PRESOLAR GRAINS AND PRIMITIVE ORGANIC MATTER IN ASTEROID RYUGU

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Introduction: Beginning in mid-2018, the Hayabusa2 spacecraft will encounter the C-rich near-Earth asteroid 162173 Ryugu, collect regolith samples, and return them to Earth in late 2020. Among the high-level science goals of the mission are to characterize presolar stardust grains and primitive organic matter that may be present [1]. Such materials are among the original building blocks of the Solar System and are known to be present in primitive extraterrestrial materials, including the least processed chondritic meteorites, interplanetary dust particles and comet Wild 2 samples returned by NASA's STARDUST mission. Their abundances and properties (e.g., isotopic compositions) are known to be sensitive tracers of parent-body processing, for example aqueous alteration and thermal metamorphism. Thus, characterizing them in Ryugu samples will help place the asteroid into context of what is already understood about primitive bodies from meteorite studies and provide useful information about its detailed alteration history at small and large scales (in conjunction with complementary data both from in situ orbital and rover observations and other sample analyses). Moreover, because the Ryugu samples will be largely collected from near the surface, they may also help provide insight into processing of primitive materials via interaction with the space environment ("space weathering").

Presolar Grains: Presolar grains are tiny (mostly < 1 micrometer) dust particles found in primitive meteoritical materials that originated in winds and explosions of previous generations of stars and were part of the starting mix of materials of the solar nebula [2]. They are identified as presolar stardust by their highly anomalous isotopic compositions in most elements, reflecting nuclear processes in their parent stars. Because they are pristine 'fossils' of stellar material and the original building blocks of the Solar System, they have proven to be extremely useful probes of a wide range of galactic, stellar, interstellar and cosmochemical processes. Identified types of presolar grains thus far include a wide range of silicates, oxides, SiC, graphite, Si_3N_4, and perhaps nm-sized diamonds. Presolar silicates are the most abundant type of presolar grain, but their abundance is widely variable among meteoritic materials, with the highest abundances in IDPs [3, 4]. They are easily destroyed by parent-body processing and their abundances in chondrites are very sensitive probes of the degree of alteration. Abundance variations are also seen within single meteorites, likely reflecting both accretional processes (e.g., differences between fine-grained rims of chondrules and inter-chondrule matrix) and localized variations in parent-body alteration [5]. Presolar SiC is less sensitive to aqueous processing but is destroyed by thermal metamorphism.

Organic Matter: Carbonaceous chondrite meteorites – thought to originate on asteroids like Ryugu - contain up to a few weight % organic C, dominated by a macromolecular organic solid that is insoluble in demineralizing acids (often referred to as insoluble organic matter or IOM) [6], though soluble organics such as amino acids are often present as well, albeit in lower abundances [7]. IOM from a large number of meteorites has been analyzed in detail by a variety of methods, including isotopic, chemical and structural measurements [8] which reveal it to be chemically similar to organic grains detected in situ at Halley's comet and to often be highly enriched in D and ^{15}N, relative to terrestrial H and N isotopic ratios. Remarkably similar isotopically anomalous organic matter is also seen in IDPs and Wild 2 samples [9, 10]. How the meteoritic IOM formed is still an open question, with an origin in the presolar interstellar medium, the solar nebula, or on asteroids and comets themselves all being proposed As with presolar grains, the properties of IOM are seen to vary in systematic ways with the degree and type of processing that occurred on parent bodies [8].

Planned Studies: High-resolution isotopic-ratio mapping with a NanoSIMS ion microprobe will be use to systematically search returned Ryugu samples for presolar silicates, SiC and other stardust phases and to characterize the distribution and isotopic composition of insoluble organic matter. These studies will help address several key scientific questions, among them: 1) Does Ryugu regolith contain a similar mix of presolar grains to known carbonaceous chondrites and does the mix vary across the asteroid? 2) Do given classes of presolar grains (e.g. silicates) have the same distributions of isotopic ratios as seen in chondrites? 3) What do presolar grain abundances tell us about the alteration history of the asteroid? 4) Do Ryugu presolar grains show chemical and/or structural effects of space weathering? 5) Does Ryugu contain D- and/or ^{15}N-rich IOM and if so, how does it compare chemically, isotopically and structurally with that in meteorites, IDPs and Wild 2 samples? 6) Are there observable effects of space weathering on the properties of Ryugu organic matter?

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