

DISTRIBUTION OF CHEMICALLY BOUND WATER IN SURFACE LAYER OF MARS BASED ON DATA ACQUIRED BY HIGH ENERGY NEUTRON SPECTROMETER, MARS ODYSSEY. M. L. Litvak¹, A. T. Basilevsky², I. G. Mitrofanov¹, W. Boynton³, R. S. Saunders⁴; ¹Institute for Space Research, RAS, Moscow, 117997, Russia; ²Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, Moscow, 117975, Russia; ³University of Arizona, Tucson, AZ 85721, USA; ⁴Jet Propulsion Laboratory, Pasadena, CA 91109, USA.

Introduction. Here we analyze data taken by High Energy Neutron Detector (HEND) which is part of the Mars Odyssey Gamma Ray Spectrometer suite. This study is emphasized on a search for signatures of chemically bound water in the surface layer of Mars. Fluxes of epithermal (characterize the upper 1-2 m) and fast (the upper 20-30 cm) neutrons, considered in this analysis, were measured since mid February till mid June 2002, time twice longer than time of accumulation of data analyzed by (1,2,3). These works reported low neutron flux in high latitudes, interpreted as signature of ground water ice, and in two low latitude areas: Arabia and SW of Olympus Mons (SWOM), interpreted as “geographic variations in the amount of chemically and/or physically bound H₂O and or OH...” (2). If chemically bound water is found to be abundant in Mars surface materials it may imply abundance of liquid water in the planet geologic past. About 1% of chemically bound water and by order of magnitude smaller amount of adsorbed water were found in soils of Viking 1 and 2 landing sites (4). Later it was concluded that “the reported values... are indirect data, reliable only to within a factor ± 5 ... Relative ratios are more dependable” (5). Recent analysis of the APXS data at Mars Pathfinder site led to conclusion that soils and rocks here contain chemically bound water in amounts comparable to those in Viking soils (6). So it is clear that surface materials of Mars do contain chemically bound water but its amounts are poorly known. Hopefully HEND and the companion instrument (2) will determine it with higher accuracy.

The approach. Because HEND data themselves cannot distinguish free water (e.g., ice) from chemically or physically bound water one can try to search for chemically bound water in the areas where presence of water ice seems to be unlikely and amounts of adsorbed water are negligible. These are believed to be areas of low (all seasons) and middle latitudes (at summer time) (7,8). So if one sees a signature of water in these areas at the appropriate time then it may be suggested that it is a signature of chemically bound water. Below we discuss areal distribution of the epithermal and fast neutron fluxes for the $\pm 60^\circ$ latitude zone that is $\pm 40^\circ$ belt, where ground ice is believed to be absent (7,8), plus additional 20° -wide poleward belts, where signatures of chemically bound water may potentially be seen. The Figure on the following page shows maps of flux of epithermal (top) and fast (middle) neutrons as well as MOLA topography map (bottom) for this zone as well as maps of epithermal and fast neutron fluxes for smaller areas of specific interest (at the right).

Flux of epithermal neutrons. It is prominently low (0.04-0.10 count/s) at longitudes 180-280°E at the northern margin of the $\pm 60^\circ$ zone and at 30-180°E at its southern margin and rather low (0.10-0.15 count/s) within Arabia Terra and geographically antipodal to it SWOM area. Very large area extending from 50°S to 50°N and from 250° to 330°E shows relatively high thermal neutron flux (0.20-0.26 count/s) with local maxima north of Argyre and in Solis Lacus. The rest of the territory in the $\pm 60^\circ$ zone shows intermediate flux (0.15-0.19 count/s) with sporadic lower and higher values. This distribution does not correlate with surface elevation. In

some places it shows correlation with local geology: in Arabia and SWOM (see below). However in most places, flux of epithermal neutrons shows no correlation with the units shown on synoptic geologic maps (9,10,11). For example, regions of high and intermediate epithermal neutrons flux include Noachian cratered, hilly and etched units (mostly impact breccias, >3.9 b.y. old), Hesperian ridged plains and Syria Planum formation (mostly lavas, 2.5-3.9 b.y. old) and Amazonian Tharsis Mons formation (mostly lavas, <2.5 b.y. old). In some places (parts of Arabia and SWOM) the epithermal neutrons fluxes correlate with thermal inertia values. But even here the correlation is partial while in most places it is absent.

Flux of fast neutrons. Its geographic distribution differs significantly from that for epithermal ones. In the northern part of the $\pm 60^\circ$ zone there is vast area of relatively low flux (0.10-0.15 counts/s) with values gradually increasing to the south. Its southern boundary does not follow any specific latitude but rather follows -1 km contour line (pink lines on the fast neutron map). At the south of the $\pm 60^\circ$ zone, the area of low (0.06-0.14 counts/s) flux is observed mostly at 40-150°E longitude range, also showing combined latitude-altitude control of its equatorward boundary while at other longitudes of the south the altitude control seems not to work (Argyre basin). Terra Arabia and partly SWOM, so different from their surrounding in low epithermal neutron flux, show no noticeable difference of that sort in fast neutron flux. Large region with high epithermal neutron flux (50°S-50°N, 250°-330°E) shows mostly intermediate flux of fast neutrons (except Solis Planum where fast neutron flux is also high). For the rest of the $\pm 60^\circ$ zone, typical values of fast neutron flux are 0.15-0.17 with sporadic higher and lower values.

Neutron flux at Viking 1,2 and Pathfinder sites and in the area of Sinus Meridiani hematite deposit. Flux of epithermal neutrons at the Viking 1 site, western Chryse Planitia (V1 in the Figure), is rather high (0.18-0.20 counts/s) while fast neutron flux is rather low (0.12-0.14 counts/s), the latter is obvious seasonal effect. Mars Pathfinder site, SE Chryse Planitia (Pf in the Figure), also shows high (0.18-0.20 counts/s) flux of epithermal neutrons and low (0.13-0.15 counts/s) flux of fast neutrons, also seasonal effect. More poleward Viking 2 site at Utopia Planitia (V2 in the Figure) shows low flux both for epithermal (0.12-0.14 counts/s) and fast (0.10-0.13 counts/s) neutrons, both obviously due to seasonal effect. The area of hematite deposit in Sinus Meridiani (12) is in the western periphery of the Arabia negative anomaly (SM in the Figure). The hematite deposit proper signature is seen neither in epithermal (E) nor in fast (F) neutron flux (Figure lower right).

Discussion and conclusions. Low flux of epithermal neutrons along the poleward margins of the $\pm 60^\circ$ zone is obviously due to presence of ground ice (1,2,3). Terra Arabia and SWOM areas have easily eroded by wind surface deposits considered by (13) as remnants of ancient polar layered deposits. It is not clear if the Arabia and SWOM anomalies are due to chemically bound water or to stability of ground ice in highly porous material (14). Further observations through Martians seasons will hopefully resolve this alternative. Ex-

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cept these two areas, no correlation of epithermal neutron flux with the units shown on synoptical geologic maps was found. Chryse Planitia, where Viking 1 and Pathfinder landed, was believed to be the oceanic bay and thus one can expect that it should have low epithermal neutron flux (signature of chemically bound water). But instead it shows rather high flux. Similarly, the area of Sinus Meridiani hematite deposit, which was believed to form in the water-rich environment (12) does not show the expected low epithermal neutron flux. All this means probably that, except Arabia and SWOM, the 1-2 m thick surface layer, where the epithermal neutron flux forms, is not compositionally linked (at least, in chemically bound water contents) to the underlying bedrock but forms the overlying mantle well mixed laterally. The HEND data show also that in the contents of chemically bound water in the ice-free areas seem to be typically higher than at the Viking and Pathfinder sites. The *fast* neutron flux is understandably (ground ice) low at high latitudes. The equatorward boundaries of these low-flux areas show obvious (although not always realized) altitude control indicating ground ice presence. At the areas, where ground ice is not expected, the fast neutron flux shows no correlation with the

bedrock geologic units even in Arabia and SWOM. This means probably that the 20-30 cm thick upper part of the mentioned overlying mantle is even less compositionally linked to the bedrock and better laterally mixed than the lower part of the mantle. If so, we may predict that major and trace elements abundances determined by gamma-ray spectroscopy will characterize the mantle rather than bedrock compositional variations.

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