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# Iron valences of plagioclase from cumulate eucrites Y-75011 and surface eucrite Y 980433 as inferred from micro-XANES an

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The HED (Howardites, Eucrites and Diogenites) meteorites are the largest group of achondrites and are widely believed to have originated on 4Vesta. 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. 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.

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. This study reveals that the $Fe^{3+}$/($Fe^{2+}$ + $Fe^{3+}$) ratios of plagioclase in cumulate eucrites are higher than those of surface eucrites, 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.

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.

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 $Fe^{3+}$/ ($Fe^{2+}$ + $Fe^{3+}$) ratios of plagioclase. The SR beam size was about 5 x 6.5 micro meter. The XANES analyses for standard kaersutites with known $Fe^{3+}$/ ($Fe^{2+}$ + $Fe^{3+}$) ratios shows a linear relationship between centroid energy position of XANES pre-edge spectra and the $Fe^{3+}$/ ($Fe^{2+}$ + $Fe^{3+}$) ratio. Based on this linear relationship, we estimated the $Fe^{3+}$/ ($Fe^{2+}$ + $Fe^{3+}$) ratio of samples.

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

The $Fe^{3+}$/ ($Fe^{2+}$ + $Fe^{3+}$) ratios of plagioclase in two eucrites studied show contrasting values (0.12 vs. 0.52). The $Fe^{3+}$/ ($Fe^{2+}$ + $Fe^{3+}$) ratio of the Y-75011 surface eucrite is consistent with our previous study of other surface eucrites (Padvarninkai, ALH 76005, Piplia Kalan and Petersburg) in its low $Fe^{3+}$/ ($Fe^{2+}$ + $Fe^{3+}$) ratio. Similarly, the $Fe^{3+}$/ ($Fe^{2+}$ + $Fe^{3+}$) ratio of the Y 980433 cumulate eucrite is consistent with our previous study of other cumulate eucrites (EETA 87520 and Moore County).

This study demonstrated that the $Fe^{3+}$/ ($Fe^{2+}$ + $Fe^{3+}$) 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. The other possibility is that the oxidized environment was originally related to the early differentiation of Vesta. 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.

Keywords: XANES, Eucrite, Vesta, Plagioclase