POTENTIAL HABITABLE ZONE WITHIN THE SUBSURFACE OF EQUATORIAL REGION ON MARS. Alian Wang1, J. J. Freeman1, J. F. Bell III2, B. L. Jolliff1, 1Dept. Earth and Planetary Sciences and McDonnell Center for Space Sciences, Washington University, One Brookings Dr., St. Louis, MO, 63130 (alianw@levee.wustl.edu), 2Dept. Astronomy, Cornell University, Ithaca, NY 14853, USA.

Introduction: Recent missions to Mars have revealed much evidence for the existence of life-friendly mineral species and potentially life-friendly environments on Mars. Such evidence includes the high level of Water-Equivalent-Hydrogen (WEH) within ~1 m depth subsurface at two equatorial regions on Mars discovered by the Neutron Spectrometer on Mars Odyssey; the ground ice excavated by meteorite impact found by HiRISE and CRISM on MRO; the wide occurrences of phyllosilicates, hydrated sulfates, and carbonates characterized by CRISM (MRO) and OMEGA (Mars Express); as well as the widespread chloride-bearing species suggested by the data analysis of APXS and Pancam spectra [1,2,3,4,5].

In this study, we concentrate on discoveries made by the Mars Exploration Rovers (MER) and on the results from related laboratory experiments, which suggest the existence of a potential habitable zone within the subsurface of equatorial regions on Mars.

Hydrous sulfates found by Spirit and Opportunity within the subsurface of equatorial regions on Mars: Gusev crater and Meridiani Planum (where the two MER rovers have been exploring for nearly six years) are both located near the equator, within the two equatorial regions where high levels of WEH were found by the NS on Mars Odyssey. A common discovery by the two rovers is the existence of hydrated sulfates within the subsurface. Mg-, Ca-, and Fe-sulfates make up ~35 wt% of Meridiani outcrop and Mg-, Ca-, and Fe-sulfates have been found in the excavated subsurface salty soils at Gusev Crater [6,7].

Through repeated Pancam multicolor imaging, Spirit has observed changes with time in VIS-NIR spectra of the salty soils excavated by dragging its non-functional right-front wheel. Such phenomena have been observed at the Tyrone, Kit Carson, and Ulysses sites after many sols of exposure to Mars’ current surface atmospheric conditions. Figure 1 compares spectra of Tyrone yellowish salty soil extracted from seven 13-filter Pancam observations repeated during the period from sol 864 to sol 1062. The major changes in spectral features are a reduction of spectral slope in the 434-673 nm spectral region and a reduction in band depth of an absorption centered near 803 nm [7,8].

Based on our laboratory experiments and relevant spectroscopic measurements, Tyrone spectral changes can be best interpreted as the result of dehydration of ferricroiapite \([\text{Fe}_2\text{(SO}_4\text{)}_3\text{(OH)}_2\cdot2\text{H}_2\text{O}]\), which can either form amorphous ferric sulfate with a lower hydration state, such as rhomboclace \([\text{FeH(SO}_4\text{)}_2\cdot4\text{H}_2\text{O}]\) [8]. The existence of ferricroiapite in Tyrone yellowish soils was supported by the data analysis of APXS and Pancam spectra [9,10].

Finding a temporal spectral change of Tyrone yellowish soil on Mars is significant because it indicates that the salty soils within the subsurface were originally not in equilibrium with the surface atmospheric conditions. In other words, there is a relative humidity gradient existing in the upper few tens of centimeters depth below the surface in the Tyrone area. The relative humidity (RH) at surface of Mars is determined by temperature (T) and the water vapor pressure \((P_{\text{H}_2\text{O}})\) in the atmosphere. At depths, where the Tyrone yellowish soils may have originated, RH would be mostly buffered by the hydrous salts buried at that level and deeper, with much less or perhaps no influence from the atmosphere.

Our measurements indicate that within an enclosure filled with epsomite \((\text{MgSO}_4\cdot7\text{H}_2\text{O})\) at -10°C, RH can be maintained in the 96-97% range. If the enclosure is filled with ferricroiapite at -10°C, a range of 75-79% RH can be maintained. The question is: can these highly hydrated sulfates be stable in a Mars relevant \(T-P_{\text{H}_2\text{O}}\) environment?

Stability of highly hydrated Mg-sulfates at Mars-relevant \(T-P_{\text{H}_2\text{O}}\) conditions: MiniTES observations on MER have revealed a surface temperature range between about 20°C and -90°C for the diurnal and seasonal cycles at Gusev Crater and Meridiani Planum [11,12,13]. Using the \(P_{\text{H}_2\text{O}}\) values obtained from TES data analysis [14], the RH at the surface calculated from the observed T range is ~0% to 100%, with extremely low RH during the daytime. Nevertheless, within the subsurface where salty soils were buried beneath a layer of ordinary Mars dust, the model cal-
calculation[15] suggested a lower average T but much narrower T range, which would imply higher RH values with less variation than the RH at the surface.

We have conducted a set of experiments on the stability fields and phase transition pathways of hydrated Mg-sulfates in the temperature range 50°C to -10°C, using ten different RH buffers and with five starting Mg-sulfates of different hydration states [10,17,18,19].

One of the major findings from our experiments at low T (-10°C)[20] was the expansion of the stability field of epsomite MgSO₄·7H₂O: which extends into the low RH range of ~14% at -10°C, compared with >40% RH at 5°C (Fig. 2). This expansion was demonstrated by (1) the starting phase epsomite (or meridianiite) stayed as epsomite (7w) at ~14% RH at -10°C after over two years’ of equilibration (the first row of data points below 0°C in Fig. 2); and (2) more importantly, a starting amorphous Mg-sulfate (that can hold a maximum of 3 structural waters) has gradually rehydrated into epsomite (bottom row of data points below 0°C in Fig. 2). This increase of hydration state, from 3w to 7w, at a very low P_H₂O and low T (similar to Mars) suggests the existence of a previously unknown stability field of an Mg-sulfate with the second highest hydration state (7w). The Mg-sulfate with the highest hydration degree, meridianiite MgSO₄·11H₂O, was stable at RH >98% at -10°C (11w in Fig. 2). At -90°C, it might be stable at <30% RH based on 11w-7w phase boundary calculation.[20].

**Figure 2.** Final Mg-sulfate phases at mid-low T for > 2y equilibration

**Stability of highly hydrated Ferric sulfates at Mars relevant T-P_H₂O conditions:** We are also conducting a set of experiments on the stability fields and phase transition pathways of ferric sulfates at mid-to-low temperatures (50°C to 5°C, with a few points at -10°C), using ten RH buffers and five starting ferric sulfates [8,19,21]. Figure 3 shows the results from stability study of ferricopiapite.

Our results show that Ferricopiapite, which has the highest degree of hydration of the common ferric sulfates, has an extremely wide stability field in T ~0°C range (lowest row in Fig. 3). It is stable at ~8% RH (5°C), in comparison to >40% RH (5°C) for epsomite (Fig. 2). Our experiments also showed that ferricopiapite can retain its structural waters much tighter than epsomite; the former retained 75% of its structural waters after 17 hrs vacuum desiccation (~0% RH) whereas the latter lost ~70% of its structural waters after 2 hrs vacuum desiccation. Both experiments run under the same experimental conditions.

Furthermore, at low temperature (-10°C), ferricopiapite is the only species that precipitated from saturated Fe-SO₄ aqueous solution and has persisted without change over the past two years. A systematic stability field study of ferric sulfates at low T is planned.

**Summary:** Temporal spectral changes observed by Spirit suggest a RH gradient within the subsurface at Gusev Crater (and possibly within the subsurface of other equatorial regions on Mars). Our laboratory experiments suggest a much wider stability field for Mg- and Fe-sulfates with the highest degrees of hydration at low T-P_H₂O relevant to past and present Mars. Thus within the subsurface where these sulfates were buried, a high relative humidity (75–98% RH) environment is maintained and perhaps provides the potential to stabilize thin films of brine at grain surfaces. As such they may provide a potentially habitable environment for salt-tolerant life forms on Mars.

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