NUMERICAL MODELLING OF THE ICE REDISTRIBUTION PROCESS WITHIN THE SURFACE LAYER OF THE REGOLITH ON THE MARS (EQUATOR) BY QUASI-PERIODIC OSCILLATIONS OF THE QBLIQUITY

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Introduction

The permafrost on Mars is globally widespread and its thickness may to approach 1-2 km in the equatorial zone and up to 6 km in the polar area [1, 2]. The permafrost may to be as one of the largest reservoir of the water ice, salt solution and gashydrates on the planet [2, 3]. Under modern climatic condition of Mars the ice in shallow regolith may to be stable (with respect to sublimation) in the both hemispheres of the planet only on the latitudes higher then 40° [2, 4]. Due to atmospheric water content deficit taking place in the latitude belt ±40°, the ground ice here is undergone to sublimation from the regolith approximately to the depth 100 m. The deficit is caused because the average soil temperatures in the latitude belt (~220K) are essentially higher then the average saturation temperature of the atmospheric water vapor (196K). On the depth from 100 to 400 m the transition layer is placed where the ice is yet stable and its content may increase with depth from several percentages of the porosity volume up to complete filling of it [5].

The orbital parameters of Mars (the eccentricity, Solar longitude (Ls) at perihelion and the obliquity) undergo to large oscillation through time due to a tidal forcing on Mars from the Sun and other planets [6, 7, 8]. By the reason, the Martian climate is characterized by quasi-periodic variations. At that, the obliquity oscillations show much stronger influence on the planet climate. The obliquity oscillations (from 11 to 40°) arise during period $1.25x10^5$ years on the background of the longer harmonica in $2.5x10^6$ years (fig.1.). At high values of the obliquity the average surface temperatures are increase on the high latitudes and are decrease on the low latitudes. At that, atmospheric water content on Mars increase in hundreds time and the average saturation temperature of the atmospheric water vapor increase on several dozes degrees [8]. In the period the water vapor diffusion is directed from atmosphere to the regolith as the average surface temperatures on the low latitudes (200-205°) are noticeably less then the water vapor freezing temperature (about 230°). By the reason the regolith porosity is becoming filled by ice [8]. At the minimum values of the obliquity (<25°) the tendency is inverse – the surface layer of the regolith is becoming desiccated due to sublimation of the ground ice.

Numerical modeling

To understand the behavior (dynamics) and scale of the ice redistribution in the upper layers of the Martian permafrost (equatorial zone) as function of quasi-periodical variations of climate we conducted numerical simulation of diffusive transfer of moisture in the atmosphere- regolith system (with the bottom boundary at 400m-depth) over the past 5 m.y. The bottom boundary is placed on the layer with pores filled completely by ice. One-dimensional task of heat-mass transfer with variable diffusion coefficient and thermal conductivity by the appropriate boundary and initial conditions were numerically solved.

It is considered the diffusion of water vapor molecules through the porous unisothermal medium undergone by quasi-periodical variations of temperature on the top boundary (atmosphere/regolith) and geothermal flux on the bottom-moving boundary. The top boundary is at the depth 5m (where the diurnal and seasonal variations of temperature and the atmospheric water vapor abundance may be neglected). Diffusion of water-vapor in regolith (taking into account phase partitioning of water: vapor, ice, adsorption moisture) results in the redistribution of initially put ice and moving the bottom boundary as result of ice sublimation from the bellow layer, where the pores are completely filled by ice. The adsorption isotherm and the saturation vapor density over ice were used to calculate the phase balance. Simultaneous solution of thermal conduction equation and diffusion equation was performed by method of finite differences with implicit algorithm.

Discussion of the results

Following to the numerical modeling results, the ice redistribution process in the upper layer of the regolith as result of obliquity oscillation during one harmonic ($1.25x10^5$ yr) is more remarkable in the surface layer up to 30 m depth (fig.2). At that, the process of directed water vapor diffusion from the atmosphere inside of the regolith associated with the time period of high values of the Mars' obliquity (>30°) had resulted in partial filling of the pores by the ice. As it is seen from fig.2, the maximum concentration of the ice in the regolith (20-40% of the pore volume) could be reached in the 10-meters surface layer during the time period about $65x10^3$ years. By the low values of the Mars' obliquity (<25°) the upper layers of the regolith have been desiccated strongly via the ice sublimation from the regolith during approximately $55x10^3$ years.

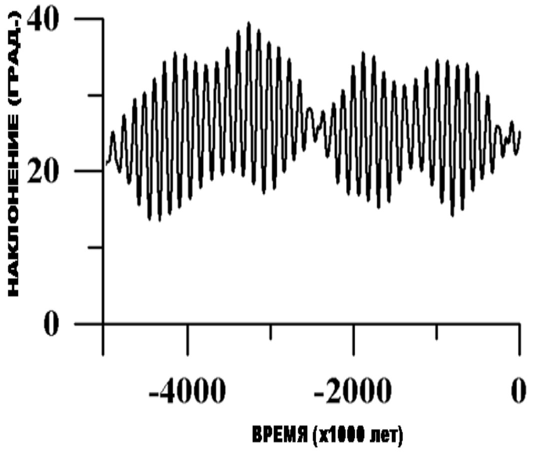

Fig.1. Quasi-periodical oscillations of Mars obliquity during the last 10 million years.

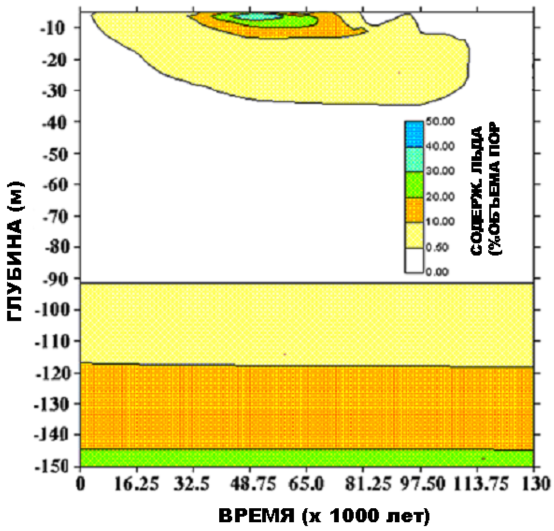

Fig.2. Dynamics of the ice content in the Martian regolith during one harmonic of the obliquity oscillation (125 thousands years).

The periodic ice enrichment of the regolith surface layer could result in decreasing of the thermal gradient along the regolith cross-section and, by the reason, to reinforcing of the ice stability in the dipper regolith layers. Episodic ice appearance in the regolith surface layer could remarkably to change the intensity of the chemical and physical weathering processes of the surface material, as well as could result in extinction of the aeolian processes on the planet. In the times the processes of the aeolian transportation and erosion on the Martian surface must to be less active because the Aeolian deposits formed earlier have been cemented by the ice and loosed the capability to transportation by the wind. Additionally, the higher atmospheric humidity associated with higher values of the obliquity could be condensed on the atmospheric dust particles and precipitated on the surface like a snow-dust deposits on relief features earlier formed. That is, such times could be favorable for the cover fine deposits formation looking like the terrestrial loess.

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