Development of Martian Regolith Simulants for Exploration of In Situ Resource Availability and Potential

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Introduction

Data obtained from Mars Global Surveyor (MGS) and Mars Reconnaissance Orbiter (MRO) has vastly increased knowledge of Martian surface mineralogy and in particular aqueously altered phases. As such, there is a need for regolith simulants that better represent these phases both chemically and mineralogically.

The goal of this study was to create multiple simulants based on current understanding of the chemistry and mineralogy of certain deposit types found on Mars. These simulants will be used to explore the potential fertility and toxicity of Martian regolith as an in situ resource. Such information is key to developing concepts for the exploration and potential colonization of Mars.

Methodology

To produce simulants, a combination of synthetic and field-collected samples were collected. Five different simulants assemblages were made: 1. Basalt (unaltered), 2. Sulfate 3. Phyllosilicate I, 4. Phyllosilicate II, and 5. Carbonate. These components will be combined at ratios on data from Mars Curiosity Rover, MRO and MGS missions, and Earth-based Martian analogs.

The simulant assemblages will be treated to eliminate organic matter and sterilized. The simulant assemblages will be examined using XRD Rietveld analysis, XRF, Mössbauer spectroscopy, and imaging spectroscopy to refine ratios and ensure they adequately represent current understanding of Martian chemistry and mineralogy for the intended application.

Simulants

- **Regolith 1: Basalt (unaltered).** The basalt (unaltered) simulant represents deposits that have not been exposed to extensive aqueous alteration.
- **Regolith 2: Sulfate.** The sulfate simulant reflects the mineralogy of sulfate-rich deposits found in Valles Marineris, Terra Meridiana and Aram Chaos.
- **Regolith 3 and 4: Phyllosilicate I and II.** A variety of phyllosilicate deposits are found on Mars associated with different formation processes. These are the most common type of aqueously altered deposit.
- **Regolith 5: Carbonate.** This simulant represents carbonate deposits found on Mars. This is the least common of the represented deposit types, but very relevant in understanding Mars past geochemical conditions.

Future Goals

The simulants developed will be used for future work in exploring the use of Martian regolith as an in situ material for planetary exploration. The most relevant and reproducible simulants will be used in plant growth experiments that seek to address some of the challenges faced in supporting a manned mission to Mars. The ultimate goal being to use simulants to address issues of toxicity and fertility of Martian regolith and understanding potential for past habitable environments on Mars.

Table 1: Martian Regolith Components

<table>
<thead>
<tr>
<th>Components</th>
<th>Regolith 1: Basalt (unaltered)</th>
<th>Regolith 2: Sulfate</th>
<th>Regolith 3: Phyllosilicate I</th>
<th>Regolith 4: Phyllosilicate II</th>
<th>Regolith 5: Carbonate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basalts and Silicates</td>
<td>Fresh basalt¹</td>
<td>Non-Fresh basalt²</td>
<td>Non-Fresh Basalt¹</td>
<td>Non-Fresh Basalt¹</td>
<td>Non-Fresh Basalt² Olivine³</td>
</tr>
<tr>
<td>Phyllosilicates</td>
<td>-</td>
<td>-</td>
<td>Nontronite²,³</td>
<td>Nontronite²,³ Chlorite⁴</td>
<td>Nontronite²,³</td>
</tr>
<tr>
<td>Sulfates</td>
<td>-</td>
<td>Copiapite⁵</td>
<td>-</td>
<td>-</td>
<td>Magnesite³</td>
</tr>
<tr>
<td>Carbonates</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Amorphous Minerals</td>
<td>Volcanic Glass¹ and/or Nano-phase ferric oxides⁶</td>
<td>Hydrated silica⁷ and Nano-phase ferric oxides⁸</td>
<td>Allophane⁹ and/or Hydrated silica¹ and/or Nano-phase ferric oxides⁸</td>
<td>Nano-phase ferric oxides⁸</td>
<td>Hydrous magnesium silicates (Deweylite)</td>
</tr>
<tr>
<td>Salts</td>
<td>Anhydrite¹ Perchlorate¹</td>
<td>Anhydrite¹ Perchlorate¹</td>
<td>Anhydrite¹ Perchlorate¹</td>
<td>Anhydrite¹ Perchlorate¹</td>
<td>Anhydrite¹ Perchlorate¹</td>
</tr>
<tr>
<td>Iron Oxides</td>
<td>Hematite¹,²</td>
<td>Valles Marineris, Terra Meridiana, Aram Chaos</td>
<td>Zejero Crater, Marswth Valles, East Nili Fossae</td>
<td>Noachian Highlands, Walls of Nili Fossae and Valles Marineris</td>
<td>Isidis Basin</td>
</tr>
</tbody>
</table>

¹Collected in New Mexico, ²Nontronite containing-Basalt collected in Eastern Washington, ³Obtained from University of Georgia, ⁴Collected from Graves Mountain, Georgia, ⁵Obtained from Fisher Scientific or other reputable facilities

Acknowledgements

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References