A SEARCH FOR METALLOPORPHYRIN ABSORPTION FEATURES IN THE REFLECTANCE SPECTRA OF OIL SANDS: IMPLICATIONS FOR ASTEROID SPECTROSCOPY

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The 0.3-0.6 μm reflectance spectra of a suite of Athabasca oil sands were examined for evidence of metalloporphyrin absorption bands. No definitive metalloporphyrin absorption bands were identified in any of the spectra. This is probably due to the low overall reflectance and interferences from overlapping organic and inorganic absorption bands. This absence suggests that the identification of metalloporphyrin absorption features in dark asteroid spectra may not be possible even when metalloporphyrins are known or inferred to be present.

INTRODUCTION: Metalloporphyrins, particularly vanadium and nickel bearing species, present in organic geological materials such as coal, oil shale, crude oil and oil sands are useful biomarkers and organic indicators because of their stability to thermal degradation and presence of multiple absorption bands in the visible region. The detection of metalloporphyrin features in asteroid spectra would permit some inferences to be made concerning the nature and types of organic materials present on their surfaces.

The major porphyrin absorption bands are found between ~0.35 and 0.65 μm. Up to 3 absorption bands may be present in this wavelength region for a single metalloporphyrin species and the wavelength positions of the bands are diagnostic of the species present. The most intense of these bands is found near 0.4 μm (Soret band) [*1,2*]. The Soret band has been identified in reflectance spectra of oil shales [*1*], the CI1 Orgueil carbonaceous chondrite [*1*], and asteroid 2 Pallas [*2*]. Metalloporphyrins have also been identified in a number of carbonaceous chondrites [*3*].

EXPERIMENTAL PROCEDURE: A suite of 18 oil sand samples from the Athabasca deposit in Alberta were spectrally characterized to search for absorption bands potentially attributable to metalloporphyrins. The 0.3-0.6 μm diffuse reflectance spectra were measured at the RELAB facility at Brown University [*4*]. The spectra were measured relative to halon at $i=0°$ and $e=15°$ with 5 nm spectral resolution.

RESULTS: The reflectance spectra of the various oil sand samples (Figure 1) exhibit wide variations in absolute reflectance and shape which are largely a function of their bitumen contents [*5-8*]. Due to the low reflectance of bitumen, the samples which are expected to be the most porphyrin rich (most bitumen rich) exhibit the lowest overall reflectance, as low as 2% (Figure 1).

None of the spectra display a Soret absorption band near 0.4 μm as resolvable as that found in oil shale spectra [*1, 9*]. The TAR01, 03, 09, 17 and 18 spectra do exhibit minor decreases in reflectance at 0.4 μm, however they also exhibit a number of other short wavelength absorption features not attributable to porphyrins.

The longer wavelength regions are better suited for detecting porphyrin absorption bands because reflectance generally increases toward longer wavelengths. Once again none of the spectra exhibit a well defined absorption band near 0.535 μm, as is found in oil shale spectra [*1,9*]. There are weak apparent absorption features near this wavelength in the TAR04, 12, 13, 14, 15, 16 and 17 spectra, but all are extremely weak and not clearly resolvable. The evidence for a porphyrin absorption band in the 0.570-0.575 μm region is also ambiguous. Only the TAR03, 07, 10 and 14 spectra show any evidence for even a slight reflectance decrease in this region.

DISCUSSION: The fact that Athabasca oil sands are generally 2-5 times more porphyrin rich than oil shales (Table 1) whose spectra exhibit well-resolved porphyrin absorption bands should bode well for detecting similar features in oil sand spectra. However, none of the measured oil sand reflectance spectra exhibit well resolved absorption bands that can confidently be ascribed to porphyrins. It appears that a number of factors can be invoked to account for this, including the fact that the most bitumen rich samples exhibit the lowest overall reflectance, being significantly darker than oil shales [*1,9*], and that for complex organic materials such as oil sands, numerous overlapping organic absorption bands are expected in the 0.3-0.6 μm region [*10*].

The spectral data for the oil sands indicate that even when metalloporphyrins are present in significant concentrations, identification of porphyrin absorption bands will be difficult for low albedo, complex organic materials. These restrictions probably apply to many low albedo asteroids such as the C,P, and D classes.

METALLOPORPHYRIN SPECTRA: E.A. Cloutis et al.

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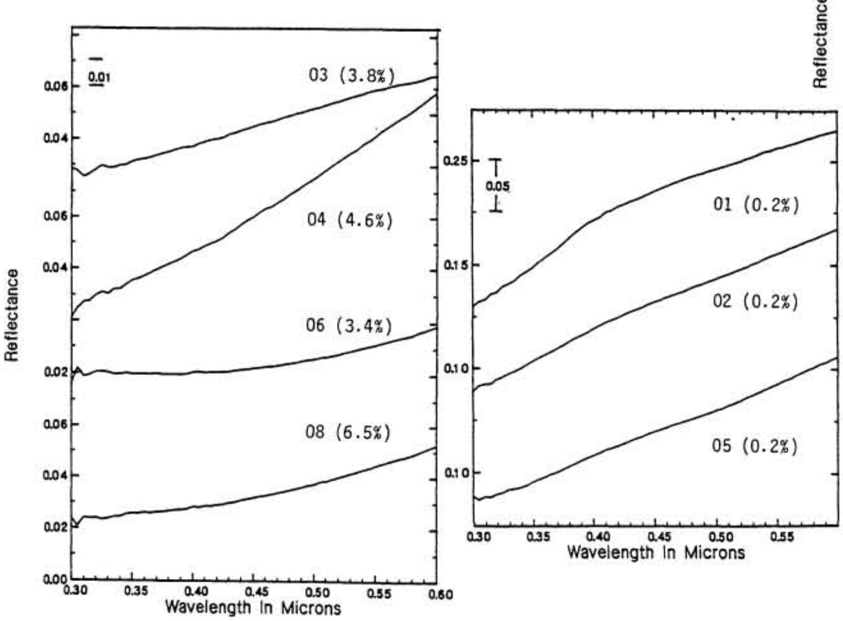
Table 1. V- and Ni-porphyrin contents of selected materials.

Material	V-Porphyrin (ppm)	Ni-Porphyrin (ppm)	Source of Data
Athabasca Oil Sands	230-500	21-45	11,12,13
Athabasca Oil Sands coal/shale inclusions	≤170	≤0.2	11,14
Bakken Oil Shale	114	8	1
Green River Oil Shale	None detected	8	1



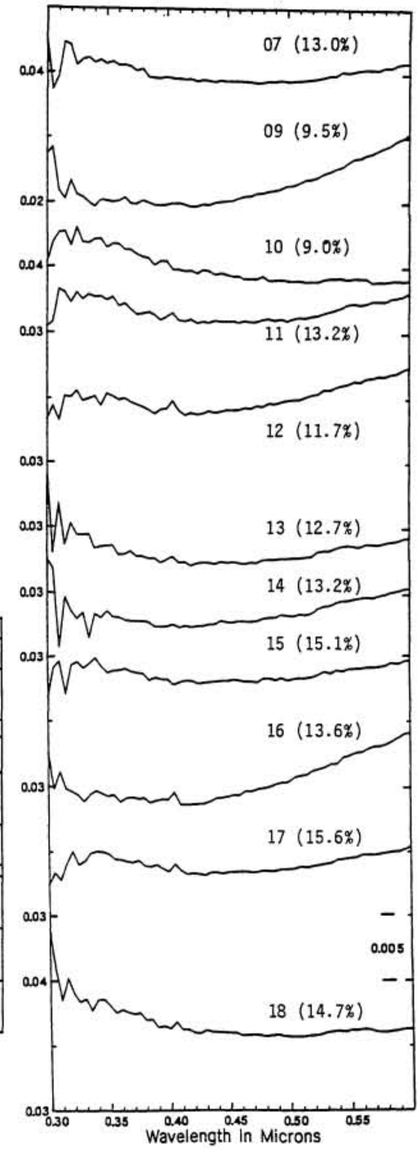


Figure 1. Reflectance spectra (0.3-0.6 μm) of the Athabasca oil sands. Vertical bars indicate the absolute reflectance scale for each group. [TAR prefixes omitted]. Bitumen contents are provided in brackets.