NEW CHALLENGES IN THE CURATION OF COLD, VOLATILE-RICH EXTRATERRESTRIAL SAMPLES. J. L. Mitchell[1], M. D. Fries[1], R. A. Zeigler[1], and F. M. McCubbin[1], [1]NASA Johnson Space Center, Houston, TX (Julie.L.Mitchell@nasa.gov)

Introduction: The Astromaterials Acquisition and Curation Office at NASA Johnson Space Center (JSC) is responsible for curating NASA's extraterrestrial sample collections. NASA Policy Directive (NPD) 7100.10E mandates the preservation of existing extraterrestrial samples with minimal alteration, extensive and quantitative documentation of alteration that is provided to investigators, and "the development of long-range plans" for samples yet to be acquired. **[1]** The Advanced Curation effort within the Curation Office is executing plans for long-range sample collection and curation, including preparations for Mars Sample Return (MSR), new techniques for sample cleaning and sterility, and the curation of temperature-sensitive, volatile-rich samples. The unique challenges associated with temperature-sensitive, volatile-rich sample curation – hereafter called "cold curation" - are currently being investigated by curators at JSC. **[2]**

Background: Previous efforts provide valuable experience to guide the way for this new cold curation development effort. The U.S. Antarctic Search for Meteorites (ANSMET) has a long history in the transport and storage of frozen extraterrestrial samples. After arrival to JSC, the ANSMET samples are thawed in a Class 1000 clean environment under a continuous flow of N_2 to minimize sample alteration during the transition to room temperature. **[3]** Recently, a small-scale laboratory for the storage and manipulation of cold extraterrestrial samples was investigated at JSC. This glovebox consisted of a cold plate and freezer at -35°C under purged N_2. Large thermal gradients were measured near the cold plate and, as a result, up to 1% of the sample's water ice mass was lost in a 24-hour period. This initial cold curation investigation provided a critical datapoint for understanding sample degradation on cold working surfaces under N_2-purged conditions **[4, 5]**. Finally, Tagish Lake – a meteorite rich in water and organics – has successfully been preserved at the University of Alberta in an Ar-purged glovebox within a -10°C walk-in freezer. This cold curation effort has produced a number of useful recommendations for the future collection, transport, and storage of volatile-rich extraterrestrial materials. **[6]**

Recent announcments for new sample-return missions have shown that a cold curation capability will be needed within the next 10-20 years. The New Frontiers Announcement of Opportunity (AO) included the option for a comet surface sample return (CSSR) mission, and the Comet Astrobiology Exploration Sample Return (CAESAR) mission was one of two proposals selected for continued development under this AO. **[7]**. Concepts for sample return from the lunar south pole are being investigated by both NASA and ESA/Roscosmos. **[8]** Additionally, recent discoveries of water and/or aqueously formed minerals have increased the priority of sample return from Europa, Enceladus, and Ceres. **[9]** Therefore, the Astromaterials Acquisition and Curation Office at JSC must be prepared for samples from each of these target bodies and the unique curatorial challenges associated with them. To this end, the Curation Office is developing simulants of both comet and volatile-rich lunar samples in the short term, and icy moon/Ceres simulants in the following years. These simulants will be used to test the effectiveness of cold curation sample handling protocols and storage systems over short- (weeks-months) and long-term (years) timescales.

Strategy: *Simulant Development.* The development of comet and lunar polar simulants relies on previous remote sensing and sample analyses of these bodies. The comet simulant, the first of the simulants to be developed under this cold curation effort, will represent the most common/abundant volatiles identified in comets to date (**Table 1,** left), with a focus on comet 67P/Churyumov-Gerasimenko as the target for the CAESAR mission. **[10]** Additional components such as intermixed silicates of various grain sizes will also be incorporated to increase the fidelity of the simulant. A lunar polar simulant will be developed using a similar approach (**Table 1**, right) based on remote sensing investigations of the lunar poles and compositional data obtained from the LCROSS and LRO missions. **[11, 12]**

Cometary Volatiles[10]		**Lunar Polar Volatiles[11,12]**	
Compound	%	Compound	%
H_2O	61.2	H_2O	77.4
CO_2	25.3	H_2S	13.0
CO	9.8	NH_3	4.7
H_2CO	2.5	SO_2	2.5
CH_3OH	1.2	C_2H_4	2.4

Table 1. The five most abundant cometary and lunar polar volatiles and their relative abundances based on recent remote sensing and surface analyses.

Detailed analyses of the simulants will be conducted to fully characterize their physical and chemical properties (organic and inorganic composition, isotopic abundances, thermal properties, grain size distribution). Analytical techniques to be used include gas chromatography-mass spectrometry (GC-MS), visible microscopy, and reflectance and emission spectroscopy. Simulant physio-chemical properties will be monitored at regular intervals to constrain the degree of sublimation, evaporation, and/or alteration during storage and after routine sample handling.

Storage System Development. The production of a cold curation storage system will begin with the development of a clean storage vessel capable of maintaining temperatures at or lower than that of liquid nitrogen (LN_2, -196°C). Because returned samples are expected to be small, low sample masses (<1 kg) will be assumed initially. A range of pressures and humidities will be evaluated to determine the conditions under which sample alteration is minimized.

Periodic sample handling will be required to assess the degree and extent of sample alteration during routine curation operations. To minimize the exposure of curation personnel to below-freezing temperatures, samples will be handled at a minimum of -20°C. New approaches to sample handling will need to be developed to minimize heat transfer and alteration of the sample (**Fig. 1**); previous investigations have shown this to be a significant technical challenge. **[4, 5]**

Figure 1. CO_2 "snow" made at JSC using bottled LCO_2 and commercial off-the-shelf hardware.

Sample transport and analysis will also be restricted to temperatures of -20°C; this temperature range poses unique technical and hardware challenges, such as the safe transport of coolant (LN_2) during clean room operations and adequate long-term sample insulation. Additionally, new sample characterization techniques (i.e. emission spectroscopy) may be integrated into the cold curation storage facility to allow non-destructive monitoring of the sample suite.

Quantitative Analysis of Alteration: The long-term storage of ices and volatiles comes with innate difficulties in maintaining the crystalline states, chemistry, and isotopic composition of the parent material. Long-term studies of sample alteration will be performed to prescribe optimal sample storage conditions.

Safety Considerations: While non-hazardous water-ice is the dominant volatile compound in cometary and lunar polar materials, other species pose hazards for health/inhalation and flammability. To mitigate these hazards, only small volumes (<5 g) of each hazardous compound will be used in each sample during initial simulant development. A sealed glovebox will be used to contain the samples during routine curation activities. Additionally, personal protective equipment (PPE) and sealed containers (dewars) will be used for sample transport when necessary. Gas monitors (i.e., O_2, CO_2, CO) will be used in proximity to sample handling areas to ensure a safe working environment for curation personnel. The safe storage and manipulation of volatile-rich samples is of paramount importance during this cold curation development effort.

Timeline: The first year of this cold curation effort will focus on the development of a comet simulant in support of the sample return plan proposed by CAESAR. This portion of the effort will include initial sample preparation and characterization using GC-MS. In parallel with the development of a comet simulant, the initial storage vessel design and fabrication will be conducted. The rate of sample alteration during routine curation activities will be quantified.

The second year of the cold curation effort will evaluate the effectiveness of the storage vessel at preventing sample sublimation, evaporation, and alteration. Non-destructive sample characterization methods using reflectance and emission spectroscopy will be developed. Initial integration of the non-destructive analysis hardware with the storage vessel will be completed.

Within two years, the preliminary cold curation hardware and storage system will be constructed and tested with high-fidelity materials. Mission proposal down-selection and planning over this timeframe will provide additional direction for the cold curation development effort. The recent selection of CAESAR now allows the cold curation development effort to focus on comet 67P/Churyumov-Gerasimenko. Knowledge of a specific lunar landing site will allow the relevant lunar simulant composition to be further refined, and its ideal long-term storage conditions to be determined. This new cold curation capability will enable future sample-return missions by providing the necessary long-term storage for their returned samples, preserving these unique materials for future analysis and thereby significantly enhancing their scientific return.

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