

UNRAVELING THE VOLATILE STORY OF REDUCED METEORITES THROUGH DJERFISHERITE

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Introduction: The MESSENGER (MERcury Surface, Space ENVironment, GEOchemistry, and Ranging) spacecraft orbited Mercury from 2011 to 2015 and provided critical information about the elemental abundances, and therefore inferred mineralogy and oxygen fugacity (f_{O_2} ; iron-wüstite [IW]-6.3 to IW-2.6) of the mercurian surface. Mercury was previously predicted to be a volatile-depleted planet [e.g., 1]. However, measurements by MESSENGER indicated the presence of S, Na, Cl, and K on the mercurian surface [i.e., 2], implying the innermost planet is not as volatile-poor as once thought. Previous studies [i.e., 3–5] have shown that the behavior of elements at reducing conditions is not well-constrained, therefore ambiguity exists concerning the minerals that could host volatile elements on reduced bodies in the solar system.

In lieu of known samples from Mercury, it is critical to examine the most reduced samples in our current meteorite collection to better constrain the behavior of volatile elements in reducing systems. Klaus Keil and other researchers have demonstrated that enstatite-rich meteorites contain FeO-free pyroxene, Si-bearing metal, and host exotic Ca-, Mg-, Mn, and Cr-bearing sulfides, and the existence of such phases attests to extremely reducing conditions of formation [i.e., 4]. Enstatite-rich meteorites span the entire range from type 3 chondrites to differentiated aubrites, and the brecciated nature of many aubrites provides a broad sampling of the diverse lithologies on their parent bodies. Fortunately for the investigation of volatiles on the enstatite chondrite and aubrite parent bodies, these samples contain a volatile-bearing sulfide called djerfisherite $[(K,Na)_6(Fe,Ni,Cu)_{26}S_{27}Cl]$. Competing hypotheses for djerfisherite formation in enstatite chondrites have been suggested, namely formation as a primary condensate [6] or from sulfidization of Fe,Ni metal [7]. Aubritic djerfisherite formation has been attributed to sulfidization of roedderite $[(K,Na)_2(Mg,Fe)_5Si_{12}O_{30}]$ as the aubritic melt evolves from peralkaline to metaluminous compositions [8]. This work identifies and characterizes occurrences of djerfisherite in the aubrites and enstatite chondrites to constrain its formation on reduced bodies in the Solar System.

Samples: Four aubrites and three enstatite chondrites contained djerfisherite suitable for detailed microanalysis: Allan Hills (ALH) 84007 (aubrite), Aubres (aubrite), Bishopville (aubrite), Peña Blanca Spring (aubrite), Allan Hills 84250 (EH3), Kota-Kota (EH3), and Miller Range (MIL) 07139 (EH3). We note that djerfisherite was only observed in the least thermally metamorphosed enstatite chondrites (EH3).

Methods: We used optical microscopy to identify occurrences of djerfisherite, metals, and other sulfides. The presence of djerfisherite and coexisting mineral assemblages were determined via scanning electron microscopy (SEM) using the FEI Nova NanoSEM 600 at the Smithsonian National Museum of Natural History's (NMNH) Department of Mineral Sciences. The quantitative chemical composition of occurrences of djerfisherite were then analyzed using the JEOL JXA-8530F electron microprobes (EMP) at the NMNH and NASA Johnson Space Center.

Discussion: Djerfisherite in enstatite chondrites co-exists with metal (kamacite and schreibersite) and sulfides (i.e., troilite and daubréelite). In Aubres and Peña Blanca Spring and past work [5], djerfisherite is ubiquitously observed as rims to troilite. Peña Blanca Spring contains djerfisherite replacing troilite and cross-cutting daubréelite exsolution. This critical observation implies that sulfidization must have occurred after the exsolution and cooling of daubréelite. We interpret this observation to represent vapor-phase metasomatism on the aubrite parent body. In such a reaction, troilite and/or metal reacts with a volatile-rich (Cl, Na, K, Cu) vapor to produce djerfisherite. From djerfisherite chemical analyses, siderophile element concentrations and volatile element concentrations show different groupings between the enstatite chondrites and aubrites. We suggest these groupings imply different mineral precursors to djerfisherite and different formation mechanisms for djerfisherite among the reduced meteorites. Our presentation at this conference will delve into the possible formation mechanisms for djerfisherite among reduced meteorites with implications for mercurian sulfides and volatiles as we look forward to results from the BepiColombo mission.

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Acknowledgements: ZEW thanks the NMNH Hevey Mineral Sciences Fellowship for funding this study.