Mineralogical Studies of Apollo 12 Samples

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This joint report presents results of petrographic, microprobe, single-crystal X-ray diffraction, and Mössbauer studies of five Apollo 12 crystalline rocks. The samples are composed of pyroxene, olivine, plagioclase, and ilmenite and contain accessory metallic Fe, troilite, pyroxferroite, and silica. The samples are generally similar to Apollo 11 samples in their igneous origin, anhydrous character, and evidently low oxidation state; however, they exhibit a wider range of compositions and contain less opaque phases.

Four of the samples (12004, 12018, 12021, and 12040) contain large (~ 2-5 mm) grains of pyroxene, olivine, and Ca-rich plagioclase which often occur in a finer crystalline groundmass. The following chemical and mineralogical data indicate that the larger grains are approximately contemporaneous with the groundmass and do not represent a period of early crystal formation deep in the lunar interior:

(1) Large pyroxene and olivine grains are variable in composition. A general increase in Fe towards grain margins is apparently related to similar Fe enrichment in the groundmass.

(2) Cores of large pyroxene grains are pigeonitic while rims tend to be subcalcic augite, but considerable compositional variation is present. In samples 12004 and 12018, groundmass pyroxenes show Ca and Fe enrichments relative to the large grains.

These data suggest that crystallization of the samples occured, briefly and continuously, over a small temperature range at or near the lunar surface. Formation of large crystals at shallow depths is promoted by the low viscosity and consequently high crystallization rates of the low-Si, high-Fe melts. Sample textures do not indicate a unique crystallization history for all specimens, a condition which may arise from slight differences in bulk compositions or temperature for melt compositions near an eutectic. However, textures in some samples (e.g., 12004) suggest that olivine and pigeonitic pyroxene crystallized first to form larger grains, followed by crystallization of a finer-grained groundmass consisting of pigeonite and/or subcalic augite, plagioclase, and ilmenite. Residual enrichment in Fe, Si, and K is indicated by the presence of pyroxferroite, silica, and a K- and Fe-rich mesostasis.

Occurrences of particular interest include:

(1) indigenous Ni-Fe grains, similar in composition to the metallic phase of stony meteorites (e.g., 12004).

(2) native copper (12040).

(3) anorthite crystals formed around pyroxene cores, probably as a result of rapid feldspar crystallization (12018, 12021).

(4) garnet (12021).

(5) late-stage metal in fractures in olivine grains, possibly as a result of vapor deposition.