

COMBINED D/H-H₂O SYSTEMATICS AND VALENCES OF IRON AND CHROMIUM IN PYROXENES IN THE LUNAR BASALTIC METEORITE ELEPHANT MORAINÉ 96008.

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Introduction: The lunar basaltic meteorite Elephant Moraine (EET) 96008 is a fragmental breccia composed mainly of basaltic clasts, and is characterized by bulk rock geochemical characteristics similar to those of very low-Ti (VLT) basalts that have experienced extreme fractional crystallization [1]. We recently reported the hydrogen isotope compositions and H₂O contents of pyroxenes in an anhydrously prepared polished mount of an interior chip of this meteorite [2]. We chose to study the D/H-H₂O systematics in this sample as it has a low terrestrial weathering grade and also has a relatively low cosmic ray exposure age of ~10 Ma, such that only minimal correction for cosmogenic deuterium was required [3–5]. We additionally reported the valences of Fe and Cr in pyroxenes determined via micro-X-ray Absorption Near Edge Structure (micro-XANES) spectroscopy on a polished epoxy-mounted thin section of this same lunar meteorite [6]. It has previously been assumed that the fraction of ferric iron (Fe³⁺/ΣFe) in lunar pyroxenes is negligible [7]. However, our recent results [6] showed that in fact the fraction of ferric iron in pyroxenes of EET 96008 ranges from negligible (0.1±0.6%) up to 9.7%. Moreover, we showed that there was excellent correlation between the valences of Fe and Cr in pyroxenes of this lunar meteorite, and also that the range of Cr valence in these pyroxenes was well within that observed in pyroxenes of Apollo 17 VLT basalts [8] (which are not affected by terrestrial weathering). This implies that the variation in Fe and Cr valences in EET 96008 pyroxenes is not likely to be the result of weathering and oxidation during this meteorite's residence in the terrestrial environment. We have now extended our previous work [2,6] by determining Fe and Cr valences in the same pyroxene grains in the anhydrously prepared polished mount for which we previously determined D/H-H₂O systematics [2]. The goal of spatially correlating the measurements of Fe and Cr valences reported here with our previous analyses of D/H-H₂O systematics [2] in the same pyroxene grains is to utilize these combined geochemical and isotopic parameters to better understand the redox conditions and magmatic processes on the Moon.

Analytical Methods: The Fe and Cr valences were determined using methods described in [9,10] and briefly summarized here. The micro-XANES analysis spots on the pyroxene grains were located adjacent to the secondary ion mass spectrometry (SIMS) pits of [2]. The Fe and Cr K-edge XANES spectra were collected at several orientations for each spot using station 13-ID-E at the GSECARS X-ray microprobe at the Advanced Photon Source at Argonne National Lab. We merged these orientation spectra for each spot that we analyzed and determined the valence from the merged spectrum. For Fe, the valence was determined using the “Lasso” (least absolute shrinkage and selection operator) method described in [11]. The Fe valence is reported as “2 + (Fe³⁺/ΣFe)”; precision of the reported Fe valence values is estimated to be ± 0.0075 (1σ) based on the average intragrain standard deviation for homogeneous grains. The Cr valence method used the normalized intensity of the derivative spectrum peak produced by a 1s → 4s electronic transition [12]. The Cr valence is reported as “2 + (Cr³⁺/ΣCr)”; precision of the reported Cr valence values is estimated to be ±0.01 (1σ).

Results and Discussion: The Fe and Cr valences determined here in pyroxenes in the anhydrously prepared EET 96008 polished mount are well-correlated with each other and overlap with those determined previously by us on the polished epoxy-mounted thin section [6]. This confirms our previous results and further bolsters our suggestion that the significant variation in Fe and Cr valences in EET 96008 pyroxenes is not likely to be the result of terrestrial alteration. Moreover, the Fe and Cr valences in EET 96008 pyroxenes appear to be somewhat positively correlated with their D/H ratios, while there does not appear to be any correlation with their H₂O contents. Taken together, the combined geochemical and isotopic systematics presented here suggest that dehydrogenation (which is expected to result in a positive correlation between Fe valence and D/H ratios, but a negative correlation between Fe valence and H₂O contents in pyroxenes) is unlikely to be involved in the petrogenesis of this lunar meteorite. Alternatively, it is possible that these geochemical and isotopic parameters in EET 96008 pyroxenes are affected by the superposition of two or more processes on the Moon.

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