A COMBINED HALOGEN AND GEOCHRONOLOGY STUDY OF ENSTATITE CHONDRITES

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Introduction: Enstatite chondrites (EC) are a rare class of meteorite which formed under extremely reducing conditions within the protoplanetary disk [1]. Their composition and mineralogy reflect these formation conditions, including Mg endmember silicates and lithophile-bearing metal and sulfides. Based on their similar chemical and isotopic compositions, EC were likely a major contributing component during Earth's accretion [1]. Despite their inner Solar System origin, they also contain significant quantities of volatiles [2]. The present study includes a correlated halogen and multi-system geochronology analysis of EC. Djerfisherite [$(K,Na)_6(Fe,Cu,Ni)_{25}S_{26}Cl$], a K- and Cl-bearing-sulfide, contains the highest potassium concentration of any phase occurring within enstatite chondrites. Therefore, within djerfisherite bearing EC, this mineral is expected to host much of the Rb and K and will thereby exert a considerable control on the Rb-Sr and Ar-Ar dating systems. EC formed broadly contemporaneously with other chondrite groups. Some EC were subject to very early shock and/or thermal metamorphism (4.50 Ga or older) [3, 4] and some to much later shock and/or thermal metamorphism (2.10 Ga) [3]. The oldest ages have been obtained from the I-Xe (4.56 Ga) [4] and Mn-Cr (4.55 Ga) [5] isotopic systems, with Rb-Sr and Ar-Ar generally recording younger ages [6]. At a high level, this variability is controlled by both variable isotopic closure temperatures and retentivity of host phases [6]. EH3 meteorites show a substantial spread in ages even within individual meteorites, e.g. Qingzhen 4.56 Ga [7] to 2.15 Ga [3]. In this study, the combination of *in situ* Rb-Sr and Ar-Ar dating, via LA-ICP-MS and NI-NGMS (neutron irradiation noble gas mass spectrometry), aims to directly address this complexity.

Samples: Samples of terrestrial djerfisherite, for use as a LA-ICP-MS standard are available from the Khiby Massif (380 - 360Ma) [8] of the Kola Peninsula. Samples with large (>1mm) djerfisherite grains were selected to ensure ease of analysis. EH3 meteorites have been targeted due to their greater abundance of djerfisherite. Meteorites with a low shock stage and weathering grade were selected to avoid measuring impact resetting ages and terrestrial contamination, respectively. Three EH3 meteorite samples, Klein Glacier 98300, Dominion Range 14021, and Larkman Nunatak 12252, were selected for study. The EH3 meteorite Miller Range 07028 was made available from a previous study. Most of these meteorites have been the subject of only limited study to date. Therefore, their mineralogy and chemistry will be used to aid detailed characterisation studies.

Methods: As part of this study, terrestrial djerfisherite and meteorite samples have been analyzed via optical microscopy, SEM-EDS and EPMA. Rb-Sr dating of terrestrial djerfisherite via LA-ICP-MS as per [9] is in progress, prior to the analysis of the meteorite samples. Whole rock meteorite samples are being prepared for neutron-irradiation for Ar-Ar dating and quantification of halogens via CO_2 laser stepped heating and noble gas mass spectrometry [10]. A later stage of the study will apply *in situ* halogen quantification and Ar-Ar dating to djerfisherite and other phases.

Findings: Results from the terrestrial djerfisherite indicate it is a promising standard for Rb-Sr dating of meteorites. Abundances of both potassium and chlorine exhibit some variation within grains, but this is relatively minor (Cl 1.27±0.1 and K 9.0±0.2 wt.%). Djerfisherite has been identified in DOM 14021, LAR 12252, and MIL 07028, but is absent in KLE 98300. Results from this study have confirmed the petrologic type of each of these meteorites, however initial results indicate additional complexity in the characterisation of KLE 98300. Most of the meteorites in this study have not been classified according to shock stage. Initial results show that these meteorites have experienced variable shock processing, with the presence of e.g., variable mineral lattice deformation in silicates.

Implications: The unique mineralogy and histories of EC are manifest in their complicated chronologies; this is especially true for the EH3 meteorites. This study will involve *in situ* dating of one of the major phases, djerfisherite, influencing the Rb-Sr and Ar-Ar dating systems in EH3 meteorites. Fortuitously, this phase is also an important halogen carrier, likely contributing to the halogen enriched nature of EC. The Rb-Sr system is sensitive to aqueous alteration while the Ar-Ar system is sensitive to thermal resetting. Together, they offer a powerful way to assess the primary and/or secondary nature of halogens in this important class of meteorite. This correlated dating and halogen quantification approach will prove a valuable means to further our understanding of volatile processes in the early inner Solar System, in particular, in elucidating the source of Earth's halogens.

References:

[1] Weisberg M.K. and Kimura M. (2012) *Chemie der Erde* 72:101-115. [2] Piani L., et al. (2020) *Science* 369:1110-1113. [3] Torigoye N. and Shima M. (1993) *Meteoritics* 28:515-527. [4] Hopp J., et al. (2016) *Geochimica et Cosmochimica Acta* 174:196-210. [5] Hopp J., et al. (2021) *Geochimica et Cosmochimica Acta* 310:79-94. [6] Hopp J., et al. (2014) *Meteoritics & Planetary Science* 49:358-372. [7] Whitby J.A., et al. (2002) *Geochimica et Cosmochimica Acta* 66:347-359. [8] Kramm U., et al. (1993) *Lithos* 30:33-44. [9] Gorojovsky L. and Alard O. (2020) *Journal of Analytical Atomic Spectrometry* 35:2322-2336. [10] Ruzié-Hamilton L., et al. (2016) *Chemical Geology* 437:77-87.