CHARACTERIZING VARIATIONS IN THE 3-MICRON HYDRATION BAND IN LUNAR ANALOGS.

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Abstract: Multiple recent datasets have revealed the presence of hydrous components on the lunar surface. Constraining the nature of these OH and/or H_2O species is essential for understanding the geologic history of the Moon and for considering potential resources in the regolith. This study of spectral data describes information on the wavelength position and shape of bands near 3 µm due to OH and H_2O in silicate minerals and lunar analogs. The objective is to provide information on hydrous species in minerals thought to be present on the Moon to support interpretation of spectral data from the Moon Mineralogy Mapper (M^3) images, and the upcoming Lunar Trailblazer and VIPER missions.

Introduction: Barnes et al. [1] investigated OH in lunar highland rocks that they argue are the oldest and most pristine materials on the Moon. Their findings on the abundance of OH coupled with H isotopic data indicate a common origin for water in the Earth-Moon system. Further, modeling of the geochemistry data for H_2O and volatiles from 377 lunar glasses by Hauri et al [2] demonstrate that degassing has been pervasive on the Moon. This is consistent with heterogeneous accretion and either a "cold start" or "warm start" to lunar formation, resulting in efficient delivery of terrestrial water to the Moon. Both of these studies support the presence of OH and/or H_2O species in lunar rocks that are similar to those in terrestrial rocks and minerals.

Grinding studies of minerals in the lab have shown that long-term abrasion breaks up the mineral structure and changes the OH bands [e.g., 3-4]. Similarly, long-term grinding of anhydrous minerals such as quartz produces poorly-crystalline grains that bind to OH and H_2O [5]. The surfaces of these poorly crystalline, impacted grains are particularly reactive and readily adsorb water. Dyar et al. [6] discuss a number of ways to incorporate OH and/or H_2O into minerals, including: fluid inclusions or non-structural OH and H_2O in "anhydrous" minerals or along grain boundaries, OH and H_2O in glasses, adsorbed water, or surface-water complexes. This study investigated the spectral properties of volcanic materials and minerals found in lunar rocks in order to document the hydrous features near 3 µm for applications to lunar remote sensing.

Olivine: A survey of olivine spectra showed that synthetic samples and fine-grained natural samples tended to include a broad band near 2.8-3.2 µm (**Fig. 1**), consistent with a broad distribution of H_2O molecules that could be present on particle surfaces. In contrast, coarse-grained natural samples exhibit a step-like spectral shape near 2.8 µm, more consistent with many similar OH groups, followed by a broad band attributed to H_2O.

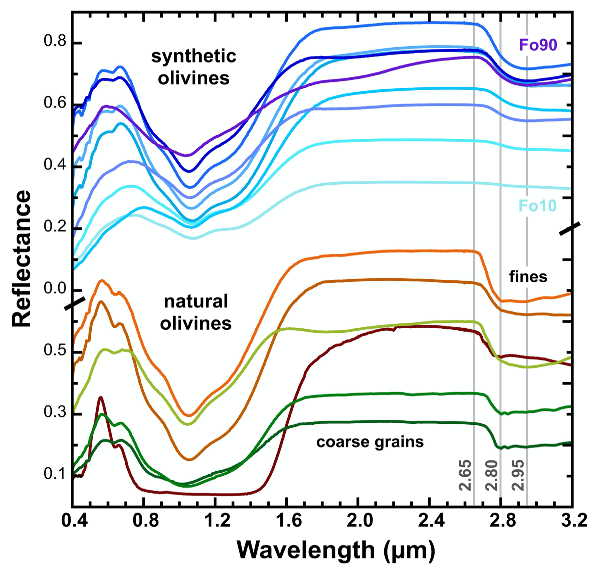

Fig. 1. Reflectance spectra of olivine samples. Data from Isaacson et al. [7] and Bishop collection.

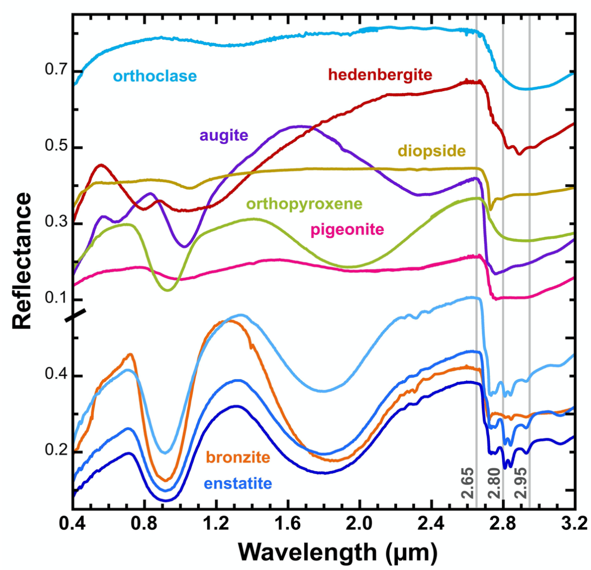

Fig. 2. Reflectance spectra of pyroxene samples. Data from the USGS library and Bishop collection. The shades of blue selected for the enstatite spectra refer to the particle size: the light blue spectrum is a fine-grained sample (20-45 µm), while the darkest blue spectrum is a coarse-grained (125-150 µm) version of this sample.

Pyroxene: A survey of pyroxene spectra showed much more variability in the 2.7-3.2 µm region (**Fig. 2**). Spectra of enstatite, bronzite, and hedenbergite all include several sharper bands from 2.7-2.9 µm, consistent with OH in repeating sites in the mineral structure. Spectra of orthoclase and orthopyroxene exhibit a broad band near 2.8-3.2 µm, similar to that observed for synthetic olivine, that is consistent with a broad distribution of H_2O molecules. Particle size could be playing a role in the ~3 µm band shape for pyroxene, although the enstatite spectra exhibit similar features for different grain sizes.

Feldspar: A survey of feldspar spectra also showed variability in the 2.7-3.2 µm region (**Fig. 3**), although additional spectra will need to be considered to better understand the character of the hydrous bands for feldspar. The spectrum of sanidine exhibits a broad band near 2.8-3.2 µm, similar to that observed for synthetic olivine, while the spectrum of microcline has a stronger and narrower H_2O band centered near 2.93 µm. This indicates H_2O molecules in more similar sites, rather than a distribution of sites. The bytownite spectrum includes a few sharper bands, similar to enstatite and other pyroxenes, that are consistent with OH in repeating sites in the mineral structure.

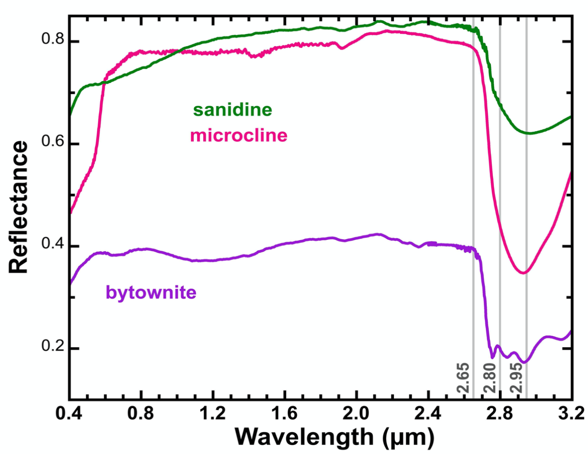

Fig. 3. *Reflectance spectra of feldspar samples. Data from the USGS library.*

Volcanic Materials and Other Minerals: A survey of spectra of volcanic materials from Iceland and the Hawaiian islands (**Fig. 4**) shows broad bands across the 2.7-3.2 mm region, although there are some differences. Spectra are also shown for cristobalite and quartz. Spectra of the quartz and Hawaiian samples are more consistent with mostly similar H_2O molecules and a narrower water band at ~2.9 µm. Spectra of the cristobalite and Icelandic samples have a sharper drop-off near 2.75-2.8 µm. This is consistent with OH groups in the samples, as well as a broad distribution of H_2O molecules to account for the broad band out to 3.2 µm.

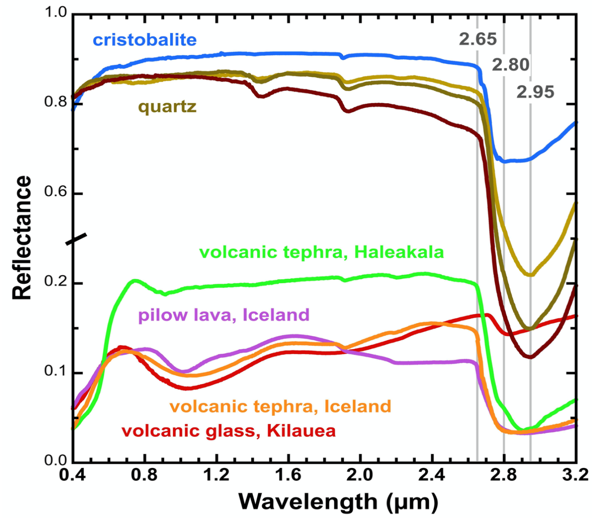

Fig. 4. *Reflectance spectra of volcanic glass and tephra and other minerals from the Bishop collection. Darker quartz spectra refer to larger particle sizes.*

Implications: Analyses of M^3 spectral variations on the Moon have shown changes in band intensity across the 2.7-3 µm range for different times of day and from maria to highlands [8]. This indicates different types of hydrous components in the lunar regolith and some H_2O that is leaving the surface during lunar midday. Characterizing lab spectra of lunar analogs and the types of OH and H_2O bands present will contribute to understanding these regional and time of day variations.

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