Sample collection from asteroid 162173 Ryugu by Hayabusa2: implications for surface evolution

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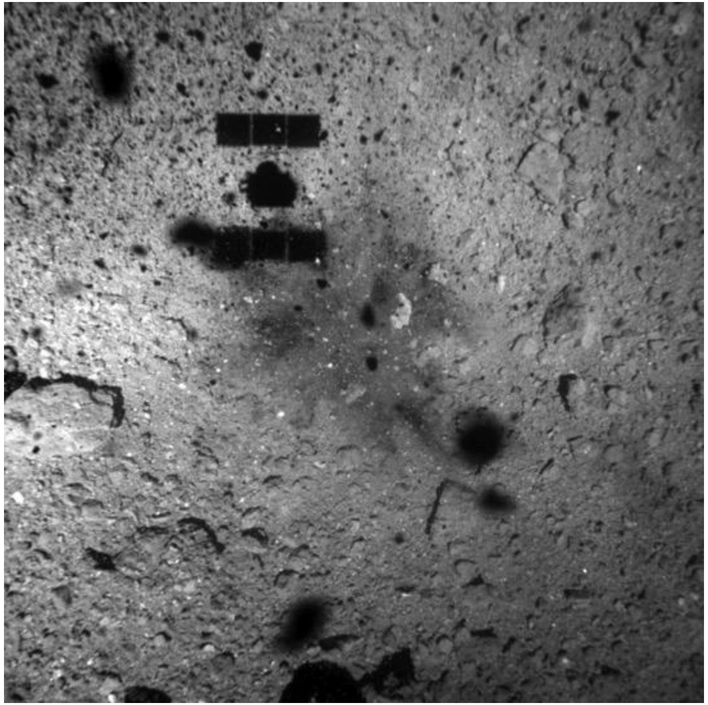
Paper highlights

- The 1st touchdown raised 1m-sized rocks and a lot of reddish-dark particles.
- The reddish-dark particles were created by the alteration of the surface of Ryugu from the heating or space weathering by the Sun.
- Surface alteration occurred during a short period in the past → Ryugu was once on a temporary orbit that approached the Sun.
- Both the altered and unaltered materials are expected to have been collected.



（Image credit：JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST.）

Background & overview

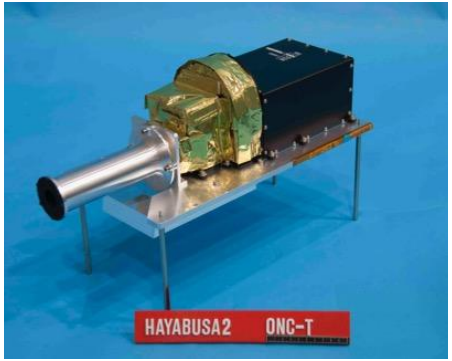
- Previous observations by Hayabusa2 have shown that the surface of asteroid Ryugu is covered mostly with large rocks; no fine particles, similar to those found on the lunar surface, were not seen.
- Hayabusa2 made the first successful landing on a C-type (carbonaceous) asteroid on February 22, 2019 (JST).
- During the landing, the projectile used for sampling and the thruster jets for lifting the spacecraft raised not only rocks, but also a large quantity of reddish-dark particles that coated rock surfaces and cracks.
- The reddish-dark material is globally present on Ryugu and formed during the alteration of the surface material by solar heating or weathering during a short period in the past.→ Ryugu was temporarily on an orbit that approached the Sun.
- Since both reddish-dark and the pre-alteration blue-bright materials were present at the landing site, it is expected that both the altered and unaltered materials have been collected.

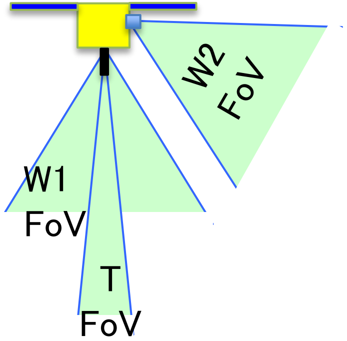
ONC : Equipment overview

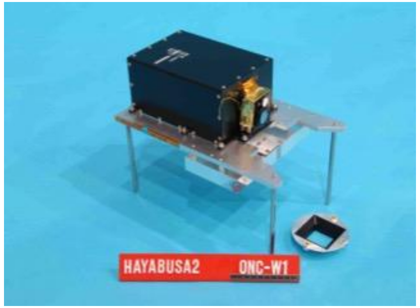
Optical Navigation Camera

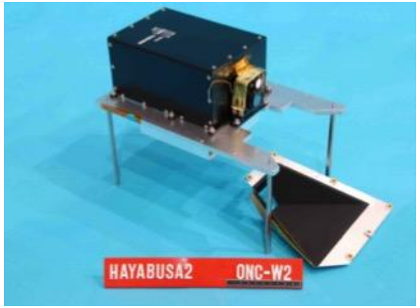
Objective : Image fixed stars and the target asteroid for spacecraft guidance and scientific measurements.

	ONC-T	ONC-W1	ONC-W2
Detector	2D Si-CCD (1024 x 1024 px)		
Viewing direction	Downward (telescopic)	Downward (wide-angle)	Sideward (wide-angle)
Viewing angle	6.35° × 6.35°	65.24° × 65.24°	
Focal length	100m～∞	1m～∞	
Spatial resolution	1m/pix @ 10km alt. 1cm/pix @ 100m alt.	10m/pix @ 10km altitude 1mm/pix @ 1m altitude	
Observation wavelength	multicolor (390, 480, 550, 700, 860, 950, 589.5nm, Wide)	Monochromatic (485nm～655nm)	



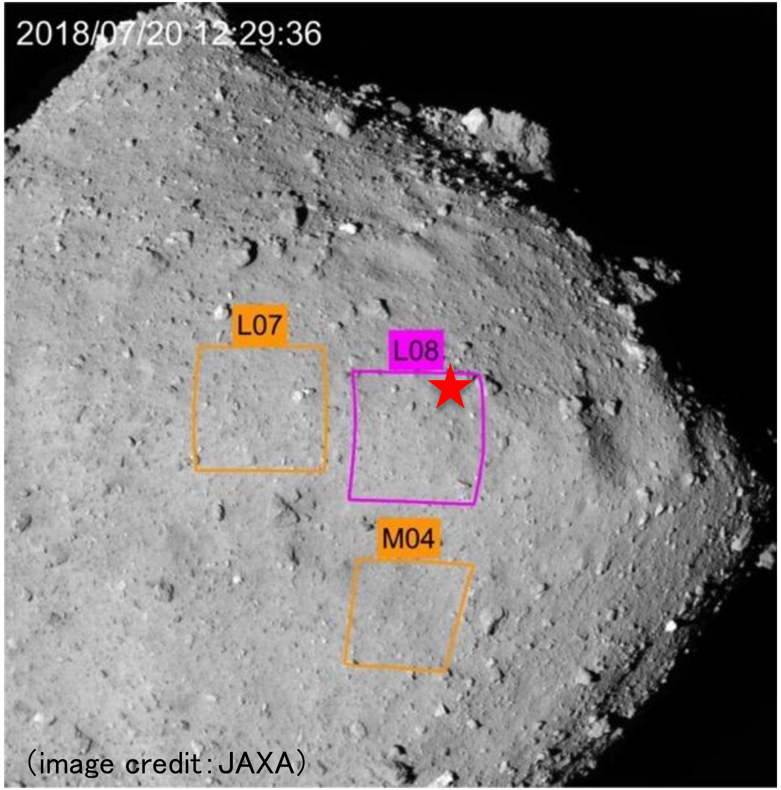




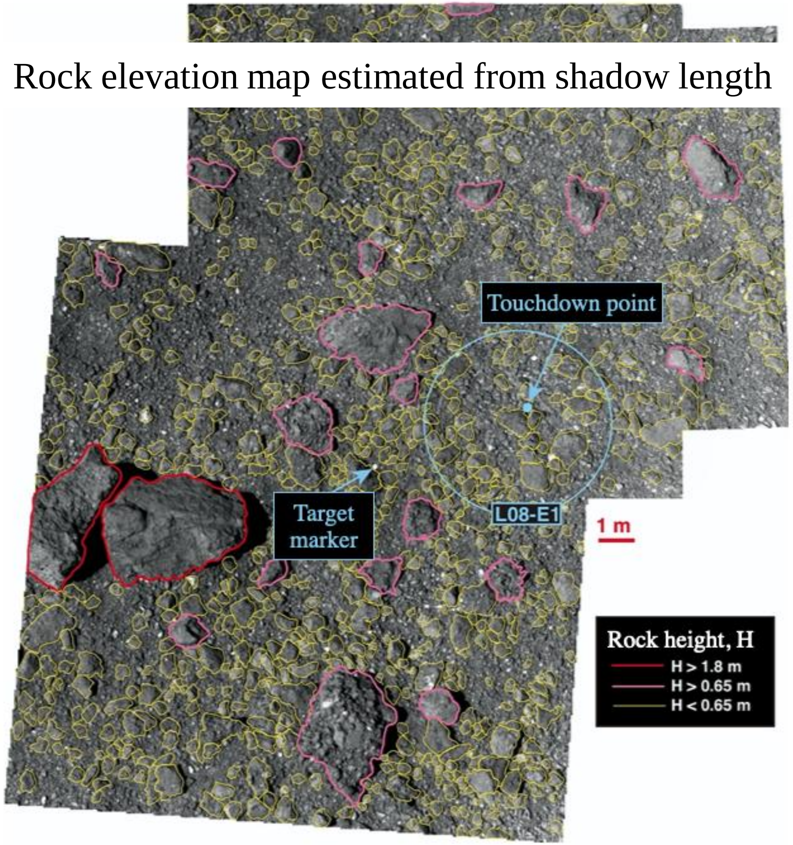


(image credit : JAXA)

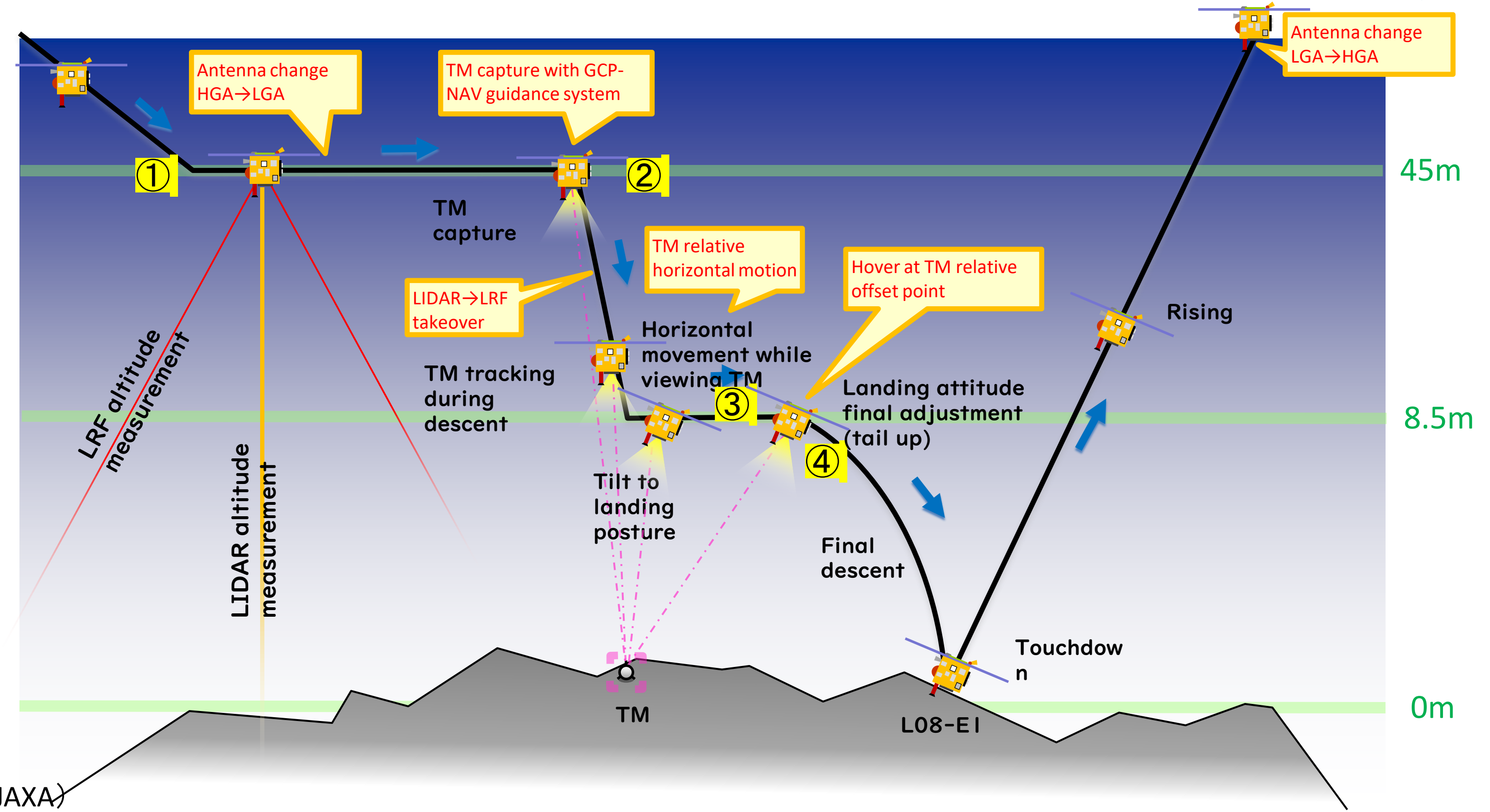
1st touchdown point (L08-E1)



Rock elevation map estimated from shadow length

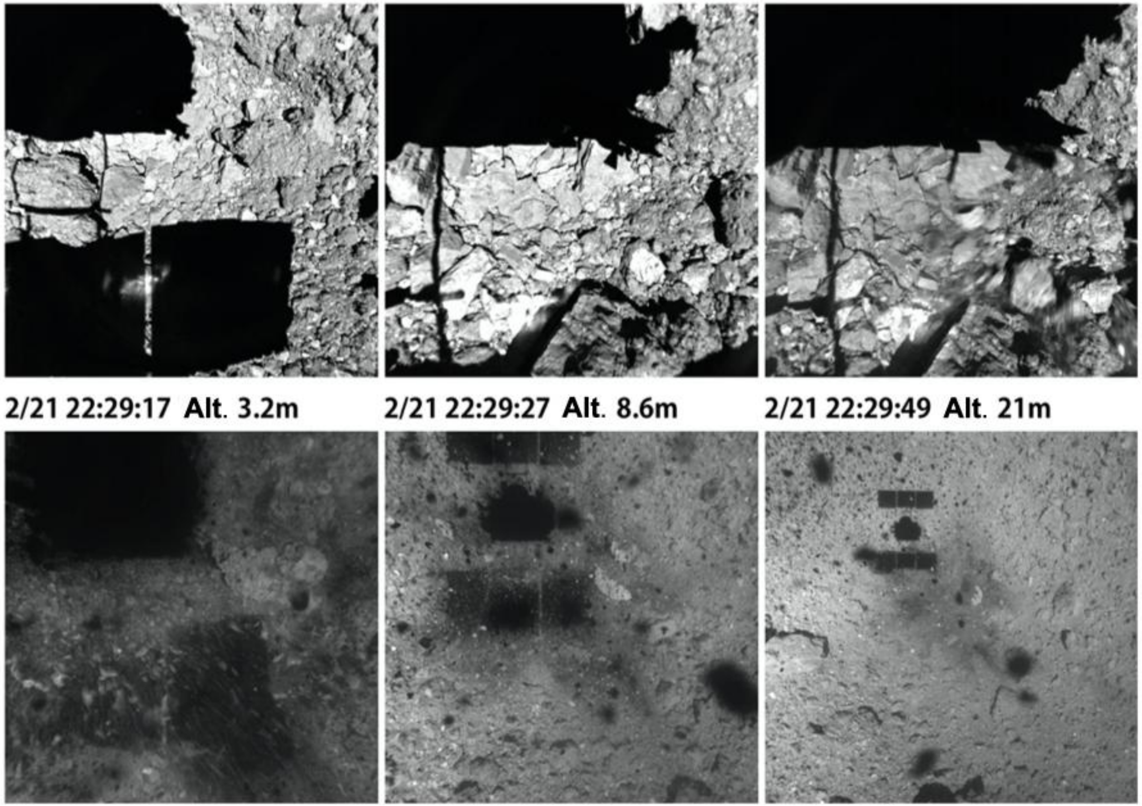


1st touchdown operation overview



（Image credit：JAXA）

1st touchdown state



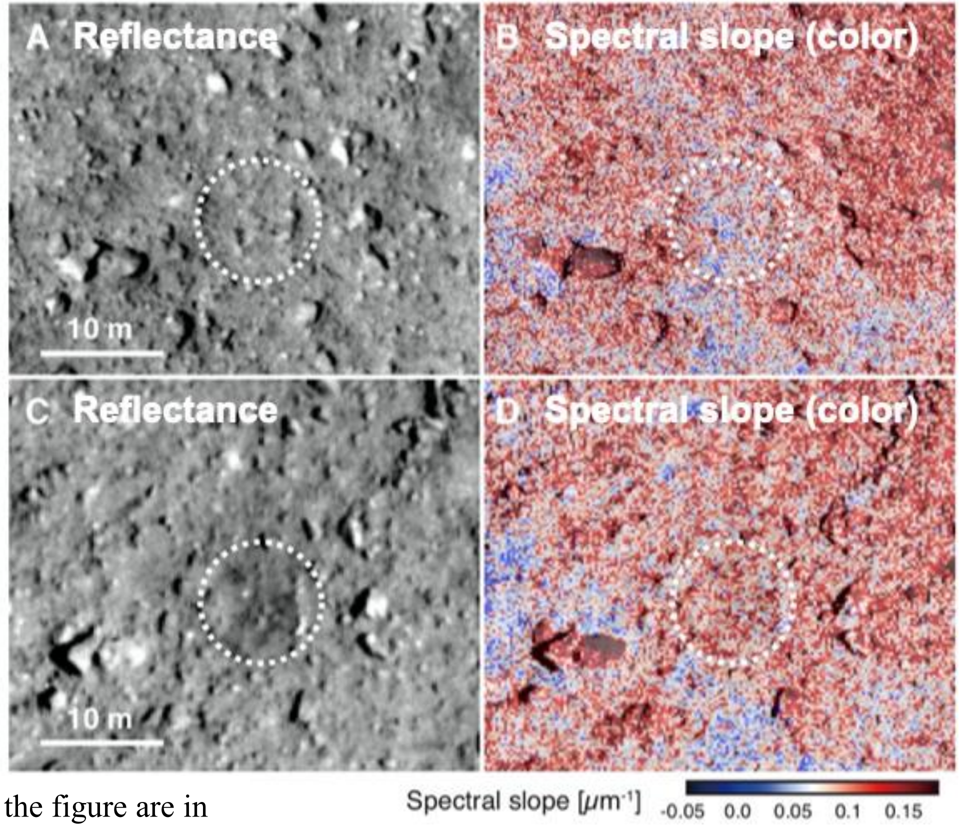
- During touchdown, bullet and thrusters threw up rocks and a large quantity of fine particles.
- The field of view of W1 darkened.
- Most of the rocks blown by the touchdown turned bright → the dark particles had been adhered to the surface and inside pores of the rocks (Ref. 5).
- The raised particles spread over a range of about 10m, centered on the touchdown point, and were deposited on the surface.
- The total mass of the lifted materials is over 12 kg.

Dates and times on the figure are in Coordinated Universal Time (UTC)

Color change before and after touchdown

Before touchdown (2018/10/2)

After touchdown (2019/4/4)



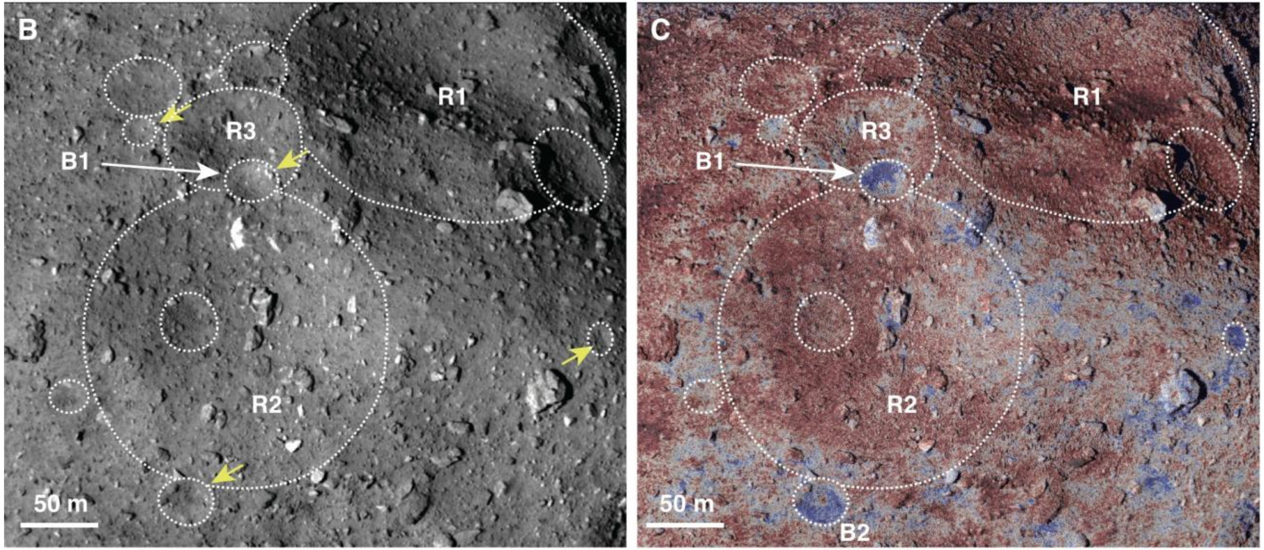
- After touchdown, fine particles were deposited over an area with diameter 10m.
- The area around the touchdown point changed to reddish-dark compared to prior to touchdown.
- The fine particles were the reddish-dark material.

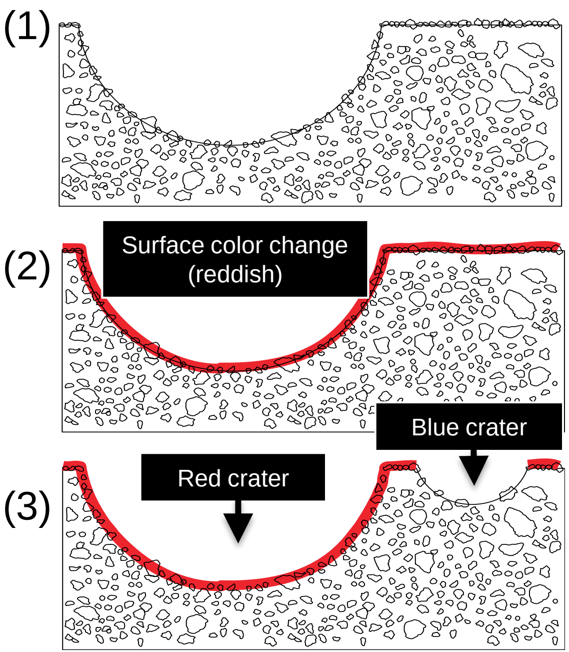
Figure is partially modified from Morota et al. (2020).

Dates and times on the figure are in Coordinated Universal Time (UTC)

Global color distribution：relation with craters

Figure is partially modified from Morota et al. (2020).





- The lower (older) craters tend to be red, while the upper (younger) craters tend to be blue.
- Red crater: A crater formed before the surface reddened.
- Blue crater: A crater formed after the surface reddened.
- Latitude dependence of the red-blue distribution (ref.1) → surface reddening caused by heating or weathering by the Sun.
- Bimodal distribution of red and blue craters (ref.2) → surface reddening occurred over a short period of time (ref.3).

Ryugu evolution history

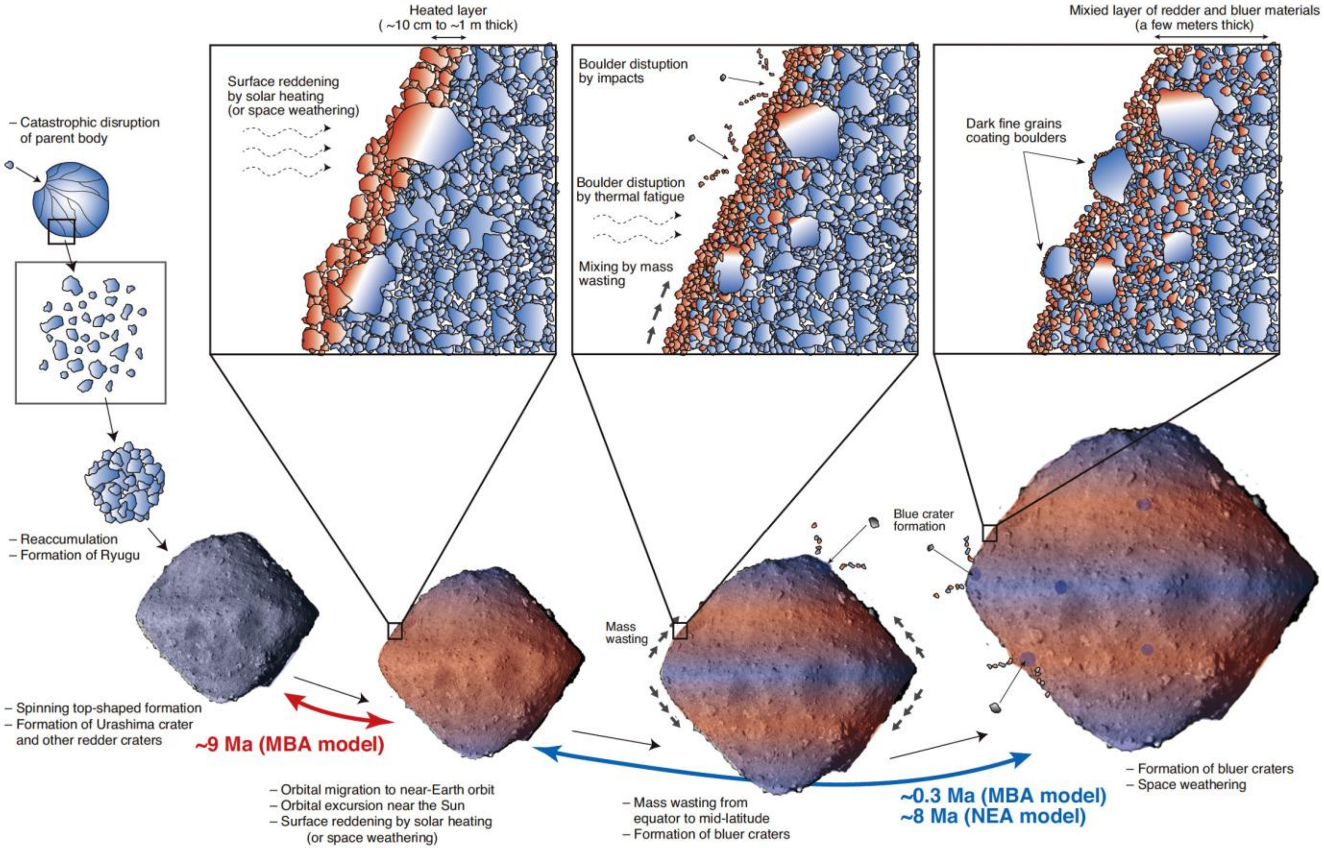


Figure from Morota et al (2020).

Summary

- A new scenario was presented for the orbital evolution and accompanying surface geological evolution for a carbonaceous asteroid transported from the asteroid belt currently in an orbit near the Earth.

  Ryugu was in an orbit closer to the Sun that present some time between 0.3 – 8 million years ago, and has undergone alteration due to the solar heating or weathering.

- It is expected that both altered and unaltered materials have been collected, as the surface of the landing landing site showed both reddish-dark material and also white material that had no been altered (ref.4).

→Detailed laboratory analyses of the retuned Ryugu's sample are expected to elucidate the alteration processes of carbonaceous material by the solar heating and weathering that occur while supplying these materials into the orbit of the Earth.

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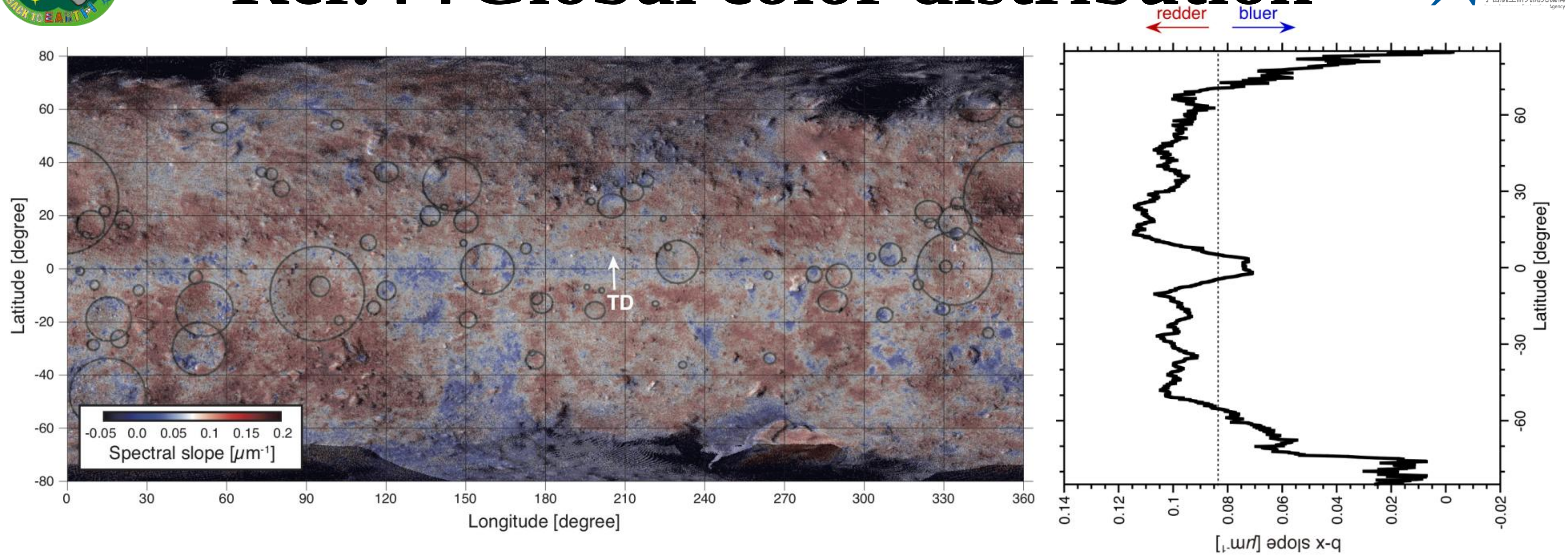
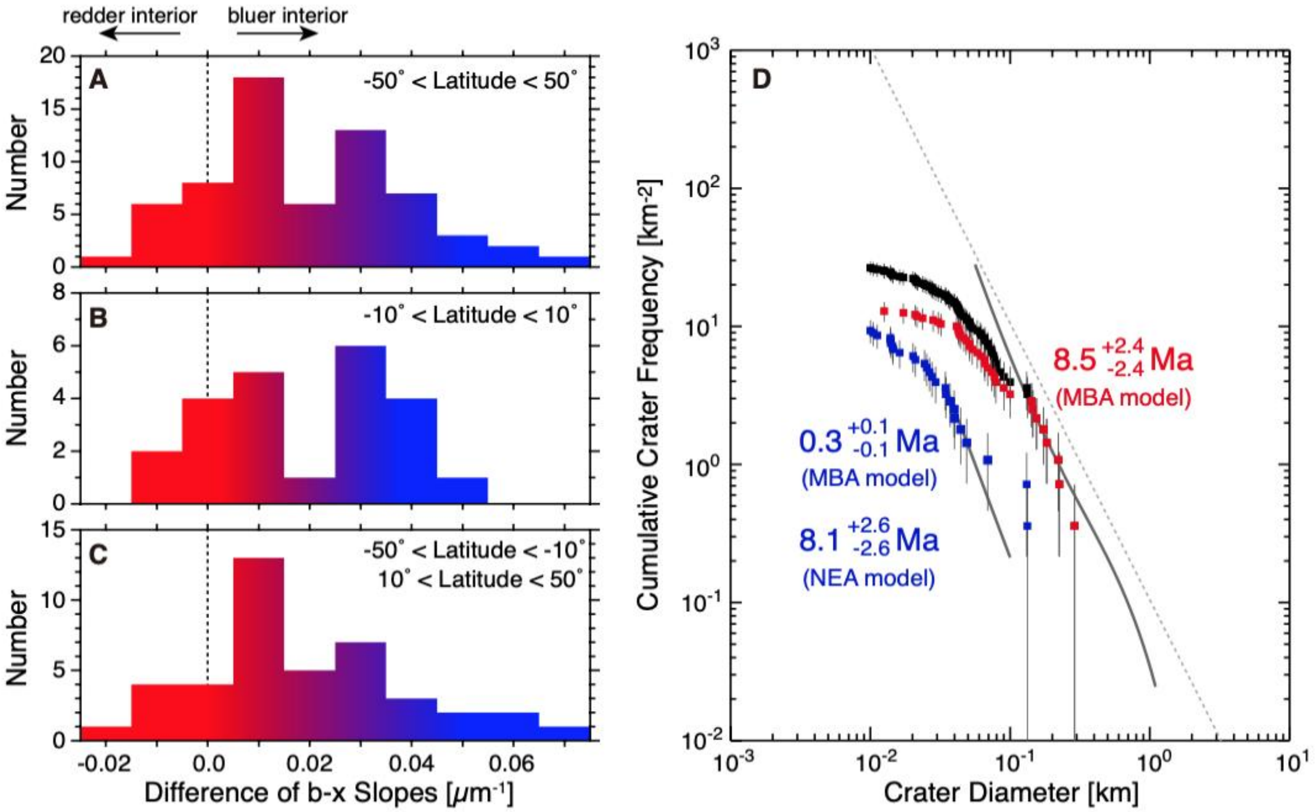
Ref.１：Global color distribution



Morota et al. (2020)

- The surface of Ryugu shows a mixture of reddish-dark material and blue-bright material. The equator is slightly blue-bright, while the mid-latitudes are reddish-dark and the poles are blue-bright [Sugita et al. Science 2019].

Ref. 2: Crater color distribution and age estimation



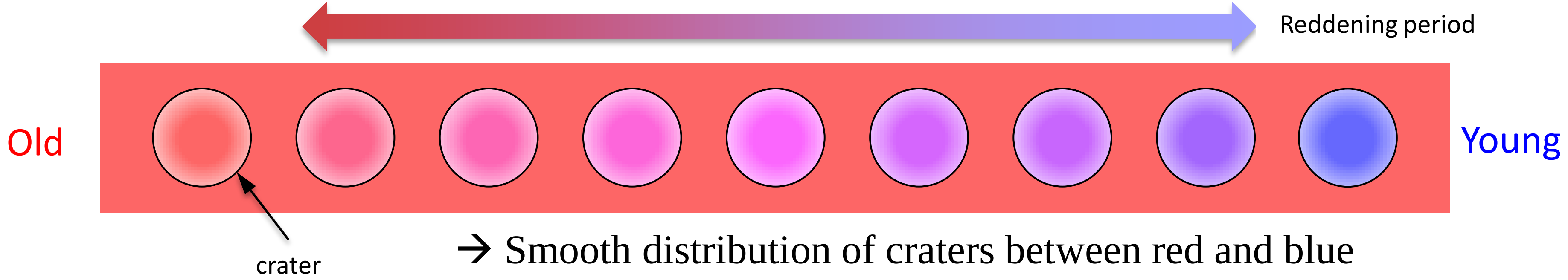
- ➢ Bimodal distribution of red and blue craters. Few of intermediate color.
- ➢ Reddening over a short time → suggests a past temporary approach to he Sun.

- ➢ From the size frequency of red craters, the time from formation of Ryugu to the surface reddening is about 9 million years.
- ➢ From the size frequency of blue craters, the time of surface reddening is 0.3 – 8 million years ago.

Figure from Morota et al (2020).

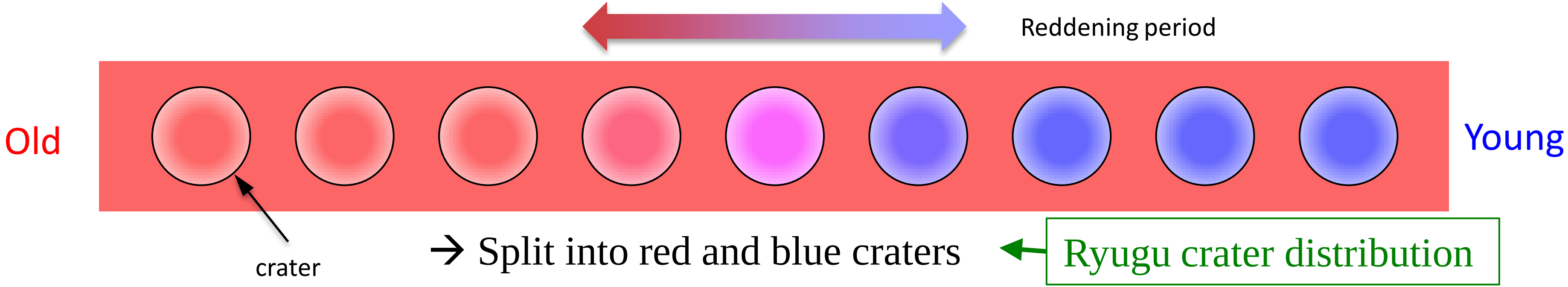
Ref.3：Surface reddening rate and crater color distribution

(a) When surface reddening occurs slowly over a long period of time



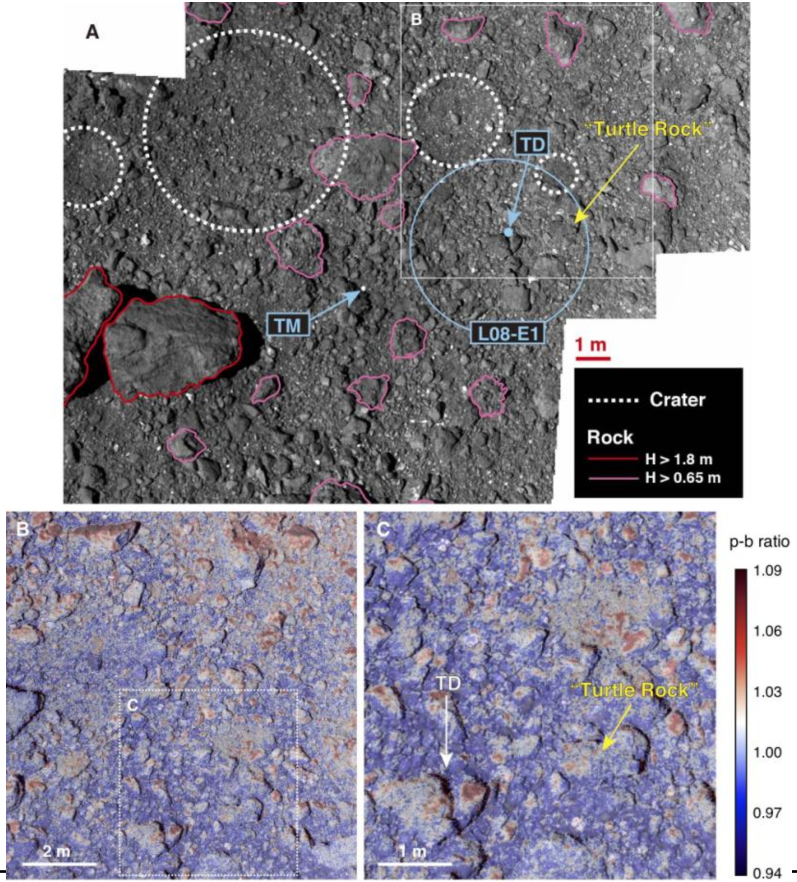
→ Smooth distribution of craters between red and blue

(b) When surface reddening occurs rapidly over a short period of time



→ Split into red and blue craters ← Ryugu crater distribution

Ref.4: Color distribution near the landing site

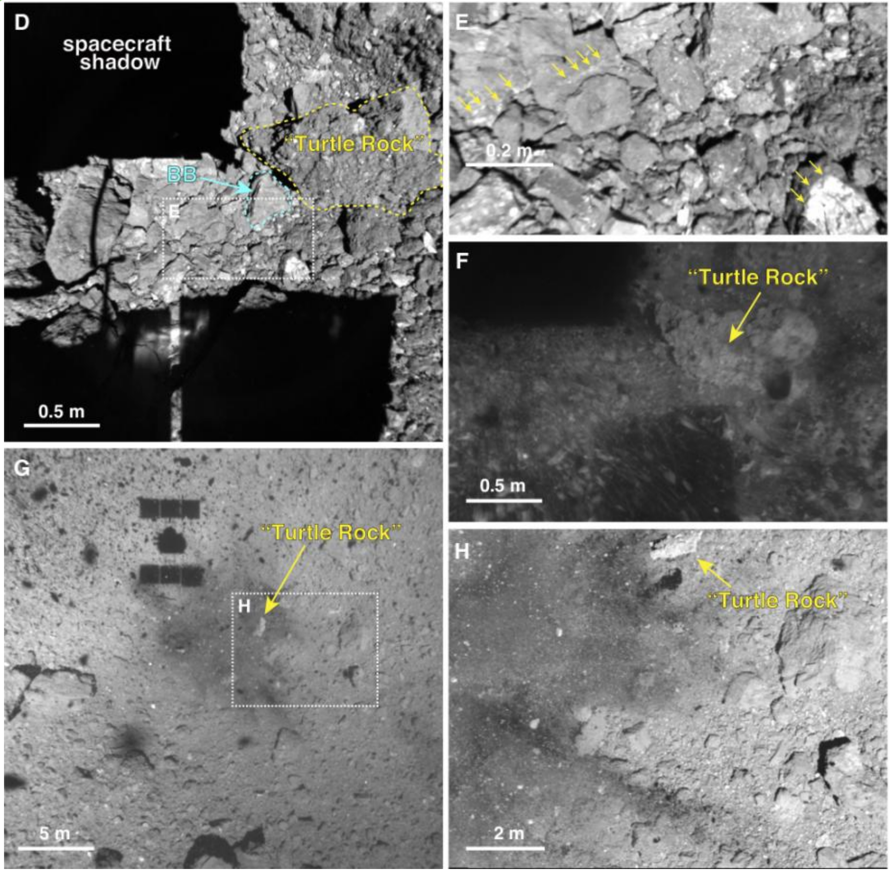


Slope of the reflectance spectrum near the 1st touchdown point

- Both red and blue materials are present near the 1st touchdown point.
- It is expected that both Sun-altered and non-Sun-altered materials have been collected.

Morota et al. (2020)

Ref.5：Rock color change and fine particle diffusion



- Fresh surfaces such as rock corners or fractured surfaces are bright (image E).
- The boulder "Turtle Rock" was originally darker than its surroundings (image D), but turned bright during touchdown as it was blown by the thruster jets (images F, G, H).

→ Reddish-dark particles adhered to the rock surface.

- The particles diffused radially across the surface (images G, H).

(D) Image just before touchdown with the ONC-W1 image (2/21 22:28:59).
(E) Enlarged image of the white dotted region in image D.
(F), (G) Images immediately after touchdown with ONC-W1 (2/21 22:29:17, 22:29:57, 47 seconds after touchdown respectively).
(H) ONC-T image taken 76 seconds after touchdown (2/21 22:31:56) .

Ref.6：Fine particles attached to ONC-W1

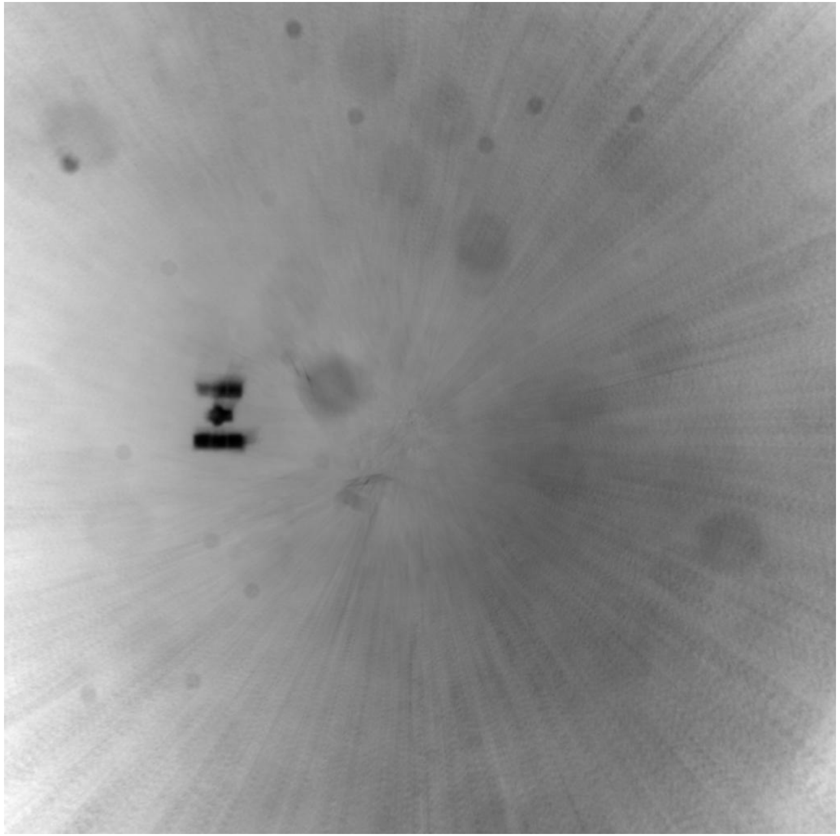


Image created by averaging each pixel value over the 31 ONC-W1 images acquired during the decent operation conducted on 2019/3/6-8.

- Fine particles adhered to the lens and CCD.
- Dust size attached to the lens ～0.3 mm。
- The deposits on the CCD may be from dust originally inside the camera.

Morota et al. (2020)