OLIVINE GRAINS EXTRACTED FROM THE JBILET WINSELWAN CM2 CHONDRITE – A REFERENCE FOR THE REGOLITH OF C-GROUP ASTEROIDS?

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Introduction: Sample-return missions underway to the near-Earth objects 101955 Bennu (OSIRIS-REx) and 162173 Ryugu (Hayabusa 2) are expected to return surface regolith from two primitive C-group asteroids for laboratory study. Spectroscopically the C-group asteroids share similarities with CI and CM chondrites and are likely parent bodies of these meteorite groups. Material returned from the Moon and S-type asteroid 25143 Itokawa has shown that phenomena related to space weathering are well-recorded on the surface of silicate grains [1]. The degree (or maturity) of space weathering can potentially provide insights into the evolution of regoliths and, therefore, shed light on the dynamical evolution of near-Earth asteroids and their orbits [2,3,4]. Olivine is a good candidate for comparative taxonomy of space weathering due to its wide-spread occurrence in lunar and asteroidal samples and its experimentally extensively studied properties. If C-group asteroids are indeed related to CI and CM chondrites, olivine is expected to be a significant mineral in their regoliths. However, aqueous and thermal alteration processes recorded in CI and CM chondrites potentially leave morphological and chemical signatures on mineral surfaces, onto which space weathering would be superposed. This motivated us to investigate olivine grains of the Jbilet Winselwan (JW) meteorite, a moderately heated (tentatively <500 °C) CM2 chondrite [5].

Material and Methods: A 37.6 gram fragment of JW was sliced using a diamond wire saw and interior slices were used to produce two polished petrographic sections (~20×30 mm^2) and cuboidal subsamples (~10×7×7 mm^3). The cuboids were subjected to 100 to 150 cycles of freeze-thaw disaggregation in high-purity water. After drying, olivine crystals were separated by hand-picking and mounted onto SEM stubs or epoxy-embedded and polished. The grain mounts and polished petrographic sections were studied by field-emission SEM. The polished grain mounts were etched in WN solution in order to reveal damage tracks produced by ionizing, high-energy particles [6].

Results and Discussion: SEM imaging of the JW petrographic sections indicates subtle textural heterogeneities, most evident by variations in the abundance of serpentine/tochilinite-like aggregates. There is no obvious brecciation as seen in other CM2 chondrites [7] and specimens of JW [8]. Many components (dominantly chondrules) are surrounded by fine-grained rims, and the general texture resembles a primary accretionary rock [7]. The freeze-thaw disaggregated material is a black, non-cohesive powder (~80% <100 µm, ~50% <50 µm).

Euhedral to subhedral olivine crystals are optically prominent objects in the powder. The hand-picked olivine grains have median sizes of ~240 µm and a size range of 100 to 600 µm. Comparison with the petrographic sections suggests that the larger grains often occur as single grains within the meteorite. The smaller ones are most probably derived from porphyritic chondrules. The surface morphologies show a large diversity and can be subdivided into 'as-grown' crystal surfaces and fractured surfaces. Pristine surfaces are smooth and featureless, fresh fracture surfaces are typically characterized by step-like hackle marks. Altered surfaces have developed significant roughness through dissolution and the formation of secondary mineral scales. Such features superposed on surfaces with hackle marks suggest that fracturing had occasionally occurred before aqueous alteration.

We have studied a total of 82 olivine grains from three interior cuboids of JW for particle tracks, and etching has revealed tracks in 65 of them. In all cases the track densities are <10^5 tracks/cm^2, which is consistent with background track densities due to galactic cosmic rays (GCR) in typical CM2 chondrites [7]. The absence of brecciation and track-rich grains (>10^6 tracks/cm^2, indicating irradiation by solar flare ions) indicates that the material of our JW specimen was never exposed in the upper few millimeters of a regolith. This is corroborated by the absence of solar wind noble gases in other samples of JW [9]. However, JW's unusually long exposure age of 6.6±1.7 Ma [9] and the relatively low GCR track count (cf. [7]) suggests that GCR tracks may have been partially annealed by the, so far unidentified, heating event. FIB-TEM studies will be used to further evaluate the extent of thermal processing and the structural and chemical states of JW olivine surfaces. The morphological features observed may serve as a reference for the effects of aqueous (and possibly thermal) alteration without an overprint by space weathering – with the goal of deciphering the latter in meteoritic and robotically returned regolith samples.

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