USING QEMSCAN MAPPING TECHNIQUES AS A METHOD OF IDENTIFYING POTENTIAL EXOGENOUSLY-DERIVED COMPONENTS IN APOLLO 17 73002 CONTINUOUS CORE THIN SECTIONS. S. K. Bell[1], K. H. Joy[1], M. Nottingham[1], R. Tartèse[1], R. H. Jones[1], J. J. Kent[2] and C.K. Shearer[3,4] and the ANGSA science team[5]. [1]Department of Earth and Environmental Sciences, University of Manchester, Oxford Road, Manchester, M19 3PL, UK (samantha.bell@manchester.ac.uk), [2]GeoControl Systems Inc., Jacobs JETS Contract, NASA/JSC, [3]Dept. of Earth and Planetary Science, Institute of Meteoritics, University of New Mexico, Albuquerque, New Mexico 87131, [4]Lunar and Planetary Institute, Houston TX 77058, [5]ANGSA Science Team list at https://www.lpi.usra.edu/ANGSA/teams/.

Introduction: The Apollo 17 landing site is located in the Taurus-Littrow Valley on the southeastern edge of Mare Serenitatis [1]. At Station 3 during EVA 2, a double drive tube was used to collect a core from the surface of the light mantle deposit, at the base of the South Massif [2]. The 73001/2 core sampled the upper ~70 cm of lunar regolith, with 73002 sampling the uppermost portion and 73001 sampling the lower portion [2-4]. This study is part of the Apollo Next Generation Sample Analysis (ANGSA) initiative to analyze the continuous thin sections from the Apollo 17 73002 drive tube opened in 2019 [5-7].

Core samples such as 73002 provide insights into the vertical mixing of the lunar regolith and the bombardment history of the lunar surface, preserving a record of the origins of meteoritic materials being transferred through the Solar System [8]. Searching for meteoritic fragments within lunar regolith and breccia samples has previously relied on collecting element maps of the samples and combining them to identify potential non-lunar mineral chemistries [9].

Quantitative Evaluation of Minerals by SCANing electron microscopy (QEMSCAN) is a non-destructive system of automated quantitative petrology that can produce mineral phase identification maps and qualitative element maps [10, 11]. The QEMSCAN software also contains a number of processors that can be used to highlight minerals of interest within a sample and physical properties (particle shape, etc.). As such, QEMSCAN has the potential to allow for rapid identification of minerals with potential non-lunar compositions in the mineralogically diverse Apollo 17 continuous core sections.

Samples: Thin sections were prepared and imaged optically using plane-polarized, cross-polarized, and reflected light at the NASA Johnson Space Center Apollo Curatorial labs. Here we present data for thin sections 73002,6011, 73002,6012, 73002,6013, and 73002,6014. These four thin sections span sampling depths of 0-4.7 cm (73002,6011), 4.8-9.5 cm (73002,6012), 9.6-14.2 cm (73002,6013) and 14.3-18.4 cm (73002,6014).

Methods: Samples were analyzed at The University of Manchester using an FEI QUANTA 650 field emission gun (FEG) scanning electron microscope (SEM), equipped with a single Bruker XFlash energy dispersive X-ray spectrometer (EDS). The QEMSCAN analysis was conducted using an accelerating voltage of 25 kV and a 10 nA beam current. All four thin sections were scanned in field image mode using a step size (i.e., pixel size) of 5 µm. The QEMSCAN software uses a Species Identification Protocol (SIP) list to assign a mineral to each pixel based on the EDS spectra and BSE brightness collected at each individual point. A modified version of a SIP list, specifically tailored towards lunar samples [10], was used to analyze the samples. In addition to mineral phase maps, backscattered electron (BSE), and elemental maps were also exported from the QEMSCAN datasets.

Our lunar specific SIP list was initially used in the iExplorer QEMSCAN software to classify all mineral phase maps. A secondary SIP list was subsequently developed to highlight minerals commonly found in meteorites (e.g., Fe-Ni alloys, Fe-sulphides, high-Mg olivine, high-Mg pyroxene, and Na-rich albitic plagioclase). Additional secondary SIP lists were also established to view the data in a number of useful ways including: (1) grouping SIP entries into broad mineral groups (i.e., augite, pigeonite, enstatite, etc. under the phase name “pyroxene”) and (2) to pinpoint specific minerals of interest, such as zircon or phosphate grains, for potential geochronology applications.

High resolution BSE images of clasts of interest, identified by the QEMSCAN analysis, were subsequently acquired using the same SEM as used to perform the QEMSCAN analysis. A Cameca SX100 electron microprobe (EPMA) at the University of Manchester was then used to measure major elements in points and line profiles across minerals within clasts of interest to help classification and identification of their sources. Analyses were performed on silicates, metals, and sulphides using a 15 keV accelerating voltage, 20 nA beam current, and a spot size of 1 µm.

Results: Several hundreds of occurrences of minerals of interest were highlighted in clasts across the four thin sections (Fig. 1). A manual review of each clast was carried out to exclude endogenous occurrences of highlighted minerals of interest (i.e., a Fe-sulphide grain in a mare basalt clast). This involved the cross-examination of other mineral phase maps (e.g. Lunar SIP list) and element maps (e.g., Mg, Fe, Al, Ca, etc.) within the QEMSCAN dataset for each thin section.

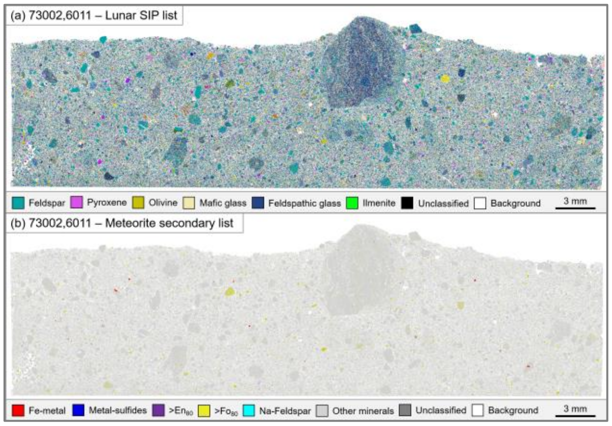

Figure 1: *(a) QEMSCAN mineral phase map of 73002,6011 shown with the full lunar SIP list and a simplified legend detailing the broad colors of the main phases present. (b) QEMSCAN mineral phase map of the same sample but shown with the "meteorite" secondary list, highlighting minerals commonly found in meteorites.*

A total of 232 clasts were considered for further investigation with high-resolution BSE imaging. A range of material was identified including igneous Mg-suite fragments, impact melt breccias, granulitic breccias, mare basalts, glass beads, feldspathic fragmental breccias, regolith breccias, granophyric material (High Alkali Suite), and clasts with sulphide-fayalite intergrowths. Following inspection of the high-resolution images, 33 clasts were selected for further study on the basis that they either have highly magnesian mafic phases, are metal or sulphide rich, have albitic plagioclase compositions, or have chondrules-like mineral textures. EPMA analysis of these clasts yielded a compositional range of Fo_{19} to Fo_{96} for olivine and Wo_{1-48} En_{29-90} Fs_{3-59} for pyroxene. Based on the Fe to Mn ratios of olivine and pyroxene in the clasts, the EPMA data suggests that these minerals are likely lunar as they have Apollo and lunar meteorite-like Fe/Mn ratios (Fig. 2). However, olivine Fo in some of the clasts is highly forsteritic (Fo_{94-96}), suggesting that these are some of the most magnesian lunar samples found to date (see also [13]).

Summary: QEMSCAN has proven to be a valuable and non-destructive tool for identifying regions of interest within petrologically complex samples, and could be applied to other existing Apollo core samples and drill cores retuned on future lunar sample-return missions, to address a range of scientific questions.

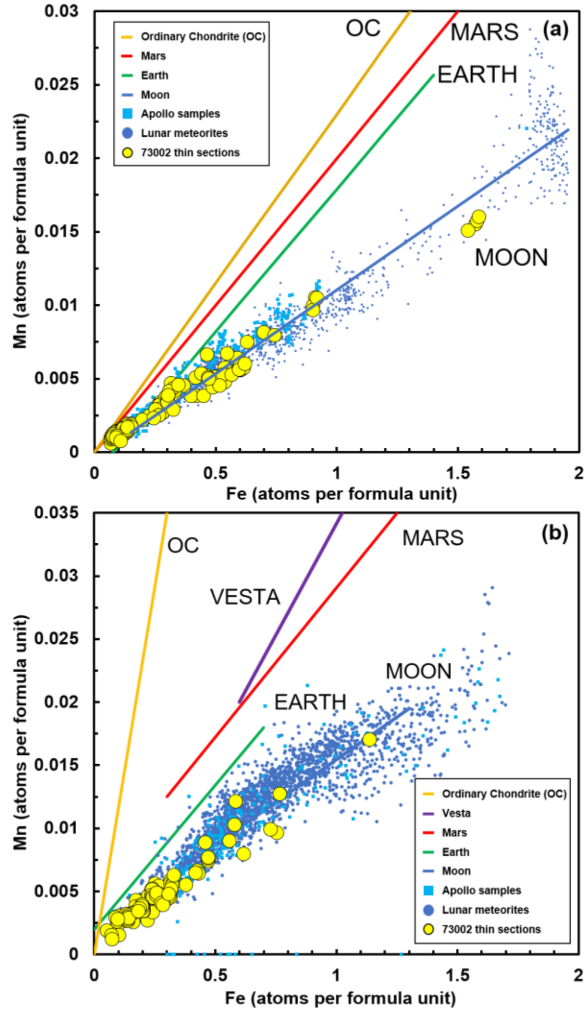

Figure 2: *Mafic mineral Fe-Mn ratios in clasts from 73002 continuous core thin sections for (a) olivine and (b) pyroxene. Planetary fractionation trend lines are shown [12], along with literature data for Apollo samples and lunar meteorites (after [9] and references therein).*

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