Predicted strength, microporosity, thermal conductivity and grain density of Ryugu rock samples

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In this presentation, we summarize the findings and interpretations of the physical and thermophysical properties of C-type asteroid 162173 Ryugu obtained from Hayabusa2 remote sensing as well as from MASCOT radiometer (MARA) data. For a typical rock on Ryugu's surface, we find a thermal inertia of 295 ± 18 $Jm^{-2}K^{-1}s^{-1/2}$ (Hamm+ 2020), a microporosity of 50 ±3% (Grott+ 2020, Hamm+, 2020), and assuming a CM chondrite composition and thus an inferred specific heat capacity of cp=890 J/kg/K (±10%, at an average temperature of 277K), we estimate a thermal conductivity of 0.069 ±0.012 J/m/K at ~277 K. These estimates are based on MARA surface brightness temperature measurements of an arguably (Biele et al, 2019) dust-free boulder at MASCOT's landing site obtained over a full diurnal cycle. Those values are consistent with the TIR instrument's global findings (Okada+ 2020). The very high deduced microporosity lets us reasonably estimate the tensile strength of those abundant "cauliflower rocks" (Jaumann+ 2019), ~200-280 kPa (Grott+, 2019).

Furthermore, also from orbital data (ONC imaging and counting, plus radiometric data for GM), we have estimated the macroporosity of Ryugu, assumed to be a homogeneous rubble pile, based on granular mixing theory and the size-frequency distribution of boulders ranging from ~0.1 m to ~100 m diameter. We find (Grott+, 2020) that the macroporosity of Ryugu is very low, 16 ±3% and that if the underlying homogeneity assumption is true, taken together with Ryugu's bulk density and the average microporosity of its boulders, the average grain density can be estimated as 2.85 ±0.15 g/cm^3, consistent with the mineralogy of CM meteorites or the ungrouped carbonaceous chondrite Tagish Lake.

It will now be extremely exciting to compare these values with actual laboratory measurements of the returned samples. For example, if our values for Ryugu's macroporosity and rock microporosity (and/or grain density) do not agree with what is found from the samples, the assumption of homogeneity might be wrong. This would mean that the surface of Ryugu has a significantly different boulder SFD than its interior. Or, simpler, the assumed relationship between rock porosity and thermal conductivity is incorrect.

As for the strength of rock pieces, besides possible size (scale) dependencies and sampling bias, a higher strength than predicted here would have to be reconciled with the very low thermal conductivity of Ryugu's blocks, which dictates rather small grain-to-grain (sinter or volatile condensate or 'salt') neck diameters.

References

Hamm, M., et al. (2020). "Thermophysical modelling and parameter estimation of small Solar system bodies via data assimilation." Monthly Notices of the Royal Astronomical Society **496**(3): 2776-2785.

Grott, M., et al. (2019). "Low thermal conductivity boulder with high porosity identified on C-type asteroid (162173) Ryugu." Nature Astronomy **3**(11): 971-976.

Biele, J., et al. (2019). "Effects of dust layers on thermal emission from airless bodies." Progress in Earth and Planetary Science **6**(1): 48.

Okada, T., et al. (2020). "Highly porous nature of a primitive asteroid revealed by thermal imaging." Nature **579**(7800): 518-522.

Jaumann, R., et al. (2019). "Images from the surface of asteroid Ryugu show rocks similar to carbonaceous chondrite meteorites." Science **365**(6455): 817-820.

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