REDOX STATES OF CUMULATE EUCRITE Y-75011 AND SURFASE EUCRITE Y 980433 AS INFERRED FROM IRON MICRO-XANES ANALYSES OF PLAGIOCLASE. W. Satake[1], P. C. Buchanan[2], H. Takeda[3], T. Mikouchi[1], and M. Miyamoto[1], [1]Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, (E-mail: satake@eps.s.u-tokyo.ac.jp), [2]Kilgore College, 1100 Broadway, Kilgore, Texas 75662-3204, USA. [3]Univ. of Tokyo, Graduate school of Sci., & Chiba Inst. of Tech., Forum Res, Japan.

Introduction: The HED (Howardites, Eucrites and Diogenites) meteorites are the largest group of achondrites and are widely believed to have originated on 4Vesta [e.g., 1]. Eucrites are mainly composed of pyroxene and plagioclase, and are considered to have been derived from the crust of the asteroid. Recently, the Dawn spacecraft observation has revealed the existence of a metallic core in Vesta and that it experienced early differentiation in the solar system [2]. Furthermore, the mineral data obtained by Dawn's visible and infrared spectrometer are consistent with the mineralogical character of HED meteorites [3]. In this way, Vesta is an important example of early differentiation in the solar system, and thus, HED meteorites may offer substantial information to understand igneous differentiation on Vesta [2-4].

The oxidation state of magmas is one of the most significant factors in controlling mineral crystallization and is relevant to the redox state of the parent body. In our previous study, we estimated redox states of six eucrites by using synchrotron radiation (SR) Fe XANES measurement of plagioclase [5,6]. This study reveals that the $Fe^{3+}/\Sigma Fe$ ratios of plagioclase in cumulate eucrites are higher than those of surface eucrites (Table 1), which indicates that the deep crust of Vesta was a relatively more oxidized environment. However, this result needs to be reassessed by analyzing minimally metamorphosed samples because most eucrites have experienced significant degrees of thermal metamorphism [7].

In this study, we focused on surface and cumulate eucrites that were not affected by annealing, in order to compare the XANES results with our previous study.

Samples and Methods: We analyzed thin sections of surface eucrite clast in Y-75011 and cumulate eucrite Y 980433. We first carefully observed them by optical and scanning electron microscopes, and analyzed them by electron microprobe in order to select representative plagioclase grains for SR Fe-XANES.

SR Fe-XANES was performed at BL-4A, Photon Factory, KEK, Tsukuba, Japan to measure $Fe^{3+}/\Sigma Fe$ ratios of plagioclase. The SR beam size was about 5 x 6.5 μm. The XANES analyses for standard kaersutites with known $Fe^{3+}/\Sigma Fe$ ratios shows a linear relationship between centroid energy position of XANES pre-edge spectra and the $Fe^{3+}/\Sigma Fe$ ratio. Based on this linear relationship, we estimated the $Fe^{3+}/\Sigma Fe$ ratio of samples [8]. The XANES results are known to be influenced by crystal orientation [8]. In order to minimize this effect, we selected elongated plagioclase grains and located the samples so that the elongation was always horizontal against the SR beam. The incident beam angle to the sample is 45° and the angle between the incident beam and the detector was fixed at 90°. In this measurement, the largest error comes from the statistical error and is calculated from the counting rate (cps).

Results: Optical and scanning electron microscope observations show that all samples are mainly composed of pyroxene and plagioclase. The plagioclase abundance in Y-75011 is about 30 vol. % and Y 980433 is about 50 vol. %, respectively.

Y-75011 is a polymict eucrite with clasts of surface eucrite that contains fine-grained pyroxene and plagioclase. This texture shows that Y-75011 is apparently composed of fragments of lavas that were extruded onto or close to the surface of Vesta [4]. We selected a representative lathy plagioclase grain (500 x 50 μm) for SR-XANES analysis (Fig. 1). The plagioclase composition is chemically zoned (An_{93-80}), and the FeO abundance is 0.3-0.4 wt%. On the other hand, Y 980433 is a cumulate eucrite showing a much coarser-grained texture and plagioclase is commonly larger than 1 mm. Y 980433 has clearly thick exsolution lamella of high-Ca pyroxene, indicating this sample slowly crystallized and cooled [9]. We selected a big plagioclase grain (2000 x 1500 μm) for SR-XANES analysis (Fig. 1). The plagioclase composition is An_{91-87} and the FeO abundance is <0.05 wt%.

As Fig. 2 shows, all plagioclase grains analyzed display clear pre-edge peaks in the obtained XANES spectra. The $Fe^{3+}/\Sigma Fe$ ratio of Y-75011 is estimated to be 0.10-0.14 and Y 980433 is 0.48-0.58, respectively.

Discussion and Conclusions: The $Fe^{3+}/\Sigma Fe$ ratios of plagioclase in two eucrites studied show contrasting values (0.12 vs. 0.52). The $Fe^{3+}/\Sigma Fe$ ratio of the Y-75011 surface eucrite is consistent with those of other surface eucrites (Padvarninkai, ALH 76005, Piplia Kalan and Petersburg) in its low $Fe^{3+}/\Sigma Fe$ ratio. Similarly, the $Fe^{3+}/\Sigma Fe$ ratio of the Y 980433 cumulate eucrite is consistent with other cumulate eucrites (EETA 87520 and Moore County).

This study demonstrated that the $Fe^{3+}/\Sigma Fe$ ratios of plagioclase from surface and cumulate eucrites have not been affected by later thermal metamorphism, and they are likely to reflect the redox state of the crystallization environment. Thus, we suggest that there was a heterogeneous redox environment in Vesta, where surface areas were more reduced than the crust and deep interior.

There are two possible scenarios for explaining these features. One is that the oxidizing environment of Vesta's deep crust was caused by water in Vesta's interior. For example, Serra de Mage cumulate eucrite contains quartz veins, suggesting the presence of liquid water [10]. Serra de Mage is estimated to have crystallized at 8 km depth [11], and it is similar to the depth of Moore County. The water is considered as secondary origin as brought by comet [10], but the finding of deep oxidized crust may suggest that water was originally present. The other possibility is that the oxidized environment was originally related to the early differentiation of Vesta. In early differentiation, the planetary surface may have formed a thin layer temporarily [12] and oxygen was not dissipated. Eventually, oxygen was lost from lava when exposed on the Vesta surface without atmosphere, but, oxygen would have been retained in magma that was under pressure in the deep environment. Although we cannot determine which model is more likely at present, this study at least reveals Vesta's deep crust shows a global oxidized environment.

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Table 1 Estimated $Fe^{3+}/\Sigma Fe$ ratios of plagioclase and type of eucrites.

Sample	The $Fe^{3+}/\Sigma Fe$ ratio	Type
Padvarninkai	0 - 5[6]	Surface
ALH 76005	0 - 23[5]	Surface
Piplia Kalan	8 – 20[5]	Surface
Petersburg	6 - 22[5]	Surface
EETA 87520	12 - 37[5]	Cumulate
Moore County	16 - 38[6]	Cumulate
Y-75011	**10 – 14**	**Surface**
Y 980433	**48 - 58**	**Cumulate**

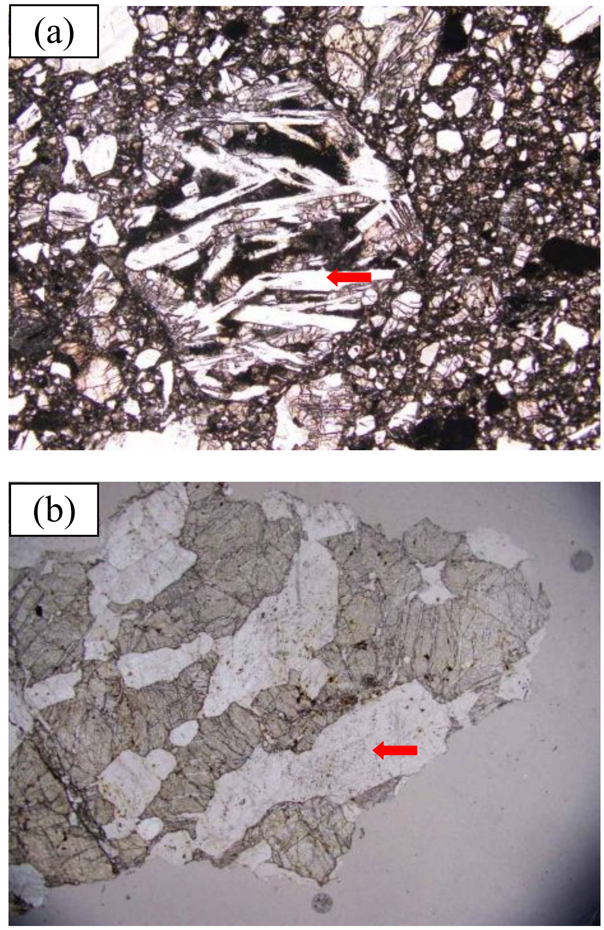

Fig. 1 Optical photomicrographs of (a) Y-75011 and (b) Y 980433. Red allows shown in each image are analyzed plagioclase grains by SR-XANES. Image (a) is about 1 x 1.4 mm in size and image (b) is about 2.6 x 3.4 mm in size.

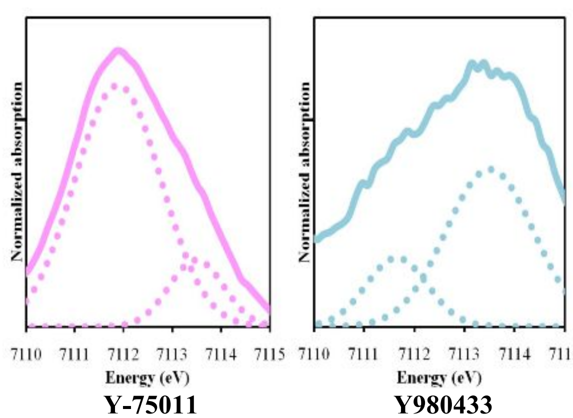

Fig. 2 Pre-edge peaks of Fe K-edge SR XANES spectra of plagioclase in Y-75011 and Y 980433.