Biosignature Preservation and Detection in Mars Analog Environments
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OBJECTIVE:
Assess the attributes and the preservation potential of the major types of biosignatures in diverse Mars-analog habitable environments in order to develop strategies to detect a range of possible biosignatures on Mars in different geologic settings.
To search for potential biosignatures, it is necessary to (a) identify sites that very likely hosted past habitable environments, (b) identify high biosignature preservation potential materials to be analyzed for potential biosignatures, and (c) perform measurements to identify potential biosignatures or materials that might contain them.
Diverse potentially habitable ancient environments

| Geologic Eras | Proposed Chemical Environments |
|---------------|--------------------------------|
| Noachian      | clays, sulfates, anhydrous ferric oxides |
| Hesperian     | clays, sulfates, anhydrous ferric oxides |
| Amazonian     | clays, sulfates, anhydrous ferric oxides |

Coupled mineralogy and morphology define aqueous environments. Their character has evolved, indicating changing environments. Data indicate complexity in local environments.

Approximate age, billions of years:
- Noachian: 3.8 to 3.6
- Hesperian: 3.3 to 2.8
- Amazonian: 2.8 to 2.8

ODY, MEX, MRO
Hydrothermal activity widespread in rocky planets
Resources & diverse conditions for habitability
Mineral deposition common - favors preservation
Diverse conditions: preserve diverse biology

Often moderate to limited areal extent & duration
Persistent fluid circulation can favor degradation
Subaqueous Environments
Examples of Pros & Cons

Highly productive & diverse habitats on Earth
Sustain phototrophs & chemotrophs
Link subsurface & surface habitats
Sedimentation & evaporites favor preservation of diverse biosignatures

Sensitive to climate variations
Phototrophy-dependent productivity (Mars?)
High-energy conditions reduce preservation
Subaerial Environments
Examples of Pros & Cons

Sustains phototrophs & chemotrophs - gradients
Broad range of climatic conditions
Widespread, diverse
Mineral deposition in soils or cold springs favors preservation

Highly climate-dependent (big constraint on Mars)
Exposure to oxidants & radiation
Subsurface Environments
Examples of Pros & Cons

Volumetrically large habitat (Earth - large biomass)
Stable, persistent conditions buffered from climate
Redox energy sources
Water-rock reactions – preservation in precipitates

Low productivity & accommodation space lead to low biomass density
Persistent fluid circulation can favor degradation

Biosignature preservation – very few studies
Iron-Rich Environments
Examples of Pros & Cons

Diverse iron species – redox energy source
Long-lived environments – seen in geologic record
Excellent photoprotection against radiation
Diverse conditions: preserve diverse biology
Minerals preserve diverse biosignature types

Ferric iron - degradation at higher T, longer times
Common Challenges

Site Identification – Orbital, Surface

- Limits in spatial & spectral resolution
- Assessing duration of habitable environments
- Accessibility – EDL, trafficability
- Identifying diverse conditions: diverse biology
- Recognizing past habitability w/o abundant life
- Spatial heterogeneity of most promising deposits
- Number & size of samples collected
- Limitations of Mars 2020 instrument suite
Common Challenges
Preservation

Destruction by chemical oxidants
Highly ionizing radiation environment
Exposure age

Recognizing biosignatures w/o abundant life
Spatial heterogeneity of most promising deposits
Number & size of samples collected
Limitations of Mars 2020 instrument suite
Challenges Specific to a Site Type

Orbital Observations

Hydrothermal spring systems
Subaqueous environments
Subaerial environments
Subsurface environments
Iron-rich environments
Challenges Specific to a Site Type

Ground Observations & Site Selection

- Hydrothermal spring systems
- Subaqueous environments
- Subaerial environments
- Subsurface environments
- Iron-rich environments
”Tension” between habitability & preservation
Thermal spring & subaqueous are best-studied
Subsurface is least studied, esp. wrt preservation
Potential “prebiotic environment” sites important
“Time-equivalent” analogs of early Mars are key
Coordinate studies across temporal & spatial scales
Favor sites with multiple habitability types
Be able to detect multiple biosignature types
Current & Future Priorities

Enhance Mars 2020 instruments’ ability to identify biosignatures in different environments

Improve spatial & spectral resolution

Improve *in situ* detection of biosignature *vs* abiotic features (esp. organics)

Subsurface needs more study, esp. preservation

Understand biosignatures in absence of phototrophy

Define implications of Mars-unique processes

Articulate synergies with search for extant Mars life
End
Landing site selection continues…

Shaded areas are above +30°N, below -30°S, and above 0 km in elevation

Grant & Golombek (2010)
Figure 1 | Clay mineral distribution and diversity on Mars. a, CRISM-targeted images surveyed for the presence of clay minerals, grouped by geological setting and superimposed on a shaded relief map. Open symbols mark sites where no clays were found. b, c, d, Percentage frequency of detection of alteration phase(s), grouped by geological setting; $n$ is the total number of images within which clay minerals were detected (a total of 365 of 639 images included in this meta-analysis). The percentage given is not areal coverage but rather the number of detections of a given phase divided by the number of detections of all alteration phases within the geological setting.

Ehlmann et al. (2011)