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SIGNS OF GLOBAL PHANEROZOIC EVENTS IN AZERBAIJAN

Global event stratigraphy is based upon presence of proven global synchronous events. Most of these events is confined to a stratigraphic scale's boundaries.

Current article attempts to distinguish and describe signs of global Phanerozoic events (mass extinctions, morphological innovations, radiation, etc.) within the territory of Azerbaijan.

There is a total of 8 global events recorded in the sections of Azerbaijan and covering the period between the Upper Devonian-Oligocene periods. Thorough analysis of all these events have been carried out to assess their environmental and biotic impacts, characterize their stratigraphic position and bring more details into the regional stratigraphic scale.

Keywords: event stratigraphy, 8 global events, Azerbaijan, Upper Devonian-Oligocene periods

Sh.A. Babayev

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

Introduction

Event stratigraphy studies processes that have been documented in sections and uses them as key chronological surface for the synchronization of sedimentary stratas.

Global event stratigraphy based on from presence of proven global synchronous events, most of which are linked to a stratigraphic scale's boundaries.

Global events are divided into abiotic and biotic ones.

Abiotic ones include climatic, geochemical, oceanographic events as well as changes in the magnetic polarity.

Biotic events cover critical changes of the biota's taxonomic composition to include massive extinctions, appearance of morphological changes and radiation.

Current article attempts to distinguish and describe signs of global Phanerozoic events within the territory of Azerbaijan. Figure 1 presents a Geological Map of Azerbaijan with highlighted sections that contain regional signs of global events.

Main results

Within the territory of Azerbaijan, most ancient faunistically proven deposits date back to the Devonian system. Late Devonian period was marked by a Hangenberg event confined to a top of the Upper Famennian substage. This event was characterized by the mass extinction of typical Devonian ammonoideas, most conodonts, ostracods and foraminifers (majority of endothyroids), as well as the bioherm structures with carcass forming organisms (Корень и др., 2000).

Hangenberg event is represented by a erosion or stratigraphic gap in the shoreface shelf facies. Within the open shelf facies, the event is marked by a black shales with increased dispersed organic matter content.

Signs of the Hangenberg event have been surveyed in detail in the Northern America, Germany, Poland (Walliser/ed, 1995), Ural (Журавлев, 1990), Northeast of Russia, etc.

Within the boundaries of Azerbaijan, Hangenberg event manifests itself in the Munhbalaoghlu (Babayev, Kangarli, Mammadov, 2016) suite recorded in Gorangalasi, Tejgar and other sections of the Nakhchivan AR (Figure 1,2). Local signs of the event are expressed by 9-16 m thick layer of dark bituminized shale line argillites without any faunistical remnants. Higher in the succession such argillites get replaced by 28-50 m thick sandy, fine-grained and medium-laminated limestones with multiple remnants of brachiopods, corals, mosses, conodonts and ostracods (Figure 2), etc. (Геология Азербайджана, т. 1, Стратиграфия, часть 1, Палеозой, 1999, figure 15, page 135).

Figure 1. Geological Map of Azerbaijan, indicating sections with signs of global events

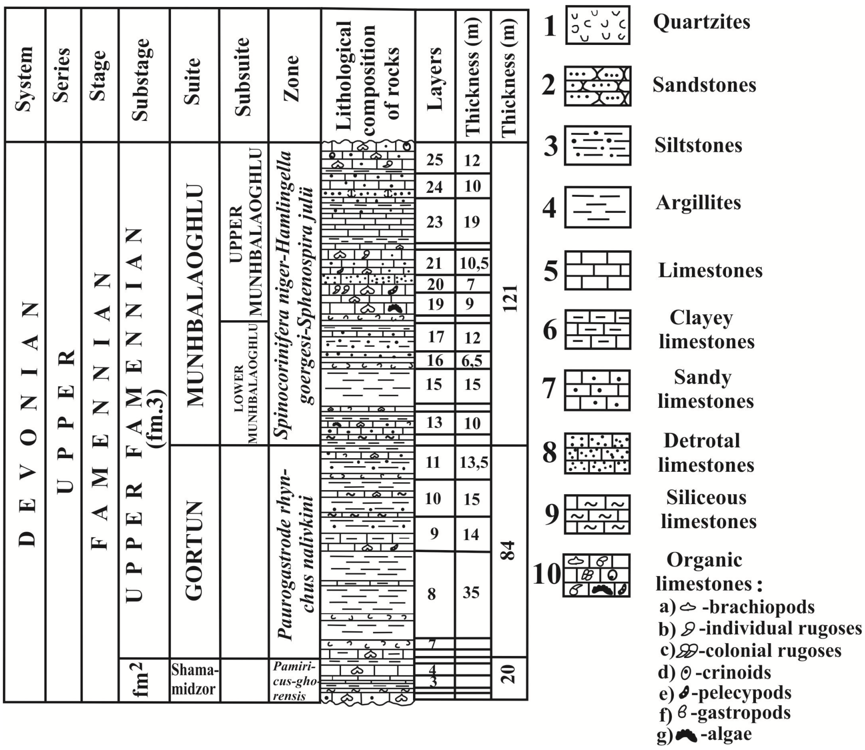

Figure 2. Section of the Upper Devonian Famennian deposits on the western slope of Tejgar mountain

According to I.A.Ovnatanova and V.A.Aristov (1984), Munhbalaoghlu suite belongs to a zone of *costatus*.

Dark argillites belong to the outer shelf, and their overlapping limestones to the inner shelf facies.

Middle part of the Tatarian stage (Median stage of the Tethyan scale) is confined to one of the most important and known biotic events that is also marked by replacement of the Kiam hyperzone by an alternating Illavar hyperzone (Молостовский, 1983). This event is characterized by largest ever biotic crisis which had covered both terrestrial and marine biota and aligned with different scale abiotic events occurred within the Boreal zone and Paleotethys (Figure 3) (Корень и др., 2000, figure 12, page 54).

Described event may be regarded as starting point of the massive Permian-Triassic crisis.

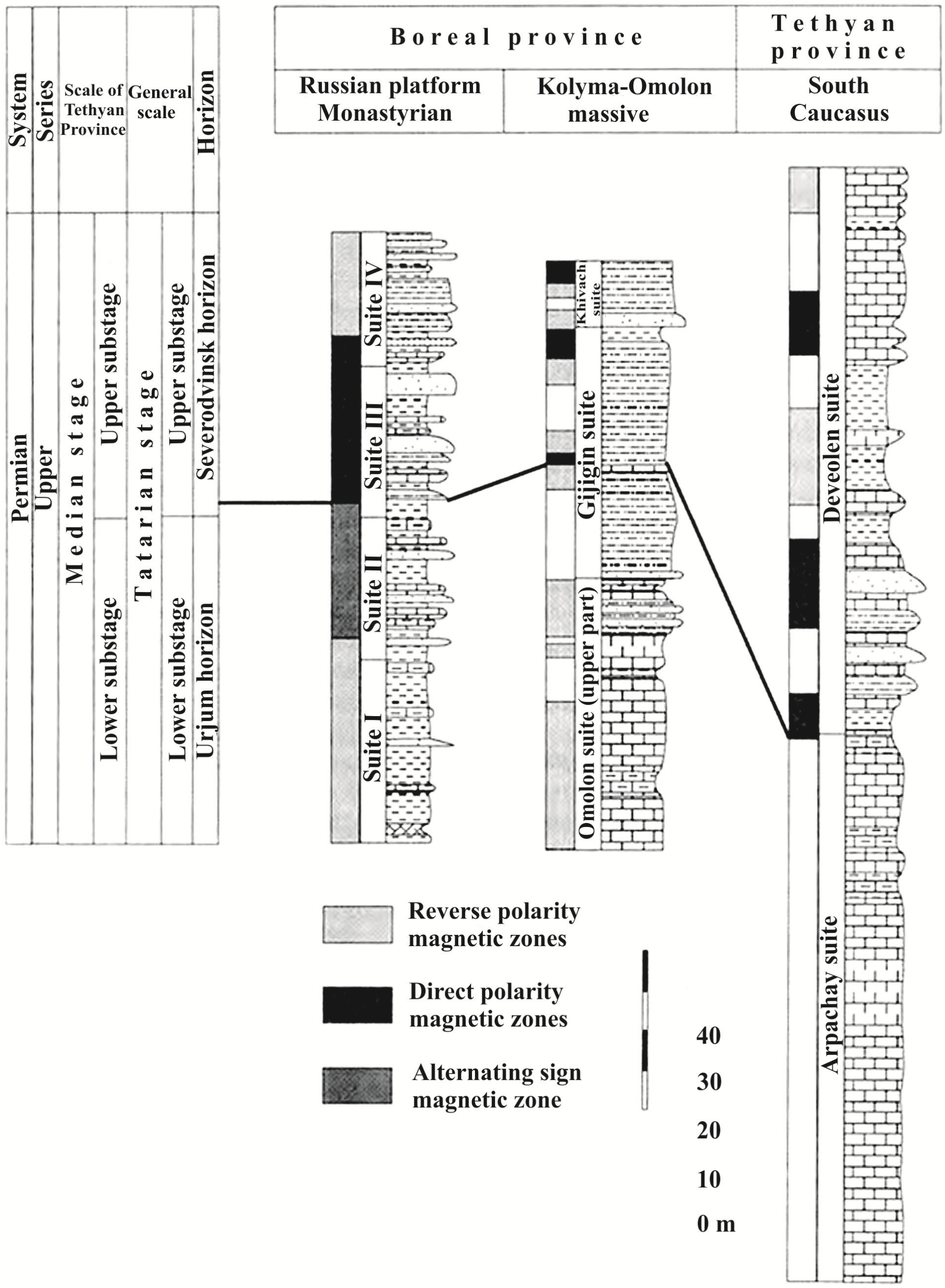

Figure 3. Signs of global Middle Tatarian paleomagnetic event in Boreal and Tethyan province

In Nakhchivan AR, this event is most sharply expressed at the basement of Deveolen suite (Khachik suite in Armenia) – Median stage (sections of Baysal and Jagadzur mountains), and in the Abade formation of Iran (Котляр и др., 1989, Taraz, 1974). Both successions are characterized by a practical disappearance of all highly specific fusulinids, extinction of massive colonial corals (Ezakl, 1993) and changing of the composition from nodosarial composition to miliolitic (Корень и др., 2000).

The Deveolen suite's basement is lithologically marked by a replacement of massive aphanitic limestones by algae-detrital foraminiferal carboniferous limestones (Figure 4) (Геология Азербайджана, т. 1, Стратиграфия, часть 1, Палеозой, 1999, figure 24, page 227). Late Median (late Guadeloupean) event is one of the morst important biotic crises to affect every single group of the marine organisms. 40% of all genera of foraminifers and 70% of genera of fusulinids became extinct, and the miliolitic complex of small foraminifers was replaced by nodosarial complex at the end of the Median age (Котляр и др., 1989). In the same period first xenodiscidaes and araksociratidaes emerged among ammonoideas. Pervasive changes occurred among corals and conodonts as well.

Key reason of the Late Median event is accepted to be a global sea level fall. This event within the territory of Nakhchivan AR is determined in the bottom of fusulinoidal zone of *Pseudodunbaria arpaensis – Codonofusiella kwangsiana* at the basement of massive light limestones that correspond to a highstand system tract (Котляр и др., 1983) (Darasham section, Figure 5) (Геология Азербайджана, т. 1, Стратиграфия, часть 1, Палеозой, 1999, figure 26, page 235).

Deposits from the upper most part of successions of the Median stage are lithologically represented by an alternation of dark algae-foraminiferal and clayey limestones with light-grey massive limestones (3-7 m) of Julfa age.

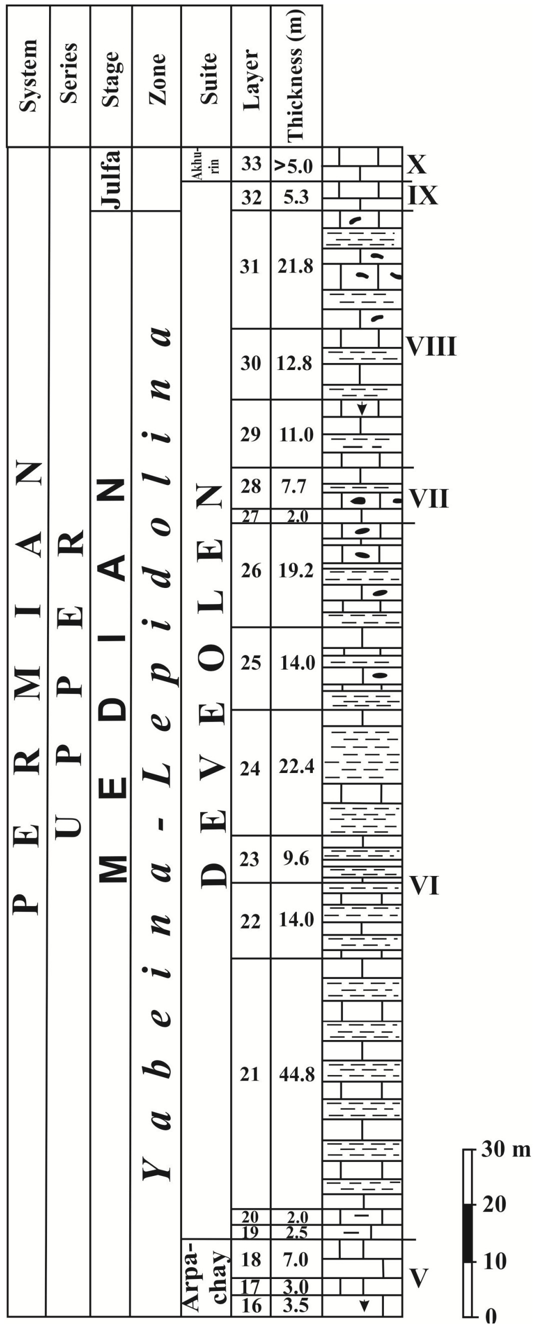

Figure 4. Section of Deveolen suite on Baysal mountain

Massive extinction event that had occurred at the boundary of Permian and Triassic periods have led to dying of ≈50% families and over 80% genera of marine animals by the end of Darasham stage (Sepkoski in Walliser/ed., 1995). Described episode was marked by extinction of 80-90% of taxons, including almost an entire variety of Paleozoic conodonts. Crisis was only survived by minor foraminifers, bivalves, nautiloidal cephalopods and bellerophon gastropods. End of Darasham age was marked by dramatic reduction in the cosmopolitan fauna of benthos and neproplankton.

One of the most likely reasons of mass extinction is global sea level fall due to aridization of climate.

Most complete section of the Permian-Triassic interval of Azerbaijan is detected in Nakhchivan AR in the section of Darasham II (Figure 6) (Корень и др., 2000, figure 13, page 59).

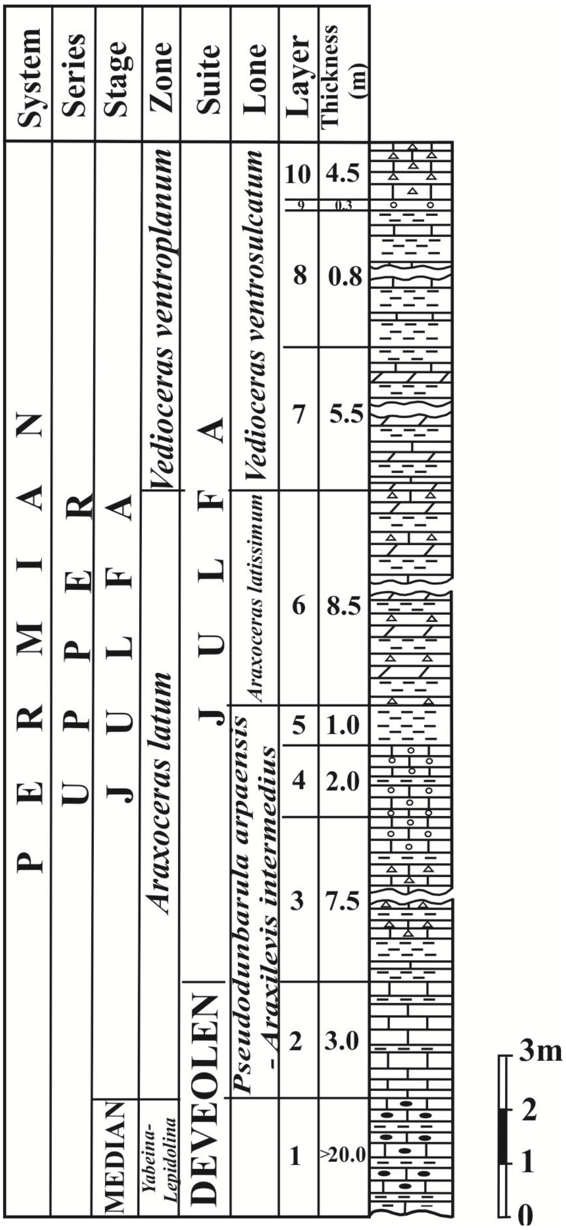

Figure 5. Stratotype section of Julfa stage on the left riverbank of Araz, 0.5 km to the north of Darasham 2

Here Upper Darasham deposits are represented by bricky-red and reddish-brown lump limestones (lone of *Paratirolites kittli*) with thin interlayers of reddish-brown, sometimes greenish-grey argillites and marls on the top (lone of *Pleuronodoceras occidentale*). Lower third of the pack of argillites contains *Hindeodus parvus* presumably occurred at a boundary between Permian and Triassic periods.

Cenomanian-Turonian borderline biotic event (crisis) is one of the wide-scale and clearly expressed minor extinctions of the Phanerozoic epoch (Алексеев, 1988). In a zonality on plankton foraminifers it corresponds to the end of *Rotalipera cushmani* zone and to the zone of *Whiteinella archaeocretacea* (Tur, 1996).

In sections of the vast territory from Northern America through Kopetdagh, hemipelagic and pelagic deposits of the borderline event's interval contain interlayers of dark-grey to black bituminous shales. Same intervals of the marginal “shallow-water” are marked by a depositional break and underwater erosion. Wide occurence of black shales and phosphorites recorded close to a boundary of Cenomanian and Turonian ages reflects global oceanic anoxic event of OAE-2 that coincided with maximum of the Late Cretaceous transgression (Schlander et al., 1987).

It should be emphasized that within the boundaries of Azerbaijan, Cenomanian deposits demonstrate a limited occurence in Greater and Lesser Caucasus and are not presented in the territory of Nakhchivan AR. Turonian deposits are developed in Greater Caucasus, Nakhchivan AR and rarely in Lesser Caucasus (Miskhana-Gafan zone (Figure 1)).

Thus, in the Sheylanli section of Lesser Caucasus, upper segments of the Upper Cenomanian successions contain dark shisty and calcareous argillites with rare interlayers of grey arenaceous limestone and calcareous sandstone. The section contains remnants of *Gavelinella frankei, Hedbergella deliroensis, Praeglobotruncana stephani, P. stephani tur-*

binate, Thalmaniella brotzeni, Rotalipora cushmani, etc. (Figure 7), (Геология Азербайджана, т. 1, часть 2, Мезозой и кайнозой, 2007, figure 80 , page 212).

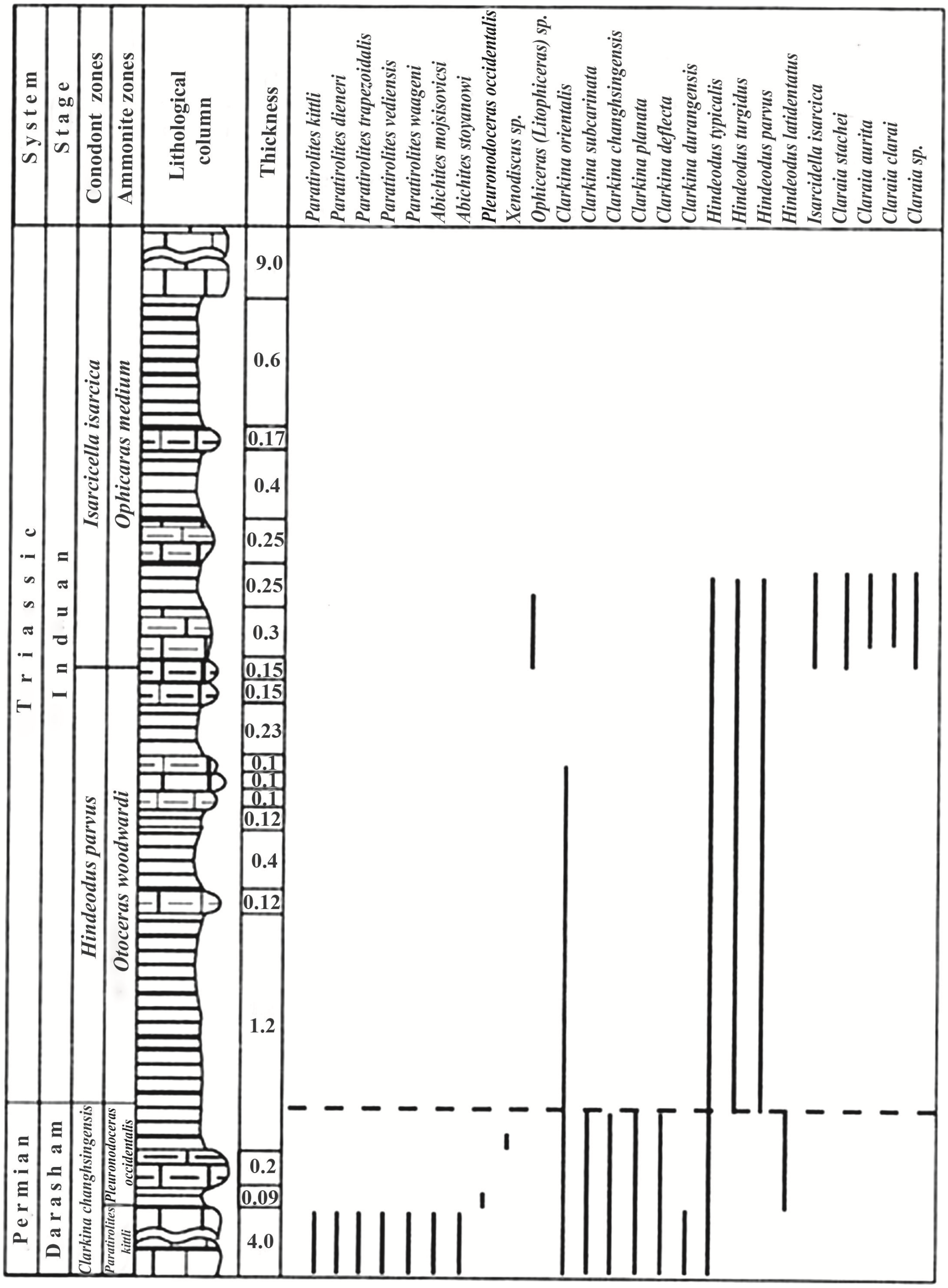

Figure 6. Regional signs of Permian-Triassic event in the section of Darasham 2 (South Caucasus)

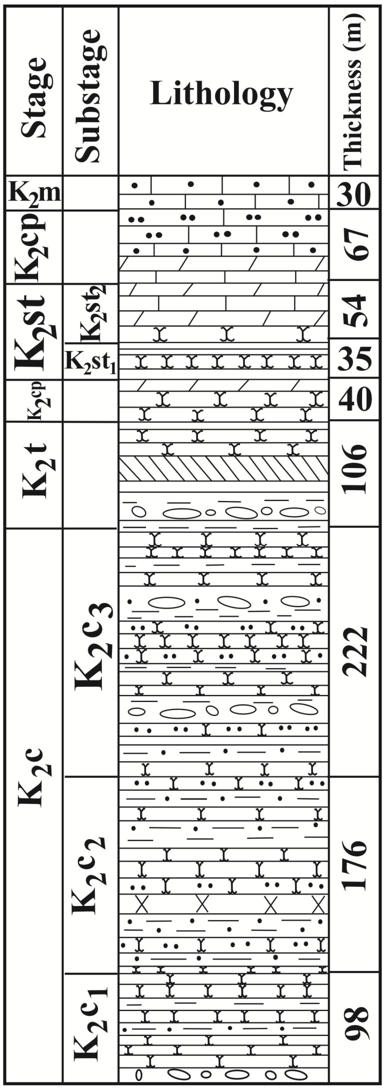

Figure 7. Cenomanian section of the Shaylanli village vicinities

Higher successions are characterized by a transgressively interbedded pack of sandy argillites, sandstones and clays with conglomerates in its' basement, containing Upper Turonian complex of foraminifers.

In Chovdar village's vicinities (foothills of Dalidagh mountain), Upper Cenomanian successions (zone of *Rotalipora turanica*) are represented by dark dense argillites with some interlayers of grey, dense fragmented marls. This section contains rich complex of foraminifers: *Lenticulina orbicular, Gavelinella cf. cenomanica, Hedbergella infracretacea, H. globigerinelloides, Praeglobotruncana stephani, Thalmanniella greenhornensis, Rotalipora cushmani, R. turanica*, etc. (Меловая фауна Азербайджана, 1988).

Limitedly occurred of Turonian deposits of the Lesser Caucasus are faunistically detected in the separate parts of Goycha-Garabagh and Araz zones (Figure 1). Turonian stage is represented by the argillite-marly and the argillite-sandy lithofacies. Discontinuity of the faunistically dated Turonian outcrops complicates dividing the stage into smaller biostratigraphic units.

Cenomanian deposits aren't recorded in Nakhchivan AR. However there are redeposited Cenomanian foraminifers discovered in Gulustan village's vicinities, which means that the local Cenomanian series had been eroded due to a Turonian transgression.

Section's Lower Turonian deposits are represented by their sandy-shaly sediments with the interlayers of brecciated limestones. These layers contain 7.6 m thick interbedded interval of black sandy shales, grey and dark-grey clayey sandstones and grey dense limestones. These successions contain *Haustator sp.,* foraminifers - *Bolivinopsis praelonga, Gavelinella vesca, Rotalypora cushmani*, ostracods and nannoplankton - *Tetralithus pyramidus, Zygodiscus diplogrammus etc.*

In Greater Caucasus, signs of the Upper Cenomanian – Lower Turonian event include Lower Turonian deposits of the Kalavudagh section (Zarat horizon) represented by an alternation of dense fragmented marls, grey limestones and argillites, dark-grey, sometimes almost black calcareous shales, containing remnants of *Inoceramus labiatus,* foraminifers – *Helvetoglobotruncana Helvetica, Gyroidinoides nitidus, Whiteinella holzli,* as well as massive accumulations of radiolarians - *Dictyomitra striata, Cyrtocapsa ovalis, Trodiodiscus splendidus etc.* The section is distinguished within the frameworks of *Helvetoglobotruncana helvetica* or *Inoceramus labiatus* zones.

One of the most drammatic global events in the planet's history is the one that had occurred at the boundary between Maastrichtian and Danian periods (65.5 Ma BP), which is famous by the extinction of dinosaurs, marine reptiles, ammonites, belemnites, many bivalves and other organisms. The total of 1/6 of the organic world had been totally extinct at that time.

Various hypotheses were proposed to explain this grandiose event including most popular theories of impact (Alvares et al., 1980) and volcanic activity.

All these theories fail to fully unveil the causes of mentioned great extinction, the more so that later it became clear that the extinction had begun in the middle and speeded up at the end of the Maastrichtian epoch.

Maastrichtian-Danian transitional layers of Azerbaijan do not manifest any iridium anomalies, and there are only several areas of the volcanosedimentary deposits located to the Muradkhanli plateau and the interfluve of Akhokhchay and Vandamchay. That confirm the impact theory.

However the boundary between Maastrichtian and Danian periods is marked by a disappearance of ammonites (*Diplomoceras, Pachydiscus*), belemnites (*Belemnella*), many bivalves (*Inoceramus* и др.), majority of heteroxenias, globotruncans among small and orbitoids among larger foraminifers (*Orbitoides, Orbitella*, etc.), etc.

Such a serious change in the organic world's composition at the boundary between Cretaceous and Paleogene periods is not probably related with impact or volcanic event. It's rather in line with the theory standing for Oceanic level drop at the end of Cretaceous epoch and large transgression during Early Paleogene.

One of the global events to seriously affect the climate change and the Earth's biota was the thermal maximum of Late Paleocene occurred about 55 Ma BP on the boundary between Paleocene and Eocene.

According to paleoclimatic reconstructions, during this event the continental temperature increased by 8^0C, whereas the water temperature in a tropical zone had equaled 20^0C which is 1.5^0C higher than the contemporary value. Rise of the arctic water temperatures was even higher and may have reached 10^0C in the surface waters of the Arctic Ocean.

Thermal maximum is most clearly expressed in the isotope composition of carbon contained in the carbonate sediments. Its' $^{13}C/C^{12}$ ratio had first rapidly reduced by 2-2,5‰ and then recovered within the period of 150 thsd years.

During thermal maximum, the atmosphere's carbon dioxide content had reached 2-3‰ (i.e. 5-8 times higher than the contemporary value of 300_{ppm}). The most of those concentrations were dissolved in the oceanic waters, which increased the water's acidity causing dissolution of the shell carbonate of dead plankton before they reached bottom of the ocean. Therefore, in sedimentary sections the thermal maximum is manifesting itself through replacement of white carbonate deposits by red shales, which turn back into the carbonate deposition upon end of thermal maximum.

It's estimated that the formation of observed isotope anomaly required decomposition of just one third of methane fixed in the form of gas-hydrates.

According to the other hypothesis, thermal maximum may have emerged as a result of a cometary impact.

Special interest is aroused by the anomaly's effect in depositional systems and the 150 thsd yearlong recovery period. The latter was compared with contemporary deposition period of the oceanic carbon into sedimentary formations. Provided that the carbonic anomaly is associated with considerable growth of a biogenic barium content, in 2000 S. Baris and others suggested that the level of ocean's productivity improved in response to intensified erosion on continents and increased sediment supply.

Paleogeographic environment of Azerbaijan underwent serious changes during Paleogene. Early Paleocene regression was replaced by a transgression that have started in the Late Paleocene.

At the same time, connection was established between the Mediterranean basin and the seas located to the south (Iran) and to the east (Pakistan, India) of Azerbaijan from one side and the basin's southern regions from another. This process had caused a northward migration of the thermophilic groups of marine animals (e.g. large foraminifers, corals, sea hedgehogs and mollusks), which have presumably occurred due to a thermal maximum of Late Paleocene.

Emerged favorable conditions (increased temperature regime, normal salinity, gas regime and bathymetric characteristics) have promoted a migration of new groups of organisms into the basins of Azerbaijan (Araz zone, central part and foothills of Lesser Caucasus system). Such migrants included various species of small and primitive nummulites, e.g. *Nummulites praexilis, N. silvanus, N. fraasi, N. deserti, N. subplanulatus, N. thalicus, N. solitarius, Operculina heberti, Panikothalia sindensis, Discocyclina seunesii etc.* (Бабаев, 1990).

Therefore, Late Paleocene maximum had created favorable conditions for an emergence of first Paleogene nummulites within the territory of contemporary Azerbaijan.

Multiple changes in the composition of benthic and planktonic foraminifers at the boundary between Paleocene and Eocene were also expressed in a global massive extinction of bathyal and abyssal forms as well as cardinal changes among benthal foraminifers.

End of the Priabonian stage is marked by a shallowing of the Global Ocean. Oligocene is marked by cooling, depositional break on the border with Oligocene and shrinkage of the Rupelian basin's area (Крашенинников, Ахметьев/ред., 1996).

It should be mentioned that the transition from Upper Eocene to Lower Oligocene was also characterized by a blunt change of the Azerbaijan's fauna composition. For example, biotic communities of the country's Early Oligocene basins contained practically no nummulites, brachiopods and corals.

Mollusk fauna remains are only detected in the Eastern part of Lesser Caucasus system. These remnants are quite few, just amounting to 11 species from 7 families of pelecypods, 1 species of gastropods, 1 species of *Planorbella*, limited amount of ostracods and minor foraminifers, fishes and marine plants.

Except for fishes, no macrofauna remains were detected in the eastern part of Azerbaijan, while remnants of ostracods and microfauna are few.

Relative plentifulness of mollusks is observed in the eastern Lesser Caucasus at the bottom part of the Chattian stage. Their variety includes 26 genera of pelecypods and gastropods from 20 families. Detected fauna is similar to that of the brackish-water or hardly communicated basins, in which the biological diversity gets limited to a couple of species with large amounts of the specimens. This time is characterized by relative improvement of bionomic conditions. Emerged molluscan fauna quickly adjusted to new environmental conditions and occupied the Oligocene sea of the Lesser Caucasus. According to K.Alizadeh (1968), there may have existed a large bay in the east of the Lesser Caucasus system, which have had a connection with Oligocene basins of Georgia. If this speculation is true, locally detected fauna might have migrated from the Georgian territory.

Temporary improvement of the bionomic conditions have been interrupted during Late Chattian age. Marine basins of that period contain almost no macrofauna (besides fishes) and extremely few remnants of foraminifers and ostracods.

This time was characterized by the sea water's increased pollution by hydrogen sulfide, which have considerably influenced the local fauna diversity.

During later periods, changed geological conditions have promoted a growth of biological diversity. As this process was rather of a regional importance, it will not be addressed in the current article. Figure 8 provides for a chronostratigraphic scale of the country-level distribution of signs of global events.

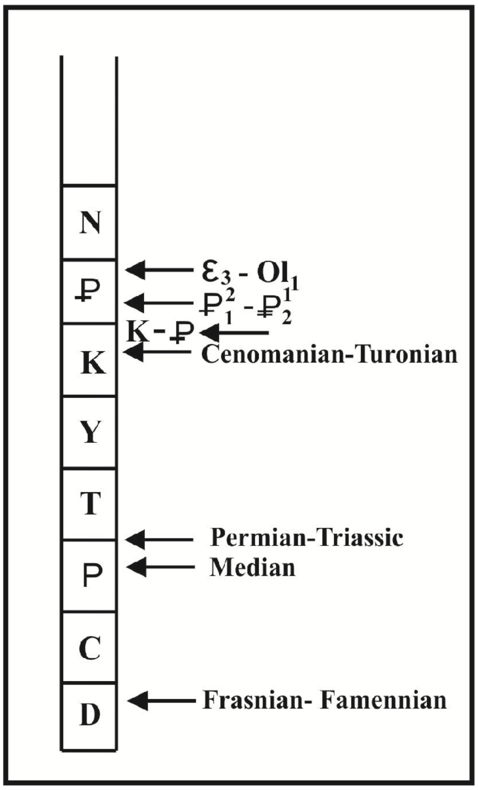

Figure 8. Signs of global events in Azerbaijan

Conclusions

1. The article reviews signs of global events in the Phanerozoic deposits of Azerbaijan
2. There are the signs of 8 global events recorded in the country's geological sections. Their stratigraphic position is characterized, which is deemed important for the stratigraphic scale's detailed elaboration
3. Most ancient Hangenberg event is locally confined to the top of the upper Nephalinian substage, and is expressed in the outer shelf facies, marked by black shales with increased dispersed organic matter content. Hangenberg event was marked by a massive extinction of typical Devonian ammonoideas, many conodonts, ostracods and foraminifers, as well as total extinction of Devonian bioherm structures with carcass forming organisms
4. Upper part of the Median stage (Deveolen suite) corresponds to one of the most important biotic events characterized by enormous biotic crisis that addressed both terrestrial and marine biota. It may be regarded as the beginning of massive Permian-Triassic crisis. Developed due to global sea level fall, the Late Median event had influenced every single group of the marine organisms. End of the Median age was marked by extinction of 40% of foraminifers and 70% of the fusulinids, emergence of first conodiscidaes and araksociratidaes, and deep changes among corals and conodonts, etc.
5. Massive extinction event at the boundary of Permian and Triassic periods (Darasham section in Nakhchivan AR) is related to extinction of of ≈50% families and over 80% genera of marine organisms by the end of Darasham stage. One of the most possible reason is global sea level drop due to a climate's aridization.
6. Cenomanian-Turonian borderline biotic event (OAE-2) is related to a maximal transgression during Late Cretaceous period. In Azerbaijan, the event is recorded in the sections of Shaylakli, Chovdar, Komvudagh, etc.
7. One of the most affective global events in terms of the organic life evolution on Earth was the mass extinction occurred at the boundary between Maastrichtian and Danian stages.

   In Azerbaijan, Maastrichtian-Danian boundary is marked by disappearance of ammonites (*Diplomoceras, Pachydiscus*), belemnites (*Belemnella*), many genera of bivalves, majority of heterochemics, globotruncans among minor and orbitoids (*Orbitoides, Orbitella*, etc.) among larger foraminifers.

   Such a serious change in the organic world's composition at the boundary between Cretaceous and Paleogene periods is not probably related with impact or volcanic events. It's rather in line with the theory standing for blunt oceanic level fall at the end of Cretaceous period and large transgression during Early Paleogene.
8. Late Paleocene thermal maximum (LPTM) occurred about 55 Ma BP at the boundary between Thanetian and Ypresian stages was

one of the global events to seriously influence the Earth's climate and biota.

Paleogeography of Azerbaijan had undergone serious changes during Paleogene. Early Paleocene regression was changed by transgression which started in Late Paleocene.

Formed favorable conditions (increased temperature regime, normal salinity, gas regime and bathymetric conditions) promoted migration of the new groups of organisms, including various representatives of the family of small and primitive nummulites, e.g. *Nummulites pracexilis, N. silvanus, N. deserti, N. thalicus, N. solitaries,* etc.

9. Late Priabonian stage is marked by shallowing, whereas Oligocene is characterized by cooling, depositional break on the boundary with Oligocene and shrinkage of the Rupelian basin. These events have negatively impacted biota of the Oligocene – Early Miocene basins in Azerbaijan.

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AZƏRBAYCANDA FANEROZOY QLOBAL HADİSƏLƏRİNİN İZLƏRİ

Ş.Ə. Babayev

Qlobal hadisələr stratiqrafiyası müasir zamanda isbat edilmiş sayılan qlobal sinxron hadisələrin baş verməsinə əsaslanır. Bu hadisələrin əksəriyyəti stratiqrafik şkalanın sərhədlərinə müvafiq gəlir.

Təqdim edilən məqalədə Azərbaycanda fanerozoyda baş vermiş qlobal hadisələrin izlərinin ayrılması və təsvirinə həsr edilmişdir. Bunların tərkibinə kütləvi qırılmalar, morfoloji yeniliklərin ayrılması, radiasiya və s. daxildir.

Azərbaycanda kəsilişlərdə 8 qlobal hadisənin izləri (devondan oliqosenə qədər) qeyd edilmiş, onların ətraf mühitə və biotaya təsiri təhlil edilmiş, onların stratiqrafik səviyyəsi qiymətləndirilmişdir ki, bunun da regionun stratiqrafik şkalasının detallaşdırılması üçün mühüm əhəmiyyəti vardır.

СЛЕДЫ ГЛОБАЛЬНЫХ СОБЫТИЙ ФАНЕРОЗОЯ В АЗЕРБАЙДЖАНЕ

Ш.А. Бабаев

Глобальная событийная стратиграфия основана на существовании глобальных синхронных событий, считающихся в настоящее время доказанными. Большинство этих событий приурочено к границам стратиграфической шкалы.

В предлагаемой статье сделана попытка выделения и описания следов глобальных событий фанерозоя в Азербайджане, в которые входят массовые вымирания, введение морфологических новшеств, радиация и др.

Всего в Азербайджане в разрезах отмечены следы 8 глобальных событий (от верхнего девона до олигоцена), проанализировано их влияние на окружающую обстановку и биоту, охарактеризована их стратиграфическая приуроченность, что имеет важное стратиграфическое значение для детализации стратиграфической шкалы региона.

KHVALYNIAN TRANSGRESSION AND ATHELIAN REGRESSION OF THE CASPIAN SEA

Modern stratigraphic scheme of the Caspian Sea coastline was developed basing on ideas formulated by P.A.Pravoslavlev more than 100 year ago (Православлев, 1900, 1908). Further, the once developed concept was regularly reworked by the other well-known researchers who have brought additional details and clarifications to the beds and boundaries between them in most complete and reliable sections (Жуков, 1935, 1936; Стратиграфия четвертичных отложений…,1953; Васильев, 1961; Москвитин, 1962; Федоров, 1957 и др.).

Large amount of data have been collected on the different sections of Lower Povolzhye (Леонов и др., 2002; Янина, 2012; Свиточ, 2014; Лаврушин и др., 2014; Tudrun et al., 2013 и др.) and Dagestan (Рычагов, 1997). New information was gathered for the eastern coast as well (Курбанов, 2014). Nevertheless, none of the newly developed factual material helped develop an understanding of history of the Caspian Sea's transgressive and regressive cycles during Pleistocene-Holocene (Варущенко и др., 1987; Шкатова, 2006; Застрожнов и др., 2013). Relatively large data set also failed to put some clarity into the problem. We know examples, when various authors have attached particular sediments to different stratigraphic units. Facies and lithological variability of deposits causes serious discrepancies, which become even more aggravated when attempting to correlate Volga river sediments in Lower Povolzhye.

Keywords: Caspian Sea, Lower Volga, transgressive-regressive cycles, sections, strata

E.N. Badyukova

Faculty of Geography,

Lomonosov Moscow State University,

E-mail: badyukova@yandex.ru

Accepted history of the Caspian Sea fluctuations

According to researchers, history of the Caspian Sea is a record of its' differently ranked fluctuations, i.e. different stages and phases of oscillation and convulsion (Свиточ, 2014). During Pleistocene, Caspian Sea had undergone following large transgressive epochs: Baku, Early Khazarian and Khvalynian. Last two transgressions had been divided by deep Athelian regression, timing and depth of which is still a subject of strong discussionst. In recent years, Hyrcanian transgression (Лаврушин и др., 2014; Янина и др., 2014) distinguished in 1967 by Popov, was brought under a new scrutiny. There is no consensus as to the age of Early Khvalynian transgression, which was then followed by Yenotayev regression and Late Khvalynian transgression. Regression stages were accompanied by an accumulation of continental, alluvial and proluvial deposits, which with well-defined contact overly the lower sediments, and are overlaid (also with well-defined contact) by marine sands, lagoon loams and shales with sand interbeds. The latter often contain malacofauna with Khvalynian appearance.

Chocolate clays

Study of history of the Caspian basin evolution is impossible without referring to a problem of genesis and age of widely developed chocolate clays (CC), which cover the broad areas starting from surface until a coastline of Late Khvalynian sea. In the south, clays are occurring until reaching the modern sea coast, and towards the Caspian Sea expose during excavations on the Caspian bottom within the shallow water zone.

CCs are characterized as distinctive and typical facies of the Khvalynian deposits. Some researchers consider them as the marine sediments deposited at the depths of 25-50 m (Шанцер Е. В. 1951; Москвитин, 1962; Леонов и др., 2002 и др.). M.P.Boritsina (1954) holds to an opinion that CCs have formed during the independent Middle Khvalynian transgression. From the other hand, A.A.Svitoch (2015) suggests that they have been deposited within pre-Khvalynian depressions and estuaries. However, there are a lot of evidences of a wider occurence of CCs in the region. For example in 1955, several sections of the Volga-Ural interfluve were presented by T.F.Yagubov (1955) to reveal CC interlayers not only in the estuaries but also in the wide adjoining areas. Additionally, CCs underlie a thin layer of deposits in the areas between Volga and Yergeni rivers (Жуков, 1936) as well as along the Yergeni ledge.

It is worth noting that clays do not form an continuous cover in their development areas. CCs are rather confined to wide firth depressions which, together with gullies, represent a typical feature of landscapes across the western Pre-Caspian region and in the interfluve of Volga and Ural. Firths have quite diverse configurations varying from oval to linear-doming. Some of these landforms reach 100-180 km in length and several tens of kilometers in width. Firths and gullies are sometimes divided by up to several hundreds of hectares large watershed areas. Broad firths are exemplified by a system of floods and lakes in the river mouth of Ascheozek, which includes 1000 small troughs connected by channels. Early Khvalynian basin was characterized by sea level's stadial retreatment and temporary stabilization (Леонтьев, 1977). İt is testified by the occurence of Northern Caspian coastline expressed by separate elongated sand benches located in the Northern Caspian Seacoast.

During transgression, river mouths used to become flooded and estuaries emerged in which CCs have been accumulated. For example, the estuary that had emerged along Volga during the Early Khvalynian time, used to extend far towards the north reaching the vicinities of Samara (Svitoch, Makshayev, 2015). Currently CCs of former estuary are occurring at a height of about 35 m (Chapayevsk town's vicinities). As demonstrated by mapping and cosmic images analysis, the estuary even reached the vicinities of Srednaya Akhtuba during one of the final stages of Khvalynian transgression. Currently the top of CC is located at the altitude of 5 m.

At the same hypsometric level the CC are encountered in Kolobovka outcrop located 40 km southwards. Therefore, samples taken from both the bottom and the top of the deposits will be dated nearly identically. Thus, the age of sediments is the same under conditions of accurate sampling.

CCs are dated as Early Khvalynian sediments. Therefore, shells found in the sand beds occurring in the CC are apriori dated as Early Khvalynian remains. We have analyzed the existing data on ages and collection sites of the Upper and Lower Khvalynian samples. It was identified that all Early Khvalynian samples (dated according to C^{14} and Th^{230}/U^{234}) were collected from the altitude range of –18 to +10 - +15 m. Only several shells from Lower Khvalynian sediments on the Azerbaijan and Dagestan coasts were collected and dated from up to 32 m hypsometric level.

Collection sites of the Upper Khvalynian samples are located at –21 – 0 m elevation interval. Therefore, Lower and Upper Khvalynian deposits of the Northern Caspian seacoast have similar age and hypsometric position (Бадюкова, 2007).

In our earlier articles, we already explained our conclusion on lagoonal origin of CCs – these typical North Caspian deposits having very variable age (Badyukova, 2000). Therefore, in this article we will only brief on their genesis. CCs are often occurring as sharply wedging lenses with multiple sand interbeds that contain shells of the various mollusks which preferred inhabiting brackish and fresh waters of the shoreface. Accumulated almost on the surface under soil, CCs directly overlie subaerial, lake, alluvial, delta or coastal-marine deposits (sometimes even the fossil soil). Reed roots and clear facies transition to the underlying deposits are recorded in their bottom.

Within the framework of project funded by INTAS, we have tested different samples of CCs in the laboratory of Utrecht University (Netherlands). Following results were produced by the implemented analysis:

1. All samples demonstrate low hydrogen and high oxygen indexes based on the pyrolysis results (HI and OI correspondingly), which uncontroversially speaks for a continental type of the initial organic matter (IOM);

2. CCs have negligibly small amount of IOM, which is an indicative for the oxidizing–shallow water and high hydrodynamics conditions*.

3. The high concentrations of ferric hydroxides in the sediments also testifies to the shoreface environment with dominating oxidization geochemical conditions.

Detailed CC studies that have replenished the existing information were recently implemented by A.A.Svitoch and other researchers (2015).

In all sections developed along the lower reaches of Volga, revealed are only the Khvalynian lagoon deposits represented by thin layers of CCs, often with sand interbeds containing mollusk shells. These deposits overlap the alluvial or subaerial sediments which in turn overlie the Khazarian sediments. At the same time, none of the studied sections appeared to contain the Early Khvalynian marine sediments. It's explained by a fact that at that regression stage, the Caspian Sea level increased from -100÷140 m (as offered by many scientists, it is apparently the Athelian regression's level) to +50 m of the true altitude. Therefore, the level of Northern Caspian must have varied from 30 to 70 m. It has to be noted that the sea level rise is always accompanied by erosion of the slope down to a depth of the wave's impact (Леонтьев, 1961). It means that sands lying under the CCs should been eroded (Figure 1). Accepting CCs as lagoon sediments, we must first explain their exceptionally wide development in almost all sections until Late Khvalynian shoreline at 2-0 m elevation (which implies hundreds of kilometers covered by CCs), and between abs. levels 30m - 0m. Secondly, we must realize why the layers of sand have been preserved in the sections. Finally, we have to clarify a reason of the absence of Early Khvalynian marine deposits.

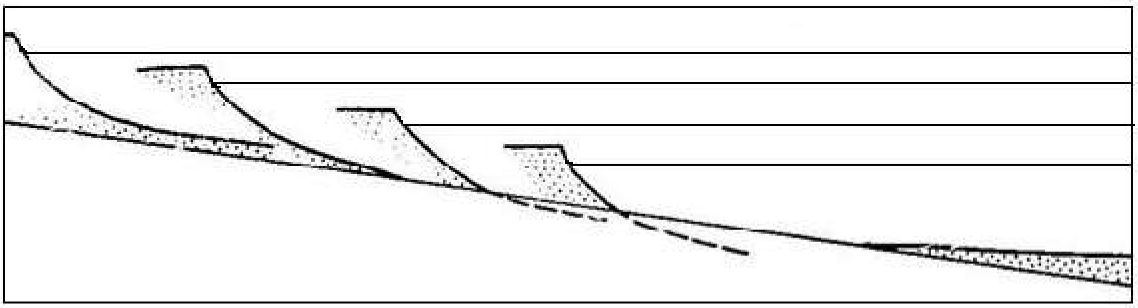

Figure 1. Erosion of the underwater shoreface during rise of the sea level (according to Zenkovich, 1962)

* Data was provided by Prof. D. Huseynov, Institute of Geology and Geophysics, ANAS, Baku

Lagoon-transgressive terraces

It's known that positive oscillation of the Caspian Sea had occurred against the background of its' level fall. Researches have shown that the shore's development during transgressions depends on the combination of gradients of flooded coast plain and underwater slope under a developed equilibrium profile. During sea's transgression, lagoons may emerge only in the areas where the initial gradients of the land area are lower than those of the nearshore zone of a sea bottom (Бадюкова и др., 1996). This is exactly what happened on the Northern Caspian coast, where multiple transgressions and regressions have flattened the coastal relief, and in which extended deltas were formed by the Volga.

In compliance with coastline's formation regularities, rise of the sea level launches continuous erosion of the upper shoreface, which previously used to constitute a margin of the coastal plain (Зенкович, 1962, Леонтьев, 2014). Together with formation of a coastal barrier, lower part of the shoreface zone becomes flattened by fine grained material that goes deeper due to a wave-driven separation of sediments in the coastal zone. This regularity is most obviously illustrated on the Dagestanian coastline through a correlation of batigraphic curves developed for transgressive and regressive periods (Соловьева и др., 2001). Under these conditions, it was already during first ten years of transgression, that the area covered by sea had increased by 7% at the expense of shoreline's retreat, and the upper part of the shoreface had become deeper and steeper as compared to a regression period. In the lower part of the slope (starting from a depth of 14-15 m), accumulation of part of the shoreline's eroded material occurred (Figure 2). Simultaneously, the lagoon had formed behind a barrier as a result of flooding of the regressive accumulative terrace by both underground and marine waters. By that time, flat surface of the terrace had become lower than level of the transgressing sea. Lagoon formation processes were also widely contributed by the rivers impounded by emerged barrier.

Therefore, two coastal relief elements (barrier and lagoon) have simultaneously emerged in close genetical relation between each other. Together they formed a single transgressive system. At the same time, two lithologically different types of deposits emerged on the same hypsometric levels. The lagoon gets filled by lagoonal or alluvial-delta deposits when it emerges near the mouth of a river, and barrier (transforms into series of barriers due to sea level oscillations) is composed of littoral marine sediments. This paragenesis of deposits must be considered when interpreting geological materials and developing paleogeographic reconstructions.

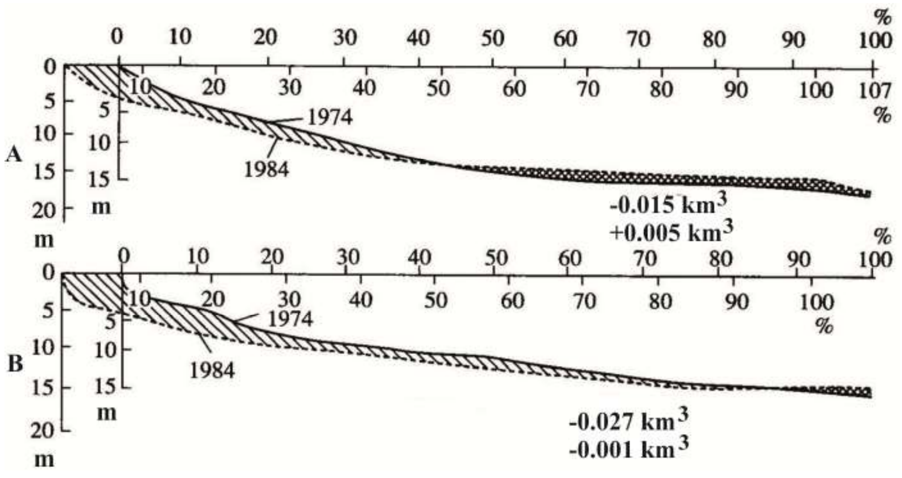

Figure 2. Comparison of bathymetric maps of one of the Dagestanian coast's areas

Given that the lagoon had emerged over the surface of former regressive terrace, its' lagoonal series were underlaid by older deposits within the section of marine transgressive sediments. Described bedding is characterized by sharp unconformity without gradual facies transition. Positive oscillations have resulted in creation of a set of large lagoons divided by separate barriers (Figure 3). With inherited development of coastal processes, multiple sea level fluctuations may lead to a situation when the coastal plain represents series of successively attached lagoon-transgressive terraces. CCs have accumulated in lagoons that gradually moved to lower hypsometric terraces, whereas marine sandy sediments are indicating to the former coastlines. It has to be mentioned that in a number of cases the barriers might have been either eroded or covered by reciprocating sea level fluctuations, once the recurrent rising event was higher than the previous (Figure 3, Terrace II). It's also important to note that the lagoonal deposits lie unconformably with heterochronous sediments of various genesis, and there is a clearly defined boundary between lagoonal and underlying sediments. Mentioned unconformity doesn't necessarily mean erosion.

Relatively longstanding rise of a sea level with sufficient volumes of alluvium and respective inclination ratio of coastline's under- and above water segments not only ensures the material's active accumulation in the swash zone of the coastline, but also stimulates the latter's retrogradation due to the upsurge-followed storm waves overthrowing a beach material towards the lagoon's interiors. In this case, coast preserves its' accumulative appearance in spite of retreat and active erosion of the shoreface. For example, this was the case with Caspian Seacoast, when 2.5 m rise of the sea level occurred at the end of XX century and one of the Dagestan's accumulative shores retreated for almost 700 m.

Barrier's occupation of the lagoon causes subhorizontal facies replacement of lagoonal loams by beach sands, which is most typical for those parts of the lagoons directly located behind a barrier. Under certain morphological and hydrological conditions, the barrier's shell sand material gets "thrown" into a lagoon and covers its' original deposits. Therefore in a transgressive series of marine deposits, lagoonal sediments get underlaid by previous regressive phase's sediments and overlapped (sometimes with sharp contact) by a shell sand material that belongs to same transgressive phase as the lagoonal loams (Бадюкова и др., 2003). On the other hand, lagoon receives larger material from the incoming rivers. Such material forms relevant interlayers within the section of lagoonal deposits. During recurrent fall of the sea level, lagoons get partially dried and their former water areas transform into an subaerial terrace, that we call a lagoon-transgressive terrace as it is formed during transgressive period. As stated by the analysis of data collected from different coasts of the World's ocean, sea level fall usually doesn't lead to formation of lagoons (Бадюкова и др., 2010).

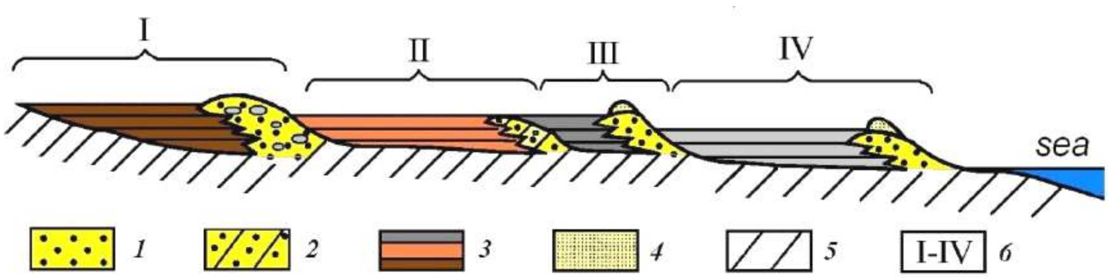

Figure 3. Formation of lagoonal-transgressive terraces.
1 – barrier deposits; 2 – buried barrier; 3 – lagoonal deposits; 4 – eolian sands; 5 – underlying deposits; 6 – series of lagoonal-transgressive terraces

If the regressive terrace is almost entirely built by beach, in lagoon-transgressive terrace marginal marine deposits are only present in the structure of their separating barrier. Remaining larger parts of lagoon-transgressive terraces are built by clays, loams and sand clays, sometimes with interlayers of laminated clays and clayey sands with lagoonal or deltaic features. Deposits are greyish-brown, reddish brown, indistinctly laminated or non-stratified, poorly sorted and with gleying spots. Some parts of their tops contain fragments of the fossil soil, finely-crushed shells and plant remains.

Sections of Lower Povolzhye

Summing up what has been said we can conclude that in case of the Caspian Sea shoreland with repeatedly changing levels, it is impossible to correlate deposits revealed in the outcrops and wells located across the strike of the ancient coastlines. There is a high probability that such correlation will result in giving a single strata's status to deposits from different lagoon-transgressive terraces that had formed on various hypsometric levels during independent transgression events.

However, this aspect isn't taken into a consideration when studying the Caspian coast's sections and implementing regular suite and layer correlation works. For example, during correlation the section's crowning loessial loams are mistakenly considered as a single layer of the Athelian loams, which earmarks a deep regression processes that had occurred between Khazarian and Early Khvalynian transgressions.

As a result of the detailed review of literature sources as well as performed field investigation activities, the author had proven that none of the known Northern Caspian sections contains series Khvalynian marine transgressive sediments deposited in the open marine conditions.

Khvalynian deposits only form thin layers with well-defined contacts within the tops of the sections. Such layers are represented by CCs with thin interlayer of sands sometimes detected in the bottom with Khvalynian shells in their structure. CCs sequentially bed over the younger alluvial-delta sand units, including sands in Akhtuba, Chorniy Yar, Tsagan-Amana quarry and other areas. Different age of the sands becomes evident when comparing the sections of Middle Akhtuba, Chorniy Yar, Lower Zaymische and Tsagan Aman. If several fossil soil layers are distinguished in the section of Middle Akhtuba, only one layer of well-defined hydromorphic fossil soil is detected in Chorniy Yar, in which it overlaps local alluvial sand deposits. At the same time, fossil soils are hardly represented In Lower Zaymische and Tsagan Aman (Figure 4).

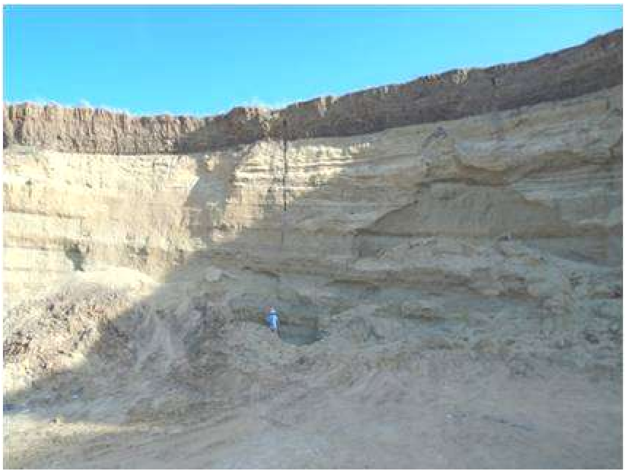

Figure 4. Section of Tsagan-Aman quarry. In the top - chocolate clays

Alluvial stratas of all sections are overlapped by subaerial deposits. These heterochronous layers are normally younger in lower hypsometric levels. As seen from a number of sections, sand bodies overlie the Khazarian transgressive sediments.

Sections of the eastern slope of Yergeney

With hardness of interpreting the Northern Caspian sections considered, field investigations have been implemented along the eastern slope of Yergeney, in which ancient coastlines were preserved with minimal impact from the river arteries. One of such investigation activities was carried out in the Tundutovo settlement, around which there is a CC production quarry developed on 30 m high subhorizontal surface that adjoins a gentle slope of Yergeney in creek's direct proximity.

Following series are revealed in the quarry's section (Figure 5 with soil cover removed):

1) 2-4 m thick layer of sands;

2) 3-5 cm thick layer of CCs with indistinct transition observed in the bottom;

3) nearly 1 m thick layer of bleached sands with brackish water Khvalynian fauna of *Didacna ebersini, Hypanis plicatus, Monodacna caspia*. The contact is distinct in the bottom;

4) about 2 m thick reddish-brown clays with gypsum, Clays are dense and gypsified with 5-10 cm large tabular and prismatic crystals of gypsum. Transition to a below layer is gradual;

5) around 2 m thick brown and yellowish-grey loams with no fauna detected.

It is important to stress that Early Khvalynian deposits are located not higher than 35-38 m of true altitude, as there are Yergeney's Neogene sandstones revealed at 40 m height on the flange of Gryaznaya creek.

Second section was studied in the Yashkul creek's estuary located to the south of the previous area and confined to an eastern slope of Yergeney as well (Figure 6). 18 m thick alluvial-marine strata is revealed there on the left flange of the creek with true crest elevation of 33-35 m. Following series are revealed in the section concealed under a thin layer of topsoil and subaerial deposits:

1) thin (0.2 m) interlayer of Early Khvalynian beach sands with detrital matter and small shells of *Hyparis plicatus, Adacna vitrea, Adacna laeviuscula, Didacna ebersini*. The contact is distinct in the bottom;

2) about 2 m thick subaerial (alluvial-proluvial) loams;

3) nearly 3 m thick layer of grey and laminated sands with shells of brackish water Khazarian mollusks of *Didacna subpyramidata, D. Pallasi, D.cristata, dreissena polymorpha.*[*]

4) about 5 m thick layer of multicolor alluvial-proluvial deposits (loams, sand clays, laminated sands) with various lithology, extending through an encroachment line of Yashkul river.

According to their high-altitude position, Khazarian deposits are confined to 30-35 m high coastline. They get overlapped by alluvial-proluvial loams, which in turn get transgressively covered by a thin layer of Lower Khvalynian deposits.

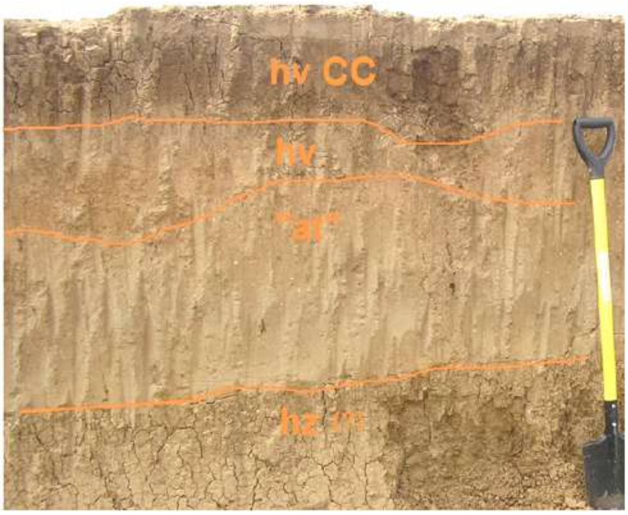

Figure 5. Tundutovo section

Figure 6. Yalmata section

[*] Malacofauna definitions are provided by Prof. T.A. Yanina

Interpretation of literature and field materials

Geology-geomorphological studies of the eastern near-Yergeney part of the Northern Caspian Seacoast have resulted in the formulation of new understanding of the Caspian Sea level fluctuations at the end of Pleistocene. Thus, maximal levels of both Early Khvalynian and Khazarian basins didn't exceed 35-40 m.

Based on thorough analysis of both literature and field work information, we drew a number of logical conclusions regarding history of the Caspian Sea's evolution in Pleistocene. Some conclusions may look a bit surprising from the first site. However it should be mentioned that they are all closely interrelated and grounded by concrete theoretical and field research outputs.

First of all we suggest that just like in the other periods of sea's evolution, there had been a long-running Khazarian transgression accompanied by temporary oscillation events (periods of level fall during general rise of the sea level). Transgression level had varied within 30-40 m interval and even exceeded it in a number of regions. As stressed by G.N.Richagov (1997), Late Khazarian terraces are located above their Early Khvalynian analogues. They form a sloping coastal plain. This statement is proven by Tundutovo and Yalmata sections (Figures 5, 6) as well, according to which level of the Khazarian transgression was close to that of the Early Khvalynian transgression.

It was mentioned by all researches that during Khazarian transgression, an entire Caspian coastline was wave dominated with brackish water environment . The author subscribes to the opinion of scientists who suggest that during that period there used to be a connection between Western Siberia and Caspian Sea through Aral. Thus, up to 1 m large blocks of straw-colored sand clays with undisturbed stratification were described by P.V.Fyodorov during his study of the Caspian Sea's eastern coastal area (1957). In this connection the researcher had mentioned that similar sediments have been usually found in the area from Cheleken and further up the Uzboyu river's channel. P.V.Fyodorov assumed that type of the mud clasts and blocks with preserved structure testifies to a short duration of the catastrophic flow, whereas presence of the shells of *Corbicula fluminaris* is an indicative for the fluvial environment.

Between Khazarian and Khvalynian deposits of Lower Povolzhye, deposited are the alluvial and lacustrine-mursh sediments overlapped by subaerial loams. On the western coast they are represented by thick alluvial-proluvial sediments built by a coarse-grained material (e.g. 10-15 m thick gravels in the section of Manas river's estuary in Dagestan). On the eastern coast, Khvalynian deposits have been deposited over the loess loams of Karakum or Khazarian suites.

Our estimate shows that in Lower Volga Khazarian transgression was followed by the sea level's 15-20 m fall (evidenced by thickness of alluvial and subaerial deposits), as well as the emergence of one of the coastline's first alluvial packs - Akhtuba sands, which later became overlapped by Athelian loessial loams. This subaerial stage extended for a long period of time, which was enough for development of a series of soils (Васильев, 1961; Москвитин, 1962). All this time the sea was somewhere close to the area and a long-running time interval have stimulated the development of Khvalynian malacofauna (Figure 7 a, b).

During recurrent rise of its' level, the see had transgressed over both lowland delta plains and river valleys, forming lagoons and estuaries in which the CCs have started to be accumulated. According to a vast majority of the Caspian Seacoast's sections, level of the Khvalynian transgression was slightly higher than that of the Khazarian transgression. Thus, in Kalmykia (Figures 5, 6), CCs and subaerial loams form up to 1 m thick cover over the Khazarian deposits. It is important to stress that the level of Early Khvalynian sea haven't exceeded 35 m along the eastern slope of Yergeney. As demonstrated by profiles acquired through satellite images across Syrt ledge and northern part of the Early Khvalynian lowland, bottom of the Northern Caspian Sea cliff is fixed on a height of 35 m as well. The same altitude is known as an upper CC development limit in the river valley of Volga.

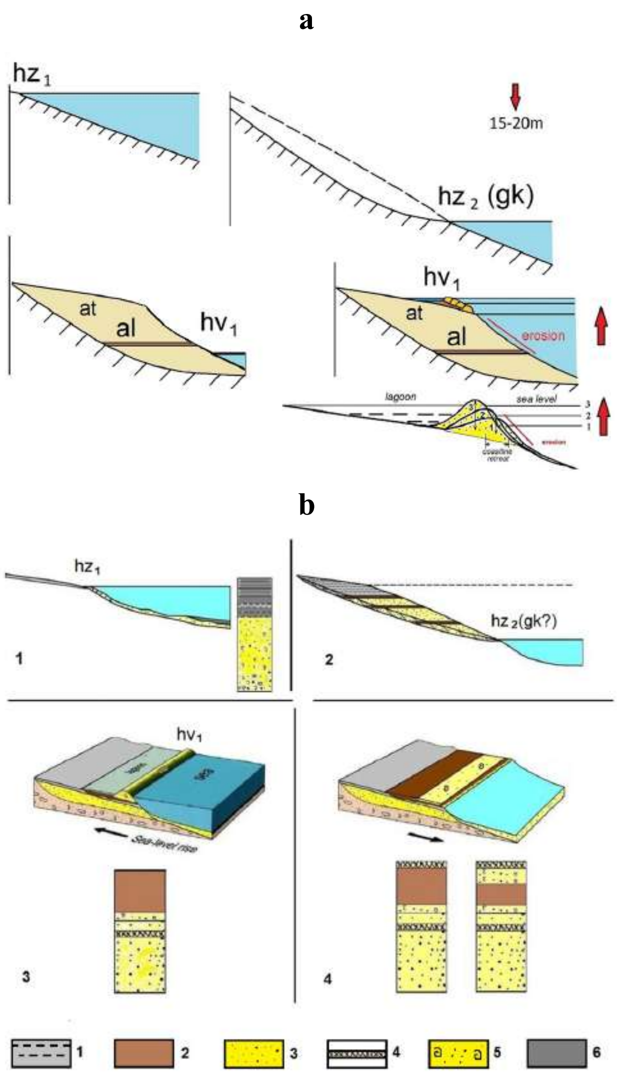

Figure 7 a, b. Schemes of the Caspian Sea coast development during sea level fluctuations.
b: 1 – subaerial deposits (Athelian loams), 2 – chocolate clays, 3 – alluvial deposits, 4 – recent and fossil soils, 5 – marine sands with shells, 6 – deep water deposits

Later, the transgression gave way to the new sea level fall and the emergence of Cherniy Yar sands overlapped by younger-than-Athelian subaerial loessial loams. This next sea level reduction wasn't deep neither. Sands of Cherniy Yar look much younger than their Akhtuba analogues and do not contain well-processed fossil soils in their structure. During recurrent rises of the sea level, subaerial deposits became overlapped by new series of thin Khvalynian lagoon deposits in Volga-Ural interfluve, and by clayey sediments in the estuaries confined to the river outfalls. Newly emerged estuaries of Volga used to reach several tens of kilometers in length. CCs revealed at similar heights of the Middle Akhtuba section had apparently emerged within the single estuary's structure.

This process continued until the Yenotay regression marked by considerable sea level fall. It's evidenced by change of the coast types during recurrent rising event, as well as formation of well-defined ledge-form abrasion coastline observed at heights of 0-2 m in the Nikolsky village's vicinities and in the other parts of the Caspian Seashore. Abrasion of coasts usually begins with change in a combination of littoral plain and continental slope angles. This occurs by a virtue of the fact that deep regression uncovers steeper continental slope than the superincumbent one, and combination of angles between coastland and slope changes in favor of the former (Бадюкова, 1996).

In conclusion, attention shall be paid to another problem related to the Caspian Sea's evolution according to sections developed along lower reaches of Volga. Each sea level drop had stimulated the erosion base level decrease and the river's downcutting. This have caused partial erosion of previous alluvial and marine deposits and redeposition of their malacofauna into a lower hypsometric level. In contradiction to near-shore areas with serious swash-borne impact, displacement of shells within flows of the rivers doesn't cause their excessive defacement. Therefore it becomes hard sometimes to establish a real position of shells within the specific section's breakdown.

Contemporary valley of Lower Volga and Akhtuba inherited the former estuary's body. It's clearly seen from relief's geomorphological analysis showing that more than 500 km long course of the river and its' multiple streams to the south of Volgograd flow through up to 20 km wide and 15-20 m deep erosional downcutting. Therefore, the large part of Northern Caspian deposits is of a redeposited nature. Even a conservative estimate results in assumption that about 70 km^3 of sediments were redeposited in the Northern Caspian coastline. As proven by several researchers (Куприн и др., 1991), such sediments constitute the Mangyshlag threshold built by a soft strata of delta-marine deposits. This factor must be considered when interpreting the latest data produced by drilling in the Northern Caspian offshore.

In spite of the fact that the produced pile of information is far from completeness and there is a huge room for future detailed investigations, it already forms basis for revising some stages of the Caspian Sea evolution. Although lots of new information (drill columns, absolute dating data, palynological test outputs, etc.) were produced in the recent years, they didn't turn out to be enough for the problem's final clarification. In particular, traditional stratigraphic scale doesn’t help with explaining the source of a tremendous water inflow into the Caspian Sea at the end of Pleistocene. At that period the sea level increased for over 100 m under the Early Khvalynian transgression, and the historically smallest Valdai glacier existed in the Northern Europe. On the other hand, none of the proposed theories (tectonic reasons, change of the Caspian hollow's volume, groundwater discharge, melting of ancient glaciers, etc.) serve to thoroughly explain numerous aspects of the Caspian Sea's evolution at the end of Pleistocene.

It is also hard to explain an emergence of the Burtas lake in Manych (Попов, 1983) simultaneously with sea's deep Athelian regression. However all these questions become invalid if we accept the proposed reconstructions. Speaking about first problem, we can say that the Early Khvalynian transgression required much smaller volumes of water, as the transgression started when the Caspian Sea's level was by 15-20 m higher than –100 -120 m. Regarding second question it can be concluded that the Burtas lake existed when its' level coincided with that of the Caspian Sea.

In this article we intentionally skipped the problem of age and correlation of the Caspian Sea's transgressive-regressive cycles with Northern European events. Doing so requires revising piles of the factual material that have been collected so far from the Caspian region.

Conclusion

1. There was the Great Khazarian transgression, the level of which have reached 30-35 m. Catastrophic rising of the Caspian Sea was caused by an inflow of waters from Western Siberia through Turgay.

2. Khazarian transgression wasn't followed by deep Athelian regression. It was completed by a regression with relatively low amplitude (15-20 m) but long duration.

3. This period was marked by a deposition of Akhtuba sands with fossil soils. By the end of the stage, these sands were overlapped by subaerial deposits, including Athelian loams. Long time interval have stimulated the development of typical Khvalynian fauna in the Caspian Sea aquatorium.

4. Recurrent Early Khvalynian rise of the sea level led to a creation of lagoon, which used to cover vast coastal delta plain with an ongoing CC accumulation. Amplitude of the Early Khvalynian transgression haven't exceeded 20-30 m. This transgression was one of the largest oscillations against the background of sea's gradual retreat after the Khazarian transgression.

5. Next period was marked by recurrent sea level drop and emergence of next cross-bedded strata of sand, which were later overlapped by subaerial loams. Sea level increase resulted in lagoon's recovery. Therefore, a series of lagoon-

transgressive lagoons have formed at lower hypsometric levels.

6. Hyrcanian transgression was probably one of the transgressive-regressive cycles in the Caspian Sea's Khvalynian time, which occurred against general background of sea level's post-Khazarian fall.

In spite of being quite open for detailed reading, Lower Volga profiles may not serve as key sections for the entire Caspian Sea. During their interpretation, it is hard and often impossible to identify sedimentation masses that belong to the certain stages of the sea's transgression or regression. Sea level's multiple fluctuations as well as Volga's erosional activity under frequently changing erosional basis have partly washed out the earlier layers and caused incompleteness of the region's geological record.

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XƏZƏR DƏNİZİNİN XVALIN TRANSQRESSİYASI VƏ ATEL REQRESSİYASI

E.N. Badyukova

Xəzər dənizi sahillərinin müasir stratiqrafik sxeminin əsasını P.A.Pravoslavlevin 100 il əvvəl əsərlərində dərc etdiyi təqdimatları təşkil edir (Православлев, 1900, 1908). Sonra bölgənin bir çox tanınmış tədqiqatçıları daha böyük kəsilişlərin lay və sərhədlərini daha dəqiq və detallı şəkildə öyrənərək öz əlavələrini ediblər. (Жуков, 1935, 1936; Стратиграфия четвертичных отложений…,1953; Васильев, 1961; Москвитин, 1962; Федоров, 1957 и др.).

Bu günə qədər, əsasən Alt Volqa (Леонов и др., 2002; Янина, 2012; Свиточ, 2014; Лаврушин и др., 2014; Tudrun et al., 2013 и др.) və Dağıstan (Рычагов, 1997) kəsilişinə aid böyük məlumatlar toplanmışdır. Şərq sahillərinə aid yeni məlumatlar da var (Курбанов, 2014). Buna baxmayaraq bu yeni və böyük faktiki material Xəzər dənizinin pleystosen-holosendə trans-gressiv-regressiv tsiklinin tarixi ilə bağlı vahid fikirlərin yaranmasına kömək etməyib (Варущенко и др., 1987; Шкатова, 2006; Застрожнов и др., 2013). Hətta geniş araşdırmalar da mövcud problemə aydınlıq gətirməyib. Eyni qatın müxtəlif tədqiqatçılar tərəfindən müxtəlif stratiqrafik lay dəstələrinə aid edildiyinə dair nümunələr var. Kəsilişdəki çöküntülərin fasial və litoloji dəyişkənliyi böyük anlaşılmazlığa gətirib çıxarır. Bu anlaşılmazlıq Aşağı Volqaboyu Alt Volga kəsilişlərində ayrılmış lay dəstə və qatların korrelyasiyası zamanı daha da artır.

О ХВАЛЫНСКОЙ ТРАНСГРЕССИИ И АТЕЛЬСКОЙ РЕГРЕССИИ КАСПИЙСКОГО МОРЯ

Е.Н. Бадюкова

Основу современной стратиграфической схемы побережий Каспийского моря со-ставляют представления П.А. Православлева, которые он излагал в своих работах более 100 лет назад (Православлев, 1900, 1908). В дальнейшем многие известные исследователи данного региона вносили свои добавления, уточняя и детализируя слои и границы между ними в наиболее полных и достоверных разрезах (Жуков, 1935, 1936; Стратиграфия чет-вертичных отложений…,1953; Васильев, 1961; Москвитин, 1962; Федоров, 1957 и др.).

К настоящему времени накоплен большой массив данных, в основном по разрезам в Нижнем Поволжье ([Леонов и др., 2002; Янина, 2012; Свиточ, 2014; Лаврушин и др., 2014; Tudrun et al., 2013 и др.) и в Дагестане (Рычагов, 1997). Есть новые данные и по восточному берегу (Курбанов, 2014). Однако, несмотря на это, большой новый фактический материал не способствовал выработке единых представлений об истории трансгрессивно-регрес-сивных циклов Каспия в плейстоцене-голоцене (Варущенко и др., 1987; Шкатова, 2006; За-строжнов и др., 2013). Сравнительно большой массив датировок также не внес ясности в данную проблему. Есть примеры, когда одна и та же толща разными исследователями от-носится к разным стратиграфическим свитам. Фациальная и литологическая изменчи-вость отложений в разрезах приводит к большим разночтениям, которые еще возрастают при корреляции свит и слоев в волжских разрезах Нижнего Поволжья.

UPPER JURASSIC COMPLEX OF GREATER CAUCASUS SIDE RANGE: LITHOFACIES AND SEDIMENTATION (AZERBAIJAN)

The article addresses sedimentation zonality and correlation of the Malmian sediments of the Side range zone of South-Eastern Caucasus. Paper presents new data about presence of the Callovian sediments in the section's bottom, draws conclusions regarding lateral changing of lithofacies from rough flysch in the south to the lagoonal sediments type in the north, which speaks for their sedimentation on the continental slope and shallow shelf of the northern flank within Jurassic marginal sea of the Greater Caucasus.

Keywords: Malmian sediments, South-Eastern Caucasus, lithofacies, continental slope, shallow shelf

T.N. Kangarli

Geology Institute of ANAS, 29A, H.Javid ave., Az 1143, Baku, Azerbaijan
E-mail: tkangarli@gmail.com

Z.N. Mehdiyeva

Geology Institute of ANAS, 29A, H.Javid ave., Az 1143, Baku, Azerbaijan
E-mail: zabita.mehdiyeva@gmail.com

Problem statement. Among other mountainous regions of Azerbaijan, Southeastern Caucasus have been most widely covered by the geological studies, which had started back in 1859 with researches of H.W.Abich. In the following 150 years, large volumes of thematic studies and geological surveys have been implemented to characterize structure and composition of the alpine cover. However, there still remains a number of uncertainties related to understanding of the region's geological-tectonic structure, depositional environment, sequence of geological events, geodynamic conditions, etc. Additionally there are several open questions concerning stratigraphy and lithological-facies zonality of the Upper Jurassic sedimentary complex in the Azerbaijani part of the Greater Caucasus, including zone of the Side range. Actuality of these problems increased in the light of revised understanding of the region's tectonics and Alpine evolution, new faunistical findings, as well as more detail stratigraphy of the sections of different facies zones based on recent geological surveys and thematic studies.

Current article aims to resolve the uncertainties that exist in detailization of the material composition, stratigraphy and lithological-facies zonality of the Upper Jurassic deposits embedded within the southeastern subsidence of Side range.

In the structure of the Greater Caucasus, Callovian stage (confirmed as part of the Middle Jurassic period according to latest amendments to the International Chronostratigraphic Chart) is represented by a sedimentary rocks that remains in genetical relation and forms single tectonic-sedimentation cycle with the Upper Jurassic complex. Therefore for the simplicity's sake, this article will name the Callovian-Late Jurassic complex as infrequently used *Malm* or *Malmian complex* that covers Callovian-Tithonian interval.

Tectonic position of the Malmian in the structure of Southeastern Caucasus. According to latest reconstructions, structure of the Greater Caucasus orogenic system represents a succession of different-scale allochthonous sheets built by the rocks of pre-Jurassic basement and the Alpine cover. It had formed as a result of Hercynian, Indosinian, late Cimmerian and Alpine deformations of nappe and ductilebrittle types occurred during lateral shifting of Northern and Southern Caucasus microplates (Baranov et al., 1990, Geology of Azerbaijan …, 2005, Kangarli, 2010, 2012). Built by Jurassic-Miocene deposits (including hetero-facies Malmian succession), nappe-fold complexes are present in the structure of all three Southeastern Caucasus megastructures, i.e. structural zones and high-order subzones of Side range, Southern slope and Vandam-Gobustan megastructure (Figure 1).

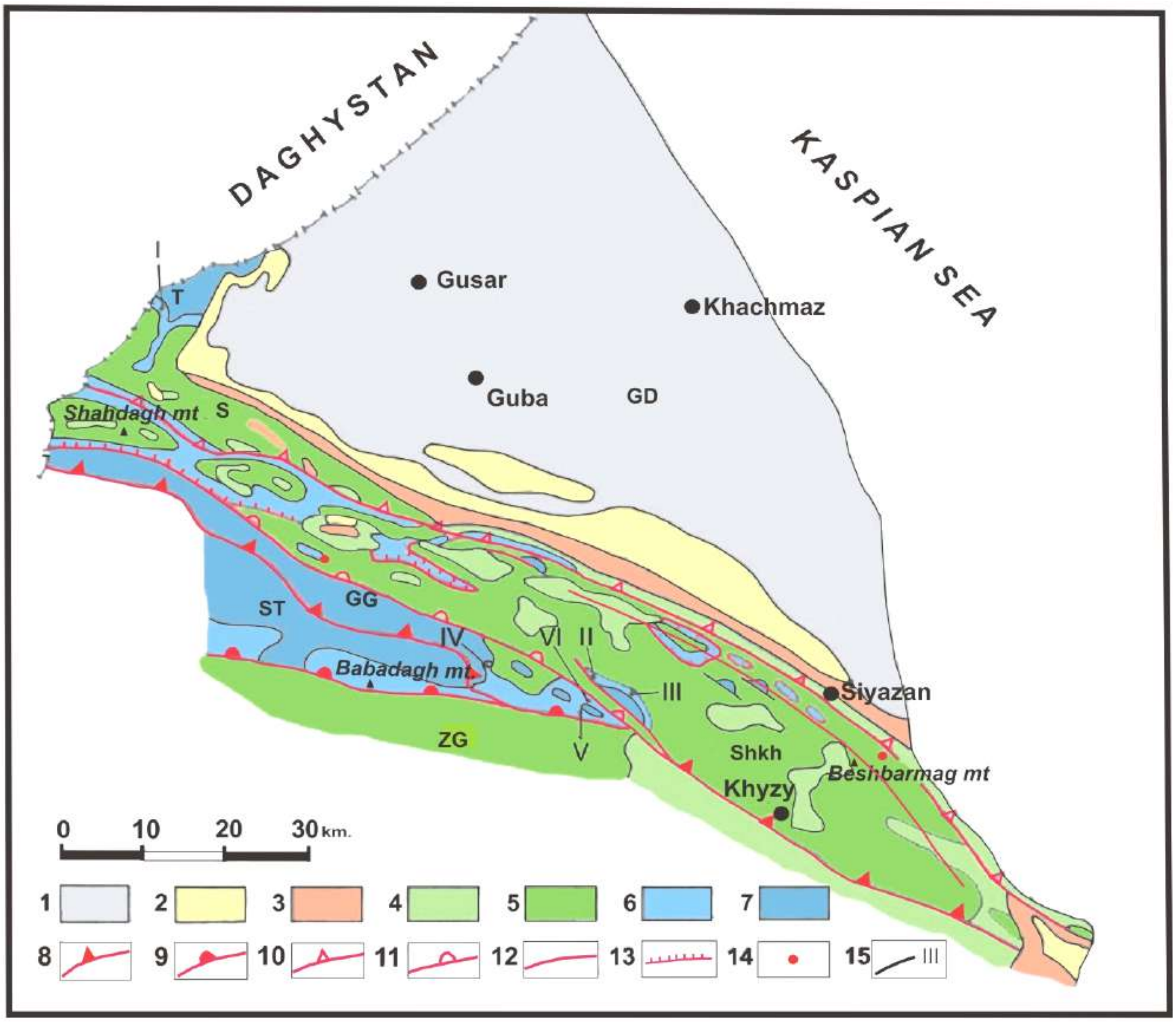

Figure 1. Location scheme of described lithological-stratigraphic sections. Developed by T.N. Kangarli. ***Structural-facial zones***: GD – Gusar-Davachi; T – Tahirjal; S – Sudur; ShKh – Shahdagh-Khyzy, GG – Guton-Gonagkend; ST – Speroza-Tufan; ZG – Zagatala-Govdagh. ***Successions (1-7):*** **1** – Pleistocene-Holocene; **2** – Neogene; **3** – Paleogene; **4** – Upper Cretaceous; **5** – Lower Cretaceous; **6** – Malmian; **7** – Aalenian-Bathonian. ***Faults (8-12):*** **8** – Major Caucasus overthrust; **9** – Gamarvan overthrust; **10** – Siyazan overthrust; **11** – Shahdagh-Gonagkend fault; **12** – other dislocations. **13** – borders of allochthonous sheets; **14** – Beshbarmag klippe; **15** – location and number of described lithological-stratigraphic sections

According to implemented paleoreconstructions (Kangarli, 2010, 2012), at the contact between Middle and Late Jurassic, the lower and middle Jurassic complex have represented succession of the nappe sheets located in front of the Major Caucasus overthrust, which are overlying each other from the north-to-the south and alltogether a volcanosedimentary complex of the northern flank of the South Caucasus microplate. During Malmian stage, separate basin with relatively narrow and shallow (as compared to Middle Jurassic basin) axial flysch depresion (depocenter) have formed on the described structure's basis, with barrier reefs isolating its' northern and southern shelves from the medial water zone.

In modern Southeastern Caucasus system, Malmian sediments of the Side range structural-formational zone are recorded in the geological sections of Sudur, Shahdagh-Khyzy and Guton-Gonagkend facies zones, in which they are represented by facies of the northern continental shelf (evaporites, carbonates), barrier reef and continental slope (coarse flysch). Southern slope's coeval sediments form a narrow line (facies of pelagial subflysch) that extends within the Galal-Rustambaz structural-facies zone's structure and separates Middle Jurassic deposits of the Tufan uplift from the Zagatala-Dibrar trough's Lower Cretaceous sediments.

Implemented researches' retrospective. Studies of the Southeastern Caucasus Malmian complex have been pioneered by H.W.Abich (Abich, 1873) and K.I.Bogdanovich (Bogdanovich, 1902, 1906). These scientists have distinguished and described Tithonian carbonates within the Jurassic section of Shahdagh, as well as Malmian carbonate-terrigenous facies within the Jurassic section of Gaytar-Goja range in the interfluve of Jimichay and Gilgilchay. Having implemented more detail stratigraphy of the section that had been earlier described by H.W.Abich, K.I.Bogdanovich was first to distinguish coarse grained Khaltan suite in Gaytar-Goja area, and combined Malmian and Valanginian deposits in the frame of this suite. He divided the suite into following three series (bottom-upwards): 1 – *Khaltan suite* itself with a stratotype studied in the riverbed of Gyzylgazmachay, 2 – *light-grey glauconitic sandstones*; 3 – *sandstones and clays with spherosiderites*.

Later, age diapason of the formation of Shahdagh-Beshbarmag line's limestones was determined thanks to a discovery of Upper Oxfordian pelecypoda fauna on Beshbarmag mountain by V.D.Golubyatnikov and its' definition by V.F.Pchelintsev (Pchelintsev, 1932). When studying the Sudur zone's Malmian section (basin of Tahirjal river) in 1936, I.F.Pustovalov has first distinguished a red-colored gypsum-bearing *argillite-arenaceous suite* and dated it back to Tithonian age. Based on fauna found in Daghystanian outcrops (Russia), age of the complex was established as Callovian-Oxfordian (Rostovtsev, 1932, 1934).

When studying the Southeastern Caucasus watershed's Jurassic deposits in 1936, V.V.Weber dated their shaly-sandy suite as the Middle Jurassic period. He also characterized the section's remaining segments (*limestone suite*) as Malm-Valanginian formations (Weber, 1936). Based on fixed-route crossings of the Babachay-Gilgilchay interfluve, Z.A.Mishunina united a Malmian complex within the structures of sandy-shaly and Lower Cretaceous *carbonate suites* (Mishunina, 1939). For the first time since research of K.I.Bogdanovich, Gaytar-Goja area's *Khaltan suite* was described by M.F.Mirchink in 1935. Then, the suite was divided into lower, middle and upper segments of Tithonian-Valanginian ages (Mirchink, 1935). Based on the outcomes of field work implemented in 1934-1935, A.A.Ali-zadeh (Ali-zadeh, 1939) divided the *Khaltan suite* into three independent horizons (bottom-upwards): 1 – *Siyagaya suite* or horizon of variegated rocks (Lower Tithonian); 2 –*Khaltan suite* itself or horizon of thermal waters (Lower Tithonian); and 3 – *Babadagh suite* or horizon of platy marly limestones (Lower-Middle Neocomian).

In 1938, N.B.Vassoyevich have published a new data on the Malm-Neocomian stratigraphy of Northeastern Azerbaijan to the east of Jimichay meridian (Vassoyevich, 1938). He had separated the Khaltan suite's lower segment into multicolored *Gyzylgazma suite* to cover a period from Kimmeridgian through Lower Tithonian ages. On the other hand, he distinguished its' upper segment into the *Nardaran suite* to cover Upper Tithonian-Valanginian ages. Later during field investigations of 1939-1940, he had distinguished the Kimmeridgian *Zemchay suite* that transgressively overlaps Middle Jurassic formations of the northern (named after the tributary of Garachay river), as well as the Tithonian *Ilisu suite* that accordantly continues Zemchay suite's formations (section along Kurmukchay in Ilisu village's vicinities) on the southern slope of the watershed.

Next to A.A.Alizadeh and proceeding from his multiyear research outcomes, V.Ye.Khain (Khain, 1937 a,b; 1939) separated the Khaltan suite's upper segment into an Upper Tithonian-Valanginian *Babadagh suite*, which corresponds to a limestone suite distinguished by V.V.Weber. He also identified following facies of the Tithonian age: Sudur, Shahdagh, Ilisu and Gyzylgazma.

Gradual transition from Middle to Upper Jurassic formations was discovered by V.Ye.Khain in a bottom of the Upper Jurassic section detected in the upper reaches of Babachay (Khain, 1939). Based on that discovery, *Garachay suite* (Bathonian-Callovian) and *Hamamchay suite* (Kimmeridgian) were distinguished. Moreover, the *Sarydash horizon* of block conglomerates was revealed and discovered on the border between those two suites, built by up to several tens of cubic meters large blocks of Lusitanian (Upper Oxfordian) limestones chaotically mixed with siderite containing packs of black Aalenian clays.

Later, V.Ye.Khain and N.B.Vassoyevich (Khain, 1947) have come to a consensus and divided the Southeastern Caucasus Malmian complex into *Zemchay* (Kimmeridgian), *Gyzylgazma* (Lower Tithonian), *Ilisu* (Lower Tithonian) and *Babadagh* (Upper Tithonian-Valanginian) suites. Meanwhile it was recognized that *Zemchay suite* does transgressively overlap the Keyvan suite's Bathonian clay-slates and siltstones. It was also agreed that *the Ilisu suite* is constituted by western clayey facies of the *Gyzylgazma suite*.

In 1939-1946, A.Sh.Shikhalibayli had mapped the region's southern slope and developed a detailed stratigraphic scale of its' Jurassic deposits (Shikhalibayli, 1956). According to this scale, the Upper Jurassic succession are divided into following three suites that transgressively overlap deposits of the Bathonian ribbon-shisty suite: a) *suite of siliceous rocks* (Kimmeridgian), b) *suite of multicolored sediments* (Lower Tithonian), and, c) *Babadagh suite* (Lower Tithonian-Valanginian).

At the same time, researchers of the neighboring areas of Mountainous Daghystan (Sayidov, 1936; Rusanov, 1938) have distinguished the area's siliceous rocks as the Callovian-Lusitanian *Salavat suite*. When studying the Mesozoic complex of Mountainous Daghystan and Northeastern Azerbaijan, N.N.Rostovtsev divided the southern slope's Malm-Neocomian section into the *Salavat* (Callovian), *Gdymchay* (Oxfordian-Kimmeridgian), *Duzsyrt* (Tithonian) and *Filfili* (Tithonian-Valanginian-Hauterivian) suites (Rostovtsev, 1934, 1938).

In 1951, V.Y.Khain, N.B.Vassoyevich, A.Sh.Shikhalibayli and V.A.Grossheim (Vassoyevich et al., 1951; Khain et al., 1951) have bridged the gaps and developed a single stratigraphic scale of the Southeastern Caucasus Mesozoic complex. Resultantly they divided the Malmian section into *Salavat* (Callovian-Oxfordian) and *Zemchay* (Kimmeridgian) suites on the southern, and *Lusitanian biogenic limestones* in Shahdagh facies (Upper Oxfordian) on the northern slopes of the system. Also established were *the Ilisu and Talystan Tithonian lithofacies* on the southern slope, as well as *Gyzylgazma, Shahdagh and Sudur Tithonian lithofacies* on the northern slope. Since then, the *Babadagh suite* was considered as transition from Upper Jurassic to Neocomian succession. At the same time, it was acknowledged that a depositional break had occurred on the Upper

Jurassic basin's marginal segments within the interval between Middle and Upper Jurassic periods (Callovian-Lower Oxfordian).

Therefore, described research period have produced a clear lithofacies definition of the southern (structural-formational zone of the Southern slope) and the northern (structural-formational zone of the Side range) slopes of the Southeastern Caucasus system.

In early 1960's, age of the Sudur zone's red-colored *argillo-arenaceous suite* was reduced to the Upper Oxfordian period. Formerly dated as Tithonian (Pustovalov, 1936), this suite was re-dated based on the exploratory surveying works of T.A.Gorshenin and the microfauna definitions of G.K.Gasymova (Gorshenin, 1964). Consequently, the limestone-dolomitic strata that overlays suite's formations with azimuthal unconformity and underlies faunistically characterized Neocomian limestones, was dated back to Kimmeridgian-Tithonian age.

In his work dedicated to formation principles of the Southeastern Caucasus structures, A.M.Shurygin had divided the Upper Jurassic section into faunistically ungrounded *Zemchay* (Callovian-Lusitanian) and *Ilisu* (Kimmeridgian-Lower Tithonian) suites (Shurygin, 1961). The author referred lower parts of *Gyzylgazma* (north) and *Babadagh* (south) suites to the Upper Tithonian period. At the same time, B.V.Grigoryants and Kh.Sh.Aliyev have studied a transition from Jurassic to Cretaceous periods in Gaytar-Goja area and concluded that within the interfluve of Jimichay and Gilgilchay, only *Zemchay* (Kimmeridgian) and *Ilisu* (Tithonian) suites may be regarded as parts of the Upper Jurassic period, while the *Gyzylgazma suite* should be referred to Lower Cretaceous formations (Grigoryants and Aliyev, 1960).

Later, A.V.Vikhert has detected a dominant Callovian and Lower Oxfordian fauna among the limestones of Beshbarmag, cobbles of Neocomian basal conglomerates and blocks of the olistostrome horizon's Shahdagh limestones among the Khyzy zone's Barremian clays (Vikhert et al., 1966). This discovery allowed broadening the age range of Shahdagh limestones to cover an entire Upper Jurassic period.

However, based on their own faunistic findings, V.B.Aghayev and G.M.Huseynov have separated the Shahdagh-Beshbarmag zone's limestones into an independent *Shahdagh suite*, and dated their formation period back to the Upper-Oxfordian-Tithonian interval (Aghayev and Huseynov, 1973). They also proposed considering red colored *argillo-arenaceous suite* of the Sudur zone as Upper Oxfordian-Tithonian complex, ignoring the fact that suite's overbuilding massive dolomites and limestones underlie faunistically characterized Lower Cretaceous limestones (Gorshenin, 1964).

Based on detailed field investigation outcomes, B.V.Grigoryants, R.G.Babayev and S.S.Mustafayev have paleontologically confirmed a presence of the Oxfordian, Kimmeridgian, Tithonian and Berriasian reef knolls within the section of Shahdagh limestones (Grigoryants et al, 1974).

Thus by the middle of 1970's, essential differences remained in dating of the Southeastern Caucasus system's multifacies Upper Jurassic formations. In addition, geographic coverage of *Zemchay* and *Ilisu suites* was expanded to the east to cover part of the Gaytar-Goja area. This means that the lithofacial identity of lower and middle parts of the Upper Jurassic section of the region's northern (Side range megazone) and southern (Southern slope megazone) slopes was admitted. This approach was used in the respective volume of "Azerbaijan Geology" (Geology of USSR …., 1972).

In 1970-1990's, systematic exploration and surveying of the Southeastern Caucasus region have been continued by several teams of the Azerbaijan State Geological Committee led by B.M. Isayeva, T.N.Kangarli, A.I.Mammadov, A.M.Gurbanov, etc. (Isayev et al., 1975; Isayev et al., 1977, Mammadov et al., 1977; Mammadov et al., 1985). These works have resulted in correlation and detailed characterization of the sections of Jurassic and Cretaceous material complexes within different structural-facial zones. Research outcomes have raised additional questions related to volume, structure and age correlation of the Upper Jurassic complexes. Current article aims to find a solution to some of these questions.

Description of sections. Malmian series of the Side range structural-formational zone are distinguished for their lithology-facies variety within the borders of Southeastern Caucasus region, conditioned by a number of eustatic, tectonic and paleogeographic factors. Analysis and correlation of Malmian lithological-stratigraphic sections studied in various structural-facies zones of the region allows implementing more detail stratigraphy and determine local subdivisions (suites and subsuites) based on geological surveys and thematic researches of the last 35-40 years.

Following paragraphs provide a description of key stratigraphic sections of the Malmian succession exposed by erosion, in different structural-facial zones (Figure 1).

Sudur zone. Its' Malmian section is represented by lagoon facies in the bottom and shelf facies on the top (Figures 2 and 3). In 1975, during investigations in the river-valley of Tahirjalchay (Isayev et al., 1977), one of the article's coauthors have first described the ***Tahirjal suite*** built by a multicolored alternation of heather, yellowish and bluish-green sandy shales with interlayers of greenish calcareous sandstones and ballstones of crystalline limestones and dolomites. These 50-60 m thick sediments transgressively lie without basal conglomerates on the different upper Aalenian horizones and deeply eroded Bajocian-Bathonian series. Observations were confirmed during later geological surveys (Mammadov et al., 1985). In younger stratigraphic levels, the suite gains more pronounced purple-red color. Its' top gets penetrated by frequent veins of gypsum-anhydrite, and unconformably overlapped by the ***Gushgala suite*** of the Upper Oxfordian gypsum-bearing argillite-arenaceous sediments. The latter was first described by I.F.Pustovalov (Pustovalov, 1936) and faunistically characterized by G.K.Gasymova (Gorshenin, 1964). According to data of the mineralogical analysis implemented in 1976 by VNIGRI (Saint Petersburg), main mass of the suite's sands and sandstones is constituted by derivatives of erosion of spodumene-beryllic range's granitic pegmatites (Isayev et al., 1977; Kangarli, 1982).

In 2011, additional study and detailed elaboration of the ***Gushgala suite's*** section was implemented according to a key section on the eastern slope of Gushgala mountain located on Tahirjalchay-Usukhchay watershed, and the following section was described (Figure 1, Section I):

Upper Oxfordian substage

1. Mottled shales of the Tahirjalchay suite are overlaid with angular and azimuthal unconformity by a basal layer with thin (up to 10 cm) interlayer of medium-gravelly gravelites passing upward into fine-pebbled conglomerates with pebbles of crystalline and marmorized limestones, red and black argillites and sandstones with light sandy-calcareous cement………1.0 m
2. White, pinky gypsum-anhydrite with interlayers of calcite and bands of red and black argillites…..………………………………1.5 m
3. Brownish red sandy shales with peas of pyrite…………………………….…………..2.5 m
4. Dark gray fine and medium-grained sand ……………………………………1.5 m
5. Light, greenish and bluish grey heavy sandy shales with separate thin (up to 1 cm) interlayers of sand and siltstones as well as streaks, lenses and peas of pyrite…….…...1.5 m
6. Thin-laminated alternating fine and medium-grained partly clayey grey, yellow and brown sands with rare interlayers of gray dolomite, peas and lenses of altered pyrite……4.5 m
7. Alternation of gray fine and medium-grained sands with thin interlayers of clayey sands and peas of altered pyrite……………….10.0 m
8. Gypsum-anhydrite layer of netted texture with cells filled by red sands and interlayers of milk-white calcite; general background is brownish-color…………………………..….8.0 m

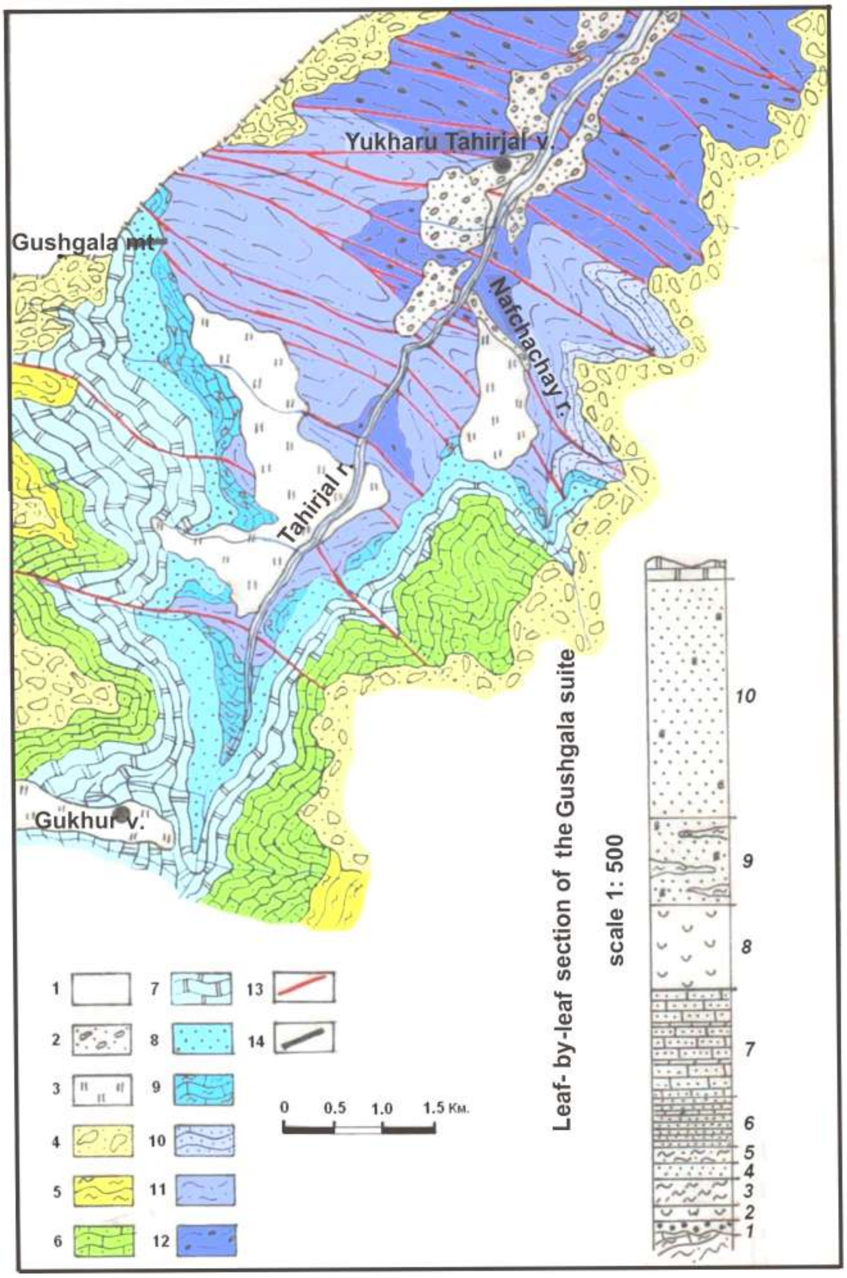

Figure 2. Lithology-structural map of the lower reaches of Tahirjal. Developed by T.N. Kangarli.
1 – Holocene: channel deposits; **2** – Holocene: deposits of river terraces; **3** – Holocene: deluvial-colluvial deposits; **4** – Lower Pliocene: gravels and conglomerates with sandy-calcareous cement and lentiform interlayers of clays, sandstones and grit; **5** – Upper Miocene, Sarmatian regional stage: shisty-grey clays with thick layers of sands and sandstones; **6** – Neocomian, Sudur suite: light-grey siliceous and dolomitized, oolitic and detrital limestones with interlayers of clayey sandstones and calcareous clays; **7** – Kimmeridgian and Tithonian stages, Gukhur suite: yellowish, pinky and greenish-grey dolomites and limestones with rare interlayers and lenses of clayey and calcareous sandstones; **8** – Lower Oxfordian, Gushgala suite: multicolored gypsum-bearing polymictic sands and sandstones with interlayers of glauconite clays, dolomites and basal conglomerates in the basement; **9** – Middle (?) Callovian – Lower Oxfordian, Tahirjal suite: multicolored sandy clays with interlayers of light calcareous sandstones; **10** – Bajocian stage: grey massively bedded sandstones with interlayers of argillites; **11** – Upper Aalenian: alternation of dark-grey argillites and sandstones with latter prevailing in the section's top; **12** – Lower Aalenian: dark-grey argillites with horizonse of siderite concretions and rare interlayers of sandstones; **13** – rupture dislocations; **14** – location of sections***. Description of the leaf-by-leaf section of the Gushgala suite see figure 3.***

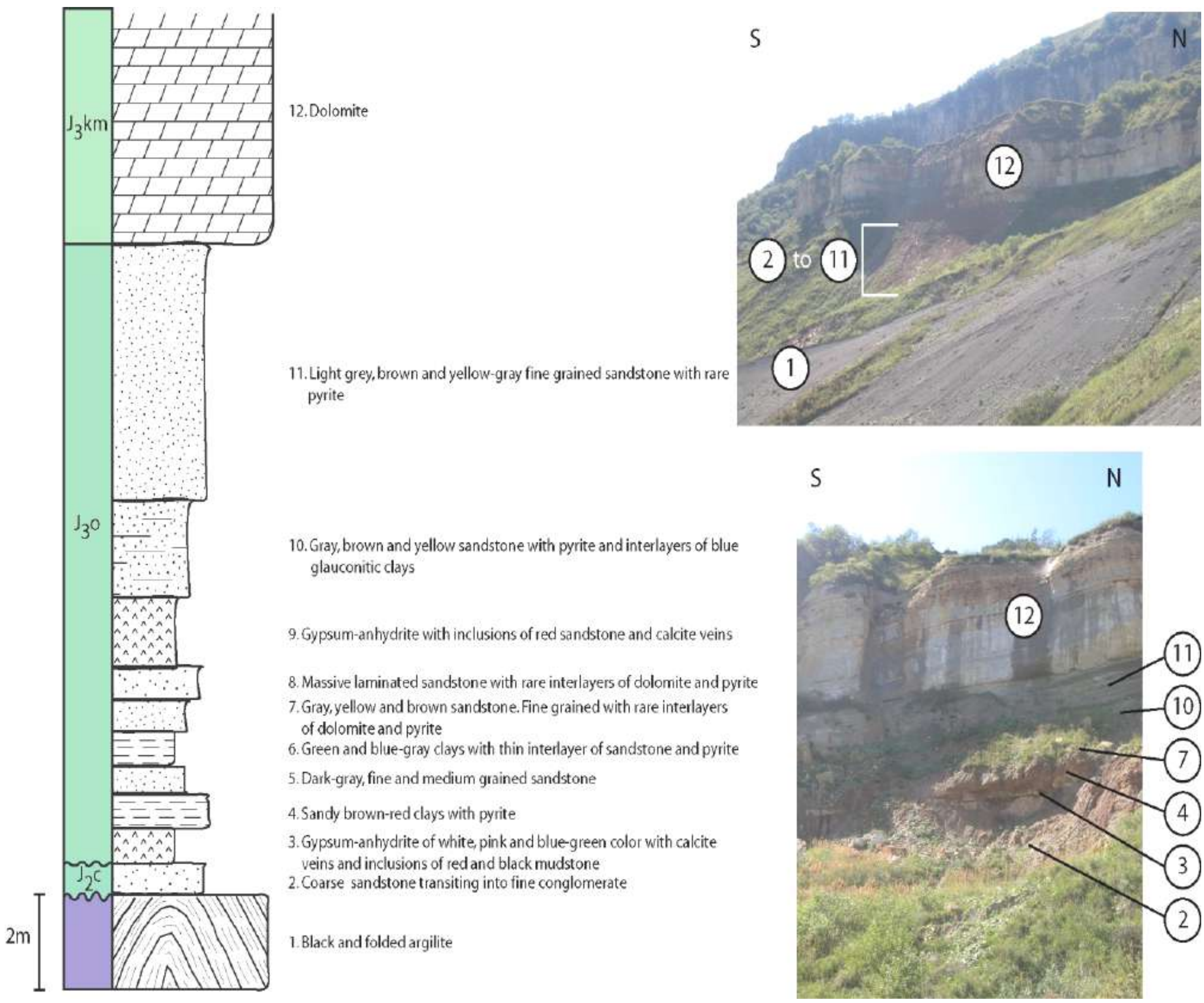

Figure 3. Sedimentological log of the Gushgaka suite. Developed by T.N.Kangarli and M. Bohud

9. Brownish- and yellowish-gray fine-grained often calcareous sands with lentiform interlayers (up to 1.2 m) of bluish glauconite clays…….8.0 m

10. Same sands without glauconite clay interlayers………………………………… 22.0 m

Summary thickness of the suite equals 60.5 m in this area and increases to 80-85 m in the upper reaches of Tahirjalchay river. Both vertically and laterally, color of the sands often changes from light and whitish to a tile-red. Described sands contain small subangular fragments of limestones of the Shahdagh facies.

As has been noted above, *Rhynchonella spattica Dok.* and *Terebratura vagelti Moiss.* were detected in the suite's section by N.N.Rostovtsev (Rostovtsev, 1932), who dated them as Callovian-Oxfordian. Later, based on microfaunistic definitions of G.K.Gasimova, T.A.Gorshenin (Gorshenin, 1963) the suite's age was defined as Upper Oxfordian.

Top of Gushgala suite is with miserable unconformity overlapped by continuous series of the ***Gukhur suite's*** limestones and dolomites. Grey, dark-grey and pink dolomites prevail in the lower successions, whereas light-grey and pinky, often brecciform, oolitic and sandy marmorized limestones build up the upper part of the suite. Like in the previous suite, thickness of these successions rises southwards toward the central most subsided part of the Sudur zone, increasing from 20-50 m in Gushgala mountain's area through 450-500 m on the slope of Garagaya mountain (Gorshenin, 1964). In the same direction that limestones start containing layers of fragmental, brecciform organic-reef limestones, which speaks for an approximation to the lateral transition line between carbonates of Sudur and Shahdagh facies. Discovery of *Cnidaris glandifera Goldf.* (def. of T.A.Hasanov) by T.A.Gorshenin (1964) in the suite's section confirms its' Upper Jurassic age.

Lithological-facies analysis of the Sudur zone's Malmian section brings us to a conclusion that it is represented by lower sulphate-terrigenous and upper carbonate facies. As the first succession's upper portion (represented by *Gushgala suite*) is referred to Upper Oxfordian age according to its' complex of foraminifers (Gorshenin, 1964), the lower *Tahirjal suite* must be of Callovian-Lower Oxfordian age. When dating the upper carbonate sediments, it has to be mentioned that it is quite unlikely that there was a serious depositional break during the post-Oxfordian period, which would have led to complete erosion of the Gushgala suite's soft sediments. Therefore, the upper carbonate facies must be dated as Kimmeridgian-Tithonian.

Shahdagh-Khyzy zone. Within the zone's boundaries, Malmian system is represented by its' reef and continental slope facies. First facies form Shahdagh-Beshbarmag allochthonous complex and the second is present in a section of the autochthone (Isayev et al., 1981; Geology of Azerbaijan …, 2005, Kangarli, 1982, 2010, 2012).

Allochthonous Malmian facies are represented by an alternation of massive dolomites, dolomitized, eugranitic, pseudo-oolitic, sandy, brecciform-fragmentary and biogenic-reef, often marmorized multicolor (light-grey to tile-red) limestones (Figure 4). Light colors prevail in the lower, and darks - in the upper part of the section. Depending on location, thickness of the carbonate massif varies from 150-200 to 750-900 m. Fragments of reef coral structures are commonly present in fragmental and organic varieties of limestones. This speaks for continuous bioherm formation process that covered the shelf's outer edge, which used to separate Sudur shallow zone from an open sea and served as a platform for barrier reef development.

Reconstruction of reef complexes of the various paleobasins (Kuznetsov, 1978; Proshlyakov and Kuznetsov, 1981) suggests that their constituent sedimentary complex normally represents polyfacies lens of the carbonate rocks, in center of which the main reef's massive organic limestones are located together with adjoining tails of different reef destruction products (e.g. fragmental limestones, calcareous breccias, detrital limestones, calcareous sandstones and silts). On the top and along the slopes of a reef lens, formation of oolitic (pseudo-oolitic), thinly and micro-laminated chemical limestones, marlstones and dolomites occurs under the increased levels of calcium concentration in water. Practically all varieties of rocks are present in the structure of Shahdagh-Beshbarmag allochthonous complex with reef destruction products and chemogenic sediments concentrated in its' frontal area, and fragments of various coral structures detected in the outcrops of inner shield, radical and root segments.

Figure 4. Shahdagh limestone massif. Panorama. View from the east. Photo by I.T. Kangarli

Speaking about the timing of sedimentation of Shahdagh limestones, it deserves mentioning that dating of numerous faunistical findings testifying to their Upper Oxfordian-Tithonian age (Aghayev and Huseynov, 1973; Vikhert et al., 1966; Geology of USSR ….. , 1972; Grigoryants and Aliyev, 1960; Grigoryants et al., 1974; Khain, 1947; Shurygin, 1961). However it has to be mentioned that some granular limestones and gravels of calcareous conglomerate-breccias contain fauna remnants of typically Bathonian-Oxfordian mollusks as well (Aghayev and Huseynov, 1973; Grigoryants et al., 1974; Khain, 1947, Khain and Shardanov, 1957). This generally supports a suggestion that the described reef had emerged in Callovian and existed through an entire Late Jurassic epoch.

Autochthonous Malmian facies are only revealed in the riverbed of Gilgilchay on the northern limb of Gyzylgazma crest-like brachyanticline (Figure 5). Southern limb of this "broken plate" shaped structure is deeply (flexurally) immersed and inverted. It composed of yonger (Neocomian) sediments comparing with core's Aalenian and northern limb's Malm-Valanginian sediments.

In 1976, one of the article's coauthors (Isayev et al., 1977, Kangarli, 1982) had first distinguished and dated the Upper Callovian-Lower Oxfordian ***Molt suite*** of basal coarse clastic sediments (Figure 6). This suite transgressively overlaps the Middle Jurassic deposits of fold's northwestern periclinal plunge, which is located on left bank of the river's upper reaches (area on the east of the estuary of its' left tributary-Molt river). Downward section of the lower part Molt suite is presented below (Figure 1, Section II):

Upper Callovian substage
Lower Molt subsuite

1. Alternation of thick (5-8 m) interlayers of fine-to-medium gravel conglomerates (with gravels of dark-gray pelitomorphic and cryptocrystalline limestones and dolomites, rarely black argillites, cement is sandy-calcareous ochreous) and beds of brownish-black jarosite containing argillites with ash-gray surface, including rust-brown, ochreous interlayers of siltstones, siderite and clayey-carbonate concretions…………………...75 m

2. Alternation of purple-red massive medium- and coarse-grained sandstones and fine-gravel gravelites with lenses of gravelites and fine-pebbled conglomerates. The succession basement is represented by solid gravelites (contact with the previous succession is tectonic with tectonic breccia developed along slip plain)……………………………………10 m

3. Medium-pebbled conglomerate with pebbles and inclisions of large boulders of the limestones…………………………….……3 m

4. Gray fragmented argillites with jarosite, siderite and carbonate concretions…………7 m

5. Alternation of thin-laminated (5-20 cm), gray, porous and dense calcareous (with altered peas of pyrite) sandstones with and lenses of medium-pebbled conglomerates that contain blocks and boulders of dark-gray pelitomorphic limestones, and thin (up to 1 cm) interlayers of greenish-gray argillites…………………..110 m

Summary thickness of the Malmian deposits is 205 m, and its' top is brought into a tectonic contact with Valanginian carbonate-terrigenous flysch.

In 2011, additional 3 samples of conglomerates (Figure 6) were collected from the suite's basement and analyzed in VSEGEI (Saint Petersburg, Russia). It was established by testing results that conglomerates contain andesibasalts and radiolarites. Extra studies and analysis are required to further clarify the issue, which will be described in a separate article.

Higher Malmian horizons (upper part of Molt suite and Kimmeridgian Gyzylgazma suite) with following composition are observed at a tectonic contact with Middle Jurassic successions in a central part of the northern limb of Gyzylgazma fold (Figure 1, Section III):

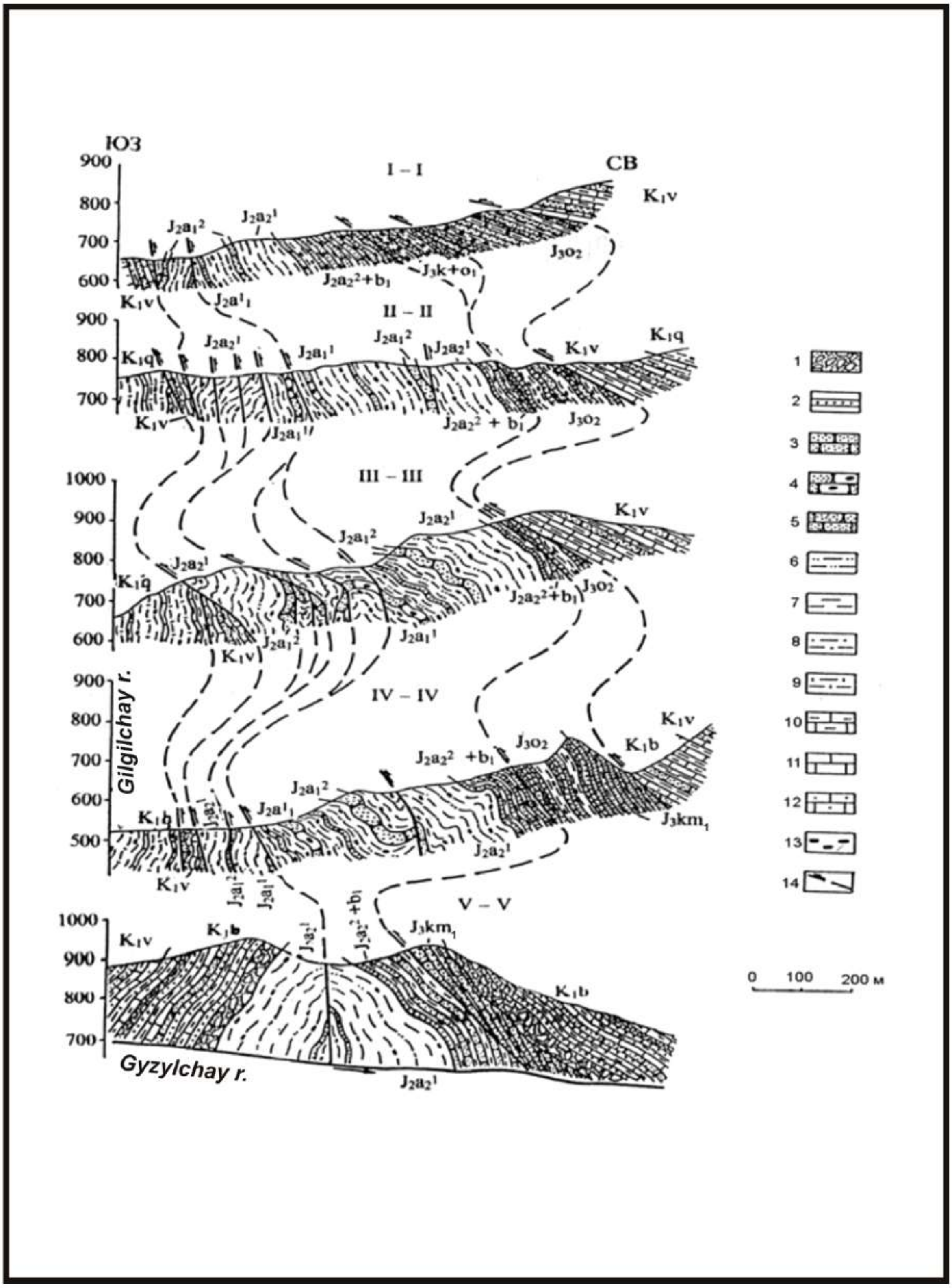

Figure 5. Geological profiles across Gyzylgazma anticline in five cross-sections. Developed by T.N. Kangarli. **1** – conglomerates, **2** – gravelites; **3** – sandstones; **4** – concretional sandstones; **5** – calcareous sandstones; **6** – siltstones; **7** – argillites and shales; **8** – argillites and sandy shales; **9** – argillites and calcareous shales; **10** – marls; **11** – limestones; **12** – sandy limestones; **13** – concretions of siderite and ankerite; **14** – faults (normal, riverse faults, faults along stratigraphic contacts)

Figure 6. Basal conglomerates in the Molt suite's bottom. Photo by I.T. Kangarli

Upper Callovian substage
Lower Molt subsuite

1. Massive coarse-gravel gravelites with separate interlayers and lenses of fine- and medium-pebbled conglomerates and thin (up to 2 cm) of dark-gray clays……………………45 m

Lower Oxfordian substage
Upper Molt subsuite

2. Alternation of beds (average thickness - 4-5 m) of the following series: a) – alternation of massive (up to 1.5 m) dark-gray, greenish- and pinky-gray coarse-gravel gravelites passing into fine-pebbled conglomerates at the bottom (clastic material is represented mainly by limestones and sandstones), and thin (up to 20 cm) interlayers of greenish-gray calcareous and sandy shales and porous calcareous sandstones; b) – dark, greenish-gray mud shales with siderite and carbonate concretions and up 50 cm thick interlayers of ferruginous marls. Boundaries between gravelite and shales contain up to 1.5 m thick interlayers and lenses of medium-grained brownish and greenish gray calcareous sandstones with thin (up to 2-3 cm) interlayers of sandy-calcareous shales. Alternating intervals of 3-5 m thick beds of gravelites, sandstones and shales are often observed. Clasts of gravelites and sandstones become smaller and color of the rocks become lighter from the bottom to the top of the section. This interval is correlated with Intervals 3 and 4 of the previous section. Summary thickness..…….80 m

Kimmeridgian stage
Gyzylgazma suite

3. Thin-laminated, platy, brownish- and greenish-gray, medium-grained calcareous sandstones with thin (up to 2-3 cm) interlayers of greenish-gray calcareous and sandy shales…………..100 m

A like previous case, the top of 225 m thick Malmian suite enter a tectonic contact with Valanginian carbonate flysch.

Finally, in the riverbed of Gyzylgazmachay (southeastern periclinal plunge of the fold's northern limb; Figure 5, Section V-V), bottom of the Upper Jurassic deposits enter a tectonic contact with the Aalenian upper siderite suite. These series are represented by an alternation of gravelites, sandstones and argillites (10 m thick incomplete section, corresponding to the upper parts of the previous section's 2nd interval). In the top, the succession gets replaced by a strata built by an alternation of dark-grey, greenish, coarse-grained calcareous sandstones (often grading into limy gravelites) and greenish-grey shales (comparable with 3rd interval of the previous section) with an observed thickness of over 200 m. This strata corresponds to Kimmeridgian Gizilgazma suite and its' top gets transgressively overlapped by Berriasian basal conglomerates (Figure 7). This cross-section of the Upper Jurassic series was previously named by N.B.Vassoyevich as the Kimmeridgian-Tithonian Gyzylgazma suite (Vassoyevich, 1938; Khain, 1947).

Figure 7. Transgressive contact (with angular and azimuthal unconformity) between Berriasian (with basal konglomerates) and Kimmeridgian sediments on r. Gyzylchay (Sections V on figure 5). Photo by I.T. Kangarli

Guton-Gonagkend zone. Within the described zone's boundaries, Malmian successions constitute major part in the exposed stratigraphic section in the complexly structured Gaytar-Goja segment of the structural plan which is flexurally subsided to the east of Jimichay river. Two stripes of the complex's outcrops are observed. Extending from Gonagkend village's southern outskirts towards the Khashy village's vicinities, southern stripe is represented by folded scales that wedge out in Dahnachay river's surroundings. Represented in the structure of Guton-Gonagkend zone's far northern Yerfi-Khashy segment, northern stripe is observed in the sections exposed along rivers of Dahnachay and Istisuchay (both are the tributaries of Gilgilchay).

Malmian succession of a southern stripe is cropping out are revealed in the meander of Jimichay in Gonagkend's southern vicinities, where they form an expessed in relief a centroclinal closure of Garovulustu brachysyncline (Figure 8) built by the Oxfordian sedimets (separated by authors into an independent ***Garovulustu suite***). Unlike Molt suite of the river basin of Gilgilchay at Jimichay intersection, bottom of the Upper Jurassic section doesn't get exposed. The syncline is built by coarse terrigenous flysch (measured thickness – 646 m, color – from greenish-grey to raisin) represented by an alternation of massive finely and medium-grained calcareous sandstones with thin interlayers of argillites. Section's top of this fold also contains gravelites with clasts of Shahdagh limestones, as well as Middle Jurassic sandstones and argillites. Overturned in northwestern rhumbs, both limbs of the fold are in a tectonic contact with Middle Jurassic succession, with following section of the western limb (Figure 1, Section IV); (from top to bottom):

Figure 8. Northwestern centroclinal closure of Garovulustu syncline on the left riverbank of Jimichay. On front view – Garovulustu village. Photo by I.T. Kangarli

Oxfordian stage
Lower Garovulustu subsuite

1. Alternation of dark gray to black, sometimes greenish-gray argillites, massive (up to 1.0 m) fine- and medium-grain poorly sorted calcareous sandstones with the occlusions of pebbles of dark argillites and rare interlayers of marly limestones........…………………….60 m

2. Alternation of dark greenish-gray and gray fine- and medium-grained sandstones (up to 30 cm) with thin interlayers of green argillites (2-5 cm). Thickness of sandy interlayers increases in the higher successions, reaching 1.5 m in the separate interlayers. With a well sorted psammitic material, these interlayers gradually become lighter and accept greenish-gray and light green color (Figure 9)……………..224 m

Upper Garovulustu subsuite

3. Alternation of medium-bedded (up to 20-30 cm) and medium-grained dark greenish-purple-gray porous sandstones with the interlayers of dark-green and purple-red argillites. Thickness of sandy interlayers increases in the higher successions………………………142 m

4. Alternation of massive (up to 1.5-2.0 m) and lighter than Interval 3 greenish-gray and purple-pink sandstones with thin (3-5 cm) interlayers of the same argillites. Their psammitic material becomes coarser in lower successions, passing from medium-grained sandstone to fine-gravel gravelite with fragmentary material represented by Shahdagh limestones as well as Middle Jurassic sandstones and argillites. In higher successions, massive sandstones also contain large fagments of these sediments ...……………......220 m

Figure 9. Stream channel of the Jimichay river. Rough flysch – interchange of the sandstones and argillites of the Lower Garovulustu subsuite (Lower Oxfordian) on western limb of Garovulustu sincline. Photo by I.T.Kangarli

Summary thickness of the section is 646 m. Higher layers of the Upper Oxsfordian series are revealed on the left riverbank of Jimichay in the synclinal core's southeastern extension, in which they are represented by an alternation of medium- and massively bedded medium-to-coarse grained brownish-grey and reddish-brown sandstones with interlayers and packs of the ochreous-brown and tile red argillites.

Detailed section of the northern part of the outcrops was described by the river-course of Istisuchay (Jarkhachichay) along the both limbs of Yerfi-Khashy anticline. Following ascending section is recorded on the fold's southern limb at its' tectonic contact with Lower Aalenian Atashgaya suite (Figure 1, Section V):

Oxfordian stage
Lower Garovulustu subsuite

1. Alternation of the following varieties of rocks: a) - tight fine- and medium-grained, dark-gray with purple calcareous sandstones containing peas and small concretions (up to 2 mm) of altered pyrite and multiple spangles of quartz grains; interlayer thickness – 5-15 cm; b) – tight, fine-grained, calcareous, light greenish-gray sandstones with small concretions of pyrite and spangles of quartz grains; interlayer thickness – 5-15 cm; c) – soft, fine-grained, partly clayey, gray with greenish shade sandstones; interlayer thickness – 25-30 cm; d) – greenish-gray sandy argillites; interlayer thickness – 20-30 cm. The section is mainly represented by the interlayers of soft sandstones and clays. However their thicknesses reduce in the section's final 30 m segment (sandstones – 5-10 cm, clays – up to 5 cm) with relatively rhythmical alternation of all rock varieties observed. Contact with above-lying deposits is tectonic. Summary thickness of the pack……………………145 m

Kimmeridgian stage
Middle Gyzylgazma subsuite

2. Soft massively bedded (layers reach 2.5 m in thickness and have thin-laminated texture), medium- and coarse-grained, calcareous, dark greenish-gray sandstones with separate up to 1 cm thick interlayers of lighter loose aleurolites and rare rounded and angular clasts fragments of dark argillites and sandstones (Figure 10)……..…56 m

Boundary between Oxfordian and Kimmeridgian deposits is tectonic. Summary thickness of the section constitutes 201 m. Its' top gets into a tectonic contact with Zagatala-Dibrar trough's Lower Cretaceous terrigenous sediments. Faulting zone (2 m) is represented by a tectonic breccia made of the blocks and boulders of gray sandstones and dark-gray to black argillites (Middle Jurassic - ?) cemented by sandy-calcareous cement. Lower Cretaceous (Berriasian) sediments are represented by 28 m thick layer of massively bedded, wavy (with thin interlayers enriched by small concretions of pyrite), fine- and medium-grained, brownish-gray sandstones.

Summary thickness of the section equals 231 m. Its' roof is brought into a tectonic contact with the bottom of Lower Cretaceous Babadagh suite (Zagatala-Dibrar trough). Extending along Major Caucasus overthrust, this contact is expressed by up to 3 m thick area of strongly ferruginized tectonically brecciated rocks.

Represented by Oxfordian (***Garovulustu suite***), Kimmeridgian (***Gyzylgazma suite***) and Tithonian (***Khashy suite*** – named after the same-named village located on the described section's west on the Shakarel-Dahnachay watershed) deposits, Malmian section is more representational on the northern limb of Yerfi-Khashy anticline. There the following ascending section is recorded along the fold's tectonic contact (represented by 1.5 m thick tectonic breccia with clay gouge) with Upper Aalenian Jimi suite (Figure 1, Section VI):

Oxfordian stage
Lower Garovulustu subsuite

1. Alternation of following rock varieties (Figure 11): a) – tight, thin-bedded, calcareous, medium- and coarse-grained, dark-gray with greenish and purple shade (dark-purple on layer surfaces) sandstones; interlayer thickness – 5-50 cm;

b) – tight, often thin-bedded, fine- and medium-grained, calcareous, green and greenish-gray sandstones with peas of quartz grains; interlayer thickness – 3-30 cm; c) – less tight, thin-bedded, fine- and medium-grained, green and greenish-gray sandstones; interlayer thickness – 3-25 cm; d) – fine-gravel, dense, dark-gray (with greenish and purple shades, dark-purple on surface) calcareous gravelites (fragmentary material is represented by Shahdagh limestones); interlayer thickness – 10-50 cm; e) – sandy, sometimes calcareous dark- and light-green, greenish-gray and gray mud shales; interlayer thickness – 1-5 cm. Rhythms become thinner in the higher successions: thickness of sandy varieties reduces to 3-8 cm; gravelites are often represented by separate up to 2 m thick intervals of alternation with sandstones. The strata is penetrated by a quite dense network of up to 3 cm thick veins of calcite. The strata's superficially observed general background is grayish-green. According to its' composition, the interval is similar to the 1st pack of Section V. Summary thickness………………….…..185 m

Figure 10. Left riverbank of Istisuchay. Sandstones of the middle part pf the Qyzylqazma suite on southern limb of the Yerfi-Khashy anticline. Photo by I.T. Kangarli

2. Similar alternation of sandstones, gravelites and argillites with 10-25 cm thick interlayers and lenses of dark fine- and medium-gravel calcareous cherry-red colored gravelites with the occlusions of small fragments of charred wood (?); enters a tectonic contact with previous interval...………………………...20 m

Upper Garovulustu subsuite

3. Thin (interlayer thickness – 1-5 cm) rhythmical alternation of shales and argillites, dense, medium- and coarse-grained sandstones and fine-gravel calcareous gravelites; color of all rock varieties changes from pinky-purple to greenish-gray shades, general background is pinky-purple; contact with previous interval is tectonic ………………………………...24 m

4. Thin rhythmical alternation (interlayer thickness – 1-5 cm) of fine-, medium- and coarse-grained sandstones with rare interlayers and lenses of dark greenish-gray fine-gravel calcareous gravelites…………………………32 m

Figure 11. Left riverbank of Istisuchay. Flysch of the Lower Garavulustu subsuite on northern limb of the Yerfi-Khashy anticline. Photo by I.T. Kangarli

Kimmeridgian stage
Lower Gyzylgazma subsuite

5. Alternation of following rock varieties: a) – massive, resonant, fine-grained, partly sandy, light-gray and greenish limestones; interlayer thickness – 50-60 cm; b) – massive to medium-bedded, calcareous, fine- and medium-grained, gray and greenish-gray sandstones; interlayer thickness – 5-10 to 50-60 cm; c) – greenish-gray argillites, interlayer thickness – 3-5 cm. Massive sandstones are more typical for bottom part of the section, whereas the medium-bedded varieties prevail in the top successions. Recorded are veinlets of calcite as well as fragments of gypsum in spillages. Contact with previous interval is tectonic. By the end of the interval sandstones become darker and purple-gray. Summary thickness ……………... 120 m

Middle Gyzylgazma subsuite

6. Alternation of massive (0.3-1.5 m) and fine-bedded, medium- and coarse-grained, dark-gray with greenish and purple shades sandstones with the inclusions of clasts of argillites and Shahdagh limestones, as well as separate up to 50 cm thick interlayers of fine-gravel calcareous gravelites; the strata is penetrated by veinlets of calcite …………………………….……72 m

7. Massive, fine-bedded, medium-grained, greenish-gray sandstones with thin (1-2 cm) interlayers of greenish-gray argillites and veins of calcite; contact with previous interval is tectonic……………………………………..…12 m

According to their composition, intervals 6 and 7 are similar to the 2nd interval of Section V.

Upper Gyzylgazma subsuite

8. Alternation of following rock varieties: a) – thin-bedded, fine- to coarse-grained, greenish- and purple-gray sandstones; interlayer thickness – up to 20 cm; b) – dense, fine- to coarse-gravel, greenish-purple-gray calcareous gravelites; interlayer thickness – up to 30 cm; c) – greenish-gray and purple argillites; interlayer thickness – up to 5 cm; d) – fine-gravel conglomerates, main fragmentary mass is represented by Shahdagh limestones; interlayer thickness – up to 40-50 cm. Conglomerates are mainly detected in the upper part of the section. Contact with previous interval is tectonic. General background of deposits is purple, greenish in the top successions. Summary thickness ……..…140 m

9. Rhythmical alternation of following rock varieties: a) – thin-bedded, slightly soft and clayey, fine- and medium-grained grayish-green sandstones; interlayer thickness – 5-15 cm; b) – thin-bedded, dense, calcareous, medium- and coarse-grained dark-green sandstones; interlayer thickness – 5-15 cm; c) – fine-gravel, dark-green, sometimes purple-green calcareous gravelites; interlayer thickness – 10-20 cm; d) – green sandy argillites; interlayer thickness – 1-2 cm. Contact with previous interval is tectonic. Alternation rhythm becomes coarser in the ascending section, thickness of coarse-grained sandstones and gravelites increases until 20-25 and 20-30 cm respectively, emerged are the medium-coarse gravel varieties of gravelites as well as lenses and interlayers of fine-coarse gravel conglomerates (mainly the gravels of Shahdagh limestones with subordinated concentrations of Middle Jurassic argillites and sandstones, cement is calcareous). Role of conglomerates increases by the end of the interval with their interlayers reaching 1.0-1.5 m in thickness. Large amount of peas and small concretions of altered pyrite and veinlets of calcite are detected all along the interval's course. Summary thickness……………………………………..….48 m

Tithonian stage
Lower Khashy subsuite

10. Coarse-gravel basal conglomerates (gravel of Shahdagh limestones, Middle Jurassic sandstones and argillites (including siliceous) and calcite) with large boulders and blocks of Shahdagh limestones, angular fragments of calcite and gypsum; cement is sandy-calcareous, soft heavily ferruginized; contact with previous interval is tectonic ……………..…………..7 m

11. Rhythmical alternation of green and greenish-gray sandy argillites and clayey sand-

stones, fine- and coarse-grained calcareous gravelites, calcareous sandstones and sandy limestones; maximal thickness of rock varieties except for gravelites (25-30 cm) doesn't exceed 10-15 cm …………………………………48 m

12. Alternation of gravelites and coarse-gravel conglomerates (composition of fragmentary material and cement is similar to the previous interval) ………………………………..8 m

13. Rhythmical alternation of gray, greenish-gray thin-bedded, strongly calcareous sandstones, microgranular and sandy limestones (interlayer thickness – 5-30 cm) with 1-10 cm thick interlayers of greenish-gray (light-gray on the top of the interval) calcareous argillites and marls; contact with previous interval is tectonic …..…....104 m

Upper Khashy subsuite

14. Alternation of gray, greenish-gray, microgranular and pelitomorphic limestones (5-15 cm) with dark purple-red and greenish-gray argillites ……………………………………10 m

Summary thickness of the northern limb's section reaches 830 m. Its' top brought into a tectonic contact with Shahdagh-Khyzy zone's Lower Cretaceous succession, which occurs along the Shahdagh-Gonagkend downthrow.

Similar section of Upper Jurassic succession is revealed in the anticline's more western (5 km) crossing along the riverbed of Dahnachay. Fragments of the Upper Oxfordian corals (*Clausostrocadubia From. and Montlivaltia sp. Indent*, def. By R.G.Babayev) were discovered by A.I.Mammadov (Mammadov et al., 1985) in the section's middle segment (corresponds to the intervals 5-7 of Istisuchay section). There is no doubt that these corals used to be inhabited in a more northern Shahdagh barrier reef. Later with the reef's destruction they were moved along the basin's continental slope and got buried among more recent terrigenous deposits (rough flysch facies).

Correlation of sections. Review and comparison of the Side range's detailed lithological-stratigraphic sections help determining the age rages of the suites with various facies, confined to a northern shelf and continental slope of the Callovian-Late Jurassic basin (Kangarli et al., 2013). Following starting assumptions were used to draw the research's key conclusions:

- Callovian-Late Jurassic transgression over the Middle Jurassic basis (deeply eroded during Late Bathonian period) of described region and northern parts of Limestone Daghystan (Russia) had proceeded from the south and the southwest – from a basin remained from the most immersed part of the Southern slope
- Lithofacies of Callovian-Late Jurassic complex undergo regular lateral variation from the deep-water facies in the south to the shallow facies in the north
- Regional color palette of Callovian – Upper Jurassic succession is characterized by regular gradational change of the described section's general background, i.e. from dark-grey, dark to dark greenish-grey in the Callovian, dark greenish-red in the Oxfordian, green in the Kimmeridgian and motley in the Tithonian succession. These variations are determined by concrete climatic and sedimentation conditions during respective intervals of the basin's geological evolution.

We suggest dating the lower contact of layers that indicate return to marine conditions into the described region's boundaries as Middle (?) Callovian. This assumption is confirmed by data on transgressive bedding of faunistically characterized Middle Callovian deposits of Limestone Daghystan over the underlying layers with clear signs of a depositional break (Brod, 1959, 1960). At the same time, faunistic data that speaks (see above) for continuous sedimentation of Malmian and Neocomian bioherms within the Shahdagh shelf's outer escarp[1], serves as indirect proof of the presence of same-age deposits[2] in the geological section both to the north and to the south of it.

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[1] This escarp used to separate shallow waters of Sudur from the open sea, and served as a barrier reef's platform since middle of the Callovian period.

[2] i.e. formed simultaneously with growth of the reef bioherms

Lithological-facies analysis of the Sudur zone's Callovian-Upper Jurassic complex brings us to a conclusion that it had formed under broad continental shelf environment of warm Late Jurassic basin. Comparison of sections of the Sudur zone's evaporite sediments with similar facies of the Limestone Daghystan's Malmian complex speaks for a northward rejuvenation of sediments. This factor is also an indicative for northward migration of the marginal sea's coastline accompanied by lateral shifting of sand beaches and parallel deepening of Sudur shelf with replacement of evaporites by deep-water dolomites and carbonates in the vertical section.

At the same time, Callovian-Upper Jurassic complex of Shahdagh-Khyzy and Gonagkend zones is generally expressed by deep terrigenous flysch developed on steep continental slope and its' basement to the south of the barrier reef. Area's psephitic material had arrived mainly from the north at the expense of destruction products and platform basement of the reefs. Only deposits from bottom and lower parts of the continental slope are detectible in exposed geological section, whereas the its' transition facies are sealed under Cretaceous sediments of the northern flank of Shahdagh-Khyzy zone.

Conclusions

1. Structural-formational zone of Side range is a classical region, where the Malmian evolution of Greater Caucasus basin's northern continental margin is traced.

2. Presence of fragments of oceanic basalts and radiolarites (Molt suite) at the bottom of the continental slope's Malmian section speaks for a proximity of the provenance area that is most probably represented by Samur-Kumdi Muis (Samur-Peschaniy Mis) Middle Caspian uplift. Meanwhile, transit of clastic material must have occurred via the channels developed by river deltas in the barrier reef.

3. Presence of well-sorted sands and sandstones (derivatives of spodumene-beryllic range's granitic pegmatites) in the bottom section of Upper Jurassic continental shelf speaks for the fact that the clastic material had been transported from afar, apparently from Russian platform.

4. Correlation based on facies and stratigraphy of Malmian sediments of the Northeastern Azerbaijan and Daghystan speaks for progressive transgression over Scythian-Turanian platform both from the south and the southwest.

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BÖYÜK QAFQAZIN YAN SIRT ZONASININ ÜST YURA KOMPLEKSİ: LİTOFASİYALAR VƏ ƏMƏLƏGƏLMƏ ŞƏRAİTLƏRİ (AZƏRBAYCAN)

T.N. Kəngərli, Z.N. Mehdiyeva

Məqalədə Cənub-Şərqi Qafqazın Yan sırt zonasının Malm törəmələrinin sedimentasion zonallığı və yaş korrelyasiyası məsələlərinə baxılmış, kəsilişin özül hissəsində kellovey yaşlı çöküntülərin iştirakı barədə yeni məlumatlar təqdim edilmiş, litofasiyaların cənubdakı kobud flişdən şimaldakı laqun tipinə doğru qanunauyğun lateral dəyişməsi, bununla da onların Yura dövrünün Böyük Qafqaz kənar dənizinin şimal yanının qitə yamacı və dayaz şelfi şəraitində formalaşması sübut edilmişdir.

ВЕРХНЕЮРСКИЙ КОМПЛЕКС БОКОВОГО ХРЕБТА БОЛЬШОГО КАВКАЗА: ЛИТОФАЦИИ И УСЛОВИЯ ОБРАЗОВАНИЯ (АЗЕРБАЙДЖАН)

Т.Н. Кенгерли, З.Н. Мехтиева

В статье рассмотрены вопросы седиментационной зональности и возрастной корреляции образований мальма зоны Бокового хребта Юго-Восточного Кавказа, приведены новые данные об участии в основании разреза осадков келловейского возраста, сделаны выводы о закономерной латеральной смене литофаций от грубых флишевых на юге к лагунным на севере, что свидетельствует о геодинамических условиях их формировании в условиях континентального склона и мелководного шельфа северного борта юрского окраинного моря Большого Кавказа.

CURRENT STATUS OF THE LONG-TERM EXPLORATION OF OIL-GAS FIELDS IN THE ABSHERON REGION OF AZERBAIJAN

Article provides for a summary of analysis of how the various exploration parameters have changed throughout the long-term oil-gas development history in the Absheron peninsula of Azerbaijan. The main factors determining the rate of change of these parameters are considered. The synchronous tendency of the fall of reservoir pressures and the decrease formation productivity has been revealed. It is shown that the degree of depletion of various production facility that are at the final stage of development is not the same.

Keywords: oil and gas, deposit, long running exploration, reservoir pressure and productivity, Azerbaijan

A.A. Feyzullayev

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

E.B. Valiyeva

V.N. Lunina

Azerbaijan National Academy of Sciences,
Institute of Geology and Geophysics,
H. Cavid ave., 119, Baku, AZ1143, Azerbaijan
E-mail: luna-az@rambler.ru

G.T. Ahmadova

Oil and Gas Production Department
of G.Z.Tagiyev,
E-mail: gunayheydarova@mail.ru

Introduction

Efficiency of oil production wells is one of the key factors to determine technical and economic indexes of the oil field development. Along with the natural geological and geophysical characteristics of productive strata, the technogenic phenomena accompanying the process of field development have a significant impact on the productivity of wells.

The drop in formation pressures during the development of the oil and gas field and the deformational processes in the reservoir accompanying them ultimately lead to a decrease in strata productivity.

It had been proved that the decrease of formation pressure reduces the productivity of wells, the rate of oil withdrawal and increases the development time of deposits, which are controlled by the initial filtration characteristics of the reservoir. The relative increase in development time is more significant for high-permeability objects.

Thus, the studies carried out in SurgutNIPIneft on the evaluation of oil recovery coefficients for low-permeability reservoirs have shown that the share of residual oil due to inelastic deformation of rocks can reach 20-30% (Черемисин, Сонич, Ефимов, 2001). Undercount of this factor in the design can lead to significant errors in assessing the technical and economic parameters of the oil field development.

The excessive decrease of formation pressures at a number of sites in the Romashkinskoye field of the Tatneft association (Russia) have considerably aggravated the development conditions of both production and injection wells, and contributed to a reduction its production rates and injection capacities (Сахипгареев, Славин, 1991).

Calculations based on the model developed by M.N.J.Al-Awad (Al-Awad, 2001), showed that the productivity of the investigated deposits is significantly affected by a decrease in permeability caused by a drop in pore pressure. The maximum decrease in the productivity of sandstone with the fall of reservoir pressure, taking into account the deformation-changed permeability reaches 33% in comparison with the productivity with unchanged permeability. Interestingly enough, the limestone demonstrates a decline of just 8%.

In the paper V.M.Dobrynin et al. (Добрынин, Мулин, Куликов, 1973), the observed drop in production rates of the productive horizons of the Samotlor field is also associated with the phenomenon of a decrease in the filtration characteristics of rocks. According to authors of this work, the main reason for the decrease in permeability is the deformation of the reservoirs as a result of the fall of reservoir pressure.

An analysis of the results of the interpretation of acoustic broadband well logging at the Astrakhan gas condensate field and the Achimov deposit of the Urengoy oil and gas condensate field showed that when reservoir pressure is reduced within 30-45 MPa, the cracks in the reservoir rocks are closed, leading to a decrease in permeability and to significant reductions in well productive rates (Попов, 2007).

Current paper assesses the level of the formation pressure fall in the long-developed fields of Absheron oil and gas bearing region (OGR) in Azerbaijan and its impact on their productivity.

Research results

Dependency between formation productivity and pressure was analyzed based on the examples of Bakakhany-Sabunchu-Ramana, Surakhany and Buzovna-Mashtaga oil fields of the Absheron peninsula and the Neft Dashlari field on the Absheron Archipelago (Figure 1).

One of the world's oldest fields of *Balakhany-Sabunchu-Ramana* is located in the central part of Absheron peninsula. This field includes three operational areas: Balakhany, Sabunchu and Ramana, which put into operation in 1873, 1875 and 1890 respectively.

Figure 1. Scheme of location of studied fields:
1 – Balakhany-Sabunchu-Ramana; **2** – Surakhany;
3 – Buzovna-Mashtaga; **4** – Neft Dashlary

From the tectonic point of view, this field represents an open brachyanticlinal fold located within 12 km long and 3 km wide asymmetric anticline line of Fatmayi-Zikh-Bahar. The entire fold is dissected by a range of longitudinal and transverse faults with various displacement amplitudes, dividing the oil-bearing area into more than 25 tectonic blocks and playing important role in the distribution of oil deposits both in the section and in the area.

The oil-bearing capacity of the field is confined to Lower Pliocene formations - Productive series (PS), thickness of which varies from 1274 m to 1680 m and more. The total of 28 oil-bearing objects (with thickness from 4 to 52 m and oil saturation of 73-81%) were revealed on the field, 10 of which are confined to the horizons of the lower division of the PS, and 18 - of the upper section of the PS. Depth occurrence of the productive objects varies from 80 to 1600 m.

Based on core analysis, permeability of the reservoir rocks is different and varies between $40\cdot10^{-3}$and $374\cdot10^{-3}$ mkm^2. Oil density under surface conditions changes from 865 to 925 kg/cm^3, the temperature varies depending on the depth, in the range of 18 - 60^{0}C.

Initial formation pressures (Pf) approximately correspond to hydrostatic pressure and vary in objects from 0.8 MPa (I hor.) to 15.0 MPa (Pre-Gyrmaki suite-PGS).

The long-term development of the field, accompanied by the continuous extraction of fluids from the reservoir, led to a significant drop in formation pressure relative to the initial pressure, which is clearly seen in Figure 2. There is a decrease in the initial formation pressure for productive objects from 40 to 95%.

The rate of fall the formation pressure in the upper division of the PS varies in the range 0.005-0.04 MPa/year and in the lower one - 0.05-0.15 MPa/year, with the highest rate of fall of Pf being confined to the lower part II Gyrmaki suite (GS) and PGS (Figure 3).

The fall in formation pressure is accompanied by reduction of well's average daily fluid production rates (oil+water) (Figure 4).

If we consider the highest total extractions for per individual developed objects, then the relative values of this parameter are distributed as follows: horizon III – 10%; horizon IV+IVab – 23%; Horizon IVcde – 8.2%, horizon V – 14.2%, PG suite – 12.6%. These values are in compliance with relative values of the formation pressure fall. Figure 5 presents development diagrams of the Horizon VI (Balakhany suite).

As can be seen from the figure 5, as a result of the development of the VI horizon from 1935 to 2001, formation pressure decreased by 10 times. The productivity of this horizon during the same period decreased by almost 4 times in comparison with its' peak value. It should be noted that water injection to maintain formation pressure increased oil production to only 9% of its peak value to a greater degree, increasing the extraction of water. This is in good agreement with the opinion of D.Moos and C.Chang (Moos, Chang, 1998), who argue that maintain pressure in the reservoir by injection water into water and other methods used in many fields of the world allow to restore pressure (and, as a consequence, increase productivity) by no more than 10%.

The process of the fall of reservoir pressure and the extraction of hydrocarbons is even more contrasted in the upper part PGS of the PS, which entered into development in a later period (1916). For all period of development (a little more than 90 years) from a deposit have been extracted about 13 % of oil from total production as a whole on a field (Figure 6), causing reduction of its' initial formation pressure from 12.8 to 1.0 MPa. It in aggregate shows, that this operational object is characterized abnormal-low formation pressures and is on the final stage of development.

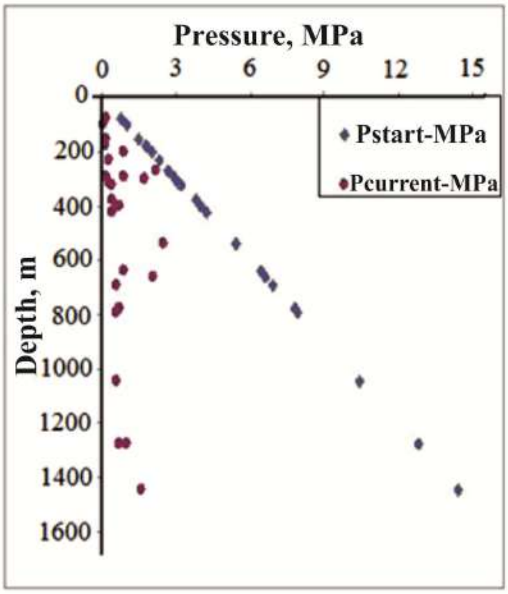

Figure 2. Initial and current formation pressures in Balakhany-Sabunchu-Ramany field vs. depth

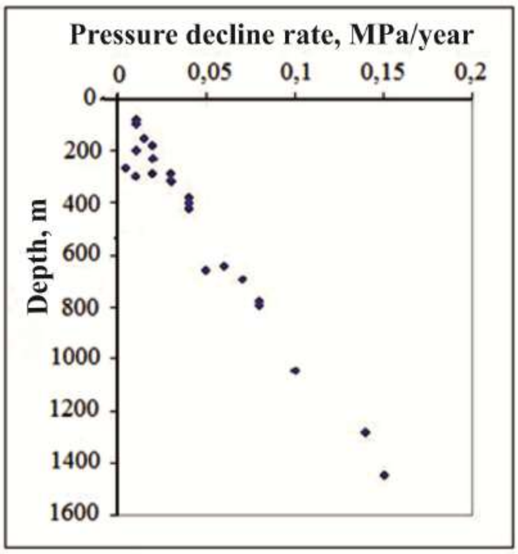

Figure 3. Rate of fall of formation pressures vs. depth in Balakhany-Sabunchu-Ramana field

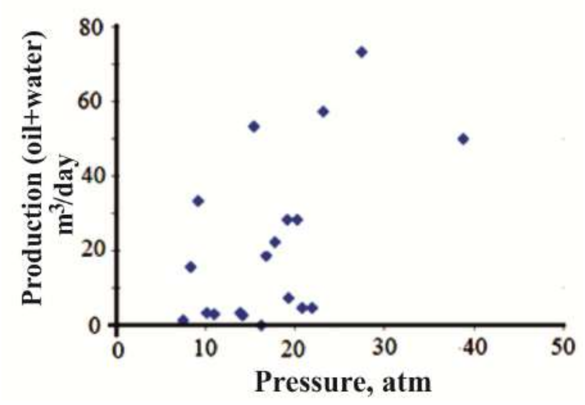

Figure 4. The graph of the relationship between average daily volume of the fluid (oil + water) extracted from the reservoir and formation pressure in Balakhany-Sabunchu-Ramana field

Surakhany field is located in the central part of Absheron peninsula, 14 km to the northeast of Baku. It represents an asymmetric northwest-southeast oriented brachyanticline complicated by multiple differently striking tectonic faults. Due to this factor oil resources were distributed unevenly both by area and section of PS.

The section of PS with total thickness more than 2000 m is mainly represented by an alternation of fine-grained quartz sands and clays. In the PS section, 40 horizons and 54 oil-and-gas bearing operational facilities with a thickness of 2 to 25 m are indicated, of which 29 objects are fallen on the upper division of the PS and 25 - on the lower division of PS. The Absheron and Akchagyl sediments are also oil and gas bearing. There are no purely gas deposits.

Occurrence depth of productive horizons varies between 180-2850 m. The oil saturation of rocks is 61-85%, their permeability varies from $50 \cdot 10^{-3}$ to $517 \cdot 10^{-3}$ mkm^2; oil density changes from 770 to 912 kg/cm^3. Depending on depth, the formation temperatures vary between 17-76^{0}C.

The development of the Surakhany field was started in 1904 with the exploration of horizons of Surakhany suite, then, from 1910 - the horizons of the Sabunchu suite, since 1924 - the Balakhany suite and since 1932 - the suites (horizons) of the lower division of PS.

Figure 7 shows the distribution of initial and current reservoir pressures with depth. Initial formation pressures vary within the limits of 2.5-27.5 MPa, while current formation pressures – (0.2-18.4) MPa. It can be seen from the figure that the current reservoir pressures along the lower division of PS differ significantly from the initial ones, especially in the horizons of the GS and PGS.

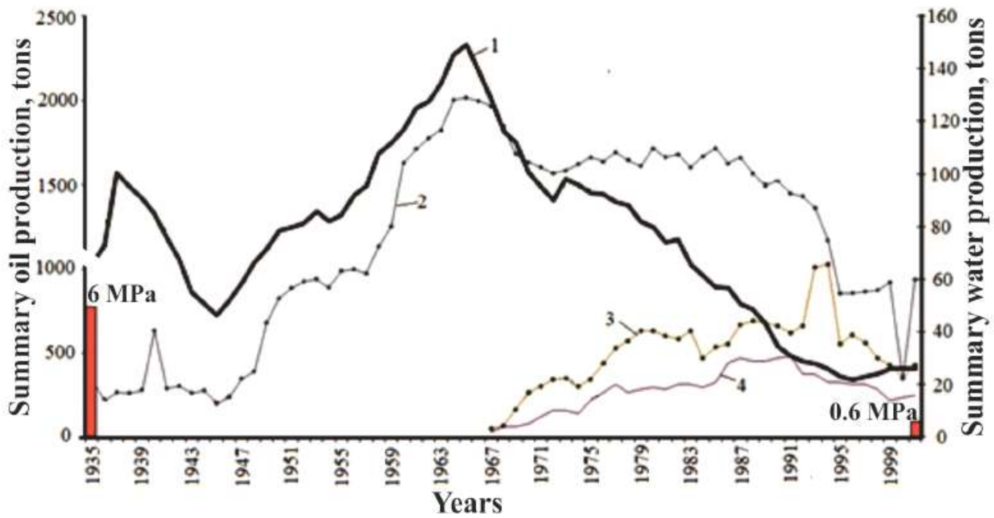

Figure 5. Development diagrams of the Horizon VI (Balakhany suite) of Balakhany-Sabunchu-Ramana field: **1** – oil production; **2** – water production; **3** – volume of injected water; **4** - number of injection wells

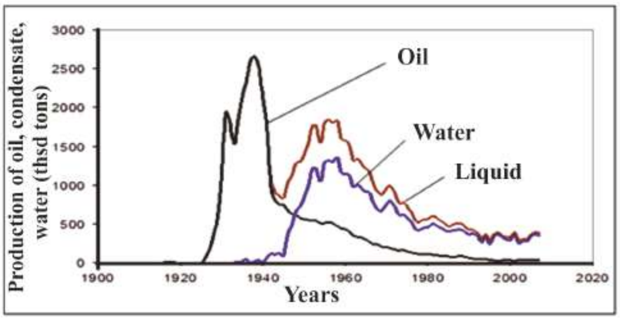

Figure 6. Main operating parameters of the lower parts of PGS, Balakhany-Sabunchu-Ramana field

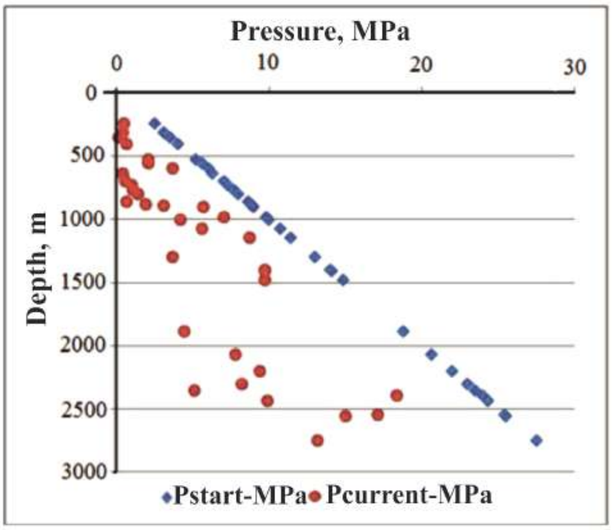

Figure 7. Initial and current formation pressures in Surakhany field vs. depth

The rate of fall of formation pressures in the upper division of PS varies in the range of 0.02-0.09 MPa /year, and in the lower division – (0.05-0.20) MPa /year. Maximal rate of (0.16-0.20) MPa/year is recorded in horizons GS and PGS.

Initial average daily production rates of one well varied within 0.2-5.4 t / day. From 1980 to the present, the average production rate of one well as a whole for the field was 0.8-1.2 tons per day, and was independent of the number of current and new operating wells. This was explained by the depletion factor of the developed deposits.

On the horizons of the upper division of the PS fall to 74% of all extracted oil in the field. The maximum amount of oil was extracted during the main development period of the field (1926-1956) - 81 million tons (70.4%), while the maximum annual oil production (4189.3 th. tons) was in 1931. Relatively high oil extraction was persisted until 1942. Since then, the extraction volumes consequently reduced, reaching 397 thsd tons in 1976 and 196 thsd tons in 2012 (Figure 8).

Just like at the Balakhany-Sabunchu-Ramana field, all operational facilities of the Surakhany field are characterized by abnormally low formation pressures (ALFP) and are at the final stage of development.

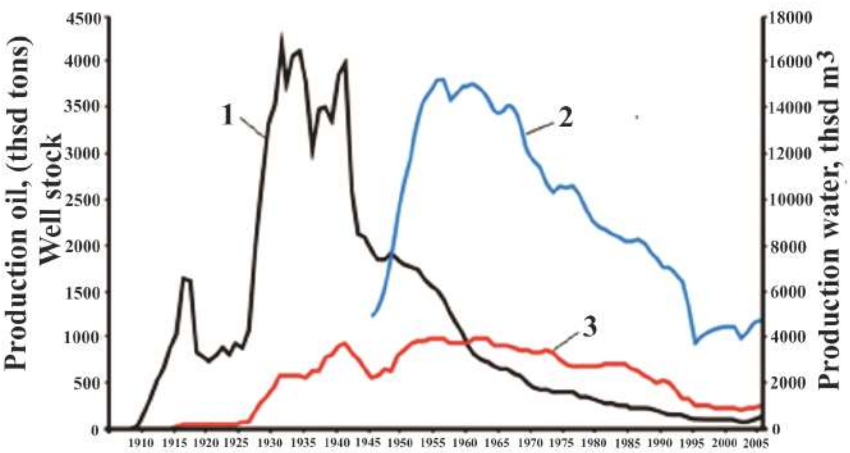

Figure 8. Surakhany field: dynamics of main operating parameters: **1** – oil; **2** – water; **3** – number of wells

Buzovna-Mashtaga field, including two operational area: Buzovna and Mashtaga, located in 24 km to the northeast of Baku. It is developed since 1940.

On Buzovna-Mashtaga field commercial oil reserves are concentrated in Post Gyrmaki Clayey suite (PGC), Post Gyrmaki Sandy suite (PGS), GS and PGS suites. Minor accumulations were also detected in sandy horizons of the Balakhanian suite (Horizons IV, V, VI, VII and X). In faulside parts on southern wing of the Buzovna fold it has been established gas presence in II horizon of the Balakhanian suite.

Dependence between the average daily extracted volume of fluid (oil + water) from operating objects and the formation pressure is shown in the Figure 9.

Neft dashlary field discovered in 1949 by deep exploration well #1, which have revealed all suites of the lower division of PS /PGC, PGS, GS, PG and Gala (GaS) suites/. On November 5, 1949, the fountain oil inflow with daily volume 100 t had been produced from the GaS (from 1000 m of depth). It has been drilled on the field about 2 thousand wells since 1949 with daily average level of oil extraction 1800-2000 t.

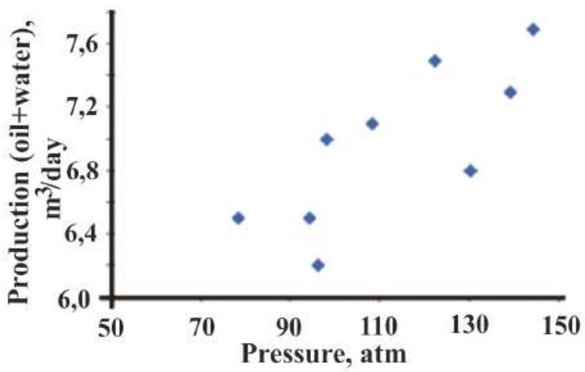

Figure 9. Dependence between average daily extracted volume of fluid (oil + water) and formation pressure on Buzovna-Mashtaga field

The basic accumulations of oil and gas on the field are confined to GaS, PG and GS suites of lower division of PS. The field is characterized by spatial non-uniformity of oil content in the PS section.

Commercial development of Neft Dashlary field has begun in 1951. For past years, more than 160 mln tons of oil and 13 blns m^3 of the oil-associated gas have been produced from this field. Currently the productivity of operating well reaches on the average up to 5 t/day.

Deposit's long-term exploitation resulted in decline of the formation pressure until 20% of its' initial value, which have had its' impact upon the reservoir productivity. Figure 10 demonstrates clearly defined reduction in summary volumes of the extracted fluids (oil+water) caused by declined formation pressure of the deposit.

Process of long-term development of the field was accompanied by the pressure drop in reservoir up to 20 % from initial pressure that was reflected on efficiency of strata. On figure 10 the clearly defined tendency of reduction of value of the total volume of the extracted fluids (oil + water) with reduction of formation pressure is observed.

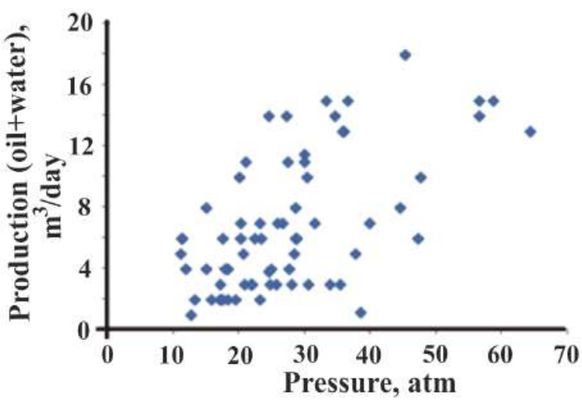

Figure 10. The chart of dependence between daily average volume of extracted fluid (oil+water) and formation pressure on Neft Dashlary field

Conclusion

As a result of the performed analysis of variation in time of parameters of development of some fields of Absheron peninsula it is established, that they are characterized by abnormal-low formation pressures, current values of which, despite of actions on maintenance of pressure by injection in a layer of water, are from 18,5 up to 94,3 % from initial, near hydrostatic pressure.

It is noted synchronism in the tendency of the fall of formation pressures and the decrease in the reservoir's productivity. The drop in well productivity is due to the fact that plastic deformations in depleted reservoirs, caused by the drop in formation pressures, predominate over the elastic ones.

This leads to additional compaction of rocks and deterioration of their reservoir features (Фейзуллаев, Велиева, Рамазанов и др., 2013), eventually resulting in a reduction of well productivity. At the same time, due to the spatial heterogeneity of the geological environment and the different rate of fluid extraction, the degree of depletion of different operational objects is not the same. This fact should be taken into account when determining the strategy for further development of fields.

At present, the energy potential of the objects of the lower division of PS is higher than that of the upper division, and therefore the lower reservoirs of PS are more perspective for further development. This is confirmed by a comparison of the degree of development of recoverable oil reserves in the upper and lower divisions of PS, which is 96.3% and 79.5%, respectively. It is also important to note that if in the lower division of PS the average production in one well is about 1.8 t / day, then in the upper division it is 0.8 t / day.

Long-term development of petroleum fields also leads to negative environmental consequences. So, in the vicinity of the of Balakhany-Sabunchu-Ramana, Surakhani and others fields, intensive subsidence (up to 47 mm / year) and their flooding, the emergence of induced seismicity (earthquake in Surakhany in 1937) were established (Фейзуллаев, 2013). These undesirable environmental consequences of long-term development of oil and gas fields in the aggregate are causing great economic damage to the existing infrastructure. In this regard, in order to minimize environmental and economic damage, it is advisable the preventive arrangement the extractive complexes with a seismic and geodynamic control systems for the purpose of predict the development of natural and technogenic geodynamic processes.

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AZƏRBAYCANIN ABŞERON RAYONUNUN NEFT VƏ QAZ YATAQLARININ UZUNMÜDDƏTLİ İŞLƏNMƏSİNİN MÜASİR VƏZİYYƏTİ

A.A. Feyzullayev, E.B. Vəliyeva, V.N. Lunina, G.T. Əhmədova

Məqalədə Azərbaycanın Abşeron yarımadasının bir sıra neft-qaz yataqlarının uzunmüddətli işlənməni əks etdirən parametrlərinin zamanda dəyişməsinin təhlilinin nəticələri əks olunub. Bu parametrlərin dəyişmə tempini müəyyən edən əsas amillər araşdırılıb. Lay təzyiqlərinin düşməsinin və lay məhsuldarlığının azalmasının sinxron tendensiyası müəyyən edilmişdir. Göstərilmişdir ki, son işlənmə mərhələsində olan müxtəlif istismar obyektlərin tükənmə dərəcəsi eyni deyildir.

СОВРЕМЕННОЕ СОСТОЯНИЕ ДЛИТЕЛЬНОЙ РАЗРАБОТКИ НЕФТЕГАЗОВЫХ МЕСТОРОЖДЕНИЙ АБШЕРОНСКОГО РАЙОНА АЗЕРБАЙДЖАНА

А.А. Фейзуллаев, Э.Б. Велиева, В.Н. Лунина, Г.Т. Ахмедова

В статье приведены результаты анализа изменения во времени параметров длительной разработки ряда нефтегазовых месторождений Абшеронского полуострова Азербайджана. Рассмотрены основные факторы, определяющие темпы изменения этих параметров. Выявлена синхронная тенденция падения пластовых давлений и снижения продуктивности пластов. Показано, что степень истощения различных эксплуатационных объектов, находящихся на заключительной стадии разработки, неодинакова.

COMPARATIVE ANALYSIS OF LITHOLOGICAL AND PETROGRAPHIC CHARACTERISTICS OF THE MIOCENE DEPOSITS IN THE SOUTH CASPIAN BASIN' WESTERN FLANK

Different areas within western flank of the South Caspian basin (Garadagh, Solakhay, Hajivali, Umbaki, Guzdak, Binagadi, Masazir, Sulutapa, Shabandagh, Rahim, Glich, Suleyman-Akhtarma, etc.) contain widely occurring Paleogene-Miocene deposits (Figure 1). Long term wide scale geological studies resulted in detailed stratigraphy of the described area's Miocene deposits as well as description of their reservoir, lithological and petrographic parameters. This paper is devoted to the detail petrography of the Miocene depofieldd drilled on the number of fields last years. The data achieved is have a particular importance to the understanding of the Miocene sediments' reservoir properties changes within the South Caspin depression's western flank.

Keywords: South Caspian basin, Miocene deposits, petrography

K.F. Mustafayev

AZLAB LLC
Baku, Azerbaijan, AZ1040
Yaver Aliyev 4B
m_kamal_f@mail.ru

Geological background

In early XX century, different parts of the territory have been covered by gravitomagnetic mapping survey. In 1941-1942 and later during 1950's, a number of gravimetric minimums were identified in correspondence with buried anticlinal highs. Many wells were drilled to sample and analyze the Miocene deposits. In 1946-1950, exploration were carried out in the Northwestern Gobustan to cover the structures of Umbaki (1946-50), Shimali Hajivali (1949-51), Gerbi Hajivali (1951-52), Cheyildagh (1950-51), Gerbi Sundu (1950-52), Nardaran-Suleyman (1952-53), Gijakiakhtarma (1952-55) and Dashmardan (1953-57). Simultaneously exploration drilling were done in Umbaki (1951-53), Shimali Hajivali (1950-55), Ilkhichy (1952-54) Nardaran-Suleyman (1953-55) and Cheyildagh (1947-55) (Rzayev, Salayev, Gadjiyev, 1973; Rzayev, Salayev, Zeynalov, 1980; Maherramov, 2008).

Comparison of drillled Miocene deposits revealed significant lithofacies lateral changes. In some fileds the upper parts of such deposits were subjected to erosion, which is recorded on a large scale in the northern part of the studied area. Erosion was so intensive in the crests of Sulutapa and Shabandagh anticlines that it leds to a disappearance of Meotian and Sarmatian deposits from the section.

The thickness of the Paleogene-Miocene deposits increases from northwest to southeast, varying between 0.5-1 and 5-6 km and sometimes reaching 7-8 km. These deposits predominantly consist of shaly-sandy sediments, and reflect structural – tectonic patterns of some anticline structures, which are located in the North-Western part of the Western Absheron, trending in the general Great Caucasus direction and composed of the Cretaceous sediments (Yunusdagh, Govundagh, Ilkhidagh, etc.). The Paleogene - Miocene sediments of these anticlines are subjected to the secondary folding and tectonic crumpling. Most anticlines' crests and crestal parts became complicated by the thrust faults (Figure 2). These processes have caused a formation of large anticline zones in the structure of the Western Absheron.

Trending parallelly to the general Great Caucasus strike anticlinales of the Absheron peninsula's northwest (Jorat, Novkhani, Saray, Binagadi, etc.) significantly vary from the Mesozoic structures.

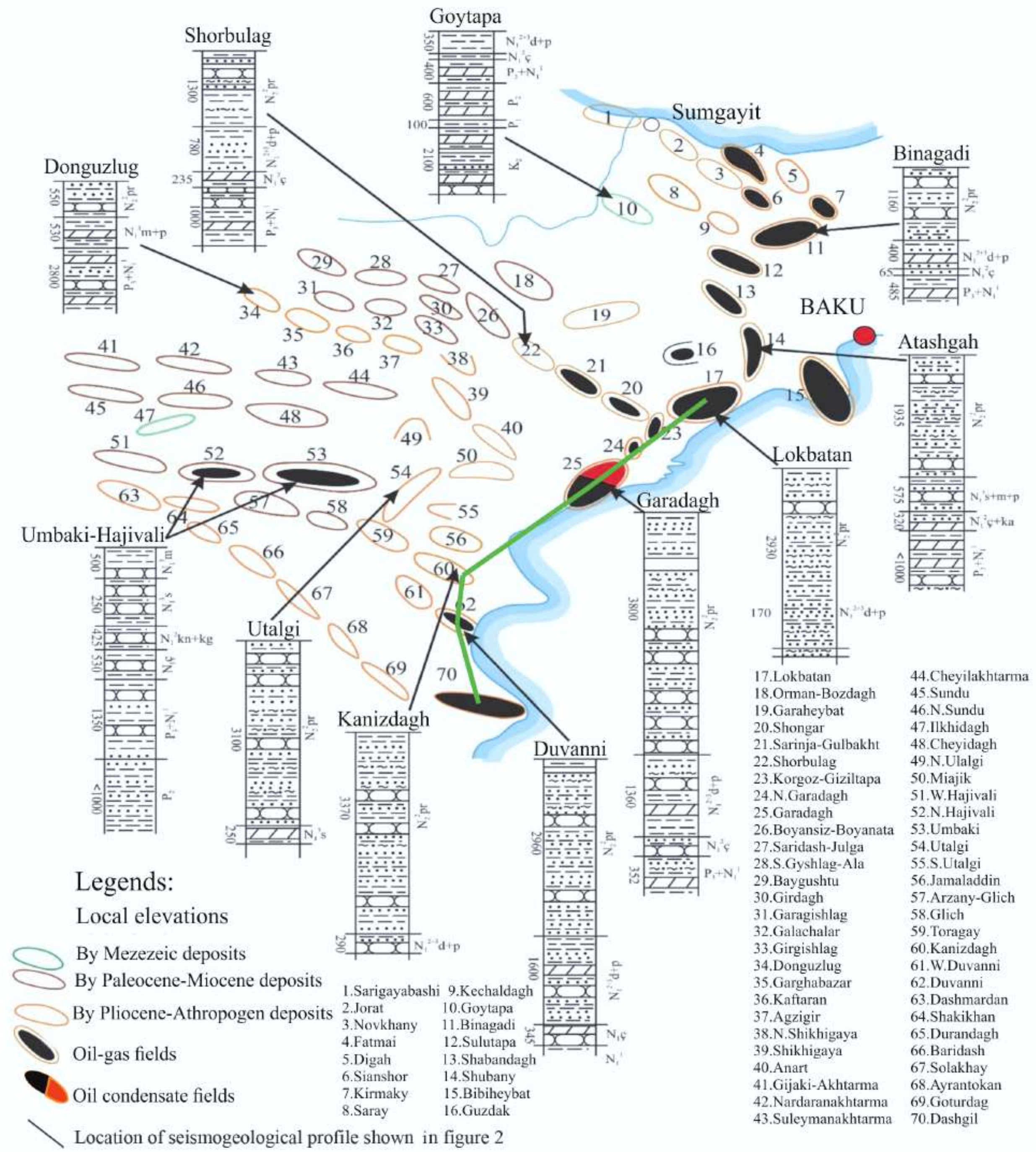

Figure 1. Location scheme of tectonic structures within the South Caspian basin western flank

Majority of the research area's anticlines is complicated by mud volcanoes. Plastic clays of the Paleogene-Miocene deposits caused creation of diapir-like structures within the zones of abundant tectonic faults.

It should be emphasized that the described area after decades turned again into arena of wide-scale research activities. We present in this paper the results of petrographic investigations of core samples collected from both old and newly drilled wells. It is commonly accepted that although Miocene deposits are lithostratigraphically represented mainly by shaly facies, in many places they also include different varieties of rocks. Therefore, these sediments require now to be studied in more details.

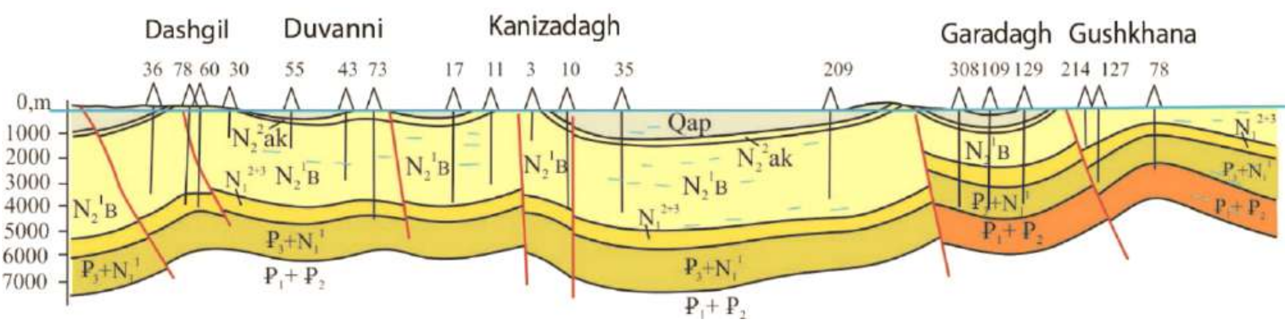

Figure 2. Seismogeological profile (profile's location see on Figure1)

Main results

Duvanny field, well – 73, Interval: 3178-3188 m

This sample is mainly composed of thin and streaky, calcareous, siliceous, sandy shales. The bulk sample consists of calc-siliceous bituminized shales (Figure 3).

Sand particles contained in this greyish-brown streaks are represented by large (0.3 mm) and medium (0.05-0.1 mm) grains, which are cemented through a basal type. Clean and unaltered crystals and aggregates of pyrite are detected in a cemented material. Wide streaks are represented by calc-siliceous sandstones.

In general, terrigenous parts of the both streaks are built by fragments of siliclastic rocks, pelitomorphic limestones, quartzites and other fragments of rocks. The altered and cataclastic field spars, epidotes, chlorites, etc. are also detected. Fragmental cementation by the siliceous, calcareous minerals is represented by basal and sometimes pore-filling types. The rock has a psammitic structure and banded texture.

Garadagh field, Well – 353, Interval: 2815-2822 m

Silty limestone. Represented by calcite, the groundmass contains unevenly distributed particles of siltstone (Figure 4). These particles are 0.01 to 0.05 mm large, represented by angular feldspatic and quartz grains. Calcified feldspars are frequently observed. The contact between them and the ground mass is weekly seen. Rock contains larger-than-crystalloclast fragments of shales, particles of glauconite (~1-2%), calcitic fauna remnants, different-sized crystals, globules and aggregates of pyrite (~4-5%), as well as rare particles of biotite and amphibole.

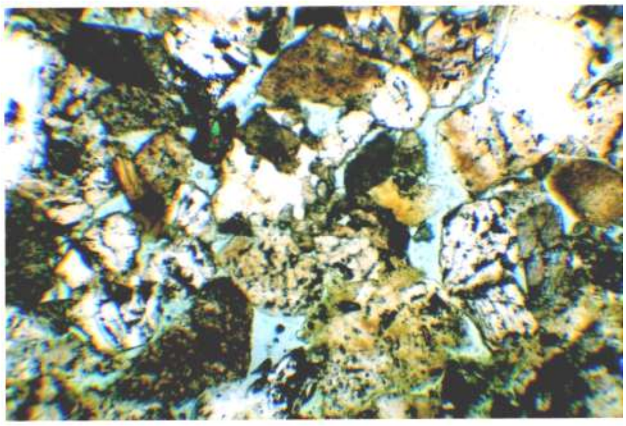

Figure 3. SEM image of Miocene sediments from Duvanny field, well – 73, Interval: 3178-3188 m

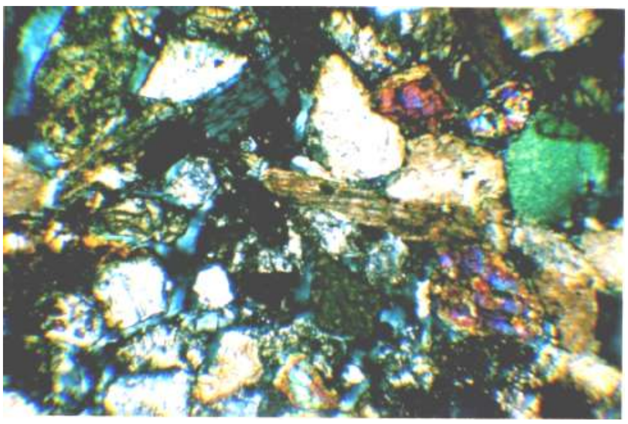

Figure 4. SEM image of Miocene sediments from Garadagh field, well – 353, Interval: 2815-2822 m

Fragments are cemented through a mixed type with finely crystalline calcites. In other parts the cementing is of a pore filling type.

Umbaky field, Well – 64, Interval: 175-179 m

Alternation of silty carbonate shales and carbonate siltstones. Figures 5, 6. Both layers of the rocks contain siliceous material. Layer of calcareous siltstones includes admixtures of clay size particles (Figure 5). All rocks are rich with pyrite.

Most parts of the sediment's clay component are sericitized. There is observed the occurence of thin fibriform ferruginized material along bedding planes. Simultaneous disappearance of clay lamellas and schistosity of clay minerals are vividly observed when looking through crossed nicols and spinning the table of a microscope. Spherical crystals are also recorded among basically oblong quartzes and feldspars. Multiple globules of pyrite are irregularly scattered and in some areas located along bedding planes. In this part, the sample has pelitomorphic structure and schistose texture. The sample's second layer of calcareous siltstones (Figure 6) is mainly built by extremely dense and quartz like feldspars, quartz and small amount of carbonate cement.

The layer contains negligible amounts of the small crystals of garnet, zirconium and calcite. Globules of pyrite are widely developed (~10-12%). Vast majority of these particles is observed inside the transition parts of the mineral rich layer of siltstones. The layer's rocks have silty structure and stratified texture.

Cheildagh field, Well – 1, Interval: 350-356 m

Silica-calcareous siltstone (Figure 7). The rock is built by field spar, quartz, calcite and glauconite, individual grains of garnet, biotite and zirconium, fragments of siliceous rocks and limestones, as well as carbonate cementing material.

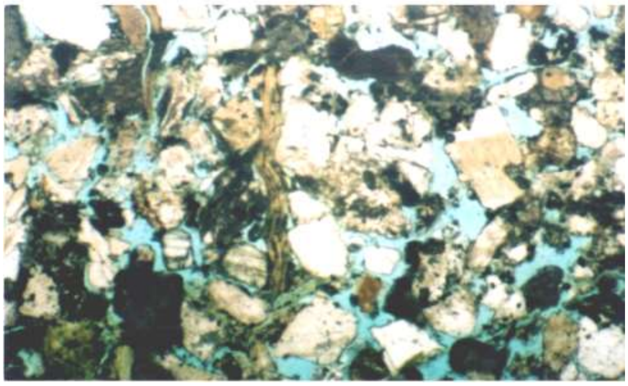

Figure 5. SEM image of Miocene sediments from Umbaky field, Well – 64, Interval: 175-179 m

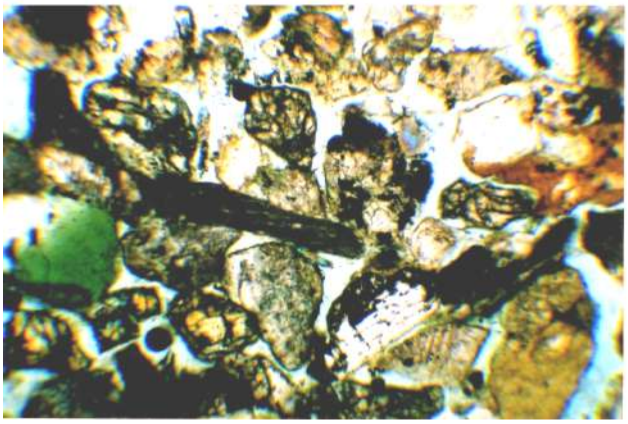

Figure 6. SEM image of Miocene sediments from Umbaky field, Well – 64, Interval: 175-179 m

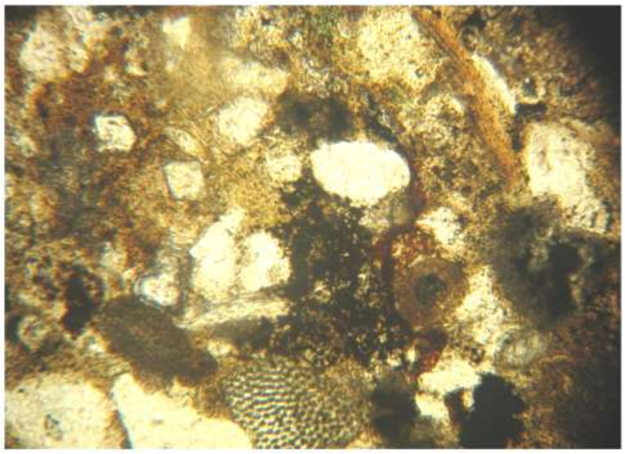

Figure 7. SEM image of Miocene sediments from Cheildagh field, Well – 1, Interval: 350-356 m

Particles are 0.02-0.09 mm in diameter. Different-size globules and aggregates of pyrite are scattered all across the rock's surface. Particles are spaced closely and almost come in touch with each other. The cement is of mixed contact and pore filling types. Rock's constituent streaks have different amounts of component particles and cement material. Light colored streaks have more particles in their composition. Contact between cement material and fragments are mainly uncertain. The rock has a silty structure and banded texture.

Masazir field, Well – 126, Interval: 329-336 m

Calcareous shale. Representing the rock's major components are pelitomorphic carbonate shales containing unevenly distributed scarce concentrations of field spar, small (0.01-0.04 mm) particles of quartz and altered minerals, different-size (0.003-0.02 mm) globules, particles and larger aggregates of pyrite (Figure 8).

In some cases, globules are spaced closely, forming lenticular and spherical accumulations. Within the lens surroundings globules of pyrite form cell-form accumulations with thin tails in the margins. The rock's spotty colorization is due to uneven distribution of pyrite and calcite. Some parts of the rock are porous, and some have multi-directional lighter-than-groundmass fibriform fractures filled with siliceous limestone.

Short needle shaped prisms of sericite are lined along their long sides, which makes it possible to record a slate structure of the rock.

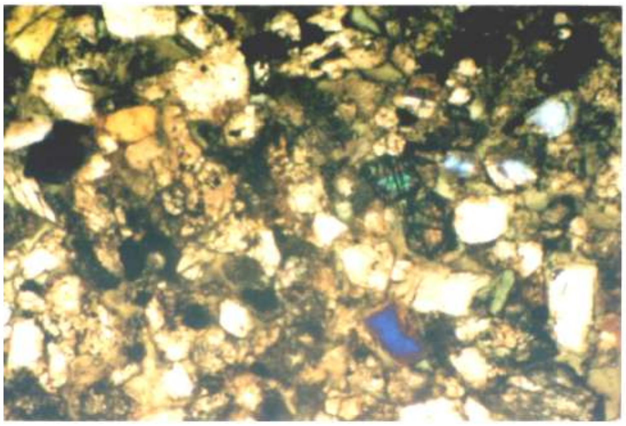

Figure 8. Masazir field, Well – 126, Interval: 329-336 m

Binagadi field, Well – 620; Interval – 970-985 m

Sandy (12-15%), siliceous, carbonate shale (Figure 9).

The rock contains 1-2 mm large fragments of pyritic schisty shales, sericitized pyritic shales and finely-crystalline limestones. Sands containing grains of quartz, feldspar and siliceous rocks are distributed unevenly, sometimes extremely close to each other. The rock has a dark color due to multiple globules and aggregates of pyrite.

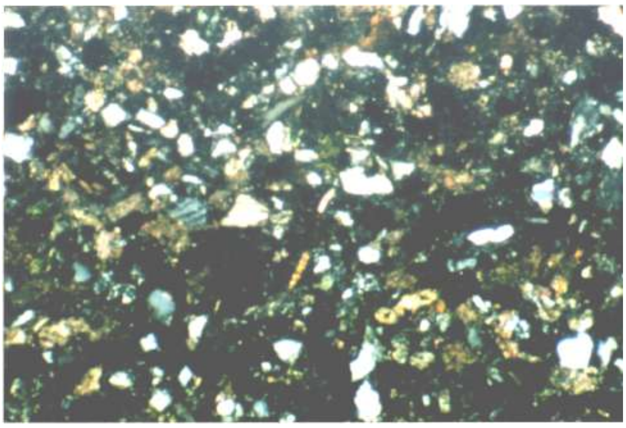

Figure 9. Binagadi field, Well – 620; Interval – 970-985 m

Conclusions

SEM analysis of Miocene deposited from different anticlines within the South Caspian basin western flank demonstarated the quite different lithological and mineralogical composition of the sediments. Along with terrigenous rocks the carbonate sediments are also recorded. In the light fraction thye rocks fragments are dominating. The second component is feldsaprs. The quarz palys a minor role.

The frequent occurrence of pyrite testifies to sharply reduction conditions in the basin.

The reservoir properties of Miocene sediments are very variable within the studied area. The presense of commercial HC accumulations in some fields and failure testing results in others require additional thorough researches aimed on the understanding of reservoir quality problems of the Miocene sediments in the South Caspian basin.

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CƏNUBİ XƏZƏR HÖVZƏSİNİN QƏRB CİNAHINDA MİOSEN ÇÖKÜNTÜLƏRİNİN LİTOLOJİ PETROQRAFİK XÜSUSİYYƏTLƏRİNİN MÜQAYİSƏLİ TƏHLİLİ

K.F. Mustafayev

Cənubi Xəzər hövzəsinin qərb cinahında yerləşən (Qaradağ, Solaxay, Hacıvəli, Umbakı, Güzdək, Binəqədi, Masazır, Sulutəpə, Şabandağ, Rəhim, Qlic, Süleyman-Axtarma və.s) sahələrdə Paleogen-Miosen çöküntüləri geniş yayılmışdır. Uzun illər ərzində bu sahələrdə aparılan geniş miqyaslı kəşfiyyat və tədqiqat işləri nəticəsində Miosen çöküntülərinin stratiqrafik bölgüsü verilmiş, killektorluq, litostratiqrafik və petroqrafik xüsusiyyətləri təyin edilmişdir. Bu məqalədə son illər Miosen horizontu kompleksinə qazılmış quyulardan götürülmüş nümunələrin ətraflı petroqrafik təhlilinə geniş yer verilmişdir. Əldə edilən məlumatlar Cənubı Xəzər hövzəsinin qərb cinahında Miosen çöküntülərinin sedimentasiya şəraitinin öyrənilməsində xüsusi əhəmiyyət kəsb edir.

СРАВНИТЕЛЬНЫЙ АНАЛИЗ ЛИТОЛОГИЧЕСКИХ И ПЕТРОГРАФИЧЕСКИХ ХАРАКТЕРИСТИК МИОЦЕНОВЫХ ОТЛОЖЕНИЙ ЗАПАДНОГО БОРТА ЮЖНО-КАСПИЙСКОГО БАССЕЙНА

К.Ф. Мустафаев

Палеоген-Миоценовые отложения широко представлены на ряде площадей западного борта Южно-Каспийского бассейна (Гарадаг, Солахай, Гадживели, Умбаки, Гуздек, Бинагади, Масазир, Сулутепе, Шабандаг, Рахим, Кылыч, Сулейман-Ахтарма и тд.). В течение многих лет в результате крупномасштабных разведочных работ на данных территориях было определено стратиграфическое расчленение Миоценовых отложений, определены коллекторские свойства, и даны их литографическая и петрографическая характеристики. В данной статье приводится подробное петрографическое описание образцов из скважин, пробуренных на Миоценовые отложения за последние годы. Полученные результаты имеют особое значение для изучения условий осадконакопления Миоценовых отложений на западном фланге Южно-Каспийского бассейна.

RESEARCHERS OF THE MISTERIES OF THE MINERAL RESOURCES OF KOMI REPUBLIC

For many years, subsoil geological structure and mineral resources of Komi have been thoroughly studied by many researchers that visited Timan and Ural from different other regions of Russia, including Ukhta, Syktyvkar, Vorkuta and other mainly European districts of the country. In other words, this interesting region had historically united a wide spectrum of Russian geologists.

Special achievements in studying the subsoil's geological structure have been maintained in 1930-1970's. Many of these geologists aren't among us anymore, but memory of their achievements and discoveries will be always embalmed in hearts and works of their colleagues and followers. Author of the current article had an honor to know most of these scientists, to participate in joint field investigations and scientific studies.

List of these researchers includes V.V.Belyayev, V.A.Dedeyev, V.G.Olovyanishnikov, G.Y.Trofimov, V.G.Chorniy and N.P.Yushkin

Keywords: Komi Republic, geologists, Timan, V.V. Belyayev, V.A. Dedeyev, V.G. Olovyanishnikov, G.Y. Trofimov, V.G. Chorniy, N.P. Yushkin

A.M. Plyakin

The Ukhta State Technical University; Ukhta, Russia
E-mails: aplyakin09@yandex.ru, zav_miggg@ugtu.net

Vyacheslav Vasilyevich Belyayev – PhD in geology and mineralogy, deputy director and academic secretary, leading research worker of the Institute of Geology, graduate of Ural Polytechnic Institute (1956). In 1959, he entered the Syktyvkar Institute of Geology and worked there until his death on September 17, 2008.

Main target of the described scientist's research were bauxites, which have been covered by his detailed studies since 1966. In 1967, Belyayev had issued his first publication dedicated to bauxites of Timan. Belyayev has thoroughly studied the weathering mantle and mineral composition of East Timanian bauxites, identified their formation circumstances, participated in a number of Union and Republic-wide scientific conferences and carried out field investigations to study the structure of bauxite deposits. In 1972, he successfully defended his PhD thesis at Kazan State University (Fishman, 1997, pages 32–33).

In 1970, deposits of a lateritic type of bauxites were discovered in Middle Timan, which proved to be older than their South Timanian analogues. Belyayev was one of the first researchers to study this new type of bauxites (Fishman, 1997, pages 6–9) and first to characterize their mineral composition and determine their iron mineral content. After becoming PhD, he entirely switched to studying these newly discovered bauxites. Materials produced by V.V.Belyayev allowed him drawing scientific conclusions as to the formation circumstances of Middle Timanian bauxites and assessing the region's perspectives in terms of a discovery of new deposits.

Belyayev had closely cooperated with geologists from Ukhta and Moscow. He had continuously published his scientific works and attended multiple scientific conferences and sessions. We jointly participated in Union-wide conferences organized in Moscow, Kyiv and Syktyvkar. It deserves mentioning that we met accidentally in a hotel in Moscow when waiting for keys for our rooms. This acquaintance and joint research have grown into an enduring friendship between us and our families. I have known Vyacheslav as decent, honest and reliable man.

Contribution of Belyayev to studies of the Timanian bauxites makes him deserving a name of the main bauxite-man of Timan.

Vladimir Alekseyevich Dedeyev – graduate of Leningrad Mining Institute (1954), ScD in geology and mineralogy, professor, honored scientist of Komi ASSR (1989) and Russia (1992). Died in 1997, this scientist could have turned 85 years old in 2016.

Over the course of his life, Dedeyev had contributed a lot to studying the tectonics and fossil fuels of the Russia's European Northeast, Northern Ural and Western Siberia, as well as describing the structures of Russia's earth crust. On completing the Leningrad Mining Institute in 1954, V.A.Dedeyev have worked in the Union-wide Oil Geological Survey Institute until 1967. In 1967-1975, he had implemented research in the Institute of Geology and Geological Chronology of AS USSR (Getzen,2016, pages 68–69).

Since 1975 until last days of his life, the scientist had worked at the Geological Institute of Komi NC of the Uralian department of Russian Academy of Sciences. He was the founder and leader of the Institute's oil department and the Syktyvkar School of Oil Workers. More than 20 years of his life were dedicated to a geology of fossil fuels of the Timan-Pechorsk petroleum province, including its' tectonic regioning in connection with oil-and-gas content, assessment of the region's hydrocarbon perspectives and planning of main geological surveying activities. Remaining supporter of the hypothesis standing for biogenic origin of hydrocarbons, Dedeyev used to assign high priority on a tectonic factor and always underlined confinement of hydrocarbon deposits to the global zones of destruction and their adjacent "resonant basins" (Plyakin, 2010, pages 67–72).

In 1983-1984, V.A.Dedeyev had actively participated in the development of functional pre-Cambrian stratigraphic sectional plane of USSR. In the same period, he chaired the commission for development of functional stratigraphic sectional plane of Timan's Late Proterozoic formations, membered by the country's well-known experts in pre-Cambrian geology. We became friends during joint field excursion, during which we have shared a single tent with him, V.G.Chernov and Y.D.Smirnov.

V.A.Dedeyev was known as good conversationalist and the man of heart and with fine sense of humor with a slight impediment giving special charm to his speeches. He has been selected a professor of the International Philatelic Society and possessed a unique collection of various topical stamps. His other interests included flora and fauna. Dr. Dedeyev left a number of serious works and preliminary studies to help properly select a direction for further activities. He could have contributed even more into the development of geological science and practice (Plyakin, 2011, pages 31–32).

Vsevolod Georgiyevich Olovyanishnikov (Getsen) was born on May 18, 1936 and completed the Perm State University in 1960. In the same year, he entered the Syktyvkar Institute of Geology where he grew from research technician to senior scientist and PhD in geology and mineralogy. Practically from his first independent steps in geology, the scientist dedicated his research to stratigraphy and geology of Timan's most ancient pre-Cambrian formations, and studied them till his death on March 27, 2006 (Getzen, 2016).

V.G.Getsen used to be very keen to examine a factual material in his attempts to explain the most ancient geological events. He persistently worked over his ScD thesis and continuously supplemented it with new information. Unfortunately he never got a chance to defend it, through completely deserved a doctoral degree according to his profound qualification.

I met Vsevolod in 1965 during fieldworks in Middle Timan. This meeting had marked the beginning of our long-running practical and scientific partnership. Always trying to deeply examine structure and occurrence mode of the local Proterozoic formations, he had left no stone unturned. Getsen was the only geologist in Komi and entire Northern Europe to visit every single location in which these interesting formations were revealed. He practically walked across the entire Southern, Central and Northern Timan, Volsk-Vym ridge, as well as Kanin and Kolsk peninsulas (Plyakin, 2010, pages 31–32). Together we have studied similar formations in Southern Ural and participated at the Union-wide conference on Perm's pre-Cambrian series. From each of his fruitful expeditions, Vsevolod usually returned with rich collection of rock materials.

V.G.Getsen actively participated at every scientific conference and sessions which have been organized in Komi Republic. He had contributed a lot to development of a stratigraphic sectional plane of the ancient formations from the north of the European part of the Soviet Union, approved by the Inter-agency pre-Cambrian Stratigraphic Committee of USSR. Outcomes of his scientific researchers have been published in more than 100 articles and monographs dedicated to stratigraphy, metamorphism and structures of the Timanian range and Kanin peninsula. Legacy of Getsen is known as the richest scientific heritage in the described sphere.

Vadim Grigoryevich Chorniy – graduate of the geological faculty of Dnepropetrovsk State University, PhD in geology and mineralogy, chief engineer of Ukhta Geological Survey Expedition, chief geologist of Ukhta Territorial Geological Administration. Having started his geological practice with the Northwestern Geological Administration, he became one of the founders of Ukhta Geological Survey Expedition (UGSE) in 1958. V.G.Chorniy was the first on-production teacher for many young geologists in Timan. He has established the first geological museum in UGSE and founded a geological coterie for young researchers, which was later transformed into Scientific and Technical Society "Gornoye". He was the one to defend hardly an importance of exploring the rare metals in Timan in front of the Geological Ministry of USSR. Vadim had first launched the exploration of bauxites in Southern and Middle Timan. It was due to his efforts that the Timanian bauxitic province was opened with complex of exploration activities. Ha had also initiated the meso- and large-scale surveying of Timan (Plyakin, 2014, pages 379– 381).

V.G.Chorniy had supervised a scientific effort to study the Timanian metallogeny and the stratigraphy of its' oldest deposits. Being a prominent manager, he had never parted with microscope while studying the ancient Timanian rocks. Vadim had a clearly defined proactive attitude. He was unable to sustain an even tenor of life and continuously tried to activate it. Vadim spent the last years of his life in the city of his youth – Leningrad (Saint Petersburg) - city in which he had once started his professional career in the Northwestern Geological Administration. Working as leading specialist of Western Geophysical Trust and Geophysical equipment factory (Plyakin, 2013, pages 79–8), Vadim died at the age of 71.

When exploring diamond deposits in Middle Timan, V.G.Chorniy had actively introduced methods of mining geophysics into a geological exploration practice. It fell upon me to cooperate with this scientist in Northern Timan and Kanin peninsula (Chetlas rock). I treasure him in memory as an exemplary practicing geologist.

Nikolay Pavlovich Yushkin completed Kirov Mining Technical School in 1955 and Tashkent Polytechnic Institute in 1965. His ranks included ScD in geology and mineralogy, professor, academician of RAS, merited scientist of Komi ASSR and Russia, winner of the awards of Lenin Komsomol, Council of the Ministers of USSR, A.Y.Fersman, etc. (Fishman, 1997, pages 302–304).

N.P.Yushkin died on September 17, 2012. In his face, both Russian and international science without an outstanding scholar-geologist, science organizer, teacher and good man of the heart. His funeral was attended by many friends and colleagues, Russian scientists, leaders of Komi Republic, representatives of universities, Syktyvkar and geological organizations. His death was an irreplaceable loss for the world's geological science. N.P.Yushkin was distinguished for his exceptional industriousness, curiosity and insistency. For 6 years after graduating from the mining and chemical college, he worked in sulphur deposits of the Middle Asia, where he collected rich material for his PhD thesis. With depth of the implemented studies and drown new scientific conclusions taken into account, the thesis was given a status of ScD dissertation. It has to be stressed that this success is a true achievement for talented geologist who had just completed correspondence courses of the Tashkent Polytechnic Institute in 1965 (Plyakin, 2013, pages 32–43).

Since 1961, N.P.Yushkin occupied various positions in the Institute of Geology, starting from research technician and ending with the institute's director. Although he has had many trials due to the hard times for practical geology, Yushkin had managed to preserve Institute's personnel and supply its' laboratory with most recent technical basis.

Being a global-scale mineralogist, Nikolay had actively supported the practical activities of Timanian geologists, especially efforts undertaken in the areas of diamond, bauxite and gold exploration. He had founded the Republic's council of young scientists, established several new laboratories within the Institute's framework, organized various scientific conferences and sessions, and developed close cooperation with many international research organizations and foreign scientists.

Due to his outstanding knowledge and experience, N.P.Yushkin was many times elected a member of the Russian National Committee of Geologists, vice-president of the Russian Mineralogical Society, member of Bureau of the RAS Department of Earth Sciences, member of Presidium of the Uralian Department of RAS, and member of the Scientific Center of Komi.

For a number of years he used to be a member of Council and vice-president of the International Mineralogical Association, as well as honorary and full member of many international scientific societies and academies.

N.P.Yushkin had developed a brilliant mineralogical school through preparing 1 academician, 9 doctors in geology and mineralogy, more than 35 PhDs. Appreciation of his scientific merits wasn't limited to various state, republic's and academician awards. His name was also given to a newly discovered Uralian mineral – *yushkinite*.

For many years, I was lucky to be a friend and colleague of N.P.Yushkin. I treasure a memory of this brilliant scientist in my heart.

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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 verməlləri 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

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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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