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Low Abundances of Strongly Bound Hydroxyl in Spinel-rich Areas of the Lunar Crater Theophilus

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Abstract

Relying on hyperspectral data acquired by the Moon Mineralogy Mapper (M^3) instrument, we describe a correlation between the integrated 3 μm band depth indicating the amount of hydroxyl (OH) on the lunar surface and the negative logarithmic band depth (NLBD) parameter that sets the absorption band depths at 1 μm and 2 μm in proportion to each other. Areas with a high NLBD value, corresponding to a strong 2 μm absorption band and a weak 1 μm absorption band as it is typical of the mineral spinel, are found to contain less hydroxyl than surrounding areas.

1. Introduction

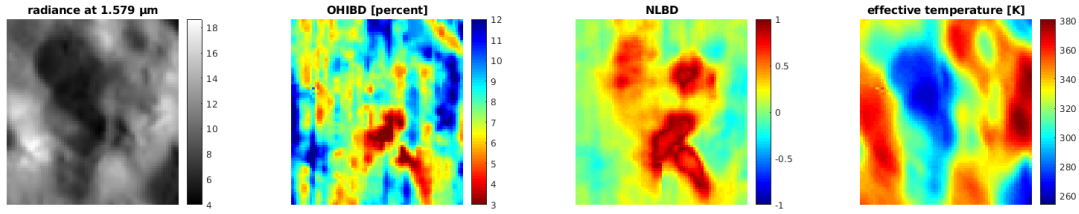
The M^3 instrument [1] measured near-infrared (NIR) spectra of the lunar surface, providing insight into the mineral composition of the surface. One important finding was that an absorption band at 3 μm, which indicates the presence of hydrated species in the form of OH and/or H_2O, can be observed [2, 3, 4]. This absorption band is not limited to high latitudes but can be found across all latitudes and at all times of day. The depth of the 3 μm absorption band is largest in the morning and decreases toward midday [2]. The most common explanation for the time-of-day-dependent variation of the 3 μm band is an origin of lunar OH from the solar wind (e.g., [3]). During the lunar morning, when the surface temperature is low, the solar wind implanted protons react with O atoms from different minerals of the regolith. Sink processes like diffusive loss and photolysis become dominant with increasing temperature [5]. Finding correlations between the integrated 3 μm band depth (OHIBD) [2], indicating the amount of hydroxyl in the uppermost layer of the regolith, and the mineral composition of the surface is of high importance for further characterization of the source and sink processes relevant for lunar OH.

2. Methods

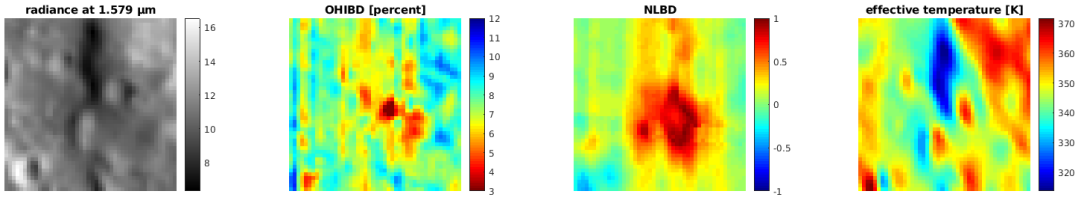
In this work, we make use of the thermal correction and surface roughness model described in [2, 5] to map the OHIBD parameter. The negative logarithmic band depth (NLBD) parameter is adapted from the framework described in [6]. NLBD corresponds to the negative base-10 logarithm of the ratio between the relative depths of the mafic absorption bands at 1 μm and 2 μm. The mineral spinel is characterized by a strong 2 μm band and a weak or absent 1 μm band [7, 8]. A high NLBD value thus indicates a high spinel content.

3. Results

Figure 1 shows maps of the parameters OHIBD and NLBD together with the determined effective temperatures for two different regions marked in Figure 2. The example regions are located on the central peak of the crater Theophilus, which is known to exhibit small areas rich in Mg-spinel [9]. The spinel-bearing areas indicated by high NLBD values coincide with low OHIBD values. Such OHIBD anomalies do not occur in parts of the crater floor and the central peak without spinel signature. The effective surface temperature in Figure 1 shows strong variations due to topography but is not correlated with NLBD, suggesting that the observed OHIBD anomalies are not an artifact of the applied correction for thermal emission. The examined M^3 image was taken at a local time of 08:45 and the crater Theophilus is located near the equator, so that we expect according to [5] that the measured OHIBD is mainly caused by the strongly bound OH component. Thus, Figure 1a suggests that spinel contains significantly smaller amounts of strongly bound OH than the surrounding material of low spinel content. This behavior is similar to the low amount of strongly bound OH in ilmenite-rich mare areas [2, 10]. Notably, both spinel and ilmenite are oxide minerals free of silicates.



(a) Region 1 located on the central peak of the crater Theophilus.



(b) Region 2 located on the crater floor of the crater Theophilus.

Figure 1: Comparison of the two areas indicated in Figure 2, which have been shown to contain spinel [9].

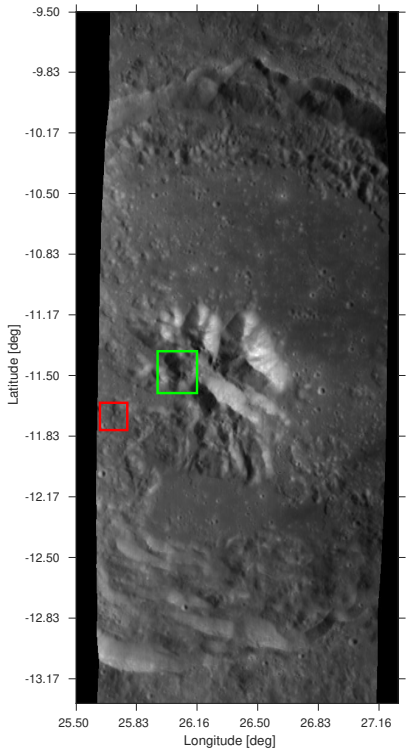


Figure 2: M^3 radiance image M3G20090203T160452. Region 1 is marked by a green rectangle and region 2 by a red rectangle. The image was taken about 81 hours after sunrise, corresponding to a local time of about 08:45.

4. Conclusion

In this work, we investigated the correlation between localized occurrences of spinel and the behaviour of the strongly bound OH component on the central peak and floor of the lunar crater Theophilus. Our data suggest that spinel-rich areas exhibit smaller amounts of strongly bound OH than the surrounding surface regions containing less or no spinel. A possible interpretation of these results is that spinels are rather unreactive and less susceptible than other minerals to space-weathering agents (see [11] for a laser-based experimental study), such as solar wind particles that disrupt the mineral structure, produce defects and induce the formation of OH on the mineral surface.

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