

CHEMICAL EVIDENCE FOR THE ORIGIN OF 76535 AS A CUMULATE. L. A. Haskin<sup>1</sup>, C.-Y. Shih<sup>2</sup>, B. M. Bansal<sup>3</sup>, J. M. Rhodes<sup>3</sup>, H. Wiesmann<sup>3</sup>, and L. E. Nyquist<sup>1</sup>. <sup>1</sup>NASA-JSC, Houston, TX 77058. <sup>2</sup>NRC, NASA-JSC, Houston, TX 77058. <sup>3</sup>LEC, Houston, TX 77058.

Sample 76535 from the North Massif at the Apollo 17 site is a coarse-grained troctolitic granulite rather well equilibrated by long annealing times. It has a modal analysis of 58% calcic plagioclase, 37% magnesian olivine, 4% bronzite, and approximately 1% interstitial material. The plagioclase aggregates average 7mm in size; olivine aggregates approximately 5mm. Bronzite crystals are smaller than 4mm (1).

Samples of the whole rock plus carefully hand-picked plagioclase and olivine were analyzed for a series of trace elements by mass spectrometric isotope dilution, and the whole rock was analyzed for major elements by x-ray fluorescence. Results of these analyses are given in Tables 1 and 2.

The low concentrations of the REE, the large positive Eu anomaly, and the highly magnesian character of the olivine ( $Fe_{88}$ ) (1) suggest that this rock originally formed by crystal accumulation from a liquid. From the data available, various restrictions can be placed on the chemical composition of the parent liquid. If the olivine and plagioclase crystals as analyzed are simply considered as having formed in equilibrium with a liquid which was cleanly separated from them, then by using values for REE distribution coefficients from the literature (2,3,4) the range of possible rare earth concentrations in that proposed parent liquid can be estimated. The liquid estimated in this manner has REE concentrations, including a significant Eu depletion, in the range found for Apollo 17 noritic breccias (KREEP) and intermediate to that for Apollo 16 KREEP and VHA basalt (5,6). If the Apollo 16 and 17 KREEP and VHA basalts are truly characteristic of frozen lunar liquids, then there were apparently liquids whose equilibrium and crystallization could yield olivine and feldspar with the rare earth concentrations observed for those minerals in 76535. This exercise, however, must be regarded as defining only an upper limit to possible REE concentrations of the parent liquid for this rock.

Cumulate rocks normally contain from a few to as much as 50% trapped liquid. As the trapped liquid crystallizes, growth of the original cumulus minerals continues until the composition of the liquid changes to the extent that further phases are produced. Most probably 76535 contained at least a few percent trapped liquid. The distribution coefficients (solid/liquid) for plagioclase and olivine are low. Therefore, trapped parent liquid even in small quantities would seriously affect the concentrations of the REE in the rock and in the constituent minerals. The long annealing time for the rock would tend to homogenize the portions of the major minerals from the trapped liquid with the cumulate portions. This process could also mask the original cumulus texture of the rock. During the formation of some cumulates, major minerals continue to grow in equilibrium with a relatively large body of parent liquid (adcumulus growth). The estimate made above would correspond to the most extreme possible case of adcumulus growth in which no parent liquid was trapped among the growing crystals. That is undoubtedly too severe an approximation.

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A better estimate can be made by recognizing that some trapped liquid is undoubtedly present and assuming that the bronzite and interstitial materials were crystallized from the trapped liquid. The 4% bronzite corresponds to approximately 10% of the rock as being produced from trapped liquid. This assumes the composition of the peritectic and simultaneous presence of olivine, orthopyroxene, and plagioclase (7). A mass balance taking into account the estimated relative amounts of the REE in the cumulate and trapped liquid (orthocumulate) portions of the rock produces a parent liquid with rare earth concentrations approximately 30 times those in chondrites and with a slight Eu depletion. If the bronzite is, indeed, orthocumulate in origin, this also provides an upper limit to the concentration of the parent liquid. Since bronzite was not accumulating from the parent liquid, that liquid would have to crystallize still further olivine and plagioclase to reach the peritectic where bronzite could appear.

It is not clear whether the Eu deficiency observed for mare basalts and trace element-rich highland materials is a result of an overall lunar deficiency in Eu resulting from the conditions of planetary accretion (8) or a result of internal differentiation of the accreted moon. It is still possible to consider that the Eu that is missing in trace element-rich mare and highland materials was previously crystallized into feldspar during the early planetary differentiation. In view of this possibility, it is interesting to consider whether a liquid with no Eu depletion could have produced 76535 by crystal accumulation plus trapped liquid. The Eu anomaly for the hypothetical parent liquid of this rock disappears for a concentration for the parent liquid of approximately 15 times that found in the chondrites. This requires that the rock contain 20% trapped liquid, which is well within the range found for terrestrial cumulates and consistent with the requirement of additional crystallization of the trapped parent liquid prior to formation of bronzite.

There is some indication in the rare earth distributions that complete equilibration of REE between plagioclase and olivine, as expected from the apparently long annealing times, has not occurred.

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Table 1. REE concentrations (ppm) in combined samples 76535,21 and 76535,22 and their separated minerals.

	Whole Rock	Plagioclase	Olivine
La	1.51	2.50	--
Ce	3.81	5.53	0.101
Nd	2.30	3.24	0.125
Sm	0.609	0.807	0.0606
Eu	0.732	1.26	0.00437
Gd	0.728	0.837	0.148
Dy	0.797	0.566	0.336
Er	0.533	0.230	0.366
Yb	0.555	0.159	0.540
Lu	0.0785	0.012	0.0995

Table 2. Major element concentrations (weight percent) in combined samples 76535,21 and 76535,22.

SiO <sub>2</sub>	42.88	CaO	11.41
TiO <sub>2</sub>	0.05	Na <sub>2</sub> O	0.2*
Al <sub>2</sub> O <sub>3</sub>	20.73	K <sub>2</sub> O	0.03
FeO	4.99	P <sub>2</sub> O <sub>5</sub>	0.03
MnO	0.07	S	<0.01
MgO	19.09	Cr <sub>2</sub> O <sub>3</sub>	0.11
		Total	99.60

\* By A. A.