

YAMATO 980459 LIQUID LINE OF DESCENT AT 0.5 GPa: APPROACHING QUE94201. D. S. Draper, Institute of Meteoritics, 1 University of New Mexico, MSC03-2050, Albuquerque NM 87131, david@draper.name.

Introduction: The martian basaltic meteorites Yamato 980459 (Y98 hereafter) and QUE94201 (QUE) are thought by many to represent bona fide liquid compositions [1-4], in contrast to the majority of martian basalts, which are likely products of protracted crystal accumulation. Y98 is the most primitive (Mg#, molar Mg/Mg+Fe, ~65) martian basalt yet studied, whereas QUE is one of the most evolved (Mg # ~37). Yet they share several important features of isotopic and trace element composition that show they probably sampled the same (or very similar) highly depleted reservoir in the martian mantle [5, 6].

Because these two samples represent the best existing candidates for genuine liquids, it is natural to seek possible petrogenetic linkages between them to maximize the information about how martian basalts are formed and evolve. Recent efforts to this end include the employment of MELTS petrological models to derive a QUE-like liquid via fractional crystallization of Y98 [7], and 1-bar experimentation [Galenas et al., this meeting] in which simulations of this process were less successful. In this contribution, I present the results of anhydrous equilibrium crystallization experiments on Y98 conducted at 0.5 GPa, and compare the down-temperature liquid compositions with that for QUE. These experiments complement those performed at 1 bar by Galenas et al. [this meeting] by simulating Y98 differentiation within the martian crust (0.5 GPa \approx 40 km) rather than upon the surface. I show that the 0.5 GPa residual liquids approach (but do not yet reach) the composition of QUE, but under quite different circumstances from those modeled by Symes et al. [7]. Additional experiments intended to mimic a fractional process will shortly be underway.

Experimental and Analytical: Experiments were conducted using talc-pyrex assemblies fitted with graphite heaters and sample capsules in a piston-cylinder apparatus. Starting material was Y98A glass powder conditioned at the iron-wüstite buffer at 1000°C for ~24 hr. This material is the same powder (except for the IW conditioning step) used in the McKay group's original 1-bar work [3, 4] and by Galenas et al. [this meeting], eliminating one possible source of discrepancy between these various studies.

Experiments were run by holding Y98A at 1550°C (well above its 0.5 GPa liquidus) for 10 min prior to dropping to target temperature over 3-4 min, where they were held for several hours before quenching by cutting power to the assembly. The experiments reported here were run with final temperatures ranging from 1300-1210°C. Successful run products were

mounted in epoxy, polished, and analyzed using the IOM/UNM JEOL 8200 Superprobe. Phase compositions of the resulting minerals and glasses were used to calculate modal abundances of all phases via least-squares mass-balance. Sums of squares of residuals for these modes were all <0.5. Olivine-liquid K_D values for Fe-Mg exchange ranged from 0.31 to 0.34, close to the accepted value of 0.33.

Results: The four experiments reported here contained the following assemblages (wt %): 88% glass + 12% Fo81 olivine; 74% glass + 26% Fo76; 65% glass + 20% Fo75 + 15% low-Ca pyroxene, En75Fs22Wo3; and 41% glass + 22% Fo69 + 37% En65Fs27Wo8 (probably pigeonite; Fig. 1). Note that this pyroxene

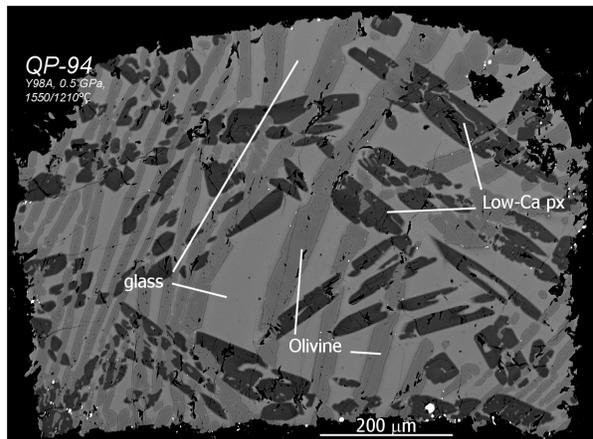


Figure 1. Backscattered electron image of representative run product (41% glass, 22% olivine, 37% low-Ca pyroxene). Black is graphite capsule, white are minute Fe blebs.

has a composition similar to the pigeonite found on the 1-bar QUE liquidus by [1] and [2] (compositional range En70Fs20Wo10 to En62Fs28Wo10) and in turn is similar to pigeonite cores in natural QUE.

Figure 2 plots wt % oxide compositions of glasses from these runs against their Mg# for comparison with the Y98 starting material and the QUE composition listed by [1]. With declining Mg# and melt fraction (indicated on lower panel), there are smooth decreases in MgO and Cr₂O₃ contents, with smooth increases in Al₂O₃ and CaO; FeO remains nearly constant. SiO₂ undergoes initial enrichment owing to olivine crystallization, followed by a decrease after low-Ca pyroxene begins crystallizing. The increases in TiO₂ and Na₂O are less smooth. The illustrative curves sketched onto Fig. 2 imply that a close match with QUE should result at a melt fraction below 41%, the lowest value produced thus far. Finally, I have run synthetic QUE glass powder at 1235 and 1210°C for comparison, but

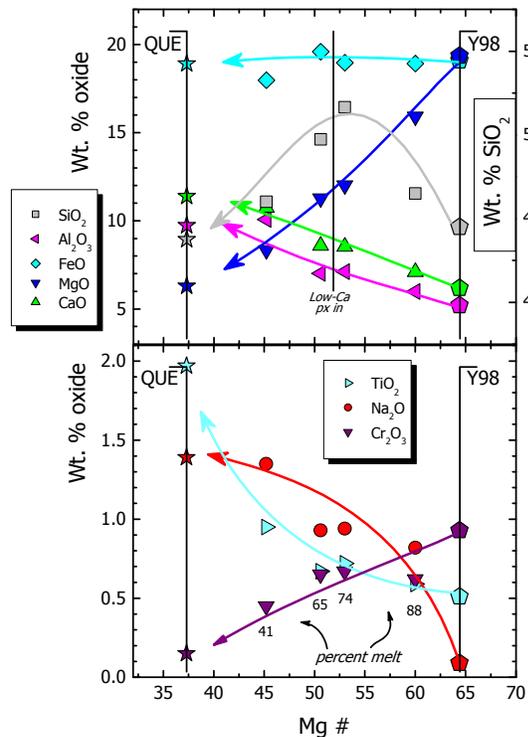


Figure 2. Compositions of liquids formed via equilibrium crystallization of Y98. QUE and Y98 compositions indicated by vertical lines. Top plot: SiO_2 uses right-hand y-axis; vertical line near center denotes onset of low-Ca pyroxene. Lower plot: melt fraction indicated on lowermost set of symbols. Curves drawn are illustrative only.

both of these are above the QUE liquidus at this pressure, yielding all-glass charges.

Discussion: The 0.5-GPa liquid line of descent for Y98 is qualitatively similar to the residual liquid compositional trends modeled by Symes et al. [7] using the MELTS algorithm (see their Fig. 6), which simulates a fractional, rather than an equilibrium, crystallization process. Although their reported match with QUE is quite close, the modeled fractional crystallization sequence is, unsurprisingly, very different from the equilibrium crystallization simulated in these experiments. First, no spinel formed in these runs (although it does at 1 bar [3, 4]); it is a ubiquitous phase in all MELTS results of [7]. Second, MELTS predicts cessation of olivine crystallization when orthopyroxene appears, and of orthopyroxene when pigeonite appears; here, olivine remains stable even as pigeonite appears at 1210°C (Fig. 1). The degree of crystallinity at which MELTS matches QUE is 43%, whereas the lowest-degree experimental liquid, at 59% crystalline, still requires additional crystallization to make a good match. Symes et al. [7] also calculated the REE contents of their modeled QUE-like melt and found that they were within the range of estimates that have been

made of QUE REE abundances. These estimates are complicated by the highly variable occurrence of phosphate minerals in QUE and the meteorite's overall small mass. In Figure 3, results of a similar exercise are plotted, comparing the REE contents calculated for the experimental liquids (using the same partitioning D values as did Symes et al. [7]) with bulk Y98 and QUE. The conclusion is essentially the same as that from the data on Fig. 2: the REE pattern approaches, but does not quite reach, QUE; some additional crystallization looks likely to yield a reasonably close match. Despite the stark disparity between experimental vs. modeled phase equilibria and crystallization sequences, the REE pattern on Fig. 3 is very close to that calculated by Symes et al. [7] from the MELTS-generated crystallization sequence.

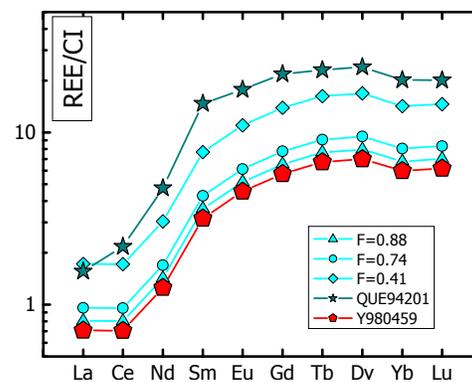


Figure 3. CI-normalized REE plot showing Y98, QUE, and calculated REE contents of liquids formed via equilibrium crystallization of olivine and low-Ca pyroxene. F is melt fraction.

Conclusions and next steps: Taken together, the results outlined here show that a broad variety of petrogenetic processes and conditions (equilibrium vs. fractional crystallization, surface vs. hypabyssal differentiation) could result in Y98-like basalts evolving to compositions close to that of QUE. Experiments currently underway will extend this work to lower melt fraction, and an upcoming set (using cooling-rate techniques similar to those described by Galenas et al. [this meeting]) will attempt to mimic fractional processes at the same pressure as the runs presented here.

References. [1] Mikouchi, T., et al. (2001) LPS XXXII, 2100 [2] McKay, G. A., et al. (2002) LPS XXXIII, 2051 [3] McKay, G., et al. (2004) LPS XXXV, 2154 [4] Koizumi, E., et al. (2004) LPS XXXV, 1494 [5] Borg, L. E., et al. (1997) LPS XXVIII, 133 [6] Shirai, N. and Ebihara, M. (2004) Antarctic Meteorite Research, 17, 55 [7] Symes, S. J. K., et al. (2008) GCA, 72, 1696