

# Relationship between Olivine Normative and Quartz Normative lunar Basalts: an experimental study.

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## Abstract

We investigate the genetic relationship between olivine-normative basalts (ONB) and quartz-normative basalts (QNB) found on the Moon. We experimentally test the hypothesis that QNB are derived from a primitive ONB through extensive polybaric and polythermal fractional crystallization.

## 1. Introduction

The Apollo 15 astronauts sampled several low-Ti basaltic lava flows of two distinct compositions (classified into ONB and QNB). They have distinctly different SiO<sub>2</sub>, FeO and TiO<sub>2</sub> contents. To explain these different compositions, several scenarios have been proposed, from different lunar mantle sources to different extents of fractional crystallization starting from the same melt.

In 2008, Schnare and co-workers [1] developed this second hypothesis. By combining REE abundance measurements in pyroxenes from ONB and QNB samples with mineral-melt partition coefficients experimentally obtained by [2], they estimated the parental-melt REE abundances for these basalts. The REE abundances of the parental melts of ONB and QNB are similar and close to the whole-rock composition. The conclusion of Schnare et al. [1] was that the ONB and the QNB were derived from the same lunar mantle source, but that the QNB basalts were transported to the surface in multiple steps, allowing a significant amount of fractional crystallization (especially at the crustal base, and later at near-surface conditions), while the ONB parental batch underwent less fractional crystallization.

In this study we set out to experimentally test this hypothesis and further investigate the possible genetic relationship between the two.

## 2. Methods

### 2.1 PT path investigated.

According to [1], the common source of the two types of basalts is located at depth, below the base of the anorthositic crust ( $P > 0.5$  GPa). In our model we assume arbitrarily that this depth corresponds to a pressure of 0.8 GPa. The composition of the source was approximated by the composition of a very primitive ONB (Apollo sample 15555, dubbed QNB1 here). We experimentally characterized the crystallization sequence of this composition at 0.8 GPa. In order to assess if QNB can be derived from this primitive source, we are performing a series of low-degree melting experiments (melt fraction  $F$  between 4 and 20%) at various  $PT$  conditions (with decreasing  $P$  to simulate a progressive way up to the surface; fig. 1).

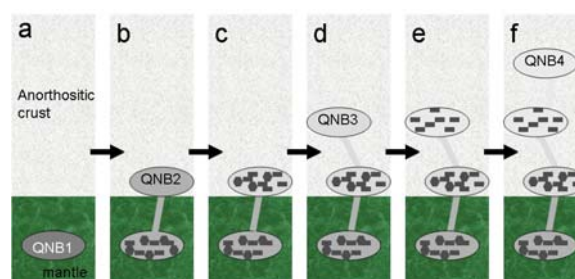


Fig. 1: a: The initial source composition QNB1 situated beneath the base of the lunar crust. b: QNB1 crystallizes and the residual melt (QNB2) is conducted upward via a fracture and settles in the crust. c: The melt pocket partially crystallizes. d: a fracture brings some residual liquid (QNB3) upward. E: the melt pocket crystallizes partially. F: again the residual melt (QNB4) is brought up via a fracture and crystallizes further (and so on until the surface).

## 2.1 Experimental set up.

The starting material (in the simplified system FeO-CaO-MgO-Al<sub>2</sub>O<sub>3</sub>-TiO<sub>2</sub>-SiO<sub>2</sub>, FCMATS) was made by mixing high purity (> 99.9%) oxides and carbonates in the appropriate proportions under ethanol and melting the resulting mixture at 1350 °C in air. The composition was subsequently doped with a cocktail of trace elements including REE (Sc, V, Co, Ni, P, La, Ce, Nd, Sm, Eu, Gd, Yb, Lu, Rb, Sr, Ba, W and Hf), at a level of 300 ppm, and remelted. The resulting glass was crushed very finely with an agate mortar and kept in an 110 °C oven. For high pressure and high melting degree experiments, the sample powder was packed in a graphite capsule with an inner compartment of 0.8 mm in length and 0.55 mm in diameter. For the low degree melting experiments, the capsule was filled up to two thirds with the starting material and with glassy carbon spheres of a diameter smaller than 63 µm for the remaining third. The glassy carbon spheres trap liquid in areas easy to analyze with the electron microprobe. The graphite capsules are inserted in an outer platinum capsule which is subsequently welded shut. Experiments were performed in piston-cylinder apparatus at VU University Amsterdam with a 0.5 inch diameter talc-pyrex cell assembly. The pressures range from 0 to 1 GPa and the temperatures from 1000 to 1300 °C. The oxygen fugacity is around 1.1 log units above the iron-wüstite buffer. Experiment duration is between 4 and 8 hours depending on the melting degree.

## 2.2 Analytical methods

The major and minor element composition of all run products were analyzed using wavelength-dispersive spectrometry with a JEOL JXA 8800 electron microprobe at VU University Amsterdam (15kV, 25nA), and checked for contamination and iron loss using mass balance. Melt fractions were determined both by mass balance calculations and area percentage with an EDAX energy-dispersive system. Grain size permitting, we plan to measure trace element abundances in co-existing minerals and melts using LA ICPMS.

## 3. Results

At this preliminary stage we are investigating the crystallization sequence of the starting composition at 0.8 GPa. Our initial results seem to agree with Walker et al. (1977) [3], with olivine and pyroxenes

appearing first, spinel and later plagioclase. Figure 2 shows some examples of experimental charges.

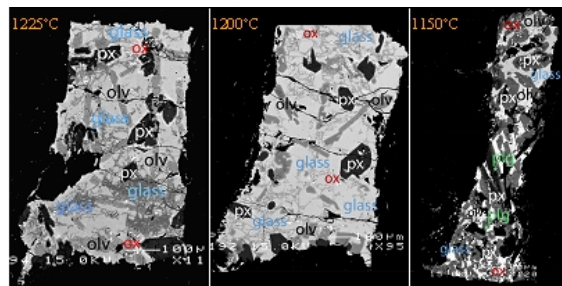


Fig. 2: Examples of experimental charges produced at 0.8GPa and various temperatures (px=pyroxene, white; olv=olivine, black; ox=oxide, red; plg=plagioclase, green).

At the meeting we will detail the crystallization sequence of the source material chosen and the evolution of residual liquids during transfer through the lunar crust. Combining our data with measurements of appropriate mineral-melt partition coefficients for this specific system, we aim to elucidate the extent of a genetic relationship between the olivine and the quartz normative lunar basalts.

## References

- [1] Schnare D. W. et al., A laser-ablation ICP-MS study of Apollo 15 low-titanium olivine normative and quartz-normative mare basalts, *Geochimica et Cosmochimica Acta*, 72, pp. 2556-2572, 2008.
- [2] McKay G., Wagstaff J. and Yang S. R., Clinopyroxene REE distribution coefficients for shergottites: the REE content of the shergotty melt. *Geochimica et Cosmochimica Acta*, 50, 927-937, 1986.
- [3] Walker D., Longhi J., Lasaga A., Stopler E.M., Grove T.L. and Hays J.F., Slowly cooled microgabbro 15555 and 15065. *Proc. Lunar Science Conference 8<sup>th</sup>*, 1521-2547, 1977.