

CONSTRAINTS ON THE ORIGIN OF LUNAR ‘WATER’ FROM D/H AND NOBLE GAS ANALYSES OF SINGLE APOLLO 17 VOLCANIC GLASSES. E. Füri, E. Deloule, A.A. Gurenko, B. Marty, CRPG-CNRS, BP20, 54501 Vandoeuvre-lès-Nancy, France (efueri@crpg.cnrs-nancy.fr)

Introduction: The recent discovery of trace amounts of water in lunar volcanic glasses (LVGs) [1, 2] and apatites [3, 4, 5] suggests that the material that formed the Moon was not completely devolatilized, or, alternatively, that volatile-rich cometary or chondritic material was delivered to the lunar magma ocean shortly after the Moon-forming impact [5, 6]. However, in order to derive the abundance and origin of indigenous water in the Moon’s interior from analyses of samples collected at the lunar surface, the contribution of hydrogen implanted by the solar wind (SW) and deuterium produced by in-situ spallation needs to be constrained. Here, we assess the proportion of different water (hydrogen) components trapped in individual Ti-rich Apollo 17 LVGs by coupling SIMS measurements of water abundances and D/H ratios with CO₂ laser extraction-static mass spectrometry analysis of noble gases (He, Ne, Ar).

Samples and experimental method: The studied soil sample is derived from 13 cm depth of the Apollo 17 74002 drive tube. Individual LVGs of ~200 μm diameter were handpicked and mounted in indium. Backscattered electron images of all grains were acquired by scanning electron microscopy (JEOL JSM-6510, CRPG), and major elements were determined with the JEOL Superprobe JXA-8200 electron microprobe at the Max Planck Institute for Chemistry, Mainz. After leaving the samples under ultra-high vacuum for ≥120 hrs to reduce the hydrogen background, water (hydrogen) abundances and D/H ratios were measured using the Cameca IMS 1280HR2 at CRPG. Following SIMS analysis, the grains were removed from the indium mount, and noble gases (He, Ne, Ar) were extracted by CO₂ laser heating and analyzed on a VG5400 mass spectrometer.

Results: While some grains are completely glassy, most show crystallization of olivine; all LVGs, however, are derived from a homogenous melt with ~8.9 ± 0.1 wt.% TiO₂ and 14.5 ± 0.2 wt.% MgO (2σ). The SIMS data reveal that the LVGs exhibit H abundances equivalent to 12 to 80 ppm H₂O (up to 50 ppm in completely glassy beads) with δD_{SMOW} values between 60 and 985 ‰ (Fig. 1). Furthermore, there is a clear inverse correlation between the water content and hydrogen isotope ratios, as observed previously for Apollo 14, 15, 17 LVGs [7].

Measured ³He/⁴He ratios range from 10.40 to 15.77 (× 10⁻⁴) and are significantly higher than SW values (4.46 × 10⁻⁴ [8, 9]), consistent with a significant contri-

bution of cosmogenic ³He. ²¹Ne/²²Ne ratios vary between 0.400 and 0.846 and can be explained by mixing between volume-correlated cosmogenic neon and a small amount of surface-sited SW-derived neon (Fig. 2).

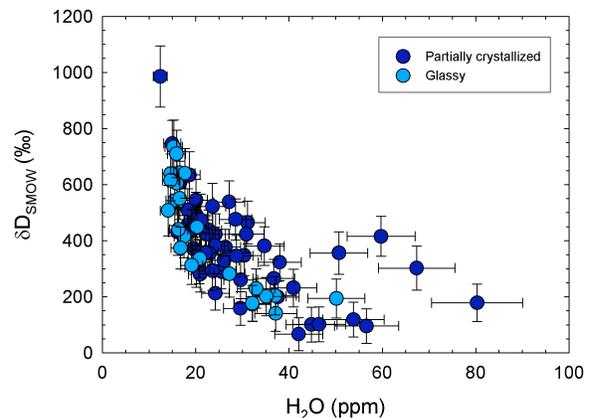


Figure 1: Measured δD_{SMOW} values (‰) versus water concentrations of Ap17 LVGs. For each grain (n = 25), between two and eight spots were analyzed by SIMS.

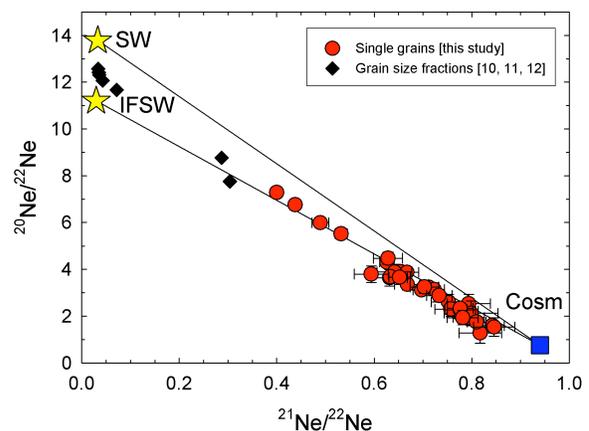


Figure 2: Three-isotope plot of neon. Neon in individual Ap17 LVGs (n = 34) and small grain size fractions from ~13 cm depth [10, 11, 12] represents a mixture of cosmogenic neon (Cosm [13]) and implantation-fractionated solar wind (IFSW; previously referred to as ‘SEP’ [14]) or solar wind (SW [8]).

Discussion: Based on the measured elemental compositions and modelled cosmogenic neon production rates [13], we calculate variable ²¹Ne exposure ages between ~10 and 31 Myrs for the individual

grains. These values are in excellent agreement with ^{38}Ar exposure ages that we estimate from empirical argon production rates [15].

Spallogenic deuterium is produced at a rate of $\sim 1 \times 10^{-12}$ mol/g/Ma at 13 cm depth [16, 17], and thus, represents ≤ 15 % of the total deuterium abundances in Ap17 LVGs. While for the water-poor grains, the correction for spallogenic D results in lower $\delta\text{D}_{\text{SMOW}}$ values by up to 200 ‰, the observed relationship between water abundances and hydrogen isotope ratios is preserved after spallation correction. The general increase in δD values with lower water contents appears consistent with hydrogen degassing of a melt with a low initial δD value of ≤ 100 ‰. However, due to fractional crystallization of olivine, the glass phase of several partially-crystallized grains is enriched in water.

Conclusions: The noble gas results show that the relatively large Ap17 LVGs studied here have been exposed at the lunar surface for a short period of time, and that they contain a negligible amount of SW-derived He, Ne, and Ar. Therefore, the contribution of water (OH) produced in-situ by interaction of SW protons with mineral oxides, as well as the generation of deuterium by cosmic ray impacts, is negligible. Consequently, the detection of water (hydrogen) in these primitive lunar melts confirms the presence of a volatile-rich mantle source within the Moon.

High δD values of Ap17 LVGs can be explained by significant hydrogen isotope fractionation during kinetic hydrogen loss from a melt with a chondritic isotope signature. Thus, our results confirm that the addition of D-enriched cometary water to the lunar interior appears to be negligible, as argued by [6].

Acknowledgements: This work was supported by the Centre National d'Etudes Spatiales (CNES) through a postdoctoral fellowship to EF, and by the European Research Council under the European Community's Seventh Framework Programme (FP7/2007-2013 grant agreement No. 267255) to BM. We thank E. Hauri for providing 'dry' synthetic forsterite and quartz glass standards for SIMS analysis.

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