OLIVINE-PORPHYRITIC VITROPHYRE 12024,15: A SAMPLE OF THE MARGIN OF A LUNAR LAVA FLOW

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Lunar sample 12024,15 is a 14.1-g (3 x 2 x 1 cm) rocklet from the coarse fraction of a soil sample obtained near Sharp Crater, at the extreme SW end of the Apollo 12 traverse. Except for a binocular-microscopic description by Marvin [1], 12024,15 was previously unstudied, perhaps in part because as first received in Houston it was covered by a thick (several mm) layer of adhering dust. Following removal of nearly all of the dust, Marvin [1] noted that on one side of the rock (the "T" side), the surface has a distinctive appearance that strongly suggests quenching of the top of a lava flow. Marvin noted in particular "a microtopography of tongues and ponds of smooth bronzy glass . . . . resembling that of quenched slags." She also described the rock as having yellow olivine crystals (up to 2 mm) evenly distributed through a cryptocrystalline or glassy matrix.

Our own binocular-microscopic examination (3/89) showed that in addition to the amorphous glassy material and euhedral olivine phenocrysts observed by Marvin [1], the rock consists largely of microlitic sheets, arranged in groups of typically ~ 20 parallel sheets, typically 0.6-0.8 mm long and spaced roughly 30-40 μm apart, to form blocks spanning roughly 0.7 x 0.7 mm in two-dimensional view. These blocks appear to resemble tiny unbound "books," composed of thick microlitic "pages" of uneven height and width. We have studied petrographically a 21 mm^2 thin section and geochemically a 360 mg chip. The thin section was taken from a zone known to contain "book" texture, but not particularly close to the suspected flow-top side of the rock. The composition of 12024,15 shows it to be an ilmenite basalt, very similar to 12008 [2], which it also resembles texturally. This classification is based on plots such as Mg (70 mg/g) vs. Ti (29 mg/g), Si (200 mg/g), Sr (160 μg/g) and Sm (5.9 μg/g), and Ca (66 mg/g) vs. Ti.

The thin section consists of ~ 10.2% olivine phenocrysts, a large trace of chromite (as blocky euhedral grains up to 120 μm across, typically in glomeroporphyritic clusters or else associated with rims of olivine phenocrysts), a trace of FeNi (associated with chromite), and the groundmass. The olivine phenocrysts are for the most part remarkably euhedral — the largest olivine visible in the Figure is fairly typical. In some cases they are slightly skeletal, with roundish enclaves of glassy, groundmass-like material. These phenocrysts are typically ~ 0.3 mm across, and occur in glomeroporphyritic clusters. The largest individual crystal is 1.0 mm across, or 2.0 mm if three widely separated outcrops that appear to be in optical continuity are regarded as a single phenocryst. Some of these phenocrysts feature thin (a few tens of μm), gradually tapering spikes grown out from from one apex of the crystal. The lengths of these spikes are in a few cases comparable to the maximum dimension of the main body of the phenocryst.

The groundmass consists mainly of glass (and submicroscopic devitrification products), but also contains abundant platy, "book"-textured olivine microlites, and a far lesser proportion of irregular-dendritic microlites, some of which might possibly be pyroxene. The regular olivine microlites are generally <3 mm in width (those shown in the Figure are relatively fat), but up to 0.7 mm long. The largest "book" of them is 1.2 mm thick. The thin section is generally too thick to ideally exhibit the "book" texture. In a few places large areas of the goundmass simply appear opaque. However, at least 3/4 of the groundmass is book-textured, and the amorphous-seeming parts may simply be zones where where the section is thickest in relation to the thin sheets of olivine. The sheets of olivine appear at high magnification to be discontinuous chains, albeit all of the microlites within a given "book" typically go to optical extinction en masse.

The olivine phenocrysts are $Fo_{68.2-70.7}$ in their interiors, but are zoned in their outermost ~ 4 μm, down to $Fo_{63.0}$. The core olivine composition is slightly less magnesian than the crystals that would be in equilibrium (Fo_{75}, assuming K_D = 0.30) with a melt having the bulk rock composition (*mg* = 0.475). However, if the olivine and chromite phenocrysts are subtracted from the bulk rock composition, to yield the composition of the groundmass that was potentially in equilibrium with the phenocrysts, the predicted

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equilibrium phenocryst composition is ~$Fo_{70.1}$. The olivine microlites are generally too slender to probe, but one of the fattest ones gave a composition of $Fo_{61.0}$. The chromite has *mg* ~0.30.

Besides 12024,15, at least three other Apollo 12 basalts are also olivine-porphyritic vitrophyres: ilmenite basalt 12008 [3], and olivine basalts 12009 and 12015 [4,5,2]. Both 12008 and 12015 are said to be texturally similar to 12009. Compared to 12024,15, the microlites in the groundmass of 12009 are much coarser, typically 30-40 μm in width [4,5], whereas in 12024,15 they are typically 30-40 μm *apart*. Thus, the final stage of cooling was probably faster for 12024,15 than for 12009. Another, perhaps related difference is that the 12009 microlites are "rarely grouped in parallel and never so uniformly as in [komatiitic] 'spinifex' rock" [5], whereas the degree of parallelism in 12015,15 is impressively similar to that seen in the most highly-developed terrestrial spinifex textures (albeit the scale is different).

Walker et al. [6] suggested that 12009 may have cooled at roughly 500°/hr, only about 3-7 cm from the top of its flow. Assuming that the slight bulk-compositional difference between 12024,15 and 12009 is not chiefly responsible for the differences between their groundmass textures, the final stage of cooling appears to have been considerably faster for 12024,15 than for 12009. Thus, the suggestion of Marvin [1] that 12024,15 represents the very top of a lava flow appears to be essentially confirmed. Alternatively, however, the rapid cooling and distinctive surface of 12024,15 might reflect genesis at the bottom, or even at one of the distal margins, of a flow.

Donaldson [7] documented systematic changes in olivine morphology related to cooling rate during growth, in experiments using a synthetic analog of 12009 as the starting liquid. Based on Donaldson's [7] scale, the 12024,15 olivine phenocrysts grew in an environment with -dT/dt nearly constant at ~1-2 °C/hr. The 12009 olivine phenocrysts are of two types [8]. The 12009 "type I" phenocrysts are comparable to the 12024,15 phenocrysts, but the "type II" phenocrysts tend to be far more skeletal [8]. Donaldson et al. [8] interpreted the cooling rate of the "type I" phenocrysts as evidence for growth as a melt of 12009 composition cooled while rising in the lunar crust, and suggested that the "type II" phenocrysts grew during a phase of intermediate-rate cooling, possibly within a mass of lava undergoing turbulent transport across the lunar surface. This general type of model is equally plausible for 12024,15, except genesis of 12024,15 apparently involved an abrupt transition from the slow, "type I" cooling environment to an environment of extremely rapid cooling.

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Figure: Thin section 12024,55, in transmitted light. The smaller two of the three olivine phenocrysts in this view are among the *least* euhedral in the TS. Near the top may be seen part of a "book" of microlitic olivines. Figure is actually a mosaic of a short-exposure photo (the lower 63%) and a short-exposure photo (the upper 37%).