QUANTITATIVE COMPOSITIONAL MAPPING OF BASALT 73002,186A FROM THE APOLLO 17 STATION THREE DOUBLE DRIVE TUBE.

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Introduction: In 1972, the Apollo 17 astronaut crew collected a ~70 cm double-drive tube core sample (73002 and 73001) at the station 3 stop and sealed it on the lunar surface. This core tube remained sealed for four decades until it became one of the subjects of the Apollo Next Generation Sample Analysis (ANGSA) program. This program seeks to study previously unopened lunar samples with methods and technologies not available to scientists when the Apollo samples were returned in 1969-1972.

While all lunar samples are precious material, this holds especially true for these previously unstudied samples. As such, it is important to maximize the scientific output of the samples before they are subjected to other scientific studies that are destructive (e.g., bulk rock noble gas analyses).

To maximize scientific return on these fragments and provide critical context for later analyses, we made quantitative compositional stage maps of the fragments. Because the output of quantitative compositional mapping is fully quantitative maps where each pixel contains a full chemical analysis, this method maximizes the major- and minor- element chemical information gathered from the samples. This technique has proven useful for the study of complex lunar samples which present analytical challenges because they are often fine-grained and heavily brecciated [1-4].

Methods: For this work, we were allotted 21 fragments from a variety of depths in the upper core, with sample masses ranging from 2 to 16 mg. This work will focus on one of those fragments.

Samples were processed at NASA Goddard Spaceflight Center (GSFC) to split fragments into two pieces – one sub-split for quantitative compositional mapping, and the other for bulk rock noble gas analyses. Samples for mapping were made into thin sections at The Smithsonian Museum of Natural History.

Quantitative Compositional maps were collected both at The Smithsonian Museum of Natural History and The Carnegie Institution for Science, following the methods of [1]. Both electron microprobes are a JEOL 8530F with 5 wavelength-dispersive spectrometers (WDS). We used JEOL and Probe for EPMA software to collect maps of representative portions of each fragment up to 575×530 pixels in size. Analytical conditions were 30 nA probe current, step and spot sizes of 1-2 µm, and count times of 100-300 msec. Prior to mapping, we completed a standard WDS calibration, and the map background removal was done using the mean atomic number (MAN) method. For each fragment, we mapped 14 common major and minor geological elements. Under these analytical conditions, map acquisition time was 15-30 hours for each fragment.

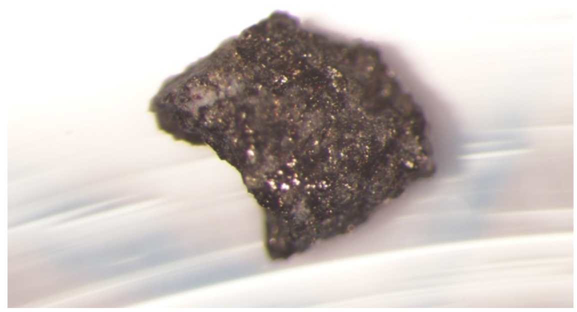

Figure 1. Fragment 73002,186A. This basalt is mostly dark black, but has lighter regions of adhered regolith. The fragment is 16.09 mg and 4 × 2.5 mm in size.

Post-collection map processing was done using CalcImage (Probe Software) and images were visualized and analyzed using Surfer (Golden Software). One challenge of mapping lunar samples is the fine-grained and brecciated nature. Thus, grain boundaries and cracks are included in the quantitative maps. To counter this issue, pixels with totals outside of the range of 97-103% were excluded from the data.

Preliminary Results: Thus far, we have made quantitative compositional maps of 12 fragments. Of the twelve fragments, one is basalt, one is norite, and the remainder are some type of breccias (impact, regolith, anorthositic). Here, we present the preliminary results of the mineralogy and composition of the single mapped basaltic fragment.

The basaltic fragment 73002,186A is a 16.09 mg rocklet taken from the 15.5-15.0 cm interval in drive tube 73002. The fragment is dark black with lighter regions where regolith has adhered to the surface. The portion used for quantitative compositional mapping is a polished 4 x 2.5 mm fragment.

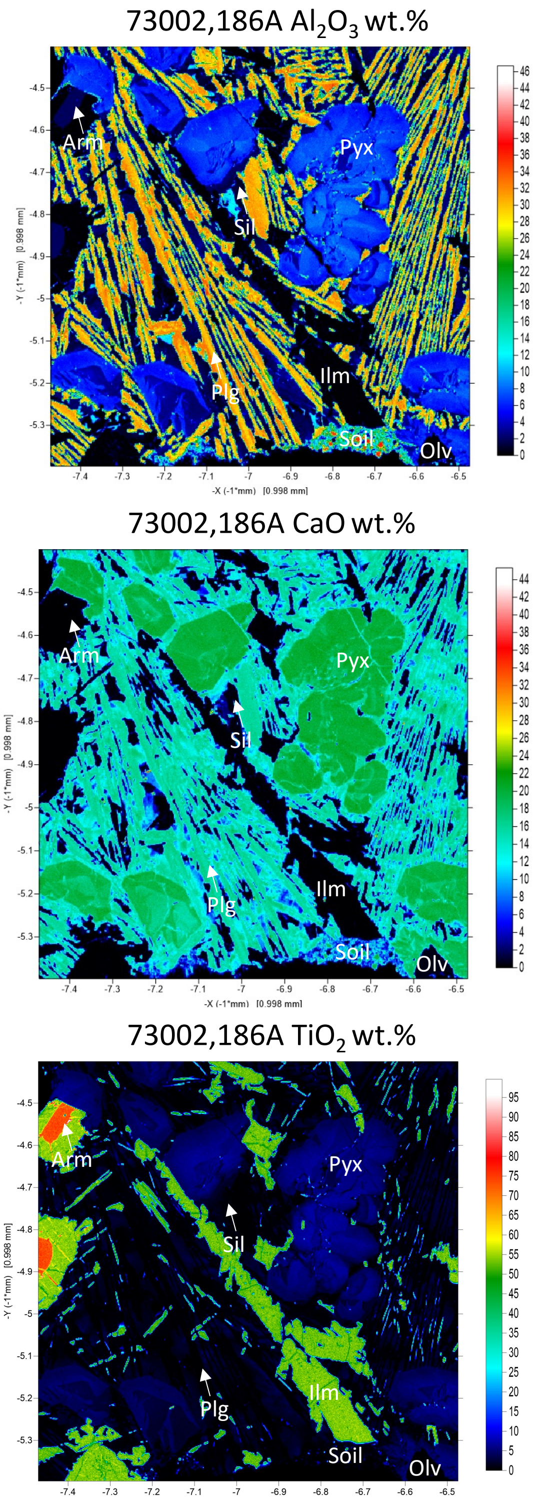

Figure 2. Quantitative compositional maps of 73002,186A. Each pixel in these maps correlates to intensity of characteristic X-rays of Al_2O_3 (top), CaO (middle), and TiO_2 (bottom). Arm = armalcolite, Ilm = ilmenite, Olv = olivine, Plg = plagioclase, Pyx = pyroxene, Sil = silica.

Sample 73002,186A is a high-Ti basalt (i.e., ilmenite basalt), which is typical for the Apollo 17 site. The major and minor mineralogy includes clinopyroxene, plagioclase, ilmenite, and silica. Fragments of olivine, troilite, phosphates, and armalcolite also occur. Clinopyroxene grains are subhedral up to 200 × 300 µm in size. Plagioclase occurs as laths intergrown with acicular ilmenite. Ilmenite also occurs as large laths, the longest being ~900 µm. Silica grains are relatively small at ~35 × 65 µm.

As seen in quantitative compositional maps in Fig. 2, armalcolite (red in TiO_2 map) occurs as cores rimmed by ilmenite (green in TiO_2 map). This rimming texture places constraints on the crystallization sequence of the basalt. In this case, ilmenite would have begun to crystallize before pyroxene, allowing reaction between the melt and armalcolite to crystallize ilmenite. If pyroxene had formed first, the armalcolite grains would have been surrounded by pyroxene and isolated from reacting with the melt [5]. Experiments by [5] demonstrate that this crystallization sequence indicates an oxygen fugacity near the iron – wüstite buffer.

Conclusions and Future Work: The textures that occur in this indicate the crystallization sequence was likely olivine → armalcolite → ilmenite → pyroxene → → plagioclase → silica. The mineralogy of 73002,186A is similar to the only basalt picked up at station 3 as an individual rock sample (73219), but differs texturally. Additional analyses of the chemistry will be needed to determine if they are from the same lava flow [6]. Next steps include bulk rock noble gas analyses of the split pair of the fragment analyzed here. We anticipate that this bulk rock noble gas analysis will provide insights into potential sources of input and destruction on the Moon. Noble-gas ratios and abundances provide important constraints on the amount and history of the solar wind and cosmic ray exposure record, indigenous degassing, and impact processing of the lunar surface [7]. These parameters help reveal the geologic history of a specific landing site as well as particles such as 73002,186A.

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