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About characteristic features of naftides in connection with the process of formation of deposits

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Abstract. Studies have been carried out to assess the qualitative features of fluids, aimed at identifying the regularities in the differentiation of the properties of naphthides during the formation of hydrocarbon deposits outside anticlinal structures. Due to the exhaustion of hydrocarbon reserves associated with anticlinal traps, the main attention is paid to the composition of fluids confined specifically to non-anticlinal structures – to traps of a combined structure. Physicochemical properties, trace element (TE) composition, phase states of naphthides in deposits affected by hypergenetic or catagenetic processes have been analyzed using specific examples; in regions with a possible additional inflow of hydrocarbons (Romashkino group of fields in the Republic of Tatarstan); in the crystalline basement of sedimentary basins. The results of the analysis make it possible to predict the characteristic features of fluids in traps of various types at certain levels of the processes of oil formation, secondary transformation and destruction of accumulations, mainly due to the tectonic regime of the sedimentary basin. With prolonged lateral migration, at great depths with good isolation from surface weathering agents, light oils, depleted in TE, more often of nickel specialization, are found in lithologically and stratigraphically screened traps, and gas condensate accumulations are possible. At shallow depths with poor regional or local seals, heavy, highly viscous hypergene-transformed oils, natural bitumens with high concentrations of industrially significant metals V, Ni, Co, Mo Cd, U were found in traps of pinch-out zones and various types of trap screening. tectonically-screened traps) with a multiphase filling of traps and, at the same time, the influence and inflow of deep ones, i.e. more catagenically transformed fluids, it is possible to detect light oils of the nickel type or gas condensates enriched with elements of "magmatic emanations" – As, Hg, Al, B, rare earth elements. Oils filling combined traps in the crystalline basement within platform oil and gas basins, as a rule, do not differ in their compositional peculiarities in comparison with oils in overlying or adjacent parts of the sedimentary section.

Keywords: combined traps, reservoir, tectonic regime, trace element composition of oil, forecast of oil composition, zones of hyperegenesis, catagenesis, basement

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Introduction

The process of naphthide genesis is complex due to the joint interaction of exogenous and endogenous factors functionally related to the geodynamic history of the region. The influence of these processes should be reflected in the geochemical appearance of the generated fluids, in particular, in their microelement (ME) composition, which is an important source of information, and, therefore, determine the genetic type of oil at various stages of formation, preservation and destruction of deposits. At present, in oil and gas basins (OGB) with a long history of resource development, there is a low probability of discovering large oil and gas fields confined to anticlinal structures. In this regard, there is a reorientation towards forecasting traps of a more complex structure – combined traps. This tendency manifests itself in the search for deposits of hydrocarbon (HC) raw materials in the territory of not only Russian, but also many foreign basins. That is why the article analyzes the influence of the geochemical factor on the properties of naphthides in deposits of various oil and gas fields of the world, and predicts their composition in combined traps in connection with the conditions of formation of deposits.

About combined traps

Assessing the prospects for oil and gas potential is impossible without identifying the nature and structure of the traps. It was proposed (Levorsen, 1970) to distinguish traps of three main types: structural (traps of anticlines and other structures associated with tectonic deformations (both plicative and disjunctive)),

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stratigraphic (stratigraphic, lithological, hydrodynamic traps) and combined traps. It is also necessary to clarify the concept of a trap: “A trap in which there is an oil and/or gas reservoir is a subsoil area consisting of reservoirs and adjacent poorly permeable deposits, capable of accumulating hydrocarbons in its reservoir part and enclosing an oil and/or gas” (Olenin, 1977). That is, when delineating traps and predicting accumulations, it should be borne in mind that not every trap will become a deposit, conditions are necessary for the safety of accumulations. A more detailed review and analysis of the classification features of traps is given in (Punanova, 2020a; 2020b).

As the world practice of oil and gas exploration shows, combined traps account for almost 5 times more deposits than hydrocarbon reservoirs controlled by one leading factor (lithological, stratigraphic, tectonic, geodynamic, hydrogeological, etc.). A characteristic feature of combined traps is a combination of structural, lithological, stratigraphic, and disjunctive components (Aleksin et al., 1992). The degree of participation of certain forming factors is reflected in the names of the corresponding groups of traps. Traps of the structural-lithological type are isolated during tectonic deformation of the wedging out layers, in the event that the fault is conductive, creating conservation. These traps and the hydrocarbon deposits controlled by them are usually located on the wings and reclines of anticlinal folds, structural noses, and can also be located in synclines (if there is no formation water in the reservoir) and within the monoclinal parts of large structural elements. Structural and stratigraphic traps are also numerous, their shape is determined by the degree of erosion of local and large uplifts, unconformably overlapped by impermeable rocks.

The importance of assessing the nature (type) of traps and their potential in terms of hydrocarbon resources is evidenced by studies carried out by a group of specialists (Dolson et al., 2018). The authors show the importance of discoveries of deposits in various types of traps for over a century in the world hydrocarbon reserves (expressed in BBOE – accumulated reserves in billions of barrels of oil equivalent) from the late 1800s to the present day. The results express the relationship between the cumulative growth in resources from discoveries and wells drilled. In addition to the abrupt initial uplifts caused by discoveries in the North American, Russian and Middle Eastern territories of hydrocarbon accumulations, there was a noticeable change in the 2000s associated with large reserves in stratigraphic and combined traps and due to the wider use of 3D seismic work. Halbouty (2003) was the first to draw attention to this change, showing that the volume of resources of stratigraphic traps in the 1990s began to account for 15 % of the volume of resources of significant basins, which is higher than the 10 % indicator throughout the entire historical period before that. The largest concentration of giants is found in the Middle East, North America and Russia, but almost every operating oil basin has the potential for giant fields, which are currently being discovered in complex traps of a combined type (Dolson et al., 2018).

Assessment of the qualitative features of fluids in connection with the conditions of formation of deposits

In order to assess the properties of fluids caused by the processes of formation of deposits, let us briefly dwell on the general laws that determine the composition of oils in the process of ontogenesis. In the sedimentary section of the earth’s crust, according to the vertical evolutionary zoning of HC formation associated with an increase in depth, temperature gradient, pressure, and type of initial organic matter, the composition of HC systems generated in their bowels is transformed – from immature (heavy) at shallow depths to transformed mature and super-mature (light) oils and condensates at great depths (Table 1).

Ontogenesis of naphthides, covering the processes of generation, accumulation, conservation and destruction of oil and gas accumulations, is due to geodynamic stress in the earth’s crust, which is one of the decisive factors leading to a variety of properties of oils and metallogenic specialization of oil and gas fields.

Analysis of the literature and experimental material on the geology and geochemistry of naphthides in the oil and gas fields of the world of various tectonic structures (Chakhmakhchev et al., 1984; Babaev, Punanova, 2014; Punanova, Vinogradova, 2016; Punanova, 2019a) quite definitely indicates that the physicochemical properties of oils, HC composition, content and ratio of ME in them are determined by the characteristics of the initial organic matter (OM), the lithofacies conditions of its burial, the subsequent accumulation and destruction of accumulations, the results of geodynamic endogenous and exogenous processes. Based on this, the genetic makeup of oil, which is functionally related to the geological history of the region, will be specific in each type of basin. In the platform and geosynclinal areas, there are quite distinct differences in the rates and scales of generation and migration of hydrocarbons, due to the features of their structure and development due to the influence of geodynamic processes in the earth’s crust. The differences are manifested in the absolute values and gradients of the thickness of sedimentary fill, temperature conditions, the nature and degree of dislocation of rocks, the degree of openness and disturbance of structures (Kravchenko, 2004).

Taking into account these features of the basins, the genetic models of oils in connection with the stages of ontogenesis in terms of their phase state, physicochemical

Stages of lithogenesis	Stages of catagenesis	Vitrinite reflectance, R°,%	Depth, km	Paleo-temperature, °C	Variety of hydrocarbon deposits	Chemical type of oil
Diagenesis		0.25			Dry gas Gas hydrates Hydrothermal oil	
Proto-catagenesis	PC_1	0.30	0.2-1.4	25-50		
	PC_2	0.40				A^a-1, A^b-1, A^c-1 B-2, B-1
	PC_3	0.50			Immature oil and condensate	
Meso-catagenesis	MC_1		1.4-2.0	50-90		
		0.65			Low mature oil	B-2, A-2, A-1
	MC_2		2.2-3.2	90-130		
		0.8			Mature oil	A-2, A-1
	MC_3	1.40	3.2-4.0	130-160	Highly mature oil	A-1
	MC_4	1.55	4.0-4.5	160-185	Wet gas Condensate	
	MC_5	2.00		185-200		
Apo-catagenesis	AC_1	2.50	>5	200-230	Dry gas	
	AC_2	3.50		>230		
	AC_3	4.70				

Tab. 1. Scheme of a fluid-geochemical model of oil and gas formation in sedimentary basins (based on materials by N.B. Vassoevich, Al.A. Petrov, S.G. Neruchev, O.K. Bazhenova, K.E. Peters, J.M. Moldowan, et al.)

properties and the degree of their enrichment with ME were characterized, and recommendations were given on the practical use of ME criteria for naphthides to assess the prospects for oil and gas potential (Punanova, 2017). The developed classification of oils in the oil and gas basin by their enrichment in ME makes it possible to predict the composition of fluids in traps of different types at certain levels of ontogenetic processes. Oils of the main zone of oil formation (vanadium metallogeny) and oils of the early stage of generation (nickel metallogeny) are more influenced by the upper sedimentary crust; they contain more chemofossils (fingerprint) and elements characteristic of the original organic material, i.e. V, Ni, Mo, Co, etc. In zones of deep catagenesis, with a strong dislocation of territories, their tectonic activity provokes the formation of traps of a mostly non-anticlinal, non-structural, combined type. It is in this type of traps that the main reserves of hydrocarbon deposits that are currently being discovered are concentrated (Dolson et al., 2018). Traps of this type can be saturated with oil of increased catagenic transformation, they are more susceptible to deep processing processes. In addition, migration may have undergone significant changes. They contain a different set of ME, toxic and volatile, associated with lighter oil components, probably some of which are associated with deep processes in the bowels of the earth (As, Hg, Al, Sb, B, Li, REE, etc.). The deposits of such oils with a low content of asphalt-resinous components from deep horizons (more than 4.5 km) can be characterized by good isolation from surface destruction agents. The described changes could also occur directly in the deposit itself, located in the zone of high temperatures and pressures. In regions of hypergene weathering, unconventional traps also often prevail. The abnormal enrichment of oils in the hyperegenesis zone in V, Ni, Mo, Re, Cd, Hg, U and other elements can be explained both by internal processes (degassing, loss of light fractions, chemical and biochemical oxidation), and by their endogenous input under the influence of intrusions and hydrothermal fluids. on the accumulations of asphalt bitumen mainly within the fold areas (Ural, Koryak-Kamchatka, Andean, etc.) and enrichment of oils with Hg, Cd, Sb gas emanations in deep fault zones (Ciscarpathian trough, California basins, etc.) (Goldberg, 1990; Punanova, 2014).

Table 2 shows the predicted values of a number of indicators in the proposed type of traps for different zones of hydrocarbon accumulations in sedimentary deposits and rocks of the crystalline basement. Based on the established regularities of HC ontogenesis, it is possible to interpret the presence of oils of a certain geochemical type in traps, mapped in oil and gas regions at a certain level of the given scheme and the typification of oils by their enrichment in ME. However, this postulate will be true if the traps were filled at the same time (period), and then the oils must be of the same genetic type, in accordance with their ontogeny. If the geological history of the formation of traps is more complex, and their formation took place in different geological epochs, and the sources of oil were different, then we can state the multiphase filling of the traps with oil of several generations. In such situations, an additional inflow of hydrocarbons into an already formed trap, which, as a rule, has a combined, complicated type, is possible.

Let us consider further, using specific examples, the features of oils concentrated in combined traps confined at shallow depths to zones of hypergenesis, at great depths under severe temperature and pressure conditions to zones of a high stage of catagenesis, to regions with possible additional inflow of hydrocarbons

Formation and transformation processes of oil and gas accumulations in various zones of lithogenesis	Depth, km	Stages of catagenesis	The predominant type of naphtides	The predominant type of predicted traps	Physico-chemical properties	ME composition (ppm), metallogeny	Examples of oil & gas regions (OGR), oil & gas basins (OGB)
Hypergenesis zone	< 2	PC^1–MC^1	Heavy oils and natural bitumens	Lithological and stratigraphically-screened, erosional ledges	$\rho = 0.953$ S=4.21 R+A=29	Enriched with ME $\sum V+Ni > 150$ $V > Ni > Fe$; $Fe > V > Ni$ vanadium or ferrous types	Tatar arch, Ukhta-Izhemsky swell, Lena-Tunguska, West Canadian, East and West Venezuelan OGB, South Tajik depression
Catagenesis zone	3-5	MC^3–AC^1	Oil, gas condensate, oil and gas condensate	Tectonically-screened, lithologically-screened	$\rho = 0.800$ S=0.5 R+A=5.0	Depleted ME $\sum V+Ni < 10$ $Ni > Fe > V$ nickel type	Lower Volga region (Buzuluk depression), Bukhara-Khiva, South-Mangyshlak OGR
Areas of multiphase filling of traps	2–4	MC^2–MC^3	Oil, oil and gas condensate, gas	Complex combined type with the formation of sub-thrust traps pinching out, lithological replacement and tectonically-screened	$\rho = 0.830$ S=0.8 R+A=10	Depleted ME $\sum V+Ni = 15\text{-}50$ $Ni > V$; $V > Ni$ nickel; rare vanadium	Volga-Ural OGB, Tatar arch (satellites of the Romashkinsky field), some deposits of the Eastern Pre-Caucasian region, Buzuluk depression, Pre-Caspian syneclise
Basement ledges	1,5–4,0	MC^2–AC^1	Oil, oil and gas condensate, gas	Combined type, in places tectonically screened in massive fractured cavernous-cellular granite blocks	Repeat the properties of oils occurring in contacting sedimentary strata (with good preservation of deposits and the absence of secondary changes in them)		Kyulongsky (Vietnam), West Venezuelan OGB, group of deposits of the Krasnoleninsky arch of the West Siberian OGB, North Sea shelf, Lancaster field

Tab. 2. Predicted values of some indicators of the properties of fluids in traps of various types in connection with the processes of oil generation, accumulation and destruction of the reservoir. MC, PC and AC are meso-, proto- and apocatagenesis; averaged data: ρ – oil density, g/cm^3; S – sulfur content, %; R+A is the sum of resins and asphaltenes, %.

and multi-stage occupancy, to decompacted massifs of the crystalline basement of sedimentary basins.

Hypergene and catagenic transformations of fluids, the influence of migration processes

The accumulation zones of hypergene oils are mainly confined to large positive structures (anticlines, megaswell, swells) that experienced intense ascending movements at the final stages of their development. The nature of the formation wedging out and the formation of hypergene heavy oils and natural bitumen on erosional incisions, as well as the change in their density, are clearly demonstrated in Fig. 1 and 2.

Oils of the Paleogene sediments of the Afghan-Tajik depression, genetically related to the carbonate strata of the Bukhara layers of the Paleocene of the Surkhandarya and Vakhsh synclinor zones and the southern part of the Kafirnigan anticlinal zone in complex lithologically and stratigraphically screened traps, experienced intense and long-term impact of hypergenerative factors. These are heavy (density 0.970 g/cm^3), viscous, resinous-asphaltene (43.2 %) and sulphurous (S = 5.2 %) oils with increased industrial concentrations of most elements. With the active manifestation of hypergene processes, as

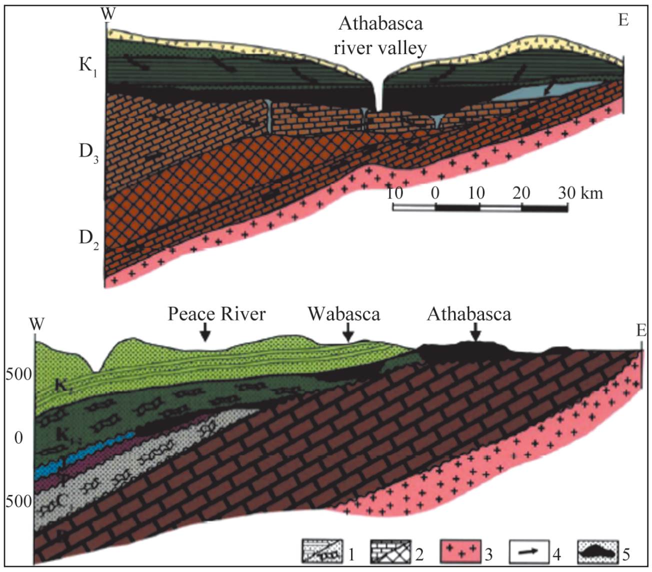

Fig. 1. Transverse profiles through the oil sands of Athabasca, Wabasca and Peace River (Western Canadian OGB) (after (Pau, 1974; Leiden, Marion, 1997); borrowed from (Yakuzeni, 2005)). 1 – sandstones K, J, T and C_1; 2 – Devonian carbonate strata; 3 – Precambrian crystalline basement, 4 – direction of groundwater movement; 5 – zones of accumulation of bitumen, maltha and heavy oils.

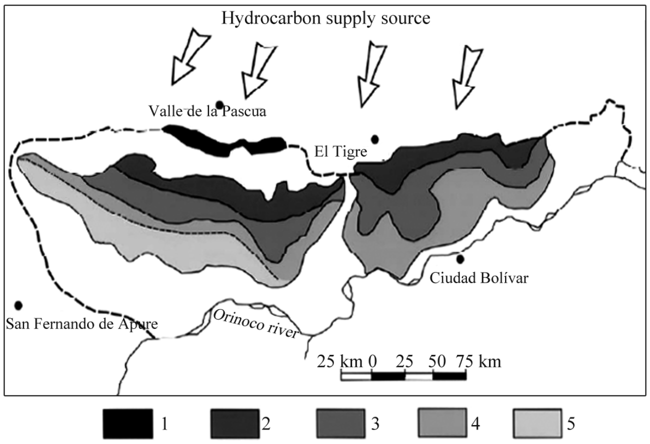

Fig. 2. Changes in the density of oil and bitumen in the sands of the Orinoco bitumen field with distance from the sources of supply (Maracaibo oil and gas basin, Venezuela) (Mendes, 2000). Zones of oils and natural bitumen with different density (g/cm^3): 1 – >0.934; 2 – 1.000–0.934; 3 – 1.076–1.025; 4 – 1.025–1.030; bitumen viscosity – 5 – 15000–100000 mPs.

they approach the surface and wedge out the layers, they pass into maltha and further into asphalts (Surkhandarya zone). Oil and especially oil ash from the Afghan-Tajik depression are enriched with respect to clarke contents: V (a thousand times), Ni and Cu (100 times), Co (10 times), Cr (5 times) (Punanova, Safranov, 1993).

Oils of the Buzachinsky arch of the Turan plate on the territory of the Republic of Kazakhstan are hypergenically altered. They are characterized as heavy (0.920–0.940 g/cm^3), highly cyclic, highly resinous (18–30 %), sulfurous (up to 2 %), high viscosity (up to 500 mPa·s), with a pour point of 20–27 °C, undersaturated with gas in reservoir conditions. These parameters increase from the crest of the structures to the contours of the deposits. Probably, these secondary changes in oils occurred in the reservoir due to the violation of conservation and the influence of oil-water contact. A feature of oils is the increased content of ME, which are of industrial importance. Traps are usually *tectonically* and *lithologically screened* (Nukenov et al., 2001).

The manifestation of sorption processes during ascending migration and the effect of hypergenesis can be observed when analyzing the ME composition and physicochemical properties of oils from the Potiguar Basin of Brazil in combined lithologically screened traps (Duyck et al., 2008) with initially low ME contents. Figure 3 shows the nature of changes in Ni, V, Co and Fe in oils from fields located along the trend line at different distances from the hydrocarbon source. Thus, up to 57 km in the process of lateral migration upward along the upwelling of the formation, a decrease in the content of ME and highly resinous polar components is observed, i.e. as the oil front moves along the formation as a result of sorption of asphalt-resinous components and related elements on the rocks. Their HC characteristics change, the density of oils, the content of V, Ni, Co and Fe decrease. Further, up to 104 km along the trend line, the content of elements increases in parallel with a significant weighting of oils as a result of hypergene processes. At the same time, a slight increase in the V and Ni contents in the asphaltene fraction is noted (Table 3).

The general picture of industrially vanadium-bearing oils with high vanadium and nickel contents accumulating in combined traps is shown in Fig. 4.

The direction of changes in the OM of rocks and oils at great depths in connection with catagenetic processes is due to their facilitation, the loss of heteroatomic, asphalt-resinous components, a corresponding drop in the complex-forming ability, and the redistribution of ME and metalloporphyrin complexes (MPC). Mature and super-mature oil corresponds to the meso-catagenetic (MC) stage with vitrinite reflectance Ro = 0.8–1.4 %. These stages are associated with oils of chemical types A-1 (super-mature) and A-2 (mature) (according to the classification of Al.A. Petrov). Oils are light and very light (ρ = 0.80–0.85 g/cm^3), low sulfur (S = 0–0.2 %), paraffinic and highly paraffinic (7–40 %), low resinous (0.3–10 %), with a high yield of light fractions (initial boiling (IB) = 300 °C) from 50 to 100 %, passing with increasing temperatures and pressures into zone of gas condensate accumulations. In the group composition of the IB = 430 °C fractions, the share of alkane hydrocarbons can reach 90 %. In the fraction IB = 200–430 °C n-alkanes (5–25 %) dominate over isoprenoid HCs (0.05–6.0 %), the content

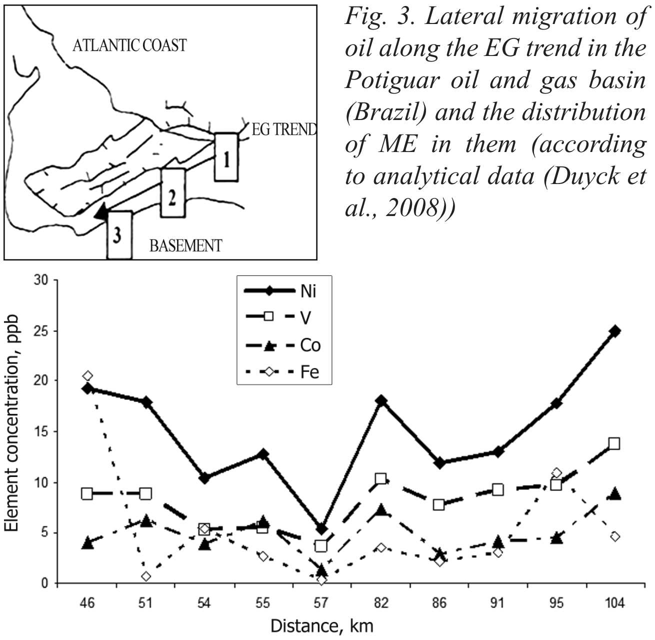

Fig. 3. Lateral migration of oil along the EG trend in the Potiguar oil and gas basin (Brazil) and the distribution of ME in them (according to analytical data (Duyck et al., 2008))

of cycloalkanes varies from 15 to 45 %, and aromatic HCs – from 10 to 70 %.

Highly converted oils in the catagenesis zones are characterized by low contents of "biogenic" elements – V and Ni, the total content of which is usually less than 10 g/t. Oil type is "nickel" (Ni > Fe > V). During these processes, MEs accumulate in naphthides, which are mainly associated with the hydrocarbon part, which leads to an increase in the contents of Cu, Fe and, in some cases, Pb and a number of other MEs in oils, and a decrease in the concentration of V and Ni associated with heavy components. Oil changes under the influence of thermolysis and/or thermal catalysis can also occur directly in the reservoir. Temperatures of 175–200 °C are called the threshold of the phase transformation of oil, above which liquid hydrocarbons pass into a gaseous state and into highly condensed aromatic compounds. In this case, the reactions of hydrogen disproportionation, hydrogenation, HC isomerization (both structural isomers and epimers), and deasphalting occur. The latter is the precipitation of asphaltenes from oil in the reservoir due to an increase in the content of dissolved associated gas and/or light liquid hydrocarbons, which come from the main zones of condensate and oil generation .

The study of the dynamics of changes in the ME composition of oils and OM of rocks, carried out by the authors on the examples of the Volga-Ural, Timan-Pechora, Ciscaucasian, as well as Pannonian (Hungary) and other oil and gas fields, showed that as the thermocatalytic conversion of oils increases, a significant decrease in the concentrations of V and Ni occurs, and the values of the ratios of a number of metals – V/Fe, V/Cu, V/Pb, Ni/Cu, etc., as well as (V+Ni)/(Fe+Cu) decline. The values of these ratios correlate well with the values of such a geochemical an indicator of the catagenetic conversion of hydrocarbons in the composition of oils, as the ratio of cyclohexanes to cyclopentanes in the gasoline fraction. The results of analytical data (ME were determined in 60 samples of oils by the atomic absorption method) showed that the ratio V/Fe and Ni Cu (Fig. 5), the content in oils ∑(V+Ni), as well as the values of the ratios of vanadyl porophyrins to the sum of resins and asphaltenes naturally decrease during the transition from the platform regions of the Permian Cis-Urals to the Pre-Ural foredeep due to a significant

Physicochemical parameters, HC ratio, ME	Parameter values		
	Distance from hydrocarbon source, km		
	46 (1) *	54–57 (2)	104 (3)
Density, g/cm^3	0.915	0.898–0.913	0.990
Depth, m	500	300	~ 250
n-alkanes	*н*-C_5–*н*-C_{38}	*н*-C_{13}–*н*-C_{38}	not detected
P/F	0.95	0.77–0.87	not detected
S/(S + R)	0.36	0.34–0.45	0.32
[C_{29}] $\beta\beta/(\beta\beta+\alpha\alpha)$	0.33	0.34–0.47	0.30
Gammacerane index: Gammacerane x 100 G_{30}	72	64	77
G_{35}/G_{34}	0.91	0.76–0.84	0.94
V, g/t	**0.009 0.063	0.005–0.004 0.06–0.07	0.014 0.08
Ni, g/t	0.019 0.15	0.010–0.005 0.16–0.12	0.025 0.19
Ni/V	2.17 2.40	1.4 2.7–1.7	1.8 2.4

*Table 3. Characterization of the studied oils from the Potiguar Basin of Brazil along the trend line (according to analytical data (Duyck et al., 2008)). * Figures 1, 2, 3 show the location of deposits on the trend in the direction of lateral migration (Fig. 3); ** above the line – the content of the element in oil, below the line – in asphaltenes.*

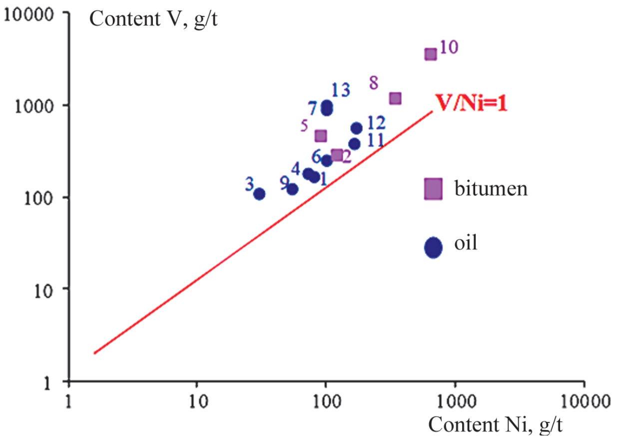

Fig. 4. Average contents of V and Ni in hypergene converted oils and natural bitumen. Regions: Western-Canadian oil and gas basin: 1 – oil, 2 – bitumen; 3 – Oil and Gas Basin (OGB) of the Rocky Mountains; East Venezuelan (Orinoco) OGB: 4 – oil, 5 – bitumen; 6 – Timan-Pechora oil and gas department; Volga-Ural OGB: 7 – oil, 8 – bitumen; Lena-Tunguska OGB: 9 – oil, 10 – bitumen; 11 – South Mangyshlak oil and gas field; 12 – Surkhan-Vakhshsky OGB; 13 – West Venezuelan (Maracaibo) OGB

decrease in the contents of V, Ni, and MPC (Punanova, Dobrynina, 2018).

It is such a lightweight composition of naphthides (where gas condensate accumulations are also encountered) that we observe in traps of a more complex combined structure than on the platform when analyzing the oil and gas content of foredeeps (Punanova, 2019b). The established differentiation of the composition of ME, MPC, as well as resinous-asphaltene components in the oils of platform and foredeep is largely due to the influence of temperature (catagenetic) and tectonic factors.

Indicative are similar trends in changes in the impact of catagenesis on the ME, the composition of syngenetic chloroform bitumoids, which we recorded when studying the Domanik deposits of the Timan-Pechora oil and gas basin, occurring at different depths (up to 6000 m) and under conditions of different paleotemperatures (from 100 to 230 °C, MC_1-AC_1) having a sapropel composition (Chakhmakhchev et al., 1984). It was revealed that as catagenesis increases, ∑(V+Ni) decreases from 2400 to 160 ppm, the V/Fe ratio – from 21.0 to 0.7, and V/Pb – from 130.0 to 4.7.

Analysis of the ME distribution features in the oils of the orogenic Pannonian Oil/Gas basin (Hungary) associated with tectonically screened traps of the combined type indicates that Co, V, Ni and Mo, which are in association with polar components, show a direct dependence on the thermal change of oils, i.e. their content decreases significantly from oils of the lowest maturity to highly mature. The relationship between the concentrations of Fe, Zn, As and Hg with thermal transformations of oils is ambiguous and more complex, which is associated with their confinement to lighter oil fractions, and, possibly, the superposition of secondary processes. The hydrocarbon composition of oils from the same deposits confirms the nature of their maturity (Sajgo et al., 2009). It is noted that during the periods of folding and immediately after them, there could be high geothermal gradients and intense heat flux, as a result of which, in some deposits, Pliocene source rocks are heated to a sufficiently high temperature.

Multiphase filling of combined traps with oil (on the example of the Romashkinskoe group of deposits)

If the geological history of the formation of traps is rather complicated, and their filling took place in different geological epochs up to the present time, then we can state the multiphase filling of the traps with oil of several generations.

The complex structure of the combined type of traps in the area of the Romashkinskoe group of oil fields is illustrated by the model of the geological structure of the Pashian horizon (D_3ps) of the Aznakaevskaya area (Loshcheva et al., 2017). According to the significantly modified by the authors of the previous model (Muslimov, 2011), instead of a layered section with a plicative nature of the reservoir surfaces, a section is proposed with a set of various facies, regularly distributed both over the area and along the section, complicated by interblock faults of submeridional and sublatitudinal strikes.

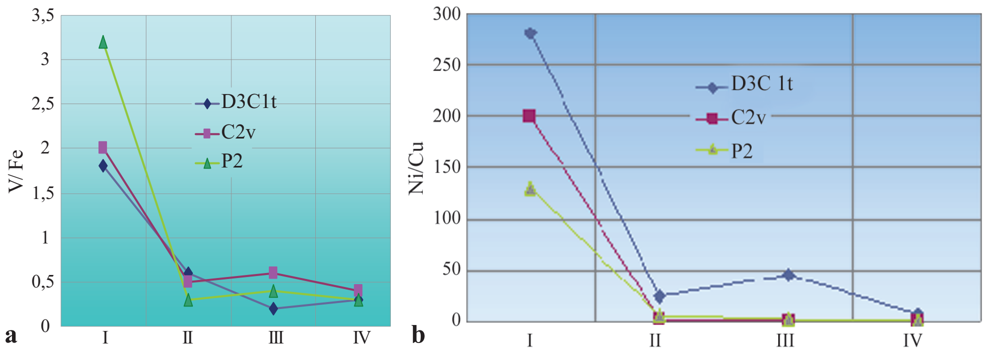

Fig. 5. ME indicators of the degree of maturity of oils from sediments of different-aged oil and gas complexes of the Perm Urals in connection with their different structural position and paleotemperatures: a) V/Fe; b) Ni/Cu. I – Bashkir and Perm swells, t_{paleo} = 100–145 °C; II – Solikamsk depression, t_{paleo} = 145–170 °C; III – Kosvinsko-Chusovskaya saddle, t_{paleo} = 170–190 °C; IV – Yuryuzan-Sylvenskaya depression, t_{paleo} = 190–250 °C)

Data on the composition of the ME of oils from the Romashkinskoe group of oil fields with a complex tectonic structure, and the previously identified correlations between the ME compositions of various geochemical substances and, in particular, with the composition of the earth's crust at various levels (Punanova, Rodkin, 2019) can confirm the fact of an additional inflow of hydrocarbons from deeper horizons, or from zones that are warmer, subject to significant hydrothermal and destructive processes in zones of increased geodynamic influence. This fact is an important link in the successful development of oil and gas fields. The influence of the processes of destruction of igneous sediments of the Cis-Ural mountain massif and the introduction of high-migration elements into deep solutions cannot be ruled out. Here, in the zones of the formation of unconventional traps (as a rule, these are non-structural deposits of a *complex combined type with the formation of sub-thrust traps of pinching out, lithological replacement and tectonically-screened ones*), it is possible to form collectors-traps in the decompressed massifs of the ancient basement, in fractured granite blocks, where it is possible fluids with the original ME composition. Light methane base oils with high gas-oil ratio can be predicted. Such traps are filled and, possibly, will be filled with oil of nickel specialization with a typical for highly transformed fluids of zones of increased catagenic influence, a set of migration mobile elements (As, Hg, Eu, La, Nb). It was noted that the contents of these MEs in oils do not correlate with the concentrations of biogenic elements such as V, Ni, Mo, Co (Punanova, Rodkin, 2019).

Oil deposits of erosional basement ledges

An example of oil fields localized in decompressed pore-cavernous projections of the crystalline basement, in fractured granite blocks-reservoirs of complex type, sometimes tectonically shielded, are the White Tiger (Vietnam), Mara and Western Mara (Venezuela), as well as groups of deposits of the Krasnoleninsky arch of Western Siberia, etc. (Punanova et al., 2018; Kerimov et al., 2019; Yurova et al., 2019). The main source of oil in the deposits of the crystalline basement is the OM of the oil source sedimentary strata enclosing the basement protrusions. That is why the geochemical features of the fluids of the basement deposits obey the same laws as the oils occurring in the sedimentary strata of the oil and gas basin. And in the sedimentary frame of the crystalline massif there are always oil source formations – sources of oil in the basement.

Conclusion

From the standpoint of the theory of ontogenesis of naphthides, it is shown that it is possible to predict the physicochemical properties, chemical composition, metallogenic specialization and phase state of fluids migrating and accumulating in traps. Combined, i.e. non-anticlinal, non-structural, complexly constructed traps become the main link in assessing the oil and gas potential of territories, and the geochemical forecast of the quality of the extracted hydrocarbon raw materials in them acquires great practical meaning. Linking the desired trap to the zoning scale, i.e. depths, tectonic elements, stages of catagenesis, features of the geodynamic regime of the basin, and will determine the geochemical type of fluids forming the deposit.

The typification of oils according to the content of "biogenic" ME revealed in the process of naphthidogenesis significant differences between early generation oils and hypergenically modified ones. Immature oils are depleted by ME and form provinces of nickel metallogeny. Hypergenically transformed oils and genetically related natural bitumen are characterized by high, up to industrial, concentrations of ME and create metallogenic provinces of vanadium type. The existence of oils with different metallogeny is associated with the composition of the initial organic matter and with the secondary processes of transformation of hydrocarbon fluids during the geological history of the development of Oil/Gas basins.

1. In the traps of *lithologically and stratigraphically screened, traps of erosional cuts* V, Ni, Co, Mo, Cd (at shallow depths with poor regional or local seals, when approaching the surface and the influence of surface biodegradation agents, hypergenically transformed oils are encountered, passing with increased hypergenesis and weathering into natural bitumens. Naphthides are characterized by high density, high concentrations of resinous-asphaltene components and are enriched with microelements V, Ni, Co, Mo, Cd, etc., which are not only industrially significant, but also potentially toxic, posing an environmental hazard during field development. Vanadium or ferruginous naphthides (V/Ni > 1; Fe/V > 1) are developed in the basins of ancient and young plates, but can be associated with tectonically mobile regions of the earth's crust, rift zones, aulacogens.

2. In traps lithologically or/and stratigraphically screened, often with tectonic limitation during prolonged lateral migration, due to the loss of asphalt-resinous components and associated ME (V, Ni, Co, Mo, Cd, U, etc.), at large depths with good isolation from surface weathering agents in zones of high catagenetic transformation, it is predicted to detect light oils of the methane base, depleted in resins, asphaltenes, ME, more often nickel specialization (V/Ni <1), oil and gas condensate accumulations are possible. At the same depths under severe thermobaric conditions of increased catagenesis in combined with a predominance of tectonically-screened traps with an active geodynamic regime of the region, it is possible to detect light oils of

the "nickel" type or gas condensates enriched in elements of deep origin – As, Hg, Al, B, Ag, Pb, Ce , and other rare earth elements, the most capable of migration. *These are laterally heterogeneous basins (boundary and interfolding depressions), marginal depressions in the body of ancient and young plates, bordering on areas of alpine folding*.

3. *In complex combined traps lithologically, stratigraphically, tectonically screened with the influence of thrust and underthrust processes with a possible reformation* of deposits and with this influence and inflow of deep (i.e., more catagenically transformed) fluids, both oil and gas condensate accumulations were encountered (with the tightening of thermobaric conditions). High correlation dependences of the ME composition of oils with the composition of deeper deposits of the earth's crust indicate the multiphase filling of the *traps*. Oils are light, "nickel"-type, with low concentrations of the main biogenic elements (V, Ni, Co, Cr, Mo, Cu, etc.) with the prevalence of deeper ones (La, Sm, Se, Li, Al, B, etc.).

4. Oils filling combined traps of a complex type, over large areas, as a rule, divided into blocks with a significant number of tectonic faults in decompacted porous-cavernous reservoirs of the crystalline basement within platform oil and gas basins, in their composition practically do not differ from the composition of oils in overlying or adjacent parts of the sedimentary section and, as a rule, completely repeat their geochemical features.

Characterization of the quality of oil and, in particular, its metallogeny in predicted traps is the most important component in assessing the profitability of field development. Depending on the composition of the extracted raw materials and the content of metals in it, the method of exploration and development, the processing technology may change, and various measures should be taken to protect the environment.

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