Evidence for Habitability in Gusev Crater

Steve Ruff
ASU - SESE
• Spirit identified two locations with clear evidence for abundant water
• Opaline silica (up to 92 wt%) occurs in outcrops and soil adjacent to “Home Plate”
• “Comanche” outcrops contain ~25 wt% Mg-Fe carbonate(s)
Home Plate

~80m

HiRISE
Silica Soil at Home Plate

Pancam approximate true color

APXS: >90% SiO$_2$
1.2% TiO$_2$
No sulfur enrichment

Squyres et al. [2008]

MI ~3 cm across
Silica Outcrop at Home Plate

Elizabeth Mahon

Clara_Zaph4

~12 cm diam.

Pancam approximate true color
Silica Outcrop at Home Plate

~12 cm diam.

APXS: >72% SiO₂
No sulfur enrichment

~5 cm across

Pancam approximate true color

Squyres et al. [2008]
Silica Outcrop at Home Plate

APXS: >72% SiO₂
No sulfur enrichment

~12 cm diam.

Elizabeth Mahon

Clara

~3 cm across

Norma Luker: brecciated

Pancam approximate true color

Squyres et al. [2008]
Opaline Silica at Home Plate

Squyres et al. [2008]
Outcrop Characteristics

Home Plate

~30 cm

~4 m

Ruff et al. JGR [2011]
Eroded stratiform outcrops

Ruff et al. *JGR* [2011]
Outcrops found in local topographic lows
Origin Hypotheses

Hot spring sinter:
Consistent with stratiform outcrops, porous and brecciated textures, and lack of sulfur enrichment

Both are habitable environments on Earth

Fumarolic silica residue:
Inconsistent with stratiform outcrops and lack of sulfur enrichment

Ruff et al. JGR [2011]
Comanche Carbonate

Spirit encountered Comanche outcrop December 2005 (sol 695)

Husband Hill

Eldorado

Home Plate
Mössbauer and APXS

Comanche Spur Pancam false-color

Morris, Ruff et al. (2010)

“Fins”
### Mössbauer and APXS

**Table 1.** Chemical composition of Comanche Spur Palomino whole rock, with light elements as CO₂ and calculated components olivine, carbonate, and residue.

<table>
<thead>
<tr>
<th>Component</th>
<th>Whole rock(^*) (wt %)</th>
<th>Olivine(^‡) (wt %)</th>
<th>Carbonate(^§) (wt %)</th>
<th>Residue (wt %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>36.1 ± 0.4</td>
<td>37.8</td>
<td>–</td>
<td>62.1</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.22 ± 0.06</td>
<td>–</td>
<td>–</td>
<td>0.66</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>2.56 ± 0.08</td>
<td>–</td>
<td>–</td>
<td>7.68</td>
</tr>
<tr>
<td>Cr₂O₃</td>
<td>0.63 ± 0.03</td>
<td>–</td>
<td>–</td>
<td>1.88</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>4.84 ± 0.03</td>
<td>–</td>
<td>–</td>
<td>14.5</td>
</tr>
<tr>
<td>FeO</td>
<td>15.4 ± 0.1</td>
<td>25.6</td>
<td>19.2</td>
<td>–</td>
</tr>
<tr>
<td>MnO</td>
<td>0.37 ± 0.01</td>
<td>–</td>
<td>1.43</td>
<td>–</td>
</tr>
<tr>
<td>MgO</td>
<td>21.6 ± 0.2</td>
<td>36.4</td>
<td>26.2</td>
<td>–</td>
</tr>
<tr>
<td>CaO</td>
<td>1.69 ± 0.02</td>
<td>–</td>
<td>6.55</td>
<td>–</td>
</tr>
<tr>
<td>Na₂O</td>
<td>1.0 ± 0.2</td>
<td>–</td>
<td>–</td>
<td>3.0</td>
</tr>
<tr>
<td>K₂O</td>
<td>0.03 ± 0.05</td>
<td>–</td>
<td>–</td>
<td>0.1</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.39 ± 0.07</td>
<td>–</td>
<td>–</td>
<td>1.16</td>
</tr>
<tr>
<td>SO₃</td>
<td>2.36 ± 0.04</td>
<td>–</td>
<td>–</td>
<td>7.08</td>
</tr>
<tr>
<td>Cl</td>
<td>0.53 ± 0.01</td>
<td>–</td>
<td>–</td>
<td>1.61</td>
</tr>
<tr>
<td>CO₂</td>
<td>12 ± 5</td>
<td>–</td>
<td>46.4</td>
<td>–</td>
</tr>
</tbody>
</table>

\(^*\)APXS data from (21) recalculated to 12 wt % CO₂. \(^‡\)All Ca and all Mn calculated as carbonate. \(^§\)Equivalent to (Mg₀.₇₂Fe₀.₂₈SiO₄). \(^§\)Equivalent to (Mg₀.₆₂Fe₀.₂₅Ca₀.₁₁Mn₀.₀₂)CO₃.

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*Morris, Ruff et al. (2010)*
Mini-TES on Comanche

Ditsakana  Comanche  Kewatsana  Saupitty  Taabe  Comanche  Spur  Tenawa

~7 m
Deconvolution of Saupitty Spectrum

Comanche Saupitty
Modeled fit
Mg–Fe carbonate (scaled)
Standard deviation

"Amorphous silicate of basaltic composition"

No phyllosilicates

Morris, Ruff et al. (2010)

<table>
<thead>
<tr>
<th>Modeled Results</th>
<th>Area %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olivine ($F_{O_{98}}$)</td>
<td>34</td>
</tr>
<tr>
<td>Basaltic glass</td>
<td>33</td>
</tr>
<tr>
<td>Mg–Fe carbonate</td>
<td>34</td>
</tr>
</tbody>
</table>
Deconvolution of Comanche with Algonquin

### Average Algonquin Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basaltic glass</td>
<td>13</td>
</tr>
<tr>
<td>Mg-Fe carbonate</td>
<td>9</td>
</tr>
<tr>
<td>Fe carbonate (siderite)</td>
<td>6</td>
</tr>
<tr>
<td>Mg carbonate (magnesite)</td>
<td>3</td>
</tr>
<tr>
<td>Spectral rms(%)</td>
<td>0.120</td>
</tr>
</tbody>
</table>

### Graphical Representation

- **Graph:**
  - X-axis: Wavenumber (cm⁻¹)
  - Y-axis: Emisivity
  - Annotation: Comanche Saupitty Model

- **Table:**
  - Wavelength (µm)
    - 6
    - 7
    - 8
    - 9
    - 10
    - 11
    - 12
    - 13
    - 14
    - 15
    - 20

- **Imagery:**
  - Comanche Saupitty
  - Algonquin outcrops
• Abundant Mg-Fe carbonate is distributed homogeneously throughout the Comanche outcrops, not just in veins
• Carbonate possibly is zoned and appears to have formed in Algonquin class precursor rocks
• No crystalline mineral phases associated with alteration of mafic rocks are evident; olivine still abundant
Morris et al. [2010] suggested hydrothermal activity; probably requires remobilized carbonates from carbonate-rich precursor.

Ruff [2011] alternative is evaporative precipitation from floodwaters or lakes onto existing rocks.

Origin Hypotheses

Petrologic evidence for low-temperature, possibly flood evaporitic origin of carbonates in the ALH84001 meteorite

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