

Environmental Signatures for Habitability: What to Measure and How to Rank the Habitability Potential of Mars

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The environmental signatures for habitability are not necessarily biosignatures, even though on Earth, they are definitive proof of habitability. It is the constant overprint of the chemical signatures of life that makes it difficult to recognize the chemical and physical properties of a potentially habitable environment as distinct from an inhabited one. Mars Science Laboratory (MSL) will soon embark on a mission to Mars to assess its past or present habitability, so it is useful to examine how we measure habitability on Earth and prepare for how that approach may differ for Mars. This exercise includes: (a) articulation of fundamental assumptions about habitability, (b) an inventory of factors that affect habitability, (c) development of metrics, measurement approach and implementation, and (d) a new classification scheme for planetary habitability that goes beyond the binary “yes” or “no.”

There may be dozens of factors that affect habitability and they can be weighted as a function of specific environment. However a robotic, in situ investigation even on Earth has constraints that prevent the measurement of every environmental factor, so metrics must be reduced to the most relevant subset, given available time, cost, technical feasibility and scientific importance. Many of the factors could be measured with a combination of orbital data and the MSL payload. We propose that, at a minimum, a designation of high habitability potential requires the following conditions be met: (a) thermally stable with respect to extremes and frequency of fluctuation, (b) has more than one energy source, (c) sufficient chemical diversity to make compounds with covalent and hydrogen bonding, (d) can moderate ionizing radiation enough to allow a stable or evolving pool of organic molecules, (e) must have water or other high quality polar solvent, (f) must be able to renew chemical resources (e.g., plate tectonics, volcanism or something else we haven't envisioned).

A measurement approach we have taken to measure habitability on Earth is [1]:

1. Study remote sensing data, maps, etc.
2. Decide how big an area to measure.
3. Determine the spatial sampling rate.
4. Determine the temporal sampling rate.
5. Determine the order of measurements
6. Decide where to begin measurements
7. Select locations at field site and proceed

While science drives each of the steps, there are additional constraints, e.g., technical, time, cost, safety (risk). This approach is also executable on Mars.

Measurement of past habitability is more challenging both for Earth and Mars where access to the past means subsurface access and confrontation with unknowns about preservation of the martian past [2]. Some environments preserve evidence of past habitability better than others, and this is where selection of the landing site to maximize the preservation potential of habitability indicators will be key.

Mars presents an opportunity to discover transitional states between habitable or not, and we offer a ranking scale for planetary habitability with Mars as the second test subject:

CLASS ONE	Uninhabitable and likely has never been so
CLASS TWO	Has a high potential but no confirmed observation of life (as defined above)
CLASS THREE	Inhabited (we find life)
A	Globally inhabited
B	Primitive life; early in its evolution, but not yet globally established
C	Exists only in refugia—planet heading toward class four
CLASS FOUR	Post-habitable (there once was life, but now it's gone)

MSL provides an opportunity to carefully investigate the habitability of at least one site on Mars and it will reveal much about the possible states of planetary habitability.

References

[1] Conrad, P.G., et al (2009), *40th Lunar Plan. Sci.* 1384. [2] Summons, R. et al (in press), *Astrobiology*.