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Evidence for Collisions Between Microspherules Preserved in Ryugu Samples

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Zoning records the evolution of composition and oxygen fugacity of the fluid from which carbonates were deposited. We characterized carbonates in five polished slices from two aggregate grains, A0026 and A0055, collected by the JAXA Hayabusa2 spacecraft. We used synchrotron-based x-ray fluorescence (XRF) and x-ray absorption spectroscopy (XAS). Ca-XAS showed these carbonate grains to be predominantly dolomite, with the larger ones having small cores of ankerite, which has not previously been reported in Ryugu samples. XRF mapping and SEM-EDX identified significant Mn in the dolomite. Mn-XAS showed it was incorporated into the dolomite structure suggesting formation from the same fluid that formed the Mn-rich apatite we reported previously in these samples [1], indicating simultaneous deposition. SEM-EDX and Mg-XRF identified a thin rim of magnesite on the dolomite. Although calcite has been reported as the core carbonate in other Ryugu samples, we found no calcite, easily identifiable by Ca-XAS, in either A0055 or A0026, Spheroidal Fe-bearing grains, identified by Fe-XAS as magnetite, were distributed in the dolomite but not ankerite, suggesting ankerite formation preceded magnetite formation. We presume Fe metal was one component of the accreted assemblage, so its presence would have buffered oxygen fugacity at a value below the stability field of magnetite while allowing ankerite precipitation. Only after all Fe-metal was oxidized would oxygen fugacity rise, allowing magnetite precipitation. This would sharply reduce available Fe^{2+}, resulting in carbonate precipitation switching from ankerite to dolomite. Mg-rich carbonate rims may indicate dolomite growth stopped when Ca in the fluid was depleted, allowing growth of magnesite as the final carbonate stage. This mineral formation sequence differs from one proposed for a Ryugu grain from the second collection site [2] and one proposed for Bennu [3]. Both proposed that magnetite formed by oxidation of Fe-Ni-metal before carbonate began forming, and that calcite was the initial carbonate. Our results demonstrate the early stages of carbonate deposition in these samples differed from those reported for Bennu and the second collection site on Ryugu.

References: [1] Flynn and Northrup, 56th LPSC, 2025. [2] Yamaguchi et al., Nature Astronomy, 2023. [3] McCoy et al., Nature, 2025.