Geological structures created by falls of galactic comets

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Abstract. With the use of the author's theoretical model are discussed geological structures which can be created by fallings of galactic comets on terrestrial planets: Mercury, Mars, Earth, Venus and the Moon. The model predicts that depending on combination of a number of conditions galactic comets may form on these planets following types of structures: craters, diatremes, lava sheets, volcanoes, dome-shaped surface uplift, as well as coronae and montes (on Venus). The main factors that influence on origin of these structures on planets are (i) density of gas shell, (ii) thickness of planetary lithosphere, (iii) composition and degree heating of lithosphere rocks, (iv) frequency of fallings galactic comets. We are discussing specific features of these structures on the Moon, Mars, Earth and Venus.

1. Introduction
Origin on the planets similar geological structures (continents, seas, volcanoes, mountains, craters, etc.) is the issue that in Planetology is still very far from adequate explanation. Things began to change for the better due to the recent discovery of the phenomenon of jet expiration of gas-dust substance out the Galactic center. Once the fact of fallings galactic comets on planets of the Solar system has been established [1–3] the physical mechanism of the interaction of these comets with atmosphere and lithosphere of our planet became to be studied theoretically [4, 5].

The author’s studies have shown that the formation of these geological structures can be caused by a falling of galactic comets. The physical mechanism of formation of these structures on terrestrial planets apparently is universal and all their differences are determined by four factors: (i) the density of gaseous envelope of the planet, (ii) the thickness of planetary lithosphere, (iii) the degree of heating and composition of lithosphere rocks, and (iv) the intensity of fallings large cosmic bodies, primarily of galactic comets.

In this paper we wish to discuss the interaction mechanism of galactic comets with atmosphere and lithosphere planets. We also analyze the specificity of action this mechanism with respect to formation of craters, diatremes, lava sheets, shield volcanoes, and other leading types of surface topography on atmosphereless Moon, Mercury and Mars that has a very tenuous gas shell, as well Earth and Venus with a sufficiently dense atmospheres. But first we will need to briefly describe some properties of galactic comets [1, 2].
2. Information about Galaxy’s comets
Galactic comets are a newly opened class of major space bodies, which move in the galactic plane and cyclically bombard all planets of the Solar system exclusively in the moments when Sun is located in the jet flows and the spiral arms of Galaxy. Those periods are repeated at 20–37 million years and have duration of 1–5 million years old. Therefore fallings of galactic comets have character of relatively short “cometary showers”. Consequences of such showers are most studied for our planet. Found that during a one bombardment to the Earth may fall of $\sim 10^4–10^7$ galactic comets. All those periods for the last 560 million years of the Earth’s history are fixed by geologists in form of boundaries stratons of the Phanerozoic geologic time scale [6, 7].

Last cometary shower “medium intensity” took place at 5.0–0.7 million years ago, at the border of Neogene and Quaternary. We estimated that in this time $\sim 3–5$ galactic comets were able to fall on square size $100 \times 100$ km$^2$ [8]. This cometary bombardment caused significant heating of lithosphere rocks that led to a marked lifting of the continents surface. This phenomenon was named “newest uplift crustal” [9]. It is known that along with the continents sharply intensified tectonic-magmatic processes and on the oceans floor [10].

Diameter nucleus of galactic comets is from 100 m to 3.5 km; their mass varies from $10^{12}$ to $10^{17}$ g and the kinetic energy from $10^{20}$ to $10^{25}$ J. Cometary substance is composed at 80–90% of water ice and at 10–15% of the carbon-containing components. Substance density is of about 1.0 g/cm$^3$. Speed of movement comets of last shower relative to the Sun was close to 450 km/s. Unlike to asteroids and comets of the Solar system, galactic comets are characterized by an exponential distribution by diameter, mass and energy, which causes an exponential distribution by sizes of geological structures that were created by their fallings on the planets. Another difference is that due to inclination of the ecliptic at angle of 62° to Galaxy plane, in one last time galactic comets bombed the southern hemispheres of terrestrial planets. Therefore leading landforms of southern and northern hemispheres of these planets are differ significantly [3].

And finally we must say that galactic comets cannot be visually detected by means of astronomy currently. Therefore all that is known about them today was obtained by studying of the consequences their falling to the Earth and other terrestrial planets, as well as using the results of their collisions with bodies of the asteroid belt [2].

3. Mechanism interaction of galactic comets with planets
We have studied this mechanism in application to the Earth as three-step process [5]. In the first step—in the Earth’s atmosphere—comet nucleus is transformed into peculiar gas-fluid jet consisting of cometary material, subjected to ablation, and shock-heated air [4]. In the second stage this jet inelastically collides with a solid surface, creating narrow-directed hypersonic shock wave which penetrates deep into lithosphere of the planet and causes heating of cylindrical column of rocks. The heating is so great that top part of column are vaporized, forming crater and the material under crater is melted, forming magma chamber. When calculating of heating effects caused shock wave we used the hydrodynamic model of first approximation Lavrentiev [11] designed to study the collisions of bodies with cosmic speeds.

In the third stage the heating energy is redistributed in system. The melted rocks which arisen in magma chamber fills crater, while magma’s excess can to flow out to surface. If heating energy is not enough, magma crystallizes in upper crust, forming the various composition of intrusives during cooling. Heating time of the rocks column by shock wave takes split second and the time of redistribution and dissipation of heat energy in the column takes $\sim 400$ thousand years for galactic comets small size and $\sim 2$ million years for largest comets.

Heat effects created by galactic comets “small”—300 m and “large”—3 km of sizes are illustrated in Figure 1. According to our calculations, “small” comets are able to create craters of deep to $\sim 1$ km, whereas “large” comets—to 7 km and more. At that, magma chambers created
by small comets are located at a depth of $\sim 1–3$ km from the surface, and at this case the melt that has been formed in magma chamber is not completely fills crater. The large comets may create cameras, which reach of asthenosphere depth $100–250$ km. In result the large amount of magma can flow to surface. In both cases the crater depth coincides with diameter of column heated rocks. On the results base of simulation processes of destruction galactic comet in the Earth’s atmosphere, we assumed that column diameter is equal to twice diameter of cometary nucleus.

Results of calculations (figure 1) are applicable also for comets falling into the World Ocean. From the energy point of view the energy losses due to evaporation of water at formation of crater are small ($\sim 1–10\%$). Therefore for large comets the size of magma chamber stays almost same, but crater depth in the oceans decreases.

4. Density of gas shell

Influence of atmosphere and its density we discuss on the basis distributions craters of diameters $D = 10–200$ km on the continental parts of surface the Moon, Mercury, Mars, Earth and Venus (figure 2). Unlike Earth the vast majority of craters on other planets and Moon were created by galactic comets. On atmosphereless Moon and Mercury the craters distribution $N(D)$ obeys by an exponential dependence, which reflects the exponential distribution of diameters of cometary nuclei. In rarefied atmosphere of Mars the function $N(D)$ is deformed. Due to the fragmentation of cometary nuclei in Martian atmosphere the amount of large craters decreases, and small
Figure 2. Integral density of craters on the Moon (1) Mercury (2), Mars (3), Earth (4) and Venus (5). Curve (4) corresponds to the inverse-square-law dependence. Distributions of 1, 2 and 3 are based on the data [12] whereas 4 and 5 were built respectively according to data [2,13].

Due to the high intensity of the last cometary shower when density fallings of galactic comets was \(\sim 5\) bodies at area \(100 \times 100\) km\(^2\) [8] currently continents of Mercury, Moon and Mars are completely saturated with craters \(D > 10\) km. This saturation limit for all planets is the same and equals to \(\approx 100\) craters on square of \(10^6\) km\(^2\) [2].

In the Earth’s atmosphere galactic comets are completely destroyed [2]. As a result the cometary craters with \(D \geq 10\) km on our planet are absent, and all craters of such size have the asteroid origin. Their distribution \(N(D)\) corresponds to the inverse square law which is intrinsic to large asteroids and comets of Solar system. However on a plot of \(D < 80\) km this dependence is distorted by observational selection.

In more dense gaseous envelope of Venus the galactic comets are destroyed even more so. Nevertheless they do create large craters. But there are two peculiarities: 1) number of these craters in \(\sim 100\) times less than at atmosphere absence or her low density and 2) their size distribution \(N(D)\) has the same exponent index as in the initial portion of this dependence at Mars. Thus firstly atmosphere of Venus significantly reduces energy of cometary gas jet which reaches surface. And secondly the mechanism of craters formation in these conditions has its own specifics.

5. Thickness lithosphere and temperature heating of rocks

We discuss the influence of these factors in two different cases when galactic comets fall on continents or into the World Ocean. In the first case (figure 1a) if the asthenosphere lies deep, the comets able to create in the column of heated rocks three zones: crater (I), magma chamber (II) and the heating zone below the melting point of rocks (III).

In the event of fall comet into the World Ocean where asthenosphere is closer to the Earth
surface, the zone (III) may absent (figure 1b). As a result will be created continuous conductive pipe—“plume” through which magma can flow to the surface from the asthenosphere. At that importantly to note that these plumes may be created not only by large comets but also vast majority of small comets.

Obviously there are other differences. We note only one thing in common for the Earth and other planets. Specificity of falls comet on the Earth surface with a “thick” lithosphere is that magma is generated not enough to fill cavity of crater. In a result, some structures are created, which we may define [14] as the kimberlitic pipes or otherwise words—diatremes. Approximately 5% such pipes contain diamonds and therefore geologically well are studied. It is believed that diamond-bearing pipes arise in explosions at depths greater than 100 km [15].

It is empirically detected [16] that kimberlitic pipes meet only on the ancient “thick” platforms. In the oceans where create the diatremes it would seem easier they are absent. The physical mechanism origin of diamond-bearing pipes also is poorly understood [15].

However problematic issues physics diatremes can try to solve on the basis of discussed mechanism heating rocks by shock waves [5, 14]. From the standpoint of given mechanism all diatremes (kimberlitic pipes) can be considered as form of intraplate magmatism which occupies an intermediate position between outpouring of lava on the Earth surface and cooling lava in cavity of crater. We attribute the formation of craters on Venus with this type magmatism.

Consequences fallings of galactic comets on the “thin” lithospheric plates in particular into the World Ocean are of a different nature. In this case much more quantity magma arises. This magma can reach surface where takes part in the formation of seamounts and hotspots in marine conditions and trappean outpourings in continental conditions [2, 17].

Basing on these representations author discusses the issues of intraplate magmatism and structure of modern ocean crust [18, 19] as well as analyzes the tectonic-magmatic processes in oceans caused by the latest and several previous cometary bombardments [10, 20, 21].

In addition the falling of galactic comets into oceans also leads to appearance in water column of hollow channel with diameter \( \sim 0.2–7 \) km. From above this channel fast is filled by water, and below by the magma, that causing powerful physical processes on the ocean bottom [21]. In some places they lead to mixing of the sedimentary rocks and basalts in the oceanic crust. As a result the sedimentary interbeds turn out within layer of basalts, whereas basalt sills are in lower part of sedimentary cover of oceanic crust [22, 23].

6. Intensity of cometary fallings

Processes of intraplate magmatism caused by mass fallings of galactic comets are very complex and diverse. They can be explored only on well-studied geological objects. We will discuss them on example of two such structures: basalt plateau Dariganga in Mongolia and the iron-ore Angara-Ilim area in Eastern Siberia [19].

6.1. Plateau Dariganga

It is known that in Cenozoic powerful tectonic-magmatic processes took place in Central Asia. They generated a large number of basalt fields in the formation of which were attended by numerous volcanic centers, which quickly migrated and died [15]. Plateau Dariganga that arose at the border of Neogene and Quaternary is one of such fields. Its area is about \( 20 \times 10^5 \) km\(^2\). There are lots of volcanoes (\( \sim 220 \)) with diameters up 3–4 km. Plateau consists of four layer basalts total power up to 200 m with age of Pliocene-Pleistocene. Basalts are alkaline and include deep-seated xenoliths. Under the terms of ultrabasites crystallization the depth of lifting magma estimated more of 100 km [24].
6.2. Angara-Ilim region

Angara-Ilim region covers an area of 400×600 km$^2$. The region refers to the Siberian trappean province, which has emerged at the Permian-Triassic boundary. In the area are revealed $\sim 50$ magnetite diatremes and same number structures with unexplored pipe structure, as well as about 10 volcanoes in the central zone. The diatremes have a diameter up to 2 km and are filled tuffs on many hundreds meters. Trappean agglomerates lie under layer tuffs. It is considered that agglomerates correspond to upper parts necks, which fill pipes below level of 1500–2000 m [25].

We believe that plateau Dariganga arose due to the cometary shower of 5–1 million years ago, whereas diatremes in Angara-Ilim region were formed in result of bombardment of 250 million years ago, which was about $\sim 100$ times more intense. The plateau origin we explain in that the quantity of a large comets fallen on its area was many more than near it. As a result the layer lithosphere under plateau received significant heating that caused appearing of large asthenospheric lenses as well as intensive basalt outpouring and lifting of surface. The surface plateau was covered by system of cracks and diatremes which transported magma for a large number of volcanoes.

The situation is different in Eastern Siberia. There maximum density of bombarding comets was located on north of Siberian platform. Moreover bombardment was so intensive and powerful that in during $\sim 1$ million years was produced volume of lava $\sim 2$ million km$^3$ which occupies area $\sim 4$ million km$^2$. As known the greatest quantity of lava was poured out near Norilsk where thickness of trappean depositions reached $\sim 1$ km. In Angara-Ilim region located 1600 km south volcanism was weaker. Except center region the magma quantity in most diatremes was insufficient, so that top of pipes were filled tuffs. However in center of arisen asthenospheric lens the magma is reached surface.

Thus galactic comets are able to create in the lithosphere of terrestrial planets the large magma chambers, and in cases of high intensity cometary fallings also very big asthenospheric lenses which cause strong lift of the surface. These fundamental conclusions may be confirmed using Venus data.

7. Venus

Lithosphere rocks on Venus and Earth are very similar. Therefore geological structures formed by galactic comets on Venus are almost the same as on the Earth. Let us briefly consider their similarities and differences.

7.1. Shield volcanoes

Volcanoes of Venus are very similar to seamounts of our planet, but smaller. Most have a diameter of 1–20 km and a height of several hundred meters. Volcanoes number is $\sim 106$ and distribution on sizes is exponentially [26]. Note that their number of the same order as the Earth seamounts and craters on planets with no atmosphere. At that, shield volcanoes Venus are grouped into fields of $\sim 60$–300 km in diameter [26], i.e. of same dimensions as diatreme fields on the Earth [15].

7.2. Craters

On Venus were found 880 large craters (figure 2). Such craters are about as many as on the Earth, but they are distributed according to an exponential law which is not compatible with the assumption their education in result of fall asteroid bodies.

7.3. Coronae and montes

On Venus there are 340 tectonic-magmatic uplifts rounded shapes called coronae and 115 large canteens (plateaus) mountains—montes. Distributions of the coronae and montes on its sizes
are shown in Figure 3, and on its latitude—in Figure 4.

Distribution of coronae and montes (figure 4) excepting area of small diameters distorted by observation selection, obeys exponential dependence which is sign of its cometary formation.

This conclusion is confirmed by Figure 4 where the densities of craters, coronae and montes on Venus are compared with similar distribution by latitude craters on Mars [2] formed by asteroids and galactic comets.

Unlike most of Martian craters which have been formed during the last cometary shower [2] coronae and montes have a much greater age. We consider that coronae and montes are the different stages evolution objects of one type which have been created by cometary fallings very high density. At that montes formed first and subsequently turn into coronae.

Of course, these author’s considerations about mechanism interaction of galactic comets with planets need further elaboration and justification.

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