

## SPECTROSCOPY OF SOLID CARBONACEOUS MATERIALS: IMPLICATIONS FOR DARK SURFACES OF OUTER BELT ASTEROIDS

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Presented here are laboratory spectra of some terrestrial organic solids for the comparison with the spectra of dark surfaces of small bodies of the Solar System. The samples are representatives of natural continuous series of organic matter with the different H content which is gradually decreasing in the following order: asphaltite, kerite, anthraxolite, shungite. The specimens are described in the work of Nikolayeva et al. (this volume). The sample of "kerogen" isolated from coal tar (received from Dr.J.Piscitelli) was studied for the comparison. The samples were powdered and sieved to obtain various particle size fractions. Bidirectional reflectance spectra were measured in the 0.3-2.6  $\mu\text{m}$  using RELAB spectrometer (Brown University, USA). Biconical diffuse reflectance spectra were obtained with Philips PU 9800 FTIR spectrometer (Vernadsky Institute, USSR). The latter equipment was also employed for transmittance measurements through KBr pellets (2.5-25  $\mu\text{m}$  range).

The spectrum of kerogen isolated from coal tar is similar to that of asphaltite in the range of 0.3-25  $\mu\text{m}$  (Fig 2). The term "kerogen" is used for the insoluble residue after the treatment by usual organic solvents (1), but the asphaltite is entirely soluble in chloroform, so should be called as "bitumen".

The gradual changes in the slope of spectral continuum are observed in the range of 0.3-2.6  $\mu\text{m}$  for all the samples. The specimens with the highest carbon content (shungite, anthraxolite) have a low reflectance for all the range with a slight increasing of reflectance from 0.3 to 25  $\mu\text{m}$ . The asphaltite is very dark in the visible and very bright in the mid-infrared. The kerite is intermediate between above mentioned cases. The reddening in the visible and near-infrared seems to be longwavelength wing of broad absorption band possibly centered in the UV region. This feature may be due to electronic transitions in polycondensed aromatic hydrocarbons (2,3,4). We also propose that progressive carbonization and gradual growth in size of condensed aromatic structural units are responsible for the decrease of overall reflectance (and transmittance) in the infrared (4).

Only asphaltite displays marked absorption features in the near-infrared. The series of overlapping bands in 2.1-2.6  $\mu\text{m}$  range and a weaker complex feature near 1.7  $\mu\text{m}$  correspond to various overtones and combinations of alkyl (and possibly aromatic) fundamentals (5). The most intense absorptions near 2.31 and 2.35  $\mu\text{m}$  correlate with  $\text{CH}_2$  and  $\text{CH}_3$  stretching and bending combinations and overtones (Fig.1a). Similar features are presented in the reflectance spectra of oil sands (5).

The infrared spectra show the considerable loss of aliphatic groups (Fig.1b,3; Table I), the increase of the fraction of aromatic carbon and the decrease of the degree of aromatic substitution in kerite as compared with asphaltite. Similar changes were documented for heated coals (4) and were proposed to result from the gradual growth of polycyclic aromatic units with the increase of carbon content. Anthraxolite and shungite are opaque and don't exhibit any features (Fig.3).

**IMPLICATIONS FOR LOW ALBEDO ASTEROIDS.** Some asteroids from Outer Solar System are known to have reddened spectra both in the visible and in the near infrared. The degree of the reddening was found to increase with solar distance (6). Taking into account our results and the literature we suppose that the reddening of these asteroidal surfaces may be due to the broad absorption band of polycyclic aromatic hydrocarbons. At the same time the considerable content of aliphatic groups prevents from the ordering of aromatic layer structure so the surfaces of the most reddened (and distant) D-type asteroids are very bright in the infrared and the longwavelength wing of broad aromatic band is well developed. As the solar distance decreases the progressive loss of total and aliphatic hydrogen occurs. The loss of aliphatic groups promotes the growth in size of condensed aromatic structural units. This process results in the decrease of infrared albedo so that the spectral slope in the visible and near infrared also decreases.

Recently the weak absorption features near 2.2-2.3  $\mu\text{m}$  were observed in the spectra of some D-type asteroids (7). Similar features were also found in the spectra of Iapetus' dark material and some comets. The band was assigned to  $\text{C}\equiv\text{N}$ -bearing compounds, but we suggest that this feature may be due to the series of overlapping overtones and combinations of aliphatic ( $\text{CH}_2$  and  $\text{CH}_3$ ) and possibly aromatic groups, as in the spectra of oil sands (5) and asphaltite (Fig. 1).

**REFERENCES:** 1) Durand B. (1980). In: Kerogen: insoluble organic matter from sedimentary rocks (B. Durand ed.), Paris, 519 p. 2) Ito O. (1988), Fuel 67, 573-578. 3) Kmetko E.A. (1951), Phys. Rev. 82, 456-457. 4) Brown J.K. (1955), J. Chem. Soc., 744-757. 5) Cloutis E.A. (1990), LPS XXI, 203-204. 6) Vilas F. and Smith B.A. (1985), Icarus 64, 503-513. 7) Cruikshank D.P. et al. (1990), BAAS 22, No.3, 1098.

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Table I. Analysis of IR absorption bands in the spectra of solid carbonaceous materials

| Frequency, $\text{cm}^{-1}$ (Wavelength, microns) |                     |             | assignment  |  |
|---|---------------------|-------------|---|--|
| coal tar kerogen                                  | apshaltite          | kerite      |   |  |
| 5000-3850 (2.1-2.6)                               | 5000-3850 (2.1-2.6) | -           | overtone and combinations of hydrocarbons (mainly $\text{CH}_2$ and $\text{CH}_3$ ) |  |
| 3449 (2.90)                                       | 3448 (2.90)         | 3452 (2.90) | O-H stretch   |  |
| 3050 (3.28)                                       | 3050 (3.28)         | 3048 (3.28) | aromatic C-H stretch  |  |
| 2949 (3.39)                                       | 2950 (3.39)         | -           | $-\text{CH}_3$ -stretch (asymm.)  |  |
| 2922 (3.42)                                       | 2924 (3.42)         | 2922 (3.42) | $-\text{CH}_2$ -stretch (asymm.)  |  |
| 2853 (3.51)                                       | 2855 (3.50)         | 2856 (3.50) | $-\text{CH}_2$ -stretch (symm.)   |  |
| 1699 (5.89)                                       | 1699 (5.89)         | 1698 (5.89) | C=C, C=O stretch?   |  |
| 1604 (6.23)                                       | 1602 (6.24)         | 1602 (6.24) | $-\text{CH}_2$ and $-\text{CH}_3$ bend (asymm.)                                     |  |
| 1458 (6.86)                                       | 1457 (6.86)         | 1440 (6.94) | mainly $-\text{CH}_3$ bend (symm.)  |  |
| 1375 (7.27)                                       | 1376 (7.27)         | 1376 (7.27) | C-C, C-O, Si-O stretch?   |  |
| 1317 (7.59)                                       | 1317 (7.59)         | -           | in-plane deformation vibrations   |  |
| 1165 (8.58)                                       | 1167 (8.57)         | -           | of aromatic C-H groups?   |  |
| 1032 (9.69)                                       | 1032 (9.69)         | 1035 (9.66) | isolated H atoms  |  |
| -   | 1003 (9.97)         | 1005 (9.95) | out-of-plane deformation  |  |
| 871 (11.48)                                       | 868 (11.52)         | 876 (9.66)  | two adjacent H atoms  |  |
| -   | -                   | 834 (11.99) | vibrations  |  |
| 813 (12.30)                                       | 813 (12.30)         | 812 (12.31) | more than two   |  |
| 748 (13.37)                                       | 745 (13.42)         | 754 (13.26) | adjacent H atoms  |  |
|   |                     |             | C-H groups  |  |

The bands at 2340, 2360, 720, 678, 648  $\text{cm}^{-1}$  are due to atmospheric  $\text{CO}_2$

Fig.1. Normalized reflectance spectra (a) and FTIR reflectance spectra (b) of carbonaceous materials (bidirectional albedo at 0.56  $\mu\text{m}$ ; particle size,  $\mu\text{m}$ ). 1. apshaltite (0.021; <100). 2. asphaltite (0.025; 100-200). 3. kerite (0.022; <200). 4. anthraxoite (0.023; <100). 5. shungite (0.025; <100). Fig.2. FTIR diffuse reflectance spectra of (1) asphaltite (<100  $\mu\text{m}$ ) and coal tar "kerogen" (<100  $\mu\text{m}$ ). Fig.3. FTIR transmittance spectra of asphaltite (1), kerite (2), anthraxolite and shungite (3).

