OSIRIS-REx

ASTEROID SAMPLE RETURN MISSION

# The Mineralogy and Organic Composition of Bennu as Observed by VNIR and TIR Spectroscopy

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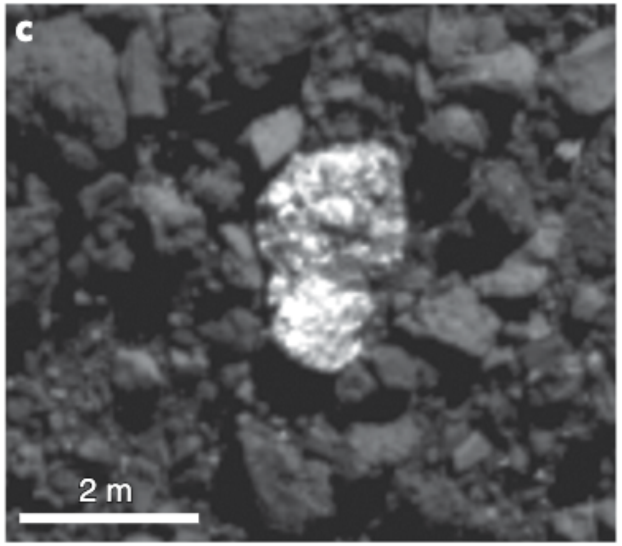
# Overview

- Results from Detailed Survey (global mapping) mission phase
  - Results from Preliminary Survey phase (detection of NIR hydration band and TIR observations of phyllosilicate and magnetite) are published in *Hamilton et al.* [2019]
- OVIRS (~0.4 — 4.2 µm point spectrometer, *Reuter et al.* [2018])
  - Exogenous, pyroxene-bearing basalts
  - C-bearing compounds
    - organics and carbonates
- OTES (~5.5 — 100 µm point spectrometer, *Christensen et al.* [2018])
  - Spectral types
  - Particle size effects
  - Mineral abundance constraints

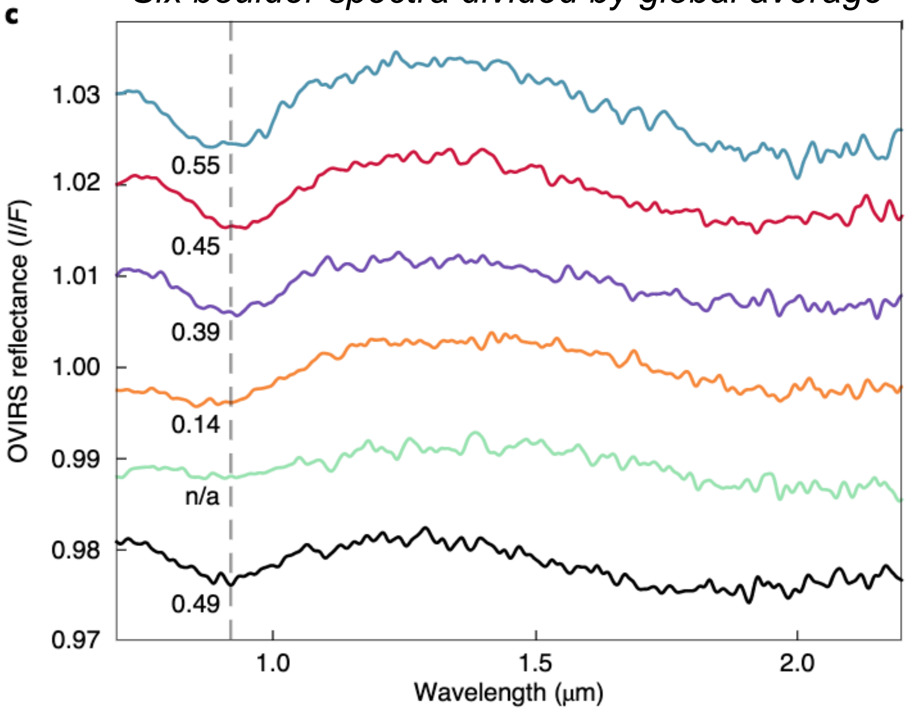
# OVIRS — Exogenic Basalt

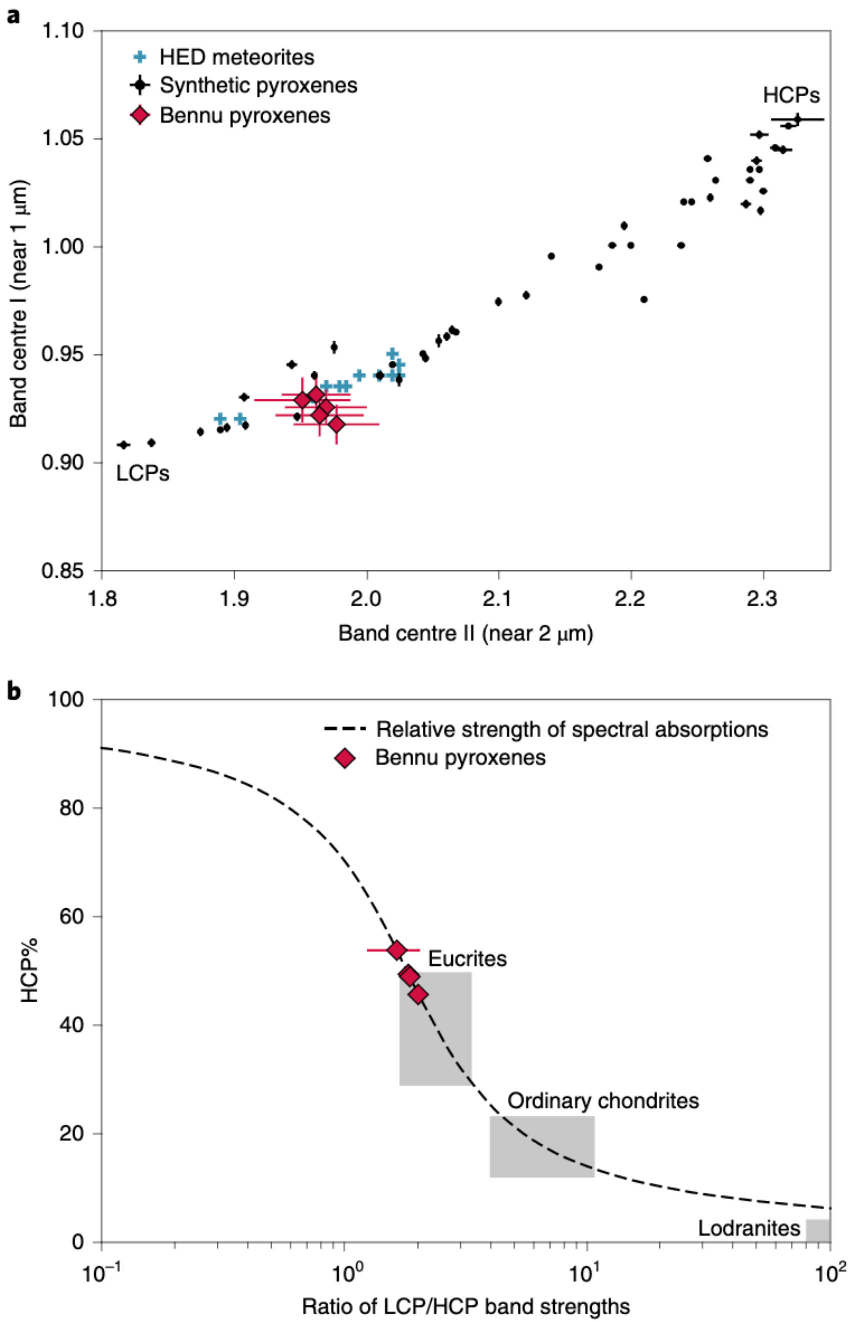
- Six unusually bright boulders (1.5 - 3.9 m) on Bennu have pyroxene signatures that are spectrally similar to HED meteorites, suggesting Vesta is their source

*Purple (3rd from top) spectrum at right*




*Six boulder spectra divided by global average*

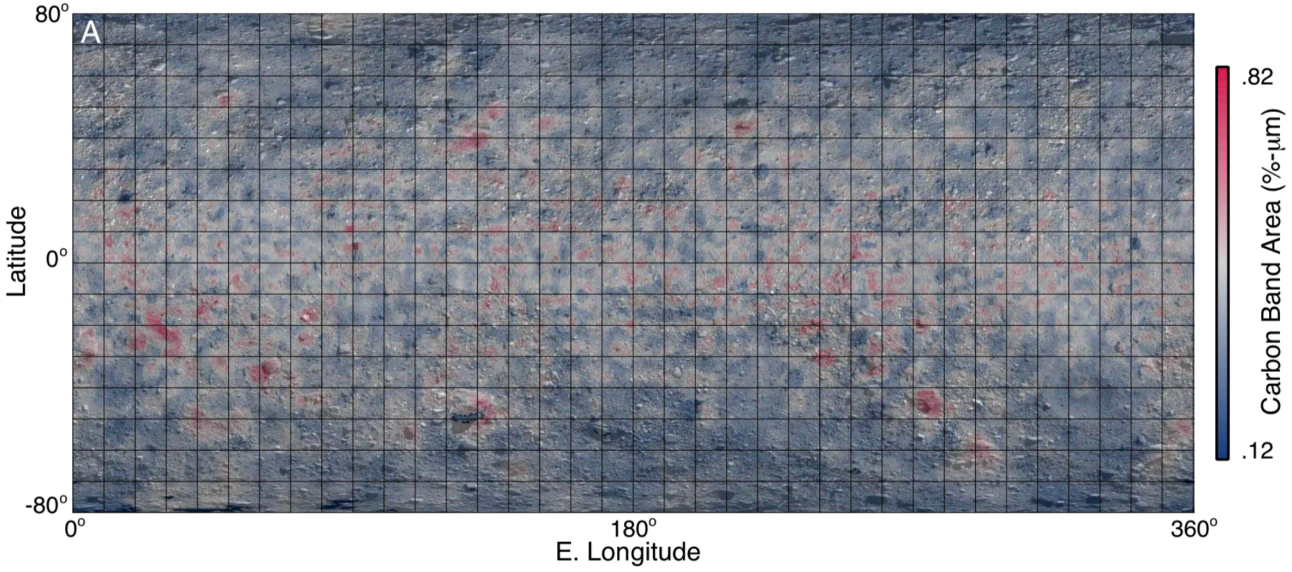


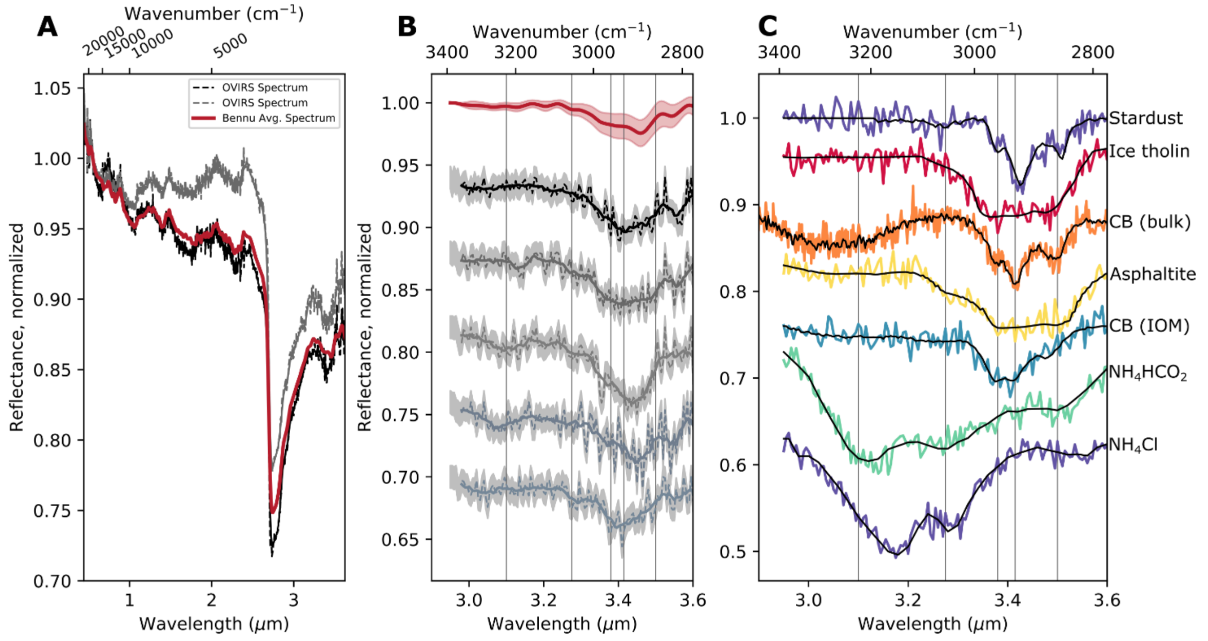

*DellaGiustina and Kaplan et al.* [2021]

# OVIRS — C-bearing Compounds/Organics

- Spectra exhibit a ubiquitous, but variable, 3.4-μm feature attributed to a mix of organic and carbonate materials; variations could be differences in abundance, exposure (fracturing), or space weathering



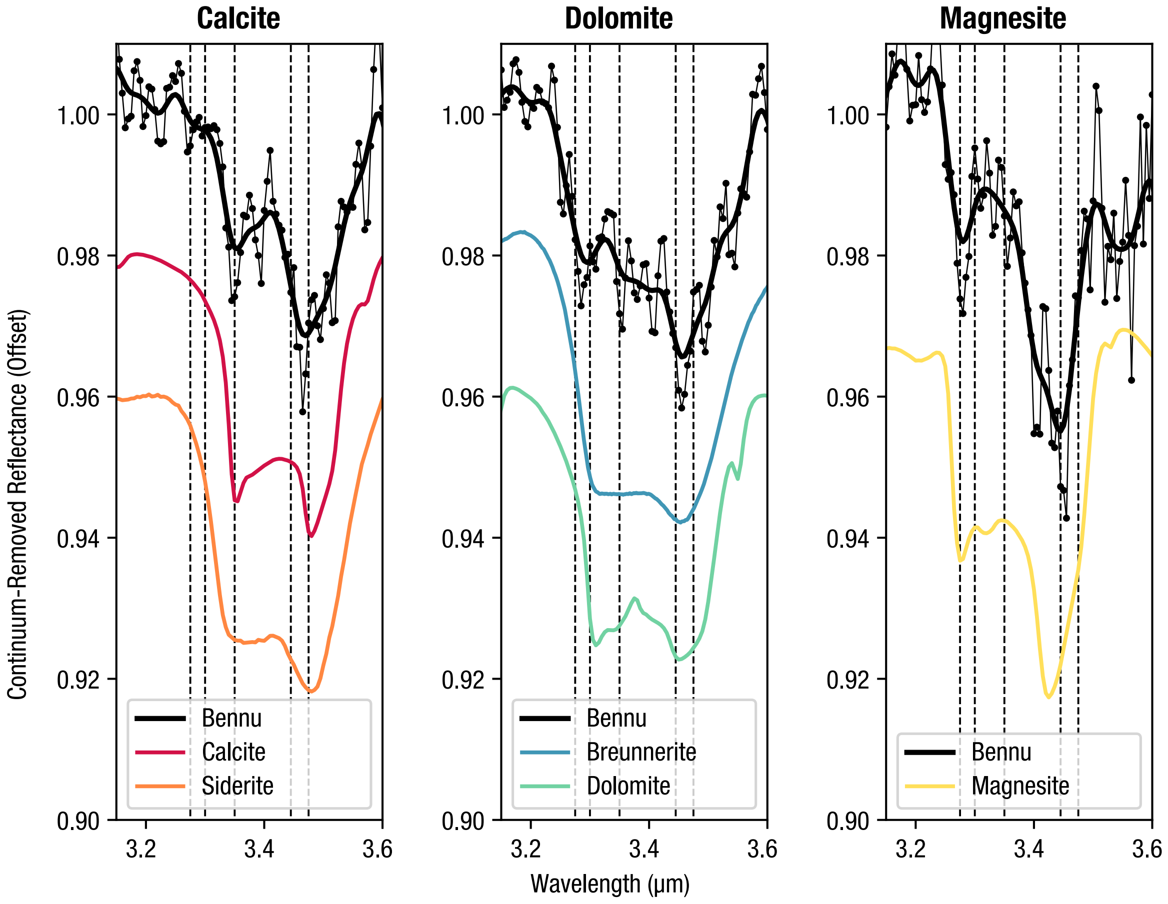

*Simon et al.* [2020]

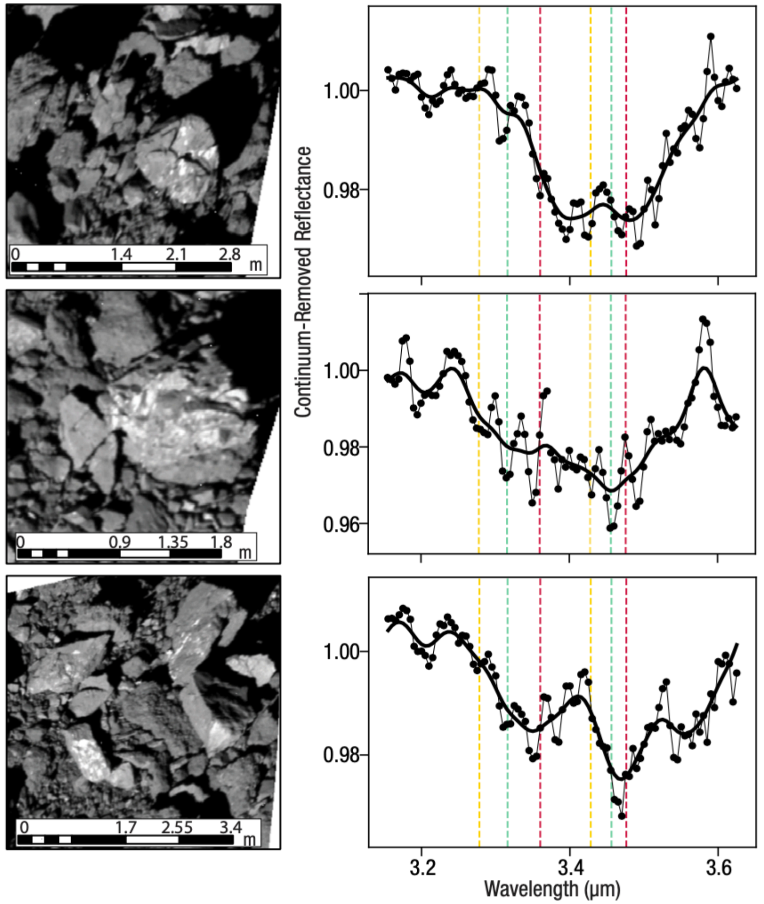



*Kaplan et al.* [2020a]

# OVIRS — Carbonates

- Spectra show features of carbonate compositions consistent with CI and CM carbonaceous chondrites; some of these correspond with boulders having bright veins

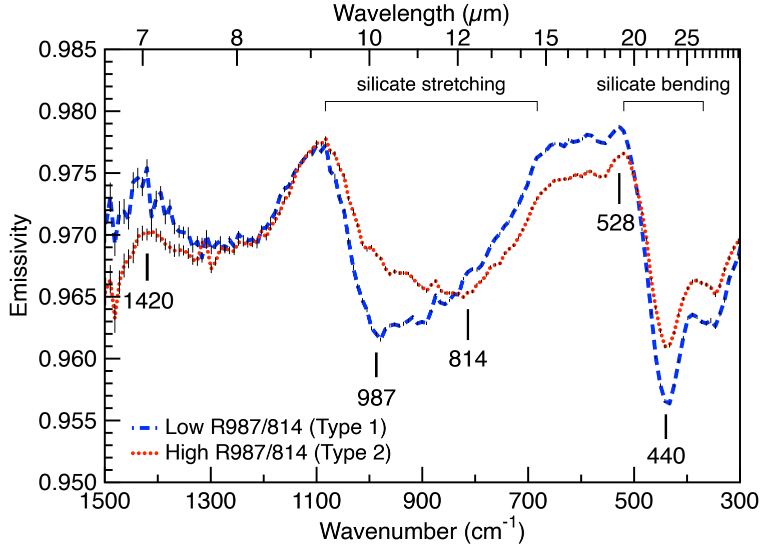


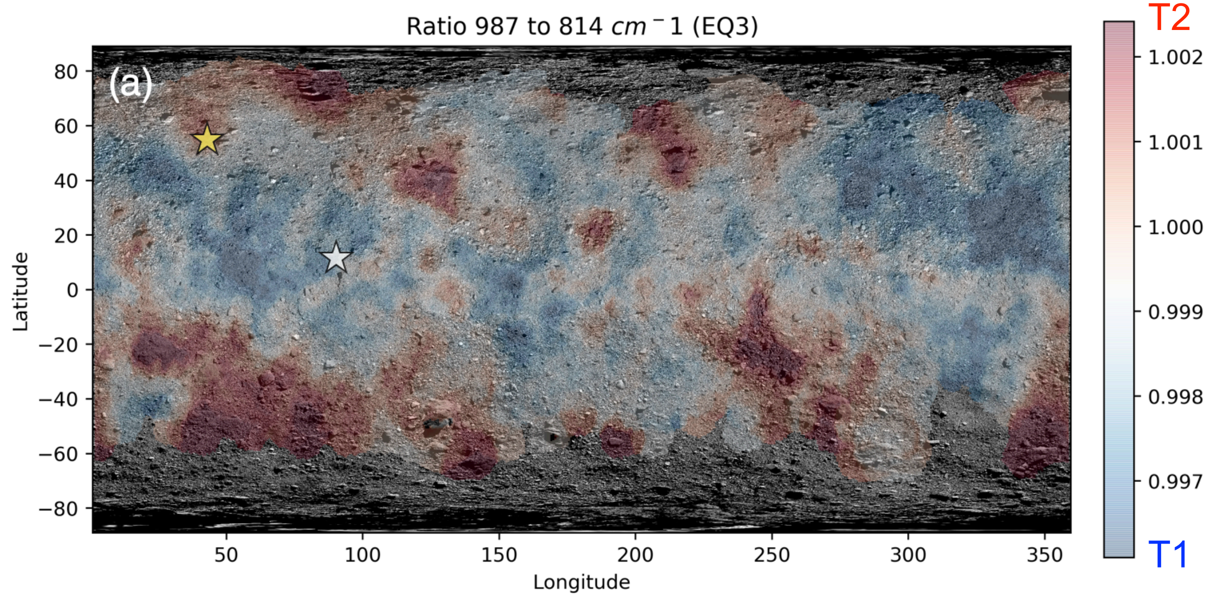




*Kaplan et al.* [2020b]

# OTES — Two Spectral Types

- Two spectral types (T1 and T2) differing primarily in the ratio of emissivities at 987 $cm^{-1}$ and 814 $cm^{-1}$
- Differences in the Si-O stretching modes in the absence of differences in shape of Si-O bending modes are attributed to volume scattering in thin (~5-10 μm) deposits of fines
    - Band depth/contrast differences in bending modes likely due to particle size, porosity, and/or roughness
- Correlation of OTES T2 ("more fines") with boulder-rich surfaces runs counter to expectations
- Hypothesis: Larger, rough boulders have surface texture that produces or traps fines
    - Consistent with thermal inertia modeling: no dust layer or checkerboard >50 μm thick [*Rozitis et al.*, 2020]



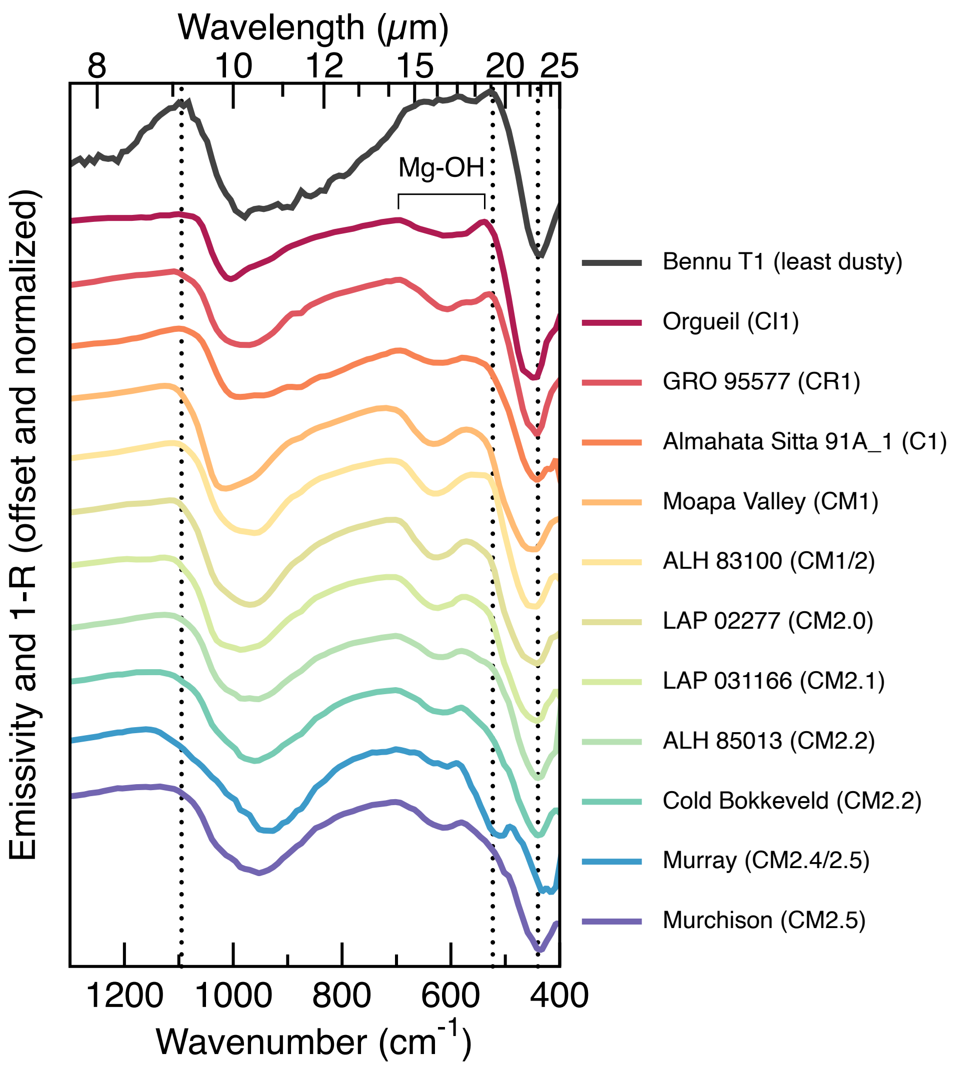

*Hamilton et al.* [2021]

# OTES — Constraints on Bulk Mineralogy (1 of 2)

- Si-O stretching minimum (T1) is most consistent with highest degrees of alteration
- 523 $cm^{-1}$ peak
  - At phyllosilicate fractions less than ~0.90 - 0.93 it shifts to higher $cm^{-1}$ and no longer matches
- At Rubin petrologic types ≥2.4, features of ol and px appear [see also *Hanna et al.*, 2020]
- Mg-OH feature not observed in T1/T2 - why?

| Meteorite | Phyllosilicate Fraction | Total Olivine (%) |
|---|---|---|
| Moapa Valley (CM1) | 0.96 | 4.10 |
| ALH 83100 (CM1/2) | 0.90 (0.91)* | 8.70 (5.30)* |
| LAP 02277 (CM1/2.0) | 0.93 | 5.30 |
| LAP 031166 (CM1/2 or 2.1) | 0.93 | 5.00 |
| ALH 85013 (CM2.0) | 0.86 | 9.80 |
| Cold Bokkeveld (CM2.2) | 0.82 | 11.50 |
| Murray (CM2.4/2.5) | 0.76 | 17.30 |
| Murchison (CM2.5) | 0.76 | 15.10 |

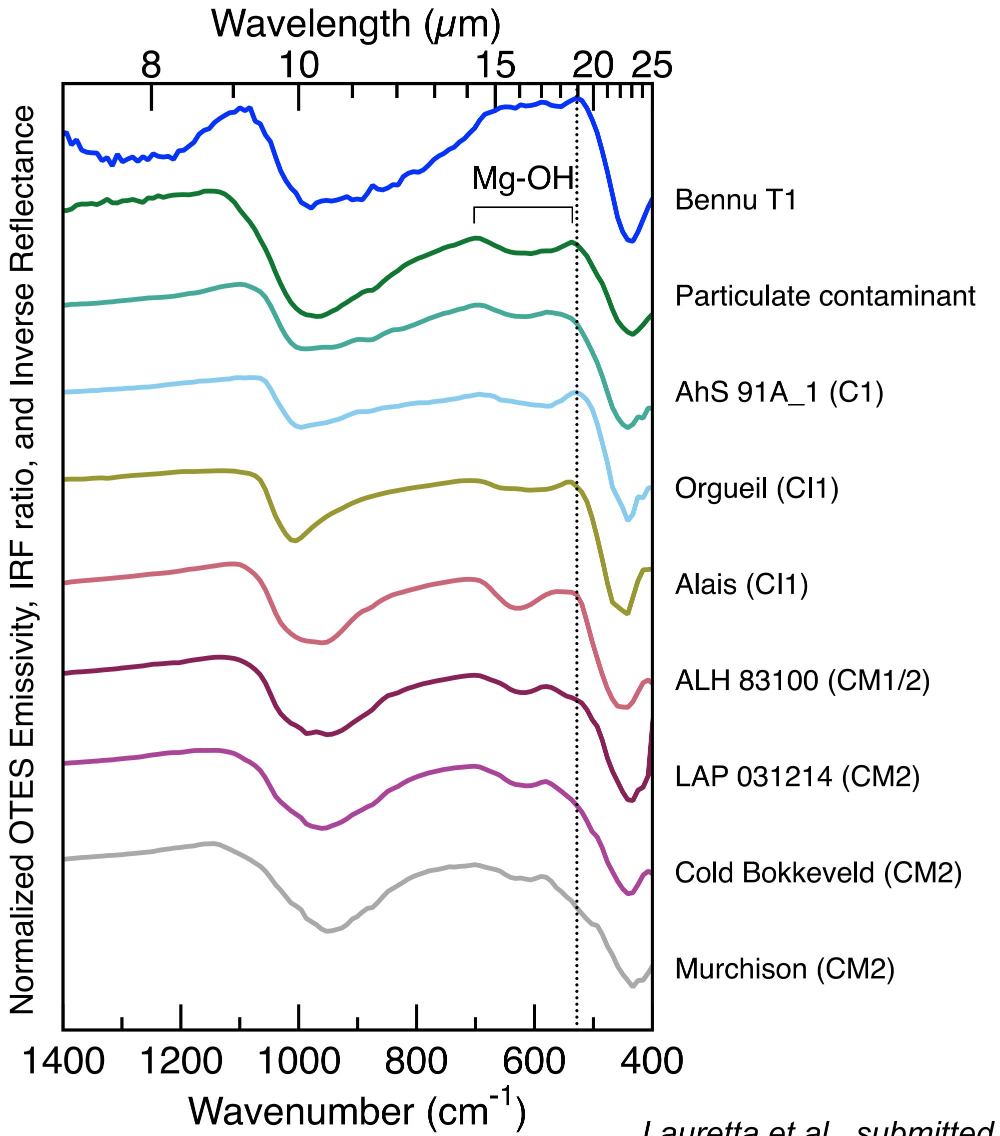
Phyllosilicate fraction & total olivine from *Howard et al.* [2015] and *King et al.* [2017] **Donaldson Hanna et al.* [2019]




*Hamilton et al.* [2021]

# OTES — Constraints on Bulk Mineralogy (2 of 2)

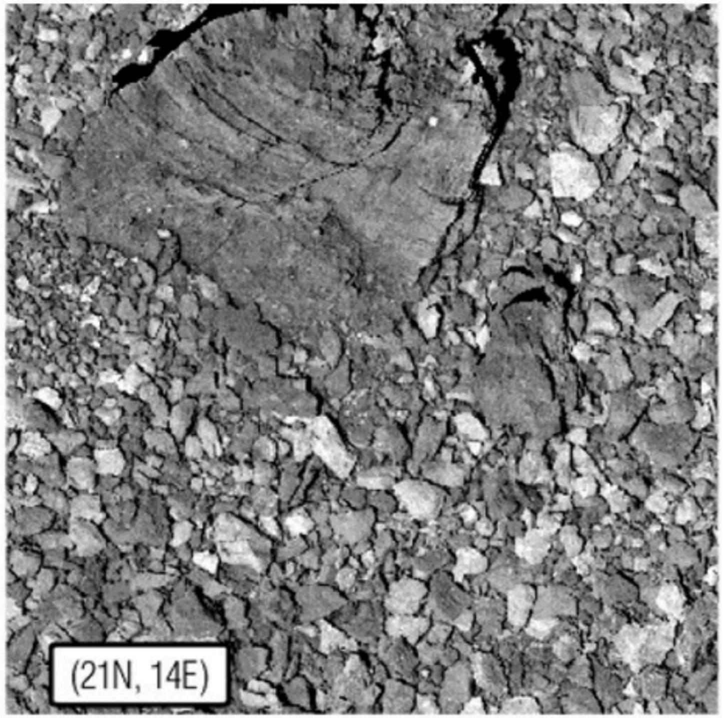
- Post-sampling, particulate contaminant observed on OTES optics; reveals Mg-OH feature “missing” from Bennu surface spectra
  - Confirms interpretation of (Mg-)phyllosilicate-dominated bulk mineralogy
- But none of the OTES spectra are a perfect match to CC spectra in Si-O stretching region (based on comparison with >100 CC spectra representing 90 unique meteorites)
  - Bennu may represent a bulk mineralogy not represented in meteorite collections
  - Mixture? (see also next slide) Modeling of T1 spectrum using library of CC meteorites does not result in a sufficiently good fit to evaluate
  - Possibly environmental (e.g., minor dust in T1)




*Lauretta et al., submitted*

# Summary and Predictions for the Returned Sample

- Spectral data do not show evidence of more than one composition, but visible image characteristics (texture, albedo) suggest there are two lithologies; if these differences represent a compositional difference as well, it may not be distinguishable at OVIRS/OTES spatial resolution (sub-pixel mixing)
- Observed mineralogy/organics most consistent with most aqueously altered CI- or CM-like carbonaceous chondrite compositions
  - The returned sample should be dominated volumetrically by hydrous silicates with less than ~10 vol% anhydrous silicates (magnetite, carbonate, and organics also should be present; sulfides are difficult to detect spectrally but may be inferred to be present by analogy with CC)
  - Carbonate, possibly in veins of much larger scale than observed in CC meteorites, suggest Bennu's parent body experienced fluid flow and hydrothermal deposition on km scales for thousands to millions of years
- Isolated boulders containing pyroxene are interpreted as exogenic, basaltic material from Vesta and fragments may be included in the returned sample
- There is evidence for the presence of both solid/coarse materials as well as fine particulates (<~100 μm) and we expect the sample to display a wide range of particle sizes



*Golish et al.* [2021]