OSIRIS-REx
ASTEROID SAMPLE RETURN MISSION

Bennu dust observed by OSIRIS-REx

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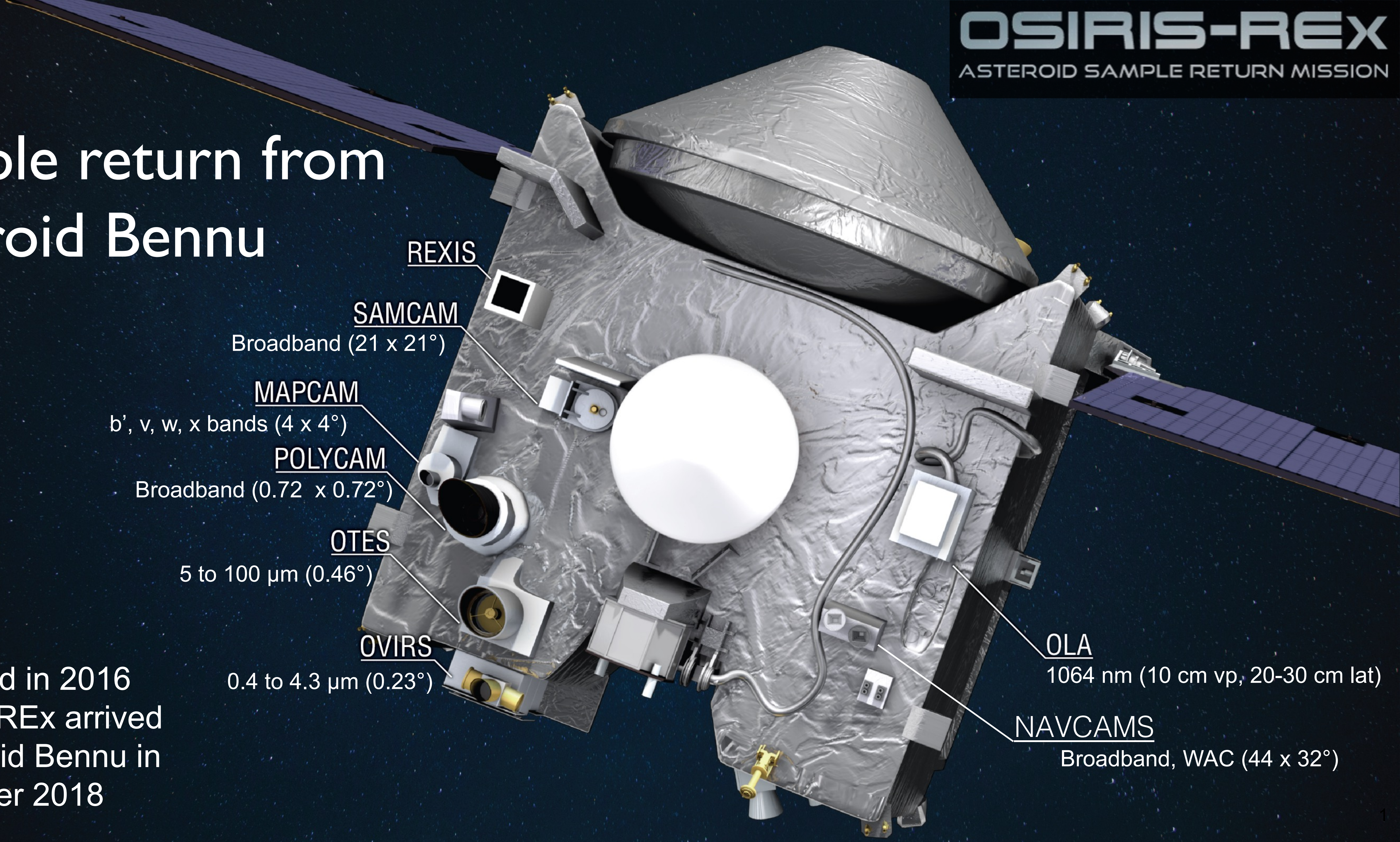
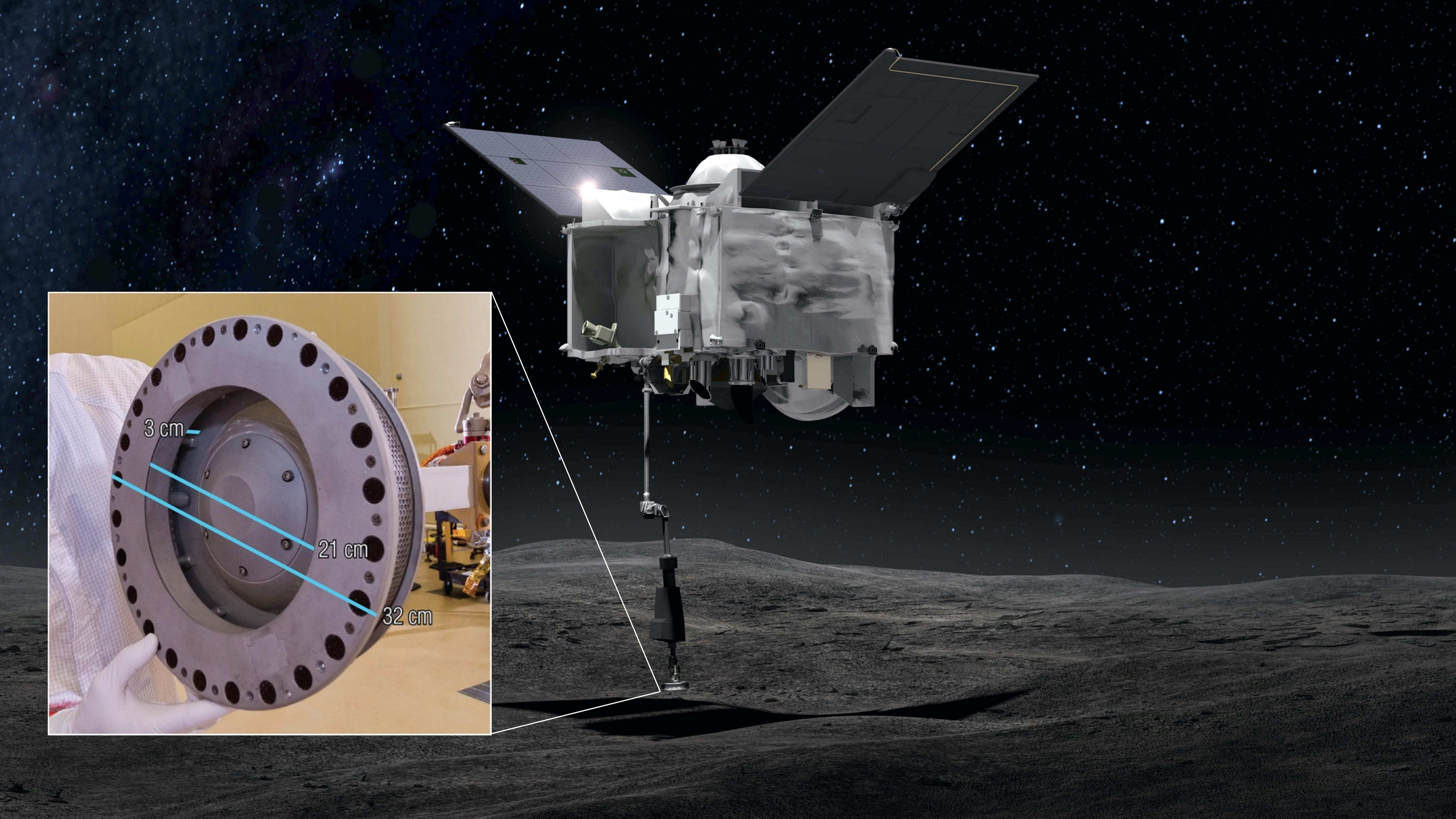
Dust, Atmosphere, and Plasma Environment of the Moon and Small Bodies

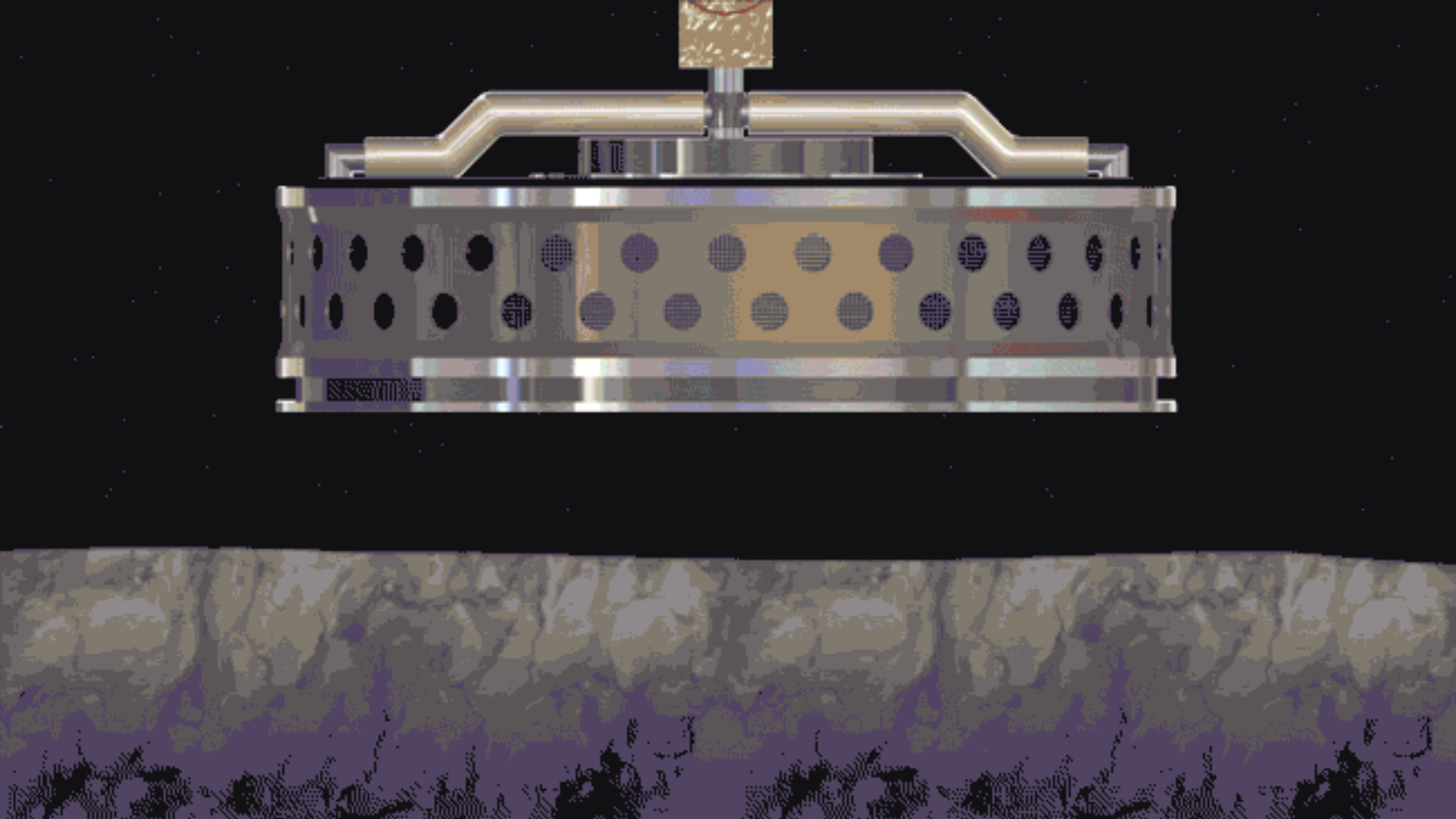
June 5, 2023

Sample return from asteroid Bennu



Launched in 2016 OSIRIS-REx arrived at asteroid Bennu in December 2018

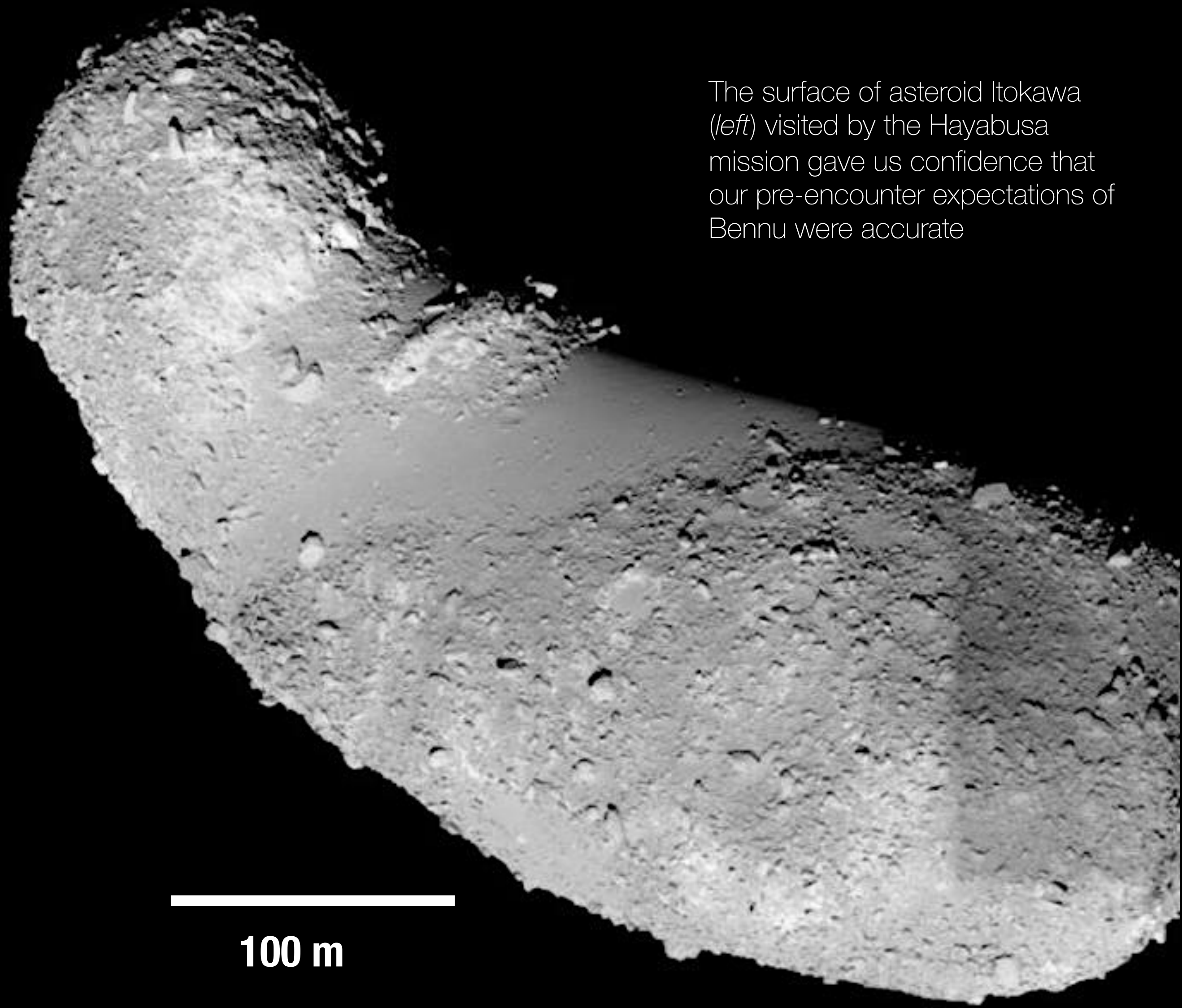

3 cm
21 cm
32 cm



Pre-encounter expectations, mission design, and sampling strategy

OSIRIS-REx mission design assumptions about Bennu (Lauretta et al., 2015, 2017).

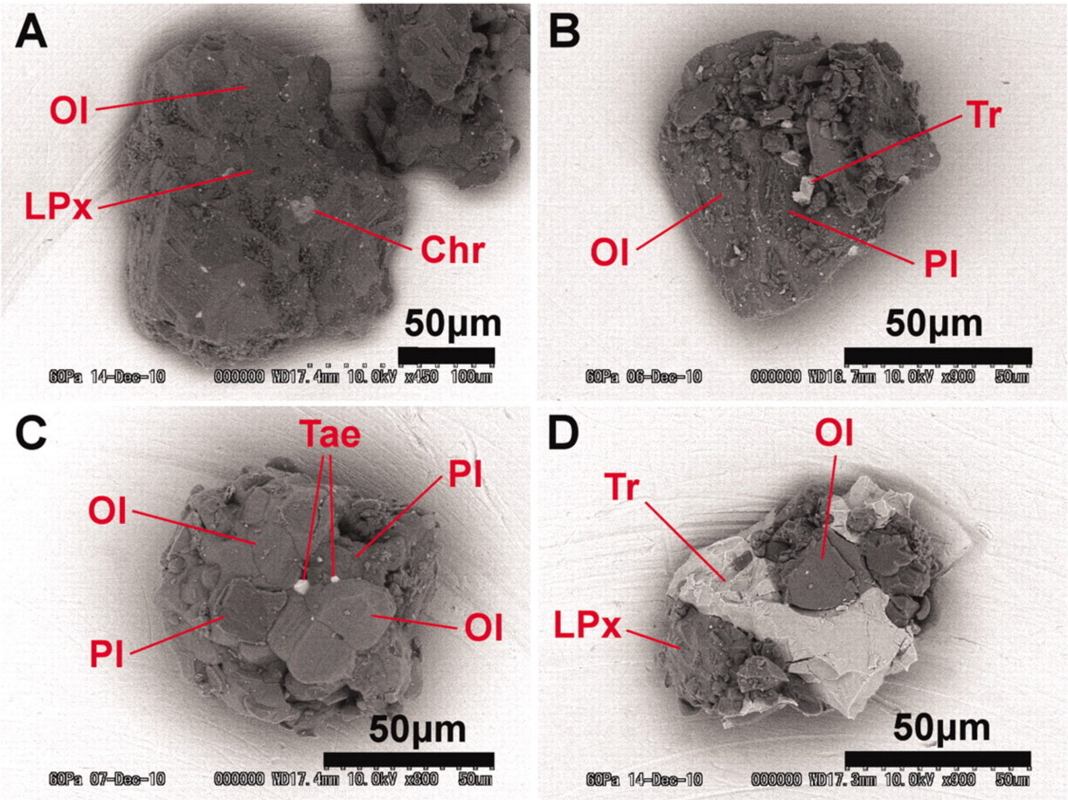
- Telescopic data implied centimeter-scale particles and smaller were widespread on Bennu's
  - Mid-infrared thermal inertia (Emery et al., 2014),
  - Near-infrared spectra (Binzel et al., 2015)
  - Radar polarization ratio measurements (Nolan et al., 2013)
- Sampling strategy was designed to target patches of loose regolith with particles smaller than 2 cm (Lauretta et al., 2017; Bierhaus et al. 2018).



The surface of asteroid Itokawa (*left*) visited by the Hayabusa mission gave us confidence that our pre-encounter expectations of Bennu were accurate

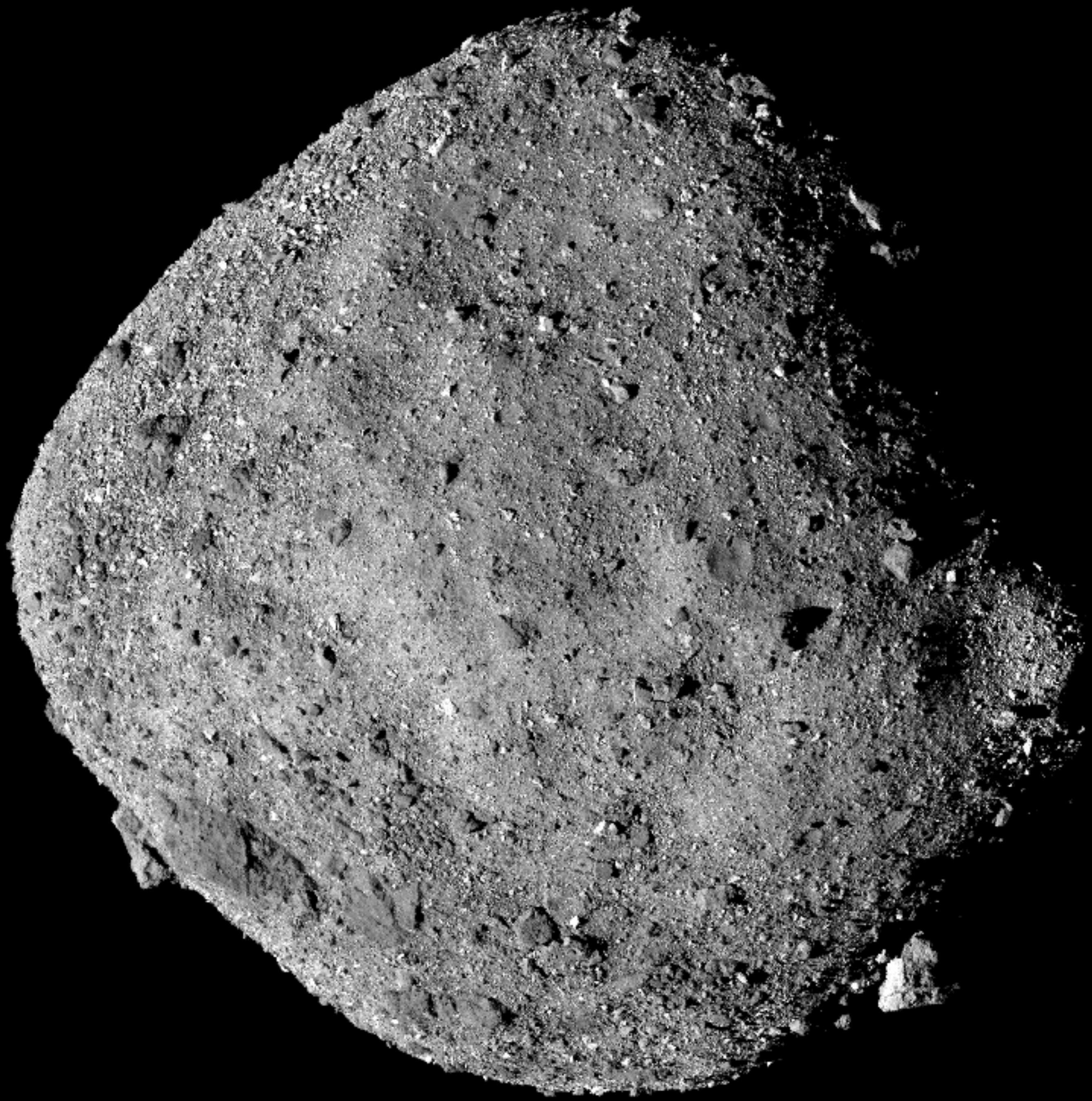
Returned Samples of Asteroid Itokawa

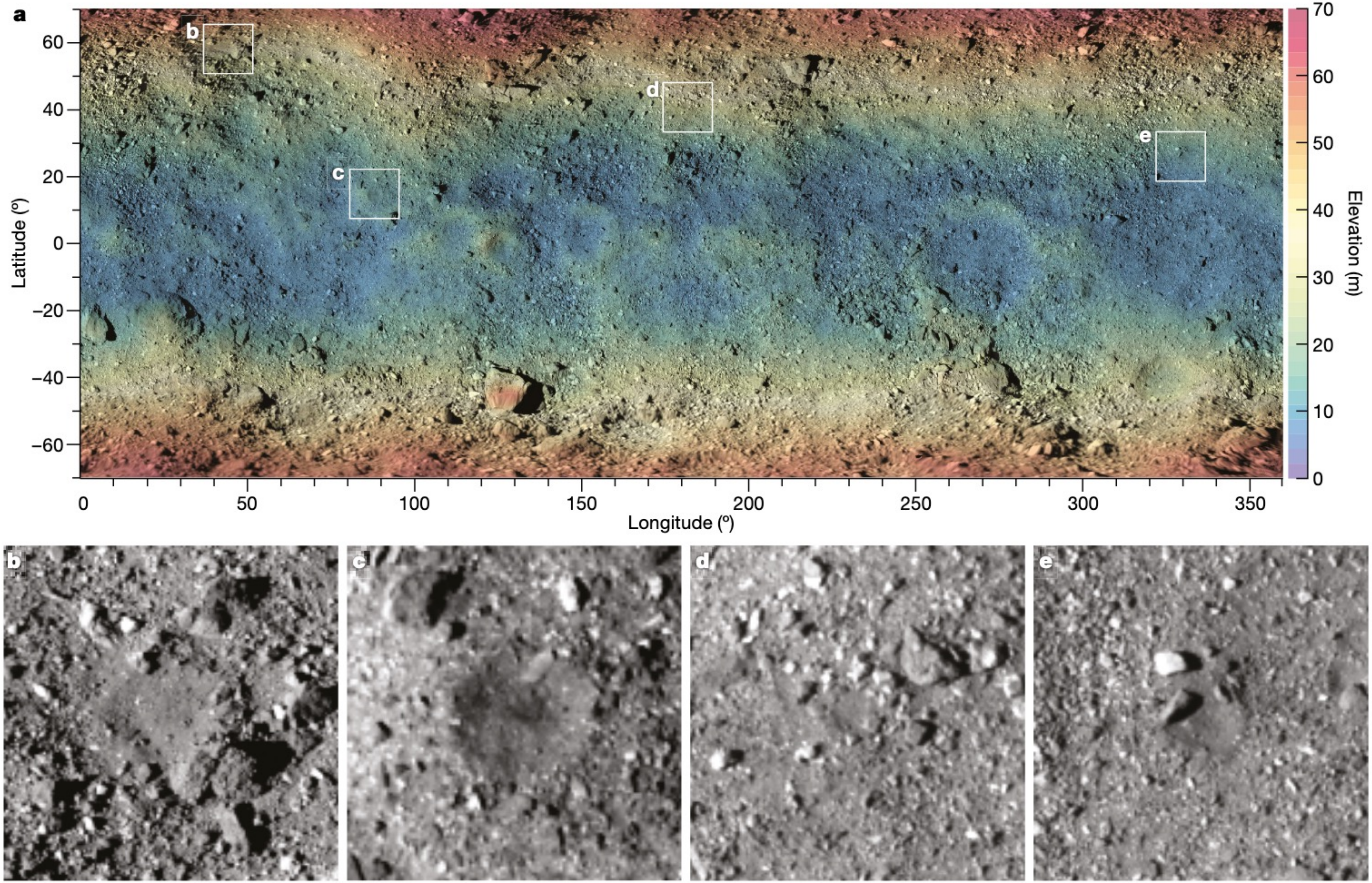
1500 grains (most ~10 um in size) from Itokawa had been recovered, comprising the minerals olivine, pyroxene, plagioclase and iron sulfide.



Nakamura et al. 2011

Meeting Bennu with OSIRIS-REx in 2018





a
b
c
d
e
Latitude (°)
Longitude (°)
Elevation (m)
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50
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250
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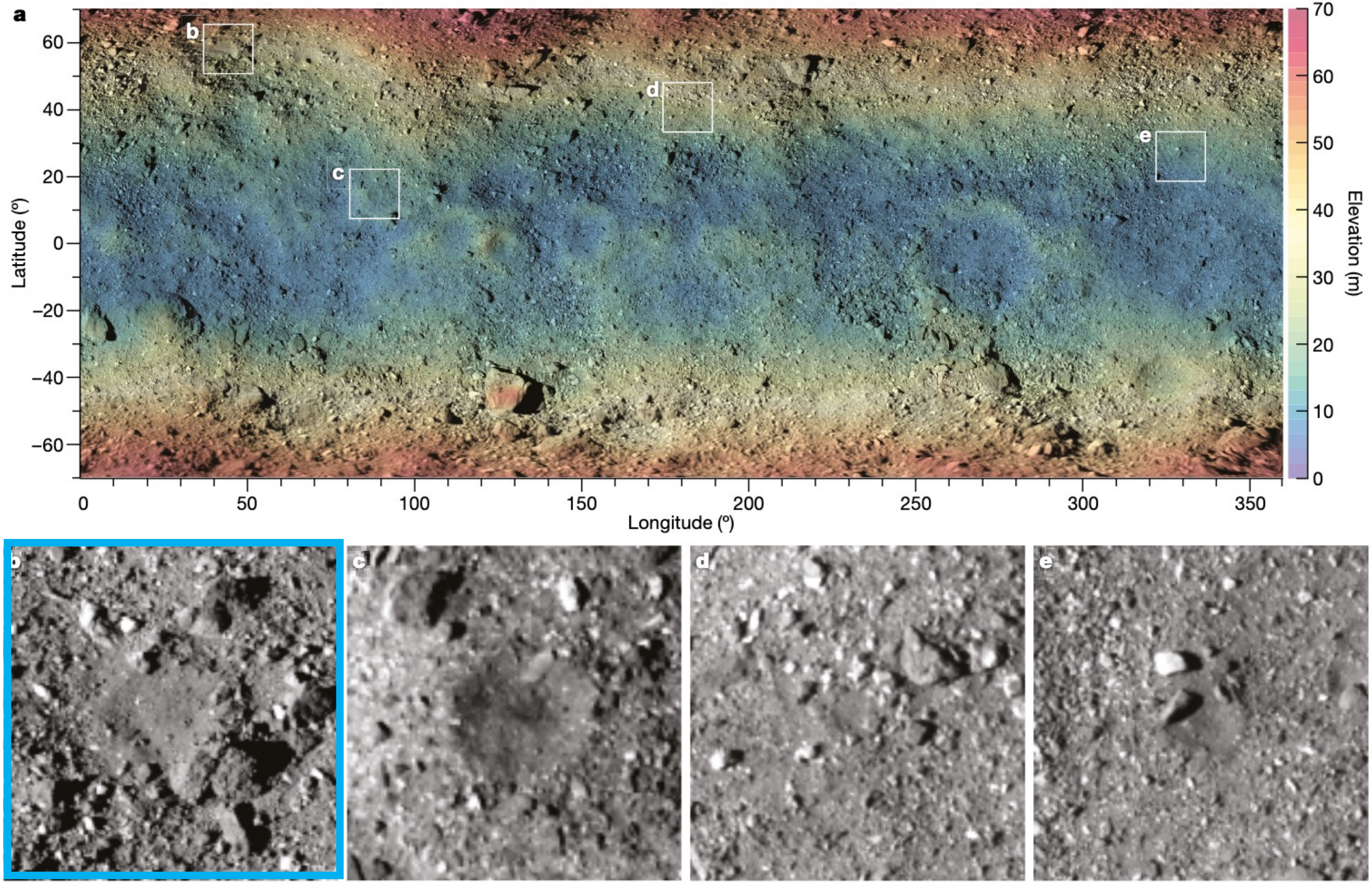
350
70
30
10


a
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Latitude (°)
Longitude (°)
Elevation (m)
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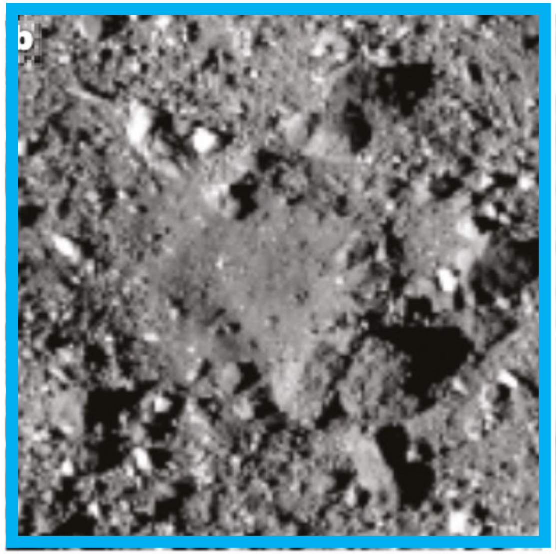
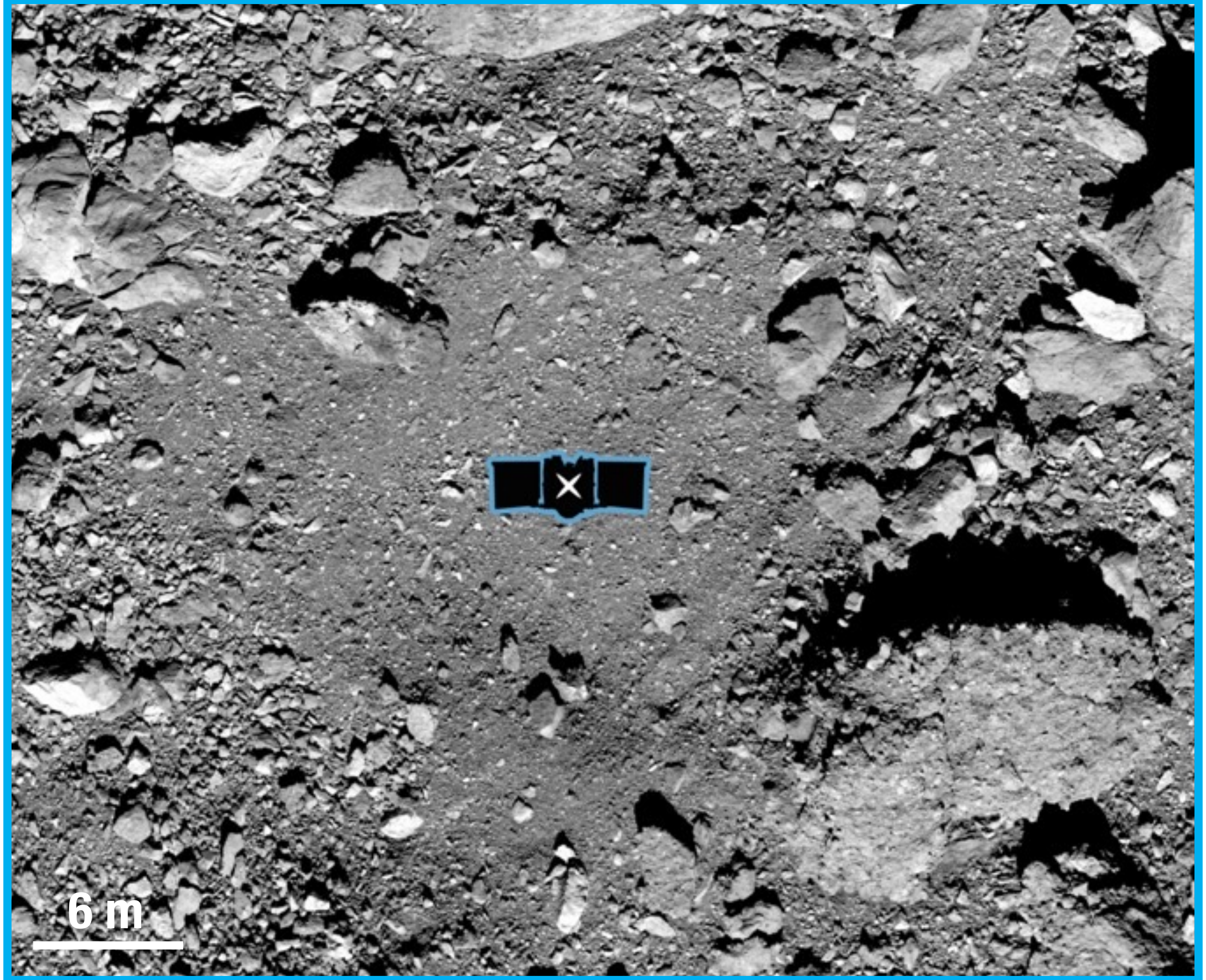
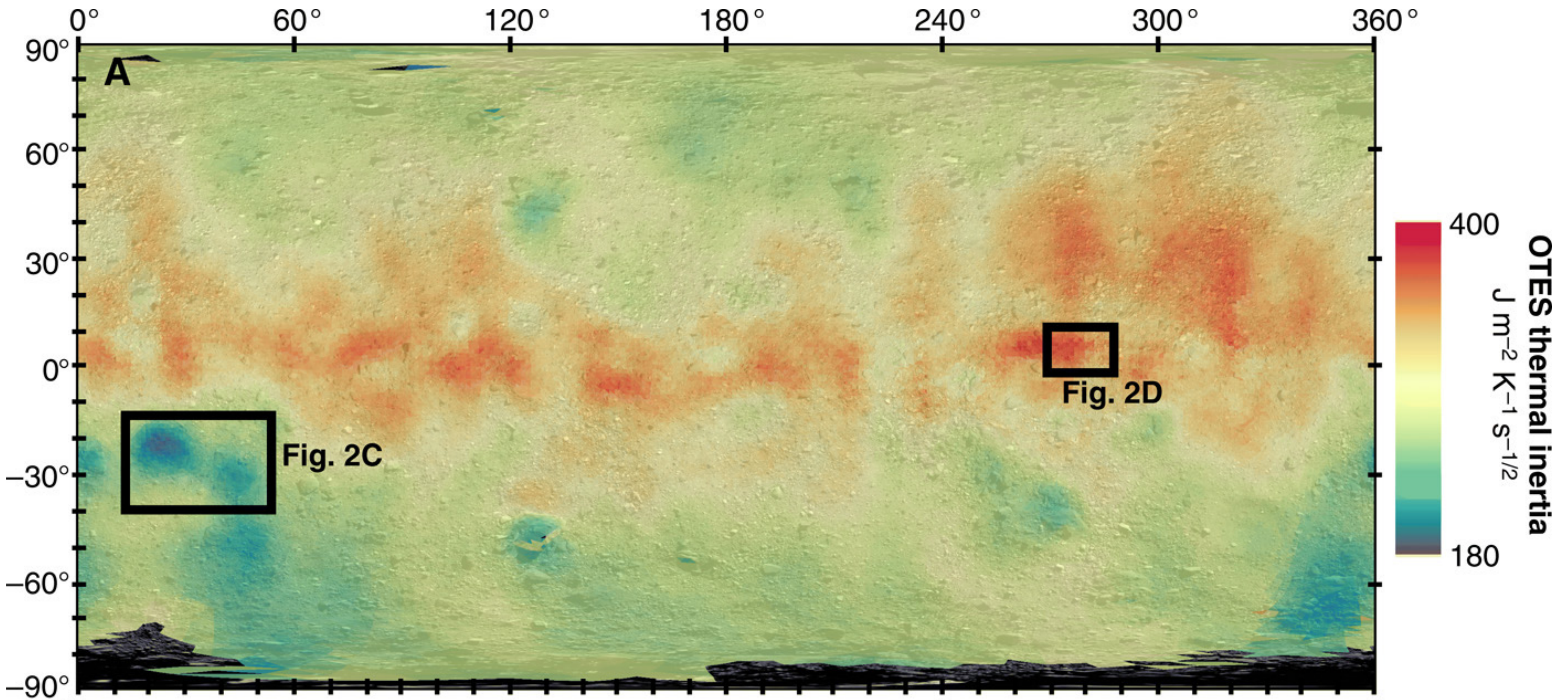

b

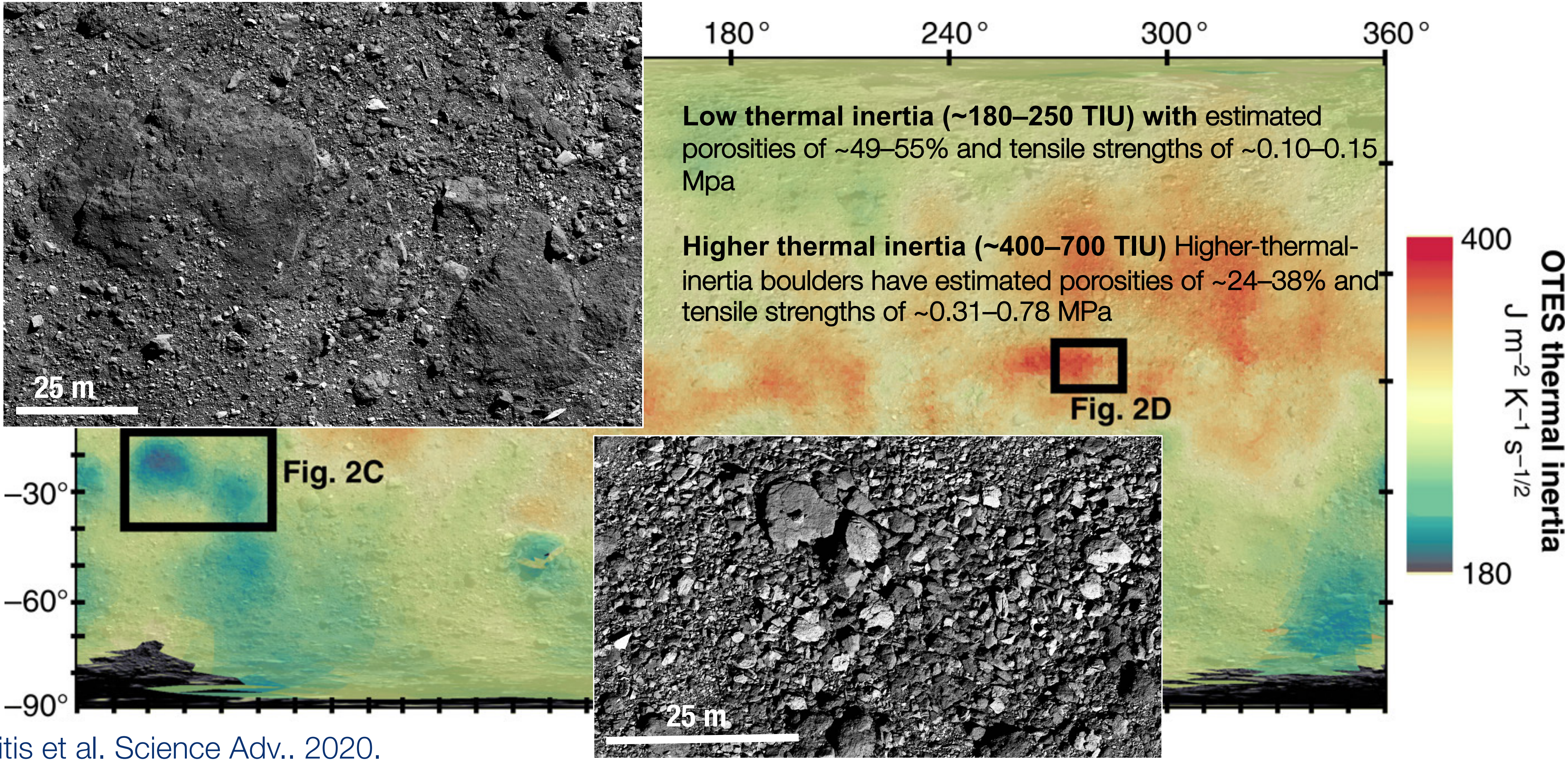

6 m

Remote Sensing Observations Bennu: Thermal Inertia



Rozitis et al. Science Adv.. 2020.

Remote Sensing Observations Bennu: Thermal Inertia

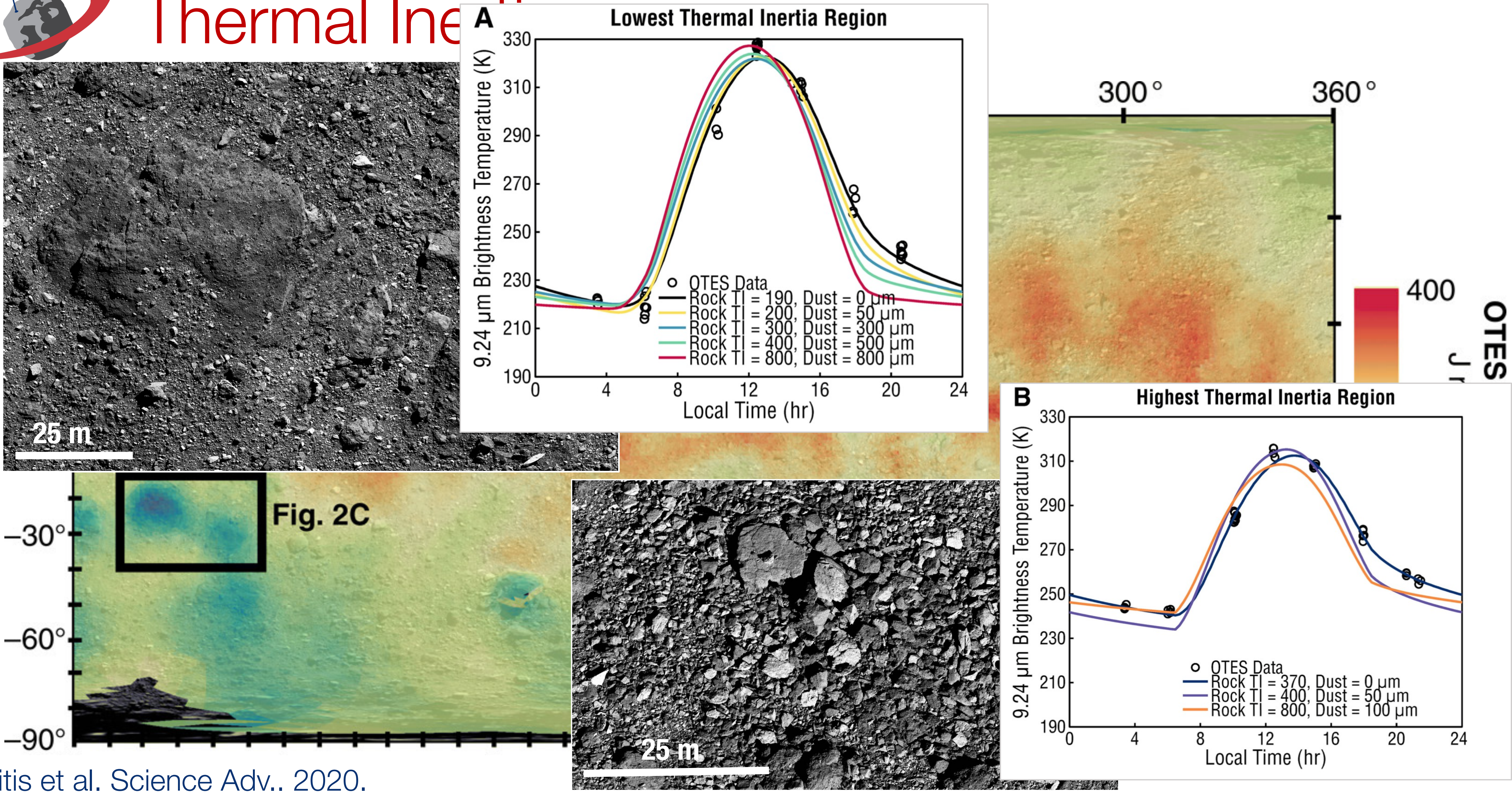


Low thermal inertia (~180–250 TIU) with estimated porosities of ~49–55% and tensile strengths of ~0.10–0.15 Mpa

Higher thermal inertia (~400–700 TIU) Higher-thermal-inertia boulders have estimated porosities of ~24–38% and tensile strengths of ~0.31–0.78 MPa

Rozitis et al. Science Adv.. 2020.

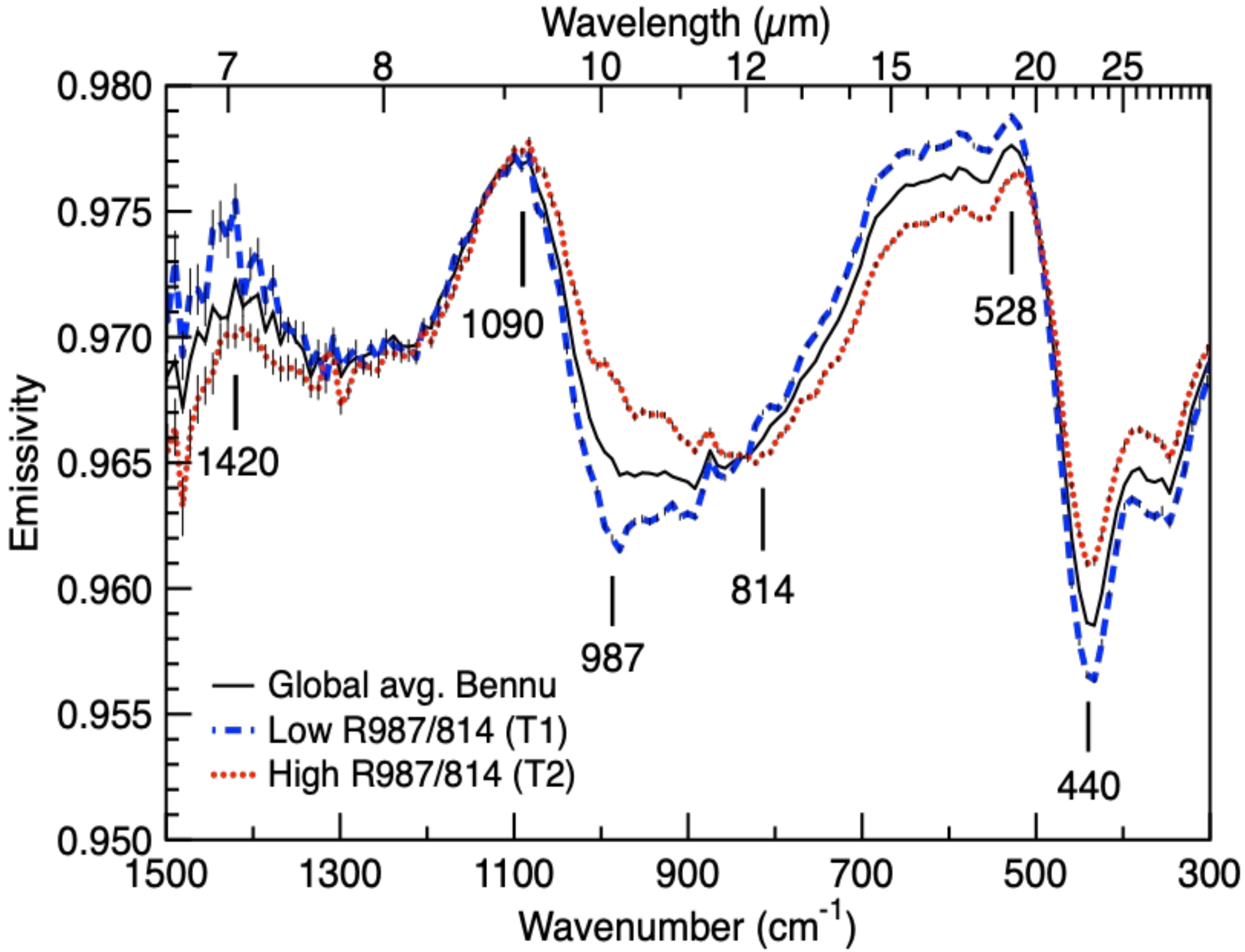
Remote Sensing Observations Bennu:
Thermal Ine



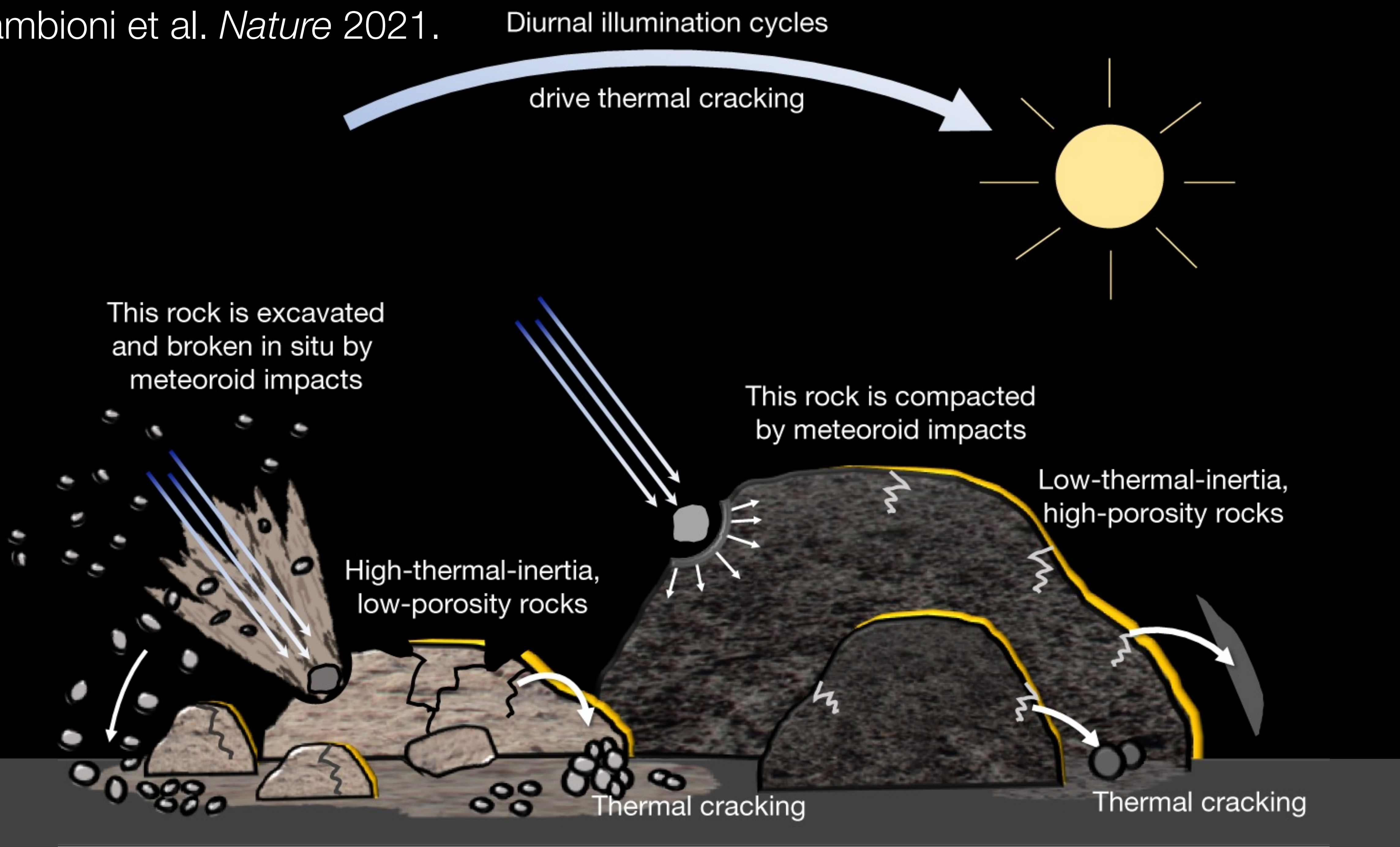
Rozitis et al. Science Adv.. 2020.

Thermal Emission Spectra of Bennu

- Two spectral end-members presented in OTES data
- 90% of are modeled as mixtures of T1 and T2
- T1-T2 variations are consistent with a weak volume scattering effect produced by relatively thin deposits (~15 μm) of fine particles on coarse particulates (>1 mm) and rocky surfaces



From Cambioni et al. *Nature* 2021.



The OSIRIS-REx Touch-and-Go sampling event

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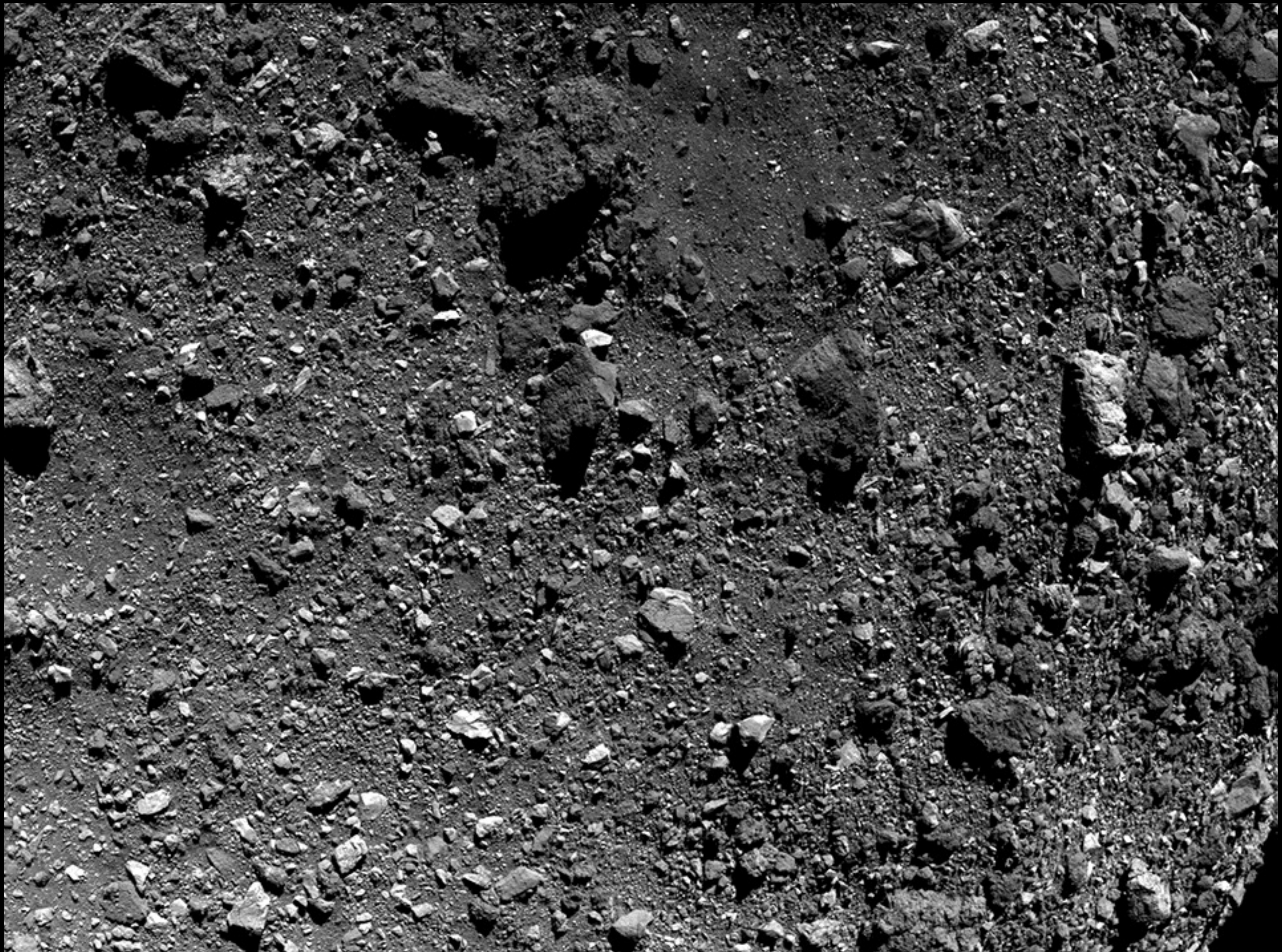
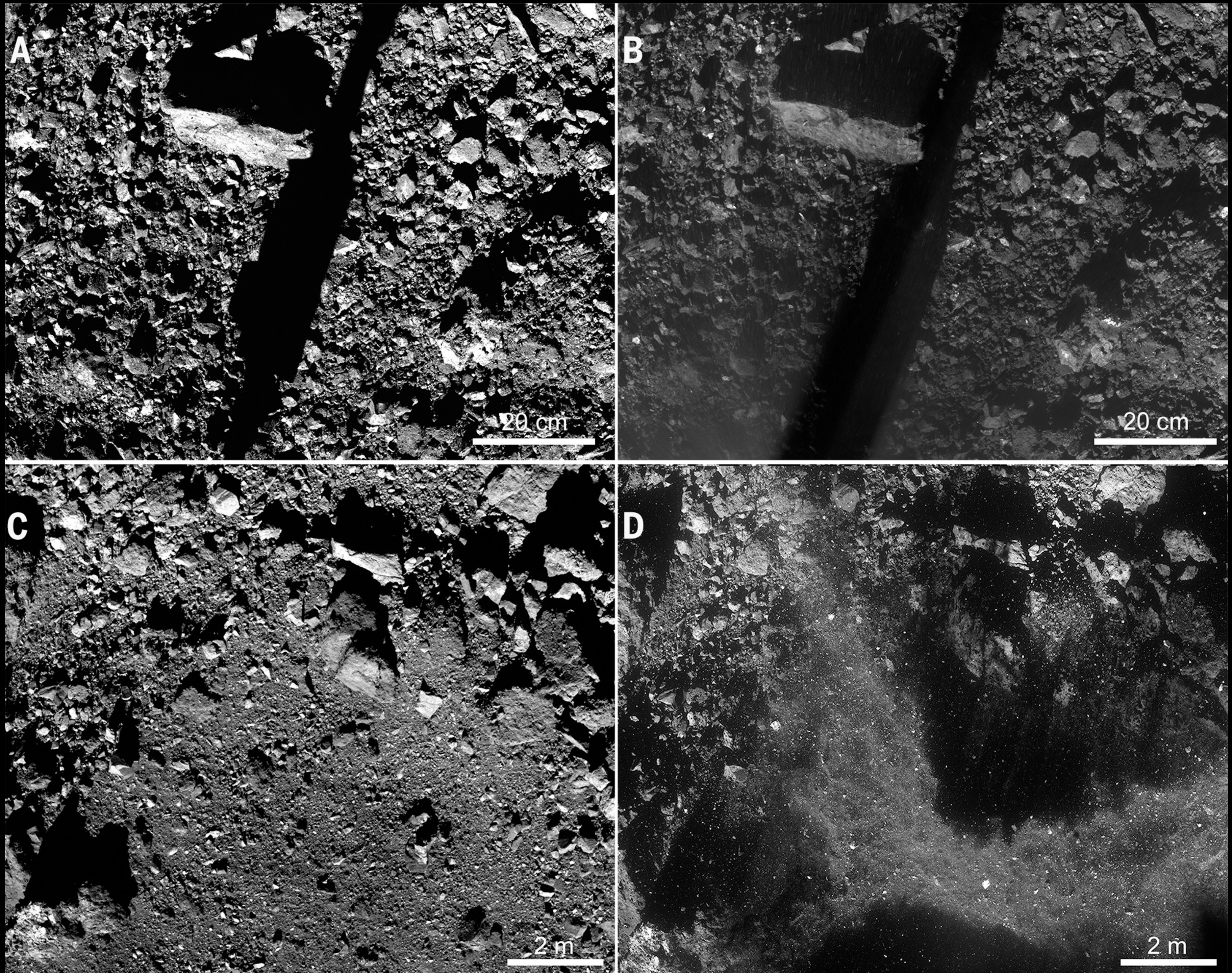
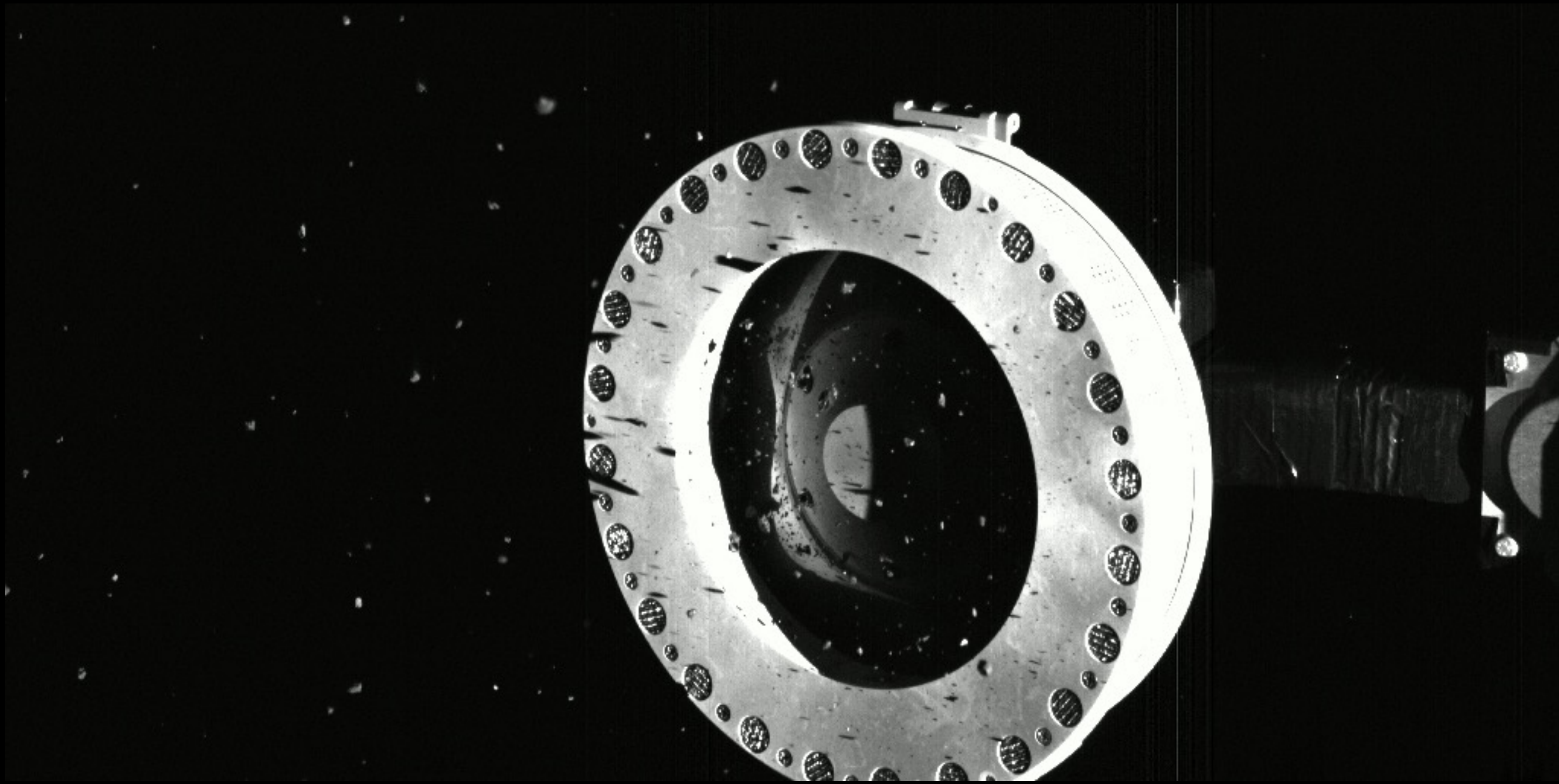



A
20 cm
B
20 cm
C
2 m
D
2 m

The OSIRIS-REx sample acquisition verification and stow



The future of OSIRIS-REx

Sample analysis of Bennu material

- Samples of Bennu will be returned to Earth in September 2023
- Afterwards will be 2 years of sample analysis
- Expecting ~100 grams of sample
- Expecting low-density water and carbon-bearing materials

APEX: AN OSIRIS-REX EXTENDED MISSION

OSIRIS-APEX
APOPHIS EXPLORATION MISSION

Limited-Life Items	Remaining Life-Limit at Launch	Used At Depart + Estimate to Earth Return	Remaining Life-Limit for EM
Battery Cycles	600	100	74%
Solar Array Outer Cycles	1,549	375	76%
TWTA On Time (h)[1]	298,831	51,250	83%
TWTA Power Cycles	4,370	1,300	66%
IMU On Time (h)	263,883	55,000	79%
RWA (Revs)	3.89E+10	6.53E+9	83%
Propellant (kg)	1,184.0	870.1±32	27%
Main Engine Throughput (kg)	305.0	189.0	38%
TCM Thruster Throughput (kg)	259.0	35.2	86%
ACS Primary Starts	1,002	211	79%
ACS Secondary Starts	1,002	123	88%
TCM Thruster Cycles	116,980	22,705	81%
MapCam Filter Wheel Steps	9,110,808	3,407,930	63%
PolyCam Focus Steps	7,786,968	873,975	89%
OLA HELT (h)	787	128	84%

Above. Table showing the OREx spacecraft components with less than 90% of their remaining life

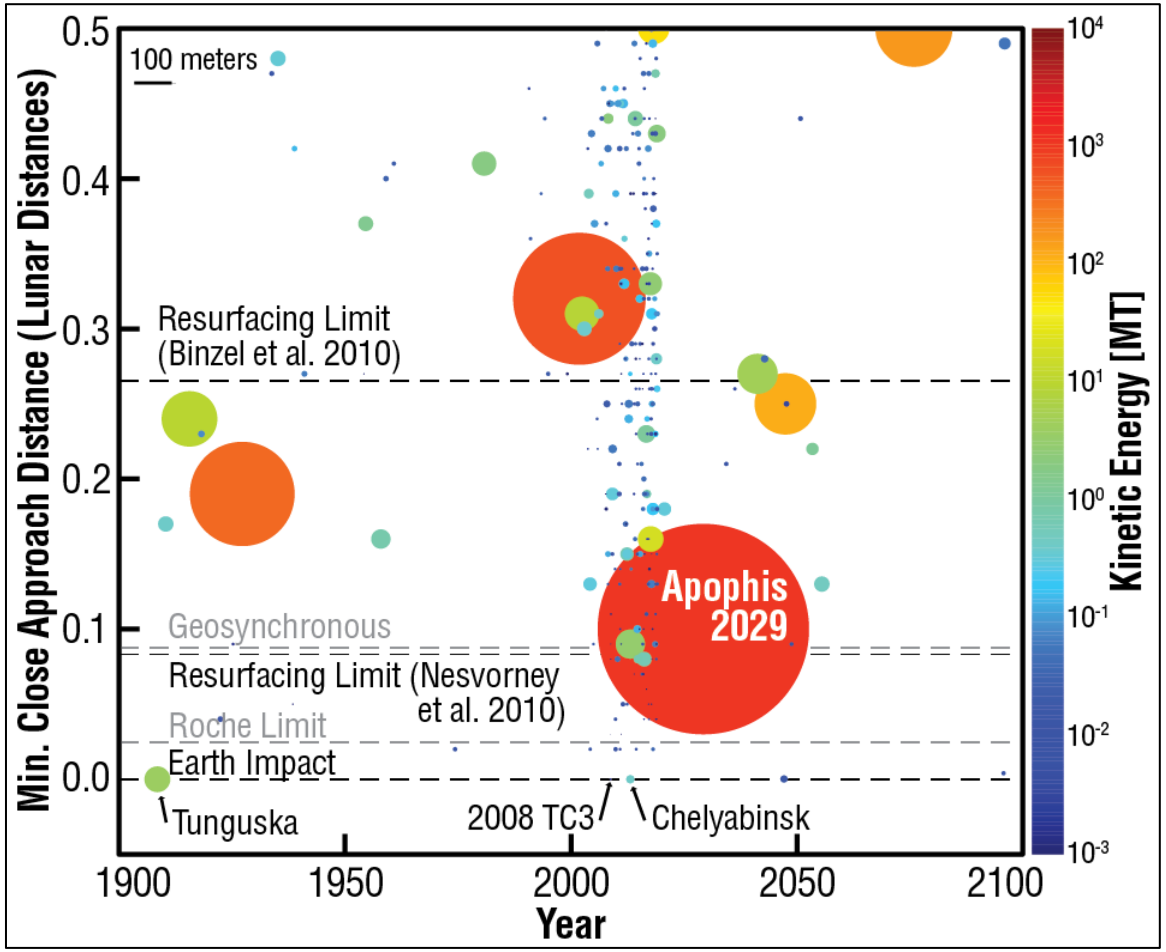
- Important subsystems have not exhausted their lifetime limits (*left, top*)
- Substantial fuel margin of >500 m/s, which can support an extended mission
- The OSIRIS-REx instruments on the spacecraft were designed for a rendezvous-style mission.
  - Not optimized for fast, distant flybys, but can achieve exceptionally high-resolution data at small surface ranges (*next slide*)
- An extensive target search was conducted (Sutter et al. 2022)
  - Searched for objects that could be rendezvoused with within 6 years of SRC release

Apophis is the most viable and scientifically compelling target identified by our search

WHY ASTEROID APOPHIS?

OSIRIS-APEX
APOPHIS EXPLORATION MISSION

- The 2029 Apophis-Earth encounter represents a once in a 7500-year opportunity (Farnocchia & Chodas, 2021).
  - Comes within 0.1 lunar distances and is tidally perturbed by Earth, changing the orbit from an Aten to Apollo.
  - The rotation state will likely change.
  - The surface may be disturbed at cm to mm-scales.
- Ground-based observers cannot view Apophis shortly after the Earth encounter.
  - S/C will be the best tool for observing Apophis respond to the close Earth encounter.
- A unique opportunity to understand the volatile content and surface response of stony asteroids.
- Addresses planetary defense, human exploration, and resource extraction "Knowledge Gaps".



Above. The size and proximity of Apophis during 2029 stands out as a rare event. Adapted with permission from Binzel et al. 2020.

OSIRIS-APEX

AN OSIRIS-REx EXTENDED MISSION TO APOPHIS

Thanks!