

ABOUT LIFE IN "DRY RIVERS" OF MARS

The presence of long valleys, resembling dried-up riverbeds on Earth, should indicate that once upon a time there were conditions on the surface of Mars under which liquid water could exist. Now water in various states is located under the surface of the planet. Areas under the surface could be a kind of oases for possible biological activity. Therefore, they, together with clay-covered areas of Mars, can be a promising place to search for traces of life. The Mars rover "Spirit" was sent to the Gusev crater with a diameter of 180 km located near the equator. The channel of an ancient river flows into this crater. In the past, this crater could have been a lake. The Mars rover "Opportunity" descended into the Eagle crater, located near the equator on the opposite side of Mars from the Gusev crater. An increased concentration of hematite, which on Earth is formed only in an aqueous environment was found there. The main mission of the Perseverance rover is to search for signs of modern bacterial life on Mars, or for its past existence. Observations using spectral instruments on the Perseverance rover have shown that organic molecules have been found in some rocks and in fossilized mud. They are the basis of all life on the planet. There is many evidence that from 3.5 to 2.5 billion years ago, a powerful hydrosphere existed on Mars. Measurements by the Curiosity rover have allowed us to indicate the volume of water lost by Mars. The data obtained have led us to conclude that Mars was not just covered in water in the past but could also retain it in liquid form for hundreds of millions of years. A study of the ratio of deuterium to hydrogen in its atmosphere has led us to conclude that greenhouse gases could retain water in liquid form. Greenhouse gases were quite capable of warming Mars enough to provide a stable climate for millions of years. This allowed conditions to be maintained for chemical evolution, a stage that precedes the emergence of life.

Keywords: Mars, polar cap, dry river, water, organics, perchlorates.

Background

The presence of numerous winding valleys with great length, with tributaries and islands, resembling dried-up riverbeds of terrestrial rivers, should indicate that previously there were conditions on the surface of Mars under which liquid water could exist (Clancy, & Nair, 1996; Vid'machenko, 2009a; Vid'machenko, 2009b). According to current estimates, the main reserves of water are concentrated in the northern polar cap (Conway et al., 2012; Vidmachenko, 2015). The southern cap consists mainly of carbon dioxide (Becerra et al., 2019). As well, layered deposits consisting of water ice and fine dust coming from various eroded areas of the surface can form in the polar cap region (Cutts, 1973).

Water reserves in the atmosphere are also insignificant. But water once flowed along the currently dry riverbeds. Now, most likely, water in one form or another is located under the surface of the planet. This is also indicated by the results obtained with the help of various spacecraft (SA). It is estimated that quite large (30–100 m thick and up to 10 km in diameter) lenses of liquid water can form in the permafrost layer, which are heated by local tectonics. Under certain conditions, the lenses can overheat, boil, and displace a certain volume of water onto the surface of Mars, forming catastrophic mudflows that can even form deep canyons (Vidmachenko, & Morozhenko, 2014; Vidmachenko, & Morozhenko, 2019). The most noticeable features of this type of Martian relief are the Maadim and Nirgal valleys (Fig. 1, left).

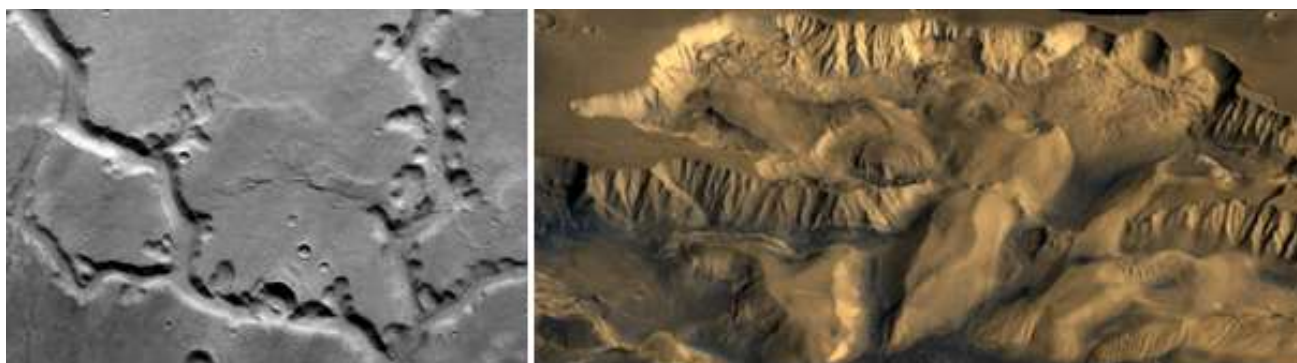


Fig. 1. Left: image of the Nirgal River (<http://photojournal.jpl.nasa.gov/>). Right: image of Candor Chasma Canyon (<http://photojournal.jpl.nasa.gov/>)

Results

"Dry channels" of Mars. Evidence that water once flowed deep beneath the surface of this planet has been revealed by faults, outcrops, and landslides now visible on the surface of the Red Planet. Such underground channels could collapse after millions of years and appear on the modern surface (Chevrier, Altheide, & Hanley, 2009). Previously, when studying traces of liquid water activity on Mars, special attention was paid to details of the relief, which were probably once either riverbeds,

lake beds, or obvious manifestations of water erosion. Now, further evidence of Mars' watery past has emerged from observations of the incised canyon Candor Chasma (Fig. 1, right) with a spatial resolution of better than 1 m, where very interesting geological details became visible.

Along some fault lines, which extend for several kilometers, thin strips of light material were found (Fig. 2). It is believed that initially it could have been a kind of "pipe" through which a liquid (water, liquid carbon dioxide with or without water) with substances dissolved in it flowed. These substances from the flow precipitated and accumulated on the walls of the "pipe". After hundreds of millions of years, erosion greatly changed this area. And what was once under the surface is now revealed on the dark background of the surface as light stripes.

These deep subsurface areas could have been havens for a variety of biological activities that may have occurred there. Therefore, they, along with clay-covered areas of Mars, could be promising places to search for signs of life (Kuznyetsova, Vidmachenko, & Steklov, 2019; Steklov, & Vidmachenko, 2019). Moreover, similar streaks along cracks and fractures in the surface have been found not only in images of the Candor Chasma region, but also in several other areas of the planet.

Some of the layered rocks are similar to terrestrial sedimentary rocks that remained after the sea retreated. Among the formations discovered on the surface of Mars, channel-like ditches, similar to dried-up riverbeds, and the so-called meander valleys deserve special attention. Of course, at this time, rivers cannot flow on the surface of Mars due to the absence of liquid water there due to insufficient atmospheric pressure and low temperatures. The temperature on Mars can be as high as 20° C or as low as about -153° C.



Fig. 2. Visible and infrared images from the Mars Reconnaissance Orbiter show bright areas on rocks that may be the result of ancient water flows (<http://photojournal.jpl.nasa.gov/>)

After all, at such a low pressure that exists currently on the planet, water boils at a very low temperature. Meanders could only appear in the presence of water flows that existed in the past, i.e. rivers. It is believed that in early eras the atmospheric pressure on Mars was significantly higher than now, and then it was warmer and wetter there (Clancy, & Nair, 1996). It is also possible that meanders could leave moving masses of glaciers, which form deep furrows on the Earth's surface. But dark areas are not always depressions. For example, the Greater Sirte is an elevated plateau with slopes in all directions. These channels originate from Valles Marineris and could have been formed during a flash flood. There is every reason to believe that there is a lot of water on Mars, and that water still exists in the form of permafrost.

Current evidence of liquid water on Mars

However, these Martian valley networks are still less developed than typical terrestrial drainage systems. Due to the lack of relatively small flows in the Martian valley networks, it can be assumed that the valleys were formed primarily by water flowing from the soil, rather than as a result of precipitation (Goldspiel, & Squyres, 2000). Liquid water is extremely unstable on the surface of Mars at this time. However, slow groundwater could still form valley networks if water flowed, for example, from under frozen ice. These valleys are limited to relatively old regions of Mars. Therefore, their presence may indicate that Mars had a warm and humid climate in its early history.

In September 2019, magnetic fluctuations were reported to be consistent with a large reservoir of liquid water deep beneath the surface. Also, spectral observations and researches at landing sites of Mars have detected abundant perchlorates (Hecht et al., 2009), (Chevrier, 2022) that induce an antifreeze effect, lowering the freezing point of liquids by tens of degrees. With the

temperature at the base of the polar cap estimated at 205 K, it is assumed that water can remain there in a liquid state precisely due to the antifreeze effect of magnesium and calcium perchlorates (Chevrier, Altheide, & Hanley, 2009), (Gough, Chevrier, & Tolbert, 2014). The 1.5 km ice sheet covering this lake is composed of 10–20 % water ice mixed with dust (Morozhenko, & Vidmachenko, 2017; Morozhenko, & Vidmachenko, 2020; Morozhenko, Vidmachenko, & Kostogryz, 2015), which is seasonally covered by a layer of CO₂ ice up to 1 m thick (Vidmachenko, & Morozhenko, 2014). It is believed that water may be present in other places beneath the surface of Mars (Vidmachenko, & Morozhenko, 2019). There is some observational evidence that liquid water could have played a significant role in the downslope flow of contaminated fluids (mud) from the seepage area. Larger falls were formed in the place of larger watercourses. The fact that there are no impact craters in such channels indicates their geological youth (less than a few million years, and possibly a few weeks or even days).

To explain this, the properties of concentrated salt solutions formed by perchlorates and sulfates of ferric iron Fe₂(SO₄)₃ were studied in detail. Their freezing point is 205 K. It is believed that Newton crater was formed probably more than 3 billion years ago in a collision with an asteroid. It is approximately 287 km in diameter. Figure 3 shows the northern wall of a small (diameter about 7 km) impact crater located in the southwestern part of Newton crater. Its northern slope is eroded by many narrow drains. Each outpouring of water with soil occurred in the upper part of the crater at a depth of about 100 m under the soil layer. Then, under the influence of gravity, it headed downward, subject to evaporation and freezing.

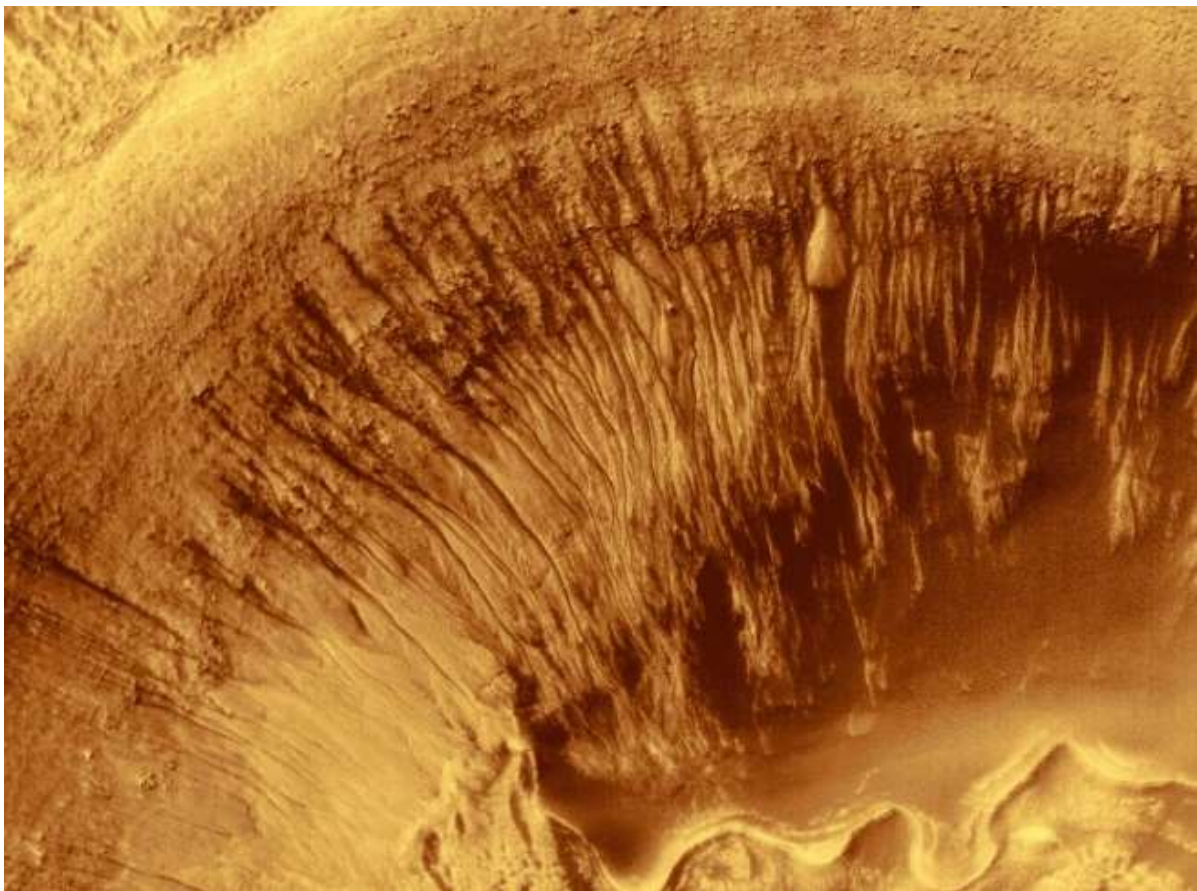


Fig. 3. Bright streaks with branching ends are "alluvial" flows in one of the impact craters in Newton Crater, 2000 (<http://photojournal.jpl.nasa.gov/>)

In order to search for geological formations that require the presence of long-lived water bodies, the Mars rover "Spirit" was sent to the Gusev crater, located near the equator, with a diameter of 180 km. An ancient river flows into this crater. Therefore, this crater could have been a lake in the past. The second rover, "Opportunity", landed in the Eagle crater, located near the equator on the opposite side of Mars from the Gusev crater. There, an increased concentration of hematite, which on Earth is formed only in an aqueous environment, was found.

The eroded features shown in Fig. 4 are also examples of many water channels. They are located on the cliff of a flat plateau. As can be seen, the layer from which the watercourses emerge has had enough time to form a ledge below the harder rock layer. In place of the relatively larger watercourses, larger collapses have also formed in the harder soil above the ledge. Below the possible aquifer, dark narrow channels are clearly visible, along which mudflows descended. Although the dark color of the channels in this image is probably not the result of the presence of wet soil there at that moment, it still indicates that water has seeped out of the soil and moved down the slopes very recently. After all, quite noticeable contrasts between dark and light areas could hardly be maintained on Mars for a long time, because dust would quickly cover the darker surface and reduce the differences in its brightness. Such an analysis suggests that the area shown in this image may have been subjected to water erosion as a result of water seepage only a few years ago. The thickness of such an aquifer in this location on Mars does not exceed 100 m (Heldmann et al., 2005), (McEwen, Ojha, & Dundas, 2011).

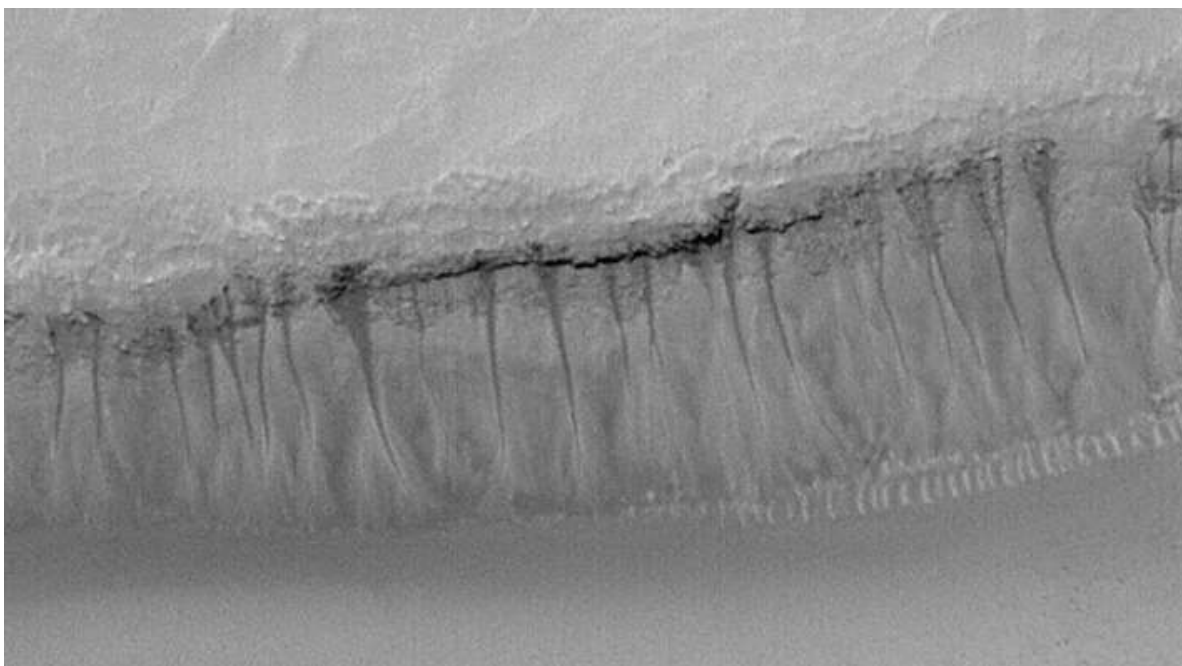


Fig. 4. Image of the subsolar slope of a valley about 1.2 km long, obtained in 2000 in the Gorgonum Chaos region (<http://photojournal.jpl.nasa.gov/>)

Discussion and conclusions

The primary ideas of this work can be listed as follows:

1. The main mission of the Perseverance rover is to search for signs of modern bacterial life on Mars, or for evidence of its existence in the past (Vidmachenko, 2016a; 2016b; 2016b). For this purpose, it was specially sent to the Jezero crater. After all, a powerful river flowed into it several billion years ago. Therefore, the development of certain life forms could well have begun in its sedimentary rocks. Observations using spectroscopic instruments on the Perseverance rover showed that organic molecules were found in some of the rocks. The presence of hydrocarbons was indicated by four different types of fluorescent signals and three types of Raman scattering signals. The rover also found individual samples of organics in fossilized mud. While in the Jezero crater, the Perseverance rover was able to collect samples containing the largest number of organic molecules ever found on Mars. The indicated location is in the area where a river flowed into this crater billions of years ago.

So, organics on the surface of Mars turned out to be more widespread than previously thought. Organic signatures obtained by the Perseverance rover in two different samples differ in the amount and types of mineral bonds. Moreover, the molecules in both samples show signs of changes that could only occur in the presence of water. That is, water could have played a role in their formation.

2. Organic molecules are compounds of carbon and, mainly, oxygen and hydrogen. They are the basis of any life on the planet, but they can also be formed by non-biological processes. Therefore, it is clear that organics found on Mars do not indicate the presence of life there (Vidmachenko, 2017). After all, to obtain such a conclusion, these samples must be delivered to Earth and studied in laboratory conditions. And although carbon is the main "building" material for life forms. However, this element is also present in many inorganic compounds. Of course, the discovery of organic compounds on Mars is very encouraging in the search for an answer to the question, whether we are alone in space.

3. There is a lot of evidence that in the period from 3.5 to 2.5 billion years ago, a powerful hydrosphere existed on the planet. It is also known that at that time, the Sun shone almost 30 % weaker. Therefore, the question of the reason why the local oceans did not freeze has been repeatedly raised. The essence of the research was to establish the ratio between ordinary hydrogen atoms and deuterium, which is a stable isotope of hydrogen. Since deuterium is heavier than ordinary hydrogen, it was much more difficult to "knock" it out of the atmosphere by the solar wind. The Curiosity apparatus measured the ratio of these atoms in the modern atmosphere, as well as in clay samples formed more than 3 billion years ago. The estimates made it possible to indicate the volume of water lost by Mars (Vidmachenko, & Morozhenko, 2014; Vidmachenko, & Morozhenko, 2019).

New data obtained by the Curiosity rover equipment allowed us to conclude that Mars was not just covered with water in the past but could also retain it in liquid form for hundreds of millions of years. It is believed that the water on Mars was not allowed to freeze by greenhouse gases. The study of the ratio of deuterium to hydrogen in its atmosphere allowed us to conclude that greenhouse gases could keep water in liquid form and not allow it to freeze due to the weak power of the Sun at that time. After that, a new model of the Martian atmosphere was created, and it was reported that powerful greenhouse gases were quite capable of warming Mars enough to provide a stable climate for millions of years. This allowed to provide conditions for chemical evolution – the stage that precedes the emergence of life.

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References

- Becerra, P., Sori, M. M., Thomas, N., Pommerol A., Simioni E., Sutton S., Tulyakov S., & Cremonese G. (2019). Timescales of the climate record in the south polar ice cap of Mars. *Geophysical Research Letters*, 46(13), 7268–7277. <https://doi.org/10.1029/2019GL083588>
- Chevrier, V. (2022) Limited stability of multi-component brines on the surface of Mars. *The Planetary Science Journal*, 3(5), 125.
- Chevrier, V. F., Hanley, J., & Altheide, T. S. (2009). Stability of perchlorate hydrates and their liquid solutions at the Phoenix landing site, Mars. *Geophysical Research Letters*, 36(10), L10209. <https://doi.org/10.1029/2009GL037497>
- Clancy, R. T., & Nair, H. (1996). Annual (perihelion-aphelion) cycles in the photochemical behavior of the global Mars atmosphere. *Journal of Geophysical Research: Planet*, 101(E5), 12785–12790. <https://doi.org/10.1029/96JE00836>
- Conway, S. J., Hovius, N., Barnie, T., Besserer, J., Le Mouélis, S., Orosei, R., & Read, N. (2012). Climate-driven deposition of water ice and the formation of mounds in craters in Mars' north polar region. *Icarus*, 220(1), 174–193. <https://doi.org/10.1016/j.icarus.2012.04.021>
- Cutts, J. A. (1973). Nature and origin of layered deposits of the Martian polar regions. *Journal of Geophysical Research*, 78(20), 4231–4249. <https://doi.org/10.1029/JB078i020p04231>
- Goldspiel, J. M., & Squyres S. W. (2000) Groundwater sapping and valley formation on Mars. *Icarus*, 148, 176–192.
- Gough, R. V., Chevrier, V. F., & Tolbert, M. A. (2014). Formation of aqueous solutions on Mars via deliquescence of chloride–perchlorate binary mixtures. *Earth and Planetary Science Letter*, 393, 73–82.
- Hecht, M., Kounaves, S. P., Quinn, R. C., West, S. J., Young, S. M. M., Ming, D. W., Catling, D. C., Clark, B. C., Boynton, W. V., Hoffman, J., DeFlores, L. P., Gospodinova, K., Kapit, J., & Smith, P. H. (2009). Detection of Perchlorate and Soluble Chemistry of Martian Soil at the Phoenix Lander Site. *Science*, 325(5936), 64–67. <https://doi.org/10.1126/science.1172466>
- Heldmann, J. L., Toon, O. B., Pollard, W. H., Mellon, M. T., Pitlick, J., McKay, C. P., & Andersen, D. T. (2005). Formation of Martian gullies by the action of liquid water flowing under current Martian environmental conditions. *Journal Geophysical Research*, 110, E05004.
- Kuznyetsova, Yu. G., Vidmachenko, A. P., & Steklov, A. F. (2019). What can be called "traces" of life on Mars. 6-th Gamow International Conference in Odessa "New Trends in Astrophysics, Cosmology and HEP after Gamow" and 19-th Gamow Summer School "Astronomy and beyond: Astrophysics, Cosmology, Radioastronomy and Astrobiology" (pp. 52–53). Odesa I. I. Mechnikov National University.
- McEwen, A. S., Ojha, L., & Dundas, C. M. (2011). Seasonal Flows on Warm Martian Slopes. *Science. American Association for the Advancement of Science*, 333(6043), 740–743.
- Morozhenko, A. V., & Vidmachenko, A. P. (2017). Optical parameters of Martian dust and its influence on the exploration of Mars. Dust in the Atmosphere of Mars and Its Impact on Human Exploration. *Proceedings conference Houston, Texas, 1966*, id. 6010. LPI Contribution.
- Morozhenko, A. V., & Vidmachenko, A. P. (2020). Dust can affect on the mastering of Mars. 22 International scientific conference Astronomical School of Young Scientists (pp. 71–73). State University "Kyiv Aviation Institute".
- Morozhenko, A. V., Vidmachenko, A. P., & Kostogryz, N. M. (2015). Spectrophotometric properties of Moon's and Mars's surfaces exploration by shadow mechanism. *Highlights of Astronomy*, 16, 182. <https://doi.org/10.1017/S1743921314005365>
- Steklov, A. F., & Vidmachenko, A. P. (2019). Where and What Exactly Can Be the "Traces" of Life on Mars? The Mars Extant Life: What's Next? *LPI Contribution*, New Mexico, 2108, id.5089.
- Vidmachenko, A. P. (2009a). Research of the Mars by space vehicles. *Astronomical School's Report*, 6(2), 131–137.
- Vidmachenko, A. P. (2009b). Water on Mars. *Astron. almanac*, 56, 225–249.
- Vidmachenko, A. P. (2016a). Is there life on Mars and where necessary to search for its traces. *Astronomy and present: materials of 5 Interregional Scientific Conference* (с. 43–48). Vinnytsia Mykhailo Kotsiubynskiy State Pedagogical University.
- Vidmachenko, A. P. (2016b). Traces of life on Mars must be sought around the valley Hellas in areas where the water coming out from under the planet's surface. 18 International scientific conference Astronomical School of Young Scientists (с. 14–16). State University "Kyiv Aviation Institute".
- Vidmachenko, A. P. (2016c). Where is Necessary to Search Traces of Life on Mars? Biosignature Preservation and Detection in Mars Analog Environments. *LPI Contribution*, Lake Tahoe, Nevada, No. 1912, id. 2002.
- Vidmachenko, A. P. (2017). Where Should Search Traces of Life, Which Could Appear on Mars in the First 300 Million Years. *Fourth ICo on Early Mars: Geologic, Hydrologic, and Climatic Evolution and the Implications for Life*, 2014, id. 3005.
- Vidmachenko, A. P., & Morozhenko, O. V. (2014). *The physical characteristics of surface Earth-like planets, dwarf and small planets, and their companions, according to distance studies*. MAO NASU, NULESU. Publishing House "Profi".
- Vidmachenko, A. P., & Morozhenko, O. V. (2019). *Physical parameters of terrestrial planets and their satellites*. Editorial and Publishing Department of NULES of Ukraine.

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ПРО ЖИТТЯ В "СУХИХ РІЧКАХ" МАРСА

Присутність довгих долин, що нагадують висохлі русла річок на Землі, має свідчити про те, що колись на поверхні Марса були умови, за яких могла існувати рідка вода. Зараз вода в різних станах міститься під поверхнею планети. Ділянки під поверхнею могли бути своєрідними оазисами для можливої біологічної активності. Тому вони, разом із покритими глиною ділянками Марса, можуть бути перспективним місцем для пошуку слідів життя. Марсохід "Spirit" був направлений до кратера Гуссеа діаметром 180 км, розташованого поблизу екватора. У цей кратер впадає русло стародавньої річки. В минулому цей кратер міг бути озером. Марсохід "Opportunity" спустився в кратер Eagle, розташований поблизу екватора на протилежному боці Марса від кратера Гуссеа. Там виявлено підвищену концентрацію гематиту, який на Землі утворюється лише у водному середовищі. Головна місія марсохода Perseverance – пошук ознак сучасного бактеріального життя на Марсі або його існування у минулому. Спостереження за допомогою спектральних приладів на марсоході Perseverance показали, що органічні молекули були знайдені в деяких гірських породах і скамянілому мулі. Вони є основою всього життя на планеті. Існує багато доказів того, що від 3,5 до 2,5 млрд р. тому на Марсі існувала потужна гідросфера. Вимрювання марсохода Curiosity дозволили нам визначити об'єм води, втраченої Марсом. Отримані дані дають нам змогу зрозуміти висновок, що Марс у минулому був не просто покритий водою, а й міг утримувати її в рідкій формі протягом сотень мільйонів років. Вивчення співвідношення дейтерію та водню в його атмосфері дозволило нам зрозуміти висновок, що парникові гази могли утримувати воду в рідкій формі. Парникові гази були цілком здатні нагріти Марс достатньо, щоб забезпечити стабільний клімат протягом мільйонів років. Це уможливило підтримання умов для хімічної еволюції – етапу, що передувє виникненню життя.

Ключові слова: Марс, полярна шапка, суха річка, вода, органіка, перхлорати.

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