FE-SULFIDES IN RYUGU PARTICLE C0025_01: A COMPARISON WITH CI AND CY CHONDRITES

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Introduction: Remote observations of C-type asteroid 162173 Ryugu show a weak absorption band at ~2.72 μm suggesting abundant Mg-rich phyllosilicates and a close affinity to the aqueously altered CI and/or thermally metamorphosed CY carbonaceous chondrites [1]. In December 2020, JAXA's Hayabusa2 mission successfully returned >5 g of material from the surface and sub-surface of Ryugu to Earth. Initial characterization of the pristine samples indicates that they are most similar to the CI chondrites [2]. The morphology, composition, and abundance of Fe-sulfides are distinctive features of the CI and CY carbonaceous chondrites, reflecting different degrees of aqueous and thermal processing on their parent bodies [3-6]. Here, we compare the coarse (>10 μm) Fe-sulfide grains in a Ryugu particle with those found within the matrices of CI and CY chondrites.

Methods: The ten largest Fe-sulfide grains in polished sections of Ryugu particle C0025_01, the CI chondrites Ivuna and Orgueil, and the CY chondrites Yamato (Y)-82162 (Stage III, ~500 – 750°C) and Y-86720 (Stage IV, >750°C) were characterized using a ZEISS EVO 15LS scanning electron microscope (SEM) equipped with an energy dispersive X-ray spectrometer (EDS). Backscattered electron (BSE) images, element maps, and spot analyses were acquired at 20 kV with a beam current of 1.5 nA. Additional BSE images of Fe-sulfide grains in Ryugu particle C0025_01 were obtained using an FEI Quanta field emission SEM at 9 kV.

Results: The ten largest Fe-sulfide grains in Ryugu particle C0025_01, and the CI and CY chondrites, are typically euhedral to subhedral and lath-like in shape, although some irregular grains are also present (Fig. 1). The size range of the largest Fe-sulfide grains in C0025_01 (~30 – 70 μm) is similar to Ivuna (~40 – 80 μm) and Orgueil (50 – 150 μm, where 70 % of the grains are <80 μm). In comparison, the Fe-sulfide grains are larger in Y-82162 (~75 – 130 μm) and Y-86720 (~190 – 330 μm). The abundance of Fe-sulfide grains >10 μm in size in Ryugu (~1 area%) differs to that of both the CI chondrites (~0.13 – 0.3 area%) and the CY chondrites (~1.5 – 2.0 area %). The Fe-sulfide grains in Ryugu particle C0025_01 are pyrrhotite [$(Fe,Ni)_{1-x}S$] with a composition close to $(Fe,Ni)_7S_8$, where the average value of x is 0.13. The pyrrhotite grains have an average Ni content of 1.80 ± 0.86 wt.% and an Fe/S ratio of 0.85 ± 0.01 at.% (no. of analyses = 6). This is consistent with the composition of the Fe-sulfide grains in Ivuna (n = 18) and Orgueil (n = 31), where the average value of x is 0.12, the Ni content is ~1.15 wt.%, and the Fe/S ratio is ~0.86 (similar to the results of [6]). Three of the Fe-sulfide grains in Ryugu particle C0025_01 contain <10 μm sized irregular inclusions of pentlandite ($[Fe,Ni]_9S_8$) that were not observed in either Ivuna or Orgueil. However, Bullock et al. [3] reported rare ~10 μm sized pentlandite inclusions in Ivuna (plus the CI chondrites Alais and Tonk). The composition of Fe-sulfides in CY chondrites is clearly distinct from Ryugu and the CIs; the laths are composed of stoichiometric troilite (FeS), and all grains contain <12 μm sized inclusions of pentlandite. In Y-82162 the pentlandite inclusions are oriented laths, whereas in Y-86720 they are unoriented irregular blebs that often occur adjacent to metal inclusions.

Discussion: The largest Fe-sulfide grains in Ryugu particle C0025_01 are compositionally and morphologically very similar to those in the CI chondrites, providing further evidence for a close relationship between these materials. The Fe-sulfides in Ryugu and the CI chondrites most likely formed during near-complete low temperature (100°C) aqueous alteration. However, the presence of pentlandite inclusions in three of the ten largest Fe-sulfide grains suggests that hydration of Ryugu particle C0025_01 was less extensive than Ivuna and Orgueil [3]. The Fe-sulfides in Ryugu differ in size, composition, and morphology from those in the thermally metamorphosed CY chondrites, indicating that they were never heated to temperatures >500°C post-hydration [4,5,7].

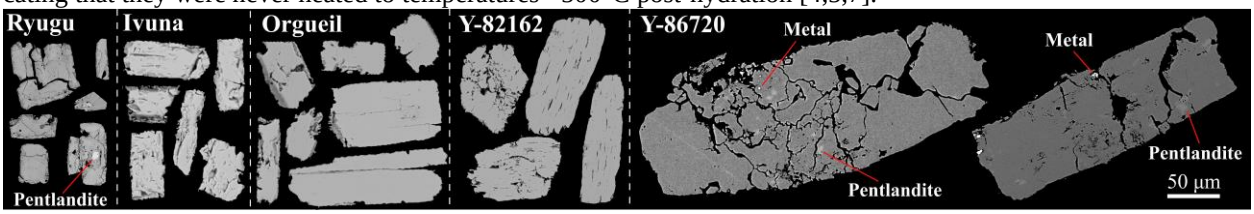

Figure 1. Selected Fe-sulfide grains from each section: scale bar of 50 μm is the same for all panels.

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