# NEW MARTIAN SOIL SIMULANT VI-M2 FOR GEOCHEMICAL AND ASTROBIOLOGICAL EXPERIMENTAL RESEARCH.

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**Introduction:** Based on data obtained from the MER and Curiosity missions, a new VI-M2 Martian soil simulator has been developed at the Laboratory of Geochemistry of the Moon and Planets. Unlike most Martian simulators, which imitate the bulk chemical composition of the average "global" Martian regolith (Martian dust), we have developed an analogue of the Martian soil, which imitates the chemical and mineral composition of the Martian soil in a certain region of Mars. Laboratory modeling of such sites is important for future missions, including as a choice of areas for colonization.

**Materials and methods:** The Spirit, Opportunity and Curiosity missions have become the main sources of data on specific regions of Mars (Table 1). The obtained information on the chemical and mineralogical composition of the rocks was analyzed, which became the basis for this research.

Table 1. Properties of the Martian soil (chemical composition), from the areas of work of the MER and Curiosity missions.

| | Gusev soil [1] | Gale crater cluster 1 [2] | MP Eagle crater [3] |
|---|---|---|---|
| $Na_2O$ | 3.2 | 2.2 | 1.4 |
| MgO | 9.1 | 7.5 | 7.2 |
| $Al_2O_3$ | 10 | 11.4 | 8.8 |
| $SiO_2$ | 46.1 | 43.5 | 45.5 |
| $P_2O_5$ | 0.89 | | 0.82 |
| $K_2O$ | 0.45 | 0.6 | 0.48 |
| CaO | 6.03 | 8 | 7.52 |
| $TiO_2$ | 0.8 | 0.6 | 1.09 |
| MnO | 0.31 | | 0.4 |
| FeO | 15.2 | 13.8 | 20.1 |
| $Cr_2O_3$ | 0.29 | | 0.52 |
| $SO_3$ | 6.36 | | 4.93 |
| Cl | 0.51 | | 0.43 |
| Sum.% | 99.24 | 87.60 | 99.19 |

Sand from the Khalaktyr beach and volcanic drainage were chosen as the most suitable components (Fig. 1). The mineral composition of the soil of the Khalaktyrsky beach is similar to the composition of some volcanoes in Kamchatka, however, a higher degree of crystallization is observed. The grain size exceeds that for the tephra of the described volcanoes. It is noted that, in general, the sand sample is more ferruginous (FeO - 12%). Minerals are represented by plagioclase, pyroxene (orthopyroxene of the enstatite-ferrosilite series), the composition also includes ore minerals - titanomagnetite and magnetite, as accessory minerals - quartz and some others. There is a high concentration of ore grains. The sample contained symplectites, micrographic aggregates of chromite (chrome spinel) and clinopyroxene. It is possible to characterize the sand from the Khalaktyrsky beach as basalt, which is close to the composition of basalt sands in the Meridiani Planum area. A sample of volcanic drainage, so named by the manufacturer, contains a large amount of calcium (19%), which is its main feature as a component. The sample contains extreme members of the isomorphic series of plagioclase and chrome spinel, namely, anorthite and chromite. Chromite is in the form of inclusions. The main minerals are clinopyroxene and pyroxferroite, which are associated with olivine, corundum is also present. As inclusions, pentlantite is also often observed, which is associated with magnetite, pyrrhotite and chalcopyrite, which are the result of oxidation in semi-desert climates. Other minerals of the pyrrhotite-pyrite series are also present as inclusions. We can conclude that the drainage sample is basaltic with the presence of acidic minerals, the nature of which is close to semi-arid conditions. Many of the minerals found in this sample are characteristic of the Martian surface.

Fig 1. Image of soil components in natural composition. On the left is a sample of volcanic drainage, on the right is a sample of sand from the Khalaktyrsky beach.

The particle size distribution of VI-M2 was determined in accordance with GOST 12536-2014To process the data obtained, it is also necessary to know the density of solid particles of the soil, which is determined using a pycnometer, the technique is described in detail in GOST 5180-2015. The porosity and porosity coefficient were calculated from the density and particle density data.

**Results and discussion:** It was determined by the selection method that the most suitable imitation is achieved by mixing the components in a ratio of 2:1, where 2 parts are volcanic drainage, and 1 is sand from the Khalaktyr beach. Using a grinder, the resulting mixture is crushed to a size comparable to the fraction previously considered for the OUEB simulator [4], about 0.4-0.9 mm. The resulting model mixture can be attributed by chemical composition (Table 2) to the main rocks, as indicated by the silica content (not more than 50%) and the high calcium content (16.65%) in the obtained analogue, despite the presence quartz in the material of the Khalaktyrsky beach. The presence of quartz makes it possible to attribute it to medium igneous rocks. The chemical composition of the resulting VI-M2 simulator was studied by X-ray spectral analysis (Table 2). If the resulting analog the VI-M2 analog soil is close to the Bounce rock [4]. This is also evidenced by the similar Fe/Mn ratio of the VI-M2 analogue soil with the Bounce rock sample (34.35% versus 36.28%), which is lower than the same ratio for the Martian soils from the Gusev and Eagle craters (50-51 %).

Fig. 2 shows the cumulative particle size distribution curves for Martian soils analogous to VI-M2, JSC Mars-1, MMS sand, and JMSS-1 (comparison of physical and mechanical properties between JSC Mars-1, MMS sand, and JMSS-1 is presented here [5]). About 20% of VI-M2 are silty particles (d<0.05 mm), 70% of the analogue particles are larger than 0.1 mm. VI-M2 is more heterogeneous compared to JSC Mars 1, it includes fractions smaller than 0.02 mm and larger than 1 mm, which are absent in JSC Mars 1. MMS sand curve is quite close to VI-M2, the main difference is the presence of a fraction less than 0.005 mm. MMS sand and JMSS-1 are very similar in particle size distribution. VI-M2 mainly differs from them in the high content of fractions of 0.006-0.15 mm. The density of the Martian regolith at the landing sites of the Viking spacecraft varies from 1.1 to 1.94 $g/cm^3$[5]. The lower limit corresponds to the analog JSC Mars-1 (1.07 $g/cm^3$) [6], and the upper limit corresponds to VI-M2 (1.92 $g/cm^3$). According to the results of studies from the landing site of the Viking-1 spacecraft, the density of Martian regolith particles was 2.8. The particle density of the Martian soil analogs is quite variable: JSC Mars-1 2.63 $g/cm^3$, JMSS-1 2.88, VI-M2 3.04.). In terms of the range of porosity and porosity coefficient, VI-M2 almost coincides with the data on the Martian regolith.

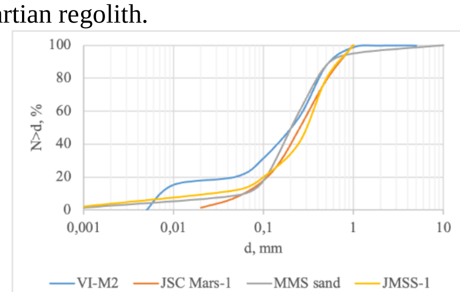


Fig. 2. Cumulative curves of particle size distribution of Martian soil analogues.

Table 2. Comparative chemical composition of rock and soil in Eagle Crater and VI-M2.

| | MP Eagle crater soil | Last chance Eagle crater | Berry bowl Eagle crater | MP bounce rock RAT | VI- M2 |
|---|---|---|---|---|---|
| $SiO_2$ | 45.5 | 38.1 | 42.4 | 50.8 | 45.86 |
| $Al_2O_3$ | 8.8 | 6.8 | 7.8 | 10.1 | 9.34 |
| CaO | 7.52 | 4.95 | 5.65 | 12.5 | 15.9 |
| FeO(T) | 20.1 | 18.6 | 16.8 | 15.6 | 16.65 |
| MgO | 7.2 | 7.1 | 7.4 | 6.4 | 6.99 |
| $Na_2O$ | 1.4 | 1.5 | 1.6 | 1.3 | 1.01 |
| $K_2O$ | 0.48 | 0.56 | 0.57 | 0.1 | 0.54 |
| $P_2O_5$ | 0.82 | 1.03 | 1 | 0.95 | 0.1 |
| $TiO_2$ | 1.09 | 0.72 | 0.88 | 0.78 | 0.61 |
| MnO | 0.4 | 0.3 | 0.36 | 0.43 | 0.48 |
| $Cr_2O_3$(T) | 0.52 | 0.19 | 0.22 | 0.78 | 1.1 |
| $SO_3$(T) | 4.93 | 18.7 | 14 | 0.52 | 0.4 |
| Cl | | 0.61 | 0.68 | 0.06 | |
| Loi | | | | | 0.01 |
| Sum.% | 98.76 | 99.16 | 99.36 | 100.32 | 99.02 |

**Summary:** The chemical, mineralogical, and physical composition of VI-M2 is excellent primarily for simulating the unweathered rocks of Eagle Crater, an be used for more than just this region. It is proposed to use this analog for geochemical, astrobiological studies, as well as for testing equipment.

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