Mars Water Mapping Projects

Background and Overview

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Background: Where should we land humans on Mars?
Exploration Zone (EZ) – Current Definition

- 100km radius site at latitude band: ±50° (to be updated)

- Contains:
  - **Habitation Site**: Flat, stable terrain for emplacement of infrastructure, located ≤5km from landing site location
  - **Landing Site(s)**: Flat, stable terrain, low rockiness, clear over length scales greater than landing ellipse
  - **Resource Regions of Interest**
    - One or more potential near-surface (≤3m) **water resource feedstocks** in a form that is minable by highly automated systems, and located within ~1-3km of ISRU processing and power infrastructure. Total extractable water should be ~100MT (supports ~5 missions)
    - Show potential for minable metal/silicon resources, mainly Fe, Al, and Si, located within ~1-2m of the surface
  - **Science Regions of Interest**
    - That address MEPAG goals (i.e. Astrobiology, Atmospheric Science, and Geoscience)
Mars Water Mapping Projects

- Ongoing projects to create the best possible maps of water distribution by combining currently available orbiter data
- Two types of mapping projects identified as highest priority:
  - **Task A – Subsurface Ice Map** (Proof of Concept)
    - Within a single 5-10° wide longitudinal swath from 0°-60°N latitude, generate a map that identifies potential locations of subsurface water ice at low- to mid-latitudes and characterizes the nature of the gradational boundary from regions of continuous ice to discontinuous ice, through to regions of no ice.
  - **Task B – Hydrated Minerals (Global Map)**
    - Develop algorithms to partially automate the processing of spectra of hydrated mineral detections. Use developed algorithms to generate global map of all existing near-surface hydrated mineral detections
- Maps expected mid-2019
## Mars Water Mapping Teams

<table>
<thead>
<tr>
<th>Task A – Subsurface Ice Mapping</th>
<th>Task B – Hydrated Minerals Mapping</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Team 1</strong></td>
<td></td>
</tr>
<tr>
<td>Putzig et al. (PSI)</td>
<td>Carter et al. (Paris-Sud Univ.)</td>
</tr>
<tr>
<td><em>Mapping Buried Water Ice in Arcadia &amp; Beyond with Radar &amp; Thermal Data</em></td>
<td><em>A Global Aqueous Mineral Abundance Catalog for Mars</em></td>
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<td></td>
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<tr>
<td>Morgan et al. (PSI)</td>
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<tr>
<td><em>Local Subsurface Ice Mapping Through the Integration of SHARAD Derived Data Products with Other Datasets</em></td>
<td></td>
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<td><strong>Team 2</strong></td>
<td></td>
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<tr>
<td>Seelos et al. (APL)</td>
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</tr>
<tr>
<td><em>CRISM-Derived Global Map of Hydrated Mineral Bearing Units</em></td>
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Subsurface Water Ice Mapping (SWIM) in the Northern Hemisphere of Mars

2019 March 6
Overview for Human Landing Sites Study Google Hangout

Than Putzig, a Gareth Morgan, a Bruce Campbell, b Hanna Sizemore, a Isaac Smith, a Zach Bain, a Marco Mastrogiuseppe, c David Hollibaugh Baker, d Matthew Perry, a Rachael Hoover, e Ali Bramson, f Eric Petersen, f Asmin Pathare, a Colin Dundas g

a Planetary Science Institute, b Smithsonian Institution, c Consultant,
d NASA Goddard Space Flight Center, e Southwest Research Institute, f University of Arizona, g USGS-Flagstaff
Outline

1. Prior State of Knowledge
2. Methods
3. Arcadia Planitia Results
4. Expanded Study Plans
Prior detection of shallow (<1 m) water ice

- Theory + Thermal Data = ice is likely present all across the high (>50°) latitudes of Mars.

- Neutron Spectrometer mapped water ice in these same regions.

- Fresh ice-exposing small impact craters provide direct evidence of shallow ice as far south at 39 °N

TES derived Depth of the ice table [Mellon et al., 2004].

HiRISE images [Byrne et al., 2009; Dundas et al., 2013]
Prior detection of ice: Morphology Studies

Combination of high resolution image (MOC) and surface roughness studies (MOLA) led to the Mars Ice Age Hypothesis (Head et al., 2003).

Mars at low obliquity?

Dissected Mantle at mid-latitudes

Kreslavsky and Head (2000)
Mustard et al (2001)
Prior detection of deep (>20 m) water ice

Shallow Radar (SHARAD) has shown that some of the glacial features are nearly pure water ice.

Mid-latitude non-glacial ice detection by SHARAD has also been reported - including Arcadia

[Plaut et al., 2009].
Ice stability zones and prior detections

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SWIM Approach to Mapping Ice

• Previous Martian subsurface ice studies used datasets in isolation or combined techniques in limited geographical areas.

• For this study, we combine previous methods with newly developed techniques to probe the subsurface for water ice. New techniques include:
  
  • Measuring **SHARAD surface power return** to infer presence of ice within the top 5 m.
  
  • State-of-the-art **super-resolution processing techniques** that increase data resolution, potentially resolving top of ice.
  
  • The “**split-chirp**” technique, sub-band processing to measure **material loss properties** - thereby constraining bulk composition.
SWIM Pilot Study Swaths and theoretical ice-stability limits + SHARAD ice detections

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Thermal Analysis

TES: MGS Thermal Emission Spectrometer
THEMIS: ODY Thermal Imaging System

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- Apparent thermal inertia (ATI) varies seasonally at locations where the subsurface is heterogeneous within ~1 m depth [Putzig & Mellon 2007].

- Comparing observed and modeled ATI, we find locations of layering consistent with shallow ice, some patches now found southward to ~30°N.

- SWIM TES: improved resolution by factor of 4 and greatly infilled layer-matching coverage.

- SWIM THEMIS: seasonal nighttime images, focused on areas of interest (sparse in Arcadia).

- TES/THEMIS differences:
  - THEMIS uses nighttime data only
  - TES uses day & night model match
In northern Arcadia Planitia, we find isolated, low-power areas, e.g. within the Erebus Montes glacial features.

An extensive belt of low-power returns (indicative of low-density materials) correlates with regions of known dust upwelling in northern Amazonis.

The Medusae Fossae Formation exhibits low power, consistent with prior estimates of low dielectric permittivity [Waters et al. 2007; Carter et al. 2009; Morgan et al. 2015].
Geomorphology

- Geomorphology bridges the gap between shallow and deep data sets.
- We investigate shallow ice by mapping landforms interpreted to be ice-rich such as patterned ground, scalloped pits and mantling units.
- Mapping is conducted using image data such as CTX and HiRISE.
- We also use SHARAD roughness (10-100 m horizontal baseline) to trace the boundary of dissected mantle and no mantle (white line at right).
We extended reflector mapping of Bramson et al. [2015], including southward extension to ~ 35.6°N.

Using 23 topographic features, we find real dielectric permittivity between 3 and 6, with a median of 5, above the shallow reflector.

Our revised permittivity allows a large fraction of non-ice material* without ruling out ice presence.

* See also Campbell & Morgan [2018].
We introduce the **SWIM Equation**, in the spirit of the famous **Drake Equation**:

\[
C_I = \frac{(C_N + C_T + C_G + C_{RS} + C_{RD})}{5}
\]

Consistency of data with the presence of buried ice

We map **consistency values** for each dataset:

<table>
<thead>
<tr>
<th>( C_N )</th>
<th>Consistency of neutron-detected hydrogen with shallow (&lt; 1 m) ice</th>
</tr>
</thead>
<tbody>
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<td>( C_T )</td>
<td>Consistency of thermal behavior with shallow (&lt; 1 m) ice</td>
</tr>
<tr>
<td>( C_G )</td>
<td>Consistency of geomorphology with shallow and deep ice</td>
</tr>
<tr>
<td>( C_{RS} )</td>
<td>Consistency of radar surface echoes with shallow (&lt; 5 m) ice</td>
</tr>
<tr>
<td>( C_{RD} )</td>
<td>Consistency of radar dielectric properties with deep (&gt; 5 m) ice</td>
</tr>
</tbody>
</table>
1. Prior State of Knowledge

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3. Arcadia Planitia Results

4. Expanded Study Plans
1. Prior State of Knowledge

2. Methods

Consistency: Integrating shallow + Deep

3. Arcadia Planitia Results

4. Expanded Study Plans

SHARAD: Depth of Potential Icy Deposit

Prior work

This work

Consistency: Shallow + Deep
Four main northern hemisphere regions:

Final products will provide further constraints to facilitate human landing site studies.
We carried out a preliminary test of consistency mapping in a subset of Deuteronilus Mensae.
Primary products for each swath

• Ice consistency maps
  From neutron & thermal data, morphological features, radar surface reflectors, subsurface dielectric values, and composites from all data

• Top of ice depth maps
  From thermal data & SHARAD surface returns

• Base of ice depth maps
  From SHARAD subsurface reflectors

• Ice concentration maps
  From SHARAD+DTM permittivity estimates

In addition, we will provide supplemental products associated with each study element & swath

Spreading the Word/Results to the Community!

@RedPlanetSWIM