60 YEARS IN A CAPSULE: THE BRUDERHEIM METEORITE AS A MEANS TO ADVANCE THE CURATION OF METEORITES AND SAMPLE RETURN MATERIAL. P. J. A. Hill[1], C. D. K. Herd[1], and L. D. Tunney[1]. Department of Earth and Atmospheric Sciences, 1-26 Earth Sciences Building, University of Alberta, Edmonton, AB, Canada. pjhill@ualberta.ca

Background: The L6 ordinary chondrite, Bruderheim, fell at 01:06 MST on March 4, 1960 near the town of Bruderheim, Alberta. 350 individual specimens amounting to over 300 kg of material were recovered. Shortly after recovery, two large specimens were sealed under vacuum conditions within blown-glass tubes. The masses of the two samples are ~1.4 kg and ~1.2 kg, including the glass capsule. Figure 1 shows sample MET4170/B-194 within its glass capsule. From Prof. H. Baadsgaard, who worked on Bruderheim immediately after it fell, the contents of the capsule are most likely under vacuum although they may be in air. It is likely that the sealing was done on a K-Ar vacuum line within the geochronology lab at the University of Alberta in April of 1960.

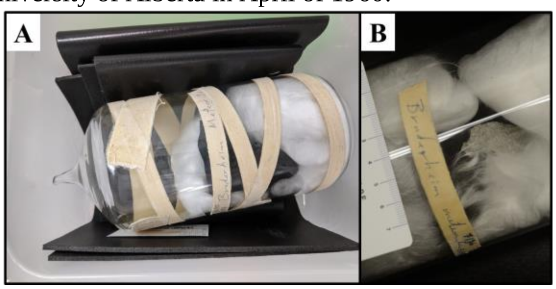

Fig. 1: A) A photograph of MET4170/B-194 within the capsule. B) A detailed view of MET4170/B-194's exposed face, with cm scale.

Here we outline a proposed procedure for the extraction of one of the specimens from its capsule, for presentation to the community for feedback. The University of Alberta's Sub-zero Facility for the Curation of Astromaterials' low temperature reduces reaction rates and its argon atmosphere glovebox provide optimal conditions for working with meteoritic material [1]. Though these two specimens were most likely sealed under vacuum conditions for preservation, these capsules provide an opportunity to not only investigate how well the vacuum has preserved the meteorite but also advanced handling and curation techniques by treating the specimens as sample return capsules. Using these specimens as analogues for sample return missions, we hope to better inform curation protocols for upcoming sample return missions such as OSIRIS-REx and Hayabusa 2. As noted by [2], current and future sample return missions will require advanced curation methods.

Sample Descriptions: Alongside MET4170/B-194, two additional samples of Bruderheim, which have not undergone prior scientific investigation, will be processed and undergo the same analytical procedures. The purpose of these samples is to act as a reference to be compared to the capsule-sealed sample. Additionally, quartz beads will be used as procedural blanks.

MET4170/B-194: As seen in Figure 1, the sample is encased in a 24 cm by 9 cm cylindrical capsule and is surrounded by, what is thought to be, quartz wool. The exposed surface of the meteorite appears fresh with no obvious oxidation and a black, glassy fusion crust.

MET4170/B-163: This is a 224.5 g sample of Bruderheim that has a smooth, dark black fusion crust. This sample was chosen for its minor exposure of the interior (Fig. 2). Unlike MET4170/B-194, the interior of the meteorite shows an orange rusting most likely the result of being exposed to the terrestrial environment for nearly 60 years. Relative to B-194, the fusion crust is dull.

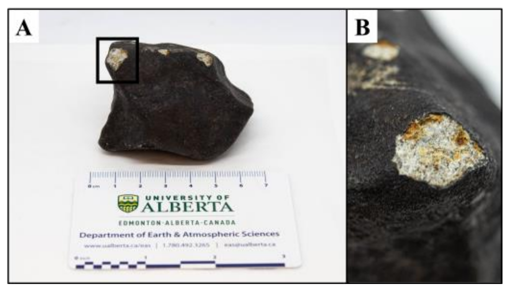

Fig. 2: A) A photograph of MET4170/B-163. Note the exposures of the interior on the top surface. B) A detailed view of the exposed face of MET4170/B-163. Note the orange-brown oxidation on the surface.

MET4170/B-196: This specimen is a 41 g sample of Bruderheim that is completely enclosed in its dark black-brown fusion crust (Fig. 3). Though significantly smaller than both the other samples, the sample was chosen due to its complete fusion crust, which will be investigated to determine the degree to which it was able to preserve the interior over the past 60 years.

Fig. 3: A photograph of MET4170/B-196. Note that the sample is completely enclosed in fusion crust.

Sterilization: Prior to any work being conducted on the samples, all tools and materials will be sterilized to remove any potential contamination. All Teflon containers will be rinsed with HPLC-grade dichloromethane (DCM) and then placed within an autoclave at 121°C and 15 psi for a minimum of 30 minutes. All glassware, metal tools, or ceramic materials will be rinsed with DCM and then wrapped in aluminium foil and placed in an oven to combust at 450°C for a minimum of 4 hours. The tools, once cooled from the oven and autoclave, will be sealed within polyethylene bags using a Uline™ Poly Bag Sealer and transferred into the glovebox.

Gas Extraction: Given the pristine nature of the sealed specimen, all appropriate measures will be taken to ensure that the sample will not be exposed to an oxygen-rich environment. Furthermore, the composition of the gas within the capsule is of interest to understand better both the potential ingas into the capsule from the air and whether the meteorite continued to outgas over the decades. Given that the capsule is thought to be made of borosilicate glass, infrared spectroscopy cannot be utilized as its absorption within the infrared range precludes this type of analysis. Therefore, the goal is to transfer the gas into a metal gas cylinder before transferring the capsule to the glovebox (Fig. 4). The cylinder can then be sent off for analysis and the capsule can be immediately transferred to the glove box, minimizing the risk of atmospheric exposure.

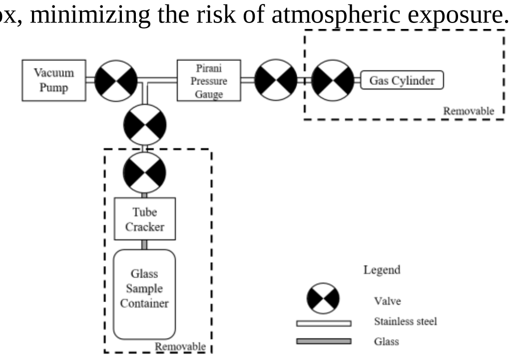

Fig. 4: Schematic of the proposed line to crack the vessel and condense any air within the capsule.

Liquid nitrogen will be utilized to make the gas cylinder a cold trap and maximize the amount of gas that can be condensed. This will distort the relative abundance of several gas species that do not condense at liquid nitrogen temperatures; however, doing so will also maximize the amount of gas that is captured within the cylinder.

With the gas captured within the gas cylinder, it can now be shipped for analysis. Two main investigations are of interest: the general chemistry of the gas (molecules such as CO_2, CO, O_2, N_2 etc.) and the potential presence of rare gases.

Glovebox Processing: The quartz bead blanks, vacuum sealed Bruderheim meteorite, and non-sealed samples will undergo the exact same process for the extraction of material for analysis. The pieces of glass from the capsule and quartz wool within the vacuum sealed sample will be isolated for additional analysis to quantify them as sources of any contamination.

As this study is an assessment on curation and preservation, the presence of different organic compounds on the surface of this meteorite are also of interest. Organic compounds from a small fragment of the fusion crust will be extracted with dichloromethane and analyzed by GC-MS to determine if contamination occurred when the sample was sealed within the glass vessel. Results will be compared to results from quartz beads and unsealed samples.

Post Processing Analysis & Comparison: To assess the pristine nature of these samples a comparison will be made to the two Bruderheim samples that were stored in standard collection conditions (B-163 and B-196). Surface analysis of the meteorites and individual mineral grain analysis will allow for an understanding of how Bruderheim has changed through time, especially with regards to oxidation. Preliminary plans include analysis of elemental distribution on broken surfaces and along grain boundaries, with x-ray photoelectron spectroscopy (XPS) and scanning electron microscopy (SEM). Other methods to examine 3D structure and chemical variations, on either thin sections; cut rocks; or mineral separates are being investigated. Atomic level analysis conducted to further examine surficial properties of different materials may be required.

Long-term Storage: As Bruderheim is an ordinary chondrite, intrinsic organic matter is expected to be very low, obviating the need for cold curation; however, exposure to oxygen is a concern. Various options for vacuum storage are being considered as potential long term storage solutions.

References: [1] Herd C. D. K. et al. (2016) *Meteoritics & Planet. Sci.*, *51*(3), 499–519. [2] McCubbin F.M. et al. (2019) *Space Sci. Rev*. 215: 48.

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Additional Information: If you have any comments or suggestions for the proposed work, please contact pjhill@ualbert.ca. We are looking for any improvements to the procedure and how we can better advance curation techniques for future sample return missions.