ADVENTURES IN LUNAR CORE PROCESSING: TIMELINE OF AND PREPARATION FOR OPENING OF CORE SAMPLE 73002 FOR THE ANGSA PROGRAM.

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Introduction: The Apollo mission returned 382 kg of rocks, soil and core samples, which have helped to advance our knowledge of lunar science. Studies of these lunar samples are crucial for our understanding of the Moon's geological evolution. Here, we present the meticulous process that involves preparing for, and ultimately opening, the unopened Apollo 17 drive tube: 73002,0, so that the next generation of lunar scientists can further our insight into the Moon's history.

Summer 2018 – T minus 18 months: First, all core processing equipment was pulled out of storage and sorting through to identify all tools and equipment by cross-referencing the procedures and previous processor experiences. The core cabinet was cleaned and purged with nitrogen gas (GN2) to prepare it for use after sitting dormant for nearly 25 years. Numerous challenges arose during this process; e.g., very few items were labeled, part numbers were misidentified in the procedure, naming convention was not consistent, and few photos existed for individual components. Furthermore, legions of screws were bagged separately from their respective equipment, many of which were Xylan coated, a material that is non-compliant for pristine lunar processing [1]. Moreover, there is limited institutional memory as most of the former core processors have retired or passed away.

Fall 2018 – T minus 12 months: The first of several table-top assembly rehearsals began with a mixture of experienced and new core processors. The goal of these sessions was two-fold: (1) identify equipment and (2) learn how it fits together. Several dry runs were completed with varying degrees of success (Fig. 1a) – parts continued to be identified and future challenges were noted.

Many of the fused silica receptacle tops (commonly called the quartz tops) had been damaged during past use, leaving only one intact and no source identified for manufacturing a new one.

May 2019 – T minus 5 months: The practice was split into two phases. Phase one involved practicing assembly and extrusion on a table top with the same dimensions as the core cabinet footprint. Phase two involved the practice of assembly, extrusion, and dissection of a lunar core simulant (Fig. 2a) inside a mockup glove box (Fig. 1a). This allowed us to become familiar with the constraints inside a glovebox, as well as working with a simulant similar to the core soil.

In the meantime, the lunar core simulant was designed, and several epoxies were examined for encapsulation of the core remainder for the formation of thin sections.

July 2019 – T minus 4 months: Phase two commenced in July 2019. A mockup core cabinet with

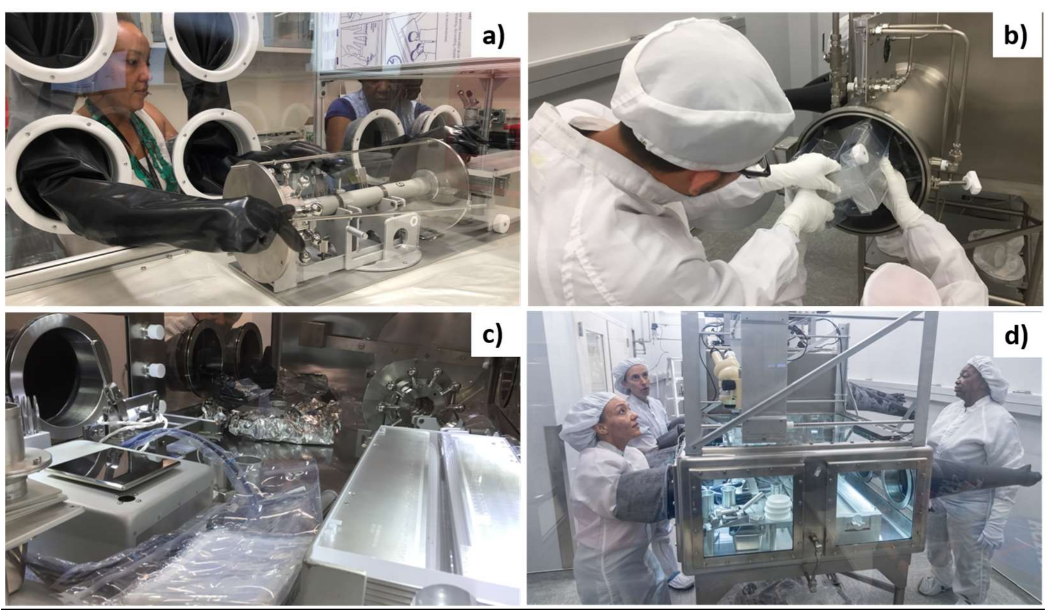

Fig. 1: *Process of opening 73002 from dry-runs (a) to loading the core cabinet (b) to fully loaded cabinet (c) and final extrusion (d).*

the same dimensions as the original core cabinet was designed and built. This set up allowed for practice assembly, extrusion, and dissection within the constraints of a glovebox without concern about cleanroom protocol.

During this time, we also discovered that the keeper removal assembly, which is required to remove the keeper from the drive tube to allow the core sample to be extruded, was missing a vital part that could not be located. A successful hunt was initiated to find a manufacturer who could fabricate the part with a short turn around.

August/September 2019 – T minus 2 months: We commenced the equipment assembly and extrusion, first using Teflon blocks to simulate the core in the mockup glovebox. During this time, we identified which assembly steps could take place outside the actual cabinet. The assembly steps would be performed after the cleaning process but before the equipment was bagged for transport to the lab. This cut down on the time and effort needed during equipment assembly in the actual glovebox.

Two practice core drive tubes were filled with the lunar core simulant: one for use during extrusion practice sessions and one used as the test subject for CT scanning prior to the actual scan of 73002,0. During the first practice extrusion session, the practice drive tube was filled fully (roughly 30 cm). During the second practice extrusion session, the practice drive tube was only filled to about 23 cm to better simulate the actual length of the 73002,0 core.

October 2019 – T minus 1 month: During the final extrusion session, a different quartz top in use was damaged due to complacency and inattention during the extrusion. Lesson learned.

As part of the prep work to get the core cabinet ready for action, lights, a webcam, webcam rack and power box from a different lunar cabinet were disassembled and retrofitted onto the core cabinet. This turned out to be a bigger project than originally intended, since the lights, camera, power box, and rack were fully integrated with one another.

Additionally, the current tool and equipment cleaning procedure was modified to include the new cleanliness and sterility requirements for the opening of 73002,0. This included blowing off all equipment with GN2 prior to a wipe-down with IPA wipes to remove all simulant alumina. Items were then cleaned per the normal procedure and then bagged in two Teflon inner bags and one polyethylene outer bag to minimize contamination.

73002,0 was transported to the University of Texas at Austin for CT scanning during this month, along with the practice tube filled with core simulant.

November 2019 – Launch: After equipment was cleaned, we assembled everything we could on the table top prior to final bagging. Witness plates and foil were prepared and deployed in the core cabinet prior to insertion of any other equipment.

The equipment loading procedure was modified to minimize biological contamination This included donning a clean smock over the cleanroom bunny suit, donning clean nitrile gloves prior to picking up and loading equipment into the airlock, and wiping down the inside of the cabinet airlock with IPA wipes prior to loading equipment (being careful not to brush against the inside of the airlock while reaching inside).

Loading the core equipment and tools into the airlock took two full days and a full crew on board (Fig. 1b). Assembly of the equipment inside the cabinet took about a day (Fig. 1c), and extrusion was successful and yielded no surprises. The extrusion was videotaped via our webcam and a NASA photographer (Fig. 1d).

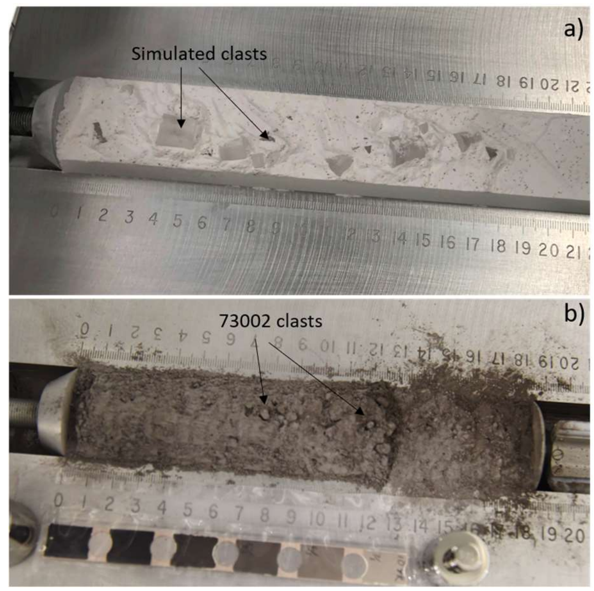

Fig. 2: *Lunar simulant core during dry-run with simulated quartz beads representing clasts and rocklets (a); Extruded lunar core sample 73002,0 during dissection of pass 1.*

Post-November 2019: We continue the dissection of the 73002,0 (Fig. 2b), working with ANGSA science team members to document the process and to extract the most information from the processing of this sample for future core extrusions.

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