CHARACTERIZATION OF TYPES AND CONTENT OF PHYLLOSILICATES IN THE SHALLOW SUBSURFACE IN DIFFERENT REGIONS OF MARS BASED ON DATA FROM GAMMA-RAY SPECTROMETER SUITE (MARS ODYSSEY). Igor Mitrofanov [1], W. V. Boynton[2], Maxim Litvak [1] and Nikita Demidov [1,3], [1]Space Research Institute, RAS, Moscow, 117997, Russia, imitrofa@space.ru, [2]Lunar and Planetary Laboratory, University of Arizona, Tucson, USA, [3]Institute for Physics of Soils, Puschino, Russia

Introduction. Signatures for phyllosilicates on the surface of Mars detected by OMEGA [1] and CRISM [2] experiments suggest long-term contact of igneous minerals with liquid water and warm climate, which is quite different from the current climate conditions on Mars. In our study we focus on characterization of types and content phyllosilicates in the shallow subsurface of different regions of Mars using the GRS data of Mars Odyssey for elementary composition of Martian soil.

GRS provides the set of global maps describing abundance of the main chemical elements in the Martian soil such as Si, Al, Fe, Ca, etc. [3] GRS does not have narrow field of view and its footprint (90% of gathered information from surface) is comparable with the large surface area of 300 x 300 km. But gamma-ray spectroscopy provides the unique technique for the depth distribution analysis (depth sensitivity in the range of 20-40 cm), which is very important for knowing the bulk composition of a particular mineral in the subsurface. Therefore, analysis of GRS data provides the complementary information to OMEGA and CRISM data for the bulk content of phyllosilicates, and even for particular type of these minerals.

Data Analysis. To derive content of phyllosilicates, we use the simplest modeling approach for the Martian soil assuming that it is a bi-modal mixture of a regolith with standard composition and some kind of phyllosilicates. In our study we use the average chemical composition of standard regolith derived from MER data [4, 5]. The reference content of Al, Fe and H for the standard regolith is thought to be 4.9 wt%, 14.6 wt% and 0.2 wt%, respectively. We assume 2 wt% of water for the standard regolith, as it was suggested according to GRS and HEND data [3, 6]. We have selected these three particular elements because they are key components of phyllosilicates chemical formula, and because their content from GRS is known quite well over the Mars surface [3]. Using the GRS data, we may obtain the measured content of Al, Fe and H for all known regions of detection of the signatures of phyllosilicates on the surface [1,2]. Table 1 presents few examples of these regions, which have been discussed for MSL landing site selection.

Table 1. GRS estimation for Al, Fe and H at several regions with detected signatures of phyllosilicates on the surface.

Tested regions	Al (wt%)	Fe (wt%)	H (wt%)
Nili Fossae Trough + Jezzero Crater	4.8±0.6	19.0±0.7	0.34±0.05
Mawrth Vallis	5.1±0.6	18.0±0.7	0.61±0.05
S. and W. Merridiani Terra	4.8±0.6	17.2±0.7	0.64±0.05
Terby crater	5.6±0.6	14.8±0.7	0.31±0.05
Holden crater	4.3±0.6	16.5±0.7	0.31±0.05
Shalbatana region	4.3±0.6	16.5±0.7	0.39±0.05

Smectites and kaolinites are the most common types of phyllosilicates distributed on the Earth [7]. They have also been suggested, as detected types of phyllosilicates on Mars (see [1,2]). Therefore, our testing minerals are

kaolinite $Al_2Si_2O_5(OH)_4$

and three types of smectites:

montmorilonite $((Na,Ca)_{0.33}Al_2Si_4O_{10}(OH)_2H_2O$,
Al-nontronite $(Na,Ca)_{0.33}Fe_2Al_4O_{10}(OH)_2H_2O$
and Si-nontronite $(Na,Ca)_{0.33}Fe_2Si_4O_{10}(OH)_2H_2O$.

According to bi-modal model of the soil composition, we use the simple formula to estimate the upper limit X for the content of a particular phyllosilicate based on the measured contents of Al, or Fe, or H:

$$\xi_i = X\,\alpha_{ij} + (1-X)\,\gamma_j \quad (1)$$

where ξ_i is measured content of a key element *i* (Al, or Fe, or H) according to GRS, α_{ij} is the known fraction *j* of this element in the particular tested type of phyllosilicate, γ_i is the reference concentration of this element in the standard regolith (all values of contents are fractions of 1). To estimate the most feasible value of *X*, it is necessary to solve equation (1) individually for each of key elements Al, Fe and H. One obtains three values for *X*, and the smallest one corresponds to the maximal acceptable content of this tested mineral, which is supported by the data from GRS.

Results. The results are presented in the Table 2 for each of four tested types of phyllosilicate and for six regions with detected signatures of the presence of phyllisilicates on the surface (in brackets we show the element, which content has been used for this estimation). Errors are based on data statistics. In several cases the presence of particular type of phyllosilicates in the subsurface is not supported by GRS observations both for Al or for Fe. It happens, when detected content of the key element is smaller than the reference value for the standard regolith. In this cases we may only indicate the upper limit for the bulk content of phyllosilicate in subsurface, as it could be derived from the statistical errors of GRS data.

Table 2. Estimated contents (or upper limits) for particular types phyllosilicates for several regions with detected signature of phyllosilicates on the surface.

Testing landing sites	*Kaolinite*	*Montmorilonite*	*Al-nontronite*	*Si-nontronite*
Nili Fossae Trough + Jezzero Crater	<2 wt% (Al)	<3 wt% (Al)	<3 wt% (Al)	18±4 wt% (H)
Mawrth Vallis	1±2 wt% (Al)	2±3 wt% (Al)	1±3 wt% (Al)	30±2 wt% (Fe)
S. and W. Merridiani Terra	<2 wt% (Al)	<3 wt% (Al)	<3 wt% (Al)	22±2 wt% (Fe)
Terby crater	4±2 wt% (Al)	8±3 wt% (Al)	<3 wt% (Fe)	<2 wt% (Fe)
Holden crater	<2 wt% (Al)	<3 wt% (Al)	<3 wt% (Al)	13±4 wt% (H)
Shalbatana region	<2 wt% (Al)	<3 wt% (Al)	<3 wt% (Al)	15±2 wt% (Fe)

Conclusions. Data from GRS allows to characterize qualitatively the bulk content of particular types of phyllosilicates in the shallow subsurface. The *Si-nontronite* (Table 2, the last column) is thought to be the most probable type of phyllosilicate. It could be found practically at each region, and its estimated bulk content is ranged from the top value of 30 wt% for the Mawrth Vallis, to 18-22 wt% for Nili Fossae and for S. and W. Merridiani, to 13-15 wt% for Shalbatana region and Holden crater, and down to practical absence (within few percents) for the Terby crater. The content of this type of phyllosilicate is mainly limited by observable content of Fe, but in two cases (Nili Fossae and Holden crater) the content of *Si-nontronite* is limited by the content of H.

On the other hand, the *montmorilonite* and *kaolinite* could not be abundant phyllosilicates on Mars. They may only be suggested for the soil at Terby crater with a moderate content of 8 wt% and 4 wt%, correspondingly. And, there is no evidence for any detectable content of *Al-nontronite* at each of six tested regions of Mars (Table 2). In future studies of Mars geology, one has to understand, why one particular type of phyllosilicates, the of *Si-nontronite*, dominates on this planet. The highest estimated content of *Si-nontronite* in the Mawrth Vallis makes this region, as one of the most attractable landing sites for Mars Science Laboratory [8].

References. [1] Bibring et al., Lunar and Planetary Science XXXVIII, 2007; [2] Chevrier and Bibring, Nature, vol. 448, p. 5, 2007; [3] Boynton et al., Journal of Geophysical Research, v. 112, issue E12, 2007; [4] Gellert et al., Science, vol. 305, 2004; [5] Rieder et al., Science, vol. 306, 2004; [6] Mitrofanov et al., Science, vol. 297, issue 5578, p. 78, 2002; [7] Deer, Howie and Zussman, An introduction to the Rock-Forming Minerals, Longman, London, 1992; [8] Mitrofanov et al., 2nd Workshop of Landing Site Selection of Mars Science Laboratory, 2007.