Preparing for asteroid sample return: The story from CM and CI meteorites

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By 2023, two space missions, OSIRIS-REx and Hayabusa-2, will have collected and returned to Earth samples from the near-Earth asteroids (NEAs) Bennu and Ryugu, respectively. Low albedo asteroids such as Bennu and Ryugu are expected to contain pristine materials that record the earliest stages of solar system formation. Here, we discuss the nature of primitive asteroids by comparison to CM and CI chondrites.

Bennu is a B-type asteroid, and while no good meteorite analogue has been identified, it may be similar to the aqueously altered CM1 and CI1 chondrites [1]. We have determined the bulk mineralogy of these meteorites and predict that if Bennu is "CM1-like" the surface will contain Mg-rich phyllosilicates (~70 vol%), plus minor magnetite (~3 %), and calcite (~1 %) [2]. A "CI1-like" surface will contain abundant phyllosilicates (serpentine and saponite, ~80 vol%), magnetite (~10 %) and dolomite (~3 %) [3].

Ryugu is a Cg-type asteroid. Vilas [4] detected a 0.7 µm absorption feature, which is seen in some CM chondrites and attributed to Fe^{2+}-Fe^{3+} in the phyllosilicates [5]. Follow-up observations have failed to identify this feature, suggesting that the surface of Ryugu is heterogeneous. We find that the 0.7 µm feature is absent from CM chondrites that experienced both aqueous alteration and thermal metamorphism. Dehydration due to impacts and/or solar radiation should be a common process at the surface of primitive asteroids. We predict that samples from Ryugu will have a diverse mineralogy consisting of materials that suffered varying degrees of aqueous and thermal alteration.

The OSIRIS-REx and Hayabusa-2 spacecraft will collect asteroid spectra in the visible and infrared (IR) range. Comparisons with spectra from well-characterized CM and CI meteorite analogues will be crucial in interpreting surface compositions, with strong absorption features in the mid-IR particularly useful for constraining the extent of hydration and dehydration, and selecting the most scientifically interesting sites for sample collection.

[1] Clark *et al.* (2011) *Icarus* **216**, 462-475. [2] King *et al.* (2017) *MAPS* in press. [3] King *et al.* (2015) *GCA* **165**, 148-160. [4] Vilas (2008) *Astron. J.* **135**, 1101-1105. [5] McAdam *et al.* (2015) *Icarus* **245**, 320-332.