INITIAL WATER CONCENTRATION AND DEGASSING OF LUNAR BASALTS INFERRED FROM MELT INCLUSIONS IN OLIVINE. Y. Chen[1] and Y. Zhang[2], Dept of Earth and Environmental Sciences, Ann Arbor, MI 48109-1005, USA. [1]yangcz@umich.edu, [2]youxue@umich.edu.

Introduction: The depletion of volatiles of the Moon is consistent with the giant impact hypothesis for the origin of the Moon. However, high water concentrations in lunar samples reported recently suggest that the Moon is not completed devolatilized [1, 2, 3, 4]. Saal et al. (2008) measured volatile concentrations in lunar volcanic glasses and suggested 745 ppm water before diffusive degassing during magma eruption. More directly, Hauri et al. (2011) reported 615-1410 ppm water in olivine-hosted melt inclusions in a lunar volcanic glass. Volatile data and models from lunar apatite are also consistent with these values [3, 4]. In this study, we measured water concentration in olivine-hosted melt inclusions in lunar basalts. Our preliminary data show water concentrations from below detection limit to 256 ppm. The recent studies and our results raise important questions about the budget and distribution of volatiles in the Moon, their roles in the magma evolution and eruption on the Moon, and the models for the Moon formation.

Methods and Results: Three lunar basalts were obtained from NASA: 10020-49, 12008-5 and 15016-47. Abundant large melt inclusions have been found in the olivine phenocrysts. All of the melt inclusions contain daughter crystals and are not transparent, hence they were homogenized in a one-atmosphere Deltech furnace at about 1544 K in high-purity nitrogen gas.

We did not homogenize the melt inclusions at high pressure (such as in piston-cylinder) to avoid any possible water gain [5]. High-pressure experiment is useful to prevent olivine fracture caused by the high internal pressure of the melt inclusions. For the lunar samples, the water concentration is expected to be low and the internal pressure is not high enough to crack olivine, hence high-pressure experiment is not necessary. For example, 1400 ppm of water in basalt would generate a pressure of 0.49 MPa at 1544 K using the solubility model in [6], which is not enough to fracture a good olivine crystal.

The homogenization temperature was chosen based on previous studies and several trial homogenization experiments at 1523-1602 K. The dwell time at high temperatures was minimized to avoid water loss from the melt inclusions via hydrogen diffusion in olivine. After homogenization, all melt inclusions still contain multiple bubbles. The olivine crystals were doubly polished and the melt inclusions were measured by Fourier transform infrared spectroscopy (FTIR).

12 melt inclusions in 6 olivines have been analyzed so far by FTIR. Due to the very low water concentration in the melt inclusions, very long counting time (10-30 minutes) was used to better resolve the water signal. The noise of the spectra is about 0.001-0.002 absorbance units. Consider an average melt inclusion thickness of about 50 μm, this noise translates to about 20-40 ppm error in water concentration. Another important error source is the uncertainty in melt inclusion thickness. Not all melt inclusions have been doubly exposed yet, hence the effect thickness within the infrared beam path cannot be accurately determined.

Water concentrations vary from below detection limit to 265 ppm (Fig 1). Among the three basalts, despite the texture and chemical differences (15016-47 is vesicular and 10020-49 and 12008-5 are non-vesicular, 15016-47 contains less TiO_2 than the other two), the limited data show a difference of no more than a factor of 2 in water concentration. All three lunar basalts contain significant amount of pre-eruptive water (≥ 100 ppm).

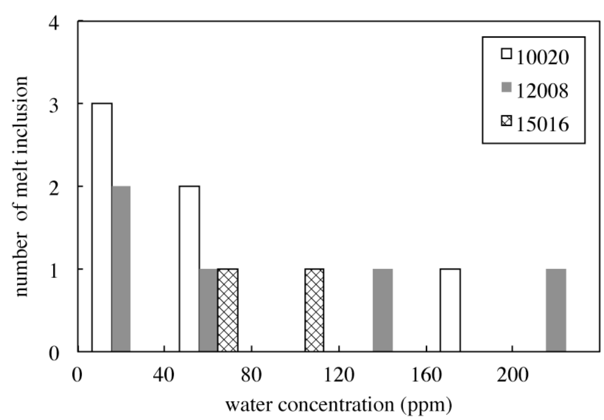

Fig. 1 Histogram of the water concentration in olivine-hosted melt inclusions in three lunar basalts

Discussion: The homogenization temperature is not all consistent with earlier studies. For 10020-49, previously reported liquidus was about 1440 K [7], about 100 K below the homogenization temperature obtained in this study. For 15016-47, previous results are similar to this study [8]. It is possible that the melt inclusions in 10020-49 are less evolved than the host basalt.

The water concentrations we obtained are significantly lower than the recent results of up to 1410 ppm water [1, 2]. This difference may be due to many reasons. We are making more measurements and evaluating various possibilities.

First, the number of measurements we have made so far is still limited. We are in the process of measuring more melt inclusions in olivine phenocrysts in these samples.

Secondly, there might be significant water loss from the melt inclusions during homogenization heating, although we made the best effort to minimize water loss (note that Saal et al. (2008) and Hauri et al. (2011) did not heat their samples). The degree of loss depends on the heating duration, heating temperature, size of the melt inclusions, the distance from the melt inclusions to the surface of the hosting olivines, whether there were initial cracks in the olivine crystals, and whether new cracks were generated during heating. Cracking of olivine crystal might be due to additional pressure from other gas components.

Thirdly, the basalts in this study may indeed have high initial water concentrations, but the melt inclusions did not capture or did not preserve this feature. Significant water degassing may have occurred before the olivine crystallization. Also, water in the melt inclusions may have diffused away through olivine during magma evolution.

Fourthly, water may be heterogeneously distributed in the Moon. Some regions in the Moon may be relatively water-rich (contain as much volatiles as the Earth's upper mantle), while other regions may be more severely devolatilized. Understanding this heterogeneity requires more detailed analysis of the giant impact, accretion and early evolution of the Moon.

References:

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