Mineralogy of Inverted Pigeonite and Plagioclase in Cumulate Eucrites Y-980433 and Y-980318 with Reference to Early Crust Formation of the Vesta-like Body.

H. Takeda[1], M. Ohtake[2], T. Hiroi[3], L. E. Nyquist [4,5], C.-Y. Shih[6], A. Yamaguchi[7]. H. Nagaoka[8], [1]Univ. of Tokyo, Graduate School of Sci., Chiba Inst. of Technology, Forum Res. , [2]JAXA/ISAS, [3]Brown Univ., Dept. Geol. Sci., [4]KR/NASA Johnson Space Center, Houston, TX 77058 U.S.A., [5]Center for Lunar Sci. and Exploration, NASA Lunar Sci. Inst. [6]ESCG Jacobs- Sverdrup, Houston, TX 77058, [7]National Inst. of Polar Res., [8]Waseda Univ., Res. Inst. for Sci. & Engn.

Introduction:

On July 16, the Dawn spacecraft became the first probe to enter orbit around asteroid 4 Vesta and will study the asteroid for a year before departing for Ceres. The Vesta-HED link is directly tied to the observed and inferred mineralogy of the asteroid and the mineralogy of the meteorites [1]. Pieters et al. [2] reported reflectance spectra of the Yamato-(Y-)980318 cumulate eucrite as a part of their study on the Asteroid-Meteorite Links in connection with the Dawn Mission. Pyroxenes and calcic plagioclase are the dominant minerals present in HED meteorites and provide multiple clues about how the parent body evolved [1]. The differentiation trends of HED meteorites are much simpler than those of the lunar crust.

Nyquist et al. [3] reported a preliminary value for the ^{147}Sm-^{143}Nd age of the Y-980318 cumulate eucrite of 4560 Ma, and a combined mineralogical/ chronological study of this cumulate eucrite with a conventional Sm-Nd age 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. Nyquist et al. continued their isotopic studies and give 4557 Ma as the crystallization age by conventional Sm-Nd technique, assuming that two samples are really the same rock [4]. 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.

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 [5,6]. We continued this line of work in order to gain more information to interpret the data, which will be obtained by the Dawn Mission.

Samples and Methods:

Two polished thin sections (PTS) Y-980318, 50-2 and Y-980433,11-1 prepared from the paired samples Y-980433 (1497.5 g) and Y-980318 (166.81g) [7] were analyzed with a JEOL 733 EPMA at AORI (Atmosph. Ocean Res. Inst.). Line analyses of plagioclase and inverted pigeonite of Y-980433 were also obtained at AORI .

The Y-980433,71 sample (1.656 g) was processed to produce plagioclase separates by the method described in [5]. Mineral separation of the Y-980433,51 sample (1.68 g) produced only ~170 mg of "good" plagioclase grains of 75-150 μm. The reflectance spectra of the Y-980433,71 sample were measured at Brown Universtiy [5,6]. Bidirectional UV-visible-NIR diffuse reflectance spectra were obtained using a reflectance spectrometer.

Results:

Y-980318 is a coarse-grained crystalline rock with sub-rounded or lath-shaped plagioclase (An_{90}) enclosed in continuous networks of pyroxene grains. A brief description of the textures of PTS Y-980318,50-2 are given in the companion abstract of this meeting by Nyquist et al. [4]. This PTS shows a nice crystalline texture with clear plagioclase crystals, but the Y-980433,11-1 PTS shows minor disturbance of the twin textures of the plagioclase grains. In this abstract, we report detailed chemistry of minor elements and the exsolution and inversion textures to show the mechanism of inversion.

A photomicrograph (Fig.1) of Serra de Magé [8] shows typical exsolution and inversion textures to orthopyroxene (Opx) of the inverted pigeonites. PTSs Y980318,50-2 (Fig. 2) and Y-980433,11-1 show similar textures to those of Fig. 1 . The chemical composition of the primary pigeonite, exsolved augite (Aug) lamellae and Opx inverted from pigeonite of Y-980318 are given in [4]. The PTS photo shows that the original pigeonite grains can be traced by a grain with common (001) exsolution lamellae, which were developed within the original pigeonite crystal. Then, the Opx nucleates in some of the low-Ca clinopyroxene host between the lamellae and grew into adjacent pigeonite grains as is also shown in Fig. 1. The blebby trend of Aug in the Opx host suggests decomposition of pigeonite at the PER line during or after the Opx growth. The texture is different from a typical Stillwater type inverted pigeonite [8]. The inversion texture and their composition of Y-980433 is similar to those of Y-980318. We proposed that such texture developed in a cumulate pile in a very slowly cooling magma as in terrestrial layered intrusions.

The spectra of Y-980433 [9] were processed by Ohtake to remove the continuum (Fig. 3). The spectra still show absorption of pyroxenes and show minor 1.25 μm absorption of plagioclase. The plagioclase grains in the bulk sample look snow white with some stains.

Line analysis of a plagioclase crystal in Y-980433,11-1 along a lath, was performed with 10 um interval, and probe beam diameter of 5 um. The oxide weight % of FeO, CaO, Na_2O, and K_2O are given below:

Oxides	FeO	CaO	Na_2O	K_2O
Mean	0.11	18.09	1.27	0.08
Mean 10	0.13	18.10	1.26	0.07
Min	0.06	18.20	1.33	0.10
Max	0.14	18.23	1.31	0.08

The mean wt % of SiO_2: 45.32, Al_2O_3: 34.26, and minor element concentrations of TiO_2, MnO, Cr_2O_3, V_2O_3, NiO, P_2O_5 are less than 0.06.

Discussion:

The ordinary eucrites probably form most of the outer crust of asteroid 4 Vesta [1]. Cumulate eucrites are widely believed to have formed deep in the crust of their parent body, probably at depths of 3 to 8 km or more, but mineral chemistry and exsolution textures suggest that each experienced a different rate of subsolidus cooling.

The microscopic textures of the Y-980433 pigeonites show the mechanism of exsolution and inversion of pyroxene in a very nice way. It is important to recognize that such slow cooling texture is essential to keep the original bulk and isotopic composition of the original crust and it is in line with the very old age of the crystallization of these cumulate eucrites. It is to be remembered that such undisturbed original crystallization and cooling textures with the old age have not been recognized in the pristine non-mare rocks of the lunar crust.

Pieters et al. [2] reported that the reflectance spectra of Y-980318 showed prominent pyroxene absorption but very weak 1.25 micron plagioclase absorption [2], and FeO of plagioclase are 0.03-0.06 wt % [6]. This plagioclase shows clear transparent appearance but those of Y-980433,11-1 are slightly disturbed and the FeO wt% are variable and a little higher. Good reflectance spectra of pyroxenes and plagioclase of cumulate eucrites are needed if this deep-seated lithology is to be identified on the surface of Vesta, possibly on the floor of a crater.

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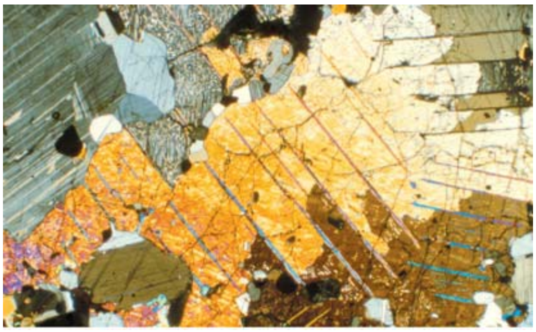

Fig. 1. Photomicrograph of Serra de Magé (Amer. Museum of Natural History). Cross polar light. Width is 6.6 mm.

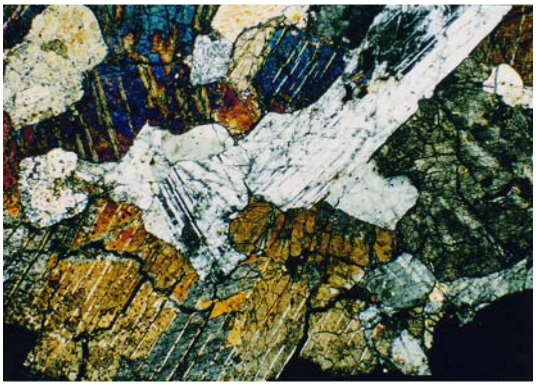

Fig. 2. Photomicrograph of the Y-980433 cumulate eucrite of NIPR. Cross polar, width 6.6mm.

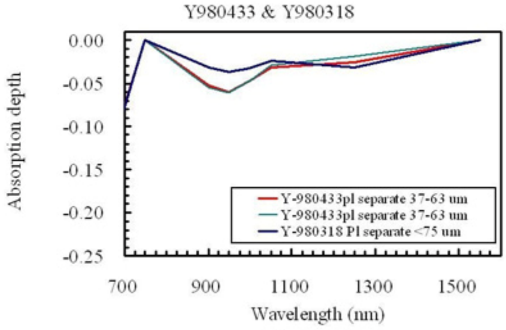

Fig. 3. Reflectance spectra of Y-980433 and Y-980318 processed by Ohtake at JAXA/ISAS