

La/Sm RATIOS IN MARE BASALTS AS A CONSEQUENCE OF MAFIC CUMULATE FRACTIONATION FROM AN INITIAL LUNAR MAGMA; Elizabeth Shaffer, James G. Brophy and Abhijit Basu, Department of Geology, Indiana University, Bloomington, IN. 47405

One scenario of lunar petrogenesis postulates plagioclase crystallization and flotation in a well-stirred magma ocean [1]. Later partial melting of mafic cumulates that may have settled out the plagioclase-deplete magma ocean could give rise to the parental liquids of mare basalts. Such a scenario would explain much of the geochemical properties of mare basalts [2]. Alternatively, one could consider partial melting of early mafic cumulates from an initial lunar magma without prior plagioclase removal, to be the parental mare basalt liquid [3]. Any realistic scenario should be able to account for the distribution of trace elements in mare basalts, such as REE abundances and ratios. One test [4], involving the abundances of Eu and Eu-anomalies in mare basalts, does not substantiate the second hypothesis but does not negate it completely either. We are extending such a test by calculating the La/Sm ratios of batch partial melts of hypothetical mafic cumulates from an initial lunar magma that is assumed to be chondritic. This will be followed by calculations of the ranges of possible abundances of La and Sm in these hypothetical partial melts, and comparing them with real values.

We have used the following formulations to calculate the ratios of La and Sm in (Eq. 1) mafic cumulates fractionating from an initial magma, and in (Eq. 2) partial melts obtained from these cumulates :

$$R_s = R_{MO} (D_{Sm} / D_{La}) (1-F)^{(D_{Sm} - D_{La})} \quad \text{Eq. 1}$$

where, $R = \text{Sm/La}$; $R_s = \text{Sm/La}$ ratio in the fractionating solid, $R_{MO} = \text{Sm/La}$ ratio in the initial magma ocean and is assumed to be 1; D_{La} and D_{Sm} are the partition coefficients of the fractionating solid for La and Sm respectively, and $F = \text{fraction crystallized}$, and

$$R_1 = R_s \{ (F_1 + D_{La} (1 - F_1)) / (F_1 + D_{Sm} (1 - F_1)) \} \quad \text{Eq. 2}$$

where, $R_1 = \text{Sm/La}$ ratio in the partial melt, and $F_1 = \text{fraction of partial melt}$.

The solid-liquid partition coefficients (PC) used in this study were all selected from experimental studies involving mineral compositions that most closely approximated those in equilibrium with an initial magma ocean with $\text{Mg\#} = 0.90-0.93$ [5]. Sm PC values for olivine and orthopyroxene are taken from [6] and [7] respectively. La PC values are estimated from the same two data sets. La and Sm PC values for clinopyroxene are from [8]. The following partition coefficients were used in the calculations :

	La	Sm
Clinopyroxene	0.29	0.55
Olivine	0.00001	0.001
Orthopyroxene	0.0015	0.022

A series of model calculations were performed, which included :
 (a) considering only clinopyroxene, orthopyroxene, and only olivine, as well as mixtures of these minerals in selected proportions crystallizing from an initial lunar magma, and (b) different proportions of partial melts being

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produced from each of these hypothetical cumulates. The results provide an array of La/Sm ratios that correspond to each of the paths calculated for a mare basalt parental liquid.

This array was compared to the La/Sm ratios of common mare basalts listed by Taylor [2: p. 302-305]. It appears that fractionation of either olivine or orthopyroxene and partial melting of such cumulates cannot produce the observed La/Sm ratios in common mare basalts. Nearly 90% of clinopyroxene crystallization followed by partial melting is required to account for many of the lunar basalt types. However, more reasonable degrees of clinopyroxene fractionation and low quantities of partial melting may produce the La/Sm ratios in common high-Ti mare basalts. Some examples of the required combinations are given below :

Basalt	1/R ₁	Approximate	
		% cumulate crystallizing	% partial melt
Apollo 12 (12002)	1.42	90	20
Green Glass	1.45	90	15
Apollo 11 Low-K (10003)	1.03	30	5
Apollo 17 (70215)	0.78	30	30

These examples and other results do not *generally* support a mafic cumulate fractionation model without prior plagioclase separation from an initial lunar magma. But our preliminary modeling does not rule out the possibility of some lunar magma to have been generated by partial melting of some clinopyroxene-rich primary cumulates of an initial lunar magma (ocean). Modeling of actual abundances of La, Sm, etc. remain to be done and may put greater constraints on the mafic fractionation hypothesis.

REFERENCES : [1] Wood (1976) PLSC 6, pp. 1087-1102. [2] Taylor (1982) Planetary Science : A Lunar Perspective, LPI, Houston, 481p. [3] Shearer & Papike (1989), LPSci. XX, pp. 994-995. [4] Brophy & Basu (1990) PLPSC 20 (in press). [5] Jones & Delano (1989) GC Acta, v. 53, pp. 513-527. [6] McKay (1986) GC Acta, v. 50, pp. 69-79. [7] McKay, Wagstaff, & Le (1989) In Workshop on Lunar Volcanic Glasses, LPI, pp. 17-18. [8] Shimizu (1980) Geochem J., v. 14, pp. 185-202.