The Moon race: Russian robotic missions and Lunar surface features

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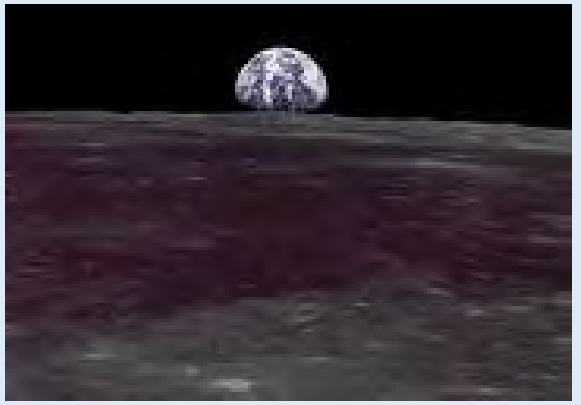
Introduction



- Historically, the Moon race in the 1960-1970s of last century has been one of the most impressive milestones and exciting events of space exploration.

- While it was driven by political motivations both American Apollo expeditions and Soviet robotic missions greatly advanced the Moon knowledge and planetary sciences in general.

- International Astronomical Union contributed to scientific exploration of our closest neighborhood, mostly through mapping/naming the Moon surface features and getting insight in lunar/planetary geology and geochemistry.

The Moon Race

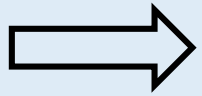
- The Soviet Union's space program was years ahead of the USA's in the 1950-1960s. However Soviets yields Americans the first man landing on the Moon surface and thus lost the Moon race and space leadership.
- Why?
- There were several reasons of this failure.
- The first (and the main one) was an unexpected sudden death of Chief Designer in the USSR rocketry-space program, Head of Energia Corporation Sergey Korolev.

- The second one was lacking of the political will and a rather poor management resulting in loosing money and inefficient governing the project of piloted flights to the Moon.
- The situation was also badly impacted by competition of chief designers in the implementation of N1-L1 (orbiting) and N1-L3 (landing) programs.

Soviet Manned Moon Mission Profile

- Heavy rocket N1 to deliver LOK orbital module with 2 cosmonauts and LK lander to land 1 cosmonaut to the Moon surface.1-L3

Governmental decisions of 1961-1962 to produce the heavy rocket N1 by 1965 and implement manned expedition to the lunar Surface by 1968



Tests of lunar orbital module (Unmanned lunar flybys
Sept 24, 1968 - Zond 5: worms, turtles
Nov 10, 1968 – Zond 6 (Moon photo)
Aug 8, 1969 – Zond 7 (Moon photo)
Oct 20 1970 – Zond 8 (Moon photo)
Generally successful

Nov 24, 1970, Feb 26, 1971
May 12, 1971
Tests of lander in near-Earth orbit
All successful

Feb 21, 1969, July 1, 1971, June 27, 1971, Nov 23 1972
Test launches of N1: All failed

May 1974 Program N1-L3 was canceled

Orbital module LOK: Zond 4, 5, 6, 7, 8 flights

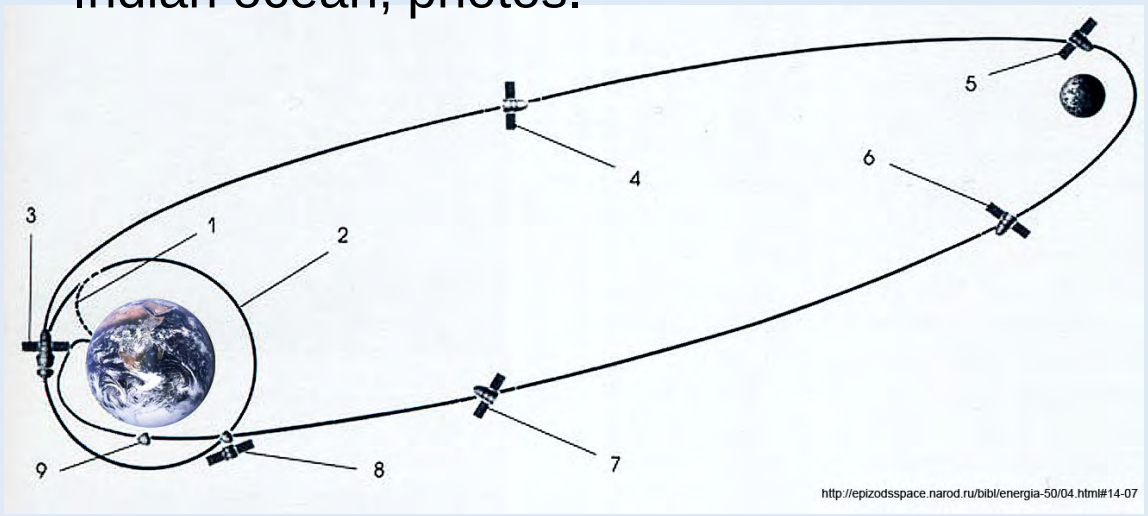
Zond 4 Testing LOK in near-Earth orbit;

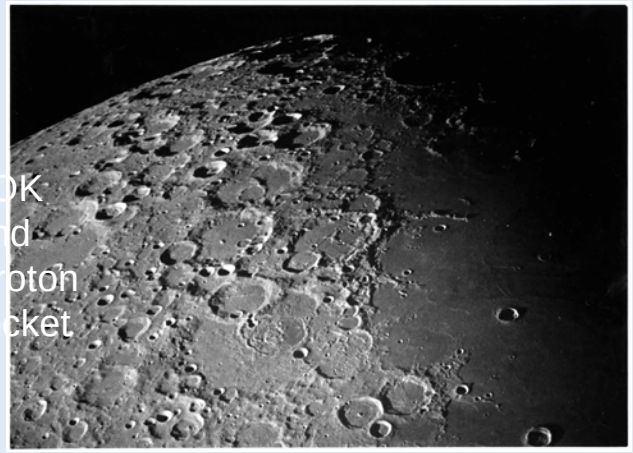
Zond 5 Lunar flyby with turtles, landing with 20g overload in the Indian ocean;

Zond 6 Lunar flyby with turtles, landing with early parachute separation overload, photos;

Zond 7 Lunar flyby, complete success, photos;

Zond 8 Lunar flyby, almost success, landing in Indian ocean, photos.





LOK and Proton rocket

Orbital module LOK and its modification for near-Earth orbit flight Soyuz TM

Lunar surface images taken by Soviet Zonds and American Lunar Orbiters were of principal importance for landing sites selection and for the study in detail the Moon properties by the IAU astronomers.

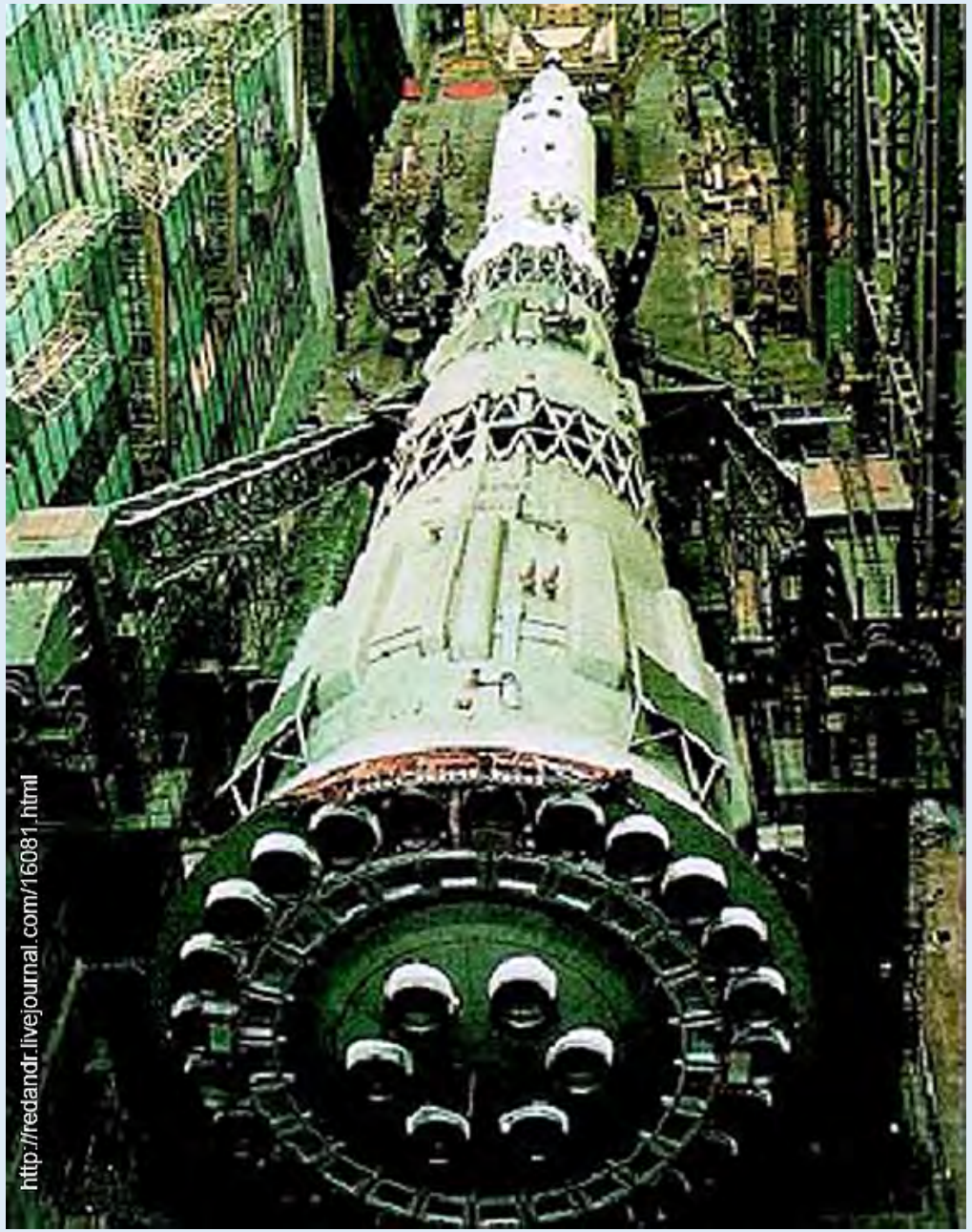
LK (L3) Moon Lander

Computer models

Successful tests in the near-Earth orbits (Maneuvers sumulating landing on the Moon, lift-off and randevous with orbital module).

Engineering mockup

Heavy N1 Rocket



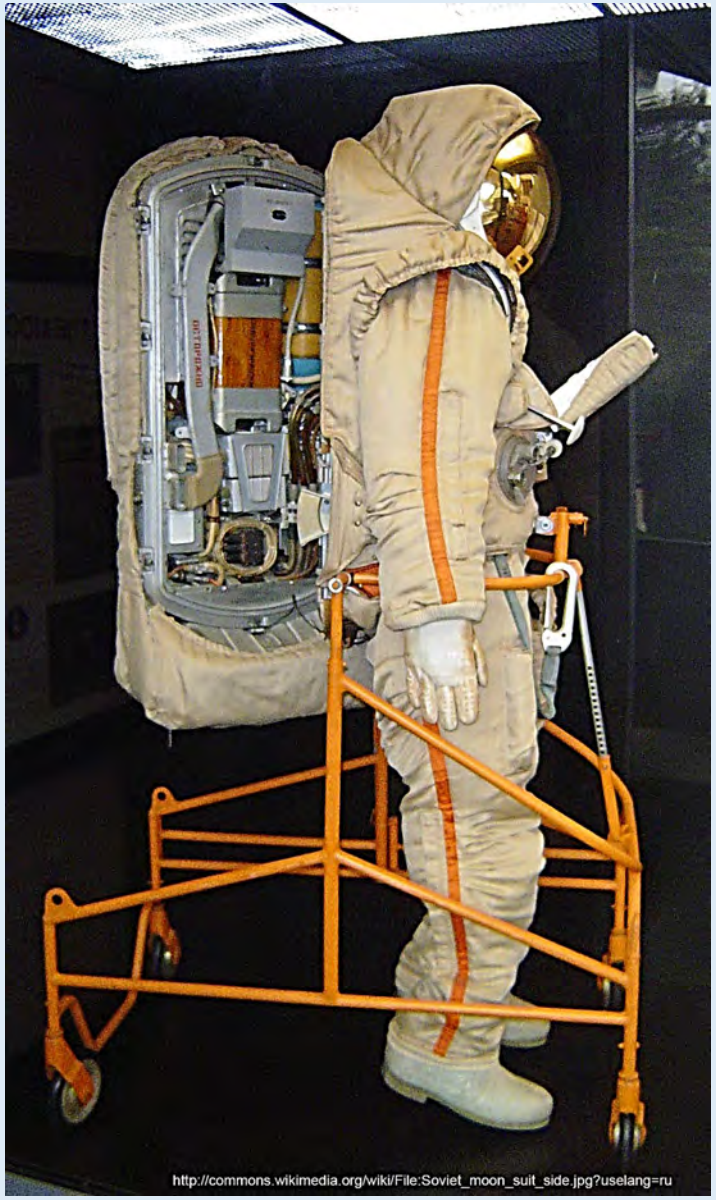
Total length 103.5 m
Total mass 2735 t, dry mass 208 t
Oxygen-kerosene engines.
Three stages:

- stage 1 – 30 engines,
- stage 2 – 8 engines,
- stage 3 – 4 engines

Landing sites selection for the Soviet manned flight to the Moon

4 sites were selected & characterized

Cosmonauts Selection



Space suit for lunar expedition

The Moon Flyby: Valery Bykovskiy and Nikolay Rukavishnikov

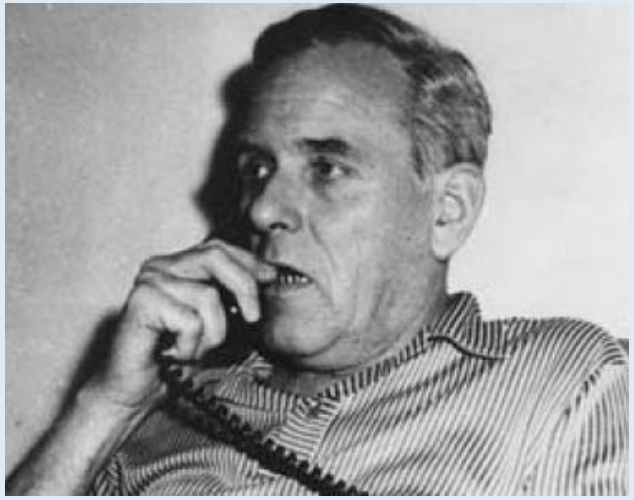
Landing on the Moon:
Alexei Leonov and Oleg Makarov

An Alternate Approach by the USSR in the Moon Race

- It is became clear by the early 1968 that USSR will loose the Moon race.
- An alternate approach to compete USA was suggested by the Head of Lavochkin Association George Babakin: to undertake robotic missions to the Moon with the new generation of space vehicles to be urgently developed.
- The idea was supported by the former President of the USSR Academy of Sciences Mstislav Keldysh and took the Soviet Government's endorsement.
- In the framework of this new program two spacecraft configurations were designed:

  - for taking automatically samples of lunar soil, and

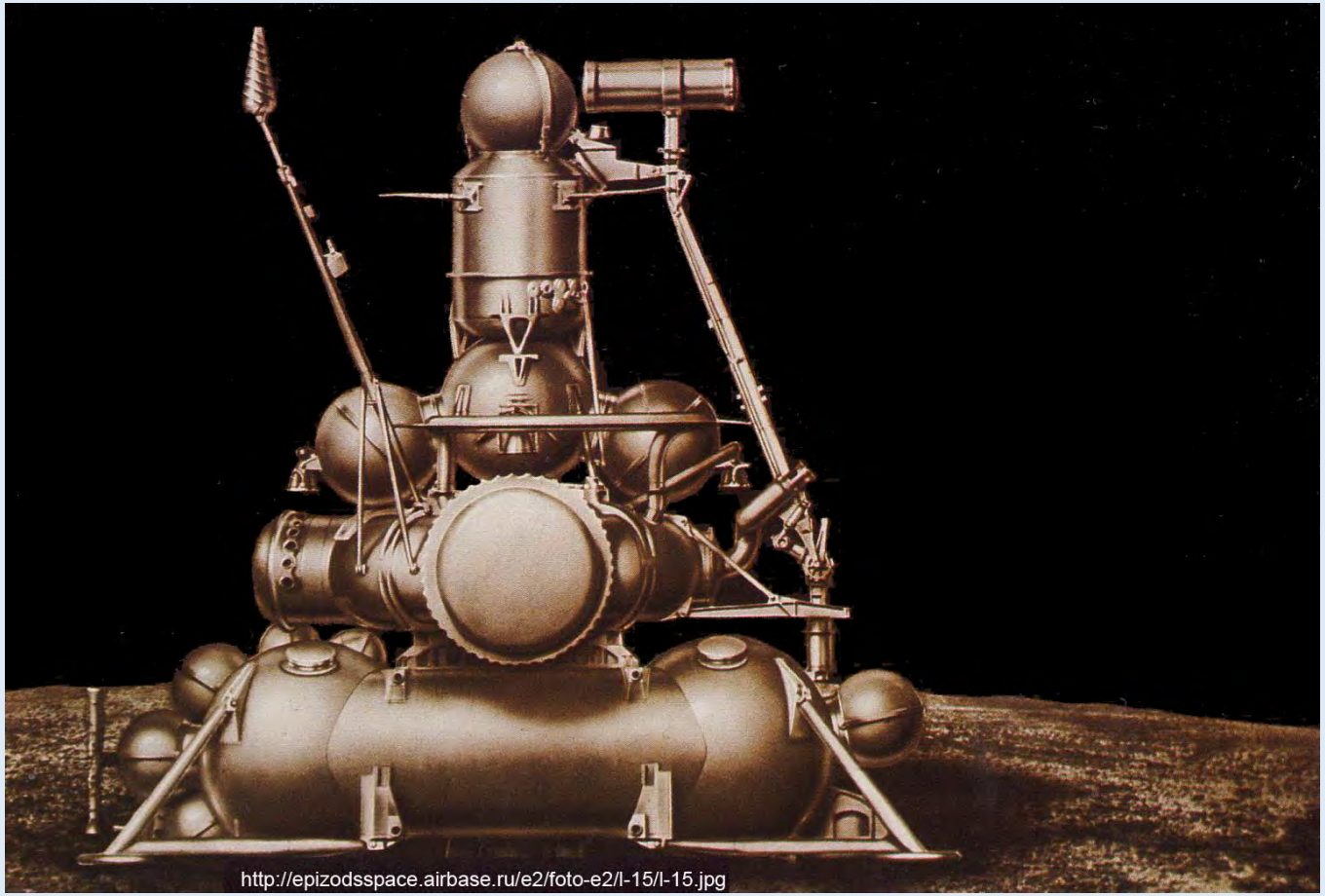
  - lunar rovers to travel over and to study on the Moon surface

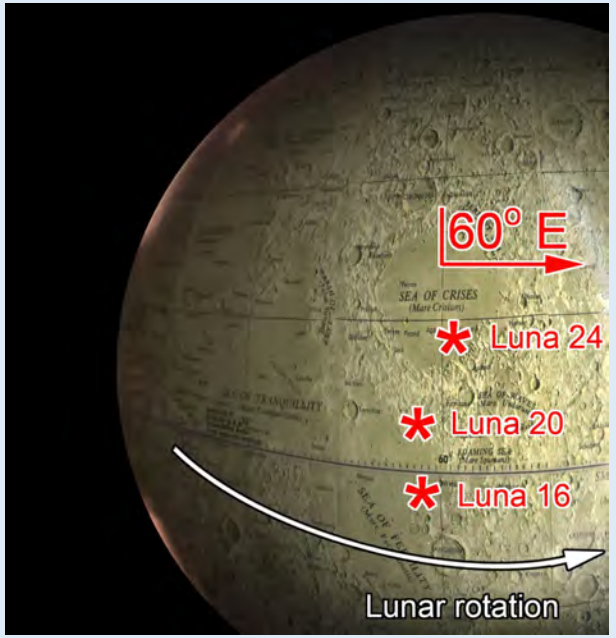


- These vehicles were successfully developed and launched.
- Luna 16 in 1970 was the first that returned back to Earth automatically taken samples of lunar matter.
- It was followed by Luna 20 in 1971 and Luna 24 in 1976.
- The first lunar rover Lunokhod 1 was launched in 1971 and Lunokhod 2 in 1973.

Robotic vehicles for lunar soil samples return

Robotic vehicle configuration

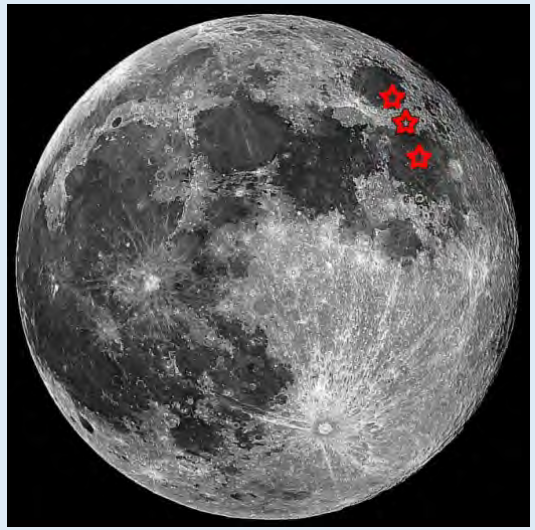




Robotic sample returns

Luna 15 lander, launch 13 July, 1969, crashed on 21 July, 1969
Attempt of robotic sample return from Mare Crisium

Luna 16 lander, launch 12 Sep 1970
First successful robotic sample return. Spacecraft landed in Mare Fecunditatis (0.68^{o}S, 56.3^{o}E).



Luna 18 lander, launch 2 Sep 1971
Failed attempt of robotic sample return from lunar highland region in between Mare Fecunditatis and Mare Crisium.

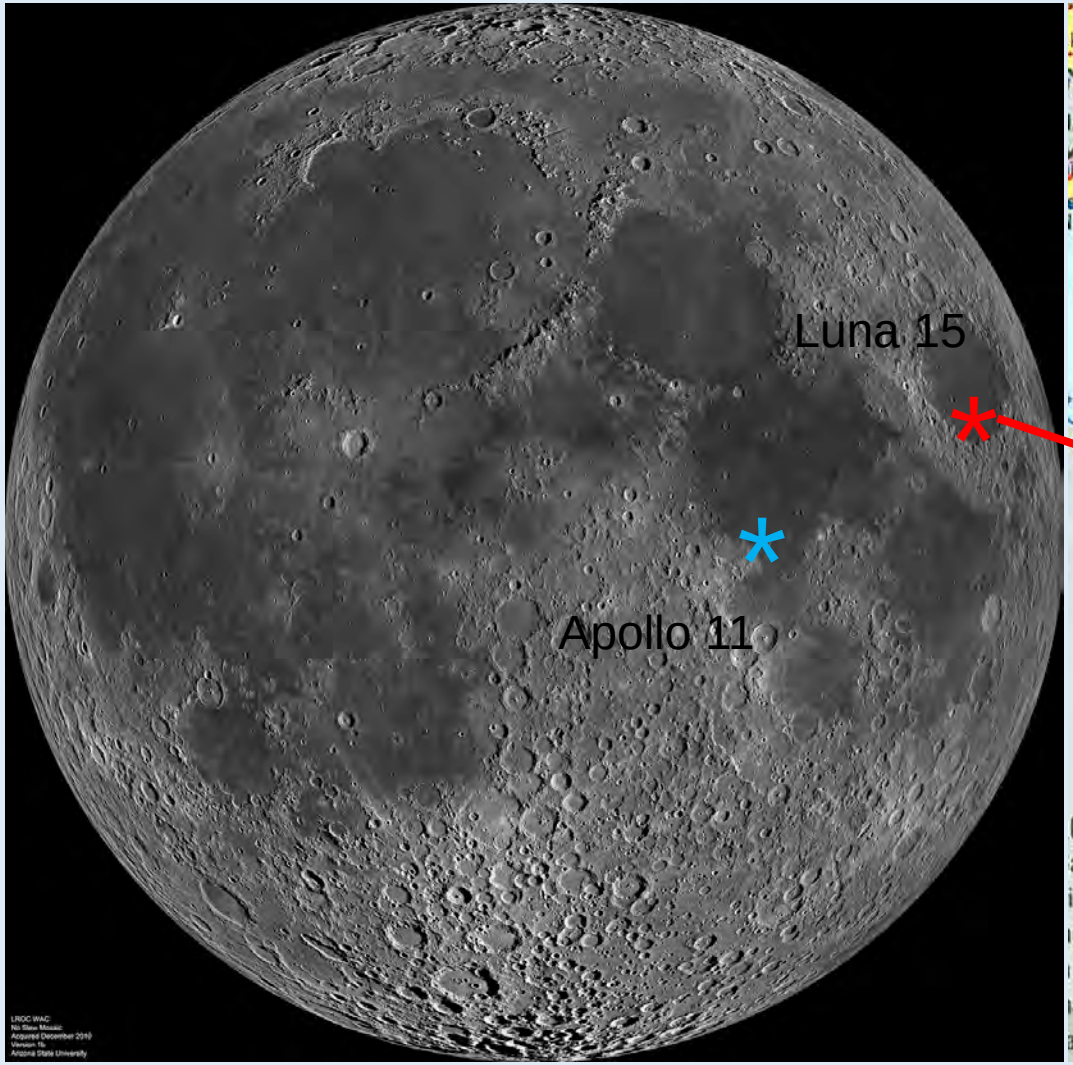
Luna 20 lander, launch 14 Feb 1972
Robotic sample return from lunar highland region in between Mare Fecunditatis and Mare Crisium (3.53^{o}N, 56.55^{o}E).

Luna 23 lander, launch 28 Oct 1974
Failed attempt of robotic sample return from Mare Crisium. The spacecraft was damaged at landing and could not function properly.

Luna 24 lander, launch 9 Aug 1976
Robotic sample return from Mare Crisium (12.75^{o}N, 62.2^{o}E).

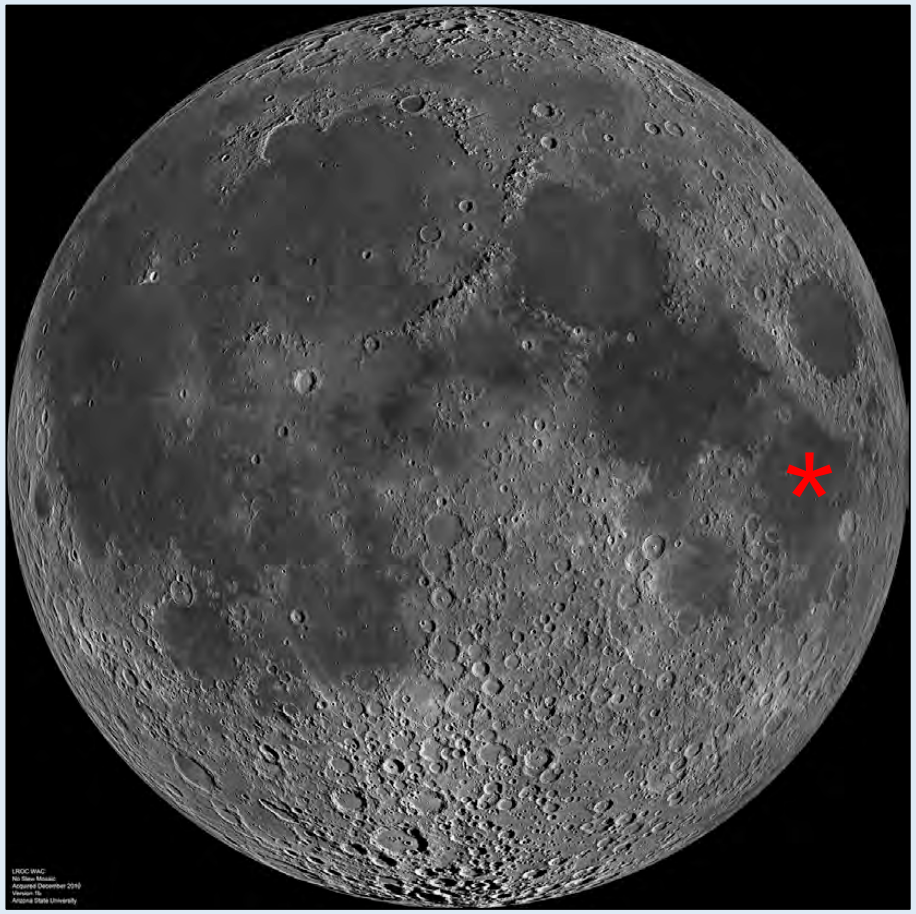
Luna 15 (July 13-21,1969) to chaise **Apollo 11** (July 16-24, 1969)

Attempt of sample return from Mare Crisium, soft landing failed.

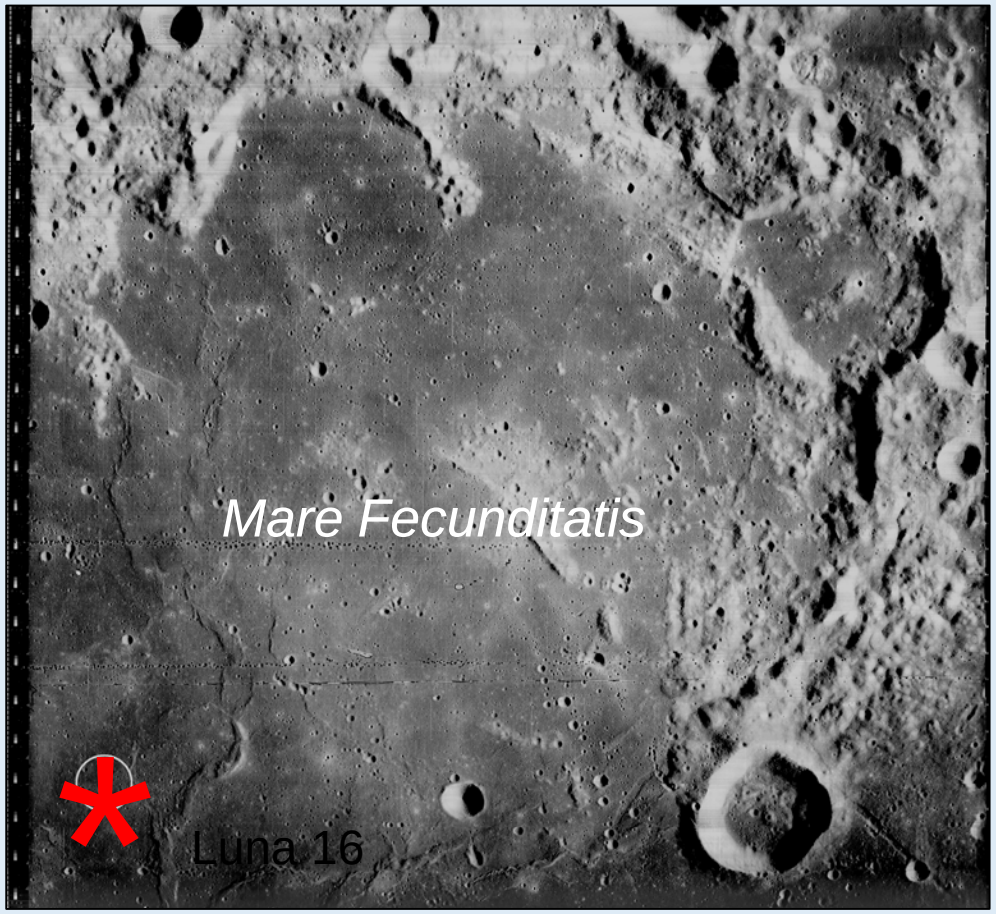


Luna 16 - the first successful robotic sample return

Launch - on Sept. 12, landed on Sept. 20 in Mare Fecunditatis.
Capsule with soil samples return back to Earth on Sept. 24, 1970
The main composition: **Aluminous basalts**, mass **101 g**.



Moon nearside, LROC WAC map



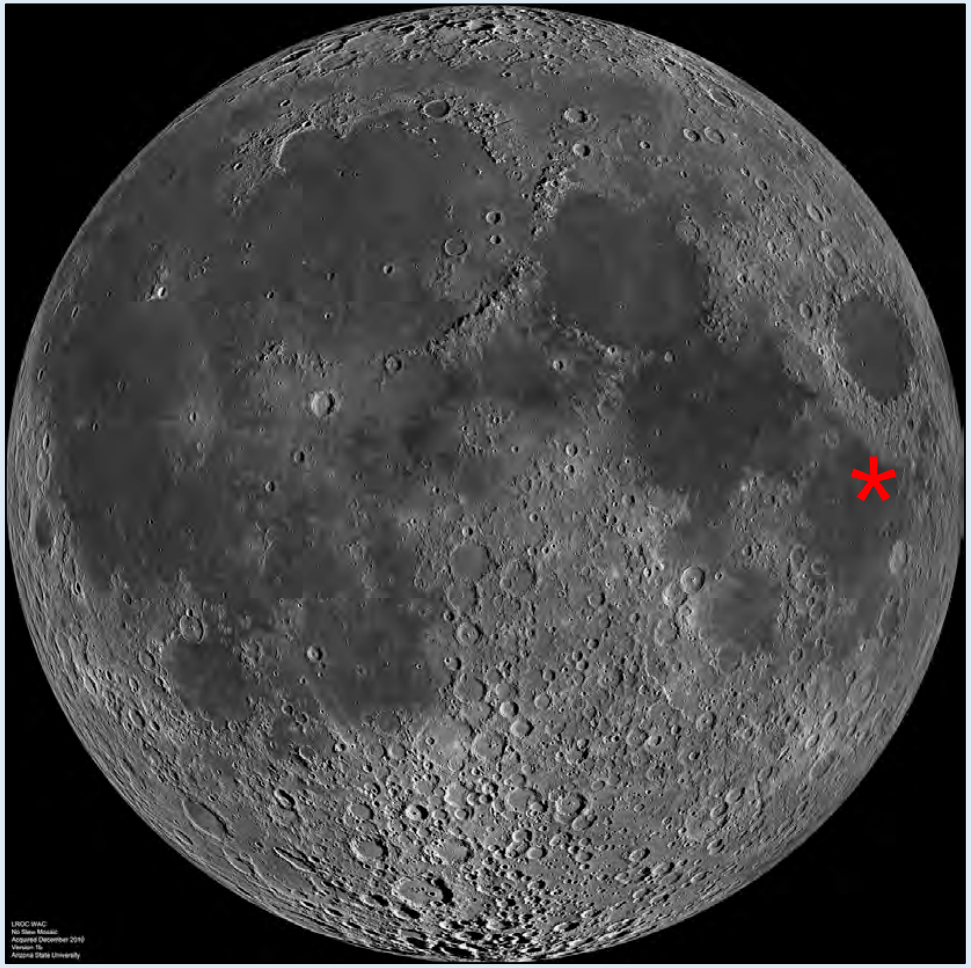
Landing site, large scale (Lunar Orbiter -1 Photo)

Luna 20 sample return

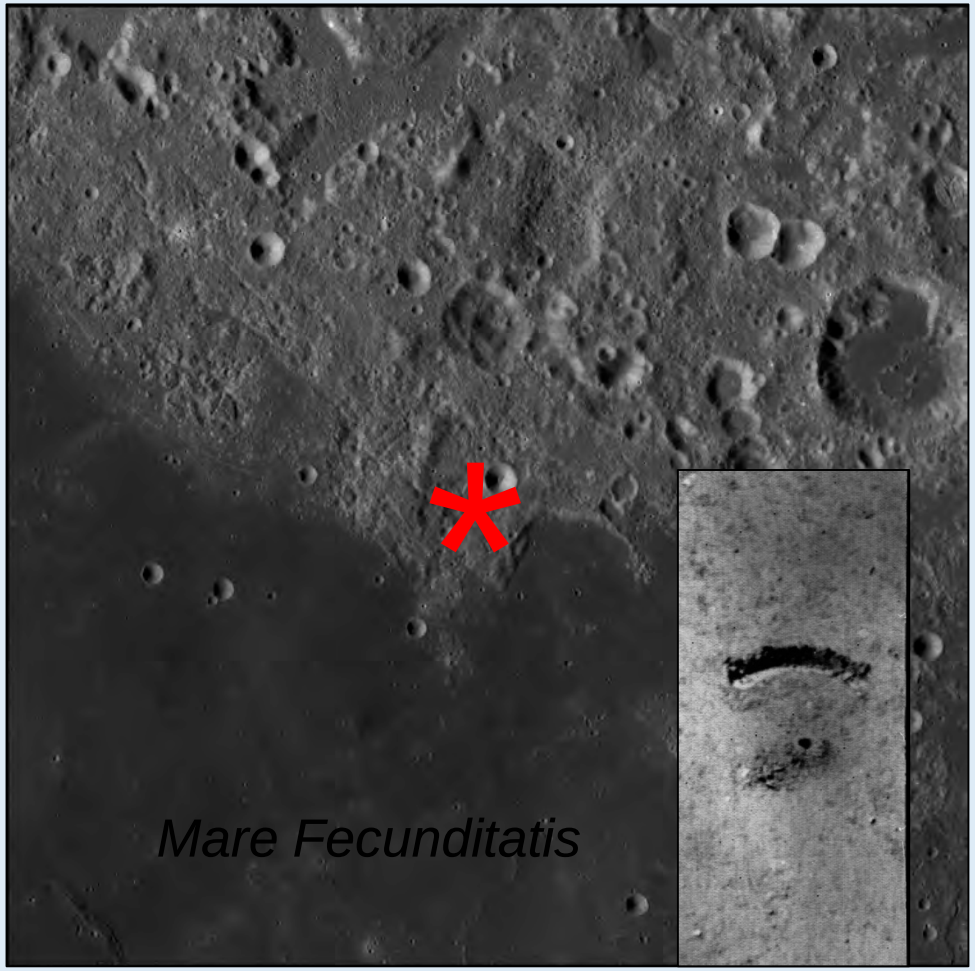
Launch on Feb. 14, landed on Feb. 21 in Fecunditatis-Crisium highland

Capsule back on Earth on Feb. 25, 1972

Second successful robotic sample return. **ANT, Hi-Al basalt, 55 g.**



Moon nearside LROC WAC map



LROC WAC mosaic

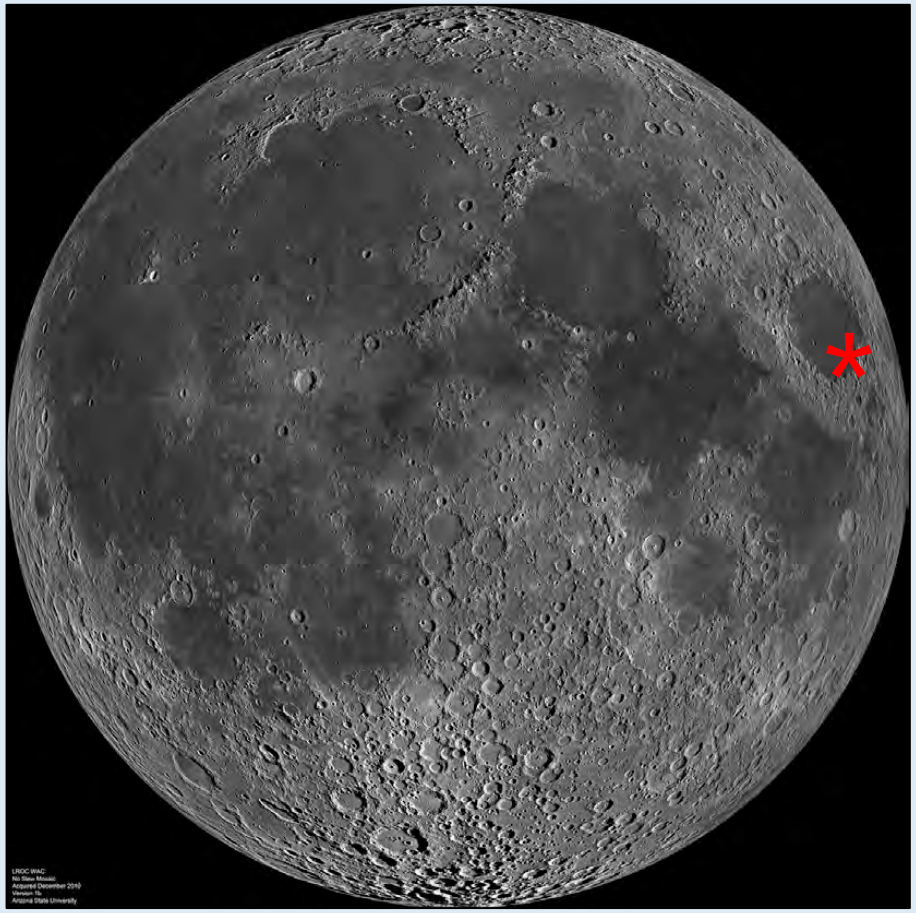
Sampling spot

Luna 24 sample return

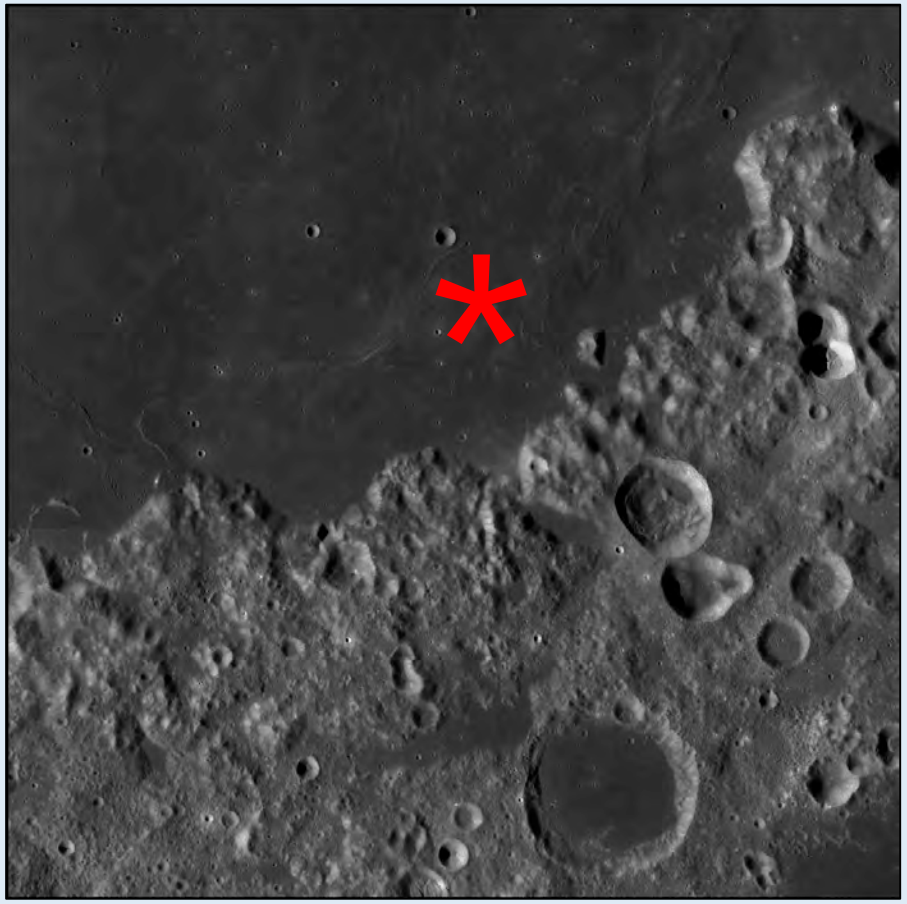
Launch on August 9, landed on August 18 in Mare Crisium.

Capsule back on Earth on August 22, 1976

Third successful robotic sample return from 2,4 m depth: **Very low-Ti basalts. 170 g**.



Moon nearside LROC WAC map



LROC WAC mosaic

Samples returned by Luna 16, 20,24

Luna 16
Drill Core
101 grams

6 cm.
21000 **A**
8 cm.

21020 B

29 cm.
21010 **G**
31 cm.

Figure 1: Copy of Russian photo of Luna 16 core after initial disection showing position of three samples provided to US workers (21000, 21010 and basalt chip B 21020). NASA S71-38646 and 38647). Location of B is approx. See also figure 9.

Lunar Sample Compendium

Luna 20
Drill Core
~50 grams

Introduction

"The Luna 20 core, weighing 50 grams exhibited no stratification when placed on a tray. The soil was light gray and has a median grain size of about 70 microns. The sample allocated to NASA was 2.036 g from the 19 to 27 cm level of the sample tray (from certificate). The sample was sieved by the NASA Curator into the

Figure 1: A 20 cm portion of the Luna 20 core. NASA S73-17207.

Lunar Sample Compendium

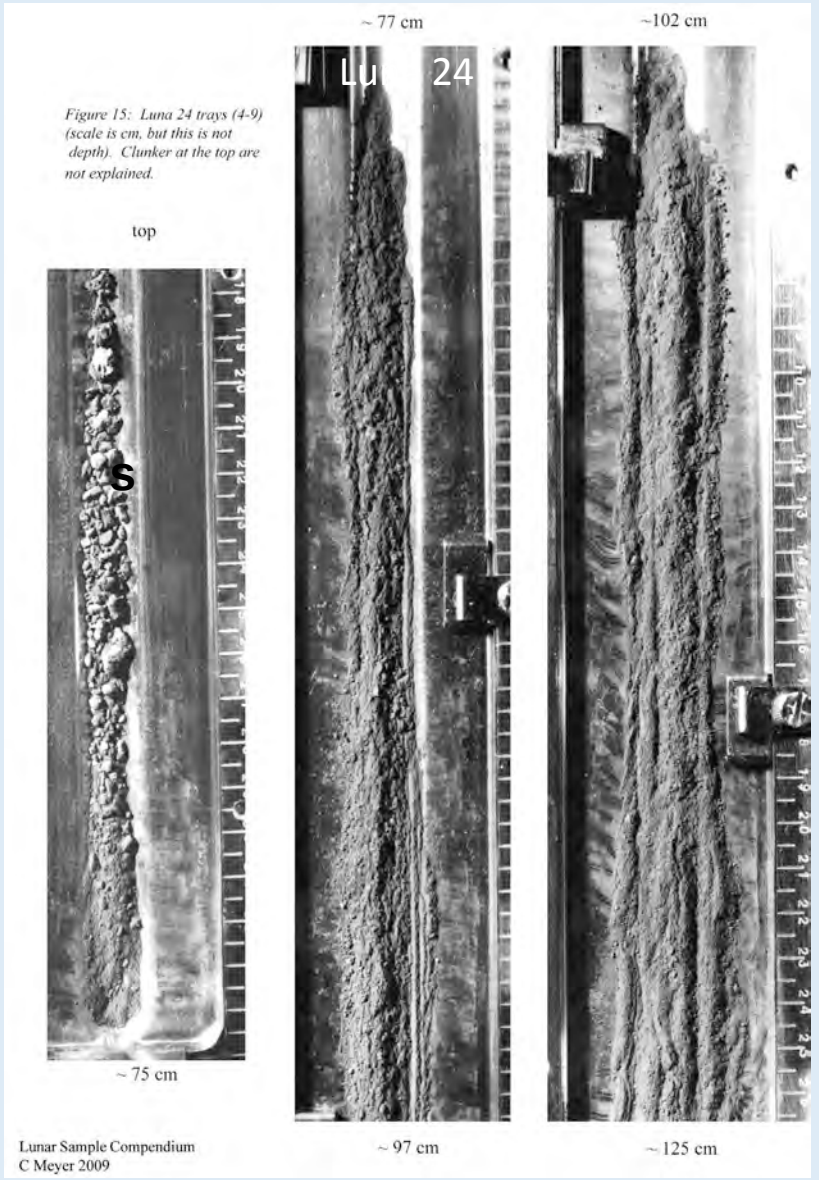


Figure 15: Luna 24 trays (4-9) (scale is cm, but this is not depth). Clunker at the top are not explained.

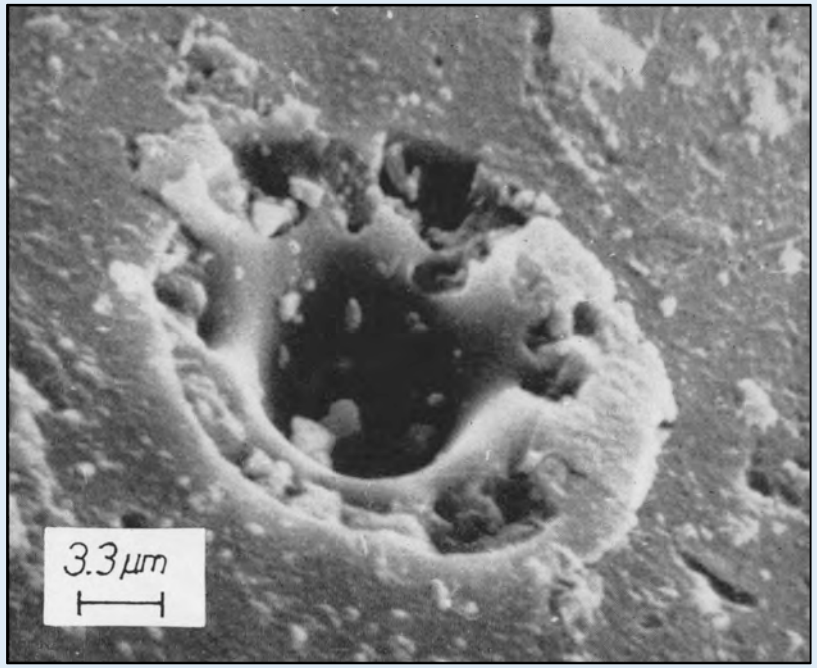
Lunar Sample Compendium
C Meyer 2009

Special boring device To keep soil column stratification

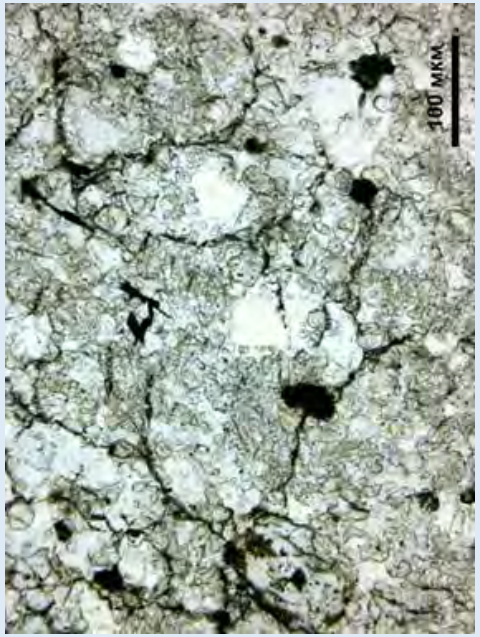
Returned samples

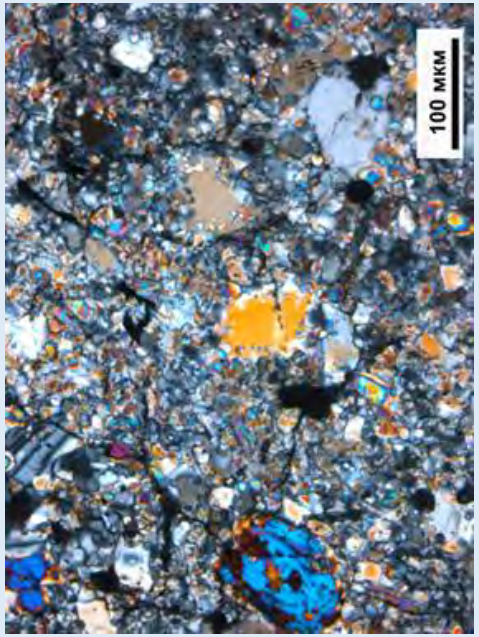
Luna 16 basalt thin section

Luna 16 microcrater electr. microscopy

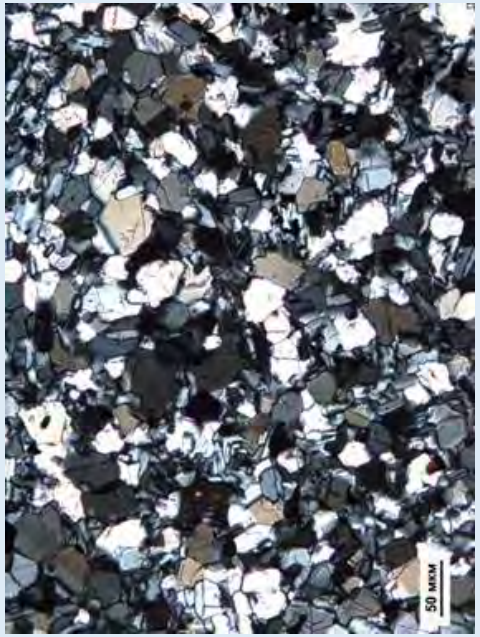


Luna 20 granulitic breccia thin section

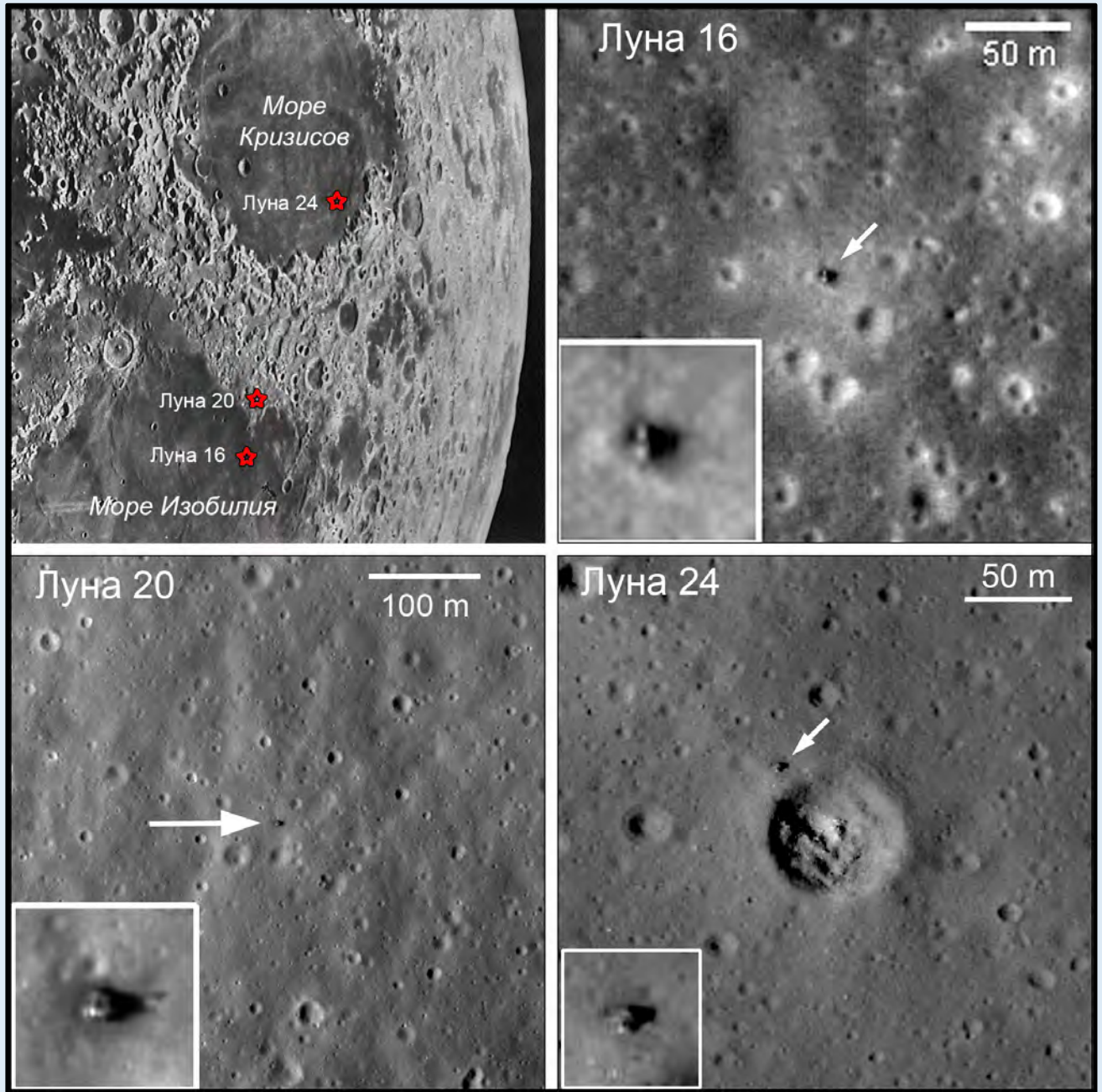




Luna 24 ferrobasalt thin section



Luna 16, 20, and 24 landers on the Moon



Lucky fortune of Luna 24:

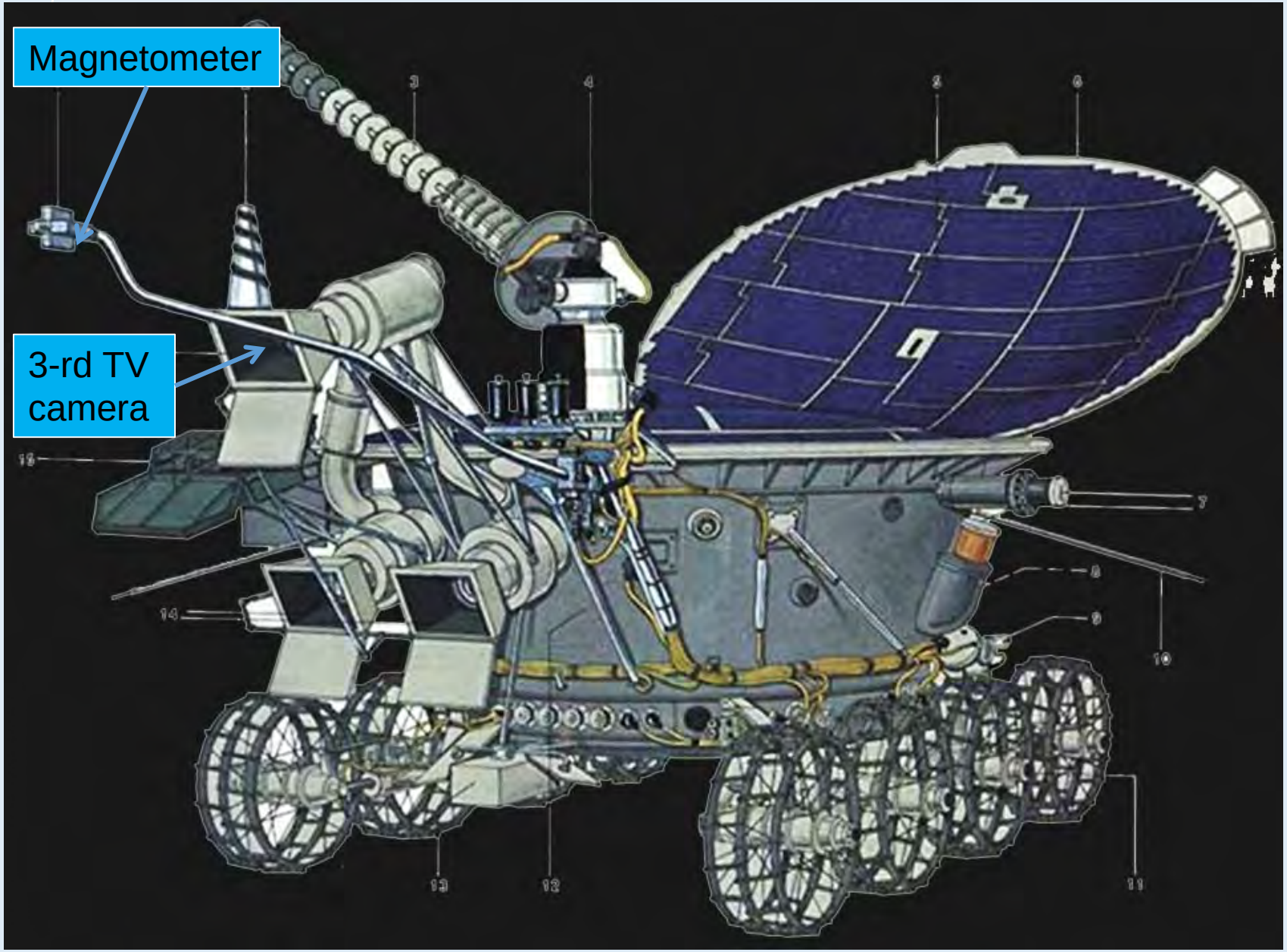
Landing of a few meters only from a steep crater rim!

(LROC NAC images
M106511834LE
M119482862RE
M119449091RE)

Lunar Rovers - Lunokhods

Lunokhod 1 - the first planetary rover, worked on the Moon surface for 11 lunar days = 10.5 Earth months, travelled 10540 m

Lunokhod 2 – the second planetary rover
Worked from January 16 untill May 10, 1973. The route covered 42 km



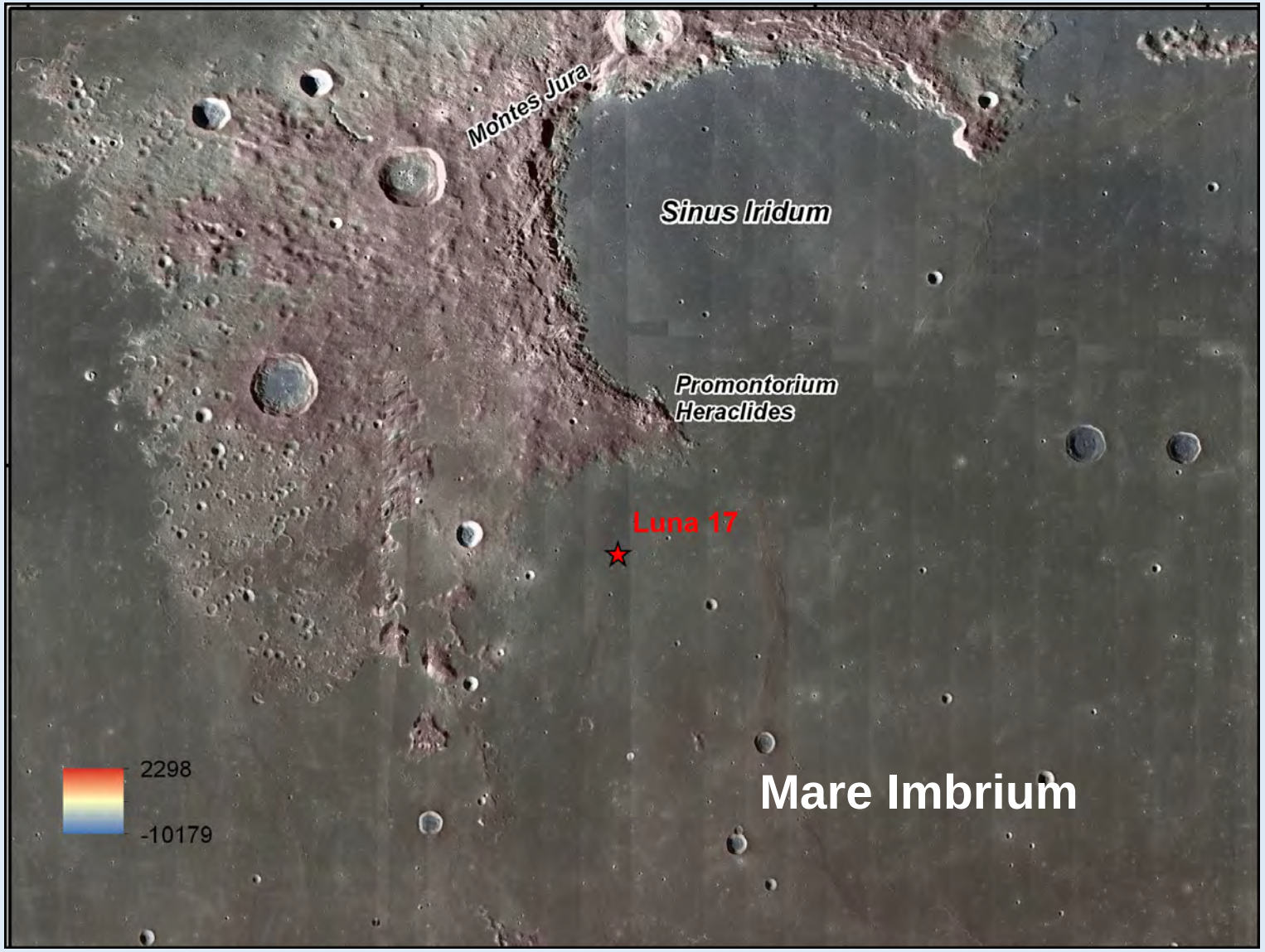
Lunokhod-1

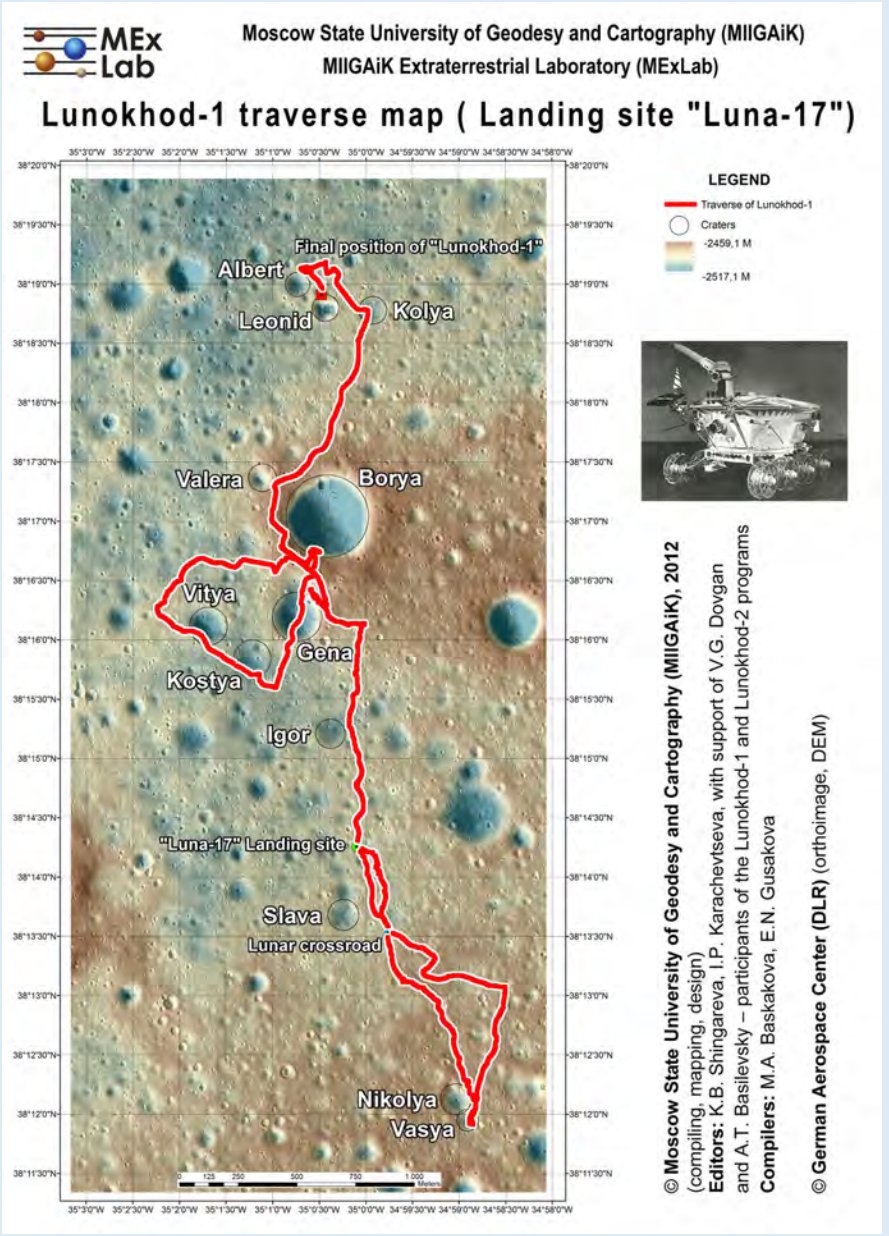
November 17, 1970 -
-September 14, 1971
Mare Imbrium

Lunokhod-2

January 16 -
- May 10 1973
Crater Le Monier,
Mare Serenitatis

Rover operations: Very high requirements to the accuracy of surface relief knowledge





Examples of morphological analysis of Lunar Orbiter photos

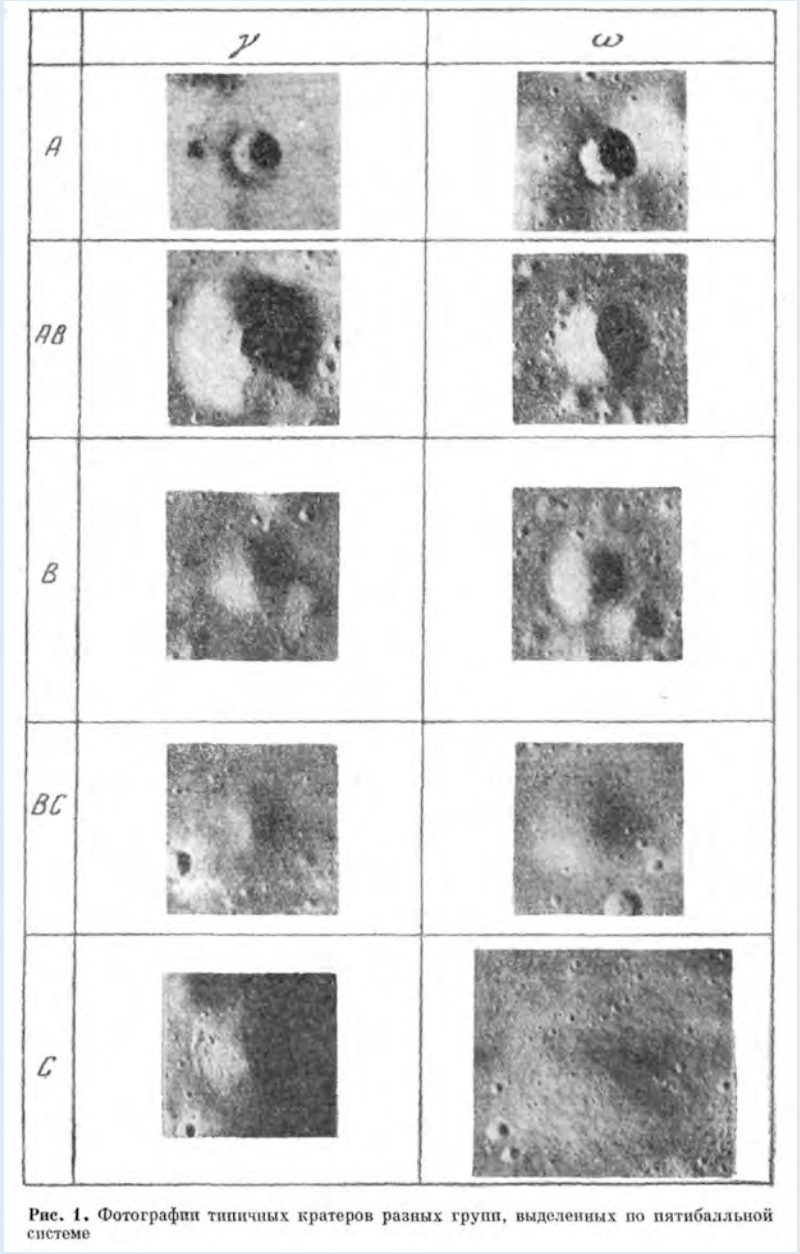


Рис. 1. Фотографии типичных кратеров разных групп, выделенных по пятибалльной системе

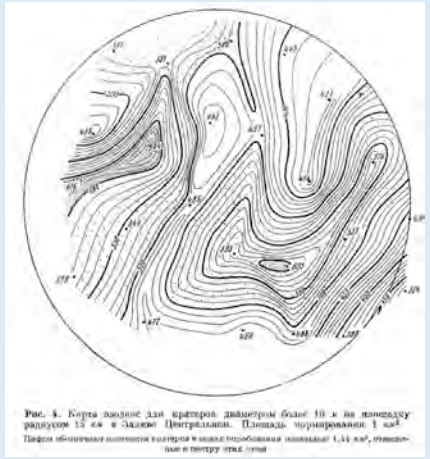


Рис. 4. Карта плотности для кратеров диаметром более 10 м на площадке радиусом 15 км в Заливе Центральном. Площадь нормирования 1 км²

Variations of spatial craters' density

Рис. 14. Изолинии распределения камней диаметром более 2 м около кратера № 1

Variations of spatial rock fragments density

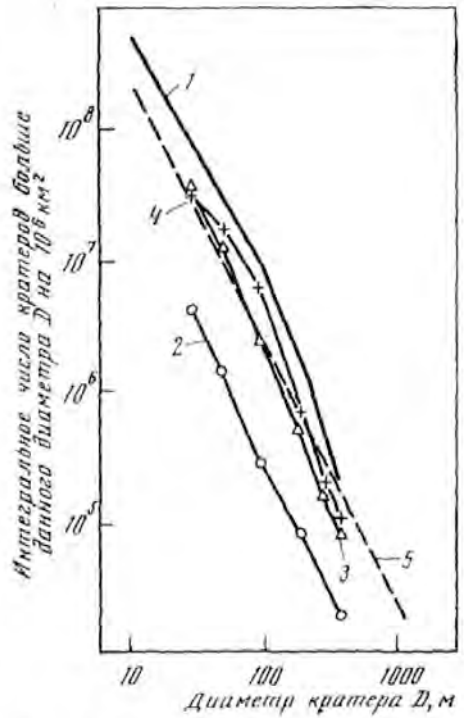


Рис. 7. Распределение по размеру кратеров разных классов в районе Океана Бурь

1 — кратеры A+B+C; 2 — кратеры A; 3 — кратеры B; 4 — кратеры C; 5 — осредненное распределение кратеров по данным КА серии Рейнджер

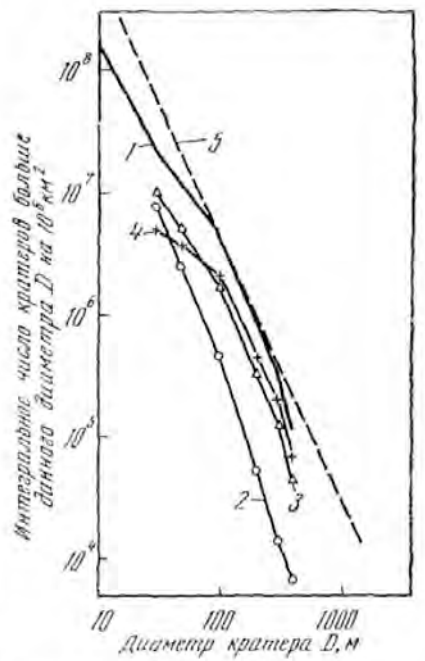
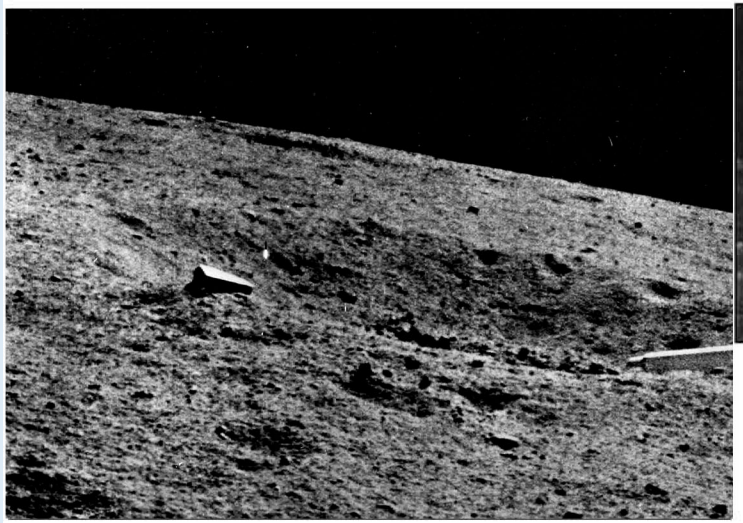
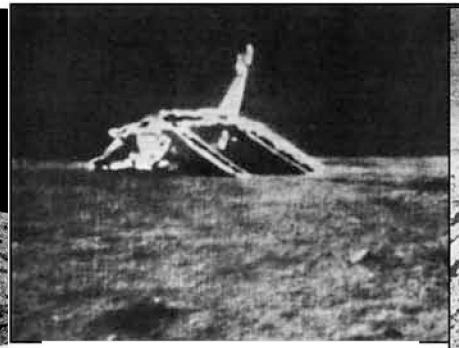


Рис. 8. Распределение по размеру кратеров разных классов в районе Залива Центрального

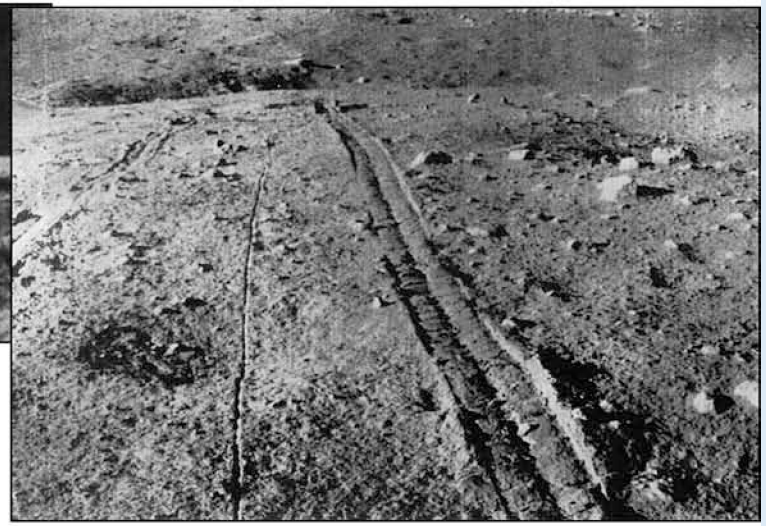
Условные обозначения те же, что и на рис. 7

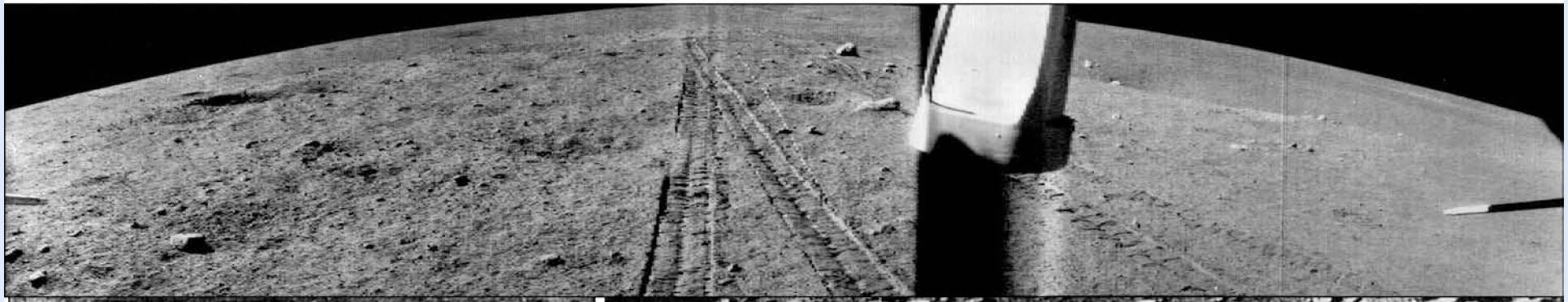
The data served as a basis for the Lunar robotic missions, specifically Lunokhods

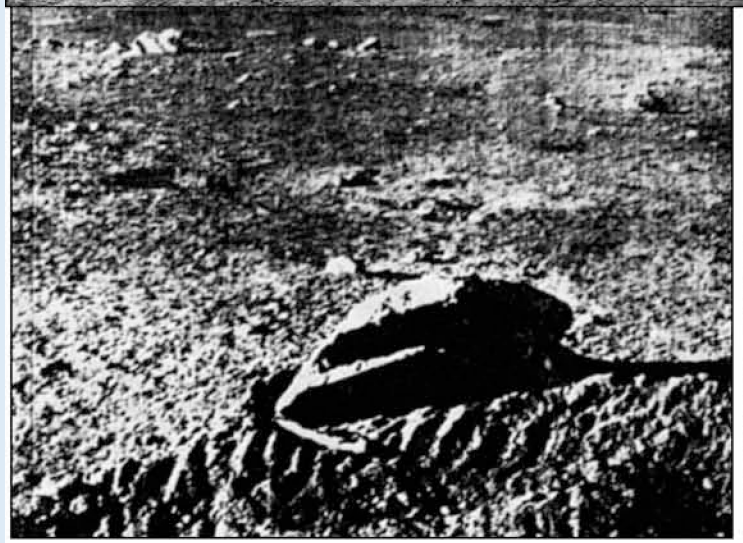




Lunokhod 1
landscapes

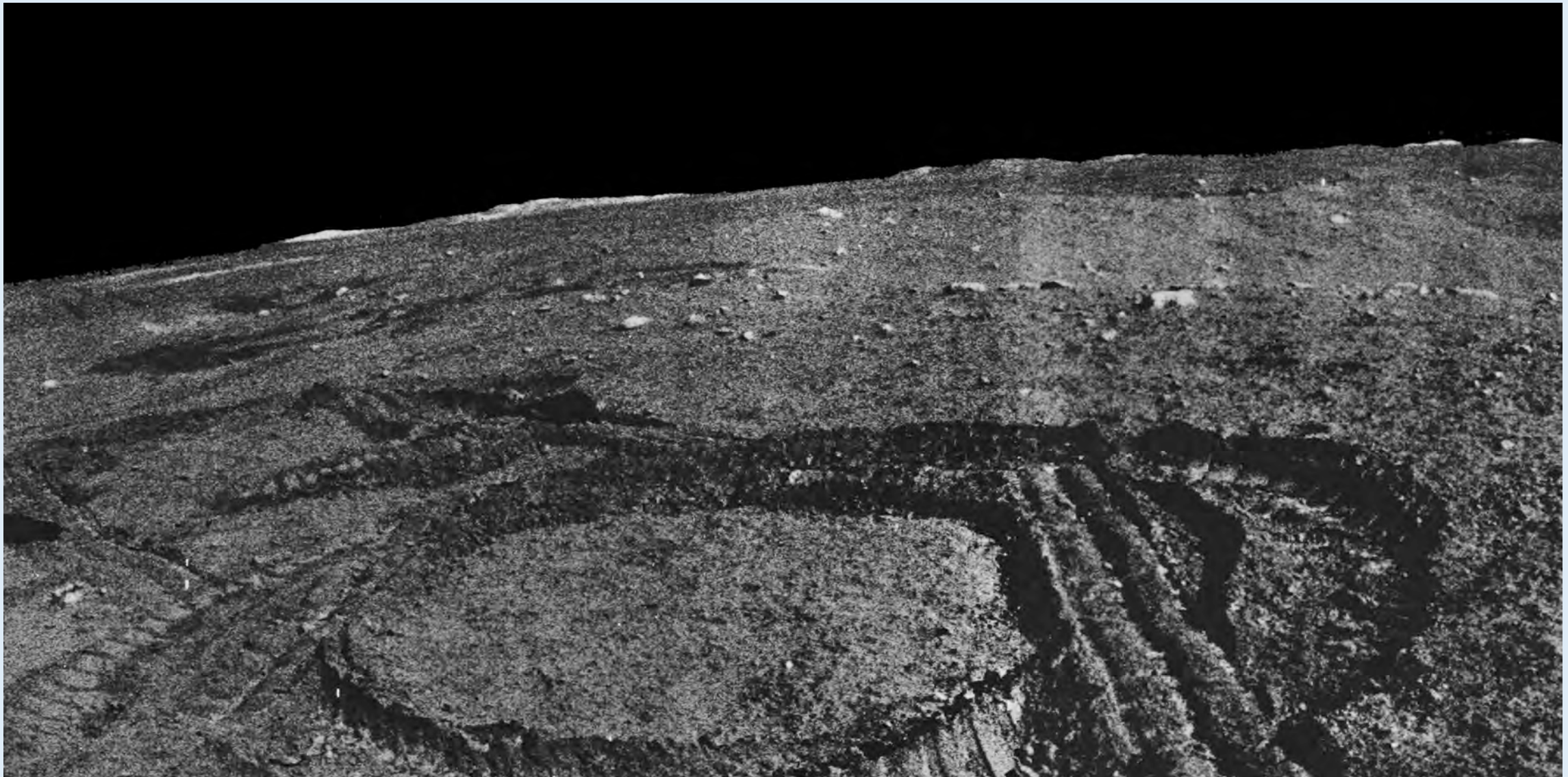




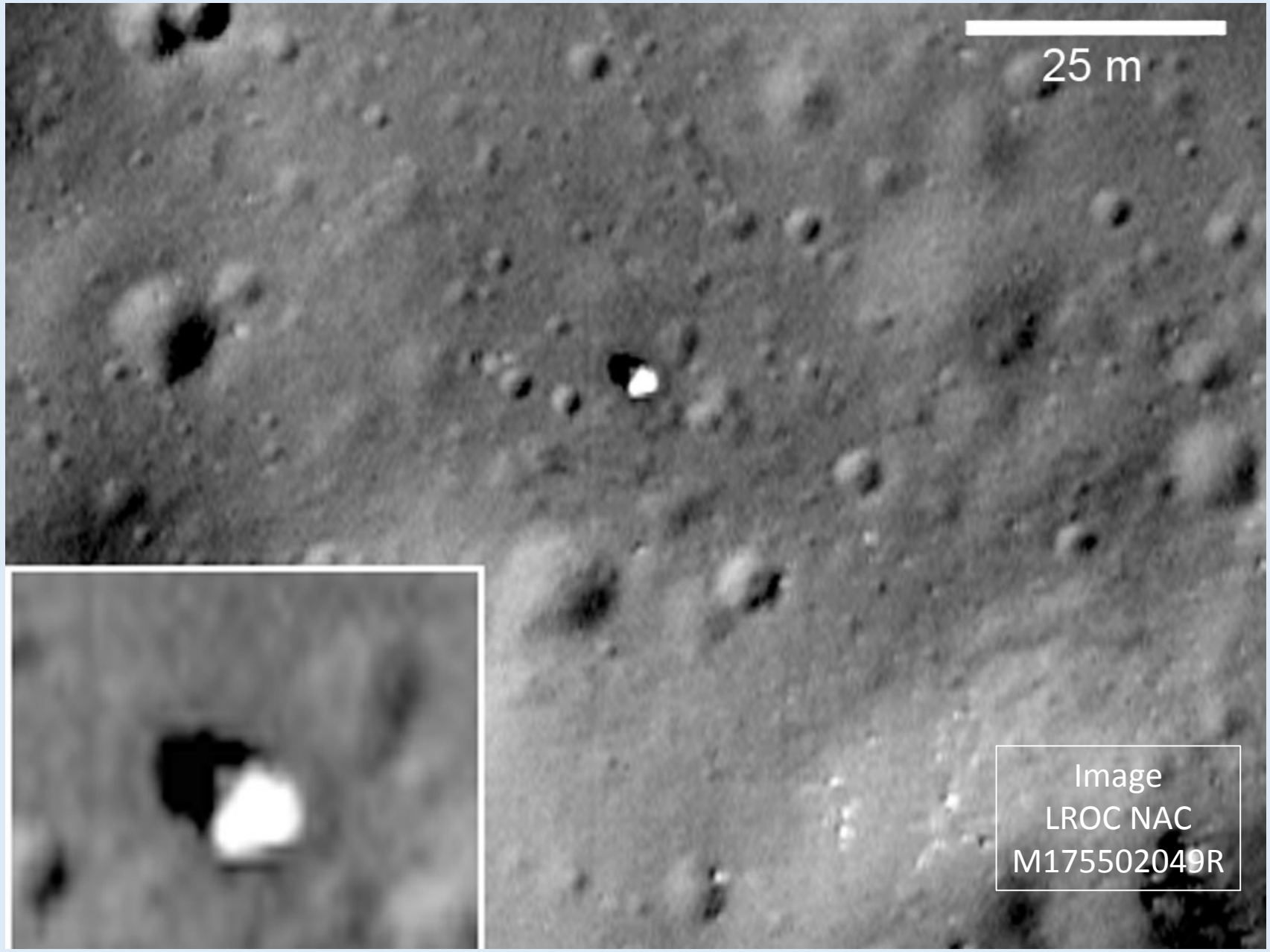


Fragment of of Lunokhod 1 panorama

Promontorium of Heraclides mountains - on the horizon .



Lunokhod 1 at the eternal parking on the Moon



Landing site of Lunokhod-2 (Luna-21)

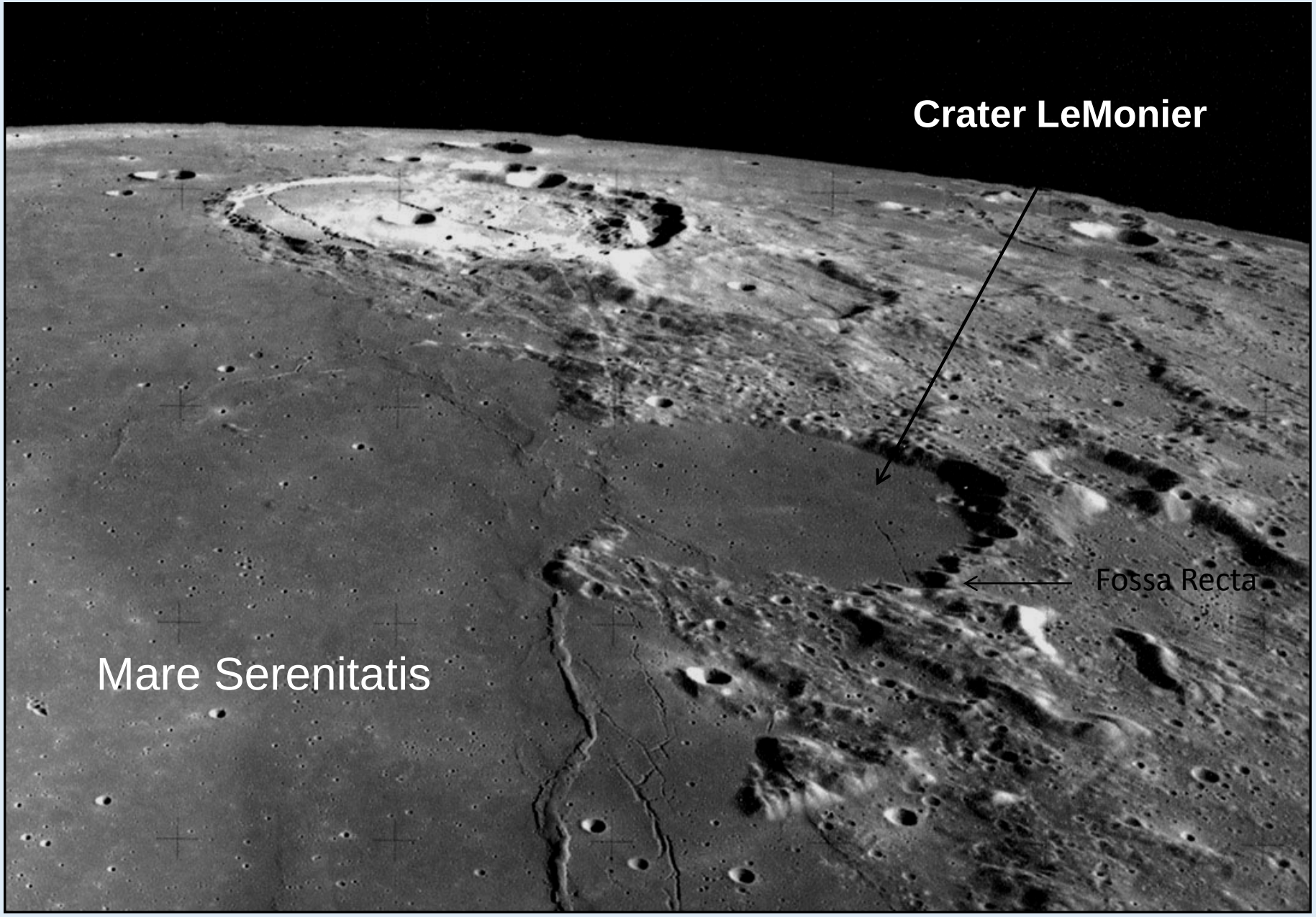
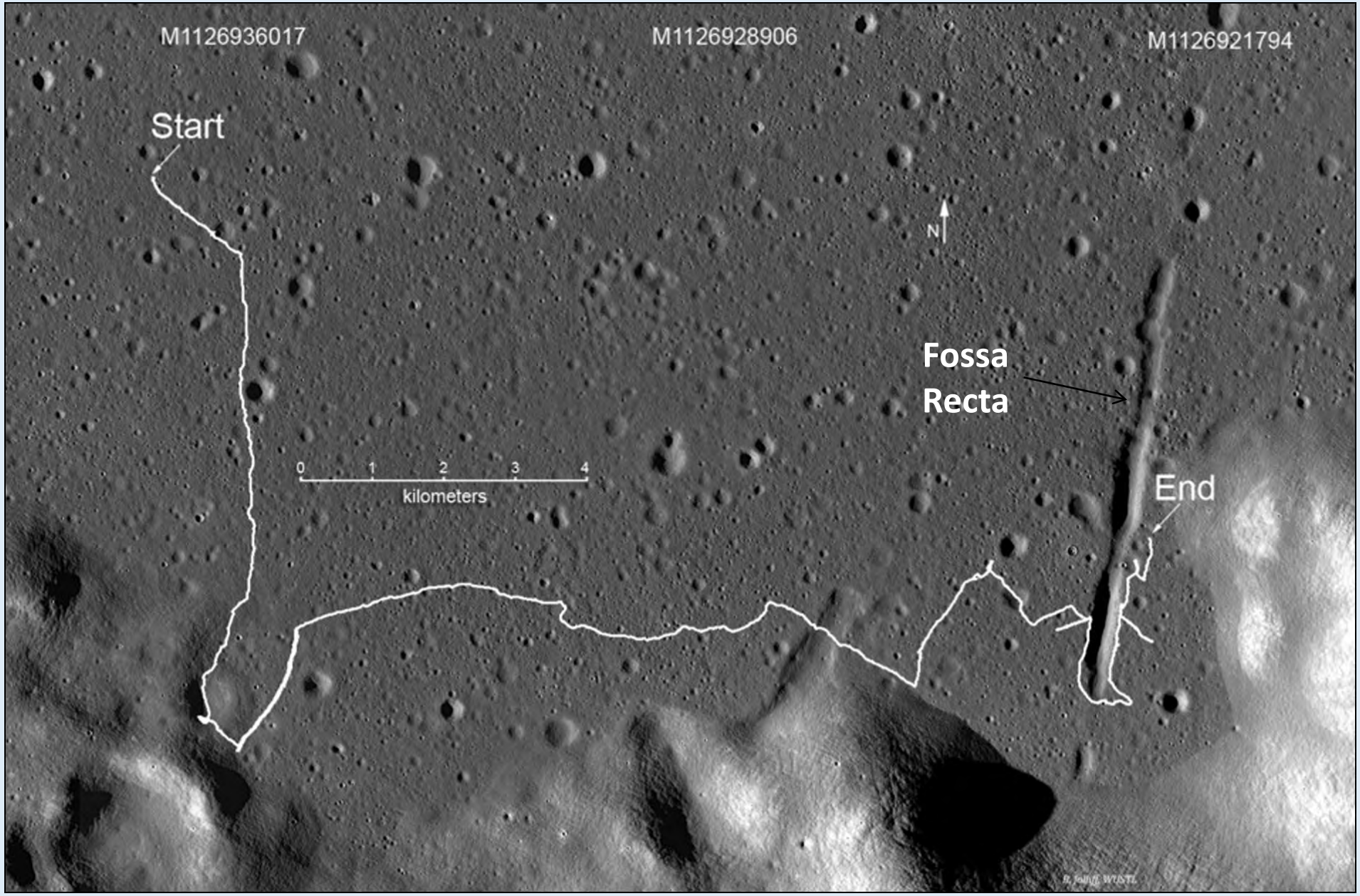


Photo of Apollo-17

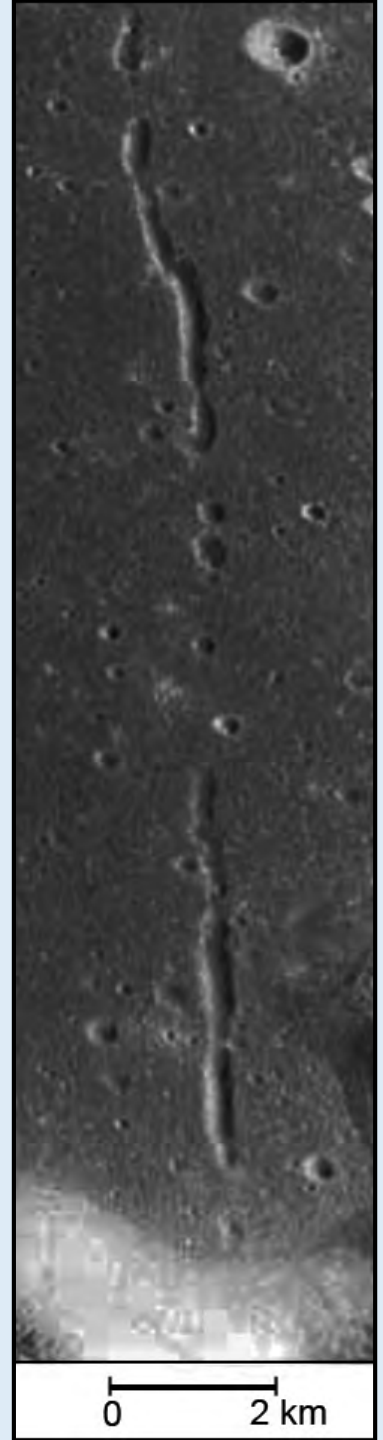
Route of Lunokhod-2 (superimposed on on the mosaic of LROC NAC images)



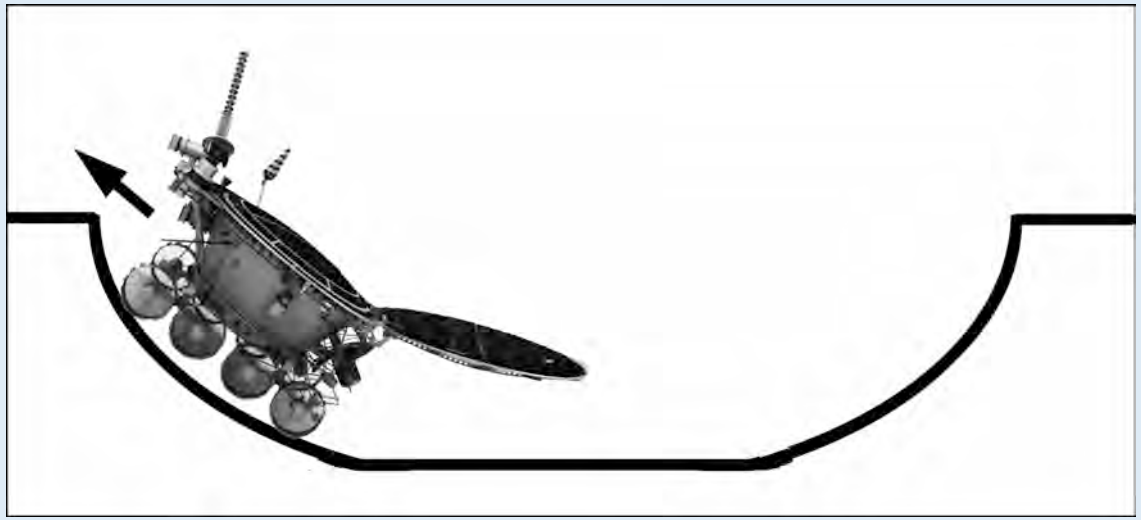
https://upload.wikimedia.org/wikipedia/ru/a/a7/Lunokhod_2_traverse-bmp.jpg

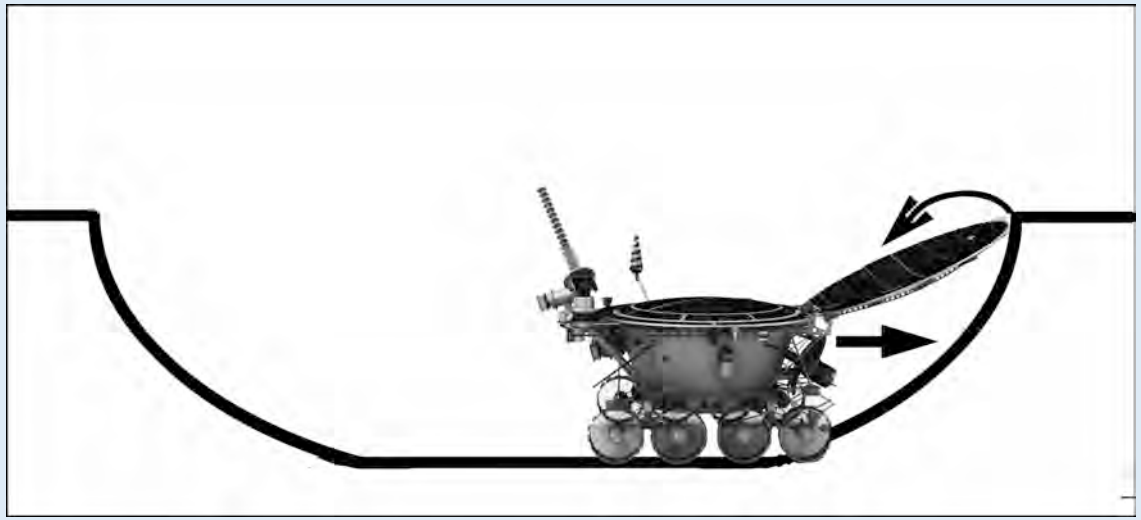
Landscape in crater LeMonier – mountains are close up

Fossa Recta graben with rocky outcrops at its edges



Fatal termination of Lunokhod 2 mission



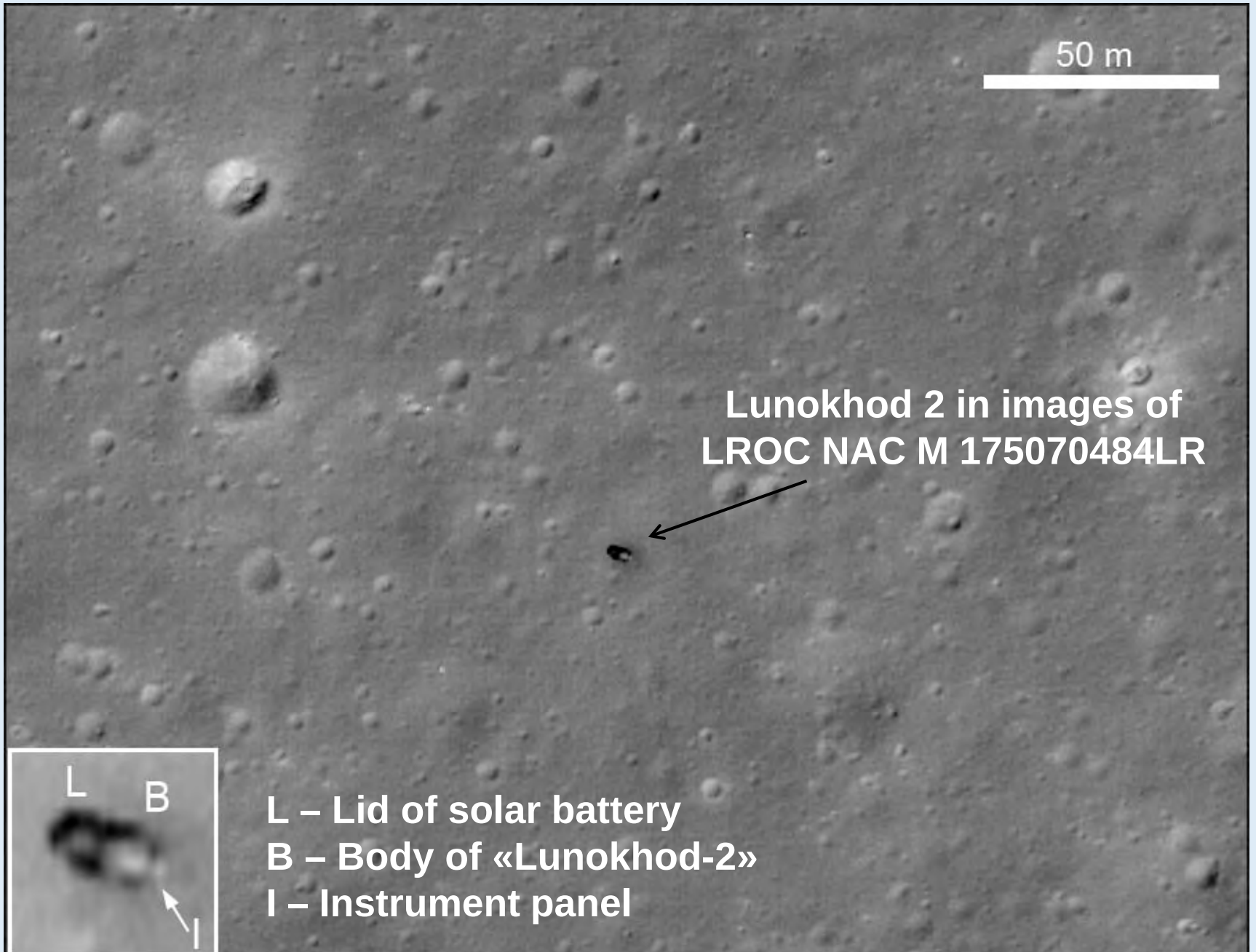


Sequence of prefatal events:

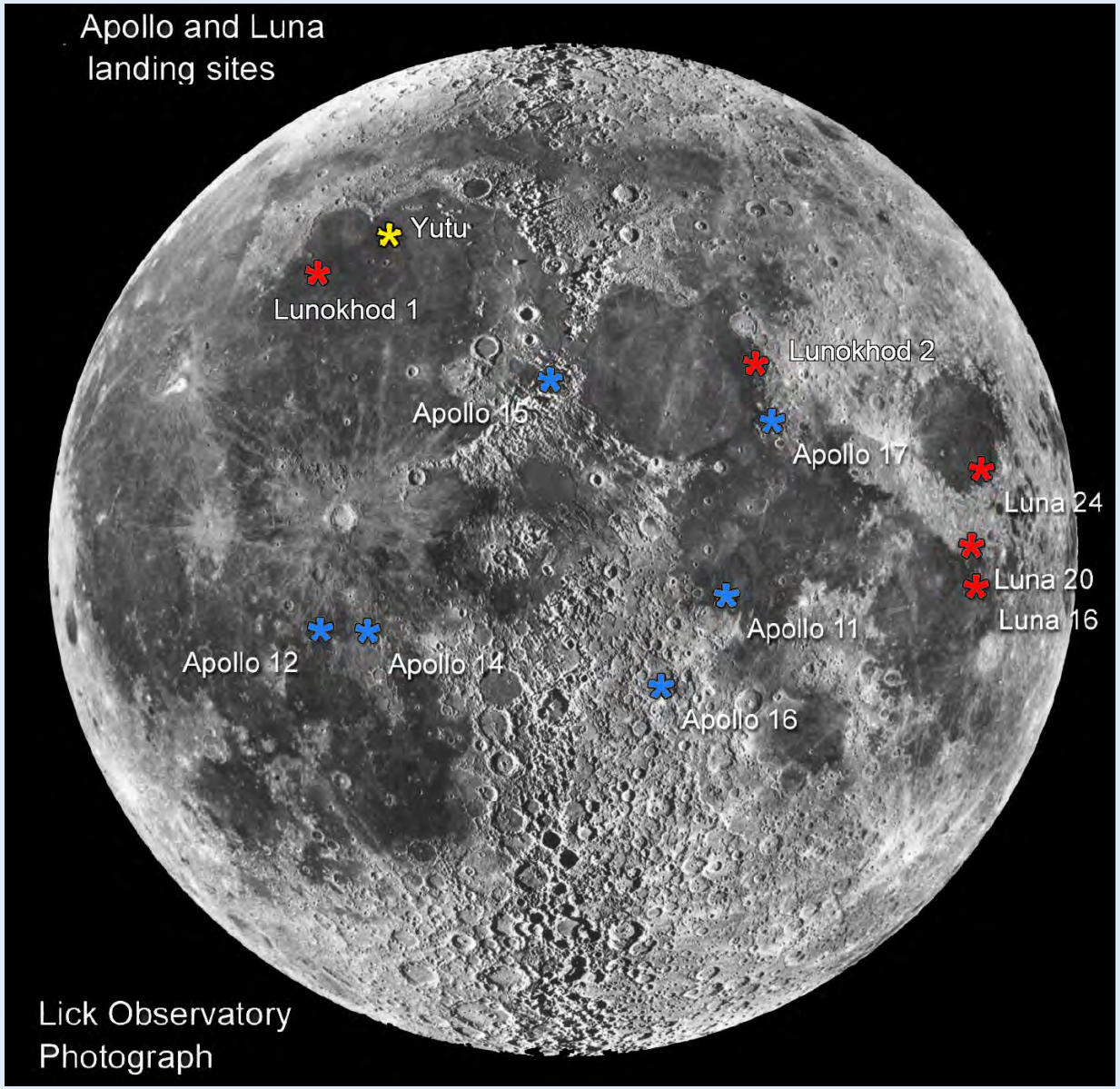
- On April 20, 1973 at the session # 411 the rover entered and maneuvered in the crater eastward of Fossa Recta with not closed solar battery lid.
- When getting out the crater lid touched upon the crater's rim and soil slipped down on the lid's surface.
- At the end of the 4-th lunar day before entering the lunar night the lid was closed and soil powdered the radiator.
- Its efficiency to radiate heat in space dropped down dramatically and at the beginning of 5-th lunar day the rover got overheated.

Morning landscape of the 5-th lunar day when Lunokhod-2 got overheated and radio communication terminated.

Lunokhod-2 at the eternal parking on the Moon



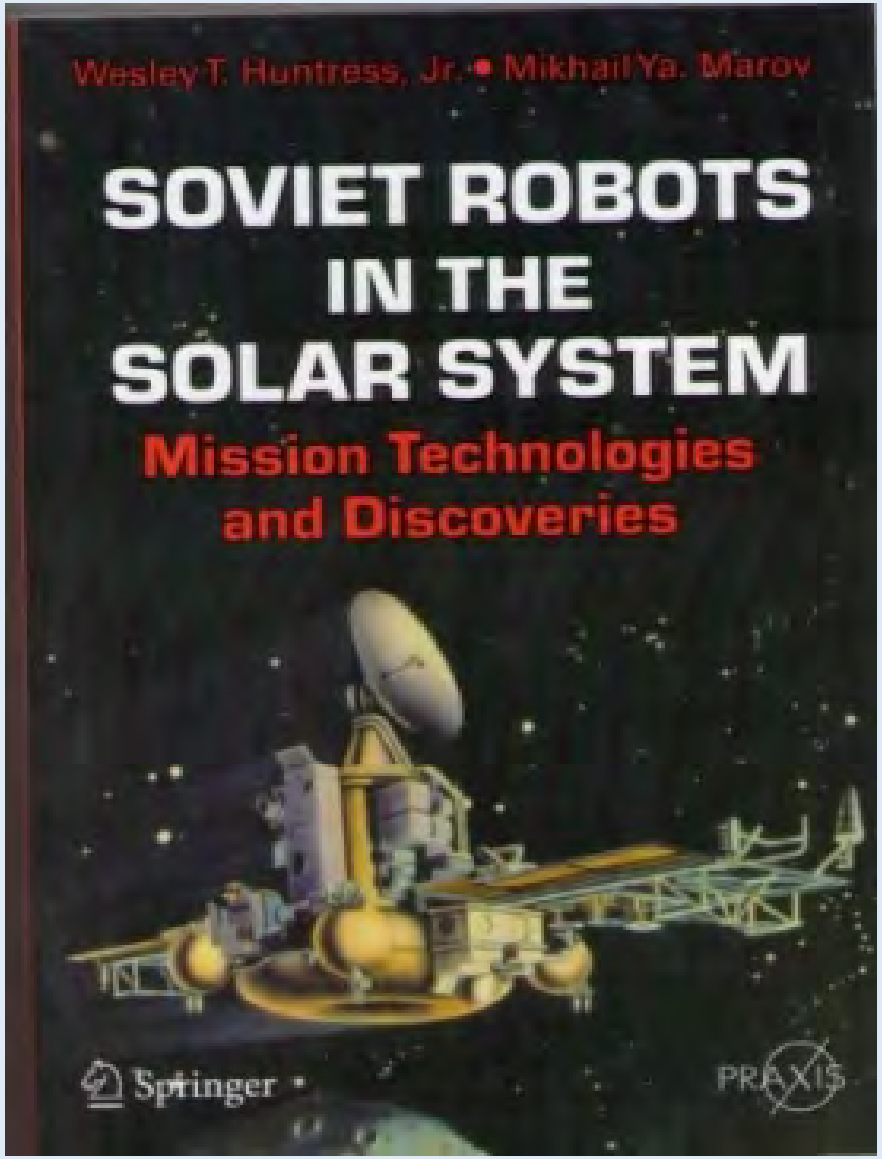
Apollo, Luna SR, Lunokhod, and Yutu 1 landing sites



- **Astronomers contributed to this process through the mapping planetary surface morphology and naming relief features in framework of the IAU Working Group of Planetary Science Nomenclature (WGPSN) activity.**

- **These activities allowed us to identify and select the site for safe landing on the Moon**

More Detailed History



INTERNATIONAL ACADEMY OF ASTRONAUTICS

BASIC SCIENCES BOOK AWARD

PRESENTED TO

Wesley T. Huntress, Jr. & Mikhail Ya. Marov

FOR OUTSTANDING ACHIEVEMENT AS EVIDENCED BY THE PUBLICATION OF

Soviet Robots in the Solar System.
Mission Technologies and Discoveries Springer-Praxis, New York, USA, 2011.

AWARDED THIS DAY OF September 30th, 2012. BY THE INTERNATIONAL ACADEMY OF ASTRONAUTICS.

S. M. Greenspoon
CHAIRMAN
BASIC SCIENCES SECTION

PRESIDENT
INTERNATIONAL ACADEMY OF ASTRONAUTICS

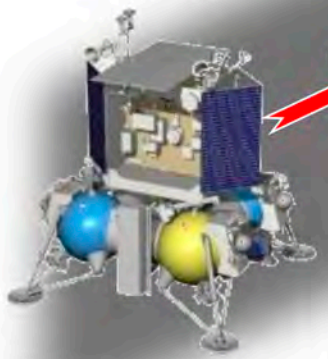
LUNAR PROGRAM

Lev Zelenyi
57th ESSC
Plenary Meeting,
Amsterdam,
May 9-10, 2019

1976

LUNA-24

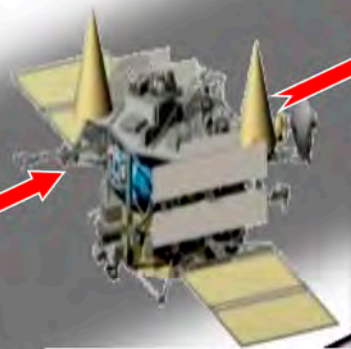
2021



LUNA-25

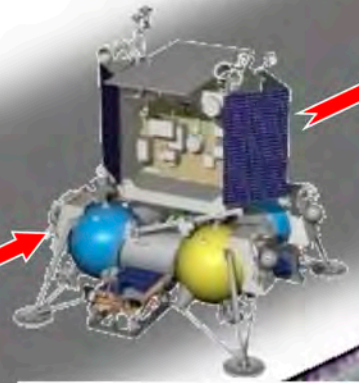
TECHNOLOGY OF POLAR SOFT LANDING, STUDY OF LUNAR SOUTH POLE (1450/530 KG)

2023-24

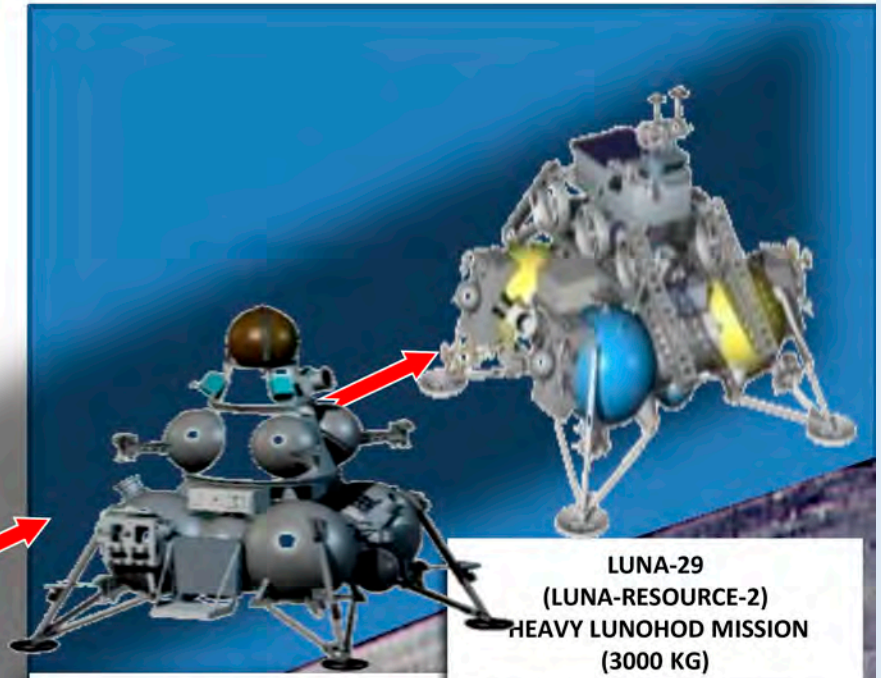


LUNA-26
GLOBAL ORBITAL STUDIES OF THE MOON

2024-2024



LUNA-27
STUDIES OF SOUTH POLE REGOLITH AND EXOSPHERE (2200/810 KG)

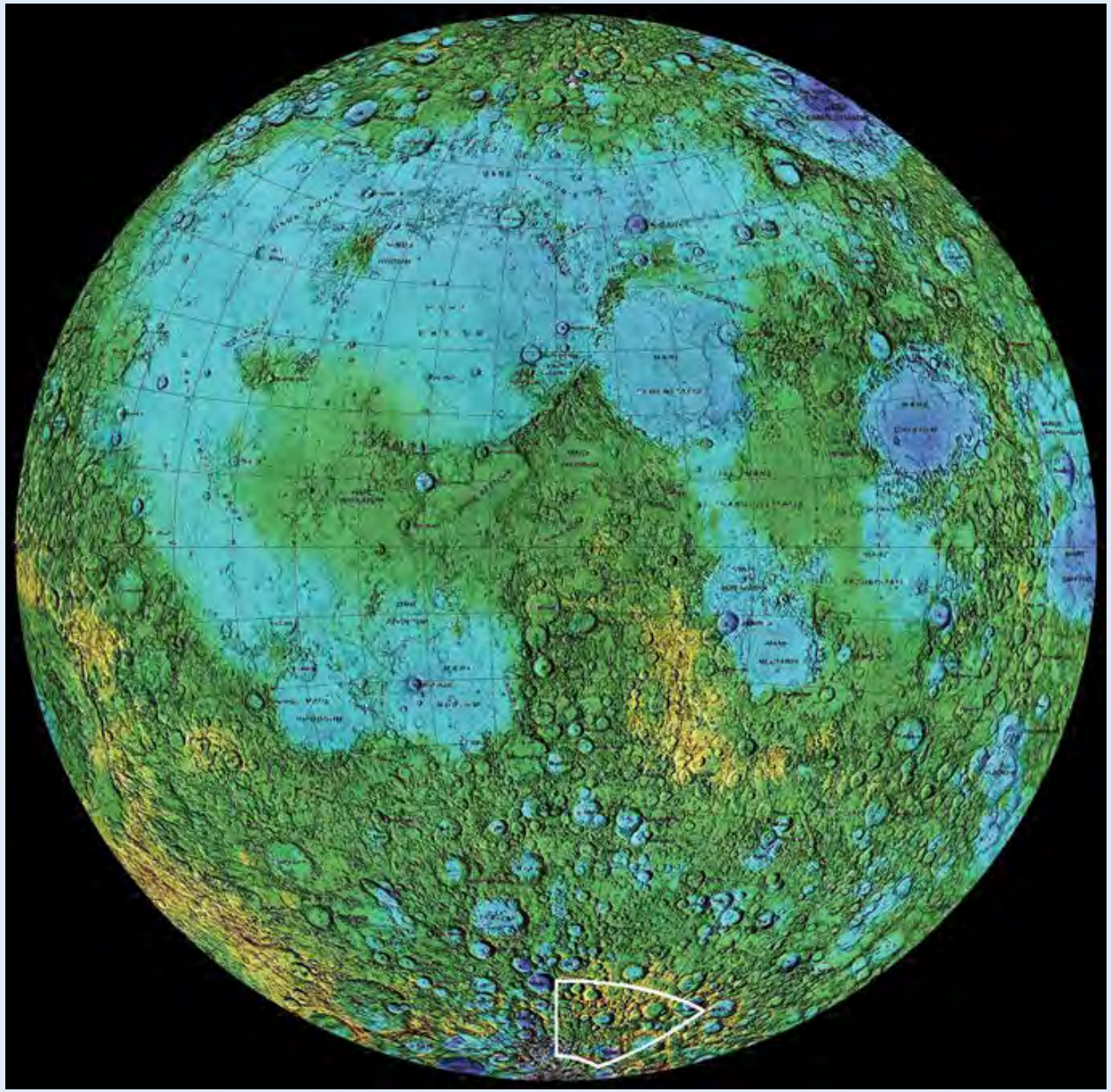


LUNA-28
(LUNA-GRUNT)
CRYOGENIC SAMPLES RETURN FROM SOUTH POLE
(3000 KG)

LUNA-29
(LUNA-RESOURCE-2)
HEAVY LUNOHOD MISSION
(3000 KG)

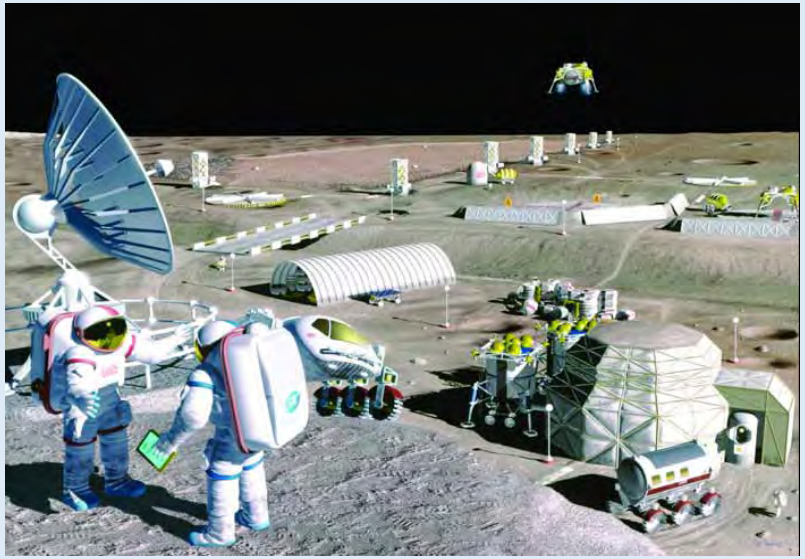
ESA CONTRIBUTIONS

South Pole: Provinces of the Main Interest

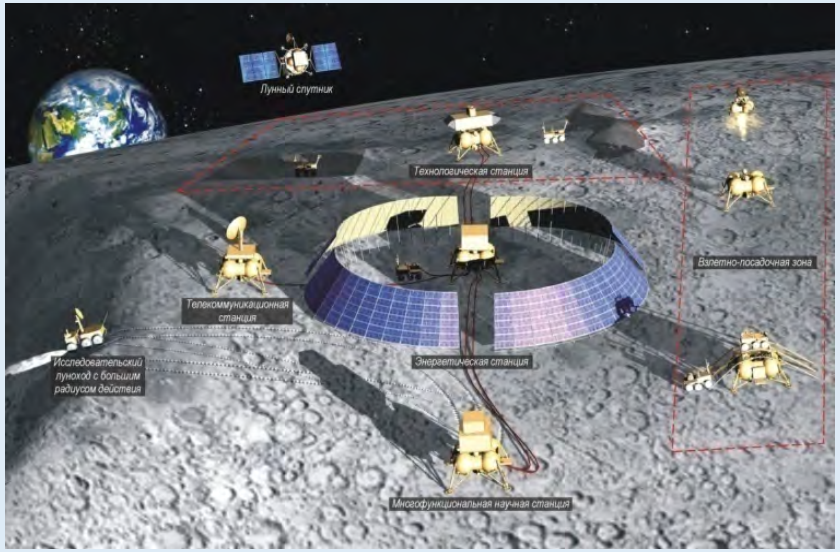


- **Water ice and other volatiles abundance, mostly in the permanently shadowing craters.**
- **Possible traces of organic compounds.**
- **Perspective for Lunar Base deployment.**
- **Growing responsibility of astronomers/geologists for an accurate sites selection to accommodate both safety and utilization requirements.**

Lunar Base Projects



NASA Concept



ROSCOSMOS Concept

Subsurface LB Deployment

Conclusions

- The Moon race was one of the most exiting milestones in space exploration.
- USSR yielded USA in an ambitious endeavor to step down on the Moon surface, which were made successfully with the six Apollo flights.
- Instead, Soviets have undertaken robotic missions to the Moon with three successful Luna sample return and two Lunokhod rover missions.
- Both Apollo human and Luna robotic missions greatly advanced the lunar and planetary sciences.
- Astronomers contributed to this process through the mapping planetary surface morphology and naming relief features in framework of the IAU Working Group of Planetary Science Nomenclature (WGPSN) activity.
- These activities allowed us to identify and select the site for safe landing on the Moon and paved the road to the future Moon exploration/exploitation.
- The experience gained at the WGPSN is invaluable legacy of the international cooperation and in particular, in resolving complicated scientific-cultural and political problems and is addressed as a good example of astronomers' actions as diplomats.