Soviet Lunas and Lunokhods: History of studies and scientific results

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with the help of

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Macau University of Science and Technology
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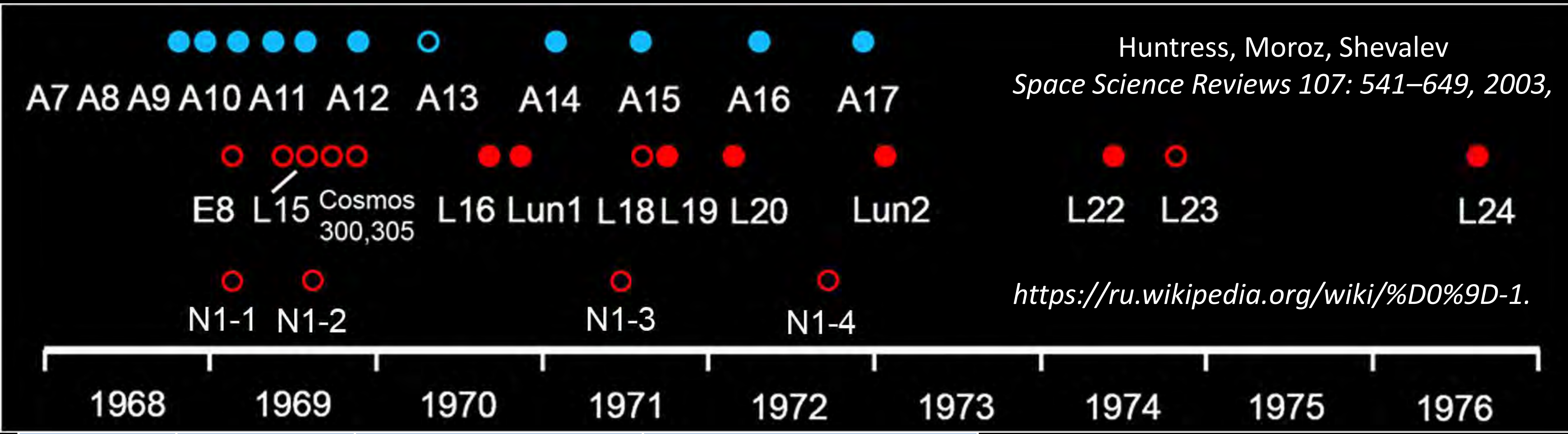
Space race 1968-1976: N1-L3 + Lunas v.s. Apollos

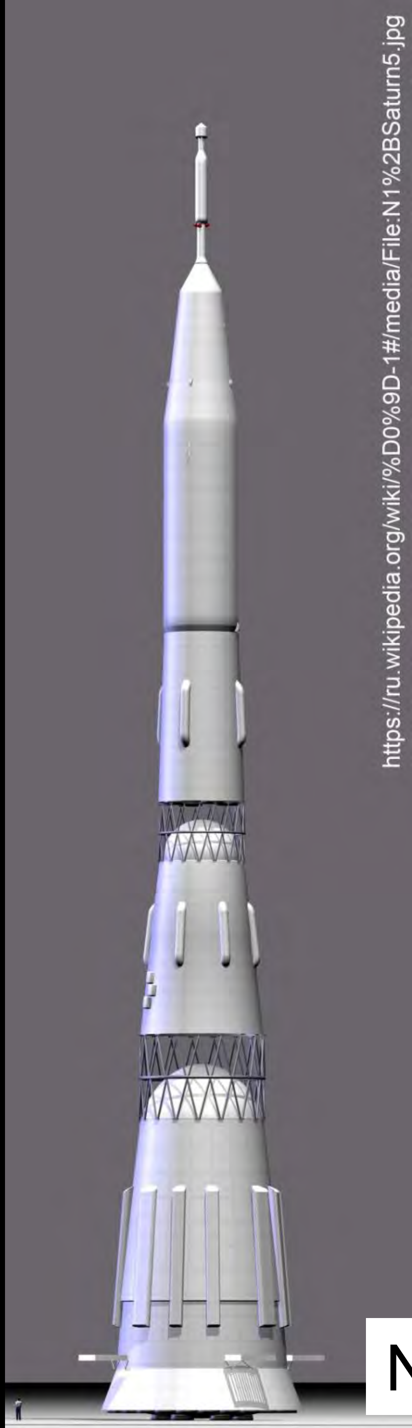


Name	Date of launch	Mission	Succ
Apollo 7	Oct 11, 1968	Prep. to land the Moon	Orbi
Apollo 8	Dec 21, 1968	Prep. to land the Moon	Orbi
Apollo 9	March 3, 1969	Prep. to land the Moon	Orbi
Apollo 10	May 18, 1969	Prep. to land the Moon	Orbi
Apollo 11	July 16, 1969	Landing on the Moon	Stud
Apollo 12	Nov 14, 1969	Landing on the Moon	Stud
Apollo 13	April 11, 1970	Landing on the Moon	Abor
Apollo 14	Jan 31, 1971	Landing on the Moon	Stud
Apollo 15	July 26, 1971	Landing on the Moon	Stud Imbr
Apollo 16	Apr 16, 1972	Landing on the Moon	Stud Plate
Apollo 17	Dec 7, 1972	Landing on the Moon	Stud

Name	Date of launch	Mission	Success
E8-201	Feb 19, 1969	Lunokhod 0	Crushed during liftoff
E8-5-402	June 14, 1969	Sample return	4th stage rocket failed to ignite
Luna 15	July 13, 1969	Sample return	Crashed at landing on the Moon
Cosmos 300	Sept 23, 1969	Sample return	4th stage rocket failed to ignite
Cosmos 305	Oct 22, 1969	Sample return	4th stage misfired
Luna 16	Sept 12, 1970	Sample return	Sample from Mare Fecunditatis
Luna 17	Nov 10, 1970	Lunokhod 1	Lunokhod studied Mare Imbriuum
Luna 18	Sept 2, 1971	Sample return	Crashed at landing on the Moon
Luna 19	Sept 28, 1971	Lunar orbiter	Orbital studies, gravity etc.
Luna 20	Feb 14, 1972	Sample return	Sample from Cris-Fecund highland
Luna 21	Jan 8, 1973	Lunokhod 2	Lunokhod studied Mare Serenitatis
Luna 22	May 29, 1974	Lunar orbiter	Orbital studies, gravity etc.
Luna 23	Oct 28, 1974	Sample return	Crashed at landing on the Moon
Luna 24	Aug 8, 1976	Sample return	Sample / core from Mare Crisium

Soviet manned expedition to the Moon (N1-L3) – did not happen

2 cosmonauts fly to the Moon, one stays in orbital module, another one lands, works, collects samples and returns to the orbital module.
Work on the mission 1962-1976,
All 4 test launches of N1 failed.



N1

Chief designer Sergey P. Korolev

https://upload.wikimedia.org/wikipedia/commons/thumb/1/19/Landef%C3%A4hren-neu.jpg/1280px-Landef%C3%A4hren-neu.jpg

N1-L3 and Apollo landers

Selection & characterization of landing sites for the Soviet manned expedition to the Moon by analysis of Lunar Orbiter high-res photos.

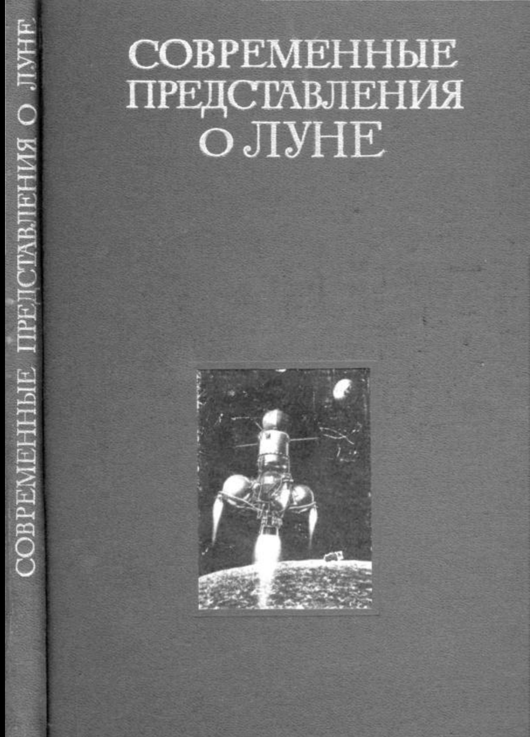
1967-1969

Space Research Institute, Moscow, USSR

Division of Geology of the Moon

Head – Cyrill Florenscky

4 sites were selected & characterized



Modern concepts of the Moon, Nauka, Moscow, 1972

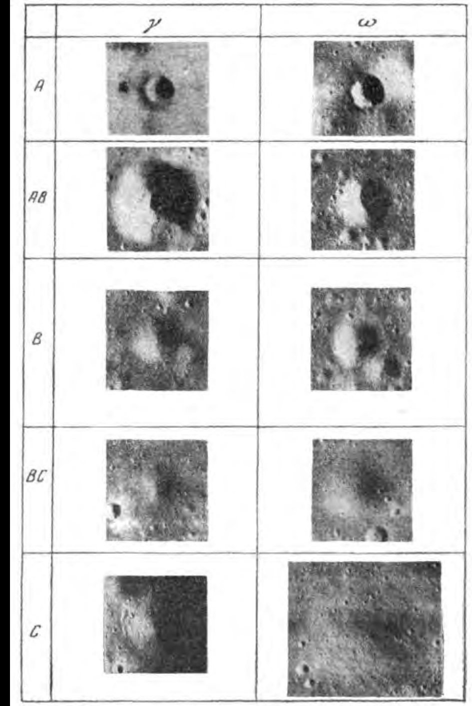


Рис. 1. Фотографии типичных кратеров разных групп, выделенных по пятибалльной системе

Morphologic classes of small craters

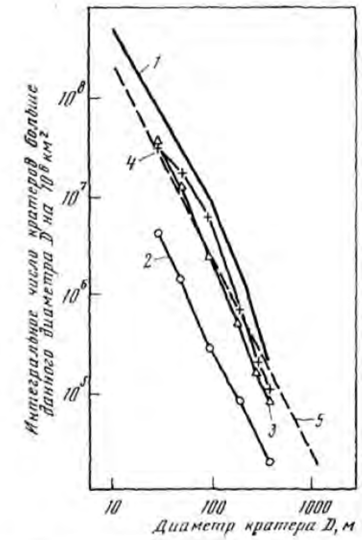


Рис. 7. Распределение по размеру кратеров разных классов в районе Океана Бурь

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

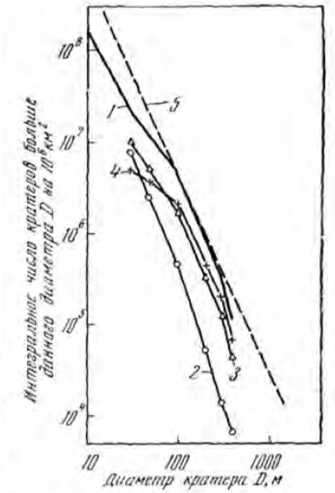


Рис. 8. Распределение по размеру кратеров разных классов в районе Залива Центрального

Условные обозначения те же, что и на рис. 7

Spatial densities of small craters in Oceanus Procellarum and Sinus Medii

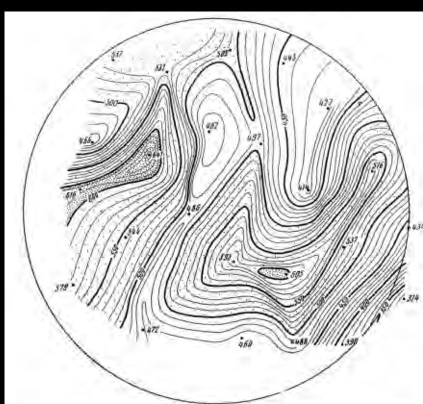


Рис. 4. Карта изоденс для кратеров диаметром более 10 м на площадку радиусом 15 км в Заливе Центральном. Площадь нормирования 1 км²

Цифры обозначают плотности кратеров в окнах опробования площадью 1,44 км², отнесенные к центру этих окон

Areal variations of spatial density of craters

Results of morphologic analysis of Lunar Orbiter photos became to be a basis for subsequent work with the Luna-Lunokhods

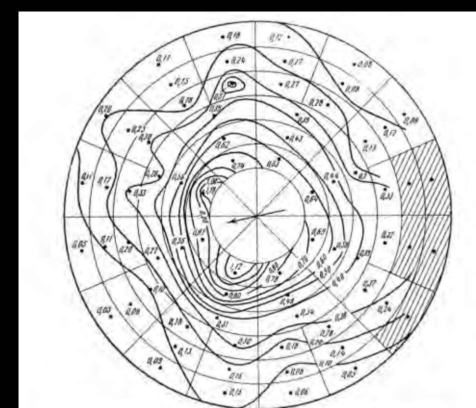


Рис. 14. Плотность распределения камней диаметром более 2 м около кратера № 1

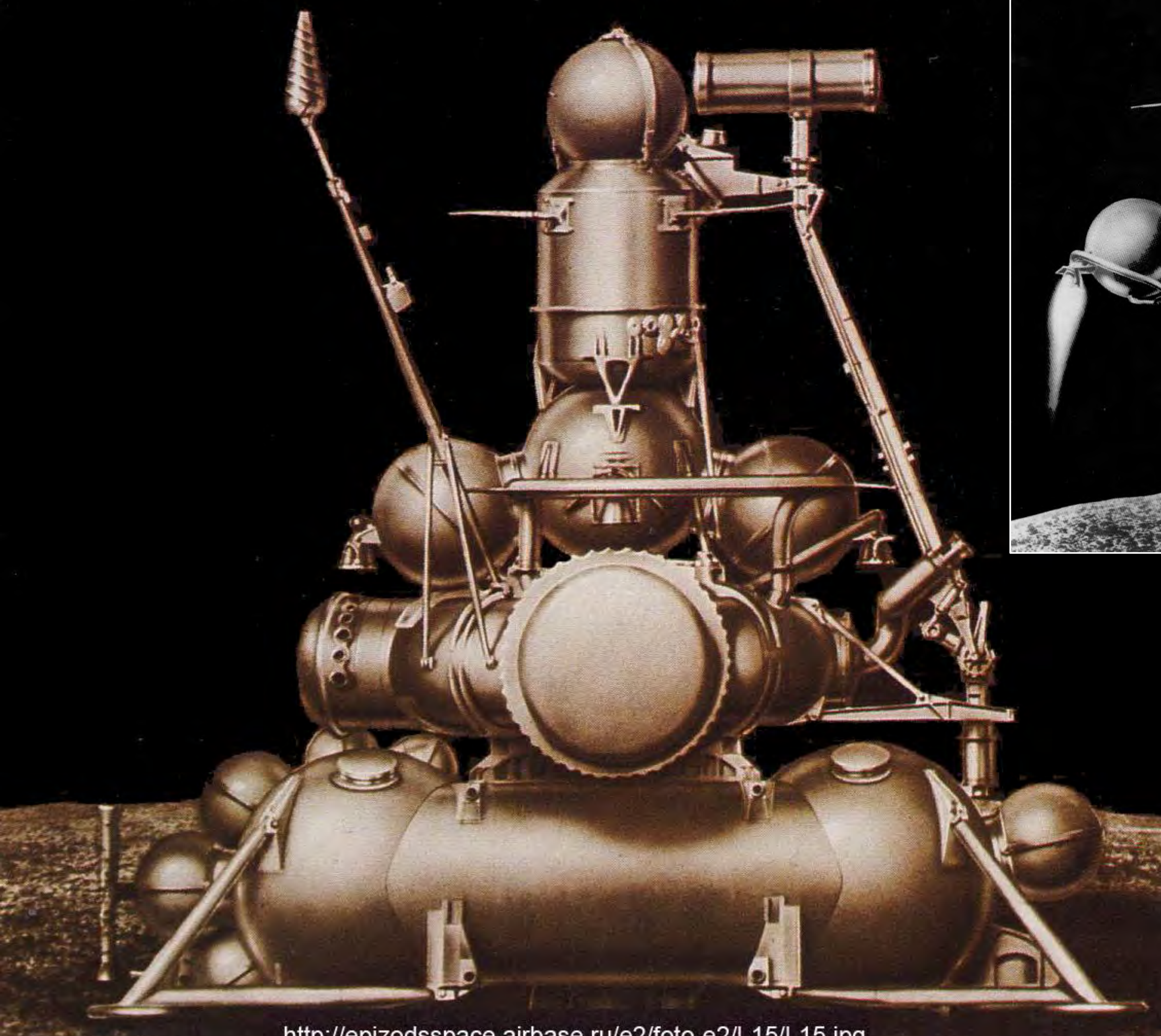
Цифры — число камней, нормированное на 100 м². Концентрические линии проведены через 0,25 диаметра кратера

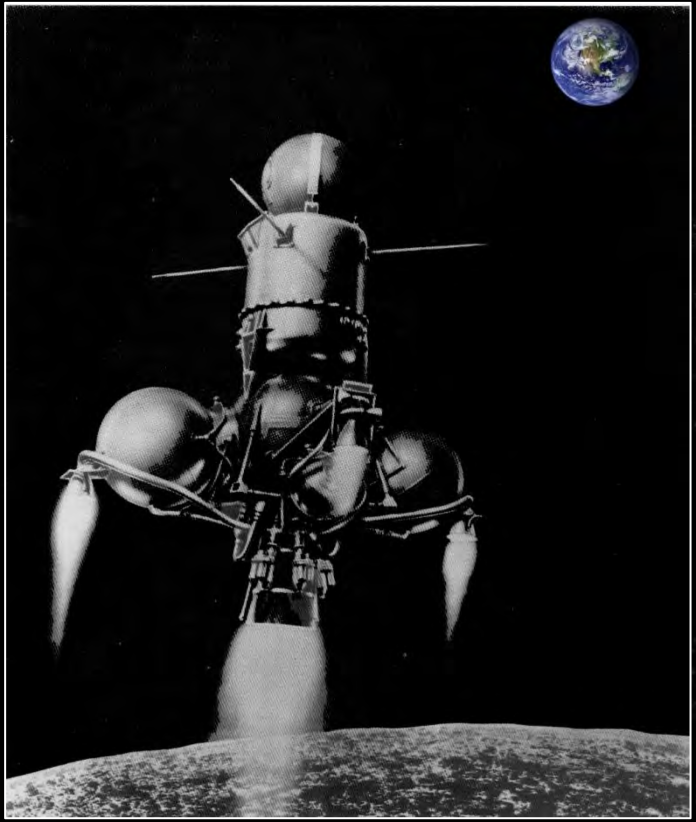
Areal variations of spatial density of rock fragments

Project E-8:
Third generation of the Soviet missions to the Moon: 1969-1976

Name	Date of launch	Mission	Success
E8-201	Feb 19, 1969	Lunokhod 0	Crushed during liftoff
E8-5-402	June 14, 1969	Sample return	4^{th} stage rocket failed to ignite
Luna 15	July 13, 1969	Sample return	Crashed at landing on the Moon
Cosmos 300	Sept 23, 1969	Sample return	4^{th} stage rocket failed to ignite
Cosmos 305	Oct 22, 1969	Sample return	4^{th} stage misfired
Luna 16	**Sept 12, 1970**	**Sample return**	**Sample from Mare Fecunditatis**
Luna 17	**Nov 10, 1970**	**Lunokhod 1**	**Lunokhod studied Mare Imbriuum**
Luna 18	Sept 2, 1971	Sample return	Crashed at landing on the Moon
Luna 19	Sept 28, 1971	Lunar orbiter	Orbital studies, gravity etc.
Luna 20	**Feb 14, 1972**	**Sample return**	**Sample from Cris-Fecund highland**
Luna 21	**Jan 8, 1973**	**Lunokhod 2**	**Lunokhod studied Mare Serenitatis**
Luna 22	May 29, 1974	Lunar orbiter	Orbital studies, gravity etc.
Luna 23	Oct 28, 1974	Sample return	Crashed at landing on the Moon
Luna 24	**Aug 8, 1976**	**Sample return**	**Sample / core from Mare Crisium**

Project E8-5: Robotic sample return





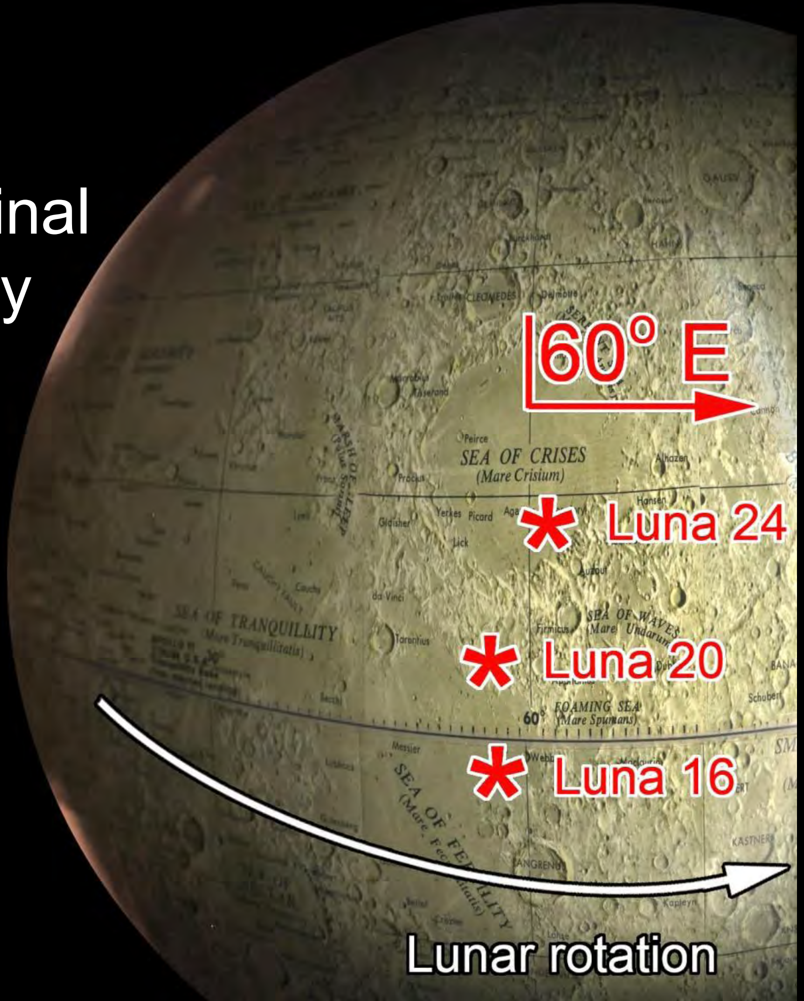
http://epizodsspace.airbase.ru/e2/foto-e2/l-15/l-15.jpg

Major difficulty in realization:

- The payload which we could deliver to the lunar surface was not able to bring back to Earth the capsule with lunar samples: Not enough mass, problems with mid-course corrections, ...

- The solution was suggested by the Lavochkin employee Yuli Volokhov: To lift off vertically from narrow latitudinal zone (changing with time but generally close to lunar equator) and if the velocity is enough the capsule will reach Earth without correction.

- To reach the necessary velocity the lift-off should be in the far eastern longitudes. Then rotation of the Moon provides the additional velocity.



Robotic sample returns:

Luna 15 lander launch 13 July 1969

Attempt of robotic sample return, crashed on 21 July

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

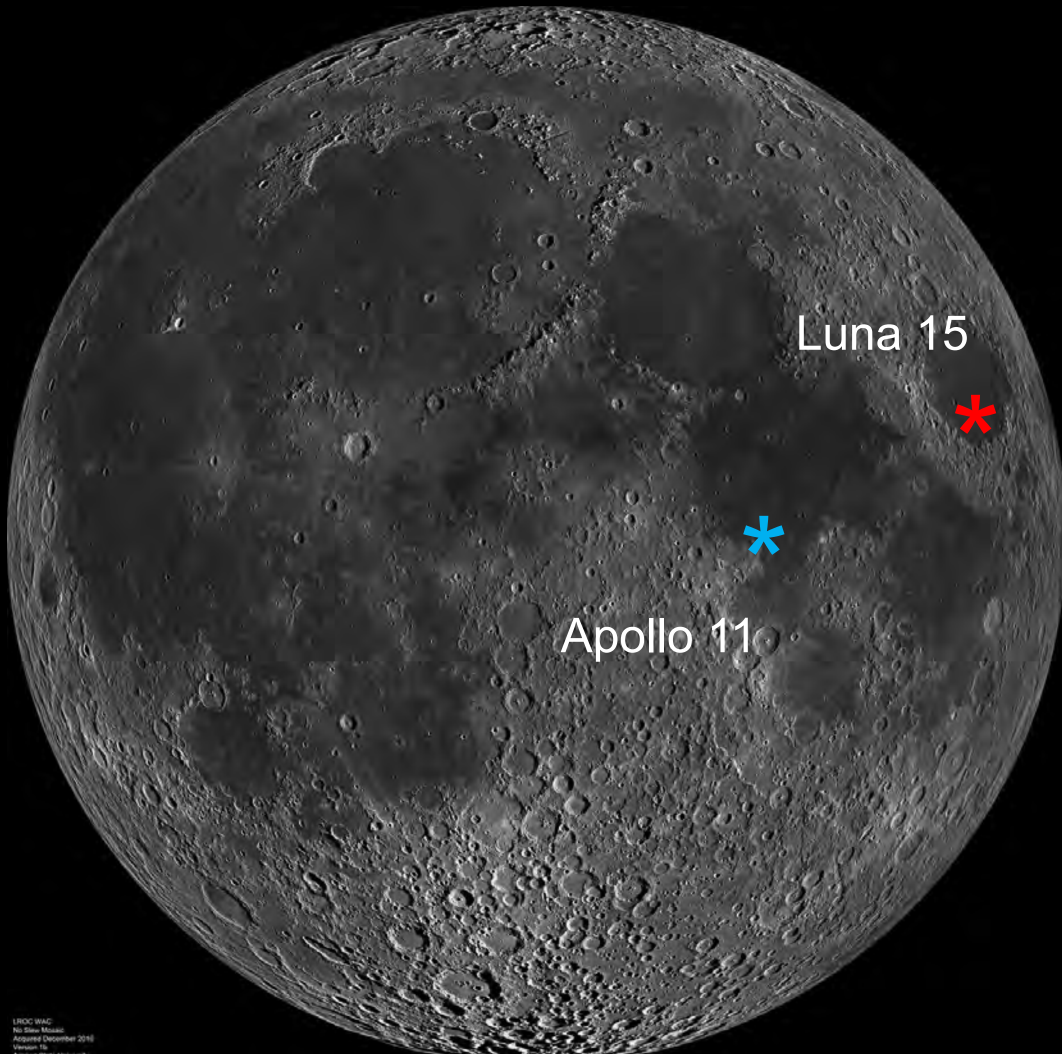
Failed attempt of robotic sample return from Mare Crisium. The spacecraft was damaged at landing and could not function properly.

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) race with Apollo 11 (July 16-24, 1969)

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

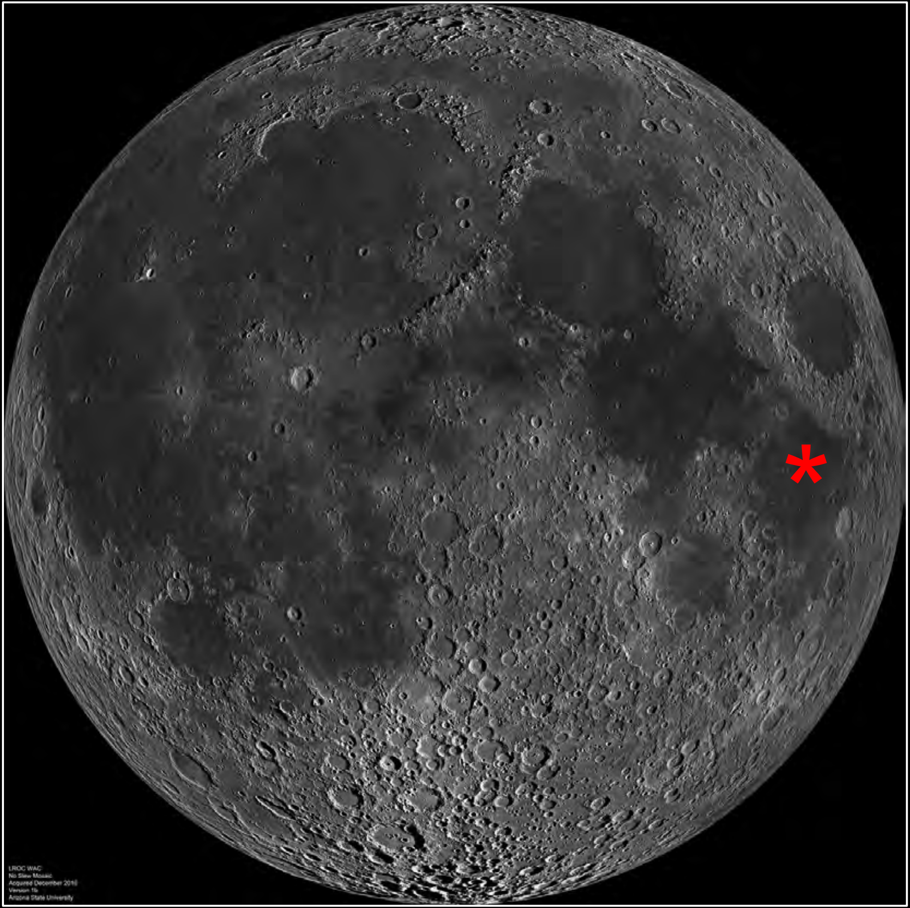


Luna 16 sample return

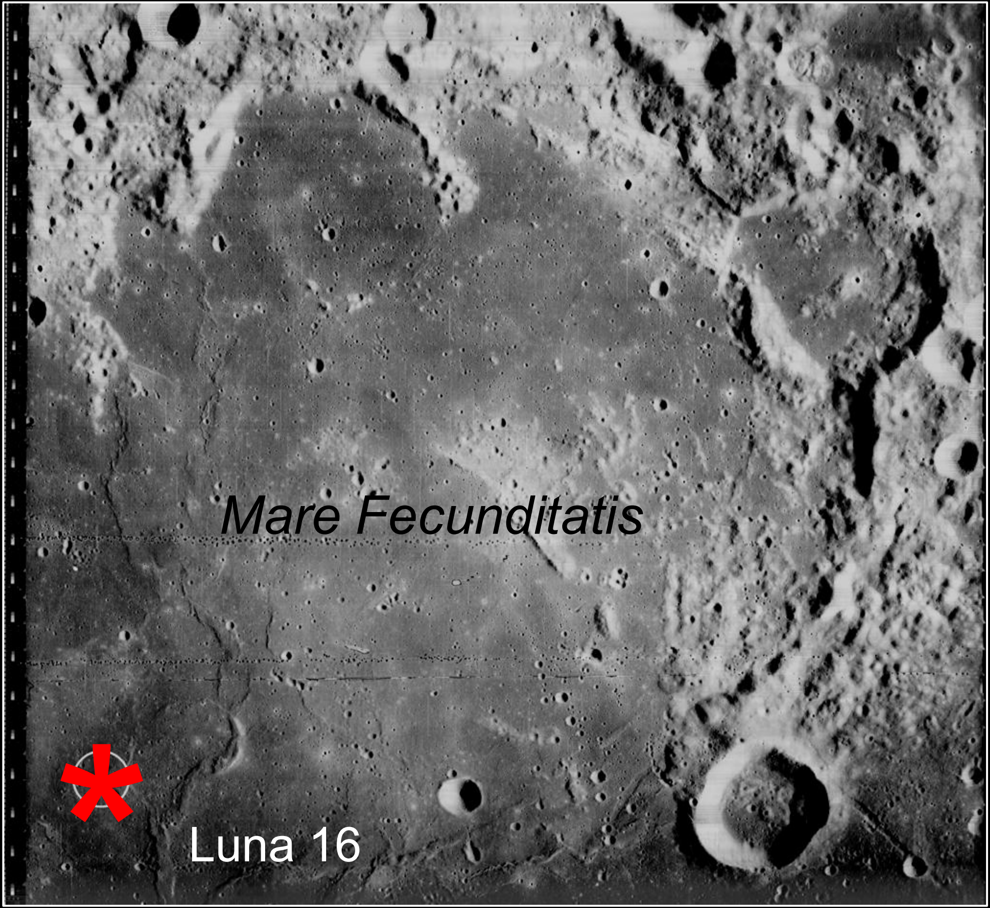
Launch - on Sept. 12, landed on Sept. 20 in Mare Fecunditatis.

Capsule back on Earth on Sept. 24, 1970

First successful robotic sample return. Aluminous basalts. 101 g.



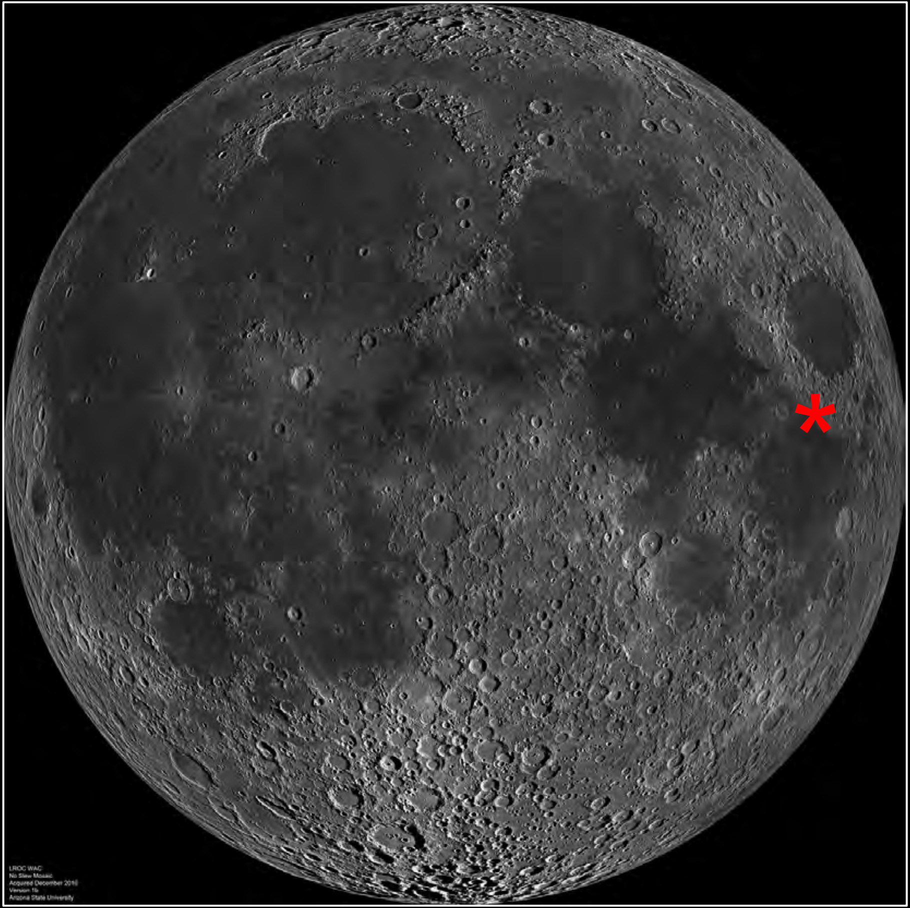
Moon nearside LROC WAC map



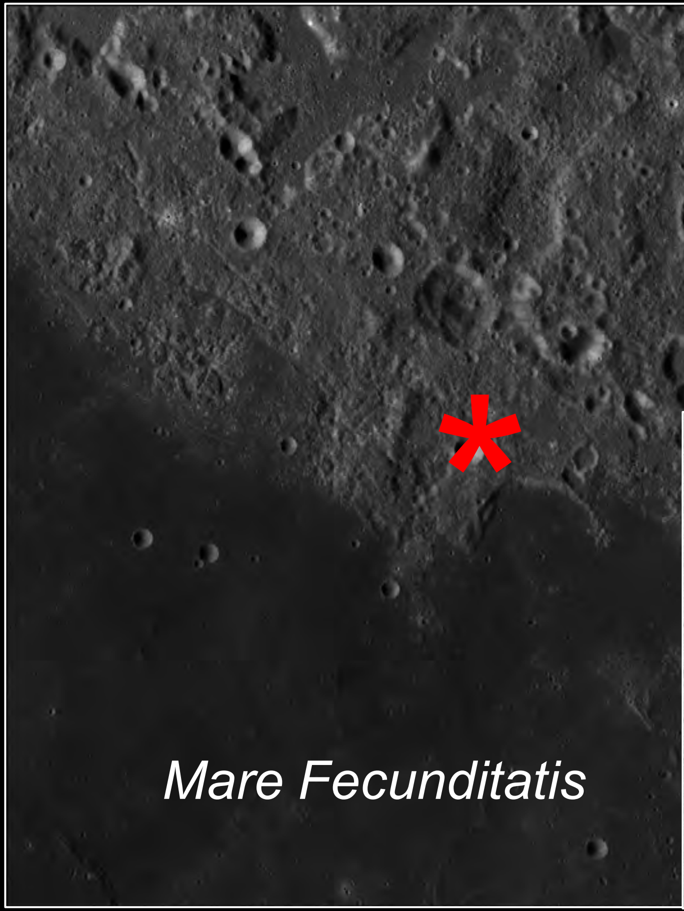
Lunar Orbiter 1 Photo 1034_med

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

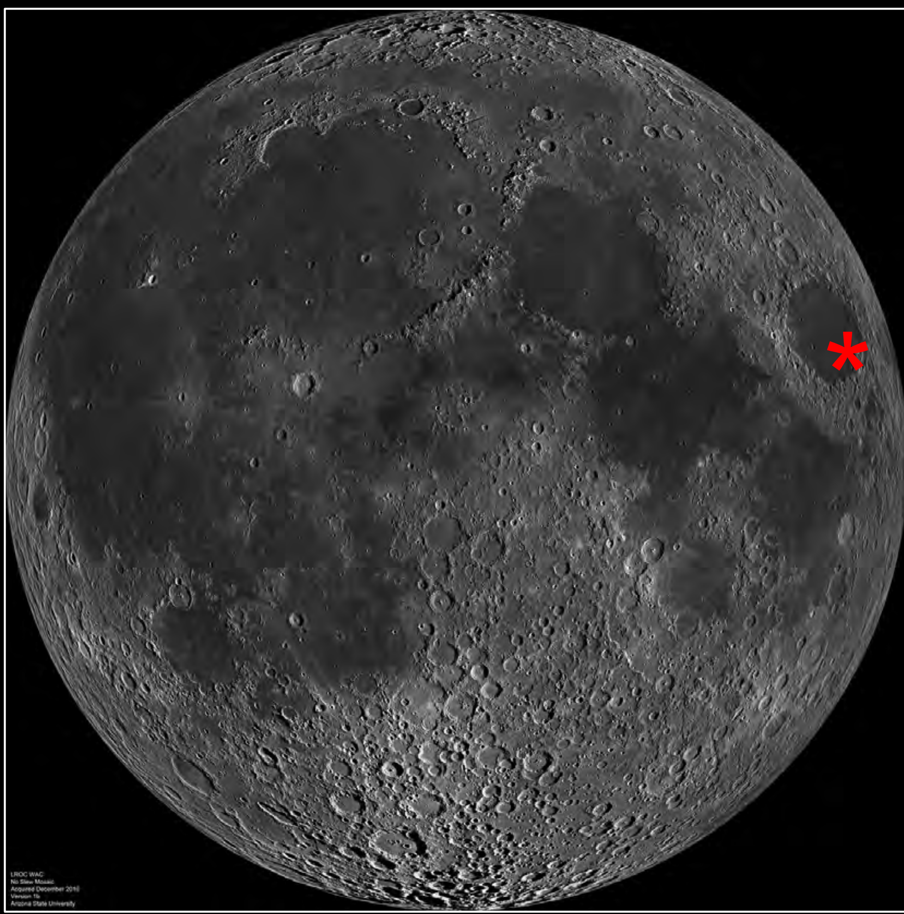
Sampling spot

Luna 24 sample return

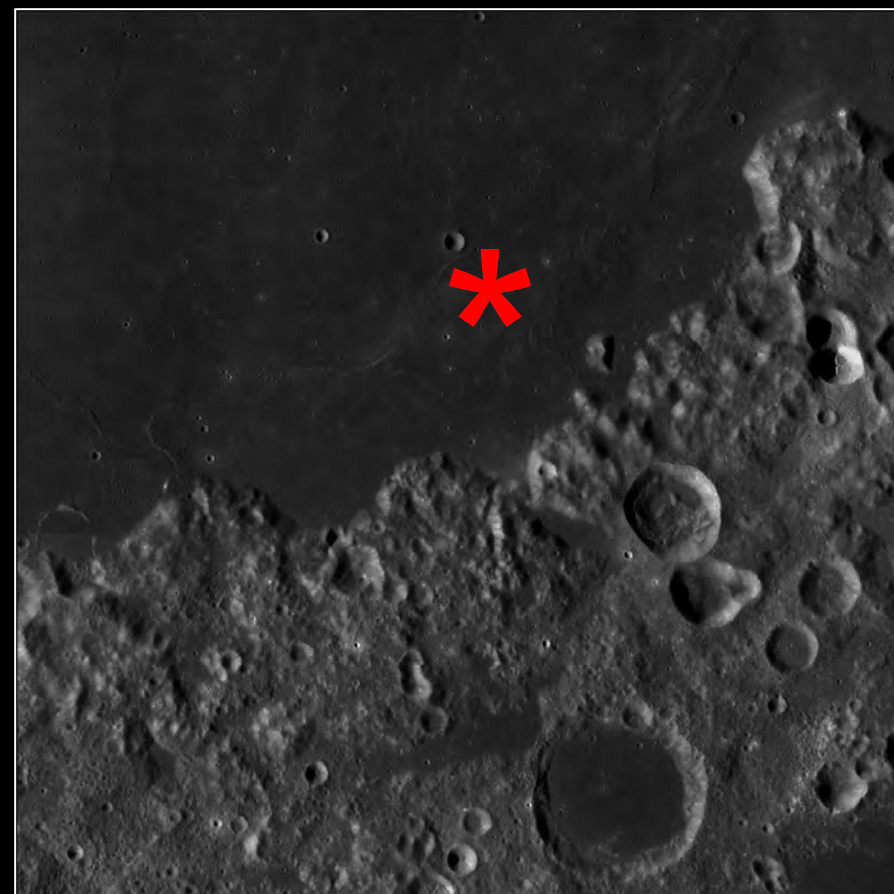
Launch - on August 9, landed on August 18 in Mare Crisium.

Capsule back on Earth on August 22, 1976

Third successful robotic sample return: Very low-Ti basalts. 170 g.



Moon nearside LROC WAC map



LROC WAC mosaic

Luna 16, 20, 24 back on Earth

https://www.laspace.ru/projects/planets/luna-16/

Returned samples of 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.

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.

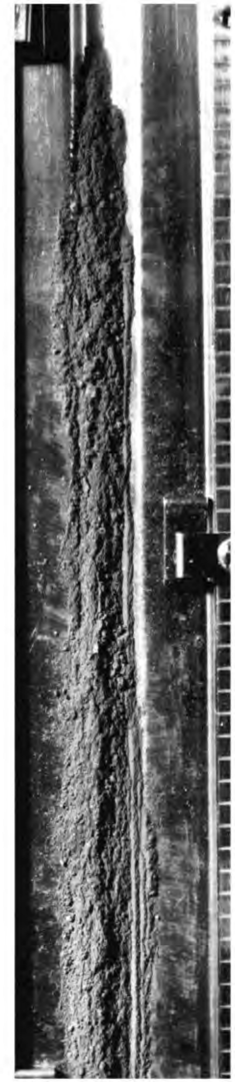
Luna 24

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

top

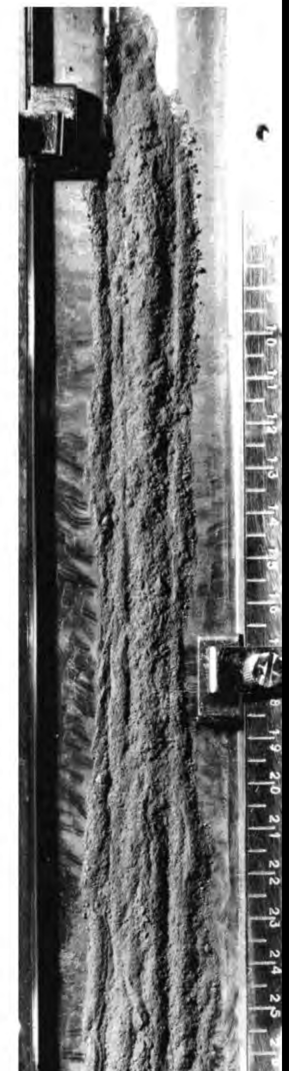
~ 75 cm

~ 77 cm



~ 97 cm

~102 cm

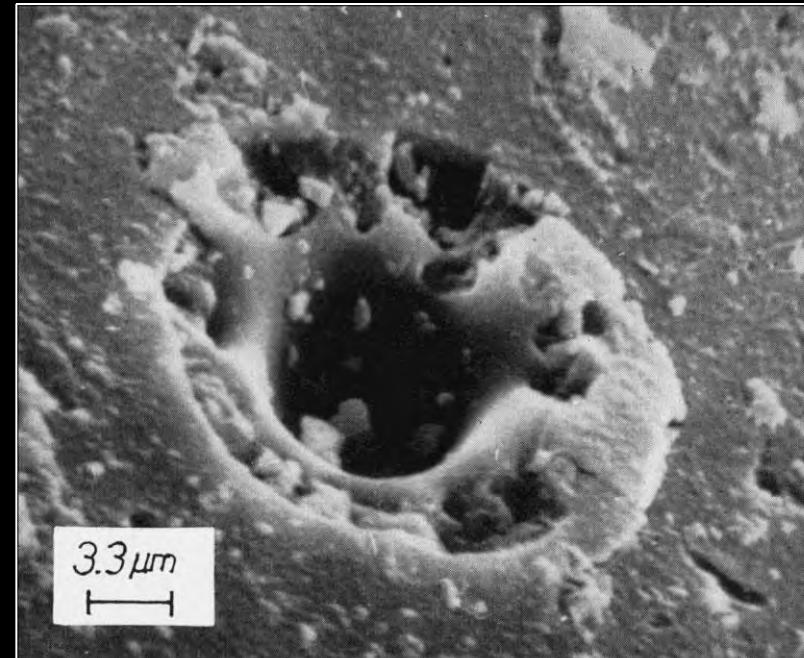


~ 125 cm

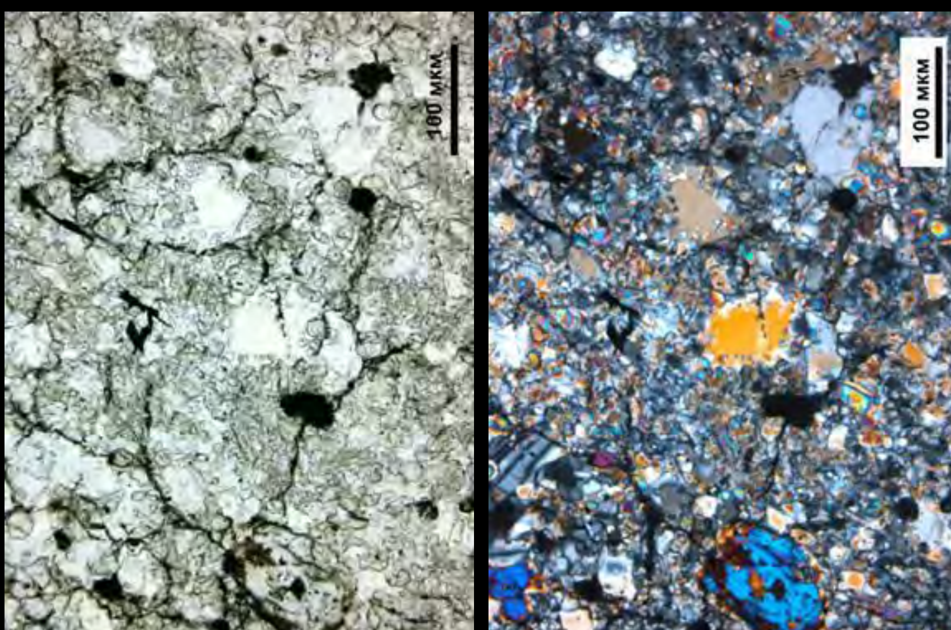
Luna 16 basalt thin section

Returned samples

Luna 16 microcrater electr. microscopy



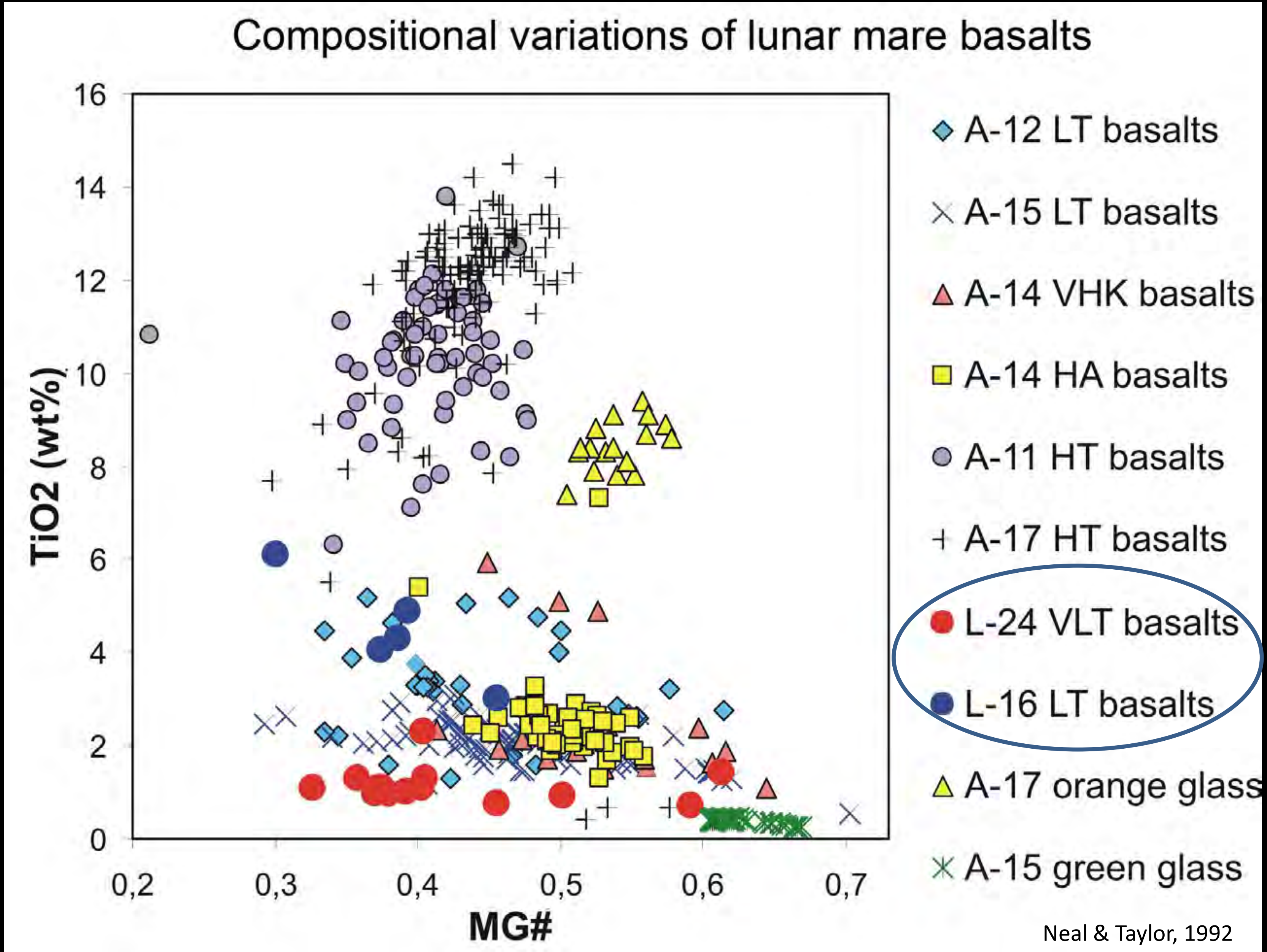
Luna 20 granulitic breccia thin section



http://www.meteorites.ru/menu/moon/

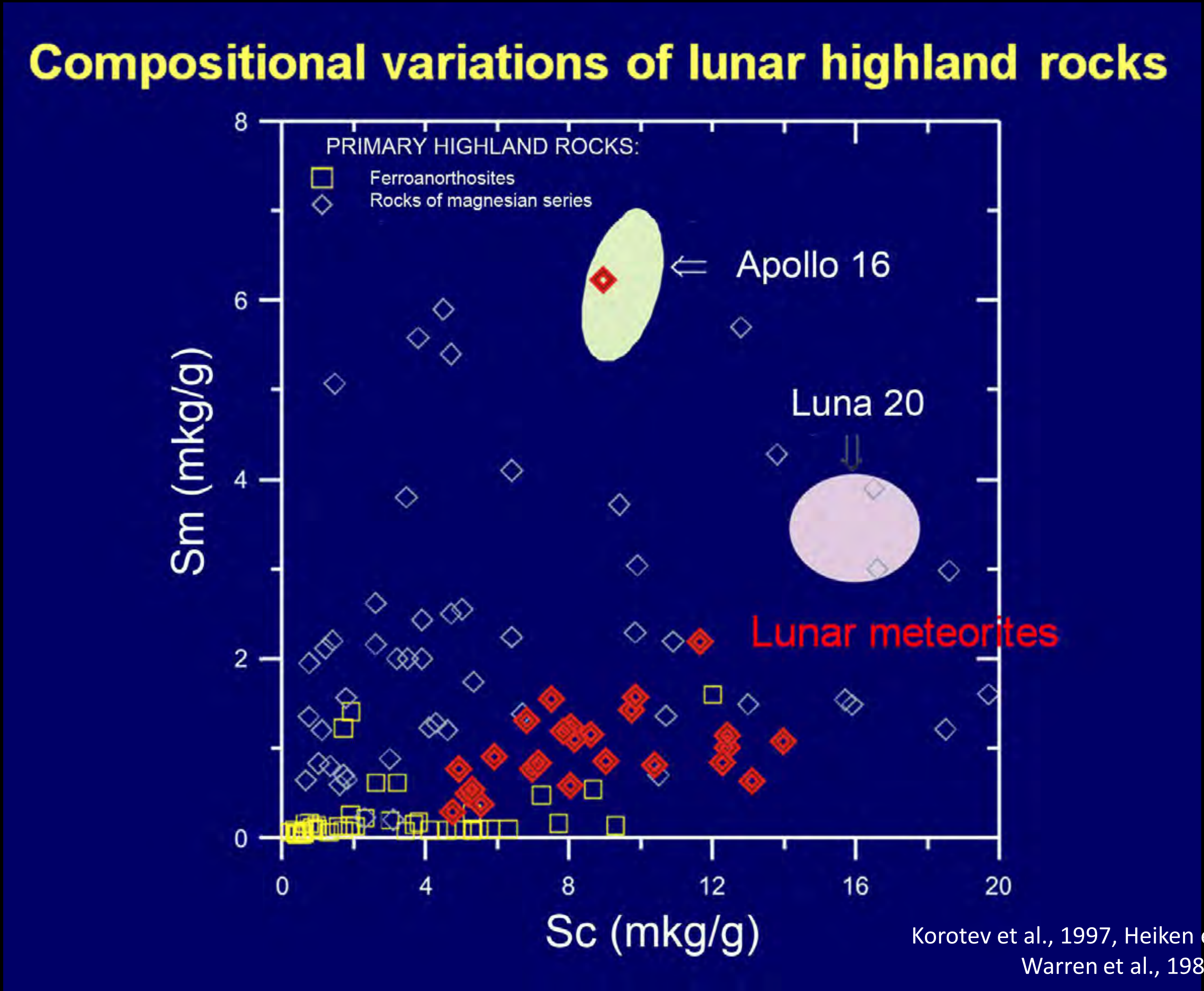
Luna 24 ferrobasalt thin section

Samples brought by Luna 16 and 24 presented new types of mare basalts

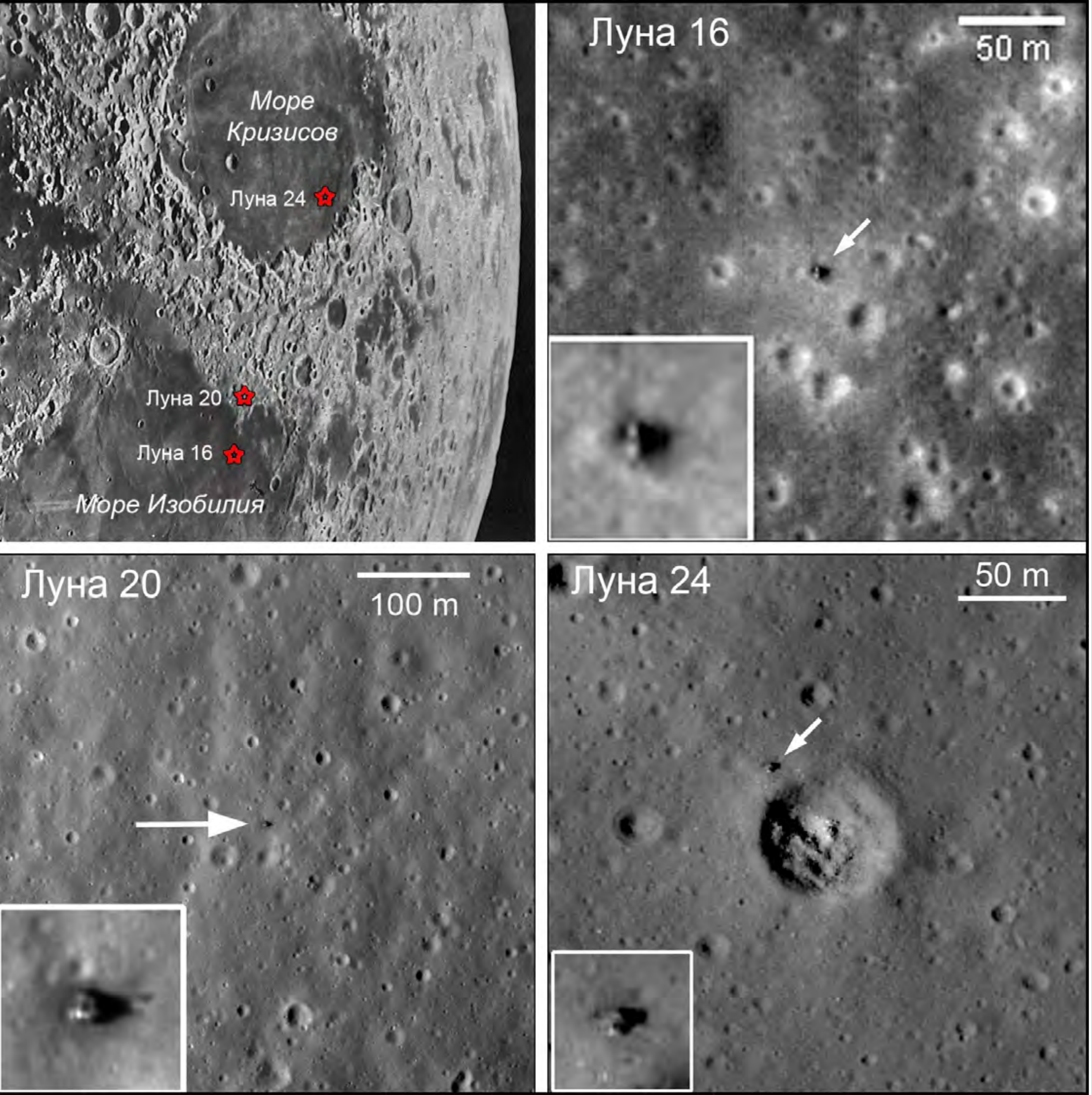


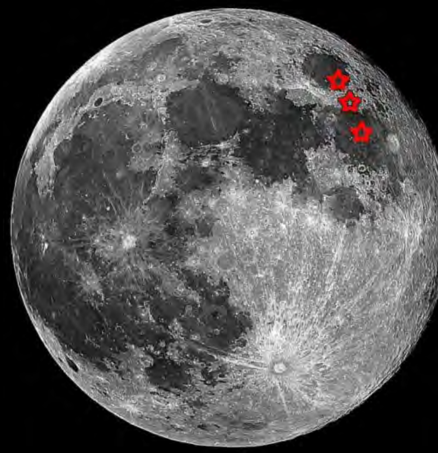
Neal & Taylor, 1992

Samples brought by Luna 20 confirmed predominance of ANT rocks and Hi-Al basalts in highland materials



Korotev et al., 1997, Heiken et al., 1991, Warren et al., 1989





The Luna 16, 20, 24 landers on the Moon.

LROC NAC images
M106511834LE
M119482862RE
M119449091RE

Luna 24:

Luck of landing in a few meters from the steep slope

What the Luna 16, 20, 24 sample returns brought to science

- New types of lunar basalts – aluminous basalts (Luna-16) and Very-low -Ti basalts (Luna 24) were discovered.

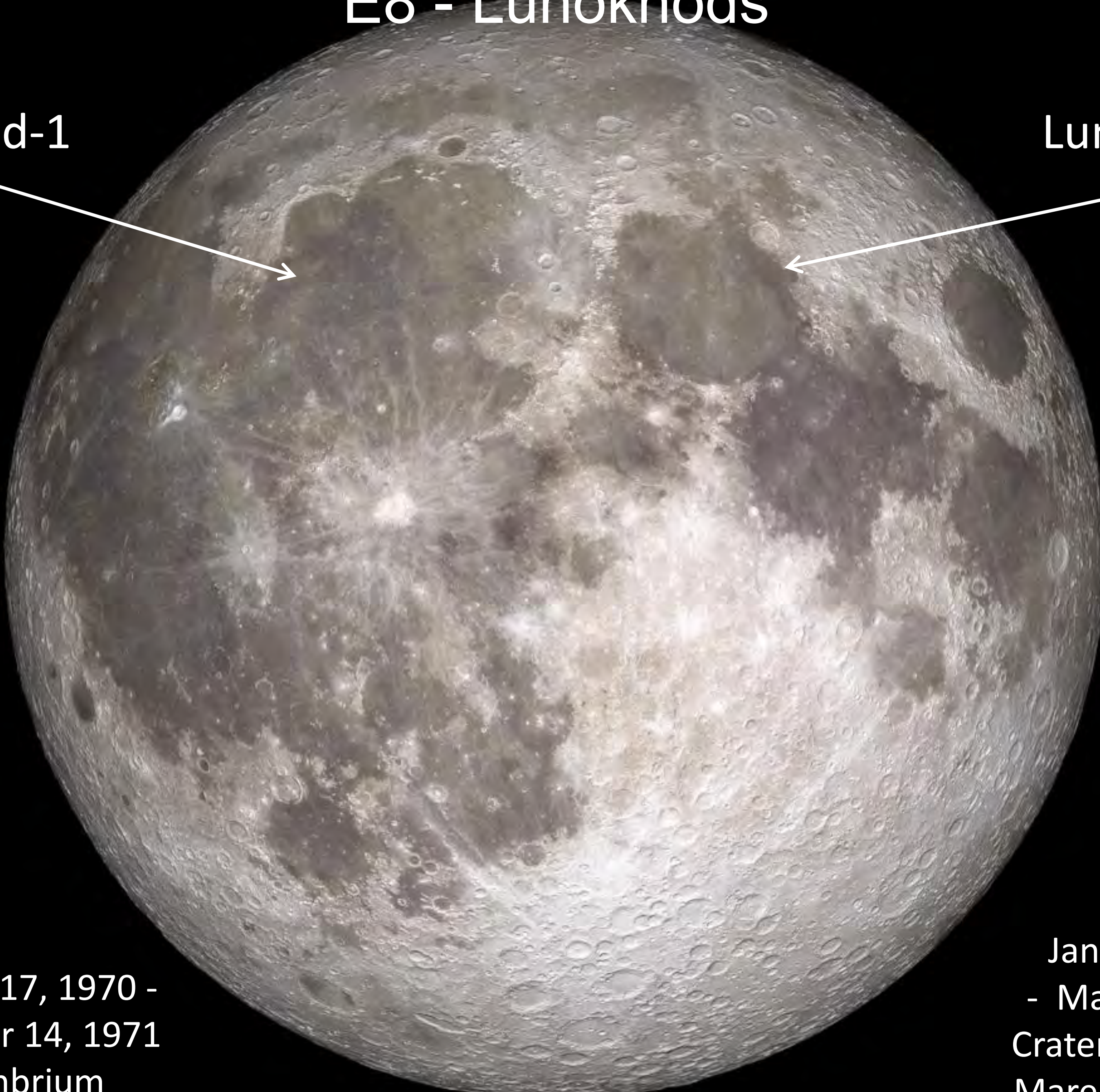
- Predominance of ANT lithologies and Hi-Al basalts in highland rocks confirmed, new rock type – spinel troctolite - was discovered.

- These results were/are being used for correlations with the compositional remote sensing studies.

- New determination of absolute ages of lunar basalts and highland materials received - dating episodes of mare volcanism and formation of impact basins.

- These results were/are being used for calibrations of the terrain absolute dating by crater counts.

E8 - Lunokhods



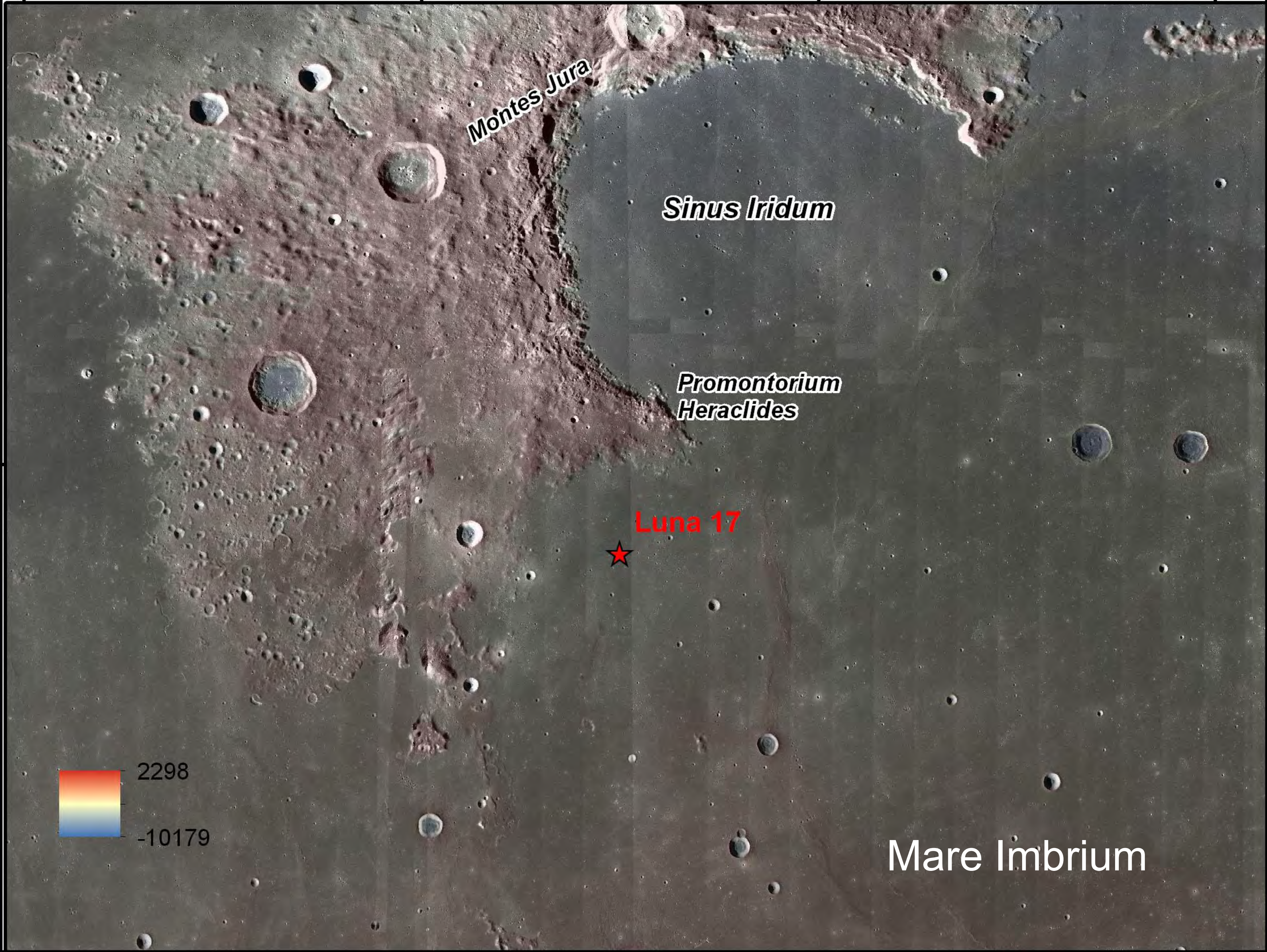
Lunokhod-1

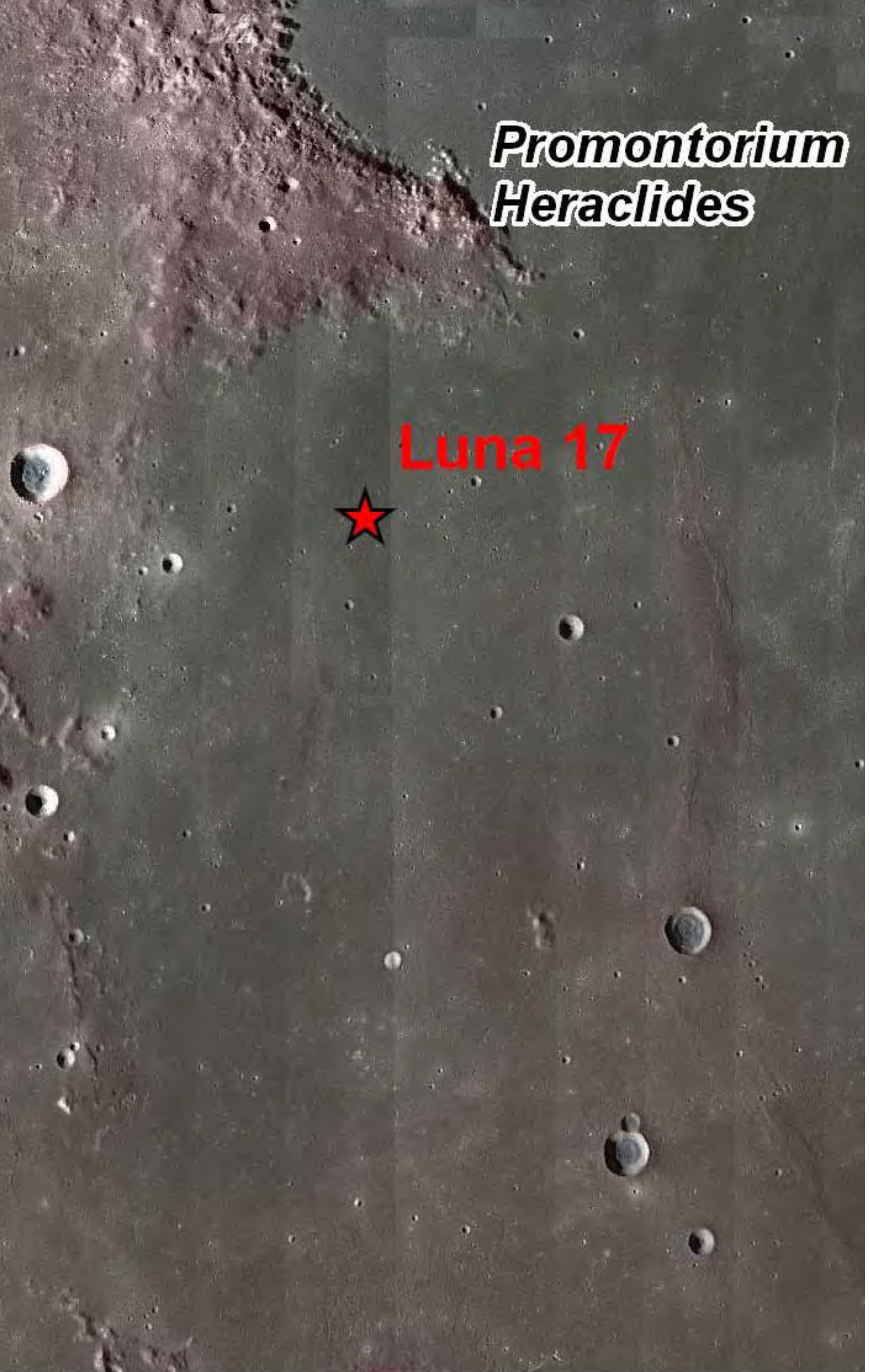
November 17, 1970 -
- September 14, 1971
Mare Imbrium

Lunokhod-2

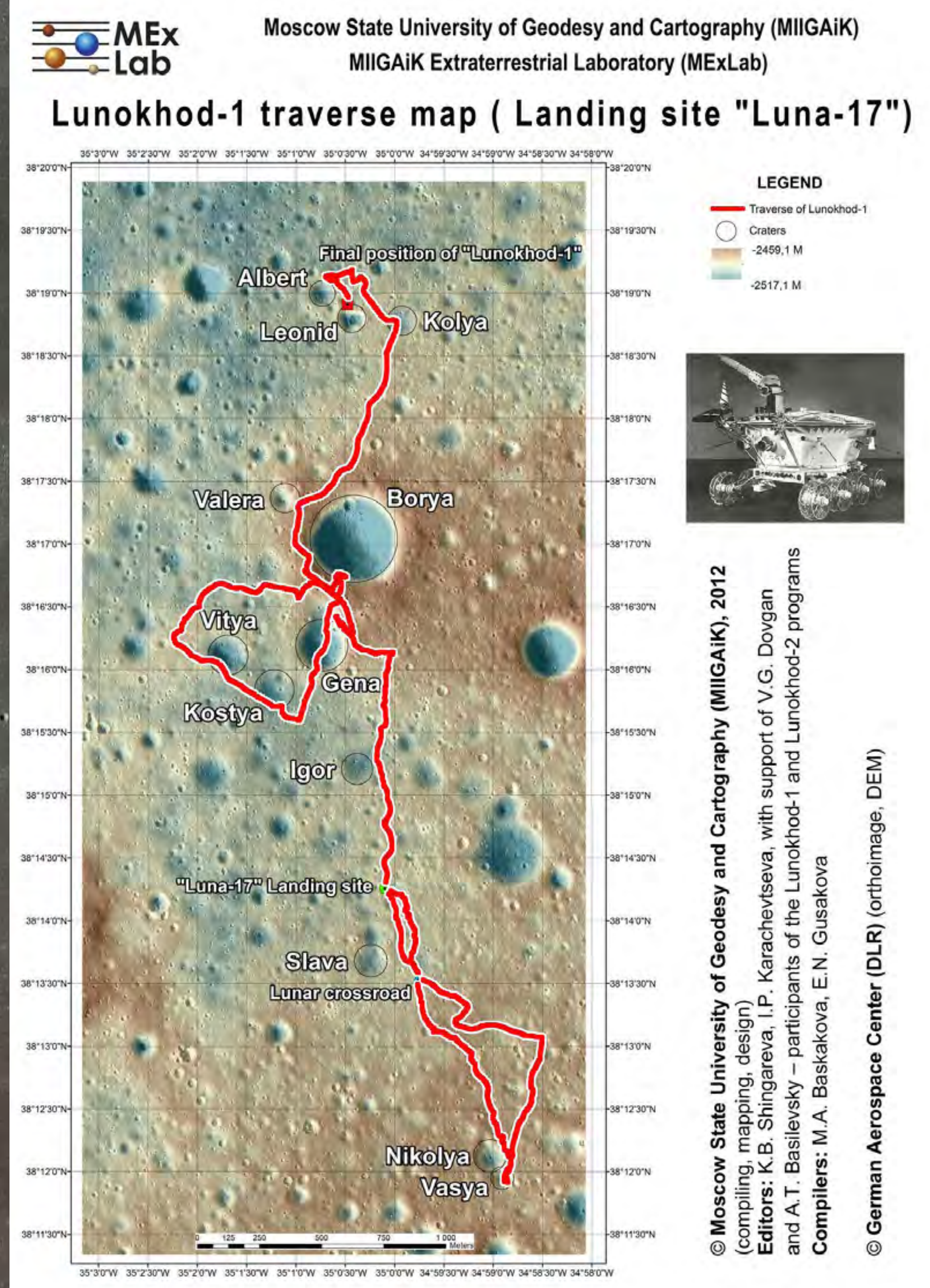
January 16 -
- May 10 1973
Crater LeMonier,
Mare Serenitatis

Lunokhod-1 - the world first planetary rover, successfully worked on the surface of another planetary body (project E8) during 11 lunar days = 10.5 Earth months, travelled 10540 m.

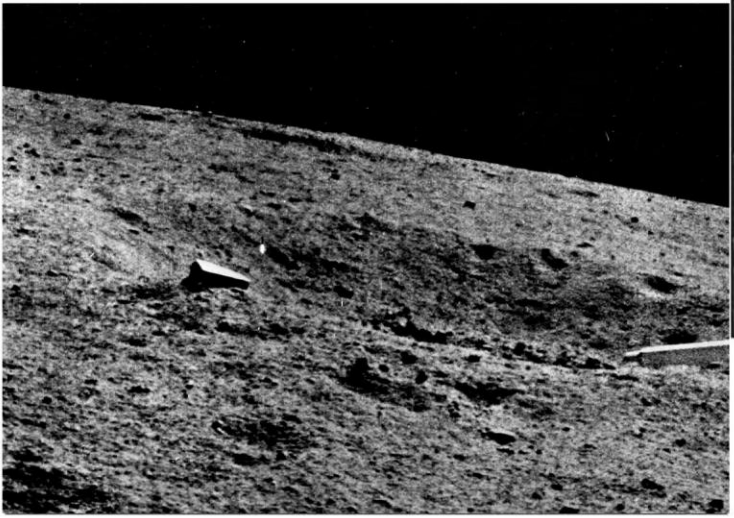

Montes Jura
Sinus Iridum
Promontorium
Heraclides
Luna 17
2298
-10179
Mare Imbrium

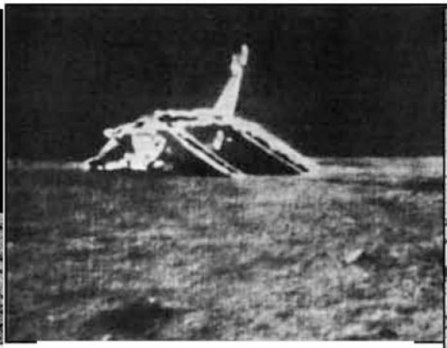


Promontorium Heraclides
Luna 17

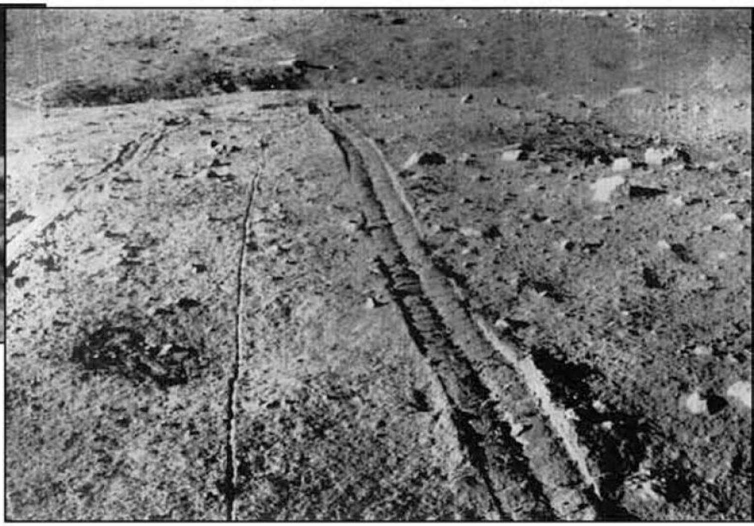


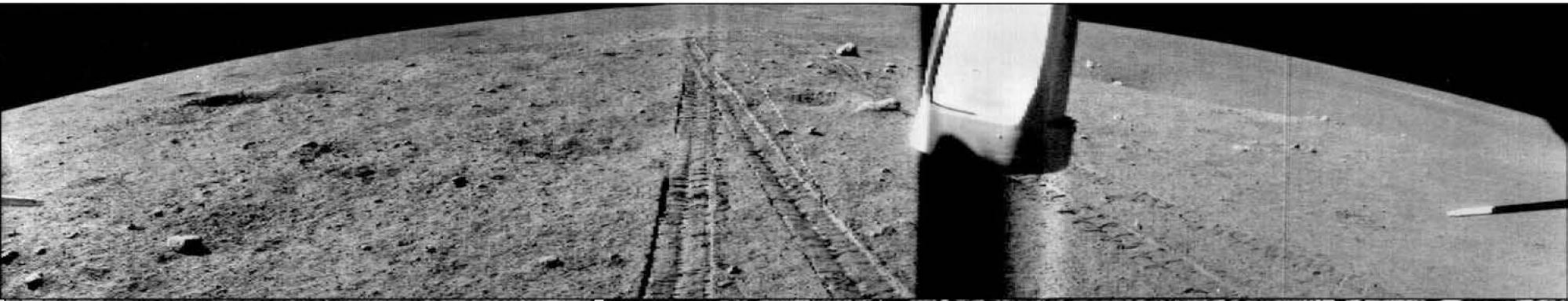
MEx Lab
Moscow State University of Geodesy and Cartography (MIIGAiK)
MIIGAiK Extraterrestrial Laboratory (MExLab)
Lunokhod-1 traverse map (Landing site "Luna-17")
LEGEND
Traverse of Lunokhod-1
Craters
-2459,1 M
-2517,1 M
Final position of "Lunokhod-1"
Albert
Leonid
Kolya
Valera
Borya
Vitya
Gena
Kostya
Igor
"Luna-17" Landing site
Slava
Lunar crossroad
Nikolya
Vasya
© Moscow State University of Geodesy and Cartography (MIIGAiK), 2012
(compiling, mapping, design)
Editors: K.B. Shingareva, I.P. Karachevtseva, with support of V.G. Dovgan
and A.T. Basilevsky – participants of the Lunokhod-1 and Lunokhod-2 programs
Compilers: M.A. Baskakova, E.N. Gusakova
© German Aerospace Center (DLR) (orthoimage, DEM)



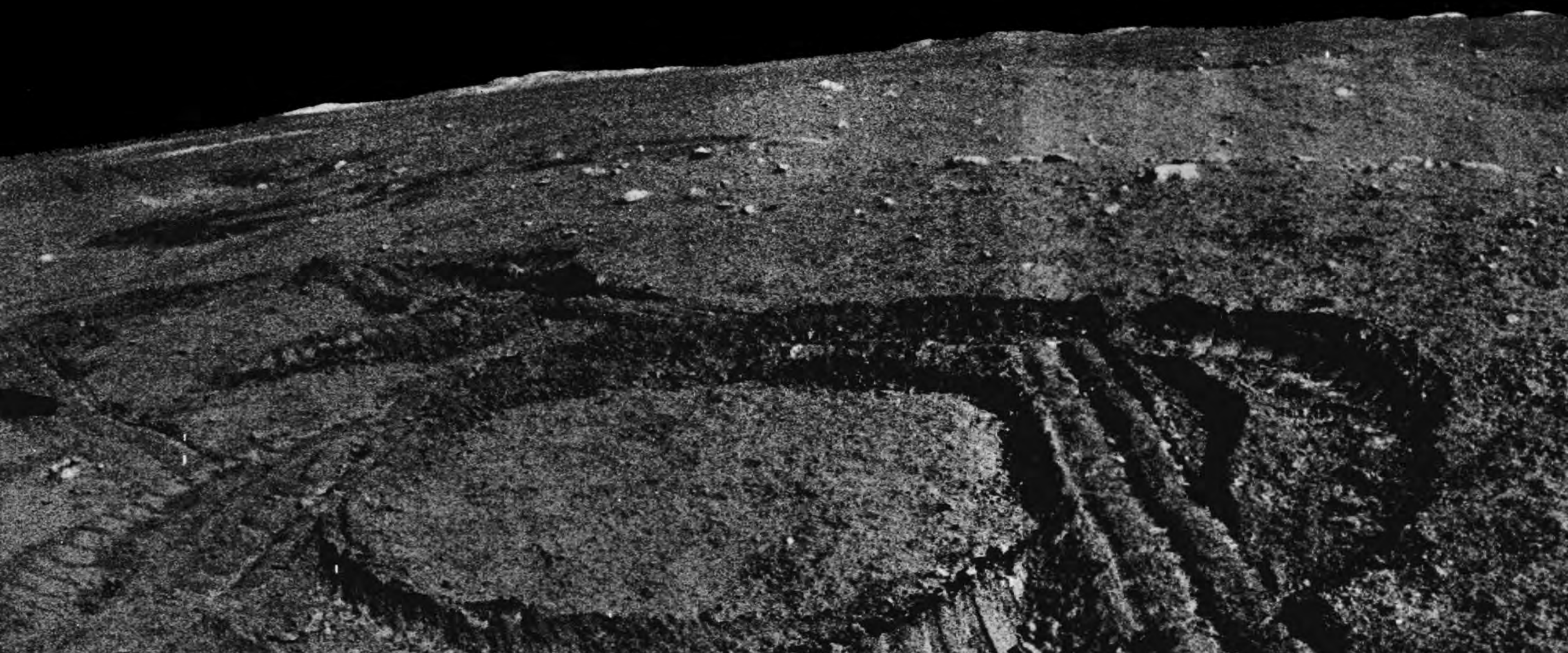


Lunokhod 1 landscapes





Fragment of panorama of Lunokhod-1. Tracks of turning on the spot.
On the horizon are seen mountains of Promontorium of Heraclides.

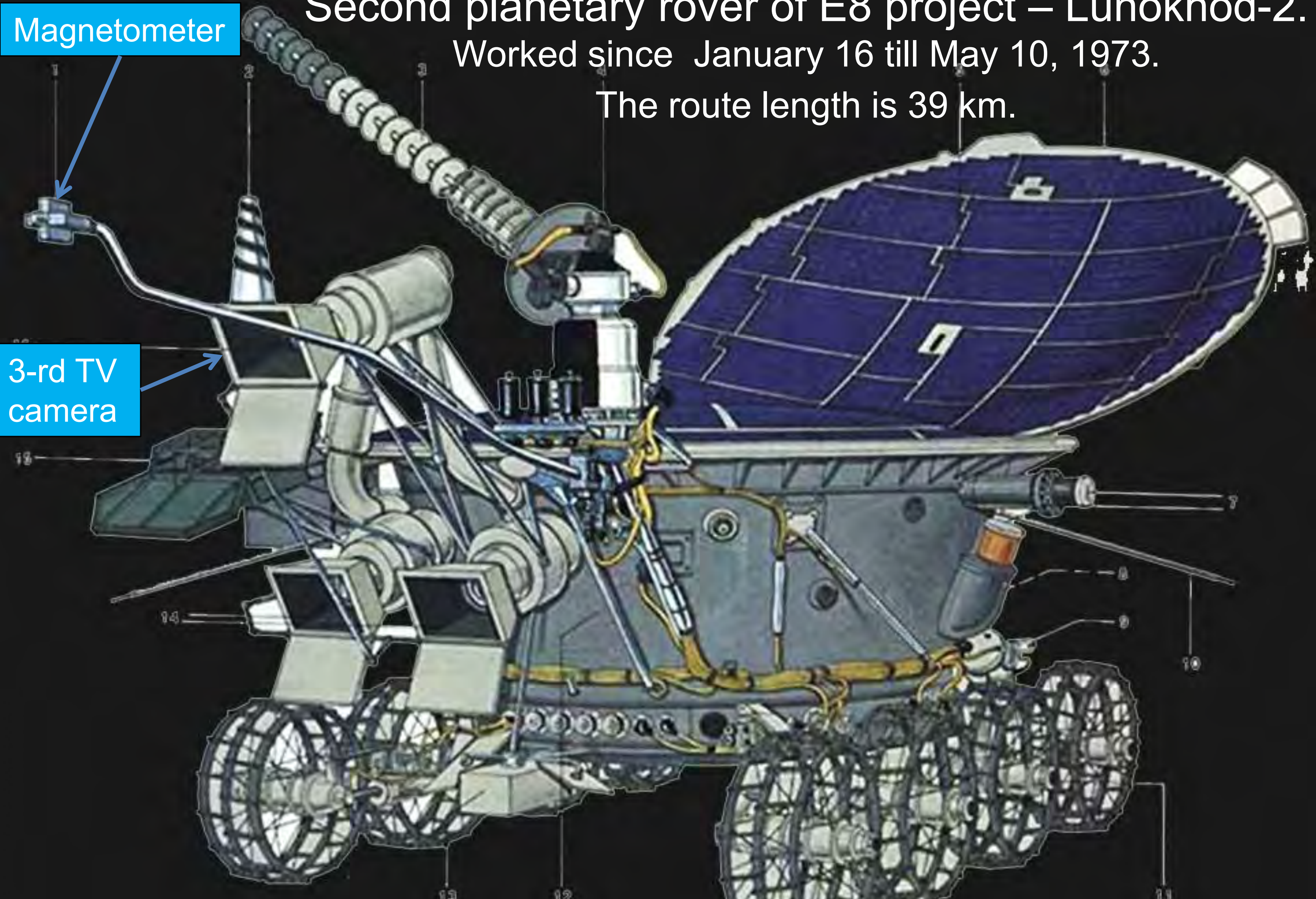



«Lunokhod-1»
at the eternal parking
on the Moon
25 m
Image
LROC NAC
M175502049R

Second planetary rover of E8 project – Lunokhod-2.

Worked since January 16 till May 10, 1973.

The route length is 39 km.



New instruments: magnetometer, 3-rd TV camera and astrophotometer

Landing area of “Luna-21”, which brought “Lunokhod-2” to lunar surface.

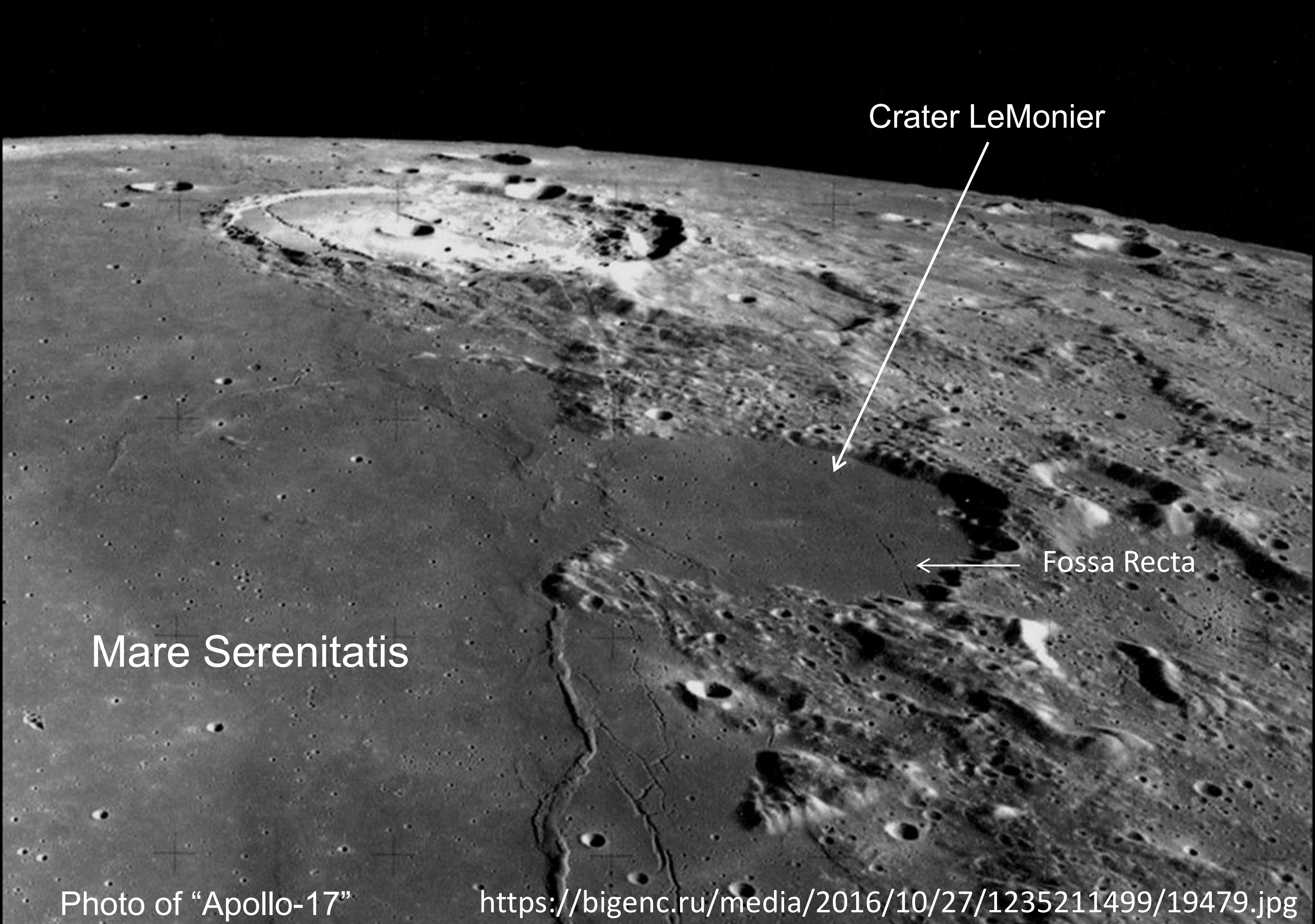
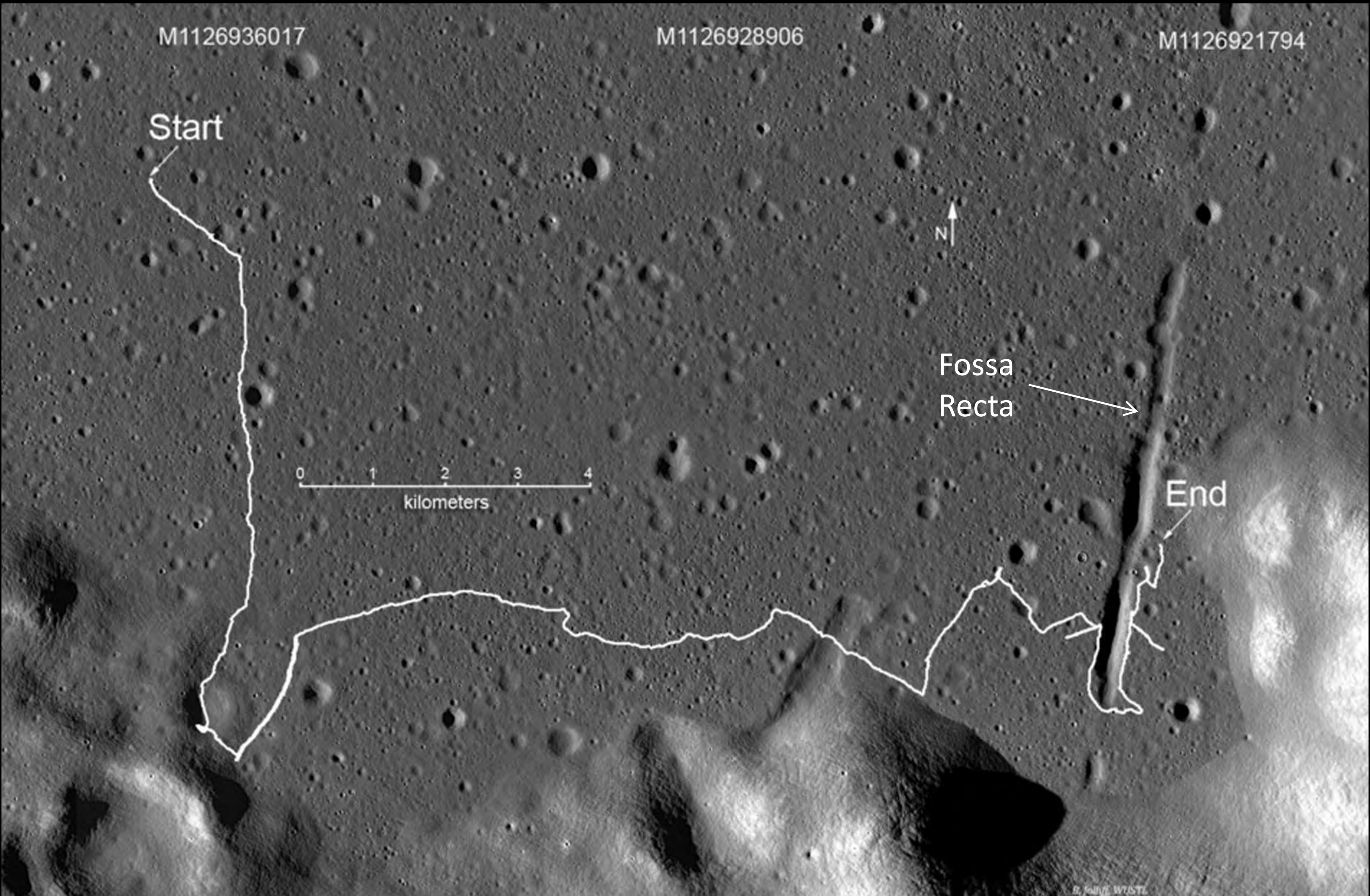


Photo of “Apollo-17” https://bigenc.ru/media/2016/10/27/1235211499/19479.jpg

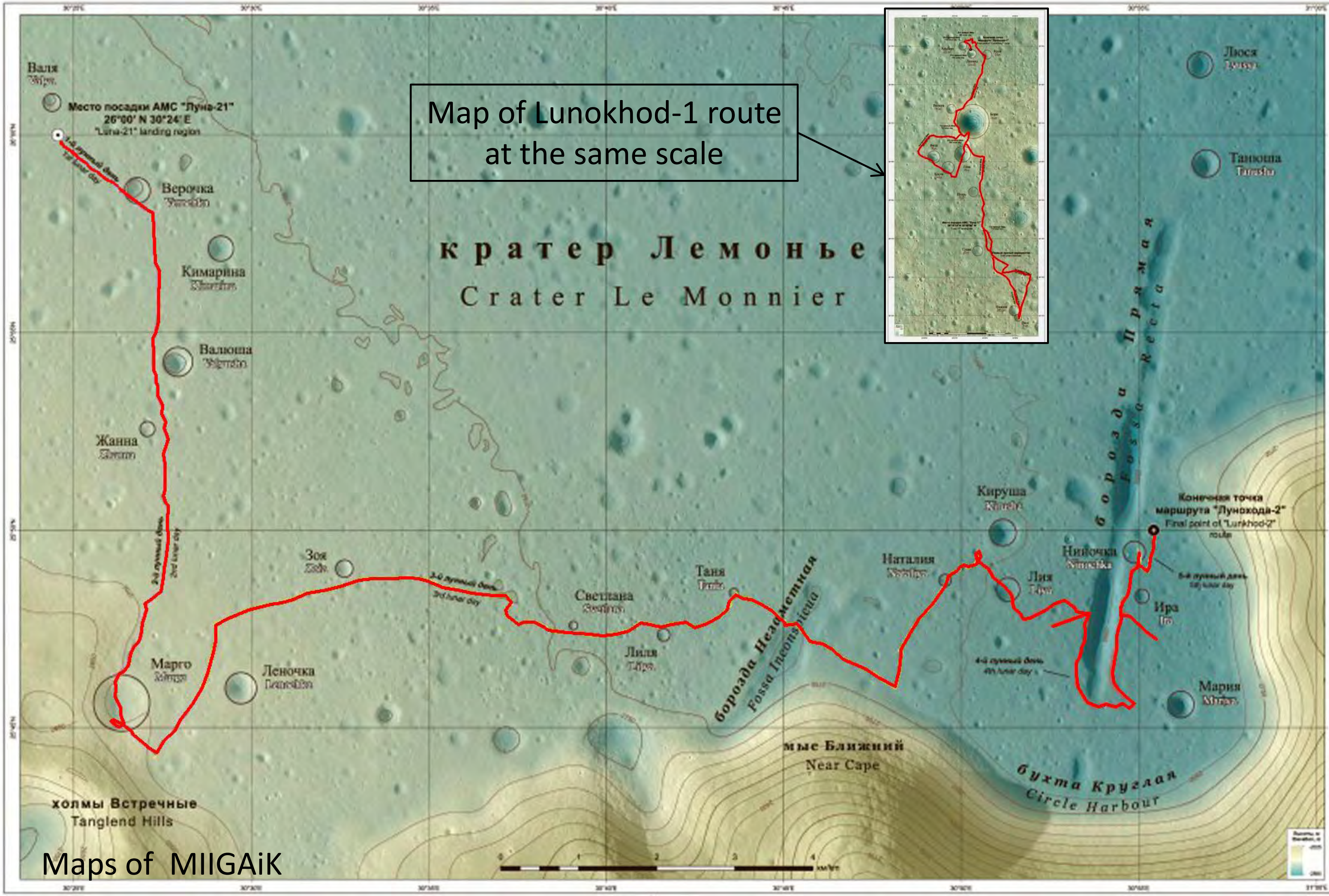
Route of "Lunokhod-2" on the mosaic of LROC NAC images

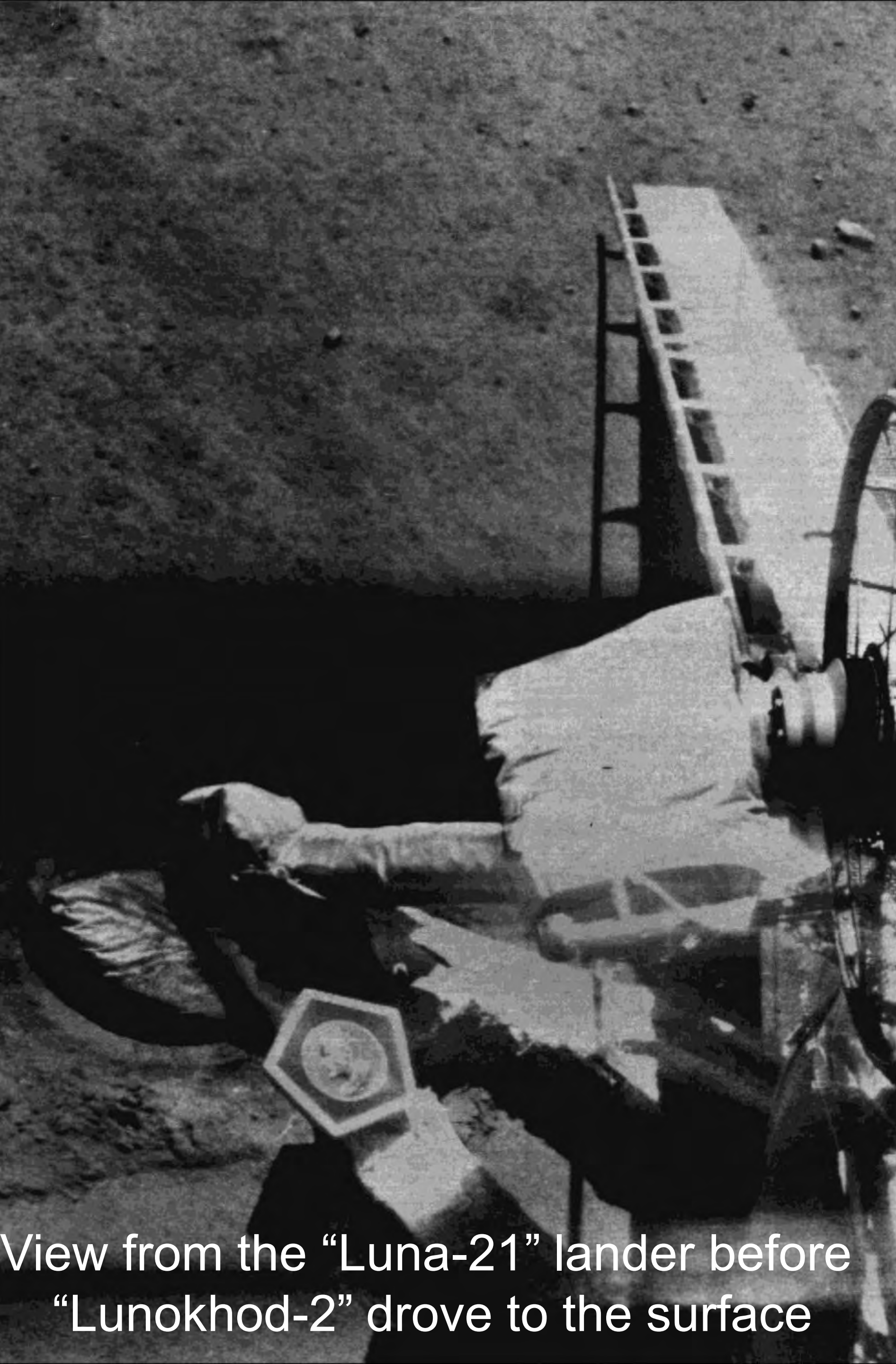


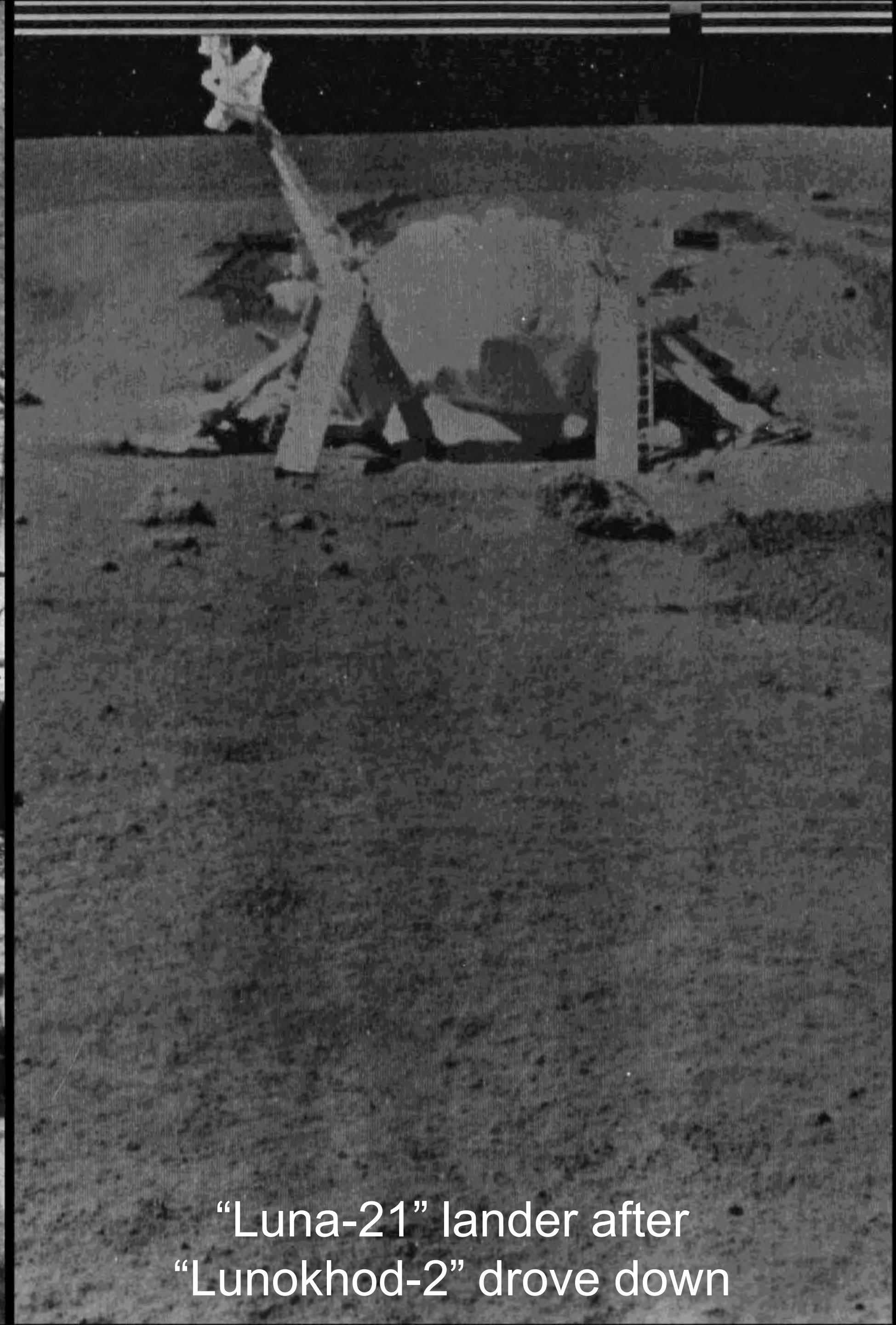
https://upload.wikimedia.org/wikipedia/ru/a/a7/Lunokhod_2_traverse-bmp.jpg

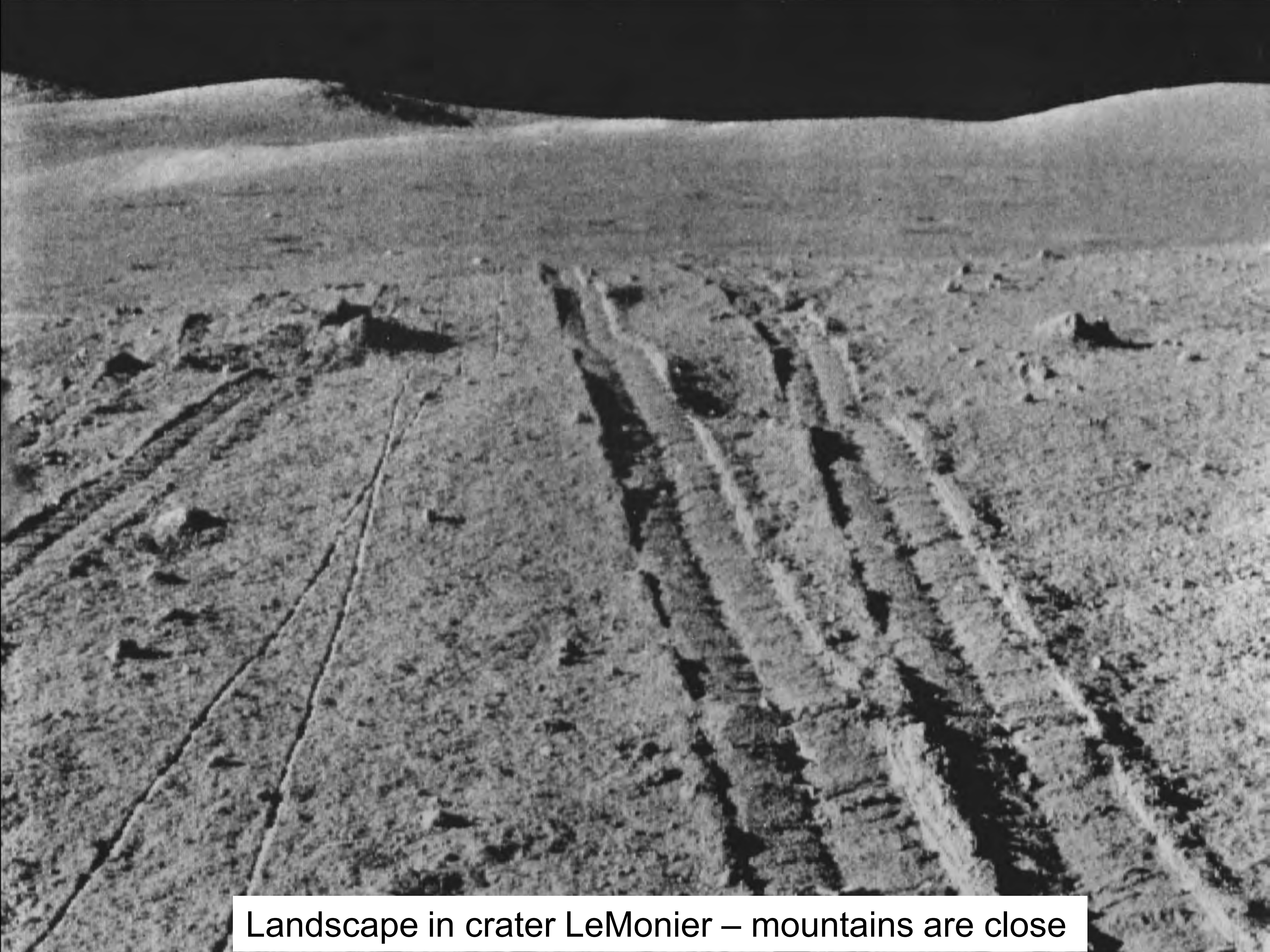
КАРТА РАЙОНА ПОСАДКИ АМС «ЛУНА-21» И МАРШРУТА «ЛУНОХОДА-2»

MAP OF “LUNA-21” LANDING REGION AND THE “LUNOKHOD-2” ROUTE

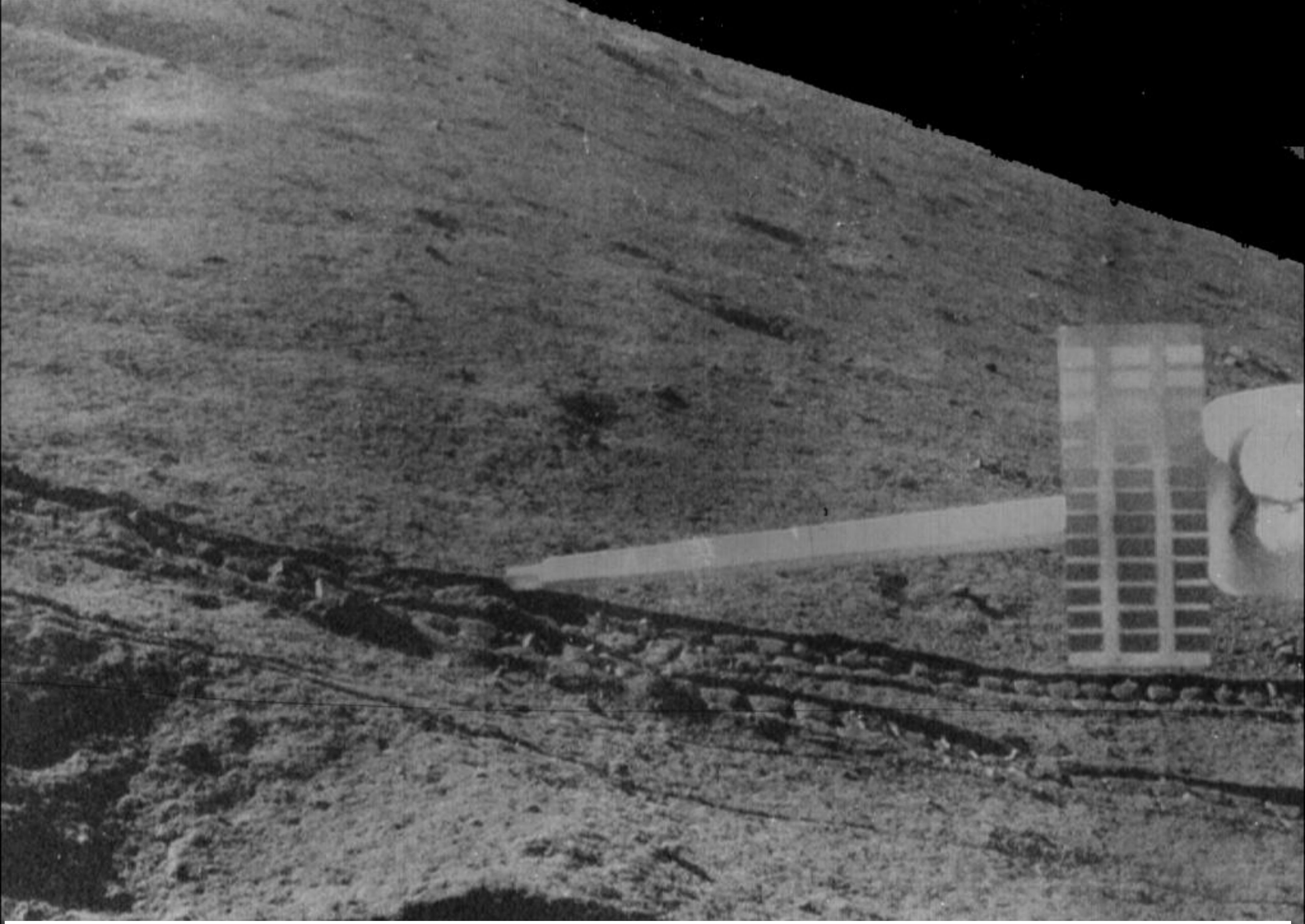



View from the “Luna-21” lander before “Lunokhod-2” drove to the surface

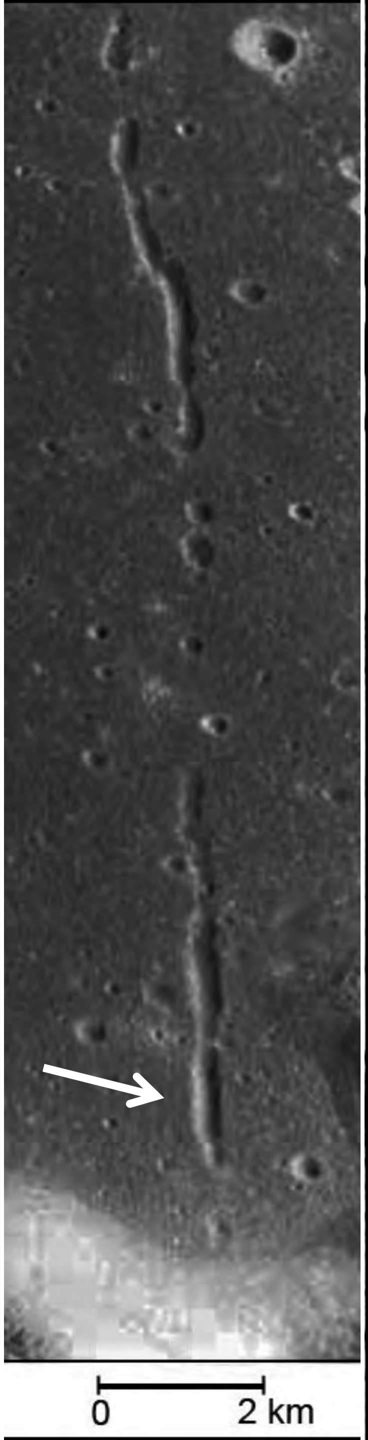

“Luna-21” lander after “Lunokhod-2” drove down



Landscape in crater LeMonier – mountains are close



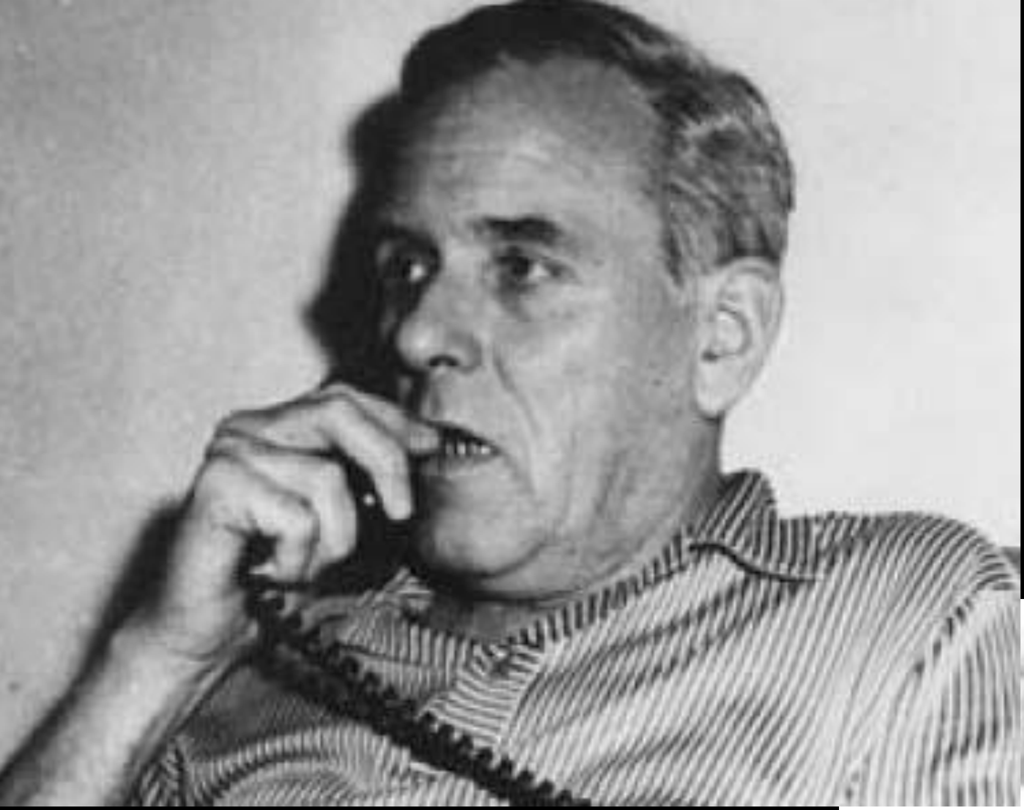
Landscape, tracks, antenna with photometric standard (contribution of GAISh)



Fossa Recta graben with rocky outcrops at its edges

The only preserved radiotelescope THA-400. Shkol'noye, Crimea. Control center for Lunokhods and training polygon, April 5, 2017

https://gdb.rferl.org/C6586DA2-3084-4B8A-88C1-A12D45765C13_w1023_r1_s.jpg



Georgii Nikolaevich
Babakin

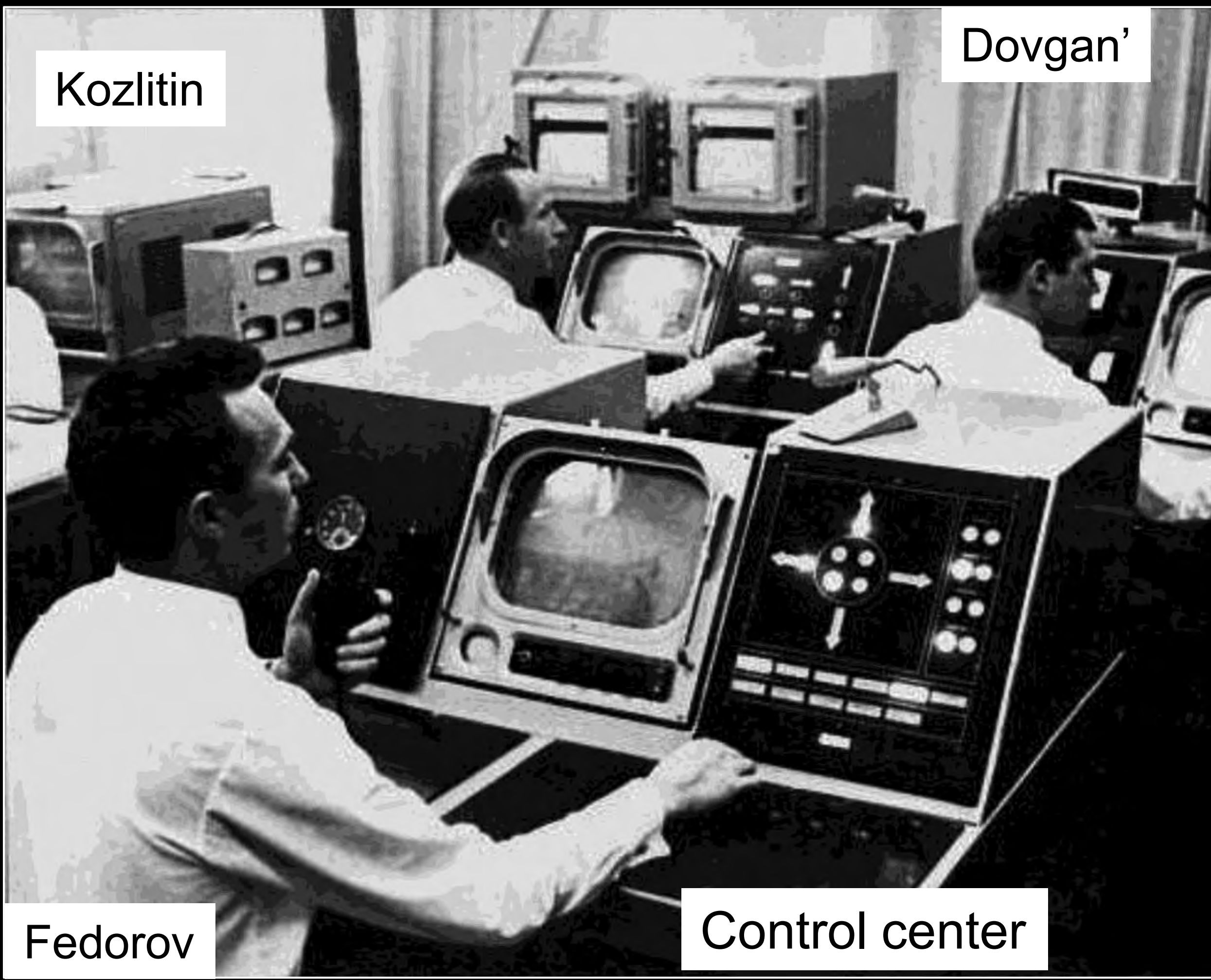
Chief designer of
our Lunas and Lunokhods

Alexander Leonovich
Kemurdzhian

Chief designer of
Lunokhod chassis

Lunokhod 1 and 2 crew:

Commanders — Nikolay Eremenko, Igor’ Fedorov;
Drivers — Gabdulkhay Latypov, Vyacheslav Dovgan’;
Navigators — Konstantin Davidovskiy, Vikentiy Samal’;
Flight engineer — Leonid Mosenzov, Albert KOzhevnikov;
Operator of high-gain antenna — Valeriy Sapranov, Nikolay Kozlitin;
Reserve driver and operator — Vasiliy Chubukin.



Control center

Boris Nepoklonov – head of Science team and I – his deputy.

Members of the State Commission with Lunokhod crew, Simferopol, 22.11.1970.
From right to left, sitting – G. Babakin, G. Tyulin, A. Bol’shoy, V. Panteleev, A. Romanov, N. Bugaev; standing – V. Samal’, G. Latypov, V. Chubukin, A. Chvikov, I. Fedorov, N. Kozlitin, L. Mosenzov, K. Davidovskiy, N. Eremenko, V. Sapranov, A. Kozhevnikov, V. Dovgan’

End of Lunokhod-2 mission

April 20, 1973, Session 411. Drive to the north being eastward of Fossa Recta. The Sun is behind. No shadows are seen. From Basilevsky's diary:

05:05 Entered in crater B – 5 м, lost radio connection (α = 20° $\neq$ крен 20° .

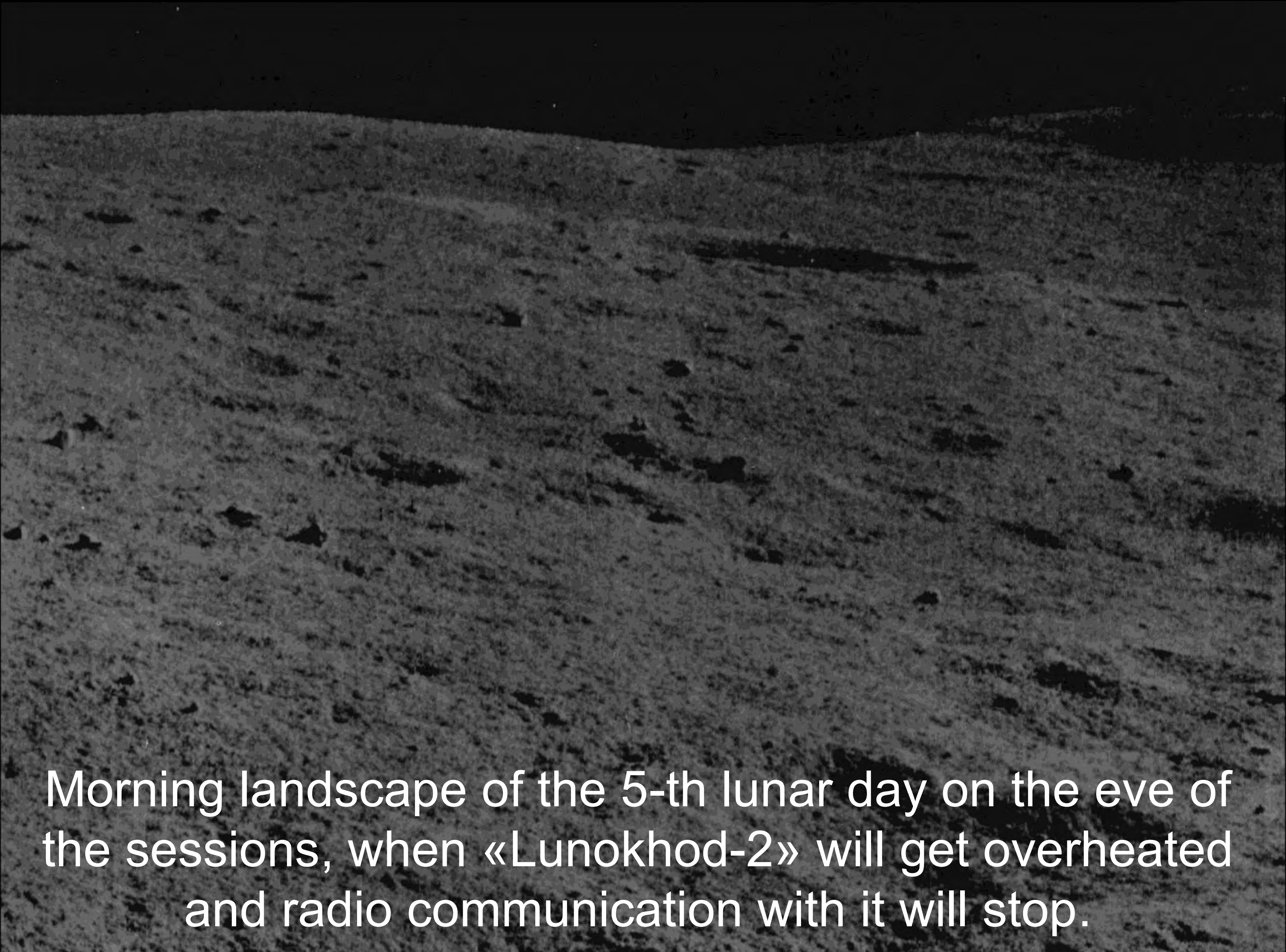
05:13 PROP inside B- 5 м at its inner slope, movement of the 9-th (*wheel*) is maximal, bur sensor did not touch the soil.

05.13 - 05.15(!!!) Moving back with opened lid of the solar battery **(***quotation from V.G. Dovgan' from March 1, 2011:* ***Decision of the crew to close the lid was rejected by the Managin Group*****)**

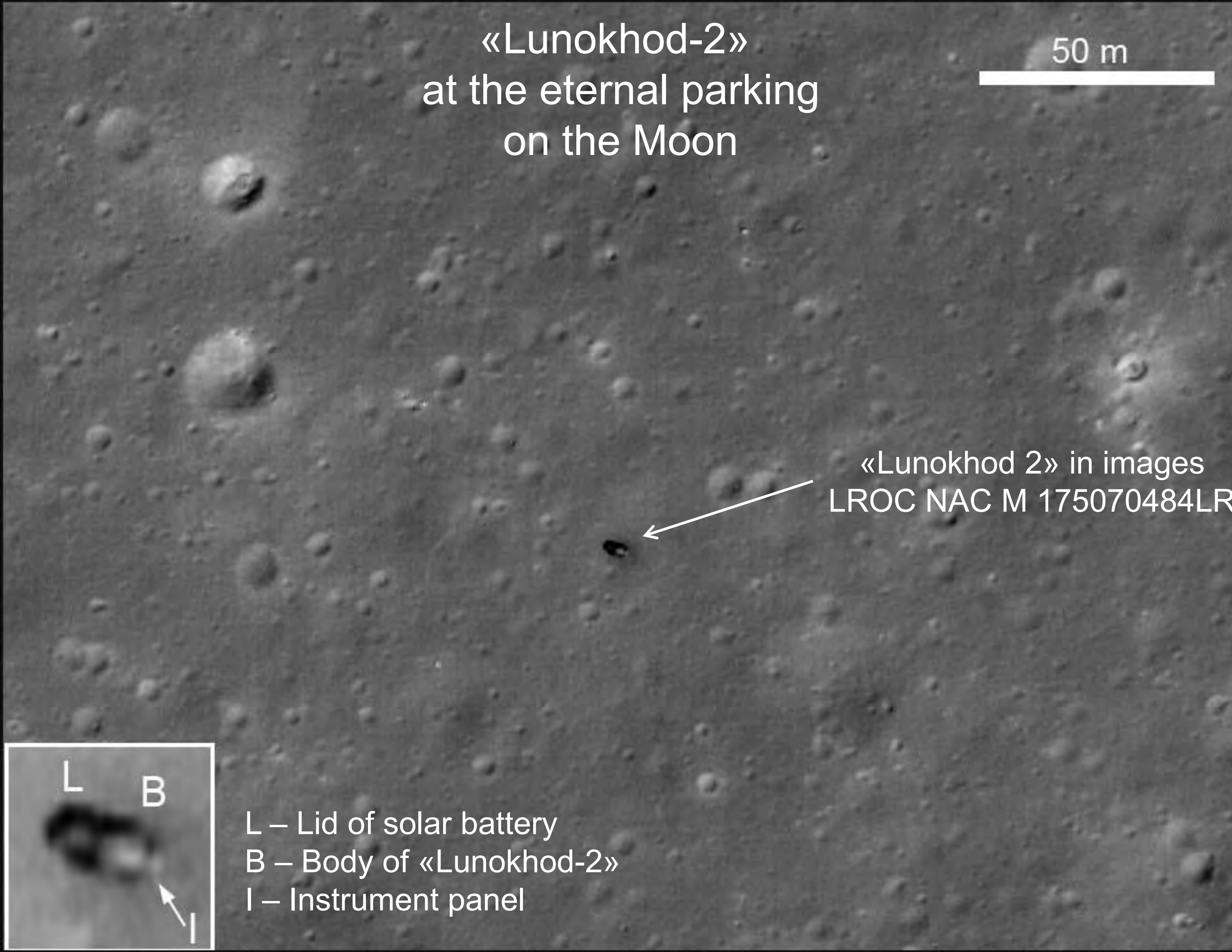
05:15 Got out from B – 5 м, drove back. Turning to the Sun.

Making maneuvers in the crater with not closed solar battery lid, Lunokhod-2 touched the slope by it and soil was put on the lid surface. At the end of the 4-th lunar day, entering the night, the lid was closed, and soil was put on the radiator.

On the next (5-th) lunar day, radiator powdered by the lunar soil radiated heat to space very ineffectively. On May 10 the rover got overheated and did not communicate anymore.



Morning landscape of the 5-th lunar day on the eve of the sessions, when «Lunokhod-2» will get overheated and radio communication with it will stop.


«Lunokhod-2»
at the eternal parking
on the Moon
50 m
«Lunokhod 2» in images
LROC NAC M 175070484LR
L
B
I
L – Lid of solar battery
B – Body of «Lunokhod-2»
I – Instrument panel

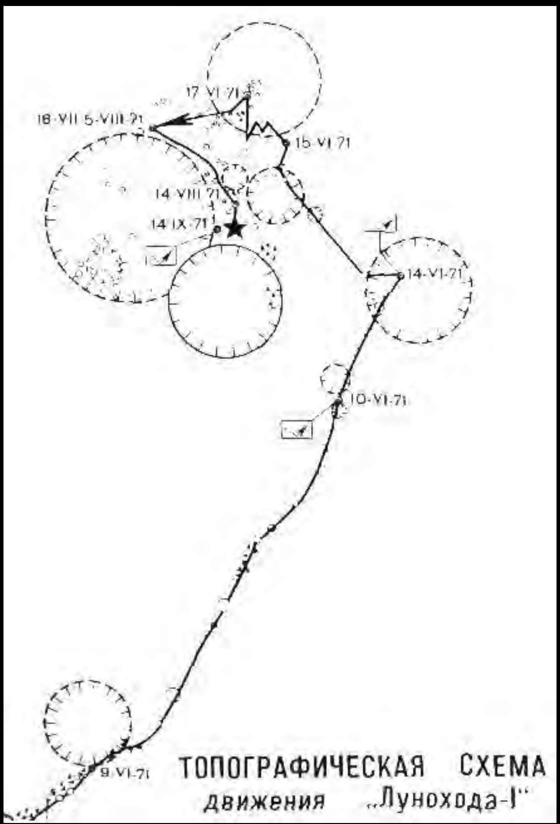
Results taken by Lunokhod 1 and 2

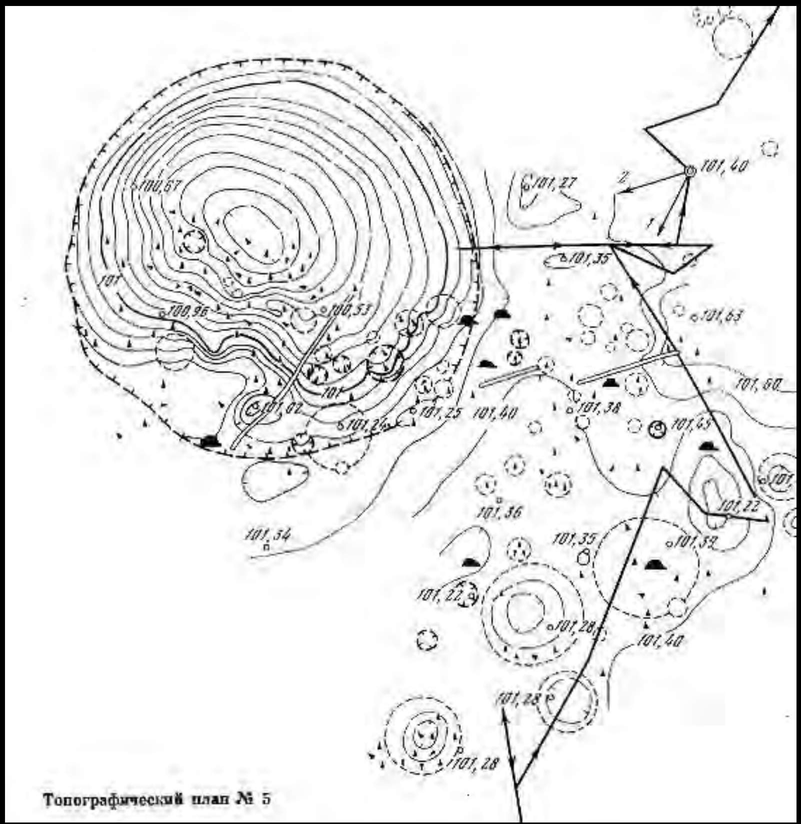
TV panoramas + navigation documentation of the traverse:

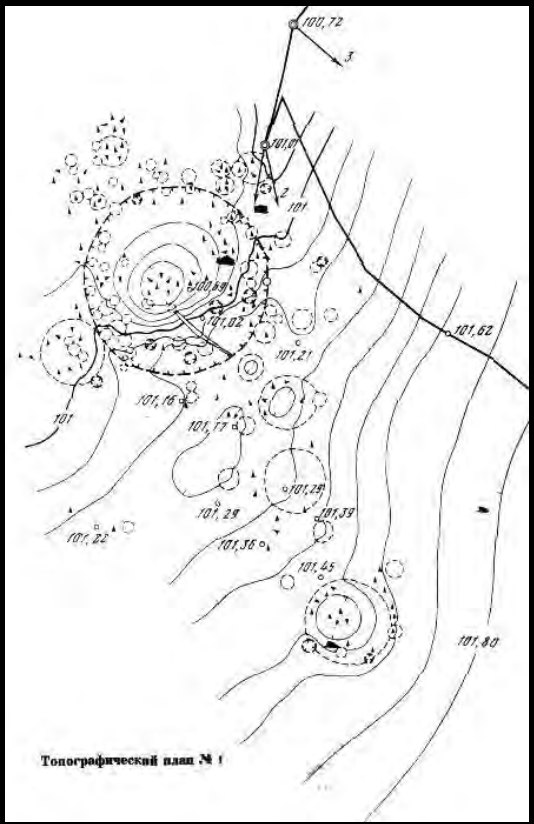
Study of surface topography along the traverses of Lunokhod-1 and 2 at the meter to kilometer scale.

Абрамова М.В. И др. Изучение топографии района исследований "Лунохода-1". В кн. Передвижная лаборатория на Луне Луноход-1. Т. 2. М. Наука. 67-79.

Родионов Б.Н., Топографические съемки на лунной поверхности с советских Автоматических космических аппаратов, Геодезия и картография, N10, 1973. 26-41.



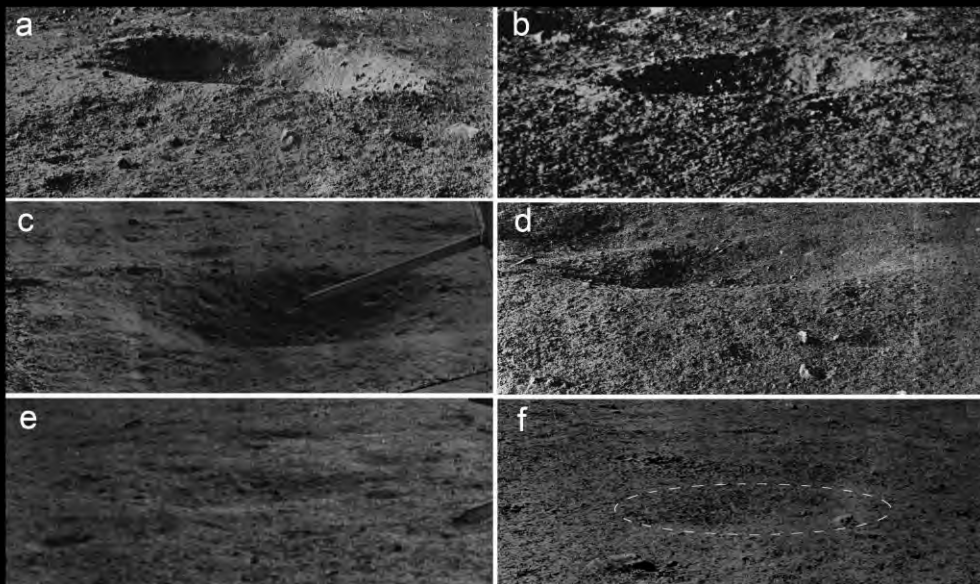


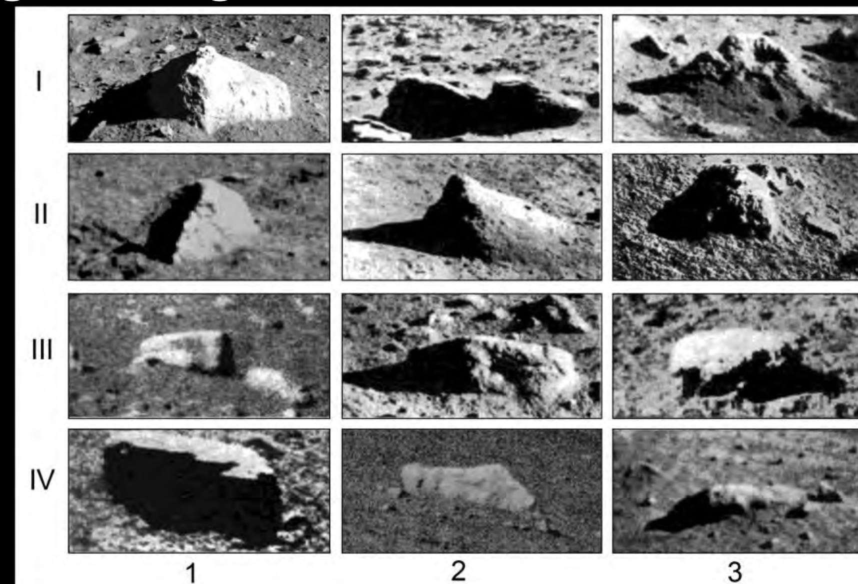


Results taken by Lunokhod 1 and 2

TV panoramas + MKTV (images taken by Navigation cameras)

Morphologies, sizes and distribution of small lunar craters and rock fragments had been studied that is important for understanding of lunar surface evolution + development of engineering models of lunar surface





Флоренский и др. Предварительные результаты геоморфологического изучения панорам. Сб."Передвижная лаборатория на Луне - Луноход-1", 1971, М., Наука, 96-115.

Florensky et al. Geomorphological analysis of the area of Mare Imbrium explored by the automatic roving vehicle Lunokhod 1. Space Research XII-Academie-Verlag, Berlin, 1972, 107-121.

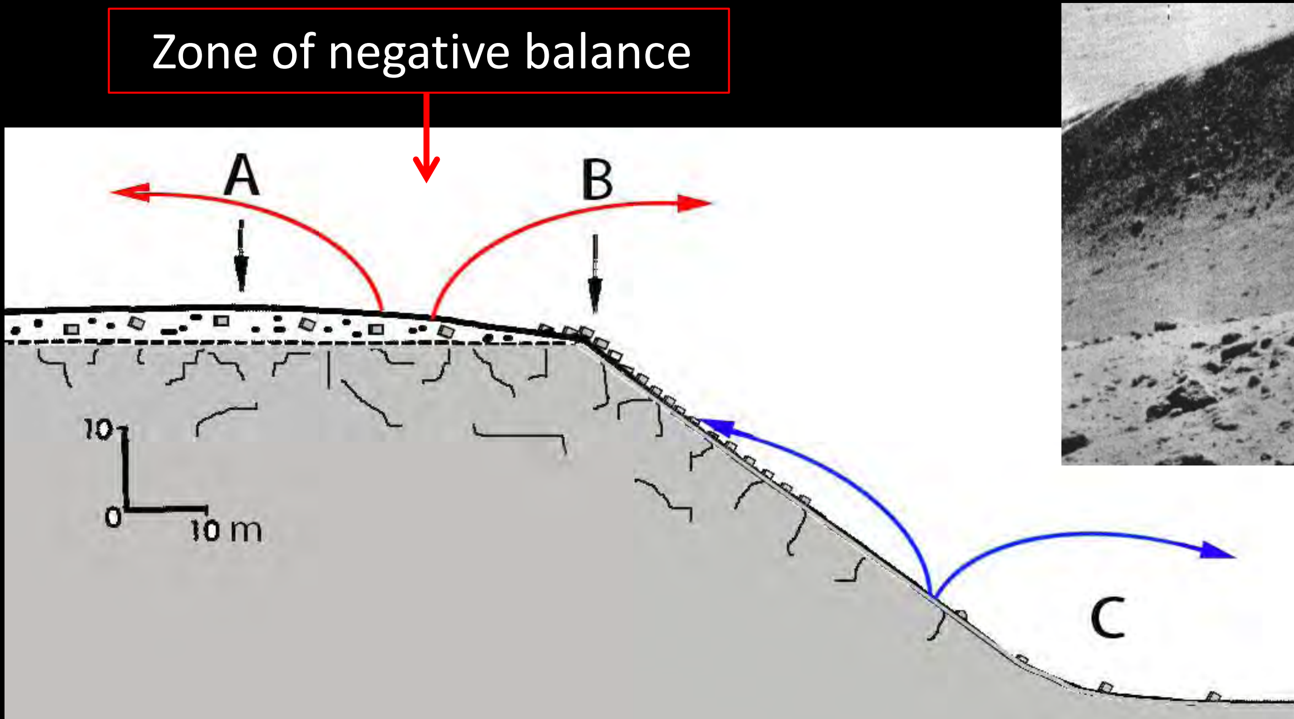
Флоренский и др. Геолого-морфологический анализ района работы "Лунохода-2". Доклады АН СССР, 1974, 214, № 1, 75-78.

Florensky et al. The floor of crater Le Monier: Proc. LPSC. 9th, Pergamon Press, 1978, 1449-1458.

Results taken by Lunokhod 1 and 2

TV panoramas + MKTV + Navigation documentation

Zone of negative balance of regolith was found on the edge of Fossa Recta that allowed to estimate distance of effective horizontal back-and-forth transportation by small meteorite impacts: tens to first hundreds of meters.



Флоренский и др. Процессы преобразования поверхности Луны в районе Лемонье по результатам детального изучения на Луноходе-2. Тектоника и структурная геология. Планетология. М. Наука. 205-234.

Basilevsky et al. Possible lunar outcrop: A study of Lunokhod-2 data. The Moon. 1977. 17. 19-28.

Results taken by Lunokhod 1 and 2

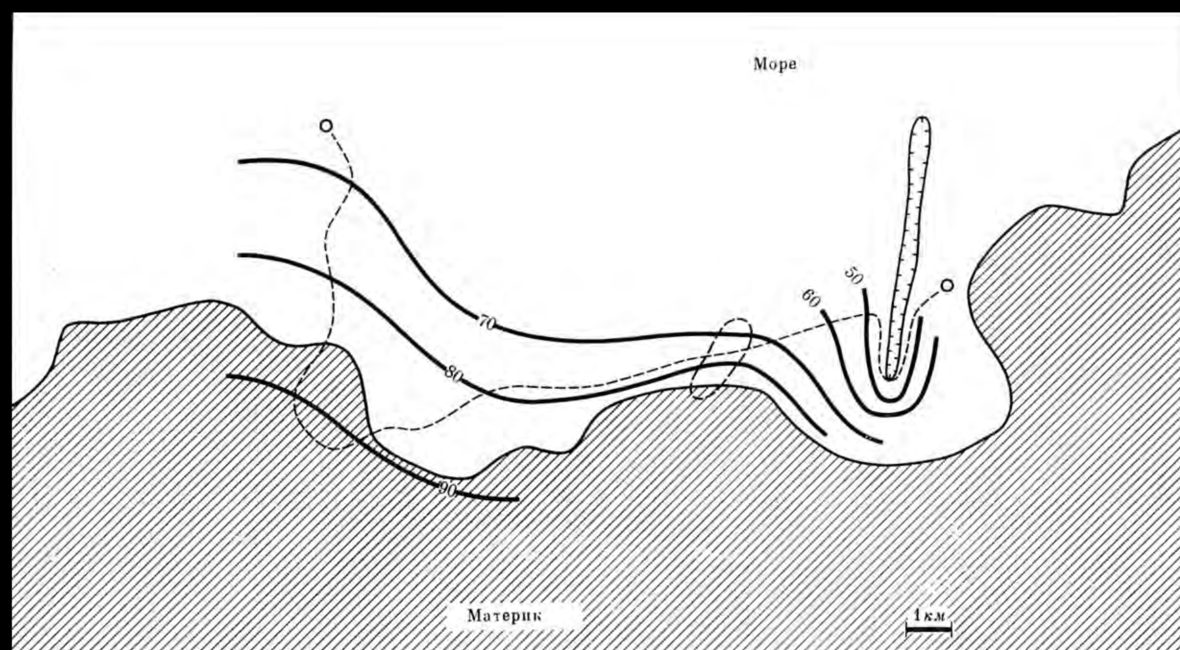
X-ray Fluorescence Spectrometer RIFMA

Measurements of chemical composition of the surface in areas of studies of Lunokhods 1 and 2, estimation of distance of the thin layer back-and-forth horizontal transportation – kilometers – tens of kilometers

Кочаров Г.Е., Викторов С.В. Химический состав лунной поверхности в районе работы «Лунохода-2». Доклады АН СССР. 1974. 214. № 1. 71-74.

Kocharov, G. E. et al. Chemical composition variations of the lunar surface in the contact zone "mare-highland. Space Research XY. Berlin. Akademie Verlag. 1975. 587-592.

Кочаров Г.Е. и др. О переносе вещества на лунной поверхно-сти. Космические исследования. 1978. т. 16. вып. 4. 544-550.



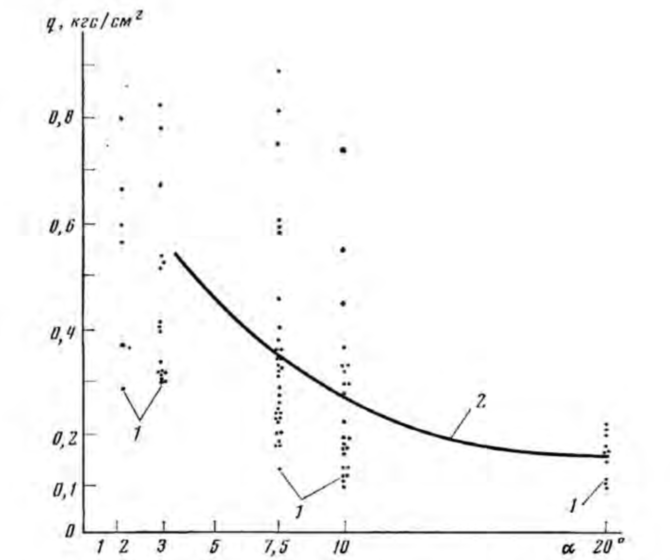
Results taken by Lunokhod 1 and 2

Instrument to measure trafficability (PROP)

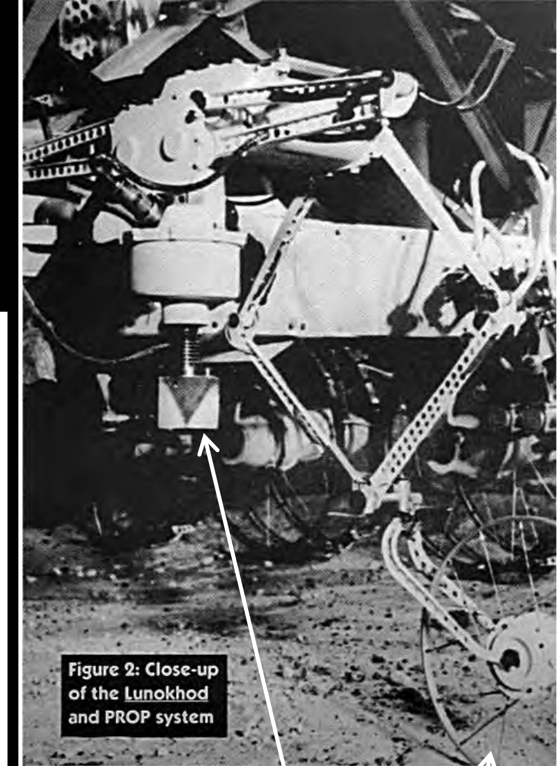
Measurement of physico-mechanical propreties of the soil and и their correlations with local geology

Леонович А.К. (Кемурджан) и др., Самоходное шасси «Лунохода-1» как инструмент для исследования лунной поверхности. В кН. Передвижная лаборатория на Луне. Т. 2. Наука. Москва. 25-43.

Леонович А.К. и др, Основные особенности процессов деформации и разрушения лунного грунтаю В кн. Космохимия Луны и планет. М.: Наука, 1975. 585–592.



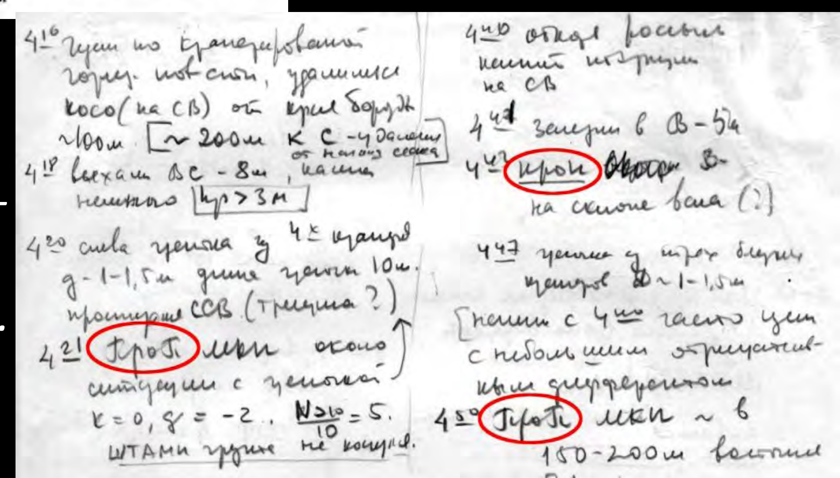
Зависимость несущей способности реголита от угла наклона поверхности
1 — данные фактических измерений; 2 — кривая, построенная по осредненным данным



PROP

9-th wheel

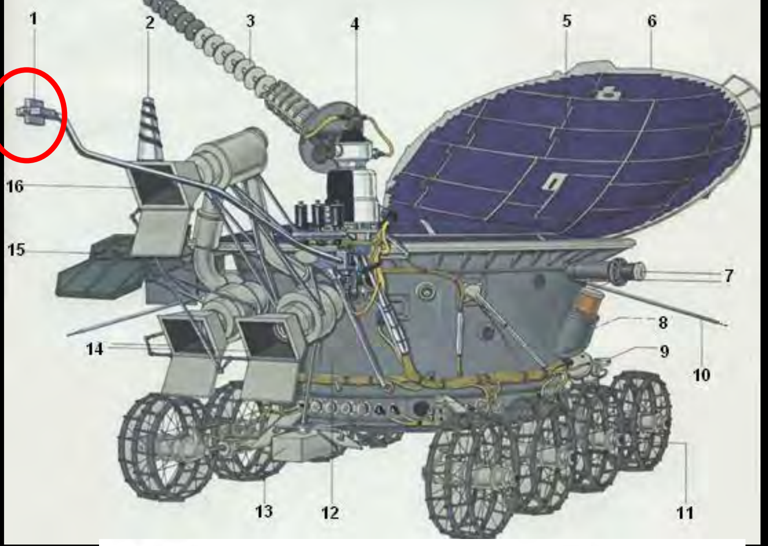
Базилевский А.Т. и др. Зависимость физико-механических свойств лунного грунта от особенностей рельефа и процессов в районе работ "Лунохода-2". Космические исследования, XXII, в. 2, 1984,243-251.



Results taken by Lunokhod 1 and 2

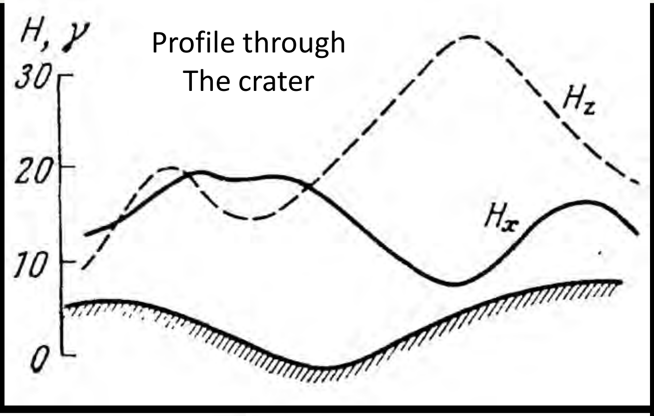
Magnetometer

Magnetometric studies along the traverse of Lunokhod-2 and at the stations



Долгинов Ш.Ш. и др. Магнетизм и электропровод-ность Луны по данным "Лунохода-2". Сб. "Космохи-мия Луны и планет". М., Наука, 1975, 314-322.

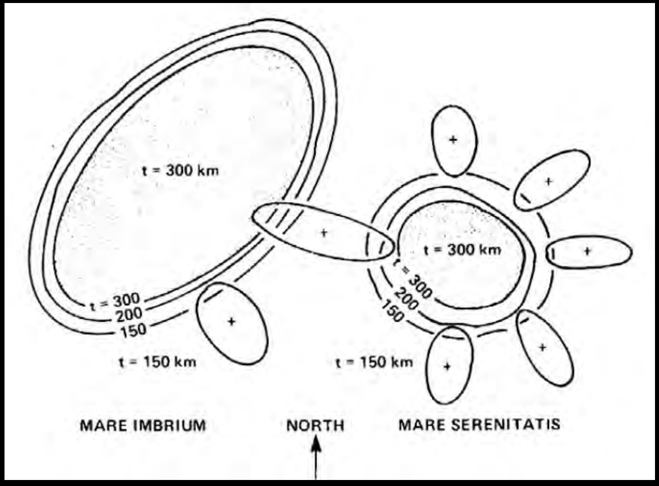
Иванов Б.А., и др. Импульсное магнитное поле при ударной поляризации горных пород как возможная причина возникновения аномалий магнитного поля на Луне, связанных с кратерами. Письма в АЖ, т. 2, № 5, 1976, 257-260.



Dolginov Sh.Sh., et al. Shock wave, a possible source of magnetic fields? Impact and Explosion Cratering. Pergamon Press, 1977, 861-867.

Vanyan L.L. et al. Electrical conductivity anomaly beneath Mare Serenitatis detected by Lunokhod 2 and Apollo 16 magnetometers. The Moon and the Planets, 21, N , 1979, 185-192.

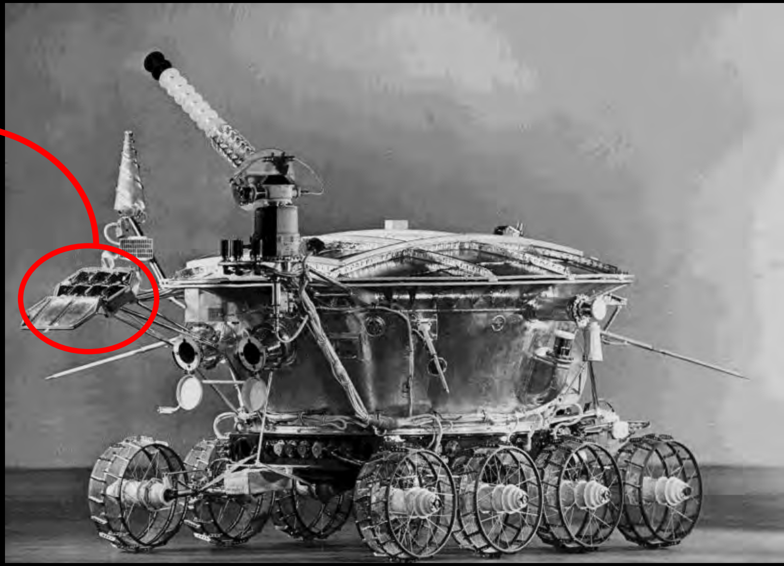
Thickness of dielectric layer



Results taken by Lunokhod 1 and 2

Laser retroreflector

Laser locations for high-precision measurements of distances laser (on Earth) – reflector (on the Moon) to get new data on internal structure of the Moon

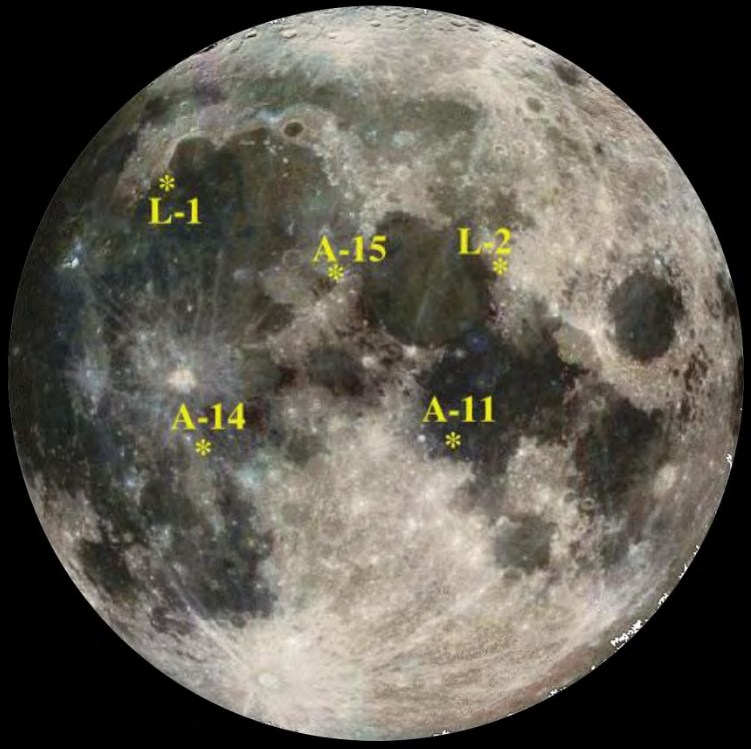


Алешкина Е.Ю. Лазерная локация Луны. Природа. 2002. №9. 57-66.

Calame, O., Free librations of the Moon determined by an analysis of laser range measurements, The Moon, 15, 343-352, 1976b.

Williams J.G., Boggs D.H. Lunar Core and Mantle. What Does LLR See? Proceedings of the 16th International Workshop on Laser Ranging. 2006. 101-120.

Murphy T.W. et al. Laser Ranging to the Lost Lunokhod~1 Reflector. Icarus 2011. V. 211, 1103-1108.



Locations of laser retroreflectors нon the Moon

Results taken by Lunokhod 1 and 2

Collimated X-ray telescope

Study of cosmic X-ray and corpuscular radiations

Бейгман И.Л. и др., Коллиматорный рентгеновский телескоп РТ-1. В кн. Передвижная Лаборатория на Луне «Луноход-1». М. Наука . 138-142.

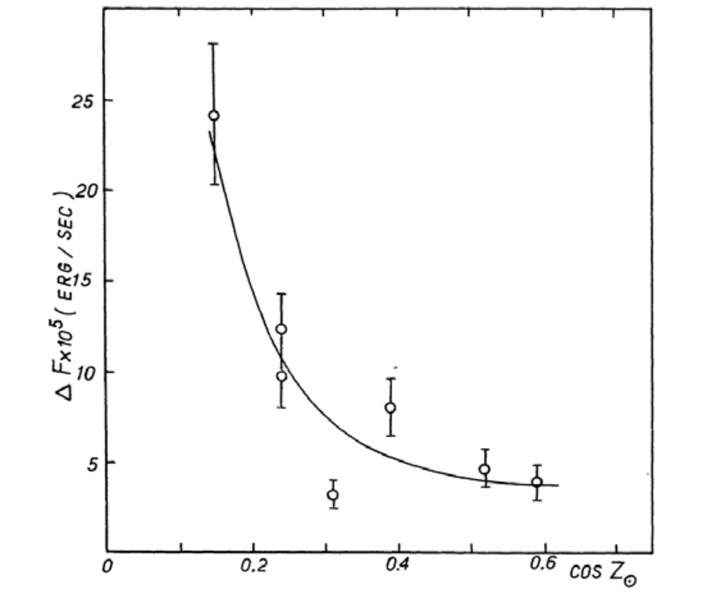
Любимов Г.П. и др. Космические лучи малых энергий на спаде 20-го цикла солнечной активности. В кн. Передвижная лаборатория на Луне «Луноход-1». М. Наука . 139-169.

Astrophotometer

Measurements of radiation of lunar sky from the lunar surface in visible and ultraviolet diapasons.

Зверева, А. М.; Северный, А. Б.; Терез, Е. И. Измерения яркости лунного неба на Луноходе-2. Космические исследования, Т. 12, Ноябрь-декабрь 1974. 910-916.

Severnyi A. B., Terez E. I., Zvereva A. M. Results of the I nvestigation of lunar sky brightness obtained by means o f the AF-3L astrophotometer on board Lunokhod-2. The Moon, vol. 14, Sept. 1975, p. 123-128.

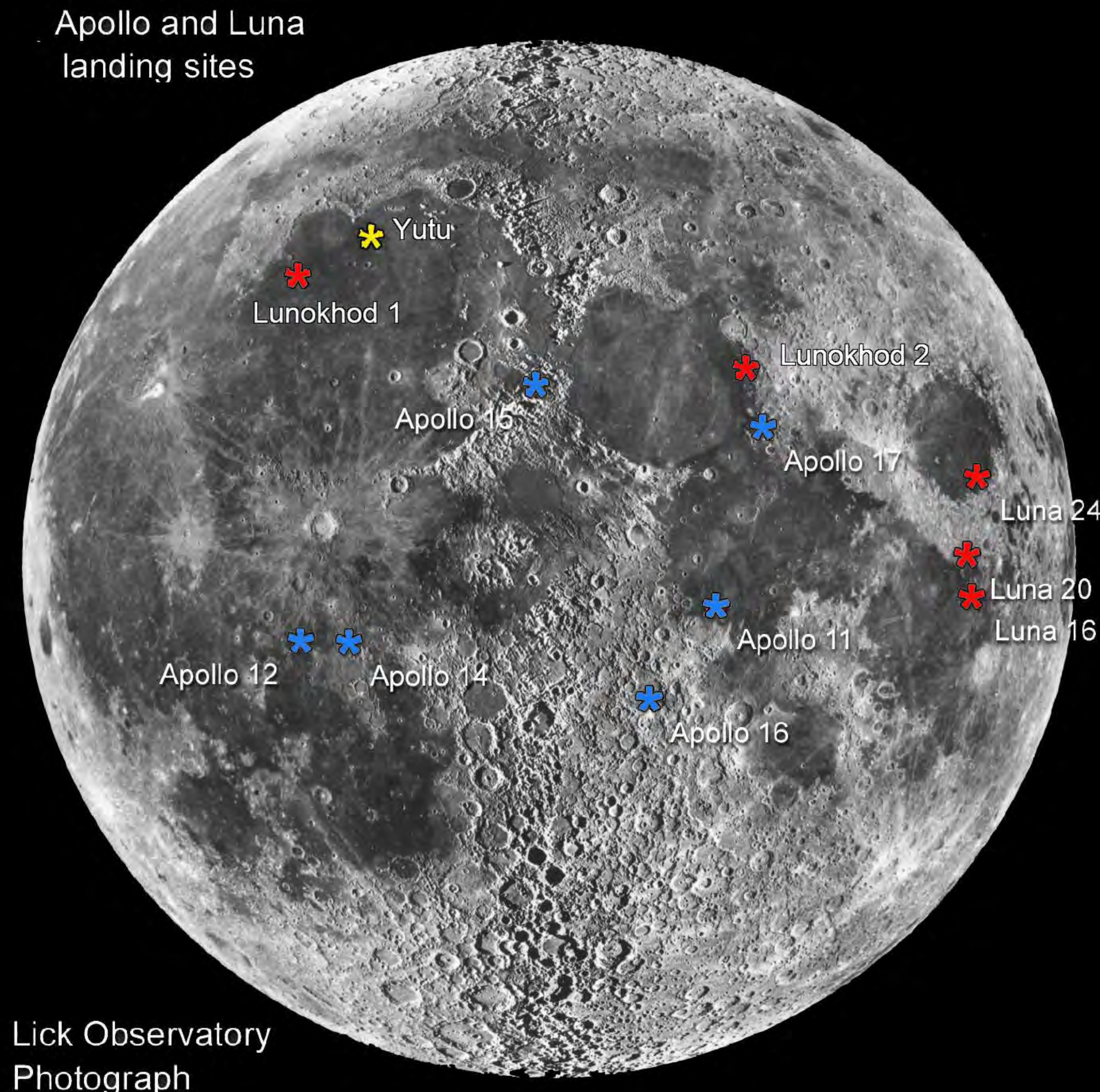


Зависимость избытка УФ яркости неба от косинуса зенитного расстояния от Солнца

Dust in the sky over the Moon

General conclusions

- Robotic sample returns by “Luna 16, 20, 24” and robotic rovers “Lunokhod 1 and 2” provided a significant contribution to lunar studies.
- These methods of lunar studies are still valid at the present time and will be valid in some future.
- Very promising way in lunar studies seems to be combination of the research rover, which collects and preliminarily studies samples and then loads them into the spacecraft delivering samples to Earth.
- The experience gained by the Luna-Lunokhod missions shows that sometimes missions fail and this should be kept in mind with no panic.
- The maneuver at the final stage of landing aimed to avoid dangerous surface features (like did Yutu, Curiosity) may essentially increase probability of success.



Thank you for your attention!