THE ICE NATURE OF THE GALE CRATER CENTRAL STRUCTURE

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Introduction. In connection with a choice of the Gale Crater as a polygon of the research mission on Mars in 2012 the abnormal central structure (CS) of this crater arouses the big interest. Inside of the 150-kilometre crater this structure occupies the central position covering a quarter of the crater floor area (fig. 1).

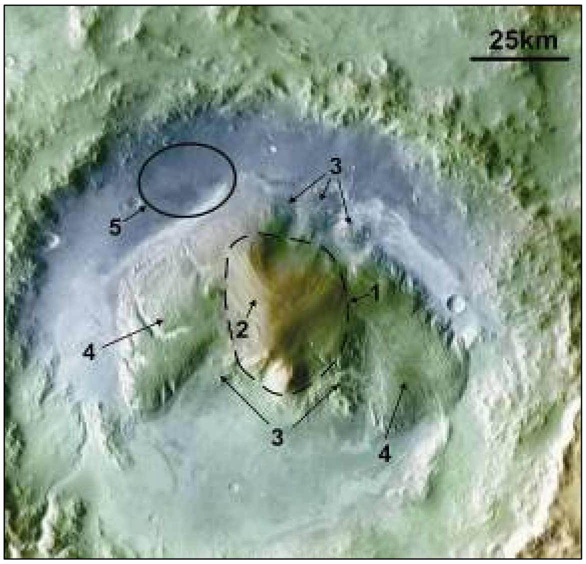

Figure 1. Gale Crater with the abnormal central structure. The arrows indicate: 1 - the contour of the supposed hydrolaccolith implanted into the crater foot; 2 - layering caused by the rhythmical accumulation of the ice and crystalline hydrates at the expense of the periodic intrusions of the underfrost waters; 3 - the landslip bodies located on the implanted hydrolaccolith contour; 4 - extensive icings; 5 - the supposed Mars Science Laboratory landing place.

At a first approximation the structure represents a semicircle with a diameter of 90 km occupying 3200 km^2. At the average height of this structure surface over the crater floor of 1.75 km its volume makes nearly 5600 км^3. The most unusual thing is the height of hills in the central part of an elevation that surpasses the crater rims in height. The second impressing feature is the parallel layering that is traced all over the given structure. This formation cannot be a consequence of the impact at the crater formation as the central hills ordinary have smaller height than crater rims, besides, the area and the form of the central structure are not characteristic for the impact phenomena. Also the considered structure could not be formed during the subsequent inside-crater processes – the rock slipping from the slopes, the accumulation of the eolian and other deposits because such processes do not lead to the formation of structures towering over the crater rims. It is necessary to find other explanation to the given form of a relief.

Hypothesis. The author offers a hypothesis of an injection origin of the central structure of Gale Crater by the underfrost water penetration generated a hydrolaccolith and an icing.

Discussion. Gale belongs to very large and ancient craters of Mars and is located on a slope between the raised plateau Terra Cimmeria and the lowered plain of Aeolis Mensae. In comparison with other large craters of this region Gale differs by the essentially greater depth – on the average 2.8 km relative to the surrounding plain, the flat part of its floor decreases from the south to the north from the marks -3350 m to -4300 m [1] that at distance between the floor points of 80 km corresponds to an average inclination 0.012. Thus the surface surrounding the crater falls with a little more inclination – 3.0 km for 200 km that corresponds – 0.015. The central structure has two peaks with the approximate marks of +833 m and +439 m that rise above the adjoining sites of the crater floor to 4183 and 4739 m respectively and on the average towers over the surface of plains surrounding the crater to 2.0 km [1]. Basing on the isostasy such structure can be formed only in case if its material has rather smaller density in comparison with the lithosphere material that is presented by the crushed frozen rocks with the porous space filled by the ice. Having assumed that the ice with the admixture of the crystalline hydrates and some silicate particles having density ρ_w to 1.0 g/sm^3 can be the CS material let's consider the conditions under which the CS isostasy is possible. The reasonable size of the porosity clastic rocs on Mars at the depths from 0.3 to 3.5 km can be accepted by analogy with the terrestrial clastics at the depths 0.1…1.2 km – from 0.3 to 0.1. The mineral component density ρ_m at a first approximation can be accepted equal to 2.7 g/sm^3. Due to it the density of the frozen rocks can approximately make: from $(0.7*\rho_m+0.3*\rho_w)/(0.7+0.3) = (0.7*2.7+0.3*1.0) = 2.19$ (t/m^3) on the depth of 0.3 km to $(0.9*2.7+0.1*1.0)/(0.9+0.1) = 2.53$ (t/m^3) on the depth of 3.5 km. The average calculating density of the frozen rocks to the depth of 3.5 km – ρ makes 2.36 t/m^3. It means that the thickness of the frozen layer approximately: $m=h*\rho_w/(\rho-\rho_w)=4740*1.0/(2.36-1.0) \approx$ $\approx$3,5 km is necessary for the relief stability with the ice massif with the height of 4740 m. It is possible to say that this was the minimal frozen ground thickness under the Gale floor at the moment of the CS formation. At the smaller thickness of the impenetrable layer of the frozen ground there would be its "floaing".

If to assume that this ice injection in volume of 5600 км^3 occurred as a result of the planetary thickening of the frozen ground then at the porosity of the rock on the frozen ground foot – 0.1 and the water volume increase at freezing on 8.3 % from the initial it is required the corresponding involving of the underfrost hydrosphere in volume: 5600/ (0.1*0.083) = 6.75*10^5 км^3 for the extrusion of such quantity of water.

If to accept following Clifford and Parker that the Martian cryosphere thickness exceeds 5 km on the equator and 13 km on the poles [2] then considering the correlation of the assumed piezometric level of the underfrost hydrosphere at the Gale CS formation (nearly +0.8 km) and the modern planet relief (more than 95 % of the surface have a mark lower than +5.8 km) it is possible to conclude that on Mars in the considered structure formation period the aeration zone under the frozen ground was almost absent. In such conditions the mechanism of the water level lifting at the frozen ground layer thickness increase is rather effective because the elastic water return of the pressure water horizons on the depth in some kilometers makes less than one percent from the gravitational. Thus we receive the real mechanism of the frozen layer weak place pushing that can be the abnormally low Gale floor where the salty waters of the hydrosphere have reduced the frozen ground thickness.

The arguments in favor of the CS ice nature are the observable landslides (see fig. 1) on the slopes of the highest CS part. The relief analysis shows that the surface inclinations on the northern and northeastern landslide sites make 0.15-0.16. It is visible that here the slipping occurs parallel to the stratification planes. On the Earth the landslides take place under three major factors: the watering, the clay presence, and the seismic influences and only stated above inclinations are not enough. Especially as in the conditions of Mars the surface inclinations, ceteris paribus, should be bigger for the compensation of three times smaller gravity. However if the substratum is presented mainly by the ice it is possible to assume that such compensation exists in the form of its increased fluidity. Therefore it is probable that in Gale the landslips are formed with ice share.

Also it is necessary to pay attention to the practical absence of the destruction products that should be taken out from the canyons cutting the CS (see fig. 1).

The CS can be divided into the central hydrolaccolith (CHL) and the adjoining icings (see fig. 1). The author connects the icing formation with the periodic intrusion of the ice portions from the hydrolaccolith through the ice body foot. The CHL height - 4.1…4.7 km is more than enough for the ice melting maintenance on the foot. Therefore the new water portions that arrived from the depths in the CHL basis and were in the thermal balance with the overlying ice could form the adjoining icing intruding along the ice and the bedrock border.

The layering that is visible on the slopes and edges of the CS canyons specifies the process rhythm of the ice formation and can be caused by the periodic development of the counteracting pressure at the phase transition of water into ice. The pseudo-blocky structure of the layers with the characteristic diameter of the fragments 2…5 m can be connected with the formation of the fresh ice crystallization centers at the first stages of the layer freezing.

One more argument in favor of the CS ice nature is the asymmetry of the southern and northern parts of the icing. The northern slopes are abrupt with the inclination to 0.15-0.30 and southern to 0.10. The icing thickness in the northern part reaches 2.5-2.8 km, to the south decreases to 1.5 km and less. It can be explained by the ice body deformation at its slipping on the crater inclined floor at the liquid layer in the basis.

As ice of Gale was generated by the water arrived from the big depths where the temperature exceeds superficial on some tens degrees there is a probability that the Martian life traces can be contained in the CS layers. The long existence of the considerable on volume subglacial tanks of the water saturated with the minerals and gases can be the favorable environment for the organisms' evolution.

The hypothesis of the Gale CS ice origin is important both from the point of view of the Mars Science Laboratory 2012 research mission success and from the point of view of the rover movement safety at the foot and on the slopes of the CS. The author suggests paying attention to the nature of the adjoining to the CS sites which surface in most cases rises to the structure. Under a thin dust cover they can be composed also of the ice containing still more of the crystalline hydrates and can be the crystallization product of the secondary brines diffusing from the CS body. Therefore also as well as within the CS the presence of the latent thermokarstic cavities and cracks is possible here.

References: [1] Neucum G., Electronic map of the Mars EDA.DLR.FU. Berlin, 2011. [2] Clifford S. M. and T. J. Parker (2001), Icarus 154, 40–79.