Apollo 17 Landing Site

Keywords:
- South Massif
- Reflectance Spectroscopy
- Pine Mountain
- Soil Maturity
- Anorthosite
- Olivine
- Clinopyroxene
- Orthopyroxene
- Taurus-Littrow Valley
- SMARCS
- Breccias
- Weathering
- Petrology
- Mineralogy
- Albedo
- Reddening
- Mare
- SMARCS
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Apollo 17 Landing Site: Comparison of the Geology with Petrology and M³ Spectroscopy
Outline

1. Location
   - Taurus Littrow Valley
   - Drawing the Map (Triangulation)
   - Site Numbers
2. Background
   - Reflectance Spectroscopy
   - M3 Data
   - Weathering
   - Maturity
3. Known Minerals and Baselines
4. 3 Regions (South Massif, North Massif, Mare) and Outliers:
5. Mineral Mixing Model: Breccias
6. Pine Mountain
Our Project

- Objective: To compare petrology, mineralogy, and reflectance spectroscopy at the Apollo 17 landing site using the M³ data to better understand the geological makeup of the area.
- Apollo 17 landing site located in the Taurus-Littrow Valley.
Why did Apollo 17 go to Taurus-Littrow?

- Soils were thought to be ancient highland material
- **Dark haloed craters are cryptomare**
- Volcanic cinder cones indicate a young age
- To determine the age of the mare
- The LEM could land safely
- Primary objectives can be completed
Drawing The Map

Triangulation

Fig. 1
M3G20090107T011405
750 nm albedo reflectance

Fig. 2 Lunar Orbiter
Apollo_17_5c.jpg
Triangulation - The Process

A. Looked for common features (red arrows)
B. Reference 3 lines and plot a point where the 3 lines intersect on the new image (green lines)
Reflectance

Reflectance Spectroscopy

- When light hits an object, some of it is absorbed into the object and some of it is reflected off.

Reflectance = \frac{\text{Reflected Radiance}}{\text{Incident Light (Irradiance)}}
• Whether a photon is reflected, absorbed, or passes through the material is dependent on the composition and structure of that material and on the energy of the photon.
• By analyzing the light reflected from the moon we can tell the composition of the soil.
Reflectance Spectroscopy

- The light is split into its full spectrum.
- Data is graphed as light reflected per wavelength.
- Remove the continuum to better observe the spectral features.
Moon Mineralogy Mapper (M³)

- 85-band imaging spectrometer
- One of the six guest instruments on the Indian Mission Chandrayaan-1
- It's objective: To map the mineralogy of the lunar crust.
Five Known Minerals

- Olivine
- Clinopyroxene (cpx)
- Orthopyroxene (opx)
- Anorthosite
- Ilmenite

OPX Absorption 930, 1900 nm

CPX Absorption 1000, 2200 nm
The Four Soils for which we have Mineralogy, Chemistry, and Spectroscopy Data

Maturity measurement based on Is/FeO level:
71061- 14    71501- 35    70181- 47    79221- 81
Effects of maturity and weathering on spectra:
Reddening (positive spectral slope)
Weaker absorption bands
Sample Graphs

Orthopyroxene

Clinopyroxene

1000 nm  2050 nm

1020 nm  2150 nm
Site 1 Spectra

Petrology (in %) 71061/71501

<table>
<thead>
<tr>
<th>Mineral</th>
<th>71061</th>
<th>71501</th>
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</thead>
<tbody>
<tr>
<td>Plagioclase</td>
<td>13.9</td>
<td>16.5</td>
</tr>
<tr>
<td>Clinopyroxene</td>
<td>21.0</td>
<td>17.0</td>
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<tr>
<td>Orthopyroxene</td>
<td>0.6</td>
<td>0.6</td>
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<tr>
<td>Olivine</td>
<td>3.9</td>
<td>3.6</td>
</tr>
<tr>
<td>Ilmenite</td>
<td>10.4</td>
<td>12.3</td>
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</tbody>
</table>

sources: Charles Meyer #20-45 split
Heiken and McKay
Site 9 Spectra

Petrology (in %) 79221
Plagioclase 16.9
Clinopyroxene 6.0
Orthopyroxene 7.3
Olivine 4.8
Ilmenite 7.3

sources:
Charles Meyer #20-45 split
Heiken and McKay
Site 0 Spectra

Petrology (in %) 70181
Plagioclase 8.9
Clinopyroxene 10.3
Orthopyroxene 0.3
Olivine 3.6
Ilmenite 8.9

sources:
Charles Meyer #20-45 split
Heiken and McKay
Putting it all Together

The Three Geologic Regions of the Taurus-Littrow Valley:
South Massif, North Massif, and Mare
M³ Spectra: How the Spectra Reflects the Three Geologic Regions
M³ Spectra: How the Spectra Reflects the Three Geologic Regions
South Massif Area Location

Fig. 1. Petrography of surface soils from the Apollo 17 landing site. These are analyses of the 90–150 μm fraction of an average of 1 to 5 soils for each station. “Vitric breccia” of this illustration is equivalent to “low-grade” breccia of Table 1 and “metamorphosed breccia” is equivalent to “medium- to high-grade breccia of Table 1. “LM” and “Station 10” refer to the same general location.
South Massif
Apollo 17 Sample Sites 2 and 3

M3 Apollo 17 Sample Sites

Reflectance

Wavelength, nm
Fig. 1. Petrography of surface soils from the Apollo 17 landing site. These are analyses of the 90–150 μm fraction of an average of 1 to 5 soils for each station. “Vitric breccia” of this illustration is equivalent to “low-grade” breccia of Table 1 and “metamorphosed breccia” is equivalent to “medium- to high-grade breccia of Table 1. “LM” and “Station 10” refer to the same general location.
Maturity of Site 4 (51), Site 6 (45-58), and Site 7 (80)

![Graph showing M3 spectra of North Massif and Shorty Crater Areas](image)

<table>
<thead>
<tr>
<th>Site</th>
<th>Reflectance Wavelengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 4</td>
<td>870 nm 2123 nm</td>
</tr>
<tr>
<td>Site 6</td>
<td>890 nm 2123 nm</td>
</tr>
<tr>
<td>Site 7</td>
<td>900 nm 2132 nm</td>
</tr>
</tbody>
</table>
Fig. 1. Petrography of surface soils from the Apollo 17 landing site. These are analyses of the 90–150 μm fraction of an average of 1 to 5 soils for each station. "Vitric breccia" of this illustration is equivalent to "low-grade" breccia of Table 1 and "metamorphosed breccia" is equivalent to "medium- to high-grade breccia of Table 1. "LM" and "Station 10" refer to the same general location.
Mare Area
Apollo 17 Sample Sites 1, 5, 0
Maturity of Site 1 (14-35), Site 5 (33), and Site 0 (47)
Fig. 1. Petrography of surface soils from the Apollo 17 landing site. These are analyses of the 90–150 μm fraction of an average of 1 to 5 soils for each station. “Vitric breccia” of this illustration is equivalent to “low-grade” breccia of Table 1 and “metamorphosed breccia” is equivalent to “medium- to high-grade breccia of Table 1. “LM” and “Station 10” refer to the same general location.
Apollo 17 Sample Sites that Lie Outside the Three Main Spectral Trends: Sample Sites 8 and 9
The Maturity of Site 8 (93) and Site 9 (81)

Site 8
890 nm
1953 nm

Site 9
930 nm
2000 nm
## Sample Sites 8 and 9: How does the mineralogy effect the albedo and spectrum?

### Site 8

**Petrology**

<table>
<thead>
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<th>Rating</th>
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<tbody>
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<td>Orthopyroxene</td>
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<tr>
<td>Olivine</td>
<td>0.6</td>
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<tr>
<td>Ilmenite</td>
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</tr>
</tbody>
</table>

**Other Observations**

Despite its rating of very mature, site 8 has a higher albedo than other North Massif samples due to a mineral composition deficient in opx, olivine and ilmenite.

### Site 9

**Petrology**

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Rating</th>
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</thead>
<tbody>
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<td>Plagioclase</td>
<td>6.9</td>
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<tr>
<td>Clinopyroxene</td>
<td>6.5</td>
</tr>
<tr>
<td>Orthopyroxene</td>
<td>--</td>
</tr>
<tr>
<td>Olivine</td>
<td>--</td>
</tr>
<tr>
<td>Ilmenite</td>
<td>1.3</td>
</tr>
</tbody>
</table>

**Other Observations**

Darker than 6,7,8 because of the presence of ilmenite and its' very mature rating. It is brighter than other mare basalts because of the increase level of plagioclase and decreased level of ilmenite. It differs from other mare basalts because it is comprised of opx.
Due to the lack of time and of complete soil mineral composition data and spectra for the same soil samples from the Apollo 17 mission, we plan to continue this investigation by determining the spectral endmembers representative of the compositional endmembers by using the modal mineralogy of breccias from each of the 10 sites to approximate the soil mineralogy.
Breccias

- Breccias are congealed fragments of lunar soil.
- Most Apollo missions collected regolith breccias, a type of breccia composed of regolith.
- The breccias provide great models for the mineralogy of the lunar sites.
Breccia

The breccias provide great models for the mineralogy of the lunar sites.
Continuation of Research

Image courtesy of Nolan Peard
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References:

References (continued):

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Thank you!