Mineralogic diversity at Holden crater

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Holden mineralogy intro

Background

• Light-toned layered deposits and overlying flood deposits have Fe/Mg-phyllosilicates (Milliken et al., Mars Conf. 2007)

• These may be smectite/chlorite mixed-layer clays (Milliken & Bish, 2010)

• Crater wall near Uzboi breach contains similar clays, pyroxene, olivine (Milliken & Bish, 2010)

Questions

• Composition of alluvial materials in landing ellipse?

• Additional phases in light-toned layered deposits?
  - Evaporites??

• “Missing salts” in the crater wall? (Milliken et al., 2009)

• Mineralogy of bedrock mound?
Mapping hydration in Holden

Alluvial fan surface is spectrally bland ... so look upstream

Credit: R. Milliken
Mafic minerals in fan source rocks

Two pyroxenes

Two olivines

HRL 18BA4
Hypersthene (low-Ca pyroxene)

Fo91 (Mg-rich olivine)

Pigeonite (higher-Ca pyroxene)

Fo11 (Fe-rich olivine)

(lab spectra scaled for comparison)
Hydrated minerals in fan source rocks

Fe/Mg-phyllosilicate

- HRL 1907C
  - Nontronite (Fe-clay)
  - Saponite (Mg-clay)

Hydrated salt / zeolite

- HRL 18BA4
  - Analcime (zeolite)
  - Bassanite (sulfate)

MSL can look for compositional differences between layers/distributaries across the fan
Breccia blocks on fan source valley wall
Light-toned layered rock, fan source valley wall

HiRISE ESP_017766_1535
Light-toned layered deposits

Lower member of lower unit has strongest Fe/Mg-clay signatures (Milliken & Bish, 2010)

Additional phase, varying in abundance?

FRT C1D1
Light-toned layered deposits

Middle member beds have variable albedos, textures ... and spectra:

HIRISE false color

FRT C1D1

Multiplied by $\frac{1}{2}$
Light-toned layered deposits

Preserved bedforms are clay-bearing

Credit: R. Milliken

Less variation than middle member
Polygonal surface overlying light-toned layers

Rare strongly hydrated material seen on polygonal (evaporite??) surface
Spectra of upper unit

Upper unit (flood deposits) have pyroxene/olivine spectral shape and Fe/Mg-clay signature
Megabreccia knob

Landing Ellipse

Light-toned layered deposits

Megabreccia knob

HRL 11A15

Knob average: Olivine+pyroxene
+Fe/Mg-clay

Clays localized within matrix/dikes(?):
Megabreccia knob (extended mission target)
Megabreccia knob (extended mission target)
Accessing the Early Noachian crust

“Ideal landing sites would include layered Noachian sediments, as well as volcanic rocks.”
—MRR-SAG Final Report

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Eastern ellipse outcrops
Eastern ellipse outcrop spectra

- Hydrated silica / Al-clay
- Opal
- Obsidian
- Montmorillonite
- Fe/Mg-phylllosilicate

Graphs and images showing spectral data for various minerals.
### Summary

- **Holden’s mineralogy is diverse!**

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<td>High-Ca pyroxene</td>
<td>Hydrated silica</td>
<td>Hydrated phase</td>
<td>Much more!</td>
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<td>Mg-rich olivine</td>
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<td>2.5 μm phase?</td>
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<td>Fe-rich olivine</td>
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<td>Hydrated salt/zeolite</td>
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- Alluvial/lacustrine deposits remain the primary science target for MSL
  - *But* MAX-C cannot go to Holden (26°S)
  - Mineralogic/astrobiologic characterization of Early Noachian materials (altered and unaltered) by MSL would feed forward to MSR