Creation of a physical model of Phobos using Mars Express mission data

© Yu.A. Kolosov,[1] A.O. Andreev,[2] N.Yu. Demina,[1] Yu.A. Nefedyev[1]

[1] Kazan Federal University,
420008 Kazan, Russia
[2] Kazan State Power Engineering University,
420066 Kazan, Russia
e-mail: koloyra@gmail.com

Received May 11, 2023
Revised May 11, 2023
Accepted October, 30, 2023

The remote sensing data of Phobos are analyzed based on the data from „MarsExpress“ and „Viking Orbiter“ space missions. Based on this study, a structural model of Phobos was constructed. According to the results obtained, we conclude that the relief of Phobos is very ambiguous. Its entire surface is covered with many traces of meteorite impacts — craters. The parameters for a series of impact craters were obtained and their multi-factor analysis was performed.

Keywords: remote sensing of Phobos, modeling of planetary parameters, astrophysical research.

Introduction

Phobos — one of the two natural satellites of Mars, the closest to the planet [1]. At the same time, Phobos moves in orbit at the closest distance to the main body relative to other planetary satellites of the Solar System [2]. The moon of Mars is 40 times closer to its surface than the Moon is to the Earth's surface. The location and orbital parameters of Phobos — is the Roche limit. The Roche limit is the radius of the circular orbit of a satellite that orbits a particular space object, with the tidal forces caused by the gravity of the central body being roughly comparable to the gravitational force of the satellite itself. Due to its own internal strength, Phobos does not tear. Tidal action from Mars is slowing down the motion of Phobos day by day, affecting its orbital altitude, and should in the next 40−80 million years either destroy it and fall to Mars, or to turn it into a ring around the planet, analogous to the rings of the giant planets. Phobos is characterized by very low reflectivity with an albedo of 0.07 and appears to have a rather loose structure with a thin outer crust. Much attention is paid to the study of Phobos in the world space practice. This is due to the fact that the physical parameters of Phobos are different from the parameters of other natural satellites of the planets, and Phobos is one of the few natural satellites in the depths of which it is possible to detect residual processes that took place at the early stages of the birth of the Solar System. An important space mission, the task of which was to study Phobos, was the experiment „MarsExpress“ [3]. The „MarsExpress“ mission explored Mars, and its main scientific goals were to create a global geological map, study the composition of the atmosphere and the structure of the planet's interior, and study the influence of the interplanetary medium on the atmosphere of Mars [4]. In addition, the mission mapped Phobos using the Phobos Remote Sensing System (PhRS). Based on the results of the PhRS, data were obtained for more than 80% of the satellite surface, and the regions not covered by the PhRS were supplemented by data obtained by the „Viking Orbiter“ mission.

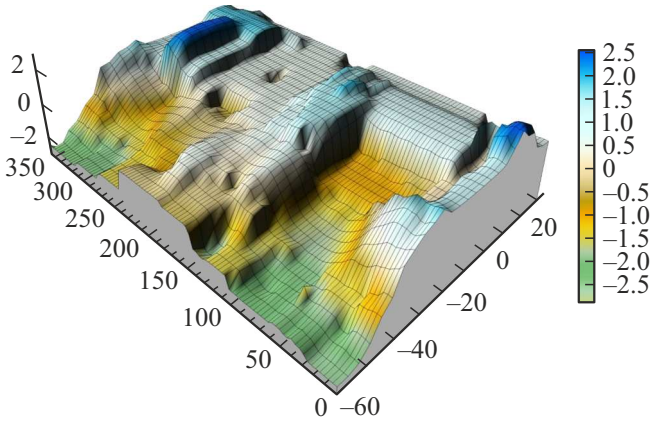

Figure 1. Three-dimensional model of Phobos.

Fig. 1, 2 shows a three-dimensional model of the Mars satellite, which was built using a program based on multiparameter analysis of harmonic data. Based on the results obtained, it can be concluded that the relief of Phobos is very ambiguous. Its entire surface is covered with many traces of meteorite impacts by craters.

The most famous crater of Phobos Stickney is located within 20−30° latitude and from −15° to 5° longitude, inside the crater Stickney there is another crater — Limtok, it is located in the range 28−30° latitude and −5−5° longitude. Nearby is the crater Drenlo, its coordinates 21−23° latitude and 15−25° longitude. The green color on the model (in the online version) is the so-called Kepler ridge, located from 0° to 110° and from 270° to 360° latitude and from −60° to −50° longitude.

The highest point is near the crater Stickney, its coordinates are 320−330° latitude and 0−30° longitude, the

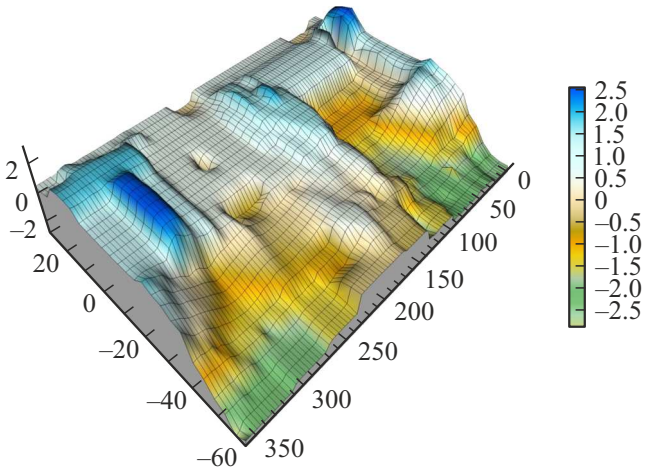

Figure 2. Three-dimensional model of Phobos.

altitude is 3073 km. The lowest point is in the Kepler ridge, with a height of −2361 km.

From the analysis of Figures 1 and 2, it follows that the most favorable places to land on a Mars satellite — is the Laputa region, which is located between 50 to 150° latitude and from −10 to 15° longitude. If this area is low to land, then there is the Lagado Plain nearby on the hill, which can also be used as a landing pad. It will also be possible to land the spacecraft near the Drenlo crater.

In conclusion, it should be noted

1. Phobos is the larger of Mars' two natural satellites and has an imperfect ellipsoidal shape. The mass of the satellite is $1.072 \cdot 10^{16}$ kg, which is why it has no atmosphere at all, and its low density (about 1.876 g/cm^3) allows us to infer the porous structure of a celestial body, 25–45% of the volume of which is occupied by voids.

2. Flights to Phobos are still only planned in the near future, inasmuch as landing on its surface is impossible due to the lack of knowledge of the area.

3. Based on the results obtained, we can conclude that the relief of Phobos is very ambiguous. Its entire surface is covered with traces of meteorite impacts — craters. The most famous crater of Phobos Stickney occupies the region of 200–300° latitude and from −15° to 5° longitude, inside the crater Stickney there is another crater — Limtok, it is located in the range 280–300° latitude and −5–5° longitude.

The spatial model of Phobos will be used to study the astrophysical parameters [5,6] and structure of Phobos at the Space Research Institute in the development of missions to Phobos and in Roscosmos systems.

Funding

The authors express their gratitude to the Russian Science Foundation for the support of the work performed, grant No. 22-72-10059.

Conflict of interest

The authors declare that they have no conflict of interest.

References

[1] P. Garnier, C. Jacquey, X. Gendre, V. Génot, C. Mazelle, X. Fang, J.R. Gruesbeck, B. Sánchez-Cano, J.S. Halekas. J. Geophys. Res. Space Phys., **127** (5), e2021JA030147 (2022). DOI: 10.1029/2021JA030147

[2] A. Sánchez-Lavega, H. Chen-Chen, I. Ordoñez-Etxeberria, R. Hueso, T. del Río-Gaztelurrutia, A. Garro, A. Cardesín-Moinelo, D. Titov, S. Wood. Icarus, **299**, 194 (2018). DOI: 10.1016/j.icarus.2017.07.026

[3] M. Giuranna, P. Wolkenberg, D. Grassi, A. Aronica, S. Aoki, D. Scaccabarozzi, B. Saggin, V. Formisano. Icarus, **353**, 113406 (2021). DOI: 10.1016/j.icarus.2019.113406

[4] V. Lainey, A. Pasewaldt, V. Robert, P. Rosenblatt, R. Jaumann, J. Oberst, T. Roatsch, K. Willner, R. Ziese, W. Thuillot. Astron. Astrophys., **650**, A64 (2021). DOI: 10.1051/0004-6361/202039406

[5] X. Yang, J.G. Yan, T. Andert, M. Ye, M. Pätzold, M. Hahn, W.T. Jin, F. Li, J.P. Barriot. Mon. Not. R. Astron. Soc., **490** (2), 2007 (2019). DOI: 10.1093/mnras/stz2695

[6] Z. Girazian, Z. Luppen, D.D. Morgan, F. Chu, L. Montabone, E.M.B. Thiemann, D.A. Gurnett, J. Halekas, A.J. Kopf, F. Němec. J. Geophys. Res. Planets, **125** (5), e2019JE006092 (2020). DOI: 10.1029/2019JE006092

Translated by 123