

THE CONTRAST OF CHEMICAL MODELING WITH PETROGRAPHIC REALITY: TAPPING OF APOLLO 15 OLIVINE-NORMATIVE MARE BASALT MAGMA; Benjamin C. Schuraytz and Graham Ryder, Lunar and Planetary Institute, 3303 NASA Road One, Houston, TX 77058

Our chemical analyses of a suite of 25 Apollo 15 olivine-normative mare basalt samples, using 4 to 5 g splits, validate previous conclusions that the suite chemistry is controlled by the removal of olivine [1-6]. Analyses of a few coarser-grained examples deviate from such control due to inhomogeneous sampling of pyroxene, plagioclase, or mesostasis even at this scale. Our analysis of chemistry, mineral separates, and petrography [7], including the results of other workers, demonstrates that short-range unmixing is not responsible for the differences *among* samples, but rather that the samples dominantly represent separate, though related magmas. If short-range unmixing took place, it did so only at the scale of a few centimeters.

The simplicity of the chemical model suggests simple relationships, with a sequence including cumulate olivines and successive fractionates. The petrography of the samples, however, is inconsistent with any simple model of production of these basalts from a common parent fractionating at the surface (unlike the Apollo 12 olivine basalts). In particular, the chemistry, morphology, and abundance of the olivine in the samples is not consistent with simplicity. We have been making a detailed study of olivine as it relates to crystallization of the samples. In particular, we are attempting to identify the most primitive magma extruded and the relationship of the other samples to it.

The suite lacks samples with apparent cumulate olivine. Nearly all of the olivines are smaller than 1 mm, and grains as large as 2 mm are extremely rare. Common descriptions of olivine as "phenocrysts" generally stretch the normal definition of the word. The modal abundances of magnesian ($Fo > 50$) olivines are rarely as great as 10%, even in the most magnesian varieties, and are inadequate to produce the least-magnesian members even if all the olivine were cumulate. Thus at least most of the olivine responsible for the chemical variation of the suite was not sampled, and may never have been extruded.

In most cases, the compositions of olivine cores are not those predicted to be in equilibrium with a liquid of the bulk rock composition, but are more iron-rich. While this in principle could indicate excess (cumulate) olivine, the low modal abundances suggest instead reaction with the melt on cooling, with diffusion first to partially re-equilibrate Mg/Fe, then reaction of olivine with the melt to produce pigeonite. The anhedral morphologies of olivine are also consistent with some reaction and resorption. Vesicular basalts tend to have olivine cores closer to the predicted compositions (Fig. 1), consistent with these samples representing liquid compositions and being rapidly cooled (and thus retaining vesicles).

The most evolved sample, 15556, is fine-grained and vesicular. The vesicles vary regularly in size across the sample [8]. The olivines show a range in abundance: where the vesicles are largest, olivine is sparse (in some cases virtually absent over 1 cm^2), but where vesicles are smallest, olivine is common ($\sim 5\%$). The core compositions are the same, regardless of location; the grains may be on average slightly larger where the olivine is more abundant, but the difference is slight, with most 0.5 to 1.0 mm. The morphology ranges from fairly equant grains to branching grains indicative of super-cooling, and such varied grains appear adjacent to each other (Fig. 2a). Some grains are compound, and in some areas are clustered or in chains (Fig. 2b). The entire

sample suggests rapid cooling but still with redistribution of olivines.

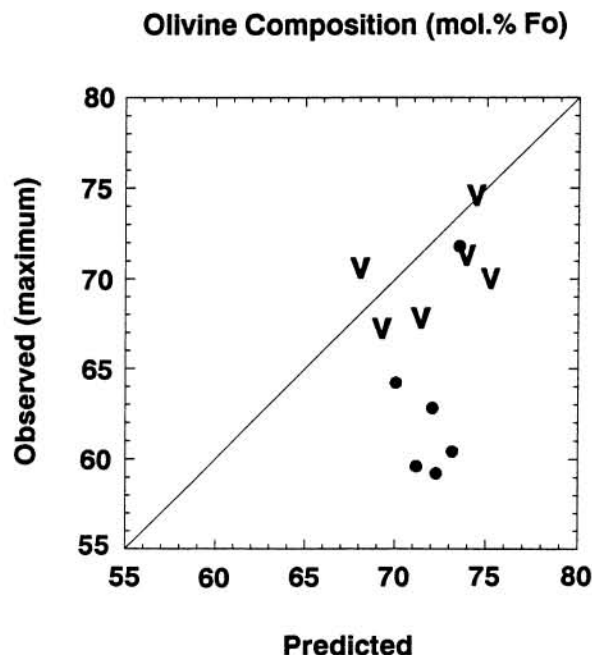


FIG. 1. Plot comparing maximum Fo content observed in olivine cores with Fo content of olivine predicted to be in equilibrium with a liquid of the bulk rock composition. Vesicular basalts (V) tend to have olivine cores closer to the predicted compositions than do the non-vesicular basalts (•).

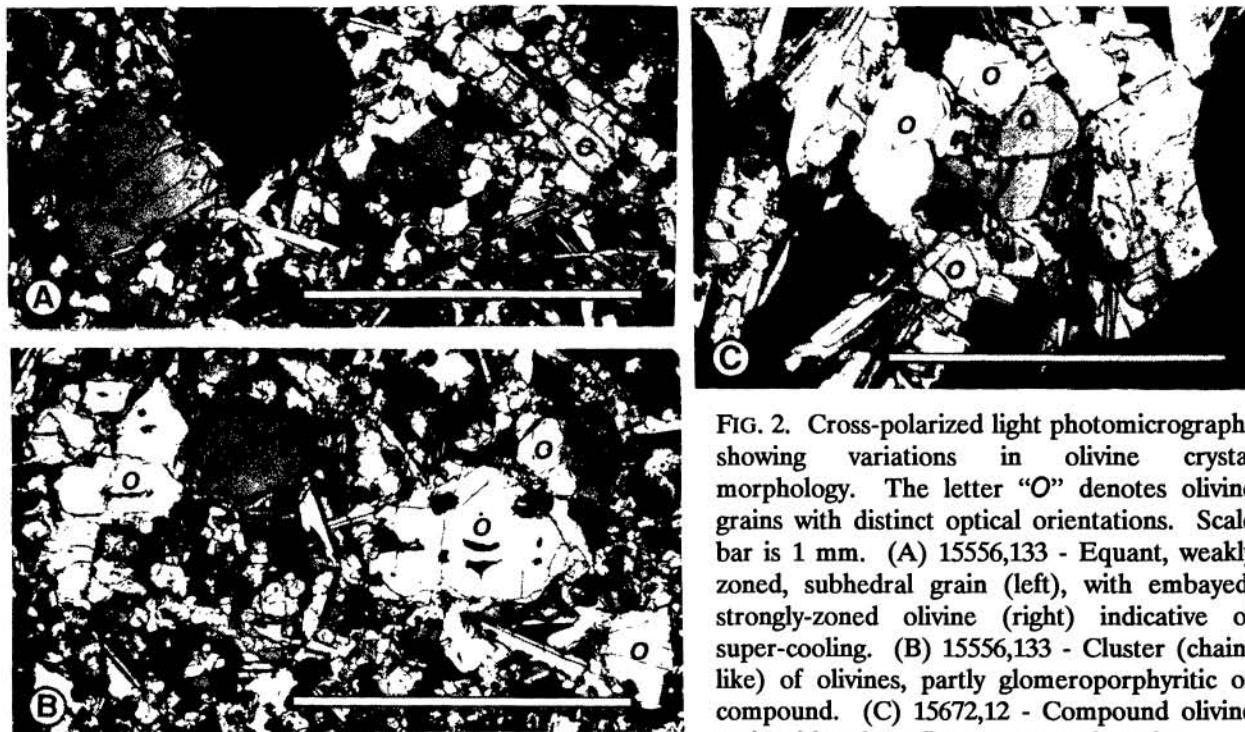


FIG. 2. Cross-polarized light photomicrographs showing variations in olivine crystal morphology. The letter "O" denotes olivine grains with distinct optical orientations. Scale bar is 1 mm. (A) 15556,133 - Equant, weakly zoned, subhedral grain (left), with embayed, strongly-zoned olivine (right) indicative of super-cooling. (B) 15556,133 - Cluster (chain-like) of olivines, partly glomeroporphyritic or compound. (C) 15672,12 - Compound olivine grain with at least five separate sub-grains.

The most magnesian vesicular samples (e.g. 15672), tend to have coarser-grained groundmasses than 15556, but their olivines are not larger. In 15672 and 15622, the most magnesian samples (and virtually identical in all respects), many olivine grains are compound (Fig. 2c), and some small, rounded olivines (not the most magnesian) are embedded in distinct *pigeonite* phenocrysts. Given that in such a composition olivine crystallizes about 100°C above pigeonite, such a texture is unusual and perhaps implies two stages of cooling. The olivines cannot be considered cumulate, and these two samples would appear to represent magmas, the most primitive of this suite extruded. Even in coarse-grained, non-vesicular (but vuggy) sample 15555, which crystallized much slower, the amount of olivine, its size, and its composition, do not suggest olivine accumulation; 15555 too is probably a liquid composition.

The varied nature of the Apollo 15 olivine-normative mare basalt suite suggests that the suite represents many separate magma compositions, related by olivine separation that took place elsewhere. The samples represent several distinct cooling histories in which olivine reaction was common. However, the common vesicularity and correlated indication of rapid cooling from the liquidus suggests that magmas were released from a source from which gases had not been released, indicating that the vents were not far away from the collection site. This is consistent with the great variety of basalts, including rapidly-cooled ones, collected within a few square meters at St. 9a. We suggest that the inferred olivine fractionation took place in a subsurface magma plumbing system that was successively tapped.

References: [1] RHODES J. M. and HUBBARD N. J. (1973) *Proc. Fourth Lunar Sci. Conf.*, 1127-1148. [2] CHAPPELL B. W. and GREEN D. H. (1973) *Earth Planet. Sci. Lett.*, 18, 237-246. [3] MASON B., et al. (1972) *Proc. Third Lunar Sci. Conf.*, 785-796. [4] HELMKE P. A., et al. (1973) *The Moon*, 8, 129-148. [5] RYDER G. and STEELE A. (1988) *Proc. Eighteenth Lunar Planet. Sci. Conf.*, 273-282. [6] SHERVAIS J. W., et al. (1990) *Proc. Twentieth Lunar Planet. Sci. Conf.*, 109-126. [7] SCHURAYTZ, B. C. and RYDER, G. (1990) *53rd Ann. Meeting Met. Soc.*, 150. [8] RYDER G. (1985) *Curatorial Branch Publication 72, JSC 20787*, NASA Johnson Space Center, Houston, 1296 p.