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Comparison of Products of Thermolysis in Steam Medium of Heavy Crude from Usinsk and Lyaokhe Oil Fields

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Abstract

Principal tendencies of variation in crude oil composition and properties during thermolysis under laboratory conditions have been studied by the example of heavy, high-viscosity crude oils from Usinsk and Lyaokhe oil fields. The experiments were conducted in an autoclave of periodic action in a range of temperatures 200–350 °C with addition of water and with application of a mineral admixture to study the nature of the influence of oil-bearing rock. Thermolysis products are represented by gases, insoluble carbonisation products, and converted oil. It has been found that the content of nitrogen, sulphur in liquid products of thermolysis differs from that for initial crude oils, the content of asphaltenes grows, the proportion of resins and oils decreases. Proportion of nitrogen bases, aromatic and oxygen-containing structural fragments in the composition of aquathermolysis products increases, amides appear in it. Specific absorption index of oils and their fractions at a wavelength of 500 nm tangibly change together with individual composition of alkanes and naphthalenes. Tendencies of variation in key parameters of composition during the aquathermolysis of Usinsk oil and crude oil from Lyaokhe oil field are quite opposite. The effect of mineral admixture on the results of thermolysis manifests itself only at the level of liquid yield, of their elemental, group, and functional (according to IR spectra) compositions and it is imperceptible at the level of functional group composition and at the level of individual composition of compounds that were identified in these oils.

Keywords: heavy crude, aquathermolysis, composition and properties of products

INTRODUCTION

Great attention is given in recent years to technologies of production and processing of heavy, highly resinous, high-viscosity crude oils, proportion of which shows an increase in the reserves pattern and in the rates of production of hydrocarbon raw [1].

An anomalously high viscosity of such oils (up to several thousand millipascal-seconds) and, as consequence, their small mobility under reservoir conditions serves the main obstruction during their extraction. Thermal methods, particularly, fire flooding, pumping hot water or steam into injection wells, steam cyclic treatments of output wells [2–5] are in general use to enhance the coefficient of extraction of heavy high-viscosity crude oils.

An action of the heat-transfer mediums listed above upon in-place oil can be followed not only by a change in its physical properties (to take an example, by a decrease of its viscosity), but it may also result in changing the crude oil composition in consequence of its aquathermolysis. With an increase of temperature above a certain limit, partial decomposition of oil and a variation in its elemental, group, and fractional compositions will occur.

Two approaches are applied to elicit the history of composition and properties of crude oils with the use of thermal methods to enhance the blow-down recovery. The first approach involves examination of oil and gas samples that were taken in different areas of an oil field and at various stages of its operation under heat-transfer medium repressuring mode

[6–8]. The second approach includes carrying out laboratory experiments that concern aquathermolysis of oils or their fractions under conditions that simulate steam action and fire flooding at a certain extent [8–17]. The necessity of laboratory simulation is caused by the circumstance that the composition history of crude oil *in situ* under the effect of the steam factor may be levelled by the previously non-extracted oil from reservoir sites of a low permeability that is involved in the process of production.

Performed in papers [9–11] are laboratory investigations with oil filled formations of the Permian-Carboniferous reservoir of Usinsk oil field or with expressly prepared laboratory formations with the use of the header formation and formation fluids of this reservoir. A coefficient of oil withdrawal, viscoelastic expansion coefficient of oil, volume of the evolved gas, and its composition were determined in an interval of temperatures 25–350 °C. A much less attention was given to the analysis of crude oil composition [7]. The works [14, 15] studied the composition history of heavy crude of Lyaokhe oil field during the course of their laboratory aquathermolysis at the temperatures from 160 to 280 °C. With an increase of the thermolysis temperature, we observed a decrease of viscosity, of the content of resin-asphaltene matter (RAM), and its average molecular weight. The content of aromatic and saturated hydrocarbons, *vice versa*, increased.

As the aforesaid suggests, practically no information is available on the composition of liquid products from laboratory aquathermolysis of Usinsk oil. The information that was gained for oil of Lyaokhe field is much wider; however, the products that were produced at a temperature of 240 °C were characterized in most detail. In addition, it is advisable to study features of the aquathermolysis of heavy high-viscosity crude that are significantly dissimilar in their properties (viscosity, elemental and group content, *i. e.* their sulphur and nitrogen content, the ratio and total gum content and content of asphaltenes).

The purpose of this work is a comparative study of the nature of varying composition and properties of high-sulphur and low-sulphur heavy crude from Usinsk and Lyaokhe oil fields under conditions that simulate steam methods of enhancing the blow-down recovery.

EXPERIMENTAL

Heavy, highly resinous, high-viscosity, low-paraffin, high-sulphur [18] crude oil of a Permian-Carboniferous reservoir of Usinsk oil field has been sampled in an area that was not influenced by thermal methods of enhancing the blow-down recovery (the well No. 8145, the cluster No. 121). Oil occurs in fractured-vugular-porosity types carbonates of bottom Permian, top and bottom carbon [18]. Its combined content of RAM we determined comprises 30 to 36 mass %. The second subject of investigation is heavy, low-sulphur, highly resinous, high-viscosity, low-paraffin crude from Lyaokhe oil field that is located in the northeast of China. This crude was not either exposed to a thermal action during the extraction (the well D84-3173). This oil occurs in sandstones, its combined content of RAM, according to our data, exceeds 46 mass %. Contrary to Usinsk oil, the crude oil from Lyaokhe oil field is deeply senile, because it is characterized by an anomalously high content of gopanes demethylated at the position 25, which, according to work [19], bears witness to a deep biodegradation of oils.

We used thermolysis of heavy crudes in a steam medium (aquathermolysis) for laboratory simulation of processes, wherein crude oil is involved during steam bed stimulation. Samples of oils were put in an autoclave from stainless steel at a mass ratio of oil to water that was equal to 7 : 3. It was found previously [14, 15] that the maximum effect was observed at such ratio upon the composition history and properties of crude oil from Lyaokhe field. We conducted also experiments in the presence of a mineral admixture to study the nature of action of oil-bearing rock on the composition of products. A carbonaceous admixture, that is marble, was used for oil from Usinsk oil field, and sandstone was used for oil from Lyaokhe field, with the mass ratio oil : admixture that was equal to 1 : 7, with the preserved initial ratio of oil to water. Samples in an autoclave were heated to 200–350 °C and kept at a given temperature over the course of 12 h. Design pressure in the autoclave ranged up to 5.8 MPa. After the autoclave was chilled and opened, a yield of the main products was determined: liquid products of thermolysis that were dissoluble in hot benzene, products of carbonisation indissoluble in it, gases (based on the difference). When used a mineral admixture, sorbed thereon liquid products of thermolysis were extracted with chloroform in a Soxhlet apparatus. Solutions of the received products were dried over anhydrous sodium sulphate. Resolvents were distilled off in vacuum; the samples were brought to a constant mass in the air at a temperature of 70 °C.

To determine the group content [20], asphaltenes were precipitated from benzene solutions of oils (2 mL/g) and liquid products of their aquathermolysis by an excess of hexane at a ratio of 40 mL/g. Separation of malthenes into oils, benzene resins (BR) and alcohol-benzene resins (ABR) was performed chromatographically on ASK silica gel, at a ratio oil : sorbent that was equal to 1 : 40 for crude from Usinsk oil field and 1 : 60 for crude oil from the Lyaokhe field. Oils were eluated with a hexane–benzene system (70 : 30 by volume), BR and ABR were eluated with benzene and with a ethanol–benzene system (50 : 50 by volume), respectively.

IR spectra were registered in a FTIR spectrometer NICOLET 5700 in the field of 400–4000 cm^{-1}. Samples of crude oils were applied onto a plate from KBr in the form of a film from their solution in CCl_4. Further treatment of the IR spectra and determination of optical density was conducted with the use of OMNIC 7.2 software of Thermo Nicolet Corp. Values of optical density of absorption bands were normalized with respect to the optical density of the band in the region of 1465 cm^{-1} [21].

Determination of a specific absorption index of solutions of the obtained samples was performed at a wavelength of 500 nm with the use of a single beam Spekol-21 visible spectrophotometer. To do this, we prepared a benzene solution with a known concentration of a being investigated sample, measured its optical density, and then the initial solution was consecutively diluted with the registration of a value of optical density at each step of dilution. We set off a linear region on the plot of optical density (D) *versus* the concentration c and the region was approximated with the least squares method by the equation $D = a + Kc$. In cases when $a = 0$ and $c = 1$ g/L, a specific absorption index of the being investigated object (K_{500}) was calculated.

Oils were analysed by the chromatography/mass spectrometry method. The analysis was conducted in a Shimadzu QP 5050A mass spectrometer. GLC analysis occurred with application of a regime of programmed temperature rise from 80 to 290 °C at a rate of 2 °C/min and then at final temperature over the course of 25 min. A DB-5-MS + D6 quartz capillary column was used for separation; it was 30 m in length, with the inner diameter of 0.25 mm with dimethylpolysiloxane phase, 0.25 μm in thickness. Helium was the carrier gas. Chromatograms and mass fragmentograms of a certain classes of compounds were reconstructed on the basis of the chromatogram from total ionic current with the use of specific ions. Full mass spectra of chromatographic peaks were analysed in most cases to reach a more reliable interpretation.

RESULTS AND DISCUSSION

A liquid yield during the aquathermolysis experiments always comprised <100 %. Mass losses during the thermolysis of Usinsk crude oil were equal to 10.80–14.78 % and from 2.50 up to 7.28 % for oil from Lyaokhe oil field. The greatest losses for both kinds of oil are evidenced at 350 °C, which is most likely to be related with an intensification of a process of pyrolysis of oils at this temperature. The mass losses are related for the most part with the formation of gases and, to a much smaller extent, with the formation of insoluble carbonisation products (carbene-carboids). No analysis of gases was performed, but it is possible to assert based on the characteristic odour that H_2S is present in them. In addition, an assumption can be made on the basis of works [11, 12] that CO, CO_2, CH_4 are present in the gases together with gases of methane series, at a small amount. It is necessary to note a different nature of the effect that the feature of a mineral admixture has on the magnitude of the mass loss. Accordingly, whereas the use of an admixture of a carbonaceous nature leads to an appreciable decrease of losses in the experiments with the Usinsk crude oil, the admixture of sandstone in the case of crude oil from Lyaokhe oil field practically in all cases produces an increase in the losses (most likely, due to the effect of clay minerals that are present in sandstone).

The formation of carbonisation products begins even at a temperature of 200 °C, and a rise in the thermolysis temperature makes for intensification of this process. The emergence of carbonisation products may have a negative effect on the blow-down recovery because of clogging of a pore space of the header formations.

Distinctions between crude oils manifest themselves also in behaviour of heteroatoms. To take an illustration, a mass fraction of nitrogen in liquid products of thermolysis for Usinsk crude oil is apparently less by comparison to that for initial crude oil (0.22–0.50 and 0.65 %, respectively). In the case of crude oil from Lyaokhe oil field, only one point (350 °C) is observed where the mass fraction of nitrogen is less by comparison to that for the initial sample (0.85 and 1.03 %, respectively). In addition, a mass fraction of sulphur in liquid products of thermolysis for Usinsk crude oil was found to be higher as compared with the initial oil (2.21–2.42 and 2.06 %, respectively), while the reversed pattern (0.33–0.40 and 0.51 %, respectively) was observed for crude oil from Lyaokhe oil field.

A change in the group content of crude oils occurs during their thermolysis in the steam medium. Shown in Fig. 1 are plots of the content of asphaltenes (A), oils (O), BR, and ABR in liquid products *versus* the thermolysis temperature. It is evident that products of aquathermolysis of crude oil from Lyaokhe oil field differ much more strongly in their group content from the initial crude oil, than they do in the case of Usinsk crude oil. The effect of changed group content shows up even at a minimal temperature of thermolysis. Contrary to our expectations, the content of oils in the liquid products that have been obtained at this temperature decreases and the content of asphaltenes and BR increases. In addition, essential growth of ABR content is evidenced for crude oil from Lyaokhe oil field while it slightly decreases for Usinsk crude oil. At a further rise in the thermolysis temperature, both crude oils are typified by a decrease of their BR and ABR content and their total, and by an increase their content of asphaltenes. The content of oils for Usinsk crude oil exceeds its initial content only in thermolysis products that have been obtained at 350 °C, and it does not reaches the initial level even at this temperature for the crude oil from Lyaokhe oil field.

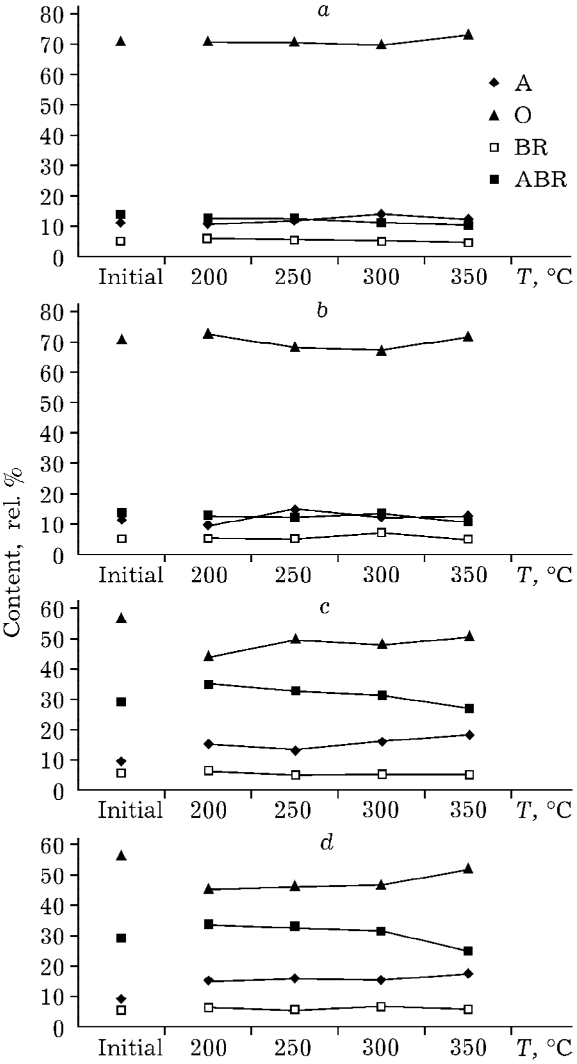


Fig. 1. Group content of liquid products that have been obtained at various temperatures from crude oil of Usinsk oil field (*a*, *b*) and crude oil from Liaokhe oil field (*c*, *d*): *a*, *c* – without mineral admixture; *b*, *d* – with marble (*b*) and sandstone (*d*); A – asphaltenes, O – oils, BR – benzene resins, ABR – alcohol-benzene resins.

A build up of the content of oils (their most low polymeric fraction) and a decrease of the gum content and the content of asphaltenes may be considered a positive effect during crude oil production and its subsequent processing.

However, the trends of a changing group content of heavy crude that were revealed in the laboratory experiment manifest themselves only in a significant decrease of combined gum content.

IR spectra of initial oils from Usinsk and Lyaokhe oil fields are distinct from each other. Accordingly, crude oil from Lyaokhe oil field is typified by a higher (by the factor of 2-3) normalized optical density of bands in the region of carbonyl-containing (1700 cm^{-1}), aromatic (1600 cm^{-1}) compounds, and sulphoxides (1030 cm^{-1}) as compared with Usinsk crude oil.

Thermolysis of crude oils in the steam medium leads to changes in the IR spectrum. The differences of liquid products of thermolysis from the initial crude oils are perceptible even upon comparison of spectra of non-separated products. Crude oils of both oilfields are typified by a gain in the optical density of bands in the absorption regions of aromatic compounds (1600, 860, 820, 760 cm^{-1}) and sulphoxides (1030 cm^{-1}). Distinctions between crude oils consist in a reverse nature of change in the optical density of the bands that correspond to alkyl units of more than 4 carbon atoms in length (730 cm^{-1}) and to carbonyl-containing structural fragments (1700 cm^{-1}). Whereas these bands are less pronounced by comparison to the initial crude oil in IR spectrum of liquid products of thermolysis of Usinsk oil, the reversed pattern is evidenced for crude oil from Lyaokhe oil field. Meanwhile, the variation of optical density of bands for crude oil from Lyaokhe oil field is more tangible when compared to the variation of optical density for Usinsk crude oil.

The effect of a mineral admixture on Usinsk crude oil manifests itself much more strongly when compared to those changes that follow the addition of a mineral admixture in the case of crude oil from Lyaokhe oil field. At last, optical density of absorption bands in IR spectra of aquathermolysis products of crude oil from

TABLE 1

Values of specific absorption indexes K_{500}, 10^{-3} L/(g · cm)

Sample*	Crude oil	Asphaltenes	Oils	Resins	
				benzene	alcohol-benzene
U initial	979	6016	64	1231	873
U-200	1103	7057	64	1242	1411
U-250	1240	7424	79	1277	1437
U-300	1059	7334	84	1077	837
U-350	1451	8071	76	1025	1201
U initial	979	6016	64	1231	873
U-200M	1082	7394	75	1154	1210
U-250M	1351	6831	81	1120	1372
U-300M	1253	7462	63	1130	1020
U-350M	1291	8421	67	1071	1180
L initial.	1622	10 783	73	1142	1309
L-200	1643	6614	41	902	1651
L-250	1701	7150	42	984	1848
L-300	1778	6772	43	863	1543
L-350	1780	8217	68	1132	1427
L initial	1622	10 783	73	1142	1309
L-200S	1405	6653	41	1144	1980
L-250S	1452	6707	47	886	1835
L-300S	1676	7010	49	1008	1538
L-350S	1821	7024	47	847	1370

*Here and in Tables 2, 3: the first letter stands for crude oil (U – Usinsk, L – Lyaokhe); the figure stands for the temperature, the last letters denote the mineral carrier (M – marble, S – sandstone).

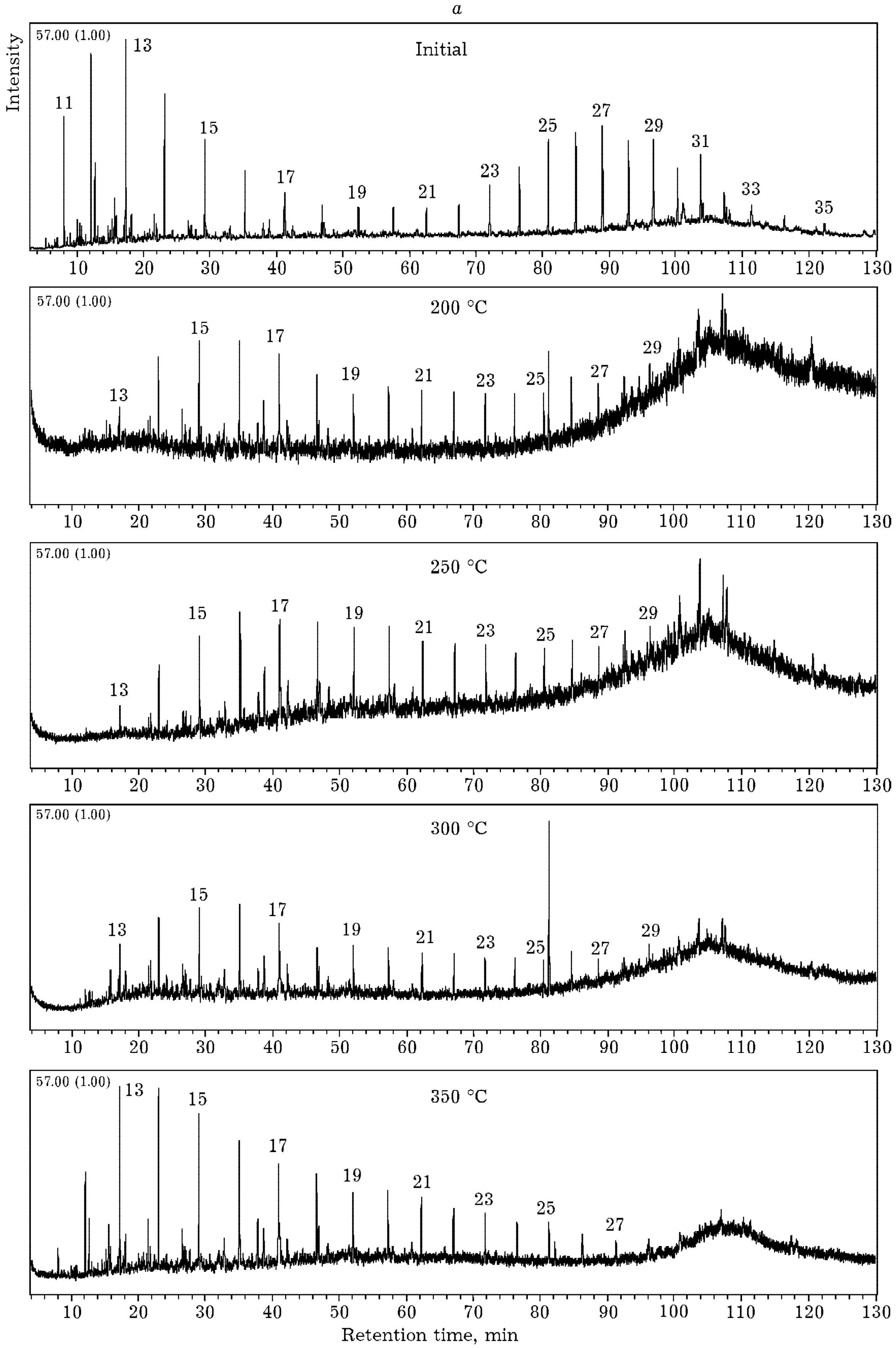
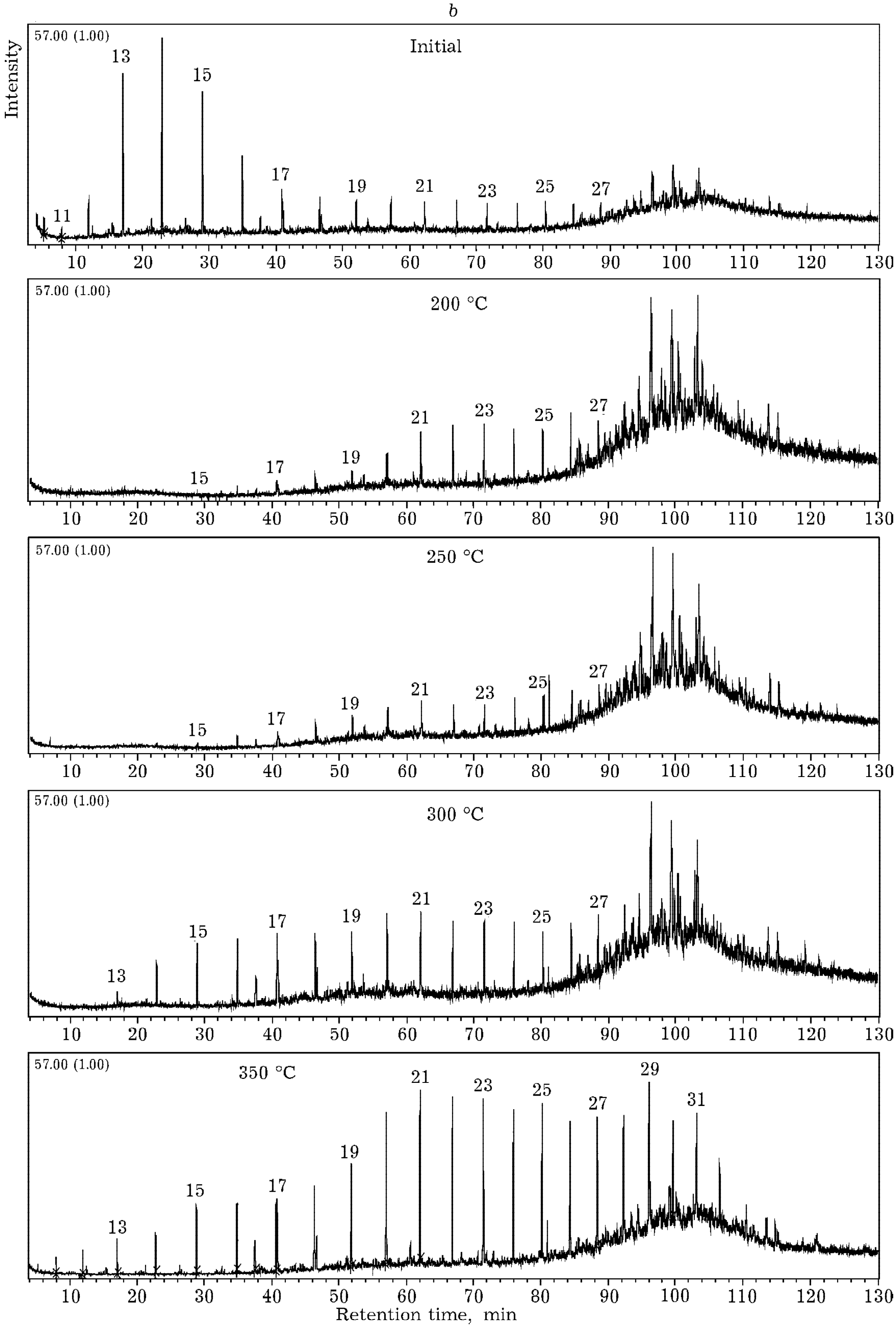


Fig. 2. Mass fragmentograms of oils from crude oil and its products of aquathermolysis of Usinsk oil field (*a*)



and from Lyaokhe oil field (*b*) with respect to an ion with m/z 57 (alkanes).

Usinsk oil field, as a rule, monotonically varies with an increase in temperature, whereas it first increases and then sharply drops down for crude oil from Lyaokhe oil field. For the products that were received at 350 °C, it is close to the optical density of the bands in the spectrum of the initial oil.

A reverse nature of change in optical density for the majority of absorption bands manifests itself also for fractions of extraction-chromatographic fractionation (asphaltenes, oils, BR, ABR) that were isolated from liquid products of thermolysis of the studied crude oils. The most interesting feature that did not manifest itself in IR spectra of non-separated products of thermolysis is an increase of optical density of absorption bands in the region of 1650 and 1560 cm^{-1} in IR spectra of ABR. The first band bears witness to an increased content of amide fragments [22], the second one bears witness to an increased content of compounds of the basic nature, for example, derivatives of quinoline [23]. In addition, ABR IR spectra of thermolysis products show an increase of optical density of bands in the region of 1700–1740 cm^{-1} that correspond to various carbonyl-containing compounds (aldehydes, acids, esters) [21, 22].

An increased mass fraction of oxygen-containing functional groups in aquathermolysis products together with compounds of the basic nature allows one to assume that surface-active properties inherent in these substances are more distinct. In its turn, this should lead to a decreased interfacial tension at the interface of water and oil, as well as to an enhanced hydrophily of the rock formation and, as a consequence, to a gain of the effect of blow-down recovery.

Significant difference in values of specific absorption index K_{500} of liquid products of aquathermolysis and ingredients that were isolated from them (asphaltenes, oils, BR, ABR) from the associated indices of initial crude oils (Table 1) is obvious testimony to a variation in not only the group content of crude oils, but also in composition of particular ingredients and their structure. In addition, the products that were obtained in the experiments practically in all cases appreciably differ from initial oil in their magnitude of K_{500}. The liquid products of aquathermolysis of both crude oils are typified by an increase in the specific absorption index with growing temperature. Alternative relationship is observed in the presence of a mineral admixture; however, the liquid products are typified in most cases by a higher value of K_{500} as compared with the initial crude oils. It should be remarked that a deviation of the K_{500} magnitude from the reference value for Usinsk crude oil is always higher when compared to that for crude oil from Lyaokhe oil field. This parameter appreciably varies also for individual ingredients of thermolysis products. Typical of crude oils of both oilfields is a decrease of this parameter for BR and its increase

TABLE 2

Certain composition parameters of alkanes for the studied crude oils and products of their aquathermolysis

Sample*	C_{27}/C_{17}	LMH/HMH	Proportion of C_{17+}, %	Sample	C_{27}/C_{17}	LMH/HMH	Proportion of C_{17+}, %
U initial	1.978	0.953	59.3	L initial	0.459	4.556	32.6
U-200	0.328	1.666	67.5	L-200	4.884	0.170	97.3
U-250	0.224	1.586	72.0	L-250	2.874	0.282	94.6
U-300	0.160	2.549	58.1	L-300	1.025	0.570	86.7
U-350	0.247	3.018	49.0	L-350	1.875	0.378	90.2
U initial	1.978	0.953	59.3	L initial	0.459	4.556	32.6
U-200M	0.763	2.828	43.8	L-200S	3.550	0.334	92.7
U-250M	0.125	2.038	62.0	L-250S	1.723	0.564	86.6
U-300M	0.343	2.586	50.3	L-300S	2.124	0.286	93.8
U-350M	0.374	1.412	72.0	L-350S	1.951	0.302	93.7

*For design. see Table 1.

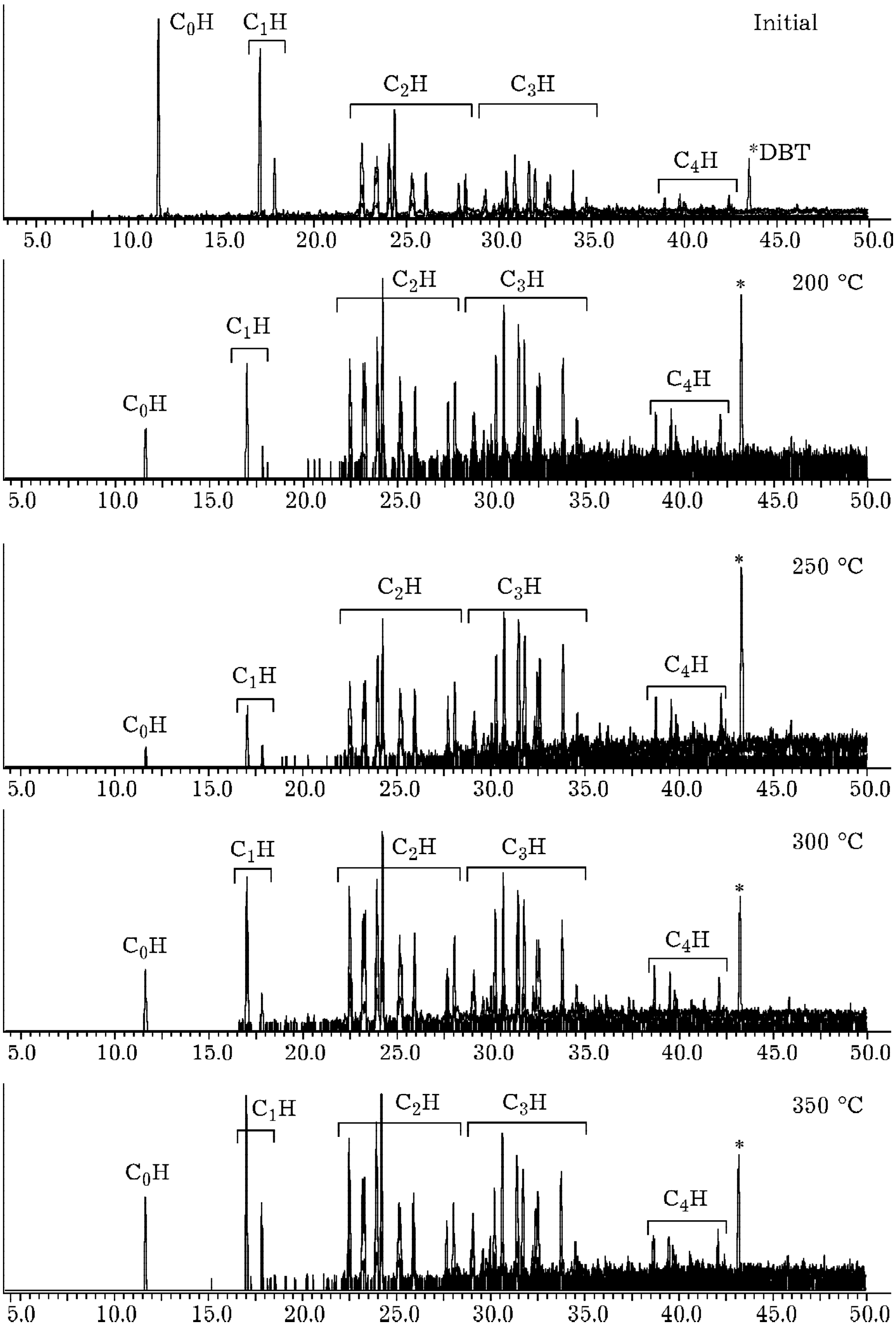


Fig. 3. Mass chromatograms of oils from Usinsk crude oil and its products of aquathermolysis with respect to ions with *m/z* 128, 141, 156, 170, 184 (naphthalenes). DBT – dibenzothiophene.

in ABR. Meanwhile, the variation in the K_{500} magnitude for asphaltenes and oils of thermolysis products for different crude oils is of a reversed nature. Accordingly, whereas this parameter drastically increases in the case of Usinsk crude oil, it *vice versa* shows an appreciable decrease for crude oil from Lyaokhe oil field. The variation in the specific absorption index may be indicative of a change in the average molecular weight of these fractions during the aquathermolysis [24].

Results of the analysis of oils by the chromatography/mass spectrometry method testify that laboratory thermolysis of the studied crude oils in a steam medium leads to an appreciable variation in the individual composition of certain classes of compounds and to a variation in their relative content in the mixture.

The most complete results have been obtained for crude oil from Usinsk oil field. The number of the identified classes of compounds is much less for oils of crude oil from Lyaokhe oil field.

Molecular mass distribution of alkanes in initial Usinsk crude oil shows a clear-cut bimodal nature, and this bimodal feature disappears in the products of thermolysis (Fig. 2, *a*). In addition, the proportion of high molecular mass homologues (HMH) decreases. It is evident from data of Table 2 that the associated parameter C_{27}/C_{17} in liquid products of aquathermolysis is apparently less by comparison to that for the initial crude oil. An increased proportion of low molecular mass homologues (LMH) is also supported by a variation in the ratio of the combined content of homologues with the number of carbon atoms in their molecule less than 21 (LMH) and higher (HMH) that is obviously increases in the products of thermolysis. It is worth noting the circumstance that at the same time, the maximum of the distribution in the low molecular mass mode is shifted from C_{13} to C_{16} and it returns to C_{13} only at the maximum temperature of aquathermolysis.

Crude oil from Lyaokhe oil field is characterized by quite opposite nature of the variation in its composition of alkanes. It has been apparent in Fig. 2, *b* and Table 2 that proportion of HMH in the products of thermolysis of this crude oil appreciably increases. It appears that it is determined by the fact that contrary to Usinsk crude oil, the extent of their generation during the aquathermolysis of RAM becomes dominant over the extent of cracking. A tangible increase in the proportion of solid alkanes (C_{17+}) in products of aquathermolysis of crude oil from Lyaokhe oil field may lead to an unwanted phenomenon, that is, to a rise in the solidification point of the produced crude oils. Application of mineral admixtures during aquathermolysis of the studied oils has no effect on the nature of the variation in the composition of alkanes.

TABLE 3

Certain composition parameters of naphthalenes from Usinsk crude oil and its products of aquathermolysis

Sample*	Content of homologues, rel. %				
	C_0H	C_1H	C_2H	C_3H	C_4H
U initial	11.10	16.44	34.34	29.25	8.87
U-200	1.91	6.11	36.82	42.33	12.83
U-250	0.63	3.77	30.63	48.19	16.77
U-300	2.38	9.11	38.18	38.68	11.64
U-350	2.78	11.46	35.69	37.81	12.26
U initial	11.10	16.44	34.34	29.25	8.87
U-200MR	7.04	14.93	35.09	34.98	7.95
U-250MR	1.92	4.53	32.07	45.84	15.63
U-300MR	3.58	7.91	34.83	40.37	13.31
U-350MR	0.88	4.38	30.29	46.79	17.65

*For design. see Table 1.

Functional group composition of compounds of naphthalene series substantially changes for Usinsk crude oil. It is evident from data of Fig. 3 and Table 3 that a proportion of alkyl-substituted homologues (C_1–C_4) in thermolysis products increases, and in so doing, the ratio of methylnaphthalenes to naphthalene rises together with the ratio of naphthalenes (C_2–C_4) to methylnaphthalenes. A mineral admixture that is present in the reaction mixture exerts no effect on the features of the revealed changes.

Less perceptible variations of composition are typical for tricyclic homo- and heteroaromatic compounds. The former ones are presented in oils of the initial crude oil by compounds of phenanthrene series. Anthracene in small proportion that appears in the products of thermolysis has been detected at a temperature of 300 °C and over. The relationship of phenanthrene to naphthalene increases by an order of magnitude in the thermolysis products.

As regards the composition of compounds of dibenzothiophene series, it has been found just a minor alteration of its relative content of various homologues. Similar to the previous case, a mineral admixture exerts no effect on the nature of variation in the composition of analysed compounds.

CONCLUSION

Thus it has been found in our laboratory experiments under conditions that model the steam bed stimulation that the studied heavy crude in the range of temperatures 200–350 °C undergo hydrothermal transformation that is followed by evolving of gases, including H_2S, by the formation of indissoluble products of carbonisation, as well as by a variation in the group content of crude oil, which manifests itself by an increased content of asphaltenes and by a decreased content of oils, BR, and ABR.

A proportion of nitrogen bases, aromatic and oxygen-containing structural fragments in the composition of aquathermolysis products increases; amides appear. A change in composition and spectral properties is typical of all oil fractions.

Laboratory thermolysis of heavy crude in the medium of steam leads to both an appreciable change in the individual composition of certain classes of compounds, and to a variation of their relative contents in oils.

Tendencies of variation of most composition parameters during the aquathermolysis of Usinsk crude oil and oil from Lyaokhe oil field are quite opposite.

The effect of a mineral admixture on the thermolysis outcomes shows up only at a level of liquid yield, of their elemental, group, and functional (according to their IR spectra) composition and it was not observed at a level of functional group composition and individual composition of the compounds that were identified in oils.

The revealed directions of transformation of heavy crude can be favourable for their easier expulsion from a bed when employing steam stimulation due to an increase in the gas factor, and due to the formation of substances with pronounced surface-active properties, enriched by nitrogen bases, by oxygen-containing structural fragments. A possible rise in the solidification point (for crude oil from Lyaokhe oil field), the formation of aggressive gases and insoluble products of carbonisation that are capable to colmatage a pore space of the header formation rank among the negative effects.

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