FORSTERITE-RICH CLASTS IN AN ASTEROID BENNU SAMPLE: POSSIBLE CHONDRULE-LIKE OBJECTS. L. Le¹, K. Thomas-Keprta², L. P. Keller³, S. J. Cleempi², P. Haenecour³, T. J. McCoy³, M. S. Thompson³, T. J. Zega³, H. C. Connolly Jr.³,⁴,⁵, and D. S. Lauretta³. ¹JACOBS, NASA-JSC, Houston, TX; ²Barrios/Keprta, NASA-JSC, Houston, TX; ³Mail Code XI3, NASA-JSC, Houston, TX; ⁴ERC Inc./Jacobs, NASA-JSC, Houston, TX; ⁵LPL, Univ. Arizona; Tucson, AZ; ⁶NMNH, Smithsonian, Washington, D.C.; ⁷Earth, Atmospheric & Planetary Science, Purdue Univ., West Lafayette, IN; ⁸Geology, Rowan Univ., Glassboro, NJ; ⁹Earth & Planetary Science, AMNH, NY.

Introduction: We report here the observation of three olivine-rich clasts in an asteroid Bennu sample returned by NASA’s OSIRIS-REx spacecraft. These objects appear comparable, both in texture and composition, to a previously reported ‘unusual’ chondrule in the Murchison CM2 carbonaceous chondrite [1].

Methods: Coarse particles (~ 0.8 – 1.5 mm in length) from the OREX-803079-0 allocation were attached to Al cylinder SEM mounts using C tape. Optical microscope images were collected prior to sputter coating the mount with ~ 21 nm of C to reduce sample charging. A JEOL 7600F SEM, equipped with Oxford Instruments Ultima Max EDX detector, was used for imaging, point spectra and mapping. AZtec ‘Point & ID’ and ‘Mapping’ software were used for data reduction. SEM operating conditions used a 15 kV beam at a current of ~ 1 nA.

Results and Discussion: Three light-colored objects on a single dark Bennu particle (OREX-803079-241) were identified using optical microscopy (Fig. 1A). The surface of this particle was then imaged using the SEM backscatter electron (BSE) mode and revealed that the light-colored regions exhibited rounded geometries with mean diameters of ~ 70, 120, and 180 μm. The largest object (yellow arrow, Fig. 1A) is composed of Mg-rich olivine, with an acicular/fibrous/spinifex-type morphology, in which are interspersed small clumps (typically < 5 μm) of phyllosilicates (Fig. 1B). The other two objects, one of which is shown at higher magnification in Fig. 1C, are dominated by partly aligned, skeletal Mg-rich olivine grains (typically < 5 μm in width), often with elongated/rounded holes (Fig. 1D). Occasionally distributed among the skeletal olivines are sub-μm size Fe-sulfides (bright spots, likely pyrrhotite, Fig. 1D). EDX analysis for all three objects reveals olivine contains ~ 2–5 wt.% Fe with minor Cr and possibly Mn (note: CrKα overlaps with the MnKα peak so detecting the latter can be problematic in the presence of Cr; see Fig. 1E). No evidence for mesostasis or replacement minerals were observed within any olivine holes and none of the objects were surrounded by distinct fine- or coarse-grain rims; they were all encased within a phyllosilicate-rich matrix. Skeletal olivine may have resulted from rapid growth during nucleation, producing a cryptocrystalline texture [2, 3]. While hole formation could occur by abrasion during reentry, alternatively the holes may have formed via incipient aqueous alteration albeit with the absence of apparent alteration products; in the latter case, this may not be surprising since the surrounding matrix is hydrous, i.e., phyllosilicate-rich.

Similar to the objects described herein, a porous, cryptocrystalline forsterite chondrule has previously been identified in Murchison [1]. In comparison to the composition of Bennu objects, the Murchison chondrule also contained minor Cr but was more Mg-rich with olivine being almost pure forsterite (Fo80). Furthermore, the olivine grains in this chondrule showed a nearly identical skeletal morphology to the two smaller Bennu objects (Fig. 1D) although not the fibrous/spinifex fabric of the largest object (Fig. 1B). As with the Bennu objects, the CM2 chondrule also lacked a rim, mesostasis and replacement minerals.

Conclusions: Rounded, forsteritic objects in a sample from asteroid Bennu appear analogous in both composition and texture to an unusual chondrule previously described in the Murchison meteorite. They are composed primarily of olivine and exhibit a distinctive skeletal, porous texture, possibly indicative of aqueous alteration and show no evidence of a mesostasis or replacement by secondary minerals.

The dominant matrix mineralogy of Bennu samples analyzed to date is a conglomeration of fine- and coarse-grained Mg-rich phyllosilicates (saponite and serpentine), magnetite with a variety of morphologies, sulfides (pyrrhotite and pentlandite) and carbonates (dolomite, primarily Mg-bearing breunnerite, and calcite) [e.g., 4-6]. While the dominant mineralogy is consistent with aqueously altered type 1 chondrites, the identification of possible chondrules indicates that this particle may reflect a different lithology that was originally of higher petrologic type than 1. Further detailed characterization by EMPA, TEM, and NanoSIMS is ongoing.

Acknowledgements: This material is based upon work supported by NASA under Contract NNM10AA11C issued through the New Frontiers Program.

Figure 1. (A) Optical image of a dark Bennu particle showing an irregular surface morphology. Three light-color objects are highlighted by arrows. (B) High magnification SEM/BSE view (region highlighted by yellow arrow in A) showing olivine grains with a fibrous (spinifex-type) texture and matrix-rich regions (arrows). (C) Magnified SEM/BSE view of the object highlighted by the red arrow in A. Object is ~ 120 µm in longest dimension and is composed of partly aligned skeletal olivine grains. (D) Magnified view of region outlined by the red box in C showing skeletal forsteritic grains with holes (white arrows). Likely pyrrhotite grains are highlighted by red arrows. (E) EDX spectrum of a forsterite grain, location highlighted by the red circle in C, also showing the presence of Cr and possible Mn.