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PECULIARITIES OF MARTIAN HYDROLOGY

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Abstract. *Mars is characterized by a rather complex hydrological cycle. The images of the planet show the northern and southern polar caps. A global cloud system often appears near aphelion. There are several million cubic kilometers of ice in the polar caps. In terms of climatic parameters, Mars is the closest planet of the solar system to Earth. Many canyons, similar to dried-up riverbeds, were discovered on the topography of the planet. And in the mouths of the great plains, structures of sedimentary origin were found, similar to sea shelves and river deltas. This indicated that about 3.5 billion years ago Mars was warm and wet; it had a dense atmosphere, rivers flowed across the surface, and seas existed. Martian channels are deep and straight. They are like the valleys in the earth's glaciers. Therefore, it is possible that glaciers are responsible for the formation of the network of canyons on Mars. The current Martian water cycle includes about* 10^8 *tons of water vapor in the atmosphere, and clouds in the form of light fog. These atmospheric processes play a decisive role in maintaining the current state of water on Mars. Layered deposits in the polar caps serve as a sign of changes in the properties of the hemispheres in the global water cycle. It is possible that the hats changed places many times throughout Martian history.*

Key words: *Mars, Polar cap, water cycle, hydrology, global variations.*

Modern Mars is like a desert. But the planet is characterized by a rather complex hydrological cycle. Images from a great distance show the northern and southern polar caps; when passing near aphelion, a global cloud system is visible [15]. The estimated capacity of the northern polar cap is up to 1.2 million km^3 of ice. This is up to 4% of the water reserves in the Antarctic glacier on Earth. Water reserves in the atmosphere of Mars are very small [10]. During the day, the temperature of the atmosphere near the surface only sometimes reaches 300 K; and at night – lower than 170 K. Under such cold conditions, it is impossible to keep a significant amount of water vapor in the atmosphere. All the water vapor in the Martian air would condense into a film ten microns thick. But even under such conditions, water circulation is possible in the weak atmosphere of Mars. According to basic climatic parameters, Mars is the closest planet of the Solar System to Earth [15]. Therefore, a climate system similar to the Earth's can be developed on this natural training ground.

When preparing manned space missions, the goal is to choose places for human landing. There should be a suitable relief, mineralogical composition of the soil [12] and water reserves nearby [2, 27]. In the middle of the 20th century, the idea of water ice deposits covered with a thin layer of dust was expressed. It was believed that during global dust storms, billions of tons of dust are raised into the atmosphere [6, 9, 15], which is carried by the wind over long distances. When dust settles from the atmosphere, it is captured by seasonal ice with CO_2 and water and accumulates there. This is indicated by the observed regularity of layering in subpolar regions. It can reflect climatic changes caused by the eccentricity of the Martian orbit [9, 25]. It was assumed that every subsequent Martian year, after the summer evaporation of a thin layer of CO_2, permanently existing layers of frozen water were opened. It was believed that in the past there could have been much higher atmospheric pressure on Mars, and liquid water should have existed on the surface of the planet [19]. Mars was formed in conditions close to the conditions of formation of other planets of the terrestrial group, from the same gas-dust disk. Therefore, the amount of volatile elements (including water) on Mars and other terrestrial planets should be approximately the same [12, 15, 23]. Many questions arose after the analysis of images of the Martian surface, obtained by the spacecraft "Mariner-9", "Viking-1, -2" in the 1970s. Many canyons similar to dried riverbeds were discovered on the topography of the planet. And in the mouths of the great plains, structures of sedimentary origin were found, similar to sea shelves and river deltas (Fig. 1).

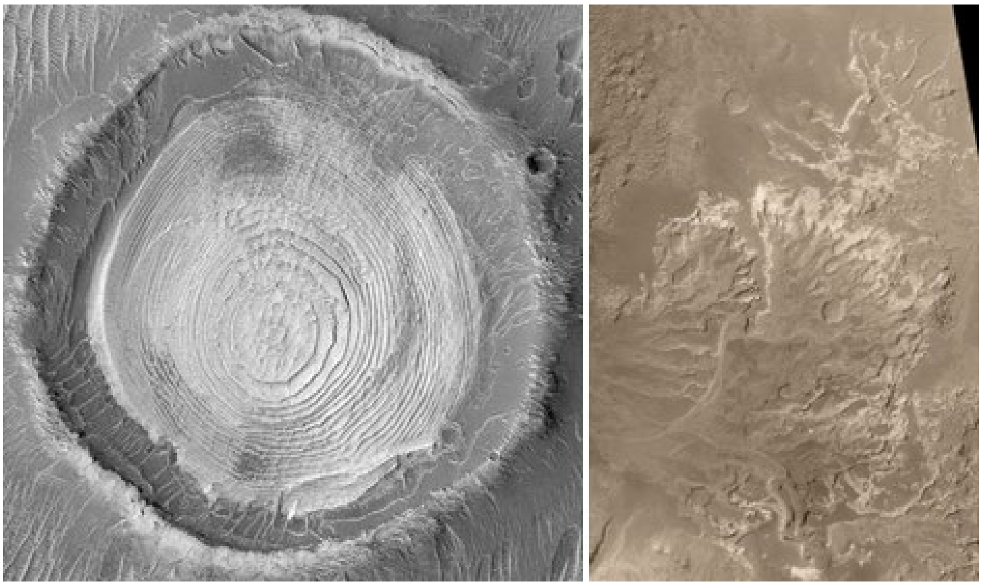

Figure 1 – Structures of sedimentary origin (left) and a possible river delta on Mars (right) *(http://photojournal.jpl.nasa.gov/).*

It was proposed that about 3.5 billion years ago, Mars was warm and humid, had a dense atmosphere, rivers flowed on the surface, and seas existed [9, 23]. But later, some climatic catastrophe befell the planet, turning it into a cold, waterless and airless desert. Now, the atmospheric pressure on Mars is often close to the triple point of water. Assuming that while the pressure exceeded this value, one of the cycles known in geochemistry was operating in the atmosphere: the carbonate-silicate cycle, which is sufficiently active on Earth as well. It consists in the fact that carbon dioxide dissolves in cloud droplets, and then settles, is transferred to the soil, and takes part in certain reactions there. This leads to the deposition of carbonates in sedimentary rocks. They can then drift towards the mantle. There, at temperatures close to 900 K, they decompose. The carbon dioxide released at the same time re-enters the atmosphere with volcanic emissions [21]. Note that some Martian channels are too deep and straight to be river channels in the usual sense. After all, flat rivers on Earth are much more winding. However, such channels are quite similar to the valleys in the earth's glaciers. Therefore, it is possible that glaciers are responsible for the formation of the network of canyons on Mars [22].

In addition, a mineral such as hematite found in Martian rocks [18] indicates hydrothermal activity on the planet. Moreover, it could take place in a relatively recent historical era. The presence of such a mineral may indicate that in the layer of permafrost on Mars, there are conditions for the formation of fairly large (30-100 m thick and up to ten kilometers in diameter) lenses of liquid water that can be heated by local tectonics. In some cases, the lens may overheat and even boil. Then the displacement of water weighing more than 10^9 tons to the surface will lead to the formation of a powerful mudflow, which can create a deep canyon.

The search for water on Mars is recognized as one of the most important tasks of all Martian expeditions. The detection of water sources on the planet would be of great importance for astrobiology [11, 17]. After all, the ability of Mars to support life would support those enthusiasts who call for serious consideration of space expansion [8, 14, 20, 26]. If there really are accessible sources of water on Mars, it would be much easier to implement such programs. Note that modern Martian hydrology is not only paleoclimate and permafrost. After all, the modern Martian water cycle covers about 10^8 tons of water vapor in the atmosphere; as well as clouds, which are clearly visible as a light haze in images obtained by various instruments. In addition, seasonal polar caps and morning fogs, which leave a microscopic layer of hoar frost on the surface of the planet, should be added. And finally, this is the "evaporation" of regolith and clay soil crushed by meteorites over billions of years, which has good absorption properties.

Despite the relatively small volume of atmospheric water reserves, it is atmospheric processes that play a decisive role in maintaining the current state of near-surface Martian water reservoirs. Studies have shown that now there is almost an order of magnitude more water in the northern hemisphere than in the southern. There are two points of view on the possible causes of the asymmetry of Martian near-surface water reserves between the hemispheres. First, the geological properties of the northern and southern hemispheres are markedly different. The surface of the northern hemisphere lies on average several kilometers lower than the southern one, in which only at the bottom of the deepest depression – Hellas – the geopotential is approximately the same as at the North Pole. Also, the northern hemisphere is lighter because there are more sedimentary clays and less ancient basalts. Clays are known to be able to absorb a large amount of water. Therefore, if the global movement of water in the atmosphere plays a small role in comparison with local exchange, then its uneven distribution between the hemispheres could be explained by the different ability of rocks on the surface of the planet to retain a certain amount of steam above it. In this case, one would expect that such an asymmetric distribution of water is very ancient. At least, it is not younger than most modern sedimentary rocks. That is, he should be about a billion years old.

According to another hypothesis, the cause of the uneven distribution of water is the asymmetry of the change of seasons [13, 16, 19] in the two hemispheres, which is caused by the significant eccentricity ($e \approx 0.09$) of the orbit of Mars. Under such conditions, the modulation of the solar flux between aphelion and perihelion reaches 40%. Therefore, summer in the northern hemisphere is longer and colder than in the southern. A lower temperature than at perihelion causes condensation of water vapor in the atmosphere at relatively low altitudes (below 10 km). That is, where global convective transport air flows directed towards the equator dominate. On Earth, such transport exists only in tropical latitudes and is the cause of trade winds. Above the condensation level, water does not penetrate due to the rapid gravitational settling of micron ice crystals. This effect leads, in particular, to the formation of a tropical belt of clouds in aphelion, which closes the water evaporated by the polar cap in the northern hemisphere. At the same time, at perihelion (a much warmer period of time), clouds have a weak effect on the transfer between the hemispheres, and therefore the water that sublimates from the southern polar cap is mixed more evenly. In a geologically short time, such a seasonal "pump" could very well pump water to the hemisphere in which summer falls on the passage of the aphelion of the orbit.

According to some other assumptions, deposits of water ice have been cyclically distributed between the north and south poles of Mars during the last 21,000 years. This time interval was calculated based on the fluctuations of the planet's axis of rotation (precession). The simulation results showed that during this time, the water at the north pole of the planet was in unstable conditions and could easily move to the south pole in the form of steam and condense there again on the surface. Thus, a layer of water ice up to 1 mm thick was accumulated at the South Pole during the year. Then, in 10,000 years, this would lead to the formation of a layer of water ice up to 6 m thick. About 10,000 years ago, the planet's precession cycle changed and its return to its current configuration began. At that time, the water ice at the South Pole was already in an unstable state, and the water began to move north. According to spectral data [4, 10], about 1000 years ago, carbon dioxide began to freeze on the surface of water ice and, thus, block the movement of water to the other pole. Considering that the tilt of the planet's axis of rotation could change many times in Milanovich cycles with a period of about 10^5 years, it can be considered that the asymmetry described above is relatively young and, perhaps, it also changes to the opposite. Concentric layered deposits in the polar caps serve as an indirect sign of changes in the properties of the hemispheres in the global water cycle. It is possible that the hats changed places throughout Martian history.

In fact, the question of the relative contribution of both mechanisms to the formation of asymmetric water distribution is a question of the relative role of local exchange and global transport. However, some researchers are inclined to another hypothesis. They believe that intensive local exchange is a necessary condition for the stabilization of the global cycle, playing the role of a dissipative factor. If the Martian regolith did not "breathe", then the seasonal migration of water to the equator would be impossible, since the water would immediately be captured in "cold traps" on the border of the corresponding polar cap.

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