Highly porous sintered materials as possible analogs for primordial boulders on the asteroid Ryugu

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Planetesimals formed through the accumulation of dust particles. Both experimental and numerical studies have investigated their bulk porosity, or bulk density (Omura and Nakamura, 2021; Tatsuuma et al., 2024). These studies suggest that the bulk porosities of planetesimals can exceed 70%, depending on their sizes and other parameters. Thermal observations by the spacecraft Hayabusa2 revealed the presence of anomalously low-thermal-inertia boulders on the asteroid (162173) Ryugu (Sakatani et al., 2021). The porosities of the boulders were estimated to be 70–90%. As boulders are considered fragments of their parent bodies (planetesimals), highly porous boulders may represent the most primordial rocks from these bodies and retain information on the accumulation of dust particles and the evolution of planetesimals. Thus, we produced highly porous samples with porosities of 77–82%, consisting of glass particles, and examined how closely they resemble the most primordial boulders. The samples prepared in this study were consolidated through sintering, a process that forms solid bonds between particles. Their porosities are about 15% higher than those in our previous study.

We sintered spherical and polydisperse glass particles in an oven under atmospheric conditions. The median diameter of the glass particles was 5 μm. We measured the tensile strength using the Brazilian test (e.g., Meisner et al., 2012) and the longitudinal wave velocity using the ultrasonic pulse transmission method (e.g., Shimaki and Arakawa, 2021). In addition, we examined the cross-section of a sample using field emission-scanning electron microscopy (FE-SEM).

From the FE-SEM images, we found that the sample contains pores that can be classified into two types based on their sizes. The lagger pores are several hundred micrometers in size, while the smaller ones are several tens of micrometers. The tensile strength of our samples is 28–160 kPa, which corresponds to approximately 10 to 100 times higher than that of dust aggregates (77% porosity) consisting of 1.5 μm silica particles (Blum et al., 2006). The longitudinal wave velocities of our samples are 800–1000 m/s.

Based on Hertzian heat conduction theory (Grott et al., 2019), the tensile strength of the boulders reported by Sakatani et al. (2021) is inferred to be 19–64 kPa, which is comparable to that of our samples. Therefore, the sintered samples produced in this study can be utilized as analogs for the most primordial boulders in future studies (e.g., collisional disruption experiments). However, the relationship between structural characteristics, such as inter-particle bonding and pore size distribution, and mechanical strength remains unclear, and further investigation is required.