COORDINATED ANALYSIS OF PHOSPHATES IN SAMPLES FROM ASTEROID (101955) BENNU.

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Introduction: Asteroid (101955) Bennu is a B-type asteroid and a prime candidate for investigating the remnants of planet formation and enhancing our understanding of potential sources of crucial bio-essential elements for the early Earth [1]. Remote observations of the surface of Bennu unveiled a terrain of boulders primarily composed of hydrated phyllosilicates [2], organic molecules [2,3], and carbonates [3-5]. The hydrated nature of Bennu, the abundance of carbonates, and the presence of cm-scale carbonate veins [5] provide clues to the nature of the building blocks of Bennu's parent body and to its complex geological history. Here we present the first mineralogical, chemical, and isotopic results of analysis of phosphates in samples returned from Bennu by NASA's OSIRIS-REx mission. We seek to test the hypothesis that heating of Bennu's parent asteroid resulted in hydrothermal alteration in which melted ice reacted with the initial constituents [6].

Samples and Methods: We studied quick-look (QL) samples collected from the avionics deck outside of the Touch-and-Go Sample Acquisition Mechanism (TAGSAM) [1,7] and aggregate material from inside the TAGSAM. Samples were analyzed in multiple laboratories and institutions using a variety of techniques including optical microscopy, scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDS), electron backscatter diffraction (EBSD), transmission electron microscopy (TEM, including EDS and selected area diffraction analysis), Ar isotopes, time-of-flight secondary ion mass spectrometry (ToF-SIMS), Fourier transform infrared spectroscopy (FTIR), and X-ray diffraction analysis (XRD) [8]. Additional analyses are underway.

Results: Thus far, we have identified two main hosts of phosphorous in both QL and aggregate samples: Mg-phosphate and Ca-phosphate. In addition, Smith et al. [9] report the presence of trace phosphides.

Mg-phosphates. They are white in visible light, abundant, and observed as loose grains (Fig. 1). Mg-phosphates also occur as grains embedded within the matrix of dark particles comprising the 'typical' Bennu lithology (Fig. 2) and as crusts on some individual particles [10]. SEM and TEM analyses of the Mg-phosphates reveal a crackled, nanoporous texture, and compositionally they contain trace K and varying amounts of Na that is sometimes zoned. TEM, XRD, and EBSD analyses indicate that the Mg-phosphates are amorphous [8]. FTIR data is consistent with a hydrated phase [7]. Ar isotope data reveals mixing between air contamination, radiogenic $^{40}Ar^*$, and a dominant trapped indigenous Ar component with a low $^{40}Ar/^{36}Ar$ (min. value of 5 ± 1) that demonstrate the Mg-phosphates are extraterrestrial in origin.

Ca-phosphates. The Ca-phosphates are less abundant and smaller in size (typically <10s μm in the longest dimension) and are typically found embedded in the matrix along with magnetite and sulfides.

Discussion: While Ca-phosphates are found in carbonaceous chondrite meteorites, Mg-phosphates are extremely rare in astromaterials, being mostly associated with igneous processes (e.g., [11]). Only recently did the Hayabusa2 team report the occurrence of hydrated Mg-phosphate [12] in primitive samples returned from asteroid (162173) Ryugu.

The texture and composition of the Mg-phosphates in Bennu samples are very similar to those reported for Ryugu [12]. The hydration feature in the FTIR spectra indicates the presence of water, yet the cracked texture is likely to be the result of dehydration, as was suggested for Ryugu particles [12]. If confirmed, this would indicate that the Mg-phosphates were originally more water-rich than they are now. Therefore, it is possible that Mg-phosphate represents a previously unrecognized carrier of water and Na in primitive type-1 carbonaceous asteroids that may be too fragile to withstand meteorite entry into Earth's atmosphere. On Bennu, Mg-phosphate could be an important recorder of aqueous activity on the parent body.

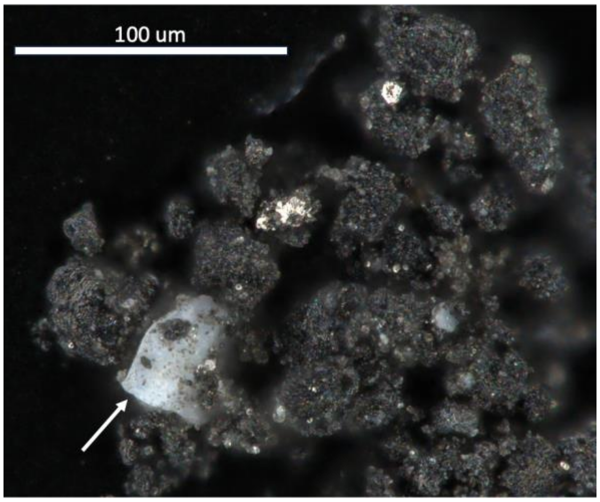

Figure 1. Optical photomicrograph of area of QL sample OREX-501050-0. Mg-phosphate is the white particle denoted with a white arrow.

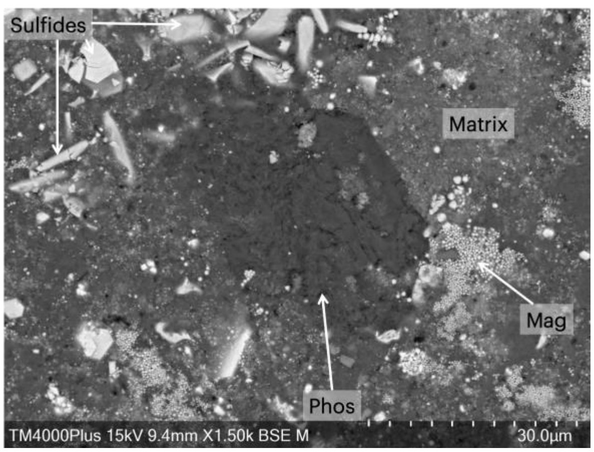

Figure 2. Backscattered electron image of an area of matrix in QL sample OREX-501049-0. Mg-phosphate is denoted with 'phos', and 'mag' is magnetite.

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References: [1] Lauretta D. S. et al. (2017) *Space Sci. Rev.*, *212*, 925-984. [2] Hamilton V. E. et al. (2019) *Nat. Astro.*, *3*, 332-340. [3] Simon A. A. et al. (2020) *Science*, *370*, eabc3522. [4] Kaplan H. et al. (2021) *Astronomy & Astrophys.*, *653*, L1. [5] Kaplan H. et al. (2020) *Science*, *370*, eabc3557. [6] Lauretta, D. S. et al. (2023) arXiv [astro-ph.EP] 2308.11794. [7] Zega T. J. et al. (2024) this meeting. [8] King A. J. et al. (2024) this meeting. [9] Smith L. R. et al. (2024) this meeting. [10] Lauretta D. S. et al. (2023) AGU meeting. [11] Buseck P. R. and Holdsworth, E. (1977) *Miner. Mag.*, *41*, 91-102. [12] Nakamura T. et al. (2022) *Science*, *379*, eabn8671.