

ANHYDROUS LIQUID LINE OF DESCENT OF YAMATO 980459 AND EVOLUTION OF MARTIAN PARENTAL MAGMAS. J. F. Rapp^{1,2}, D. S. Draper² and C. M. Mercer³, ¹Lunar and Planetary Institute, USRA Houston TX (jennifer.f.rapp@nasa.gov). ²Astromaterials Research Office, ARES Directorate, NASA Johnson Space Center, Houston TX (david.draper@nasa.gov). ³School of Earth and Space Science, University of Arizona, Tucson AZ.

Introduction: Martian basalts represented by the shergottite meteorites reflect derivation from highly depleted mantle sources (high ϵ_{Nd} , strong LREE depletions, low $f(\text{O}_2)$) [1 – 3], with evidence of mixing with a much more enriched and oxidized reservoir, most likely a late-stage product of crystallization of an initial martian magma ocean [3–6]. The martian basaltic meteorites Yamato 980459 (Y98) and QUE 94201 (QUE) have bulk compositions that appear to represent bona fide liquids, rather than products of protracted crystallization. These two meteorites also represent the most primitive and evolved examples of the depleted basaltic shergottite suite. Magmatic liquids serve as effective probes of their source regions, and thus studying the potential relationship between magmas represented by Y98 and QUE can yield important information on the formation and evolution of martian basalts.

Although the ages of these meteorites preclude that they are petrogenetically related to each other, they represent the best existing candidates for genuine liquids (other meteorites are suggested to represent liquid compositions, including LAR 06319 [7] and NWA 5789 [8], but only Y98 and QUE have been verified experimentally). They span much of the bulk-compositional range of martian basaltic meteorites, and represent end-member liquid compositions likely to arise from partial melting of the martian mantle. Recent efforts to model Y98-like parent liquid evolution by fractional crystallization using MELTS [6] produced a derivative liquid composition that closely matches QUE bulk composition, although it required a somewhat unusual crystallization sequence. Experimental endeavours to verify this result at 1 bar have, however, been inconclusive [9].

We present the results of nominally anhydrous crystallization experiments on a Y98 liquid composition at 0.5 GPa (martian mid-crust) under both equilibrium and fractional crystallization regimes. We compare the down-temperature liquid compositions with that of QUE, and the resulting phase assemblages and compositions with those inferred by the MELTS models of Symes et al. [6]. We show that, although Y98 and QUE appear to sample a similar mantle source, neither equilibrium nor fractional crystallization seem to derive a QUE-like magma (i.e. liquid plus phase assemblage). We also show that the spectrum of magmas derived from a Y98-like precursor melt encompasses composi-

tions similar to calculated parental melts of shergottite meteorites, including those which are suggested to also represent liquid compositions.

Experimental and Analytical: Starting material was a synthetic Y98 glass powder, Y98A, conditioned at the iron-wüstite buffer at 1000°C for 24 hours. This material has been used in several previous experimental studies [10 – 12], eliminating at least one source of discrepancy between them. Experiments were performed in a 13mm QuickPress piston-cylinder at NASA Johnson Space Center using BaCO_3 cells fitted with graphite heaters and sample capsules. BaCO_3 was used to maximize the anhydrous conditions in the experiments, as previous runs in talc-pyrex cells [10] were determined to contain small and variable amounts of H_2O . Equilibrium crystallization was simulated by performing a series of experiments at decreasing temperatures, in which charges were heated to 1600°C (well above the liquidus) and then cooled swiftly to the temperature of interest, then held for at least 3 hours. Fractional crystallization was simulated by carrying out iterative experiments in which each bulk composition was synthesized to match the measured liquid composition from the previous, higher-temperature experiment. Run products were analyzed by electron microprobe at NASA Johnson Space Center, using a 15kV, 20nA beam.

Results: Experiments reported here were conducted at final temperatures ranging from 1500 – 1000°C. In the equilibrium experiments, liquid composition evolves to a composition similar to QUE by 1200°C. However, the crystallizing assemblage does not resemble that in QUE (Fig. 1A) as had been predicted by MELTS [6]. Olivine is present in all experiments, and plagioclase occurs in low abundance at high degrees of crystallization. Experimental pyroxene compositions evolve towards those of QUE, but remain within the range of pyroxene compositions found in Y98.

In the fractional experiments, the liquid composition does not match QUE, particularly in terms of minor elements such as P and Ti. Crystallizing assemblages are also not a good match for QUE (Fig. 1B), and the pyroxene compositions produced match neither Y98 nor QUE. These experiments also produced no low-Ca pyroxene, making it difficult to account for the

formation of zoned pyroxenes observed in QUE [13] by fractional crystallization.

Discussion: The experimental results indicate that QUE did not form by fractional crystallization of a Y98-like parental melt, as had been suggested by MELTS. Moreover, the crystallization sequence observed in both sets of experiments does not match with that predicted by MELTS. However, a QUE-like melt composition is produced by approximately 90% equilibrium crystallization of a Y98 parental melt. When this composition was crystallized at 1000°C, the assemblage matched QUE quite well (experiment Y98_QP13, Fig. 1B).

The melt compositions produced by equilibrium crystallization of Y98 also follow a trend that encompasses the calculated parental melts of other shergottites (Fig. 2). This relationship indicates that the bulk source lithologies of shergottites are similar, regardless of trace element enrichment, which must arise later. This enrichment may be due to crustal contamination, although other element correlations one might expect from contamination are lacking. Therefore our findings are more consistent with the notion of very enriched, residual material resulting from crystallization of a magma ocean [3, 6], which is later incorporated into shergottite basalts. In this model, no systematic major element variation is expected with trace element enrichment, due to the exotic nature of the enriched material.

Implications for the petrogenesis of martian basalts: Although there is no petrogenetic link between Y98 and QUE since they have different crystallization ages, our experiments have shown that a melt composition similar to QUE can be produced by large degree crystallization of Y98. Subsequent isolation and crystallization of this melt could have produced a basalt similar to QUE. This is somewhat similar to bimodal volcanism on Earth. Our experiments also suggest that different degrees of partial melting of a narrow range of mantle sources can produce all of the shergottites, and support the existence of highly enriched material within the martian mantle to produce the observed trace element variations in shergottites. This material is probably the residual melt from crystallization of a magma ocean of unknown extent.

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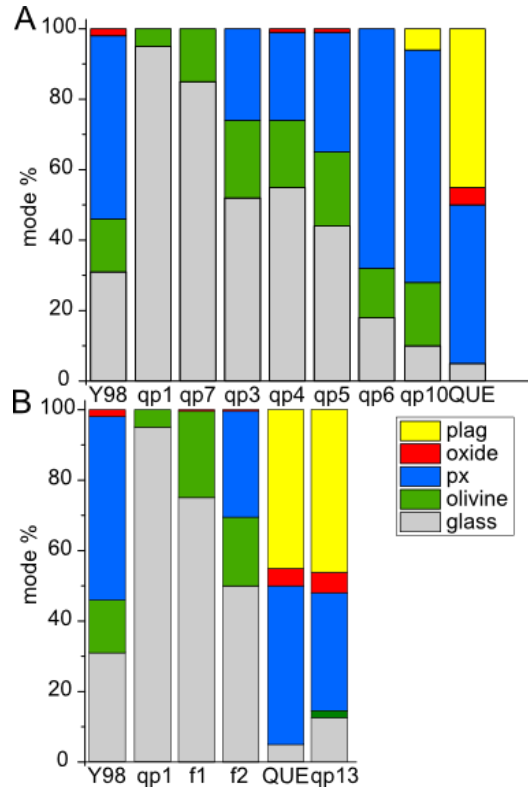


Figure 1: Crystal assemblages in equilibrium (A) and fractional (B) experiments. None of the experiments produce an assemblage comparable to QUE other than qp13, which is the starting composition of the most QUE-like liquid produced in equilibrium experiment qp10.

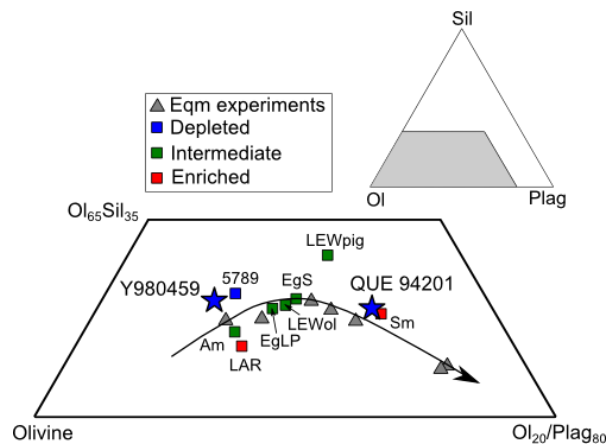


Figure 2: Projection of liquid compositions after Longhi [14] from experiments (gray triangles) compared to various calculated parental compositions of shergottite meteorites. Depleted shergottites are represented as blue (Y98 and QUE are stars), enriched as red and intermediate as green.