

THE CHLORINE ISOTOPE COMPOSITION OF THE MOON AND EVIDENCE FOR AN ANHYDROUS MANTLE. Z.D. Sharp¹, C.K. Shearer², K.D. McKeegan³, J.D. Barnes⁴, ¹Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87122, USA, ²Institute of Meteoritics, University of New Mexico, Albuquerque, NM 87122, USA, ³Earth and Space Sciences, UCLA, Los Angeles, Los Angeles, CA, 90095, USA, ⁴UT Austin, Dept. of Geological Sciences, Austin, TX 78712, USA

The chlorine isotope composition ($^{37}\text{Cl}/^{35}\text{Cl}$ ratio) of lunar basalts and glasses span a range of over 25‰ (Fig. 1) in contrast to terrestrial and meteoritic materials that generally have a spread of only 2-3‰. Water-soluble and insoluble (silicate) portions of basalts and glasses were analyzed using gas source mass spectrometry, and apatite grains were analyzed using a Cameca 1270 large-radius ion microprobe. The water-soluble fractions, which represents vapor condensates of a degassing lava, always have lower $\delta^{37}\text{Cl}$ values than the corresponding silicate fraction. There is no correlation of $\delta^{37}\text{Cl}$ value with rock type or degree of surface exposure. The uniquely large range of $^{37}\text{Cl}/^{35}\text{Cl}$ ratios of lunar materials could be due to 1) heterogeneities inherited or induced during the Moon forming event, 2) isotopic fractionation by solar wind bombardment, or 3) fractionation during volatile degassing of lunar lavas related to the distinctive chemistry of the Moon. We believe that only the third possibility is reasonable, and can be explained if lunar magmas/lavas were H-free (anhydrous).

It is possible that the impactor responsible for the formation of the Moon had a different composition than the proto-Earth. It is also possible that volatilization and condensation during Moon formation would lead to unique $\delta^{37}\text{Cl}$ values of the Moon. However, it is unlikely that small scale heterogeneities could be preserved in a body that had an extensive magma ocean. Similarly, proton or micrometeorite bombardment could lead to a preferential loss of ^{35}Cl as HCl gas, but there is no correlation between $\delta^{37}\text{Cl}$

value and degree of surface exposure/weathering. Furthermore, the highest $\delta^{37}\text{Cl}$ value was measured on an apatite grain that was completely shielded from the solar wind. Instead, we propose that the large range of $\delta^{37}\text{Cl}$ values of lunar samples is due to the unique anhydrous conditions of the Moon. On Earth, the $\delta^{37}\text{Cl}$ values of basalts are generally close to 0‰, the same as the mantle source. The volatilizing species is always HCl, which preferentially incorporates ^{37}Cl due to the strong H-Cl bond. This fractionation is offset by the preferential loss of ^{35}Cl based on kinetic considerations. On an anhydrous Moon, the vapor phase would be metal chlorides (NaCl , KCl , FeCl_2 , ZnCl_2) which have similar bonding to Cl in the melt. Vaporization into a vacuum causes a preferential removal ^{35}Cl , leading to ever-increasing $\delta^{37}\text{Cl}$ values of the remaining melt. The lowest $\delta^{37}\text{Cl}$ values are close to Earth values; all higher values are explained by volatilization. The consistently lower $\delta^{37}\text{Cl}$ values of the water-soluble fraction supports the idea of a light vapor phase.

The initial Cl concentrations of degassed lavas are variable but are in the range of 10-100 ppm. Assuming that H contents must be lower than this (to prevent HCl formation), we calculate that the lunar mantle must have had H contents below 30 ppb, significantly lower than Earth and suggesting that the lunar mantle is anhydrous.

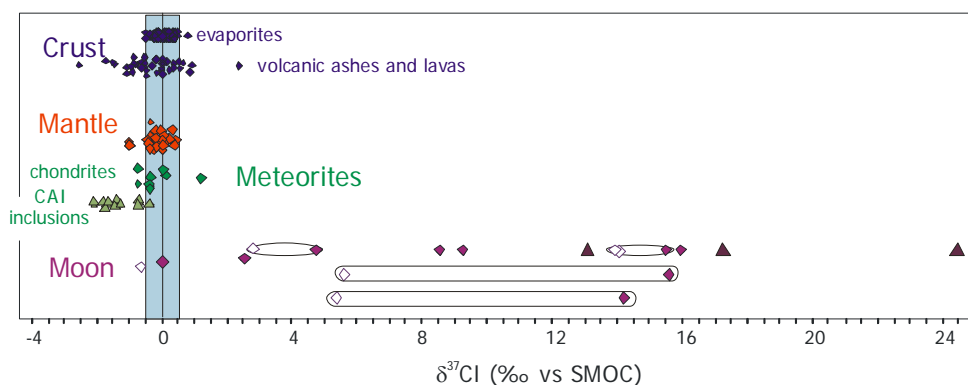


Fig. 1. Isotopic composition of terrestrial, meteorite and lunar materials. Triangles – ion probe; diamonds, bulk. Leached samples –unfilled, silicate samples-filled. Paired samples are circled.