DETECTION LIMITS FOR REMOTE SENSING IDENTIFICATION OF HYDROCARBON-BEARING SURFACES; Edward A. Cloutis, Department of Geology, University of Alberta, Edmonton, Alberta T6G 2E3

Introduction: To date, very little laboratory data exists concerning the spectral reflectance properties of geologically significant hydrocarbons. A recent study of the reflectance spectra of oil sands provides some guidelines as to the usefulness of ultraviolet-visible-near infrared spectroscopy for the remote sensing identification of extraterrestrial hydrocarbon occurrences. Oil sands are useful analogues of some of these occurrences because the terrestrial materials are composed predominantly of clay and hydrocarbons embedded in a spectrally neutral quartz sand matrix [1]. The details of particular oil sand spectral features are presented elsewhere [2,3].

Results: A suite of oil sand samples from the Athabasca deposit in north eastern Alberta have been spectrally and chemically characterized. The samples range in bitumen content from 0-15 wt. % and a subset of these have been selected for more detailed spectral analysis. A typical oil sand spectrum containing 8.1 wt. % bitumen is shown in Figure 1. It displays absorption features characteristic of clay/water near 1.4 and 1.9μm, and hydrocarbon absorption features near 1.7μm and between ~2.3 and 2.6μm [2,3]. The intensities of the hydrocarbon absorption features increase with increasing bitumen content. Band depths, as defined in equation (32) of Clark and Roush [4], can be used as a quantitative measure of this intensity. Straight line continua have been used to isolate specific absorption features. For the 1.7μm feature a straight line continuum was constructed tangent to the spectrum on either side of the feature. For the 2.2-2.6μm region, a horizontal continuum tangent to the reflectance maximum in the 2μm region was constructed.

Analytical data avialable for the samples are only approximate because they represent the average of a much larger amount of material than was spectrally characterized. Thus sample inhomogeneities, which are known to exist, are the likeliest explanation of the scatter in the data. Improved chemical analyses are planned.

Discussion: A good correlation exists between the depth of the 1.7μm feature and the bitumen content (Figure 2). A detailed look at this feature for three samples containing 3, 8 and 13 wt. % bitumen is presented in Figure 3, along with band depths (Db). The complexity of this feature is readily apparent. The fact that the intercept of a linear least squares fit to the data in Figure 2 is very close to zero suggests that, theoretically, even very low hydrocarbon abundances may be potentially resolvable. In the 2.2-2.6μm spectral region discrete absorption bands can be identified at 2.31, 2.35 and 2.45μm (Figure 4). The most prominent of these bands (2.31μm) again shows a good correlation between bitumen abundance and band depth (Figure 5). However, because of the presence of clays, the intercept of the linear least squares fit at 0 wt. % bitumen indicates a band depth of ~14 %. Presumably this value represents the band depth of the clay fraction in oil sands, since almost all clays display absorption bands in this wavelength region due to lattice-OH vibrations.

Both the 1.7 and 2.3-2.6μm spectral region possess certain advantages and disadvantages for their use in detecting hydrocarbons. The 1.7μm feature is not interfered by most other minerals and can, potentially, be used to detect any abundance of level of hydrocarbons, provided S/N ratios are sufficiently high to permit this. The hydrocarbon absorption bands in the 2.3-2.6μm region are more intense than the 1.7μm feature but are overlapped by clay lattice absorption bands. This could very easily lead to erroneous spectral interpretations.

An examination of existing remotely sensed reflectance spectra of extraterrestrial objects provides no clear evidence for unambiguous hydrocarbon absorption bands at 1.7 and 2.3-2.6μm. An upper limit of ~3 wt. % hydrocarbons has been assigned to the dark material on Iapetus which exhibits a number of other spectral features consistent with an organic component [3]. A fundamental organic absorption band at 3.4μm has been detected in the infrared spectrum of asteroid 130 Elektra [5], but no lower wavelength data are available to search for the various combination and overtone bands. Other telescopic spectra of presumed organic-rich asteroids are generally too noisy to unambiguously identify hydrocarbon absorption bands near 1.7μm, although very weak features may be present in the reflectance spectra of the D-type asteroid 849 Ara [6], and 2 Pallas [7]. However, hydrocarbon-rich meteorites, such as CI and CM carbonaceous chondrites, which contain sufficient organic matter to display hydrocarbon absorption bands, do not [8,9,10].

The decided absence of resolvable hydrocarbon absorption bands in both known and presumed organic-rich objects is problematic. It seems likely that this absence is due in some cases to insufficient spectral resolution. In the cases of spectrally featureless asteroids the absence is probably due to the presence of a spectrally neutral opaque phase which can strongly suppress not only hydrocarbon, but also silicate mineral absorption bands. Recent improvements in telescopic spectral resolution seem to support both interpretations [11]. It is expected that further advances will permit the identification of hydrocarbon absorption bands which had escaped earlier searches.

Acknowledgments: This study was supported by a Grant-in-Aid of Research from the American Association of Petroleum Geologists and a scholarship, research grants, and fellowship from the Alberta Oil Sands Technology and Research Authority.

References: [1] Bichard, J.A., *Oil Sand Composition and Behaviour Research,* AOSTRA Tech. Publ. Ser. #4 (1987). [2] Cloutis, E.A., this volume. [3] Cloutis, E.A., *Science, 245*, 165-168 (1989). [4] Clark, R.N., and Roush, T.L., *J. Geophys. Res., 89*, 6329-6340 (1984). [5] Cruikshank, D.P., and Brown, R.H., *Science, 238*, 183-184 (1987). [6] Bell, J.F., Hawke, B.R., and Gaffey, M.J., *Lunar Plan. Sci. Conf. XV*, 46-47 (1984). [7] Feierberg, M.A., Lebofsky, L.A., and Larson, H.P., *Geochim. Cosmochim. Acta, 45*, 971-981 (1981). [8] Wagner, J.K., Hapke, B.W., and Wells, E.N., *Icarus, 69*, 14-28 (1987). [9] Johnson, T.V., and Fanale, F.P., *J. Geophys. Res., 78*, 8507-8518 (1973). [10] Gaffey, M.J., *J. Geophys. Res., 81*, 905-920 (1976). [11] Vilas, F., and Gaffey, M.J., *Lunar Plan. Sci. Conf. XX*, 1156-1157 (1989).

SPECTRAL DETECTION OF HYDROCARBON-BEARING SURFACES: Cloutis, E.A.

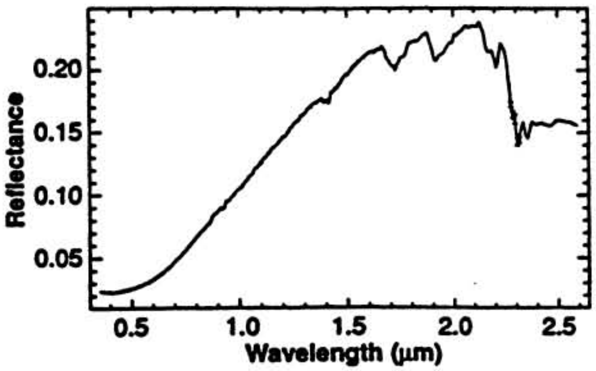

Figure 1. Reflectance spectrum of an oil sand containing 8 wt. % bitumen.

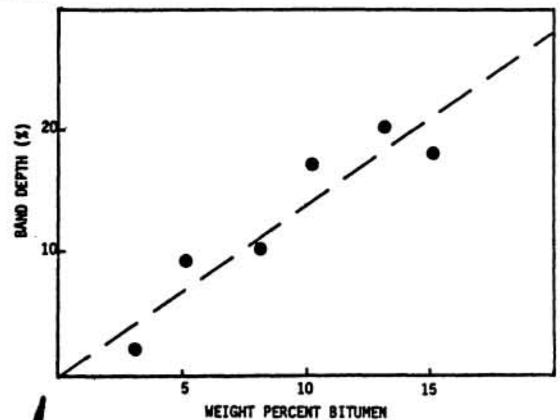

Figure 2. Band depth of 1.7μm feature versus wt. % bitumen for various oil sand samples.

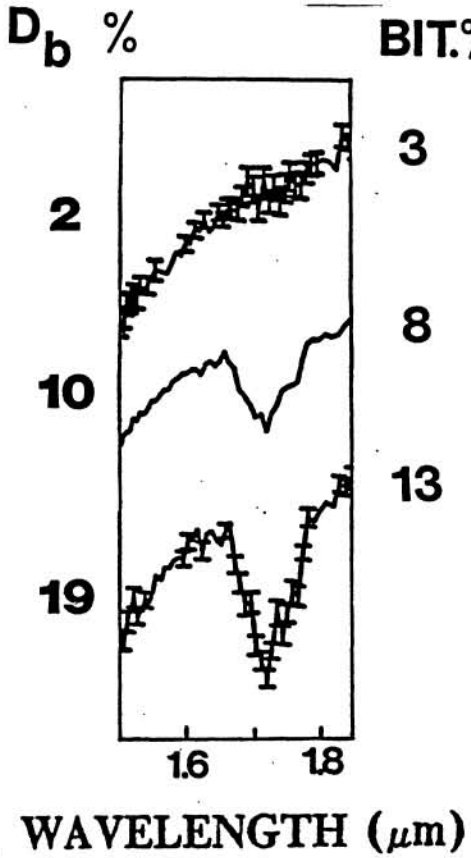

Figure 3. Details of the 1.7μm absorption feature as a function of bitumen content and band depth (Db).

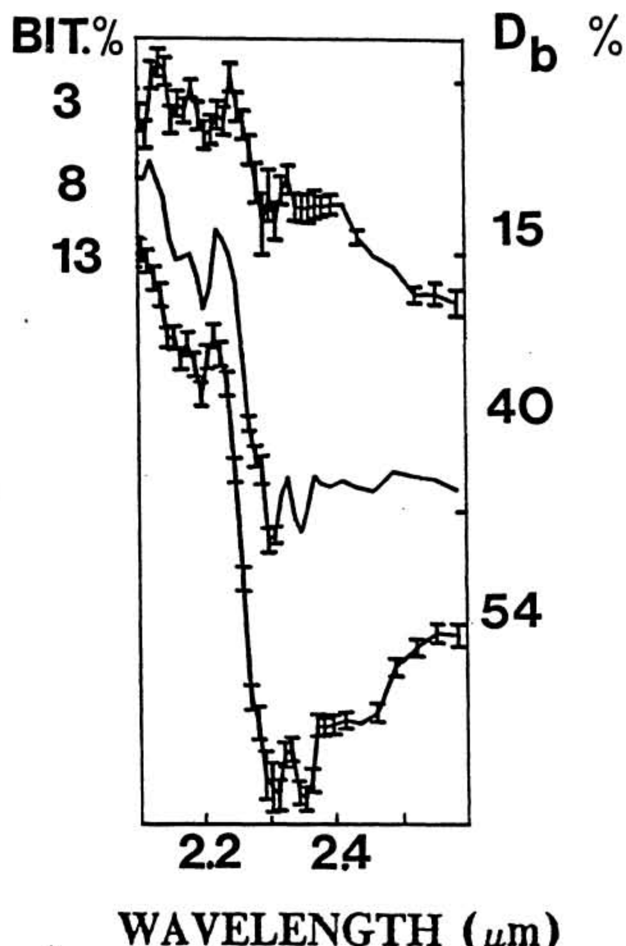

Figure 4. Details of absorptions in the 2.2-2.6μm region as a function of bitumen content and band depth (Db).

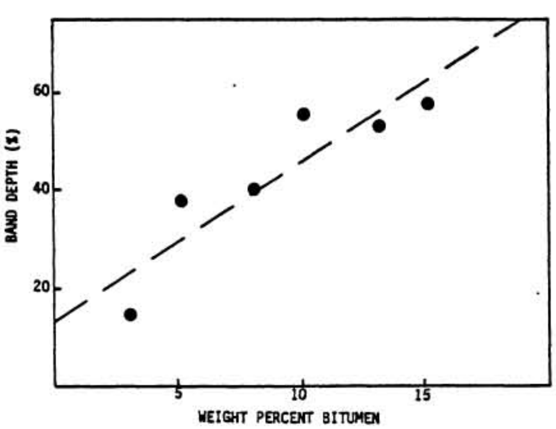

Figure 5. Band depth of the 2.31μm absorption feature versus wt. % bitumen for various oil sand samples.