Vestnik Otdelenia nauk o Zemle RAN, VOL. 3, NZ6011, doi:10.2205/2011NZ000141, 2011

About age of the lunar surface

A. A. Barenbaum[1], M. I. Shpekin[2]
[1] Oil and Gas Research Institute RAS
azary@mail.ru тел.: 8 (499) 135 7221
[2] Kazan University
Michael.Shpekin@ksu.ru тел.: 8 (843) 292 7797

Key words: Planets, craters, galactic comets, volcanic and tectonic processes.

Citation: Barenbaum, A. A., M. I. Shpekin (2011), About age of the lunar surface, *Vestn. Otd. nauk Zemle, 3*, NZ6011, doi:10.2205/2011NZ000141.

Abstract. Most part of the lunar surface relief was formed during the last 5 Ma. This conclusion was received on the basis of detail analysis of large craters of the Moon, Earth, Mars and Mercury. Falling of the galactic comets in the period 5–0.6 Ma, and the tectonomagmatic processes induced by the comets falling played major role in shaping of the Moon topography. Processes of tectonics and volcanism are occurring on the Moon today also. We found volcano in the Tsiolkovsky crater on the reverse side of the Moon that can serve as good example of that. The volcano has a height of 102 m and is located almost in the bottom center of the crater with a diameter of 180 km on a low oval elevation of plume nature 24–26 km in size.

Introduction. It is believed that the relief of the lunar surface, as well as Mercury and Mars have formed more than 3000 Ma as a result of falls on these celestial bodies planetesimals that remained in the interplanetary space after the Solar system formation [*Hiesinger et al*., 2010]. To substantiate this view are used data on the craters, as well as measurements of the isotopic age samples of lunar rocks delivered to Earth and testifying to their formation more than 3000 Ma [*Hayes, Walker*, 1975]. The planetary exploration by spacecraft made in recent years, however, cast doubt on such an ancient age of the surface topography, in particular, the Moon and Mars. Large masses of frozen water were discovered at the poles this celestial bodies. Moreover recently dry riverbeds can be seen on the Mars [*Wikipedia*]. These and many other facts do not find a convincing explanation within the framework of existing concepts.

We suggest another interpretation of the observed facts. It is based on attracting galaxycentric paradigm [*Barenbaum*, 2010] to analyze the distribution a cometary craters on surface planets as well as on the discovery in one of them (in the Tsiolkovsky crater on the reverse side of the Moon) modern volcano [*Shpekin*, 2009]. Our studies show that most of the surface of the Moon, Mars and Mercury are completely saturated by such craters. Owing to that formation the craters is associated with ejection of rocks from depths of ~ 3 km or more large age of the lunar rocks samples says in the first place about the time of solidification of their material but not about the actual age of the formation of the lunar surface.

Below we present arguments and evidence that the age of lunar surface is hardly older 5 Ma and the process formation of surface the Moon continues today.

General characteristics of the Moon relief. The main topographical features of the topography of the Moon, Mars and Mercury are uplifted the areas of surface – "continents" and the more lower areas of the surface –"seas". Continents uninterruptedly dotted with large craters, while the seas covered by craters to a much lesser degree. It is significant that the continents tend to be located the southern hemisphere of the celestial bodies whereas marine surfaces is mainly located in its northern hemisphere.

There is also an important specificity in the morphology and distribution of craters. According to [*Pike*, 1977] on the moon we can distinguish two different populations of craters – with a diameter D < 15 *km*, and with D > 15 km. The first are the most numerous in the seas, and the second – on the continents. The depth H of the first is approximately equal to 1/5 of their diameter, while depth craters of the second type is smaller. The first type of craters has a simple structure and is best described by the dependence $H = 0.196\ D^{1.01}$, whereas the second type is more complicated. The second type craters has central hills and gentle slopes. In the diameter range from 11 to 400 km these craters are followed the depending $H = 1.044D^{0.301}$. Thus in the process of impact origin craters on the surface may be ejected rocks from a depth of ~3–7 km.

The transition between the types of craters on the curve H(D) is not monotonic, forming a region of overlap. The same applies to craters on the Mars and the Mercury [*Melosh*, 1989].

The distributions of craters by diameter as well as their density on the continents and in seas are also turn out peculiar (Fig. 1-a). For craters with D ~100 km their density on the continents is 100 times higher than in the seas, and at D ~10 km this difference is reduced to ~10. Significant differences in the density craters on different planets appear only for D > 400 km, where the density of craters on the Moon in 4–10 times higher than on the Mars.

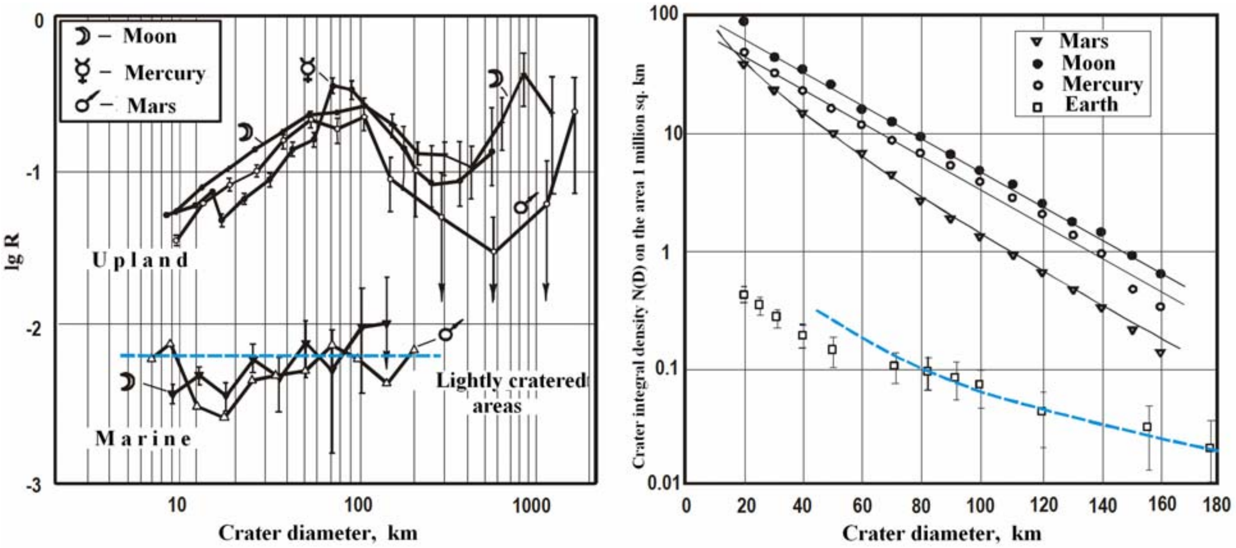

Fig. 1. Density distribution of craters by diameter: a) the differential N(ΔD) with a step ΔD = D÷√2D in a double logarithmic scale [*Voronov et al*, 1986], and b) the integral N(>D) in a logarithmic scale [*Barenbaum*, 2010], constructed according to data [*Kazimirov et al*, 1980]. The dotted line in the figure corresponds inversely quadratic dependence on D.

The distributions craters of the Moon, the Mars and the Mercury are similar in configuration and are close in numerical parameters. Since the last craters are more numerous the exponential distribution of craters by diameter is intrinsic for these planets in general (Fig. 1-b).

Bending curves in Fig. 1-a for the continents at D = 60–100 km and line graphs for the seas are explained by two [*Voronov et al*, 1986] or even by three [*Urey*, 1975] space bodies bombardments of different ages that that partially destroyed the traces of more early fallings. Modeling the distribution of craters by means of special selection of sizes cosmic bodies [*Voronov et al*, 1986], however, is not allowed to conclusively resolve this question [*Melosh*, 1989].

It is more difficult to explain [*Marov*, 1981] similarity in the distribution of craters in so much different celestial bodies like the Moon, Mars and Mercury that are differ by its geological history, the force of gravity on the surface and the distance from the asteroid belt and the Sun. The basic idea for explaining is associated with the possibility of complete saturation of large craters at least the surface of the continents [*Gault*, 1970; *Basilevsky*, 1977; *Woronov*, 1977; *Voronov et al*, 1986]. This problem was not resolved. Currently accepted view is [*Melosh*, 1989] that planets are far from the state of saturation by the large craters.

A new approach to the problem. According to [*Barenbaum*, 2010] the Sun in its motion in the Galaxy once in every 20–37 Ma is crosses the jet streams of substance flowing from the center of our star system. In moments of these intersections duration ~2–5 Ma the Solar system is exposed to intense bombardments by galactic comets. In the Earth's geological history all these times are marked as the eras of global natural catastrophes. These events are accepted as the boundaries straton of modern geochronological scale.

Last bombardment by galactic comets occurred in the period 0.6–5.0 Ma at the boundary of the Neogene and the Quarter [*Barenbaum et al*, 2002]. Today these comets are absolutely unavailable for detection from the Earth by means of astronomy. Therefore we are judging about the properties of these objects proceeding from the consequences of their falling on our and other planets, as well as the results of their collisions with a bodies of the asteroid belt [*Barenbaum*, 2010].

Available data suggest that the masses of the nuclei of galactic comets are varied in the range from 10^{12} to 10^{17} g and their kinetic energy is varied from 10^{20} to 10^{25} J. The matter density of the comet is close to 1.0 g/cm^3. It is composed of 80–90% water ice and of ~10–15% the carbonic component. Chemical elements heavier than carbon and oxygen are possessed by space prevalence. Their content is not more than one percent [*Barenbaum*, 2010].

The falls of galactic comets are characterized as "cometary showers" when during one bombardment ~10^4–10^7 such bodies could fall on the Earth. In contrast to large asteroids and comets of solar system these comets are characterized by an exponential distribution of mass and energy that causes the same distribution of diameters of the craters created by them (Fig. 1-b).

At the same time the number of the falling comets is so great that full saturation of the surface by craters is reached even during one bombardment period. The theoretical value of the "ultimate" density of the craters for the Moon, Mars and Mercury is ≈100 craters with a diameter D ≥ 10 km on area 1 million km^2 [*Barenbaum*, 2010]. Because of the obliquity of the ecliptic at an angle of 62° to the galactic plane in which occur comets moving, their latest bombardment came mainly to the southern hemisphere of the planets. Thus the complete saturation of the craters exists only in that hemisphere of the Moon and the Mars. Data in Fig. 1-b confirm this conclusion.

There is another important fact that should be noted in discussing the data of Fig. 1-b. This is the absence of craters on the Earth, created by galactic comets. All the large craters on Earth are formed owing to asteroids downs. The distribution diameter of these craters by in region D≥70 km, slightly garbled observational selection, well described by inversely quadratic dependence.

The facts and calculations suggest that fragile nuclei of galactic comets are inevitably disintegrated in the atmospheres of the Earth and the Venus. In result raises the powerful hypersonic jet [*Barenbaum and Shuvalov*, 2007], which does not create a crater and the whole enormous kinetic energy of the comets is directed to heating and melting of the rocks up under the surface planet. Subsequently, this energy is released in different tectonic and volcanic processes [*Barenbaum et al*, 2004]. Typical manifestations of these processes [*Barenbaum*, 2008] in a "thin layer" lithosphere are the formation of seamounts on the Earth, and shield volcanoes on the Venus, whereas in case "powerful" lithosphere takes place the so called phenomenon of "newest raisings".

This phenomenon consists in almost synchronous uplift of the half surface area continents of the globe at the past 5 Ma. Different geological structures have tested significant rise during this period. Among them: the Antarctic continent; most part of Africa; the Central and North-Eastern Asia; the Western North and South America; Guiana and Brazilian shields; the Scandinavian Mountains; the Greenland; the Urals; the Siberian platform; the Alps and other structures [*Artyushkov*, 1994].

The lifting height was different. On most of the Pacific coast, she was the first hundreds of meters, on the Siberian platform ~200–1000 m, in South Africa ~300–400 m in the west and ~900–1200 m in the east. The fastest growth occurred in mountainous terrain. For example the Arabian platform increased the height of 2 km, the Alps – up to 3 km, and the Himalayas – up to 6 km. The rising of asthenosphere is observed under most of the mountains. In separate flat sections the lift leads to the uplift of crystal blocks in diameter ~ n(10-100) km to a height of up to ~1 km at distance between the elevations greater than their diameter. In some places rising of asthenosphere was accompanied by modern intense outpourings of magma [*Artyushkov*, 1994].

Similar processes occur on the Mars. Calculations show that even ~100 times less dense than on the Earth, its atmosphere leads to two important physical effects. On the one hand, it causes severe ablation of the galactic nuclei of comets, which reduces the diameter of a crater and shifts the distribution in Fig. 1-b relative to the Moon. And on the other hand, the part of comet's energy goes into heating asthenosphere under the southern hemisphere of Mars, It is explains uplifting of southern hemisphere of Mars on 2–4 km relatively flat northern hemisphere which has much less craters. Huge volcanoes of the Mars, with clear indexes of recent activity are probably the channels of excess heat from the asthenosphere of the planet.

Volcanic and tectonic processes have occurred on the Moon in last 5 million years albeit on a smaller scale. They continue today.

Modern volcano-tectonic processes on the Moon. Many researchers mark the evidences of such processes in form craters filled by caked lava with inclined surface as well as craters destroyed by deep rifts. In 1958 Kozyrev [1959] established on the Moon volcanic activity is directly. He found small emission of volcanic ash and gas in the Alphonsus crater with a diameter of 120 km on the visible side of the Moon. Spectral analysis showed the presence in the ejection of molecules C_2, CN, etc.

Another, even more compelling example of volcanic processes is a small volcano [*Shpekin*, 2009]. The volcano is located at the bottom of the Tsiolkovsky crater on the far side of the Moon and was discovered on the basis of images delivered to the Earth by "Apollo-17" mission. Crater has a diameter of 180 km. He is characterized by a complicated structure and by existence the central peak, typical for craters of cometary origin.

The volcano is located almost in the center of the crater on a small flat oval raising by diameter 24–26 km. This raising very probably has nature of plume. On high-resolution images are visible lava flows, indicating about almost contemporary eruption of the volcano (Fig. 3).

Estimates made on the basis of images photogrammetry showed that the height of the volcano is about 102 meters. Diameter at the base of the volcanic cone is 1,760 meters. Slopes of the volcano have an inclination toward the bottom of the crater on angle about 7–8°. Emissions of the material are observed only in one direction and this trend points to the central peak on the bottom of Tsiolkovsky crater. Other characteristics are listed in Table 1 [*Shpekin*, 2009; *Shpekin and Barenbaum*, 2011].

Table 1. Characteristics of the plume and the volcano at the Tsiolkovsky crater bottom

Plume

Diameter	24 – 26 km
Longitude of center	129 33 E
Latitude of center	-19 27 S
Distance from central peak	32 km

Volcano

Longitude	129 52 E
Latitude	-19 30 S
Base diameter	1760 m
Cone hight	102 m
Throat diameter	50-70 m
Cone inclination	7-8 degrees
Material ejection	2 x 1 km
Distance from central peak	36 km

Fig.2 Above left: central part of Tsiollkovsky crater bottom
Above right: studied site to the East from central peak

Fig.3 Below: Volcano and its vicinity in the rays of sunset
This territory is noted by white rectangular on Fig.2

(AS17-M-2798. Credit:NASA/JSC/Arizona State University)

Several small craters we can see at the top of the cone if closer to look in Fig.3. It is probably the canals through which volcanic material in form of lava turns out on lunar surface. The diameter of the central conduit is about 50-70 meters. Volcanic cone contains no small impact craters that indicating at its young age. Reflective properties of the volcano say about the same. The surface of cone volcano is noticeably brighter than the surrounding terrain, because it had not yet covered with dark lunar dust. This evidence supports our conclusion that volcanic activity ended or recently, or perhaps it even has a modern character.

It is significant that the volcano is located in the center of the small sublime structure of tectonic-magmatic nature. Such combination of both geological objects on the Earth is typical for shallow "magmatic chambers" that arise under planet surface into the place of galactic comet falling [*Barenbaum*, 2010a]. Very probably such magmatic chamber has arisen and exists today under the bottom of the Tsiolkovsky crater.

Summary and conclusions.

• The time of formation of the main topographic structures (continents and seas) on the Moon as well as all the planets are not uniquely associated with the age of rocks composing these structures.

• The main factor that determined the modern look of the Moon, Mars and Mercury was the bombardment of the solar system by galactic comets between 5–0.6 Ma.

• Mass fallings of galactic comets are causes of abrupt activization of tectonic and volcanic processes that continue on the Moon and planets to this day.

• An example of these processes is discovery at the Tsiolkovsky crater, apparently, an active volcano 102 meters high, locating on a low plume base with diameter of 24–26 km.

In this regard it should be emphasized that the questions formation of the "Geodynamic Camera" located under large impact craters still have not been studied theoretically [*Barenbaum*, 2010b].

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