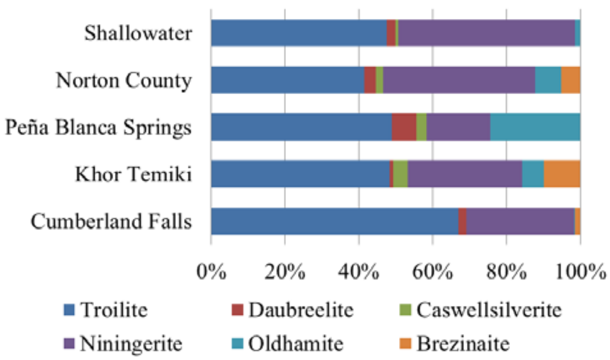

Fig. 2: Abundances of sulfides present in aubrites.

Modal abundances: The studied aubrites contain enstatite (63-97 mod.%), forsterite (0.5-13 mod.%), and albite (0.1-13 mod.%). The sulfides in aubrites are mostly represented by troilite (0.3-1.4%) and niningerite (0.1-0.6%) (Fig. 2). The impact melt enstatite chondrites are also composed of FeS and MgS phases (Fig. 3). Because these samples lack Cr and Mn X-ray maps, we cannot distinguish the modal percentage of each phase specifically, rather the elemental modal percentages. However, from EMP work, the impact melt enstatite chondrites generally display a lower sulfide diversity compared to the aubrites.

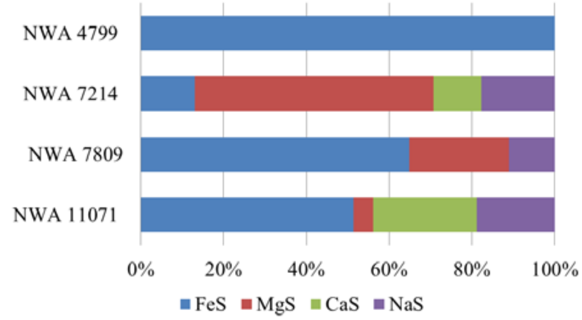

Fig. 3: Abundances of sulfides present in impact melt enstatite chondrites.

Discussion: *NWA impact melt enstatite chondrites:* Although the impact melt enstatite chondrite samples were previously classified as aubrites, petrographic and mineralogical analyses show that the NWA samples included in this study are not aubrites. This is supported by: The presence of graphite, a greater mod.% of Fe-Ni metals (0-10 mod.%) compared to aubrites (trace-2 mod.%), as well as euhedral granular enstatite grains and melt pockets indicating impact melting.

Mercurian Comparison: The aubrite and impact melt enstatite chondrites have a mineralogy similar to the mercurian surface, including exotic sulfides, such as oldhamite and niningerite [1, 6-7, 9-10, 12-13]. However, our calculated modal abundances of the aubrites and impact melt enstatite chondrites differ from the normative mercurian surface data [9]. Albitic plagioclase values are lower, and our EMP data of the impact melt enstatite chondrites show higher SiO_2 values than the calculated normative values of the mercurian surface [5], and both of these differences are attributed to Mercury having much higher abundances of Na at its surface compared to the meteorite analogs we studied. However, MgO values do reflect similar abundances in the HMR (high Mg region) and HMR-CaS (subregion of the HMR with high Ca and S contents) [4-5, 10]. We will continue analysis of additional aubrite samples and compare the results to the mercurian surface data [7,9].

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