The Mineralogy of Asteroid Ryugu and its Relationship to Highly Altered Extraterrestrial Materials

Ashley King[1], Sara Russell[1], Martin Suttle[2], Catherine Harrison[1],
Paul Schofield[1], Helena Bates[1], and the Hayabusa2 "Stone" team
[1]*Natural History Museum, London, UK (a.king@nhm.ac.uk)*
[2]*The Open University, Milton Keynes, UK*

The Hayabusa2 mission returned to Earth with ~5.4 g of material collected from two sites on the surface of the Cb-type asteroid (162173) Ryugu [e.g., 1]. In hand specimen, Ryugu particles are dark, often highly friable, and have bulk densities in the range of ~1.2 – 1.8 gcm^{-3} [2–4]. Most Ryugu particles examined to date are breccias consisting of an abundant (~80 – 90 vol.%) fine-grained (<1 μm) matrix of phyllosilicates (interlayered serpentine and saponite) in which coarser (~10's – 100's μm in size) grains, fragments, and clusters of oxides (~4 vol.%), sulphides (~3 vol.%), carbonates (~3 vol.%), and phosphates (<1 vol.%) are embedded [2–6]. Several CAI-like fragments (<30 μm) have been identified, as have small (<10 μm), rounded objects with characteristics, such as barred textures, related to melting and crystallisation in chondrules [e.g., 4, 7]. The mineralogy, petrography, and physical properties of Ryugu particles are consistent with them being having formed through near-complete, low temperature (<50°C) water-rock reactions during the first few million years of the Solar System [2–6].

If samples of Ryugu were to land on Earth as meteorites, we could classify them as petrologic type 1 [8]. Such materials were completely altered to secondary mineral assemblages by aqueous processing and contain various phyllosilicates, carbonates, sulphides, and magnetite. Type 1 materials are represented in four meteorite groups (CI, CM, CR, and CY), a handful of ungrouped chondrites (e.g., Flensburg [9]), as xenoliths within meteorites [e.g., 10], and as fine-grained micrometeorites [e.g., 11] and interplanetary dust particles (IDPs) [e.g., 12]. The mineralogy and chemistry of Ryugu particles are closely related to the CI1 ("Ivuna-like") carbonaceous chondrites, except for the presence of sulphates and ferrihydrite in the latter, which are most likely terrestrial weathering products [13, 14]. However, type 1 samples exhibit a remarkably high diversity of starting materials and alteration conditions, with variations in mineralogy, textures, and oxygen isotopic compositions pointing towards multiple parent bodies. Despite type 1 materials being relatively rare in our collections, in part due to their fragile nature hindering survival during atmospheric entry, highly altered bodies appear to be common throughout the Solar System. These bodies could include primitive asteroids that accreted within the inner and/or outer Solar System, or transition objects such as Main Belt comets or D-type asteroids. Characterising the sources of type 1 materials through laboratory analysis of meteorites and Ryugu particles is therefore an important step towards understanding volatile reservoirs in the early Solar System.

References

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