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Thermal History of Lunar Silicic Magmas

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Silicic magmatism on the Moon has been a long-standing interest owing to the lack of water and plate tectonics typically invoked in the genesis of high-SiO_2 magmas on Earth. Processes such as extensive fractional crystallization, basaltic underplating, and silicate liquid immiscibility have been proposed as mechanisms for producing lunar silicic magmas [c.f., 1]. To inform these models, we have conducted coordinated microanalytical studies of felsic igneous rock fragments from Apollo 12, 14, 15, 16, and 17.

Thin and thick section samples were imaged and compositionally mapped using a scanning electron microscope (SEM). Mineralogy and microstructures were characterized using electron backscatter diffraction (EBSD) and transmission electron microscopy (TEM), and mineral compositions were analyzed using an electron probe microanalyzer (EPMA) at NASA Johnson Space Center. Our EBSD results indicate that felsite groups can be distinguished by the presence or absence of tridymite, a high-temperature silica polymorph. We interpret the existence of tridymite in select felsite samples to reflect higher equilibration temperatures, in contrast to relatively cooler samples where only quartz is stable.

To quantitatively estimate the equilibration temperature for each felsite sample, we have conducted EPMA analyses for Ti-in-quartz [2] and Ti-in-tridymite [3]. Our thermometry results support the temperatures inferred from the stability of each silica polymorph. We complement our Ti-in-quartz and Ti-in-tridymite interpretations with two-feldspar and two-pyroxene thermometry when possible. Additionally, we find extensive evidence for "ternary" feldspar compositions with significant solid solution between anorthite and orthoclase. Our SEM, EBSD, EPMA, and TEM analyses indicate that these ternary feldspars are stoichiometric, homogeneous single crystals.

Our microanalytical campaign reveals complex thermal histories recorded in the Apollo felsite samples and support multiple styles of silicic magmatism on the Moon. Remote sensing has identified extrusive silicic domes on the lunar surface, and we identified felsite microstructures similar to those found in terrestrial rhyolites. We also found geochemical and mineralogical evidence consistent with a non-extrusive thermal history in a shallow intrusive granite body, such as those proposed at Aristarchus and Compton-Belkovich.

[1] Shearer et al. (2023) RiMG, *89,* 147-206.
[2] Osborne et al. (2022), CMP, *177*, 31.
[3] Ackerson and Mysen (2020), AmMin, *105*(10), 1547-1555.