ANHYDROUS SILICATES IN ASTEROID BENNU SAMPLES: EVIDENCE FOR PRIMORDIAL PROTOPLANETARY DISK COMPONENTS. S. S. Russell1, A. J. King1, H. C. Connolly Jr.2,3,4, T. Salge1, N. Almeida1, H. C. Bates1, P. F. Schofield1, C. Harrison1, R. Jones5, I. A. Franchi6, X. Zhao6, P.A. Bland7, T. Ireland8, F. Jourdan7, S. Reddy7, W. Rickard7, D. Saxey7, N. Timms7, T. J. Zega7, T. J. McCoy7,8, J. Barnes4, A. Nyugen10, and D. S. Lauretta4. 1Natural History Museum, London, UK (sara.russell@nhm.ac.uk); 2Rowan University, Glassboro, NJ; 3American Museum of Natural History, New York, NY; 4Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ; 5University of Manchester, UK; 6Open University, Milton Keynes, UK; 7Curtin University, Western Australia; 8The University of Queensland, Australia; 9Smithsonian Institution, Washington, D.C.; 10NASA JSC, Houston, TX.

Introduction: NASA’s OSIRIS-REx mission returned regolith material of asteroid Bennu to Earth [1–3]. Remote sensing measurements indicated that the asteroid was rich in hydrated minerals and was perhaps analogous to highly aqueously altered carbonaceous chondrites [2], with <10% anhydrous silicates [4]. Such anhydrous components enable characterization of pre-accretionary epoch of Bennu, and can be used to test the mission hypothesis that Bennu formed beyond the snow line by accretion of protoplanetary disk material [5]. XRD and SEM analyses during the quick-look procedure [4,6] identified anhydrous forsteritic olivine as a minor phase, and we subsequently undertook a search for additional minerals within the returned sample that predate this pervasive alteration and may represent components of the protoplanetary disk.

Samples: We studied the mineralogy and petrology of ~μm-sized particles separated from aggregate OREX-800032-0, a ~100 mg sample made up of fines and intermediates. We also studied particles OREX-501054-0 and OREX-501059-0 allocated during the quick-look procedure [5].

Analytical methods: Chips were studied by optical microscopy, SEM, then mounted in epoxy, polished, and carbon coated. Anhydrous silicates were located using elemental EDX mapping on a Zeiss UltraPlus FEG-SEM. Quantitative data were obtained on a Zeiss EVO LS15 at 20 kV. Cameca SX100 (20kV, 10 nA 1 μm spot) microprobe and Cameca NanoSIMS oxygen isotope analyses (Open University) are ongoing.

Results: Olivine and pyroxene grains were observed in unprepared chips, embedded in phyllosilicate, and as individual massive grains. Anhydrous silicates were located in each of two polished mounts analyzed to date.

In the EDX element map for OREX-501054-0 (Fig. 1), Mg-rich phyllosilicate dominates with minor magnetite, sulfides and carbonates, in good agreement the quick-look results [4,6]. Olivine and pyroxene grains are minor (not rare) components (Fig. 2), showing as red in Fig. 1, in this example having an abundance of ~ 0.5–0.7 area%. They are typically up to 10 μm across and exist as isolated rounded to angular or irregularly shaped chemically homogeneous grains, with orthopyroxene less abundant than olivine. Olivine compositions tend to be forsteritic, most commonly Fo95.99, though more fayalitic compositions are occasionally observed. Chromium is present in olivine typically well above detection limit. Orthopyroxene grains are typically enstatitic rich, En96.98 and Wo91–1.

Discussion: Crystalline olivine and pyroxene likely formed during high temperature disk processing and represent fragments of chondrule or ameboid olivine aggregates [7,8]. Our observations confirm that Bennu accreted from protoplanetary disk components and that some of these escaped the extensive water-rock interactions experienced by the Bennu parent body. Minor levels of anhydrous silicates have been reported from Ryugu [7,8,9], and the abundance of olivine in CI chondrites is <0.1 wt.% [10]. Initial results suggest compositions of Bennu olivine are broadly similar to those observed for Ryugu [7,8] and CIIs [11]. The variations observed in composition and the relatively high levels of Cr2O3 in olivine suggest that these grains did not experience significant thermal metamorphism in the Bennu parent body, consistent with XRD [4]. Ongoing oxygen isotopic compositions from these will shed further light on their origins.

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Figure 1. False color element map of OREX-501054-0. Phyllosilicates appear as dull red/brown; magnetite and sulfides as green; carbonates as blue; olivine and pyroxene as bright red.

Figure 2. Closeup of OREX-501059-0. Left: Backscattered electron image. Right: EDS image showing anhydrous silicates in red — an olivine grain in the lower part of the image and a pyroxene grain enclosing a small olivine at the top. Field of view is approximately 100 microns across.