HABITABILITY APPROACH FOR MSL

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Introduction: During the first 100 sols MSL has measured relevant ambient parameters [1] as air temperature, pressure, UV radiation and humidity, and has carried out other mineralogical and soil composition analysis that have direct implication on habitability quantification. Habitability can quantified in terms of the probability of the factors required to sustain life as we know it on Earth to occur simultaneously. Since habitability involves joint probabilities, we can quantify it by assessing the availability, in the proper form, of energy sources, radiation shielding and liquid water. Some geomorphological features reported in Gale crater are congruent with regional drainage basins (fluvio-lacustrine features) with widespread evidence for a water-rich environment (surface and sub-surface deposits). These data support the idea of a possible habitable environment at some point in the past. Along the same line, the identification of sulphates and other minerals indicate the high probability of an energy gradient and therefore a putative micro niche.

We will present an Habitability Index model (developed during Earth analogue campaigns) dominated by four factors:

- Liquid water.
- A biologically available energy source.
- The availability of the chemical building blocks of life
- Radiative environment

Approach: These elements are implemented into an expression where some of them play a major role, as

Liquid water for example. Humidity data from REMS is used to quantify this term. Data from the first 100 sols are implemented and used for a first habitability approach [2]. Data from DAN would be of great interest to determine the habitability of the subsurface.

Salt deliquescence is a hygroscopic process that retains and increases water content in microniches [3]. When the Relative humidity rises above a threshold value known as Deliquescence Relative Humidity (DRH) salts absorb water from the atmosphere and form an aqueous liquid solutions. DRH depends on the salt composition but for a given salt it depends on temperature. Ambient parameters as temperature determine habitability potential due to this interrelated dependence. Particular cracks and fractures in rocks are specifically considered due to their interest as protected micro niches. Model predictions for Gale Crater predict fog generation; chemical processes such as deliquescence over deposited soils is of great interest for dedicated campaigns.

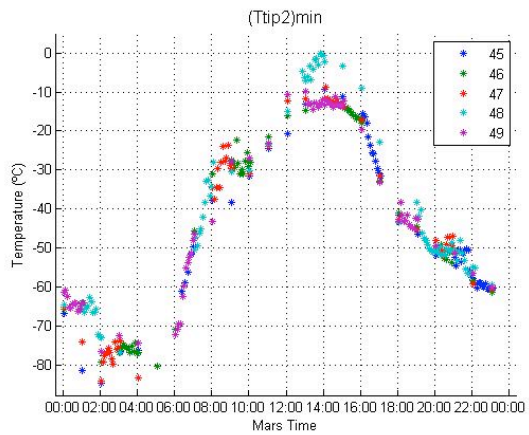

Fig. 1: 5 sols serie of REMS Boom 2 air temperature data. Variation in the data along the 5 sols serie are observed with higher values between -10 and 0 ºC. Ambient parameters have strong influence in the habitability potential.

Energy as a oxidation gradient following Gibbs Free Energy. Gale Crater mineralogy includes identified phyllosilicates [4], Fe-Mg Smectite and dehydrated Nontronite. Sulphates and other oxidate minerals could be the support of some microniches in the past. Some minerals and elements form oxidation/reduction redox couples that deliver energy for basal life on Earth. Results from the first 100 sols are included as energy input in order to compare with similar redox couples on Earth. Some energy sources biologically available for chemolithoautotrophic bacteria, and their energy output are:

$$\mathbf{Fe^{++} + H^{+} + .25\ O_2(aq) = Fe^{+++} + .5\ H_2O\ (3404.78\ J/mol)}$$

Fe^{+++} + .5 H_2O = Fe^{++} + H^+ + .25 O_2(aq) (-3404.78 J/mol)
$Fe(OH)_2$ (aq) + 2 H^+ = Fe^{++} + 2 H_2O (482.79 J/mol)
$Al(OH)^3$ (aq) + 3 H^+ = Al^{+++} + 3 H_2O (3899.84 J/mol)
Mg^{++} + H_2O = $MgOH^+$ + H^+ (-1367.13 J/mol)
Mn^{++} + 1.5 H_2O = 1.5 H^+ + .5 $Mn_2(OH)_3{}^+$ (-1367.13 J/mol)
SO_4^{--} + Fe^{+++} = $FeSO_4^+$ (-8202.36 J/mol)

Those reactions render low energy output but they provide enough energy for Earth chemolithoautotrophic bacteria supporting wide biodiversity ecosystems in some extreme environments.

Using the soil composition data on Gale´s surface we could identify the redox couples and their energy values that could act as support for basal life. Using mineralogical and element composition data reported by ChemCam and APSX in the different locations (JakeMatijevic, Coronation, Rocknest soil, etc.) a comparison of potential energy output values at the different places could be established.

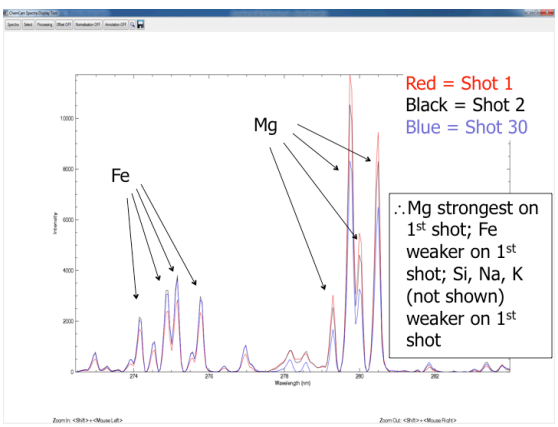

Fig. 2: Preliminary results from ChemCam at Coronation [5,6] just as example of the input for composition of the rock for identification of elements presents.

Weak signal on some elements with energy potential as iron was observed [5,6,7]. Lower energy contribution for a potential chemolithoautotropic metabolism could be expected from those samples with lower compostion on elements with energy potential. The comparison between the compositional data and elements allow us to rank final energy values for the different samples and locations.

Radiative environment. High radiation doses are damaging for life as we know it on Earth but some previous experiments reported high protection effect of iron oxides powder and soil [8]. Layered sedimentary deposits or rock burnish can play shielding role against radiation and can be colonized by bacteria. Endolithic niches inside salt deposits or rock surface on Earth are used by phototrophs for taking advantage of sheltering particular light wavelengths [9].

Shielding materials and/or protected micro environments (rocks cracks and fractures) are of especial interest from the habitability point of view due to the possibility of lower radiation doses, particular attenuated restrictive conditions on temperature and winds and higher potential in hygroscopic process to occur increasing the values on habitability potential. UV radiation data from REMS during the first 100 sols are included as damaging input for the habitability potential measurement. RAD data would be of great interest from the habitability point of view.

Summary. We will use REMS first 100 sols data as well as other instrument data (ChemCam, APXS,…) to provide values for water content and probable energy inputs from mineralogy observed in the Rocknest and the other areas studied by MSL rover as inputs for the terms and factors that dominate habitability. Those terms are inputs for the mathematical model, to obtain a final quantification of a putative habitability index adapted to MSL environment conditions. This habitability index can be used for ranking habitability potential values at the different estudied locations and samples and for developing focused campaigns in particular locations where conditions could be more favorable for sustaining life as well.

References.

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