CUMULATE EUCRITES FORMED FROM NORMAL EUCRITIC MAGMAS Allan H. Treiman. Lunar and Planetary Institute, Houston TX 77058 (treiman@lpi.jsc.nasa.gov).

The cumulate eucrites are pyroxene-plagioclase gabbros which do not represent magma compositions. Most studies have concluded that the cumulate eucrites did not form simply from known eucrite basalts, but rather from extremely fractionated magmas derived from eucrites or through complex petrogenetic processes [1-5]. However, the compositions of many cumulate eucrites can be modeled as simple, closed-system cumulates of pigeonite + plagioclase + known eucritic magmas (e.g., [6,7]). Thus, the cumulate eucrites require only simple processes (e.g., gravitational settling) on the eucrite parent body, and provide little support for extreme fractionation or complex petrogenesis.

Problem: The cumulate eucrite meteorites are closely related to the eucrites in mineral chemistry, bulk chemistry, and isotope compositions. The parent magmas of the cumulate eucrites have been inferred to be highly fractionated, e.g. La to 1000×CI, La/Lu to 10×CI [1-5]. However, the eucrite basalts themselves are little fractionated; the most extreme have La ~ 25×CI and La/Lu ~ 2×CI [8]. These inferences of highly fractionated parent magmas are flawed, as they relied on inappropriate methods. First, magma compositions were calculated from mineral analyses and Dmineral/basalt, which is inappropriate as minerals in the cumulate eucrites equilibrated with each other in the absence of magma [7]. Second, bulk compositions of the cumulate eucrites were modeled as plagioclase + pyroxene only, without consideration of magma trapped among the crystals. Trapped magma must be considered, as the trace element content of the cumulate can be dominated by small proportions of trapped magma.

Method: To avoid these problems, the bulk compositions of cumulate eucrites can be modeled as cumulates of eucritic magma + equilibrium plagioclase + equilibrium pigeonite. These cumulates are assumed to chemically isolated and sealed from their surroundings. For rare earth elements (REE), bulk compositions are calculated using equilibrium partition coefficients [9], Dmineral/basalt:

\[ C_E^{cumulate} = C_E^{basalt}(X_{basalt} + X_{plag} \cdot D_{E}^{plag/basalt} + X_{pig} \cdot D_{E}^{pig/basalt}) \]

where \( C_E \) is the concentration of element \( E \), and \( X^p \) is the mass fraction of the phase \( p \). For major and minor elements, magma and mineral compositions are taken or interpolated from [1,8,10,11] consistent with equilibrium partitioning. The \( X \) are allowed to range freely, and \( C_E \) includes only known eucrite basalts. Goodness of fit for the calculated REE patterns is taken as

\[ R^2 = \sum_{REE} \left( C_{REE}^{rock,calc} - C_{REE}^{rock,meas} \right)^2 / \left( C_{REE}^{rock,meas} \right)^2 \]

summed over Ce, Nd, Sm, Eu, Gd, and Yb; \( R^2 < 0.1 \) implies an acceptable fit. The second screen was MgO content of the cumulate. For \( X \) values that yield acceptable REEs and MgO, other major and minor elements abundances were calculated and compared to analyzed values. It is critical that the analyzed sample be truly representative of the bulk rock, as non-representative samples can lead to unrealistic results [12]. If major and trace elements are both used, it is critical that both sets of analyses be on the same sample.

Serra de Magé: Serra de Magé is fairly typical of the cumulate eucrites [8, 13]. Its REE pattern [14,15] can be adequately modeled \( (R^2 < 0.045) \) as pigeonite + plagioclase + magma from any known eucrite parent magma. MgO is measured at 10.66% wt [14], and calculated fits were
considered acceptable if 10.4%<MgO<11.0%. With parent magmas along the Stannern trend, this model cannot satisfy both REE and MgO simultaneously. However, Serra de Magé can be modeled nearly exactly as 11.0% Nuevo Laredo eucrite magma, 52.5% cumulus pigeonite, and 36.5% cumulus plagioclase (Figure 1, Table 1). The REE fit is adequate, considering that Er and Dy are poorly constrained, and that La and Lu appear unnaturally high compared to Ce and Yb. The major and minor element fit is superb except for Cr and Na; the deficiency in model Cr may suggest that Serra de Magé contains cumulus chromite.

Other Cumulate Eucrites: Similar calculations have been performed for the Moore County and Moama cumulate eucrites. Unfortunately, no aliquots of either meteorite have been analyzed for both REE and major elements. Moore County's REE and major element contents [8,15,16] are adequately modeled as 35% Nuevo Laredo eucrite magma + 37.5% cumulus pigeonite + 27.5% cumulus plagioclase. This model yields FeO a bit low; a better fit is obtained using a parent magma evolved slightly beyond Nuevo Laredo (La-17.5xCl). However, the simple cumulate model is unable to replicate Moama's LREE depletion [17]. From known eucrite parent magmas, the lowest R² for Moama consistent with MgO [18] is 0.155. The model's failure suggests either that Moama accumulated from a magma that is not represented among known eucrites, or that one of the model's inherent assumptions (e.g., chemical closure) did not hold.

Conclusion: Many cumulate eucrites can be modeled as crystal cumulates with trapped eucritic magma in equilibrium with the crystals. This model does ignore mineral zoning, magma mixing, assimilation, and a host of reasonable to obscure petrogenetic processes. Yet its success in modeling Serra de Magé and Moore County suggests that eucrite genesis and cumulation involved a minimum of petrologic complexity, consistent with their formation in a short time interval on an asteroidal body.