GEOLOGIC CHARACTERISTICS OF THE LUNOKHOD 1 AND YUTU ROVER LANDING SITES, NW MARE IMBRIUM OF THE MOON

A.T. Basilevsky[1,2], A.M. Abdrakhimov[1], J.W. Head[2], C.M. Pieters[2], Wu Yunzhao[3], Xiao Long[4]
[1]Vernadsky Institute, Russian Academy of Sciences, Moscow, 119991, Russia.
atbas@geokhi.ru;
[2]Department of Earth, Environmental and Planetary Studies, Brown University, Providence RI, 02912, USA;
[3]School of Geographic and Oceanographic Sciences, Nanjing University, Nanjing, 210023, China;
[4]Planetary Science Institute, China University of Geosciences, Wuhan, 430074, China

This work is a part of a joint research project between the Vernadsky Institute, Moscow, Russia, Brown Uni-versity, Providence, RI, USA, Nanjing University, Nanjing, China and China University of Geosciences, Wuhan, China. We compared and assessed the results of measurements and observations by the Lunokhod 1 and Yutu rovers, both of which explored the northwestern part of Mare Imbrium [1-7,12] (Figure 1). Both sites are within the distinctive Eratosthenian-aged lava flow geologic unit and our comparisons showed that the geologies of these exploration sites are very similar.

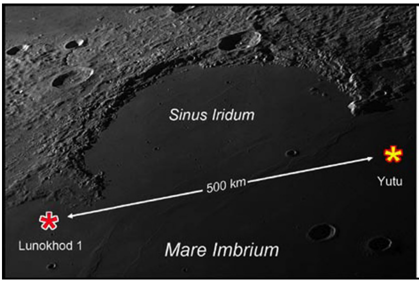

Fig. 1. Area of work of Lunokhod-1 and Yutu rover at the NW part of Mare Imbrium. Image source: http:// www.visit-the-moon.com/ sinus-iridumr13-04-05-07.

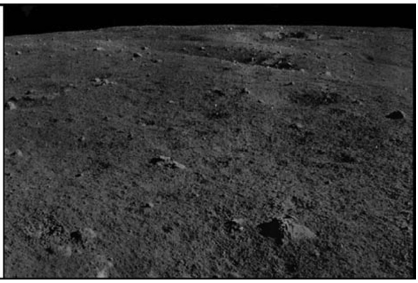

Fig. 2. Typical landscape at the Lunokhod-1 work area. Small craters and rock fragments are dominating features. Portion of Lunokhod-1 panorama L1_D09_S05_P10.

As in the majority of other areas of the Moon, the dominant landforms in these sites are small impact craters, having various degrees of morphologic prominence and states of preservation, and rock fragments, mostly asso-ciated with the rims and interiors of fresh craters (Figures 2 and 3). The shape and the degree of preservation of the observed rock fragments in these two sites are similar.

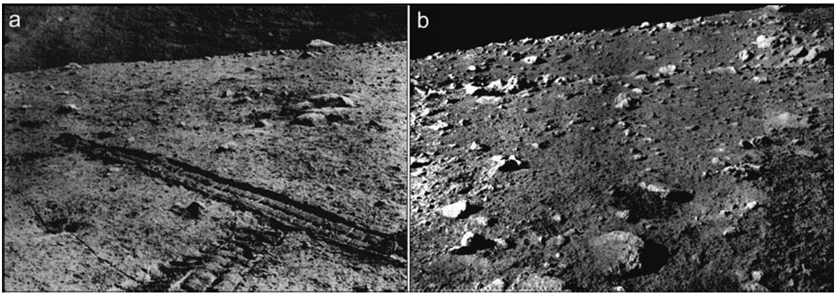

Fig. 3. a) Moderately rocky surface in the WSW part of the rim of the relatively large (D = 470 m) crater Borya. In the upper part of the image the opposite internal slope of this crater is seen. The Lunokhod track width is 20 cm. b) Rocky surface on the western internal slope of crater Borya. Parts of panoramas L1_D07_S04_P08 and L1_D06_S02_P03.

In both sites sporadic rock fragments were observed whose morphologies suggest that their source rocks had columnar jointing (Figure 4). Localization of these specific rocks on the rims of 450-470 m in diameter craters implies that the source rocks are at depths of 40-50 m.

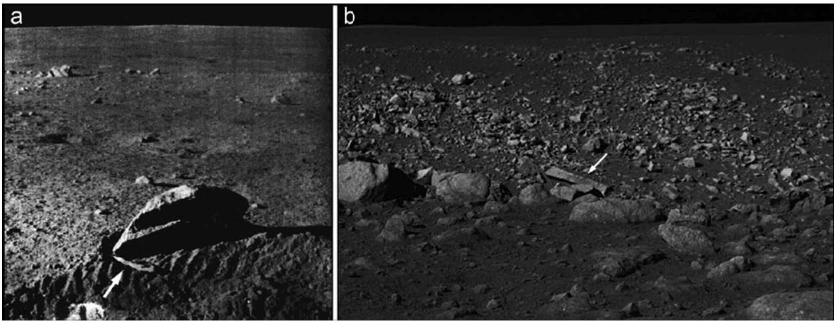

Fig. 4. Fragments of rocks whose morphology suggests a columnar jointing. Portions of Lunokhod-1 panora-ma L1_D05_S01_P01 and Yutu image ID: CE3_BMYK_PCAML-C-015_SCI_N_20140113191514_ 20140113191514_0008_A.

Regolith in the study areas is typically a few meters thick, but locally can be much thicker. The ground pene-trating radar of the Yutu rover revealed the multilayer regolith structure [10,11, 13,14], which is determined by superposition of crater ejecta. With some local variations, this type of the regolith stratigraphy should be typical of the majority of lunar mare sites. The physico-mechanical properties of the regolith in these two sites appear to be rather similar and close to values measured by PROP instrument along the Lunokhod-1 route [9]: the bearing capacity ranges from 0.04 to 1.44 kg/cm2, with a modal value ~0.45 kg/cm2, and the shear strength ranges from 0.02 to 0.1 kg/cm2, with a modal value ~0.05 kg/cm2. Both these parameters decrease by a factor of 3 to 4 with an increase of surface slope from ~2 to 12o. The chemical composition of surface materials determined by the rover instruments at these two sites differ from those derived from the remote sensing data for the Eratosthenian-aged basalts on which the two sites are located. This could be partly due to low measurement accuracies, espe-cially in the case of Lunokhod 1, but may also represent real variations in the composition of the surface materi-als compared to returned lunar samples.

Recommendations for future lunar rover missions are: 1) to use ground penetrating radar and a robotic arm, and 2) to employ radial study tactics for impact crater documentation and analysis.

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References

[1] Abdrakhimov A.M. et al., 2014. 45th Lunar and Planetary Science Conference. Abs. #1239.
[2] Basilevsky A.T. et al., 2014. Planetary and Space Science. V. 92, 77–87.
[3] Fa W. et al., 2014. Journal of Geophysical Research. V. 119, No. E8, 1914-1935.
[4] Florensky C.P. et al., 1971. Preliminary results of geomorphological analysis of panoramas. In: Mobile
Laboratory on the Moon Lunokhod-1. A.P. Vinogradov ed. Nauka Press. Moscow. 96-115. (in Russian).
[5] Florensky C.P. et al., 1972. Geomorphological analysis of the area of Mare Imbrium explored by the automatic roving vehicle Lunokhod 1. Space Research XII. Akademie-Verlag. 107-121.
[6] Florensky C.P. et a., 1978. Geologic-morphologic studies of lunar surface. In: Mobile Laboratory on the Moon Lunokhod-1. V. 2. V.L. Barsukov ed. Nauka Press. Moscow. 102-135. (in Russian).
[7] Karachevtseva I. et al., 2013. Planetary and Space Science. V. 85, 175–187.
[8] Kocharov G.E. et al., 1971. Lunar automatic spectrometric instrument RIFMA. In:

Mobile Laboratory on the Moon Lunokhod-1. A.P. Vinogradov ed. Nauka Press. Moscow. 89-95 (in Russian).
[9] Leonovich A.K. et al., 1978. Automotive chassis of Lunokhod 1 as instrument for the lunar surface study. In: Mobile Laboratory on the Moon Lunokhod-1. V. 2. V.L. Barsukov ed. Nauka Press. Moscow. 25-43.
[10] Qiao L., et al., 2015. 46th Lunar and Planetary Science Conference. Abs. #1050.
[11] Su Y. et al., 2014. Research in Astronomy and Astrophysics. V. 14. No 12, 1623-1632.
[12] Wu Y. et al., 2015. Compositional diversity and geologic context of the northwest Imbrium region. (in preparation).
[13] Xiao L. et al., 2015.. Science. V. 347. No 6227, 1226-1229.
[14] Zhao J N. et al., Science China - Physics, Mechanics & Astronomy, 2014, 57: 569-576.