SPATIAL AND TEMPORAL VARIATIONS OF BOUND WATER CONTENT IN THE MARTIAN SOIL WITHIN THE GUSEV CRATER: PRELIMINARY RESULTS OF THE TES AND MINI-TES DATA ANALYSIS.
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Introduction: Bound water (BW) on the martian surface has been detected with ground-based spectroscopy in the near-infrared [1- 3, 5] and thermal infrared spectral range [4]. The presence of BW has been confirmed by *in situ* measurements from the Viking 1 and 2 landers [6,7], by Sojourner rover [8] and recently by MER rovers [9, 10], as well as from orbit by OMEGA/Mars Express observations [11]. The BW absorption and emission bands in near- and thermal infrared spectral range represent one of the most sensitive spectral indicators of the presence of hydrated minerals in the martian soil. The emission band of the BW in the TES spectra of Mars is characterized by distinctive emission peak at 6.1 µm [12], which is pronounced in the spectra of the fine-grained bright soils due to multiple scattering effects, and significantly lower in the spectra of course-grained, dark areas. The global mapping of the BW spectral index conducted based on the TES data [13] has shown that the BW abundance in the martian soil strongly correlates with dusty bright areas in the broad range of the latitude from the polar area to equatorial zone, and is characterized by regional and seasonal variations [14, 15]. New data from the Mini-TES instruments on the MER rovers provides the opportunity to study the presence of BW as a function of local variations in the soil properties and season for separate small areas of the planet. Here we present the preliminary observations of the BW regime in the surface soils along the Spirit rover traverse in the Gusev crater during the observation period equal to almost one martian year from Sol 7 to Sol 676 (Fig.1).

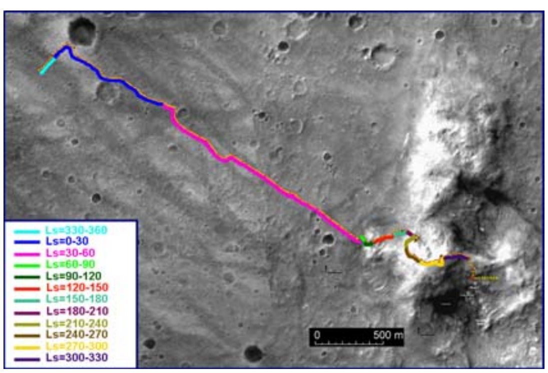

Fig. 1. The ***traverse of the Spirit rover showing the 30° Ls ranges, over which the Mini-TES spectra of the soils were averaged.***

Methodology: For the study we selected all spectra collected by the Mini-TES from different soils targets during the warmest time of the day (from 12 noon to 15 PM). For this study all the spectra from each soil targets collected in each separate observation in "stare" and "raster" modes were averaged and then the spectra were analyzed to determine the presence or absence of the BW emission peak at 6.1 µm. At this stage all the spectra that were very noisy in the wavenumber range > 1500 cm^{-1} or were anomalous in any way were excluded from analysis. All representative spectral observations of the soil targets (with distinctive BW emission peak) were sorted into 30° Ls ranges and then averaged within each of the ranges during one martian year of observations. The BW index has been calculated for each averaged spectrum within 30° Ls range in the same way as was done before for the TES observations [13-15].

Bound water emission in soils: The analysis of the martian soil spectra along the Spirit traverse shows that the intensity of the BW emission varies depending on subtype of the soil and locality. The spectra of undisturbed soils are similar for all regions. Several different subtypes of the soils were isolated during analysis of the Mini-TES spectra based on the microstructures and the abundance of small rock clasts on the surface (Fig. 2). The emission peak of the BW is significantly stronger in the spectra of the bright dusty soils, and in deflated soils that do not have rock fragments and characterized by a small scale structure of the surface. The spectra of some ripples and small dunes with moderate dust covering also have the distinctive emission peak of the BW, while the spectra of both the deflated and granular surface of the features and other active aeolian drifts generally lack the BW emission. The spectra of the soils disturbed by the rover's wheels, as well as rocky soils, have a less intense BW emission peak.

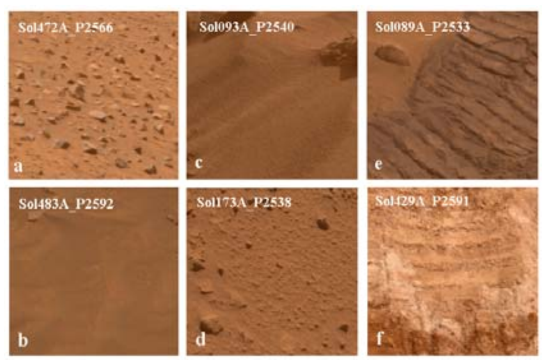

Fig. 2. ***Different subtypes of soils, targeted by the Mini-TES: a, rocky soil surface; b, drift material surface; c, dune surface; d, deflated soil surface; e, soil surface disturbed by rover's wheels; f, sulfate-enriched soil. It is used the fragments of Pancam true color images*** **[18]**.

The strongest peaks of the BW have been observed primarily within the Columbia Hills area in two places: on the west slope of the West Spur hilly terrain (Sol 166-180) and within the Larry's Loockout (Sol 400-470). Following the chemical measurements of soils and rocks by the APXS [10], there is distinct tendency to increasing of the sulfates in the soils (magnesium, calcium and ferric) while approaching the Columbia Hills. Visible color evidence for white salts in the soils of both places is seen in Pancam imaging [18] of the soil surface disturbed by the rover's wheels (Fig. 2f). The averaged Mini-TES spectra from the indicated sol's ranges are shown in Fig.3 in comparison with the averaged spectrum of the soils observed by Mini-TES in the period from Sol 1 to Sol 676. As can be seen in Fig. 3, the BW emission peaks are much higher in the cases of the Columbia Hills soils than for averaged soil spectrum along the rover's traverse.

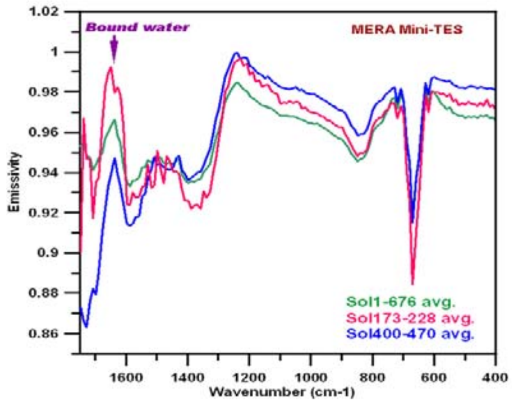

Fig. 3. ***Averaged Mini-TES spectra of the soils within the western part of the Columbia Hills (red and blue) and the averaged soil spectrum from observations from Sol1 to Sol676 (green).***

Seasonal variations of bound water emission: To analyze the seasonal dynamics of the BW content, all spectra of the soil's targets were sorted into 30° Ls ranges and averaged in each such range for one martian year. For comparison with orbital observations we conducted the same procedure with the TES spectra for the interior part of the Gusev crater. The analysis of the TES data (Fig. 4) reveal one distinctive seasonal maximum of BW index in the Ls range of 30°-120° and other weaker maximum in the Ls range of 210°-300°. Both peaks are consistent with

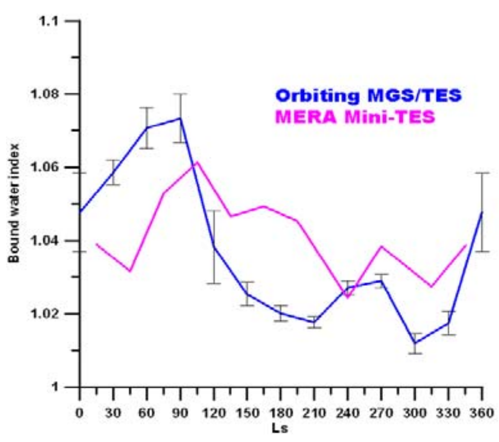

Fig. 4. ***Seasonal variations of the BW index over the Gusev crater floor (blue) and along Spirit rover traverse (pink). Vertical bar: mean error.***

seasonal maxima of BW emission during aphelion and perihelia periods, as inferred with global mapping [15]. Although seasonal changes of BW emission obtained with Mini-TES (Fig. 4) are different from orbital data, both sets of data show a decrease in BW abundance from 90° L_s to 330° L_s. In the case of Mini-TES data, the seasonal maximum of the BW content (at Ls range 90°-120°) is a slightly lower and appears later in time than it is observed with TES data.

Discussion: The analysis of the Mini-TES spectra for the Spirit rover traverse has shown that BW abundance in the surface soil experience distinct local and temporal variations. The maximum of the BW emission corresponds to the local soils at the Columbia Hills with anomalously high sulfate concentration. The South equatorial region is characterized by the low atmospheric water content and relatively high surface temperature. These conditions do not favor formation of highly hydrated minerals at the dry surface [16]. High amounts of BW associated with sulfates may be indicative of aqueous origin of sulfates in the Columbia Hills soils. This is consistent with an impact-driven aqueous alteration of deposits that contributed to local sulfate-rich soils. Because the Spirit rover operated for much of the martian year within the Columbia Hills (from 60° to 330° of Ls) the observed seasonal dynamics of the BW is associated mostly with soil types on the surface of the Hills. The observed difference between TES and Mini-TES data may be related to different sizes of imaging spots (3 × 3 km and from tens cm to several meters, respectively). In addition, the surface of the traverse area is remarkably darker (albedo 0.19) than the typical surface of the floor of the Gusev crater (albedo 0.23-0.26). This means that amount of the dust material along the rover's traverse is more variable from place to place than on the most area of the crater's floor. The higher BW index shown in Figure 4 for the Spirit traverse area (in the Ls range 150°-210°) could be related with the presence of the sulfate-rich local soils on the western part of the Columbia Hills. Wind abrasion of the highly altered rocks on the Columbia Hills may to be one of the reasons for salts enriching in the local soils. These sulfates may not have dehydrated easily, consistent with slow dehydration of magnesium sulfates [17]. The delayed dehydration at Ls=(90°-120°) observed in the Mini-TES observations (Fig. 4) could be related to higher concentration in local Mg-salts at the Columbia Hills, which dehydrate more slowly than some other salts. The Gusev dusty soils observed from orbit could be enriched in salts that hydrate and dehydrate more rapidly (e.g., Na sulfate [14].) These salts could represent planetary averaged dust and contribute into seasonal changes of BW emission in middle latitudes [14, 15].

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