THE MINERALOGY OF ASTEROID BENNU: FIRST RESULTS FROM X-RAY POWDER DIFFRACTION OF RETURNED SAMPLES. A. J. King[1], V. Tu[2], P. F. Schofield[1], J. Najorka[1], S. S. Russell[1], H. C. Bates[1], T. J. Zega[3], T. J. McCoy[4], L. P. Keller[5], P. Haenecour[3], M. S. Thompson[6], K. Thomas-Keprta[7], L. Le[2], H. C. Connolly Jr.[8,9], and D. S. Lauretta[3]. [1]Natural History Museum, London, UK (a.king@nhm.ac.uk); [2]Jacobs, NASA JSC, Houston, TX; [3]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ; [4]National Museum of Natural History, Smithsonian Institution, Washington, D.C.; [5]NASA JSC, Houston, TX; [6]Purdue University, West Lafayette, IN; [7]Barrios Technology/Jacobs, NASA JSC, Houston, TX; [8]Rowan University, Glassboro, NJ; [9]American Museum of Natural History, New York, NY.

Introduction: On September 24, 2023, NASA's Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) mission returned to Earth a sample of the carbonaceous asteroid Bennu. Based on spacecraft observations of the sample site, it was hypothesized that the sample would consist of abundant phyllosilicates plus carbonates, oxides, and carbon, similar to the mineralogy of highly aqueously altered CI ("Ivuna-like") and CM ("Mighei-like") carbonaceous chondrite meteorites [1–3]. Here, we have used X-ray diffraction (XRD) to characterize the bulk mineralogy of the returned sample and provide some initial insights into the geological history of Bennu.

Samples: We investigated sample OREX-500005-0 as part of the quick look analysis of the fine-grained aggregate collected from the avionics deck of the sample return canister (SRC) [4]. The sample (~88 mg) was imaged in a glass vial using an optical microscope and found to mainly consist of fine (<100 μm) particles, although several intermediate particles up to ~500 μm in size were also observed.

Analytical methods: The sample was poured onto a zero-background substrate and gently pressed to ensure the largest sample surface area was exposed to the X-ray beam. XRD patterns were then acquired using a Malvern Panalytical X'Pert Pro scanning XRD instrument at NASA Johnson Space Center (JSC). Analyses were conducted under ambient conditions using Co K_α radiation, with diffraction patterns collected from 2 - 90° (2θ) with a step size of 0.006°. An initial measurement (~90 mins) was used to identify the main phases, followed by a longer measurement (~17 hrs) to achieve good signal-to-noise. The 2θ accuracy and the baseline were verified using various standards (silicon [NIST 640f], LaB_6 [NIST 660c], novaculite) and a blank substrate.

Results: The phases with the highest abundances that were identified from the XRD pattern of OREX-500005-0 include phyllosilicates, magnetite, Fe-sulfides (pyrrhotite + pentlandite), and carbonates (dolomite + calcite). Relatively broad phyllosilicate reflections at ~8°, ~14°, ~22.5°, ~29°, ~42°, and ~71.5° (2θ Co K_α) are attributed to Mg-rich smectite, serpentine, and potentially interstratified serpentine/smectite. Preliminary quantitative analysis indicates a bulk mineralogy of ~80 vol.% phyllosilicate, ~9 vol.% Fe-sulfides, ~5 vol.% magnetite, and ~4 vol.% carbonates. A small, sharp diffraction peak at ~43° (2θ) is likely from crystalline forsteritic olivine present in low (~2 vol.%) abundances. We found no evidence for sulfate or Fe-(oxy)hydroxide phases.

Discussion: XRD results confirm that Bennu has experienced extensive aqueous alteration. The mineralogy of OREX-500005-0 is dominated by phyllosilicates, with minor amounts of Fe-sulfide, magnetite, carbonates, and anhydrous silicates. This is in good agreement with remote observations of Bennu's surface that predicted abundant phyllosilicates, some magnetite, and <10 vol.% anhydrous silicate in the returned sample [5]. Based on the preliminary phase quantification, the phyllosilicate fraction (PSF = total phyllosilicate abundance / [total anhydrous silicate + total phyllosilicate abundance]) of OREX-500005-0 is 0.98, which corresponds to a petrologic sub-type of 1.1 on the alteration scale of [6]. This is comparable to the most aqueously altered CI and CM chondrites, as well as samples of asteroid Ryugu, and attests to water-rock reactions that reached near completion [7–9]. Bennu phyllosilicates are Mg-rich, reflecting the hydration of increasingly Mg-rich olivine and pyroxene as alteration progressed [e.g., 8]. Furthermore, XRD indicates that Bennu phyllosilicates are hydrated and did not experience temperatures >~300°C.

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