MEDUSAE FOSSAE-ELYSIUM REGION, MARS: DEPRESSION IN THE HEND/ODYSSEY MAP OF MARS EPITHERMAL NEUTRONS

M. A. Ivanov[1], M. L. Litvak[2], I. G. Mitrofanov[2], W. Boynton[3], R. S. Saunders[4]. 1 - Vernadsky Institute of Geochemistry and Analytical Chemistry, RAS, Moscow, 119991, Russia, mishaivn@mtu-net.ru; 2 - Institute for Space Research, RAS, Moscow, 117997, Russia; 3 - University of Arizona, Tucson, AZ 85721, USA, 4 - Jet Propulsion Laboratory, Pasadena, CA 91109, USA.

Introduction. The first data from the Gamma Ray Spectrometer (GRS) onboard Mars Odyssey spacecraft showed that the low neutron fluxes characterize both subpolar regions of Mars [1-3]. The low neutron fluxes mean the presence of hydrogen-rich soils and have been interpreted as an indication on abundant water ice in these areas. The equatorial region of Mars (equatorward of ~50^o) is characterized by higher fluxes of both epithermal (0.4 eV-100 keV, come from depth 1-2 m) and fast (3.4-7.3 MeV, come from depth 0.2-0.3 m) [3] neutrons meaning that this area is mostly dry. The pattern of distribution of the neutron fluxes is in a good agreement with the theoretical predictions on the stability of ground ice on present Mars [4,5]. The actual distribution of the ice, however, depends on variations of thermal inertia of soils and albedo of the surface [6]. The flux of the epithermal neutrons detected by the HEND instrument, which is part of GRS, has two noticeable depressions in the equatorial region, one in Arabia Terra and another in the Medusae Fossae-Elysium region (MFER) [1-3]. Here we present the initial results of analysis of characteristics of the neutron fluxes and regional geological setting of the epithermal neutron depression in this area. The main goal of our study was to put some constraints on the time of the anomaly formation and to assess possible form of hydrogen (ground ice vs. chemically bound water) there.

Data analyzed. We analyzed data acquired by the HEND instrument during the first seven months of the experiment, from 19 February to 13 September 2002 [7,8]. The whole data set corrected for the Solar flares has been binned into 5 x 5^o (~300 km) pixels (2592 pixels) and grouped into five time series corresponding to mean areocentric longitudes from 339.9 (northern winter), through 1.2, 19.7, 35.4, to 55.4 (mid northern spring). This allows characterizing changes in the neutron fluxes as a function of the Martian seasons. For the purposes of our study, a data subset extending from 50^o S to 50^o N and from 120^o W (Arsia Mons) to 240^o W (western edge of Elysium Planitia), 480 pixels, was extracted from the global data set.

Neutron fluxes in the Medusae Fossae-Elysium Region. In the area under study, pattern of areal distribution of the fast neutron flux does not display any consistent, positive or negative, signature that would be distinguishable from the rest of the equatorial region of Mars. Mean value of the flux of fast neutrons in MFER averaged over seven month of measurements is ~0.116±0.012 counts/s, which is the same as for the rest of the equatorial region, 0.119±0.011 counts/s. The average latitudinal profile (a profile of mean values of the flux in 5^o latitudinal zones within the studied area) of the flux of fast neutrons in MFER lacks characteristic features and displays monotonic decrease of the flux from ~0.125 counts/s at the southern edge of the area to ~0.1 counts/s at its northern margin. Correlation of the flux values among different time series is very low and is characterized by correlation coefficients ranging from 0.171 to 0.275. Such a low correlation means that the pattern of areal distribution of the flux of fast neutrons in MFER is not self-repetitive through time.

The most peculiar feature in MFER is a distinct negative depression of flux of epithermal neutrons. The depression appears in each time series, is consistently outlined by ~0.160-0.170 counts/s contour line, and the drop of the flux inside the depression is up to 18-19% (0.130-0.140 counts/s). The average latitudinal profiles across MFER corresponding to each time series have characteristic minimum that occurs within narrow latitudinal interval, from 12.5^{o}S to 7.5^{o}S. The position of maxima on both sides of the minimum is also stable through time and occurs at 42.5-47.5^{o}S and 7.5^{o}N. Correlation of the flux values among the time series is significantly higher than in the case of the fast neutrons ranging from 0.647 to 0.698. Thus, the areal pattern of the epithermal neutrons flux in MFER appears to be self-repetitive and stable in space displaying little changes as a function of the Martian seasons.

Regional geological setting of the depression of epithermal neutrons in MFER. The depression of the epithermal neutrons in MFER extends as an arcuate latitudinal band up to ~2000 km wide and ~7000 km long from the western edge of Tharsis to SW portion of Elysium Planitia where the depression turns to N and runs along western slopes of Elysium highland. The major portion of the depression occurs along the dichotomy boundary and broadly coincides with a large topographic trough between the southern edge of the cratered uplands and the highland of Elysium. The depression covers a wide variety of geological units [9,10] from NPl_1 (Noachian cratered terrain) through Hr (Hesperian ridged plains) to Amu (upper member of the Medusae Fossae Formation, Amazonian in age). To the South of the depression, areas of relatively high flux of the epithermal neutrons are located within the southern cratered uplands (mostly Noachian units) and to the North of the depression areas of the high flux coincide with Amazonian units Ael_1 (member 1 of the Elysium Formation) and Achu (undivided younger channels and flood-plain materials). Although the footprint of the neutron detector is large (~300 km across), the areas occupied by different units within and outside the depression are typically far larger than the footprint. Thus, if some of the units were responsible for the appearance of the depression, it should be visible even at the coarse resolution of the HEND instrument. It is, however, not the case and the depression runs through the mosaic of units displaying no areal correlation with any of them. This means that there is no specific unit or units the emplacement of which led to the formation of the depression.

Discussion. The flux of the fast neutrons from the surface of Mars characterizes a few uppermost tens of centimeters of the surficial layer [1-3]. The epithermal neutrons, on the other hand, come from deeper portions of the layer, up to a few meters deep [1-3]. In MFER, characteristics of the fluxes of the fast and epithermal neutrons are strongly different. The MFER area as viewed in the fast neutrons energy diapason is a common place within the equatorial region of Mars while a distinct depression of the flux characterizes MFER in the epithermal neutrons energy range. The low correlation between the fluxes of the fast and epithermal neutrons in MFER, from 0.182 to 0.297, indicates that the fluxes are practically independent and reflect different modes of distribution of hydrogen in the near subsurface. The different distribution of hydrogen suggests that the two layered model with the thin hydrogen poorer upper layer superimposed on a hydrogen richer, thicker, and deeper layer [1-3] is applicable not only to the sub-polar regions but to the area of MFER as well.

The characteristics of the flux of fast neutrons suggest that the surficial layer a few cm thick in MFER and probably in the equatorial region as well is uniform and well mixed, at least in respect of the hydrogen content. This layer may represent areas of “stippled and granular appearance” [11] that are seen in many MOC images [12,11] and characterize significant areas in the equatorial region [11].

In MFER, the flux of the epithermal neutrons is characterized by a distinct depression, which is due to either higher content of water ice or water bearing minerals or both in a relatively deep (1-2 meters) layer in the area under study. The important characteristic of the depression is that neither its shape nor the latitudinal position has changed during several month of observations. This suggests that regardless of the specific form of water (ground ice vs. chemically bound water), the area of the depression may be related to the long-term water cycle on Mars.

Another major feature of the depression is that it does not correlate with the geology of the surface and occurs in a suite of units that have been formed from Noachian to Amazonian epoch. Such an absence of the correlation leads to two conclusions. First, the formation of none of the mapped [9,10] units in the area under study was responsible for the epithermal neutrons depression there. Second, the depression must be younger than the youngest units in MFER. Among the youngest units are those that make up the Medusae Fossae Formation, upper Amazonian in age [9,10]. Thus, the depression in the flux of epithermal neutrons in MFER has been formed rather late in the geologic history of Mars.

This puts strong restrictions on the modes of origin of the epithermal neutron depression in MFER. For instance, the depression could not be directly related to possible ancient (Hesperian in age) large bodies of water within the northern lowlands [13-15]. A plausible explanation of the depression is that it may be related to relict ground ice. If Mars had higher obliquity in the relatively recent geological past [16], the ground ice then was stable everywhere on the planet [5]. The low thermal inertia of the soil in combination with high albedo of the surface are favorable factors for ground ice to remain [6] in the equatorial region at the present obliquity. MFER is in the large area west of Tharsis that is characterized by low thermal inertia [17] and high albedo [18].

The comparison of the depression of the epithermal neutrons with the maps of thermal inertia [17] and albedo [18] shows that the widest and deepest portion of the neutron anomaly is within the low inertia/high albedo area to the West of Tharsis. Another minimum of the epithermal neutron flux also coincides with an area of low inertia/high albedo at the north-western slope of Elysium. The local maximum of the neutron flux in the southern portion of Elysium Planitia is, however, in the area of low inertia/high albedo and the western continuation of the neutron anomaly coincides with the an area of relatively high inertia/moderate albedo in the SW portion of Elysium Planitia. Thus, the pattern of areal distribution of the flux of epithermal neutrons and thermal inertia and albedo are poorly correlated in MFER.

Rather poor correlation of the depression of epithermal neutrons with the low thermal inertia/high albedo areas in MFER does not favor the presence of water ice, interstitial or in massive bodies, in this area and, more likely, suggest that the neutron depression there is due to chemically bound water.

References: 1) Boynton et al., *Science*, 297, 2002 81-85, 2) Feldman et al., *ibid*, 75-78, 3) Mitrofanov et al., *ibid*,78-81, 4) Farmer and Doms, *JGR*, 84, 2881-2888 1979, 5) Mellon and Jakosky, *JGR*, 98, 3345-3364 1993, 6) Paige, *Nature*, 356, 43-45, 1992, 7) I. G. Mitrofanov et al., *LPSC XXXIV*, 2003, 8) M. L. Litvak et al., *LPSC XXXIV*, 2003, 9) Scott & Tanaka, USGS Map I-1802-A, 1986, 10) Greeley & Guest, USGS Map I-1802-B, 1987, 11) Carr, M. H., *JGR*, 106, 23571-23593, 2001, 12) Malin, M. C. and K. S. Edgett, *JGR*, 106 23429-23570, 2001, 13) Parker, T. J., et al., *Icarus* 82, 111-145, 1989, 14) Parker, T. J., et al., *JGR*, 98, 11061-11078, 1993, 15) Head, J. W., et al., *Sciense*, 286, 2134-2137, 1999, 16) Ward, W. R., *in: Mars, Kieffer, H. H. et al., eds, Univ. Arizona Press, Tucson*, 298-320, 1992, 17) Mellon et al., *Icarus*, 148, 2000, 437-455, 18) Christensen et al., *JGR*, 106, 2001, 23,873-23,885.