Venus Surface Oxidation and Weathering as Viewed from Orbit with 6-Window VNIR Spectroscopy

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and many, many others!
Dashed lines = windows in CO2 spectrum of Venus' atmosphere.
Gilmore et al. (2015)
Tri-Color near-IR Venus Surface Emissivity
Akatsuki IR1 Camera – Jan 21, 2016
Jan 21, 2016 – Red 1.01 μm, Green 0.97 μm, Blue 0.90 μm
Bell et al. (2006) In-flight calibration and performance of the Mars Exploration Rover Panoramic Camera (Pancam) instruments
VEM Data, Helbert lab, DLR

The graph shows the relationship between emissivity and wavelength for various materials. Each line represents a different sample or category, such as Holyoke 7.50/2.00, Spain 3.4/2.8, PEL 1525 4.04/1.83, Norway 59/.31, Italy 0/36, hematite, pyrite, Newberry 1.32/0.20, magnetite 18.90/38.59, and Forsteritic Olivine. The x-axis represents wavelength in micrometers (μm), while the y-axis represents emissivity.
Idunn Mons

hematite

feldspar

olivine

magnetite
Melting of a basaltic parent will yield a range of compositions from basaltic andesite, through andesite, dacite, and finally rhyolite. How well can we distinguish these rock types using orbital VNIR spectroscopy?
Table 1. Samples Studied

<table>
<thead>
<tr>
<th>Sample</th>
<th>DLR #</th>
<th>Type</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSL basalt</td>
<td>1525</td>
<td>rock</td>
<td>PSL collections, locality unknown</td>
</tr>
<tr>
<td>Labrador amphibolite</td>
<td>1535</td>
<td>rock</td>
<td>MHC collections, locality unknown</td>
</tr>
<tr>
<td>Holyoke basalt</td>
<td>1802</td>
<td>rock</td>
<td>East Granby, CT</td>
</tr>
<tr>
<td>Padova basalt</td>
<td>1848</td>
<td>rock</td>
<td>Lanzarote Island, Spain</td>
</tr>
<tr>
<td>Newberry andesitic glass</td>
<td>1804</td>
<td>rock</td>
<td>Newberry volcano, Oregon</td>
</tr>
<tr>
<td>Padova rhyolite</td>
<td>1846</td>
<td>rock</td>
<td>Seiser Alm, Italy</td>
</tr>
<tr>
<td>Padova granite</td>
<td>1847</td>
<td>rock</td>
<td>Lofoten Islands, Norway</td>
</tr>
<tr>
<td>magnetite</td>
<td>1805</td>
<td>mineral</td>
<td>MHC collections, locality unknown</td>
</tr>
<tr>
<td>pyrite</td>
<td>1814</td>
<td>mineral</td>
<td>MHC collections, locality unknown</td>
</tr>
<tr>
<td>pyrrhotite</td>
<td>1815</td>
<td>mineral</td>
<td>MHC collections, locality unknown</td>
</tr>
<tr>
<td>hematite</td>
<td>1813</td>
<td>mineral</td>
<td>MHC collections, locality unknown</td>
</tr>
<tr>
<td>forsterite olivine</td>
<td>2369</td>
<td>mineral</td>
<td>San Carlos, NM</td>
</tr>
<tr>
<td>apatite</td>
<td>tbd</td>
<td>mineral</td>
<td>MHC collections, locality unknown</td>
</tr>
<tr>
<td>pyroxene</td>
<td>tbd</td>
<td>mineral</td>
<td>MHC collections, locality unknown</td>
</tr>
</tbody>
</table>

PSL = Planetary Spectroscopy Laboratory, DLR, MHC = Mount Holyoke College

**Compositions** were determined by x-ray fluorescence (**XRF**) at the University of Massachusetts or by **electron microprobe** at Brown University. Fe\(^{3+}\)/Fe\(^{2+}\) ratios were measured using **Mössbauer spectroscopy** in the Mineral Spectroscopy Laboratory at Mount Holyoke. **Visible near-infrared (VNIR)** data for this project were collected in the Planetary Spectroscopy Laboratory (PSL) at the German Aerospace Center DLR in Berlin.
Discriminating among rock types

- Basaltic andesite
- Basalt
- Trachybasalt
- Rhyolite N
- Granite

Emissivity vs. Energy (µm)

% Fe³⁺
| Basalt* and felsic | 9.0 | 100.0% | 0.0% | 94.6 | 0.6 | 93.7 | 0.6 |
| Basalt* and dacite | 6.75 | 100.0% | 0.0% | 88.5 | 0.9 | 86.4 | 0.9 |
| Basalt* and andesite | 4.50 | 100.0% | 0.0% | 80.4 | 1.0 | 80.2 | 0.9 |
| Basalt* and basaltic andesite | 2.24 | 100.0% | 0.0% | 65.4 | 1.2 | 60.1 | 1.3 |

*actual average of specific samples measured in the lab at DLR as shown with solid lines in Figure 1. Dacite, andesite, and basaltic andesite spectra used in the models came from model spectra interpolated between the lab data on the basis of Fe content.
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Dependence of emissivity on energy (μm) and Fe$^{3+}$ percentage.
$y = 0.0084x + 0.9041$

$R^2 = 0.9262$

Rocks only
Pyroxene features vary in intensity with Fe content (Fs).
“snow line” on Venus mountains
Emissivity at 1.18 μm vs. %Fe$^{3+}$

The graph shows a linear relationship between emissivity at 1.18 μm and %Fe$^{3+}$ for various rocks:

- Basaltic andesite
- Rhyolitic glass
- Basalt
- Granite
- Rhyolite
- Pyrite
- Pyrrhotite
- Magnetite
- Hematite

The equation of the best fit line is:

$$y = -0.002x + 1.013$$

with a coefficient of determination $R^2 = 0.820$. The data points for each rock type are represented by circles with error bars.
What can we learn from orbit using 6-window spectroscopy?