THE ASTROMATERIALS X-RAY COMPUTED TOMOGRAPHY LABORATORY AT JOHNSON SPACE CENTER.

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Overview: The Astromaterials Acquisition and Curation Office at NASA's Johnson Space Center (hereafter JSC curation) is the past, present, and future home of all of NASA's astromaterials sample collections. JSC curation currently houses all or part of nine different sample collections. Our primary goals are to maintain the long-term integrity of the samples and ensure that the samples are distributed for scientific study in a fair, timely, and responsible manner, thus maximizing the return on each sample. Part of the curation process is planning for the future, thus we also perform fundamental research in advanced curation initiatives. Advanced Curation is tasked with developing procedures, technology, and data sets necessary for curating new types of sample collections, or getting new results from existing sample collections [1]. As part of these advanced curation efforts we are augmenting our analytical facilities. A micro X-ray computed tomography (micro-XCT) laboratory dedicated to the study of astromaterials came online within the JSC Curation office this summer, and we plan to add additional facilities that will enable non-destructive (or minimally-destructive) analyses of astromaterials in the near future (micro-XRF, confocal imaging Raman Spectroscopy). These facilities will be available to: (1) develop sample handling and storage techniques for future sample return missions, (2) be utilized by PET for future sample return missions, (3) be used for retroactive PET-style analyses of our existing collections, and (4) for periodic assessments of the existing sample collections. Here we describe the new micro-XCT system, as well as some of the ongoing or anticipated applications of the instrument, as well as the issues related to making the large volume of data available to the public.

Instrument: We have installed a Nikon XTH 320 micro-XCT system in JSC curation. It has four interchangeable X-ray sources: 180 kV nano focus transmission source, 225 kV reflection source with multi-metal target (Mo, W, Ag, Cu), a 225 kV rotating target (W) reflection source, and a 320 kV reflection source. The system also has a 16-bit, 400 mm^2 (2000 x 2000 pixel) CCD detector, as well as a heavy-duty stage that will accommodate large (up to 30 cm) and heavy (up to 100 kg) samples. The multiple sources, high-resolution detector, and large stage allow us the flexibility to analyze a wide range of sample sizes. The 180 kV transmission

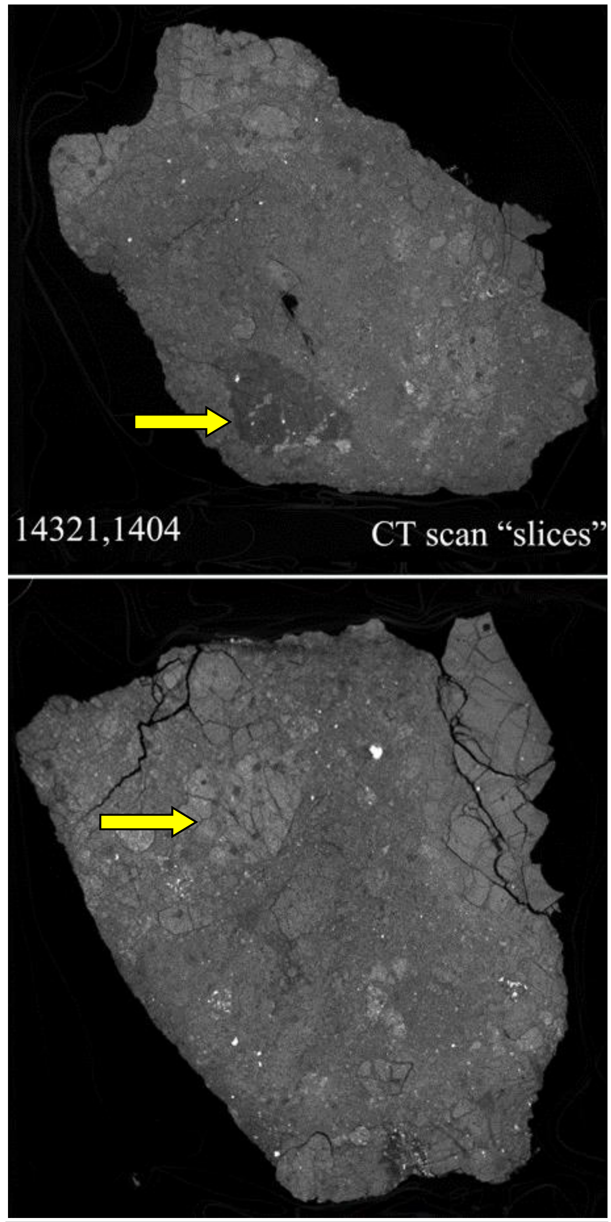

Figure 1: Slices of the micro-CT scan of sample 14321,1404. Brightness of the phases are proportional to x-ray attenuation (a measure of composition and density of the phase). Yellow arrows highlight interesting feldspathic (top) and mafic (bottom) clasts. Sample is ~ 6 cm in diameter.

source will allow for high resolution (submicron) scans on small samples (less than ~5 mm), whereas the 225 kV and 320 kV sources will allow scans of larger samples at resolutions on the order of 10s or 100s of microns per voxel depending on the sample size. The maximum size high-density rock sample that can be scanned has yet to be determined, but test scans on basalt samples >15 cm in diameter have been successful.

Discussion: High-intensity XCT scanners have been used to study astromaterials (and other geologic samples) for over 15 years [2-3], and the practice is becoming ever more prevalent. They have a wide range of scientific uses, including (but certainly not limited to) measuring porosity, determining the modal abundance and 3D distribution of phases inside samples, and identification of fabrics or strain patterns in samples. In addition to their use for research, XCT scans have increasingly been utilized as a part of the astromaterials curation process, beginning with meteorites [4-5], and more recently with the Apollo samples [6]. Their utility in curation lies in their ability to non-destructively map out the phases and voids within a sample. As an example, we have scanned several large Apollo polymict breccias, and we were able to identify and tentatively classify the lithologies in these clasts. The samples can then be subdivided, either through sawing or careful chipping, and those "new" clasts made available to scientists. In addition to the myriad curatorial uses, we have begun to use the XCT system as an integral part of coordinated analyses of astromaterials. An example of this is the mapping of textures within ungrouped achondrite NWA 11119 (Figure 2). The XCT scans were able to characterize the major phases with the meteorites, and identify areas of interest for additional higher resolution study (e.g., by TEM). The penetrative nature of the XCT scans allows for astromaterials samples to be analyzed within sealed low-density containers, preserving the pristinity of the samples. The XCT technique is not completely non-destructive, however. A recent study by [7] has shown that XCT scans of meteorites can alter the natural radiation dose of the sample. The number of techniques where this is applicable (e.g., thermoluminescence) is limited, however. In the meantime, the percentage of any one sample that is studied by XCT will be limited to ensure that no irreparable damage is done to an entire sample. In addition to stand-alone XCT scans, we have an ongoing project to pair image-based 3D reconstructions of Apollo Lunar Samples correlated to 3D reconstruction of the same sample's Micro-XCT data [8].

The data from XCT scans and related 3D imaging represents large volumes of data (many 10s of GB per scan) that will need to be curated for the long term and served to the public in a useful way; both are formibable challenges.

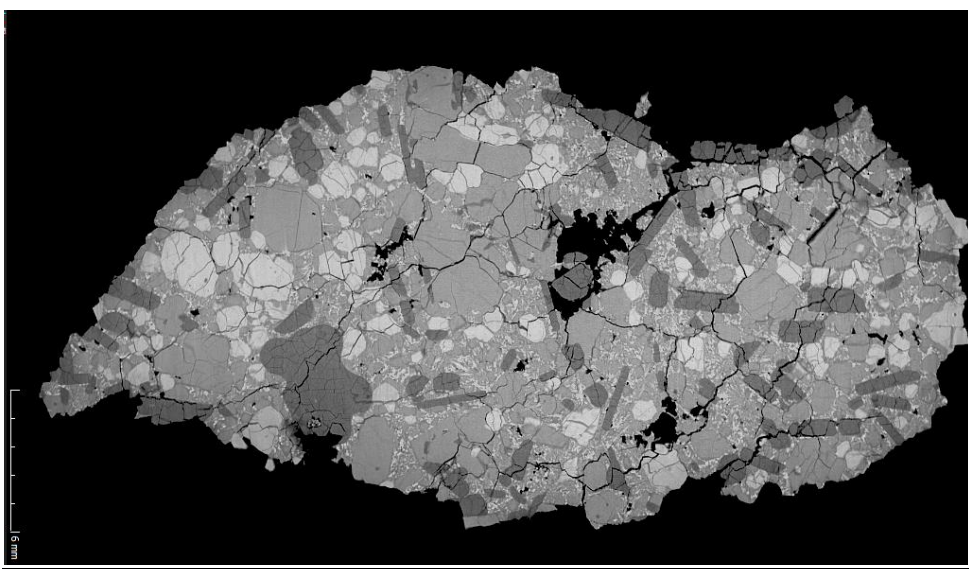

Figure 2: Single 2D slice of the micro-CT scan of ungrouped achondrite NWA 11119 showing the igneous textures and major mineralogical phases within the sample. Sample is ~ 3 cm long.

References [1] McCubbin et. al. (2016) 47th LPSC, abstract #2668. [2] McCoy et al. (2002) EPSL 246, 102-108. [3] Zolensky et al. (2014) MAPS 49, 1997-2016. [4] Almeida et al. (2014), MAPS 77 abstract #5033. [5] Smith C. L. (2013) MAPS 76, abstract #5323. [6] Zeigler (2014) 45th LPSC, abstract #2665. [7] Sears, et al. (2016) MAPS 51.4, 833-838. [8] Blumenfeld et al. (2016) AGU abstract # ED42B-05.