COMPARISONS OF MINERALOGY BETWEEN CUMULATE EUCRITES AND LUNAR METEORITES POSSIBLY FROM THE FARSIDE ANORSOTHITIC CRUST.

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Introduction: Anorthosites composed of nearly pure anorthite (PAN) at many locations in the farside highlands have been observed by the Kaguya multiband imager and spectral profiler [1]. Mineralogical studies of lunar meteorites of the Dhofar 489 group [2,3] and Yamato (Y-) 86032 [4], all possibly from the farside highlands, showed some aspects of the farside crust. Nyquist et al. [5] performed Sm-Nd and Ar-Ar studies of pristine ferroan anorthosites (FANs) of the returned Apollo samples and of Dhofar 908 and 489, and discussed implications for lunar crustal history. Nyquist et al. [6] reported initial results of a combined mineralogical/chronological study of the Yamato (Y-) 980318 cumulate eucrite with a conventional Sm-Nd age of 4567±24 Ma and suggested that all eucrites, including cumulate eucrites, crystallized from parental magmas within a short interval following differentiation of their parent body, and most eucrites participated in an event or events in the time interval ~4400-4560 Ma in which many isotopic systems were partially reset. During the foregoing studies, we recognized that variations in mineralogy and chronology of lunar anorthosites are more complex than those of the crustal materials of the HED parent body.

In this study, we compared the mineralogies and reflectance spectra of the cumulate eucrites, Y-980433 and 980318, to those of the Dhofar 307 lunar meteorite of the Dhofar 489 group [2]. Here we consider information from these samples to gain a better understanding of the feldspathic farside highlands and the Vesta-like body.

Samples and Methods: Samples Y-980433 (1497.5 g) and Y-980318 (166.81g) are proposed to be paired [7]. Two polished thin sections (PTS) prepared from the paired samples and one of Dho 307 were studied at ORI and NIPR. Line analyses of plagioclase and inverted pigeonite of Y-980433 were performed with a JEOL 733 EPMA at ORI. The Y-980433,71 sample (1.656 g) was crushed and sieved with 100-200 mesh sieve and plagioclase portion with 75-150 μm grains was obtained by magnetic separator. Then, the plagioclase sample was split into two portions about 70 mg each. One portion was washed with 1N HCl acid to remove the weathering materials and the other portion was not cleaned with the acid. Mineral separation of Y-980433,51 (1.68 g) produced only ~170 mg of "good" plagioclase grains of 75-150 μm.

The reflectance spectra of the Y-980433,71 whole rock sample with grain size of <63 μm, plagioclase separate of size 37-63 μm and 75-150 μm and pyroxene separate of size 37-63 μm of the Y-980433 sample [8] and cut surface of Dho 307 were measured at Brown Univ. Bidirectional UV-visible-NIR diffuse reflectance spectra were obtained using a reflectance spectrometer. In addition, a cut surface of the Dho 307 lunar meteorite was measured for compareson.

Results: The reflectance spectra of mineralogically well characterized samples of one of the oldest crustal rocks of the HED parent body are useful in interpreting the earliest crustal rocks of the lunar farside highland.

Mineralogy of Y-980433 cumulate eucrite. PTS Y980318,50-2 is of a coarse-grained crystalline rock with sub-rounded or lath-shaped plagioclase (An_{90}) up to 4.5×1.5 mm in size enclosed in continuous networks of pyroxene grains up to 4.4×2.9 mm in dimension. Exsolution and inversion textures to orthopyroxene of the inverted pigeonites are similar to those of Serra de Magé [9]. The bulk composition of the primary pigeonite is $Ca_{12}Mg_{47}Fe_{41}$ [6]. The thickness of augite lamellae ($Ca_{45}Mg_{37}Fe_{18}$) [6] on (001) of the original pigeonite is ~30 μm. The host low-Ca pyroxene between the thick lamellae has decomposed into blebby augite inclusions in orthopyroxene (Opx $Ca_2Mg_{50}Fe_{48}$) [6], and the orthopyroxene grew into adjacent pigeonites. The inversion texture and Opx composition ($Ca_2Mg_{51}Fe_{47}$) of Y-980433 is similar to those of Y980318. We proposed that such texture developed in a cumulate pile in a very slowly cooling magma as in terrestrial layered intrusions.

The spectra of Y980433 do not show 1.25 μm absorption of plagioclase. This cumulate eucrite is a nice crystalline rock with clear plagioclase crystals, and PTS Y-980318,50-2 shows crystalline textures, but the Y-980433 PTS shows minor disturbance of the twin textures of the plagioclase grains. The plagioclase grains in the bulk sample look snow white with some

stains. The effective grain size of this plagioclase is small and its powder separates are snow white. The mean plagioclase FeO composition is less than 0.10 wt %, but individual analysis shows minor variations.

Discussion: The Vesta-HED link is directly tied to the observed and inferred mineralogy of the asteroid and the mineralogy of the meteorites [9]. Pyroxenes and calcic plagioclase are the dominant minerals present in HED meteorites and provide multiple clues about how the parent body evolved [9]. The differentiation trends of HED meteorites are much simpler than those of the lunar crust, and may provide some clues useful in the more complex lunar case.

Mineralogy of the cumulate eucrites. Pieters et al. [10] reported that the Y-980318 cumulate eucrite showed very weak 1.25 micron plagioclase absorption, and FeO of plagioclase are 0.03-0.06 wt % [6]. This plagioclase shows clear transparent appearance. The Y-980433 plagioclase grains look sugary white and shows no 1.25 μm plagioclase absorption, and FeO contents of 0.11 wt % on average (high 0.25, low 0.07). In order to explain this difference, Hiroi et al. [8] introduced "effective grain size". If we measure the spectra of very clear transparent plagioclase, the effective path length is long and shows stronger absorption. If we make sugar cube like fine-grained plagioclase, their effective grain size is small and no absorption will be observed. If mafic silicates at the grain boundaries around large plagioclase crystals are covered by fine plagioclase powders, their spectra might still show a little mafic silicate absorption.

Mayne et al. [11] reported on petrologic insights from the spectra of the unbrecciated eucrites on the basis of MGM analyses as a tool for modeling the relative proportions of Low Ca Pyroxene (LCP) and High Ca Pyroxene (HCP) from spectra. However, their LCP includes both orthopyroexe and pigeonite which do not have identical spectra. As is shown by the Y-980433 pyroxene, inverted pigeonite is now mixtures of orthopyroxne and augite, and in some cumulate eucrites such as Moore County, some pigeonite parts remain uninverted. The absorption of plagioclase has not been considered in their study, since we are the first to measure the spectra of the plagioclase separate.

Lunar anorthosites. It is widely assumed that FANs formed as flotation cumulates on the LMO. Nyquist et al. [5] think that many FANs were approximately contemporaneous and formed with the same initial $^{143}Nd/^{144}Nd$ ratio. They showed that a whole rock Sm-Nd isochron for selected FANs yields an isochron age of 4.42±0.13 Ga and initial $^{143}Nd/^{144}Nd$, expressed in ε-units, of $\varepsilon_{Nd,CHUR} = 0.3\pm0.3$ relative to the CHondritic Uniform Reservoir, or $\varepsilon_{Nd,HEDPB} =$-

0.6±0.3 relative to the HED Parent Body [6]. Their $\varepsilon_{Nd,HEDPB}$ is based on the values obtained on the Y-980318 cumulate eucrite. They also have studied anorthositic clasts in the Dhofar 908 and 489 lunar highland meteorites containing clasts of magnesian anorthosites with Mg# ~75 [3]. In order to explain the formation of both FANs and the farside anorthosites, we may have to invoke a convection model for the LMO [12].

Hiroi et al. [8] measusred the reflectance spectrum of the 60015 plagioclase sample and compared it to the spectrum of an anorthositic clast in Y-86032, the 15415 spectrum, and a PAN spectrum of the Jackson central peak [1]. The spectra of 60015 with FeO 0.26-0.36 wt% show similar absorption bands up to around 1.0 μm but differ from those of the Y-980433 spectra. Because plagioclase in cumulate eucrites was crystallized from a thin magma ocean with higher FeO content than those of the LMO, it is rather surprising to note that lunar highland plagioclase shows much stronger absorption of the main plagioclase band. The spectra of Dho 307 show absorption of minor olivine, in agreement with the PTS observation, while the Kaguya spectra of the farside highlands are dominated by the pyroxene band. Fine orthopyroxene crystals are present in the recrystallized impact melt matrices of Dho 307 and Dho 489. The complex history of the lunar farside crust should be interpreted in terms of the possible influence of the formation of large basins. We have to interpret the spectra of lunar plagioclase in light of mineralogical modifications produced by this impact and thermal history.

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