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ABIOGENIC AND ORGANIC COMPONENTS OF MODERN TERRESTRIAL GASTROPODES OF AZERBAIJAN: STUDY OF MACRO-, MICRO- AND BIOELEMENTS

As a result of field campaign in the Greater Caucasus the big faunal material has been collected from the southern and northern slopes of these mountains. The material included shells of both living and dead terrestrial gastropods, found mainly on the territory of Guba district – an administrative region within Azerbaijan, located on the northern slope of the Greater Caucasus. The collected shells were then compared to gastropods found in the Shamakhi, Sheki and Gakh regions in the southern slope of the Greater Caucasus, and with shells from the Caspian Sea coast. In total, 70 samples of shells belonging to mollusk Helix lucorum L. have been analyzed.

The total organic matter (TOM) and several bioelements - organic carbon, protein nitrogen and phosphorus, have been determined in the shell material. Besides that macro- and microelement distribution in skeleton remains of the collected mollusks has been investigated. The results achieved allowed conclusion about the controling factors on the composition of calcium carbonate and the organic component of the shell material of studied gastropods.

Keywords: South-Eastern Caucasus, terrestrial gastropods, shells, organic matter, calcium carbonate, proteins, chemical elements

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Material and methodology

In order to ensure the study accuracy of the organic components and elemental composition of the terrestrial gastropod skeletons, the well-developed and undamaged shells were selected. The study was implemented on a vast area covering the northern part of the Azerbaijani segment of the Caspian coast and the southern and northern slopes of the Greater Caucasus mountain system (Figure 1). Different individual age representatives of the same species were selected to study ontogenetic factors affecting the accumulation of the organic matter. The samples were prepared following a single procedure: the soft tissue was separated and shells were washed for one hour under running water at 20–22ºC. The soft tissue attachment sites and foreign matters were carefully scraped. After that the gastropod skeletons were dryed in the dark room. In order to produce reliable analytical results the parallel analyses were performed.

Organic carbon was determined by the method of I.V.Tyurin (Standard method …., 2021). The method is based on the oxidation of an organic matter in shells with chromic acid until forming of carbon dioxide. Protein nitrogen analysis was performed according to the Bremner method (1965). Macro- and microelement contents were determined by the X-ray spectroscopy technique.

Discussion of results

Distribution of organic component in the shell material of terrestrial gastropods

Samples of this terrestrial mollusk species were collected in six areas of Azerbaijan located on the southern and northern slopes of the

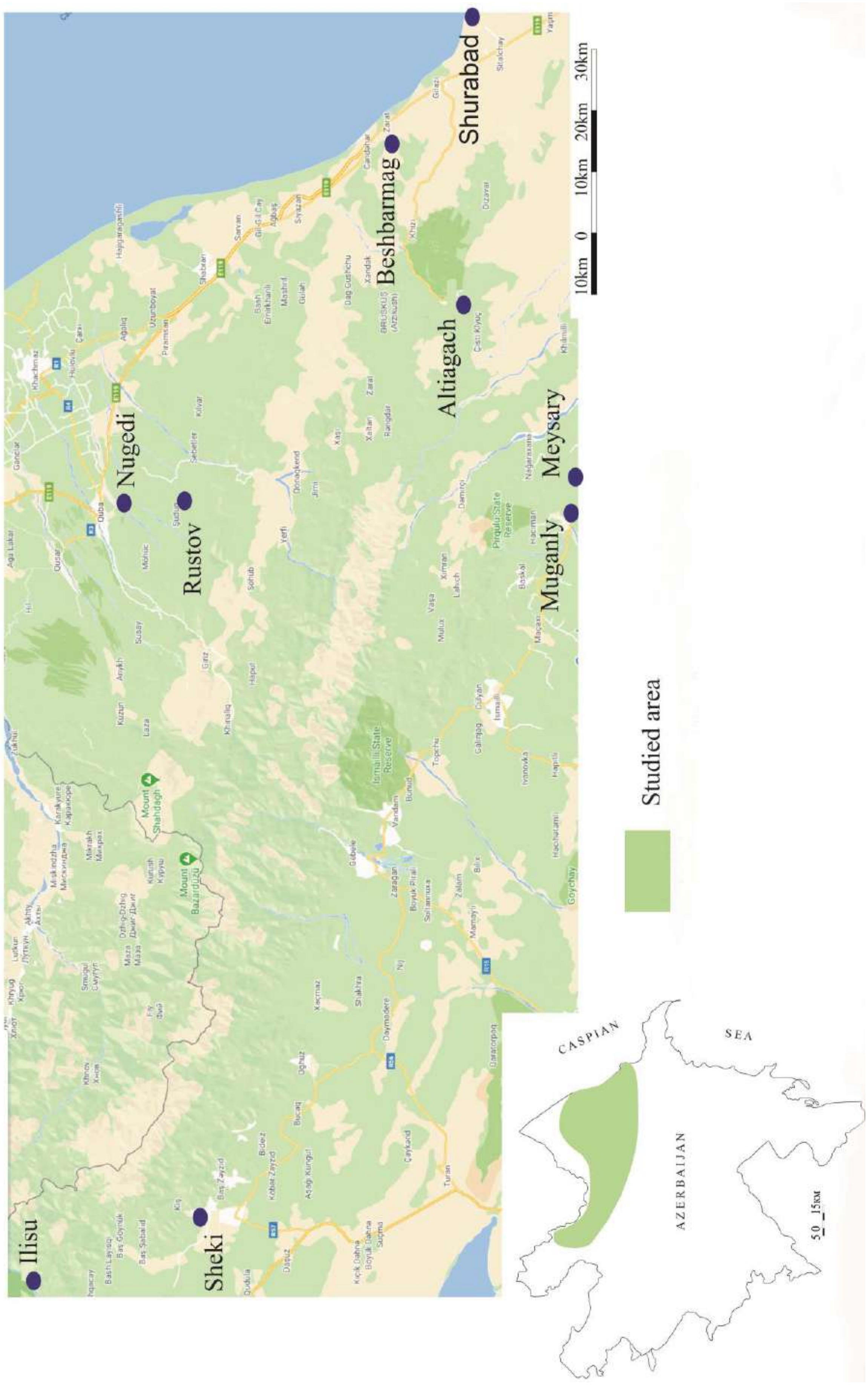

Figure 1. Location map of the collected shell samples of terrestrial gastropods within studied area

Greater Caucasus that not significantly differing by the environmental and geochemical characteristics. Samples found in the Guba area in the northern slope were compared with those ones collected from the Shamakhi, Sheki and Gakh regions in the southern slope. The shells found in four localities in the Guba and Shamakhi regions (Nugedi, Rustov, Meysary and Muganly) belonged to the adult gastropods, while the other sample sets collected in Sheki and Ilisu sites contain different-age individuals. In total, 26 samples with well formed and undamaged shells have been analyzed.

We have recorded that amount of bioelements in the studied skeletons is varying in a wide range – from 0.17% to 0.50% with an average value equaling to 0.25% in case of organic carbon (C_{org}), and from 0.37% to 0, 125% with an average value of 0.057% in case of $N_{protein}$ (Figure 2).

The highest organic carbon and protein nitrogen quantities were identified in the samples collected from Rustov and Nugedi localities (Guba region), and the smallest – in the shells found in Muganly and Meysary (Shamakhi region). Relatively high contents of the bioelements were determined in the samples collected from Ilisu locality (Gakh region) hypsometrically located 1300 m above sea level, and in shells from Sheki region.

We can report that these bioelement concentration differences are mainly due to ontogenetic control. It was recognized that organic carbon and protein nitrogen amounts are equal on average to 0.5% and 0.125% respectively in the young forms; 0.31% and 0.075% in the middle-aged samples, and 0.20% and 0.0049% in the adult shels (Figure 2). These data testify to gradual decrease of the bioelement quantities in the skeleton material of *Helix lucorum* L. mollusk with the age.

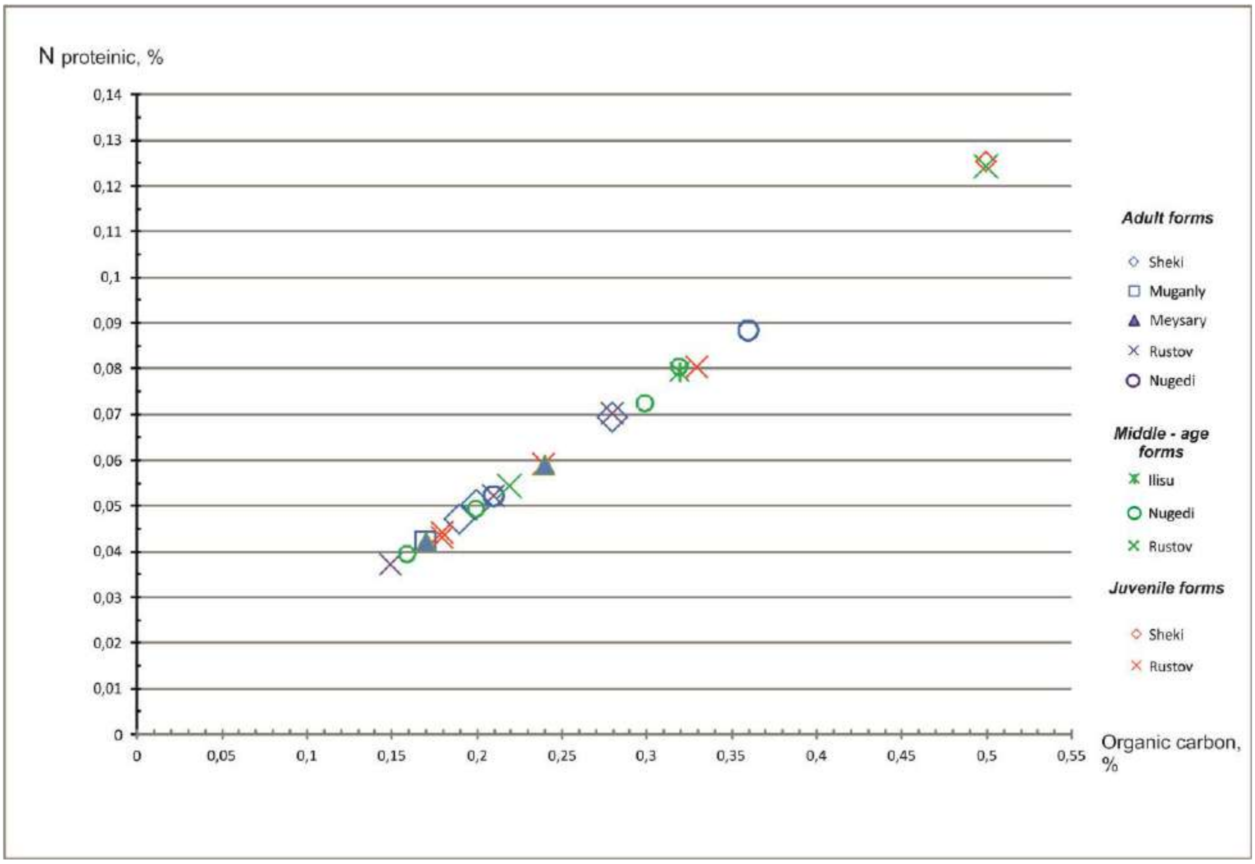

Figure 2. Plot of organic carbon and proteinic nitrogen content values in the different-age shells of *Helix lucorum* L.

Another reason for the wide variations of the bioelement amounts is the individual impact of the studied mollusks. In order to assess this effect on the in-shell concentrations of the organic carbon and protein nitrogen, four specimens of *Helix lucorum* L. of the equal age and size in each locality – Rustov and Nugedi, were analyzed. The age of the analyzed skeletons was determined to be equal to three years. The shells from the Rustov locality have the height of 35 mm, height of the last whorl – 25 mm, and diameter of the last whorl – 28 mm (Table 1). We should mention that these shells differed from each other by wall thickness and color.

According to the analysis results, light colored thick-walled shell contains 0.18% of the organic carbon and 0.043% of protein nitrogen. $C_{org.}$ / $N_{prot.}$ ratio is equaling to 4.18 (Figure 3, Table 1). The less light thick-walled shell demonstrates the organic carbon amount of 0.18%, the protein nitrogen – 0.044%, and the $C_{org.}$ / $N_{prot.}$ ratio of 4.09. The less thick-walled dark shell contains 0.24% of the organic carbon and 0.059% of the protein nitrogen, $C_{org.}$ / $N_{prot.}$ ratio of 4.06. Finally, the thin-walled dark shell is characterized by 0.33% of the organic carbon, 0.080% of the protein nitrogen, and $C_{org.}$ / $N_{prot.}$ ratio is equaling to 4.12.

Table 1

Composition of the organic component of the *Helix lucorum* L. gastropod shells

#	Location	Ontogenetic age / size	Note	C org. %	N prot. %	C org. / N prot.	Org. matter, %	Protein, %
1	2	3	4	5	6	7	8	9
1	Ilisu	Middle age	Did’t treated w/dist.w.	0,32	0,079	4,06	0,628	0, 475
2	-------	Adult	Treated w/dist. water	0,28	0,069	4,07	0,547	0,415
3	Sheki	Middle age	Light form	0,22	0,054	4,07	0,430	0,331
4	-------	Middle age	Dark form	0,16	0,040	4,00	0,313	0,240
5	Sheki	Adult		0,20	0,050	4,00	0,319	0,301
6	--------	Adult		0,19	0,047	4,04	0,372	0,283
7	-------	Middle age	3 specimens	0,30	0,075	4,00	0,587	0,452
8	-------	juvenile	5 speciments	0,50	0,125	4,00	0,978	0,753
9	Muganly	Adult	4 specimens	0,17	0,042	4,05	0,332	0,253
10	Meysary	Adult	3 speciments	0,17	0,042	4,05	0,332	0,853
11	Rustov	Adult	Thin-walled light form	0,28	0,070	4,00	0.547	0,421
12	Nugedi	Adult	Thin-walled light form	0,36	0,088	4,09	0,704	0,530
13	Rustov	43*30*45	Thin-walled dark form	0,21	0,052	4,03	0,410	0,313
14	------	-------	Thin-walled dark	0,15	0,037	4,08	0,283	0,231
15	Meysary	44*30*45	Thin-walled dark	0,24	0,059	4,06	0,469	0,355
16	Nugedi	44*28*43	Thick-walled light	0,21	0,052	4,03	0,410	0,313
17	Rustov	35*25*38	Thick-walled light	0,18	0,043	4,18	0,355	0,259
18	-	35*25*38	Thin-walled dark	0,18	0,044	4,09	0,355	0,265
19	-		Thin-walled	0,24	0,059	4,06	0,469	0,355
20	-		Thin-walled	0,33	0,080	4,12	0,645	0,482
21	Nugedi	38*27*42	Thin-walled	0,32	0,080	4,00	0,628	0,482
22	-		Thick-walled	0,30	0,072	4,03	0,587	0,434
23	-		Thick-walled	0,16	0,039	4,1	0,313	0,235
24	-		Thick-walled	0,20	0,049	4,08	0,391	0,295
25	*Rustov*	38*28*43	Thick-walled	0,22	0,054	4,08	0,430	0,325

1	2	3	4	5	6	7	8	9
26	-		Thick-walled dark	0,16	0,039	4,10	0,313	0,325
27	-			0,50	0,124	4,03	0,978	0,747

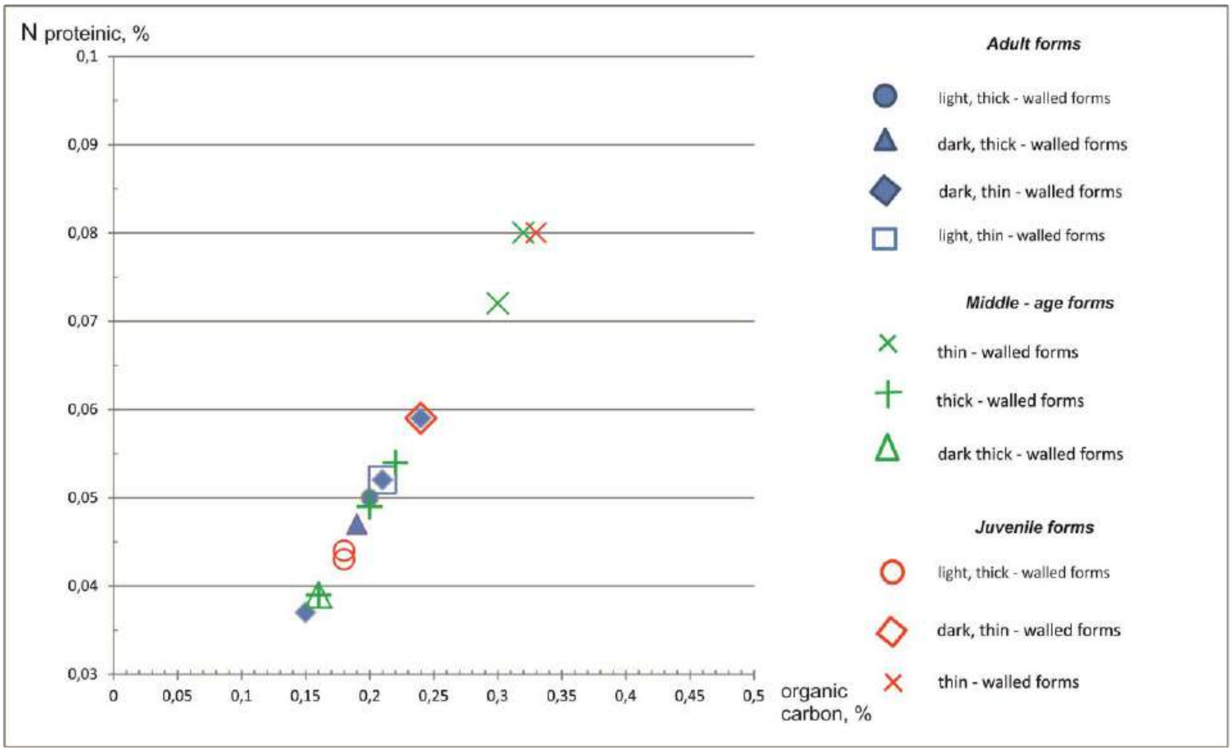

Figure 3. Plot of organic carbon and proteinic content values in the shells of *Helix lucorum* L. by the thickness and color of the shell walls

The Nugedi site shells have the following parameters: shell height – 38 mm, height of the last whorl – 27 mm, diameter of the last whorl – 42 mm. The shells are dark in color.

According to the analysis results, the first thin-walled shell demonstrates 0.32% of the organic carbon and 0.080% of the protein nitrogen in the organic matter composition. The shell has a $C_{org.}$ / $N_{prot.}$ ratio equaling to 4.00.

The second thin-walled shell has the carbon content of 0.30%, nitrogen content of 0.072%, and the $C_{org.}$ / $N_{prot.}$ ratio of 4.03. The third thin-wall shell contains 0.20% of the organic carbon and 0.049% of the protein nitrogen, with $C_{org.}$ / $N_{prot.}$ ratio equaling to 4.08. Finally, the fourth relatively thick-walled shell had 0.16% of the organic carbon, 0.039% of the protein nitrogen, and $C_{org.}$ / $N_{prot.}$ ratio of 4.1.

The data indicate the different bioelements concentrations identified in the shell material of *Helix lucorum* L. even collected from the same area and sometimes from the same plant. It is worth to mention that content levels of the organic carbon and protein nitrogen are higher in the specimens with thin-walled shells rather in thick-walled forms. As it was demonstrated by the investigations of skeletons collected from the Nugedi locality, those mollusks have the least calcified shells and higher organic carbon and protein nitrogen. Shells from Meysary and Muganly localities are well calcified with lower amount of the both bioelements.

These results allowing conclusion on significant individual controls on the quantity of bioelements in the *Helix lucorum* L. shells.

The interesting point in these investigations is the similar $C_{org.}$ / $N_{prot.}$ ratio values in the shells with very different bioelement quantity values.

Thus, this study demonstrated that the $C_{org.}$ / $N_{prot.}$ ratio in the shell material of the *Helix lu-*

corum L. is a typical species character that is not affected by environmental variations, geochemical factors and mollusk ontogeny. The calculations indicate the narrow range of the $C_{org.}$ / $N_{prot.}$ ratio variations in the *Helix lucorum* L. shell material – from 4.00 to 4.09 with average value equaling to 4.04. Vriously colored forms have the same ratio value. For example, $C_{org.}$ / N_{prot} ratio equals four in both light and dark colored shells collected in the southwestern outskirts of the Sheki city.

It is important to clarify whether this ratio can be considered as a typical chemical sign of the separate species of terrestrial gastropods.

Relatively low $C_{org.}$ / N_{prot} ratio in the shells of *Helix lucorum* L. is due to large protein matter in the organic component of their skeletons. In the adult forms of this mollusk selected in the Ilisu locality (the altitude is 1300 m), proteins make up about 76% of the entire organic phase, while the remaining 24% are non-protein matter. Protein and non-protein fractions relate to each other as 3 to 1. Similar relation between the proteins and the sum of non-protein compounds were identified in shells collected from the other localities. Such constancy of the protein to non-protein ratio is typical biochemical characteristic of the *Helix lucorum* L. mollusc, as it neither changes in ontogeny and nor depends on the environmental conditions and geochemical factors of the habitats.

Correlation analysis between the amounts of organic matter and proteins in the samples collected from the various places, didn't demonstrate any geographical patterns in this parameter's value (Figure 4).

The lowest ratio values speaking for the increased protein quantity in the organic component were determined in the shells from Sheki and Rustov. The highest values of 1.35 were detected in the shells from Rustov and Nugedi. Finally, majority of the samples collected from different places was characterized by the medium ratio values of 1.3–1.35.

We also tried to find other controls affecting this ratio such as wall thickness and color of the shells as well as individual age of the specimens. We have revealed thatthis parameter demonstrates the greater variations in the thick-walled shells (Figure 5). In such samples values of the ratio vary within the wide range of 0.95–1.37. However, in the thin-walled shells it appears to be more constant (1.23–1.34), which is hard to be explained by degree of calcification of the gastropod's skeletons.

Speaking about values of the OM / N_{prot} ratio in different-color shells, it has to be noted that it is relatively higher in the light-colored shells due to slightly less amount of proteins comparing to dark-colored samples (Figure 6). The minimal value of this ratio equals to 1.05, the maximum one – to 1.37. In the dark shells, the values change between 0.95 and 1.33.

At this stage, it is quite difficult to find an explanation of this fact. Probably, the reason lies more in the ontogenetic control over the content of organic components rather in the morphological characteristics of the shells. The plot displaying OM / N_{prot} ratio depending on the individual age of the studied mollusks supports this idea (Figure 7).

It is clear from this plot that the discussed ratio is relatively lower and more variable in the mature forms and displays more or less constant values in the young specimens.

It allows coming to conclusion about relatively lower protein content in the juvenile forms of the terrestrial gastropods. Based on this result we tend to think that the lower protein content in the light-colored shells of the *Helix lucorum* L. is due to their young individual age.

Distribution of some macro and microelements in the shell carbonate of terrestrial gastropods

Along with organic components, the studies also covered distribution of some macro and microelements in a skeleton material of the analyzed gastropods.

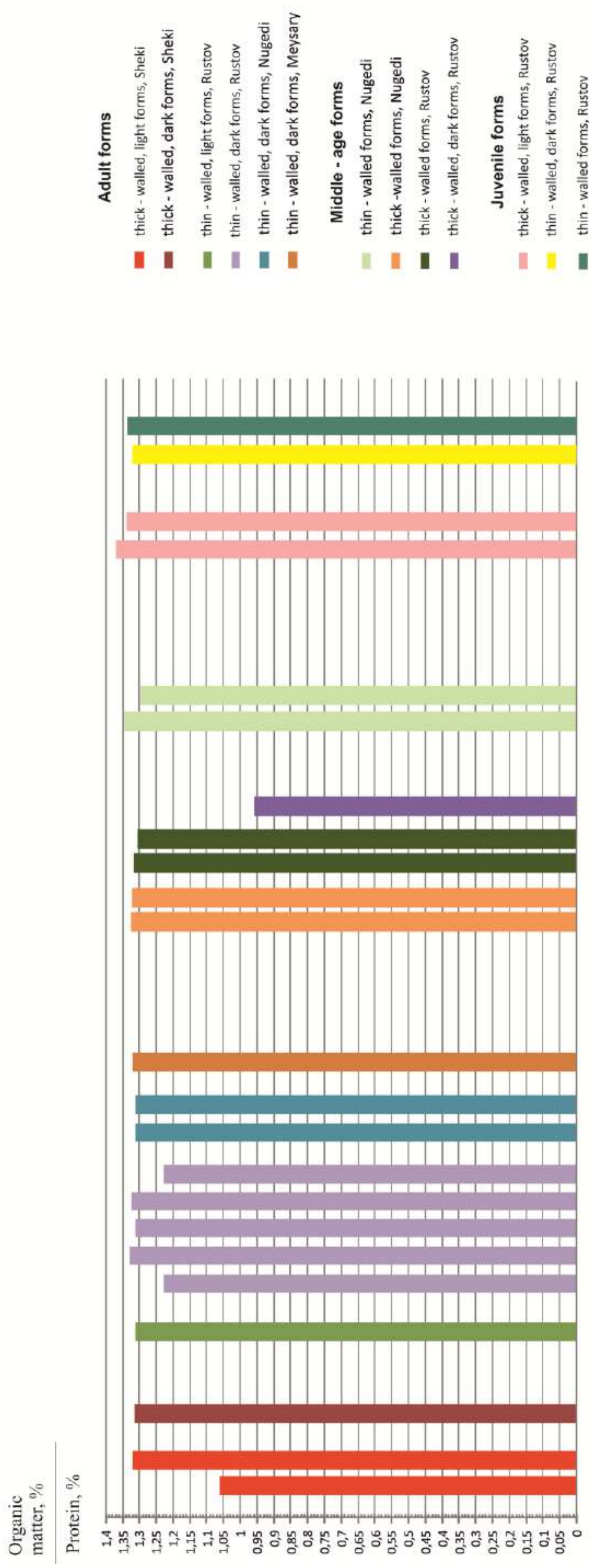

Figure 4. Organic matter to proteins ratio in the shells of *Helix lucorum* L. collected from various localities

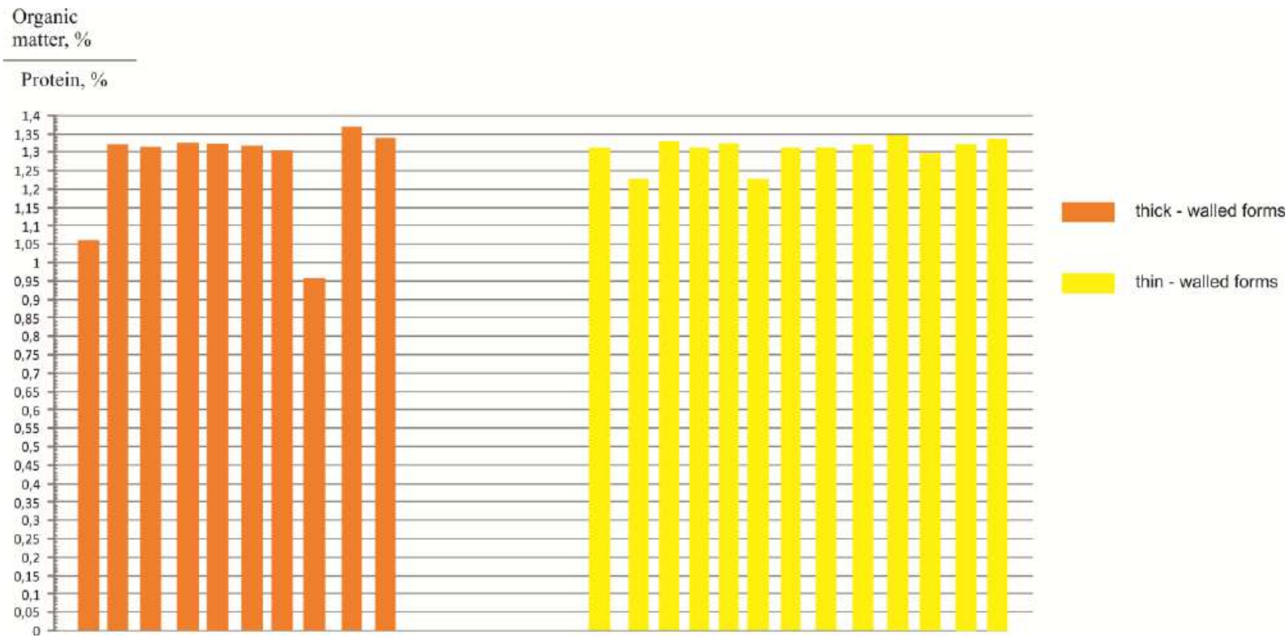

Figure 5. Organic matter to proteins ratio in the shells of *Helix lucorum* L. versus shell-wall thickness

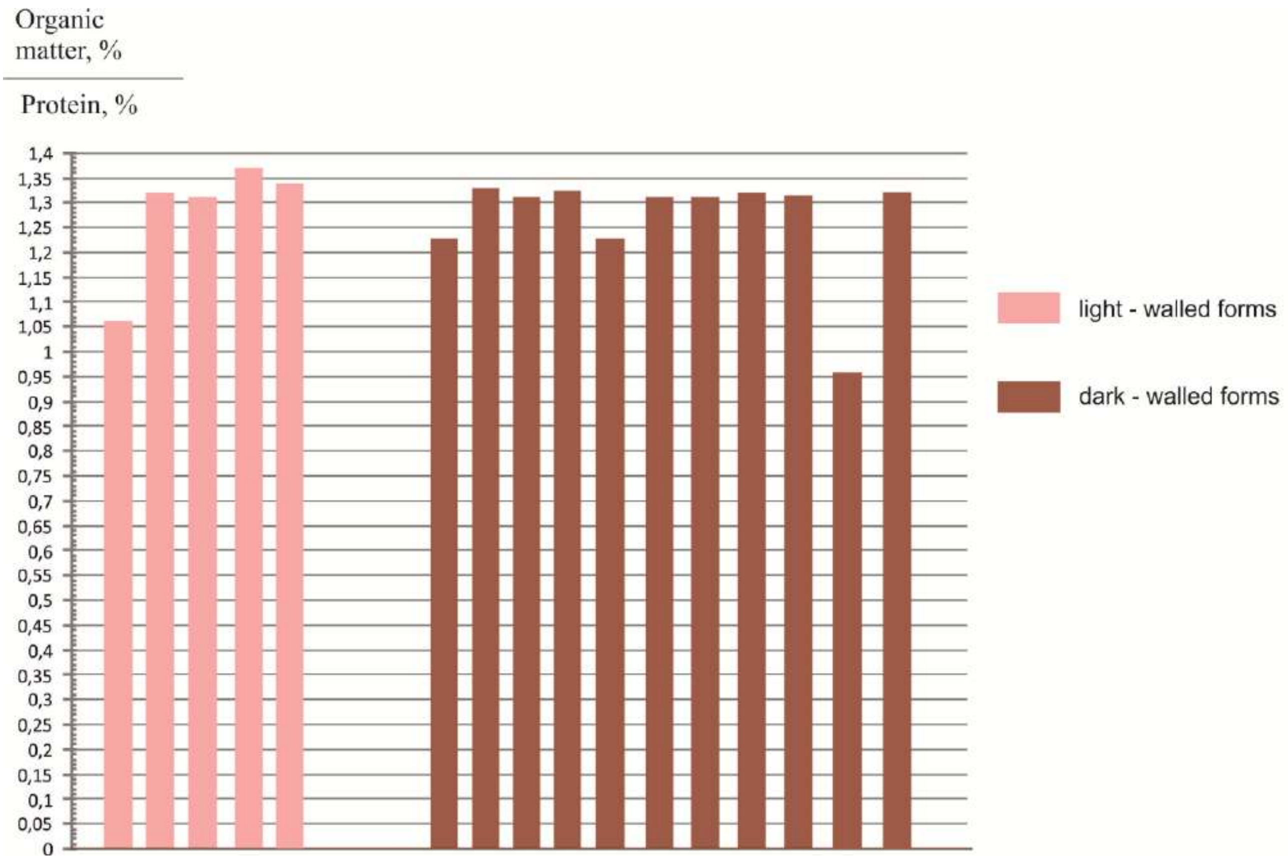

Figure 6. Organic matter to proteins ratio in the differently colored shells of *Helix lucorum* L.

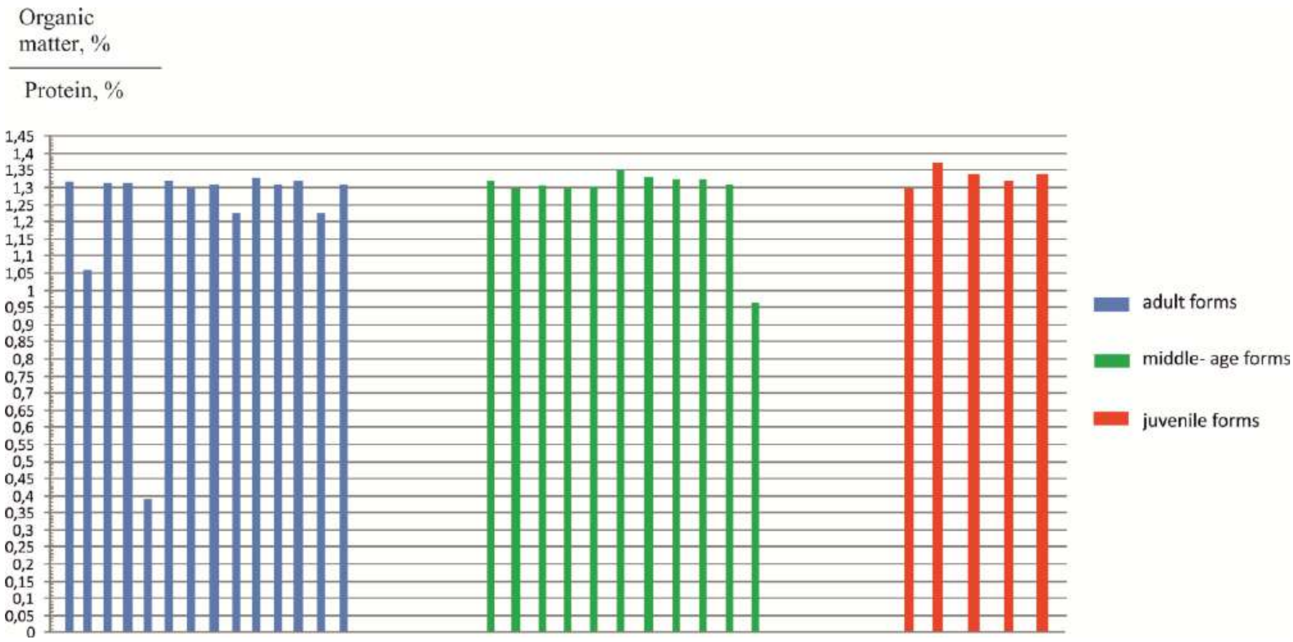

Figure 7. Organic matter to proteins ratio in the various individual age shells of *Helix lucorum* L.

It was identified by the studies that calcium content is slightly higher (nearly 1%) in more mature forms (Figure 8a). For example, *Ca* content of the samples collected in Altiaghach site (location in Figure 1) makes up 35.5% in the young and 36.5% in the middle-age specimens. In case of the samples collected in Shurabad, difference in *Ca* content between young and middle-age gastropods makes 0.65%. Although the calcium proportion in the adult forms is relatively reduced, it is still higher than in the young ones.

The highest calcium content was recorded in the shells collected in Shurabad (location in Figure 1). This phenomenon is observed in both young and middle-age individuals. Difference in the calcium content between Altiaghach and Shurabad samples reaches 2% in the both age groups.

The opposite tendency is observed in the silicon content. The highest concentrations were found in the specimens from Altiaghach locality, while the lowest amounts were registered in the samples collected in Shurabad site (Figure 8b). Difference in the amounts makes up 2–2.5 times in all age groups. Meanwhile, shells collected from Beshbarmag and Shurabad sites are characterized by similar silicon contents. The same regularity is observed in potassium and aluminum geographical distribution (Figure 8e, f).

In ontogeny silicon demonstrates rather inconsistent behavior. In the samples from Altiaghach silicon content in the young shells is by 1.5 times higher than in the adults. Difference in the silicon content between the young and middle age samples from Shurabad is just 0.07%, varying from 0.92% in the young to 0.85% in the middle age specimens. At the same time, content in the adults sharply increases and reaches 1.62%.

It is commonly known that phosphorus is a vital element involved in the structure of the bone tissue (up to 85%) and being a part of the organism's proteins. Some authors formerly argued that there is a difference in phosphorus content of the different-size shells, and the highest contents are usually registered in the big forms (Jurkiewicz-Karnkowska, 2002). The opposite tendency has been recorded in our samples. For example, phosphorus content in the middle age specimens from Altiaghach locality appeared to be 3.5 times lower than in young specimens (Figure 8c). In the samples collected from Shurabad locality, this difference is just 1.5 times.

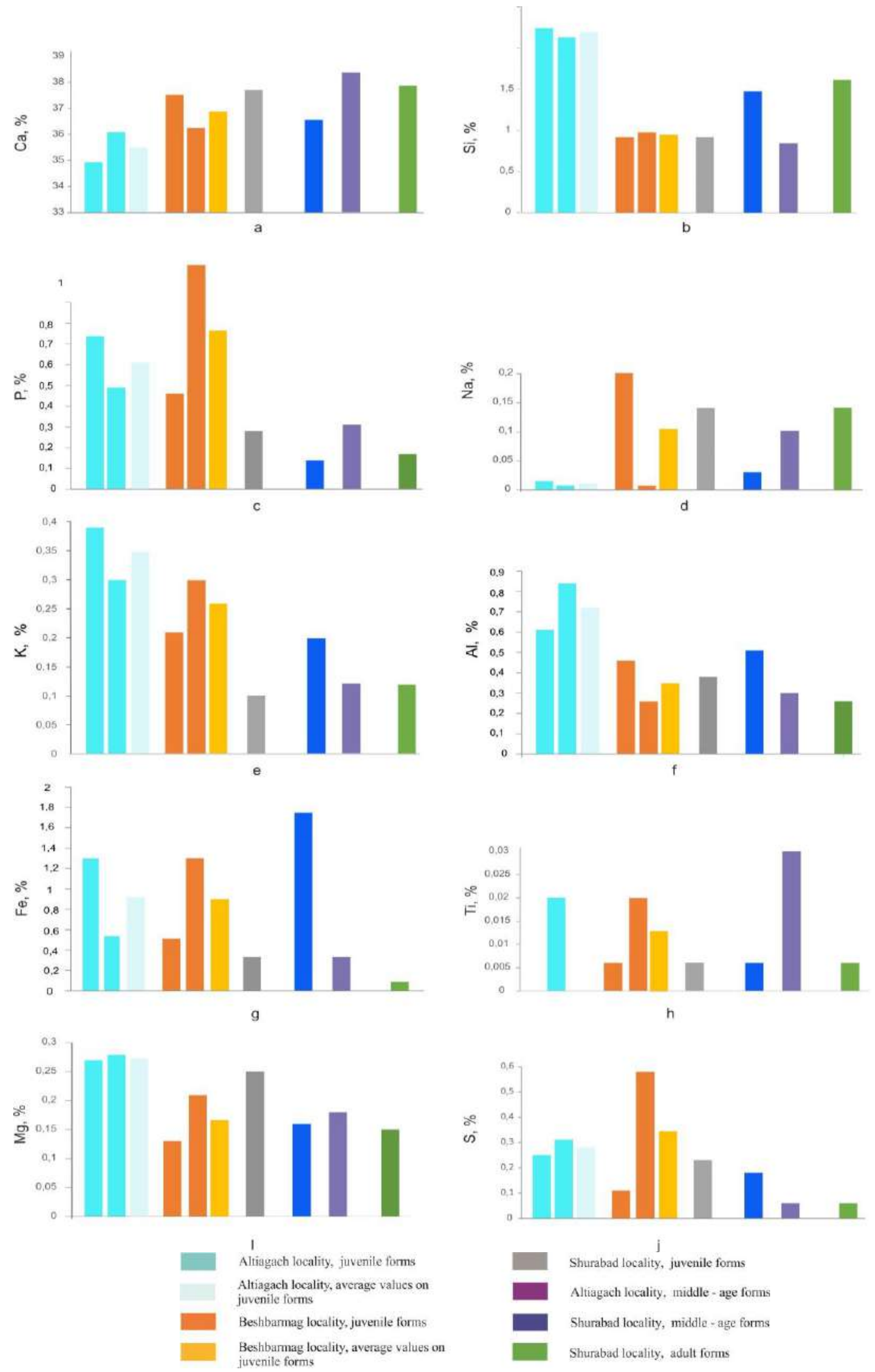

Figure 8. Content values of some macro- and microelements in the shells of different-age terrestrial gastropods found in Azerbaijan

There are no geographical regularities observed in the distribution of phosphorus content of the shells.

Sodium content of the shells doesn't demonstrate any distribution by the mollusk age. Thus, sodium amount in the young shells from Altiaghach site exceeds that of the middle age samples by 3 times (Figure 8d). This tendency is the opposite in the specimens found in Shurabad site. Here the difference in the sodium contents is not more than 1.5 times.

The highest sodium content was recorded in the same-age samples collected from Shurabad site, while the lowest values are reported in the Altiaghach forms. This difference is 14 times in the young forms, and 3.5 times in the middle age shells. Such geographical distribution of sodium is similar to that of calcium.

Potassium contents in the gastropod shell material do not also demonstrate any ontogenetic regularities (Figure 8e). However, geographical variations of this element are observed. Alike *Al*, potassium contents are the highest in Altiaghach and lowest in Shurabad forms. Difference makes up nearly 3.5–1.5 times. The wide range of the variations is observed in the young forms. Samples collected in Beshbarmag site occupy intermediate position.

Distribution of aluminum contents demonstrates both age and geographical variations (Figure 8e). Thus, amount of this element becomes 1.3–1.5 times lower with age of the specimens. On the other hand, aluminum content of the shells from Shurabad site is 1.8–1.6 lower than in the same-age skeletons from Altiaghach locality. Aluminum content in the shell material in Beshbarmag samples is similar to that in the Shurabad forms.

There are no ongenetic variations in the iron contents (Figure 8g). Meanwhile, there are strong geographical variations expressed in the 3 to 6-times higher *Fe* content in the samples from Altiaghach locality comparing to shells collected in the Shurabad site. Also, it should be mentioned that the variation range increases with age of the studied gastropods. Average *Fe* content in the young forms found in the Beshbarmagh site is close to that in the shells from Altiaghach locality.

The plotted data on macro-, microelemental composition of the shell material demonstrate that the titanium content doesn't reveal neither ontogenetic nor geographical regularities (Figure 8h). For this reason, it is difficult to speak about controls for this element concentrations in the shell carbonate.

Magnesium content in the shell carbonate doesn't express any geographical regularities (Figure 8i). Meanwhile, it changes in the different age groups, declining by 1.7–1.4 times in the older specimens.

Distribution of sulphur is subject to both ontogenetic and geographical control (Figure 8j).

Our investigations also covered the analysis of correlation between the various elements (Figure 9). It was recorded that *Mg* content displays the moderate negative correlation with the amount of *Ca* (Figure 9a). It is known that magnesium is able to replace calcium in the crystal lattice of calcium carbonate that conditioned the negative relationship between these two elements. Judging by the differences in *Mg* contents in the young and adult shells, we can assume that the amount of magnesium is controlled not only by post-life transformations in the mollusk's skeleton, but also by biogenic processes. In other words, replacement of calcium by magnesium in the shell calcium carbonate takes place already during mollusk's lifetime, and this process is weakining in the mollusk ontogenesis.

On the other hand, the moderate – strong negative correlation with calcium is also characteristic of a number of the other elements constituting the calcium carbonate of the gastropod shells. Such negative correlation is demonstrated by silicon, iron, titanium, aluminum, phosphorus and sulphur, and very strong negative correlation is recorded for potassium. The good positive correlation was reported only for sodium. Such negative relationship between some elements and the calcium in an abiogenic component of the shell material can be explained by silicification processes and replacement of calcite by silicon oxide containing some admixtures.

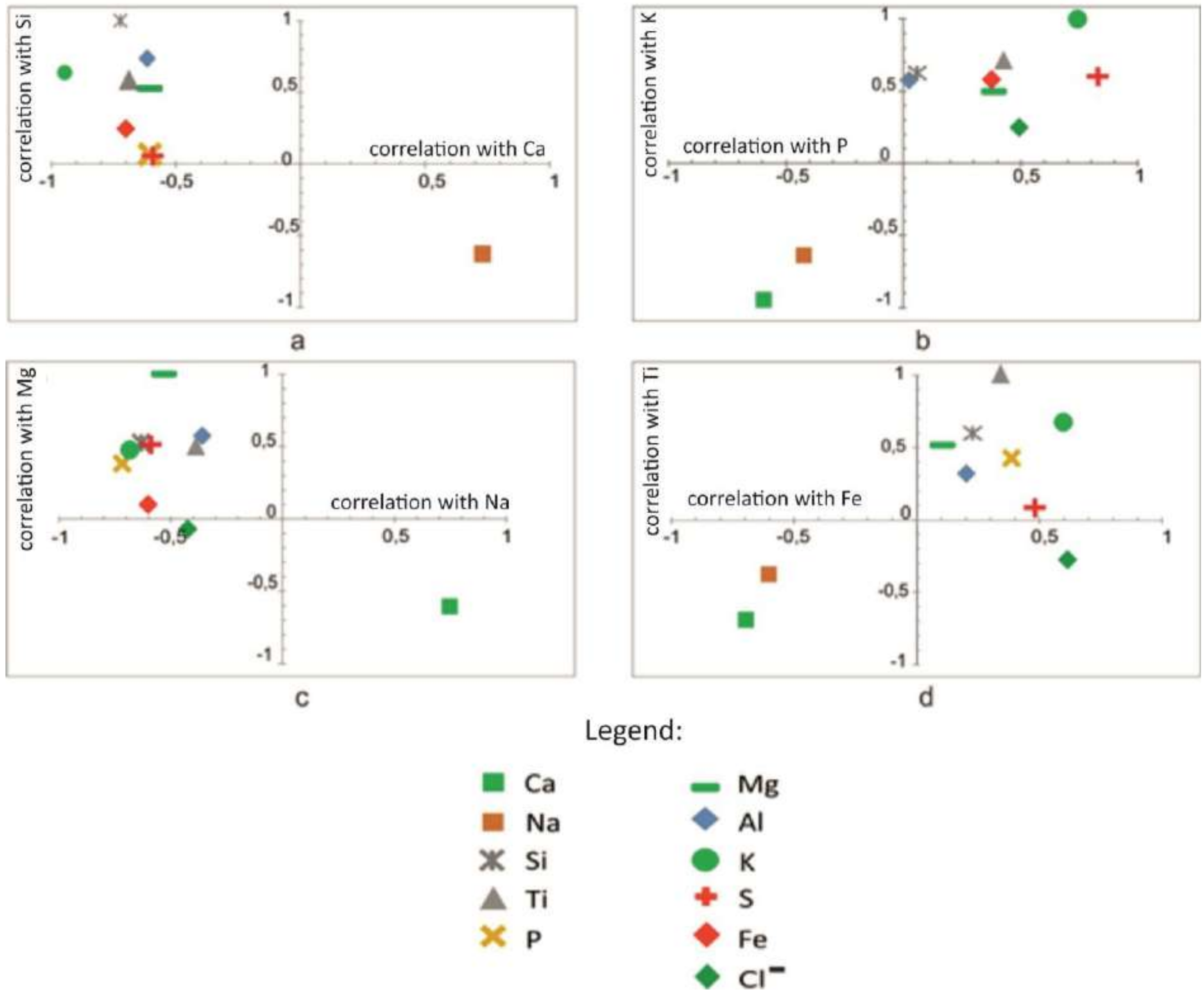

Figure 9. Correlations between macro- and microelements in the shell material of the terrestrial gastropods collected in Azerbaijan

Regarding to negative correlation between the phosphorus and calcium, we assume that this phenomenon is a result of binding capacity of phosphorus and decrease of free calcium content as the phosphorus amount is increasing in the organism.

As it was demonstrated above, both phosphorus and calcium show opposite behavior in ontogenesis. Reduction of phosphorus content in the older forms apparently causes growth of the calcium amount.

There is a significant positive correlation between many elements and silicon. Especially, the strong correlation is observed between silicon and aluminum contents that testifies to the presence of aluminum silicates in the studied shells, probably, in the contaminating terrigenous material. Besides main elements (aluminum and silicon), aluminum silicates may contain cations of potassium and magnesium as well. Revealed positive correlation between *Si*, *Al* and *K* contents in the calcium carbonate of gastropod shells confirms our conclusion about similarity of these elements' geographical distribution, to wit – the lowest amount in the shells collected in the Shurabad site and the highest – in the samples from the Altiaghach locality that is, probably, due to contamination of these shells with terrigenous particles. At the same time, magnesium and titanium displaying good positive correlation with the *Si* content do not demonstrate such geographical variations. Therefore, it gives us a ground to assume that positive correlation of these elements with silicon is a result of silicification rather than terrigenous contamination.

Weak positive correlation between silicon and sulphur, phosphorus observed against the background of negative moderate relationship of these elements with calcium, indicates the absence of significant changes of the above mentioned elments' amount due to silicification of the shell material and dominating biogenic controls that is proved by the positive significant correlation between sulphur and phosphorus (Figure 9b).

The significant positive correlation with phosphorus is also demonstrated by potassium (Figure 9b) that can be considered as an indication of the biogenic character of these elements and their participation in the metabolic processes of the mollusks. Sulphur, silicon, aluminum, magnesium, titanium and iron manifest considerable positive relation with potassium content in the studied shells. Meanwhile, absence of correlation between these elements (except for sulphur) and the phosphorus is apparently an evidence of their relation with abiogenic processes, such as silicification, contamination of mollusk skeletons with soil and rock particles as well as replacement of the atoms of calcium during post-life transformations in the crystal lattice of shells. The study results also suggest that potassium plays a dual role in the shell carbonate of the gastropods. The primary role is connected to biogenic component, while the secondary role is related with shell contamination.

Accumulation of sodium in the gastropod shells demonstrates no changes by age and clearly pronounced geographical variations. The latter is expressed in higher sodium content in the specimens collected in the Shurabad site. Similar tendency is observed for the calcium content that indicates the better preservation of Shurabad samples. Increased sodium content in these shells can be, probably, related to higher concentrations of this element in the soils and plants in this site. It should be mentioned that the sampling points are located close to the Caspian coast, and the background sodium content in this area is high due to salt precipitation from the seawater. Thus, in spite of completely different controlling factors for calcium and sodium accumulation in the shell material of studied gastropods, the similar geographical variations of the both elements within the research area brought to positive correlation between these two elements' content.

The other revealed elements in the shell matter of gastropods are characterized by negative, mainly moderate, correlation with sodium content (Figure 9). We think that this fact is additional evidence to that the sodium content in the studied shell substance is most likely not controlled by the post-life processes of skeleton silicification and contamination with terrigenous particles, but is rather determined by the other factors, which have already been discussed above. Observed inverse correlation between the quantities of sodium and *Si*, *Al*, *K* is apparently caused by the opposite character of their accumulation in shell material within the study area.

To explain the negative correlation between the sodium and phosphorus contents is more complicated. One of the possible explanations may lie in the Na^+ toxicity and depressing effect of sodium on the vital processes of organisms (this impact was discussed early based on the coastal plants' study results) (Du, Hesp, 2020) .

Another question is the reason standing behind the negative even weak correlation between the amounts of sodium and chlorine ion. Possibly, such phenomenon is connected to a selective ability of the gastropods to absorb certain elements from the ambient environment.

The role of magnesium in the shell matter and its' correlation with calcium content was discussed above. Correlation of magnesium with the other elements is weak, which is, probably, an indication of the absence of any dominating factor affecting its' accumulation (Figure 9c). The only exception is a moderate correlation with aluminum (the correlation ratio is 0.57).

Iron content in the shells demonstrates direct correlation with all elements, except for *Ca* and *Na*, with which the iron displays inverse moderate correlation (Figure 9d). The positive correlation of *Fe* with all elements is weak or negligible except for potassium and chlorine. The inverse correlation with calcium and absence of any correlation with silicon and aluminum indicates that iron is not binded to aluminum silicates in the shell matter. Accumulation of this element in the mollusk skeletons is, probably, a result of either oxidization and calcium replacement processes in the shell carbonate, or rich iron content in the soil substrate. At the same time, inverse correlation between the iron and sodium contents is, apparently, caused by the opposite character of their accumulation within the area under study.

The significant positive correlation between iron and potassium, chlorine we explain by an enrichment of the substrate and plants with all three elements. Similar explanation can be given to the behavior of titanium. A good direct correlation of this element with silicon tells about possible occurrence of titanium in the silicon compounds (Figure 9d).

Conclusions

1. The organic matter in the shell material of the terrestrial gastropods *Helix lucorum* L. displays an ontogenetic variations of its composition. Protein content in the young forms is relatively low as compared to the older speciemens. The juvenile shells are also characterized by higher organic carbon and protein nitrogen amount. Finally, calcified shells have reduced bioelements concentrations;

2. The impact of wall thickness and color of gastropod shells on the ratio of protein-nonprotein components in the organic matter is not registered. The geographical variations are not also recorded.
The ontogenetic development is a dominanting control on the organic matter formation and relationship of its components in the gastropod skeletons.

3. Studied macro- and microelements in the shell material can be grouped as follows:

a. biogenic elements directly contributing to a mollusk's life cycle – calcium, phosphorus, sulphur and magnesium. The accumulation of these elements is affected by the ontogenetic variations.
b. such elements as *K*, *Mg* and possibly *Ti* are accumulated in the shell material as a result of the post-life transformations due to either silicification of the calcium carbonate or its contamination with terrigenous components. Amounts of these elements demonstrate good positive correlation with silicon and aluminum.
c. elements accumulated through the replacement of calcium as a result of metabolic processes and post-life transformations. Such element is magnesium. It was recorded that replacement ability of calcium with magnesium in a shell's crystal lattice decreases with the age of the mollusk.
d. elements – *Na, Fe, Ti, K, Cl,* controlled by the habitat of the mollusk.
e. dual nature elements. Their concentration in the shell carbonate is affected by both biogenic and abiogenic factors, for instance, potassium in the shells. Being associated with physiological processes of an organism, this element contributes to organism development and demonstrates a well-pronounced ontogenetic variations. At the same time, potassium content is closely related to the shell's post-life transformation processes, including silicification and contamination with soil elements. Finally, the third factor influencing potassium amount in the shell material is its concentrations in the ambient environment.

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AZƏRBAYCANIN MÜASİR YERÜSTÜ QASTROPODLARININ ABİOGEN VƏ ÜZVİ TƏRKİBLİ QABIQLARININ ƏSAS, MİKRO VƏ BİOELEMENTLƏRİNİN ÖYRƏNİLMƏSİ

E.H. Əliyeva, S.A. İsayev

Həyata keçirilmiş çöl tədqiqatları zamanı Böyük Qafqaz dağlarının cənub və şimal yamaclarından faunistik material yığılmışdır ki, həmin materiala əsasən Böyük Qafqazın şimal yamacının Azərbaycan sektorunda yerləşən Quba rayonunda yığılmış mövcud həm də nəsli kəsilmiş yerüstü qastropodların qabıqları daxildir. Qubada aşkar edilmiş qastropod nümunələri Böyük Qafqazın cənub yamacına cavab verən Şamaxı, Şəki və Qax rayonlarında, eləcə də Xəzər dənizinin sahilində tapılmış analoqları ilə müqayisə edilmişdir. Tədqiqatlar zamanı Helix lucorum L. cinsinə aid olan 70 qabıq nümunəsi xüsusi analizlərdən keçirilmişdir.

Aparılmış analizlər çərçivəsində mollyuskların skelet qalıqlarında üzvi maddələrin tərkibi həm ümumi olaraq, həm də üzvi karbon, zülali azot və fosfor kimi ayrı-ayrı bioelementlər səviyyəsində təhlil olunmuşdur. Tədqiqatlara həmçinin bəzi əsas və mikroelementlərin qabıq cismində paylanmasının təhlili daxil olmuşdur.

Həyata keçirilmiş araşdırmalar nəticəsində tədqiqatın predmetini təşkil edən qastropodların qabıq cismlərində kalsium karbonatın və üzvi maddələrin tərkibinə təsir göstərən amillər haqqında mülahizələr irəli sürülmüşdür.

АБИОГЕННАЯ И ОРГАНИЧЕСКАЯ СОСТАВЛЯЮЩИЕ РАКОВИН СОВРЕМЕННЫХ НАЗЕМНЫХ ГАСТРОПОД АЗЕРБАЙДЖАНА: ИЗУЧЕНИЕ ОСНОВНЫХ, МИКРО, И БИОЭЛЕМЕНТОВ

Э.Г. Алиева, С.А. Исаев

В результате проведения полевых работ был собран фаунистический материал с южного и северного склонов Большого Кавказа, включающий в себя раковины, как живых, так и умерших наземных гастропод из, преимущественно, Губинского района, расположенного на северном склоне азербайджанской части Большого Кавказа. Для сравнения изучались гастроподы Шемахинского, Шекинского и Гахского районов, расположенных на южном склоне данной горной системы, а также раковины из прибрежной части Каспийского моря. Всего было проанализировано 70 образцов раковин, принадлежащих моллюску Helix lucorum L.

В скелетных остатках определялась как содержание органического вещества в целом, так и отдельных биоэлементов органического углерода, белкового азота, фосфора. Также изучалось распределение некоторых основных и микроэлементов в раковинном веществе этих моллюсков. Полученные результаты позволяют сделать выводы о факторах, контролирующих состав карбоната кальция и органической составляющей раковинного материала изученных гастропод.

SEISMOSTRATIGRAPHY AND PREDICTION OF GEOLOGICAL SECTION OF AZERBAIJAN

The paper describes evolution history of the methods of seismostratigraphic analysis and geological section prediction, and provides a brief methodology for these studies supported by the seismic data. Based on the interpretation results of the Sovetler-Kalamadin regional profile, the possibility of identification of structural evolution stages, seismic complexes and seismic facies in the Meso-Cenozoic succession is demonstrated. Several exploration wells drilled on the prospects in the Jafarli field (##1, 5, 21, 22) produced oil, thereby confirming our forecasts.

Keywords: seismic stratigraphy, prediction of geological section, seismic facies, seismic prospecting, wave dynamics, interpretation, "bright spot", "dark spot", oil accumulation

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It is interesting to see how some scientific terms change their original meaning over time. So it was, for example, with the term "facies", by which the Gressly, the scientist who had introduced the term in 1839, understood horizontal changes in the petrographic and paleontological features of synchronous deposits. Later, initial meaning of the term had significantly changed, and at present, it has more than 10 different explanations.

It was also rather ambiguous how the researchers, especially paleontologists and stratigraphers had accepted the term "seismostratigraphy", introduced in the early 1970s by American geophysicists P. Weil and others. Even the authors of the Russian geological and geophysical studies proposed using alternative terms such as "seismic facies" (perhaps more realistically reflecting the essence of the matter), structural-formational complexes, etc. Nevertheless, despite the expressed objections, seismostratigraphy had managed to rank itself in the scientific glossary. Nowadays, seismostratigraphic methods are successfully used in geophysical oil-gas prospecting studies, together with structural-formational studies, prediction of geological section, AVO analysis, etc.

Well, how did these methods come about?

Until the early 1970s, although there were separate attempts of individual geophysicists, in particular, K.A.Mustafaev who locally predicted oil and gas potential based on refracted seismic waves, almost all geophysical methods (gravity, electrical and seismic exploration) engaged in study of structural features of the earth's crust and its individual components, had not include any interpretation of the material composition of the component rocks and saturating fluids.

Since the 1970s, as the seismic surveys started to be implemented using common depth point method (CDPM), and, most importantly, as seismic data recording and processing took a digital form, the accuracy and reliability of seismic surveys has sharply increased.

Since this period, along with solving strictly structural tasks, this innovation has also allowed implementing kinematics and wave dynamics based assessment of the material composition of section building sediments, and, in favorable geological environment, to predict their oil and gas content[1].

[1] During the same period, i.e. from the beginning of the 1970s, oil and gas saturation forecast of the new areas began to be carried out using other geophysical methods, in particular, detailed gravimetric and electrical surveys. The greatest success in this field was achieved by the prospectors of Western Siberia, where several dozen hydrocarbon deposits were discovered based on the electrical exploration data.

The next levels of these studies were reached with the possibility of mapping thin-layered geological bodies, studying lithological-facies changes in synchronous formations with the identification of lithological-stratigraphic traps, and, most recently, monitoring the deposit development processes (Gogonenkov, 1987, Mammadov, 2009, Kunin, 1990, Schlesinger, 1998).

It should be noted that the solution these complex problems is achieved in combination with the data of borehole geophysical and petrophysical investigations. Interpretation methods of seismostratigraphic studies include tracing seismic complexes (cyclites) or sequences in time sections, conditioned by the sea level changes and the presence of large breaks in sedimentation. The next step in the seismic data interpretation is to analyze the main wave pattern parameters of each seismic complex (form, amplitude and frequency of reflections, etc.) and identify the seismic facies, which are considered as analogues of geological facies. In complex with borehole data, it is possible to identify lower rank units in a seismostratigraphic complex, including seismic horizons, layers, etc., and to restore the historical sedimentation conditions.

In Azerbaijan, seismostratigraphic studies were started in the early 1980s, more precisely in 1982–1983, when the trust "Azneftegofizika" carried out interpretation of Sovetler-Muradkhanli-Jarli-Kalamadin regional geophysical profile. According to these data, the following structural stages were identified in the Yevlakh-Agjabedi trough in the section of Meso-Cenozoic deposits: 1) the most intensively dislocated Cretaceous stage, 2) enveloping Paleogene-Miocene stage; and 3) Pliocene-Anthropogenic stage not involved in folding.

According to the character of the seismogram, individual stratigraphic intervals of these stages correspond to a complex of nappe sedimentation (Lower Pliocene pay section, lower sections Maikopian and Paleogene – until the Cretaceous) and lateral accretion (Absheron-Akchagyl and Miocene deposits).

Structural interpretation of the section clearly showed main regional and local elements of the region, in particular, the Yevlakh-Agjabedi trough, Saatli-Goychay uplift zone with corresponding local structures. In addition to this interpretation, structural-formational analysis of the section was carried out. The studies resulted in the identification of more than 8 seismic complexes in the section of the Meso-Cenozoic deposits. These complexes are separated by large unconformities in the P horizon type sedimentation (unconformity between surfaces of the Upper Cretaceous and Cenozoic deposits), or small unconformities and horizons with high dynamic expressiveness.

As the seismogram character differed significantly in each of the seismic complexes, preliminary judgements were made about the sedimentation conditions, geological evolution and the potential for identifying lithological-stratigraphic and other types of non-anticlinal traps in the region.

Later, these studies were replicated in the other on- and offshore regions of the country.

With the successful change of seismogeological surveys in favorable conditions, it is also possible to solve the problems of predicting the geological section (PGR), which includes the study of the lithological-stratigraphic section, the identification of the zones with abnormally high formation pressures and understanding the nature of oil and gas saturation of reservoirs.

Interpretation of CDPM data using the AVO analysis method is also based on correlations between the physical properties of rocks that make up the geological section of the study area with the seismic wave field parameters of the (velocity of longitudinal waves, amplitude, etc.).

Depending on change in the physical properties of deposits in the sedimentary complex, it is expected to register an anomalous increase in the intensity of reflections (“bright spot”) from the Pliocene rocks from one side, and an anomalous weakening of the intensity of reflections (“dark spot”) of the Miocene-Oligocene and Eocene rocks from the other (Kocharli, Polonsky et al., 1989). Based on these criteria, more than twenty deposit-type anomalies (DTA) have been identified for various stratigraphic complexes in the Yevlakh-Agjabedi trough. Distribution of these anomalies is shown in the Figure 1.

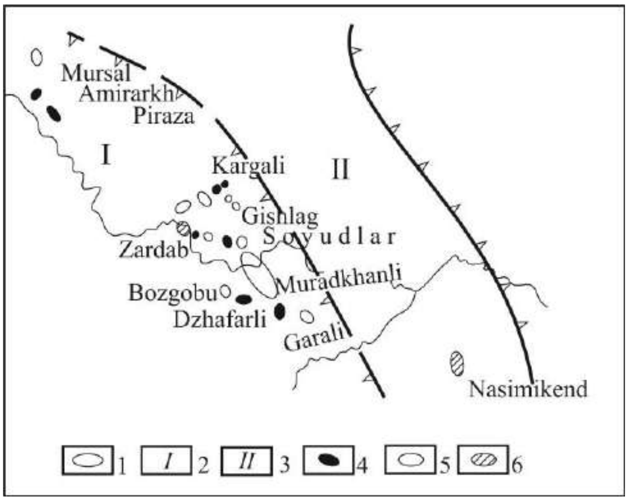

Figure 1. Distribution scheme of the deposit-type anomalies
1 – oil (gas condensate) deposits; **2** – Yevlakh-Agjabedi trough; **3** – Saatli-Goychay zone of uplifts; **4** – DTAs in the Lower Maikopian – Upper Cretaceous deposits, identified and prepared for deep exploration drilling based on CDPM seismic survey data; **5** – DTAs detected in Oligocene deposits; **4** – DTAs detected and prepared in Oligocene deposits

By the areas and stratigraphic complexes, the DTAs are distributed as follows:

1. Dark spot localized in the Pliocene-Miocene deposits on Zardab (2 objects) and Nasimikend (1 object) fields;
2. Dark spot corresponding to the Eocene deposits on Muradkhanli (2 objects), Garali (1 object), Mursal (1 object), Gishlag (1 object), Eastern Shikhbaghi (1 object), Zardab (4 objects), Garghali (2 objects) fields;
3. Dark spot covering the Upper Jurassic-Chokrakian deposits on Amirarkh (3 objects), Zardab (1 object), Jafarli (1 object), Bozgobu (1 object) and Soyudlar (1 object) fields.

Later, some of the cited objects were investigated by drilling. The drilling produced positive results, particularly for the Jafarli field. This field, located southeast of the Muradkhanli field, was prepared for seismic exploration drilling in 1982. Moreover, in addition to the structural interpretation of the seismic survey data, geological section prediction studies were carried out which confirmed the presence of a DTA here.

Curators from Moscow had argued that the Jafarli field is located on the southeastern periclinal of the Muradkhanli field. However, the objection proved to be incorrect as the results of velocity tests and other materials clearly indicated standalone character of the Jafarli field.

In 1983–84 wells No. 1, 5, 21, and 22 were drilled in the field. Having reached the Middle Eocene deposits, all of these wells produced oil with a flow rate of 100–200 m^3/s. This achievement has proven the reliability of forecasts developed based on geological section prediction (Figure 2).

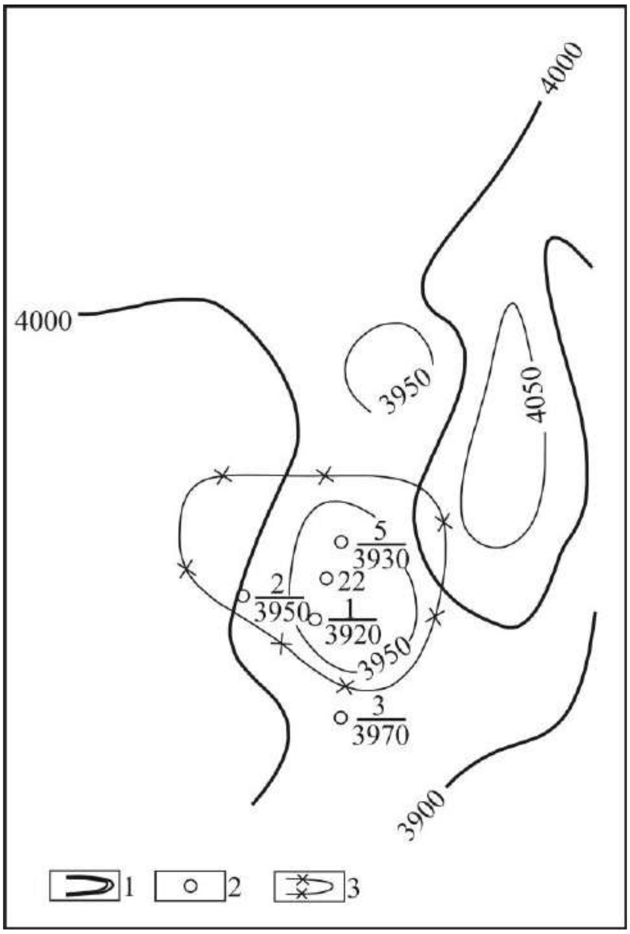

Figure 2. Structural map of Jafarli area:
1 – isolines of depths; **2** – deep wells; **3** – oil drainage boundary forecasted according to the data produced by CDPM seismic surveys implemented using GSP methods

Another area where the GSP is used, is the study of 4D in order to control the development of oil and gas fields. These studies gave positive geological results in the deposits of Kurovdagh, Kursanga, Garabaghli, Azeri-Guneshli, etc. With the help of these studies, additional hydrocarbon resources have been identified, and therefore, it is highly recommended to implement such studies in the other fields.

Later, popularity of the GSP studies has declined both in Azerbaijan and in the world's other oil and gas bearing regions. Apparently, it happened due to certain unconfirmed facts. Considering that the forecasts developed based on geological section prediction bear rather advisory than a mandatory character, obtaining additional information on the oil and gas saturation of the sections would always play a positive role, especially in the areas with favorable seismic conditions (Yevlakh-Agjabedi and Lower Kur troughs, Southern Kur Depression, etc.).

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AZƏRBAYCAN ŞƏRAİTİNDƏ APARILAN GEOLOJİ KƏSİLİŞİN STRATİQRAFİYA VƏ PROQNOZLAŞDIRILMASI

Ş.S. Köçərli

Məqalədə seysmostratiqrafik analizin və geoloji kəsilişlərin proqnozlaşdırılması işlərinin inkişafı tarixinə dair məlumat təqdim olunmuş, bu növ tədqiqatların seysmik məlumatlar əsasında aparılması metodologiyasının xülasəsi verilmişdir. Məqalədə həmçinin Sovetlər-Qalamadın regional kəsilişin interpretasiyası nəticələrinin timsalında Mezo-Kaynozoy çöküntülərində struktur mərhələlərinin, seysmik komplekslərin və seysmik fasiyaların müəyyən edilməsinin mümkünlüyü əsaslandırılmışdır. Neft-qazlılığı proqnozlaşdırılan obyektlər sırasında Cəfərli sahəsində qazılmış bir neçə kəşfiyyat quyusundan (1, 5, 21, 22) neftin alınması həmin proqnozları təsdiqləməyə imkan yaratmışdır.

СЕЙСМОСТРАТИГРАФИЯ И ПРОГНОЗИРОВАНИЕ ГЕОЛОГИЧЕСКОГО РАЗРЕЗА В УСЛОВИЯХ АЗЕРБАЙДЖАНА

Ш.С. Кочарли

В статье, после рассмотрения истории образования сейсмостратиграфического анализа и прогнозирования геологического разреза, приводится краткая методика этих исследований по сейсмическим данным. На примере интепретации регионального профиля Советляр-Каламадын, обосновывается возможность выделения структурных этажей, сейсмокомплексов, сейсмофаций в разрезе мезокайнозойских отложений. Из прогнозируемых нефтеносных объектов, на площади Джафарлы было пробурено несколько разведочных скважин (1, 5, 21, 22), давших нефть, тем самым подтвердивших прогнозы.

TRACE ELEMENT GEOCHEMISTRY OF THE PLIOCENE SEDIMENTS, THE SOUTH CASPIAN BASIN

Based on study of the trace element composition of the Pliocene Productive Series sediments exposed in the Kirmaki and Yasamal Valleys located in the Absheron Peninsula, a number of paleoenvironmental indicators were identified. It was shown based on study of the strontium to barium ratio that the highest salinity was in the Fasila Suite sedimentary basin. The Balakhani and Sabunchy Suites' sediments were accumulated in a brackish-water environment. A general trend of the salinity decrease from the PreKirmaki Suite to the PostKirmaki Clay Suite is recorded in the lower portion of the Productive Series.

Also, it was recorded that in the case of migration of element in the form of solution, its maximum occurs in the muddy sediments of the deep-water zone wheares under condition of transportation of an element by clastic particles, its maximum concentration is reported in sandy sediments of the shoreface zone.

Keywords: the South Caspian basin, Pliocene Productive Series, trace elements, salinity, order factor

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Geological background

Sedimentation in the South Caspian basin in the beginning of Pliocene occurred under conditions of small, closed basin, isolated from the Eastern Paratethys due to intensive orogenic movements, uplifts of the adjacent land, subsidence of central part of the South-Caspian depression and fall of the Caspian Sea level that reached according to some estimations 600 m (Reynolds et al., 1998).

The Pliocene South Caspian succession referred to as "the Productive Series" is a fluvial-deltaic and lacustrine depositional system. The early phase of deposition was mostly controlled by the incision of the Paleo-Volga, which delivered large volumes of terrigenous clastics into the basin.

The Productive Series (PS) succession is composed of the rhythmically alternating sandy-shaly sediments reaching the thickness of 7 km in the deeply subsided parts of the South-Caspian depression.

It consists of 9 Suites (Gala (KaS), Prekirmaki (PK), Kirmaki (KS), Post Kirmaki sand (NKP), Post Kirmaki clay (NKG), Fasila, Balakhani, Sabunchi, Surakhani), and occurs in a large area – Absheron peninsula, Absheron and Baku archipelagos, Jeyrankechmez depression, Alyat ridge, Pre-Caspian-Guba region.

The PaleoVolga sediments have been extensively studied during XIX, XX, XXI centuries. The most attention was paid to the lithology, environmental changes, oil-gas prospects. However, many questions remain unexplored. This paper is aimed at addressing the controlling factors on microelemental quantification, particularly, relationship between environmental and microelemental variations.

The research is focused on the microelemental response in the small order forestepping and backstepping PaleoVolga deltaic sequences formed as a result of changing balance between sediment supply and lake levels controlled by climatic changes.

The addressed questions have been studied on the large amount of the PaleoVolga sediment samples exposed in the Absheron peninsula: the lower portion of the PS succession – in the Kirmaki Valley, the upper portion – in the Yasamal Valley.

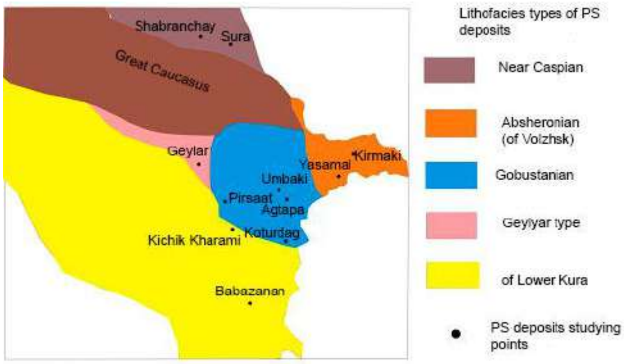


Figure 1. The map of the Productive Series sediments occurrence (from Aliyeva E., 2008)

Main results

Microelements in studied sediments were analyzed by X-ray method.

The results are presented in Tables 1, 2, 3 which are organized by different lithological varieties of sediments.

On the whole average contents of microelements, except Sr and Mn in shales and silts is higher than in sands, and variations of their quantities are more pronounced in sandstones. The similar distribution in sandstones and shales is recorded only for strontium.

The microelemental variations along the PS section demonstrate some patterns. We grouped these trace elements by similarities of their distribution.

Five groups are distinguished: 1) Ba, Ti, V (Figure 2; Figure 3); 2) Fe, Co, Ni, Cr, Cu, Zn (Figure 4; Figure 5), Pb (Figure 6); 4), Sr (Figure 7) and 5) Mn (Figure 8).

Elements of the first group (Ba, Ti, V) form a deep minimum in the NKP and Fasila Suites, and clearly expressed maximums in sediments of Kirmaki (KS), NKG and Sabunchi Suites.

Elements of the second group (Fe, Co, Ni, Cr, Cu, Zn) have one deep minimum in the NKP Suite sediments, one strong maximum in the NKG succession, and less expressed maximums in the Kirmaki and Sabunchi Suites (Figure 4; Figure 5), i.e. maximums are similar to those ones in group I (Figure 2; Figure 3).

The members of the third group consisting of just one trace element – lead, display an inverse behavior with respect to the first and second groups. The maximum of Pb amount is recorded in the NKP and Fasila Suites, minimum – in NKG and Balakhany Suites (Figure 6).

Elements of the forth group (Sr) is characterized by one minimum in NKG Suite sediments, and maximum in the PK and Surakhany Suites (Figure 7).

Maximum in Fasila and two minimums in PK and Surakhany Suites successions are recorded in the fifth group consisting of Mn (Figure 8).

The analyzed curves of the trace element content values variations in the Productive Series demonstrate that mudstones are depleted by a number of elements – Ba, Sr, Mn, Fe, Cr, Co, Ni, Pb, regarding to their clark values. Clark exceeding average cintent values have been recorded only for Ti (1.5 times higher), and V (2 times higher) in all suites shales and siltstones excepting PK Suite (Table 1, 2).

For the sandstones the amount values variations demonstrate inverse character. These sediments are enriched by Ba (the average amount 5–10 times exceeds the clark values), Sr (average content is 10 times higher than clark value), Mn (10–100 times higher), Fe (2–3 times exceeds), Co (5–10 times exceeds), Ni (5–10 times higher), Zn (2–5 time higher), Cu (5–10 times higher than clark value), Pb (2 times higher). The PS sandstones are depleted by Cr, Ti, V relative to clark values (Table 3).

Trace elements show divers behavior in the different stratigraphic unites of the Productive Series displaying various lithology.

The PK Suite is characterized by most heterogeneity that is characterized by growth of Co, Cu, Pb, Cr and Ni content values from sandstones to siltstones, and vice-versa distribution of Fe, Mn, Ba, Ti, Zn, Sr and V (Figure 9).

Table 1

Distribution of trace elements in the PS shales

Horizon	Ba	Sr	Mn	Ti	Fe	V	Cr	Co	Ni	Zn	Cu	Pb
PK												
KS	0.054	0.028	0.056	0.61	3.96	0.027	0.0033	0.0011	0.0029	0.0097	0.0076	0.0012
NKP	0.054	0.020	0.029	0.60	3.84	0.027	0.0042	0.0015	0.0041	0.0079	0.0043	0.0024
NKG	0.055	0.024	0.038	0.60	4.34	0.027	0.0011	0.0014	0.0037	0.0118	0.0038	0.0026
Break suite	0.051	0.033	0.015	0.61	4.19	0.026	0.0017	0.001	0.0058	0.015	0.008	0.0007
Balakhany	0.051	0.022	0.032	0.60	4.65	0.025	0.0064	0.0019	0.0058	0.0087	0.0044	0.0017
Sabuncni	0.053	0.025	0.065	0.61	4.08	0.026	0.0039	0.0013	0.0042	0.011	0.0041	0.002
Surakhany	0.053	0.032	0.065	0.60	3.98	0.025	0.0047	0.0012	0.0049	0.0091	0.0034	0.0016

Table 2

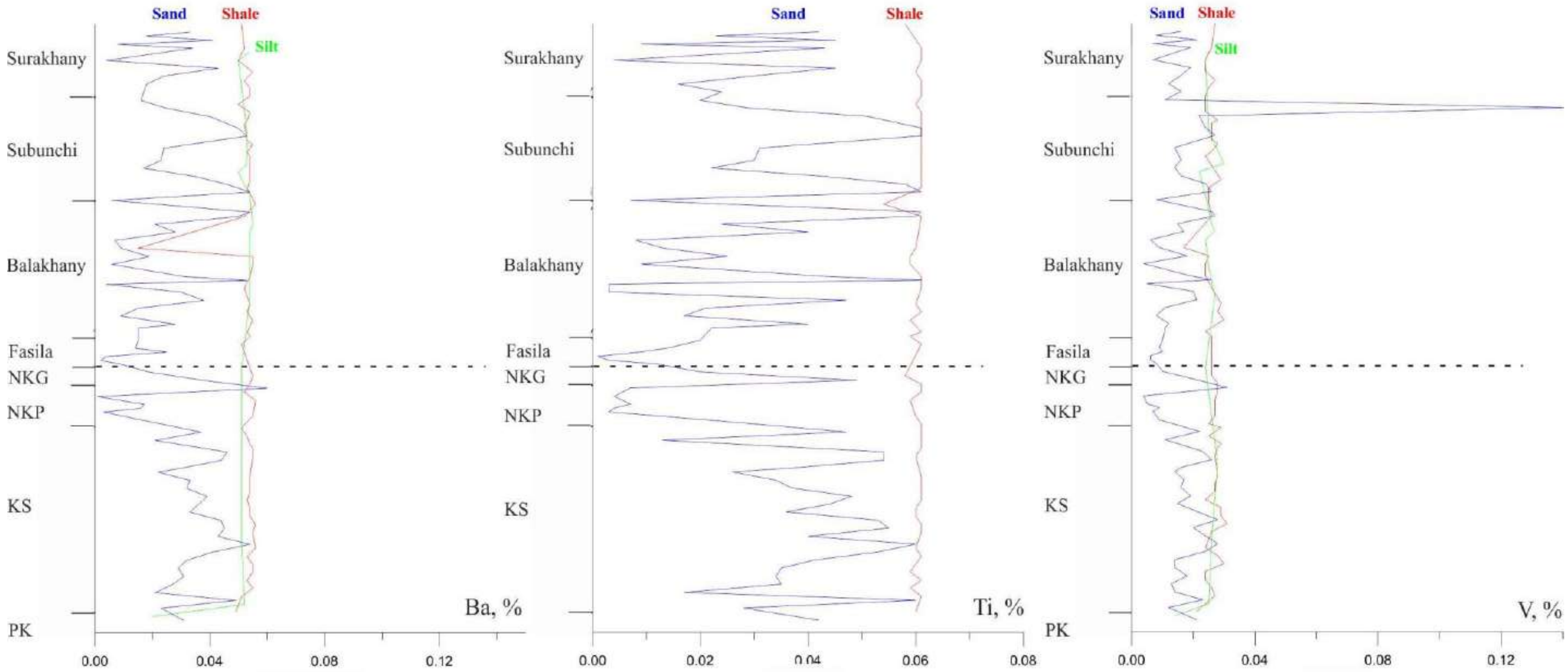
Distribution of trace elements in the PS silts

Horizon	Ba	Sr	Mn	Ti	Fe	V	Cr	Co	Ni	Zn	Cu	Pb
PK	0.020	0.030	0.010	0.22	1.01	0.014	0.0075	0.0008	0.0019	0.0025	0.0055	0.002
KS	0.052	0.023	0.054	0.61	3.11	0.027	0.0034	0.0018	0.0033	0.0073	0.0051	0.0016
NKP												
NKG	0.051	0.022	0.061	0.61	3.66	0.024	0.0044	0.0009	0.0009	0.015	0.007	0.0008
Breat suite												
Balakhany	0.054	0.019	0.031	0.60	4.71	0.026	0.006	0.0017	0.0054	0.01	0.0058	0.0018
Sabuncni	0.053	0.025	0.047	0.62	4.40	0.025	0.0023	0.0013	0.004	0.011	0.0038	0.001
Average by:												
Turekian and												
Wedepohl, 1961	**0.058**	**0.03**	**0.085**	**0.46**	**4.72**	**0.013**	**0.009**	**0.0019**	**0.0068**	**0.0095**	**0.0045**	**0.002**
Vinogradov, 1962	**0.08**	**0.045**	**0.067**	**0.45**	**3.33**	**0.013**	**0.01**	**0.002**	**0.0095**	**0.008**	**0.0057**	**0.002**

Table 3

Distribution of trace elements in the PS sands

Horizon	Ba	Sr	Mn	Ti	Fe	V	Cr	Co	Ni	Zn	Cu	Pb
PK	0.031	0.043	0.021	0.42	1.28	0.021	0.001	0.0007	0.0014	0.004	0.002	0.0011
KS	0.035	0.038	0.048	0.41	1.91	0.019	0.0034	0.0008	0.0019	0.0047	0.0028	0.0012
NKP	0.019	0.023	0.083	0.08	0.60	0.011	0.0007	0.0004	0.0005	0.0016	0.0015	0.0015
NKG	0.029	0.019	0.103	0.35	4.88	0.016	0.0016	0.0011	0.003	0.0085	0.0047	0.0008
Break suite	0.012	0.025	0.153	0.10	2.18	0.008	0.0028	0.0009	0.0020	0.0032	0.0027	0.0017
Balakhany	0.025	0.025	0.113	0.29	1.48	0.015	0.0027	0.0008	0.0018	0.0036	0.0018	0.0011
Sabuncni	0.032	0.035	0.071	0.40	2.05	0.029	0.0029	0.0008	0.0020	0.0049	0.0031	0.0015
Surakhany	0.023	0.054	0.037	0.27	1.42	0.014	0.0023	0.0006	0.0012	0.0042	0.0020	0.0014
Average by:												
Turekian and												
Wedepohl, 1961	**$n*10^{-3}$**	**0.003**	**$n*10^{-4}$**	**0.15**	**0.98**	**0.002**	**0.0035**	**$3*10^{-5}$**	**0.0002**	**0.0016**	**$n*10^{-4}$**	**0.0007**



a b c

Figure 2. The plot displaying the Ba, Ti, V quantity variations in the ProductivepSeries section

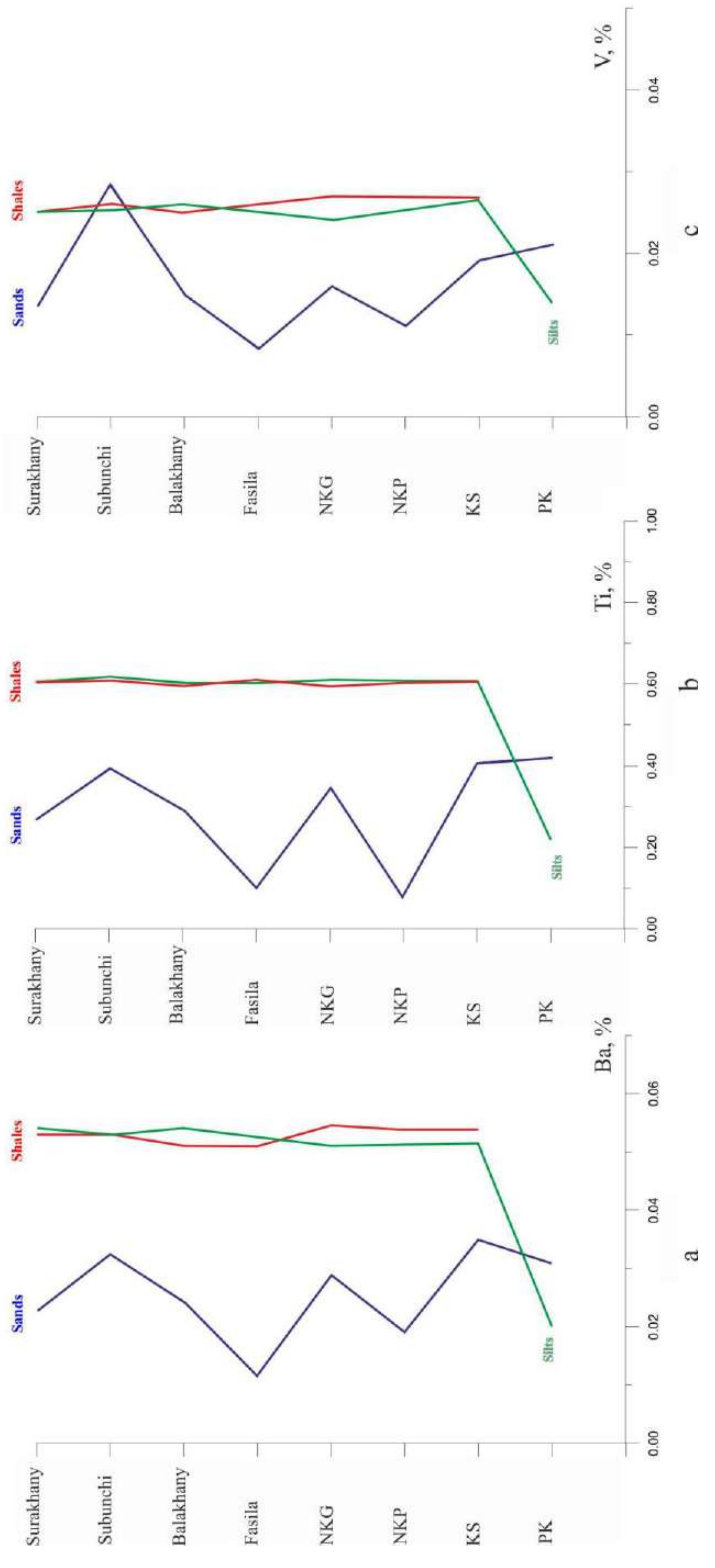


Figure 3. The plot displaying variations of the Ba, Ti, V average contents in the Productive Series section

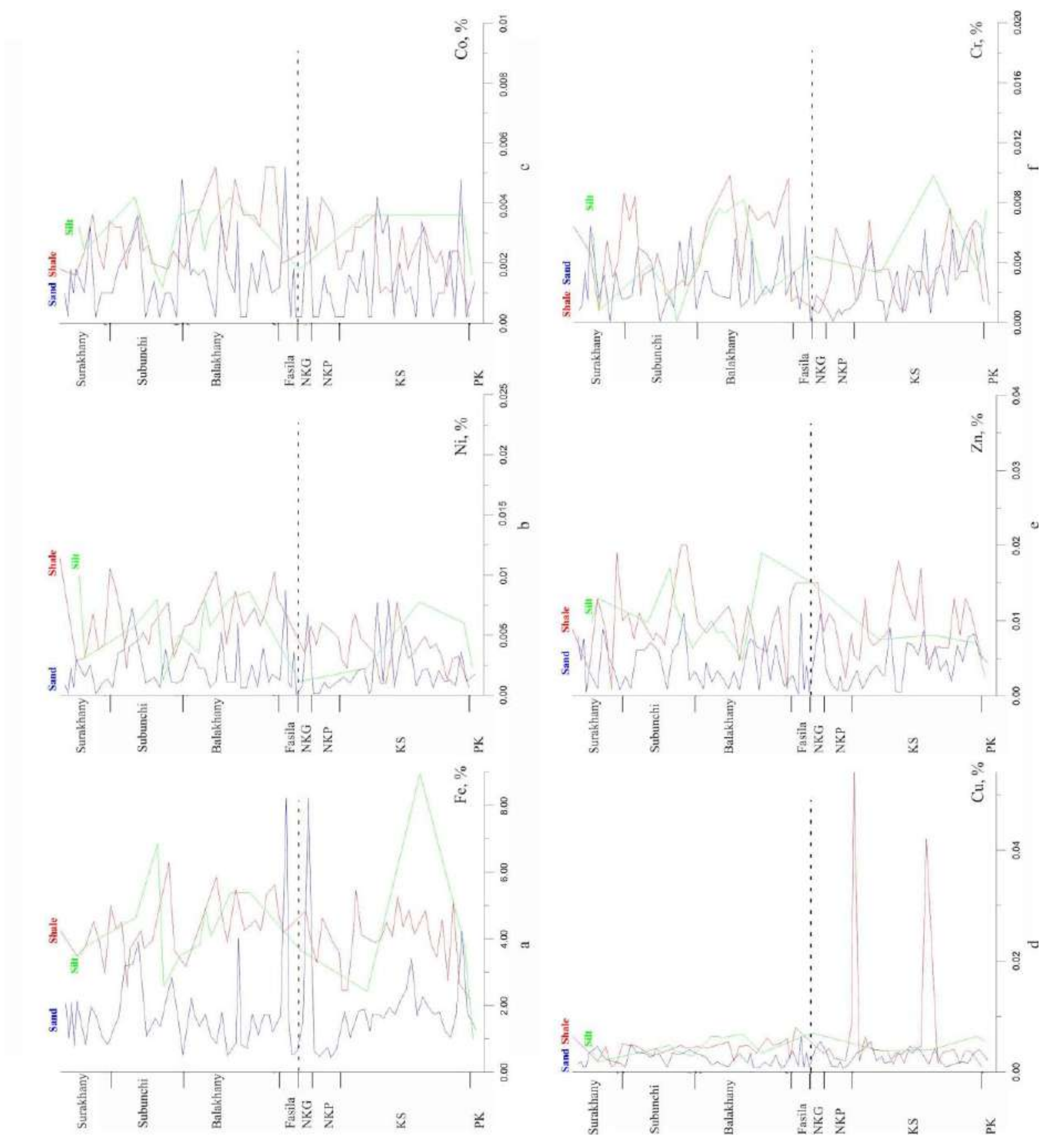


Figure 4. The plot displaying the Fe, Ni, Co, Cu, Zn, Cr quantities variations in the Productive Series section

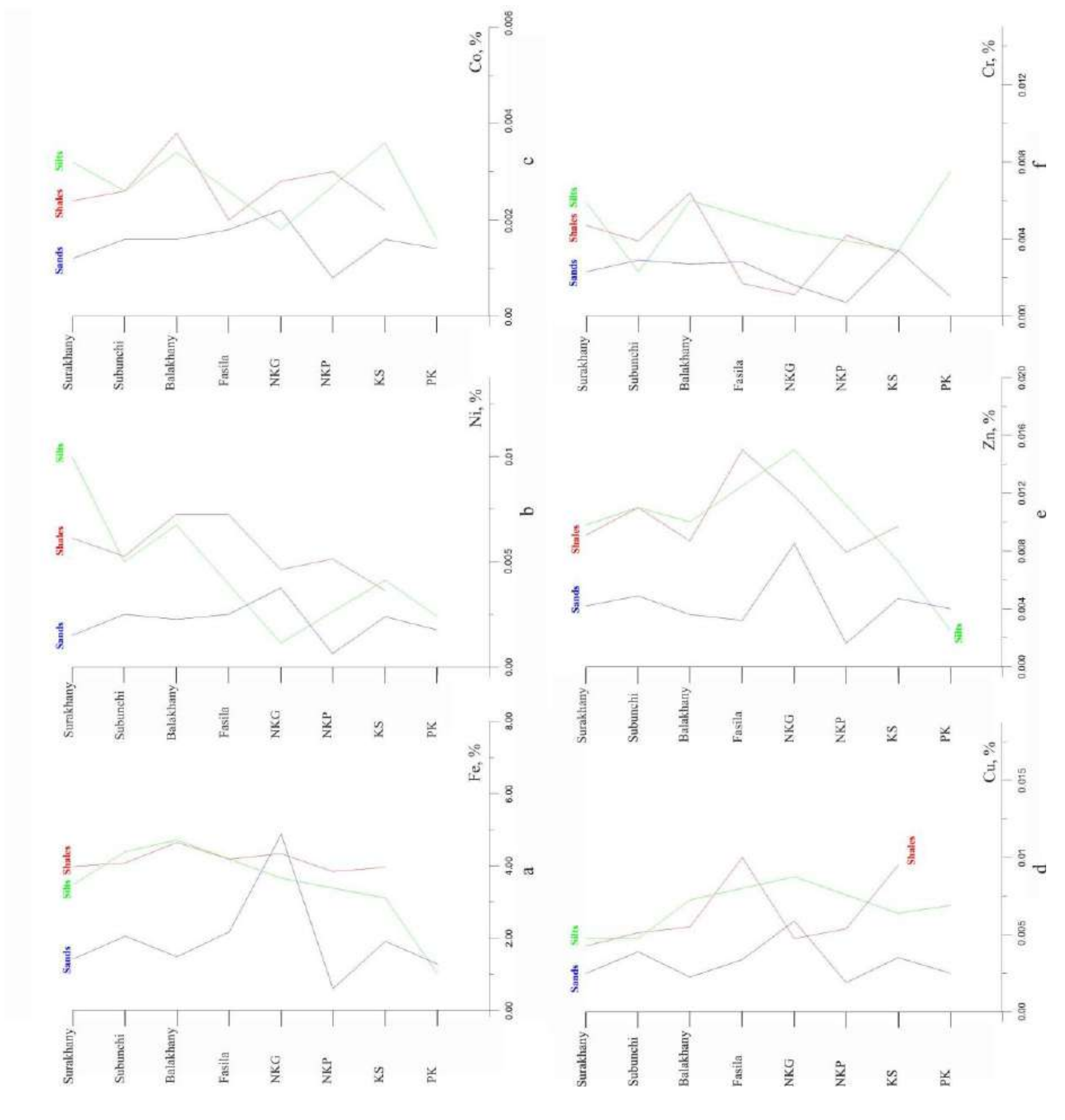


Figure 5. The plot displaying variations of the Fe, Ni, Co, Cu, Zn, Cr average contents in the Productive Series section

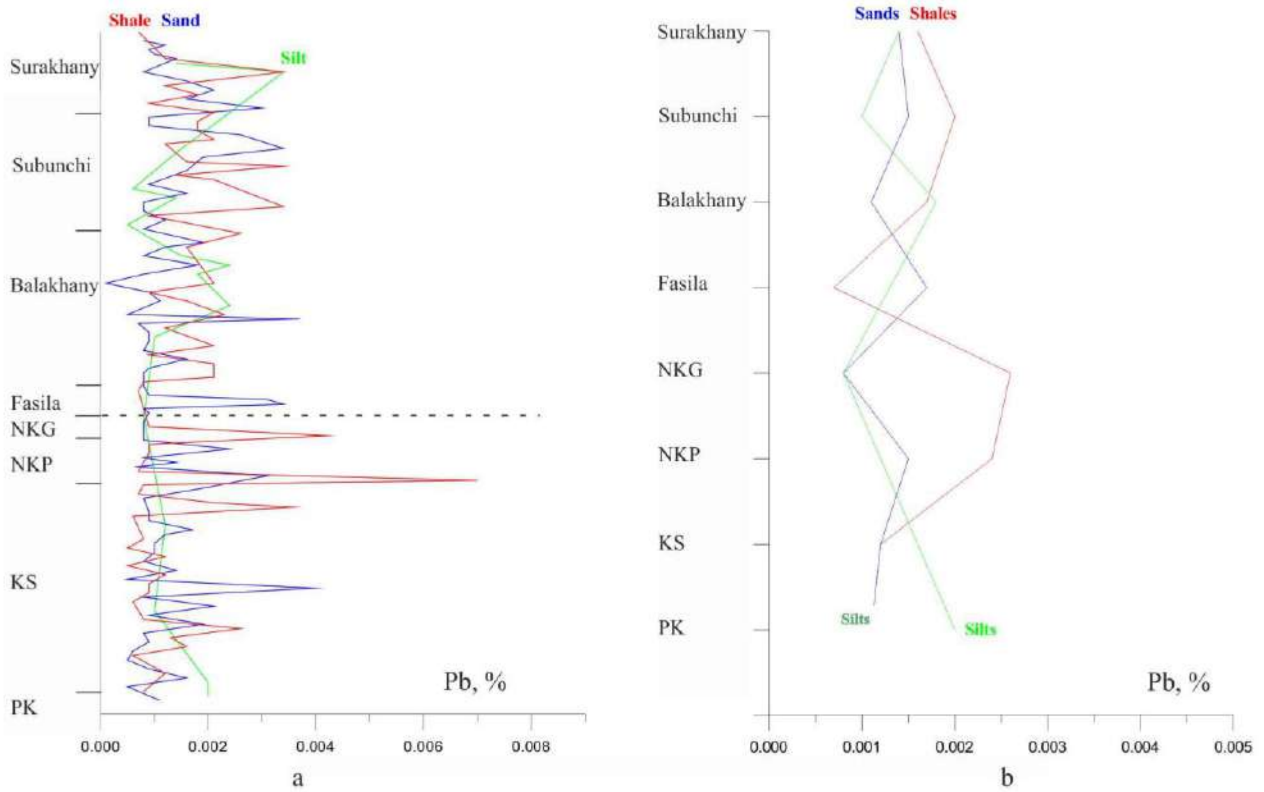


Figure 6. Lead content values variations along the Productive Series section.
a. lead amount in all analyzed samples of the various PS suites; **b.** lead average content in the various PS suites

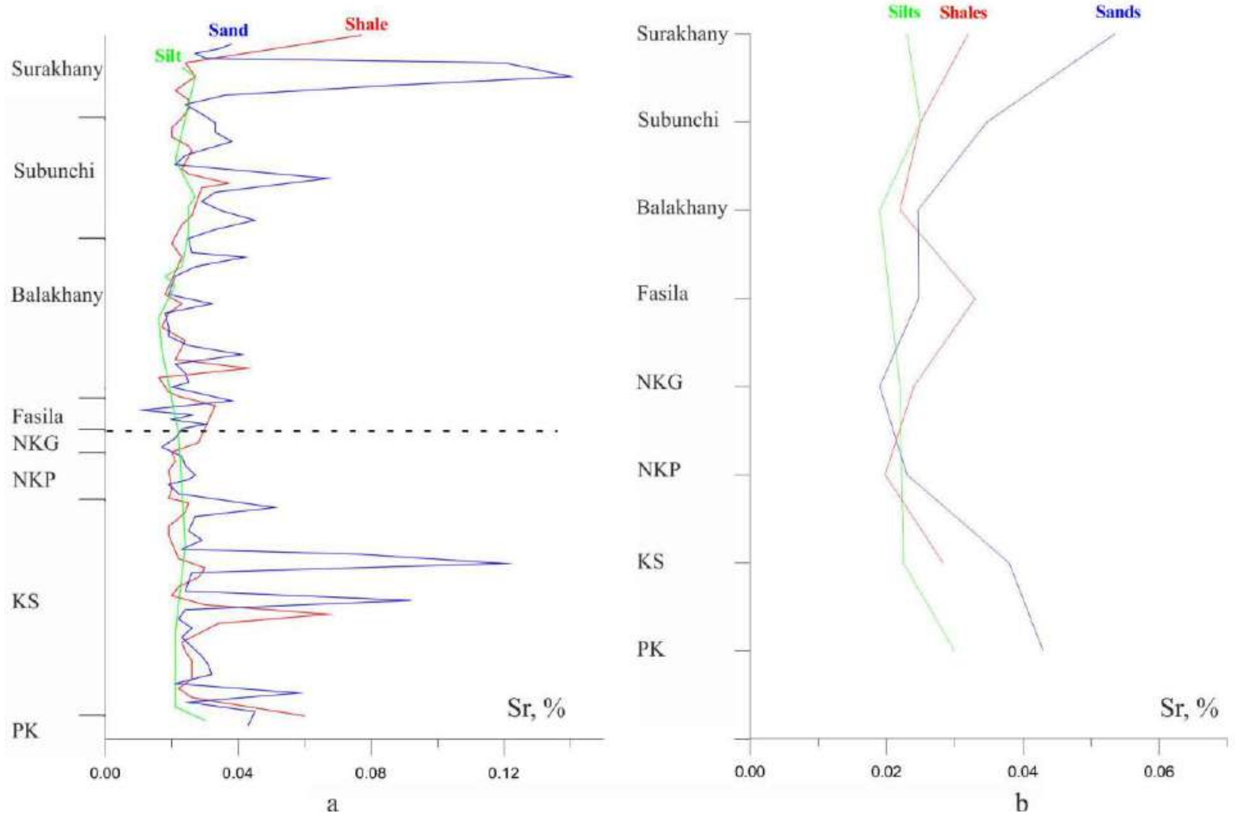


Figure 7. Strontium content values variations along the Productive Series section.
a. Sr amount in all analyzed samples of the various PS suites; **b.** Sr average content in the various PS suites

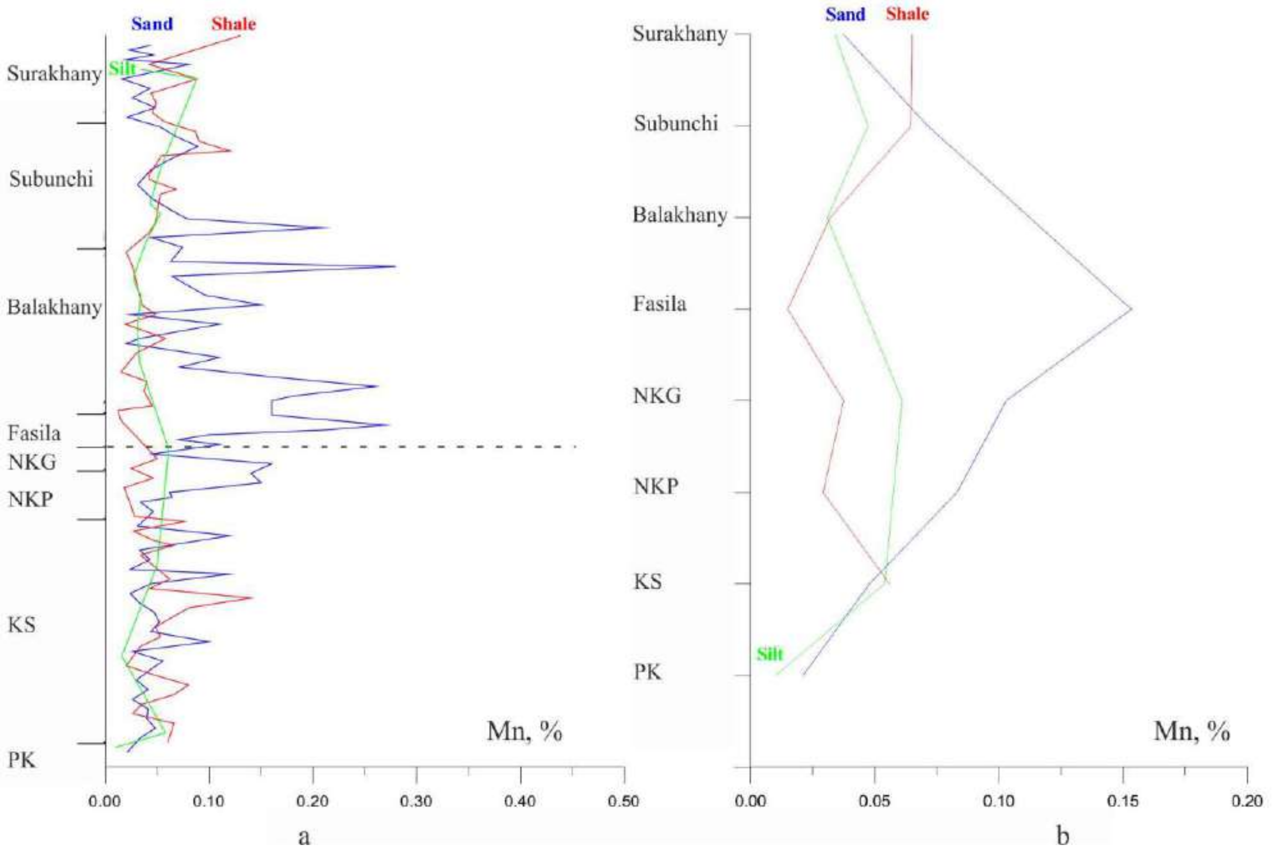


Figure 8. Manganese content values variations along the Productive Series section.
a. Mn amount in all analyzed samples of the various PS suites; **b.** Mn average content in the various PS suites

Distribution of elements in sediments of the Kirmaki Suite becomes more uniform (Figure 9). Only two elements Cr and Sr stand out. Clear trend of element content value growth from sandstones to siltstones and shales is observed for six elements (V, Fe, Ba, Mn, Cu and Zn). The rest four elements (Co, Ni, Ti, Pb) display their maximum in siltstones.

The NKP Suite sediments are characterized by a growth of amount of almost all elements from sandstones to shales excluding Sr and Mn that display the opposite trend (Figure 9).

In the NKG Suite sediments only 4 elements – Pb, Sr, V and Ba demonstrate a clear trend of content value increase from coarse sediments to fine (Figure 9). The rest elements do not have any regularity of their distribution.

The same trend is observed in the Fasila Suite sediments excepting quantities of Mn, Pb and Cr that vary in the opposite manner (Figure 10).

In the Balakhany Suite sediments the described above trend of the element content values increase from sandstone to siltstones and shales is observed in the Cr, Ni, Co variations. No trend is recorded in the Mn and Sr behavior. For 7 elements – Pb, V, Fe, Ba, Cu, Ti, Zn, the maximum values fall to siltstones (Figure 10).

In the Sabunchi Suite sediments only two elements – Cu and Ni, have the gradual amount growth from coarse to fine grained varieties (Figure 10). For the most trace elements no clear trend is observed.

The same is true for the Surakhany Suite (Figure 10).

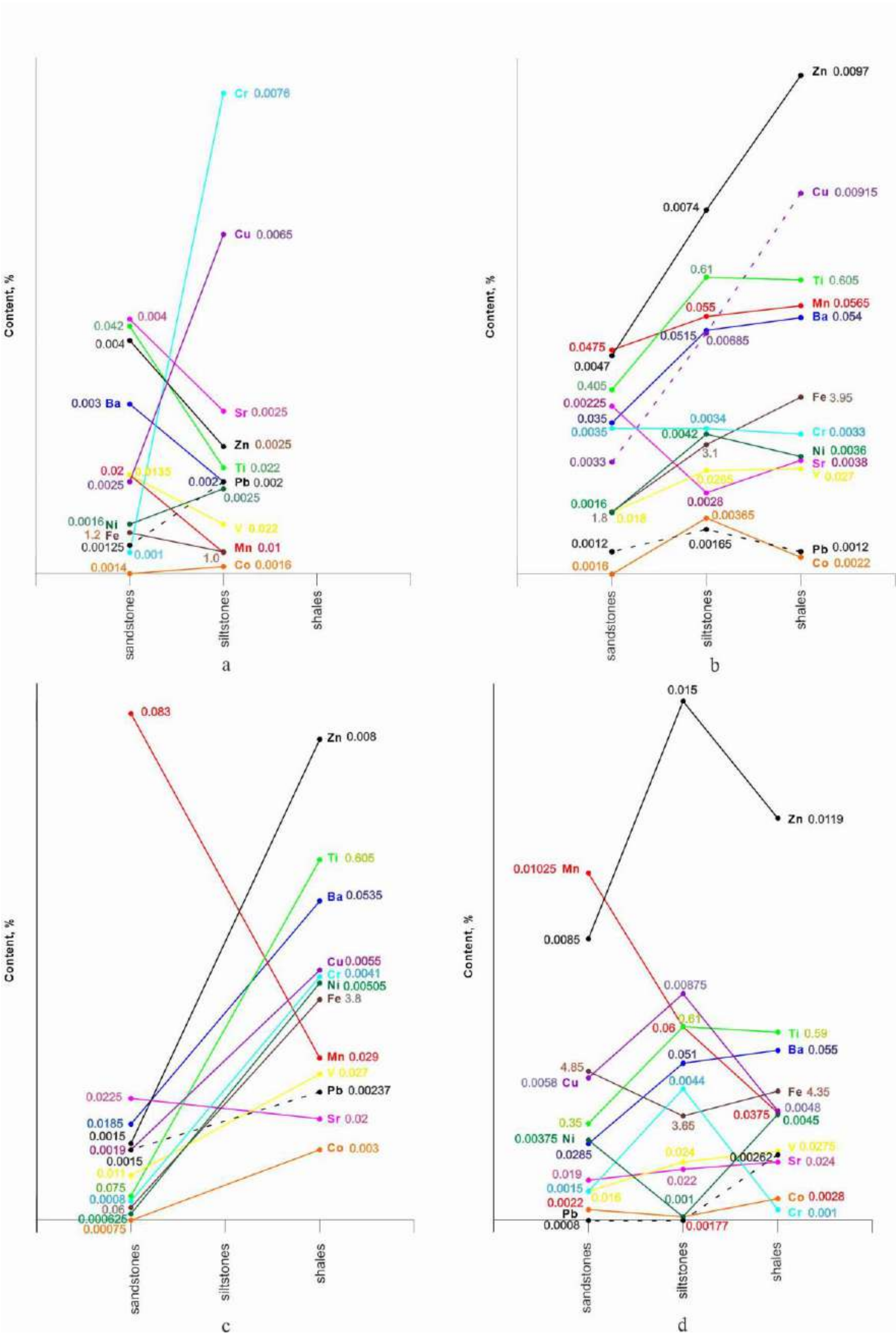


Figure 9. Trace elements content values variations between different lithological sediment varieties of the lower portion of the Productive Series: **a.** the PK Suite; **b.** the Kirmaki Suite; **c.** the NKP Suite; **d.** the NKG Suite

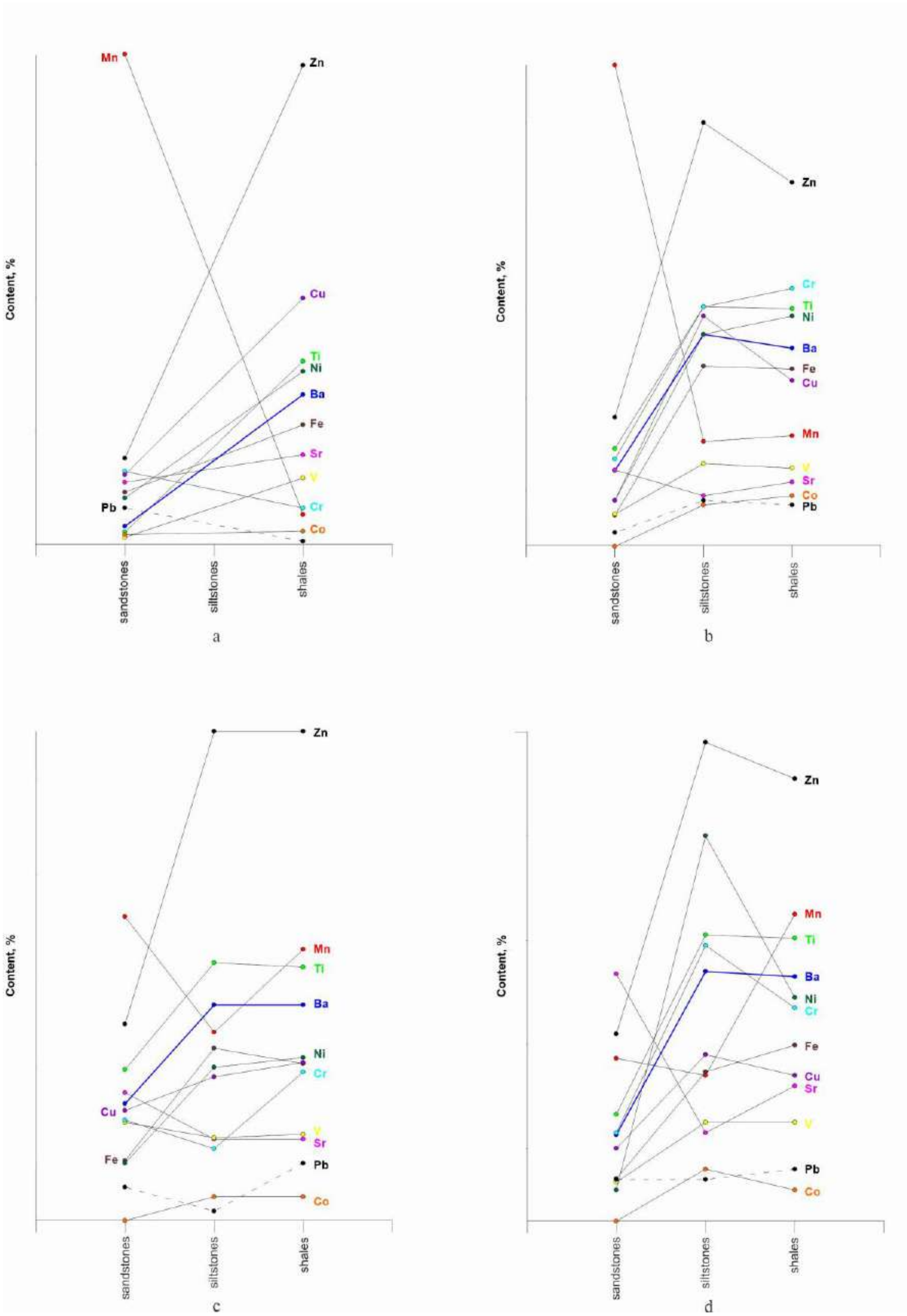


Figure 10. Trace elements content values variations between different lithological sediment varieties of the upper portion of the Productive Series: **a.** the Fasila Suite; **b.** the Balakhany Suite; **c.** the Sabunchi Suite; **d.** the Surakhany Suite

In the river water elements migrate with the terrigenous clasts, suspension or in the solution. The same element can migrate in the different ways that is determined by mineral composition of parent rocks. For instance, the common minerals of Fe are limonite, hematite, siderite, ilmenite, titanomagnetite, magnetite, garnet-andradite, pyrite, chalcopyrite, etc. Besides that, Fe in less amount is found in epidote, chlorite, hornblende, biotite, pyroxenes and other minerals. Some of these minerals are stable and preserve well during weathering. The other minerals can be easily disintegrated due to erosional processes that bring to transition of iron into a dissolved form. Fast oxidation of Fe in the river waters enables the formation of thin ferric suspension, which is transported to the sedimentary basins. Study of Kura and Terek rivers waters shows that 99.5–99.9% of Fe occur in the suspended form, and enter the Caspian Sea as the thin muddy flakes.

Unlike the Fe the biggest portion of manganese, nickel, cobalt, molybdenum, copper, zinc, lead usually is concentrated in the mica, amphiboles, feldspars, sulfide hydrates. These minerals during weathering processes are disintegrated quite fast. As a result the considerable part of elements contained in these minerals is released and transferred into solution. In the Caspian rivers (Volga, Ural, Kura, Terek) in the form of dissolved components migrate on average 0.25% of Fe; 1.7% of Mn; 23% of Ni and 33.7% of Cu.

Chrome is element of stable in the hypergenesis zone minerals such as chrome spinel (chromepikotite), chrome-containing mica. It is characterized by extremely low mobility and migrate in with the terrigenous particles containing chrome rich minerals.

Titan and vanadium are concentrated in magnetite, titanomagnetite, rutile, ilmenite. All these minerals are resistant to weathering that causes migration of these elements with clastic material.

Strontium and barium usually do not occur in the parent rocks in the form of their minerals. They are presented in the crystal lattice of calcite, plagioclases, potassium feldspars, augite, etc. These minerals are unstable in zone of hypergenesis. During weathering processes Sr and Ba are dissolved and can migrate in the form of bicarbonates, chlorides and sulphates in the water solutions. Quantity of Sr in the river water is $1.3x10^{-5}$ % on average, in the marine water – 1.3×10^{-2} %, i.e. river water is considerably depleted by Sr. If salts concentration in the marine water exceeds normal values for 4–5 times, the chemical accumulation of Sr in the form of Sr SO_4 (celestine) starts. This explains the lower proportion of Sr in sediments deposited in the fresh water environment, usually 0.01–0.02%. In terrigenous marine sediments the hight content of Sr is due to absorption by clay particles. This element also occurs in the crystal lattice of the shell aragonite.

In the sea basins barium ions supplied by river waters form a poorly dissolved mineral barite ($BaSO_4$). Barite is deposited and absorbed mainly in the near-shore sediments. In the sea water barium concentration is $5\times10\text{-}^{6}$% on average. Content of barium in the freshwater is significantly high – 1.7×10^{-4}%.

Different geochemical behavior of Ba and Sr allows using Sr to Ba ration to determine conditions of sedimentation: in the freshwater sediments it is lesser comparing with sediments accumulated in the marine environment.

From the plot summarizing data on the Sr / Ba ratio it is clear that 63% of the PS sandstones displays Sr / Ba ration values exceeding 1, while only 6.8% of mudstones are characterized by Sr / Ba >1 (from 1 to 1.51) (Figure 11). It means that sandy and muddy sediments were deposited in the different salinity regime, i.e. coarse-grained sediments were accumulated, mainly, in the marine environment with normal salinity, and mudstones – in from brackish to fresh water setting.

It should be mentioned that even we take the Sr / Ba ration equal to 0.56 that corresponds to average Sr / Ba ration in modern sediments of the Caspian Sea, no more than 12% of mudstones demonstrate this ratio exceeding the given threshold (Figure 12).

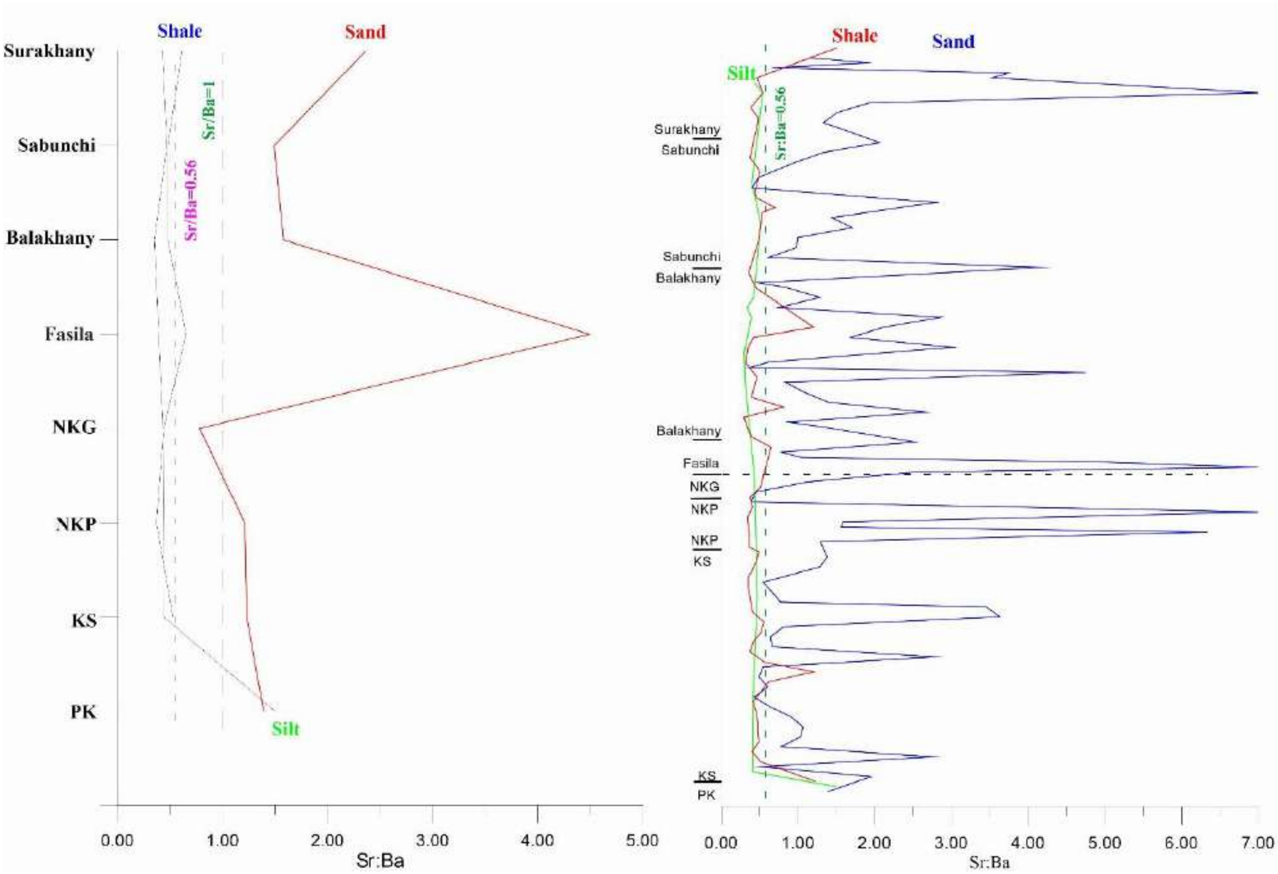


Figure 11. Average (**a**) and all (**b**) values of Sr / Ba ratio in the sandstones, siltstones shales of the different Productive Series suites exposed in the Kirmaki and Yasamal Valleys

In the low portion of PS the general trend of salinity decrease from the PK Suite to the NKG Suite is well pronounced. The NKG Suite sediments judging by Sr / Ba ratio both in shales and sandstones are dominated by freshwater conditions that are proved by micro faunistic studies of these deposits (Babazadeh, 2011). The foraminifera shells collected from the NKG Suite sediments are strongly stressed, that is manifested in their strong transparency and very small sizes.

Maximal salinity was recorded in the NKP Suite (Figure 11, 12).

In the upper portion of the Productive Series the most saline was the Fasila Suite basin during sand deposition (Figure11).

In Balakhany and Sabunchi time the salinity decreased, but didn't fall lower the normal sea salinity.

Below in the Table 4 we summarized the data on the maximal and minimal values of Sr / Ba ratio.

As it comes from the table 4 and Sr / Ba variations presented in the plots (Figure 11, 12) the most dramatic salinity variations occurred during accumulation of sediments of NKP, Fasila and Surakhany suites.

The lowest salinity is recorded for the NKG Suite basin.

Thus, the PS section represents a rhythmic alternation of freshwater-marine sediments that repeats with certain regularity. Based on the Sr / Ba ratio the 47 full cycles were distinguished. Taking the duration of the Productive Series equal to 2 Ma years, each such a cycle was continued for around 42 Ka years that corresponds to Milankovich cycles.

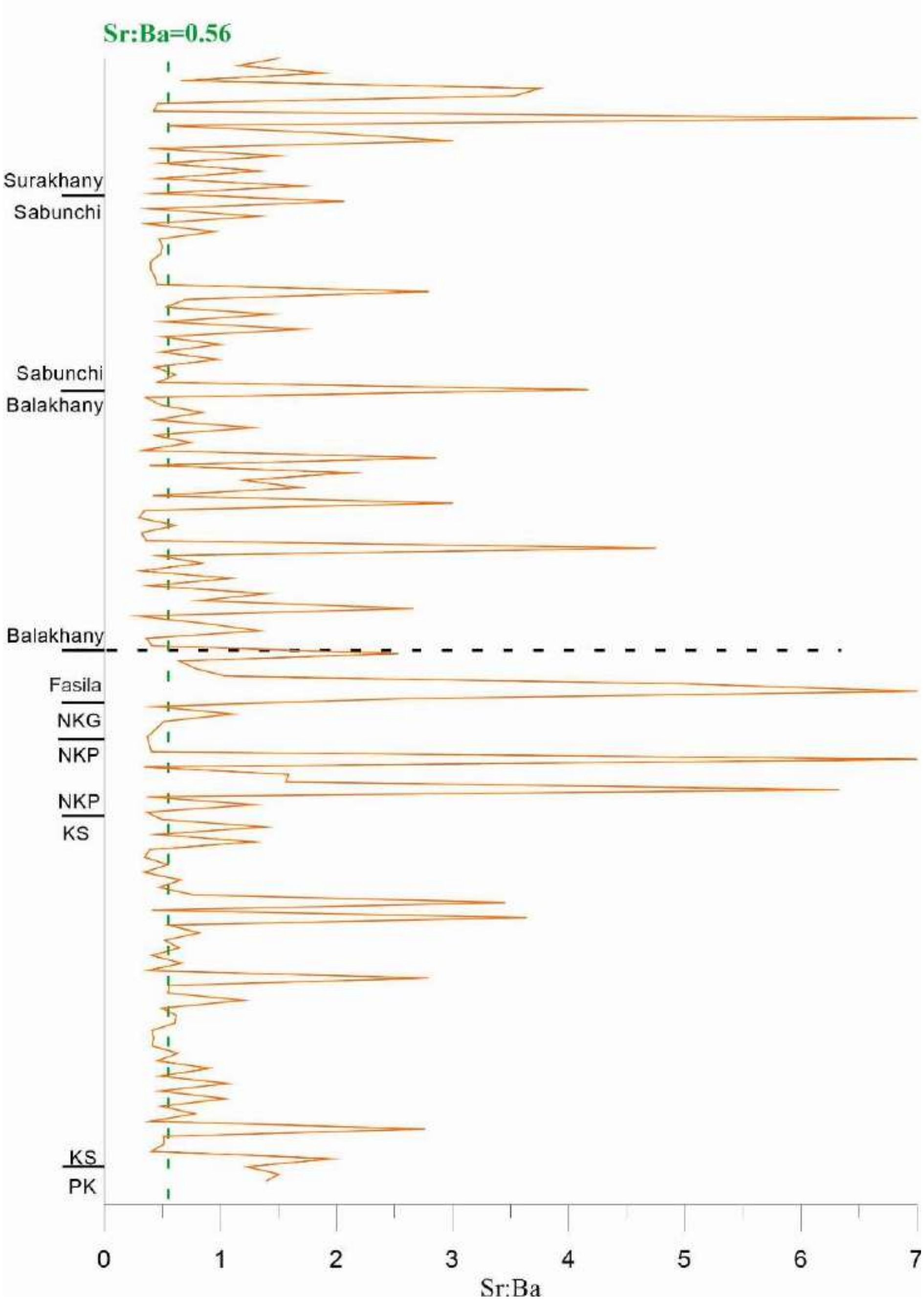


Figure 12. Sr / Ba ratio values variations in the Productive Series section, the Kirmaki and Yasamal Valleys

The Sr / Ba ratio indicate the sandstones accumulation in the saline environment, and muddy sediments – in the freshwater – brakishwater conditions. We explain it by increase evaporation during sand deposition that was accompanied by decrease of volume of water coming to basin resulted in the sea level fall. Water salinity reached high values that prevented mixing of river and sea water in the sand deposition sites dominated by deltaic facies. In contrast, during cooler periods the amount of fresh water running to the PaleoCaspain Sea was increasing, the sea water salinity decreasing, the sea level raising, and as a result, the studied locality was covered by distal sedimentation in the prodelta setting dominated by muddy sediments.

Table 4

Range of Sr / Ba variations in the various PS suite sediments

Suite	Shales			Siltstones			Sandstones			suite		
	Min.	Max.	Var.	Min.	Max.	Var.	Min.	Max.	Var.	Min.	Max.	Var.
Surakhany	0.38	1.51	1.13	0.43	0.54	0.17	0.66	35	34.34	0.38	35	34.62
Sabunchi	0.37	0.7	0.33	0.4	0.5	0.11	0.4	4.17	3.77	0.37	4.17	3.8
Balakhany	0.29	1.2	0.91	0.3	0.42	0.12	0.36	4.75	4.39	0.29	4.75	4.46
Fasila	0.65						0.79	15	14.21	0.29	15	14.71
NKG	0.37	0.51	0.14				0.45	1.11	0.66	0.37	1.11	0.74
NKP	0.34	0.4	0.06				0.38	24	23.62	0.34	24	23.66
Kirmaki	0.35	1.22	0.87	0.4	0.47	0.07	0.43	3.64	3.21	0.35	3.64	3.29
PK				1.5			1.3			1.39	1.5	0.11

Thus, studies of trace elements provide an opportunity for various paleoenvironmental reconstructions. For instance, knowing the element transportation mode promote our understanding of the basin facies zones. The migration of element in the form of solution brings the maximum of its accumulation to the muddy sediments of the pelagic zone. If element is transported by terrigenous particles, its maximal amount is recorded in the shoreface zone in the coarse-grained sediments.

If element migrates mainly as absorbed by colloid micelle, then its content values maximum falls to muddy rocks. But if the element is transported by terrigenous particles and occurs in the crystal lattice of minerals composing this clastic material, then the element maximum content can be recorded in the silty and sandy rocks.

Thus, the transportation mode and grain size are the basic factors affecting chemical elements distribution. As well as sediments are sorted the levels of element content in series sandstones-siltstones-shales are more contrasted; in the poorly sorted rocks distribution of elements is more smoothed. To describe patterns of elements distribution we used such parameter as an order factor (OF) that is a ratio of number of elements displaying graded content values from sandstones to siltstones and shales, to a total number of elements found in the sediments.

The smallest ration of OF equal to 0.416 is recorded in the sediments of the lower portion of PS - PK and NKG suites which testifies to poor differentiation of clastic material (Figure 13).

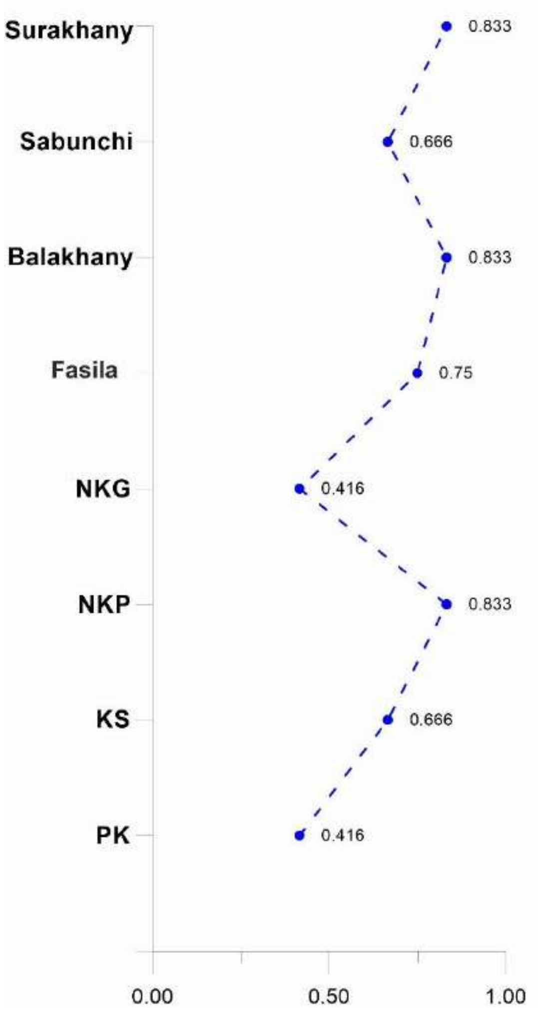


Figure 13. Order factor values in sediments of the Productive Series various suites exposed in the Kirmaki and Yasamal valleys

In the NKP Suite the maximal OF value equal to 0.833 is recorded that indicates the solution transportation mode (Figure 13).

In the upper section of PS the OF values are increasing from the Fasila Suite to the Surakhany Suite (Figure 13). It testifies to prevailing solution transportation mode in the upper suites of the Productive Series.

Trace element studies provide a good opportunity for reconstruction of paleoenvironmental characteristics such as salinity, depth and facies distribution in the paleobasins.

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CƏNUBİ XƏZƏR HÖVZƏSİNİN PLİOSEN ÇÖKÜNTÜLƏRİNİN MİKROELEMENTLƏRİNİN GEOKİMYASI

D.A. Hüseynov, E.H. Əliyeva

Abşeron yarımadasında yerləşən Yasamal və Kirməki dərələrinin məhsuldar qatının çöküntülərində aşkar edilən mikroelementlərin tərkibinin öyrənilməsi nəticəsində sedimentasiya şəraitinin yenidən qurulmasının praktiki əhəmiyyət kəsb edən bir sıra göstəriciləri müəyyən edilmişdir. Stronsiumun bariuma nisbətinin tədqiqindən belə nəticə əldə edilmişdir ki, çöküntü toplanma hövzəsinin fasilə lay dəstəsi daha yüksək duzluluğa malikdir. Buna baxmayaraq Balaxanı və Suraxanı lay dəstələrinin çöküntüləri az duzlu su hövzəsində toplanmışdır. Məhsuldar qatın alt hissəsində Kirməkialtı lay dəstəsindən Kirməkiüstü gilli lay dəstəsinə doğru duzluluğun azalması müşahidə olunur.

Məhlul şəklində elementin miqrasiyası zamanı onun maksimal həddi dərinsulu zonanın gilli çöküntülərində həmçinin aşkar edilməmişdir. Əgər element qırıntılı hissəciklərlə daşınırsa, onun maksimum konsentrasiyası dayazsulu zonanın qumlu çöküntülərində baş verəcəkdir.

ГЕОХИМИЯ МИКРОЭЛЕМЕНТОВ ПЛИОЦЕНОВЫХ ОТЛОЖЕНИЙ, ЮЖНО-КАСПИЙСКИЙ БАССЕЙН

Д.А. Гусейнов, Э.Г. Алиева

На основе изучения микроэлементного состава отложений продуктивной толщи, обнажающихся в Кирмакинской и Ясамальской долинах, расположенных на Абшероснком полуострове, было выявлен ряд показателей, имеющих практическое значение при проведении реконструкции условий осадконакопления. Было показано по данным изучения отношения стронция к барию, что наибольшей соленостью обладал бассейн накопления отложений свиты перерыва. При этом отложения балаханской и сабунчинской свит накапливались в условиях солоноватоводного бассейна. В нижнем отделе продуктивной толщи отмечается тренд падения солености от подкирмакинской свиты к надкирмакинской глинистой свите.

Также, не было выявлено, что при миграции элемента в виде растворов его максимум отмечается в глинистых отложениях глубоководной зоны. Если элемент переносится обломочными частицами, максимальная концентрация его будет иметь место в песчанистых отложениях мелководной зоны.

EOCENE-MIOCENE OIL SHALES IN AZERBAIJAN: STRATIGRAPHIC CONTROLS ON FORMATION, DISTRIBUTION AND HYDROCARBON GENERATION

Based on the results of many years of field surveys, new information is presented on previously unknown oil shale outcrops in Azerbaijan. New boundaries of the distribution of oil shale-bearing facies were established. Role of stratigraphic controls in the distribution of oil shales within areas and outcrop sections, and their oil or gas generation capabilities were substantiated. The study of the source of oil shale parent rocks, and the features of oil shale basin that formed in the Eocene, Lower Maikop (first discovered in this study) and Miocene (Upper Maikop, Chokrakian and Diatom), made it possible to obtain some new regularities. Our results show that the kerogens of Eocene and Diatom oil shales demonstrate similar evolutionary histories that are noticeably different from the Maikop ones. Eocene oil shale kerogens, which show a closer connection with the marine environment demonstrate the ability to generate only oil, like Diatom kerogens, while the kerogen evolved in the Upper Maikop basin, which is subject to more terrigenous inputs and formed in a relatively freshwater environment, mainly shows the ability to generate gas.

Keywords: Azerbaijan, oil shale, formation, stratigraphic controls, regularity, oil generation capacity

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Introduction and research status

The territories of East Azerbaijan, which located in the zone of collision of large geodynamic units, were characterized by rapid and large-scale sedimentation, processes of regional compression and rich oil and gas formation (Aliyev et al., 2019; Aliyev and Abbasov, 2019; Odonne et al., 2021). In terms of the density of mud volcanoes, the region has no analogues in the world. In areas where rich hydrocarbon deposits, bituminous rock outcrops and mud volcanoes have been found, oil shale has also been discovered (Aliyev et al., 2014; Aliyev et al., 2018; Aliyev and Abbasov, 2020), which is considered the best source rock among sedimentary rocks.

Analyzing the published literature concerning the study oil shale of Azerbaijan in different directions, in two periods until the end of the 1930s and then the beginning of the 1960s, it is necessary to note the work done by K.N.Bogdanovich, I.M.Gubkin, V.V.Weber, Z.A.Mishunina, A.J.Sultanov, R.H.Sultanov, A.A.Ali-zadeh and others. Along with the identification of oil shale outcrop sections in the early periods, their lithostratigraphic features were studied. In the subsequent period, it includes the study of physical and chemical and geochemical characteristics of oil shale rocks, and the calculation of initial reserves of some deposits. If we exclude the book created by Salayev and his co-authors in 1989 (Salayev et al., 1989), then after a long break, precisely since 2000, the period began to study oil shale in Azerbaijan, along with oil sands, with more modern approaches and methods. During this period Ad.A.Aliyev and O.R.Abbasov restored the study of oil shale (Abbasov, 2009). In addition to surface outcrops, oil shales found in ejecta from mud volcanoes were included in their studies (Aliyev et al., 2018). In publications (Isaksen et al., 2007; Hudson et al., 2008; Baldermann et al., 2020; Aghayeva et al.,

2021) covering this period, along with samples taken from the mud volcano areas, several outcrop sections which contains oil shale layers were also investigated using modern approaches. In these studies, a small number of oil shale samples have been investigated not as oil shales, but as shale and argillite.

Long-term exploitation of rich oil and gas fields leads to a decrease in their production indicators. This necessitates a more detailed and appropriate study of oil shale (as well as oil sands) with a large reserve (Aliyev et al., 2014) that has not been used in Azerbaijan so far. In other words, the study of formation conditions of such rocks in previously known oil shale areas of Eastern Azerbaijan was not based on the methodological principles of the researches performed in this direction on a global scale, but at best, based on the hypotheses formed on the basis of analyzes of lithostratigraphic changes observed in the studied outcrop sections. However, in the few works published by foreign researchers together with local researchers (Baldermann et al., 2020; Aghayeva et al., 2021), more detailed studies were carried out in the study of two outcrops (Pirekeshkul and Islamdag sections). However, in these studies, oil shales found among the lithofacies of the sections were considered as argillaceous rocks. In addition, except for Eastern Azerbaijan, the possible distribution areas of oil shale in other regions of the country have not been specified, and the role of stratigraphic controls in their enrichment with the organic matter in the Middle Eocene-Upper Miocene stratigraphic range has not been substantiated. Another issue attracting attention is the type of oil shale kerogens associated with different stratigraphic units, as well as the as well as the definition of their ability to generate oil or gas hydrocarbons. This research work is devoted to the study of additional distribution areas of oil shale in Azerbaijan and the substantiation of the role of stratigraphic controls in distribution of oil shale lithofacies within areas (fold structures) and stratigraphic units, and their oil or gas generation potential.

Distribution of oil shale throughout the country, folded structures and outcrop sections

The results of our many years of field research show that the distribution of oil shale in Azerbaijan is characterized by Middle Eocene, Maikop, Chokrakian (partially) and Diatom deposits (Figure 1). With the exception of the Middle Eocene, oil shale stratigraphy correlates very well with Maikop and Diatom deposits, which contain potential oil and gas source rocks.

The oldest, Cretaceous oil shales of Azerbaijan are found along the southern slopes of the Greater Caucasus, including in areas extending almost to the Absheron Peninsula. They are established in the Altyaghaj, Bakhyshly (Atachay), Sarydashchay, Zarat, Talyshnuru, Gyzmeydan, Khilmilli, and Kurkechidagh outcrop sections belonging to the Albian stage of the Lower Cretaceous, as well as to the Cenomanian, Coniacian and Turonian stages of the Upper Cretaceous. Dark-colored oil shales of the Cretaceous period are not of economic interest due to the thinness of their layers traced in limited areas.

Middle Eocene deposits (mainly Paradashian (Bartonian) and relatively Lutetian stages (Figure 1)) can be considered as oil shale facies in Azerbaijan. If we do not take into account several meters of dark brown bituminous-paper oil shale in the area of the village of Susay on the left bank of the Guruchay, as well as local outcrop sections found in Gusarchay and other areas in the Pre-Caspian-Guba oil and gas region, significant outcrops of Middle Eocene oil shale in other areas were not recorded. Significant units of oil shale belonging to the Middle Eocene can be found in areas ranging from Ilkhydag to the centre of Gobustan, and from there to the western part of Shamakhy. In the north of the Shamakhy-Gobustan oil and gas region, the alternation of oil shale layers was established in the Agburun, Yashma, Chargyshlak and other areas. Particular attention is drawn to oil shale outcrops in the northwestern zones of the oil and gas region, especially in the Agsu, Gurjuvan, Girdimanchay, Sediyan, Diyalli, Juliyan, Erebshalbashy, Khilmilli and others. Middle Eocene oil shale, common in Central Gobustan, with a thickness of about 200–450 m, is present in the Jengichay and Kecheller outcrop sections with sufficient thickness and frequent alternation. Together with the Middle Eocene, thick layers of oil shale of younger Diatom are also characteristic of the Mayash, Kichik-Siyeki and other areas. In the course of fieldwork in Central Gobustan, we were able to discover several new outcrops of Eocene oil shales, such as Boyuk Siyeki and Chaily, which are of particular importance.

According to our estimates, the potential sites that give positive results in the search for Paleogene oil shale lithofacies are: the strip from Gusarchay to Shurabad; Inchechay and Terter interfluve zones in Naftalan; areas where Paradash stage of Middle Eocene sediments was recorded in Nakhchivan (especially in the interfluve zones Garadere-Dulyun); in Talysh, areas belonging to the Pirasora and predominantly Nesli facies (thin brown coal layers have also been identified (Babayev et al., 2015) correspond to Paradsh stage. According to the results of numerous previous studies (Sultanov, 1948; Abbasov, 2009) of the Gobustan region, the German fault was recognized as typical of the northern boundary of oil shales of the Middle Eocene.

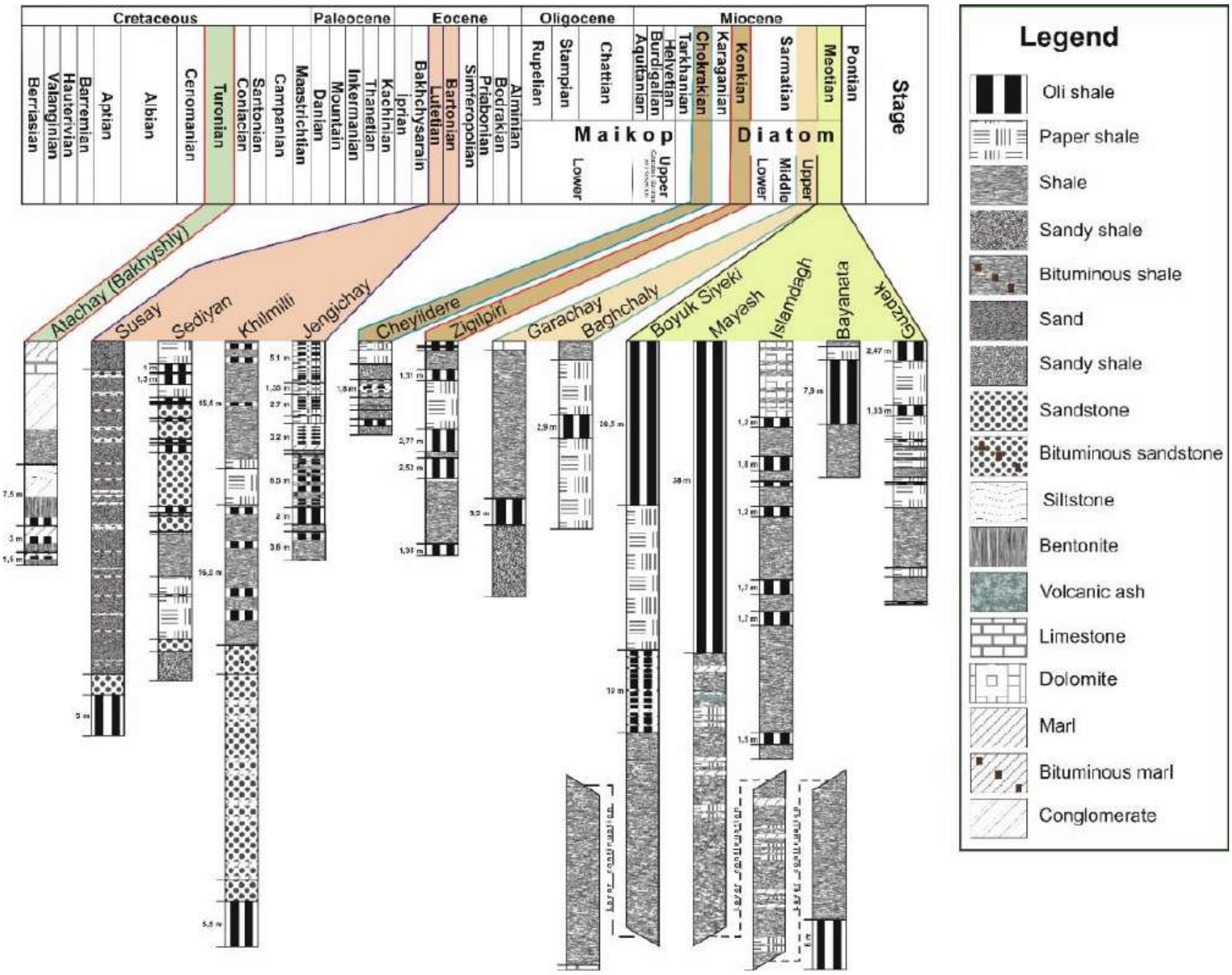

Figure 1. Cretaceous-Miocene sections of some oil shale-bearing outcrops in Eastern Azerbaijan

But our new research shows that the distribution areas of oil shale are typical for a more northern zone, including the Guba basin. In our opinion, the prospect of discovering Middle Eocene oil shales in the northern zones of Eastern Azerbaijan should be limited to the zones that continued until the Imamgulukend-Khachmaz fault.

Oil shales are not considered typical of the Lower Maikop deposits identified in the country. However, in our studies, black oil shales of the Lower Maikop age of considerable thickness are traced over large areas in Guba (Figure 2A), in the northwest of Gobustan (in Lahij (Figure 2B)) and in its center (Figure 2C), as well as in Yardimly (Figure 2D).

The identification of oil shale facies of the Lower Maikop age, which are not considered typical for Azerbaijan, in large areas in Pre-Caspian-Guba region and Talysh necessitates the expansion of the search for their analogues in the south of Guba, including in Gobustan. The presence of oil shales in sedimentary lithofacies of the Maikop age, known in Nakhchivan as volcanogenic facies, is called into question.

The Upper Maikop deposits, which play the main feeding role for the hydrocarbon reservoirs of Azerbaijan, are also of particular importance in terms of oil shale facies. The areas located to the east of the zones of the Girdimanchay current are characterized by a denser manifestation of the Lower Miocene facies, which preserve oil shale. They are observed in Kurkechidagh, Kemishdagh, Khilmilli, Engikharan, Aghdere, Erebshalbashy, Gibledagh, Shikhzerli, Shaibler, Gaibler, Jengidagh, Bayanata, Islamdagh and other areas. In the course of field research in Central Gobustan, we discovered previously unknown areas of oil shale in the Upper Maikop. They are located: southeast of the Kichik-Mereze mud volcano, northeast of Mount Gaibler; about 2.6 km southwest of Mount Gaibler, 1.2 km east of the cemetery, on the right and left banks Baku-Shamakhy-Yevlakh highways; in a low field between the mountains of Boyuk-Siyeki and Kichik-Siyeki; in the northwest of the Iyimish mud volcano. To date, oil shale facies related to the Upper Maikop have not been found in the south of Shamakhy-Gobustan, but as a result of our field research, we were able to establish them in several areas: in the in the northwest East Cheyildag volcano; about 1 km southwest of the Gylynj mud volcano. The most important new outcrops on the Absheron Peninsula are related to the southern flanks of Agchala Lake, located southeast of the Uchtepe volcano. The next new outcrop in Western Absheron was discovered exactly 1.3 km south of the Aghchala field, on both sides of the Tagiyev-Sahil road. The oil shale rocks found in this area, which we have named the "Mushvigabad road", are covered with abundant jarosite rocks. In our opinion, it is highly probable that analogues of the oil shale facies of Maikop series extending east of Girdimanchay can also be observed in the west of this river, especially in the Naftalan region and in the near-surface intervals of the sites, located between the Kura and Gabirri rivers. Conducting exploration work in this direction will most likely make it possible to discover new oil shale-bearing areas.

Figure 2. Lower Maikop-aged oil shale outcrops discovered for the first time in Guba (**A**), Lahij, Gobustan (**B** and **C**) and Talish (**D**)

The surface outcrops of oil shale in the Chokrakian deposits, representing the Middle Miocene, were revealed by us only in the southern limb of the Cheyildagh fold, covering the extreme eastern part of the Sundu-Cheyildag anticline zone of South Gobustan.

Oil shales of Middle and Upper Miocene in East Azerbaijan are associated with the Konkian, Upper Sarmatian and Meotian (together called Diatom (Figure 1)). The Upper Sarmatian deposits of the Pre-Caspian-Guba region require special attention in for Diatom oil shale facies. Here, the lower part of the Upper Sarmatian lithofacies is confined to the Rostov suite, which is composed of carbonate and shale deposits together with oil shale. A long strip of o shale facies stretches from Gilgilchay in the southeast to Gudiyalchay in the northwest, up to the watersheds of Gusarchay-Tahyrzhalchay and the village of Enig. However, more significant outcrops are established in a small-scale strip between Velvelechay and Gudiyalchay, which reaches about 30 km. Moving south, in the Shamakhy-Gobustan oil and gas region, the Rustov analogue (Akhudag suite) is found in the central parts of Gobustan, including between the Akhudag and Baygushlu sites, as well as in Kichik Siyeki and others. The unsatisfactory thickness of oil shale layers does not attract attention.

In most of the territory of Gobustan and Absheron, outcrops of oil shale of Konkian age, identified under the name of the Baygushgaya suite, are registered in some outcrop sections along with the Birgut suite (Meotian), which is considered as another stratigraphic composition of Diatom. Outcrops of Meotian oil shales are widespread in Gobustan and on the Absheron Peninsula. Moving to the north and northwest of Gobustan, they are marked in small layers only in certain local areas, such as the Jeyirli and Nabur sections. In the north, Meotian oil shales do not attract much attention. Thus, with the exception of the Yashma region, there are none in nearby places. To the south, Birgut paper oil shale lithofacies are exposed along the low-mountain sections of the Langebiz and Alat rige, and also extend eastward from large mud volcanic fields traced south of Gobustan. The oil shale layers of Meotian age, together with the Konkian ones (tens of meters thick), are very significant in the thick (up to 500 m) sections of Birgut, recorded in the area of the Kichik Siyeki, Boyuk Siyeki and Baygushgaya mountains, located in the central part of Gobustan. In addition to, Meotian oil shale was found in Bayanata, Islamdagh, Mayash, Sungur, Akhudagh, Baygushlu, Alagyshlag, Garagyshlag, Saridash and other areas almost together with Konkian one in Central and South Gobustan.

At the transition to the Absheron Peninsula, outcrops of Diatom oil shale are observed in the areas of Shorbulag, Garaheybat, Damlamaja, Uchtepe, Goytepe, as well as in areas continuing to Ilkhydagh. Along with the southern outskirts of Central Gobustan, the western part of the Absheron Peninsula is the most common zone for recording oil shales belonging to the Konkan and Meotian ages. Here, attention is drawn to the alternation of oil shale layers of different thicknesses in the sections of Diatom, belonging to the Kecheldagh, Khyrdalan, Shabandagh, Masazyr, Zigilpiri (Figure 1), Binegedi, Fatmayi, Saray and other outcrops. In areas where, along with Diatom oil shales, outcrops of other bituminous rocks (oil sands and marls) were recorded, both in the southern suburbs of Gobustan and in Western Absheron, we regularly found signs of oil during field studies.

In our opinion, there is a high probability of finding analogues of Diatom oil shale facies of the Shamakhy-Gobustan and Absheron peninsulas, in the interfluve of the Kura and Gabirri, as well as in the northern zones of Talysh and especially in the western and northwestern parts of Nakhchivan.

Summarizing the results of our many years of field research, from a spatial point of view, it is clear that deposits containing surface oil shale in the territory of Azerbaijan are distributed over large areas belonging to the Pre-Caspian-Guba, Shamakhy-Gobustan, Absheron and

Talysh (Jalilabad) oil and gas regions. However, an analysis of the published literature on the lithostratigraphic characteristics of outcrop sections identified on the territory of the country gives good reason to assume that some areas belonging to the Ganja and Nakhchivan oil and gas regions are also oil shale-bearing. Figure 3 shows the identified areas of oil shale in the territory of Azerbaijan, as well as the proposed potential areas for their prospecting in the future.

With a few minor exceptions, the location of more than 70 oil shale outcrops we identified in East Azerbaijan (Aliyev and Abbasov, 2019), also correlates very well with basins where mud volcanoes have also been recorded. Of particular importance for the distribution of oil shale in East Azerbaijan are the areas of the Paleotethys Sea basin, corresponding to the zones of the accretionary prism (southern slope of the Greater Caucasus), or the Bayanata microblock located in the Jeyrankechmez-South Caspian Megabasin. (Figure 4). To the north of the Zangi-Garajuzlu fault, the areas corresponding to the accretionary prism are more favourable for the distribution of Eocene oil shale outcrops. This fault and its southern zones, as well as Western Absheron, located east of the Boransyz-Jylgha fault, are more distinguished by the distribution of Diatom oil shales.

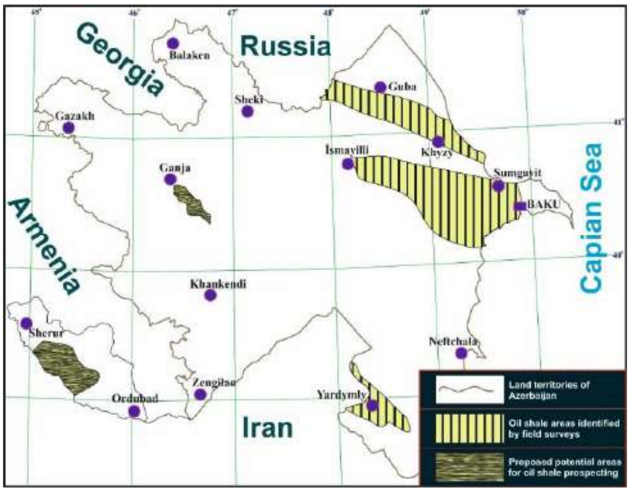

Figure 3. Exacted and assumed distribution areas of oil shale in the territory of Azerbaijan

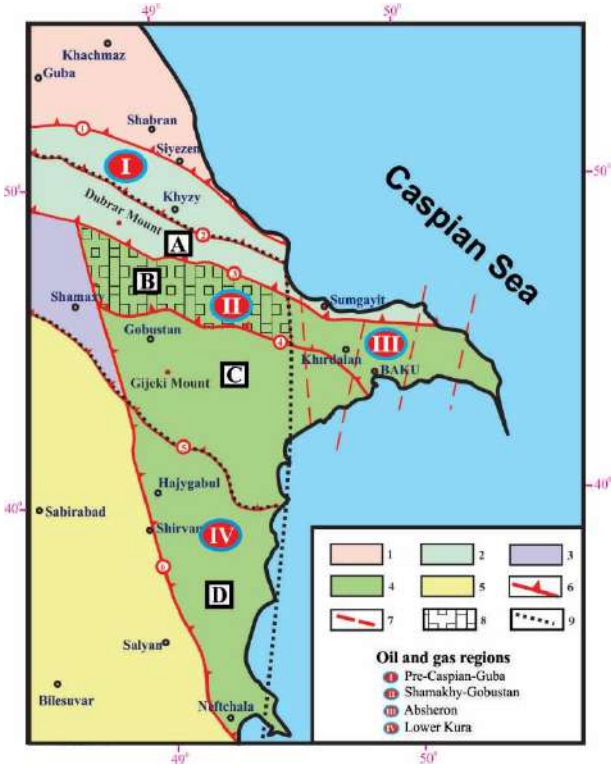

Figure 4. Tectonic scheme of oil shale-bearing and mud volcanic regions of East Azerbaijan (Modified after (Aliyev et al., 2015; Kengerli et al., 2012): **1** – Guba basin (Megazone of Gusar-Devechi); **2** – Shahdagh-Khizi basin (Megazone of the Lateral Range of the Greater Caucasus), Zagatala-Govdagh and Absheron basins (Megazone of the Southern Slope), Shamakhy-Gobustan basin (Megazone of Kakheti-Vendam-Gobustan (**A** – Northern Gobustan Allochthonous)), **3** – Shamakhy zone; **4** – Jeyrankechmez-South Caspian Megabasin (**B** – Bayanata microblock (accretion prism areas), **C** – Toraghay microblock, **D** – South-Eastern Shirvan); **5** – South Caucasus island arc system; **6** – Deep faults (**1** – Siyezen, **2** – Main Caucasus; **3** – Goredil-Masazyr convergence zone (Suvagil fault); **4** – Gujur-Gyzyldash (Zangi-Garajuzlu fault); **5** – Ajıchay; **6** – Shamakhy-Neftchala; **7** – Fault (from left to right: Boransyz-Jylgha and left sided slides); **8** – Parautochthonous; **9** – Border of the oil and gas region

Oil shale rocks are also recorded in the ejecta of mud volcanoes erupting in Azerbaijan. They are mainly found in a median zone (Figure 5), characterized by conjugate logarithmic spirals showing axial symmetry with respect to the emission centre that have been established

(Odonne et al., 2020, p. 10) on the breccia area of the volcanoes. The zone closest to the vent (corresponding to the feeding area of a mud volcano, consisting of the most recent mudflows) is called a central zone, and the zone covering the outer part of the plateau and upper slopes is called a distal zone (Figure 5 (Odonne et al., 2020)), which are not typical for oil shale rock ejecta.

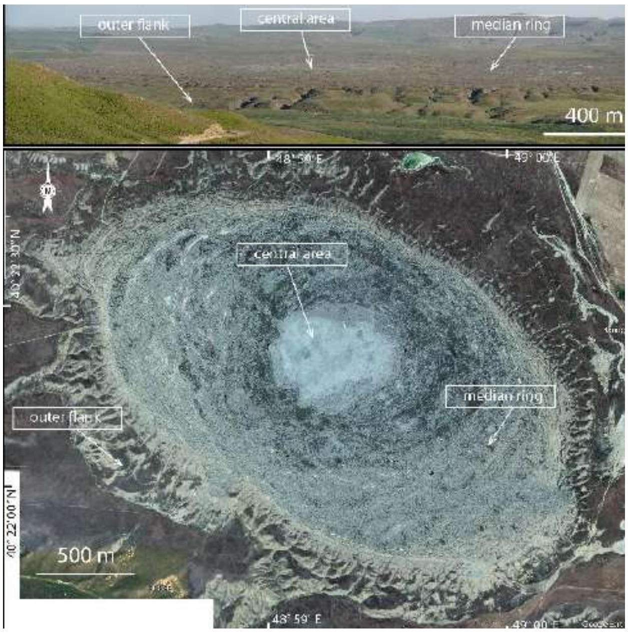

Figure 5. Central, median and distal zones were established in the breccia zone of the Ayazakhtarma mud volcano **(**Odonne et al, 2020)

The conical shape and large dimensions are more characteristic of mud volcanoes, whose eruption centres are located in the areas of distribution of younger deposits (mainly Pliocene and Quaternary) (Figure 6B), not related to the geological age of Azerbaijan oil shales. (Abbasov et al., 2022). Such mud volcanoes are characterized by ejections of Eocene, Upper Maikop and younger Diatom oil shales. They were recorded in deeper, i.e., in places of the greatest subsidence of the Cretaceous deposits (Figure 6B), where the thickness of the Cenozoic deposits is much higher. Volcanoes identified in Western Absheron, south of Gobustan, which are part of the Jeyrankechmez-South Caspian megabasin, can serve as an example (see Figure 3). On the contrary, for volcanoes in areas whose geological structure is composed of older (mainly Eocene and Miocene) deposits **(**Figure 6A and 6B), the mud chambers are located at a relatively shallow depth, the breccia extends over a more limited area and cannot be stacked and demonstrate a plateau-like extension. With the exception of Diatom, they are mainly characterized by ejections of the Eocene and Upper Maikop oil shale rocks. A large number of oil shale outcrops have been recorded in areas with such geological characteristics (Figure 6A). An example of such territories is the central part of Gobustan (Bayanata microblock (see Figure 4 and Figure 6)).

With the exception of the steepest northeastern zones of the Lower Kura oil and gas region, where the mud volcanoes Injabel, Kelameddin, Akhtarmaardy, Akhtarma-Pashaly, etc. were found, no oil shale was found in the ejecta of mud volcanoes located in its southern zones. This pattern can only be explained by the geological structure of the Lower Kura basin. Thus, the thickness of sedimentary layer here reaches 20 km, and more than half of the deposits in lower regions located near the sea belong to the Upper Neogene and Anthropogene (Aliyev and Rahmanov, 2018). In our opinion, this factor makes it impossible for the mud volcanoes located in this part of the Lower Kura to erupt Paleogene-Miocene deposits (as well as oil shale rocks), in contrast to other oil and gas regions.

Our studies have revealed some regularities in relation to the folded structures of the occurrence of oil shale. Thus, the Middle Eocene oil shales developed mainly in synclines. Examples in this respect are Shahandagh, Chargyshlag, Embizler, Aghdere, Boyuk Siyeki, Kichik Siyeki and others. In addition, very few anticlines, including the Diyally (Sediyan) and Jengichay, contain Middle Eocene oil shales, and the thickness of their layers is noticeable in the sections found in these areas (see Figure 1). In most oil shale-bearing synclines, the limbs dip at angles >60°. The Koun oil shales, found in the northern parts of Shamakhy-Gobustan, are often associated with the cores of synclines. Eocene oil shales appear in the limbs of structures in the south. The oil shales identified in the northern flank of the anticline at the Diyalli deposit belong to layers that occur at a lower angle. In addition to the limbs of the Jengichay anticline, oil shale layers were found in its core part.

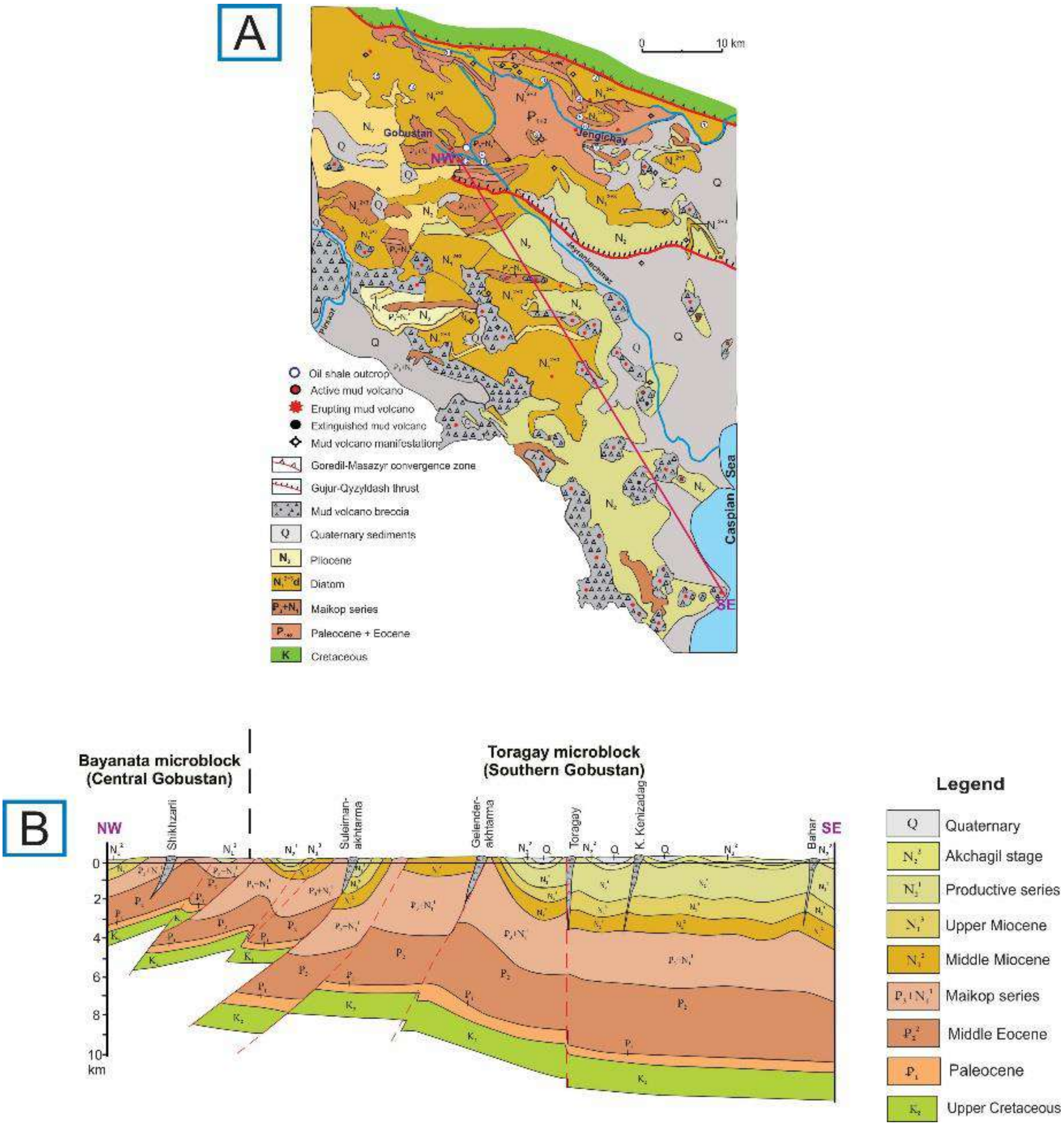

Figure 6. Geological map (**A**) and geological profile (**B**) of Gobustan (modified after (Aliyev et al., 2015; Abbasov, 2009)). Previously known and newly discovered shale outcrops. **1** – Mayash; **2** – Boyuk Siyeki; **3** – Kichik Siyeki; **4** – Siyekilerarasy; **5** – Jengidagh; **6** – Jengichay; **7** – Bayanata; **8** – Iyimish; **9** – Gaibler; **10** – Jeyrankechməz; **11** – Kichik Mereze; **12** – Shihkzerli; **13** – Nabur; **14** – Jeyirli; **15** – Erebshalbashy

In Talysh, Guba, Lahij, and Central Gobustan, the oil shales belonging to the Lower Maikop were also registered in the synclinal folds.

Oil shales of Lower Miocene age are found in the cores and limbs of most synclines in the north, northeast of Gobustan and east of Shamakhy. However, as in some western outcrops of Gobustan (between Aghsu and Girdimanchay rivers), in the direction of Absheron (for example, in the Uchtepe and Agchala regions) and in areas to the north-west of it (for example, in Orjandagh), Upper Maikop oil shale provides outcrops mainly in the cores, as well as on the lims of the anticlines.

As mentioned above, the Chokrak oil shale layers were identified by us only in the southern flank of the Cheyildagh anticline; their total thickness is slightly more than 1 m (Figure 1).

As for oil shales of Diatom age, the main stratigraphic complex that attracts attention among them undoubtedly belongs to the Sarmatian (Figure 1). The outcrops of this stage, identified in the Guba basin (see Garachay and Baghchaly sections in Figure 1), have a monoclinal occurrence. The angles of occurrence of shale layers fluctuate between 50 and 70°.

In the Bayanata microblock, Meotian oil shales are exposed in some synclinals, including Kichik Siyeki and Boyuk Siyeki (Figure 1), as well as on the Baygushgaya structure. The oil shale layers belonging to the Meotian and Konkian stages in all three of these areas lie at an angle of about 40–50° on the limbs of the structures. In the direction of Shamakhy, they are also exposed on the limbs of the Khydyrli anticline. The layer of Diatom oil shales found in the village of Jeyirli has a very low angle of occurrence. South of Gobustan, in the syncline defined between the Akhtarma and Cheyil anticlines, as well as on the limbs of the latter and Gungormez anticlines, Konkian, Sarmatian and Meotian oil shale are distinguished. Continuing towards the western Absheron, the Buransyz-Jylgha anticline can be mentioned as the next structure where oil shale associated with Diatom has been found. The Meotian oil shale section on the northeastern slope of Mount Bayanata (Figure 1) is also very important. Analogous of wich are also observed in the centroclinal of the Garaislam syncline, where the number and thickness of Diatom oil shale layers (in Figure 1 see Islamdagh section) are especially important in the sections observed here.

The Diatom oil shales more characteristic of the Western Absheron, are recorded in the structures of large anticlinal structures. Zigilpiri, Binegedi, Fatmayi, Novkhani, Saray, Ateshgah, Damlamaja and others contain shale outcrops in almost satisfactory areas. In general, in the zones corresponding to the arches (for example, Lokbatan and Shorbulag) and periclinals (for example, Bozdag-Guzdak and Deveboynu) of anticlines in Peninsular, especially in the crests of mud volcanoes in the south and southeast of Western Absheron, almost no oil shale outcrops were found on the surface, but the erupting volcanoes here are quite typical for the ejection of oil shale of Eocene-Miocene age. Mud volcanic manifestations are also characteristic of the central and northern zones of Western Absheron, since the anticlines found here are complicated by the intersections of tectonic lines. The Diatom oil shales have also been found in the periclinal and arch parts of these structures (Zigilpiri, Saray, Binegedi, Jorat, Fatmayi, and others). The fact that their outcrops are often lenticular in shape and most often refer to areas in which oil seeps have also been found (Aliyev et al., 2014). This dependence indicates that their high content of organic matter is enriched due to allochthonous hydrocarbons.

Beridash, Solakhay, Ayrantoken, Goturdagh, Gyrdagh and other structures are registered along the Langebiz-Alat tectonic zone. Oil-bearing sands and marls with large reserves were found here, associated with the outcrops of those structures that are complicated by mud volcanoes of the same name. In the sections studied by us in these structures, oil shales of the facies overlying the oil sand unut, contain paper oil shale with a strong bituminous content. Visually, such shale is difficult to distinguish from oil shale. Unlike oil shales, which are associated with kerogen, the bitumen concentrated in such shales is allochthonous in nature. In other words, the bitumen released from the bottom layer of oil sand saturates the top layer of shale, resulting in the formation of bituminous shale. In this regard, such oil shales are widespread in Cheyldere, Solakhay, especially in Rahim, Gyrgyshlag and others, which are considered areas of oil sands and marls. The lenticular outcrops of bituminous shale in the areas of distribution of oil-bearing gryphons and salsas, which we have identified in Iyimish, Gotur and many other areas of mud volcanoes, do not escape attention. On the northeastern flank of the Gyrgyshlag anticline, where the oil-bearing mud volcano Gyrdag is located, Sarmatian and Meotian deposits are also noted in the area dominated by oil-bearing deposits of the Chokrakian age. Approximately 1.2 km northwest of the oil-producing Gyrdag oil gryphons, strong bituminous features are observed in the dolomite deposits on both lower slopes of the valley stretching for hundreds of meters. Here, the Diatom paper oil shale overlays carbonate facies accompanied by oil seeps (Figure 7). It is assumed that the organic parts of such oil shales are similar to the underlying dolomite oil reservoirs. According to our visual observations, the contribution of allochthonous hydrocarbons to the rich bituminous content of paper oil shales of Chokrakian and Diatom ages is quite large.

With the exception of some shale deposits in the transition zones from Gobstan to Absheron (Uchtepa, Aghchala, Guzdek, etc.), shale deposits of the Apsheron Peninsula are currently used as objects for various purposes, so their economic efficiency is doubtful.

Stratigraphic control on formation and hydrocarbon generation

By studying the mineralogical-chemical, organic-geochemical composition and petrographic characteristics of oil shale sampled from outcrops and mud volcano eruption areas, we have identified some regularities related to the formation of oil shale of the Eocene, Lower Maikop and Miocene epochs. The main points of interest regarding the mineralogical composition are related to quartz, calcite and jarosite. Miocene-aged oil shales significantly exceed the Lower Maikop and Eocene, according to quartz and jarozite. In contrast to the Eocene and Lower Maikop shales, calcite is relatively less important for the Miocene oil shales. The concentration of this mineral in the oil shales of Yardymly is around 40%.

Figure 7. Paper oil shales of Diatom age in lithofacies above the dolomitic oil-bearing unit in the Gyrgyshlag section

The average CIA value of Azerbaijan oil shale is 67, which is higher than NASC (Gromet et al., 1984) and UCC, and about the same number as PAAS (Taylor and McLennan, 1985) and Average shale (Turekian and Wedepohl, 1961). An analysis of the CIA values shows that the studied oil shales are derived from source rocks that have undergone moderate chemical weathering. With some exceptions, along with feldspars, minerals consisting of Fe associations can be considered as typical primary components of the studied oil shales. In general, the role of deposits brought from areas of tholeiitic volcanism in the formation of the studied oil shales is obvious. Although iron-containing basalts are the main source of sediments entering the oil shale paleobasin, intermediate magmatic formations consisting of andesites also played a role in the accumulation of sediments. In particular, it is an indisputable fact that a number of Upper Maikop samples belonging to Agchala, Siyakilerarasi, and Jengidagh have different protolith characteristics, and at the same time, belong to relatively higher acid igneous associations. It is also necessary to note that among the samples of Absheron and Shamakhy-Gobustan, the group of oil shale of the Eocene age reveals a greater connection with andesitic volcanism.

Along with the significant presence of a representative of the smectite group in some Eocene samples, the identification of other clay minerals characteristic of ash formations (for example, about 12% clinoptilolite), as well as the fixation of signs of dacite in their protolithic nature, shows the role of tephra in their genesis. In addition, the calculation of the amount of terrigenous material brought by erosional igneous sources showed that in some Eocene samples (for example, in Otmanbozdagh, Shekikhan and Aghtirme), the degree of participation of terrigenous material is relatively low compared to other samples. To elucidate the role of terrigenous and pyroclastic composition, our analysis based on several metals including V, Cr, Ni, Zn, Fe and Al confirms the volcanoclastic nature of some Eocene samples. We hypothesize that those samples that reflect weak paleoweathering, retain carbonate minerals, and are associated with tephra, probably formed from volcanic ash. Our idea that some samples can be formed from volcanic ash under the influence of wind is supported by the fact that some explosive volcanisms registered in the Lesser Caucasus and Talysh in the Eocene.

The results of the approach based on the Fe_2O_3/TiO_2 and $Al_2O_3/(Al_2O_3+Fe_2O_3+MnO)$ indices of the samples show that all the analyzed samples exhibit a close nature to PAAS and NASC, indicating that they are not associated with hydrothermal sources.

The results of paleoclimatic reconstruction studies unambiguously reflect the arid-climatic conditions of the formation of the analyzed samples. In terms of regularity, it is concluded that the Eocene was subjected to relativly higher temperature conditions than the Miocene. This is in good agreement with the results (Zachos et al., 2001) on global climate changes occurring 65 million years ago.

The enrichment of oil shale with organic matter is facilitated by a number of factors, including the trophic nature of the basin, its connection with the sea, salinity, primary productivity, depth, redox conditions, sedimentation rate, etc. Thus, our approaches related to Al, Fe, Mn, and other compositions show the relationship of the studied oil shales with oligotrophic water bodies. The mineralogical composition of the rocks also confirms this idea. In the case of carbonates, with the exception of some samples, their amount in samples is low in terms of general indicators.

Most of Miocene samples formed in the more peripheral zones of the basin. An increase in the amount of quartz in their composition also confirms this possibility. In the formation of most Eocene samples, a relatively high influence of the marine environment is evident. The oil shales of Nardaranakhtarma, Khilimilli and Yardymly areas are more prone to the marine zone.

Ca, Fe, Sr, Br, and Mn analyzes also suggest that the Miocene shale basin was fresher than the

Eocene. With few exceptions, in the Absheron Peninsula and in Shamakhi-Gobustan, the Miocene basins were shallower (<20 m), while the Eocene basins were of medium depth (>20 m). On the other hand, the oil shale basins near the Caspian Sea were deeper than others located in Gobustan and Absheron. For comparison, the deepest shale-forming basins in Azerbaijan were located in the Lower Maikop, which is typical for the Guba and Talysh regions.

Predominantly oxic-dysoxic conditions can be considered typical for the environments of the oil shale paleobasin. Most of the Eocene samples were deposited in environments containing more oxygen than in the Miocene. Some samples of the Upper Maikop correlate with the depths at which sulfate reduction occurred.

The presence of intensive tectonic activity during the Eocene, especially the transport of volcanic ash into the paleobasin, created favorable conditions in terms of providing essential nutrients such as Fe, P and Cu. In the analyzed samples, a change in the aluminum concentration within 6–8% has a greater effect on the enrichment of Eocene and Diatom oil shale with organic matter (Figure 8). As terrigenous inputs increase in the pleobasin, when the Al concentrations reach the range of about 7–10%, the sediments provide a not-too-high content of organic matter, which is typical for most Maikop oil shales. Therefore, the Eocene sediments were subjected to less terrigenous inputs than the Miocene. In this regard, the role of primary bioproductivity was key in the enrichment of Eocene and, probably, Diatom kerogen with organic matter. For the Miocene, on the contrary, terrestrial plants were the dominant source. This supports our conclusion that the Eocene was associated with saltier seawater and the Miocene with fresher aquatic environments with abundant river flow. Volcanic ash was more involved in the accumulation of Eocene basin, and this nutrient-rich igneous association probably influenced the growth of algae in the water as well as the redox state of the water column.

Our extraction studies also confirm the results obtained for the kerogen type according to the data of inorganic chemistry. So, in Miocene oil shales, alcohol-benzene bitumen (1.69%) prevails over chloroform bitumen (1.24%). However, for the Eocene samples, the opposite trend is recorded. These different geochemical characteristics may be related to the more soluble chloroform bitumen in Eocene oil shales, where such organic molecules are associated with lipids, i.e. algae (source of autochthonous organic matter). On the other hand, the obvious predominance of the alcohol-benzene fraction in Miocene oil shales can be explained by the contribution of terrestrial plants to the formation of Miocene oil shale.

The average parametric indices of structural groups calculated from the ^{1}H NMR spectra of extracted bitumen from the Eocene samples of the Keyreki volcano and the section of the Bayanata outcrop of Diatom age show that the degree of aromaticity of bitumen belonging to the Bayanata oil shale is significantly lower (only in asphaltenes it reaches 11.5%). On the contrary, noteworthy is the high rates of paraffin compounds (in benzene = 61.4%, in 4:1 alcohol-benzene = 45.2%). In the Keyreki sample, the degree of aromaticity is 14% in total due to the sum of all extracted fractions. Spectral analysis showed that the kerogen of Bayanata sample of Diatom age is significantly enriched in organic matter of autochthonous origin.

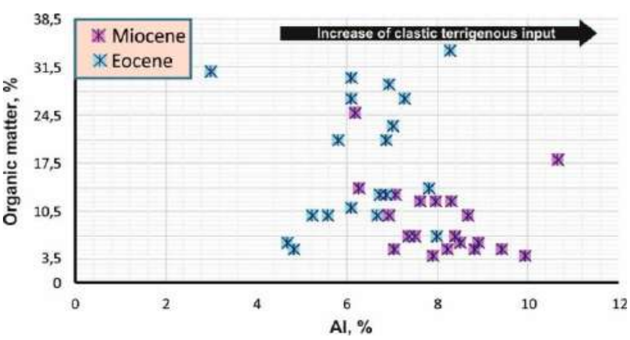

Figure 8. Diagram showing the effect of terrigenous inputs on the concentration of organic matter in Miocene and Eocene oil shale

According to the results of the diagrams associated with the corresponding parameters of "Rock-Eval" (Figure 9), the Eocene and Diatom oil shales sampled from both the mud volcanic area and from the outcrop sections clearly correspond to type II kerogen, as was seen in the above discussion. The samples belonging to the Upper Maikop are plotted in areas corresponding to the mixed type II–III and III.

Compared to other samples, the Islamdag oil shale shows a relatively high CIA value with several other Diatom samples. Chemical weathering is known to play an important role in the regulation of primary productivity. Thus, the increasing intensity of chemical weathering stimulates the entry of biogenic elements into the paleobasin, which has a positive effect on the primary production of organic carbon. Petrographic studies have also shown that Diatom paper oil shales are rich in alginite. The total content of vitrinite and inertinite is about 30%. In general, such oil shales contain diatoms and fossil fish, as well as an abundance of lamalginite and telalginite. The oil shales of the Upper Maikop section of the Islamdag are dominated by vitrinite and pyrite (Aghayeva et al., 2021). (Isaksen, et al., 2007) also stated that the organic-rich rocks of the Upper Maikop, selected from the mud volcanic area and outcrops, mainly contain organic matter of plant origin, consisting of spores and pollen, as well as amorphous and woody materials as secondary components.

The results of mineralogical, inorganic chemical, organic-geochemical, extraction, spectral and petrographic studies demonstrate the history of the evolution of Eocene and Miocene (mainly Upper Maikop) oil shale in various basin conditions and with different types of kerogen, generalized in schematic illustration showing in Figure 10.

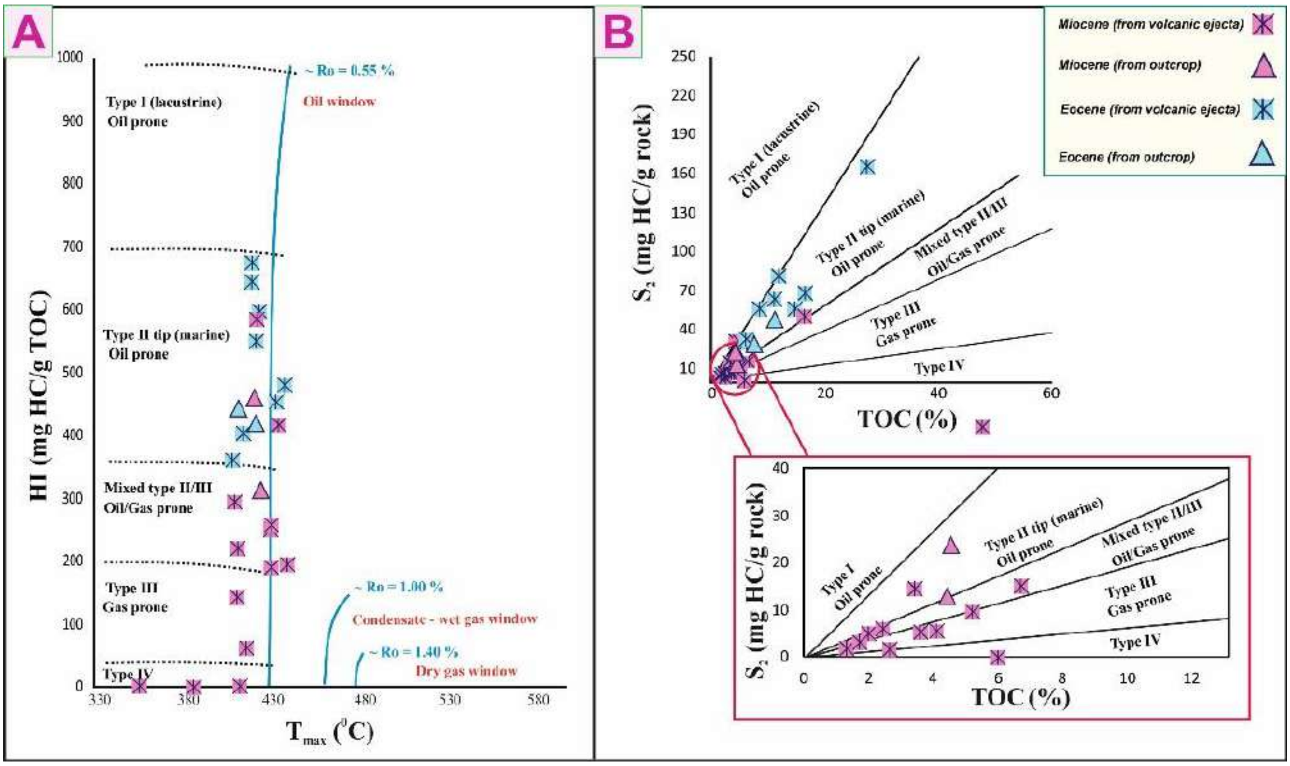

Figure 9. Cross plots between hydrogen index versus maximum pyrolysis temperature, and S_2 versus TOC indicating the kerogen types of Eocene-Miocene oil shale samples

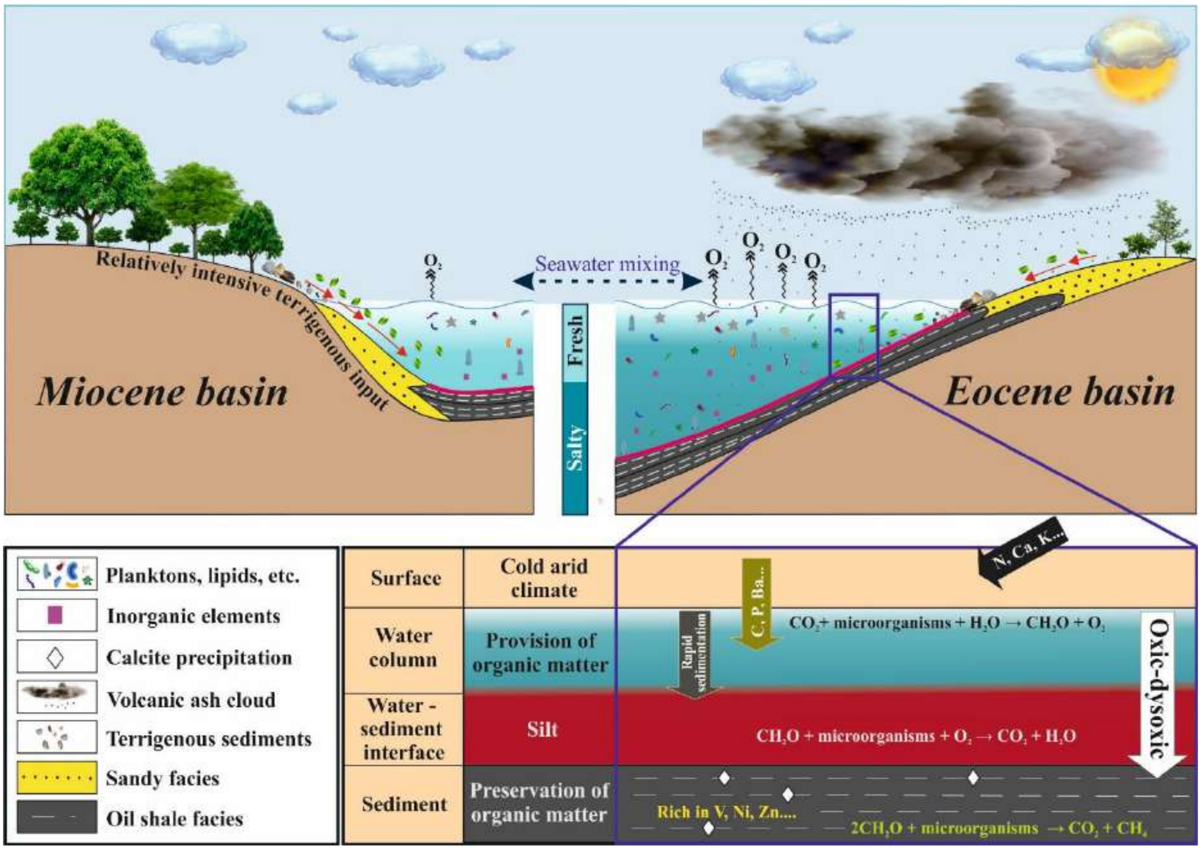

Figure 10. Generalized schematic illustration showing the evolutionary history of the Miocene and Eocene oil shale

Compared with the Upper Maikop, it has been established that the Diatom and especially Eocene oil shales, provided with organic matter of autochthonous origin and having a high hydrogen index, bitumen index, generation potential and pyrolyzable carbon indicators, mainly have the potential to generate oil hydrocarbon. Agayeva and her co-authors in their paper (Aghayeva et al., 2021, p. 380), based on the study of only a few samples from the Pirekeshkul outcrop, note that in the Middle Eocene section, there are layers rich in organic matter containing type II kerogen, which cannot be considered an important source of rocks on onshore of Eastern Azerbaijan because for their low thickness. However, according to our studies, the total thickness of the Middle Eocene in East Azerbaijan, especially in Gobustan (> 300 m (Aliyev et al., 2015, p. 44)) and the Absheron Peninsula, as well as the frequent alternation and significant thickness of oil shale layers in their sections (see Figure 1), especially the presence of thick and large fragments of oil shale, often found in the ejecta of mud volcanoes shows that the opinion formed in the study of only one section is incorrect. In addition, the fact that the Upper Maikop deposits, considered in many studies to be the best source rocks, have satisfactory indicators of the quality and productivity index and the generation potential index of allochthonous organic compounds in oil shale samples, but contain low hydrogen and bitumen index, indicates their potential for gas generation.

Compared to other stratigraphic units, the Chokrakian oil shales, which have a negative impact on the general organic-geochemical parameters of the Miocene deposits, are characterized by the highest values of the average productive index, but the lowest values of pyrolyzable carbon and maximum pyrolysis temperature (see Figure 9), associated with the presence of organic compounds of allochthonous origin, corresponding to the peak S_1 in their hydrocarbon composition. This is also confirmed by the fact that strong oil shows are characteristic of sandstone and dolomite formations of the same age deposits in the oil and gas regions of Azerbaijan (see Figure 7).

The average geochemical parameters of oil shale samples currently do not show positive feature in terms of the possibility of oil and gas generation. But in some coastal regions, where the Upper Cretaceous roof descends deeper, the Upper Maikop and Middle Eocene deposits promise favourable signs for hydrocarbon generation. On the other hand, the Eocene and Maikop oil shales have great prospects for obtaining synthetic oil and gas, respectively.

Conclusion

The results of many years of field research made it possible to discover new areas of oil shale within Azerbaijan and remap (Figure 1) their distribution areas.

Surface outcrops of oil shale are found mainly in the distribution areas of Middle Eocene, Maikop, Chokrakian (partially) and Diatom deposits.

Lower and Upper Cretaceous shales found in the north of Gobustan are associated with low net thickness and limited areas, which reduces their economic significance.

In Central Gobustan, zones of distribution of accretionary-prismatic deposits are characteristic of significant outcrops of Middle Eocene and Upper Maikop oil shale.

Analogues of surface oil shale of Upper Samatian age, characteristic only for the Guba basin, were not found in Shamakhy-Gobustan and Absheron.

The oil shale outcrops of Konkian and Meotian, which are manifested in thick layers in Central Gobustan, are more common, especially in its east, in Western Absheron. These Diatom oil shales are also noted in the periclinal and arch parts of anticlines, the outcrops of which are often lenticular in shape and most often touch areas of seepage of oil and oil-bearing rocks (sands and marls). We believe that their high organic content is enriched in allochthonous hydrocarbons. The role of allochthonous hydrocarbons in the formation of organic matter in the Chokrakian oil shale is also substantiated.

In the formation of Guba oil shale, the uplift zones of the Greater Caucasus Megazone, called the Lateral Range, served as the source area, and in the evolution of the Shamakhi-Gobustan oil shale, the sediments brought from the Tufan and Vandam uplifts were of special importance. Volcanic ash brought by the wind into the basin also contributed to the formation of oil shale in some Eocene areas of East Azerbaijan.

Both Eocene and Diatom oil shales, which have closer contact with seawater and contain the largest amount of organic matter, sampled from the ejecta of mud volcanoes and outcrop sections, are compatible with type II (oil-bearing) kerogen. However, oil shales of Upper Maikop age, which show a closer relationship with freshwater sources (rivers), mainly correspond to type III (gas-generating) kerogen.

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AZƏRBAYCANIN EOSEN-MİOSEN YAŞLI YANAR ŞİSTLƏRİ: ƏMƏLƏGƏLMƏYƏ, YAYILMAYA VƏ NEFT-QAZTÖRƏTMƏYƏ STRATİQRAFİK NƏZARƏT

O.R. Abbasov

Məqalədə, çoxillik çöl-tədqiqatları əsasında Azərbaycan yanar şistlərinin daha əvəllər məlum olmayan açılışlarına dair yeni məlumatlar təqdim olunur. Yanar şistli fasiyaların yeni yayılma areal-ları müəyyənləşdirilir. Onların sahə və kəsilişlər üzrə paylanmasında, həmçinin neft və yaxud qaztö-rətmə xüsusiyyətlərinin formalaşmasında stratiqrafik nəzarətin rolu əsaslandırılır. Eosendə, Alt Maykopda (ilk dəfə olaraq bu tədqiqatda aşkarlanıb) və Miosendə (Üst Maykopda, Çokrakda və Diatomda) formalaşan çökmə hövzələrin və bura gətirilən ana süxurların genezisi ilə əlaqəli tədqiqatlar bəzi qanunauyğunluqların əldə olunmasına imkan vermişdir. Nəticələrimiz, Maykopdan fərqli olaraq, Eosen və Diatom yaşlı yanar şistlərə aid kerogenlərin oxşar təkamül xüsusiyyətləri ehtiva etdiklərini göstərir. Dəniz mühiti ilə daha yaxın əlaqə göstərən Diatom kimi, Eosenə məxsus kerogenlər yalnız neft, lakin şirinsulu və nisbətən intensiv terrigen daxilolmaları şəraitində təkamül tapmış Üst Maykop yaşlı kerogenlər isə əsasən qaz törətmək imkanına malikdirlər.

ЭОЦЕН-МИОЦЕНОВЫЕ ГОРЮЧИЕ СЛАНЦЫ АЗЕРБАЙДЖАНА: СТРАТИГРАФИЧЕСКИЕ РЕГУЛЯТОРЫ ФОРМИРОВАНИЯ, РАСПРЕДЕЛЕНИЯ И ГЕНЕРАЦИИ УГЛЕВОДОРОДОВ

О.Р. Аббасов

В данной статье представлена новая информация о ранее неизвестных обнажениях горючих сланцев в Азербайджане, полученная по результатам многолетних полевых исследований. Установлены новые границы распространения фаций, содержащих горючие сланцы. Обоснована роль стратиграфического контроля над распределением горючих сланцев по площади и разрезам обнажений, показан их нефте-газообразующий потенциал. Исследование источников сноса пород – горючих сланцев и выявление особенностей эоценовых, нижне-майкопских (определены впервые в ходе данного исследования) и миоценовых (верхне-майкопских, чокракских и диатомовых) бассейнов седиментации горючих сланцев, позволили выявить новые закономерности. Согласно результатом проведенных работ, керогены эоценовых и диатомовых сланцев прошли схожий эволюционный путь, заметно отличающийся от майкопских горючих сланцев. Так, керогены горючих сланцев эоцена и диатомового яруса больше связаны с морской средой и могут генерировать преимущественно нефть. В то же время керогены, образовавшиеся в бассейнах верхнего майкопа, содержат больше терригенного органического материала, образовались в сравнительно пресноводных условиях и могут производить, в основном, газ.

CHARACTERISTICS AND CONDITIONS OF ACCUMULATION OF THE UPPER JURASSIC SEDIMENTS IN THE SOUTH-EASTERN CAUCASUS

The article discusses characteristic structural features of the Southeastern Caucasus region and some geochemical aspects of the lithogenesis of the Upper Jurassic deposits. It studies and characterizes sediments of the various zones (Sudur, Shahdagh-Khizi and Guton-Gonagkend) based on the sections exposed in the river valleys of Gilgilchay, Babachay and Jimichay. Although many studies had covered tectonics, structural geology, stratigraphy and paleontology of the Jurassic succession in the Southeastern Caucasus, there are still questions that require more detail investigations of the stratigraphy, genesis and typification of various rhythmically bedded successions as well as sources of the clastic material. Experienced difficulties in these studies are caused, firstly, by the complex tectonic structure of the region and, secondly, by the lack of necessary paleontological data.

Upper Jurassic succession in the studied areas is composed of conglomerates, sandstones, siltstones, mudstones, and carbonate rocks, all combined in the local suites. In general, the color and lithological patterns of these terrigenous-carbonate and carbonate sequences differ in the various localities.

Based on chemical and mineralogical analysis of the rocks, and the collection and interpretation of archive and published materials, the article provides a ground for the lithochemical characterization of the studied sections in the Shahdagh-Khizi zone, stratigraphically identified as the Upper Oxfordian-Kimmeridgian (Gyzylgazma Formation).

Keywords: Southeastern Caucasus, facies variability, Gyzylgazma Formation, Shahdagh-Khizi zone, geochemical indicators, felsic provenance

Introduction

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In the Southeastern Caucasus, relatively complete and well exposed sections of Upper Jurassic deposits are recorded within the boundaries of Sudur, Shahdagh-Khizi and Guton-Gonagkend zones. These well visualized and accessible sections are the appropriate objects for studying and identifying the structural-facies and geodynamic formation conditions of the Late Mesozoic sedimentary complexes of the Greater Caucasus basin. Represented by terrigenous and carbonate deposits with sharp facies variability in the rocks' horizontal and vertical composition, the Upper Jurassic complexes are almost devoid of any faunal remains. This circumstance greatly complicates the task of breaking down and correlating the different sections.

The problems of stratigraphy, facies peculiarities, lithology and petrography were studied by many prominent geologists (Abich, 1865; Bogdanovich, 1902, 1906; Vassoyevich, 1938, 1940; Weber, 1936; Alizadeh, 1939; Khain, 1937, 1939; Shikhalibeyli, 1956; Shardanov, 1957; Isaev et al., 1981; Kangarli, 1978, 1982, 1986, 1997).

The first microsection-based petrographic studies of the Jurassic deposits of the Southeastern Caucasus region were implemented by K.I.Bogdanovich. In his work "System of Dibrar in Southeastern Caucasus", Bogdanovich had described microsections of the separate types of Mesozoic limestones and sandstones, supporting the coverage with microphotos.

The purpose of this article is to study material constitution of the Upper Jurassic deposits of the sections exposed in the Southeast Caucasus region, to highlight their facies variability and accumulation environment, to clarify a nature of the source of terrigenous deposits based on the study of the rocks' chemical composition, and to compare them with literature data.

Study materials and methodology. The study is based on the results of fieldwork implemented in 2014–2018, and on the analysis of archive and literature materials.

On the northern slope, survey routes were drawn from Derk village upstream of the river Babachay, and from the Istisu (thermal sulphide spring) down the river Jimichay. The studies also covered the sections detected in the river valley of Gilgilchay (Figure 1). The total number of survey points exceeded 15. The detected outcrops were described and about 60 samples were taken for chemical and petrographic tests. On the southern slope, the surveys were conducted in the river valley of Akhokhchay.

Characteristics of the deposits from the various structural-facies zones

Shahdagh-Khizi zone occupies central position on the Northern slope of the Side megazone. Despite a plenty of published studies dedicated to a stratigraphy of this interval of the Southeastern Caucasus region, there are too few publications that would complexly describe the sections of this zone.

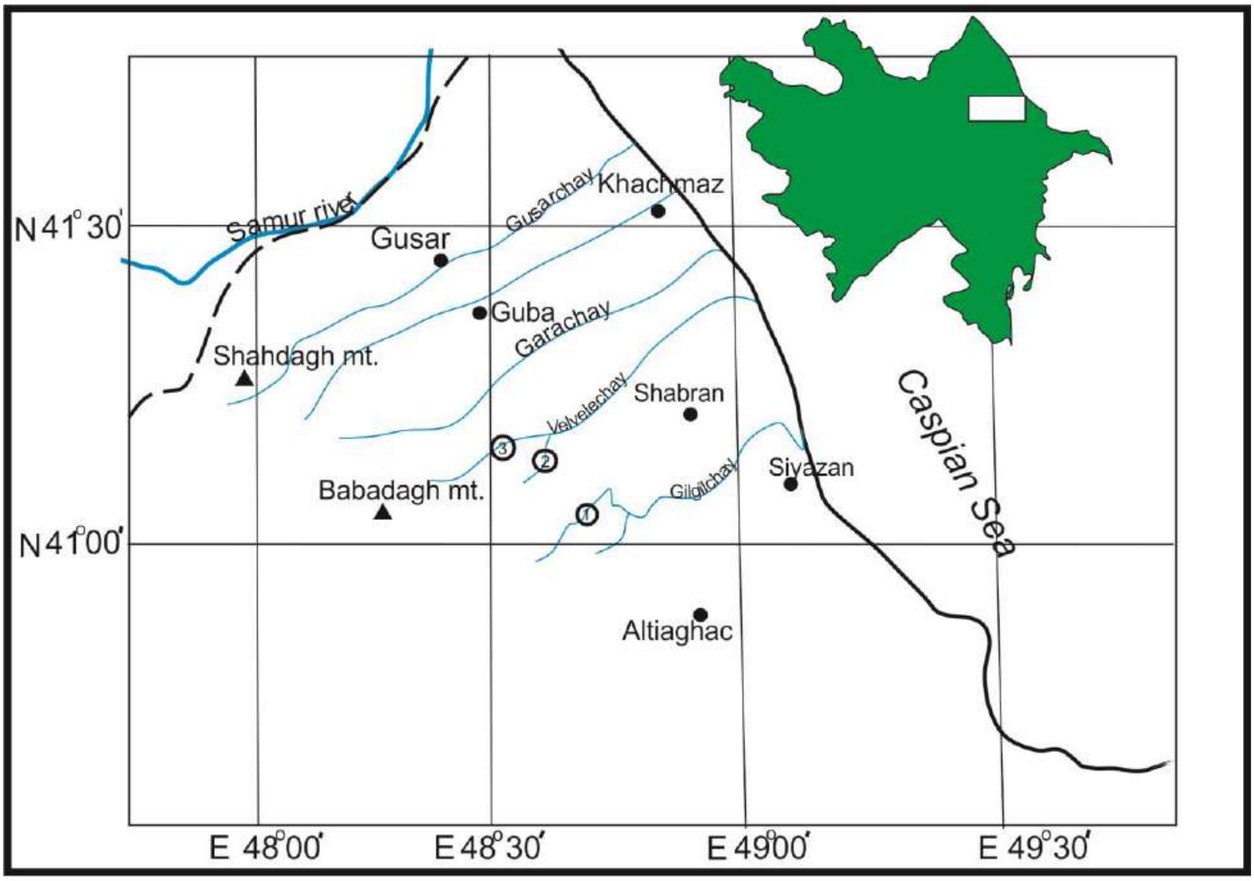

Figure 1. Location scheme of the studied sections

Callovian – Upper Jurassic section of the zone is divided into Molt, Gyzylgazma and Shahdagh formations.

The Molt formation (Upper Callovian – Oxfordian) is incompletely exposed on the northern limb of Gyzylgazma anticline, where it constitutes basement of the Upper Jurassic section on Girdimanchay River (Figure 2). On the basement of the formation, there are the outcrops of small and medium pebble conglomerates alternating with brownish-black, ash-gray on surface, argillites. Higher in the succession, there is a transition into arhythmic alternation of muddy sandstones, small pebble gravelites, small and medium pebble conglomerates, rarely argillites. Having thickness of nearly 300 m, the formation transgressively overlies the Upper Jurassic series. Its' roof is brought to a tectonic contact with the Valanginian carbonate rocks (Isayev et al., 1977; Kangarli, 1982; Kangarli et al., 2013).

The Gyzylgazma formation (Kimmeridgian-Tithonian) was distinguished by N.B.Vassoyevich from the structure of the Khaltan formation identified by K.I.Bogdanovich (1906) and was dated as Tithonian according to its' stratigraphic position (Vassoyevich, 1938; Khain, 1947). In the Shahdagh-Khizi zone, the formation is represented by more than 200 m thick alternation of gravelites, sandstones and argillites, coarse-grained muddy sandstones, and greenish-grey clays. The roof of the formation is transgressively overlapped by Neocomian basal conglomerates.

The Shahdagh formation (Middle Oxfordian – Tithonian). The lower part of the formation is nearly 260 m thick and built by gray coarsely stratified massive rift dolomitized limestones. The upper part is about 550 m thick and constituted by pink coarsely stratified brecciate limestones and dolomites with layers of red calcareous breccias and conglomerates.

Sudur zone. Callovian – Upper Jurassic section of the zone is represented by muddy Tahirjal, gypsum-bearing argillo-arenaceous Gushgala formation and carbonate Gukhur formation. Upper Jurassic section of the zone begins with Callovian – Lower Oxfordian Tahirjal formation consisting of a variegated alternation of lilac-pink, yellowish and bluish-green sandy clays with interlayers of calcareous sandstones and nodules of crystalline limestones and dolomites. The Tahirjal formation was first described in 1975 in the river valley of Tahirjal (Isayev et al., 1977; Kangarli et al., 2013). The formation is unconformably overlapped by 60–80 m thick Upper Oxfordian Gushgala argillo-arenaceous formation. The Upper Jurassic section of the zone is crowned by a seamless series of limestones and dolomites of the Gukhur formation dated as Kimmeridgian-Tithonian according to its' stratigraphic position (Kangarli et al., 2013).

Outcrops of Callovian-Upper Jurassic deposits occur only in the eastern structures of the Guton-Gonagkend zone. They are exposed as part of the section of Girdimanchay-Valvalachay flexure-rupture zone, and to the east of it. On the Jimichay River, there is an outcrop of the member of alternation of dark gray sandstones, argillites and rarely limestones. The member is parallelized with the upper part of the Molt Formation and the conformably superstructed over 200 m thick alternation of greenish-gray sandstones and argillites.

There are the following three formations distinguished within the Upper Jurassic section of the zone: Garovulustu (Oxfordian), Gyzylgazma (Kimmeridgian) and Khashi (Tithonian).

In a centroclinal closure zone of the Garovulustu brachysyncline (the southern outskirts of Gonagkend village, the right riverbank of Jimichay, both limbs of Yerfi-Khashi anticline), exposed is a member of alternating gray, greenish-gray argillites, poorly graded, calcareous, fine- and medium-grained sandstones, and limestones. Dated as Oxfordian according to its' stratigraphic position, the member was identified as the Garovulustu Formation (Kangarli, Mehdiyeva, 2017). Thickness of the formation varies within the range of 145–224 m.

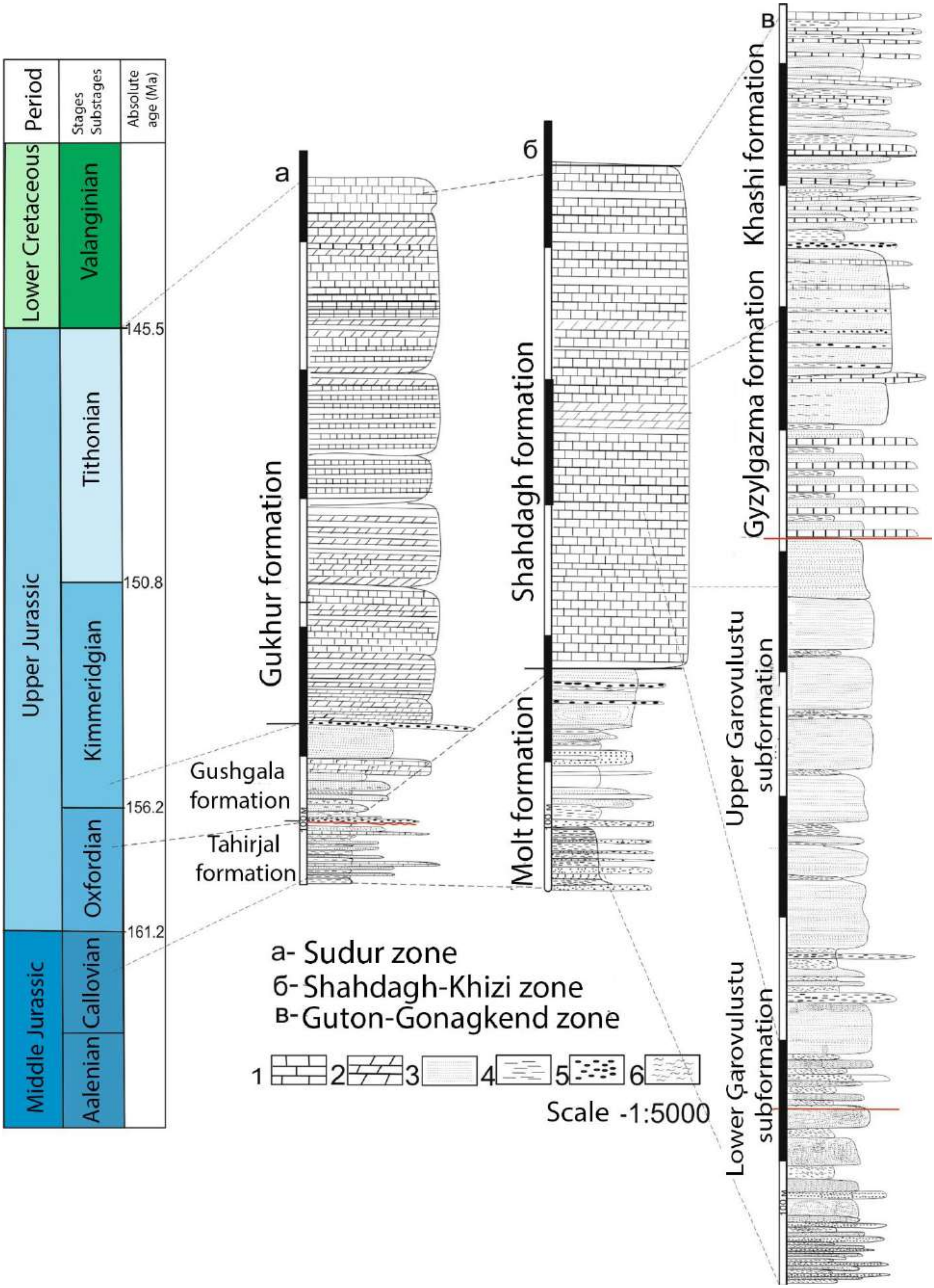

Figure 2. Correlation chart of sections in the studied zones (Azerbaijan)

***Symbols: 1** – limestone; **2** – dolomite; **3** – sandstone; **4** – clays and argillites; **5** – gravelites and conglomerates; **6** – siltstones*

The Gyzylgazma formation consists of three subcomponents. The lower subformation is represented by greenish-gray, gray, relatively sandy massive limestones, as well as medium-bedded, fine- and medium-grained sandstones and argillites.

Tithonian stage of the zone is represented by the Khashi formation, exposed at the more western intersection of the Yerfi-Khashin anticline along the Dahnachay River (Kangarli, Mehdiyeva, 2017). Significant part of the formation is composed of rhythmically alternating gray and greenish-gray sandy argillites, calcareous sandstones, limestones, and conglomerates.

Main rock types and dissemination

The studied Upper Jurassic sections of the Southeastern Caucasus region are mainly represented by coarse clastic, sandy, silty, muddy and carbonate rock types. Colour and lithological properties of these terrigenous-carbonate and carbonate rocks generally vary across sections. Detected rock types vary from coarse-grained conglomerates to fine-grained sandstones, siltstones and clays.

The coarse clastic rocks are detected in all studied sections and in all stages of the Upper Jurassic period. These rocks are mainly represented by thin layers of basal conglomerates found at the basements of some formations (Kangarli et al., 2013), as well as by separate layers inside the Shahdagh formation (Aghayev, 1990). In the Sudur zone, there are thin layers of basal small-pebble conglomerates and gravelites with pebbles of crystalline and marbled limestones, argillites and loose sandstones. The conglomerates are also widespread in the structure of Shahdagh-Beshbarmag allochthonous complex. According to literature data (Gavrilov, 2018), the basal sedimentary complex of the Shahdagh massif is characterized by a rather complex and heterogeneous structure. They show significant facies changes observed towards the southwest.

The coarse clastic rocks are widely developed at the basement of the Upper Jurassic section on the Gilgilchay River, and on the northern limb of the Gyzylgazma anticline. Alternation thick (5–8 m) stratas of small and medium-pebble conglomerates with the argillites constitutes 75 m thick lower segment of the Molt formation.

The coarse clastic rocks are most developed in the Tithonian series of the Ugakh section, amounting to 200 m of the section thickness. Thickness of the Tithonian rocks of this type is 58 m in Khaltan, and 32 m in Gizilchay sections.

In the Kimmeridgian stage, the coarse clastic rocks are of sharply subordinate significance, being observed in the form of individual thin interlayers of gravel and pebble conglomerates. The pebble conglomerates are represented by the layers composed of compacted, well-rounded pebbles (3–5 cm in size, up to 40 cm in diameter) of dark muddy shales, as well as small pebbles of sandstones and limestones.

Coarse clastic rock types are widely developed in the Tithonian deposits. According to size of a clastic material, these rocks are represented by boulders and blocky, pebble and gravel conglomerates. Most of them are composed of unrounded, sometimes noticeably rounded fragments of carbonate rocks, forming 100–150-meter strata of conglomerates. The pebble and gravel conglomerates are commonly developed in almost all of the sections.

Muddy deposits are widely developed. They are one of the key components of the Callovian-Upper Jurassic sections of the studied area. They are abundant in the lower and middle parts of the sections exposed in the Sudur (river valley of Tahirjal) and Shahdagh-Khizi (river valley of Gilgilchay) zones. Forming up to 10–15 m thick stratas, the muddy rocks are mainly represented by mainly gray, dark gray, greenish-gray dense, non-soaking, partly calcareous argillites.

Muddy rocks of the Kimmeridgian stage are represented by gray, greenish-gray, light gray arenaceous varieties. These rocks are most developed in the river valleys of Tahirjal, Gilgilchay and its' right-bank tributaries, and in the section of Babachay. A characteristic feature of these rocks is their siliceous content. Interlayer thicknesses vary from fractions of a centimeter to 10–20 cm or more. Muddy rocks of the Tithonian stage are represented by gray, dark gray, grayish-brown and reddish-brown varieties. Thickness of the clay interlayers varies from 1–2 cm to 1–2 m and more. Individual parts of the sections are mainly built by muddy deposits.

Sandy and siltstone rocks in a general complex of the Callovian – Upper Jurassic deposits had developed greatly in the Kimmeridgian stage. Macroscopically the sandstones are represented by gray, dark gray and greenish gray densely cemented varieties. They are always calcareous and muddy, often passing to the siltstone varieties. A characteristic feature of the sandy and silty rocks is their lamination.

Erosion grooves, marks of a runoff and fucoids, which are typical textural features of sandy and, to the great extent, silty rocks of the region, speak for the existence of a basin with significant near-bottom flows (Aliyev, Akayeva, 1957). Such flows had stimulated an even distribution and sorting of terrigenous material at the bottom of the basin, which had significant slopes in some areas. The coarsest grained sandy rock varieties were found in the Callovian-Oxfordian stages. The sandy series of the Kimmeridgian stage are silty.

Carbonate rocks. Development degree of the carbonate rocks changes from a minimum at the basement to the maximum on the top of the Upper Jurassic section. The main rock types of the Oxfordian-Kimmeridgian age are muddy, organic and brecciated oolitic limestones. Rocks from the middle parts of the sections are represented by flaglike and thin flaglike, microgranular gray, greenish-gray and sometimes dark gray limestones. The fragmentary oolitic limestones are developed all over the studied sections, forming as thin as 5–10 cm thick interlayers. The sandy and silty limestones are less commonly developed than the oolitic and fragmentary oolitic varieties. Carbonate rocks of the Tithonian stage are represented by mainly limestones and less commonly marls. The limestones are represented by fragmentary, oolitic, sandy, crystalline and pelitomorphic varieties (Aliyev, Akayeva, 1957).

Geochemical studies. Analyzing geochemical composition of the sedimentary rocks is an important tool for understanding the nature of primary rocks, as well as the weathering and erosion dynamics and the tectonic environment of sedimentation basins (Nesbitt and Young, 1982).

Collected rock samples were tested at the Analytical Center of the ANAS Institute of Geology and Geophysics. The testing resulted in a data on the composition of the main oxide compounds and chemical elements of the Upper Jurassic deposits. The muddy rock samples were mainly collected from the outcrops exposed in the Gilgilchay valley, whereas the samples of sandstone were taken from the Babachay section.

Chemical analysis results has shown that the material composition of the muddy rocks (argillites – 12 samples) is characterized by the following components: SiO_2 – 44.23–66.27, Al_2O_3 – 12.89–19.53, Fe_2O_3 – 4.04–9.88, CaO – 0.74–11.21, MgO – 1.39–2.50, Na_2O – 0.97–1.50, K_2O – 2.94–4.28. According to a ratio of the molecular amounts of SiO_2 to Al_2O_3, these rocks belong to hydromicas and mixed muddy rocks. SiO_2 and Al_2O_3 values of the hydromicaceous clays are intermediate as compared to kaolinite and montmorillonite. The SiO_2:Al_2O_3 ratio of these clays is equal to or lower than montmorillonite (Frolov, 1965).

The main component in the chemical composition of sandstones is SiO_2, concentration levels of which varied from 51.13 to 67.70% in the analyzed samples.

Na_2O was less than K_2O in all tested samples. This indicates that the deposits were accumulated because of the erosion of the felsic rocks. Another indicator of the felsic provenance is the titanium module (TM = TiO_2 / Al_2O_3), which equals 0.05–0.06 in all muddy samples.

Among geochemical indicators, the hydrolysate module is the most universal weathering maturity indicator (HM = TiO_2 + Al_2O_3 + Fe_2O_3 + Fe_2O_3 + MnO) / SiO_2). The higher the HM value, the more “mature” the sedimentary material is (Yudovich, Ketris, 2011). GM>0.55 characterize the products of humid (rarely arid) eolation.

All the studied samples are characterized by the hydrolysate module of less than 0.55, averaging at 0.43 in muddy, 0.59 in carbonate, and 0.28 in sandy and silty rock samples. These parameters indicate an arid sedimentation.

The alkaline module (AM = Na_2O/K_2O) can be used to distinguish between mafic and felsic sources (Yudovich, Ketris, 2011). For most sedimentary rocks, the AM value remains in the range of 0.30–1.50. Exceeding this value data indicate a significant admixture of plagioclases occurring due to erosion of the mafic rocks. The alkaline module of almost all studied samples is 0.23–1.75, which is an evidence of the erosion of felsic parent rocks. The only exception was a couple of carbonate rock samples, in which extremal AM values were recorded (15.8 in the sample #104, and 3.06 in the sample #207). In our opinion, this rare case is related rather to the saline Na than to the sodium silicate, which testifies to the erosion of evaporites.

The SiO_2 /Al_2O_3 ratio is a widely used indicator of rocks maturity. This ratio indicates an increase in the quartz values at the expense of the less stable components such as feldspar, etc. A ratio greater than 5 or 6 in sedimentary rocks testifies to their maturity. Average ratio values for the studied samples varies in the range of 2.25–7.48, making up 3.4 for muddy rocks, 4.6 for sandstones and 3.3 for carbonate rocks. All these values point at the moderate maturity of the rocks.

Increased alumina content of the Callovian – Upper Jurassic sedimentary rocks from one hand, as well as low alumosilicic module values (AM = Al_2O_3/SiO_2) from the other, indicate the erosion of arid weathering rinds.

Chemical composition (%) and geochemical indicators of sandstones of the Gyzylgazma formation

№№ Sample / Oxides	503	505	506	507	508	509	511	512	513	514
Na_2O	0.32	0.28	1.55	0.76	0.36	1.21	1.39	1.17	1.32	1.60
MgO	1.36	0.84	1.03	1.71	1.38	1.16	0.94	0.90	1.50	0.99
Al_2O_3	4.91	2.69	6.51	7.82	4.51	6.40	5.57	4.64	9.46	7.69
SiO_2	19.14	15.96	42.08	33.60	23.97	47.01	38.15	29.65	52.29	46.48
P_2O_5	0.04	0.05	0.10	0.10	0.08	0.07	0.08	0.08	0.14	0.09
SO_3	0.05	0.03	0.50	0.04	0.11	0.47	0.14	0.03	0.04	0.03
K_2O	1.29	0.60	1.12	1.77	0.94	1.13	0.93	0.82	1.74	0.82
CaO	40.20	44.26	27.08	28.23	37.60	23.36	31.02	36.28	12.84	23.24
TiO_2	0.24	0.14	0.39	0.45	0.22	0.36	0.34	0.26	0.55	0.30
Fe_2O_3	2.57	1.74	2.43	4.60	3.14	2.90	2.63	2.04	5.26	3.61
MnO	0.09	0.10	0.07	0,09	0,09	0,07	0.09	0,13	0,16	0,30
SiO_2/Al_2O_3	3,90	5,93	6,46	4,30	5,31	7,34	6,85	6,39	5,53	7,48
K_2O/ Na_2O	4.03	2.14	0.72	2.32	2.61	0.88	0.67	0.70	1.32	0.51
K_2O /Al_2O_3	0.26	0.22	0.17	0.22	0.21	0.18	0.17	0.18	0.18	0.13
CIA	75	75	70	75	77	73	76	69	75	71
HM	0,41	0,29	0,22	0,38	0,33	0,21	0,23	0,24	0,30	0,22

Results

When studying lithologically similar rocks characterized by lack of faunal remains, it is insufficient just to use the traditional methods. It is required to apply an integrated study approach to determine the formation conditions and environment of such geological bodies.

Callovian – Upper Jurassic series of the Southeastern Caucasus region demonstrate facies variability both in the area and sections, which is associated with structural and morphological elements of the paleobasin. The studied deposits are exposed in the different modern structural zones. There is a regular lateral lithofacies change observed in their distribution, varying from coarse flysch in the south to lagoon in the north. Such a change in the facies character testifies that these deposits had formed under the continental slope and shallow shelf environment of the northern flank of the Greater Caucasus marginal sea of Jurassic.

The main transport of the terrigenous material at that time was from the northeast.

Distribution nature of the main elements reflects mineralogy of the studied samples. Al_2O_3 content of the sandstone samples is lower than that of the samples enriched in microgranular silt.

According to the X-ray diffraction analysis results, deposits of the studied region mainly consist of calcite, quartz, feldspar, dolomite, hematite and muddy minerals such as chlorite, illite, montmorillonite and kaolinite. Values of the weathering index speak for a moderate weathering in the source area and deposition of the terrigenous material in an area with relatively high uplift. Judging by the ratio of the main elements, the eroded substrate was probably characterized by a felsic and/or intermediate rock composition.

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CƏNUB-ŞƏRQİ QAFQAZIN ÜST YURA LAY DƏSTƏLƏRİNİN XARAKTERİSTİKA VƏ FORMALAŞMA ŞƏRAİTLƏRİ

Z.H. Mehdiyeva

Təqdim olunan məqalədə Cənub-Şərqi Qafqaz regionun üst yura yaşlı süxur komplekslərinin quruluşu və geokimyəvi xarakterinin bəzi məsələləri nəzərdən keçirilir. Gilgilçay, Babaçay və Cimiçay çayları ilə açılmış kəsilişlərin struktur quruluşuna əsaslanaraq ayrı-ayrı zonaların hüdudlarında (Sudur, Şahdağ-Xızı və Quton-Qonaqkənd zonaları) təşəkkül tapmış süxur tiplərinin təsviri verilir. Regionun tektonikası, geoloji quruluşu, stratiqrafiyası və paleontologiyası məsələləri uzun illər bir çox tanınmış geoloq və alimlər tərəfindən tədqiq olunmuşdur. Buna baxmayaraq, burada hələ də bir sıra qeyri-müəyyən məsələlər mövcuddur. Bu qeyri-müəyyənliklər ilk növbədə üst yura süxurlarının detallı yaş bölgüsü, müxtəlif süxur komplekslərinin mənşəyi, terrigen məhsulun daxili və xarici mənbəyi məsələlərini əhatə edir. Regionun mürəkkəb tektonik quruluşu və süxur komplekslərinin paleontoloji yoxsulluğu bu məsələlərin həllini daha da çətinləşdirir.

Tədqiq olunan kəsilişlərdə üst yura maddi-kompleksləri yerli lay dəstələrində birləşdirilmiş kobudqırıntılı terrigen, qumdaşılı, alevrolitli, gilli və karbonat süxurlarla təmsil olunurlar. Ümumilikdə, burada iri çaqıllı konqlomeratlardan tutmuş narındənəvər qumdaşılara və gillərə qədər süxur tiplərinə rast gəlinir. Müxtəlif kəsilişlərdə lay dəstələri fərqli litoloji tərkibli süxurlardan təşkil olunurlar.

Keçən əsrin ortalarından başlayaraq litologiya və sedimentologiya məsələlərinin həllində geokimyəvi diaqnostikanın rolu artmışdır. Süxurların kimyəvi tərkibinin öyrənilməsi, bir sıra geokimyəvi indikatorların hesablanması və təhlili çöküntü qatlarını formalaşdıran obyektiv prosesləri izah etməyə kömək edir.

Məqalədə Şahdağ-Xızı zonasının stratiqrafik vəziyyətinə görə üst oksford-kimmeric intervalına aid edilən gilli və qumlu süxurlarının (Qızılqazıma lay dəstəsi) kimyəvi və mineraloji analizinin əsasında litokimyəvi səciyyəsi verilmişdir.

ХАРАКТЕРИСТИКА И УСЛОВИЯ ФОРМИРОВАНИЯ ВЕРХНЕЮРСКИХ ОТЛОЖЕНИЙ ЮГО-ВОСТОЧНОГО КАВКАЗА

З.Н. Мехтиева

В статье рассмотрены характерные особенности строения и некоторые вопросы геохимии литогенеза верхнеюрских отложений Юго-Восточного Кавказа. На примере разрезов, расположенных в долинах рек Гильгильчай, Бабачай и Джимичай, изучены и охарактеризованы отложения отдельных зон (Судурская, Шахдаг-Хызы и Гутон-Гонагкенд). Несмотря на обилие работ по тектонике, структурной геологии, стратиграфии и палеонтологии юрских отложений Юго-Восточного Кавказа, еще существуют вопросы, требующие более детального возрастного расчленения, генезиса и типизации, разнообразных ритмично построенных комплексов, выявления внутренних и внешних источников сноса кластического материала. Трудности решения этих вопросов связаны, во-первых, со сложной тектонической структурой региона и во- вторых, с отсутствием необходимых палеонтологических данных.

В изученных разрезах верхнеюрские отложения представлены грубообломочными, песчаными, алевролитовыми, глинистыми и карбонатными породами, которые объединены в местных свитах. В целом цвет и литологические свойства пород, представленных терригенно-карбонатной и карбонатной фациями, различаются в разных разрезах, и здесь наблюдаются типы пород от крупнозернистых конгломератов до мелкозернистых песчаников, алевролитов и глин.

В статье описаны выделенные местные свиты, развитые в вышесказанных зонах.

С недавних пор геохимическая диагностика отложений стала актуальным вопросом литологии и седиментологии. Изучение химического состава пород дает информацию об объективных процессах, контролирующих формирование осадочных чехлов. На основании проведенного химического и минералогического анализа пород, а также сбора и обобщения фондовых и опубликованных материалов, осуществлена литохимическая характеристика глинистых и песчаных отложений Шахдаг-Хызынской зоны, стратиграфически определенных как верхний оксфорд-кимеридж (Кызылгазминская свита).

CLASSIC OF THE PETROLEUM GEOLOGY OF AZERBAIJAN

This man was considered and really was an encyclopedist or a classic of the petroleum geology of Azerbaijan. We all had knowledge on the petroleum geology of the republic and part of the world, some more, some less. But he knew everything, better than anyone, in detail.

When speaking to Ahmad Ahmadov, many eminent professors and academicians tried not to lose their “vigilance”, as they stood in front of an expert not only in petroleum geology, but also in field development, deep drilling and other areas. Meanwhile, the expert they spoke to, was neither a doctor, nor even a candidate of sciences, he was simply an engineer – engineer Ahmadov.

Within the course of his professional career, engineer A.M.Ahmadov (1910–1988) did a lot for the national oil industry sector of Azerbaijan. He had led and contributed to the discovery of many unique on- and offshore oil and gas fields, including Kurovdagh, Mishovdagh, Garabaghli, Kalmas, Kursanga, Muradkhanli, Gum Adasi, Bahar, Sangachal-sea, Bulla-sea, etc.

In the 1940–1950s, there was no complete information on the geology and oil-gas potential of the oil provinces of Azerbaijan. Working then as a head of the geological service of “Azneft” Production Association, Ahmadov had managed to draw a comprehensive strategy of petrogeological and geophysical works.

By the end of the 1940s, geography of the oil-gas bearing potential of the productive strata in Azerbaijan was limited by Western Absheron in the west. Erudition and performance of Ahmad Ahmadov helped with marking out the strata into Jeyrankechmez depression, Baku archipelago and Lower Kur depression. By-horizon productive strata correlation proposed by Ahmadov was accepted unconditionally by the entire geological society of Azerbaijan, even though, both before and later, other options, e.g. mineralogical, rhythmic-lithological, etc., were also developed.

A.M.Ahmadov had great merit in the petrogeological zoning of Azerbaijan, and in the resource and oil-gas potential assessment of the individual regions. On one hand, he actively promoted the prospects of Paleogene-Miocene deposits in the western regions of the republic. At the same time, he approached Mesozoic deposits with caution, emphasizing insufficiency of the initial criteria for their oil-gas bearing potential. Later researches had confirmed Ahmadov’s fears about the perspectives of Mesozoic series.

In the 1940s–1950s, it was still a rarity to meet Azerbaijanis occupying leading positions in oil and gas exploration. Ahmad Muallim put a lot of efforts to improve these statistics. In 1976, he showed the author of this article an excerpt from a book published in St. Petersburg in 1896. The excerpt was about personnel of then’s Baku oil production industry. It said: “There are only two types of positions occupied by Tatars (Azerbaijanis Sh.K.) in the oil business – managers and laborers. The cast of middle workers are represented by representatives of other nations”. “God forbid that this situation should be repeated!” – warned Ahmadov.

For almost 10 years, I have had an honor to work directly with this outstandingly talented and highly cultured person, and share with him the same room. I believed, all that Ahmad Muallim had, had been granted to him by the God, and doubled by himself.

Ahmadov was sent to us as an example of high erudition, great efficiency and culture. And when he passed away in 1988, all the oil workers fell orphaned.

Rest in Peace!

Shahvalad Kocharli

CONFERENCE INFORMATION

INTERNATIONAL CONFERENCE ON EXPLORATION SEISMOLOGY AND GEOPHYSICAL SIGNAL PROCESSING ICESGSP

04–05 February, 2023, Bangkok, Thailand

Website: https://waset.org
Website: https://waset.org/exploration-seismology-and-geophysical-signal-processing-conference-in-february-2023-in-bangkok
Website: https://waset.org/conferences-in-february-2023-in-bangkok/program

INTERNATIONAL CONFERENCE ON GEOLOGY AND GEOCHEMISTRY ICGG

29–30 March, 2023, Paris, France

Website: https://waset.org/geology-and-geochemistry-conference-in-march-2023-in-paris
Program: https://waset.org/conferences-in-march-2023-in-paris/program
Contact: https://waset.org

INTERNATIONAL CONFERENCE ON APPLIED GEOPHYSICS AND SEISMOLOGY ICAGS

05–06 April, 2023, Cancún, Mexico

Website: https://waset.org/applied-geophysics-and-seismology-conference-in-april-2023-in-cancun
Program: https://waset.org/conferences-in-april-2023-in-cancun/program
Contact: https://waset.org

INTERNATIONAL CONFERENCE ON GEOSCIENCES AND SEISMOLOGY ICGS

26–27 April, 2023, Istanbul, Turkey

Website: https://waset.org/geosciences-and-seismology-conference-in-april-2023-in-istanbul
Program: https://waset.org/conferences-in-april-2023-in-istanbul/program
Contact: https://waset.org

INTERNATIONAL CONFERENCE ON GEOLOGY AND GEOCHEMISTRY ICGG

11–12 May, 2023, Florence, Italy

Website: https://waset.org/geology-and-geochemistry-conference-in-may-2023-in-florence
Program: https://waset.org/conferences-in-may-2023-in-florence/program
Contact: https://waset.org

INTERNATIONAL CONFERENCE ON SUSTAINABLE FUTURES: ENVIRONMENTAL, TECHNOLOGICAL, SOCIAL AND ECONOMIC MATTERS ICSF

23–26 May, 2023, Kryvyi Rih, Ukraine

Website: https://icsf.ccjournals.eu/2023/index4.html
Contact E-mail: konf.knu@gmail.com

INTERNATIONAL CONFERENCE ON GEOMORPHOLOGY, ROCK MECHANICS AND SEISMOLOGY ICGRMS

03–04 June, 2023, New York, United States

Website: https://waset.org/geomorphology-rock-mechanics-and-seismology-conference-in-june-2023-in-new-york
Program: https://waset.org/conferences-in-june-2023-in-new-york/program
Contact: https://waset.org

INTERNATIONAL CONFERENCE ON GEOLOGY AND EARTH SCIENCES ICGES

15–17 June, 2023, Bangkok, Thailand

Website: http://www.icges.org/
Program: http://www.icges.org/program.html
Contact: http://www.icges.org/contact.html
Contact E-mail: icges_contact@academic.net

INTERNATIONAL CONFERENCE ON GEOLOGICAL MODELLING AND SEISMOLOGY ICGMS

19–20 July, 2023, Copenhagen, Denmark

Website: https://waset.org/geological-modelling-and-seismology-conference-in-july-2023-in-copenhagen
Program: https://waset.org/conferences-in-july-2023-in-copenhagen/program
Contact: https://waset.org

INTERNATIONAL CONFERENCE ON ADVANCED MINE SEISMOLOGY ICAMS

29–30 July, 2023, Vienna, Austria

Website: https://waset.org/advanced-mine-seismology-conference-in-july-2023-in-vienna
Program: https://waset.org/conferences-in-july-2023-in-vienna/program
Contact: https://waset.org

INTERNATIONAL CONFERENCE ON TECTONIC GEOMORPHOLOGY AND PALEOSEISMOLOGY ICTGP

09–10 August, 2023 in Lagos, Nigeria

Website: https://waset.org/tectonic-geomorphology-and-paleoseismology-conference-in-august-2023-in-lagos
Program: https://waset.org/conferences-in-august-2023-in-lagos/program
Contact: https://waset.org

WORLD CONGRESS ON GEOLOGY AND EARTH SCIENCE

04–06 September, 2023, Rome, Italy

Website: https://geology-earthscience.com/
Program: https://geology-earthscience.com/agenda
Contact: https://geology-earthscience.com/contact-us

INTERNATIONAL CONFERENCE ON ARCHAEOSEISMOLOGY, PALEOSEISMOLOGY AND ACTIVE TECTONICS ICAPAT

23–24 September, 2023, Vancouver, Canada

Website: https://waset.org/archaeoseismology-paleoseismology-and-active-tectonics-conference-in-september-2023-in-vancouver
Program: https://waset.org/conferences-in-september-2023-in-vancouver/program
Contact: https://waset.org

INTERNATIONAL CONFERENCE ON PALEOSEISMOLOGY, ACTIVE TECTONICS AND ARCHEOSEISMOLOGY ICPATA

04–05 October, 2023, Dubrovnik, Croatia

Website: https://waset.org/paleoseismology-active-tectonics-and-archeoseismology-conference-in-october-2023-in-dubrovnik
Program: https://waset.org/conferences-in-october-2023-in-dubrovnik/program
Contact: https://waset.org

GUIDE FOR AUTHORS

The International Scientific Journal "*Stratigraphy and sedimentology of oil-gas basins*" covers the broad topic related to sedimentology and startigraphy of oil-gas basins around the Globe. We publish papers focusing on modern and ancient depositional environments with emphasis on depositional setting of source and reservoir rocks, modeling of the sediment flow, soil formation and diagenesis, paleoclimate, sea level change and sedimentation, modern and ancient faunal, floral assemblages and fossils records for sedimentary environment analysis, stable isotope geochemistry and biogeochemistry, reservoir properties changes in the environmental framework, integration of different stratigraphic methods such as bio-, litho-, chemo, eco-, chrono-, seismo-, sequence startigraphy applied to the sedimentary successions in the oil rich provinces.

The journal is produced twice a year and accepts papers, reviews, discussions and brief information. Papers might be submitted in Azeri, English or Russian.

Manuscripts

Authors should submit their manuscripts to the e-mail address info@isjss.com as a single file. The name of the file should contain the initials of the first author. Figures should be supplied as separate files, but the text should also include the number of figures as position indicators. The name of the files containing figures should include the initials of the first author and the number of the figure.

The text of article should be prepared as a Microsoft Word document (Word 6,0 – 8,0). The body of article should not exceed 20 A4 pages in length, margins from all sides – 2 cm. Recommended font Times New Roman 12 pts. Files should be formatted with 1,5 line spacing. Indent every paragraph 0,8 cm from the left side of a column. Text of a paper should be formatted (lines of the text should be rectified from left and tight and does not break its margins).

The article should include text, supportable figures (at least one figure), references, tables if necessary, and extended summary. The Editorial board does not accept alone text.

The Editorial board also kindly asks authors to provide two hard copies sent to the following postal address: Editorial board of the International Scientific Journal "Stratigraphy and sedimentology of oil-gas basins", Geology Institute of Azerbaijan National Academy of Sciences, 29A H.Javid avenue, Baku, AZ 1143, Azerbaijan. The electronic version should correspond to the hard copy.

Pages **should not be** numbered in the electronic version of article, and **should be** numbered in the top right-hand corner in the hard copy.

The paper should be signed on the last page by all authors and show the date of its submission to the editorial board.

Text should include:

Title should be typed in the middle of page. Please, use font Times New Roman 14 pts, capital bold letters.

Initials and surnames of authors should be typed in the middle of page in a two-line space after the title. Please, use font Times New Roman 12 pts, bold letters, and indicate the corresponding author.

Authors' affiliation should be typed in the middle of page in a two-line space after authors' name using Times New Roman 12 pts, bold letters. Please, provide a full postal address of the place where the study was carried out, and present address of authors if different. If there are several authors the Arabic numerals before their affiliation's name should be placed in the sequential order. The same numerals should be indicated above the author's surname, e.g. I.S. Guliyev[1], A.A. Feizullayev[2].

Abstract should contain a brief summary of the article – maximum 1 page, and key words – up to 8 words. Please, use font Times New Roman 12 pts. The key words should be typed in the bold letters.

The main body of the article should be typed in a two-line space after the abstract and written in compliance with a general form adopted in the international journals with the following subdivisions: "Introduction", "Material", "Methods", "Results and discussion", "Conclusion". The headings should be typed in font Times New Roman 12 pts, bold letters, and given in the middle of page. Each subdivision should be typed in one-line space after the previous one.

Tables are placed in the text of paper, and should be submitted in the Word format, and numbered consecutively above the table in the right – hand corner with Arabic numerals. Use font Times new Roman 12 pts, bold letters, e.g. **Table 1…** Each table should be accompanied by caption given after the table number, font Times New Roman 12 pts, bold letters. Column headings should be brief, with units of measurement in parentheses. The tables should not be beyond the text, and hyphenated to the next page. The maximum number of tables in an article is 5.

Abbreviations except for those generally accepted should be clearly explained in a footnote.

Fossils should be described according to "The International Code of Zoological Nomenclature". Latin names of flora and fauna should be accompanied by the surname of the taxon's author. Latin characters should be printed in italics.

Mathematics

Equations should be typed as text and contain physical units and symbols used in the International System SI. Formulas are given without interstitial calculations, with necessary deciphering of used symbols immediately after the formula. Referred in the text formulas should be numbered using Arabic numerals. Numbers should be given in parenthesis on the right margin of the text and on the same line with the formula. It is recommended to use Microsoft Equation 3 to type the formulas.

References in the text should be given in a two-line space after the main body of the text. They should be cited by giving the author's name with the year of publication in parentheses, and should be given in date order (e.g. Guliyev, 1995; Feyzullayev, 2000). When reference is made to a paper/book by more than three authors, the first name followed by et al. should be used in the reference. If a paper does not refer to authors but to a paper/book's name the first two words of its name should be given, e.g. Stratigraphic code..., 1998.

References should be listed alphabetically at the end of the manuscript and must include names and initials of all authors, year of publication, title of paper/book referred to, journal name, volume, and first and last page numbers. When reference is made to a book, please, indicate an amount of pages. If reference contains several papers by the same author and from the same year, a, b, c, etc. should be put after the year of publication Published abstracts should be cited in the same way as published papers. Surnames and initials of the author(s) are printed in italics.

The references given in Cyrillic should be given at the begging of the reference list, and followed by references in Roman characters.

Authors should use the system illustrated below.

Books:

Meyen, S.V., 1987. Fundamentals of Paleobotany. Chapman and Hall, London, 432 pp.

Kothe, A., 1990. Paleogene Dinoflagellates from Northwest Germany – Biostratigraphy and Paleoenvironment, Hanover, 111 p.

Papers published in periodical journals:

Hinds, D., Aliyeva, E., Allen, M.B., Davies, C.E., Kroonenberg, S.B.,Simmons, M.D., Vincent, S.J., 2004. Sedimentation in a discharge-dominated fluvial-lacustrine system: the Neogene Productive series of the South Caspian Basin, Azerbaijan // Marine and Petroleum Geology, № 21, p. 113–138.

Hallam, A., 2001. A review of the broad pattern of Jurassic sea-level changes and their possible causes in the light of current knowledge // Palaeogeogr., Palaeoclimatol., Palaeoecol., v. 167, pp. 23–37.

Papers published in volumes (including periodical):

Delamette, M., Caron, M., Brehert, J., 1986. Essai d'interpretation genetique des facies euxiniques de l'Eo-Albien du bassin vocontien (SE France) sur la base des donnees macro- et microfauniques // C.R. Acad. Sc. Paris. ser. II, v.302, pp. 1085–1090.

Summary. An extended summary of the paper designed for further translation into Russian and Azeri should be provided. The aim of the summary is to familiarize the Russian and Azeri speaking readers with the articles published in English. The summary should contain essential information, and include the scope and objectives of the work, methods used, results obtained, and conclusions. The Editorial board will provide the translation of the summary submitted in English into Russian and Azeri.

Illustrations. Top quality, high resolution graphics and images are needed in digital form and should be submitted in the separate files. The file's name should contain the first author's initials and the figure number. Please, supply figures as TIFF (300 dpi), high resolution PDF or CDR files. Please export graphics generated in MS Office applications (Word, Excel) as high resolution PDFs. Illustrations should be numbered as they are referred in the text. Size of every figure should not exceed 160 mm x 230 mm. Maps should contain scale. The hard copy of each figure should be numbered on its back side with a pencil, the first author's name and the article's title should be also indicated.

Each illustration must have a caption. The list of captions should be provided in a separate sheet, and submitted electronically and in a hard copy. The number of figures should not exceed 10.**Color figures** are eligible for free color printing.

The editorial board reserves the rights to submit a paper for the review. The makeup of accepted papers will be electronically sent to authors for final checking and corrections. We expect to have authors' response within two weeks after receiving of the makeup paper.

Submitted articles should be original, had not been published anywhere before and has not been forwarded to other publishing houses.

MÜƏLLİFLƏR ÜÇÜN QAYDALAR

“Neftli-qazlı hövzələrin stratiqrafiyası və sedimentologiyası” elmi beynəlxalq jurnalı dünyanın müxtəlif yerlərində neftli-qazlı hövzələrin stratiqrafiyası və sementologiyasının müxtəlif aspektlərini işıqlandıran məqalələri nəşr edir. Jurnal ildə iki dəfə nəşr olunur və burada məqalələr, icmallar, müzakirələr və qısa məlumatlar çap edilir. Məqalələr azərbaycan, rus və ingilis dillərində təqdim oluna bilər. Jurnalın maraqlarına aşağıdakılar aiddir: çöküntütoplanmasının, xüsusən, ana süxurların və kollektorların müasir və qədim şəraitləri, çökmə prosesinin modelləşməsi, torpaqəmələgəlmə və diogenez, paleoiglim, dənizlərin səviyyəsinin dəyişməsi və süxurların çökməsi, müasir və qazıntı fauna və flora kompleksləri və fasial analizdə onların istifadəsi, stabil izotopların geokimyası və biogeokimyası, süxurların çökmə şəraitindən asılı olaraq kollektorların xarakterlərinin dəyişməsi, neftli-qazlı çöküntü qatlarına tətbiq olunan bio-, lito-, xemo-, eko-, xromo-, seysmo-, sekvensstratiqrafiya və bu kimi başqa stratiqrafiya üsullarının inteqrasiyası.

Məqalələrin təqdim olunma forması

Müəlliflər öz məqalələrinin mətnlərini aşağıdakı elektron ünvana göndərməlidirlər: info@isjss.com

Kompüter faylının adında birinci müəllifin inisialları olmalıdır. Rəsmlər ayrıca fayllarda göndərilməlidir, lakin rəsmlərin yeri məqalənin mətnində rəsmin nömrəsini göstərməklə qeyd edilməlidir. Rəsm olan faylların adlarında birinci müəllifin inisialları və rəsmin nömrəsi olmalıdır.

Məqalənin mətni Word formatında (Word 6.0 – 8.0) təqdim edilməlidir. Məqalə A4 formatına uyğun 20 səhifə həcmindən artıq olmamalıdır. Tövsiyə olunan şrift Times New Roman, şriftin ölçüsü 12, sətirlərarası interval – 1,5, hər tərəfdən kənar 2 sm., hər abzas sütunun sol tərəfindən 0,8 sm məsafə ilə başlayır. Məqalənin mətni bu tələblərə uyğun format edilməlidir, bütün sətirlər soldan və sağdan mətnin kənarından çıxmamaq şərtilə düzəldilməlidir. Məqaləyə mətndən başqa müvafiq qrafik material (bir rəsmdən az olmayaraq), istifadə edilmiş ədəbiyyatın siyahısı, cədvəllər, və ehtiyac olarsa geniş rezüme də daxil olmalıdır. Jurnalın redaksiya heyəti rəsmləri olmayan məqalələri qəbul etmir.

Redaksiya heyəti həmçinin məqalələrin çap variantını aşağıdakı ünvana göndərməyinizi xahiş edir: “Neftli-qazlı hövzələrin stratiqrafiyası və sedimentologiyası” jurnalının redaksiyası, Hüseyn Cavid prospekti 29A, Azərbaycan Elmlər Akademiyasının Geologiya İnstitutu, Bakı, AZ 1143. Kompüter faylı (məqalənin mətni) məqalənin çap olunmuş variantına uyğun olmalıdır.

Məqalənin elektron variantında səhifələr nömrələnməməlidir. Çap olunmuş variantda hər səhifənin yuxarı sağ küncündə səhifələrin nömrələri yazılmalıdır.

Məqalənin çap variantının sonuncu səhifəsi müəlliflərin hər biri tərəfindən imzalanmalı və onun redaksiyaya təqdim olunma tarixi göstərilməlidir.

Məqalənin mətninə aşağıdakılar daxil edilməlidir:

Universal Onluq Təsnifatı (UOT) – sol küncdə, Times New Roman – 12 pt şrifti ilə, iki interval ötürməklə məqalənin adı yazılmalıdır.

Məqalənin adı – Times New Roman – 14 pt şrifti ilə, qalın baş hərflərlə, mətnin eni boyunca və səhifənin ortasına nisbətən simmetrik olaraq yazılır, daha sonra isə iki interval ötürməklə müəllifin soyadı və inisialı yazılmalıdır. Xahiş edirik əlaqə saxlanılacaq müəllifi göstərin.

Müəllifin inisialı və soyadı – Times New Roman – 12 pt şrifti ilə, qalın hərflərlə, səhifənin ortasına nisbətən simmetrik olaraq yazılır, daha sonra isə iki interval ötürməklə təşkilatın adı və onun elektron ünvanı yazılmalıdır.

Müəllifin çalışdığı təşkilatın adı və elektron ünvanı - Times New Roman – 12 pt şrifti ilə, qalın hərflərlə, səhifənin ortasına nisbətən simmetrik olaraq yazılır. Xahiş edirik məqalənin yazıldığı təşkilatın tam ünvanını, və müəlliflərin cari ünvanını (əgər dəyişibsə) göstərin. Məqalənin bir neçə müəllifi olduqda və onlar müxtəlif təşkilatlarda çalışdıqda, onların adlarının qarşısında artan sıra ilə rəqəmlər yazılmalıdır. Həmin rəqəmlər çalışdıqları təşkilatlara müvafiq olaraq müəlliflərin soyadlarından sonra sətirüstü indeksdə verilməlidir, məsələn İ.S.Quliyev[1], A.A.Feyzullayev[2] və s. Daha sonra iki intervalla məqalənin annotasiyası verilməlidir.

Annotasiya – qısa xülasə (1 səhifəyədək), daha sonra başlıca sözlər (8 sözə qədər). Times New Roman – 12 pt. şrifti. Başlıca sözlər qalın şriftlə yazılmalıdır. Daha sonra 2 intervalla məqalənin əsas mətni yazılmalıdır.

Məqalənin mətni – beynəlxalq jurnal sxeminə uyğun olaraq qurulmalı olan əsas mətn. Burada “Giriş”, “Material”, “Metodika”, “Nəticələr və müzakirələr”, “Son nəticə”, “Ədəbiyyatın siyahısı” kimi yarımsərlövhələrdən istifadə edilməsi tövsiyə olunur. Yarımsərlövhələr qalın Times New Roman – 12 şrifti ilə səhifənin ortasına nisbətən simmetrik olaraq yazılmalı, və hər yarımfəsil əvvəlkindən bir intervalla ayrılmalıdır.

Cədvəllər məqalənin mətni çərçivəsində yerləşdirilir və Word formatında təqdim edilir. Cədvəllər yuxarı sağ küncündən ardıcıl olaraq nömrələnməlidir. Hər bir cədvəlin adı olmalıdır və bu ad nömrədən sonra yazılmalıdır. Cədvəllərin ad və nömrələri qalın Times New Roman – 12 şrifti ilə yazılmalıdır. Cədvəllərdəki sütunların yarımsərlövhələri qısa olmalı, ölçü vahidlərinin adları dəyirmi mötərizələrdə verilməlidir. Cədvəllər mətnin kənarlarından qırağa çıxmamalıdır. Cədvəlin bir səhifədən digər səhifəyə keçməsi yolverilməzdir. Mətnə aid cədvəllərin maksimum sayı 5 ola bilər.

İxtisarlar, ümumi qəbul edilmiş bir neçə ixtisarlar (və s., məs.,) istisna olmaqla, istinadlarda açılmalıdır.

Qazıntı halında tapılan qalıqlar “Beynəlxalq zooloji nomenklatura məcəlləsinə” əsasən təsvir olunmalıdırlar. Mətndə flora və faunanın növlərinin latın adları taksonun müəllifinin soyadı ilə müşayiət olunmalıdır. Latın sözləri kursivlə verilməlidir.

Formulları yazarkən Beynəlxalq Sİ sistemində qəbul olunmuş fiziki vahidlərdən və işarələrdən istifadə etmək lazımdır. Formullar aralıq hesablamalarsız, orada istifadə olunan simvolların mütləq açılması şərti ilə formuldan dərhal sonra verilməlidir. Mətndə, adı çəkilərsə, formulların nömrələri böyük mötərizələrdə, mətnin sağ həddinə yaxın, formul ilə eyni xətdə yazılır. Formulların yazılması üçün Microsoft Equation 3 redaktorundan istifadə tövsiyə olunur. Sonra isə iki interval ötürməklə ədəbiyyatın siyahısı verilməlidir.

Ədəbiyyat – mətndə ədəbiyyata istinad xronoloji qaydada, dəyirmi mötərizələrdə verilir (müəllif/lər, il). Üçdən artıq müəllifin işinə istinad edildikdə isə, birinci müəllifin soyadı göstərilir (məs. Quliyev və digərləri, 2005). Məqalədə hər hansı müəllifsiz yazıya istinad etmədikdə, onda həmin yazının adının ilk iki sözü yazılır (məs. Stratiqrafiya məcəlləsi..., 2005). Ədəbiyyatın siyahısı məqalənin sonunda əlifba sırası ilə verilir. Burada bütün müəlliflərin soyadları və inisialları, nəşr olunan il, məqalə və ya kitabın adı, jurnalda çap olunubsa jurnalın adı və nömrəsi və məqalənin ilk və sonuncu səhifələri göstərilməlidir. Kitaba istinad edildikdə isə kitabdakı səhifələrinin sayı da göstərilməlidir.

Siyahıda eyni müəllifin eyni ildə nəşr olunmuş yazılarına istinad etdikdə, onda onları ilini qeyd etdikdən sonra indeksləşdirmək lazımdır: a, b, c və s. Tezislərə verilən istinadlar da eyni qaydada yerinə yetirilməlidir. Müəllifin(lərin) soyad və inisialları kursivlə yazılır.

Aşağıda müxtəlif biblioqrafik istinadların nümunələri verilir:

Kitablar:

Бабаев, Д.Х., Гаджиев, А.Н., 2006. Глубинное строение и перспективы нефтегазоносности бассейна Каспийского моря, Б., «Nafta-Press», 305 с.

Kőthe, A., 1990. Paleogene Dinoflagellates from Northwest Germany – Biostratigraphy and Paleoenvironment, Hanover, 111 p.

Dövri nəşrlərdə/jurnallardakı məqalələr:

Бабаев, Ш.А., 2005.Влияние условий окружающей среды на морфологию раковин нуммулитов //

Известия АН. Серия наук о Земле, № 2, с. 62–66.

Hallam, A., 2001. A review of the broad pattern of Jurassic sea-level changes and their possible causes in the light of current knowledge. Palaeogeogr., Palaeoclimatol., Palaeoecol, v. 167, pp. 23–37.

Məcmuələrdəki (o cümlədən dövri məcmuələrdəki) məqalələr:

Кузнецова, З.В., 1959. Нижнемиоценовые отложения Азербайджана, их расчленение и сопоставление с синхроничными отложениями Грузии // Вопросы геологии и геохимии. – Б.: Азернешр, 207–216.

Delamette, M., Caron, M., Brehert, J., 1986. Essai d'interpretation genetique des facies euxiniques de l'Eo-Albien du bassin vocontien (SE France) sur la base des donnees macro- et microfauniques. C.R. Acad. Sc. Paris. ser. II, v. 302, pp. 1085–1090.

Rezüme. Özündə məqalə haqqında əsas məlumatı, araşdırmanın məqsəd və vəzifələri, istifadə olunan metodikanı, əldə edilən nəticələri özündə əks etdirən geniş rezüme ingilis dilində təqdim edilməlidir. Rezümenin məqsədi ingilisdilli auditoriyanın rus və ya azərbaycan dillərində çap olunmuş məqalələrlə tanış olmasıdır.

İllüstrasiyalar. Hər bir rəsm (xəritə, diaqram, sxem və s.) ayrıca fayl şəklinə təqdim olunur. Yuxarıda qeyd edildiyi kimi faylın adında rəsmin nömrəsi və müəllifin inisialları olmalıdır.

Rəsmlər TIFF, 300 dpi , PDF və ya CDR formatında qəbul edilir. İllüstrasiyalar mətndə onlara edilən istinada uyğun nömrələnməlidir. Hər bir rəsm 160 mm x 230 mm ölçüsündən böyük olmamalıdır. Xəritələrdə miqyas göstərilməlidir.

Məqalənin çap olunmuş variantında rəsmlərin arxasında karandaşla onların nömrələri, məqalənin birinci müəllifinin soyadı və məqalənin adı göstərilir.

Hər rəsmin başlığı olmalıdır. Rəsmlərə aid olan izahatların siyahısı ayrıca vərəqdə, elektron və ya çap olunmuş variantda təqdim olunmalıdır. Mətnə aid olan rəsmlərin sayı 10-dan artıq olmamalıdır.

Jurnalın redaksiya heyəti rəngli şəkillərin ödənişsiz çapını təmin edir.

Redaksiya məqaləni resenziya üçün təqdim etmə hüququnu özündə saxlayır. Məqalənin çap olunmuş variantı yoxlama və çap və redaktə zamanı yol verilən səhvlərin düzəldilməsi üçün geri müəllifə göndərilir. Müəllif məqalənin çap olunmuş variantında çapa hazır edilmiş mətn və digər materiallara düzəliş etməməlidir.

Gecikmələrin qarşısını almaq məqsədilə, müəlliflərə son variantın redaksiyaya geri qaytarılmasının elektron poçt ilə həyata keçirmələri və çapa hazır variantın alındığı gündən iki həftə müddətində düzəlişlər barədə məlumat verməlri tövsiyə olunur.

Məqaləyə müəllifin arayışı və ekspertiza aktı əlavə olunmalıdır.

Məqalənin jurnala verilməsi onun əsli olduğu, heç vaxt çap edilmədiyi və digər nəşrlərə göndərilmədiyi anlamındadır. Məqalə müəlliflərin hər biri tərəfindən imzalanmalı və onun redaksiyaya təqdim olunma tarixi göstərilməlidir.

ПРАВИЛА ДЛЯ АВТОРОВ

Международный научный журнал «*Стратиграфия и седиментология нефтегазоносных бассейнов*» публикует статьи, освещающие различные аспекты стратиграфии и седиментологии нефтегазоносных бассейнов в различных частях мира. Сферой интересов журнала являются современные и древние условия осадконакопления, в особенности, нефтематеринских пород и коллекторов, моделирование процесса седиментации, почвообразование и диагенезис, палеоклимат, изменения уровня моря и седиментация, современные и ископаемые комплексы фауны и флоры и их использование в фациальном анализе, геохимия стабильных изотопов и биогеохимия, изменения коллекторских свойств в зависимости от условий отложения осадков, интеграция различных стратиграфических методов, таких, как био-, лито-, хемо-, эко-, хроно-, сейсмо-, секвенсстратиграфия применительно к осадочным толщам нефтегазоносных областей.

Журнал выходит два раза в год и публикует статьи, обзорную информацию, дискуссии и краткие сообщения. Статьи могут быть представлены на азербайджанском, английском и русском языках.

Форма представления статьи

Авторы должны высылать тексты своих статей на следующий электронный адрес: info@isjss.com

Название компьютерного файла должно содержать инициалы первого автора. Рисунки должны быть высланы в отдельных файлах, однако, местоположение рисунков должно быть показано в тексте статьи путем указания номера рисунка. Названия файлов, содержащих рисунки, должны включать инициалы первого автора и номер рисунка.

Текст статьи должен быть представлен в Word формате (Word 6,0 – 8,0). Размер статьи не должен превышать 20 страниц формата А4, отступ со всех сторон – 2 см, рекомендуемый шрифт – Times New Roman, размер шрифта – 12, межстрочный интервал – 1,5, каждый абзац начинается с отступом 0,8 см от левого края колонки. Текст статьи должен быть отформатирован в соответствии с этими требованиями, все строки должны быть выровнены слева направо, не выходя за поля текста. Статья должна включать также соответствующий графический материал (не менее одного рисунка), список используемой литературы, таблицы, если необходимо, и расширенное резюме. Редакция журнала не принимает не содержащие рисунки статьи.

Редакция журнала также просит высылать распечатанные варианты статей по адресу: Редакция журнала «Седиментология и стратиграфия нефтегазоносных бассейнов», Институт геологии НАН Азербайджана, пр. Г. Джавида 29А, Баку, AZ 1143, Азербайджан. Компьютерный файл (текст статьи) должен соответствовать распечатанному варианту статьи.

Страницы не должны быть пронумерованы в электронном варианте статьи. В распечатанном варианте статьи номера страниц проставляются в верхнем правом углу.

Статья должна быть подписана всеми авторами на последней странице распечатанного варианта с указанием даты представления статьи в редакцию.

Текст статьи должен включать:

УДК – в левом углу, шрифт Times New Roman – 12 pt, через два интервала печатать название статьи

Название статьи – шрифт Times New Roman – 14 pt, буквы заглавные, утолщенные (bold), расположенные симметрично относительно середины страницы по всей ширине текстового поля, далее через два интервала печатать инициалы и фамилии авторов. Пожалуйста, укажите автора, с которым необходимо поддерживать связь.

Инициалы и фамилии авторов – шрифт Times New Roman – 12 pt, буквы строчные (bold), расположить симметрично относительно середины страницы, далее через два интервала печатать название организации и ее e-mail.

Название организации, в которой работают авторы и ее e-mail: шрифт Times New Roman – 12 pt, буквы строчные (bold), расположить симметрично относительно середины страницы. Пожалуйста, дайте полный адрес организации, где работа была выполнена, а также адрес авторов в настоящий момент, если он изменился. Если авторов несколько и они имеют различное место работы, то перед названиями этих организаций следует проставить цифры в порядке возрастания. Ту же цифру указать и в надстрочном индексе после фамилии авторов, работающего в этой организации, например, И.С.Гулиев [1], А.А. Фейзуллаев[2] и т.д. Далее через два интервала печатать аннотацию.

Аннотация - краткая аннотация (до 1 страницы), далее ключевые слова (до 8 слов). Шрифт Times New Roman – 12 pt., ключевые слова печатать жирным шрифтом. Далее через два интервала печатать основной текст статьи.

Текст статьи – основной текст, который рекомендуется строить по общепринятой в международных журналах схеме, используя следующие подзаголовки: «Введение», «Материал», «Методика», «Результаты и обсуждение», «Заключение (выводы)», «Список литературы». Подзаголовки печатать жирным шрифтом Times New Roman – 12 pt и расположить симметрично относительно середины страницы, каждый подраздел отделять от предыдущего одним интервалом.

Таблицы размещаются в пределах текста статьи и должны быть представлены в формате Word. Они должны быть пронумерованы последовательно в верхнем правом углу над самой таблицей. Каждая таблица должна иметь название, которое следует за номером таблицы. Печатаются номера таблиц и их названия шрифтом Times New Roman – 12 pt жирными буквами. Подзаголовки в колонках таблицы должны быть краткими, наименования единиц измерения должны даваться в круглых скобках.

Таблицы не должны выходить за пределы текстового поля, перенос таблицы с одной страницы на другую не допускается. Максимальное допустимое количество таблиц в статье 5.

Сокращения за исключением немногих общепринятых (т.е., др., т.д.) должны быть расшифрованы в ссылках.

Ископаемые остатки следует описывать согласно «Международному кодексу зоологической номенклатуры». Приводимые в тексте латинские названия видов флоры и фауны должны сопровождаться фамилией автора таксона. Латынь следует набирать курсивом.

При написании **формул** следует использовать физические единицы и обозначения, принятые в Международной системе СИ. Формулы даются без промежуточных выкладок с обязательной расшифровкой используемых в них символов, которые даются сразу после формулы. Номера формул, если они упоминаются в тексте, проставляются в круглых скобках около правой границы текста на одной линии с формулой. Для набора формул рекомендуется использовать редактор Microsoft Equation 3, далее через два интервала печатать список литературы.

Литература. В тексте статьи ссылка на литературу дается в круглых скобках (Автор/ы, год) в хронологическом порядке. Если ссылка дается на работу где более трех авторов, то указывается фамилия первого автора (например, Гулиев и др., 2005). Если ссылаемая работа приводится без авторов, то пишутся два первых слова ее названия (например, Стратиграфический кодекс…., 1998). Список литературы приводится в алфавитном порядке в конце статьи и должен включать фамилии и инициалы всех авторов, год издания, название статьи/книги, в случае публикации в журнале – его название и номер выпуска, номера первой и последней страниц статьи. Если ссылка сделана на книгу, то необходимо указать количество страниц в книге.

Если список содержит ссылки на работы одного и того же автора, опубликованные в один и тот же год, то необходимо придать им индексы а, б, в и т.д. после указания года издания. Ссылки на тезисы докладов даются аналогичным образом. Фамилии и инициалы авторов приводятся курсивом.

В списке литературы вначале приводятся публикации, изданные на кириллице, а затем латинским шрифтом.

Ниже приводятся примеры различных библиографических ссылок.

Книги:

Бабаев, Д.Х., Гаджиев, А.Н., 2006. Глубинное строение и перспективы нефтегазоносности бассейна Каспийского моря, Б. – «Nafta-Press», 305 с.

Kőthe, A., 1990. Paleogene Dinoflagellates from Northwest Germany – Biostratigraphy and Paleoenvironment, Hanover, 111 p.

Статьи в периодических журналах:

Бабаев, Ш.А., 2005. Влияние условий окружающей среды на морфологию раковин нуммулитов // Известия НАНА. Серия наук о Земле, № 2, с.62–66.

Hallam, A., 2001. A review of the broad pattern of Jurassic sea-level changes and their possible causes in the light of current knowledge // Palaeogeogr., Palaeoclimatol., Palaeoecol., v.1 67, pp. 23–37.

Статьи в сборниках (в том числе перодических):

Delamette, M., Caron, M., Brehert, J., 1986. Essai d'interpretation genetique des facies euxiniques de l'Eo-Albien du bassin vocontien (SE France) sur la base des donnees macro- et microfauniques // C.R. Acad. Sc. Paris. ser. II., v.302, pp. 1085–1090.

Резюме. Расширенное резюме на английском языке, содержащее основную информацию о статье, в том числе цель и задачи исследования, использованная методика, полученные результаты и выводы, должно быть также представлено. Цель резюме – ознакомление англоязычной аудитории со статьями, опубликованными на русском и азербайджанском языках.

Иллюстрации. Каждый рисунок (карта, диаграмма, схема и т.д.) представляется в виде отдельного файла. Как выше уже было указано, название файла должно содержать инициалы первого автора и номер рисунка.

Рисунки принимаются в форматах TIFF (300 dpi), PDF or CDR files Иллюстрации обязательно нумеруются в порядке их указания в тексте. Каждый рисунок не должен превышать размера 160 мм х 230 мм. На картах обязательно указывать масштаб.

В распечатанном варианте статьи номера рисунков указываются на их обороте простым карандашом с указанием фамилии первого автора и названия статьи.

Каждый рисунок должен иметь заглавие. Список подрисуночных подписей должен быть представлен в электронном и распечатанном виде на отдельном листе. Количество рисунков в статье не должно превышать 10.

Редакция журнала обеспечивает **бесплатное** печатание цветных рисунков.

Редакция оставляет за собой право передать статью на рецензию. Верстка статьи направляется автору для проверки и исправления ошибок, допущенных при наборе и редактировании.

Для исключения задержек с возвращением верстки в редакцию авторам рекомендуется пользоваться электронной почтой и сообщать об исправлениях в течение двух недель после получения верстки.

К статье должны прилагаться авторская справка и акт экспертизы.

Подача статьи в журнал означает, что она оригинальна, нигде не публиковалась и не была направлена в другие издательства.

CONTENTS

MÜNDƏRİCAT

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