

SUMMARY OF RESULTS OF THE LUNOKHOD 1/2 AND YUTU ROVER MISSIONS

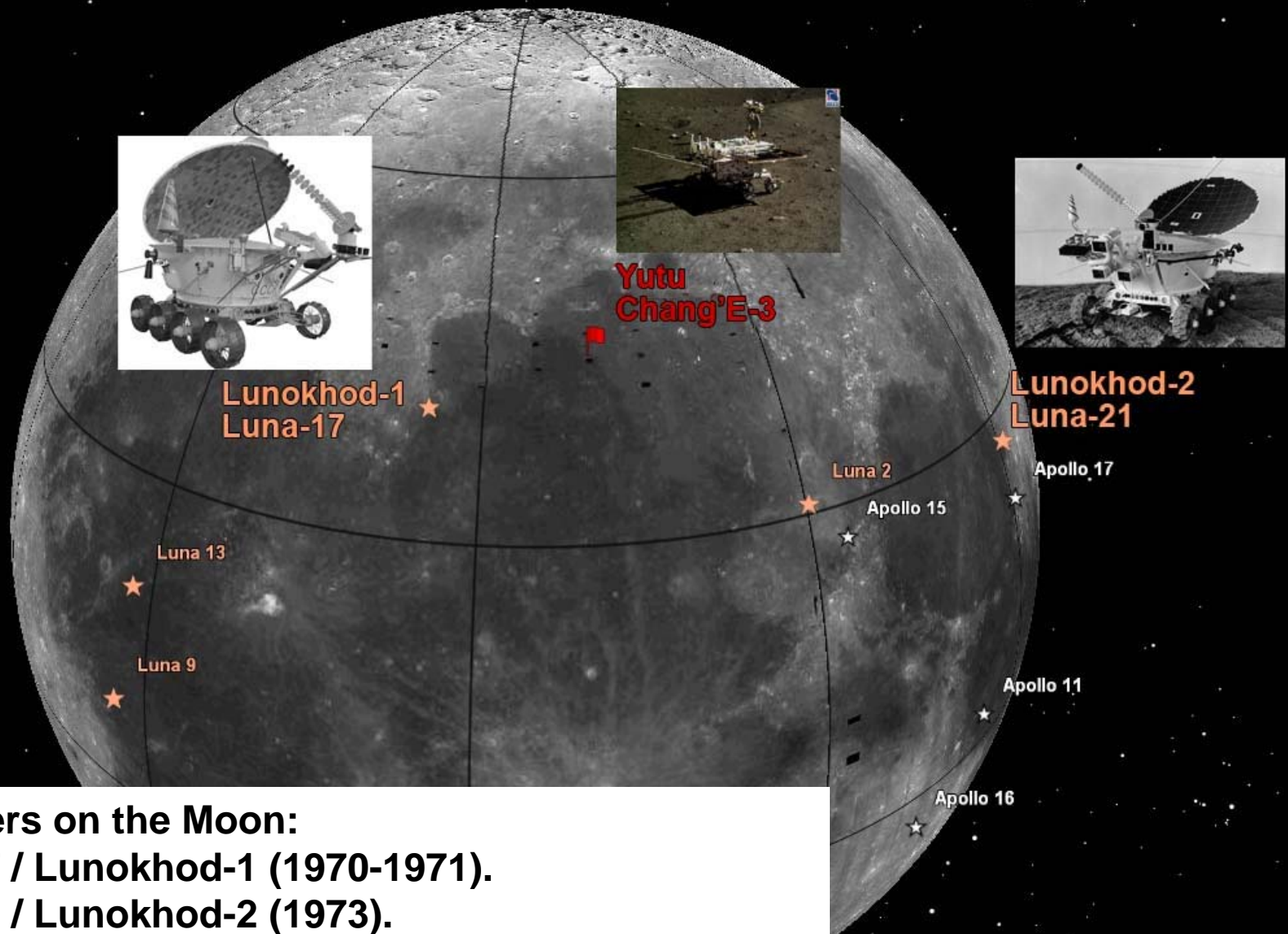
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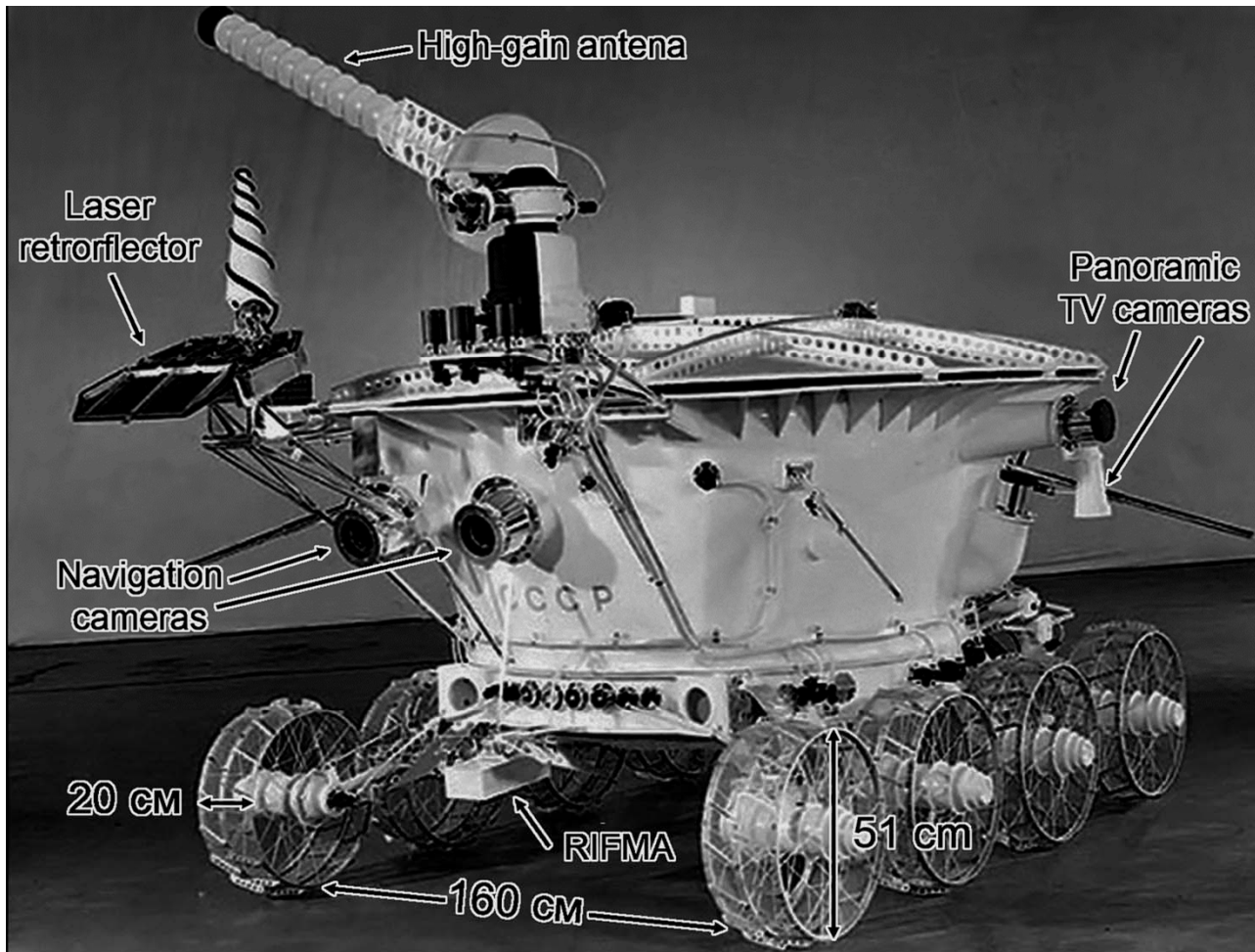
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Three rovers on the Moon:

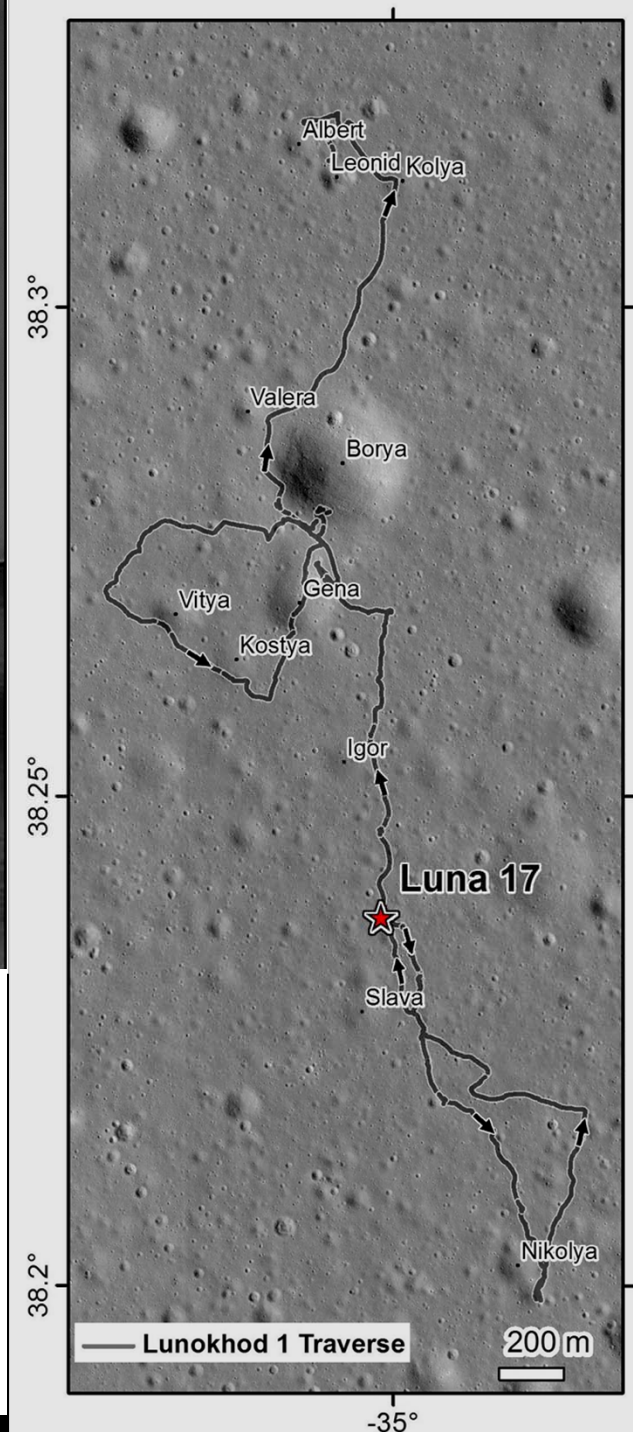
- 1) Luna-17 / Lunokhod-1 (1970-1971).
- 2) Luna-21 / Lunokhod-2 (1973).
- 3) Chang'e / Yutu (2013-2014).

Far from the manned/automatic mission landing sites.
Provide valuable data on the surface characteristics.



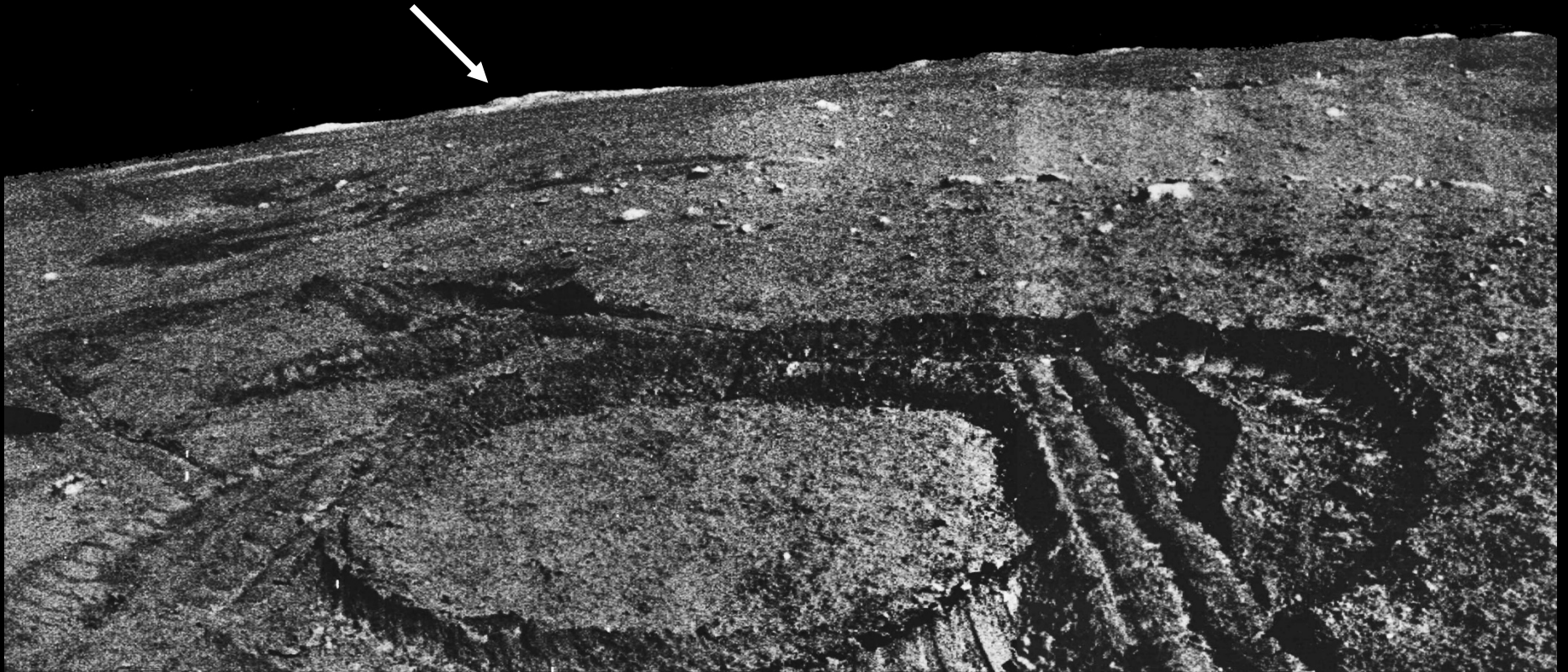
Lunokhod-1:

- A 760-kg, 8-wheel rover.
- 4 panoramic cameras,
- A penetrometer (mechanical properties of regolith).
- A X-ray fluorescence spectrometer (chemical composition of regolith).
- Total travel distance: ~9 km.



The Lunokhod-1 study area

Highlands on the horizon



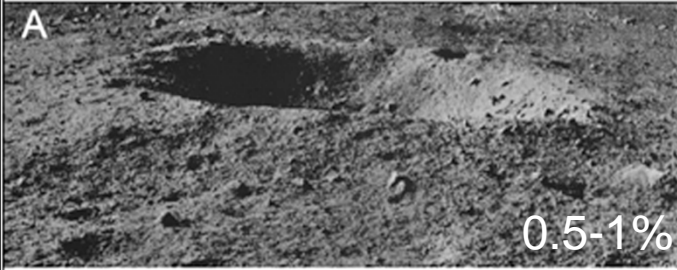
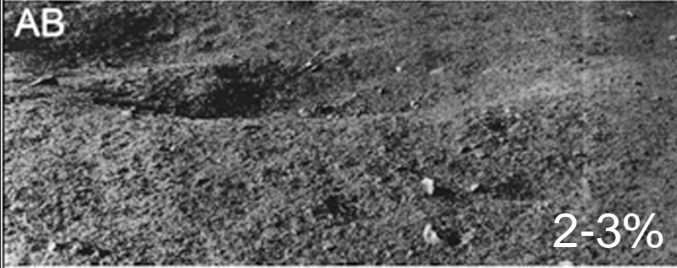
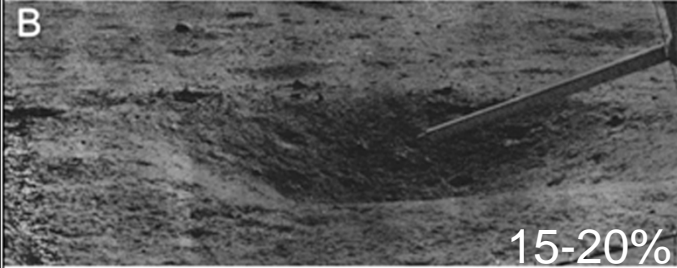
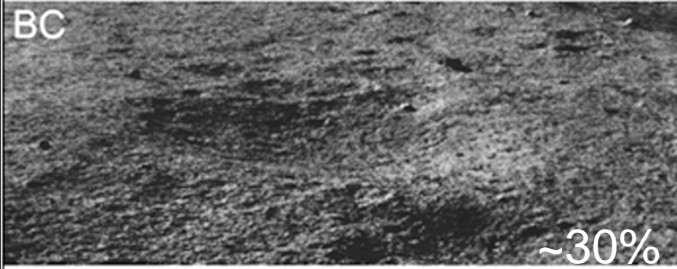
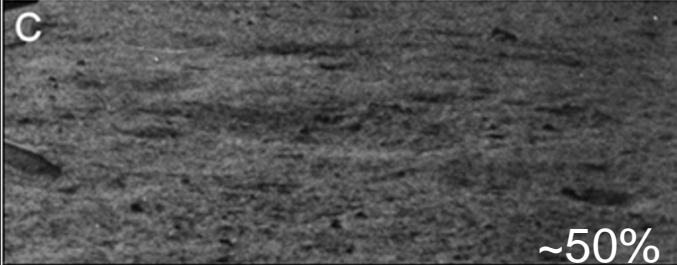
Mare surface

Regolith: a mixture of small rocks and fines.

Highly cohesive material (deep, steep-sided wheel tracks).

Abundant rock fragments on the surface.

Small craters at different state of degradation.

Image	H/D and maximum slope
 <p>A</p> <p>0.5-1%</p>	<p>1/3 - 1/5 35 - 45°</p>
 <p>AB</p> <p>2-3%</p>	<p>1/5 - 1/7 25 - 35°</p>
 <p>B</p> <p>15-20%</p>	<p>1/7 - 1/10 15 - 25°</p>
 <p>BC</p> <p>~30%</p>	<p>1/10 - 1/12 10 - 15°</p>
 <p>C</p> <p>~50%</p>	<p><1/10 <10°</p>

Crater degradation

Craters smaller than ~150 m: lifetime, T , is estimated to be $T=2.5 D$, T - m.y., D - meters.

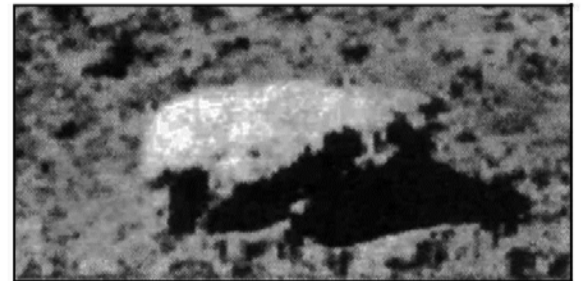
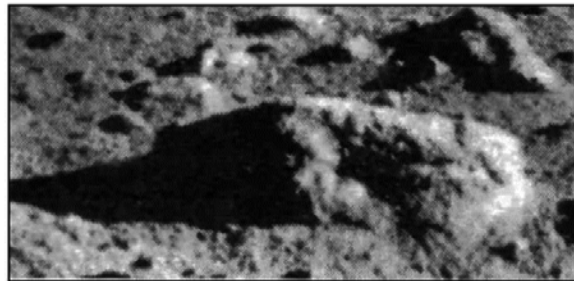
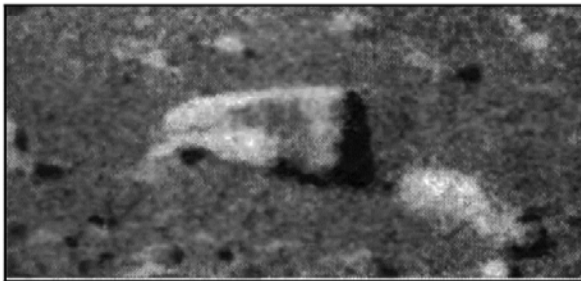
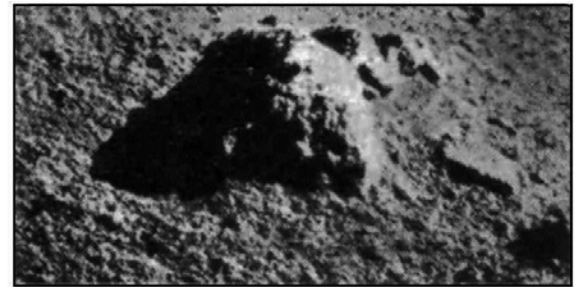
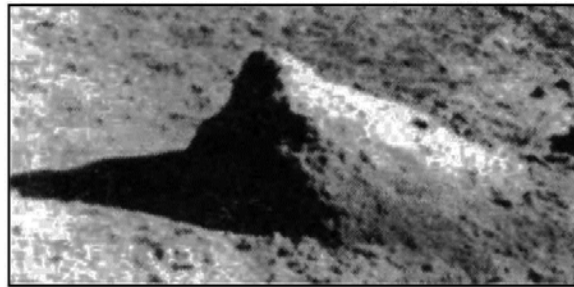
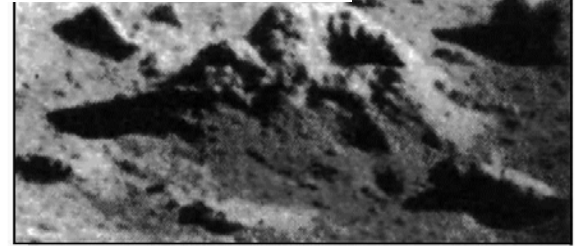
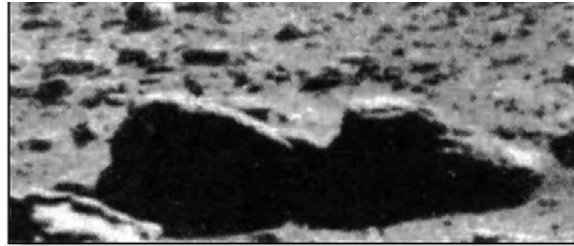
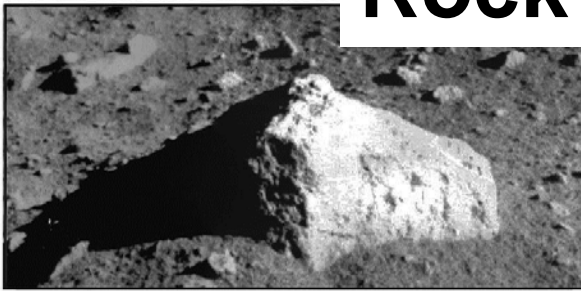
Craters larger than ~150 m: lifetime, T , is estimated to be $T=8D-900(\text{Ma})$ (Basilevsky, 1976).

Most of the craters in the Lunokhod-1 site are 5-10 m in diameter. They are likely not older than 12-25 Ma.

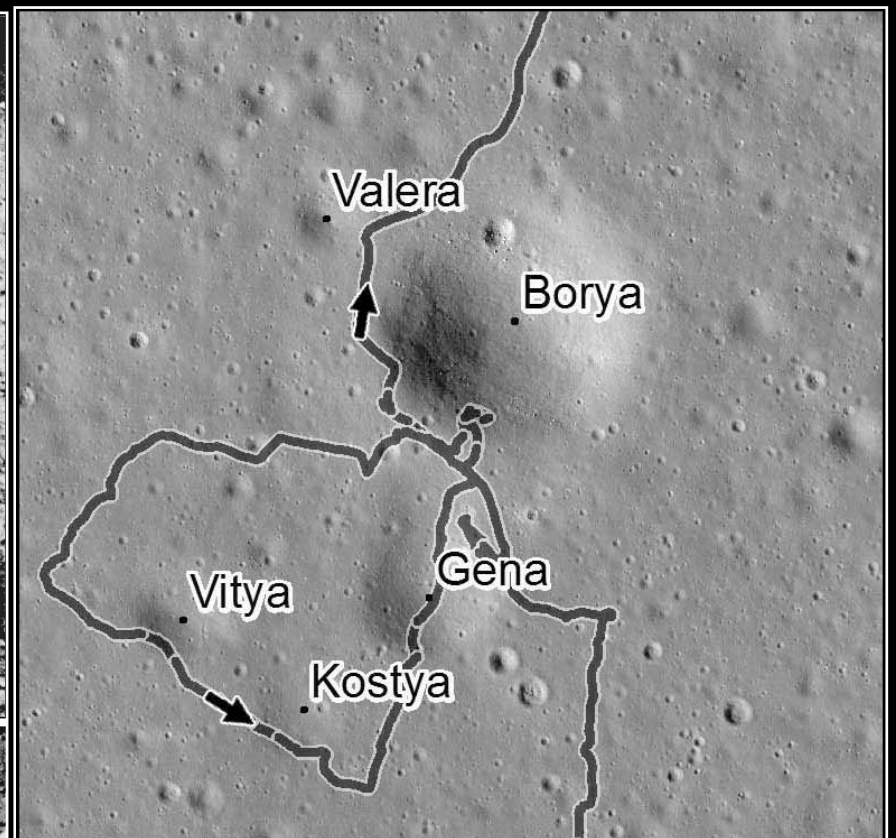
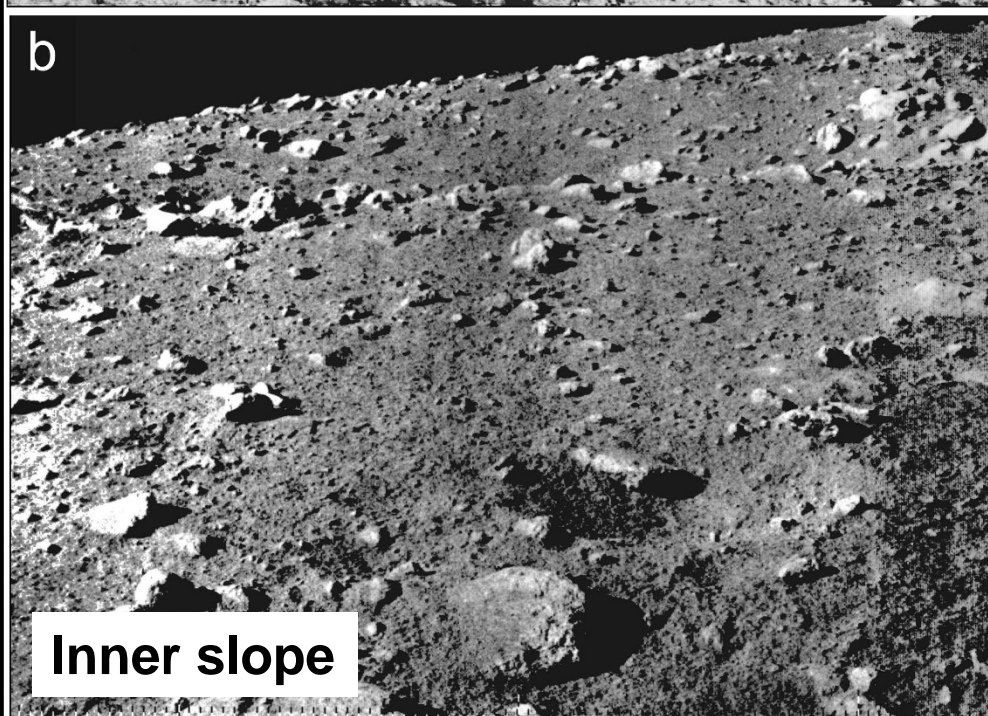
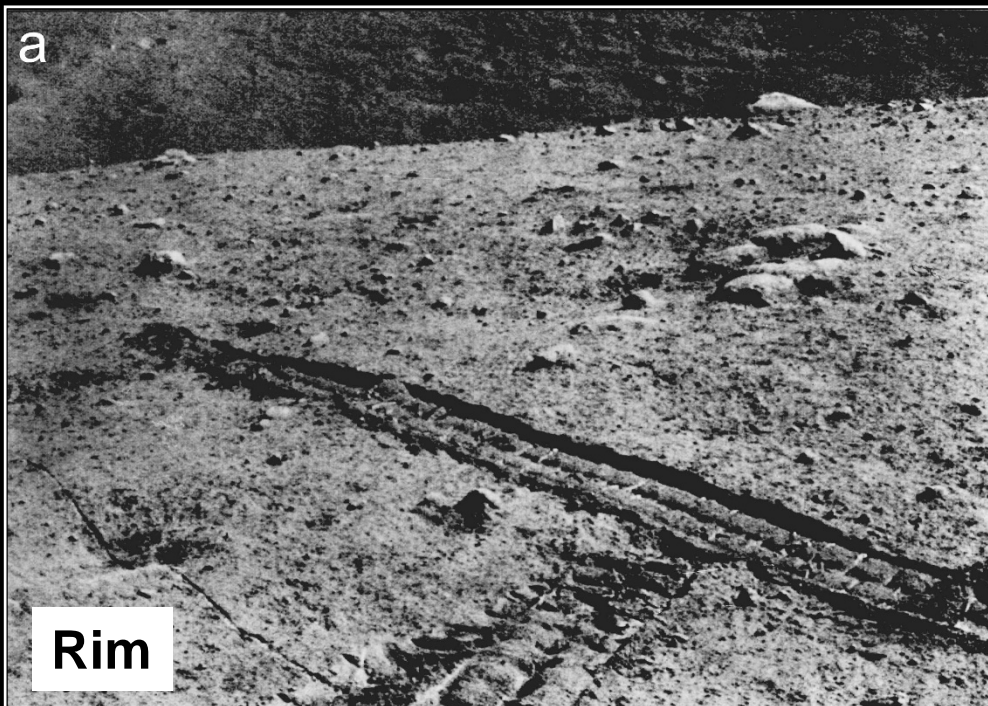
Crater Borya, the largest in the Lunokhod-1 area ($D = 470$ m), is ~400-600 Ma old.

Rock shape and degradation

more irregular
↓
more flat



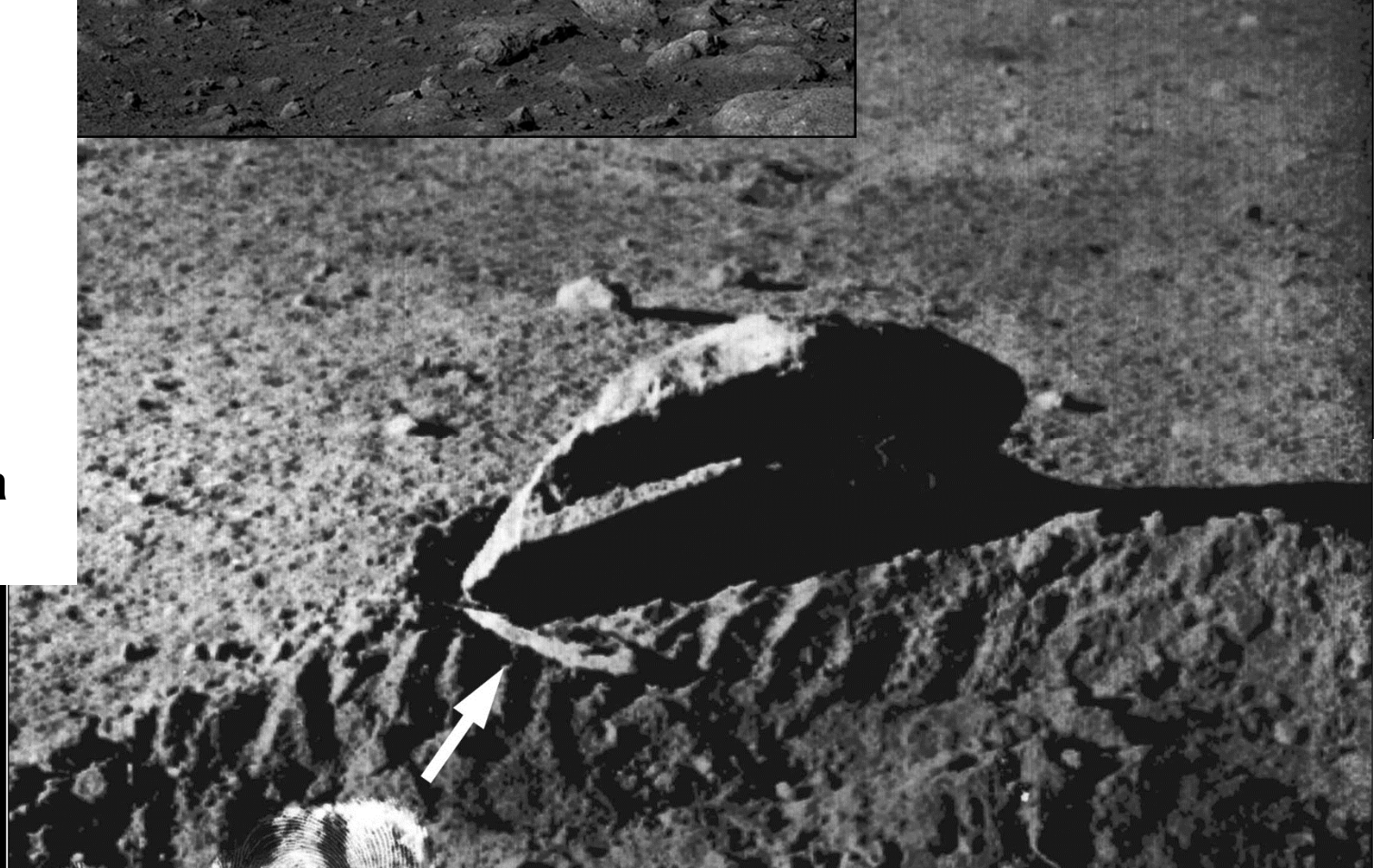
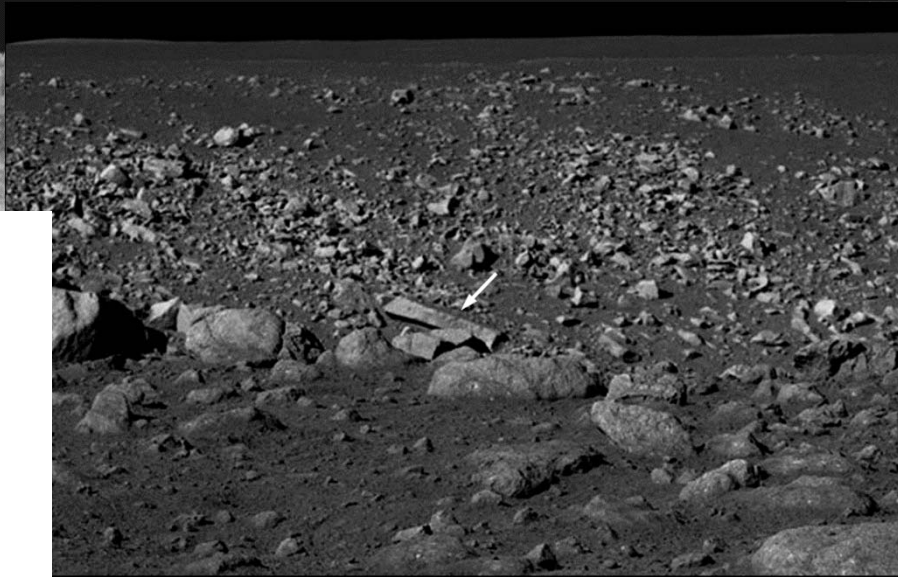
more angular → more rounded

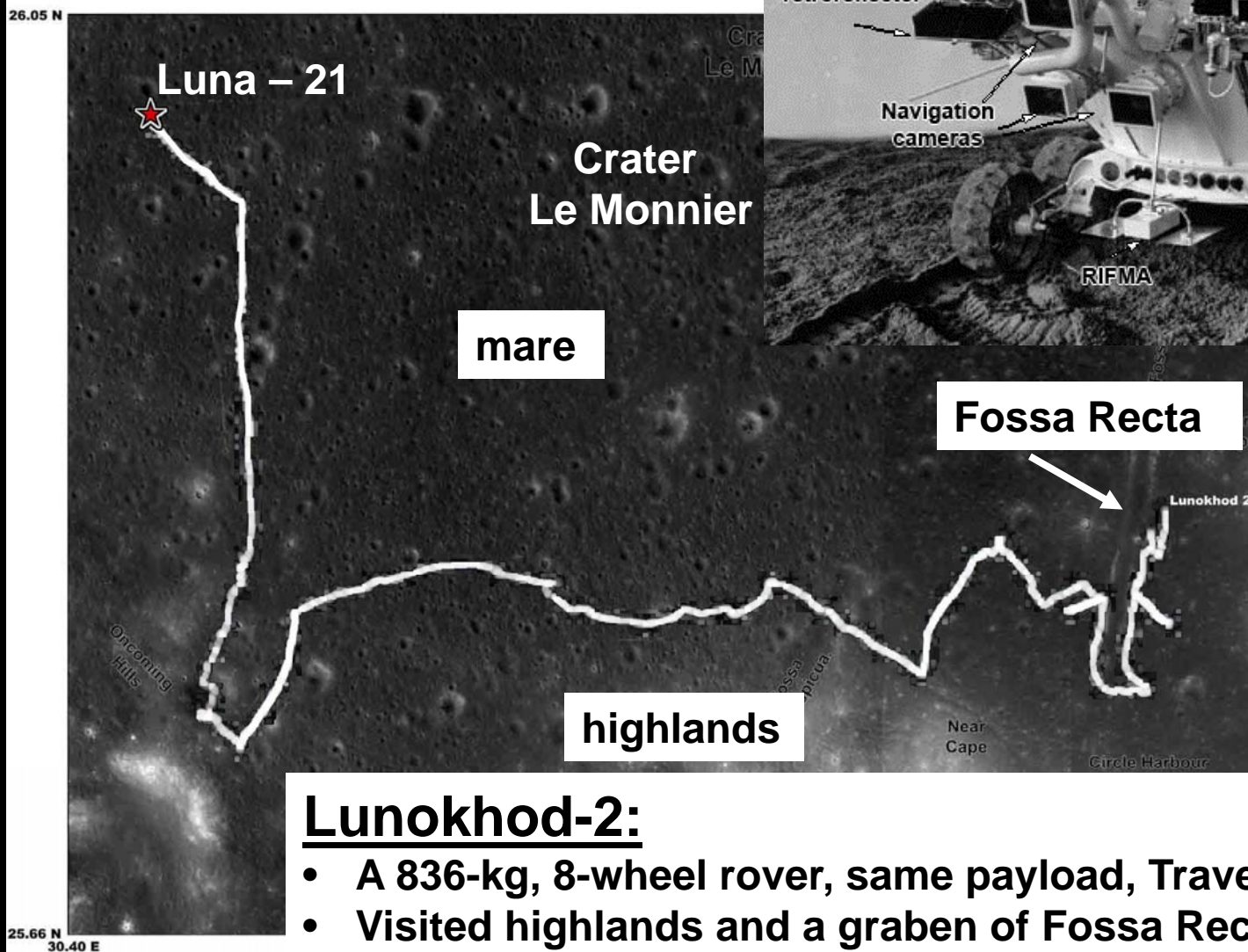
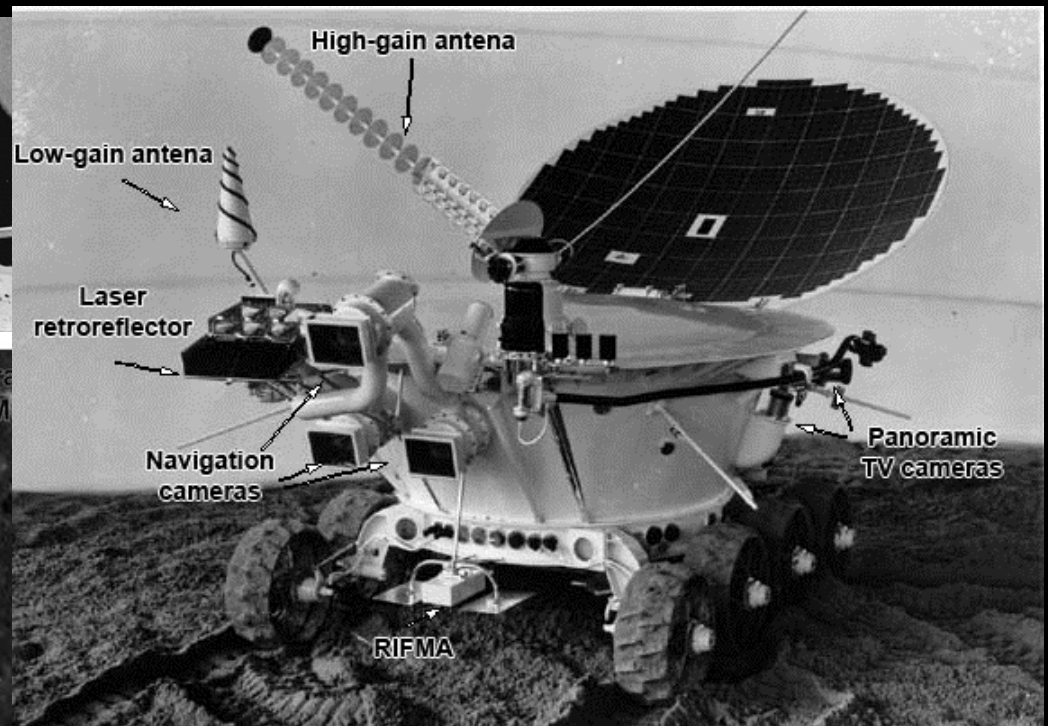
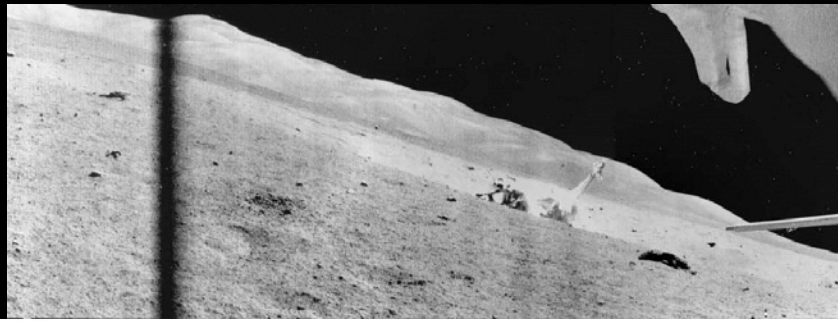


Rock fragments on the rim and inner slope of the crater Borya ($D = 470$ m, ~400-600 m.y. old):
 rim: rare, rounded
 slope: abundant, angular.

**Angular
rock
fragments
on the rim
of crater
Borya.**

**Possible
columnar
jointing:
typical of
basaltic lava
flows.**





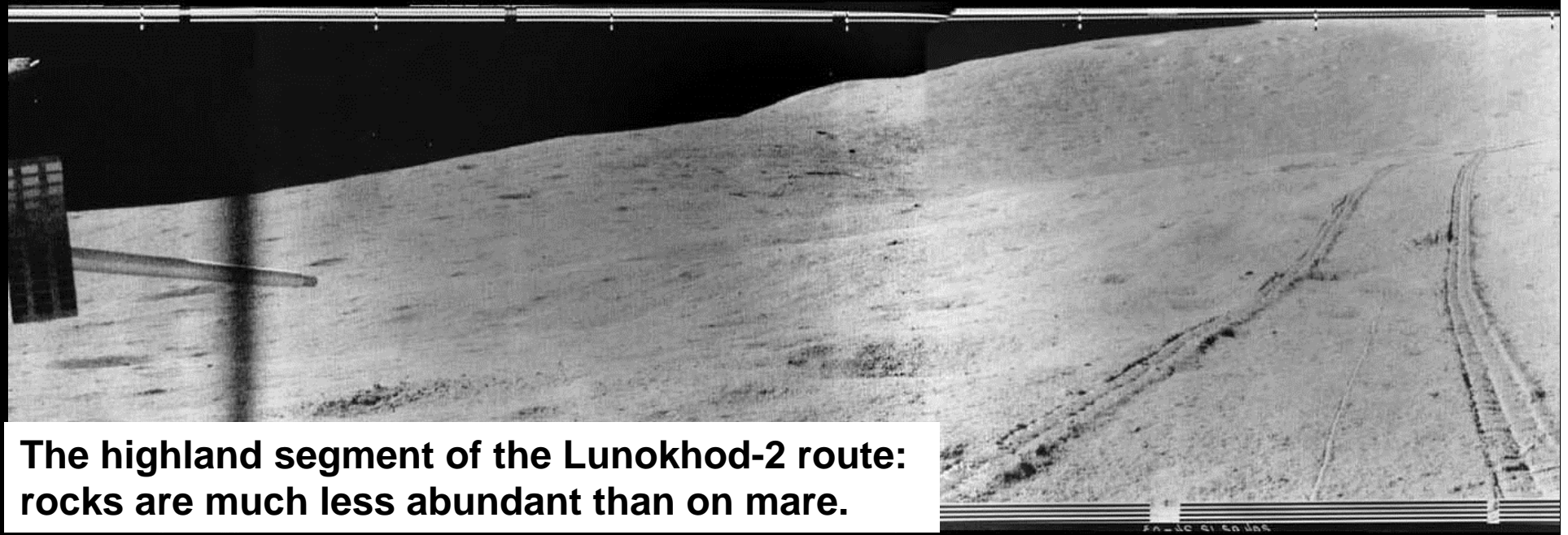
Lunokhod-2:

- A 836-kg, 8-wheel rover, same payload, Travel distance: ~39 km.
- Visited highlands and a graben of Fossa Recta.

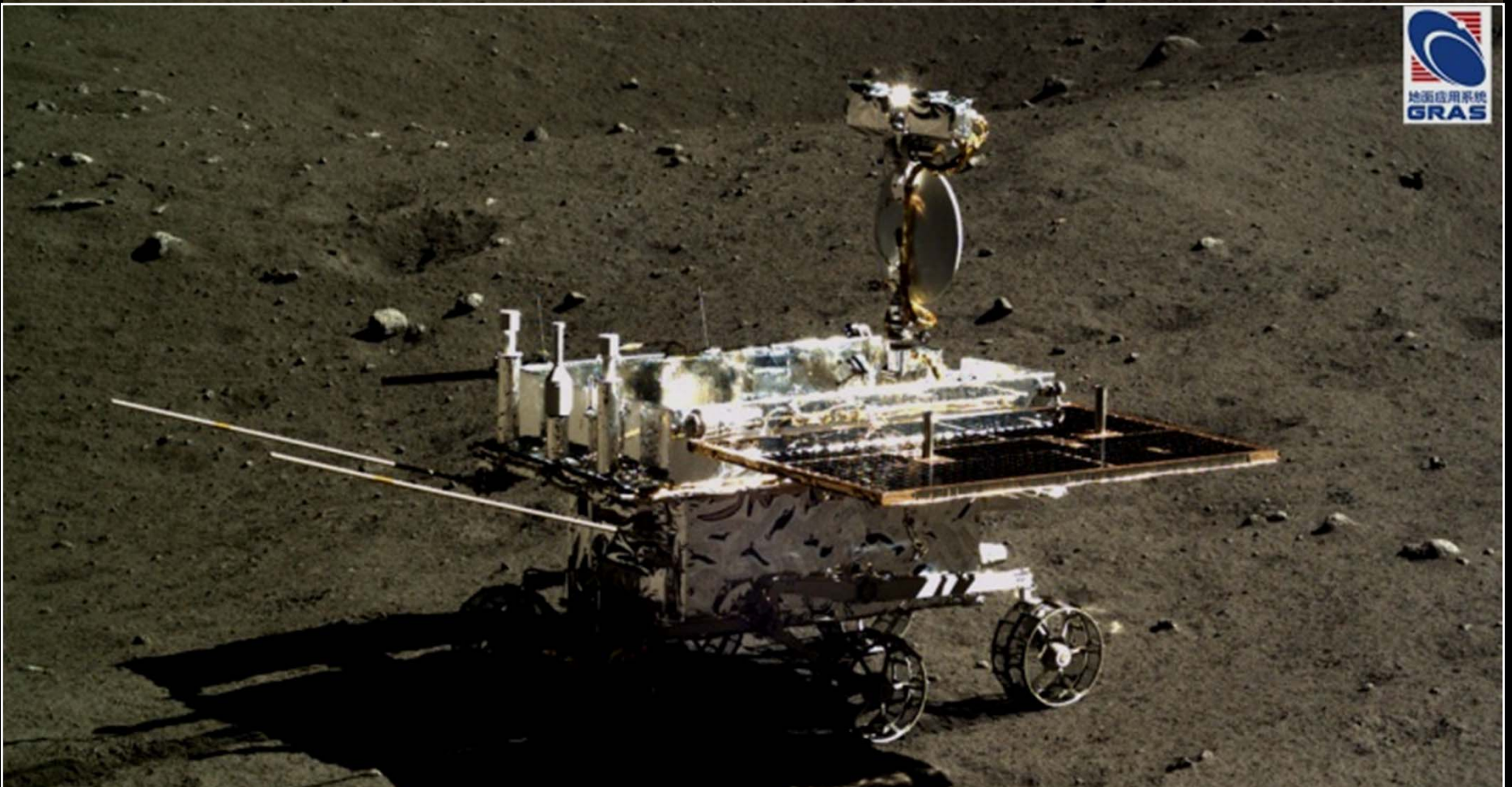
The Lunokhod-2 study area



Small crater with landslide



The highland segment of the Lunokhod-2 route:
rocks are much less abundant than on mare.



Yutu:

- A 140-kg, 6-wheel rover.
- 2 TV stereo cameras,
- A ground penetrating radar (structure of regolith).
- IR spectrometer.
- Alpha-particle X-ray spectrometer.
- Travel distance: ~114 m.

a LRO NAC image M114258277

The Yutu study area

Crater C1

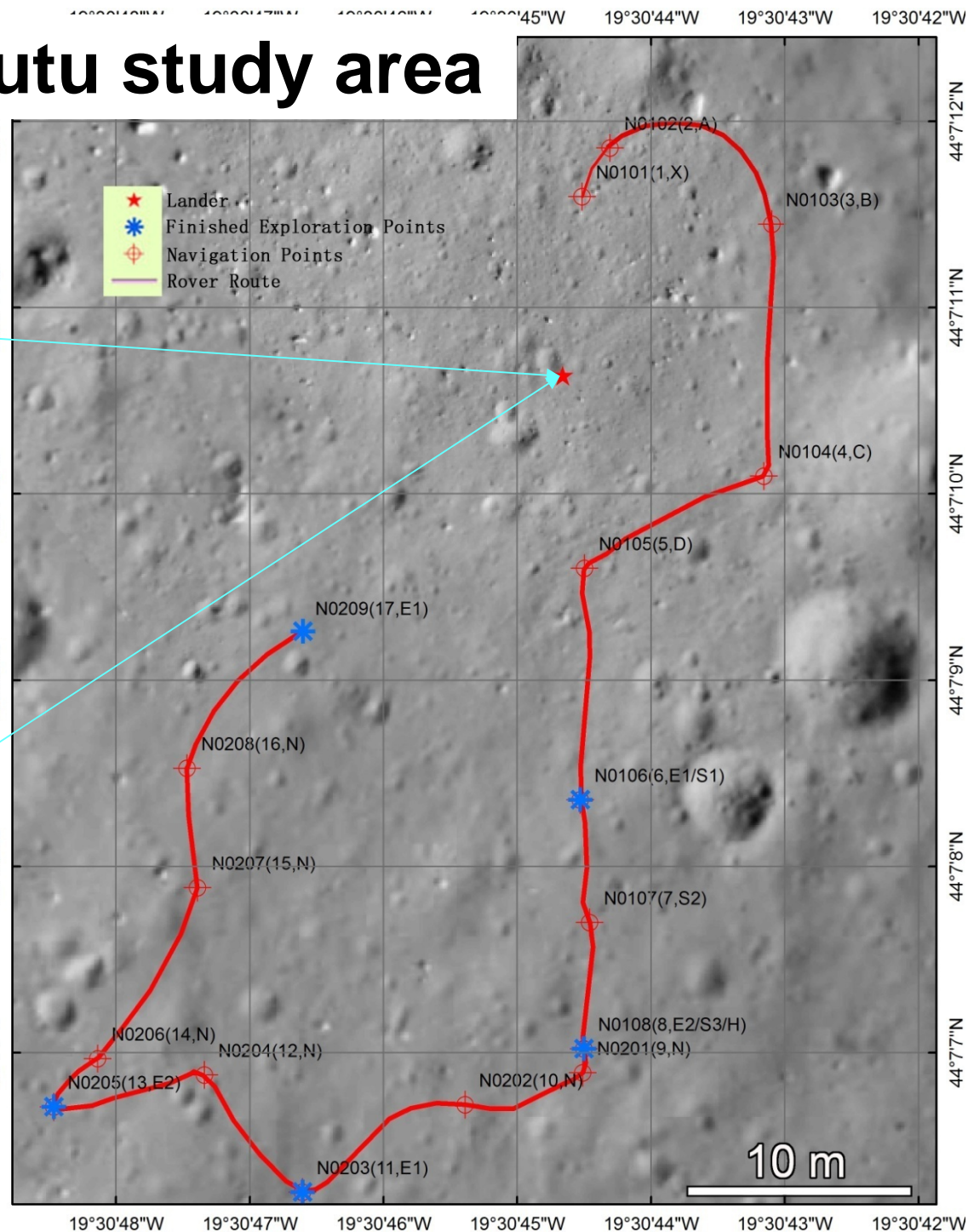
200 m

b

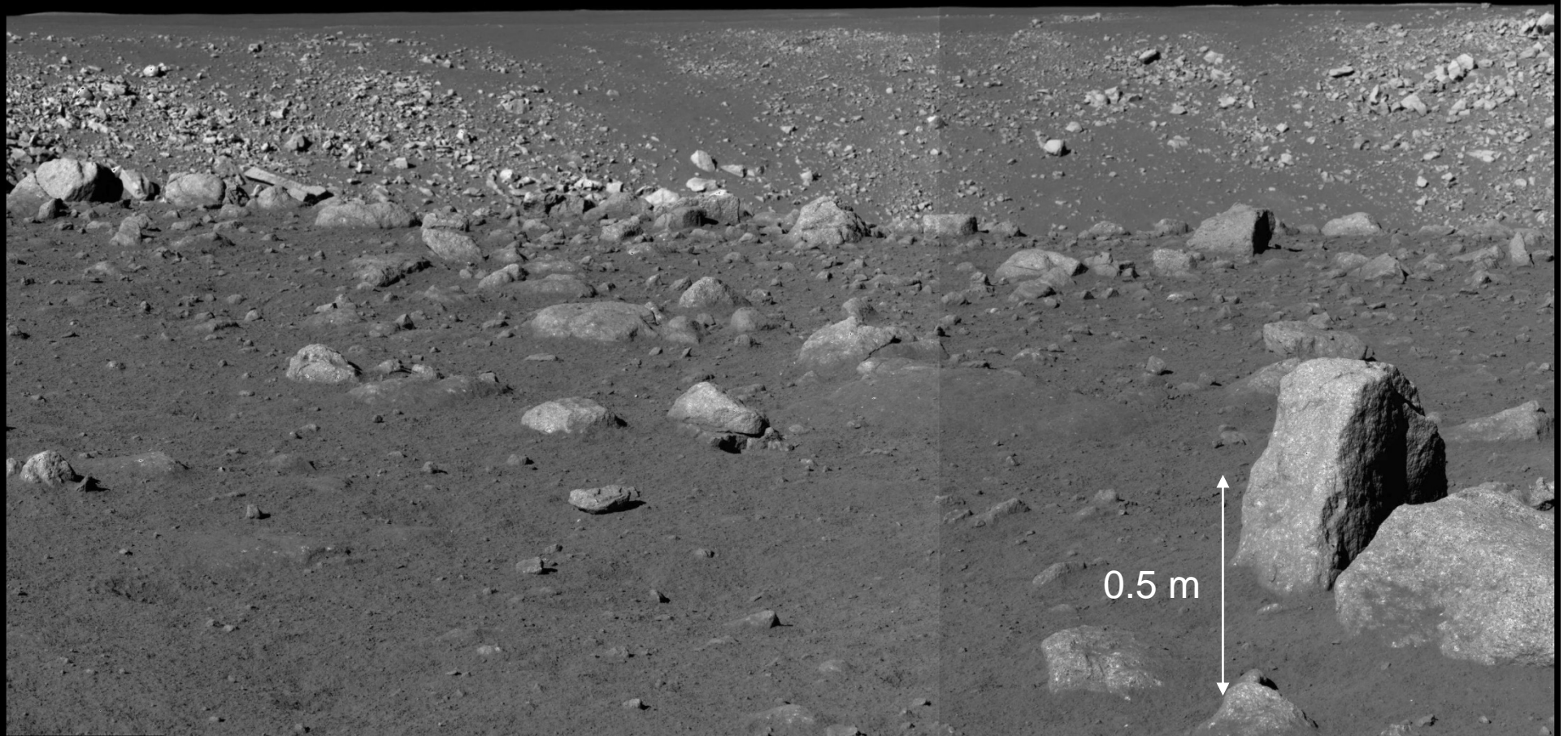
Crater C2

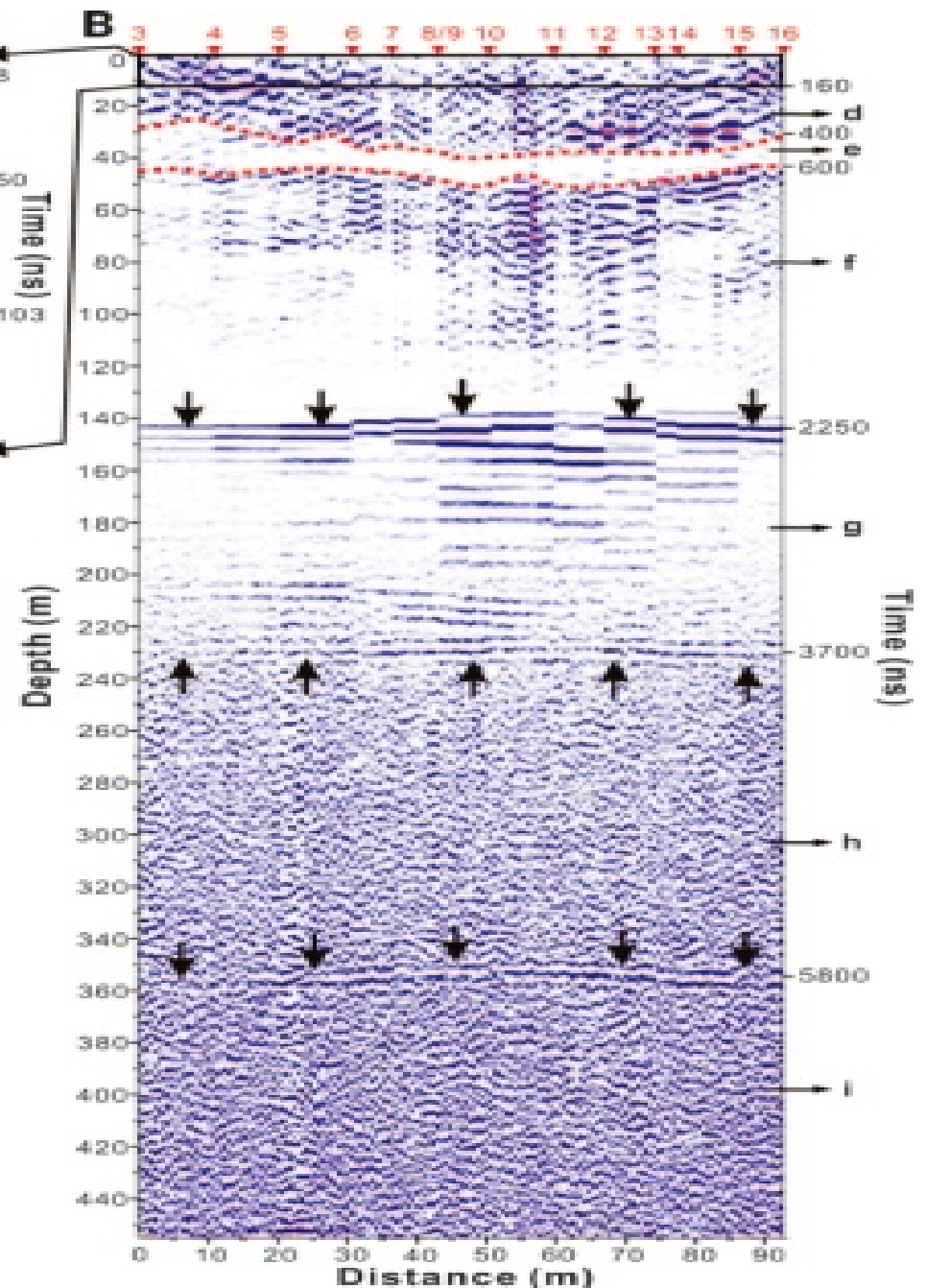
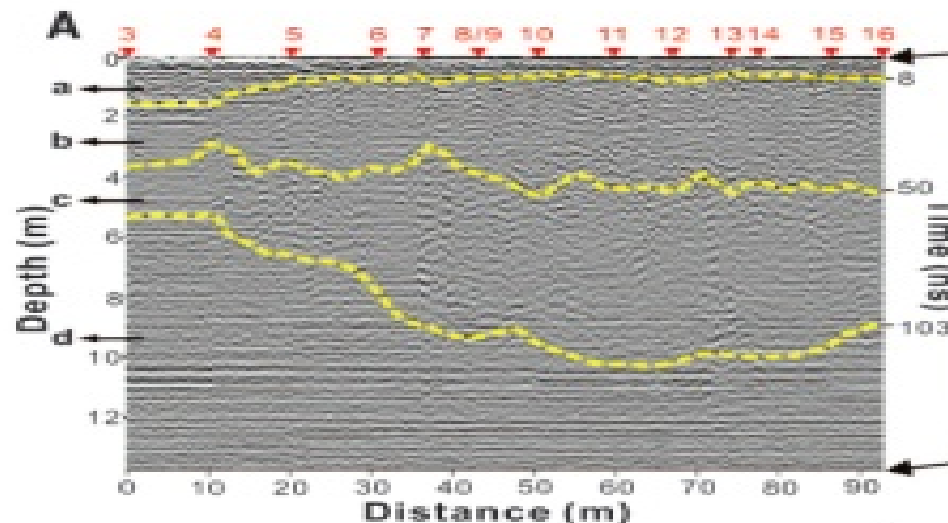
10 m

Portion of Chang'E3 image 4'57"



Rock fragments on the western rim and inner slopes of crater C1





The ground penetrating radar:

- vertical cross-section of the regolith in the Yutu landing site,
- several reflectors are prominent.

[Fa et al., 2015; Dai et al., 2015]

Summary

Lunokhod-1, -2, and Yutu (mare/highland areas):

- Similar landscapes in remote regions.
- Rock fragments up to a few meters are the most abundant features on mare. Highland surfaces are less rocky.
- Uppermost regolith: mixture of small rock fragments and fines.
- Close-up of the morphology and degradation state of the small craters and rocks. Assessment of the degradation state.
- Assessment of the timing of degradation of small craters and rocks.
- Columnar jointing: evidence for the near subsurface lavas.
- Distinct and prominent reflectors in the shallow subsurface: evidence for the ejecta blankets and multiple lava flows.
- The 240-m reflector: either possible base of the mare fill at the Yutu site or a major disconformity (the major episodes of lava filling).