リュウグウ粉末試料のX線回折による研究：炭素質コンドライトとの比較

X-ray diffraction study of the Ryugu powder: Comparison with carbonaceous chondrites

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Introduction

On December 6, 2020, the Hayabusa2 sample mission returned in total ~5.4 g of samples from asteroid Ryugu to Earth without exposure to terrestrial contaminations [1-3]. After the initial examinations of Ryugu particles at the JAXA curation facility, some samples of chambers A and C were allocated to the Phase2 Kochi curation team for advanced characterization [2]. The chambers A and C particles were acquired from the surface at the time of initial touchdown and from subsurface after the crater formation experiment at the second touchdown by Hayabusa2, respectively [1,4]. We have evaluated bulk mineralogical characterizations of the limited amount samples using a non-destructive, laboratory-based X-ray diffractometry technique (XRD) [5], and the technique was applied to the Ryugu analyses in the present study. The XRD data were compared with those of available Antarctic meteorites and non-Antarctic meteorites to clarify the differences and similarities among the samples.

Experiments

The SmartLab (RIGAKU) X-ray diffractometer at NIPR was used under the condition of CuKa at 40 kV and 40 mA, length limiting slit 10 mm, divergence angle (1/6)º, 1-dimensional strip detector (D/tex Ultra 250), double Bragg angle (2theta) 3–100º, 28 hrs on measurement time, and the Bragg and Brentano optics. A0029 and A0037 being mixed each other, the powdered Ryugu of A0029 (<1mg) and A0037 (<<1mg), and C0087 (<1mg) samples were prepared in a clean bench, pressed using a sapphire glass plate on a silicon non-reflection plate. The diffraction data of powdered minerals provided by International Centre for Diffraction Data were used as references for diffraction peak assignments: saponite (00-013-0086), antigorite (00-002-0098), magnetite (00-019-0629), dolomite (01-071-1662), pyrrhotite 4C (01-074-7398), and pyrrhotite 3C (01-071-0591) as well as inhouse data from natural and synthetic minerals available at the laboratory.

Results and discussion
The diffraction data of the particles A and C show that both of the grains mainly consist of phyllosilicates (mostly matched with saponite), magnetite, dolomite, and pyrrhotite. The dolomite peaks from chamber A are more intense than those from C. The higher abundance of dolomite in chamber A than C is consistent with petrological observations (e.g., [6]).
The diffraction patterns of Ryugu particles are also entirely different from those of known CY and CM Antarctic carbonaceous chondrites which experienced extensive hydrous alteration, but overall agree with those of the CI chondrite Orgueil. The only exception is gypsum, which is common in Orgueil [7,8] but absent in Ryugu. The feature is also for ferrihydrite [9]. One explanation is that these two phases may be terrestrial alteration products. In addition, the pyrrhotite peaks of Ryugu are more intense than those of Orgueil (e.g., [10]). The pyrrhotite grains in Ryugu were identified mostly as the superstructure 4C based on single-crystal electron diffraction patterns [9], however, the broad single peak at d=2.06Å in the bulk XRD patterns may include the 3C pyrrhotite [11]. Since the 3C pyrrhotite is a metastable phase synthesized as a quench product from ~500ºC [12], the coexistence of the phase may imply the unique origin such as shock effect.

References
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