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GARABAGH. STRATIGRAPHIC ESSAY
Chapter II: Cenozoic

This article summarizes the materials on geological mapping and scientific results obtained during long-term studies of the Paleogene-Neogene sedimentary complex occurring in the geological structure of the Mountainous and Lowland Garabagh. Identified and paleontological justified local stratigraphic units (suites) have been incorporated into local stratigraphic chart, which can be used for the stratigraphic correlations of the Cenozoic sections over the Southern Caucasus. This is the first essay on the Garabagh stratigraphy in English.

Keywords: Cenozoic, Paleogene, Neogene, stratigraphy, paleontology, stratigraphic scale, lithology, local stratigraphic units

T.N. Kangarli

Azerbaijan National Academy of Sciences,
Institute of Geology and Geophysics,
H. Cavid ave., 119, Baku, AZ1143, Azerbaijan
E-mail: tkangarli@gmail.com

Sh.A. Babayev

Azerbaijan National Academy of Sciences,
Institute of Geology and Geophysics,
H. Cavid ave., 119, Baku, AZ1143, Azerbaijan

H.A. Allahverdiyeva

Azerbaijan National Academy of Sciences,
Institute of Geology and Geophysics,
H. Cavid ave., 119, Baku, AZ1143, Azerbaijan
E-mail: hallahverdiyeva63@gmail.com

Geological background

Cenozoic Series take a subordinate position in the geologic structure of the Mountainous Garabagh. Although they are sporadically occurring in the sedimentary section of Lok-Garabagh, Goycha-Hakari, Kalbajar and Gafan structural zones, they are dominant only in the surface and deep structures of Garabagh and Pre-Araz lowlands (Figures 1, 2).

According to the data on hand (Azerbaijanin geologiyası, 2015; Geologiya Azerbaijana, 1997, 2007; Geologiya SSR, 1972; Shikhalibeyli, 1964), Cenozoic complexes of Garabagh include sediments of Paleogene, Neogene and Quaternary systems. In the Lesser Caucasus, the total thickness of terrigenous-carbonate Paleogene succession is 1700 m. In a central segment of the Lesser Caucasus terrigenous-carbonate, volcanogenic-sedimentary and volcanogenic Paleogene successions are recorded in the geological section of Shahdagh (the thikness varies from 1200m to 3800 m) and Kalbajar (1100-2650 m) troughs, while in the southeastern subsided part only carbonate-terrigenous rocks (1100-1400 m) are unconformably overlapping Upper Cretaceous Series. Within the middle segment of the Kur lowland, Paleogene sequence (700-2850 m) was penetrated by multiple wells. It is mostly composed of terrigenous rocks.

The Miocene-Pliocene succession constitutes the upper part of Kalbajar trough and contains volcanogenic Series (850-900 m). Geological section of the Kur depression consists of Miocene marine sediments (4000-4100 m) overlapped by a Pliocene complex composed of continental molasses in the northwest (1700-2000 m) and marine terrigenous sediments in the east (7000-8500 m).

Quaternary system composed of all Series - Eopleistocene, Pleistocene and Holocene, is occurring across the low-mountain, piedmont and lowland areas (continental molasse facies, river terraces, colluvial, alluvial, lacustrine and aeolian sediments), as well as in the considerable part of Garabagh volcanic plateau (volcanic facies) (Azerbaijanin geologiyası, 2015; Alizadeh et al., 1978; Akhverdiyev, 1970; Geologiya Azerbaijana, 1997, 2007; Geologiya SSR, 1972). Thickness of these successions is estimated as tens, sometimes hundreds of meters.

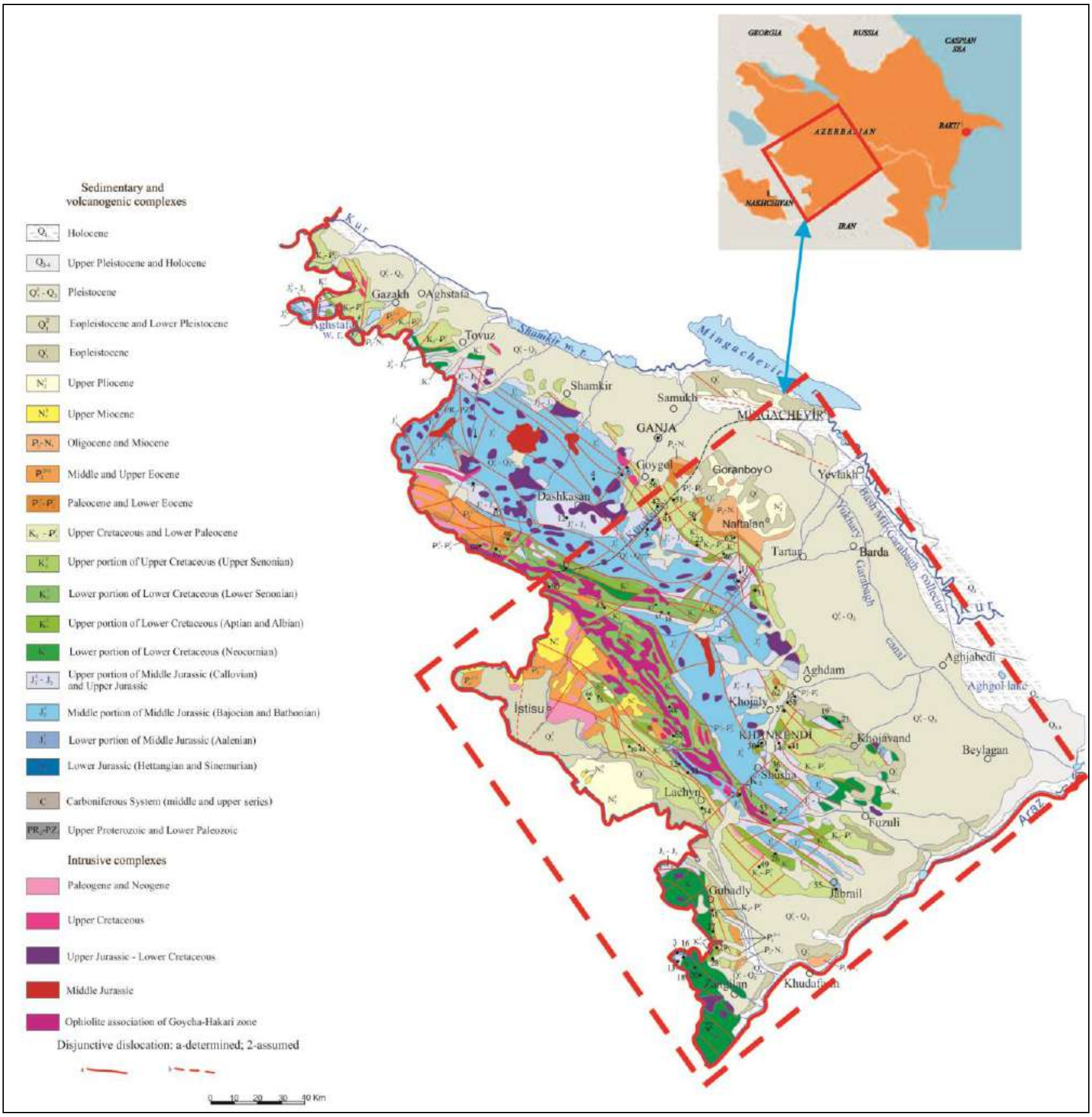

Figure 1. Geological map of the Azerbaijani part of the Lesser Caucasus – by T.N. Kangarli (National Atlas of Azerbaijan, 2014)

Suites: 1 - Zayamchay, **2** - Gyzylja, **3** - Aghkend, **4** - Dashkasan, **5** - Kurakchay, **6** - Khachagaya, **7** - Kichik Garamurad, **8** - Kapaz, **9** - Tapakend, **10** - Galakend, **11** - Gulustan, **12** - Gonaggormaz, **13** - Gungishlag, **14** - Gushchu-lar, **15** - Aranzamin, **16** - Kaganly, **17** - Bughdadagh, **18** - Okhchuchay, **19** - Shelli, **20** - Burunlu, **21** - Gulably, **22** - Bartaz, **23** - Garachay, **24** - Farjan, **25** - Alijanly, **26** - Sirik, **27** - Gartiz, **28** - Guyudara Khashtab, **29** - Sarili Khashtab, **30** - Khankendi, **31** - Lulasaz, **32** - Altintakhta, **33** - Ayibazary, **34** - Dashbashy, **35** - Chovdarsu, **36** - Damirchilar, **37** - Aghdaban, **38** - Charakdar, **39** - Tilloid, **40** - Sheylanly, **41** - Dashkend, **42** - Chaykend, **43** - Nadirkhanly, **44** - Hochazsu, **45** - Garabulag, **46** - Injachay, **47** - Bulanligsu, **48** - Qarabayli, **49** - Dolanlar, **50** - Todan, **51** - Shorsu, **52** - Mahuchay, **53** - Yurtiyal, **54** - Lachin, **55** - Tulusdagh, **56** - Tulakdagh, **57** - Dahraz, **58** - Asgaran, **59** - Darvadagh, **60** - Gonur, **61** - Gubadly, **62** - Gargarchay, **63** - Aghjakend, **64** - Gojadagh, **65** - Chichakli, **66** - Aghgaya.

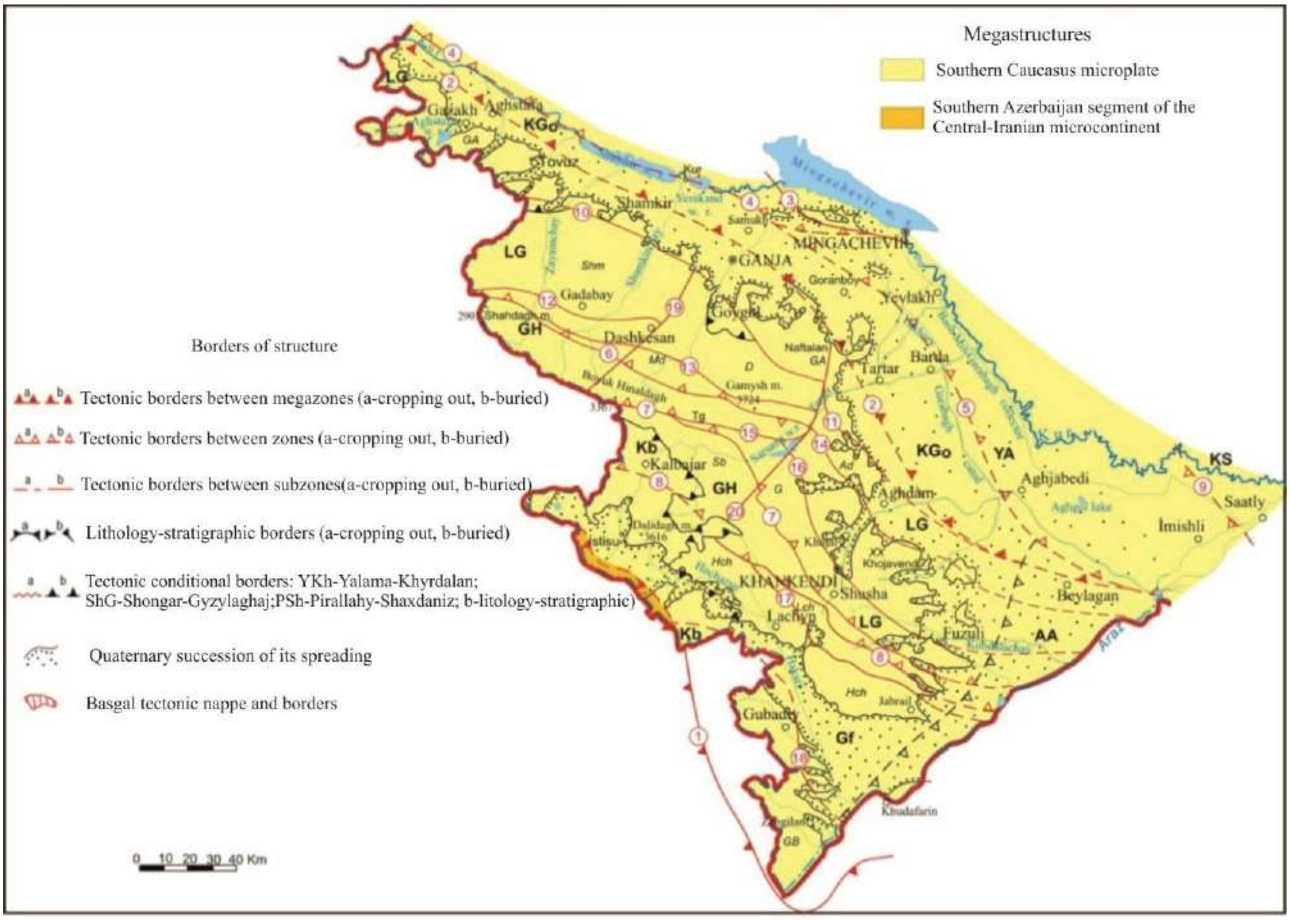

Figure 2. Tectonic scheme of the Azerbaijani part of the Lesser Caucasus – by T.N. Kangarli (National Atlas of Azerbaijan, 2014)

Kur intermountain depression (Miocene-Pliocene superimposed depression): ***Middle Kur (Orta Kur) megazone:*** zones: **KGy** – Pre-Lesser Caucasus (Kichikgafgazonu); **YA** – Yevlakh-Aghjabadi. **Orogenic system of the Lesser Caucasus:** ***Artvin-Garabagh megazone:*** zones: **LG** – Lok-Garabagh; **GH** – Goycha-Hakari; **Qf** – Gafan; **Kb** – Kalbajar (Eocene-Pliocene superimposed depression); **AA** – Lower Araz (Ashaghy Araz – Eopleistocene-Holocene superimposed depression); **subzones:** ***GA*** – Gazakh-Aghburun; ***Shm*** – Shamkir; ***Ad*** – Aghdam; ***D*** – Dashkasan; **XX** – Khachynchay-Khojavand; ***Md*** – Murovdagh; ***G*** – Garabagh; ***Tg*** – Toraghaychay; ***Sb*** – Saribaba; ***Lch***– Lachin; ***Hch*** – Hochaz; ***GB*** – Gafan-Basitchay. **Faults: on the boundaries of megazones: 1** – Girratagh; **on the boundaries of zones: 2** – Pre-Lesser Caucasus (Kichikgafgazonu); **3** – Arikdar-Bozdagh-Padar; **4** – Kur; **5** – Southern Kur (Janubi Kur); **6** – Murovdagh; **7** – Garabagh; **8** – Lachin-Bashlibel; **9** – Goychay-Imishli; **on the boundaries of subzones: 10** – Yasamal; **11** – Aghdara; **12** – Aryghdam; **13** –Arisu-Zivlan-Balligaya; 14 – Aghdam; **15** – Sarsang; **16** – Meydanchay–Shusha; **17** – Deyhan; **18** – Hakari; **19** – Goshgarchay; **20** – Tartar-Injachay.

Similar studies had been implemented by A.Z.Abdullayev, R.N.Abdullayev, G.V.Abikh, A.G.Aliyev, A.A.Alizadeh, G.A.Alizadeh, G.İ.Allahverdiyev, V.M.Allahverdiyev, G.Artgaber, I.N.Aslanova, Sh.A.Azizbayov, Sh.A.Babayev, M.A.Bagmanov, A.E.Baghyrov, A.A.Bayramov, V.V.Bogachov, P.Bonnet, O.D.Hamzayev, H.M.Hasanov, T.Ab.Hasanov, A.A.Florenskiy, F.Frech, M.A.Gashgay, A.Y.Ismayilov, S.A.Kazimov, B.G.Kerimov, V.Ye.Khain, D.M.Khalilov, A.V.Mammadov, M.N.Mammadov, T.A.Mammadov, B.F.Meffert, K.N.Paffenholtz, V.P.Rengarten, A.N.Ryabinin, A.Sh.Shikhalibayli, İ.N.Sitkovsky, M.M.Valiyev, V.A.Varentsov, etc.

In their studies the authors operated by both multi-year scientific researches, and the data of the State Geological Survey.

Description of lithological-stratigraphic sections

Paleogene System

Paleogene succession is composed of different types of sedimentary, volcanogenic-sedimentary and volcanogenic rocks of a large thickness and recorded in the structure of large tectonic units of the Mountainous Garabagh and Middle Kur depression. Most complete sections of Paleogene are reported in the Agjakend trough **(**Azerbaijanin geologiyası, 2015; Alizadeh, 1968; Bagmanov, 1980; Gasanov, 2004; Geologiya Azerbaijana, 1997, 2007; Geologiya SSR, 1972; Ismailov, 1973; Regionalnaya stratigraficheskaya..., 1989; Shikhalibeyli, 1964**)**. Incomplete sections and outcrops are also des cribed in Aghdara, Khojavand, Saribaba, Kalbjar and Hochaz troughs **(**Abdullayev, 1965; Alizadeh, 1968; Alizadeh, 1980; Alizadeh, 1959; Bagmanov, 1980; Gasanov, 1981; Gasanov, Garalov, 1994; Gasanov, Kayabekov, 1975; Gasanov, Kazimov, 1989; Gasanov et al., 1987; Geologiya Azerbaijana, 1997, 2007; Geologiya SSR, 1972**)**

Paleocene succession. Within the region under study the Paleocene sequence transgressively overlies the Cretaceous complex in some submerged areas of the Lok-Garabagh, Goycha-Hakari and Kalbajar structural zone (Figure 3). Within the Yevlakh-Agjabadi trough of the Middle Kur depression the Paleocene deposits are exposed in Duzdagh mountain, Amirarkh and Muradkhanly areas. The Paleocene complex is composed of sedimentary and volcanic-sedimentary facies.

Danian succession is exposed in Lok-Garabagh, Goycha-Hakari and zones. In the Aghjakend trough (Dozular, Shorbulag, Boru villages) the Danian deposits form the ***Birgoz suite*** that unconformably overlies the Maastrichtian succession. The basal portion of the section is built by the alternating limestones and marls, and its' upper portion is mostly consisting of carbonate and sandy shales (20-70 m). In some parts of Agdere and Hojavend troughs, conglomerates are recorded at the suite's base. Above lying sediments are composed of 20-50 m thick detrital, pelitomorphic, crystalline, sandy limestones and marls.

Figure 3. Outcrop of the Paleocene (the lower portion of the section) and Eocene (the upper portion of the section) successions along the right bank of the Kurakchay river (Dozular village)

The limestones contain fossils of *Verneuilinae kelleri Morozova, Stensioina caucasica Subb., Anomailina danica Brotz., Echinocorys sdhemi Bohm., Coraster sphaericus Seunes, Globigerina triloculinoides Plumm., G. pseudobulloides* Plumm., *G. fringa* Subb., *G. quadrata* White, *Acarinina inconstans* (Subb.), *Hercoglossa danica* Schloth., *Homoeaster abichi, Cyclaster danicus* Schlut., etc.

In Goycha-Hakari zone, Danian stage (including the basal part of Selandian stage) is represented by the ***Jamilli suite***, which is consisting of terrigenous-carbonate and terrigenous flysch exposed on the Saribaba trough's northwestern segment in the Chichakli syncline's core. Age of these 40-250 m thick deposits is defined by the presence of *Guroidina globasa Hagen., Pullenia coryelli White, Globorotalia angulata White, Ammodiscus incertus d'Orb., Gaudryina retuşa Cushm., Bulimina inflata Sequen., Bolivina subincrassata Chalil., Stensioina caucasica Subb.* and *Eponides praemegastamus Mjatl*.

Within the Yevlakh-Agjabadi trough Danian stage is composed of limestones, marls and shales (20-40 m) with *Globigerina quadritriloculinoides Chal., G.edita Subb., Acarinina shachdagica Chal., Marcalius inversus Defl.*, etc.

Selandian succession is cropping out in the Aghjakend (Dozular, Ajidara, Shorbulag, Boru, Injachay, Gulustan, etc.) trough and consists of carbonate shales, limestones, marls with *Globorotalia angulate* (White), *Bolivina subincrassata* Chal., *Stensioina cucasica* (Subb.), etc. (thickness of the sediments ranges within 20-100 m).

In Hojavend, the outcrops are observed in the Khanabad village's vicinities, where they form the ***Tazabina suite*** composed of marls, argillites and limestones with sandy shale interbeds (25 m). Age of the deposits is defined by the occurrence of the fauna of *Glomospira charoides, Eponides sparrksi, Globorotalia angulata, G. pseudobulloides, G. conicotruncata, Subbotina trilioculinoides, Chiloguembelina crinita*.

In Saribaba trough, the stage is constituted of the ***Sariyokhush suite*** built by the alternating of shistous clays, argillites and siltstones (380-500 m). The argillites contain fossils of *Globigerina nana Chalil., G. conicotruncata Subb., Globoconusa chasconova Loeb. et Tapp., Osangularia culter Jon. et Park., Cibicides praeventrotumidus Masl., C. suecedeus Brotz*., etc.

On the southeastern margin of Kalbajar trough (Mikhtokan range) in the headstreams of Mamalichay, Selandian stage forms the ***Mamali suite*** composed of specific pyroclastic-sedimentary facies of trachybasalt pillows, tuffs and tuff-conglomerates (300-330 m). Absolute age of samples collected from the section, is determined as between 60 ± 3 Ma and 63 ± 2 Ma.

Within the Yevlakh-Agjabadi trough sediments of the Selandian stage are exposed in the same areas and composed of shales, marls with interbeds of sandstones, limestones with *Globorotalia angulata (White), Gaedita Subb., Fasciculithus tympaniformis Hay et Mohl*, etc.

Thanetian stage is represented by 50-80 m thick succession recorded in the Agjakend trough of Lok-Garabagh and composed of the shale, siltstone and muddy limestone beds unconformably overlied by the Birgoz suite. On the left bank of Tartar river (surroundings of Sugovushan village) the stage is composed of the marly shales, and in Hojavend trough it consists of the alternating argillites and siltstones with shale and marl interbeds **(*Gilijbagh suite*)**, containing typical fauna of *Heterostomella gigantica Subb., Ammodiscus incertus Orb., Bolivinoides aragonensis İrit., Proceonina complanata Franue., İgorina (Avcarinina) tadjikistanensis djanensis*, *Acarinae acarinata*, etc.

In Goycha-Hakari zone, the Thanetian stage sediments have been only preserved in the Chichakli syncline (Saribaba trough), where it conformably rests on the Danian-Selandian succession and forms the ***Dalikdash suite*** built by the alternating argillites, marls, sandstones and gravelites with shistous clay interbeds (50-500 m). Age of the suite is defined by the occurrence of several fossils, e.g. *Allomorphinita* *inasperta Vetr. in litt., Globorotalia coinpressa Pl., G. angulata White., Gl. pseudomenardii Bolli, Globigerina nane Chalil., Gl. compressaformis Chalil., Cl. bacuana Chalil., Globoconusa chasconova Zueb. et Tapp., Ozangularia culfer Jon. cf. Perc., Cibicides praeventratumidus Masl., C. succedeus Brotren, Tixtularia varians Glauss., Stensionia caucasica Subb., Bulimina ovata Orb., Proteonina complanata France, Reusella paleocenica Brotz., Tritaxia aff. piramidata Reuss.,* etc.

In Kalbajar trough, the stage is constituted of the ***Sarimsagli suite*** built by the limestones containing gravelite and nummulitic limestone (13-80 m) beds, and characterized by rich fossil assemblage (*Nummulites fraasi de la Harpe, N. silvanus Schaub., N. solitarius de la Happe, Discocyclina seunesii Douv.*).

The Tanethian stage is exposed in the Duzdagh, Amirarkh, Muradkhanly and Mil areas and consists of shales and marls with interbeds of limestone (25-95 m) containing fauna *Acarinina subsphaerica Subb., A.acarinata Subb., Discoaster multiradiatus Bram. Et Ried*, etc.

Eocene succession. All Eocene stages are reported in the geological structure of Garabagh, and unlike Paleocene, there are both sedimentary, volcanic-sedimentary and volcanic rocks are recorded. The Eocene deposits in the Yevlakh-Aghjabadi trough are exposed in the Duzdagh, Amirarkh, Shirvanly-Barda, Zardab, Muradkhanly, Shiringum and Mil areas.

Lower Eocene succession. Within the Lok-Garabagh zone, Ypresian complex conformably overlies the Paleocene sediments, and forms the ***Sardarkend suite*** with *Nummulites exilis* and *Nummulites planulatus* zones. In Aghjakend trough, the suite is composed of 15-100 m thick alternating marly and sandy shales and argillites with polimictic sandstones and organogenic limestones. In Khojavand trough (Khanabad village's surroundings), its section is composed of the rhythmic alternation of argillites, sandstones, marls and muddy limestones in the base, and muddy, marly and sandy limestones in the top (200-245 m). The age of the suite is determined based on a presence of the following fauna: *Nummulites exilis Douv., N. praemurchisoni Nem. et Barkh., N. bolcensis Munier-Chalmas, N. spileccensis Munier-Chalmas, N. pernotus Schaub., Operculina parva Douv., Discocyclina archiachi Schlimb., Asterocyclina sp., Globoratalia crassata Cushm., Acarinina pentacamerata Subb., Eponids trümpyi Nuttall, Globigerina varianta Subb., Bulimina pseudopuschi Subb., Truncoratalia lensiformis Subb., Cardita minutula Nom.*, etc.

In Toraghaychay and Saribaba troughs the Ypresian stage is composed of the ***Chobandagh suite*** exposed to the northwest of Garabagh within the Shahdagh ridge's boundaries. The suite is consisting of 300-400 m thick strata of sandstones, tuffaceous sandstones, tuffites, tuff-conglomerates and andesites containing thin lenses of organogenic limestones with following typical fossils: *Nummulites ex gr. praemurchisoni Nem. et Barkh., H. ex gr. planulatus Lem., Nikulana sp., Discocylina sp., Variamussium sp.*, etc.

On the southeastern limb of Kalbajar trough (Mikhtokan and Saribulag ranges), Ypresian rocks form the ***Bashlibel suite***, which is constituted by 100-120 m thick gravelite-detrital and nummulite limestones containing the carbonate sandstones, gravelites and argillites beds. In some sections (upper reaches of Tartar, Tutgun and Shalva, slopes of Dalidagh and Keyidagh mountains), the suite is built by marly, detrital and organogenic limstones and muddy-detrital sandstones interbedded by the flows and sheets of andesites and andesite-tuffs. The suite is characterized by rich nummulite association with following faunal assemblage: *Nummulites nitudus, N. fraasi de la H., N. silvanus Schaub., N. akkuurdanensis Nemkov, N. urchisoni Rut., N. praemurchisoni Rat., N. muratovi, N. praelucasi, N. leupoldi, N. irregularis, N. burdigalensis, N. partschi, Acarinina subglabra Cushm., A. dosularensis Chalil., Marsonella indentata Cushm. et Jarv., Glomospira gordialis Park. et Jon., Gumbelina subglara (Cush.) var. dozularensis Chalil.*

On the southwestern flank of Hochaz trough, Ypresian age is represented by the ***Mahmudlu***

suite – 5-30 m thick strata of sandy-muddy limestones, argillites, shales and sandstones, containing the following fossils: *Xiphosphara aff. venus Haeckel, Tripospyris euscenium Haeckel, Globigerina tricolulionides Plummer, Nuttallites trümpyi Nuttall, Globorotalia crassiformis Gall. et Wissler, G. quetra Bolli, Acarinata Subb., Spiroplectammina richardi Mart., Lagena apiculata Reuss*, etc.

Within the Yevlakh-Agjabadi trough the Lower Eocene succession unlike the younger Eocene sdiments is exposed only in the Duzdagh, Amirarh, Shirvanly-Barda, Muradkhanly areas and represented by marls, shales, siltstones with interbeds of limestones, the thickness of which is 100-200 m. They contain faunal remains: *Globorotalia subbotinae Moroz., G.caucasica Glaessn.* And *Marthasterites tribrachiatus Br.et Ried.*

Middle Eocene succession is represented by Lutetian and Bartonian stages. Along the northeastern margin of Lok-Garabagh zone, the age's sedimentary facies are detected both on the natural outcrops and in the drill logs. Within the boundaries of Goycha-Hakari and Gafan zones, Middle Eocene complex consists of the volcanic-sedimentary Series.

Lutetian stage. Within the Aghjakend trough's structure, the stage is represented by the ***Panahlilar suite,*** which is built by 20-35 m thick strata of carbonate shales, marls, sandstones and sandy limestones (Figure 4). Fossils of *Trincorotalia aragonensis Nuttall, Acarinina crassiformis Gall., A. pentacamerata Subb., Globigerina pseudobulloides Plumm., Globoratalia rotundimarginata Subb., Gl. frontosa Subb*. are detected within the suite's composition. In Aghdara trough, the suite is built by 79 m thick alternation of marls and marly shales with sandstone interlayers. Following fossils are contained within the structure of the suite: *Acarinina bullbrooki, Globigerinatheka subconglobata, Globigerina frontasa, G. pseudoeocaena, G. inaequispira, Nummulites anomalus*, etc. In Khojavand trough, Lutetian basal conglomerates (0.5 m) overlap the Kimmeridgian volcanosedimentary deposits. Remaining part of the section is built by argillites, siltstones, sandstones, tuffaceous sandstones, tuffites and muddy limestones (40-50 m).

Figure 4. Outcrop of the Middle Eocene sediments along the right bank of the Garachay river (Meshali village)

On the western limb of Toraghaychay trough that is confined to the Shahdagh range's structure, composite section of Middle Eocene volcanosedimentary rocks (1700-2800 m) forms the ***Shahdagh suite***, which is built by polimictous sandstones, gravelites, tuff-siltstones, tuff-breccias, tuff-conglomerates, tuffs and detrital limestones in the bottom, and by porphyrite volcanics in the upper part of its' section. The suite's limestones contain fauna fossils of *Nummulites irregularis Desh., N. distans Desh., N. murchisoni Rut., N. pratti d'Arch. N. partschi de la Harpe, N. atacicus Leum., N. gistans Desh., Discocyclina reatli*, etc.

In Saribaba trough, Lutetian deposits are represented by up to 100 thick ***Sarisu suite*** built by the alternation of nummulite containing limestones and carbonate sandstones. The suite's age is determined by presence of *Nummulites subataicus Daw*. və *Discocylina sela Arch*.

In the upper basins of Hakari and Tutgun (Kalbajar trough), Lutetian section begins with 180-230 m thick ***Zod (nummulite containing) suite***, which overlies the Bashlibel suite's limestones (conformably) and basal conglomerates (unconformably) and consists of the alternation of nummulite limestones with tuffs, tuff-gravelites, limestones and sheets of andesites. The suite's limestones are rich with the fauna fossils of nummulites and foraminifers. Including *Nummulites distans Desh., N. pratti Arch. et H., N. murchisoni Rut., N. irregularis Desh., N. striatus Brugiere, N. suldistans Harpe, N. heberti Arch. et Haime, N. atacicus Leym., N. globulus Leym., Discocyclina pratti Mich., Chamys cf. infumata Lam*, etc.

Upper part of the stage (450-600 m) forms the tuffaceous complex of the ***Dalidagh suite***, the section of which includes tuffaceous sandstones, tuffites, tuffs, tuff-siltstones, tuff-gravelites, tuff-conglomerates, tuff-breccias, argillite, marls and hornblendes with stratified layer of tuffite-limestones. The suite's age is determined based on the presence of typical fossil foraminifers, including *Discoculina discus, D. (umbo) fortsi, D. pratti Mich., D. sella, D. varians, D. Nummulitica, Chamys cf. infumata Lam.* və b.) və nummulut (*Nummulites (uranensis) uranensis, Nummulites distans Desh., N. pratti Arch. et H., N. murchisoni Rut., N. aracicus, N. gizehensis*, etc. To the west of that area, lithological composition of the Lutetian succession changes. Here over 1000 m thick ***Kalbajar suite*** consisting of lavas and pyroclastic rocks (agglomerate-blocky rhyolite-dacite tuffs, plagioclase-andesite and andesite-plagioclase flows and their tuff-breccias) is observed in the basin of Tartar river (Figure 5). Beds of tuffaceous sandstones and marls are recorded within the volcanic Series.

In the region's southwest in the river basins of Hakari and Bargushad (Bazarchay), composite Middle Eocene section is confined to the ***Gilyatag suite*** represented by muddy limestones, argillites, sandstones, gravelites, siltstones, silt-tuffites, tuff-conglomerates and tuff-breccias (200-260 m). Bottom part of the section contains fossils of the Lutetian microfauna, e.g. *Globigerina rotundaenana Schutzk., G. angipora Stashl., G. pseudoeocaena pseudoeocaena Subb., Acarinina triplex Subb., A. pseudotopileusis Subb., A. pentacamerata Subb., Cibicides westi arguta N.Byk., Nodosaria milwayensis Cushm.*, etc. Upper, Bartonian part of the section contains microfauna fossils of *Acarinina bullbrooki Bolli, A. rotundimarginata Subb., Globigerinatheka subconglobata, Globigerina frontasa, G. subtriloculinoides Plumm., G. pseudoeocaena Subb., G. inaequispira Subb., Globorotalia aragonensis Nutt.*, etc.

Bartonian stage. In Lok-Garabagh zone within the structure of Aghjakend suite, the stage is represented by the ***Garachinar suite*** (15-70 m) that contains typical fossils of *Acarinina crassiformis Goll. et Wessl., Globoratalia rotundimarginata Subb., Globigerina turcmenica, G. frontosa Subb., G. azerbaidjanica, G. pseudocorpulenta, G. posttrilocolinoides, Hantkenina alabamensis*, etc. In the area of Mughanli village (little to the southwest of Aghdam town), the same-named Bartonian complex of shales, argillites, sandstones, gravelites and sandy limestones outcrops among the alluvial-proluvial deposits of Lower Pleistocene.

Figure 5. Outcrop of the Middle Eocene sediments of the Kalbajar trough in the upstream of the Tartar river (near Mollabayramli village)

Age of the rocks is determined based on a presence of the fauna fossils of *Globigerina azerbaidjanica, Caucasina eocoenika, C. aziderensis*. Similar Bartonian deposits were also detected by boreholes, protruding at the depth of over 150 m from under the Quaternary and Oligocene Series of the southeastern plunge of Khojavand trough.

In the Saribaba trough's northwest (slopes of the left riverbank of Tartar), Bartonian deposits are represented by the ***Guneytapa suite*** (285 m) of gravelites, tuffaceous sandstones, tuffites, sandstones and argillites, which unconformably overlies the Upper Senonian limestones. The suite's sandstones and argillites contain typical fauna fossils of , *Ostrea sp., Vulsella reflexa Koenen., Diastoma costellata Lam., Pycnodonta brongniarti Bronn., Ammusium sp., Cerithium seperatum Desh., C. velicatum Bell., Pecten ct. unguiculus May., Cardita latesulcata Nyst., Lucina lugioni Boriss., Corbula galbica Lam*.etc.

Within the Kalbajar trough's structure, Bartonian stage is represented by the ***Baritli suite*** built by 570-900 m thick alternation of striped hornblendes, marls, dark limestones, tuff-breccias, tuffaceous sandstones, andesites and andesite tuffs. The suite's limestones contain typical fossils of nummulites (*Nummulites globulus Leum., N. cf. pratti d'Arch., N. cf. murchisoni Rut., N. ironiensis Heym., N. nummulitica Guemb., N. gizehensis Forsk., N. atacicus Leum.*, etc.) and foraminifers (*Acarinina cf. rotundimarginata Subb., A. pentacamerata Subb., Globigerina cf. eocaenica Terq., Gl. cf. subtriloculinoides Chal., Globigerinella micra Cole, Cibicides midwayensis Plumm*., etc.).

The Middle Eocene deposits of the Yevlakh-Agjabadi trough are represented by shales with interbeds of marls, limestones, sandstones the thickness of which is 50-460 m. They contain *Acarinina rotundimarginata Subb., Globigerina turkmenica Chal., Nannotetrina fulgence Str., Reticulofernestra umbilica (Levin)*, etc.

Upper Eocene succession. Within the Aghjakend trough the Upper Eocene (Priabonian stage) is constituted by the ***Chadirdara suite*** containing sandstones, marls, marly and sandy shales, argillites and siltstones (20-200 m). Age of these deposits is determined according to a typical complex of the following foraminifers: *Globigerina* *turkmenica Chlil., Gl. bulloides d'Orb., Globigerinella micra Cole, Globigerinoides conglobatus Brady, Bolivina antegressa Subb., Bulimina pupoides d'Orb., B. ovata d'Orb., Glomospira charoides Park. et Jon., Nonion curviseptum Subb., Chlamys solea Desh., Nucula peregrina Desh., Nuculana alexeevi Mir. et Jar., Corbula costata Sow., Eponides umbonatus Reuss.*, etc.

In Goycha-Hakari zone, the stage is mainly present in the Toraghaychay trough's Shahdagh segment, located in the west out of the region's territory. The area's Priabonian deposits are represented by the ***Ganli suite.*** which is composed of three (sedimentary-pyroclastic, lavaclastic and volcanomictous layers) layers of deposits. Thickness of these volcanics with andesibasalt, dacite and liparite-dacite composition reaches 700 m, while their age is established as 43 ± 1 myr.

Within the Kalbajar trough's boundaries, Upper Eocene period is represented by the ***Orujlu suite*** observed on the eastern and northern slopes of Dalidagh and on Saribulagdagh. The suite is composed of the layers of conglomerates, rare flows of andesites, thin lenses of tuff-breccias, argillites and rarely limestones, as well as the layers of tuffaceous sandstones (80-250 m). The suite's age is determined by a presence of multiple fossils of *Nummulites striatus Brug., N. cf. garnieri Bouss., N. incrassatus de la Harpe, N. ex gr. pulchellus Hantken, Discocyclina varians Kauf., D. nummulitica Gumb.*, etc., among the complex's limestones.

In the basin of Hakari river, the 50-160 m thick strata of argillites, siltstones, sandstones and muddy limestones transgressively with conglomerate lag overlaps the Lutetian stage (***Charali suite***). Age of these rocks is determined based on the following fossils: *Globigerina inflatiformis Mjalt., G. eocaenica Terg., G. eocaenica irregularis Subb., G. pseudoeocaena Subb., G. frontosa Subb., Globigerapsis index Finlay, Uvigerina jacksonensis delicatula Kzaj., U. jacksonensis Cushm., Lenticulina cf. inornata d'Orb., Nonionelleta caspia Chal.. Cibicides costatus Hantk., C. perlucides Nutt., Bolivina caucasensis Chal., Bulimina aksuatica Moroz., Anomalina affinis Hantk., Eponides parasubumbonatus Mjatl., Pullenia coryelli White, Glomospira charoides Jon et Park., Guroidina soldanii d'Orb.*, etc.

The Upper Eocene deposits of the Yevlakh-Agjabadi trough are represented by sandy carbonates with interbeds of marls, limestones and tuffs the thickness of which is 120-140 m. They contain *Globigerina corpulenta Subb., G.officinalis Subb., Istmolithus recurves Defl., Sphenolithus pseudoradians Br.et Wil.*, etc.

Oligocene succession. Within the Garabagh territory two Oligocene stages are reported in the geological structure of Aghjakend (Figure 6) and Hochaz troughs.

In Aghjakend trough, Rupelian Series form the ***Ajidara suite*** (*Planorbella* horizon) which is built by the schisted shales with sandstone interlayers (130-440 m). Its' age is determined based on the numerous fossils of typical microfauna *Globigerina officinalis Subb., G. tumbuli Chal., Caucasina schischkinskayae (Samoil) oligocaenica Chal., Cibicides lobatulas Walk. et Jac.*), ichthyofauna (*Pomolobus curtus Danbt., Vinciguerria obscura Danilt., Merluccius inferus Danilt*., etc.), plants (*Sequoia landsdorffi (Br.) Heer., Quercus neriifolis A. Br., Ginnamomun lanceolatum Heer.*, etc.) and ostracods, as well as multiple fragments of bones and scales.

In Hochaz trough, Rupelian Series are exposed on the left bank of Hakari river to the east of Ishigli and Muradkhanli villages. These deposits are also traced in the river basin of Bargushad, where they first outcrop in the vicinities of Gubadli, and then extend southeastwards for 20-25 km along the river's left and then the right banks, reach river valley of Gilyatagchay (Hakari's right tributary) and plunge towards the Araz in the area of Khojakhan, Mughanli and Vanadli villages, getting covered by the alluvial-proluvial rocks of Lower Pleistocene. On the right riverbank of Gilyatagchay, bottom part of the Rupelian section is represented by 80-120 m thick alternation of argillites and sandstones with blocky conglomerate-breccias that unconformably overlie the Middle Eocene Deposits, and its' upper part is built by 450-800 m thick strata of sandstones, tuffaceous sandstones, tuffs, microfragmental conglomerates and shales **(*Mughanli suite*)**. Layer of basal conglomerates disappears from the section in the north. Resultantly 230-340 m thick strata becomes traced in the surroundings of Gubadli, built by the tuffaceous sandstones, sandstones, siltstones, shales, gravelites, conglomerates and sometimes various limestones, containing the interlayers of brown coals and gypsum. The suite's deposits contain typical fossil mollusks, including *Lentidium donaciforme Nyst., Corbula (Lenticorbula) sokolovi slussarevi Merkl., Astarte trigonelloides Merkl. et Gontsch., Cardium cingulatum Goldf., Area sandbergeri Desh., Loxoconcha tunicata Mand., Cutherura plançıda Mand., Trachyleberis nativa Mand., Nonionella azerbaidjanica plana Chal., Rotalia bessariformis Chal.*, etc.

Chattian stage of the Upper Oligocene is constituted by 700-720 m thick ***Naftalan suite***, which is occurring within the Aghjakend trough. Basal portion of the section comprises the iron oxidized and gypsified shale containing marlstones. These strata are overlaid by the successive layers of sandstone-conglomerates. In Zeyva valley, the suite is consisting of conglomerates, gravelites and sandy shales in the base, and thick layer of shales in the upper portion of the section. Described sediments contain following typical fossils: *Pectunculus obovatus Desh., Astartekickxi Nyst., Balbylonia caronis Brongn., Cassidaria buchi Boll., Melanopsis callosa Braun., Lentidium elongatum Sandb., L. lamberti Cossm., L. georgiana Zot., Ostrea callifera Lam., Pleurotoma duchastelli Nyst., Tornatella simulata Soland., Typhis cuniculosus Nyst., Neritina fluvioiatilis L.*, etc.

In a buried southeastern margin of the Hochaz trough (Diridagh area on the left riverbank of Araz), there is the ***Khudaferin suite*** (Figure 7) composed of about 650 m thick alternation of medium and coarse-grained sandstones, tuffaceous sandstones, shales, gravelites and conglomerates. Age of the section is established as Upper Oligocene based on a presence of typical fauna fossils of *Glycymeris obovatus Lmk., Cordiposis incrassata Sow., Panope heberti, Lentidium lamberti Cossm., Babylonia caronis Brongn., Cassidaria buchi, Natica hantoniansis Pilk., Globigerina bulloides, Pseudohastigerina micra, Bulimina pupoides,* etc.

According to a drilling data produced in the northeastern vicinities of Aghdam, in Garabagh lowland, the Maykopian Series (400-500 m) contain thick layer of basal conglomerates in its' basement and is overlaid by the **Giyasli suite** built by shales, sandy shales and muddy limestones with fauna fossils of *Hastigerina cf. micra* and *Caucasina locaenica*. Within the structure of Pre-Araz plain, faunistically justified Upper Maykopian Series with similar lithofacies have been revealed by the boreholes. Top of these 500 m thick uccession is found at a depth of 550-1075 m.

Figure 6. Outcrop of the Maykopian Series in the Ajidara area (Goranchay river basin)

Figure 7. Outcrop of the Oligicene sediments in the Araz river basin near the Khudafarin reservoir (southern slope of the Diridag mount)

Neogene system

Neogene succession is exposed in the northeast of the region under study (Aghjakend trough), in the southeastern subsided part of the Lesser Caucasus (Miocene), and on the Garabagh volcanic plateau (Upper Miocene and Pliocene). **(**Azerbaijanin geologiyası, 2015; Alizadeh et al., 1959; Geologiya Azerbaijana, 1997, 2007; Geologiya SSR, 1972; Shikhalibeyli, 1964**)** and geological surveys **(**Abdullayev, 1965; Gasanov, 1981; Gasanov, Garalov, 1994; Gasanov et al., 1987; Ismailov, 1973**)**. In Garabagh lowland, these deposits have been revealed by drilling below the Quaternary continental sediments.

Miocene sedimentary complexes are exposed in the Aghjakend trough, as well as in the Diridagh area on the left bank of the Araz river (surroundings of Hasanli and Mashanli villages of Jabrayil district), where they conformably rest on the Upper Oligocene succession. Upper Miocene is represented by a volcanic complex observed in the upstream of Tartar, Tutgunchay and Hakari rivers (Kalbajar superimposed depression). Upper Miocene deposits were also revealed by drilling at different depths in Ganja, Garabagh and Mil lowlands.

In the lowland part of Garabagh, ***Lower Miocene*** deposits were discovered in Gulluja-Beylaghan, Aghdam, Duzdagh and Sarygamysh areas. Mudstones of **Sakaraulian regional stage** belong to a faunistical zone of *Neobulimina elongata*. Shales also contain fossils of *Bulimina tumidula Bogd., Virgulinella pertusa Reuss., Elphidium kvesanensis Artchv., Cibicides stavropolensis Bogd.,* etc.

Mudstones of **Kotsakhurian regional stage** do not contain microfauna, and they're therefore named as the "microfauna-free sediments".

In a transition zone between the Aghjakend trough and the Middle Kur depression, the whole Lower Miocene section is exposed between Zeyva and Shafag villages in the river valley of Goranchay.

Caucasus regional stage is represented by up to 150-160 m thick strata of shales interbedded with marls **(*Zeyva suite*)**, which is conformably overlaid by the Upper Maykopian section.

Sakaraulian regional stage is represented by 60-80 m thick alternation of fine and medium-grained sandstones with shales **(*Shafag horizon*)**. The horizon's age was determined according to a presence of rich mollusk fauna (*Laevicardium cingulatum Goldf., Parvicardium abundans Liv., Lenticorbula helmerseni Mien., Lucinoma ustjurtensis (İlyna, 1953), Bathytoma crenata crenata Nyst.*, etc.) and multiple plant fossils (*Cinnamomum lanceolatum (Ung.) Heer., Myrtophyllum sp., Litsea sp., Magnolia sp., Apollonias sp., Lauraceae gen., Leguminosae*, etc.) in its' section. Finally, **Kotsakhurian stage** is represented by the ***Garagoyunlu suite*** built by 102-130 m thick strata of jarosite shales with thin interlayers of microgranular sandstones. Shales contain various fauna and plant fossils.

In the Hochaz trough's southeastern termination (Lower Araz structural zone), the Lower Miocene deposits form the ***Diridagh suite*** which is reported on the left bank of the Araz river (Diridagh area). This succession gradually overlaps the Upper Oligocene rocks, and is composed of 350 m thick alternating thin sandstone and shalestone beds that contain marly, sandstone and ferrous concretions. Further to the northeast in Hasanli village's vicinities, upper portion of the section contains 145 m thick strata of pebbly fine-grained sandstones with brecciated conglomerates recorded in the top. The shale and siltstone strata that were revealed by drilling at a depth of 200-210 m in the Aghdam town's vicinities, contain typical Lower Miocene foram *Neobulimina elonqata*.

Outcropping only in Diridagh area on the left riverbank of Araz, ***Middle Miocene*** is represented by all of its' regional stages in the geological section of Garabagh. ***Tarkhanian regional stage*** is represented by 80-90 m thick ***Khalafli suite*** built by the layers of sandy shales with interlayers of sands and sandstones. The suite's sandstones contain fossils of *Ostrea lamellosa Brocc., O. digitalina Dub., O. lamellosa Brocc., Grassostrea gryphoides Schloth., Gr. gryphoides angustata de Serr., Gr. gryphoides Bast., Cordiopsis islandicoides Lmk., Globigerina ex gr. tarchanensis Subb. et Chutz., G. bulloides Orb., Florilus boueanus Orb.*, etc., as well as spicules, fishes and balanuses.

Tarkhanian deposits of the Yevlakh-Agjabadi trough are revealed by deep wells within the areas of Duzdagh, Shirvanly, Agjabadi, Beylagan and Sovetlar. By well logging characteristics they do not differ from Chokrakian succession, and composed of shales. In well № 10, their thickness makes up 25-30 m.

Chokrakian regional stage (Diridagh area) is represented by the ***Hasanli suite*** built by 95-140 m thick alternation of non-cabonate shales, calcareous medium-grain sandstones and conglomerates. The suite's sandstones contain fossils of *Congeria sandbergeri (Andrus.) Lask., Turritella gradata Menke in Hoem., T. terebralis Lamk., T. atamanica Boc., T. turris Bast., T. (Haustator) desmareshana Bast., T. vermicularis Brocc., T. bicarinata Eichw., Cerithium deforme Eichw., Loripes dujardini Desh., Parvicardium hispidiforme David., Cultellus probus Merkl., Donax natjurus Gat.*, etc.

Within the Middle Kur depression (areas of Duzdagh, Shirvanly, Agjabadi, Beylagan and Sovetlar), Chokrakian deposits are also represented by their deep-water lithofacies. Their thickness increases from flanks towards center of the depression, reaching 250 m in Duzdagh area. Chokrakian regiostage deposits are characterized by large content ancient plans' farina.

Karaganian regional stage in Diridagh area (Lower Araz structural zone) is represented by 130 thick ***Mashanli suite*** of shales with sandstone interlayers, containing fossils of *Spaniodontella, Otolithus (Rhombus) corius Chal., Discorbis arculus Chutz., Quinqueloculina consobrina Orb.*

In the interior part of the Middle Kur depression deposits of the Karaganian regiostage are developed in the areas of Barda, Agjabadi and Sovetlar. Their sections contain almost no sandy interlayers. Rare and thin (0.1-0.3 m) interlayers are only detected in sections of Duzdagh, Shirvanly (90-115 m) and Beylagan (50 m).

Finally, **Konkian regional stage** is composed of freshwater facies forming 40 m thick ***Alikeykhali suite*** comprised of alternating sands and shales (Diridagh area). Sandstones in the suite's top contain fossils of *Mytilaster incrassatus Orb., Dorsanium duplicatum Sow., Hydrobia kubanica Zhizh., Mactra basteroti konkensis Sok., Ervilia pusilla trigonula Sok., Bornea ustjurtensis Eichw*. Maximal thickness in the Diridagh area exposed Middle Miocene complex is approximately 400 m.

Upper Miocene complex is observed in the high altitude mountains and Pre-Araz part of Garabagh. In the Diridagh area of Lower Araz structural zone, the complex is represented by the freshwater-continental facies of its' Sarmatian substage, which form 115 m thick ***Chaymakhchaylag suite*** of shales with sandstone interlayers. The suite conformably continues the and-shale section of Konkian regional stage. Similar Series are present in sections revealed by multiple boreholes drilled across the pre-Araz and Garabagh lowlands.

Within the Kalbajar trough's structure, double-layered Upper Miocene volcanics are reported in the Eastern Goycha, Saribulagdagh and Mikhtokan ridges (Figure 8). Lower portion of the **Upper Sarmatian** succession forms the ***Agjagyz suite*** of medium and alkaline volcanics, e.g. andesites, dacites, liparites, liparite-dacite flows and their tuffs and tuff-breccias (10-520 m). Upper portion together with **Meotian** and **Pontian** deposits constitutes 100-120 m thick ***Basarkechar suite*** composed of megaplagioporphyry andesites, andesidacites, rhyodacites, rhyolites, quartz latites and their pyroclasts.

Pliocene succession. Within the region's boundaries, Pliocene Series is represented by sedimentary and volcanic facies of the Upper Akchagyl regional stage. As proven by the drilling data, in Pre-Araz and Garabagh lowlands, marine Akchagylian sediments underlie Quaternary continental molasses, forming the ***Arazbari suite*** composed of 230-480 m thick alternation of shales, sands, sandstones, sometimes gravels and conglomerates. Same-aged volcanic complex forms 550-600 m thick ***Ishigli suite*** (Figure 9) of andesites, dacites, trachytes, liparite-dacites, liparites and other lava flows. These rocks are composing the peaks and the slopes of Boyuk and Kichik Ishigli, Gyzylboghaz, Jangurtaran, Kiliseli, Gilijdagh, Garadagh, Chobanbatandagh, Alagollar and several other mountains (550-600 m).

Figure 8. Outcrop of the Upper Miocene deposits at the Saribulag ridge (interfluve of the Tartar and Tutgunchay rivers, Kalbajar region)

Figure 9. Outcrop of the Upper Pliosene sediments at the Gizilbogaz ridge located within the Garabagh volcanic plateau

In the lowland part of Garabagh, faunistically characterized sections of marine sediments are observed in the Naftalan region (to 300 m), near the spring Gazanbulag (145 m), in Ajidara (120 m), in the villages of Gashalty (90 m) and Tapgaragoyunlu (78 m). In the bearing section of the Naftalan region, the largest part of the Lower Akchagyl is discovered by prospecting drilling. According to the drilling data, the Lower Akchagyl is represented by shales with sand, sandstone, and shelly limestone. These rocks contain mollusks *Mactra subcaspia*, *Clessiniolla sp*, *Microfauna*, *Cassudilina grassa*, *Leptocythere gubkini*, etc. The thickness of the Lower Akchagyl is 100-120 m. The outcropped Lower Akchagyl has thickness of 27 m, and is represented with the alternation of sandy shales with sand layers, volcanic ash (2 m). Here following mollusks were found: *Mactra garabugazica*, *Ceras-toderma dombra*, *Potamides* (*Pirinella*) *caspius*, etc. The total thickness of the Lower Akchagyl in the sections of Naftalan is accepted within the limits of 127-147 m. The lower portion of the Upper Akchagyl is composed of alternating sands, sandy shales with the layers of shelly limestone and volcanic ash and contains the rich fauna of mollusks: *Mactra venjucovi*, *Avimactra aviculoides*, *Cryptomactra carinatacurvata*, *Cerastoderma sulini*, *Avicardium nikitini*, *Potamides* (Pirinella) *levis*, etc. The upper part of the Upper Akchagyl is represented with the shales, sands, sandstones, detritus limestone and the layer of micro conglomerate characterized small shells of marine Mactra subcaspia, Cerastoderma dombra and with the presence of solt-water Dreissena, fresh-water-Pyrgula Naphtalanica, Avardaria andrussovi and other mollusks. The thickness of the Upper Akchagyl is 163 m. Incomplete, but faunistically, richly characterized sections Akchagyl are observed in Ajydara (118 m), by Gazanbulag spring (140 m), in the areas Gashalty (90 m) and Tapgaragoyunlu (78 m).

The Akchagyl deposits are revealed in numerous wells in the right bank of the Kur river – from the Gazakh region to Beylagan. These are represented in the lower part by shales, sands, sandstone, shingles and sometimes – conglomerates. Along the whole section sandy shells containing mollusks were observed: *Cerastoderma dombra*, *Mactra subcaspia* and *M.garabugazica*.

Quaternary succession

Represented by all Series (Eopleistocene, Pleistocene and Holocene), Quaternary system is mostly occurring across the region's low-mountain, piedmont and lowland areas (continental molasse facies), as well as in the considerable part of Garabagh volcanic plateau (volcanic facies). (Azerbaijanin geologiyası, 2015; Abdullayev, 1965; Alizadeh et al., 1978; Akhverdiyev, 1970; Gasanov, Garalov, 1994; Geologiya Azerbaijana, 1997, 2007; Geologiya SSR, 1972; Shikhalibeyli, 1964).

Eopleistocene succession. Represented by the Absheronianian regional stage, Eopleistocene succession is occurring as a narrow line that extends along the left bank of the Araz river. Also it is reported in the catchment area of the Bargushad, Hakari rivers and its' right tributary Zabukhchay. Lithological composition of this regional stage is characterised by the lateral facies variability from the northwest towards the southeast.

On the slopes of Garabagh volcanic plateau and Hakari river's catchment, the regional stage is constituted by the ***Hakari suite*** composed of the mixed alluvial, deluvial, proluvial, fluvioglacial, lacustrine and pyroclastic rocks. Along the right riverbank of Zabukhchay (Figure 10), the suites enters into a contact with Ishigli suite's deposits, and becomes mainly built by volcanic ash and pumice tuffs, tuff-breccias, tuff bombs and lapillies as well as interlayers and lenses of volcanic gravel (100-120 m). Role of pyroclastic rocks reduces with distance, and some other parts of the suite become built by complexly interrelated layers, interbeds and lenses of shales, sands and gravels, sometimes containing volcanic ash and dolomite interlayers (30-200 m). Upper section successions of the suite is presumably dated as Lower Pleistocene.

Another Eopleistocene succession extends from southwest towards northeast along the banks of the Araz river, where it forms 200-250 m thick ***Araz suite*** built by a thick strata of conglomerates, gravels, sands, shale loams and shales, containing the volcanic ash beds (Figure 11). Lateral transition zone between Hakari and Araz suites is buried under the Pleistocene deposits. The section's shales and shale loams contain typical freshwater gastropods, e.g. *Buthinia aff. tentaculata, Melania ex gr. rhodensis, Pisidium cf. amnicum, valvata sp*. According to geological planning and drilling information, the northeastern parts of pre-Araz and the Garabagh lowlands do not contain any pyroclastic rocks in their sections. In this area, the suite is mainly built by 160-260 m thick alternation of sands, grey sandstones, gravels and shales, sometimes limestones and marls. The section's limestones contain fauna fossils of *Helox (Helicella) aff. criceturum* and *Planorbis margaritatus*.

Figure 10. Outcrop of the Eopleistocene sediments at the right bank of the Zabukhchay river (the right tributary of the Hakari river)

Figure 11. Outcrop of the Eopleistocene sediments at the left bank of the Araz river, southeastward of Jabrail town

The sections of Absheronian sediments in lowland part of Garabagh are classic both for Azerbaijan and for the whole South Caucasus. Their outcrops can be observed within the Boz-dagh, Duzdagh and Garaja folds. Faunistically they are represented by the marine fauna with fresh-water and in some places – by semi fresh-water forms. They have the basal conglomerate, and can be characterized by the occurrence of all three subregiostages in the section: the low, the middle and the upper. The low subregio-stage (90-180 m) consists of shales interbedded with sands, sandstones. The middle subregio-stage (100-380 m) consists of mudstones with thick sand interbeds. The upper subregiostage (up to 500 m) is composed of alternating con-glomerates, sandstones and ashes.

Pleistocene succession is composed of the continental molasses (alluvial-proluvial, deluvi-al, deluvial-proluvial, fluvioglacial sediments) and volcanic products. The Pleistocene success-sion is comprised of the Turkanian beds, Baku-nian stage and Mingachevir beds (Lower Pleis-tocene), Khazarian and Lower Khvalynian (Middle Pleistocene) and Upper Khvalynian (Upper Pleistocene) stages.

Turkanian beds are not widely occurring in Azerbaijan and characterized mainly by the fresh-water complex of fauna. Based on such faunal assemblage they had been recognised as a separate stratigraphic unit. In sections of Duz-dagh mount and Garaja in the lowland part of Garabagh (Figures 12, 13), the Turkanian sedi-ments are composed of dark-grey, greyish-brown shales, silts, crossbedded sandstones and sands. Their thickness is about 35-40 m.

Bakunian stage. The rocks of this age dif-fer from the Turkan sediments by the occur-rence of a great amount of sandy-silty fragmen-tal and shelly limestones. The faunal complex is characterized by the presence of the follow-ing marine mollusks and ostracods: *Didacna parvula* Nal., *D.catillus* Eichw, *Dreissena pol-ymortha* (Pal), *Dr.rostriformis* Desh., *Micro-melania caspia* Eichw and *Theodoxus pallasi* Lindh. Here three complexes of ostracods are distinguished: (1) *Caspiocypris filona* (Schw.), *Loxoconcha endocapra* Shar., *Leptocythere martha* (Liv), *L.lunata* Step. And *L.aff. resupi-na* Step., (2) *Caspiola liventalina* (Evlach.), *Leptocythere medicata* Step., *L.pondoplicata* Step., *Xestoleberis ementis* Mand, and (3) *Cas-piola gracilis* (Liv), *Bacunella dorsorcuata* (Zal), *Loxoconcha gibboida* Liv. and *Lepto-cythere bakinica* Scheid. The Upper Bakunian substage is confirmed by the occurrence of mollusk fauna: *Didacna rudis* Nal., *D.carditoides* Andrus., *Dr.polymortha* (Pall.), *Dr.ponto-caspia* Andrus., *Clessiniola triton* (Eichw.), *ostracod-Pseudoctenocypria asiatica* Schn., *Bacunella dorsuarcuata* (Zal.) and *Leptocythere aff.referata* Step. Stratotypical section of Bakunian stage is the "Bakunian stage" mount in the Absheronian peninsula. In lowland part of Garabagh the deposits of Bakunian age occur in the Bozdagh ridges, Duzdagh mount and Garaja area. These sediments are more rudaceous comparing to the Absheronian peninsula. Eastward grain size decrease trend is observed. On the whole, the deposits (120-140 m) consist of grey, greyish-brown shales, coarse-grained sandstones including shingles, conglomerates and volcanic ash.

Figure 12. Duzdagh section

Figure 13. Garaja section

Lower Pleistocene (Bakunian regional stage) sediments are also developed in the catchment area of Hakari (middle and upper reaches), Bargushad, Okhchuchay and Basitchay rivers, where they are consisting of 25-30 m thick alluvial-proluvial beds (shale loams, sands and gravels) which unconformably overlie Araz and Hakari suites and even older complexes. In the Pre-Araz lowland's southwest, basal part of the section contains layers of volcanic ashes and pumice. On Garabagh volcanic plateau and in the river basin of Ildirimsuchay (Hakari's right tributary), Lower Pleistocene is represented by 10-130 m thick sheet **(*Ildirimsu suite*)** of andesibasalt lava flows with volcanic ash beds (Figure 14).

Mingachevir beds. These sediments contain *Didacna eulachia* Bog. first time described by V.V.Bogachov in the Mingachevir region. (Bogachev, 1926) Later on P.V.Fyodorov recognized the analogue beds with *D.eulachia* Bog in Turkmenia and gave them name *Urundjik beds.* (Fedorov, 1957) He assigned a rank of horizon to these sediments in the Quaternary stratigraphic chart. However, some authors placed the Mingachevir beds in the upper Bakuniannian substage. The shape of *Didacna eulachia* shells have the both features of catiloid (elongated) forms of Bakuniannian age and the trigonoid (triangula) shells of the Khazarianian *Didacna*. This supports the transitional position of the *Didacna eulachia* beds (Mingachevir beds) between the Bakuniannian and Khazarianian stages and the validity of these sediments in the Azerbaijan Quaternary chart. Lithologically they are represented by coquinas, sands, gravel-shingle material and in the fold limbs- by sandy shales. The ash beds are also observed (Duzdagh mount).

The biggest thickness 100 m was recorded in the Duzdagh mt. The following faunal assemblage (besides *Didacha eulachia* Bog) were described: *D.pravoslavlevi* Fed., *D.karelini* Fed., *D.mingetschaurica* Vekil; *Ostracoda-Loxoconcha liventali* Scheid., *L.endo-capra* Schar., *L.kalickyi* Lub., *Leptocythere periculosa* Step., *L.posteriobiplicata* Step., *L.pondoplicata* Step., *Paraleptocythere caspia* (Liv), *Trachileberis pseudoconvexa* (Liv) and others.

Khazarian regiostage is usually composed of coarse alluvial-proluvial sediments, and overlaps the Lower Pleistocene succession of Garabagh and Mil lowlands (100-120 m). Well preserved outcrops of the Middle Pleistocene volcanic-sedimentary succession – the ***Khojakhan suite,*** are observed in the interfluve of Bargushad and Hakari rivers. In Khojakhan village's vicinity (right bank of Hakari river), the suite contains 170-210 m thick strata of tuff-breccias, tuff-conglomerates, andesites and andesitic-basaltic lava with sandstone and shale interbeds. To the northwest of this area, in the basins of Zabukhchay and Ildirimsuchay rivers, the same-aged volcanics overlie Hakari suite and old river terraces, and composed of tuff-breccias, tuff-conglomerates, ash tuffs and andesite lava flows with shale loam interlayers (100-400 m). The upper portion of the volcanic cover is dated as the Upper Pleistocene.

In the northern area of the Garabagh lowland, the Khazarian succession is characterized by the sand material with conglomeratic beds. They consist of greenish-grey, yellowish, strongly sandy shales, sands, sandstones, pebbles, and conglomerates.

Khvalynian regiostage. In Garabagh and Mil lowlands these sediments are consisting of 50-200 m thick alternating alluvial-proluvial gravels and loams accumulated in alluvial fans and debris flows. Khvalynian sediments oftenly form river terraces. Analysis of available fauna enables to clearly reveal two substages: Lower Khvalynian belonging to the Middle Pleistocene, and Upper Khvalynian considered as the Upper Pleistocene. The diagnostic fauna complex of the Lower Khvalynian substage include *Didacna parallella* Bog., *D.praetrigonoides* Nal. et Anis. In the Upper Khvalynian substage the *Didacna praetrigonoides* Nal. et Anis and *D.trigonoides* Eichw. are recognized.

The Lower Khvalynian sediments are mostly encountered in the Kur depression. The farthest west locality is the Mingachevir area. Here an abrasion-accumulative terrace at 30-35 m altitude is dated as the Lower Khvalynian. At present, this terrace is submerged by the Mingachevir water reservoir.

Figure 14. Outcrop of the Lower Pleistocene sediments in the upstream area of the Zabukhchay river (the right tributary of the Hakari river)

Deluvial and deluvial-colluvial sediments consisting of gravels, loam and shales are widely developed in the slopes of the Lesser Caucasus.

In Pre-Araz lowland and in the mountain area, the complex is represented by 5-30 m thick strata of deluvial loams, loamy sands and shales.

Holocene succession **(*Yeni Khazar stage*)** of Garabagh is represented by a) alluvial and alluvial-proluvial sediments; b) deluvial-proluvial and eluvial-deluvial sediments accumulated in dry valleys and mountain slopes; c) landslide masses; and d) travertines formed from the active mineral springs. The thickness varies between 1-2 and 20-30 m. Fluvioglacial sediments of the last Ice Age have been preserved in some high elevated places of Garabagh volcanic plateau. Also, the andesite-containing Series of young tuffs, tuff-lavas, tuff-breccias and lavas are surrounding the volcanic centers.

Lacustrine sediments have sporadic occurrence in the Kur-Araz lowland where they cover areas of currently existing and almost completely dried up lakes. They are represented by alternating thin layers of shale and silt containing lenses of fine-grained sands. A color of the sedi ments is dark and bluish-gray. A specific charac teristic is an abundance of plant debris. Thickness of the deposits does not exceed 5-7 m.

Lacustrine-alluvial and lacustrine-salt-marsh sediments are widely recorded at the border between the Shirvan plain and old Kur river channels in the Mil plain. Lacustrine-alluvial sediments are consisting of silts, heavy loams and shales, and lacustrine-salt-marsh – by salty silts, sandy loam, loam with lenses and thin layers of various salts. Their thickness does not exceed 2-5 meters.

Alluvial sediments are widely occurring along the Kur and Araz rivers and their tributaries. They compose low accumulative terraces with relative elevation from 1.5-2.5 to 20-25 m. Their lithological composition is caused by the geomorphological setting. Alluvium of the mountain rivers is composed of gravel with boulders, sand and silt aggregates. Alluvium of the Kur and Araz rivers comprises sands, sandy loams, loams and shales. A thickness of the modern alluvial sediments varies from 10 m to 20-30 m, and increases downstream.

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QARABAĞ. SRTATİQRAFİK ESSE
Oçerk II: Kaynozoy

T.N. Kəngərli, Ş.Ə. Babayev, H.Ə. Allahverdiyeva

Məqalədə Dağlıq və Düzən Qarabağın geoloji quruluşunda iştirak edən Paleogen-Neogen maddi komplekslərinin litoloji və stratiqrafik xüsusiyyətlərini daha yaxşı anlamaq məqsədilə əvvəlki illərin geoloji planalma və elmi-tədqiqat işlərinin nəticələri ümumiləşdirilmişdir. Bölgənin Mezozoy stratiqrafiyasına həsr olunmuş əvvəlki məqalə, hazırkı tədqiqat çərçivəsindəki məlumatlar Azərbaycanın Stratiqrafik koduna əsasən yenidən nəzərdən keçirilmiş və təfsir edilmişdir. Üstəlik, stratiqrafik bölmələrin təsviri, habelə yerli stratiqrafik vahidlərin (lay dəstələrinin) eyniləşdirilməsi və paleontoloji əsaslandırılması Ümumi və Beynəlxalq Stratiqrafik Cədvəllər əsasında həyata keçirilmişdir.

КАРАБАХ. СТРАТИГРАФИЧЕСКОЕ ЭССЕ
Очерк II: Кайнозой

Т.Н. Кенгерли, Ш.А. Бабаев, Х.А. Аллахвердиева

В данной статье в целях лучшего понимания литологии и стратиграфии палеоген-неогеновых вещественных комплексов Нагорного и Равнинного Гарабага обобщены материалы геологического картирования и результаты научно-исследовательских работ предыдущих лет. Приведенные материалы были подвергнуты ревизии и обобщению на основе Стратиграфического кодекса Азербайджана. Кроме того, описание стратиграфических подразделений, а также идентификация и палеонтологическое обоснование местных стратиграфических единиц (свит) проводились на основе действующих Общей и Международной Стратиграфических Шкал.

OLIGOCENE RECORDS OF THE CLIMATE AND SEA LEVEL CHANGES IN THE SOUTH-CASPIAN BASIN: INTEGRATION OF LITHOFACIES AND DIATOM ANALYSES

We integrated the lithostratigraphic, biostratigraphic (diatom analysis) data from the well documented continuous Oligocene (Lower Maykopian) succession cropping out in the Azerbaijan part of the South Caspian basin, and correlated them with the oxygen isotopic composition in the Oligocene benthic foraminifera shells, as well as the Global Ocean and the Eastern Paratethys level fluctuation curves.

This article displays the variability of diatom algae associations throughout Oligocene, and emphases on the link of these floral complexes changes with the climatic variations and consequent sea level fluctuations reflected in the corresponding depositional environmental changes. Based on paleoenvironmental analysis of the diatom assemblages the bionomic conditions' variations in the Early Maykopian (Oligocene) basin were recorded. Neritic and littoral species of diatoms are frequently observed in the studied section.

The distribution of the thermophile and cryophile diatom species throughout Oligocene succession enabled distinguishing of warming and cooling stages in the Oligocene history of the Caspian segment of the Eastern Paratethys, and correlate them with Maykopian Sea level fluctuations. The predominance of the marine diatom forms in the basal and top portions of the studied succession is well explained by the more warmer climatic conditions established this time in the Oligocene basin.

The recorded facies heterogeneity throughout the studied Oligocene succession is well linked to the climatically forced sea level changes.

The article also provides the ground for correlation of the Eastern Paratethys Maykopian Sea level with Global Ocean level curve.

Keywords: Lower Maykopian (Oligocene) sediments, facies variability, Maykopian Sea level change, diatom algae, cooling - warming climatic stages

E.G. Aliyeva

Institute of Geology and Geophysics,
Azerbaijan National Academy of Sciences
E-mail: e_aliyeva@gia.ab.az

N.T. Karimova

Geology and Geophysics Institute,
Azerbaijan National Academy of Sciences
E-mail: nayila_kerimova@mail.ru

H.A. Allahverdiyeva

Azerbaijan National Academy of Sciences,
Institute of Geology and Geophysics,
H. Cavid ave., 119, Baku, AZ1143, Azerbaijan
E-mail: hallahverdiyeva63@gmail.com

Introduction

Eocene-Oligocene transition is one of the important time intervals in the global climate change in the geological past (Miller, 1992; Zachos et al., 2001; Miller at al., 2008; Zanazzi et al., 2015). However, in the area of the Caspian Sea this dramatic changes as well as climatic variations in the Oligocene are not understood well. The main reason lies in the lack of benthos fauna, and poor plankton assemblages. In this context the diatom algae represent one of the important groups providing opportunity for paleoenvironmental reconstractions.

The paper is dealing with study of Oligocene succession exposed in Pirakushkul locality in the South Caspian basin, and focused on the climatic variations in the Caspian segment of the Eastern Paratethys throughout Oligocene proved by the recovered diatom complexes changes. The link with global climatic events and World Ocean fluctuations is the main outcome of the article.

Background information

The Lower Maykopian succession (Oligocene) was studied on the southeastern limb of Eastern Jangi sincline located within Shamakhi-Gobustan oil-gas region of the South Caspian basin.

The section was described in the vicinities of Pirakushkul village 500-800 m northward of 41st km of Baku-Shamakhi road, and has a summary thickness of 616.4 m (Figure 1, 2).

Pirakushkul section covers the stratigraphic interval from the base of the Maykopian Series (Khadum horizon) to the contact with the Upper Maykopian. Studied sediments are underlied by the Eocene succession. The contact is clearly seen in the field, and defined based on the biostratigraphic and lithostratigraphic data.

In order to develop a stratigraphic scheme of the Maykopian Series based on the floral assemblages Y. Zaklinskaya (1953 a, b) had summarized data on microscopic studies of the spore-pollen spectrums of the Cenozoic deposits exposed in the Northern Caucasus, Pre-Caspian, Pre-Azov and Volga regions.

Y.Zaklinskaya had identified 4 stages in the floral changes occurred during the Oligocene-Miocene (Zaklinskaya, 1953 a,b):

1. **Stages 1 & 2** correspond to the Lower Maykopian; stage 1 covers the lower horizon - Khadum stage (analogue to Rupelian), and contains *subtropical flora*, and second stage is corresponding to the upper horizons containing *subtropical flora with some forms typical for moderate climate.*

2. **Stage 3** distinguished in the Middle Maykopian, and containing *subtropical forms with significant proportion of moderate* flora.

3. **Stage 4** in the Upper Maykopian includes *moderate climate flora with some subtropical elements* of mixed large-leaved forests.

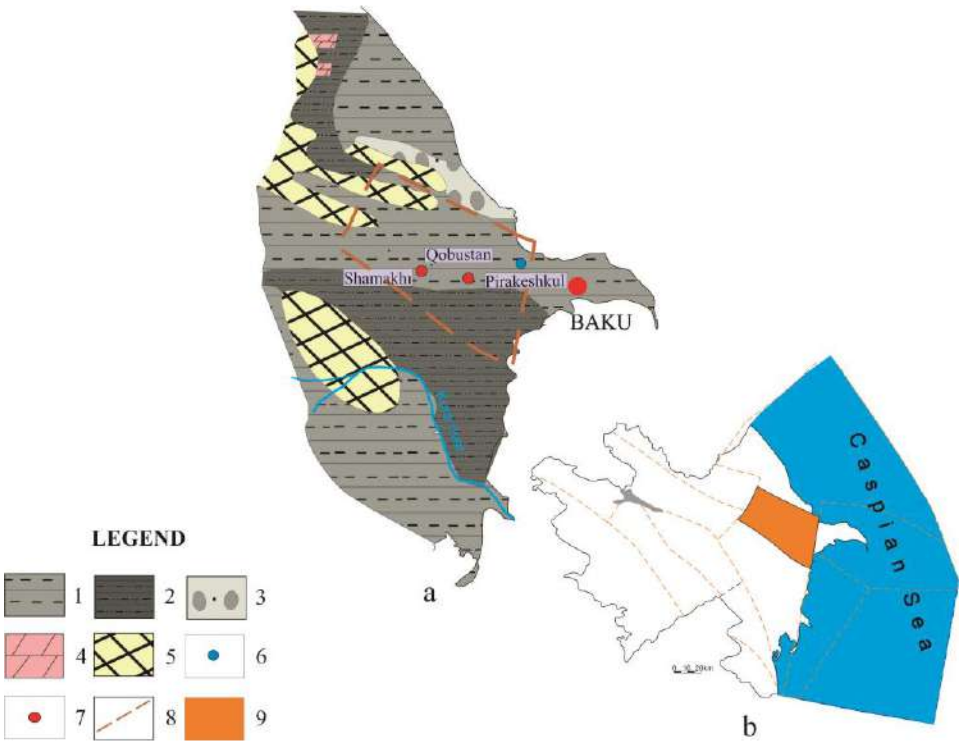


Figure 1. Location map of the Pirakushkul section:
a. Lithofacies map of the Lower Maykopian subseries within the area of the Eastern Azerbaijan**.**
b. Location map of the Azerbaijan segment of the Caspian basins.
Legend: 1 – shalestones, **2** – sandy shales, **3** – conglomerates, **4** – marls, **5** –land, **6** – studied outcrop of the Lower Maykopian sediments, **7** – settlements, **8** – boundaries of oil-gas regions in Azerbaijan, **9** – Shamakhi-Gobustan oil-gas region (Geology of Azerbaijan, 2005)

According to the palynological data two floral stages are identified in the Maykopian sections in the Shamakhi-Gobustan region (Figure 2):

1. Lower Maykopian (Rupelian, Hattian), represented by *subtropical Mediterranean flora with elements of warm-moderate* flora (Bayramova, Tagiyeva, 2009);

2. Upper Maykopian, represented by *subtropical Mediterranean flora with elements of moderate* flora (Bayramova, Tagiyeva, 2009).

Shamakhi-Gobustan region was located at the boundary between the moderate-warm humid, and the subtropical - tropical warm climatic zones of the northern hemisphere. The floral composition underwent seasonal variations and was quite rich (Bayramova, Tagiyeva, 2009).

Material and methods

Pirakushkul section as it was mentioned above is composed of the Lower Maykopian (Oligocene) sediments and located in the vicinities of Pirakushkul village on the southeastern limb of the Eastern Jangi syncline, which is situated within the Shamakhi-Gobustan region of the South –Caspian basin (Figure 1). The total thickness of the Oligocene sediments here is 616.4 m.

The section was measured, and sixteen samples were collected. The collected samples were processed in the laboratory for the diatom analysis. The most samples are characterized by the lack of fauna. However, almost all samples contain diatom algae as well as the sponge spiculas and dinoflagellates of the Tertiary period. The most diatom forms have been identified to a genus. However, in some cases it was possible to define the relationship of diatoms to the certain species.

Lithology and depositional setting of the Oligocene sediments

The Maykopian sediments in the Perikashkul section are divided into two horizons: the *lower horizon* (215 m) composed of the shales, rare sandstone and marl beds, and the *upper horizon* (380 m) consisting of lilac and brown shales interbedded with sandstones containing concretions. Based on the occurrence of plankton foraminiferas *Globigerina wfainalis* Subb., *G.* ex gr. *bulloides*, *Globanomalita micra* (Cole) (Alizadeh, Babazadeh, 1967), 36 m thick Khadumian horizon in the base of the succession composed of shales with the interlayers of yellow sandstones (successions 1 and 2) is distinguished within the lower portion.

SUCCESSION 1. Thickness is 9 m.

Lithology: alternation of laminated grey (1-2 cm) and ochreous (3-5 cm) shales, sometimes containing concretions (average size 16x4 cm). In the lower portion of the Succession 4-5 cm thick layer of fine-grained sandstone is observed.

Microfauna: *Globigerina offcinalis*, *G. bulloides*, *Globanomalina micra*, *Globorotalia* sp.

Dominant spore and pollen genera: *Fagaceae* 36%, *Juglandaceae* 19%, *Taxodiaceae* 4%.

Dominant diatom species: *Actinoptychus undulatus* var. *minor*, *Biddulphia auria* var. *atusa*, *Bacterosira fragilis* Grun, *Melosira sulcate*.

SUCCESSION 2. Thickness - 27 m.

Lithology: monotonous grey laminated poorly carbonated shales with sharp bluish laminas. On the 9th meter from the Succession's base two dolomite beds and one 5 cm thick sandstone layer are recorded. The 4 cm thick basal portion starts with calcareous fine-grained sandstones with the interlayers of jarosite.

Microfauna: *Globigerina off cinalis* Subb., *G.* ex gr. *bulloides*, *Globanomalina micra*.

Dominant spore and pollen genera: *Fagaceae* 34%, *Juglandaceae* 25%, *Taxodiaceae* 5%.

Dominant diatom species: *Actinocyclus ingens* Rattr, *Melosira undulata* sp.1, *Melosira sulcate* var. *siberica*, *Podosira maculata*, *Triceratium* Ehrenberg.

SUCCESSION 3. Thickness is 27 m.

Lithology: Grey to brown from laminated to massive shales. In the mid-section, there is several cm thick layer of fine-grained sandstone containing jarosite and gypsum grains.

Microfauna: not recorded.

Dominant spore and pollen genera: *Juglandaceae* 40%, *Fagaceae* 23%, *Taxodiaceae* 15%.

Dominant diatom species: *Coscinodiscus subsalsus, Melosira undulata* sp.1, *Navicula* sp., *Podosira* sp.

SUCCESSION 4. Thickness is 9 m.

Lithology: Brown, chocolate massive shales containing jarosite.

Microfauna: not recorded.

Dominant spore and pollen genera: *Fagaceae* 28%, *Juglandaceae* 27 %, *Taxodiaceae* 13%.

Dominant diatom species: *Coscinodiscus subsalsus, Coscinodiscus granulosus, Podosira* sp., *Hyalodiscus rossii.*

SUCCESSION 5. Thickness is 36 м.

Lithology: Alternation of light and dark grey from laminated to massive, poorly sandy shales containing jarosite. On the 9th meter from the succession's top the massive fine-grained sandstone is observed.

Microfauna: *Psammospaera fusca*, *Saccammina variabilis*, *S.* aff. *barbaria*.

Dominant spore and pollen genera: *Juglandaceae* 32%, *Fagaceae* 25%, *Taxodiaceae* 12%.

Dominant diatom species: *Biddulphia auria* var. *atusa*, *Cyclotella* sp.4, *Hyalodiscus rossii, Nitzchia panduriformis* var. *delicatus, Thallasiossira praefraga.*

SUCCESSION 6. Thickness is 45 m.

Lithology: Grey, light to dark, very dark laminated (11 cm) and massive shales. Fossil flora is recorded.

Microfauna: not found.

Dominant spore and pollen genera: *Juglandaceae* 36%, *Fagaceae* 28%, *Taxodiaceae* 21%.

Dominant diatom species: *Thallasiossira* sp.1, *Stephanocyclus* sp., *Thallasiossira* native Sheshuk.

SUCCESSION 7. Thickness is 115 m.

Lithology: Massive grey, partly dark, brownish-grey, brown chocolate shales, hard, sometimes chipped or having paper textures, containing nestlike jarosite, bed gypsum and fish remains. Lower portion of the Succession contains interlayers of purple (1.5-2 cm), yellow (1 cm), brown (1.5-2 cm) and dark grey (1-2 cm) shales with dark films between separate layers, and thin sandstone bed.

Microfauna: not reported.

Dominant spore and pollen genera: *Fagaceae* 55%, *Juglandaceae* 22%, *Taxodiaceae* 12%.

Dominant diatom species: *Coscinodiscus subsalsus, Coscinodiscus granulosus, Hyalodiscus laevis, Ploiaria petasiformis* Pant, *Pyxilla* sp., *Thallasiossira* native Sheshuk, *Podosira maxima*, *Podosira* sp.1, *Stephanocyclus* sp., *Polaria* Heiberg, *Thallasiossira* sp.3.

SUCCESSION 8. Thickness is 90 м.

Lithology: Alternation of massive, chip, grey, brownish-grey, almost dark, purple and chocolate shales with thin (2-4 mm) interlayers of yellowish from fine to medium-grained platy sandstones.

Microfauna: *Globigerina* ex gr. *bulloides* Orb., *Saccammina* aff. *variabilis* Bogd., *S. fusiformis* (Williamsson), *S.* aff. *barbaria* (Mjatl.).

Dominant spore and pollen genera: *Fagaceae* 51%, *Juglandaceae* 26%, *Taxodiaceae* 7%.

Dominant diatom species: *Biddulphia auria* var. *atusa*, *Eunotogramma bivittatum* Grun. et Pant, *Synedra parasitica* Hust. var., *Thallasiossira* sp.4, *Pseudopodosira hyalina* Joise.

SUCCESSION 9. Thickness is 63 m.

Lithology: grey (light to extremely dark) and brown, sandy, argillaceous laminated and massive shales. Two cm thick layer of yellow sands is recorded in the mid-section.

Microfauna: *Haplophragmoides* aff. *kjurendagensis* Kosir., *Textularia* aff. *agglutinans* Orb., as well as spheroidal, nodular, lenticular radiolarias.

Dominant spore and pollen genera: *Fagaceae* 48%, *Juglandaceae* 37%, *Taxodiaceae* 4%.

Dominant diatom species: *Bacterosira fragilis* Grun, *Biddulphia* sp., *Thallasiossira* sp.4, *Thalossirothrix* sp.

SUCCESSION 10. Thickness is 9 м.

Lithology: light to extremely dark grey laminated (6-7 cm) shales with massive structure. Bottom of the Succession contains lens (length – 2-2.5 m, thickness in center – 6 cm) of dark-grey and very hard ochreous shales.

Microfauna: *Ammobaculites* aff. *agglutinans* (Orb.), *Triplasia variabilis* (Brady).

Dominant spore and pollen genera: Не обнаружены.

Dominant diatom species: Thalossirothrix sp., Thallasiossira sp.4, *Xantiopyxis umbonata* Grev.

SUCCESSION 11. Thickness is 112 м.

Lithology: light to dark grey, compact chip shales, partly shelly and oxidized. In the middle of the Succession, shales are light with a blue tint, psammitic. The marl concretions and thin jarositic beds are common.

Microfauna: not reported.

Dominant spore and pollen genera: *Fagaceae* 62%, *Taxodiaceae* 16%, *Juglandaceae* 14%.

Dominant diatom species: *Biddulphia auria* var. *atusa, Gyrodiscus radiosus, Nitzchia panduriformis* var. *delicatus, Hyalodiscus* sp.1, *Nitzchia brevissima, Ploiaria petasiformis* Pant.

SUCCESSION 12. Thickness is 0.4 m.

Lithology: yellow fine-grained subhorizontally bedded sandstones.

Microfauna: not found.

Dominant spore and pollen genera: *Fagaceae* 47%, *Juglandaceae* 20%.

Dominant diatom species: *Gyrodiscus radiosus, Synedra ulna.*

SUCCESSION 13. Thickness is 11 m.

Lithology: Grey, brownish-grey and brown massive shales.

Microfauna: not recorded.

Dominant spore and pollen genera: *Fagaceae* 45%, *Taxodiaceae* 24%, *Juglandaceae* 23%.

Dominant diatom species: Thallasiossira sp.1-4, *Denticula praelauta, Gyrodiscus radiosus, Odentella* sp., *Eunotogramma bivittatum* Grun. et Pant, *Podosira maculata.*

SUCCESSION 14. Thickness is 63 m.

Lithology: purple, brown, strongly fractured shales with jarosite thin beds. The Succession contains several up to 80 cm thick layers of platy sandstone, enriched by jarosite. The oval shaped concretions with broken cores are common.

Microfauna: *Fllabellammina* sp., *Ammobaculites* aff. *agglutinans* (Orb.), *Triplasia* aff. *variabilis* Bogd., *Verneuilina* sp., *Spiroplectammina* aff. *morozovae* Maslak..

Dominant spore and pollen genera: *Fagaceae* 29%, *Juglandaceae* 26%, *Betulaceae* 11%.

Dominant diatom species: *Gyrodiscus radiosus, Chaetoserriis* sp., *Eunotogramma bivittatum* Grun., *Hantzschia amphioxis* var. *intermedia Grun., Denticula praelauta.*

The shelf depositional environment is dominating in the Pirakushkul section that is clear from both lithofacies associations and diatom assemblages. The thin intervals of accumulation of sand material are related to the large storm events affecting sedimentation on the proximal portion of the shelf. Such facies shifts from the outer shelf to the inner shelf were recorded almost in all successions, and are related to the Sea level fall as it will be shown in the next chapters of the paper. The most proximal environment in the studied section is observed in the succession 8, and is represented by the alternating shales and mm-thick sandstones deposited in the transition zone facies.

Diatom assemblages recovered from the Oligocene sediments

Almost all rock samples collected in the field contain diatomic algae, as well as the sponge spiculas and dinoflagellates of the Tertiary period. Diatom complex of the Pirakushkul section is composed of 61 taxons belonging to 38 species and 32 genera. These diatom assemblages are classified as marine inhabiting the oligotrophic waters. As to their geographic cposition, most species are characterized as cosmopolitan organisms.

Each slide contains 97-103 diatom shells, and from 7 to 14 forms belonging to separate species. It means that the number of diatom algae identified in the slides is not high, that can be explained by the following reasons:

- contamination of the basin by the hydrogen sulphide that is widely known;
- poor resistance to solvent

Most frequently recorded (20-47 individuums in each slide) are the diatoms belonging to a genus *Thallasiossira* – marine flora representatives that are dominant in the upper portion of the section.

Mainly neritic and littoral forms of diatom algae are reported along the section. Those are *Ploiaria petasiformis* Pant, *Hantzschia virqata* Grun, *Synedra parasitica* Hust. var., *Grammaphora angulosa* Ehr., *Podosira maculata*, *Xantiopyxis umbonata* Grev., *Hyalodiscus laevis*, *Nitzchia panduriformis* var. *delicatus*, *Thalossirothrix* sp., as well as typically neritic species *Bacterosira fragilis Grun*, *Nitzchia panduriformis var delicatula*, *Gyrodiscus radiosus.*

Less common are the freshwater forms, e.g. *Melosira udulata* sp.1, *Achnanthes minutissima* var. *crypta*, *Coscinodiscus subsalsus*, *Hyalodiscus scoticus*, *Rhaphaneneis maeotica* (Milov) Sheshuk, *Odentella* sp. and *Cyclotella.* Limited number of freshwater species is observed in samples # 11-16.

Bottom and top layers of the section are characterized by the large marine-type diatom assemblages. Their number is slightly reducing towards the mid-section (Samples 4-9). Upward the section from Sample 9, marine diatoms become dominant again.

Brackish water species (*Hantzschia virqata* Grun., *Hantzschia amphioxis* var. *intermedia* Grun., and *Nitzchia panduriformis* var. *delicatus)* are recorded all over the section in different percentage. Growth in their amount begins from the middle of the section and continues upward (samples #5-16).

The section contains typical representatives of the Tertiary diatoms *Actinocyclus ingens* Rattr., *Melosira undulata*, *Hualodiscus rosii*, *Pseudopodosira hyalina* Joise, *Actinoptychus undulatus* var. *crypta*, *Navicula hennedyi* var. *luxuosa*, *Synedra parasitica* Hust. var., *Stephanopyxis* sp., *Ploiaria petasiformis* Pant. Some of these species exist until the present time. Several other forms are also recorded all over the section (*Ploiaria petasiformis* Pant, *Actinoptychus undulatus* var. *crypta*, *Eunotogramma bivittatum* Grun. et Pant, *Xanthiopyxsis umbonata* Grev.). All these species belong to a marine flora. *Actinoptychus undulatus* var. *crypta* is known both from the Tertiary deposits and the Upper Eocene of the Western Siberia.

Most widely developed forms of plankton diatoms are *Eunotogramma bivittatum* Grun. et Pant, *Actinocyclus ingens* Rattr., *Thallassiosira* nativa Sheshuk.

Thermophyle diatoms are represented by the following genera: *Hualodiscus rosii*, *Hyalodiscus laevis, Melosira polaris, Melosira sulcata, Melosira undulata* sp.1, *Podosira maculata*, *Triceratium Ehrenberg*, *Triceratium grovei* Pant., *Biddulphia auria* var. *atusa*. These warm-loving species are common in the lower (samples 1-7), rare in the middle, and become common again in the upper (samples 13-15) portions of the studied succession.

Cryophile forms belong to the genera *Actinoptychus undulatus* var. *crypta*, *Hantzschia virqata* Grun, *Synedra parasitica* Hust. var. *parasitica*, *Navicula hennedyi var. luxuosa*, *Xanthiopyxsis umbonata* Grev., *Denticula praelauta*, *Podosira* sp., *Eunotogramma bivittatum* Grun. et Pant, etc. Moderate quantities of these marine species are found all across the Maykopian section.

Figure 2 provides palaeotemperature reconstructions developed based on the diatom assosiation change. Temperature variations are highlighted in the grey color, and darker color indicates to a reduction in amount of thermophile diatoms.

Some diatom individuums belonging to Thallassiothrix genera (Bukry, 1973) remain unidentified to a species. Being typical for Oligocene-Miocene these diatoms are most commonly found in the samples 11-16. Also the Oligocene marine dinoflagellates are found in the most slides. They are quite large and vary in size between 45μ -150μ (Tables 2 and 3). There is a plenty of these algae in samples 6-16. Thus, the entire section is dominated by a marine flora over the freshwater species. We also could not recognize several diatoms from Cyclotella, Hualodiscus, Stephanopyxis, Stephanodiscus and Biddulphia genera. Similar diatom algae have been recovered from Upper Maykopian sediments in Shikhzagirli section (Kerimova, 2017).

The fragments of diatoms from *Istmia genus* as well as *Podosira maxima* are widely ocurring in all portions of the section. Highest concentrations of these fragments are reported in samples 49, 52 and 73, collected from the upper part of the section. The well-preserved dinoflagellates belonging to the *Tasmanites*, *Dracodinium*, *Rhombodinium genera* are frequently recorded.

The composition of the diatom assemblages of the Maykopian Series cropping out in the Pirakushkul section are summarized in the plates 1, 2, 3. As a result we can state that the assemblage composition is as follows: marine forms – 88%, brackish-water specimens – 10%, freshwater forms – 2%.

Climatic variations in the Caspian segment of the Eastern Paratethys in Oligocene and their link to the global environmental events

Based on the amounts of thermophile and cryophile forms of diatoms, we can state that during the Oligocene there were several peaks of cooling and warming (Figure 2).

In the section lowers the growth of thermophile diatoms indicates to the warming stage conventionally marked by the letter A (Figure 2). It is replaced by a stage of dominating cryophile species of diatoms, marked by the letter B. Stratigraphically higher a stage C is distinguished, that is characterized by a slight increase amount of thermophile diatoms. This is followed, as we assume, by a cooling stage, reflected in a slightly increased number of cryophile diatoms (stage D). Upward the section there are, possibly, two warming stages— E and F, separated by a short period of decrease in the amount of thermophile diatoms. It should be noted that the warming stage E, corresponding to the increased number of thermophile diatoms, is not confirmed by the cryophile forms the increased amount of which testifies to the opposite trend, i.e. decline in water temperatures of their habitat. At the same time, in sample 11, corresponding to the warming stage F the trend of growing amount of thermophyle species is confirmed by the drop in the number of shells of cryophile diatoms. The section terminates with the succeeded stages of cooling and warming marked as G, H, and E, and well identified in the composition of diatom associations. Thus, based on the change of diatom associations, we can conclude that in the Oligocene history of the Caspian segment of the Eastern Parathethys there were eight stages of domination of the thermophile and cryophile species of these algae that, possibly, reflects the changes in the Oligocene climatic conditions.

In general, it can be stated that the number of cryophile diatoms in the cooling stages exceeds the number of thermophile forms in their peak contents. However, thermophile forms turned out to be more sensitive to the rapid environmental changes, which are reflected in the greater variability of their amount in the studied section.

The maximum of freshwater forms (three specimens) found in sample 13 coincided with the peak proportion of cryophile diatoms - stage G (Figure 2). The maximum of marine diatoms recorded in the sample 1 correlates with approximately equal amount of warm-loving and cold-loving diatoms - 10-12 forms of each type. However, in sample 15 the highest number of typical marine species is corresponded to the warming stage H, identified by the maximum number of thermophile forms (25 shells). Along with this, the minimum content of marine species in sample 11 also corresponds to the warming stage shown by the letter F. In the section uppers the quantities of all three types of diatoms is increasing. These data tell that climatic interpretation of halophile and halophobic diatom algae distribution is ambiguous, and needs further clarification. The diatom assemblages displaying frequent climate dependent variations arises the questions on their relationships with the global environmental processes. Figure 3 shows the curves of the thermophile, cryophile diatom shells' number in the Oligocene sediments collected from the Perikushkul outcrop, oxygen isotope composition of the Oligocene benthic foraminiferas, the World Ocean and Eastern Paratethys level fluctuations in Oligocene.

It should be noted that despite the general single trend in the Lower Oligocene Sea level behavior observed on all three curves, the scales of oscillations are estimated differently by different authors. Thus, by B. Haq et al. (1987) the amplitude of the World Ocean level changes in the Lower Oligocene was 100m – from +100 to +200m; by K. Miller et al. (2005) 75 m – from -25m to about +50m; in the Eastern Paratethys accordingly to S. Popov et al.(2010) 150 m - from -50m to +100m. Further, in the Upper Oligocene, these estimations do not coincide.

The Eocene – Oligocene boundary is the onset of the large climatic changes and development of the Antarctic sheet (Miller, 1992; Zachos et al., 2001; Miller at al., 2008; Zanazzi et al., 2015). The temperature drop continued for almost the entire Oligocene, and covered a time interval of 32.5 Ma – 25.5 Ma. This was accompanied by the extinction of organisms, mostly, marine in nature (Ivany et al., 2000; Molina et al., 2006). We also have found some evidence of this event in the composition and character of the diatom complex we studied, but the complete extinction of marine diatoms is not observed. Thus, in lowermost portion of the section there is a reduction in the amount of both types of diatom algae – warm-loving and cold-loving. We have recovered 10-15 shells of each type –thermophile and cryophile diatoms (Figure 2). However, we have recorded the maximum content of marine species here.

In general, the overall cooling trend that lasted during the entire Oligocene was not continuous. There were climatic variations reflected in the alternation of warming and cooling stages, which is clearly seen both in the composition of the diatom complex, and in the behavior of the oxygen isotope composition obtained on benthic foraminiferas (Miller et al., 2005). Comparison of diatom assemblages' variations with the oxygen isotope curve shows a good correlation.

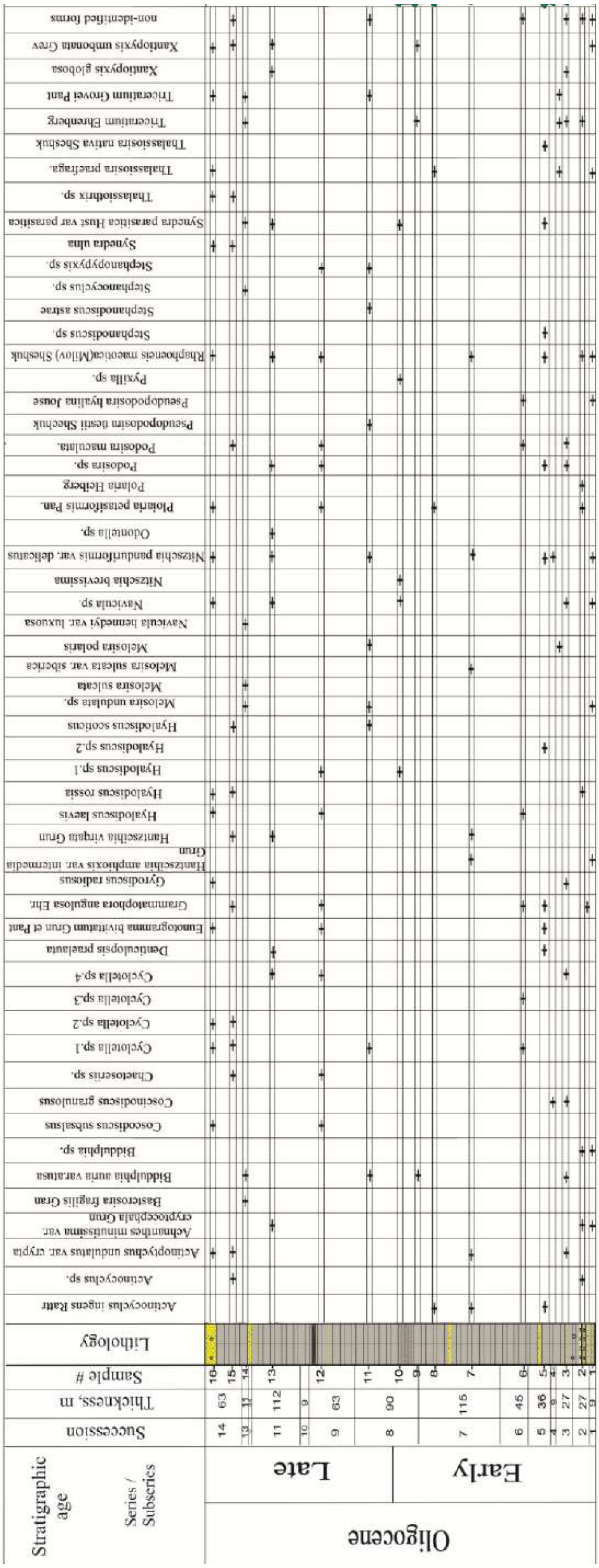
Earlier, Pekar et al. showed 9 eustatic sea level falls on the continental margin of New Jersey, which are well corresponded to 9 isotope events (Pekar et al., 2003).

The first isotope event is corresponding to the transition from the Eocene to the Oligocene, and was accompanied by a gradual temperature decline, which reached its peak at 33.55 Ma — the isotope event Oi1 (Miller et al., 1991).

Judging by the composition of diatom assemblages we can conclude that in the Caspian segment of the Eastern Paratethys a gradual change of the relatively warm climatic conditions occurring at the Eocene-Oligocene boundary at 33.8 Ma and correlating with a lighter oxy gen isotopic composition (warm period marked by the letter A) by the cooling stage B (purple square) corresponding to the isotopic events Oi1 and Oi1a is also observed (Figure 3). This cooling stage is well correlated with the World Ocean (Miller et al., 2005; Haq et al., 1987) and the East Paratethys level drops (Popov et al., 2010).

Thus, we believe that the isotope event known as Oi1, and recorded in the Atlantic, Pacific, Indian and Southern oceans (Shackleton and Kennett, 1975; Savin et al., 1975; Kennett and Shackleton, 1976; Keigwin, 1980 ; Corliss et al., 1984; Miller et al., 1987; Zachos et al., 2001; Coxall et al., 2005) has also found its proof in the Caspian basin.

We assume that accumulation of sandstones in the basal portion of the Pirakushkul section, probably, indicating to more proximal depositional setting is associated with this event. Accordingly, the thin sandstones recorded upward the section at the stratigraphic depth 48 meters we link with the isotope event Oi1a.


Stratigraphic age
Series / Subseries
Succession
Thickness, m
Sample #
Lithology
Oligocene
Late
Early
Actinocyclus ingens Rattr
Actinocyclus sp.
Actinoptychus undulatus var. crypta
Achnanthes minutissima var. cryptocephala Grun
Basterosira fragilis Gran
Biddulphia auria var.atusa
Biddulphia sp.
Coscodiscus subsalsus
Coscinodiscus granulosus
Chaetoseriis sp.
Cyclotella sp.1
Cyclotella sp.2
Cyclotella sp.3
Cyclotella sp.4
Denticulopsis praelauta
Eunotogramma bivittatum Grun et Pant
Grammatophora angulosa Ehr.
Gyrodiscus radiosus
Hantzscihia amphioxis var. intermedia Grun
Hantzscihia virgata Grun
Hyalodiscus laevis
Hyalodiscus rossia
Hyalodiscus sp.1
Hyalodiscus sp.2
Hyalodiscus scoticus
Melosira undulata sp.
Melosira sulcata
Melosira sulcata var. siberica
Melosira polaris
Navicula hennedyi var. luxuosa
Navicula sp.
Nitzschia brevissima
Nitzschia panduriformis var. delicatus
Odontella sp.
Ploiaria petasiformis Pan.
Polaria Heiberg
Podosira sp.
Podosira maculata.
Pseudopodosira ilestii Shechuk
Pseudopodosira hyalina Jouse
Pyxilla sp.
Rhaphoeneis maeotica(Milov) Sheshuk
Stephanodiscus sp.
Stephanodiscus astrae
Stephanocyclus sp.
Stephanopyxis sp.
Synedra ulna
Synedra parasitica Hust var parasitica
Thalassiothrix sp.
Thalassiosira praefraga.
Thalassiosira nativa Sheshuk
Triceratium Ehrenberg
Triceratium Grovei Pant
Xantiopyxis globosa
Xantiopyxis umbonata Grev
non-identified forms

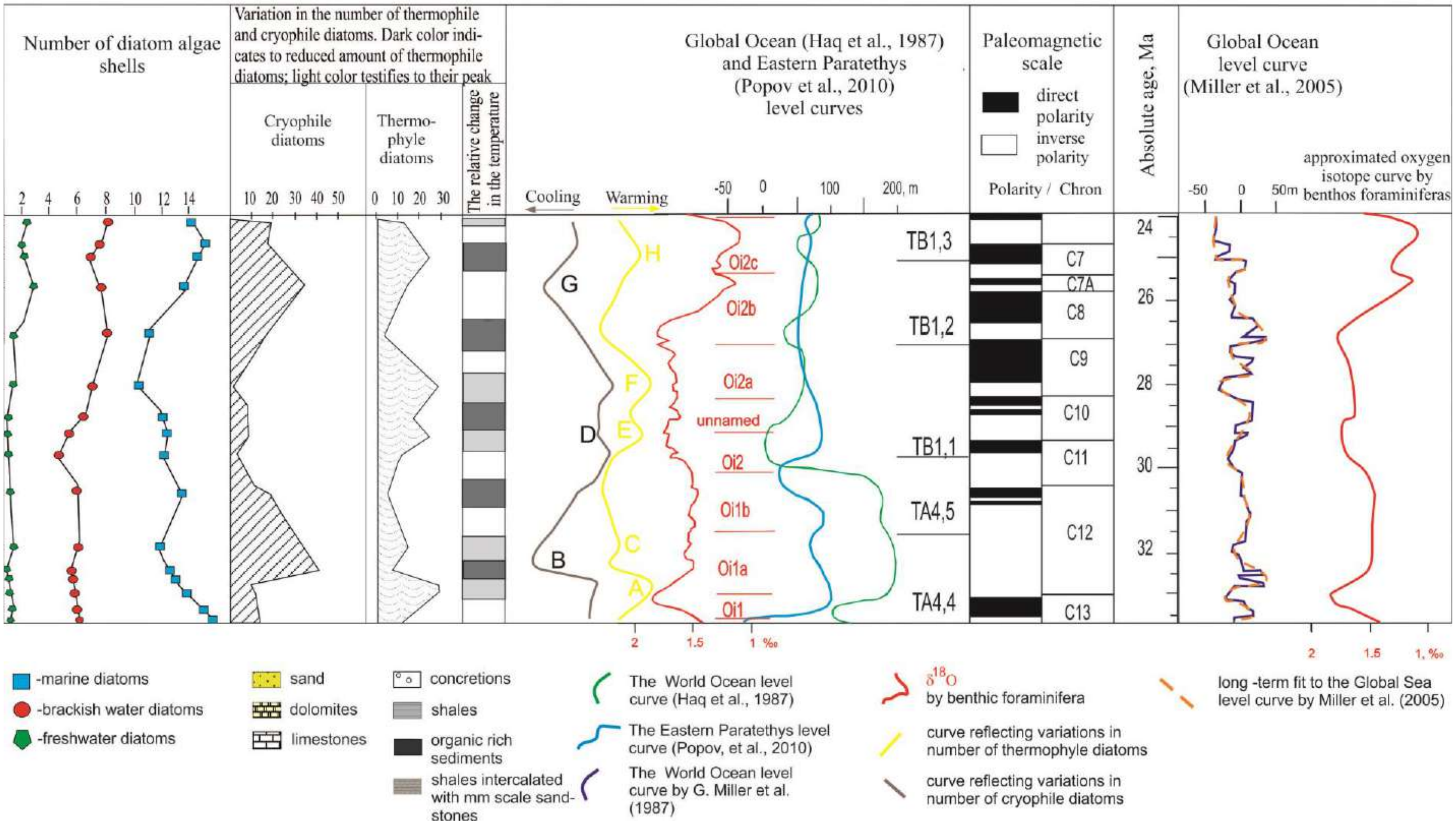


Figure 2. Distribution of diatom flora in the Maykopian sediments of the Pirakashkul section

The warming stage C distinguished on the increased amount of the warm-loving diatoms and reduction in the number of shells belonging to cold-loving species is the most extended in time (yellow square) and, judging by the oxygen isotope curve, lasted more than 2.5 Ma (Figure 3). The slight decrease of the thermophile diatoms is, probably, associated with the isotope event Oi1b, although the number of cryophile forms is also slightly reduced.

The next isotope event Oi2 at the absolute age of 30.1 Ma (blue square) affected both the composition of diatoms (event D) and at the Global Sea level. Within this episode, there is a slight drop in the quantities of thermophile diatoms (the peak between the two episodes E and F), which may correlate with an isotopic event dated back to 29.1 Ma. In the Pirakushkul section, these two isotope events correspond to the accumulation of sand beds at the stratigraphic depths of 213m and 318m (Figures 2, 3).

The subsequent warming (event F by the diatom complex) was replaced by another cooling (isotope events Oi2a and Oi2b, green square). These cooling stages are well documented in the World Ocean level that based on the K. Miller et al. data (2005) twicely experienced a fall in the time span of 28.3 Ma - 27 Ma. However, in the Eastern Paratethys only one episode of the sea level decline from the altitude +60 m to + 50m is recorded (Popov et al., 2010). Also, judging by the composition of diatoms there is only one cooling episode indicated by the letter G is recorded.

In the Caspian segment of the Eastern Paratethys the isotope event Oi2b, we believe, correlates with the shale beds alternating with mm scale sand interlayers, the base of which lies at the 421m stratigraphic depth (Figure 2, 3).

The warming stage H (pink square) occupied a large time span of more than 2.5 Myr. The isotope event Oi2c recorded within this time interval did not affect the composition of diatoms, but can be clearly seen in the behavior of the World Ocean level, which dropped following estimations of K. Miller et al., (2005) from the altitude + 40m to -20m (Figure 2, 3). At the same time, judging from the data of S. Popov and others, this climatic episode was not reflected in the fluctuations of the Eastern Paratethys level (Popov et al., 2010). However, in the Pirakushkul section the 40 cm thick sandstone bed observed at the stratigraphic depth of 555 meters, probably, is associated with this isotopic event and related to a decline of the Oligocene sea level.

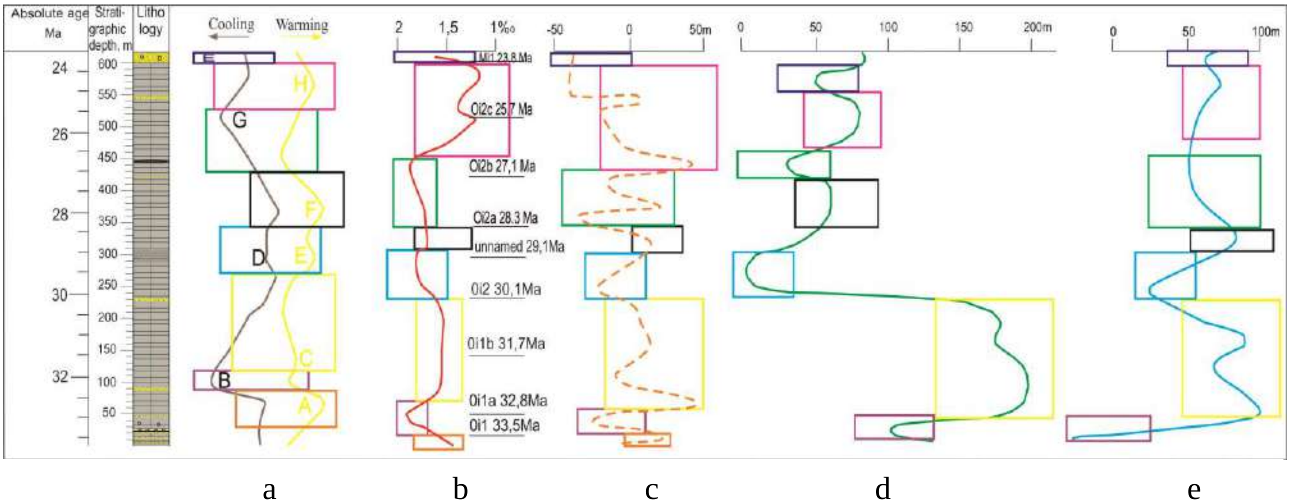


Figure 3. Curves displaying the changes in the: **(a)** number of cryophile (in brown) and thermophile (in yellow) diatoms; **(b)** oxygen isotope composition of benthic foraminiferas; **(c)** World Ocean level: by K.Miller et al. (2005) orange dotted line; by B.Haq et al. (1987) green line; Eastern Paratethys level by S. Popov et al. (2010), blue line.

The last isotopic event Mi1, which terminates the Oligocene and indicates the onset of Miocene is well reflected both in the composition of diatoms (cooling stage E) and in the curves of the World Ocean and Eastern Paratethys level change.

In our section, the transition to the Miocene was marked by the accumulation of several sand beds up to 80 cm thick each (sucession 14) (Figures 2, 3).

Plate 1

1– *Melosira undulata sp.*1, **2** – *Actinocyclus ingens Rattr*, **3** – *Actinocyclus sp.*, **4** – *Melosira sulcata*, **5** – *Actinoptychus undulatus var. minor*, **6** – *Triceratium Grovei Pant*, **7** – *Hyalodiscus sp.1*, **8** – *Coscinodiscus subsalsus*, **9** – *Thalassiothrix sp ?*, **10** – *Thalassiosira praefraga*, **11** – *Stephanodiscus astrae*, **12** – *Xanthiopyxis umbonata Grev*, **13** – *Cyclotella sp. 1*, **14** – *Grammatophora angulosa Ehr. var.*, **15** – *Eunotogramma bivittatum Grun. et. Pant.*, **16** – *Cyclotella sp.2*, **17** – *Nitzschia brevissima*, **18** – *Melosira sulcata var. siberica.*

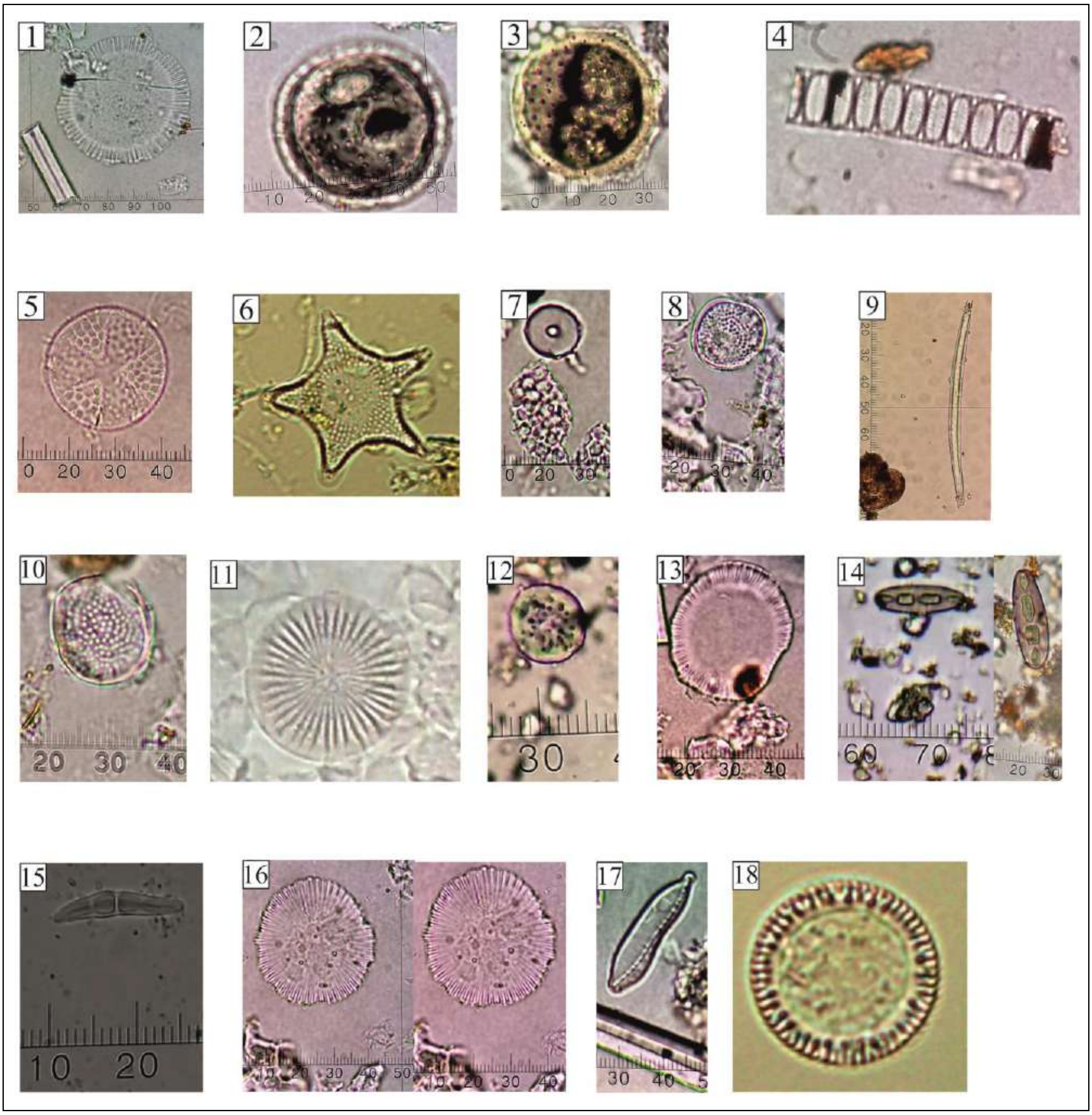


Plate 2

20 – *Melosira polaris,* **21** – *Denticulopsis praelauta,* **22** – *Hyalodiscus sp.2,* **23** – *Navicula sp.,* **24** – *Pseudopodosira westii Sheshuk,* **25** – *Polaria Heiberg,* **26** – *Navicula hennedyi var. luxuosa,* **27** – *Stephanodiscus sp.,* **28** – *Pseudo-podosira hualina Jouse,* **29** – *Hantzschia virqata Grun,* **30** – *Hyalodiscus scoticus,* **31** – *Stephanopyxis sp.,* **32** – *Odontella sp.,* **33** –*Synedra parasitica Hust var. parasitica,* **34** – *Podosira maculata,* **35** – *Hantzschia amphioxis var. intermedia Grun,* **36** – *Stephanocyclus sp.,* **37 –** *Podosira sp.*

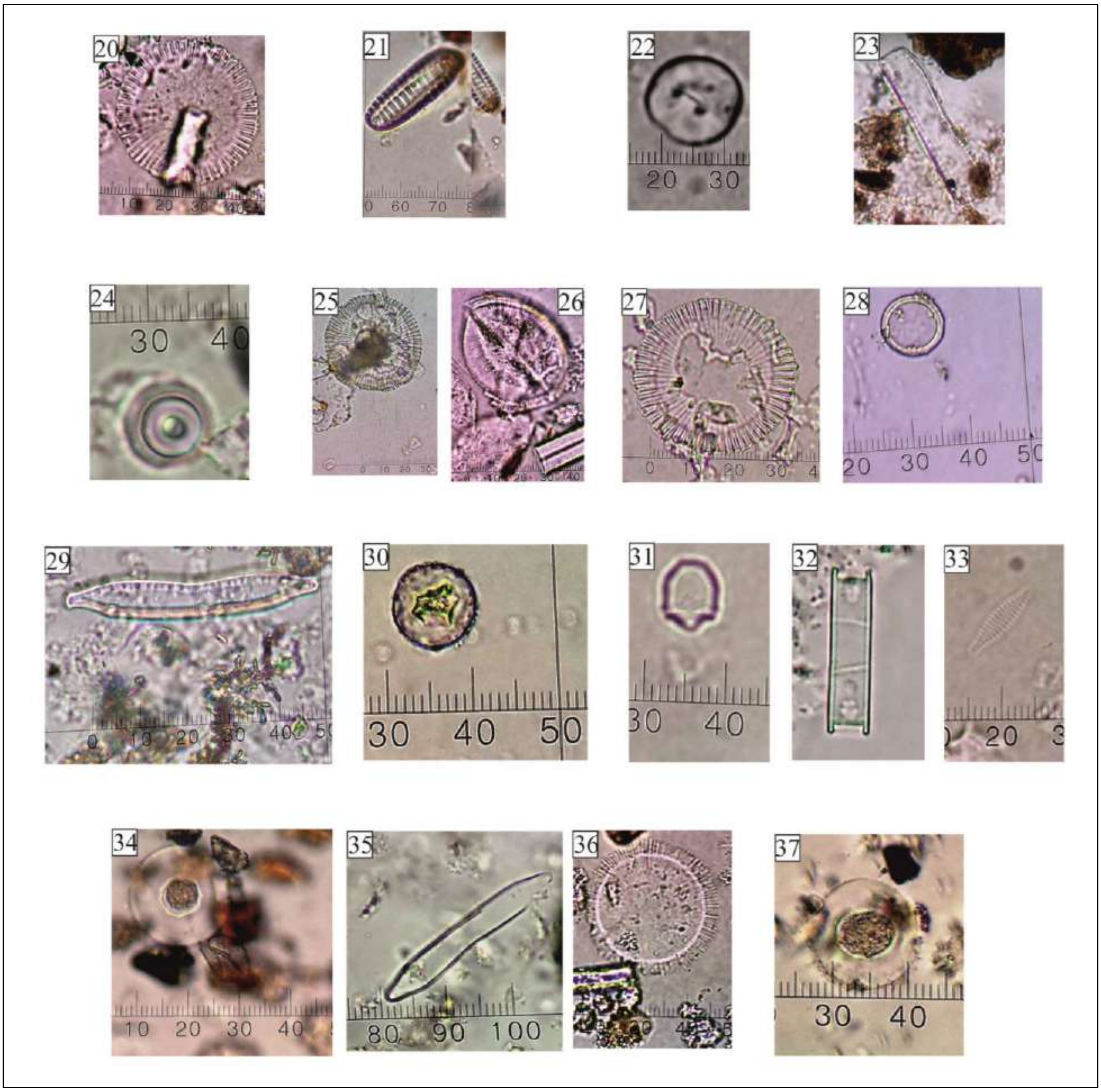
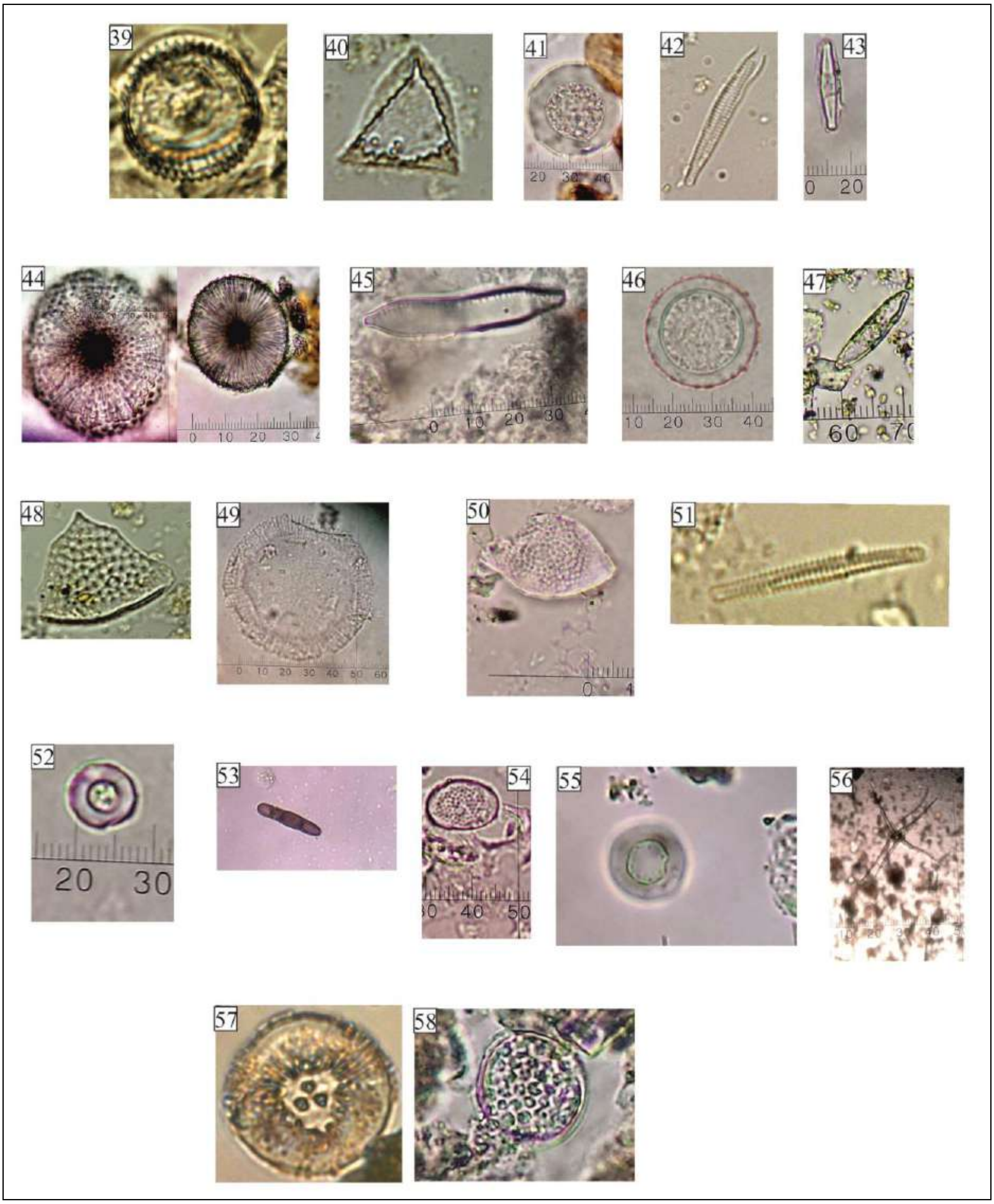


Plate 3

39 *– Coscinodiscus granulosus,* ***40*** *– Biddulphia sp.,* ***41*** *– Hyalodiscus laevis,* ***42*** *– Synedra ulna,* ***43*** *– Achnanthes minutissima var. cryptocephala Grun,* ***44*** *– Gyrodiscus radiosus,* ***45*** *– Hantzschia amphioxis var. intermedia Grun,* ***46*** *– Hyalodiscus rossii,* ***47*** *– Nitzschia panduriformis var. delicatus,* ***48*** *– Triceratium Ehrenberg,* ***49*** *– Pyxilla sp.,* ***50*** *– Ploiaria petasiformis Pant,* ***51*** *– Rhaphoeneis maeotica (Milov) Sheshuk,* ***52*** *– Cyclotella sp.3,* ***53*** *– Biddulphia auria var. atusa,* ***54*** *– Basterosira fragilis Grun,* ***55*** *– Cyclotella sp.4,* ***56*** *– Chaetoseriis sp.,* ***57*** *– Cyclotel-laschambik,* ***58*** *– Thalassiosira nativa Sheshuk*



Conclusions

The diatom analysis done on the Oligocene sediments in the onshore part of the South Caspian basin allowed us qualification of the climatic variations, and revealing the mln year scale climatic cyclicity in the Oligocene history of the - Caspian segment of the Eastern Paratethys. This cyclicity was reflected in the Eastern Paratethys level fluctuations of the third order.

The absence of absolute dating of the Oligocene sediments exposed in the Pirakushkul section makes the accurate tie of the climatic episodes identified on the basis of variations in the composition of diatom associations to the global oxygen isotope events difficult. However, an exact recognition of the base and top of the Oligocene succession in the studied section, its continuity and good exposure allow us with a high degree of confidence the synchronization of the registered climatic episodes with the global climatic and sea level changes.

We can conclude that the studied section is dominated by marine species of diatom algae; the brackish-water forms take a subordinated position. It tells about dominating normal marine conditions in the Lower Maykopian basin. Salinity of the basin did not variated much. Based on the large amount of cold-loving species we can state that temperature in the Oligocene within area of the study was low - 5ºC -15ºC. In some time intervals it could icrease up to 20ºC.

The achieved data display that during the Oligocene the quantitative ratios of the warm-loving and cold-loving diatom species changed several times that is well compared with the oxygen isotope ratio in the shells of benthic foraminiferas.

There are 4 warming stages and 4 cooling stages in the Oligocene history of the Caspian basin, which was part of the Eastern Paratethys. These climatic events fully coincide with the Eastern Paratethys level fluctuations (Popov et al., 2010).

According to the results obtained the cold stages defined by diatom algae assemblages correspond to the Eastern Paratethys level decline. In the Pirakushkul section these time intervals are associated with the accumulation of thin sand beds, that, probably, reflects depositional environment changes from the outer shelf setting dominating in the section to the more proximal inner shelf exposed to storm processes resulted in the accumulation of coarse terrigenous sediments.

Recorded increase in number of marine forms of diatom algae in the lower and upper portions of the Pirakushkul section is well coinciding with warming stages C and H that explains this phenomenon, i.e. more favorable environment for diatom growth in the warm waters.

Our data also show that the changes in the diatom algae associations occur a little bit later with the respect to climatic and facies variations that testify to some time interval between biocoenosis's reaction and caused it environmental process.

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OLİQOSEN DÖVRÜNDƏ CƏNUBİ-XƏZƏR ÇÖKMƏ HÖVZƏSİNDƏ İQLİM HADİSƏLƏRİ VƏ DƏNİZ SƏVİYYƏSİNİN DƏYİŞMƏSİ: LİTOFASİAL VƏ DİATOM ANALİZLƏRİN İNTEQRASİYASI

E.H. Əliyeva, N.T. Kərimova, H.Ə. Allahverdiyeva

Məqalədə Cənubi Xəzər hövzəsinin Azərbaycan hissəsində yerləşən, yaxşı kəsilişlərə malik və davamlı izlənilə bilən Oliqosen çöküntülərinin litofasial və diatom analizlərin nəticələri təhlil olunub. Əldə olunan məlumatlar bentik foraminiferlərin oksigen izotop tərkibinin, Dünya Okeanının və Şərqi Paratetisin səviyyəsinin dəyişməsinin əyriləri ilə müqayisə olunur.

Tədqiqatın nəticələri Oliqosen dövründə diatom assosiasiyalarının tərkibinin dəyişməsi iqlim hadisələri, onlarla sinxron şəkildə baş verən dəniz səviyyəsinin və sedimentasiya şəraitinin dəyişilməsi ilə əlaqələndirməyə imkan verir.

Diatom komplekslərinin ekoloji təhlilinə əsaslanaraq, tədqiqat sahəsinin Erkən Maykop hövzəsində bionomik şəraitinin dəyişkənlikləri qeyd edildi. Ən çox diatomların nerit və litoral formaları tapıldı. Tədqiq edilən sahədə isti su və soyuq su diatomlarının yayılma xarakterinin analizi, Şərqi Paratetisin Xəzər seqmentinin Oliqosen tarixində soyuma və istiləşmə mərhələlərini müəyyənləşdirməyə və onları Maykop dəniz səviyyəsinin dəyişkənlikləri ilə əlaqələndirməsinə imkan vermişdi. Kəsilişin daban və tavan hissələrində bu yosunların dəniz növlərinin dominantlığı bu dövrdə isti iqlim şəraitinin olması ilə bağlamaq olar.

Oliqosen qatının qeyd edilən fasial qeyri-cinslik iqlim təsiri nəticəsində dənizin səyiyyəsinin dəyişməsi ilə izah olunur.

Məqalə həmçinin Şərqi Paratetisin və Dünya Okeanının Maykop Dəniz səviyyəsinin korrelyasiyası üçün əsas verir.

КЛИМАТИЧЕСКИЕ СОБЫТИЯ И КОЛЕБАНИЯ УРОВНЯ МОРЯ В ОЛИГОЦЕНЕ ЮЖНО-КАСПИЙСКОГО ОСАДОЧНОГО БАССЕЙНА: ИНТЕГРАЦИЯ ЛИТОФАЦИАЛЬНОГО И ДИАТОМОВОГО АНАЛИЗОВ

Э.Г. Алиева, Н.Т. Керимова, Х.А. Аллахвердиева

В статье интегрированы результаты литофациального и диатомового анализов, проведенных на хорошо обнажающихся, непрерывно прослеживаемых олигоценовых отложениях, расположенных в азербайджанской части Южно-Каспийского бассейна. Полученные данные сопоставляются с кривыми изотопного состава кислорода бентосных фораминифер, колебаний уровней Мирового Океана и Восточного Паратетиса.

Результаты исследований показывают вариабильность состава диатомовых ассоциаций в течение олигоцена, и дают возможность увязать их с климатическими событиями и синхронными с ними колебаниями уровня моря, находящими свое отражение в изменении условий осадконакопления.

Основываясь на экологическом анализе диатомовых комплексов, были отмечены изменения биономических условий в раннемайкопском бассейне района исследований. Наиболее часто обнаружены неритовые и литоральный формы диатомей. Анализ характера распределения тепловодных и холодноводных диатомей по изученному разрезу позволил выявить стадии похолоданий и потеплений в олигоценовой истории Каспийского сегмента Восточного Паратетиса, и скоррелировать их с колебаниями уровня майкопского моря. Доминирование в подошвенной и кровельной частях разреза морских видов этих водорослей хорошо объясняется установлением более теплых климатических условий в эти периоды времени.

Отмеченная фациальная неоднородность олигоценовой толщи хорошо коррелирует с климатически обусловленнными колебаниями моря.

Статья также дает основу для корреляции уровней майкопского моря Восточного Паратетиса и Мирового Океана.

FIRST DISCOVERIES OF TERRIGENOUS GOLD AND PLATINUM IN THE MIOCENE DEPOSITS OF THE EASTERN CAUCASUS (DAGESTAN)

Outcrops of Miocene (Chokrak-Karaganian) sediments represented by poorly cemented from medium to fine-grained quartz sandstones, are occurring in the front ranges (Kara-burun, Narat-Tube, etc.) of Dagestan within the transition zone between the northern slope of Eastern Caucasus orogen and the Terek-Caspian foredeep trough. The commercial concentrations of gold and platinum in the Miocene sediments were proved by the atomic absorption spectroscopy. The reserves were evaluated.

Keywords: Eastern Caucasus, Miocene, quartz sandstones, gold and platinum commercial accumulations

V.U. Matsapulin

Institute of Geology,
Dagestan Scientific Center of RAS

A.R. Yusupov

Institute of Geology,
Dagestan Scientific Center of RAS

V.I. Cherkashin

Institute of Geology,
Dagestan Scientific Center of RAS
E-mail: dangeo@mail.ru

Introduction

There are no magmatic formations reported in the Eastern Caucasus region, to which the ore and placer gold or platinum occurrences could have been linked. Therefore, these metals distribution hasn't been studied by the special survey. Gold and silver content have been identified *pari passu* during geological exploration on pyrite and quartz-sulfide ores, as well as by survey implemented by "SevKavkazGeologiya" (North Caucasus Geology). It was believed that there are not elevated concentrations of *Au*, *Pt* and *Pd* in the Miocene sandy-muddy successions located on the conjunction between the amagmatic northern slope of the Eastern Caucasus orogen and the Terek-Caspian foredeep trough.

Single placer gold discoveries in the unconsolidated fluvial sediments of the northeastern slope of the Greater Caucasus have been recorded in the vicinity of Kubachi village (Ullu-chay river basin), Vachi and Kuli (Gazikumukh Koysu river basin), as well as in the downstream tributaries of the Sulak river.

The silver was found by spectral analyses performed on the sediment samples collected from stream beds in the Greater Caucasus northern slope. The results displayed extended aureoles of *Ag* reaching content to 10-100 g/t. The Upper Jurassic and the Lower Cretaceous sandstones contain elevated concentrations of Ag reaching to 10-20 g/t. However, these studies have not been continued as the sources of precious metals were not defined. At the end of the XX century the Geological Institute of the Dagestan Scientific Center affiliated to the Russian Academy of Sciences (DSC of RAS) initiated the long-term researches on the placer noble metals in the North Caucasus.

Material, Methods

Since 1990's, the Geological Institute of DSC, RAS continuously studies a heavy fraction mineral composition in samples selectively collected from the loose sediments of stream beds and the Caspian coast as well as from the Mesozoic-Cenozoic bedrocks, mostly poorly cemented Chokrakian-Karaganian (Middle Miocene) quartz sandstones (Matsapulin, Hasanov, 1991; Matsapulin, Yusupov, 1994; Matsapulin, Magomedov, Yusubov, 1995; Cherkashin, Matsapulin, Yusupov, 2006; Cherkashin, Matsapulin, Yusupov, 2006).

During sampling on heavy concentrates in these sediments aimed on the exploration of the titanium and zirconium ores, individual, less than 0.2 mm in size grains of the gold and the platinum have been also recorded in the areas of Buglen, Shura-Ozen, Cherkez-Ozen and Khuchni. It should be noticed that samples have been collected following the methodology applied for the exploration of titanium-zirconium placers, and the weight of collected samples did not exceed 0.2 kg, whereas the sediment samples collected for gold concentrate detection shall be as twice as heavier. Therefore, it's reasonable to assume that the actual quantity of gold, and, particularly, its' finely dispersed variety, is much higher in the studied rocks than it has been revealed. Moreover, it has to be accounted that the rocks have been manually washed in the trays, and the gold is represented by its' less than 0.2 mm fraction. Only 5-10% of a free gold can be identified by using that method (Shilo, 2002).

In 2007, bromoform was introduced for separation of a heavy fraction from the stream bed sediments. It allows detecting gold grains in each 50 g weighting sample (up to 7 grains in some samples). Besides gold the platinum was also detected. Gold and platinum contents in the sampled sediments have been calculated based on the number of grains. The results on heavy concentrates are summarized in Table 1.

The placer gold and platinum have been also examined under the microscope to determine their sizes and morphological patterns.

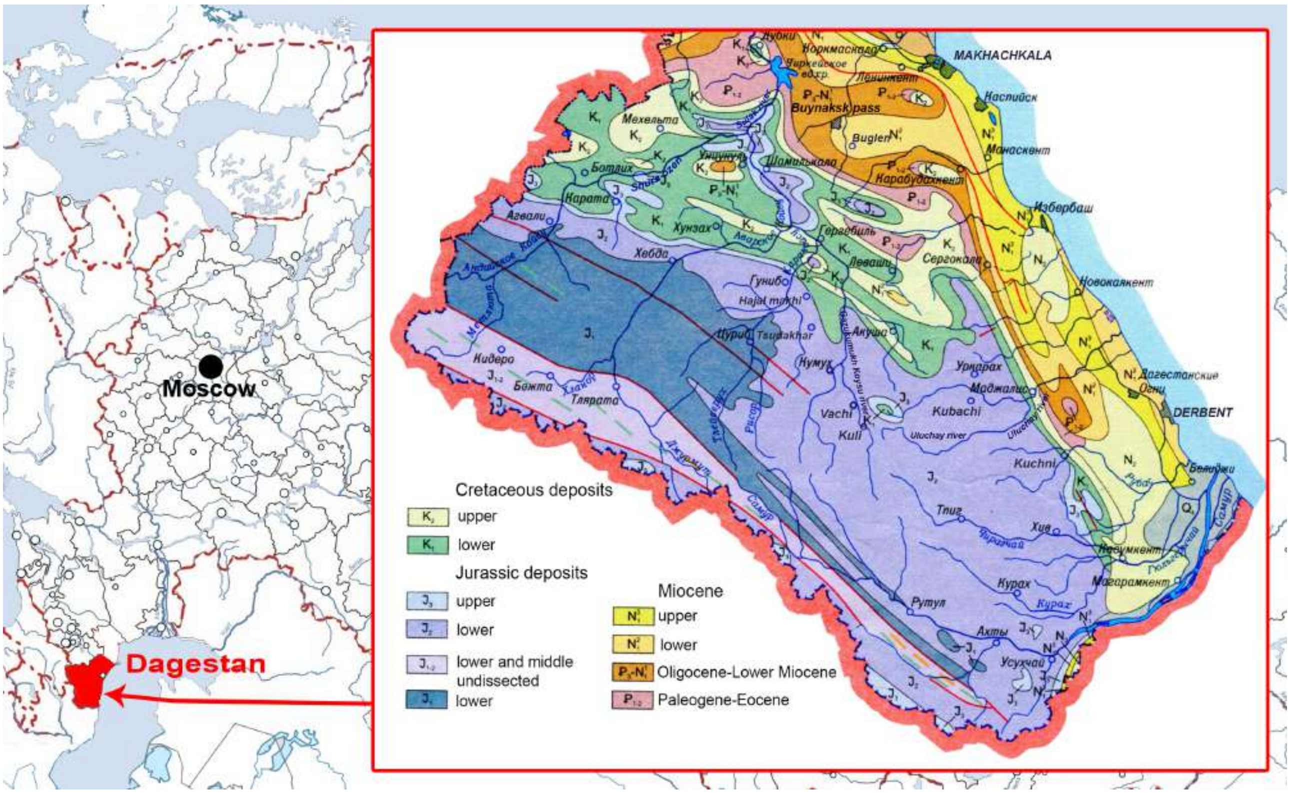

Figure 1. Location map of the studied sites

Table 1

Placer gold and platinum contents in the Chokrakian-Karaganian quartz sandstones (g/t), determined based on heavy concentrate sampling

№ п/п	Sample number	Strati-graphic age	Share of heavy fraction, %	*Au* content		*Pt* content	
				grains	g/t	grains	g/t
1	100/06	Chokrakian	0,6	1	-	-	-
2	107/06	Karaganian	1,0	1	-	2	-
3	120/06	–	0,3	-	-	2	-
4	130/06	–	0,7	1	-	1	-
5	101/06	Chokrakian	0,7	7	2	5	3
6	131/06	–	0,3	3	0,5	2	2
7	116/06	–	1,0	2	0,2	1	0,5
8	103/06	Karaganian	0,6	3	1	5	7
9	104/06	–	2,5	2	1	3	20
10	105/06	–	0,5	4	1,5	5	2
11	115/06	–	0,7	1	0,2	2	0,7
12	102/06	–	0,3	4	1,5	2	0,3

Note: Samples # 5-12 were processed with heavy liquid fractionation.

To define the noble metal concentrations the selected samples were analysed with the application of atomic absorption spectroscopy.

Results

It was identified that the gold grains are up to 0.13 mm in size and have the wire-like, isometric and oblong forms. In one sample, the gold grain has dark-brown colored cover. In some cases, the grains are poorly rounded. Platinum grains are up to 0.2 mm large. The isometric lamellas intergrowing with a green coloured mineral are observed. Lamellas are oblong and rarely poorly rounded (Figure 2).

In order to define gold and platinum concentrations in the analysed sediments the bulk sampling was applied to these rocks with further implementation of atomic absorption spectroscopy (Table 2). We can state that commercial concentrations of these metals are recorded in the Chokrakian-Karaganian sandstones. Individual samples containing *Au* and *Pt* have been reported in the Upper Jurassic – Lower Cretaceous terrigenous-carbonate rocks. Alternating with sandstones Chokrakian-Karaganian black shales are appeared to bear gold and platinum, too. Five samples of these rocks contained 1.0-2.9 (av. 1.72) g/t of gold, 2.2-7.2 (av. 3.46) g/t of platinum, 1.3-3.2 (av. 1.96) g/t of palladium, and 0.06-0.2 (av. 0.13) g/t of silver.

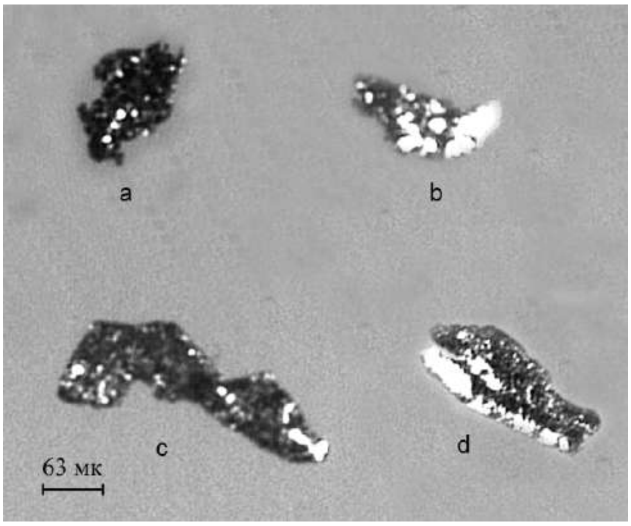

Figure 2. Placer gold (a, b) and platinum (c, d) extracted from Miocene quartz weakly cemented fine-medium-grained sandstones (Dagestan)
a – v. Buglen, Chokrakian; b – v. Kapchugay, Chokrakian; c – v. Kumtorkala, Karaganian; d – v. Buglen, Chokrakian

Table 2

Gold, silver and platinoids concentrations in the Miocene sandstones and shales (in g/t)

№	Sampling localities	Number of samples	Stratigraphic age	Au	Pt	Pd	Ag	∑ Au, Pt, Pd.
1	Buglen village	4	Chokrakian	0.2–0.8 / 3.05	1.8–4.7 / 2.4	0.1–0.3 / 0.27	-	5,72
2	Kulzeb village	2	Sarmatian	0,3–1,8 / 1,05	0 – 1,2 / 0,6	0 – 0,3 / 0,15	-	1,8
3	Khuchni village	2	Karaganian	2,0–6,8 / 4,4	3,2–25,5 / 14,35	0 – 0,7 / 0,35	-	19,2
4	Shura-Ozen river	26	Chokrakian	0,10–18,8 / 2,17	0 – 24,7 / 3,74	0 – 1,0 / 0,35	-	6,26
5	Buynak pass	2	Karaganian	0,5 – 1,0 / 0,75	4,7 – 7,2 / 5,95	0,7 – 1,7 / 1,2	-	7,9
6	Ekibulag arroyo	2	Sarmatian	1,4 – 2,2 / 1,82	3,0 – 9,4 / 6,2	2,2 – 3,2 / 2,7	-	10,72
7	Sulak river downstream	2	Sarmatian	1,3 – 2,2 / 1,75	1,7 – 2,2 / 1,95	1,7 – 2,5 / 2,1	-	5,8
		15	Karaganian	*Сл* – 2,3 / 0,8	0,2 – 2,6 / 0,92	0,1 – 3,0 / 0,9	0,02–0,06 / 0,03	2,65
8	Kulzeb village	1	Sarmatian	0,3	1,2	0,3	-	1,8
9	Uchkent village	4	Karaganian	0,2 – 0,6 / 0,36	0,2 – 1,0 / 0,48	0,2 – 0,4 / 0,3	0,02–0,06 / 0,036	1,14
10	Hajal-makhi	2	Upper Jurassic	1,25–1,50 / 1,37	2,2 / 2,2	1,3 – 1,4 / 1,35	0,06 – 0,2 / 0,13	5,05
11	Tsudakhar	1	Lower Cretaceous	2,3	2,2	1,2	-	5,7

Note: Ag concentration is shown only for the areas where this metal was detected

Occurrence of titanium-zirconium minerals, gold and silver in the terrigenous rocks is the result of erosion distal sources. Such provenance areas for these metals might be Voronezh crystalline massif and more proximal volcanic source in the northern flank of the Terek-Caspian depression.

These provenances had repeatedly gone through the continental evolution, experienced the peneplinization and formation of chemical weathering crust. According to the data of "Dagneft" OJSC (K.A.Sabanayev, oral communication), these provenance regions experienced 12 such epochs starting from Permian-Triassic and ending in Holocene, that was highly favourable for the release of noble metals from the mother rocks and their placer accumulations' formation.

Similar fine-grained forms of the gold and platinoids are widely occurring in other regions, such as Azov-Black Sea (sourced from the Voronezh massif), Ural, Siberia and Far East (Volkov, Yushin, Shashorin, 2005; Matveyeva, Filippov, Prokofyeva, 2006.). Paragenesis of these metals indicates to a polytypicality of their sources. Precious metal accumulations do not correlate with elevated titanium-zirconium minerals' concentrations, which is apparently due to the density difference.

Conclusions

Conducted studies allow us to conclude:

- regarding huge volumes (billions of cubic meters) of weakly cemented Chokrak-Karaganian quartz sandstones as a multicomponent material for gold, platinoids, titanium, zirconium and quartz accumulations;

- highly rating the region's potential for discovering commercial accumulations of popular precious metals; and

- recommending the widescale geochemical studies of the region's gold, silver and platinoid bearing perspectives, and the exploration and forecasting of its' Chokrak-Karaganian deposits.

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ŞƏRQİ QAFQAZIN (DAĞISTAN) MİOSEN ÇÖKÜNTÜLƏRİNDƏ TERRİGEN QIZILININ VƏ PLATİNİN İLK TAPINTILARI

V.U. Matsapulin, A.R. Yusupov, V.İ. Çerkaşin

Zəif sementlənmiş orta və incə dənəli kvars qumları ilə təmsil olunan miosen çıxışlarının (Çokrak, Karaqan) çöküntüləri Şərqi Qafqazın Şimal yamacı orogeninin Terek-Xəzər ön çökəyinə keçid zonasında, Dağıstanın ön silsilələrində (Kara-qırıcı, Narat-Tyube və s.) yayılmışdır. Son illər aparılan işlərlə süxurlarda şlix sınaqlaşdırması və cəm sınaqlaşdırma ilə – atom-absorbsiya üsulu ilə qızıl və platin müəyyən edilmişdir. Kifayət qədər ehtiyatları olan qiymətli metalların miqdarı sənaye əhəmiyyətlidir.

ПЕРВЫЕ НАХОДКИ ТЕРРИГЕННОГО ЗОЛОТА, ПЛАТИНЫ В МИОЦЕНОВЫХ ОТЛОЖЕНИЯХ ВОСТОЧНОГО КАВКАЗА (ДАГЕСТАН)

В.У. Мацапулин, А.Р. Юсупов, В.И. Черкашин

Выходы миоценовых (чокрак, караган) отложений, представленных слабосцементированными средне- и мелкозернистыми кварцевыми песчаниками, распространены в передовых хребтах (Кара-бурун, Нарат-Тюбе и др.) Дагестана, в зоне перехода северного склона орогена Восточного Кавказа в Терско-Каспийский передовой прогиб. В породах работами последних лет установлены золото, платина шлиховым опробованием и при валовом опробовании – атомно-абсорбционным методом. Содержание драгоценных металлов при достаточном объёме запасов является промышленным.

TERRIGENOUS MINERALOGY OF A HEAVY FRACTION OF THE MESOZOIC-CENOZOIC SERIES IN THE EASTERN CAUCASUS AND Ti-Zr PLACER FORMATION PERSPECTIVES

The article is dedicated to the studies of a heavy fraction of sediments (alluvial, diluvial) deposited by Uluchay, Gazikumukh Koysu and Usukhchay rivers. First two rivers are located within the area supplied from the northern provenance, and the last one is situated in Major Caucasus range affected by sediment supply from the southern provenance. The different composition of heavy fraction in both southern and northern Paleozoic lands, which used to be the sources of terrigenous material goverened the formation of placer deposits in the Mesozoic-Cenozoic Series.

Keywords: Meso-Cenozoic, alluvial sediments, heavy fraction, sediment provenance

V.I. Cherkashin
Institute of Geology,
Dagestan Scientific Center of RAS
E-mail: dangeo@mail.ru

V.U. Matsapulin
Institute of Geology,
Dagestan Scientific Center of RAS

A.R. Yusupov
Institute of Geology,
Dagestan Scientific Center of RAS

Introduction

Core of the eastern segment of the Greater Caucasus mega-anticlinorium is composed of Jurassic sedimentary rocks, i.e. sandstones, siltstones, argillites and shales. Cretaceous series are developed on the subsided parts of the mega-anticlinorium - limbs (northern and southern slopes) and the axis (in the southeast). Terrigenous mineralogy of both light and heavy fractions has been studied on the sedimentary rocks and soft sediments deposited by streamflows running within the Mesozoic-Cenozoic sedimentary series' occurrence area (Aliyev, Akayeva, 1957; Gavrilov, 2002; Gmid, 1953; Zgenti, Slinko, 1978; Zgenti, Slinko, 1977; Zgenti et al., 1989; Matsapulin, Yusupov, 1994; Khalifazadeh, Magomedov, 1982).

We have studied heavy fraction of the soft sediments (alluvial, diluvial) of the Ulluchay river midstream tributaries (Kubachi village), as well as the upperstream sediments of Gazikumukh Koysu (Vachi and Kuli villages) and Usukhchay (Kurush village) rivers. According to the paleogeographic data (Aliyev, Akayeva, 1957; Zgenti, Slinko, 1977; Matsapulin, Yusupov, 1994; Khalifazadeh, Magomedov, 1982). First three areas are located within the zone supplied from the northern provenance, and Usukhchay is situated in the Main Caucasus ridge feeded from the southern provenance.

We have studied mineralogy of terrigeneous sediments from the placers' formation position. New data indicated to the occurrence of a cosmogenic material as well as noble metals in the heavy fraction of schlichs.

Results

Alluvial sediments

We have detected the following minerals in the Kubachi area (% of the heavy fraction): magnetite - 16.86-98, ilmenite 0.43-7.07, limonite+goethite - 0.29 - 26.72, leucoxene signs 11.11, garnet signs - 0.33, sphen - 0.01 - 0.23, rutile signs - 0.07, cinnabar (signs are recorded in 6 samples), barite 0.016 - 2.18, tourmaline (signs in separate samples 0,03), manganese oxides signs -

2.11, corundum signs - 0.92. Signs of biotite, anatase, glauconite, amphibole, carbonate and monazite are detected in separate samples. Distinguished were the secondary (cerussite, pyromorphite, cuprite, malachite, chalcosine, scorodite) and man-made mineral formations. According to L.G.Vasilyeva (PA "Northern Caucasus Geology"), the latter include most part of magnetite, ilmenite, mill scale, silver, metallic melts, copper + zinc-?, iron-?, lead+glass, partly corund, transparent glassy globules. Native gold is detected in the grain content, and the silver is in grain weights. Gold and silver grains are also detected in the diluvial-eluvial tail that adjoins the area's alluvial deposits. In Vachi area, dominating minerals of the heavy fraction of the concentrates are limonite + goethite, with grains of gold detected as well. The Kuli area is mainly represented by pyrite with individual gold/silver grains established.

According to high magnetite content of the concentrates, Kubachi area is quite unique among the studied Meso-Cenozoic deposits of the Dagestani part of the Eastern Caucasus system. Magnetite is represented by its' three morphological varieties, including massive, platy and in the form of ideally spherical globules. According to L.G.Vasilyeva, massive and platy forms are developed in the other parts of the Greater Caucasus as well, whereas the spherical forms have been first discovered in Kubachi and are exotic for the Northern Caucasus region. It has to be mentioned that the spherical forms are widely developed in the Northeast of Russia, where they are commonly known as "Yanite". Genesis of those is related to the cosmogenic processes. Their parameters are quite similar to those of the spherical formations detected by us. Separate globules were also discovered in the alluvium of Gazikumukh Koysu and Karakoysu. Presence of the magnetite globules among the eluvial-diluvial deposits and in the crushed bedrock samples of Kubachi, as well as in the alluvium of 2nd and 3rd fluvial terraces of Gazikumukh Koysu, allows referring them to the terrigenous mineral formations of Lower-Middle Jurassic sedimentary series. Spherical formations of magnetite and volcanic glass are the placers' typical cosmogenic substance (Armand et al., 1985).

Heavy fraction of the concentrates from the headwater alluvium of Gazikumukh Koysu (Kuli village) appear to have mineralogical characteristics that are in general similar to those which were described above. However, dominating mineral of this part of the streamflow is the authigenic pyrite, besides which the fraction contains minor amounts of magnetite and individual grains of gold and silver (Figure 1). Heavy fractions of the Major Caucasus Range's streamflow alluvium (upper reaches of Usukhchay) are dominantly built by sulphides (galenite, pyrite, sphalerite, chalcopyrite) of the widely developed veined quartz-sulphide and pyrite-polymetallic bodies of the Near water-divide metallogenic zone. Grain weight values are established for leucoxene, zirconium, garnet, rutile, barite, pyroxene, carbonate, cerussite, chlorite and epidote. Grain contents are recorded for sphen. The area doesn't contain any native gold, silver, magnetite and ilmenite.

Speaking about panning gold detected on the territory of Dagestan, it deserves mentioning that according to V.I.Korjov (Korjov, 1974), it was discovered on 27 concentrate survey sites, 4 of which contained grains of silver. Most intensive gold grain manifestations have been recorded in Kubachi (Figures 2, 3). Besides noble metals, the area's concentrates are distinguished for the higher concentrations of cinnabar, magnetite (including spherical forms), ilmenite, leucoxene, zirconium, garnet, sphen, tourmaline, staurolite and corund.

The native gold is characterized by fine dispersity, prevalence of platy forms, presence of dendrite-like and other crystalline formations, etc. These features allow equating it to the terrigenous gold of the ancient placers (gold-bearing conglomerates), described by Y.P.Ivensen and other researchers (Ivensen et al., 1969). Heavy fraction of the described concentrates and the ancient placers have identical mineral composition represented by the minerals that are resistant to physiochemical processes.

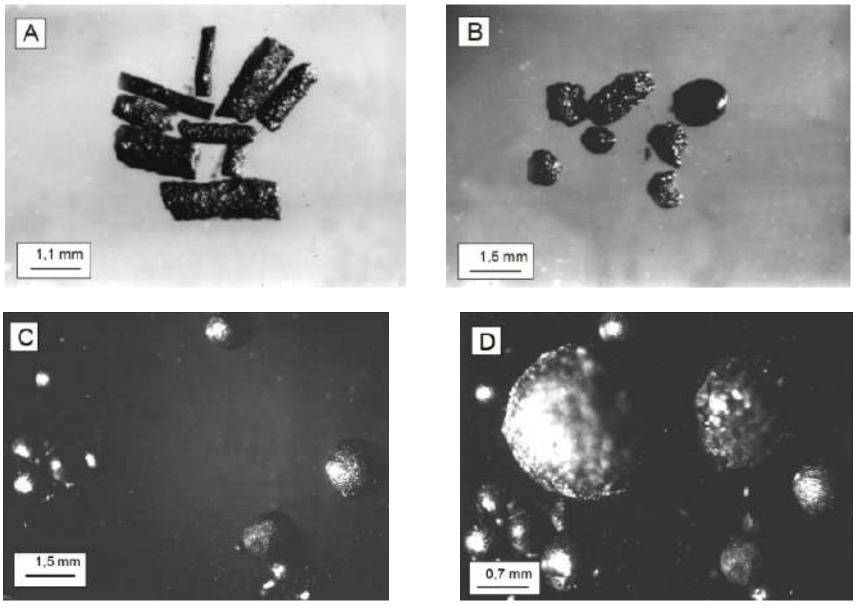

Figure 1. Minerals of the heavy fraction of alluvium (Kuli village, Nakhchu-cheynanikh brook).
(A) – cluster cylindric aggregates of framboidal pyrite;
(B) – granular aggregates and globules of magnetite (Kubachi village, arroyo, alluvium, heavy fraction;
(C) – globules of magnetite, with vesicular surface on the right;
(D) – small globules with smooth shiny surface, large globules have vesicular surface

When prospecting for gold, researchers from the Dagestan Geological Survey Expedition tried to correlate gold placers with unascertained ore occurrences. This assumption led the studies to a blind alley, for which they were not continued in the subsequent years. At the same time, there is a number of characteristics to speak about the placer gold's terrigenous nature with remote source of a transfer, including the light size of the gold, lack of its' accretion with quartz, location together with heavy minerals that are typical with titanium-zirconic placers with remote source of a transfer, as well as the presence of similar gold in the Karaganian coastal-marine deposits. Such gold first enters the initial collectors represented by the continental (paleovalley alluvium) coastal-marine sediments, terrigenous-carbonate stratas and sandstones. Then, after the former's decay, the gold passes into the unconsolidated deposits. According to our understanding, similar are the nature and development areas of the silver, identified by spectral analysis of the samples collected during studies of the foothill and coastal plain parts of the area's river valleys (Northern Caucasus Geological Administration).

Coastal-marine sediments

Placer formation of titanium, zirconium and other noble metals in the Eastern Caucasus region haven't been studied so far by the geologists. Data on increased concentrations of the placer forming minerals like ilmenite, zirconium, rutile and leucoxene have been provided in the studies of terrigenous mineralogy of the Meso-Cenozoic formations, implemented mainly for the oil-and-gas geology, and later for the paleogeographic back-stripping - identification of nature and directions of the terrigenous material's ablation, and characterization of the eroded strata (Aliyev, Akayeva, 1957; Gmid, 1953; Zgenti, Slinko, 1977; Khalifazadeh, Magomedov, 1982 and archive reports). In 1960's, O.K.Leontyev was the first to assume the possibility of zirconium and rutile placer formation in the Caspian coastal-marine deposits. Then in 1958-1960, members of the Dagestan Expedition (N.T.Romanov, V.I.Shmirin, etc.) had implemented prospecting works with manual drilling and footage of trial pits, developed in the modern Caspian beach zone in the estuary parts pf Cherkez-Ozen, Shura-Ozen and Terek. Commercial heavy fraction component concentrations of the Jurassic deposits (according to Khalifazadeh) are provided in Table 1. Similar concentrations have been reported in the monographs authored by A.G.Aliyev, L.P.Gmid, T.G.Jgenti and other researchers (Table 2).

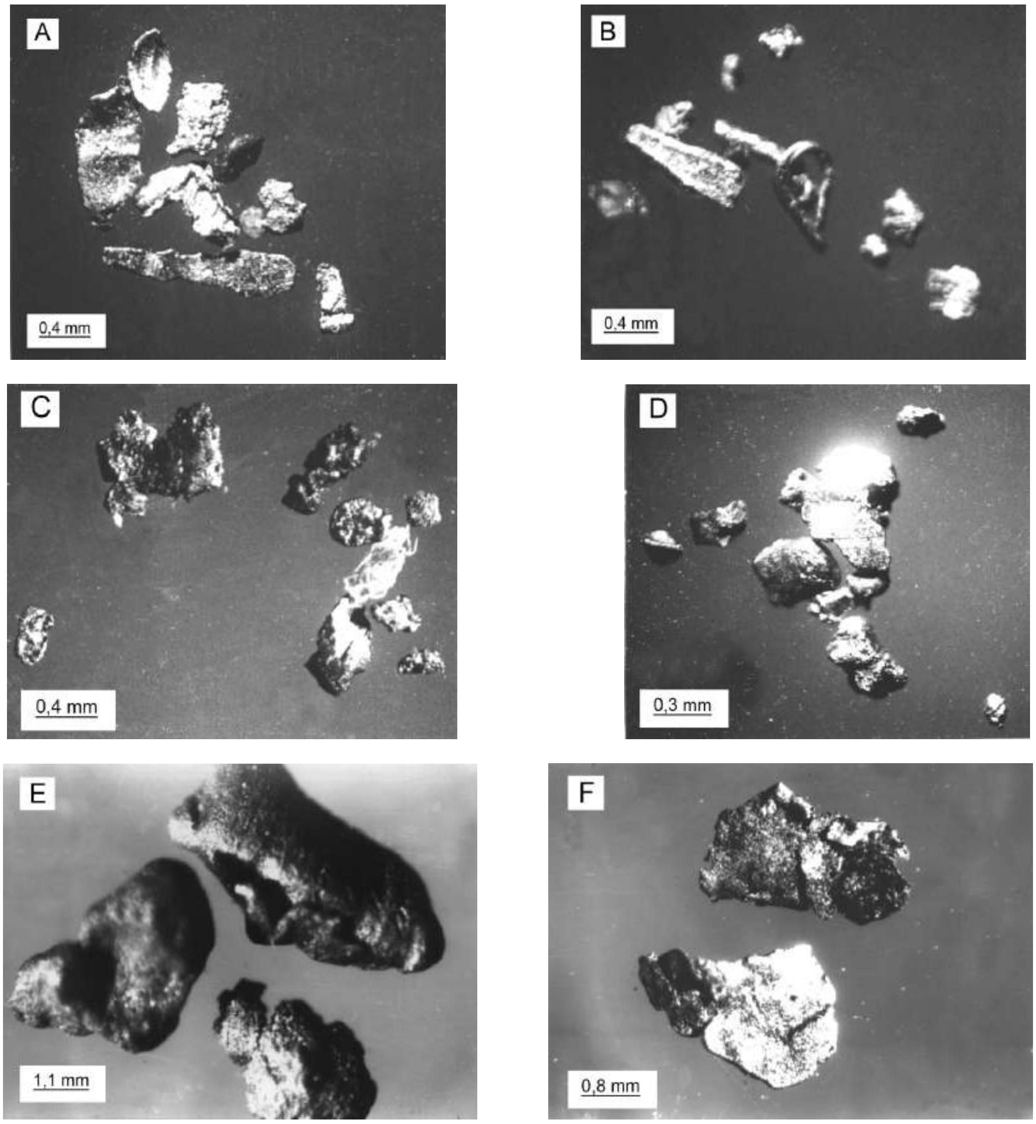

Figure 2. Minerals of the heavy fraction of alluvium (Kubachi village, arroyo).

(A) – platy gold;
(B) – wire-like, elongated platy, isometric and lumpy forms of a gold;
(C) – isometric and elongated forms of a silver;
(D) – lumpy forms of a gold;
(E) – technogenic silver;
(F) – folded thin plates of a gold.

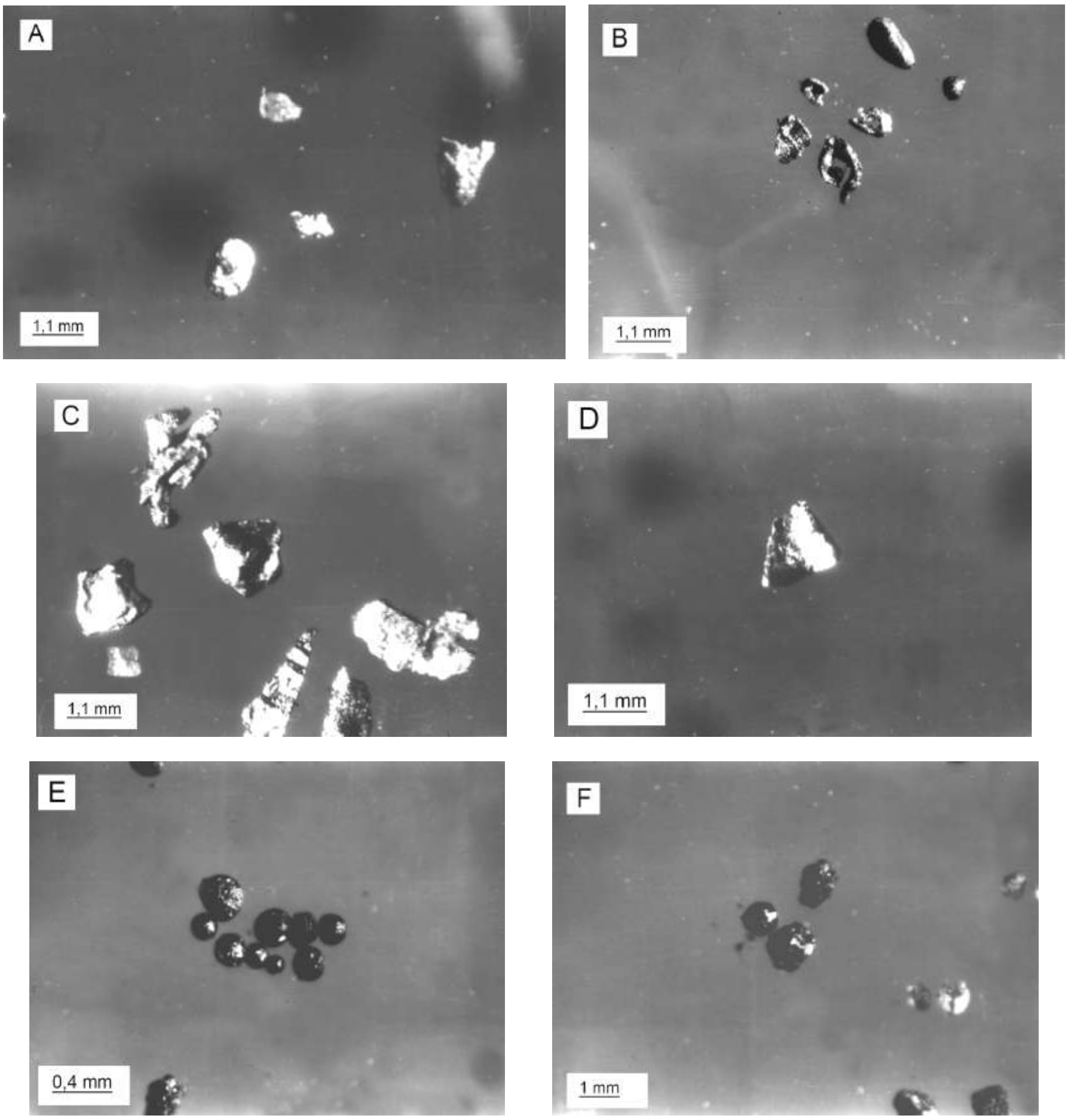

Figure 3. Minerals of the heavy fraction of alluvium concentrates (Kuli village, Nakhchucheynanikh brook).

(A) – on the right: subrounded grain of a gold;

(B) – on the top: two rounded grains of magnetite, others – gold grains;

(C) – on the far right: plate of a silver, on the top: three irregularly shaped plates of a gold (from the alluvium of Kubachi arroyo);

(D) – gold scale;

(E) – globules of magnetite;

(F) – aggregate grains of magnetite.

Assessed through the lithologic-mineralogical and stratigraphic studies of the Tertiary deposits of Eastern Fore-Caucasus region (1935-1964), commercial component concentrations of the heavy fraction of concentrates are provided in the Table 3.

Sampling of heavy mineral concentrate of the Quaternary deposits (alluvial and coastal-marine, including recent beach sediments), determined was their regional charge by the heavy fraction in the structure of ilmenite, zirconium and rutile. In the river valley of Samur, established are about 0.5 kg/m^3 concentrations of zirconium, the content of which even reaches 16 kg/m^3 in the separate samples. Increase commercial component concentrations are recorded in the estuary parts of Terek, Sulak, Achi-Su, Cherkez-Ozen, etc.

As commercial titanium-zirconic placers have coastal-marine origin, it's just the valuable components of the littoral sediments that are of a special interest. Various concentrations of zirconium, rutile and ilmenite have been detected among the region's beach deposits as a result of exploratory-surveying and other types of the studies. For example, we discovered up to 8 kg/t concentrations of zirconium in 2003. Earlier in 2002, M.M.Gurbanov detected maximum concentrations of zirconium (30-40 kg/m^3) and rutile (80 kg/m^3). Although the commercial component concentrations of samples do not necessarily bear record to a presence of the placers with similar concentrations, they definitely favour the further prospecting activities.

Table 1

Concentration of the heavy fraction of terrigenous material in the Aalenian deposits, %% of a heavy fraction

№ n/n	Sampling location	Zirconium	Rutile	Titanite	Leucoxene	Magnetite-ilmenite	Number of analysis	Heavy fraction output
				Kurakh suite				
1	Andian Koysu	52,5	1,5	1,6	10,3	1,2	8	0,6
2	Avarian Koysu	54,0	2,0	0,5	12,0	1,0	1,0	0,8
3	Kara-Koysu	57,0	3,0	0,6	11,0	1,5	13	1,0
4	Salatau	45,0	2,0	2,0	0,8	1,7	7	1,0
5	Uluchara	43,0	1,5	1,5	5,0	0,6	15	-
6	Trisanchi	37,0	4,0	-	4,0	2,0	11	-
7	Rubaschay	32,0	5,0	2,0	3,2	3,0	12	1,0
8	Chirakh-chay	34,6	1,5	5,0	6,0	4,0	16	-
9	Kurakh-chay	50,0	4,0	2,0	7,0	2,0	10	-
10	Gestenkil	49,0	5,5	-	10,0	5,0	8	-
11	Eldama	16,6	0,3	2,0	30,0	17,5	6	-
12	Babachay	20,5	0,8	0,5	4,0	2,0	15	1,0
				Khiva suite				
1	Ulluchara	47	5,0	0,3	4,5	2,0	6	
2	Chirakh-chay	26	4,5	1,5	3,0	1,0	14	
3	Trisanchi	31	4,0	0,3	5,0	2,0	10	
4	Rubaschay	27	4,0	0,2	2,4	1,0	12	
5	Getengil	20	1,6	0,5	3,0	3,0	15	
6	Jimichay	17	5,0	2,0	12,0	4,0	15	
7	Babachay	13	2,0	-	11,0	2,0	20	

Table 2

Zirconium content of the Jurassic series, %% of a heavy fraction

Age of deposits	Sampling location	Sandy rocks		Silty rocks		Clayey rocks	
		Zirconium %	Heavy fraction %	Zirconium %	Heavy fraction %	Zirconium %	Heavy fraction %
Toarcian	Rutul	7,2(8)	0,7	9,5(10)	0,3	6,5(13)	0,5
	Avarian Koysu	8,2(12)	0,63	2,8(5)	0,5	1,0(5)	0,6
Aalenian	Gestingil	5,9(7)	0,6	7,5(18)	0,05	4,9(24)	0,09
	Ulluchay	6,6(5)	0,3	8,0(19)	0,2	13,6(6)	0,7
	Eldama	13,3(39)	0,15	10,0(3)	0,16	3,8(23)	0,16
	Avarian Koysu	16,8(30)	0,37	10,4(15)	0,07	5,6(16)	1,05
Bajocian	Gestingil	11,2(5)	0,21	7,0(9)	0,8	3,0(15)	0,42
	Ulluchay	8,2(25)	0,53	4,0(19)	0,37	7,0(8)	0,19
	Eldama	12,5(4)	0,27	3,8(5)	0,8	6,3(19)	2,6
	Arakani Avarian Koysu	10,5(4)	0,11	13,2(25)	0,20	7,8(20)	0,09
	Avarian Koysu	19,9(6)	0,12	11,5(6)	0,17	5,0(7)	0,27
Bathonian	Mulakhchay					1,0(14)	1,67
	Kurmukhchay					2,0(7)	0,2
	Gamzilchay					3,6(33)	0,03
	Babachay					9,8(15)	0,2
	Afurja					4,7(16)	0,19
	Arakani					1,0(51)	0,15
	Avarian Koysu					7,7(45)	0,02
Kim-meridgian	Kurmukhchay					15,03(28)	0,04
	Babachay					7,3(41)	0,2
	Jimichay					9,8(28)	0,5
	Khalgen					9,9(47)	0,18
Tithonian	Kurmukhchay					5,9(22)	0,64
	Babachay					12,0(42)	2,4
	Jimichay					2,5(48)	0,99
	Gyzylchay					10(29)	0,20

Table 3

Concentration of some heavy fraction minerals in the Karagan-Chokrakian deposits, kg/m^3

#	Sampling location	Number of samples	İlmenite	Rutile	Zirconium	Heavy fraction output %%
1	Uytash st.	18	13,8 – 15,2 / 14,3	0,77 – 3,0 / 2,6	2,07 – 3,5 / 2,43	1, 76
2	Kumtorkala vil.	22	2,8 – 15,0 / 8,6	0,4 – 4,0 / 3,2	1,2 – 7,3 / 6,5	2,02
3	Kapchugay vil.	16	3,5 – 16,0 / 12,0	1,2 – 4,7 / 3,6	1,6 – 5,2 / 3,8	1,95
4	Sulak riv.	11	-	-	up to 6,0	1,96
5	Aktash riv.	11	2,2 – 15,0 / 12,2	0,9 – 3,9 / 2,6	1,1 – 6,0 / 4,8	1,46
6	Bulak riv.	7	5,4 – 21,6 / 18,4	1,1 – 4,2 / 2,8	3,0 – 5,0 / 4,0	2,47

Special assessment and prospecting works have been implemented in Cherkez-Ozen and Manas-Ozen areas with the use of trial pits and manual wells. These activities were also carried out during exploratory surveying works (1:200000) in the west of the Dagestan near-shore plain that is adjacent to the gulf of Kizlyar. In the first two locations, up to 20 m wide non-commercial placers with separate thin (up to 1 m thick) lenses have been detected with an untraced direction and up to 8-10 kg/t of the zirconium concentrations. Most workings haven't reached neither the primary rocks nor the clayey rock-floor. Section of the soft deposits is characterised by throughout distribution of the valuable components (zirconium, rutile) with concentrations levels of O,on; O,n; 1-2 kg/t, and rarely up to 8-10 kg/t. Sampling of the near-shore marine deposits indicated at the zirconium's 3-4 kg/t concentrations.

In Kizlyar gulf, samples have been collected from the area which was 5-10 km away from the modern beach area. Sampling analysis recorded non-commercial concentrations of O, n kg/t, reaching 1 kg/t in the separate samples. Samples were collected from a depth of 3-4 m and mainly didn't reach the rock floor.

Further to the west of the Kizlyar gulf, commercial placers of zirconium (Beshpagir deposit and other occurrences) have been detected among the Sarmatian coastal-marine deposits in the river valley of Kalaus (Stavropol). Therefore it can be said that the littoral sediments contain different, up to commercial concentrations of zirconium, rutile and ilmenite with placer accumulations emerged across 300-400 km long area between the riverbed of Samur, Kizlyar gulf and Stavropol krai. In a vertical extension, commercial concentrations of the valuable components are detected in the soft sediments of Holocene through Sarmatian. As will be shown below, within the Chokrak-Karaganian weakly cemented fine-grained sand-quartz deposits as well as in the lithified sandy-slate stratas of Dagestan, increased concentrations of zirconium and rutile are detected starting from the Lower Jurassic formations. This wide regional charge by a heavy fraction with valuable components speaks for the assumption that there are the considerable volumes of terrigenous heavy minerals with potentially commercial accumulations which have been transferred into the region's coastal-marine deposits.

Weaknesses of the implemented studies consist in the facts that there were no key geology-geomorphological sections with soft sediment sampling from the daylight through the layer of bedrocks, and that the sampling activities implemented in Dagestan didn't cover Early Quaternary deposits of Baku, Khazarian and Khvalynian stages. It is important to collect samples from all levels of the coastal plane terraces.

It is also desirable to conduct thematic researches to identify the soft sediments' real commercial component concentration, as well as to refuse washing samples with a pan and start using more modern titanium-zirconic placer sampling methods. Difference between zirconium and rutile concentrations in the washed and "untouched" samples may reach one order and more with continuous reduction in the washed ones (Table 4).

As concluded from the geomorphological studies of the Eastern part of the Dagestan coastal plain, there are three gulf-shaped areas (namely, Terekmey, Kayakent and Rubas-Gulgerichay) that most perspective in terms the placer discovery. These areas have all of the identified levels of terraces (7 surface, and 2 submarine) which cover an entire section of the Anthropogen deposits, starting from the Baku stage until Holocene. Unlike the plain's north-western segment with poorly defined levels of terraces, this area is quite appropriate for developing key sections and implementing a sampling program.

Field investigations have been carried out in the river valleys of Cherkez-Ozen and Shura-Ozen, and samples have been collected in the areas where the rivers are cutting through the soft sediments and make Sarmatian bedrock clays revealed. As shown by the data produced, the highest titaniferous and zirconic mineral concentrations are detected in the near-bedrock parts of the marine deposits with Khazarian дидакнами (the layer's thickness is 1-1.5 m). It is necessary to continue such works in the future in order to assess placer perspectives of the plain's soft Baku-Khvalynian sediments, and to collect samples from an entire thickness of plain parts of the valleys which make the underlying bedrocks revealed. Such spots allow developing a set of the key sections, which would then form basis for assessing the titanium-zirconium bearing perspectives and implementing more detailed research in the region.

Table 4

Comparison of zirconium and rutile contents of the washed and not washed (selected in blocks) samples

#	Sample #	Concentration, kg/m^3		Remark
		Zirconium	**Rutile**	
1	267 267	0,257 10,538a 40p	0,054 1,258 23p	Unindexed samples are adjusted to the grey sand a- samples from block p- concentration increase value.
2	273 273	0,067 1,575a 23p	0,018 0,572 31p	
3	277 277	0,112 3,448a 30p	0,023 2,375 103p	
4	450 450	0,112 0,792a 6,5p	0,057 0,277 49p	

Apart from the forecited sampling activities, terrigenous heavy fraction minerals have been studied under the geological investigation of marine oil-gas bearing provinces implemented in 1957-1960 by the Institute of Geology and Fossil Fuel Development. Investigations included sampling of 330 columns of the bottom sediments collected from the deeper part of the Caspian Sea. In Dagestan, the sampling area was confined to the Middle Caspian Darband depression. Each column reached 10-12 m in length. Heavy fractions with potential zirconium concentrations of 5-10, 5-3, 3-2, 2-1 and below 1 % have been identified. Areas with the zirconium's maximal concentrations form a narrow line on the western slope of the Darband depression, just on the opposite site of Darband town. The line corresponds to the development area of rutile as well (1-0.5%). Concentration levels of magnetite and ilmenite vary between 0.5 and 20.3%, and average at 9.2% in the western Middle Caspian zone. Heavy fraction output is 0.75%. With this in mind, concentration levels of magnetite-ilmenite are 2-2.5 kg/t, and of zirconium are 2.5-3 kg/t. It is assumed that the terrigenous heavy fraction minerals are transferred by Volga and Ural, as to the lesser extend by the Caucasus rivers.

Eolian processes

Eolian processes are widely developed in the littoral plain, which is best evidenced by Sari-kum – the largest dune of the Europe. Undoubtedly, eolation had influenced the placer formation process. It is commonly expected that in the areas around large eolian deposits, there are high heavy fraction concentrations of the terrigenous minerals. Apparently, it was the combination of eolian and alluvial processes which caused increased heavy fraction concentrations in the river drift of Shura-ozen, in the part of its' stream which borders the Sari-kum dune. Eolian impacts upon the placer formation process deserves more detailed investigation.

At the end of 2004 and in 2005, studies had mainly covered the sandy-quartz fine-grained deposits of Chokrakian and Karaganian ages, developed at 180 km long area between the estuary of Sulak river and the town of Darband. Starting from 1:100000 map of Brod (1958), geological maps define these deposits as an unbroken sections of Miocene (N1), Karaganian and Konkian (N1kg-kn), Tarkhanian and Chokrakian horizons (N1tr+c). Main sandy series of Dagestan are related with these very deposits. In the area's southeast (east of Darband), there are the sandy-quartz horizons in the Sarmatian series as well. In different sections sands have different summary thicknesses, which vary from tens to hundreds of meters. Largest thicknesses are detected in the river valleys of Shura-Ozen, Sulak, Ulluchay. To the west of Sulak and to the east to Darband, deposits become noticeably thinner. Concentrations of valuable heavy fraction components within the deposits of Miocene are provided in Table 3 (data collected from literature and archive materials) and Table 5 (data produced through our own research).

Represented by weakly cemented and fine-grained quartz sands which contain heavy fraction of terrigenous minerals with valuable components (ilmenite, rutile, zirconium, leucoxene), Karaganian and Chokrakian series have been studied and sampled by us in the river valleys of Sulak, Cherkez-Ozen, Manas-Ozen, Gamri-Uzen, Achisu, Ulluchay, Rubas and Gulgerichay, as well as in the arroyos of Ekibulak, Uchkent and Shura-Ozen, and on the pass of Buynak. Sampling and washing of sands have been implemented with different level of detail, and the idea behind these works was to identify metal content along the strike of the series. According to the sampling outcomes, heavy fraction and its' constituent valuable component concentrations increase from the northwest towards the southeast. Remarkable southeastward increase of the concentrations is recorded starting from the right riverbanks of Cherkez-Ozen and Achisu (Table 5). Maximal concentrations are recorded in white, quartzy, well washed and sorted fine-grained Karaganian sands in the river valley of Rubas (Khuchni road). But, besides increased valuable component contents, these series are characterised by reduced summary thickness of a sandy pack. As compared to the area's northwestern segments, here the rocks are covered by a thicker alluvial soil, and their investigation requires drilling and surface trenching operations. Additionally, samples have been collected from marine sand series detected near the estuary of Rubas, including modern sediments of beaches, spits and the other landforms. It was determined that unlike the other parts of the Caspian coastline, these sands have dark and brownish-rusty colour. As stated by the conducted analysis, the heavy fraction is by 70-80% built by the iron oxides that are developed by ilmenite. The heavy fraction output reaches 50%. According to the produced information, the river valley of Rubas is perspective in terms of finding commercially valuable ilmenite-zirconium placer, and needs to be covered by more detailed investigations.

Terrigenous mineral characteristics

Integrated analysis of Karaganian heavy fraction concentrate (mineralogist E.A.Andrianova, Institute of Ore Deposit Geology - IODG) had identified the total of 26 minerals (Table 6), including 10 minerals with increased concentrations, e.g. groups of magnetite (1-2%) and ilmenite (73-77%), rutile (0.5-2%), leucoxene (0.3-1%), garnet (6.5-13%), tourmaline (1-2%), kyanite (up to 2%), staurolite (4.5-7%), zirconium (0.5-1%) and micaceous mineral (1-2%). In total, valuable placer forming components (ilmenite, rutile, zirconium, leucoxene) constitute 81% of the heavy fraction.

One sample of the Karaganian sandstones collected from the Leninkent village's vicinities, contained two grains of silver in the form of compressed scales. The gold is found as separate 0.2 mm large grains among the Karaganian sandstones in the river valley of Shura-Ozen.

Table 5

Results of the heavy mineral concentrate sampling of Chokrakian and Karaganian weakly cemented quartz sandstones (2004-2005)

№	Sampling location	Heavy Fraction Output (%)	Ilmenite, % of heavy fraction	Rutile, % of heavy fraction	Zirconium, % of heavy fraction	Number of samples
1	Karabudakhkent village	0,5	60	15	7-10	3
2	Cherkez-Ozen river (landfill)	0,5-1,0	50-60	5-15	10-15	4
3	Buynak pass	0,2-0,3	10-60	10-15	5-50	5
4	Shura-Ozen, Kapchugay village	0,2-0,6	20-60	7-20	7-30	7
5	Shura-Ozen, Kumtorkala village	0,3-1,0	30-70	0,5-10	0,5-15	9
6	Cherkez-Ozen river	0,1-0,3	40-60	10	5-50	5
7	Achisu river	0,5-1,5	50-70	5-10	1-30	7
8	Uchkent	0,3-0,5	60	5-10	7-10	3
9	Sulak river (Sultan deposit)	0,2-0,3	60	5	10	6
10	Buynaksk (Buglen village)	0,5-0,7	70	5	5-7	7
11	Rubas Khuchni river	1,0-2,5	40-60	5-10	15-25	5

Comparing mineralogy of the heavy fraction of described concentrates and Pleistocene marine deposits in Shura-Ozen (Table 6) leads us to a conclusion that, unlike the series of Miocene, these deposits are characterized by sharply declined concentrations of ilmenite (28-39%), increased concentrations of iron oxides (20-49%), zirconium and garnet. Summary content of the valuable heavy fraction components reduces to 31-52% due to reduced concentrations of ilmenite.

As demonstrated by the field investigations, heavy fraction content of Chokrakian and Karaganian quartz-sands is generally high in the areas with paloedynamically active sedimentation environment, expressed by the emergence of littoral facies with fine-grained structure, intercalation with different bedding elements and oblique bedding. Another favourable factor is the finely washed sand, fine-grained quartz material and the other lithological features.

As concluded from the studies by IODG (N.G. Patik-Kara et al.), Dagestan's Miocene deposits with *Ti* and *Zr* perspectives have a number of peculiarities that are common for most marginal-marine placers. Specific point of the described placer formation process consists in the association of minerals with high chemical and abrasive stability, moderately high density (3.2-4.4) and fine-grained structure. This factor determines similarity of their migration capacity, hydraulic size and ability to get concentrated under close lithogenetical environment within the dimensional range of 0.04-0.16 mm.

Among other mineral types of the placer deposits, coastal-marine sediments are distinguished for depending not so much on the kind of a nourishment source as on the volumes of refined rocks with miserable ore mineral contents. Small size of their separations is preferable as it corresponds to a hydraulic size of the quartz grains with coarse-silty and fine-powdery dimension, among which ore minerals are usually concentrated. Main large-scale concentration forming processes are the deep chemical erosion that enables release of the small-size grains, and their gravity separation in the nearshore waters. According to what has been said, productive titanium-zirconic placer formations are the minerally mature quartz and fieldspar-quartz oligomictic formations represented by well sorted fine-grained sands and large siltstones from the foreshore's high-energy environment. These characteristics are true about the region's potentially placer forming Miocene formations.

During the post-Pliocene neotectonic stage, the modern Caucasus orogen had started to rise, making the material's migration proceed in a reversed direction, the same direction in which the modern streamflows are running, arising in the Eastern Greater Caucasus mountains and flowing into the Caspian Sea (river basins of Samur, Sulak, Terek). Such flows used to wash out the ancient lithified placers. Washing, ablation and transfer of the weathering rinds had occurred in their basins, developed on the multiple-aged peneplanation planes. At that time, a new complex of Quaternary placers had started to emerge (Figure 4). Quaternary alluvial placers are characterised by the heavy fraction's mineral composition which has been described above. Most perspective in terms of detecting such young placers are the modern Caspian coastal-marine deposits, developed at 4-10 m deep parts of the sea, marine terraces, as well as deltas and near-delta areas of the contemporary rivers. According to Y.N.Nevessky (Nevessky, 1971), these sediments produce 2.5-7.8% of zirconium and 0.4-0.8% of rutile concentrations.

It can be imagined, that there had been a gigantic "apron" in the Greater Caucasus region, and during Meso-Cenozoic, it used to be flanged by the paleo-lands of Paleozoic platforms, while its' trough had been constituted by a geosynclinal trench of the Caucasus mega-anticlinorium. During post-Pliocene, the "apron" had split, and the northern and southern slopes of the Greater Caucasus system had formed the one of its' flanges. Favourable conditions for the heavy fraction accumulation had emerged in the trenches of such aprons, and therefore these trenches have to be a main target for the placer exploration activities.

Table 6

Mineralogical analysis of concentrates

#	Minerals	Concentration, % of the heavy fraction	
1.	Group of magnetites	1,5	4
2.	Group of ilmenite	75	23
3.	Sphen	<<1	<<1
4.	Rutile	1,2	2,4
5.	Nigrine	0,3	0,9
6.	Sagenite	<<1	-
7.	Anatase	<1	<<1
8.	Brookite	-	<<1
9.	Leucoxene	0,6	1,2
10.	Dark-coloured spinel	1	<1
11.	Ortopyroxene	-	<<1
12.	Clinopyroxene	1 grain	<<1
13.	Coloured spinel	<<1	<<1
14.	Amphibole	-	<1
15.	Epidote	<1	<1
16.	Garnet	9,8	13,2
17.	Tourmaline	1,5	1,2
18.	Monazite	<<1	<<1
19.	Xenotime	<<1	<<1
20.	Group of kyanite	1	0,9
21.	Staurolite	5,7	8
22.	Zirconium	0,8	4,7
23.	Malacone	<<1	<<1
24.	Cytrolite	<<1	<<1
25.	Apatite	-	0,2
26.	Barite	<<1	<1
27.	Iron oxide	<1	37,7
28.	Micaceous mineral aggregate	1,5	<1
29.	Pyrite	-	grain
30.	Oxidised pyrite	-	<<1
31.	Oxidised marcasite	-	1 grain
32.	Chlorite	-	<<1
33.	Blue corundum	-	1 grain
34.	Cinnabar		1 grain
35.	Malachite		1 grain
	Total	**100%**	**100%**
		Chokrak-Karaganian series, 5 samples	Pleistocene series, 4 samples

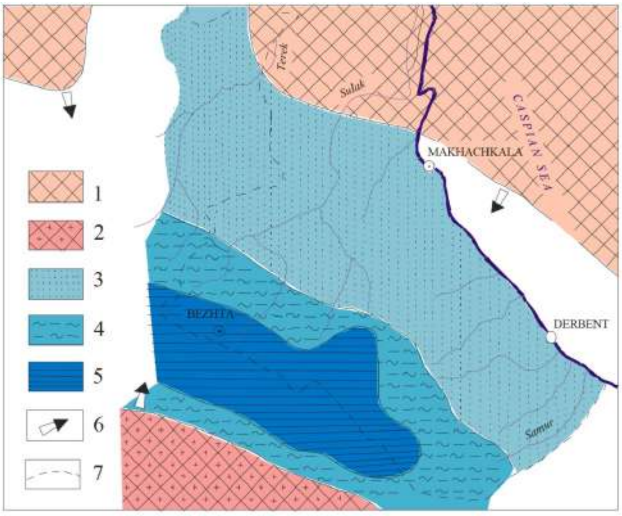

Figure 4. Facies-paleogeographic part of the part of the Eastern Caucasus, Jurassic period, Toarcian age. Author: T.G. Jgenti et al. (1978)

1 - altered metamorphic, sedimentary rocks and tuffs;

2 - erupted metamorphic and sedimentary rocks;

3 - silty-sandstone coastal-marine, coastal-delta deposits with subordinate development of alluvial and flood-plain facies

4 - siltstone-clayey deposits of marine coastal-shallow water and submarine-delta facies

5 - clayey deposits of marine shallow water facies and the facies of relatively deep-water part of the shallow sea

6 - direction of the fragmentary material drift

7 - border of Dagestan.

It deserves mentioning that there are the historical records indicating the presence of gold and silver deposits on the territory of the Northern Dagestan, in the river basins of Aktash and Terek that flow over the coastal plain's Quaternary deposits (Muhammad Avabi Aktashi, 1992). These records conform with the perception above.

No large commercial placers have been discovered in the studied territory so far, which is due to the fact that the area haven't been practically explored. Therefore, we decided to analyse general placer formation processes and then mark out the most perspective areas for the formation of increased titanium and zirconium concentrations. Speaking about evolutionary aspect of the placer formation, it has to be stated that the exclusion of primary ore-bearing formations of the bedrock from their nourishment areas had presumably occurred in Permian-Triassic (Figure 5), or long before the emergence of increased concentrations during Miocene-Pleistocene (Gavrilov, 2002; Gmid, 1953; Zgenti, Slinko, 1978; Zgenti, Slinko, 1977; Zgenti et al., 1989). Later, the material had become re-deposited from Permian-Triassic volcanics (Gavrilov, 2002; Zgenti, Slinko; 1978. Zgenti et al., 1989) into the Jurassic, Lower-Upper Cretaceous and Paleogene-Neogene intermediary collectors. We brought Figure 6 as an example, bu the paleogeographic environment used to be nearly the same in the remaining sections of Jurassic and Cretaceous periods. Increased heavy fraction concentrations of zirconium, ilmenite and rutile are detected in those collectors, too. Demolition of such lithified collectors supplies valuable components into soft alluvial, coastal-marine and other deposits.

Placer formations – transfer source of the valuable components

According to paleogeographic studies of the described territory (Aliyev, Akayeva, 1957; Zgenti, Slinko, 1977; Khalifazadeh, Magomedov, 1982), migration of a terrigenous material during formation of Jurassic deposits occurred within the ravinement zones distinguished in the northern (Middle Caspian land) and southern (today, Kur depression) parts of the region (Figure 6).

Therefore, the mentioned terrigenous minerals are the most unalterable Paleozoic formations which had been preserved during physio-chemical weathering. Produced materials allow identifying a placer formation mechanism which used to be active in Mesozoic era, when the nourishing provinces existed to the south and the north of the Greater Caucasus Range. According to N.A.Shilo (Shilo, 1970), mentioned provinces used to have developed placer formations represented by metamorphic and volcanic series with valuable components like zirconium, rutile, monazite, gold and silver. This mechanism helps with explaining a placer formation model, according to which there was a remote source of migration, similar to the ancient gold-bearing conglomerates of Witwatersrand and Pretorius (Pretorius, 1984). It also allows justifying the territory's zirconium, rutile, ilmenite and precious metal bearing perspectives. Gold prospectivity of the Eastern Greater Caucasus region have been stated in the previous studies (Prokurnov, Vedenyapin, 1974.), too. It has been predicted by L.N.Kazarinov (Kazarinov, 1965.) that there are the increased zirconium concentrations in the Central Northern Caucasus region. This assumption was based upon the gold's presence in the soft sediments and did not explain the metal's potential sources. Region-wide Meso-Cenozoic circulation of the material's transfer is demonstrated in Figure 4. Keeping this figure in mind, it has to be considered that the Paleozoic lands could have been both close-by and remote (e.g. Voronezh massif).

When it comes to the terrigenous quartz of Chokrak-Karaganian deposits, there are two hypothesises regarding their source of origin.

1. V.A.Alferov, A.A.Khutsiyev, V.D.Golubyatnikov, D.D.Drobishev and other researchers assume that this source could be granitoids from the central part of the Greater Caucasus system. G.I. Brovkov and some other scientists supposed that the Central Caucasus magmatic massifs might have supplied a quartz material via the longshore currents. This assumption is confirmed by the discoveries of granite boulders that are similar to Central Caucasian granites among the Eastern Caucasus Upper Jurassic conglomerates, as well as by the distribution features of coarse and fine fractions of Chokrak-Karaganian sandy-quartz deposits in relation to the Eastern Caucasus orogen.

2. Researchers such as N.S.Shatsky, V.P.Jijchenko, V.A.Grossheim and N.B.Vassoyevich believed that most part of the Middle Miocene terrigenous material has a non-Caucasus origin. According to these authors, the fact that the quartz sands had arrived from outside of the Caucasus is evidenced by the fact that dimensions of the sand's quartzy material increase with distance from the Caucasus orogen, and vice versa. Heavy Chokrakian and Karaganian fractions are characterized by widespread occurrence of the metamorphic minerals such as kyanite, staurolite and epidote. On the other hand, there are almost no such minerals in a heavy fraction of the Mesozoic series. This data allows assuming that the main source of transfer of the terrigenous material during Middle Miocene used to be located to the northeast of Grozny-Dagestan area in the Caspian Sea.

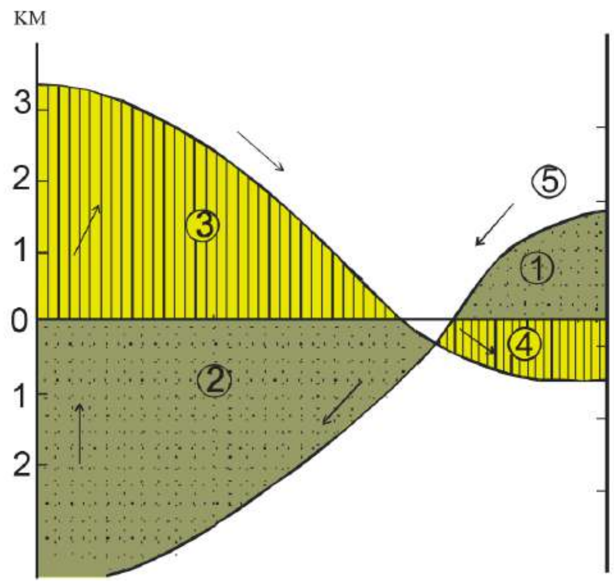

Figure 5. Vertical location scheme of the areas of transfer and accumulation of terrigenous material during Meso-Cenozoic: northern slope of the Eastern Greater Caucasus system.

1 – ravinement of Paleozoic land

2 – accumulation of terrigenous material, corresponding to the ancient land's ravinement

3 – ravinement of modern orogen

4 – accumulation of terrigenous material, corresponding to destruction of the modern orogen, starting from its' formation moment (Pliocene)

5 – circulation of terrigenous material, position of the ancient land above the sea level. According to Ch.M. Khalifazadeh et al. (1982)

Zero level – sedimentation basin level

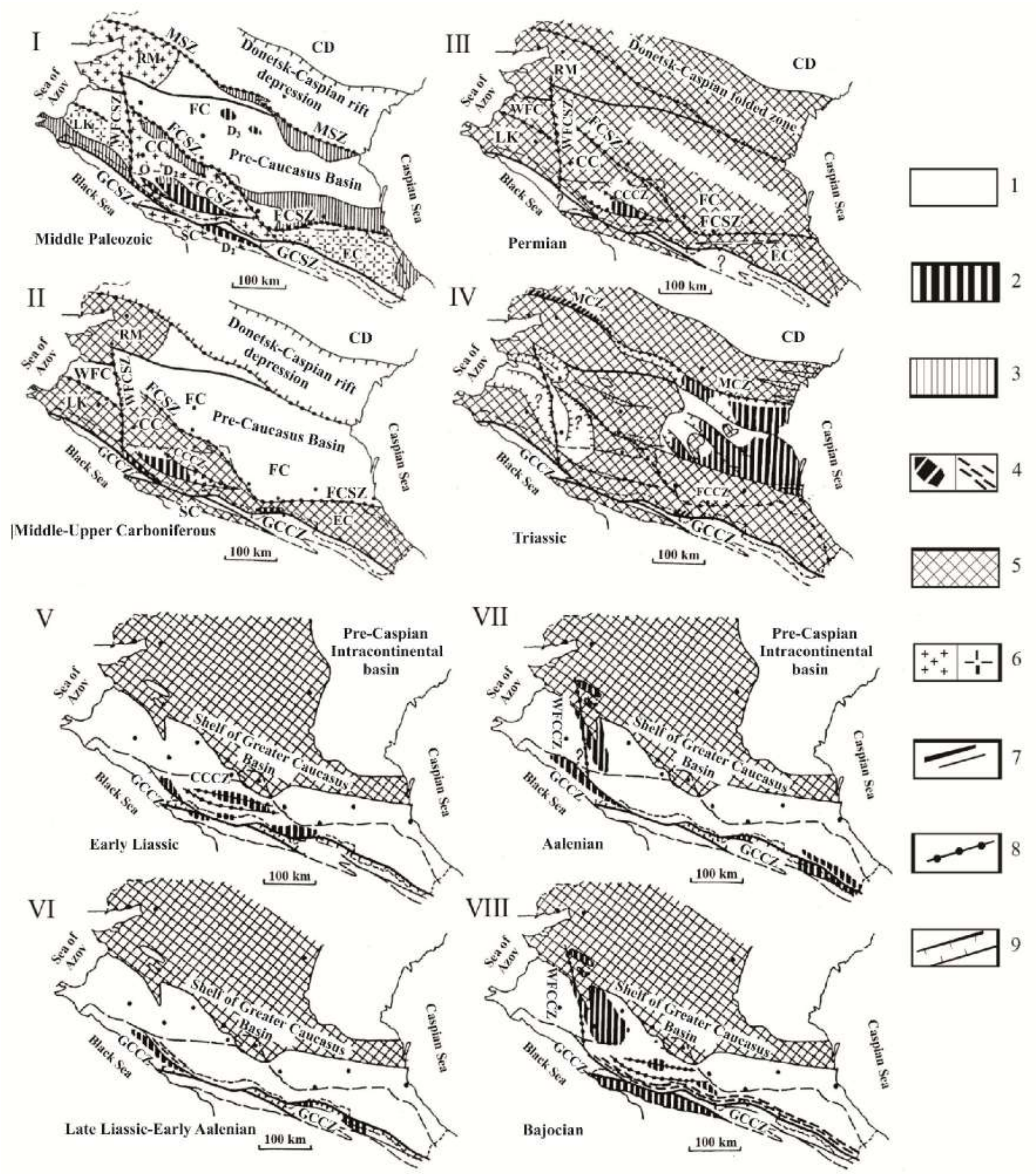

Figure 6. Development scheme of the Northern Caucasus tectonomagmatic formations during Hercynian, Indosinian (I-IV) and Cimmerian (V-VIII) tectonic cycles

1 – development areas of the deposits of respective age; **2-3** – development areas of volcanics: **2** – in natural outcrops or as revealed by boreholes; **3** – assumed according to the geophysical data. **4** – development areas of intrusions (except for Hercynian) (a), and development zones of Cimmerian dykes (b). **5** – areas where the respective age's deposits haven't been detected for their absence of erosion. **6** – crystalline massifs, studied in natural outcrops and revealed by boreholes (a), or assumed according to geophysical data (b). **7** – marginal sutures (a) and other borders (b). **8** – Suture zones between different blocks. **9** – Assumed rifting zones. **Crystalline massifs: CC** – Central Caucasus, **EC** – Eastern Caucasus, **LK** – Lower Kuban, **SC** – South Caucasus, **RM** – Rostov. **Microplates: FC** – Fore-Caucasus, **WFC** – Western Fore-Caucasus. **Depressions: CD** – Caspian. **Interblock suture zones: MSZ** – Manich suture zone, **FCSZ** – Fore-Caucasus suture zone, **WFCSZ** – Western Fore-Caucasus suture zone, **CCSZ** – Central Caucasus suture zone, **GCSZ** – Greater Caucasus suture zone. **Core zones: MCZ** – Manich core zone, **FCCZ -** Fore-Caucasus core zone, **WFCCZ** – Western Fore-Caucasus core zone, **CCCZ** – Central Caucasus core zone, **GCCZ** – Greater Caucasus core zone.

According to Ch.M.Khalifazadeh, A.G.Aliyev and other researchers, during Jurassic and Cretaceous periods, there were the northern and the southern lands to serve as a source for the terrigenous material's transfer into a marine basin of Thetis, which had then existed in place of the modern Caucasus orogen. The northern land had covered the modern Northern Caucasus region and used to supply terrigenous material to the areas of the current research. According to the deep-drilling data, there are the magmatic rocks of intrusive, effusive, acid and basic facies revealed in the region (Aliyev, Akayeva, 1957; Zgenti, Slinko, 1977; Zgenti et al., 1989).

General characterization of the composition and structure of the Northern Caucasus Paleozoic basement have been developed by I.I.Grekov et al. According to their survey, there is a broad (45000 km^2) area (Figure 5) of Triassic volcanics, which ends up with the Caspian shore in the east. However, there is a ground to expect that this volcanic strata extends further towards the east under the bottom of the Caspian Sea. This speculation is indirectly confirmed by the increased heavy fraction concentrations in the Karaganian sandy-quartz deposits around Darband and in the river valley of Rubas. It can be believed that an unrevealed part of the Caspian volcanics is as large as the one which has been discovered and mapped (Figure 5). Therefore, the entire area of the Eastern Caucasus volcanics may constitute about 90-100 thsd km^2. This huge magmatic massif is a potential source of terrigenous material required for the emergence of sandy-quarts formations with titanium-zirconium content, for a long period of time (Triassic, Jurassic, Cretaceous, Paleogene-Neogene?) developed under the continental environment. According to E.A.Adrianova, there are the following sources of placer-forming minerals:

- Metamorphic rocks of various facies and genesis, from weakly cemented sandstones and gneisses to charnokitoids and granulites formed along both magmatic and sedimentary rocks;
- Multi-age and unequally distant magmatic granitoids and their apical parts, together with associated greisens and pegmatites;
- Multi-age and unequally distant basic and ultrabasic magmatic rocks.
- Rocks of the eclogete facies of depth;
- Kimberlites;
- Multi-age and unequally distant intermediate collectors of all above types of the rocks.

As concluded from the outcomes of our own research, there potentially can be a local closely situated source of the quartzy material. On Ekibulag arroyo (Narat-Tube - drainage front range that opens out to the coastal plain), there are the following series detected among the area's proluvial-diluvial deposits: 1) boulders (20x30x30 cm) of gravelites represented by up to 2 cm large purely quartzy fragments with poorly-rounded but well burnished varieties; 2) up to 5-8 cm large quartz gravel (milk-white typically ferrous varieties) with poorly-rounded but well burnished varieties (Figure 7) absolutely crude and flat light-colored fragments built by an extremely fine-grained quartz, described by us as submarine-hydrothermal quartzites.

Conclusions

1. Part of the region with placer perspectives is confined to a joining of the Eastern Caucasus Alpine orogen and the Scythian plate – southern segment of the Eastern European platform. This area used to be a place where all the final drainage basins used to be located before and after the orogen. This factor predetermined the wide development of coastal-marine deposits in which the respective placers are usually formed.

2. In the region to the north of the Eastern Caucasus orogen, there is a huge area (45000 km^2) of volcanics, which for a long period of time (Triassic, Jurassic and Cretaceous) used to exist in the continental environment, that is deemed highly favorable for the release of valuable components due to a physiochemical erosion, as well as their transfer and accumulation in the coastal-marine facies of the final drainage basin.

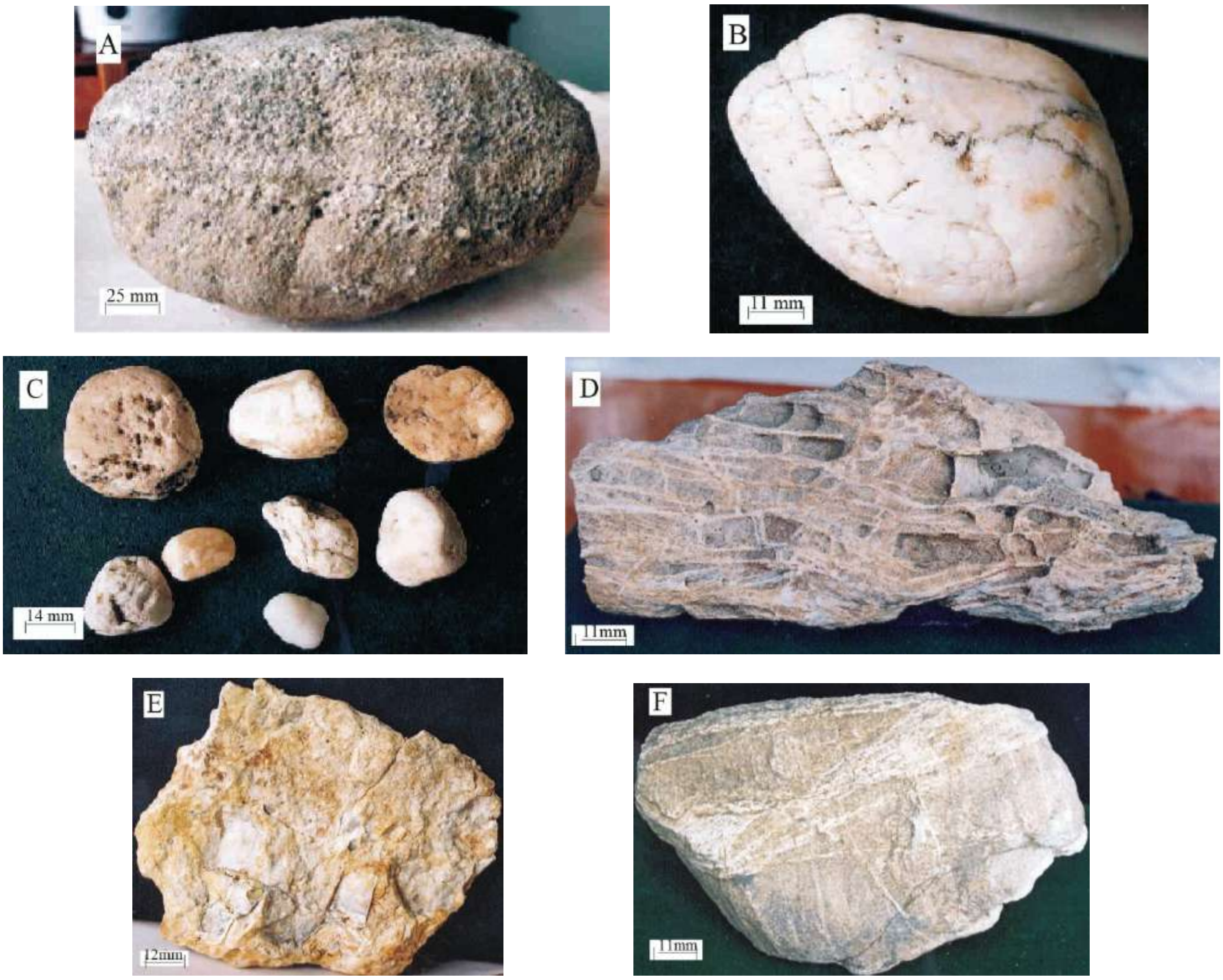

Figure 8-7. Boulders and gravels of quartz from the alluvial-diluvial deposits of Ekibulag arroyo
A – medium-size (up to 30 cm) boulder represented by a gravel with quartzy composition (gravelite) with quartz-sand charge. Fragments of quartz may reach 2 cm in size. Fragmentary material is mainly poorly-rounded but well burnished. **B** – Gravel with quartz composition (milk-white colored quartz), poorly-rounded but well burnished. Has tiny fractures by which strongly acidified sulfide material is developed (FeS_2?). **C** – poorly-rounded but well burnished quartzy gravel. Composition is similar to the one in picture B. **D** – Absolutely crude cavernous rock. The carcass is represented by silicitic material, caverns are filled by a sandy material. **E**– Siliceous rock fragment, not rounded at all. **F**– Absolutely crude fragment of a siliceous rock, similar to those in the pictures C and D, with noticeable signs of fluvial processing.

3. According to N.A.Shilo, there are two signposts that speak to a formation of placers in the region, namely presence of formations that are favorable for the valuable component release, and favorable conditions for the component transfer and deposition.

4. Chokrak-Karaganian deposits are represented by mature, fine-grained quartzy, well washed and sorted sands containing the fine-grained (‹ 0.2 mm) heavy fraction with valuable components (titanium-zirconic minerals). This is typical for all coastal-marine placers of that class.

5. Among the Eastern Caucasus Meso-Cenozoic series (from the modern Caspian beach deposits and bottom sediments to the

Lower Jurassic sandy-shale rocks on the Eastern Caucasus main range), the region is charged by a heavy fraction of the terrigenous minerals which constitute valuable components of the titanium-zirconic placers and are pass-through for the entire sedimentary complex. Proceeding from valuable component concentrations, mining conditions and deposit lithification, following stratas are characterized as perspective in terms of a placer detection: 1) primarily perspective Miocene (Karaganian, Chokrakian, Sarmatian) fine-grained and sand-quartz sediments, and 2) second priority Pleistocene (Baku-Khvalynian) soft sandy formations of the coastal plain.

6. Practical recommendations

Heavy fraction terrigenous minerals of the region have to be covered by special studies to address the placer formation processes within sandstones, terrigenous-carbonate rocks and soft coastal-marine deposits. First priority objects that require more detailed investigation, are the river valley of Rubas, Karaganian deposits in Buynaksk, and Chokrak-Karaganian deposits to the east of Cherkez-Ozen river. Within the future studies framework, sampling has to be implemented with deployment of modern technologies, and washing samples with a pan has to be abandoned.

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ŞƏRQİ QAFQAZIN MEZO-KAYNOZOY SÜXURLARININ AĞIR FRAKSİYASININ TERRİGEN MİNERALOGIYASI VƏ SƏPƏLƏNTİ ƏMƏLƏ GƏLMƏSİNİN PERSPEKTİVLƏRİ

V.İ. Çerkaşin, B.U.Matsapulin, A.R. Yusupov

Məqalədə Uluçay, Kazıkumux-Koysu və Sux çaylarının kövrək çöküntülərinin ağır fraksiyasına (allüvium, delüvium) baxılmışdır. Bunlardan ilk iki sahə Şimal qidalanma əyalətinin təsir sahəsindədir, ikinci isə Baş Qafqaz silsiləsi hüdudlarında və Cənub qidalanma əyalətinin təsiri sahəsində yerləşir. Terrigen materialların seçilən mənbələri Paleozoy yaşlı cənub və şimal qurularının ağır fraksiyasının mineralogiyasını əks etdirir. Onu mezo-kaynozoyda geosinklinal hövzəyə çatdırır.

ТЕРРИГЕННАЯ МИНЕРАЛОГИЯ ТЯЖЕЛОЙ ФРАКЦИИ ПОРОД МЕЗО-КАЙНОЗОЯ ВОСТОЧНОГО КАВКАЗА И ПЕРСПЕКТИВЫ (Tİ-ZR) РОССЫПЕОБРАЗОВАНИЯ

В.И. Черкашин, В.У. Мацапулин, А.Р. Юсупов

В статье рассмотрены вопросы изучения тяжелой фракции рыхлых отложений (аллювий, делювий) рек Улучай, Казикумухского Койсу и Усух-чай, из которых первые два участка находятся в области влияния северной питающей провинции, а последний расположен в пределах Главного Кавказского хребта в области влияния южной питающей провинции. Выделенные источники терригенного материала отражают минералогию тяжелой фракции южной и северной суш палеозойского возраста, поставляющих в мезокайнозое терригенный материал в геосинклинальный бассейн.

MICROROENTGEN SPECTRAL ORE MINERAL ANALYSIS OF SAATLI WELL COLUMN VOLCANICS

Microroentgen spectral ore mineral analysis of the volcanics produced from the column of Saatli ultradeep well had revealed relatively small (~2-10 mkm) grains of magnetite, and identified inhomogeneities in large grains of titanomagnetite (~10-100 mkm and over). In deeper depth intervals of 3540-5500 m, development of low-temperature metamorphism is almost not reflected on two generations: 1) large grain of titanomagnetite, homogenous or with a decay structure, and 2) small-sized usually well faceted grain of practically stoichiometric magnetite. The fact that there is no hematite (martite) and that the ilmenite is only present in the structures of decay suggests that the ore grains hasn't been intensively oxidized after their crystallization process. Metamorphism and metasomatism occurred in within the depth intervals of 7000-8126 m, causes the occurrence, development and spread of a "mosaic" structure of grains, and the formation of their "mottled" structure connected with dotty emissions of rutile in a basic mass of the grain of titanomagnetite and not determined by a hidden structure of decay. Detected are the acicular generations of secondary hematite as well as regularly and irregularly faceted grains of pyrite. Presence of secondary hematite and pyrite generations confirms that there has been a metasomatism process developed and that the fluids with different oxidation-reduction potential had penetrated the deeper-seated rocks.

Keywords: titanomagnetite, magnetite, decay, metamorphism and metasomatism, "mosaic" and "mottled" structures

Z.A. Novruzov

Institute of Geology and Geophysics of ANAS,
119, H.Javid ave., Az 1143, Baku, Azerbaijan
znovruz@yahoo.com

V.A. Tselmovich

Geophysical Observatory «Borok»,
Institute of Physics of the Earth, RAS,
Borok, Yaroslavl oblast, Russia
E-mail: tselm@mail.ru

Introduction

Ore mineral studies are often complicated by the fact that they produce extremely fine-grained or inhomogeneous emissions (Craig, Vogan, 1983.). For this reason, high-resolution (about 1-2 mkm) microprobe analysis of the ore minerals allows diagnosing relatively small (2-10 mkm) grains and large grain (10-100 mkm and over) inhomogeneities with sufficiently high accuracy level (Gouldstein, Iakovica, 1978.). Another benefit of such analysis is that it enables quantitative and qualitative analysis of the grain, implemented by both the separate spots and the specified grain profile and area (Toisimis, Martona, 1974.). Analysis results are apparently more informative than those produced by conventional methods of mineralogical studies.

Current article is based on results of the microprobe ore mineral analysis of volcanics revealed by the Saatli ultradeep well from the depth interval of 3540-8126 m. Implemented studies had pursued the following goals:

1. Qualitative ore mineral analysis;
2. Identifying inhomogeneity level of the ore grains;
3. Determining how the metamorphic processes do impact the ore mineral changes.

Before starting the narrated research, complex petrographic studies of the volcanics have been implemented at Geological Institute of the

Academy of Sciences of Azerbaijan SSR under the supervision of R.N.Abdullayev (Abdullayev, Salayeva, Salakhov, 1984; Abdullayev, Salakhov, 1983.). The studies produced the following outcomes:

1. Within the section's 3540-8126 m depth interval, composition of volcanics changes from acidic (rhyodacites, dacites) to average (andesites) and basic (andesite-basalts, basalts) differences. It means that these volcanics are characterized by an antidromous sequence of the volcanic process.

2. Volcanic rocks from 3540-5500 m depth interval are characterized by weakly developed metamorphic processes. According to a set of metamorphic minerals they characterize the initial phase (zeolite stage) of low-temperature metamorphism which is mainly developed in the rocks of volcanoclastic facies and practically do not affect the lavas.

3. In the deepest part of the section (5500-8126 m), intensive metamorphic changes are registered to the extent of complete transformation of rocks into the secondary quartzites. This transformation is conditioned by both low-temperature metasomatism and the hydrothermal processes.

It is logical to expect that the chronological evolution sequence of volcanic process and especially metamorphic changes have a direct impact on grains of the ore magnetic minerals.

Research object and equipment

Ultradeep well have been drilled not far from Saatli town (λ=39.91° N, φ=48.36° E) in Azerbaijan (Figure 1). Location area of this 15 km deep well is confined to Kur intermountain depression situated between large tectonic structures of Greater and Lesser Caucasus. According to its' deep structure, the depression is divided into three troughs, namely Upper, Middle and Lower Kur depressions, with Saatli area belonging to a structure of the Middle Kur intermountain depression.

As it was mentioned above, targets of research were the ore magnetic grains of the volcanic series detected in the 3540-8126 m depth interval of the deep well's column. All types of the research have been conducted by the RAS Institute of Physics of the Earth at the laboratory of Geophysical Observatory "Borok", specialized in physiochemical and magnetic rock analysis methods. Samples have been tested on the roentgen spectral analyzer "Camebax" with three wavelength dispersion spectrometers. Analyzed samples have been placed in Wood's alloy, grinded in and delicately polished. Chromite with concentrations of FeO–26,74%, Al_2O_3–8,68%, TiO_2–4,62% have been used as a standard for determining Fe, Ti and Al contents. Before starting the analysis, samples and standards have been sputtered by thin layer of carbon. Analysis was conducted under a boosting voltage of 15 KV, current intensity of 10 NA, and sound diameter of 1-3 mkm. Spot counting duration equalled 10 seconds. Microprobe analysis had normally addressed those ore mineral grains the areas of which were larger than the coverage area of sound (e.g. more than 2 mkm). This approach helped produce data on a grain's general characteristics, inhomogeneity and sufficiently large impurities. Profile scanning had mainly covered Fe and Ti, and partly Al concentrations. Less than 0.5% concentrations haven't been analyzed.

Results and Discussion

According to petrographic analysis data, the studied column was conventionally divided into two integral components, corresponding to the depth intervals of 3540-5500 m and 5500-8126 m.

The entire column appeared to contain large (~10–100 mkm) and small (~2-10 mkm) grains of titanomagnetites with low concentration levels of Ti (2-9%). Large grains were significantly inhomogeneous and fractured with silicate mineral inclusions. Small grains were homogeneous.

Figure 1. Geographic position of the Saatly section

Microphotos 2 and 3 present sufficiently large grain of titanomagnetite with Ti content of about 8%. As confirmed by Ti (top) and Fe (bottom) scanning implemented by the large grain's profile (Figure 2), the mineral has a homogeneous structure. As demonstrated by Figure 3, the small grain has a regular cutting (from this point forward *Fe, Ti and Al concentrations are calculated by* Fe_2O_3, TiO_2, Al_2O_3 *contents).*

The sample is quite typical for the depth interval of 4310-4315 m and generally characterized by a prevalence of small ore grains of stoichiometric magnetite. It's evident that the grains of this horizon's titanomagnetic minerals haven't been remarkably changed since the time of their emergence and that the presence of two generations rather reflects stadiality of their crystallization process.

Similar picture is observed in the rocks collected from 4423-4428 m deep horizon. The only difference is that its' large grains are much more intensively fractured and inhomogeneous (Figure 4), while the small grains are represented by stoichiometric magnetite (Figures 5 and 6), have almost regular cutting and are developed in association with sphene. Ti content of the large grains doesn't exceed 3-6%.

Figure 2. Microphoto of large grain of titanomagnetite. x400

Figure 3. Microphoto of small homogeneous grain of titanomagnetite. x4000

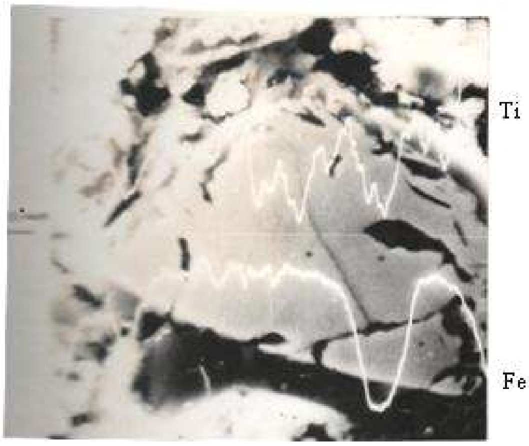


Figure 4. Microphoto of a large inhomogeneous grain of titanomagnetite. x3200

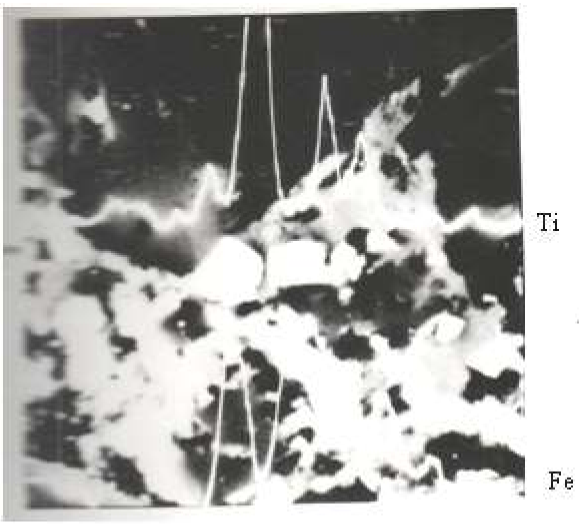


Figure 5. Microphoto of small grains of magnetite. x3200

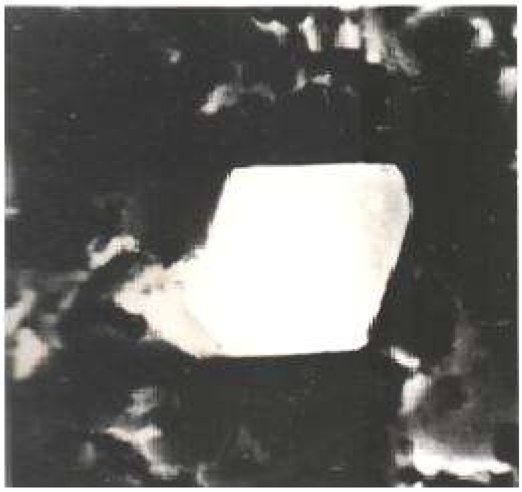


Figure 6. Microphoto of small grain of magnetite

Rocks of 4686-4689 m horizon normally contain large and inhomogeneous grains of titanomagnetite with Ti content of 4-5% (Figure 7-9). These grains usually form associations with sphene. Also registered are the emissions of ilmenite.

Profile scanning of Ti (top) and Fe (bottom) concentrations identified inhomogenities developed along margins of the grains. Grains are mainly homogeneous enough and not touched by secondary changes.

Decay structures of the titanomagnetic grains haven't been detected in the upper series of studied horizons. However, they are widely represented in basalts starting from the depth interval of 4770-4777 m (Figure 10-13). According to spot sounding and profile scanning of Ti and Fe contents, the grains are represented by titanomagnetites with Ti content of 3-8%. Decay structures and aggregates of these grains contain ilmenite and rutile.

Figure 13 presents a microphoto of stoichiometric magnetite, small-size grains of which are detected in the rocks of the column's studied horizon.

Apparently decay structure of large titanomagnetic grains is related with their heterophase oxidation at the initial stage of crystallization.

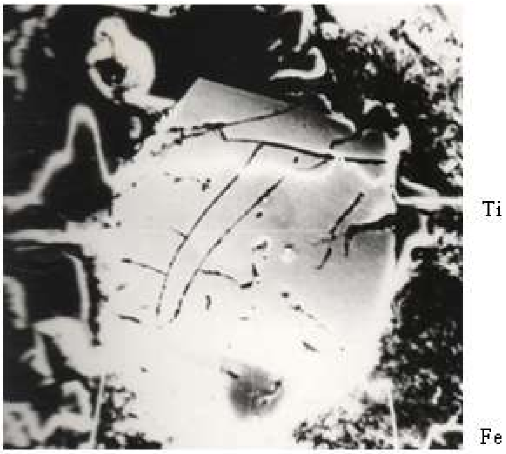


Figure 7. Microphoto of titanomagnetite grain in association with ilmenite. x1000

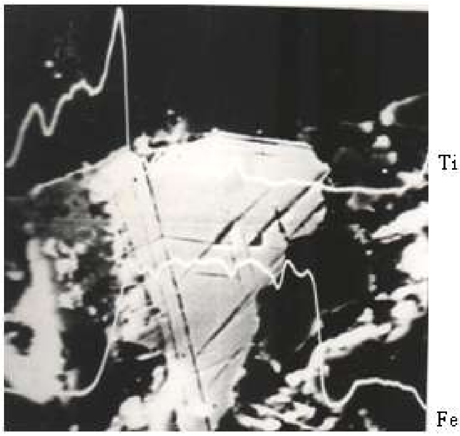


Figure 10. Microphoto of titanomagnetite grain with decay structure in association with ilmenite and sphene. x1600

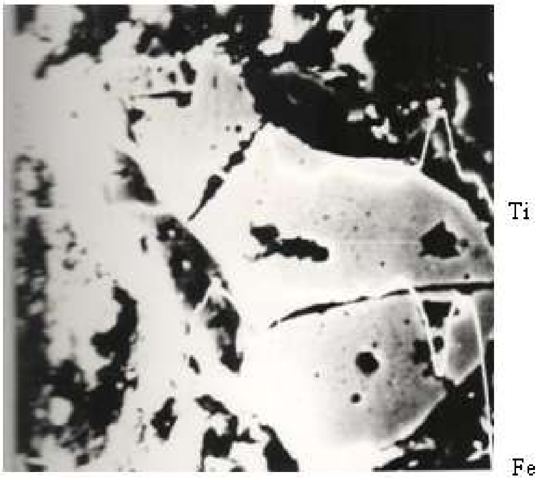


Figure 8. Microphoto of titanomagnetite grain in association with sphene. x2000

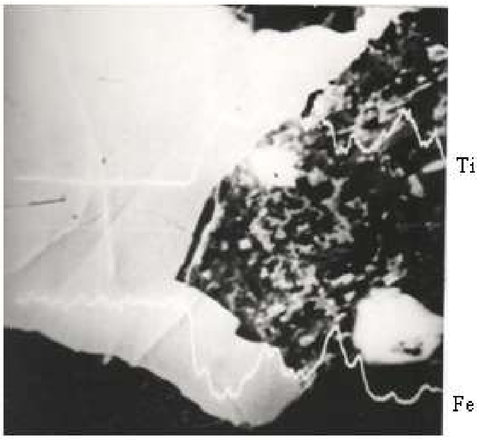


Figure 11. Microphoto of titanomagnetite grain with decay structure in association with ilmenite and rutile. x2000

Figure 9. Microphoto of titanomagnetite grain in association with sphene. x2200

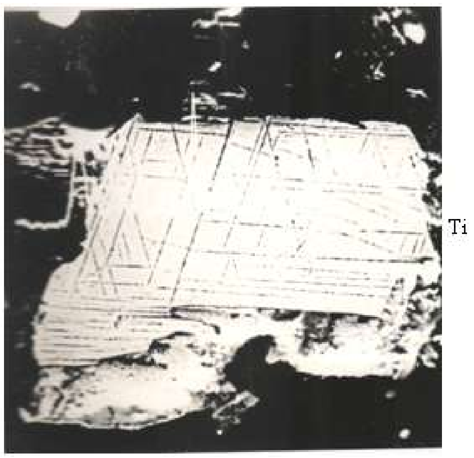


Figure 12. Microphoto of titanomagnetite grain with decay structure and ilmenite. x1000

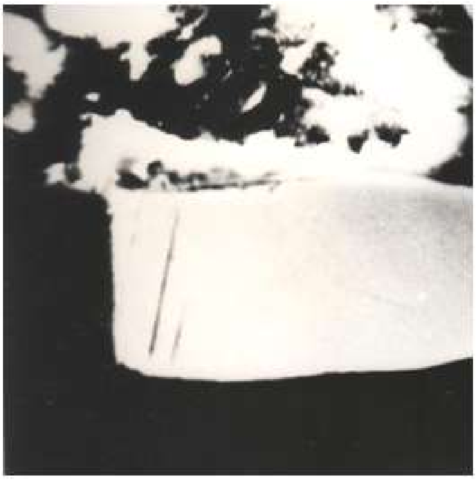


Figure 13. Microphoto of magnetite grain. x3800

Considerable compositional inhomogeneity of the titanomagnetic grains is established in the rocks of 5036-5040 m deep horizon (Figures 14, 15). As demonstrated by profile *Ti* and *Fe* scanning, the monitored grains have decay structures that are typical for the heterophase oxidation. Individual sounding allowed determining that the main mass of the grain is built by titanomagnetite with titanium content of about 5-6%. Deepest horizon of the studied section's upper segment (5467-5474 m) is characterized by the development mosaic structure which is typical for the deep stage of heterophase oxidation and probably conditioned by low-temperature metamorphism (Figures 16, 17, 18). It was identified by the individual sounding that the monitored grains contain 8-12% of *Ti* and about 6% of *Al*, which are in general higher concentrations than those of the shallower horizons. *Ti* and *Al* contents sharply reduce in the grain margins which speaks to a change of their composition.

Therefore, microprobe analysis results of the ore grains of basalts and andesibasalts collected from 3540-5500 m depth interval confirmed one of the major petrographic study conclusions standing for underdeveloped low-temperature metamorphism in the studied section's upper segment. Except for the grains collected from 5467-5474 m depth interval, ore grains of the studied series appeared not to undergo any essential secondary changes that could have been driven by metamorphic processes. Observed grain structures are homogenous. Apparently, they realize with a structure of decay during the stage of initial crystallization.

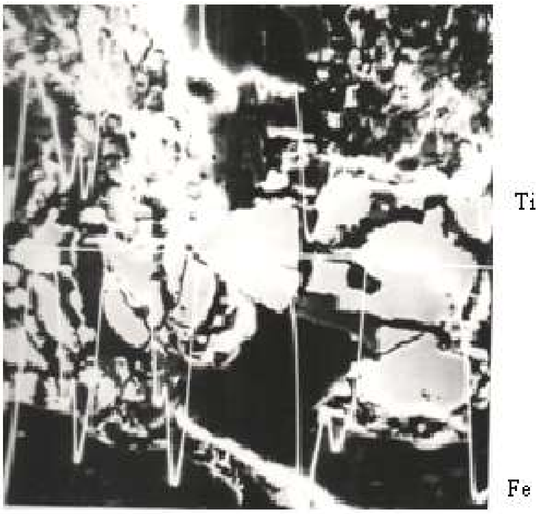
The fact that in separate horizons there are small and normally well faceted grains of practically stoichiometric magnetite allows concluding that these grains could have been crystallized pending the cooling of lava and due to secondary processes. This conclusion is also supported by the fact that the titanium content of these grains is rather reduced, whereas small grains of primary crystallization usually have higher *Ti* concentrations than the large grains of titanomagnetite (Pechorsky et al., 1975).

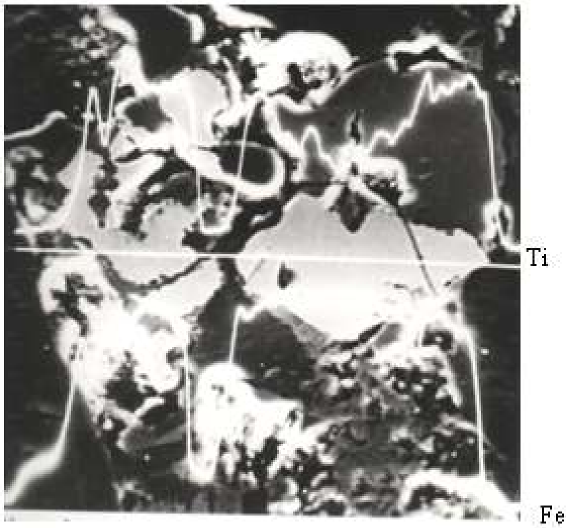
Absence of hematite (martite) and presence of only ilmenite in the decay structures and rutile in the aggregates hold that after the rocks had been formed their ore grains haven't been oxidized. This factor is an indicative of the system's closedness and absence of the processes that accompany an increase of the oxygen's partial pressure in the ambient environment. This conclusion contradicts to a data the ore grain microscopy. Controversy is mainly explained by the latter's limited resources for analysing emissions and heterophase structures[1].

It has to be mentioned however, that as far as just separate horizons of the column have been covered by the microprobe analysis performed, some of the ore mineral manifestations and changes could have been missed. This statement is fare for the section's deeper segments, too.

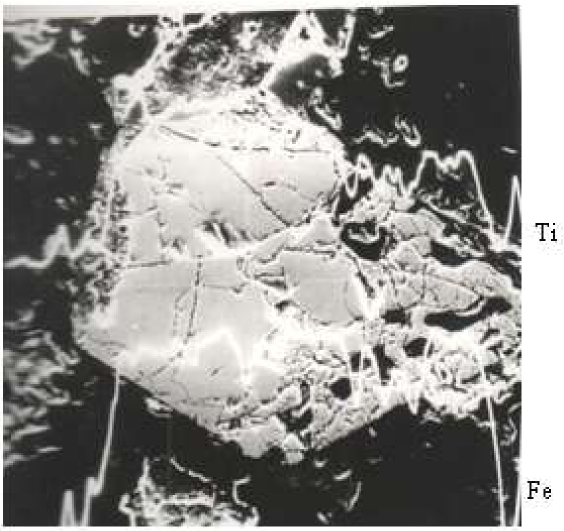
Speaking about microprobe analysis results of volcanics collected from a depth interval of 5500-8126 m, it has to be mentioned that unlike their 3540-5500 m deep analogues rocks of the deeper horizons had undergone considerable metamorphic changes which affected the appearance of their ore minerals. According to the analysis results, the section's deepest formations deeply vary from their shallower analogues.

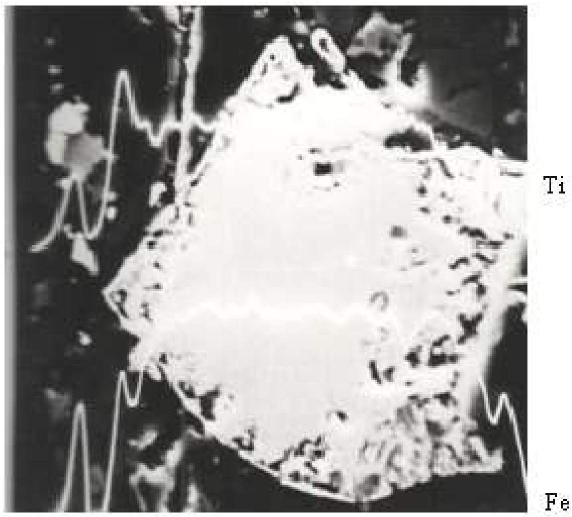
[1] Produced outcome is also confirmed by the fact that the small ore grains have been well preserved, remaining unoxidized and homogenous.





Figures 14, 15. Microphotos of titanomagnetic grains with decay structure. x1000





Figures 16, 17. Microphotos of mosaic structure. x240 and x1200

It was established that starting from 5544-5500 m deep horizons so-called mosaic structures start to manifest themselves with extreme inhomogeneity. As seen from the ore grain microphotographs presented in Figures 19-21, mosaic structure is developed both on the margins and across the bodies of the grains. Grains are often fractured. As demonstrated by profile scanning of Ti, Fe and Al contents, "non-mosaic" parts of the grains are steadily homogenous, whereas mosaic structured segments are to highly inhomogeneous (Figure 21). Spot sounding of the samples established 5-8% Ti and 6% Al contents. It can be assumed that the mosaic structure had developed due to a decay of the grains of titanomagnetite within the zone weakened by metamorphic processes.

With increase of a depth, ore grains become more fractured and start containing the cavities filled by secondary formations with higher Al (chlorite) contents than the grain's main mass. Microphotos 22 and 23 show large grains of titanomagnetite with Ti content of 6% and Al content of 2-3%. Cited inhomogeneities are confirmed by the Profile scanning results. Grains with such characteristics were detected in the depth intervals of 6290-6295 m.

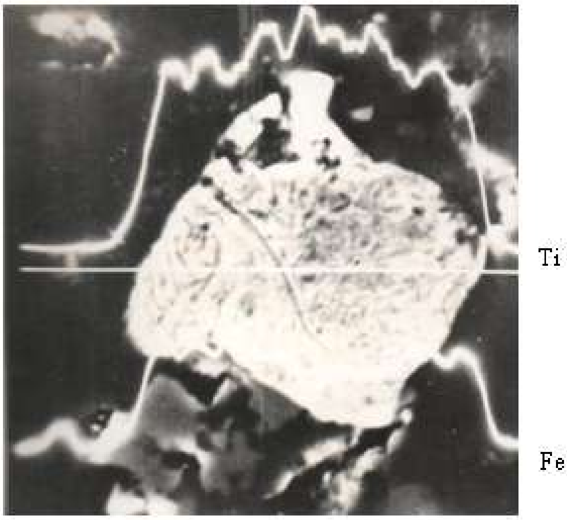


Figure 18. Microphoto of mosaic structure. x2000

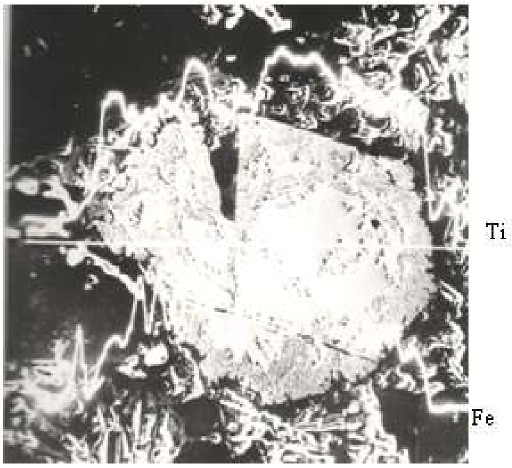


Figure 19. Microphoto of mosaic structure. x200

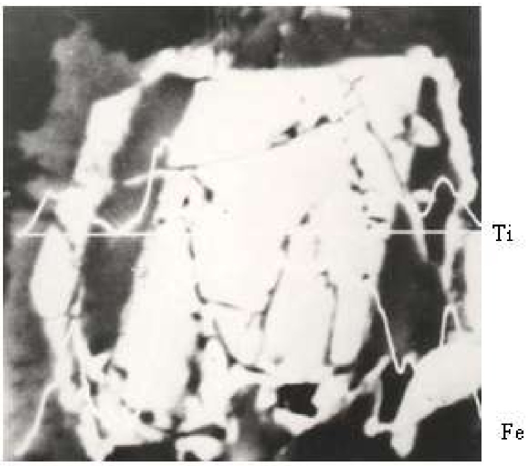


Figure 20. Microphoto of small grain of titanomagnetite. x4000

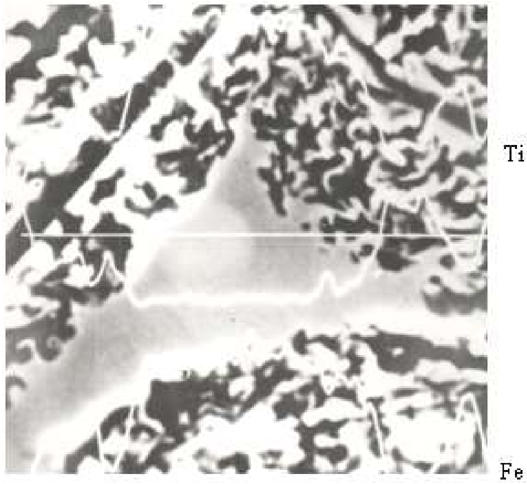


Figure 21. Microphoto of mosaic structure. Grain margin, x2400

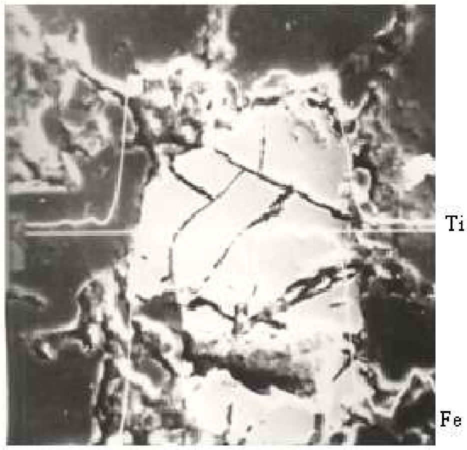


Figure 22. Microphoto of large grain of titanomagnetite. x800

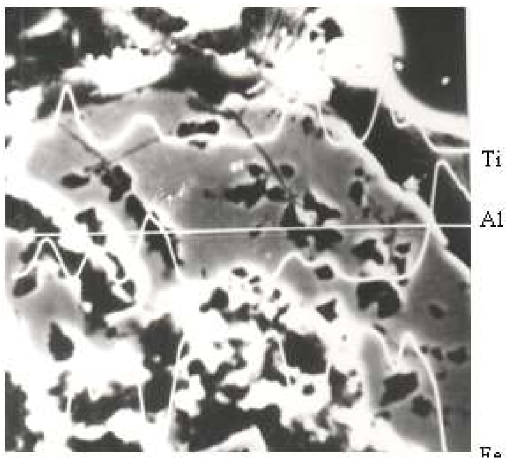


Figure 23. Microphoto of large grain of titanomagnetite. x2000

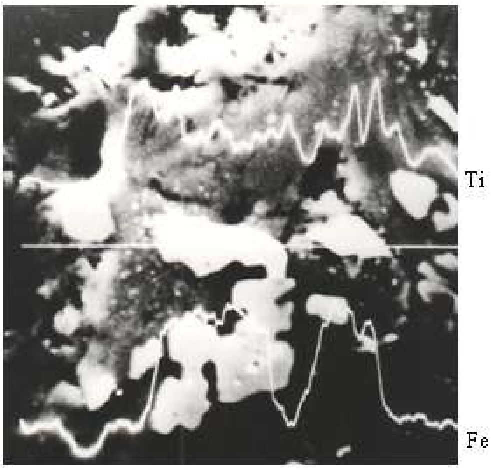


Figure 24. Microphoto of the generations of large and small ore grains. x2000

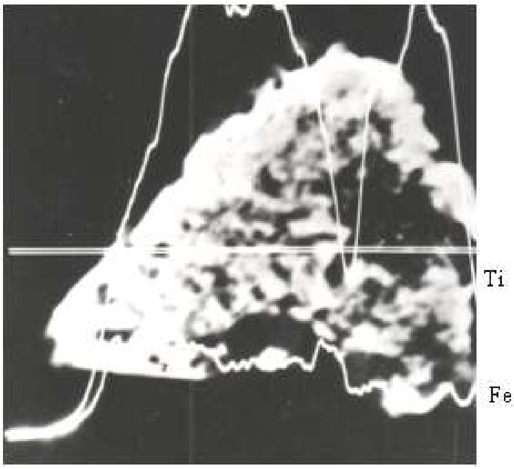


Figure 25. Microphoto of inhomogeneous grain of titanomagnetite. x3800

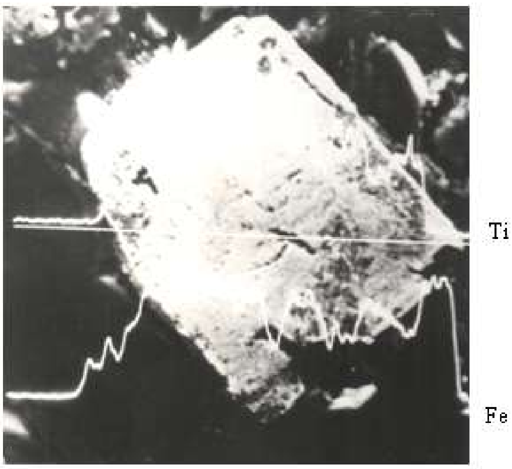


Figure 26. Microphoto of inhomogeneous grain of titanomagnetite. x1200

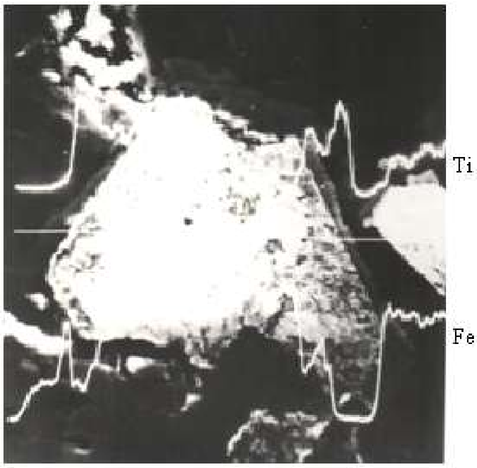


Figure 27. Microphoto of inhomogeneous grain of titanomagnetite. x1200

In 7038-7048 m depth intervals, there are two ore grain generations, namely finest “dust” that cannot be analyzed even qualitatively, and large corroded grains of titanomagnetite (Figure 24). As concluded from the profile scanning of Ti and Fe contents, these grains are extremely inhomogeneous. According to spot sounding outcomes, they are represented by titanomagnetite with 4% Ti content (Al is absent).

Examples of strongly decayed and inhomogeneous grains of titanomagnetite can be seen on Figures 25, 26, 27. Their high inhomogeneity is confirmed by the profile scanning outcomes of Ti and Fe contents. Spot sounding allowed identifying the emissions of ilmenite as well as magnetite along the grain margins. Grains are characterized by Al contents of about 0.5%, and their main mass is by 6% built of titanium. As concluded from the analysis outcomes, small ore grains are much more homogenous than their larger analogues, and their Ti contents reach 6%. Equal Ti contents of these two types of grains suggest that the fine grains are the fragments of their altered larger analogues. Such grains have been detected in the rock samples collected from 7332-7343 m depth interval.

Rocks from the interval of 7576-7578 m appeared to represent a new type of the ore mineralization. Microphotos 28 and 29 demonstrate needles of stoichiometric hematite (Ti[1] content ~ 2 %) with cross-sectional dimensions of less than 0.5 mkm. This is confirmed by both the profile scanning results of Ti and Fe contents and the spot sounding of grains. Rocks of this horizon contain large and heavily altered grains of titanomagnetite with pronouncedly developed mosaic structure (Figure 30). As seen from scanning and sounding results, preserved relicts of a grain are represented by titanomagnetite with 5% of Ti content, and spacings between these relicts are filled by chlorite.

Metamorphic processes do not only change a grain internally but also affect its' geometry. Such changes are exemplified by the Figure 31, in which there is an oviform grain that is heavily fractured, containing cavities filled by secondary chlorite. As demonstrated by Ti and Fe scanning results, the grain is very inhomogeneous. According to spot sounding preserved areas of the grain are represented by titanomagnetite with nearly 6% of Ti content.

In the same depth interval of 7728-7738 m, rocks contain much smaller but less altered grains of titanomagnetite with Ti content of about 5% (Figure 32), which are most probably the fragments of altered larger grains. Also detected are the dust-like grains of rutile.

In one of the deepest intervals (7874-7878 m) detected was a new “spotty” type of a grain structure, examples of which are shown on the microphotos 33 and 34. As concluded from spot sounding and profile scanning of Ti and Fe contents, main mass of the grains is represented by relatively stoichiometric magnetite with Ti content of about 2%, while inhomogeneities (seen as dark spots on the photos) are represented by rutile. More detailed investigation of these grains was conducted after their still etching in HCL solution, but did not detect any structures of decay. Manifestation of such structures is presumably the direct outcome of intensive deep metamorphic processes. It is anticipated that the spotty structure can be realized under the impact of sulfur containing fluids upon titanomagnetite grains with a structure of decay. When this happens, ilmenite within the structure of decay gives up an iron and transforms into rutile, while the iron then can make up a source for the formation of pyrite (Ryabchikov, 1972.).

Rocks of the depth intervals of 7991-7993 m contain mixed-phase grains of titanomagnetite with weakly pronounced spotty structure. As demonstrated by the outcomes of spot sounding and profile scanning of Ti and Fe contents (Figures 35 and 36), main mass of these grains is represented by titanomagnetite with Ti content of about 5%. Grain margins and dark spots within their bodies contain rutile.

In the deepest interval of 8100-8126 m, there occur to be some new types of the ore grain manifestation, which are not detected in any of the shallower horizons.

Figure 37 presents a microphoto of the grain of decayed ilmenite. This picture have been produced based on the results of spot sounding and profile scanning of Ti and Fe contents. As seen from the samples, the grain contains fine emissions of ilmenites.

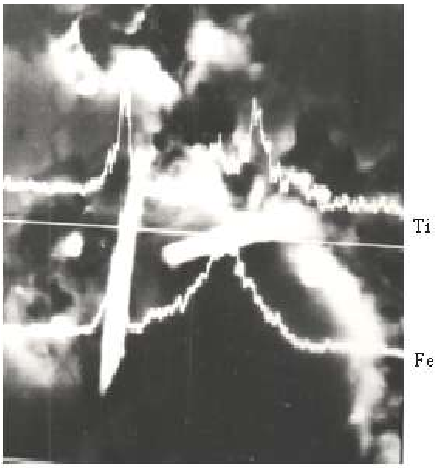
Alongside with occurrences of the marginal stages of ore grain alteration, detected are sufficiently homogenous grains of titanomagnetite with Ti content of about 2% (Figure 38), as well as “regularly” and “irregularly” shaped grains of the evidently secondary pyrite (Figures 39, 40). The latter were detected through spot sounding of grains, and the former were found by both sounding and profile scanning of Ti and Fe contents.

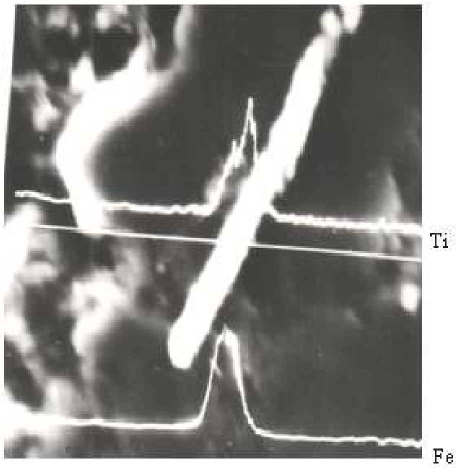
Therefore, microprobe analysis of the section's deepest rocks had detected the new types of the ore mineral alterations, and produced the following outcomes:

1. Development and spread of a “mosaic” structure were registered;

2. New formation of hematite “needles” were for the first time established in the greater depth intervals;

[1] Ti content was identified by the analysis of the largest needles of hematite.





Figures 28 and 29. Microphotos hematite needles. x3800

Figure 30. Microphoto of mosaic structure – association of titanomagnetite grain with chlorite. x800

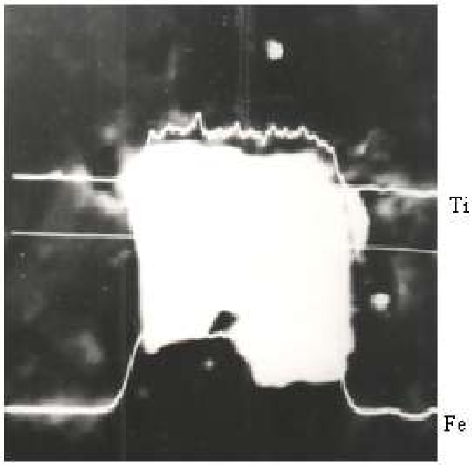


Figure 32. Microphoto of small titanomagnetite grain. x2500

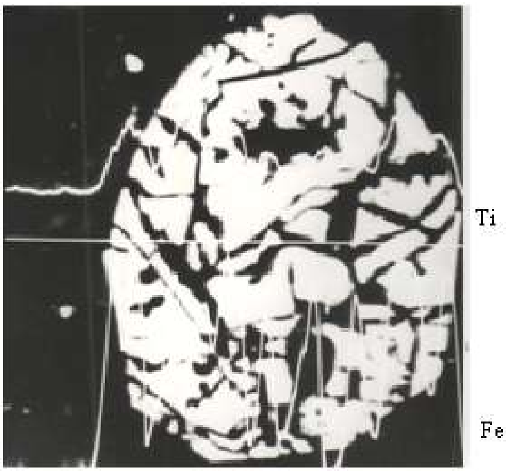


Figure 31. Microphoto of titanomagnetite grain with altered geometry. x2000

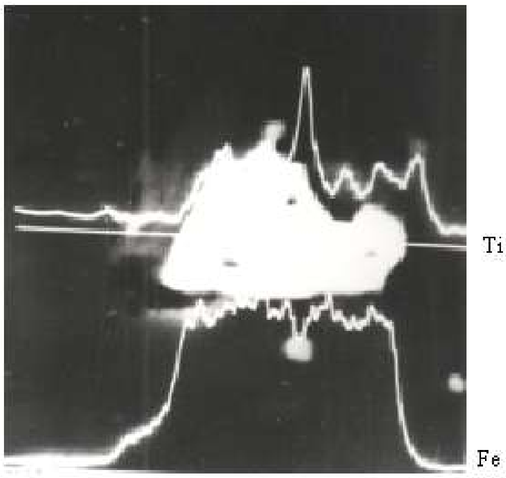


Figure 33. Microphoto of developed spotty structure. x4000

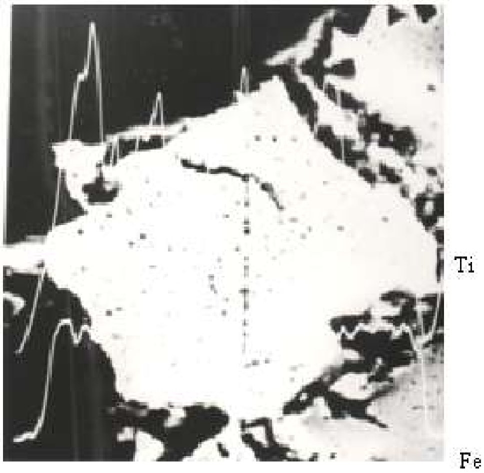


Figure 34. Microphoto of developed spotty structure. x1200

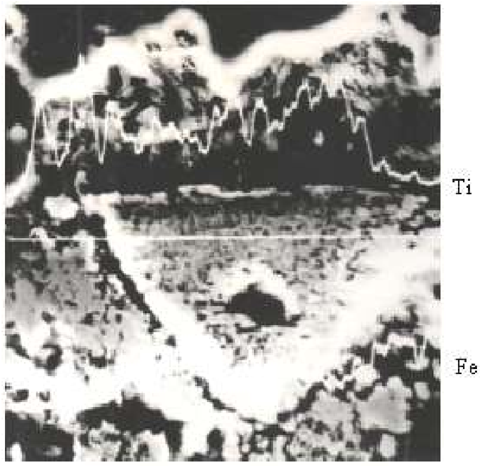


Figure 37. Microphoto of the grain ofdecayed ilmenite. X1200

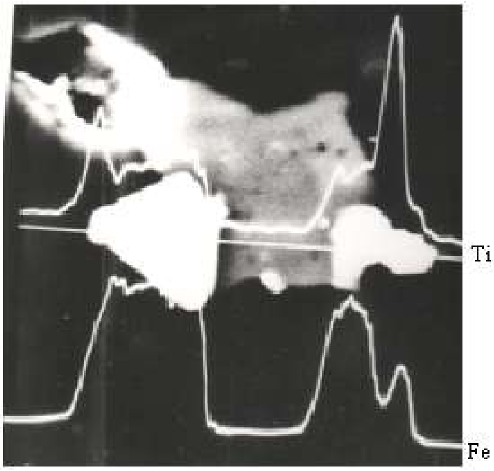


Figure 35. Microphoto of titanomagnetite grain with weakly pronounced spotty structure. x4000

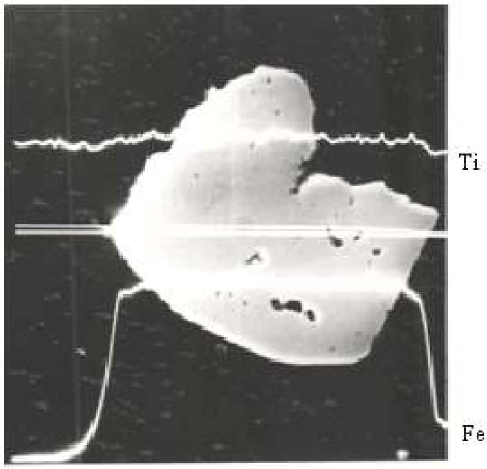


Figure 38. Microphoto of homogeneous grain of titanomagnetite. X1200

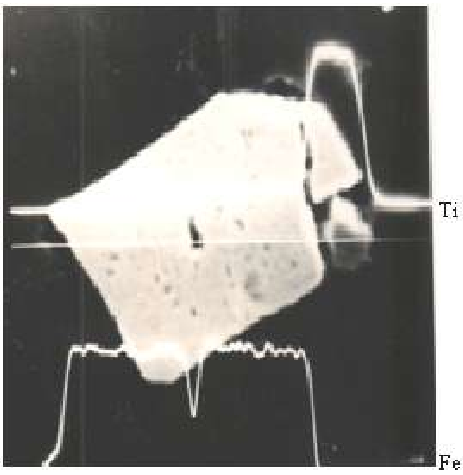


Figure 36. Microphoto of titanomagnetite grain with weakly pronounced spotty structure. x2000

Figure 39. Microphoto of grain of pyrite. X240

Figure 40. Microphoto of grain of pyrite. X2400

3. For the first time in the deeper horizons, detected were the "spotty" structures which can be realized under the interaction between sulfur containing fluids and titanomagnetite grains with a structure of decay;

4. Secondary generations of regularly and irregularly shaped pyrite were detected in the deepest intervals.

According to petrographic survey results, structures and separate minerals detected in the deepest horizon series had been formed as a direct result of development and strengthening of metamorphic processes. Formation of hematite and pyrite could have only taken place in diverse oxidation-reduction environment. Detection of such minerals in the deepest and their absence in the shallower well column horizons are the indicatives of thermodynamically "closed" system in up to 7000 m deep horizons, and thermodynamically "open" system in deeper intervals of the section.

Conclusions

1. It was established that the low-temperature metamorphism developed in deeper horizons of the 3540-5500 m depth interval is almost not reflected on the ore minerals of rocks. There are the grains of two generations detected in the interval. First generation includes the large grains of titanomagnetite, either homogeneous or with a structure of decay (heterophase low-temperature oxidation). Second generation usually includes well-faceted grains of practically stoichiometric magnetite. The second generation is a secondary crystallization product of the small ore grains of rocks occurred pending the cooling of a lava. Absence of hematite (martite) and presence of just ilmenite (rutile in the aggregates) in the structures of decay suggest that the ore grains haven't been intensively oxidized after their crystallization.

2. In the deep part of the section (7000-8126 m) with intensively developed low-temperature metamorphism and metasomatism is characterized by the presence of different minerals and structures. This includes occurrence, development and spread of the grains' "mosaic" structure, detection of "spotty" structure related with spotted emissions of rutile occurred within the main mass of the grains of titanomagnetite and not conditioned by hidden structure of decay. Detected are the acicular generations of secondary hematite, as well as regularly and irregularly shaped grains of pyrite. Appearance of new structures can be conditioned by the development of metamorphic processes, leading to the grain's partial destruction and processing. Presence of the secondary generations of hematite and pyrite is an indicative of developed metasomatism processes and penetration of fluids with diverse oxidation-reduction potential into the section's deeper horizons.

Produced outcomes can be used for forecasting the region's ore-bearing potential.

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SAATLI QUYUSUNUN VULKANİTLƏRİNDƏ FİLİZ MİNERALLARININ MİKRORENTGENSPEKTRAL TƏHLİLİ

Z.A. Novruzov, V.A. Tselmoviç

Saatlı aşırı dərin quyusunun kəsilişində filiz minerallarının mikrorentgenspektral təhlili üsullarıyla nisbətən xırda maqnetit zərrəcikləri (~2-10 mikron) və iri qeyribircinsli titanomagnetit zərrəciklər (~10-100 mikron və daha böyük) aşkar edilmişdir. Aşağı temperaturlu metamorfizmin (3540-5500 m intervalın ən dərin hissələrində) inkişaf etməsi bu iki generasiyaya (iri homogen strukturu və ya parçalanma strukturu ilə titanomaqnetit zərrəcikləri və xırda, adətən yaxşı təraşlanmış zərrəcik praktiki olaraq stexiometrik maqnetit) təsir göstərmir. Hematitin (martitin) olmaması və parçalanma strukturlarda yalnız ilmenitin (bitişmələrdə-rutilin) olması onu görsədir ki, kristallaşmadan sonra filiz zərrəcikləri intensiv oksidləşməyə məruz qalmamışlar. Metamorfizm və metasomatoz prosesləri inkişafılə əlaqəli (7000-8126 m dərinliklərdə) "mozaik" strukturun ortaya çıxması, inkişafı və yayılması qeyd olunmuş, titanomaqnetit zərrəciklərin əsas kütləsində rutilin nöqtəli çıxıntıları (ayrılmaları) ilə bağlı olan və qizli parçalanma strukturu ilə şərtlənməmiş "xallı" struktur aşkar olunmuşdur. İynə şəkilli ikinci generasiyalı hematitdə düzgün olan və düzgün olmayan təraşlanan pirit zərrəcikləri aşkar olunmuşdur. İkinci generasiyalı hematit və piritin mövcudluğu metasomatoz proseslərin inkişafını təsdiqləyir. Bu eyni zamanda müxtəlif oksidləşmə-reduksiya potensialı flüidlərin dərinliklərdə olan süxurlara sızılmasını təsdiqləyir.

МИКРОРЕНТГЕНСПЕКТРАЛЬНЫЙ АНАЛИЗ РУДНЫХ МИНЕРАЛОВ ВУЛКАНИТОВ РАЗРЕЗА СААТЛИНСКОЙ СКВАЖИНЫ

З.А. Новрузов, В.А. Цельмович

Методам микрорентгеноспектрального анализа рудных минералов вулканитов разреза Саатлинской сверхглубокой скважины выявлены относительно мелкие (~2-10 мкм) зернамагнетита и неоднородности в крупных зернах титаномагнетита (~10-100 мкм и более). На двух генерациях (крупного гомогенного или со структурой распада титаномагнетитового зерна и мелкого, как правило, хорошо ограненного зерна практически стехиометрического магнетита)почти не отражается развитие низкотемпературного метаморфизма (в наиболее глубоких горизонтах интервала 3540-5500 м). Отсутствие гематита (мартита) и наличие в структурах распада лишь ильменита (в сростках–рутила) показывает, что после кристаллизации рудные зерна не испытывали интенсивного окисления. В связи с развитием метаморфизма и метасоматоза (глубины 7000–8126 м) отмечено появление, развитие и распространение «мозаичной» структуры зерен, выявлена «пятнистая» структура, связанная с точечными выделениями рутила в основной массе зерна титаномагнетита и не обусловленная скрытой структурой распада. Обнаружены игольчатые генерации вторичного гематита, а также правильные и неправильные по огранке зерна пирита Наличие вторичных генераций гематита и пирита подтверждает развитие процессов метасоматоза. Это также подтверждает проникновение в глубокие породы флюидов с разным окислительно-восстановительным потенциалом.

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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 vermələri 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.

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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.

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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.

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