SIMULATION OF WATER ICE GLACIAL SURGES IN NORTH POLAR CRATERS ON MARS

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Introduction. Formation of lobate moraine-like ridges (LMLR) in north high latitudes of Mars was earlier interpreted as result of viscousplastic downslope flow of solid carbon dioxide (CO₂) [5; 7]. However, if we rely on the morphology of relief and numerical simulation results, H₂O ice glacial surge from the sloping surface is more likely to take place than flow of solid CO₂.

Local position, possible age and morphology features of LMLR. We have studied two craters centered at 70.4°N 266.4°E and 67.2°N 249.5°E (fig.1). LMLR are observed on their inner craters slopes, whereas concentric moraine-like ridges (arrows on fig.1B) are located on the outers slopes, similar to frontal moraines of glaciers on the Earth. Studied regions are located on the North Plains at the base of shield volcano Alba Patera, on the Vastitas Borealis territory (Interior unit, Early Amazonian) [11] and have Late to Middle Amazonian age.

We suggest that LMLR were formed by H₂O glacial down-slope surge on the inner rim of the craters. This happened when mass of ice reached the critical unstable condition. At what time these forms in the craters could have been formed? According to Tanaka 2005a research, polar layered deposits (PLD), as the possible analogs of H₂O ice on the inner craters rim, have the age of 30-100 Myr. However, we can not exclude that this happened later. Taking into account the stabilization of obliquity during the last Myr [8] and compose mean value of ~25°obliquity, we assume that form of local H₂O ice deposits on the same latitudes could be formed under different obliquity. Local accumulation of these deposits could occur in the period of 0.5 - 2 Myr ago [6] when the border of polar cup moved to the lower latitudes. As a result, the masses of H₂O ice deposits within the craters could be were formed in 1 - 2 Myr ago.

Excessive accumulation mass of H₂O ice on the steep slope could be the cause to catastrophic glacial surge, similar to long-runout avalanche, which formed LMLR. The latter on the floor and slopes show features resembling those of the long-runout avalanche or glacial surge on the Earth [9, 3]. Unidirectional and elongation of LMLR may confirm the hypothesis of H₂O ice glacial surge. Concentric moraine-like ridges on the outers craters slopes (70,4°N 266,4°E and 67,2°N 249,5°E) (fig. 1B) indicate on availability of sheet glacier in the past ages [5].

Results of numerical modeling. To check our hypothesis we made numerical modeling of surge process and movement process of H₂O ice deposit downhill on the inner slope of crater. We made a digital terrain model (DTM) over CTX stereo images (P22_009658_2505; B01_009935_2505). Total root-mean-square is 0.4 pixel on images and vertical accuracy is equal 15 m.

Area where H₂O ice deposits are located on the inner slope is 27 km². This calculation was made with analysis of CTX images. We calculate density, assuming that deposits with PLD where H₂O ice have 70%

Fig.1. Lobate moraine-like ridges in craters 67,2°N 249,5°E (A) and 70,4°N 266,4°E (B). B - arrows show concentric moraine-like ridges on the outer slope of crater.
of the volume and dust grains have 30% [4; 1]. This proportion mean density result is ~1.01 g/cm$^3$. Numerical modeling was done for different thickness of H$_2$O ice (100 and 500 m). LMLR ~14 - 15 km long, 7.5 km wide and ice body fall down on ~1500 m, which is similar to long-runout avalanche [9].

Modeling of surge process was carried out with Rapid Mass Movement Simulation (RAMMS) software [2]. This software package was developed in Switzerland for the numerical modeling of gravitational mass movements such as snow avalanches, debris flows and rockfalls. For this case we use the RAMMS::AVALANCHE module. We set the release density to 1 g/cm$^3$ according to the density of ice on Mars and adapted the gravity to 3.77 m/s$^2$. At this stage we have done two scenarios for ice release with 100 m and 500 m thickness. Modeling with 500 m thickness shows results with overlapping of the big part of crater floor and overlap the borders of the observed LMLR. The scenario with 100 m release height gives better results, arrived LMLR and flow around central peak (fig. 2). The deposits of modeled long-runout avalanche were essentially accumulated inside of LMLR’s contour. Our modeling results confirm the hypothesis of LMLR formation by H$_2$O ice glacial surge processes. Thus for future modeling scenarios we will use release height ~150 m. As one can see in modeling results, surge of H$_2$O ice in the inner slope in these two craters is more likely to be the cause of LMLR formation.

Future research. The connection between surges formation of long-runout avalanche with climate changes in the history of Mars is not fully understood yet. Higher-precision identification input parameters of H$_2$O ice deposits will give more detailed modeling of process in RAMMS program.

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