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Impact and radiation influence on solid hydrocarbon transformation and structuring (by IR-spectroscopy)

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Solid hydrocarbons (bitumens)–typical specimens of natural organic minerals–are one of the most essential objects of petroleum geology and at the same time–one of the least investigated objects of organic mineralogy. Moreover they can be treated as admissible analogs of meteorite carbonaceous materials. According to terrestrial analog of meteoritic organic matter it's possible to estimate the chemical structure of extraterrestrial matter. Further investigation of impact force and radiation influence on the bitumen chemical structure change will make it possible to connect them with extraterrestrial organic matter.

This work represents the research of impact influence on the processes of transformation and structuring of asphaltite and changes in the molecular structure of solid bitumens constituting the carbonization series (asphaltite–kerite–anthraxolite), which were subjected to the impact of high radiation doses (10 and 100 Mrad) by infrared spectroscopy (IRS). In percussion experiments peak pressure varied from 10 to 63.4 GPa; temperature – from the first tens degrees to several hundreds degrees Celsius. The radiation experiment was performed in the Arzamas-16 Federal Nuclear Center in line with conditions described in [1].

Asphaltite, which sustained shock load from 17.3 to 23 GPa, didn't undergo considerable changes in its element composition. Though their IR-spectra differ from the spectrum of initial asphaltite by heightened intensity of absorption bands of aromatic groups, as well as by insignificant rise of heterogroups and condensed structures oscillation strength. At the same time the intensity of aliphatic (2 and 3) groups absorption hasn't changed. Probably there've just been the carbon and hydrogen atomic rearrangement. However, shock load up to 26.7 GPa leads to asphaltite transformation into the albertite. There've been observed the intensity decrease of aliphatic groups on its IR-spectrum. Under growth of shock load up to 60 GPa bitumen has lost essential part of aliphatic, hetero-groups. Relative intensity of absorption bands of aromatic groups has dramatically increased. By nature and intensity of absorption bands this spectrum looks more similar to the impsonite/lower anthraxolite.

A pressure of 60 GPa has lead to further matter carbonization. IR-spectra of these specimens have weak absorption bands and are mostly presented by aromatic structures. They've become similar to middle/high anthraxolite. A pressure of more than 60 GPa (with kamacite) has resulted in dramatic coalification of the material. The details have completely vanished in their spectra and they've grown similar with graphite. It should be noted that these specimens have been taken from the lower parts of ampoules. At the same time it has been established that IR-spectra of specimens from the upper parts are indicative of less coalification. Their spectra illustrate absorption bands of aliphatic, aromatic, and hetero-groups. They look similar to impsonite.

Gamma radiation of up to 10 Mrad on slightly metamorphosed solid bitumens of the asphaltite category substantially changed their molecular structures. In addition to the predominance of aliphatic components, the content of condensed structures is also increased in the molecular structures. The increase in the share of aliphatic groups (as compared with natural samples) is probably explained by the fact that alkyl radicals, which occur in the structure and/or form by radiation processes, interact to form aliphatic products with both higher and lower molecular masses. This process is accompanied by the significant loss of heterofunctional groups, because they are usually less resistant to radiation than hydrocarbons. The loss of the functional group is one of the main processes that accompany their radiation. An increase in radiation dose up to 100 Mrad results in further notable changes of the asphaltite molecular structure, which are reflected by the substantial loss of some aliphatic, aromatic, condensed, and heterofunctional groups. According to these spectral characteristics, the substance becomes similar to natural lower anthraxolites. The IR spectra of kerites subjected to radiation of up to 10 and 100 Mrad appeared to be generally identical to each other in terms of the set and intensity of absorption bands. However, in addition to areas with the aromatic structure, some segments with the aliphatic structure (CH2 and CH3 groups) are also present in kerite subjected to radiation of up to 10 Mrad. These groups probably occur inside benzene rings or replace marginal hydrocarbon cycles. Consequently, this element may enter the structure of cyclic and aromatic compounds as a "stitcher." In addition, oxygen-bearing groups of the C–O type are also present, although in insignificant quantities. It can be assumed that radioactive decay breaks down C–C bonds and produces C–O structures due to the linkage with oxygen atoms or the detachment of the hydrogen atom nearest to the functional group.It should be noted that natural kerites represent a complex combination of planar polycyclic and linear (aliphatic) areas with different degrees of their structure ordering [2]; i.e., they contain substantially more aromatic fragments than asphaltites. The content of C=C oscillation groups in the benzene ring is probably retained owing to the high radiation resistance of benzene in the IR spectra of kerites subjected to radiation. In general, the structure of radiated kerites demonstrates features typical of natural high anthraxolies. Absorption bands disappear as a result of the increase in the carbon content in the bitumen structure and the consequent increase in the share of aromatic rings. Therefore, the IR spectra of anthraxolites after the radiation impact become similar to those of graphites, although the IR spectra of anthraxolites subjected to radiation of up to 10 Mrad still demonstrate weak absorption bands characteristic of the benzene ring. Thus it might be supposed that if solid bitumens can be extraterrestrial matter analog (asteroids) than it might be probable that the formation of the whole spectrum of solid bitumens from kerite-like to antraxolite-like can be the result of impact events on asteroids. The results show that, in addition to temperature and impact, radiation can also affect the process of coalification. Using carbonization of the asphaltite–kerite–anthraxolite series as an example, we have established that traces of the influence of high-energy radiation on a substance are reflected in the modification of its structure and the appearance of features similar to those of graphite.

1. N. P. Yushkin, Vestn. Inst. Geol., No. 9, 2 (1999) [in Russian]. 2. V. G. Melkov and A. M. Sergeeva. Role of Solid Carbonaceous Substances in the Formation of Endogenic Uranium Mineralization. (Nedra, Moscow, 1990) [in Russian].

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