GEOCHEMICAL CONSTRAINTS ON THE ORIGIN OF THE MOON. Michael J. Drake, Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721

INTRODUCTION. The abundances of siderophile elements in the mantles of the terrestrial planets are keys to the interpretation of metal/silicate fractionation events. In the case of the Earth and Moon, differing estimates of mantle abundances fuel the controversy surrounding the possible origin of the Moon by fission from the Earth following terrestrial core formation [1-5]. These differing estimates arise in part from our uncertainty concerning the partitioning behavior of siderophile elements among solid and liquid metal and silicate phases.

DATA. One way to penetrate through 4.5 billion years of complex differentiation to examine metal/silicate fractionation events such as core formation is to utilize elements which are sensitive to metal/silicate fractionation but are insensitive to or predictable in silicate mineral/silicate melt fractionation. Examples of the only elements known to the author to rigorously satisfy such conditions are shown schematically in Figure 1. Tungsten and P partition strongly into metal but behave as lithophile incompatible elements like La in subsequent events [3-5]. In contrast, Ge also partitions strongly into metal but behaves as if it had a mean mantle/magma partition coefficient of approximately unity in subsequent igneous events (Fig. 2). Gallium may or may not partition into metal depending on the ambient redox conditions, but behaves similarly to Ge in subsequent igneous events (see the figure in [6]).

A trace element which probably is not rigorously insensitive to or predictable in silicate mineral/silicate melt fractionation is the refractory siderophile element Re. This element is important because it may be expected to be present in chondritic relative abundances in the Earth, Moon and EPB. The abundances of Re in terrestrial, lunar and eucritic volcanic rocks are shown in Figure 3.

DISCUSSION. The abundance of Ga in the Earth is not distinguishable from the chondritic value ([6]). This observation, and the result [3,5] that the abundances of W and P in mare basalts presumably representative of the lunar mantle may be accounted for by separation into a geophysically plausible metallic lunar core, suggests that the Moon was also chondritic with respect to elements with 50% condensation temperatures above that of P (Fig. 4). This conclusion may be tested by calculating the metal/silicate partition coefficient for Re necessary to extract Re initially present in chondritic abundance into a lunar core of no more than 2 wt% of the mass of the Moon. The calculated partition coefficient is approximately $5 \times 10^4$, in accord with the only available experimentally determined values [7]. The EPB may be similarly modelled in a manner consistent with previous calculations [4,5] for W and P. Gallium and Ge abundances suggest initially subchondritic abundances in the Moon and EPB.

SUMMARY. Experiments and calculations are consistent with extraction of refractory siderophile elements with well-understood geochemical behavior (W,P) into a geophysically plausible lunar core. Analysis of the less well understood element Re supports this conclusion. Abundances of less refractory siderophile elements such as Ga and Ge appear to record effects of volatility during planetary assembly. The behavior of other siderophile elements cannot be interpreted unambiguously in the absence of reliable measurements of metal/silicate and silicate mineral/silicate melt partition coefficients. Lunar redox conditions were below iron-wustite [8], effectively ruling out possible loss of Re as a volatile oxidized species [9]. The differences of factors of approximately two in P abundances and approximately 1000 in Re abundances inferred for the mantles of the Earth and Moon are difficult to reconcile with a fission origin for the Moon and are more readily understood in terms of independent formation of Earth and Moon.

REFERENCES
Drake, M.J.


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