Hydrothermal alteration in the NW Hellas Region

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Hellas

- Formed in Early Noachian by impact of ~250 km object (e.g., Leonard and Tanaka, 2001)
- Subsequent modification by aeolian, fluvial, glacial/periglacial, volcanic processes gave rise to a diversity of geological environments and landforms inside Hellas and in the circum-Hellas region.
- Of particular interest to the question of habitability is the possibility that a variety of aqueous systems may have developed in the region after the Hellas impact.
  - Hydrothermal systems (e.g., Newsom, 1980).
  - Marine/lacustrine (e.g., Wilson et al., 2007; Condit et al., 2010 and references therein)
- Energy deposited by impact should have produced elevated temperatures for a prolonged period (how long? how hot?)
- Impact also thought to have triggered vent volcanism (e.g., Williams et al., 2009)
- Evidence for aqueous activity in the region during that time period:
  - Mineralogical: phyllosilicates in Tyrrhena Terra (Pelkey et al., 2007; Loizeau et al., 2009) and around Hellas (e.g., Ansan et al., 2011; Crown et al., LPSC 2011).
  - Morphological: heavy dissection of the region, layered intracrater deposits
<table>
<thead>
<tr>
<th>Primary mineral or rock</th>
<th>Reported alteration minerals</th>
<th>Hydrothermal Alteration environment</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basalt</td>
<td>Kaolinite, smectite, jarosite, alunite</td>
<td>Acidic pH</td>
<td>Morris et al., 2001; Morris et al., 2003</td>
</tr>
<tr>
<td>Pyroxene-amphibole andesite</td>
<td>Cristobalite, alunite, pyrite, kaolinite, goethite, hematite</td>
<td>Acidic pH</td>
<td>Isobe and Korenaga, 2010</td>
</tr>
<tr>
<td>Basalt</td>
<td>Mg-carbonate, talc</td>
<td>Neutral to basic pH</td>
<td>Brown et al., 2010</td>
</tr>
<tr>
<td>Wollastonite</td>
<td>Mg-montmorillonite, talc, mixed layer stevensite/chlorite</td>
<td>Neutral to basic pH groundwater</td>
<td>DeRudder and Beck, 1963; Whitney and Eberl, 1982</td>
</tr>
<tr>
<td>Granite, K-feldspar</td>
<td>Kaolinite, muscovite, biotite, halloysite</td>
<td>-</td>
<td>Thomas and Walter, 2004;</td>
</tr>
<tr>
<td>Impact melt rock</td>
<td>Fe-chlorite, Fe smectite, silica, K feldspar, zeolite</td>
<td>-</td>
<td>Newsom, 1980; Allen et al., 1982</td>
</tr>
<tr>
<td>Olivine</td>
<td>serpentine</td>
<td>-</td>
<td>Normand et al., 2002</td>
</tr>
<tr>
<td>Basalt, grabbro</td>
<td>Prehnite, quartz, calcite, epidote</td>
<td>Also in low-grade metamorphism</td>
<td>Freedman et al., 2009</td>
</tr>
</tbody>
</table>
Potential Hydrothermal/low grade metamorphic alteration products on Mars

- Prehnite: Nili Fossae (Ehlman et al., 2009), Argyre rim (Buczkowski et al., 2010), NW Hellas (Crown et al., LPSC 2011)
- Serpentine: Nili Fossae (Ehlman et al., 2009)
- Chlorite: Nili Fossae (e.g., Ehlman et al., 2009; Poulet et al., 2005); NW Hellas (Crown et al., LPSC 2011)
- Hydrated silica: Nili Fossae (Skok et al., this session)

- Of particular interest is Prehnite (Ca$_2$Al$_2$Si$_3$O$_{10}$(OH)$_2$)
  - Metamorphic grade transitional between zeolite and greenschist facies
  - Forms under specific conditions: 2-7 kbar, 200 – 350°C, and XCO$_2$< 0.004 (Blatt and Tracy, 1995)
  - Typically associated with chlorite and pumpellyite (e.g., Frey and Robinson, 1999).
• Prehnite: absorptions at 2.35-2.36, 1.48, 2.23, 2.28, 2.57 µm
• Chlorite: absorptions at 1.40, shoulder at 2.25-2.26, 2.33-2.35
• Serpentine: absorptions at 1.40, 2.32-2.33, 2.50-2.51
• “Vermiculite” – mixed layer vermiculite/biotite. Can also be other mixed layer smectite/chlorite: absorption at 1.92, steep drop-off at 2.30-2.31
• Illite/muscovite - absorptions at 2.2, 2.35
Results

Spectral library hydothermal alteration products

- Vermiculite
- Serpentine
- Chlorite
- Prehnite
- Illite

Examples of alteration products in NW Hellas observed in CRISM data

- FRT989C
- FRT1214D
- FRT1384C
- FRT124B3
NW Hellas Region preserves record of diverse geological processes
NW Hellas Region

Preserves record of diverse geological processes
Prehnite in unit Nh – Hilly Unit – Forms rugged, high-relief, densely cratered terrain with numerous isolated massifs. Channels and ridges common; faults along west rim.

**Interpretation:** Uplifted crustal material and ejecta from Hellas impact and post-impact structural and erosional modification

(Leonard and Tanaka, 2001)
Prehnite units
Prehnite + Chlorite (units contains ripple-forming material and indurated rough unit)

Prehnite (ripple-forming unit)
Prehnite + Chlorite (Rough rocky unit)

Illite/muscovite (rocky unit)

Prehnite

Prehnite + Chlorite (Rough rocky unit)
FRT0001214D

Prehnite
(smooth and
ripple-forming
unit)
1000-m slopes

26°14' S, 56°26' E

Prehnite (in unit Nh)

Mixed-layer

-700 m elev

Slopes (deg)

0 - 2.5
2.5 - 5
5.0 - 15
15 - 20
20 - 38

N

0 km
20 km
Pitted Plains Deposits

Yardanged
Layered
100-250 meters deep
Occur at elevations < -500 m
Pitted Crater Floors

- Polygonally-fractured unit
- Scooped unit
- Layers

Layered Morphologic stratigraphy ~300-500 m thick
Pitted Plains Deposits: FRT0001366A

Mixed-layer S/C
Geological inferences

- We observe a variety of alteration products including prehnite, chlorite, illite/muscovite, mixed-layer S/C or B/V, saponite.

- Prehnite + chlorite + illite in close spatial association on plains unit strongly suggestive of hydrothermal activity.
  - observed in Hilly Unit, which has been interpreted to be uplifted crustal material and ejecta from Hellas impact and post-impact structural and erosional modifications.

- Subsequent erosion of Noachian plains material resulted in dissection and redeposition to form smooth embaying plains and intracrater units 200-400 m in thickness.

- Low-grade metamorphic materials (mixed-layer S/C) identified within pit walls in plains units.

- Plains units have very gentle (<2.5°) slopes throughout, and are easily accessible to landing system. Scarcity of boulders in this unit would make traversability very straightforward.
• Unit above 500 m – Npl2 – Subdued cratered unit – Forms widespread moderate to heavily cratered, relatively smooth plains marked by subdued crater rims, small channels, ridges, and uneven terrain. Crater floors partly to completely infilled with smooth material; ejecta blankets rare. Some heavily eroded craters dissected by small channels. Faults rare. Material gradational with most adjacent units. **Interpretation** – Ancient veneer of aeolian, fluvial, and perhaps volcanic materials that partly resurface underlying cratered and dissected units (units Npl1 and Npld).

• Prehnite in unit Nh – Hilly Unit – Forms rugged, high-relief, densely cratered terrain with numerous isolated massifs. Channels and ridges common; faults along west rim. **Interpretation**: Uplifted crustal material and ejecta from Hellas impact and post-impact structural and erosional modifications.

• Smooth pitted plains in unit Hpl3 – Smooth unit – Forms moderately cratered, smooth, flat to undulating, relatively featureless plains and patches around the rim and within highlands surrounding Hellas basin. Channel common; faults and flow fronts rare. Embays all other materials of plateau sequence and fills many impact craters. **Interpretation**: Thick fluvial, aeolian, and volcanic deposits burying most underlying rocks.

• (Leonard and Tanaka, 2001)
Knob exposed in pitted plains unit
Mixed layer at base
Saponite at top
Top of knob rises above surrounding pitted plains