SPECTRAL REFLECTANCE PROPERTIES OF LICHENS: IMPLICATIONS FOR BIOLOGICAL SPECTROSCOPIC EXPLORATION OF MARS

Edward A. Cloutis, ER Georesearch Ltd., 4 Huntstrom Road N.E., Calgary, Alberta, T2K 5W3.

The spectral reflectance properties of a number of lichen species have been measured. The results indicate that different lichen species exhibit unique spectral properties that would be amenable to detection by multispectral remote sensing. The wavelength region which is most diagnostic for lichen species discrimination is located between 0.35 and 0.85μm. For discrimination of lichens from lichen-free surfaces, the wavelength region between 1.65 and 1.8μm is most diagnostic. This suggests that spectroscopic remote sensing could be used to detect the presence or absence of lichens on the surface of Mars.

INTRODUCTION: The possibility of life having evolved on Mars is an area of debate which has not yet been satisfactorily resolved. Paleoclimatic and geomorphological studies suggest that the climate of Mars may have been much more clement in the past, leading to the possibility of life having evolved on its surface [*1-4*]. Among the simplest terrestrial life forms are lichens. Lichens are ubiquitous in cold and polar desert regions of the earth and have recently been identified in the Dry Valley region of Antarctica, a region with some climatic similarities to Mars and previously thought to be too dry to support epilithic lichen growth [*5*]. In order to investigate the potential applications of optical remote sensing to the detection of lichens on Mars, the spectral reflectance properties of a number of lichens and lichen-covered rocks have been examined.

EXPERIMENTAL PROCEDURE: A number of lichen-covered rocks were obtained from the Contwoyto Lake-Point Lake area in the Northwest Territory [*6*]. These samples include a micaceous greywacke (BOREA04) partially covered with 2 different species of lichen, a diorite (BOREA08) partially covered with *Buellia stigmaea*, a foliated biotite granite (BOREA09) partially covered with *Arctoparmelia centrifuga, Melanelia stygia* and *Pseudephebe minuscala*, and a muscovite pegmatite (BOREA10) covered with *Arctoparmelia centrifuga, Arctoparmelia incurva* and *Melanelia stygia*. The rock samples were the subject of earlier studies [*7,8*]. The 0.35-2.6μm diffuse reflectance spectra of the weathered lichen-free and lichen-covered surfaces were measured at an average spectral resolution of 5 nm relative to halon at the U.S.G.S. Denver spectrometer facility using an integrating sphere arrangement.

RESULTS: The reflectance spectrum of a 100% black lichen-covered portion of the outer surface of the BOREA04 sample is shown in Figure 1. The lichen spectrum exhibits absorption features in the 0.35-0.7μm, 1.4μm and 2.1μm regions, as well as near 1.7μm. The reflectance spectrum of the BOREA08 sample (80% lichen covered) is also shown in Figure 1. The overall shape at longer wavelengths is similar to the BOREA04 sample but it exhibits differences in the visible region. The reflectance spectra of an 80% lichen covered surface of BOREA09 is also shown in Figure 1. The measured lichen covered surface consists of 50% *Arctoparmelia centrifuga* and 30% *Melanelia stygia*. Compared to the weathered lichen-free surface, the lichens result in the appearance of a number of absorption bands between 0.35 and 0.8μm, near 1.7μm and 2.1μm, and a broadening of the absorption feature near 1.4μm. The reflectance spectrum of the 80% lichen covered surface of BOREA10 is also shown in Figure 1. Compared to the other lichen spectra its visible region spectrum is relatively featureless. At longer wavelength its spectrum is similar to the other lichen spectra.

DISCUSSION: The lichen-free and lichen-covered surface spectra were compared to determine which spectral features are attributable to the lichen. It was found that all four spectra shown in Figure 1 represent essentially pure lichen spectra, the contributions by the underlying rocks are negligible. These spectra are also similar to those measured by other investigators [*9-11*]. The visible color is due to chlorophyll and usnic acid absorption [*12-13*]. The complexity seen in the lichen spectra in the visible region indicates that additional components are contributing to the reflectance spectra. The visible region spectral differences can best be ascribed to the different visual colors of each species. This region appears to be best suited for discriminating different lichen species.

All of the samples exhibit roughly similar absorption features in the 1.4μm region as well as similar absorption features near 1.9μm, 2.1μm, 2.2μm and 2.5μm. The absorption features near 1.4 and 1.9μm are attributable to water in various forms. The features near 2.1 and 2.3μm are related to cellulose, a major constituent of lichen [*10,11*].

The lichen spectra all exhibit absorption features in the 1.7μm region. The absorption bands in this wavelength region are attributable to cellulose and various combinations and overtones of organic fundamental vibrations [*10,11,14*]. The 1.7μm region is probably best suited for spectroscopic detection of lichens because it is not significantly

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overlapped by any absorption bands due to commonly occurring minerals [*11*].

Some of the absorption bands in the visible region which can be used to distinguish the different lichen species are as narrow as 30 nm. This dictates that spectral resolution in the diagnostic regions should be on the order of 10-15 nm so that these bands could be identified and some level of band depth information retrieved. Band depth information would be necessary for determining the areal extent of lichen cover at the pixel or subpixel scale.

The spectral differences and similarities seen in the lichen spectra indicate that spectroscopic methods are potentially capable of identifying the presence of lichens and for some level of species discrimination. The 1.7μm region is particularly useful for spectroscopic detection of lichens on Mars because absorption bands in this region are most commonly associated with organic matter and would not be significantly overlapped by either Martian atmospheric absorptions or presumed geological surface constituents [*15*].

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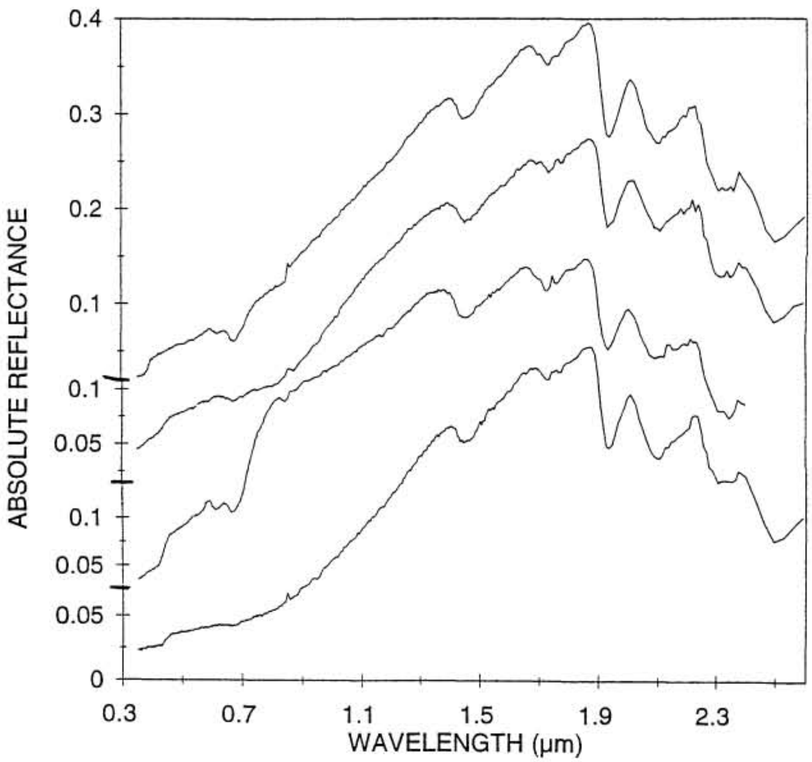

Figure 1. Reflectance spectra of lichen-covered weathered rock surfaces (top to bottom): BOREA04 (100% lichen covered), BOREA08 (80% covered), BOREA09 (80% lichen covered), and BOREA10 (80% lichen covered).