THE HOWARDITE PARENT BODY: COMPOSITION AND CRYSTALLIZATION MODELS

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Origin of Eucrites Stolper (1) argued that eucrites could not be produced by fractional crystallization, if the olivine-orthopyroxene boundary in the Fo-An-Sil projection is a reaction curve, and are primary magmas because they cluster around the peritectic. However, as the boundary is probably a cotectic over most of its length (2-7,12), fractionation could produce liquids projecting near the peritectic, and subsequent fractionation is highly compressed in this projection (8). Eucrites rich in incompatible elements, such as Stannern, might have been formed by low degrees of partial melting (1) but can also be explained by fractionation of Trend B basalts (5,6) just as other eucrites can be derived from Trend A basalts of Ikeda and Takeda. Consideration of siderophile trace elements and core formation also favors an origin by fractionation (9,10).

Magma Ocean Crystallization Many eucrite parent body compositions (e.g. 11,12) are based on the interpretation of (1) and clearly should be compared with alternative models, including those which add olivine to selected howardite data (5,14) for their ability to explain all the clasts in howardites and diogenites. Howardite parent body compositions were evaluated using a computer program which simulates fractional crystallization, MAGMAF.FOR by John Longhi. This program was adapted for HED by permitting cotectic crystallization of olivine with orthopyroxene until pigeonite appears, since olivine occurs in diogenites but not in cumulate eucrites. MAGMAF shows that basalts like Yamato 7308 PE1 and Kapoeta Rho, possible parental liquids on Trends A and B (5,6), could have formed cumulates comparable to the most ferroan diogenites, cumulate eucrites and fayalite-silica ferrogabbros (as in polymict eucrites).

Magma oceans of different HED parent body compositions produce different ranges of mineral compositions with MAGMAF. Table 1 compares initial olivine and pyroxene compositions, plus pyroxenes when plagioclase appears. There exists a range of models (5,13,14) which reproduce observed mineral compositions, based on howardites and Binda, reasonably well. The main difference is that plagioclase appears at rather ferroan pigeonite compositions, making it easier to simulate Moore County than Binda. An arbitrary mixture of E and CV chondrites, minus volatiles, is also acceptable. Models based on eucrites as primary magmas (11,12) do not perform as well. They produce less magnesian initial olivine, no orthopyroxene at all, very ferroan initial pigeonite and very late plagioclase. These models were not intended as magma oceans and the compositions cannot produce diogenites, etc. (12), even if initial melt or olivine residue are subtracted.

Serial Magmatism Crystallization models show that parent body compositions based on eucrites as primary magmas do not reproduce observed cumulates as well as magma oceans based on different

HEDPB CRYSTALLIZATION
Hewins, R.H.

assumptions. This does not prove that a magma ocean existed, however, as there are two main suites of basalts, trends A and B (5,6,7). Trend B liquids are richer in incompatible elements, especially Na, Ti and La, than Trend A and are therefore interpreted as daughters of a primary magma produced by lower degrees of partial melting than for Trend A. This requires a relatively plagioclase-rich parent body in which plagioclase survives melting until fairly high Mg/Fe ratios are reached. The HED data can thus be explained by a serial magmatism model very similar to that of (1), with the important exception that primary magmas (at least two) were high degree partial melts which were not preserved. The abundance of common eucrite meteorites is explained by the extrusion of late Trend A liquids over the earlier Trend B lavas.

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Table 1

Model	Ref	Fo1	En1	EnAn
C&D	11	87	59	16
J84	12	87	39	27
ECV	-	94	91	65
I&T	5	94	85	33
D80	14	92	92	50
D77	13	92	88	61
obs	-	92	86	65