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Effect of Oil Potential and Deep Tectonics on the Trace Element Composition of Soils: An Example of the Tatarstan Republic

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Abstract—Published seismic data were considered in combination with the results of lithogeochemical and electrochemical data on soils above oil reservoirs and subvertical dynamic anomalies at the territory of Tatarstan. The effect of oil potential and deep-seated tectonics on the trace element composition of soils was exemplified along several seismic profiles across the Southern Tatar and Northern Tatar arches. Elevated contents of Li, B, Al, and As were recorded above dynamic anomalies, while oil accumulations are marked by high contents of V, Ni, Cu, Mo, and Ag.

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INTRODUCTION

Deep seismic CMP regional profiling showed an anomalous structure of the Earth's crust around known oil fields in the western slope of the Southern Tatar Arch [1]. The time section beneath these fields recorded two distinct types of anomalies: (1) volume anomalies of wide lateral extension at a depth of 15–20 km and (2) subvertical anomalies that are pinched out down the zone of high intensity record, reaching anomalies of the first type. It was assumed that the subvertical dynamic anomalies (SDA) are the zones of disintegrated fractured rocks and, likely, served as fluid migration paths [2].

The most interesting areas of regional seismic profiles were studied using diverse methods, including detailed lithogeochemical and geoelectrochemical surveys, to determine the nature of the revealed anomalies and their effect on the geochemical composition of soil. More than 1000 samples were taken from a depth of 0.3–0.4 m with a 500-m step along the profile by geologists of TSNIIgeolnerud (Kazan) under the supervision of A.A. Ozol. These samples were studied by spectral and, selectively, atomic absorption methods [3, 4]. Then, the trace element composition of the soils was correlated with the SDA distinguished in the seismic time sections and HC reservoirs.

TRACE ELEMENT COMPOSITION OF SOILS AND OILS

Table 1 demonstrates the average, minimum, and maximum contents of 32 elements in soil along the studied profiles in comparison with their clarkes in soils [5], compositional variations in the uncultured soils of America [6–8], and trace element abundances in oils and oil ashes [9–11].

Two studied profiles running across the western slope of the Southern Tatar Arch and the southeastern slope of the Northern Tatar Arch widely vary in contents of different elements from high (6% Al) to low (1.5×10^{-5}% Hg) values. However, they are similar in trace element patterns, with the exception of higher maximum concentrations of Mn, P, Mo, and Ag along profile 11.

The contents of some elements show a wide scatter from extremely high to extremely low values, typically by a factor of two–four, however, some elements (P, Zr, Cr, Zn, Pb, Be, Mo, Ag) show six–eight times variations.

The 10-day distribution of average element contents in soils (Table 2) indicates that the highest contents (I decade 1–10%) are typical of major elements (Al, Fe, Ca, and Mg), while trace elements, REE, and some metals (Hg, Ag, Ge, Y, Be, and Yb) were found in trace amounts only in V–VII decades (10^{-4}–10^{-6}%). Thus, the soils are enriched in major elements (Al, Na, Ca, and Mg), transition elements (Ti and Fe), and some ore elements, whereas in trace elements, some metals and metalloids (Ag, Hg, Mo, and Ge) occur in significantly lesser abundances.

The comparison of the trace element composition of the studied soils (Table 1) with the clarkes and variations in the concentrations of some elements in normal uncultured soils shown in Fig. 1 revealed differences in

Table 1. Variations in the element contents (%) of soils, oil ashes, and oils

Element	Study object																	
	soils, profile 11				soils, profile 6				soils from different regions of USA [6]			soil [5]		oil ash (Pz)*	oil (D)		oil (Pz)	
	av	max	min	*n*	av	max	min	*n*	max	min	*n*	av	*n*	av	av	*n*	av	*n*
Al	3.1	6.0	1.5	1	3.1	6.0	1.5	1	6.5	1.1	1	5.4	1	5.8	8.5	–4	2.4	–4
Fe	2.5	3.5	1.0	1	3.5	3.0	2.0	1	4.3	0.5	1	1.39	1	3.5	1.5	–3	1.8	–3
Ca	1.95	3.0	0.5	1	2.0	6.0	1.0	1	1.7	0.07	1	0.7	1	9.7	3.5	–3	2.6	–3
Mg	1.2	3.0	0.5	1	1.5	2.5	1.0	1	8.4	0.3	–1	0.5	1	0.9	4.2	–4	3.0	–4
Na	5.97	15.0	3.0	–1	7.0	8.0	3.0	–1	6.2	0.2	–1	0.56	1	0.04	–	–	2.1	–3
Ti	3.9	8.0	2.0	–1	5.0	8.0	2.5	–1	6.6	1.7	–1	0.2	1	0.003	6.1	–5	0.002	–5
Mn	8.4	30.0	4.0	–2	10.0	15.0	4.0	–2	11.0	0.6	–2	3.2	–2	0.019	1.2	–4	2.9	–5
P	5.2	50.0	2.0	–2	6.0	8.0	2.0	–2	8.0	0.4	–2	5.3	–2	–	–	–	–	–
Ba	4.2	6.0	2.0	–2	5.0	6.0	2.0	–2	7.4	0.9	–2	7.0	–3	0.02	2.4	–6	1.3	–5
Zr	1.7	4.0	0.5	–2	2.0	3.5	0.8	–2	4.6	1.2	–2	7.0	–3	–	–	–	1.0	–6
V	1.3	3.0	0.7	–2	1.5	2.5	0.6	–2	1.1	0.15	–2	4.0	–3	16.2	9.6	–3	7.5	–3
Sr	1.0	2.5	0.7	–2	1.0	1.5	0.7	–2	1.6	0.06	–2	8.2	–3	0.1	1.0	–5	8.0	–5
Cr	8.4	20.0	3.0	–3	15.0	20.0	3.0	–3	7.8	1.1	–3	8.0	–3	0.03	4.0	–6	3.2	–5
Zn	6.2	15.0	2.0	–3	8.0	15.0	2.0	–3	6.7	2.5	–3	2.0	–3	0.13	1.4	–4	1.2	–4
Cu	5.3	10.0	2.5	–3	2.5	15.0	1.5	–3	3.3	0.9	–3	6.0	–4	0.15	3.0	–5	3.0	–5
Li	4.4	6.0	2.5	–3	5.0	6.0	3.0	–3	3.2	1.5	–3	9.0	–3	–	–	–	1.0	–5
B	3.6	6.0	3.0	–3	5.0	6.0	0.8	–3	6.3	1.8	–3	2.0	–3	–	–	–	3.0	–3
Ni	2.6	7.0	2.0	–3	4.0	8.0	2.5	–3	2.3	0.4	–3	1.0	–3	6.4	2.0	–3	2.7	–3
Y	2.5	3.0	1.5	–3	3.0	3.5	2.0	–3	3.9	1.7	–3	9.0	–6	–	–	–	–	–
Pb	1.7	3.0	0.5	–3	1.5	5.0	2.0	–3	2.5	0.3	–3	1.0	–4	0.68	5.2	–4	1.0	–7
As	1.4	4.0	0.6	–3	0.16	4.0	0.03	–3	1.3	0.7	–3	1.0	–4	–	–	–	4.6	–6
Nb	1.1	2.6	0.8	–3	1.5	2.0	0.9	–3	1.9	0.6	–3	–	–	–	–	–	–	–
Sc	1.1	2.6	0.8	–3	1.0	2.0	0.8	–3	1.3	0.2	–3	–	–	–	–	–	2.0	–7
Ga	9.2	15.0	5.0	–4	1.0	3.0	0.7	–3	29.0	1.9	–4	–	–	–	1.4	–5	0.14	–7
Sn	3.5	7.0	2.0	–4	4.0	6.0	2.0	–4	–	–	–	–	–	0.42	–	–	0.3	–7
Yb	3.5	4.0	2.0	–4	2.0	2.5	0.8	–4	28.0	1.8	–4	–	–	–	–	–	–	–
Be	2.2	5.0	0.8	–4	2.0	3.5	0.7	–4	1.3	0.76	–4	–	–	–	–	–	–	–
Mo	1.7	8.0	0.8	–4	2.0	4.0	1.0	–4	–	–	–	6.0	–5	–	1.4	–6	1.5	–6
Ge	1.5	2.5	1.0	–4	2.0	2.5	1.0	–4	–	–	–	–	–	–	–	–	4.8	–6
Co	1.2	2.5	0.8	–4	2.0	2.5	0.7	–4	14.0	1.0	–4	7.0	–5	–	4.1	–5	8.0	–5
Ag	1.6	25.0	0	–5	1.0	4.0	0	–5	–	–	–	–	–	–	–	–	9.7	–7
Hg	8.0	15.0	3.0	–6	6.0	15.0	3.0	–6	16.0	4.5	-6	–	–	–	–	–	7.0	–6

Note: Dashes denote the absence of data; *n* is the degree;

* Age of host rocks.

Table 2. Distribution of the average contents of elements in soils and oils by decades

Number by decades	Decades	Elements		
		profile 11	profile 6	oil (central pat of the Volga–Ural area, Devonian sediments) [9, 10]
I	1–10	Al, Fe, Ca, Mg	Al, Fe, Ca, Mg	–
II	10^{-1}–1	Na, Ti	Na, Ti	–
III	10^{-2}–10^{-1}	Mn, P, Ba, Zr, V, Sr	Mn, P, Ba, Zr, V, Sr	–
IV	10^{-3}–10^{-2}	Cr, Zn, Cu, Li, B, Ni, Y, Pd, As, Nd, Sc	Cr, Zn, Cu, Li, B, Ni, Y, Pd, As, Nd, Sc, Ga	V, Ca, Ni, Fe
V	10^{-4}–10^{-3}	Ga, Sn, Yb, Be, Mo, Ge, Co	Sn, Yb, Be, Mo, Ge, Co	Al, Pd, Mg, Zn, Mn, Na
VI	10^{-5}–10^{-4}	Ag	Ag	Co, Cu, Ti, Sr, Ga
VII	10^{-6}–10^{-5}	Hg	Hg	Cr, Ba, Mo, Hg, Ge, Ag, Zr
VIII	10^{-7}–10^{-6}	–	–	Sc
IX	10^{-8}–10^{-7}	–	–	Sn

both the average and the maximum contents of elements in these objects. The soils of the Tatarstan Republic are enriched in major (Ca and Mg), ore, and trace (V, Cr, Cu, Zn, Ni, Pb, As, and Be) elements compared to the clarkes. As compared to the American soils, they are higher in Cu, B, Ag, and Mo and insignificantly lower in Ga, Co, Zr, and Sr, which can be related to facies conditions. In particular, the carbonate-rich sedimentary sequence of the Southern Tatar and Northern Tatar arches are high in Ca and Mg. The differences in trace element abundances can also be related to the deep-seated processes, the ore and bitumen formation, which is typical of the geological evolution of the region. The elevated tectonic activity of this zone [1, 2] was favorable for the penetration of endogenous elements into the sedimentary cover, and soil as well as the accumulation of mobile species of variable-valence elements, in particular, V, Ni, Cr, Cu, Zn, and Pb.

The high permeability and mobility of hydrocarbon systems lead to the appearance of trace element anomalies in soils above naphthide occurrences. These anomalies have long served as an important prospecting guide but have no unambiguous interpretation. However, the “breath” of the reservoir expressed in the disturbance of the redox potential, ionic–salt exchange, or the direct diffusion scattering of liquid and volatile HC together with trace elements, as well as temporal changes in the gravity, are well pronounced and have already been found in many basins [3, 4, 12].

The oils and soils have different trace element distribution patterns (Fig. 1). Since trace elements in the plot were arranged in decreasing order of their maximum contents in the American soils, the distribution patterns for soils show a gradual decrease from high (Ti) to low (Ag) values, whereas trace elements in the oils have saw-tooth variations, approaching or deviating from the trace element patterns in soils. The strongest differences were found between the concentrations of major elements and some metals. For example, the contents of Al, Fe, Mg, and Ti in the soils are four orders of magnitude higher than those in the oils; the soils are three times higher in Zr, Mn, Sc, Sn, Cr, and Cu, but one order of magnitude or less lower in V, Ni, Pb, B, Ag, Hg, and Ga.

It was difficult to expect similar distribution patterns in the soils and oils. However, given that our studies are aimed at revealing cause–effect relationships between oil–gas potential, deep-seated tectonics, and geochemical fields (trace element composition of soil), the fact that the elements typical of the oil and predominant in the oil ash were also found in soils in similar contents and proportions is of great importance.

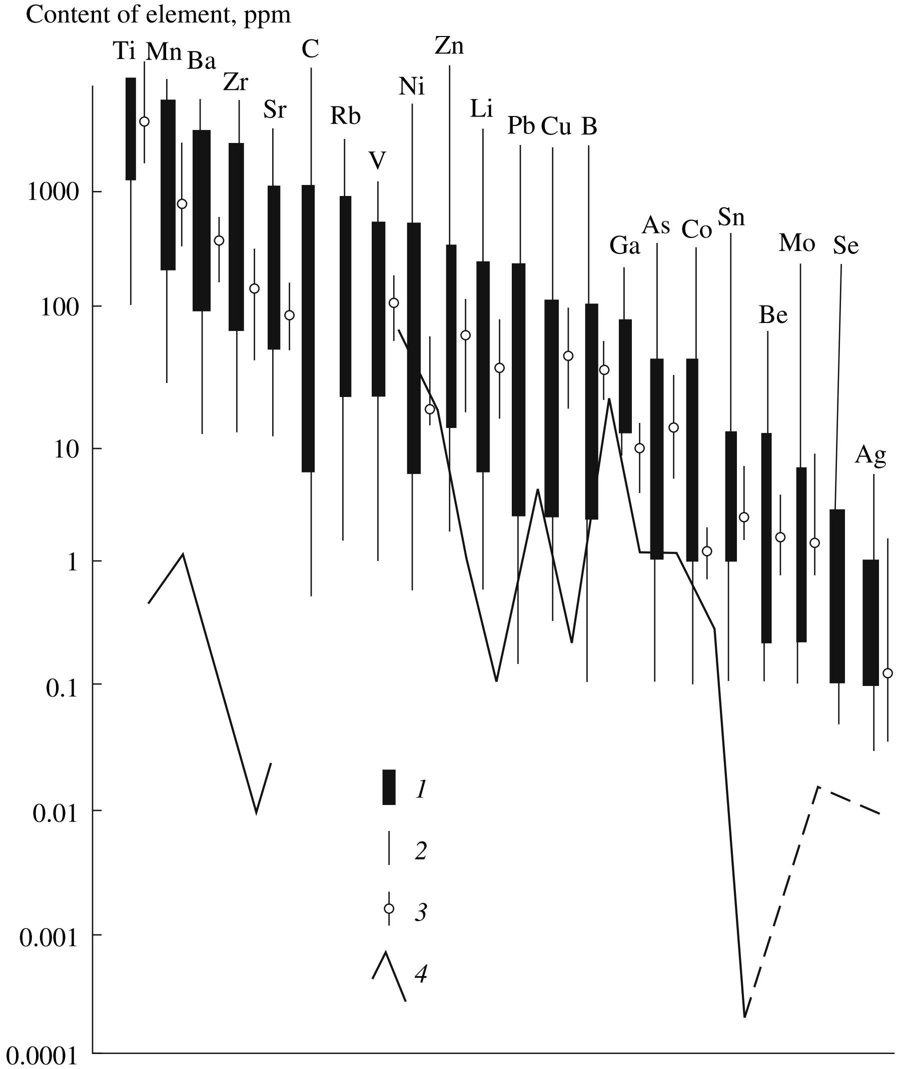

Fig. 1. Variations of element contents in soils and oils. Contents: in the American noncultured soils [6]: (*1*) most frequent values; (*2*) rare values; values in the Tatarstan soil along profiles 11 and 6; (*3*) range of contents: circles denote average value; (*4*) in oils of Volga–Ural [9–11].

There are concepts on direct and indirect effect of deep-seated degassing on the formation of the deposits of oil and gas, natural bitumens, radioactive elements, base, trace, and noble metals. Some researchers (Sharov et al., 1997; Makushin, 1994) suggest a direct correlation between the deep-seated structure of the Earth's crust and zones of oil–gas generation in the Paleozoic deposits of the Volga–Ural oil–gas area. Promising areas are mantle degassing zones at the margins of crustal megablocks, the walls of Riphean aulacogens, and deep fault intersections, which control the localization of polygenetic hydrocarbon reservoirs. Economic oil and gas fields are related to the discontinuous paths of deep-seated degassing, whereas bitumens in the form of bituminous sands result from discharge of deep-seated hydrocarbons.

Magmatic gases (Voitov, 1980) in continental rifts contain H_2, hydrocarbons, CO and CO_2; gas–hydrothermal solutions are dominated by sodium hydrocarbonates and carbonates, which contain up to 26.4–162 ppm, occasionally 4630 ppm F, and 7.8–12.2 ppm B. Magmatic gases in marginal–continental orogens contain halide and sulfur compounds in amounts comparable to those of CO and CO_2. Depending on their origin, hydrothermal solutions are subdivided into hydrochloride with relatively high Al content (up to 4000 ppm) and hydrocarbonate–chloride–sodium with up to 80 ppm F, up to 600–900 ppm B, as well as sharply elevated content of As, Sb, and other metals. In addition to H_2, hydrocarbons, CO, and CO_2, mantle components include He, Rn, Li, and Hg, which serve as indicators of the deep-seated provenance of mineral matter.

Table 3. Correlation of anomalous zones along profile 11

Element	Anomalies in the Earth's crust along profile 11 from the west to the east						
	I	II	III	IV	V	VI	Number of coincidences
Al	+	+	–	+	–	+	4
Fe	+	–	–	+	–	–	2
Ca	–	+	–	–	–	–	1
Mg	+	–	–	–	–	+	2
Na	–	+	–	–	–	–	1
Mn	+	+	–	+	–	+	4
Zr	–	+	–	–	–	+	2
V	+	+	+	–	+	+	5
Sr	+	+	–	–	+	–	3
Cr	+	+	+	+	–	+	5
Cu	–	–	+	–	–	+	2
Li	+	+	+	+	+	+	6
B	+	+	+	+	+	–	5
Ni	–	–	–	–	+	+	2
Pb	–	+	–	–	–	–	1
Ga	–	–	–	–	–	+	1
Nb	+	+	–	–	+	–	3
Sc	–	–	+	–	+	–	2
As	+	–	+	+	+	–	4
Sn	+	–	+	–	+	+	4
Yb	+	+	–	+	+	+	5
Be	+	+	+	+	+	+	6
Mo	–	–	+	–	–	–	1
Ge	+	+	+	+	+	+	6
Ag	–	–	+	–	+	–	2
Hg	+	–	+	+	–	–	3
Σ elements	16	15	13	11	13	14	

During the migration of deep-seated fluids, HC are spent on the reduction of variable-valence elements in the rocks, thus forming the primary and secondary scattering halos of these elements, in particular, Fe, V, Co, Ni, Mn, Cu, and others.

Thus, deep-seated fluids can affect the geochemical composition of metalliferous deposits of platform covers, as well as the formation of oil, gas and ores. These processes presumably were responsible for the trace element composition of oils and their derivatives. However, available data are too scarce to completely solve this problem.

Many researchers attach much importance to rare-earth elements found in oils as related to endogenous process. Based on the Eu predominance over Sm, Eu/Sm and Yb/Ce ratios, as well as Rb–Sr and Sm–Nd isotope composition in the oils of the Tatarstan domanikites, the source of these elements was inferred to be located beyond the sedimentary cover and to be related to deep-seated reduction zones of the Earth's crust. However, the Eu anomaly is not universal for oils. For example, the Caspian oil [15] contains from 0.6 to 20 Eu and from 1 to 50 Sm (10^{-7}%), i.e., shows Sm predominance over Eu.

Some data on distribution of magmatophile trace elements (As, Sb, Hg, La, and Eu) in oils around the world (Libya, Russia, Western Siberia included, Kazakhstan, United States, and Iraq) are reported in [9]. These data were systematized in accordance to the depth of the reservoirs and the lithological composition of host rocks. It was found that deep oil reservoirs lying in the proximity of the basement show a significant drop in the contents of studied elements; the enrichment of oils in these metals is likely related to the paleofacies conditions of sedimentation: carbonate and terrigenous parent rocks. No correlation was found between the distribution of trace elements typical of deep-seated processes and magmatic emanations in oils and distance to the basement, i.e., the effect of deep-seated processes on the trace element composition of oils remains controversial.

CORRELATION OF GEOPHYSICAL AND GEOCHEMICAL ANOMALIES

To correlate seismic time profiles and geochemical survey data on the soils, the distribution of 32 elements in the soils along the profiles was examined using projections of the dynamic anomalies and oil reservoirs. The data obtained on profile 11 are shown in Table 3; the plus sign marks the coincidence of seismic (dynamic) and geochemical anomalies, and the minus sign indicates the absence of this consistency. Our data display a correlation between SDA (possible deep-seated fracture zones in the Earth's crust) and the distri-

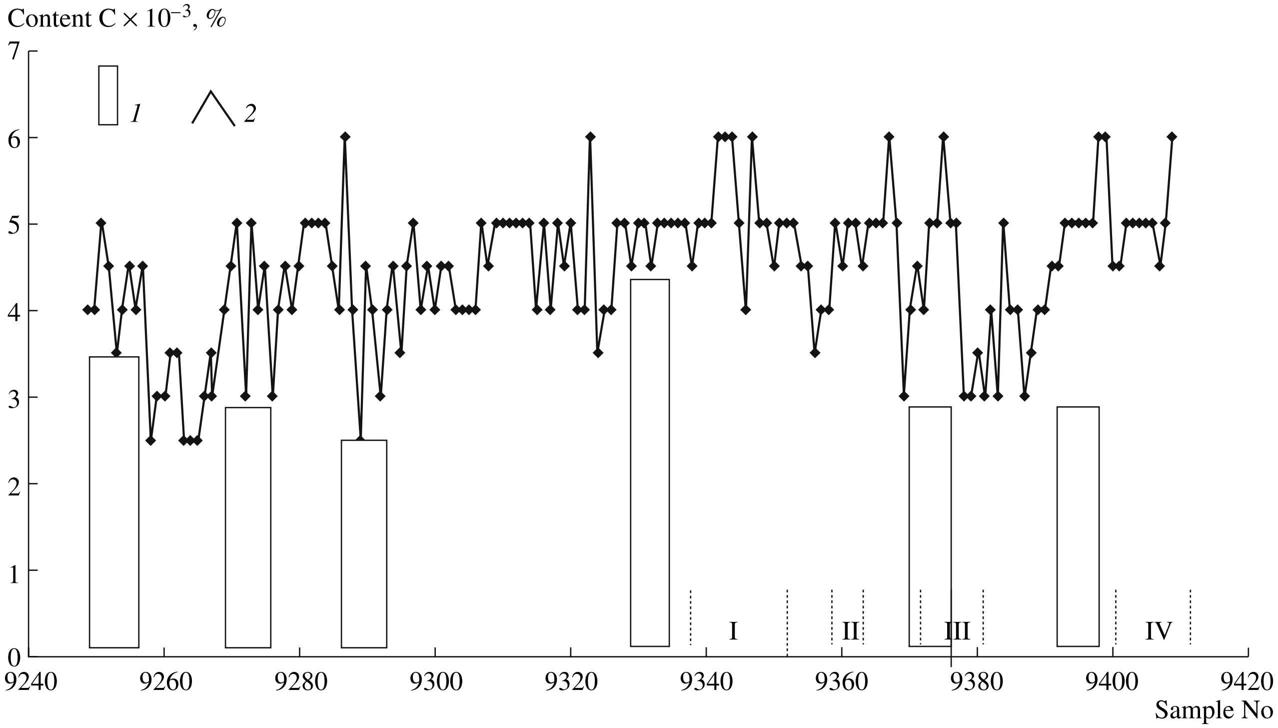

Fig. 2. Li content in soils along the profile 11. (*1*) Not-to-scale projection of deep-seated anomalies onto the geochemical profile; (*2*) contents of elements; oil deposits: (I) Cheremukhovskoe; (II) Novo-Sheshminskoe; (III) Letnee; (IV) Ashal'chinskoe.

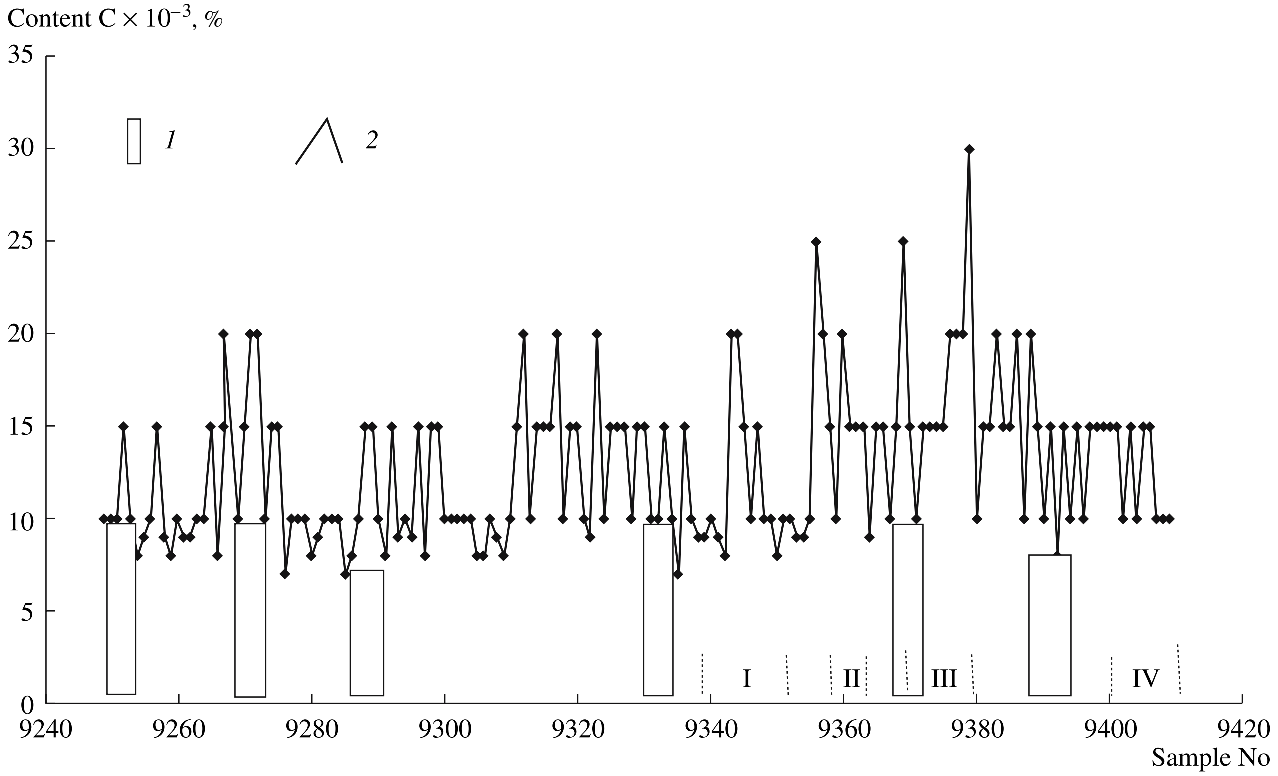

Fig. 3. V content in soils along profile 11. Symbols are as in Fig. 2.

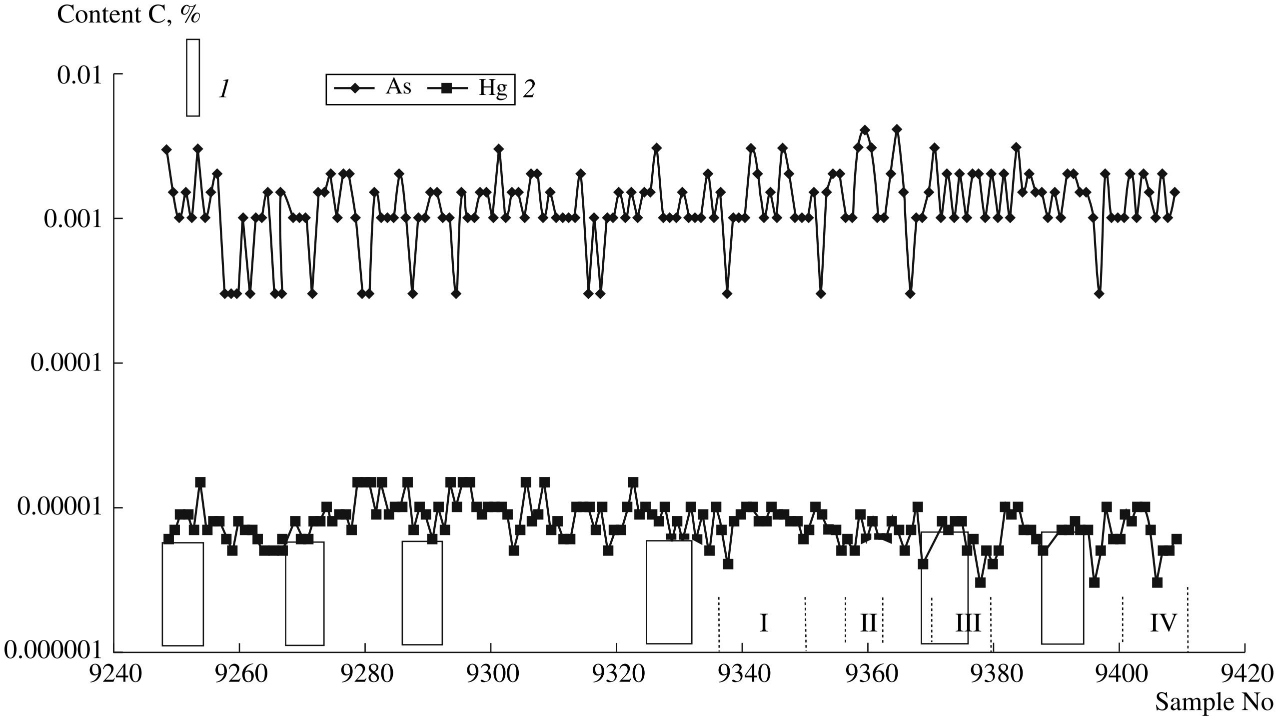

Fig. 4. As and Hg contents in soils along profile 11. Symbols as shown in Fig. 2.

bution of some elements in soils. There are maximum, strong, moderate, and poor correlations. Li, Be, and Ge show the maximum correlation with tectonic processes in the basement. Their anomalies were found above all six geophysical anomalies. V, Cr, B, and Yb exhibit a strong correlation (geochemical anomaly above five geophysical anomalies). Al, Mn, As, and Sn demonstrate a moderate correlation (four of six anomalies). Weak correlation denotes three and less coincidences between anomalous values and SDA. The distribution of Li, V, As, and Hg (Figs. 2– 4) is shown as an example. Each of these elements belongs to one of four groups. Some anomaly-forming elements, for example, Li, B, As, and Al, are indicative of deep-seated and magmatic processes. No correlation was found between geochemical data and seismic time section along profile 6. Only Mo, Be, Ni, Yb, and Mn demonstrated correlation with SDA.

Geoelectrochemical sampling of soils was conducted by VIRG-Rudgeofizika along profile 11 (50 km) [16]. Geoelectrochemical methods are based on the separation and examination of a narrow spectrum of easily mobile modes of occurrences of the elements instead of their bulk contents. The most widespread geoelectrochemical methods are PEM (partial extraction of metal); DEM (diffusion extraction of metals), SOM (search for organometallic compounds); and TMGM (thermomagnetic geochemical method). Geoelectrochemical methods showed high geological and economic efficiency in prospecting for deep-seated ore deposits in the territory of CIS, Canada, Australia, United States, China, India, as well as for oil fields in Belarus, Kaliningrad area, and in the Volga–Ural and Western Siberia oil and gas provinces. The geoelectrochemical studies conducted by VIRG-Rudgeofizika partially spanned the seismic time section along profile 11, which made it possible to correlate the trace element composition of the soils and tectonic anomalies (IV, V, and VI). The comparison of geochemical and seismic data is shown in Table 4.

Among elements measured by DEM, only Ni and Co contents show tight correlation with anomalies; the contents of practically all elements extracted with SOM (Ni, Cd, Co, Cu, Zn, and Pb) are correlated with the anomalies; and only Cr demonstrated correlation with anomalies among the elements measured by the TMGM method. Hence, the most informative method is SOM, because most elements measured by this method exhibit a tight correlation with deep-seated anomalies.

Anomaly VI is best identified by SOM (maximums of Ni, Cd, Co, Cu, Zn, and Pb) and DEM (maximums of Ni, Cd, Co, and Zn), while TMGM well identifies anomaly IV by Ni, Mn, Cr, Zn, and Pb.

Table 4. Correlation of tectonic anomalies and geochemical fields

Element	DEM method			SOM method			Element	TMGM method		
	Geophys. anomaly			Geophys. anomaly				Geophys. anomaly		
	IV	V	VI	IV	V	VI		IV	V	VI
Ni	+	–	+	–	+	+	Ni	+	–	–
Cd	–	–	+	+	–	+	Mn	+	–	–
Co	–	+	+	+	+	+	Cr	+	–	+
Cu	–	+	–	–	+	+	Cu	–	–	–
Zn	–	–	+	+	–	–	Zn	+	–	–
Pb	–	+	–	–	+	+	Pb	+	–	–
Σ	1	3	4	3	4	6	Σ	5	–	1

Thus, only the complex DEM, SOM, and TMGM study of soils allows identification of deep-seated anomalies by an extremely high content of elements. The most informative elements are Ni, Co, and Pb; the less informative ones are Cd, Cu, and Zn.

The results of soil lithogeochemical survey were correlated with the oil–gas potential along profiles 11 and 6 using the same diagrams. The projections of oil fields (Cheremukhovskoe, Novo Sheshminskoe, Letnee, and Ashal'chinskoe) are shown along the *x* axis (Figs. 2–4). Among the trace elements studied along profile 11, V shows the maximum correlation (anomalous V contents were found above all the fields) with the oil–gas potential. A strong correlation is typical of Al, Na, Ti, Ba, Cr, Y, and Mo; their anomalous contents were obtained above three fields. Moderate correlations were found for Li, B, Ni, Nb, Sc, Be, and Ag. Along profile 6, the oil reservoir is correlated with anomalous contents of V, Cu, P, Ag, Sn, Li, and Hg.

Sharp changes were found in the contents of the aforementioned elements in soil layer above the oil reservoir along the profiles 11 and 6. Usually, extremely high contents of these elements above the reservoir margin give way to minimum values immediately above the reservoir, then the values increase again reaching maximum values. This is most distinctly seen on the Ashal'chinskii field, profile 11.

Thus, the correlation between the geochemical soil survey, geophysical anomalies, and oil potential can be interpreted as (1) the effect of oil reservoirs with V, Cu, P, Ag, Sn, Li, Hg, Al, Mo, B, Ni, Cr, and other elements (as anomaly-forming elements) on the soil; and (2) the influence of deep-seated tectonic processes recorded as anomalies of Li, Be, Ge, V, Cr, B, Yb, Al, Mn, Sn, As, Ni, and Mo.

Figure 5 demonstrates the distribution of multiplicative parameters along profile 11 (Alekseev et al., 2000). This plot also shows zones promising for oil: according to (a) these authors and (b) our data. The correlation of the geoelectrochemical data with the oil–gas potential of this area showed that the zones distinguished by Alekseev as promising for oil are not oil-bearing. In our opinion, the most promising areas are 4–6, 11–13, 16–18, 23–25, 37–39, 42–44, and 48–50 km, i.e., 7 zones (the numbers correspond to the distance in kilometers along the profile measured from the west to the east). Alekseev and coauthors believed that the most promising areas for oil exploration are located beneath extremely high metal contents in soil. However, as follows from previous experience, the anomalies mark the marginal parts of oil fields, i.e., are projected above the zones of water–oil contacts, while oil reservoirs are typically correlated with extremely low contents. The correlation of the most promising zones distinguished by us with oil fields found along this profile showed a fairly good agreement. Three fields are marked by extremely low contents, which increased to maximum contents above their margins. Special attention must be given to promising zones 1 and 2 (distances of 4–6 and 11–13 km along the profile). The geophysical data showed that this area contains a trap and can be drilled for exploration of the for HC reservoir.

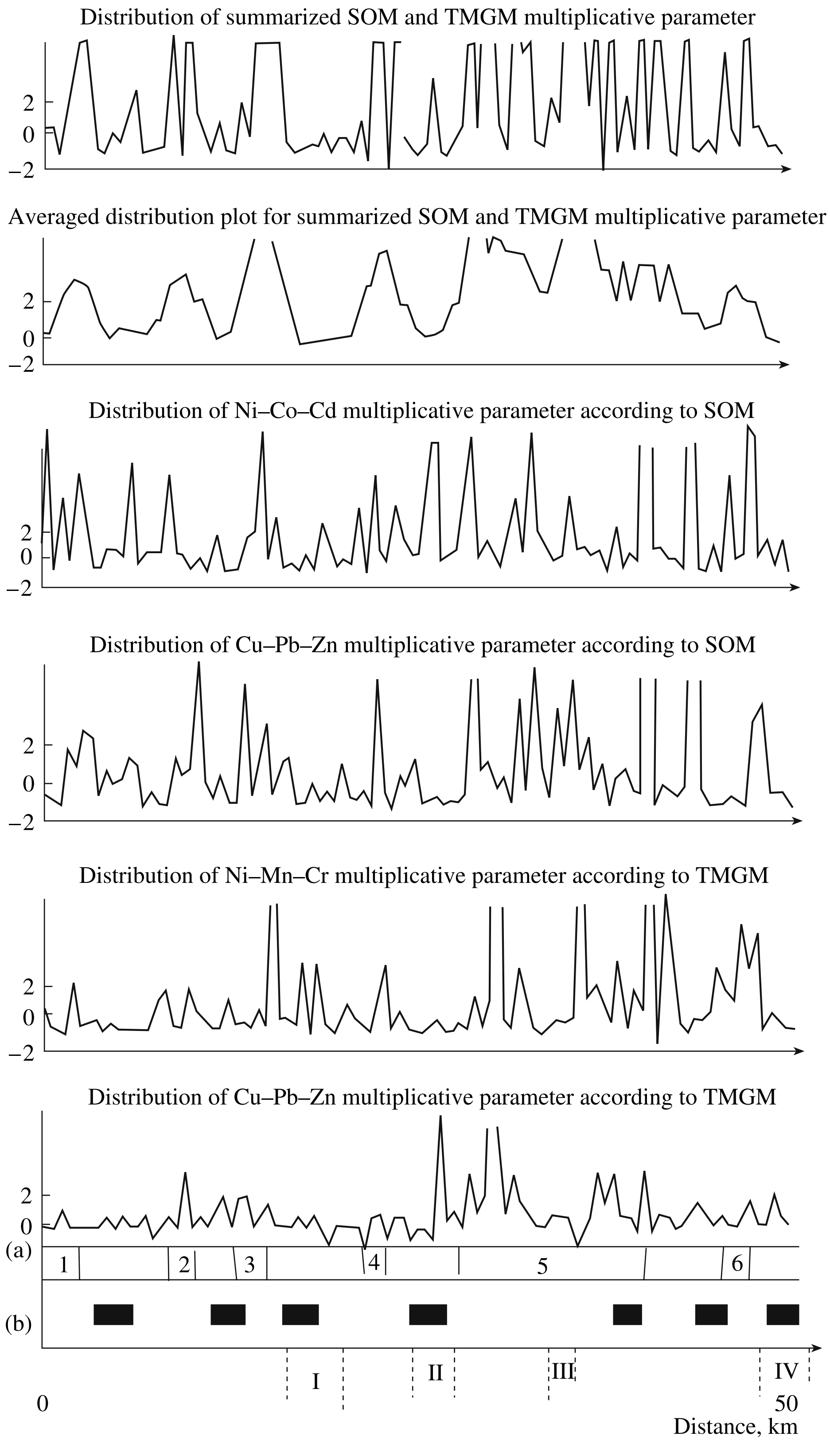

Fig. 5. Distribution of multiplicative parameters along profile 11 (Alekseev et al., 2000). Oil deposits: (I) Cheremukhovskoe; (II) Novo-Sheshminskoe; (III) Letnee; (IV) Ashal'chinskoe; (a) zones promising for oil potential (according to Alekseev et al., 2000); (b) zones recommended by us as promising for oil.

CONCLUSIONS

The analysis and generalization of a large body of analytical material showed that crustal anomalies caused by tectonic processes are correlated with the trace element composition of the soils. Along profile 11, the strongest correlation with deep-seated tectonic processes was found for Li, Be, Ge, V, Cr, B, and Yb. Less significant correlation was noted for Al, Mn, As, and Sn. Some of these elements are typomorphic of deep-seated and magmatic processes. Along profile 6, a lesser number of elements (Mo, Be, Ni, Yb, and Mn) demonstrated correlations with geophysical anomalies, which is possibly explained by the different character of anomalies. The sharp change in the contents of V, Cu, P, Ag, Sn, Al, Na, Mo, B, Li, and Hg could be interpreted as the effect of oil generation in the soil. It is interesting that this list includes magmatophile elements, easily mobile elements with variable valence, and biogenic elements.

The extremely high contents of magmatic emanation-related Li, B, Al, and As in soil are indicative of tectonic anomalies. Oil reservoirs are correlated with the anomalies of V, Ni, Cu, Mo, and Ag, which are typomorphic of oils and their ashes. The effect of subvertical fracturing in the basement rocks on the trace element composition of soils is related to the modern circulation of deep-seated fluids along the revealed subvertical fracture zones.

Thus, the anomalies found in the element contents can be used as prospecting guides for oil reservoirs and tectonic dislocations in the deep-seated zones of the Earth's crust.

However, the modes of trace element migration from oil reservoir to the surface, the effect of intermediate oil accumulations on the soil, and the presence of black shales and scattered organic matter enriched in trace elements remain unsolved problems. The anthropogenic pollution and the problem of analytical accuracy also should be taken into account.

During the subsequent study, our results will be specified and appended with data along other profiles. This study outlined only the common tendencies. In the future, we plan to identify elements informative for the purposes of exploration and to evaluate the ranges of element contents above hydrocarbon reservoirs. In addition, it is necessary to study in detail the trace element composition of oil reservoirs located above subvertical dynamic anomalies in order to determine the sources of HC fluids in the sedimentary sequence of Tatarstan.

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