**XRD ANALYSES OF BASALTIC AND CUMULATE EUCRITES: IMPLICATION FOR SHOCK METAMORPHISM.** R. Kanemaru1, N. Imae1,2, A. Yamaguchi1,2, and H. Nishido3, 1Department of Polar Science, School of Multidisciplinary Science, The Graduate University for Advanced Studies (SOKENDAI), Tokyo 190-8518, Japan, 2National Institute of Polar Research (NIPR), Tokyo 190-8518, Japan, 3Okayama University of Science (OUS), Okayama 700-005, Japan. Email: kanemaru.rei@nipr.ac.jp

**Introduction:** After the initial crystallization, most of the eucrites experienced complex secondary processes such as impact, brecciation, melting, thermal metamorphism, and metasomatism on the parent body (probably asteroid 4 Vesta). The understanding for post-crystallization histories of eucrites is important to clarify the formation process of Vestan crust. The thermal metamorphic degrees (type 1-6) for eucrites have been mainly suggested by mineralogical features in pyroxene [1]. However, the shock degrees for eucrites have not been established.

Recent studies of X-ray diffraction (XRD) analyses using the in-place rotation of polished thin sections (PTSs) for ordinary chondrites [2] showed that the XRD technique has a potential for the classification and identification of shock and metamorphic stages. We applied this technique for basaltic and cumulate eucrites to understand the shock and thermal metamorphism.

**Measurement methods:** X-ray measurements (RIGAKU, SmartLab) were performed on the condition of Cu Kα with 40 kV and 40 mA through the slit of 10 mm in height and 5 mm in width with the divergence angle of (1/6)°. The measured 2θ range is 8-75°. Compositional data for mineral phases were obtained with an electron probe microanalyzer (EPMA: JEOL JXA-8200) at National Institute of Polar Research, Tokyo (NIPR). Textures were observed by an optical microscope and FE-SEM (JEOL JSM-7100) equipped with an energy dispersive spectrometer (EDS) (Oxford AZtec Energy) and cathodoluminescence (CL) system (GATAN Chroma CL) at NIPR. For identification of maskelynite and plagioclase, luminoscope (ELM-3) at Okayama University of Science (OUS) and a Raman spectroscopy (JASCO NRS-1000) at NIPR were used.

**Analytical methods:** We defined the shock degrees of studied eucrites from A to D on the basis of the petrographic and mineralogical features. Shock degree A: (unshocked)-sharp optical extinction of plagioclase and pyroxenes; shock degree B (low): undulatory extinction or mosaicism of plagioclase and pyroxene; shock degree C (moderate): the presence of shock veins and/or maskelynite; shock degree D (high): most of plagioclase converted to maskelynite.

**Samples and descriptions:** We used PTSs of 13 basaltic eucrites and 3 cumulate eucrites. We described the petrographic and mineralogical features of the representative samples for this study below.

**Basaltic eucrites:**
Agoult, EET 90020, Juvinas, and A-87272 are basaltic eucrites. Agoult and EET 90020 are unbrecciated eucrites. Almost all of the grains of pyroxene and plagioclase in both samples have sharp optical extinction, indicating that these samples did not experience significant shock metamorphism. Juvinas is a monomict breccia that experienced complex metamorphic history [3]. Juvinas has fine-grained polygonal pyroxenes (granoblastic pyroxenes) in the crystalline portion. The mineralogical features of the granoblastic pyroxene imply that the texture formed by recrystallization by shock and thermal metamorphism. A-87272 is a coarse-grained unbrecciated eucrite. A-87272 has been known as one of the most severely-shocked samples [4]. Most plagioclase grains in A-87272 are converted to maskelynite. On the base of the above descriptions, the likely shock degrees of Agoult, EET90020, Juvinas, and A-87272 are A, A, B, and D, respectively.

**Cumulate eucrites:**
Moama, Y-791195, and Y 980433 are cumulate eucrites. Moama and Y 980433 are composed of coarse-grained (<3 mm in diameter) minerals, whereas Y-791195 is composed of a finer-grained (<0.5 mm in diameter) granular minerals. Most of the grain of pyroxene and plagioclase in Moama and Y-791195 have sharp optical extinction, indicating that these eucrites do not have any evidence of significant shock metamorphism. We observed fine-grained polygonal pyroxenes in Y-791195. Y 980433 has a small number of shock veins and maskelynite. On the base of the above observations, the shock degrees of Moama, Y-791195, and Y 980433 are A, B, and C, respectively.

**XRD results and discussion:** We identified the diffraction peaks of plagioclase, pigeonite, augite, and orthopyroxene from the studied samples. The XRD patterns of 12 eucrites (e.g., Fig. 1: Agoult) exhibiting the high degree of randomness similar to powder sample. However, the other eucrites especially Moama (Fig. 1: Moama-4943 and -4471) show different diffraction patterns. The diffraction patterns may reflect the concentration of crystal orientation in the sample. The feature may be available to search for the presence of fabric in the rock. The feature is strongly developed in Moama, and the crystalline portion of Y-790266, A-881747, and Camel Donga.
The integrated peak intensities and full width at half maximum (FWHM) values of mineral indices in the eucrites studied here have been affected by shock metamorphism (Fig. 2: A-87272). We suggest that the averaged FWHM value, calculated from bulk X-ray diffraction is a good indicator for determining the shock degrees of eucrites (Fig. 2). The averaged FWHM value positively correlates with the likely shock degree. The averaged FWHM value corresponds for two features. (i) The X-ray diffraction peaks of eucrites become weaker and broader by increasing the shock degree. As a result, the FWHM value is positively correlated with the shock stage. (ii) The total number of the peaks decreases by increasing the shock stage (negative correlation) due to the breakdown of several peaks in the diffraction and the fusion of the peaks. Actually, as the unshocked eucrites, Agoult, EET 90020, and Moama-4943 show the total number of the peak as 163, 159, 148, respectively. Shocked eucrites, A-87272, Cachari, and Y 980433 show the total number of the peak at 35, 70, 64, respectively. Thus, the averaged FWHM value (total FWHM value/ the total number of peak) is composed of two effective parameters for shock degree. This is not affected by the crystal orientation of the sample, because two Moama samples show a relatively close value.

The peak integrated intensity of plagioclase decreases more than that of pyroxene by shock metamorphism. The peak integrated intensity of the plagioclase 202 position is negatively correlated with the likely shock degree (Fig. 3). The feature may be related to the breakdown of plagioclase to maskelynite. The suggestion is consistent with the likely shock degree in this study. However, plagioclase 202 is simply not available for determining the shock stage because several eucrites (e.g., A-881747, Camel Donga, Moama, and Y-790266) have a concentration of crystal orientation.

Summary and Implication: The present study showed that the features of the XRD pattern are correlated with the likely shock degree. Thus the averaged FWHM value may be an especially good indicator to determine the shock degrees for eucrites. However, metamorphism. We will develop the quantitative scheme to identify shock degrees of eucrites. Moreover, we plan to obtain the data for the degrees of thermal metamorphism from XRD data. The relative intensity of clinopyroxene and orthopyroxene may become the useful indicator for distinguishing the type 5 and type 6 eucrites.