STUDY OF ZEEMAN CRATER IN THE SOUTH POLAR REGION OF THE MOON ACCORDING TO THE LUNA-25 AND LRO DATA. M. V. Djachkova¹, A. B. Sanin¹, Y. D. Elyashev¹, M. L. Litvak¹, I. G. Mitrofanov¹, ¹Space Research Institute of the Russian Academy of Sciences (IKI), 117997, 84/32 Profsoyuznaya st., Moscow, Russia; djachkova@np.cosmos.ru.

Introduction: Zeeman Crater is an impact crater located on the far side of the Moon near the southern boundary of the South Pole-Aitken Basin.

The South Pole-Aitken Basin is the largest and oldest feature on the lunar surface [1–3]. It is a record of a powerful impact event that played a significant role in the formation of the Moon and may have resulted in the impact melting of large amounts of material in the south polar region [4, 5].

The landing cameras of the STS-L [6] equipment of the Luna-25 spacecraft took pictures of the Zeeman crater on August 17, 2023, during an orbit flight around the Moon. The resulting images significantly supplemented the currently available information about this crater.

Measurements: An important feature of the image obtained by the STS-L cameras was the visible difference in the surface roughness of the Zeeman crater. Visual analysis of the image shows that its bottom, covered with small craters, is much rougher than its smooth walls, creating a “blurred” effect in the image.

Based on the differences in visual appearance, the surface of the Zeeman crater in the image of the STS-L cameras was divided into 3 types: 1) smooth, corresponding to the crater walls, 2) the less rough northern part of the crater floor, 3) the rougher southern part of the crater floor (Fig. 1).

![Fig. 1. STS-L image of a section of the Zeeman crater. The red line divides its surface into types according to visual roughness.](image)

Data Analysis: To quantitatively analyze the crater surface roughness, the Vector Ruggedness Measure (VRM) technique was used [7]. The essence of the VRM technique is to measure surface roughness as a change in the three-dimensional orientation of the grid cells of a digital elevation model within a given neighborhood. Surface roughness values calculated using the VRM method can range from 0 (no change in topography) to 1 (complete change in topography).

As the initial digital terrain model, we used a terrain model created using data from the LOLA instrument (Lunar Orbiter Laser Altimeter, [8]) with a resolution of 60 m. As a result, the southern part of the crater floor is indeed the roughest in the case of assessment using the VRM method. The smooth surface of the crater walls has greater surface variability, which creates the “blurred” effect in the image taken by the STS-L cameras. However, this surface is characterized by the largest scatter of roughness values, amounting to 0.195.

Due to the fact that the Zeeman crater is located on the outer boundary of the south polar region of the Moon, and the absence of permanently shadowed areas within the crater or its surroundings, the expected water content in its regolith is low.

Fig. 2 shows a map of water content in the Zeeman crater and its surroundings according to data from the LEND instrument [9]. According to the spatial distribution of surface water values, the highest values correspond to the younger craters Zeeman E, Zeeman X and Zeeman Y, superimposed on the Zeeman crater rim. Here the water content in the upper layer of regolith reaches to about 0.2% by weight. At the same time, the bottom of the crater is drier; a fairly large part of it contains no water at all in the regolith to the depths of tens of centimeters, according to the LEND instrument.

It is characteristic that the central peak of the crater, where the presence of olivine has already been indicated, does not contain any signs of water content in the regolith according to the LEND instrument.

Discussion: The formation of the Zeeman crater dates back to the Nectarian period. Since Zeeman crater formed at the bottom of the South Pole–Aitken Basin, its floor lies more than 6000 m below the mean radius of the Moon, and the highest point, corresponding to the massif in the northeast of the rim, rises only slightly more than 2400 m above the mean radius. The younger craters Zeeman E and Zeeman Y, superim-
posed on the rim of the Zeeman crater, are believed to have formed during the Imbrian epoch of the geological history of the Moon.

Fig. 2 shows a map of water with the boundaries of geological units marked on it. The floor of the crater belongs to the Nectarian plains (Ntp), its walls, rim and surroundings belong to the Nectarian crater material (Nc), and the younger craters superimposed on the rim belong to the Early Imbrian and Late Imbrian periods (Ic2 and Ic1). When comparing the water distribution and the geological boundaries, one can notice the inclination of higher water values towards the younger surface of impact craters and the material of the walls and crater rim compared to its bottom.

Conclusions: Due to the successful operation of the scientific instruments of the Luna-25 spacecraft in lunar orbit, new knowledge was obtained about the surface of the Zeeman crater in the south polar region of the Moon. Images taken by STS-L cameras made it possible to evaluate the differences in the surface roughness of the crater bottom, its walls and rim. Roughness estimates calculated using the digital model of the LOLA laser altimeter showed a similar result.

The water content in the regolith of the Zeeman crater, according to the LEND neutron spectrometer, correlates with the geological structures of this crater. The effect of correlating water content in regolith with age and geological surface type will be the subject of further research.