

Evaluation of shock metamorphism of eucrites by X-ray diffraction analysis

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Introduction

Eucrites have been considered to come from the surface crust of asteroid 4 Vesta. Eucrites experienced varying degrees of shock and thermal metamorphism. The scaling of the degree of shock metamorphism necessary for the understanding of the formation history of Vesta. However, the degree of shock metamorphism has not been established. Recent studies of X-ray diffraction (XRD) analyses using the in-plane 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. In this study, we applied this technique for the thin or thick sections of 13 basaltic and 3 cumulate eucrites. We show that the bulk XRD data may be a useful indicator for characterizing the shock degree for eucrites.

Measurement and analytical methods

We performed X-ray measurement by SmartLab (RIGAKU) at National Institute of Polar Research, Tokyo, on the condition of Cu K α with 40 kV and 40 mA through the slit of 10 x 5 mm in size.

We defined the shock degrees of studied eucrites from A to D by the petrographic and mineralogical features of thin and thick sections: shock degree A (unshocked) = sharp optical extinction of plagioclase and pyroxenes, shock degree B (low) = weak undulatory extinction or mosaicism of plagioclase and pyroxene, shock degree C (moderate) = the presence of maskelynite, and shock degree D (high) = most (>70-80 vol%) of the plagioclase converted to maskelynite. The degrees of A, B, and C, D for eucrites roughly correspond to 0, 1 and 2 of shock stage for basaltic meteorites defined by Bischoff and Stöffler. (1992) [3], and S1, S2-4, and S5 for enstatite chondrites by defined Rubin et al. (1997) [4], respectively.

Results

We obtained the XRD patterns of 12 eucrites exhibiting the high degree of randomness (e.g., Agoult), whereas four eucrites show the feature of the crystal orientation (e.g., Moama). We identified the peaks of plagioclase, pigeonite, and augite from the XRD patterns of eucrites. The bulk XRD data of each eucrite shows the positive correlation between the full width at half maximum (FWHM) values (for both mean and total) and the shock degree estimated from the textures. On the other hand, the number of the peak in the XRD pattern shows a negative correlation for the increasing of shock degree.

The specific peaks of plagioclase (especially -202) show the decreasing peak intensity and the increasing FWHM values for the increasing shock degree. The peak of pyroxene (pigeonite 310 and augite -311) (2 θ = ~30.7°) also shows the increasing FWHM value of pyroxenes for the increasing shock degree.

Discussion

The increase of the averaged FWHM values for each eucrite are related to the shock metamorphism of pyroxene and plagioclase. The negative correlation between the peak intensities of plagioclase and shock degree implies the maskelynitization of plagioclase by shock metamorphism. In particular, most of the plagioclase peaks in A-87272, the strongest shocked sample (D) studied here, have disappeared. The pyroxene peaks show a positive correlation between the FWHM value and shock degree, whereas there is no correlation between the peak intensity and shock degree. This indicates that the shock metamorphism produces the strain in pyroxenes.

In-plane rotation of PTSs method of XRD analysis for eucrites is affected by the crystal orientation in the meteorites, especially coarse-grained unbrecciated rocks and crystalline portions in brecciated rocks. Nevertheless, we suggest that the FWHM is a useful indicator for measurements of the shock degree of eucrites, since this factor is not affected by the randomness of the crystal orientation of the meteorites.

References

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