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Geochemistry, petrology, and cooling history of 14161,7373: A plutonic lunar sample with textural evidence of granitic-fraction separation by silicate-liquid immiscibility

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Abstract

We report new findings related to sample 14161,7373, the first analyzed lunar intrusive rock to show textural evidence for the formation of granitic material by silicate liquid immiscibility (SLI) and geochemical evidence for separation of that material, at least on a small scale, from mafic residua. Ion microprobe analyses of rare-earth element (REE) concentrations in silicates record the compositional evolution of this late-stage assemblage. For a sample whose bulk assemblage, that of whitlockite monzogabbro, has REE concentrations at ~5–6× KREEP levels, the silicates have only moderately high REE concentrations. The calculated REE concentrations of melt in equilibrium with pigeonite, after re-integration of pigeonite host and augite lamellae, is approximately 2× high-K KREEP. The high bulk REE concentrations of the assemblage are the result of a high proportion of whitlockite, probably an excess, i.e., the assemblage is a whitlockite cumulate. Variations in silicate REE concentrations reflect the co-crystallization of whitlockite, which we interpret to have begun crystallizing prior to the onset of late-stage immiscibility of the felsic melt fraction. Calculated cooling rates, based on a quantitative model of pyroxene exsolution, reveal a two-stage thermal history, which involved initial crystallization at a minimum depth of 700–800 m during which the primary augite and pigeonite grains unmixed to form the observed host-lamella pairs. Unusual compositional profiles close to the host-lamella interface are consistent with a second stage of mild reheating followed by rapid cooling at a depth of ~30 m, most likely in an ejecta blanket. The shallow depth of origin indicated for 14161,7373 is consistent with other studies of evolved lunar intrusive rocks, supporting the interpretation that lunar QMD and granite, as found among the Apollo samples, are late-stage differentiates of high-level intrusions and are not related to differentiation of deep crustal KREEP reservoirs.