MICROSTRUCTURAL CHARACTERIZATION OF FELSITE FRAGMENTS FROM THE APOLLO NEXT GENERATION SAMPLE ANALYSIS (ANGSA) DOUBLE DRIVE TUBE 73001/73002.

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Introduction: While the Moon's surface is dominated by the mafic igneous products formed through crystallization of the lunar magma ocean, and the subsequent eruption of mare basalts – felsic lithologies (variably referred to as felsites, granites, rhyolites or granophyres) have been identified from a number of Apollo samples (*e.g.* 12013[1], 14321[2], 15405[3] and 73215[4]). Magmatic edifices like the Gruithuisen Domes – silicic constructs sometimes found proximal to the basaltic mare provinces filling nearside basins, may represent a petrogenetic origin. However, this is complicated by the fact that they apparently predate mare volcanism (e.g. [5]). Additionally, crater-counting indicates that these silicic surface features also postdate radiogenic ages of Apollo felsites [6].

Various modes of felsic magmatism have been invoked to explain the presence of felsic lithologies on the Moon, including: 1) fractional crystallization and silicate liquid immiscibility; 2) partial melting of lunar crust through basaltic underplating; and 3) fractional crystallization of the mare parent magmas. Although these models are plausible, based on known Apollo samples and lunar meteorites, they are complicated by the lack of sample lithologies with intermediate composition between basaltic magmas and the felsic components, and the fact that partial melting of many crustal rock types on the Moon (e.g., anorthosite, troctolites) are unlikely to form granites.

Along with other unique magmatic lithologies, new felsites have been identified within the < 1 mm size fractions of the ANGSA double drive core tube (73001/73002) from Apollo 17 Station 3, sampling the light mantle landslide deposit from the South Massif [7]. These additional examples of lunar felsite will help us to better constrain the processes that led to the formation of these evolved lithologies. To do this, we have employed a suite of high-resolution scanning electron microscopy (SEM) and scanning transmission electron microscopy (TEM) analytical techniques, including electron backscatter diffraction (EBSD), cathodoluminescence and conventional TEM dark field imaging. These data provide unique insights into the felsite mineralogy and microstructures including the

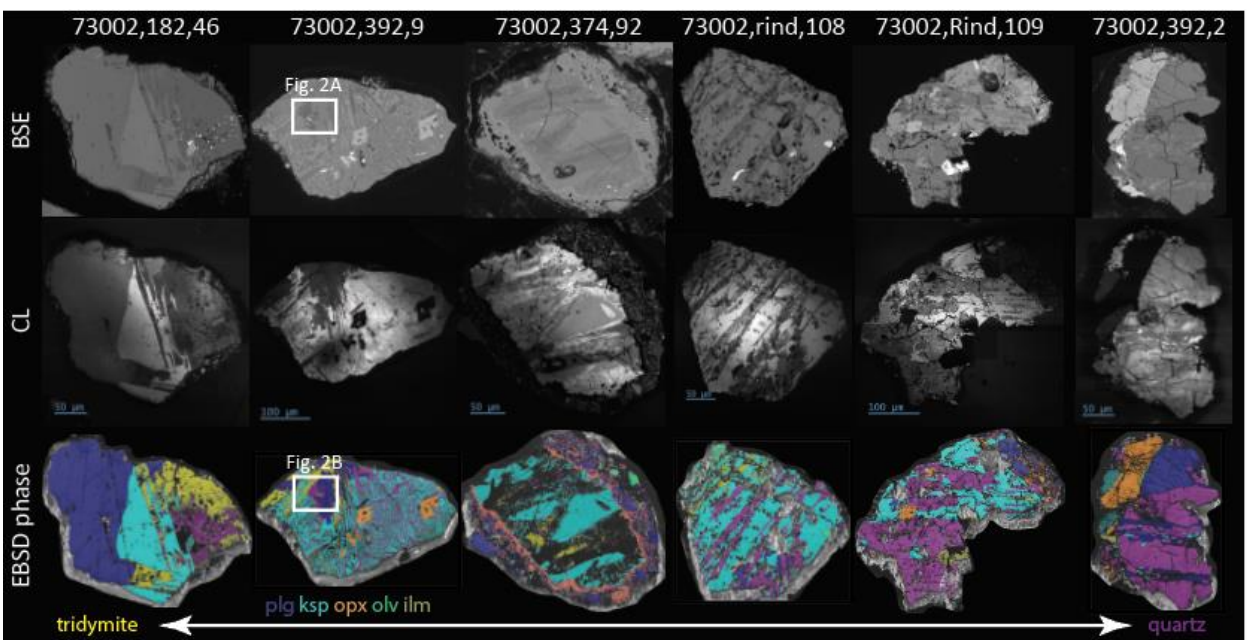

Figure 1. Backscatter electron (BSE), cathodoluminescence (CL) and electron backscatter diffraction (EBSD) phase maps of granophyric felsites from the >1 mm size fraction from 73002. The felsite fragments are composed of alkali feldspar, plagioclase, silica with minor pyroxene and ilmenite. Many of the felsites contain two polymorphs of silica - quartz and tridymite – that commonly appears intergrown. Box denotes area of Fig. 2.

coexistence of quartz and tridymite in many of the fragments. In addition, these analyses provide petrological context that will assist targeted *in situ* secondary ion mass spectrometry (SIMS) measurements of the U-Pb systematics of accessory minerals, and the volatile abundances and D/H ratios of apatite grains identified within the clasts.

Methods: The < 1 mm size fraction from the 73001/73002 double drive tube were initially sieved into multiple size fractions at the University of New Mexico (UNM). Each size fraction from the individual samples were then mounted in epoxy on circular thin sections and polished at UNM or NASA Johnson Space Center (JSC). During the determination of the modal mineralogy of each size fraction using scanning electron microscopy (SEM), felsic lithologies were identified and documented. Mineral phases were analyzed using a JEOL 8200 electron probe microanalyzer (EPMA) at UNM. The EBSD and CL analyses of the felsites was conducted using an Oxford Instruments Symmetry™ detector and a Gatan Monarc detector, respectively, mounted on a JEOL 7900F field emission SEM at NASA JSC. Based on EBSD microstructural characterization, an electron transparent foil was extracted from a felsite fragment using an FEI Quanta focused ion beam (FIB). The foil was then analyzed using an JEOL 25000 FE-STEM instrument. Future analyses will include laser Raman characterization of the SiO_2 polymorphs; SIMS U-Pb analyses of zircon, baddeleyite and phosphates; *in situ* volatile, D/H and $^{37}Cl/^{35}Cl$ measurements of apatite; and LA-ICP-MS trace element analyses of the major phases.

Results: To date, one felsite fragment has been identified in the 500-250 µm size fractions, and eight fragments have been recovered from the 250-125 µm size fractions. Of the nine felsites, six exhibit a micro-granophyric texture with intergrown lamellae of alkali-feldspar, plagioclase and SiO_2 (Fig. 1). The alkali feldspar is Or_{85-98} with 0.8-3.6 wt.% BaO, and plagioclase are $\sim An_{67}Ab_{25}Or_{08}$. Preliminary analyses of SiO_2 phases indicate relatively high Ti concentrations (450 to 1700 ppm; [7]). The felsites also contain minor pyroxene, ilmenite, and accessory zircon, baddeleyite, apatite and merrillite, which will be used to study the chronology and volatile reservoirs of these fragments. Of particular interest, many of the granophyric felsites contain two polymorphs of SiO_2 (quartz and tridymite) as indexed by EBSD (Fig 1 and 2). The quartz appears hackle textured, contains numerous dauphiné twins, and potentially replaces the tridymite (Fig. 2B). To better resolve the relationship of the SiO_2 polymorphs, one of the FIB foils was extracted across the boundary between these two phases. Conventional TEM brightfield imaging of this interface reveals a complex, ragged intergrowth of quartz and tridymite (Fig. 2C – D).

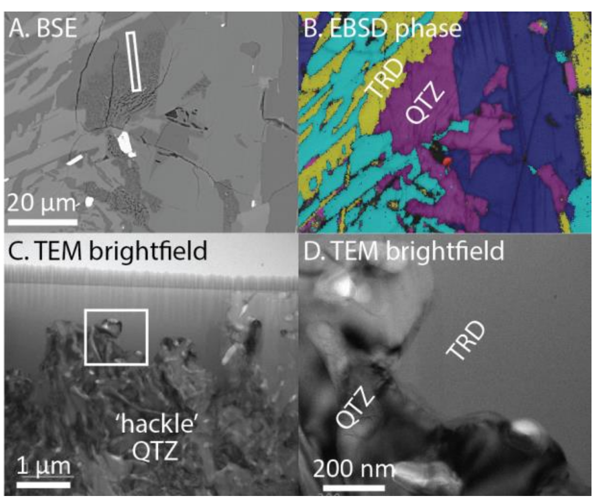

Figure 2. BSE, EBSD and conventional TEM brightfield images of quartz (QTZ) and tridymite (TRD) intergrowth from 73002,392 clast 9.

Discussion: The presence of felsic fragments in the light mantle deposit at Station 3 was unexpected, as these materials have not been detected by remote sensing within the source region of the South Massif. Nevertheless, the intergrowth of tridymite and quartz within the felsite fragments suggests high-temperature formation followed by a complex cooling history. This microstructural characterization will help guide the collection and interpretation of volatile element and isotopic analyses, as well as accessory mineral U-Pb geochronology from these felsite fragments, helping resolve the origin of these fragments, and thus silicic magmatism on the Moon.

References: [1] Quick J. E. et al. (1981) *Proc. 12th Lunar Planet. Sci. Conf.*, 117-172. [2] Warren et al. (1983) *EPSL*, v. 64, 175-185. [3] Ryder G. (1976) *EPSL*, v. 29, 255-268. [4] James O.B. and Hammarstrom J.G. (1977) *Proc. 8th Lunar Sci. Conf.* 2459-2494. [5] Grange et al. (2013) *J. Geophys. Res. Planets*, v. 118, 2180-2197, [6] Simon J 2018 *New Views of the Moon 2 – Asia* #6021 [7] Shearer et al. (2022) *Apollo 17 - ANGSA Workshop* #2004.