THE O-ISOTOPE COMPOSITION OF RYUGU PARTICLES: THE MOST PRISTINE CIs?

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Introduction: Between June 2018 and November 2019, the JAXA Hayabusa2 spacecraft made detailed observations and measurements of the C-type asteroid 162173 Ryugu. Two samples were collected and returned to Earth on 6th December 2020: a surface sample stored in Chamber A of the return capsule and a sub-surface sample in Chamber C. Near-IR orbital spectroscopic data indicated that Ryugu comprised material "similar to thermally and/or shock-metamorphosed carbonaceous chondrite meteorites" [1], with a possible match to the CY (Yamato-type) chondrites [2]. In contrast, initial studies at the JAXA ISAS facility suggested that the samples were "most similar to CI chondrites" [3]. Resolving these contradictory classifications requires detailed sample analysis studies. Here we present high precision O-isotopic results undertaken as part of Phase2 Kochi curation studies [4]. Ryugu particles show evidence of pervasive asteroidal aqueous alteration [4, 5], with only minor preservation of relict primary silicates [6].

Methods: Seven sub-samples from four of the particles allocated to Kochi curation were analysed by laser fluorination [7]. Three particles were from Chamber C (C0014,21; C0068,21; C0087,2) and one from Chamber A (A0098, 2). Orgueil (CI) (n=7) and Y-82162 (CY) (n=7) were analysed for comparison purposes. Sample transport, loading and analysis techniques employed ensured that the particles were never exposed to atmospheric contamination [8]. All Ryugu samples were run in "single shot" mode [9]. In most cases the amount of O_2 gas liberated was less than 140 µg, the approximate limit for bellows analysis on the MAT 253. In these cases analysis was undertaken using the MAT 253 cryogenic microvolume. $\Delta^{17}O$ values were calculated as $\Delta^{17}O = \delta^{17}O - 0.52\delta^{18}O$.

Results: The weighted average of the Ryugu analyses, both in terms of $\Delta^{17}O$ and $\delta^{18}O$, is close to that for Orgueil (CI), but plots away from that of the CY chondrite Y-82162. This data supports the proposed relationship between Ryugu and the CI chondrites [3-5]. Individual Ryugu analyses show a large range in $\delta^{18}O$ values, from 11.46‰ to 19.30‰ (blank corrected values). This large range reflects intrinsic isotopic heterogeneity at the sampling scale involved, with detailed mineralogical studies [4, 5] indicating a significant level of heterogeneity within individual Ryugu particles. In addition, SIMS analysis reveals that Ryugu mineral phases are isotopically heterogeneous, with magnetite and Ca-carbonate differing by more than 30‰ [10]. In contrast, analyses for Orgueil and Y-82162 were drawn from homogenized powders. Calculations, using Ryugu modal data [4], yield bulk $\delta^{18}O$ values close to the range determined in this study. There is a small resolvable difference between the average $\Delta^{17}O$ composition of the Ryugu particles and Orgueil, (0.66 ± 0.09‰ and 0.0.58 ± 0.09‰ respectively (2SD weighted)). Calculation indicates that this difference reflects the terrestrial contamination of Orgueil [8].

Discussion and conclusions: Despite the close O-isotope similarities between Ryugu particles and Orgueil, suggesting a genetic relationship between them, our data reveal higher $\Delta^{17}O$ values for Ryugu particles compared to Orgueil. This difference likely reflects terrestrial contamination of Orgueil since its fall in 1864 [11]. Weathering in the terrestrial environment would pull the bulk analysis closer to the TFL. This conclusion is consistent with evidence that interlayer water in Orgueil is of terrestrial origin [12], and that Orgueil contains ferrihydrite and sulphate [13], whereas Ryugu particles do not [4, 5]. While Ryugu particles are the most uncontaminated CI-related material we have [8], they are not pristine and have been modified by a variety of processes in the regolith [14]. The evidence from Ryugu suggests that care needs to be taken when using CI meteorite data as Solar System proxy values e.g. [15].

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