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TECTONIC EVOLUTION AND SEDIMENTARY MODELS OF THE MESOZOIC DEPOSITIONAL COMPLEX IN THE SOUTH-EASTERN FLANK OF THE TEREK-CASPIAN DEPRESSION: NEW INSIGHTS FROM INTEGRATED GEOLOGICAL AND GEOPHYSICAL DATA

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A B S T R A C T

Based on an integrated analysis of recent seismic surveys and drilling data conducted in the southeastern part of the Terek–Caspian Depression, within the Caspian coastal Guba oil and gas region and the Northern Absheron uplift zone, which is considered one of the main tectonic elements of the Absheron Archipelago, seismic horizons corresponding to the Lower Jurassic, Middle Jurassic, Lower Cretaceous, and Upper Cretaceous surfaces were correlated on dynamic depth sections of regional seismic profiles oriented in different directions and reflecting the distribution patterns of Mesozoic deposits within the geological section. Using seismic sections reinterpreted through modern approaches, structural maps of the Mesozoic horizons were compiled and geologically interpreted. The structural framework of the Mesozoic complex was refined, and several structural uplifts were identified. The lithostratigraphic characteristics and depositional environments of the strata within the study area and adjacent zones were investigated, and the distribution patterns of these deposits were determined. Organic-rich and reefal limestones formed under shallow-marine conditions on the southeastern flank of the Greater Caucasus are considered favorable reservoirs for hydrocarbon accumulation. Their paleotectonic and paleogeographic settings were also examined. Analysis of the reconstructed paleoseismogeological sections indicates that sedimentation in the Khudat area occurred under relatively shallow-marine conditions and at higher sedimentation rates, whereas south of the Aghzibirchala uplift sedimentation took place in a deeper-marine environment. During the Middle Jurassic, the Aghzibirchala and Khachmaz uplifts, which originated in the Early Jurassic, continued their development. The timing of structural formation and the hydrocarbon potential of these structures were also assessed.

Keywords: seismic exploration; Mesozoic complex; sedimentation; hydrocarbon potential; tectonic structure; paleotectonic and paleogeographic conditions; oil and gas potential.

Date submitted: 04.03.2026 **Date accepted:** 05.06.2026 **Date published:** 10.06.2026

Introduction

In Azerbaijan, within the South Caspian oil-gas basin, hydrocarbon generation is primarily associated with thick clay-dominated Cenozoic sedimentary complexes accumulated from the Middle Eocene to the Upper Miocene. In this basin, industrially significant hydrocarbon accumulations have been realized most effectively in younger reservoirs, particularly within the Pliocene Productive Series deposits. However, against the background of a gradual decline in production from conventional exploitation targets, exploration focus has been compelled to shift toward deeper stratigraphic levels — the Mesozoic sedimentary complexes [1–4]. At the regional scale, the relevance of this direction is further reinforced by the presence of productive petroleum systems confirmed in adjacent regions, especially in the directly bordering Terek–Caspian foredeep. From this perspective, the onshore and offshore sectors of the study area located on the southeastern flank of the basin are regarded as the most prospective zone in Eastern Azerbaijan with respect to Mesozoic hydrocarbon systems. Despite the drilling of more than 300 wells penetrating the Mesozoic complex in the area, the discovery of industrially significant oil and gas accumulations remains unsatisfactory. This deficiency mainly arises not only from the stratigraphic affiliation of the source rocks but also from the insufficiently clarified mechanisms of reservoir formation. Specifically, evaluation of the spatial distribution limits of source rocks and reservoirs without considering the direct control exerted by paleotectonic and paleogeographic conditions on sedimentation has restricted the attainment of reliable results. In this regard, accurate reconstruction of the geological evolution history and sedimentation models is essential for reducing exploration risk. The principal objective of the present study is to fill this scientific gap through comprehensive analysis of new geological-geophysical data.

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http://dx.doi.org/10.5510/OGP2026SI101187

Geological and geophysical exploration status

Results obtained from long-term studies of the Mesozoic source rocks of the region are not unequivocal and exhibit a contradictory character. Thus, in early investigations, K. A. Ismayilov (1955) and A. A. Alizade (1969, 1972) attributed the principal role in petroleum generation to the Jurassic (particularly the Middle Jurassic) deposits, whereas later S. S. Hajiyev (1981) substantiated the Upper and Lower Cretaceous (Campanian–Maastrichtian), A. A. Alizade et al. (1999) the Upper Jurassic, and A. H. Gojayev (2009) and G. A. Suleymanov (2010) the high potential of the Neocomian deposits together with the Middle Jurassic. In more recent studies, Ak. A. Alizade et al. (2015, 2024), who performed a more precise differentiation by fluid types, classified the Middle Jurassic (Aalenian–Bajocian) deposits mainly as gas-prone, and the Cretaceous (especially Lower Cretaceous) deposits as sources of oil and condensate. In order to eliminate the existing contradictions, A. I. Khuduzade et al. (2026) applied a new integrated approach combining the geochemical indicators of the basin located at the Eurasia–Gondwana junction with global paleogeographic events (particularly OAE 2). As a result of the study, the thick shale deposits of the Upper Cretaceous Cenomanian–Coniacian interval were identified as the most productive oil-prone complex (containing Type II kerogen) directly associated with global events (especially the Oceanic Anoxic Event – OAE 2). In contrast, the massive black shales of the Middle Jurassic (Aalenian–Bajocian), showing analogous features to European basins, were characterized mainly as a gas-generating source, whereas within the heterogeneous Lower Cretaceous (Neocomian) succession high-quality source rocks were determined to form only within local intervals (primarily related to the Hauterivian–Barremian transgressive pulses of the Tethys). This refined stratigraphic model has resolved long-standing debates regarding the source-rock potential of the region and differentiated the degrees of thermal maturity between onshore (unequivocally Jurassic) and offshore (throughout the entire succession) areas. Geological and geophysical exploration activities in individual parts of the study zone were initiated in the early 1930s. The materials obtained over the past period have been analyzed by numerous researchers, and as a result it has been demonstrated that favorable conditions for hydrocarbon accumulation exist within sedimentary complexes of different ages and at their contact zones [5–40]. In areas subjected to geophysical (gravimetric, electrical, and seismic) exploration, a number of structural uplifts were identified and prepared for deep drilling [6, 7, 9].

Within the study object known as the Khazaryani–Guba oil–gas region, drilling operations onshore recorded industrially significant oil and gas shows from the Middle Jurassic Bajocian (Beyimdagh–Tekchay, Yalama, Khudat and Keshchay areas), the Lower Cretaceous Valanginian–Hauterivian (Beyimdagh–Tekchay, Shurabad areas) and Albian (Yalama, Khudat, Afurja, Keshchay, Beyimdagh–Tekchay, Sitalchay areas) reservoirs. In the Siyazan monocline areas, oil and gas shows were observed within the Upper Cretaceous succession [8, 10, 12].

As for the offshore sector, the most important fact in terms of Mesozoic prospectivity in this zone is the recorded presence of hydrocarbons within the Lower Cretaceous rocks of the Khazri area.

Exploration activities within the study zone and analytical work in this direction are currently ongoing [19–26]. In many studies, for example [14, 23, 24, 26, 28–30], the structural–tectonic framework of the areas has been refined on maps reflecting the structural configuration of the Mesozoic surface, lithofacies analyses have been carried out, and their interrelations have been established. In addition, paleoseismogeological sections have been compiled along regional seismic profiles covering numerous tectonic zones for the Lower and Middle Jurassic, Cretaceous, Maykop and Pontian deposits [27, 29, 30].

Based on the results obtained from the analysis of the numerous studies listed, it can be noted that the main factor reducing the efficiency of exploration within the Mesozoic complex is associated precisely with the недостатacies in integrating existing geological and geophysical materials using advanced approaches.

Geological framework and stratigraphic characteristics

Geological and geophysical exploration conducted in the study has enabled the delineation of major structural-tectonic zones that differ sharply in their structural characteristics from southeast to northwest: the Khizi tectonic zone; the Tangi-Beshbarmagh anticlinorium; and the Gusar-Devechi superimposed trough [40]. Within the latter zone lie the Gaynarja (Guba-Devechi) and Zeykhur troughs, separated by the Gusar-Khachmaz and Samuryani uplift zones (located northeast of the Zeykhur trough). Additionally, the Siyazan monocline, where a major oil field has been discovered, is distinguished at the transition from the Gaynarja trough to the Tangi-Beshbarmag anticlinorium. Local uplifts within the Cenozoic sediments have also been identified in the southwestern part of the Gusar-Devechi trough (fig. 1).

The thickness of the Meso-Cenozoic sedimentary complex in the eastern Azerbaijan ranges from 5 to 12 km. The maximum thickness is recorded in the Gusar-Devechi trough. Surface exposures of Mesozoic sediments are observed in the Khizi zone, while Paleogene-Miocene outcrops occur in the Siyazan monocline. The litho-stratigraphic analysis of the Mesozoic complex reveals that the Upper Triassic consists of metamorphic rocks, whereas the Lower Jurassic comprises volcanogenic-sedimentary formations, penetrated only in the Aghzibirchala area. The Middle Jurassic, with a thickness of 500-1500 m, is characterized by terrigenous rocks and has

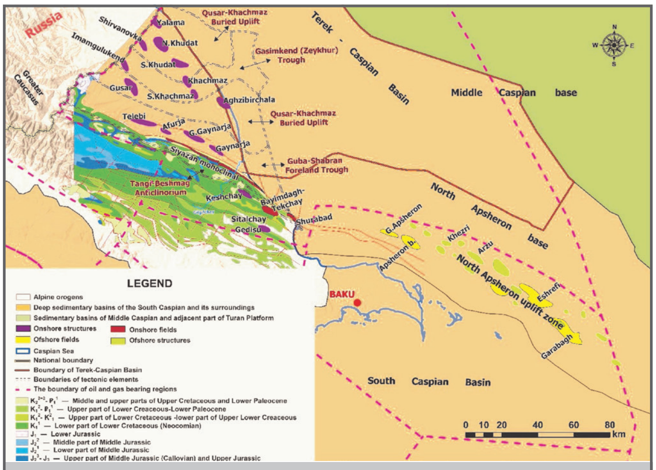

Fig. 1. Geological-tectonic units of the study area

been penetrated in the Yalama, Khudat, Khachmaz, Telebi, Aghzibirchala, and Bayimdagh-Tekchay areas.

During the Upper Jurassic, general uplift in the southeastern Caucasus resulted in continental conditions across most of the study area. Consequently, Upper Jurassic sediments are absent in most of the zone, and Berriasian-Valanginian deposits rest transgressively on the Middle Jurassic. However, in the Shahdagh and Gizilchay areas, the Upper Jurassic is represented by 700 m thick biogenic limestones. Dolomite beds are also encountered in the section. West of the Gilgilchay, outcropping Tithonian limestones pinch out in a southeasterly direction.

In the northeastern part of the region (Yalama, Khudat, Khachmaz, Aghzibirchala, Gusar, Telebi areas), the lower stages of the Lower Cretaceous (Berriasian-Valanginian and Hauterivian) are absent from the sections of drilled wells. These sediments consist of alternating limestone, sandstone, marl, and conglomerate in the Keshchay uplift, and sandstone, limestone, clays, and micro-conglomerates in the Bayimdagh-Tekchay area. Although clay beds predominate in the Gedisu area section, marl layers are also encountered. Barremian deposits are characterized by sandstone, clay, and marls in the Yalama area, but are represented by clayey lithofacies in the Khizi zone.

Due to intense erosion in the Gusar, Khachmaz, and Telebi areas, the Middle Jurassic is transgressively overlain directly by Sarmatian deposits, and by Pliocene sediments in the Aghzibirchala area. Furthermore, with the exception of the Yalama and Khudat uplifts, Cretaceous sediments have been eroded at the crest of other uplifts within the Gusar-Devechi trough. In the Yalama and Khudat areas, the Lower Cretaceous encompasses the Barremian, Aptian, and Albian stages, while the Upper Cretaceous covers the Turonian-Maastrichtian intervals. Lithologically, these sediments mainly consist of alternating calcareous sandstones, limestones, marls, and clays.

Tectonic activation in the southeastern Caucasus during the end of the Cretaceous and the Early Paleogene resulted in Paleogene sediments overlying Maastrichtian-Aptian deposits with angular and azimuthal unconformity. The Cenozoic cover over the Mesozoic deepens and expands towards the northeast into the Caspian Sea.

Paleotectonic analyses — paleoseismogeological sections were compiled along regional seismic profiles of various orientations within the Khazaryani–Guba OGR for the Lower and Middle Jurassic, Cretaceous, Maykop and Pontian deposits [27, 29, 30].

In the paleoseismogeological section of profile I–I, extending from the eastern flank of the Khudat uplift to the Aghzibirchala area, faults formed as a result of tectonic processes during the Early Jurassic are observed (fig. 2). These faults caused the Lower Jurassic strata to be downthrown southward with small amplitudes. During this period, sediments accumulated under relatively shallow-marine conditions and at a higher rate in the Khudat area, whereas south of Aghzibirchala deposition occurred in deep-marine settings. As seen from the paleosection, in the indicated southern zone the deepest part of the basin during the Early Jurassic exceeded 2000 m.

According to the paleosection constructed for the Middle Jurassic, the thickness of these deposits reaches 240 m on the southern flank of the Khudat uplift, 500 m within the Aghzibirchala structure, and increases up to 1 km toward the south. During this period, the Aghzibirchala and Khachmaz uplifts that formed in the Early Jurassic became further developed. Small-amplitude faults also formed in the southeastern direction.

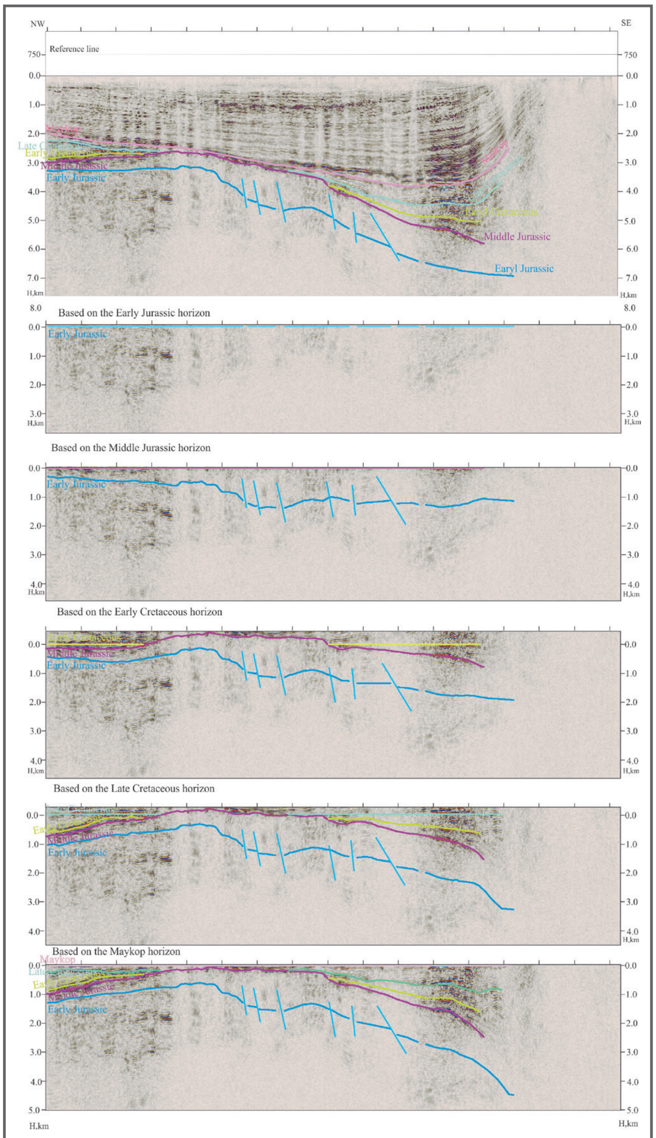

Fig. 2. Paleoseismogeological section along profile I–I (Khazaryani–Guba OGR)

Based on the paleosections compiled for the Cretaceous, the thickness of the Lower Cretaceous deposits accumulated in the Khudat area is smaller than that of the Upper Cretaceous deposits (550 m) and varies approximately between 90 and 20 m. Toward the southeastern flank of the structure, their thickness gradually decreases and wedges out into the Middle Jurassic deposits.

Similarly, a decrease in thickness of these deposits toward the Aghzibirchala structure from the Khachmaz uplift and their wedging out into the Middle Jurassic deposits is also noted.

In the paleoseismogeological section, the Maykop deposits are well traced throughout the section. Their thickness varies between 100–200 m in the northeastern continuation of the Khudat uplift and 120–250 m within the Aghzibirchala structure. A slight subsidence is observed southward from Aghzibirchala and the thickness of the deposits increases up to 700 m. Toward the end of the profile, tectonic uplift

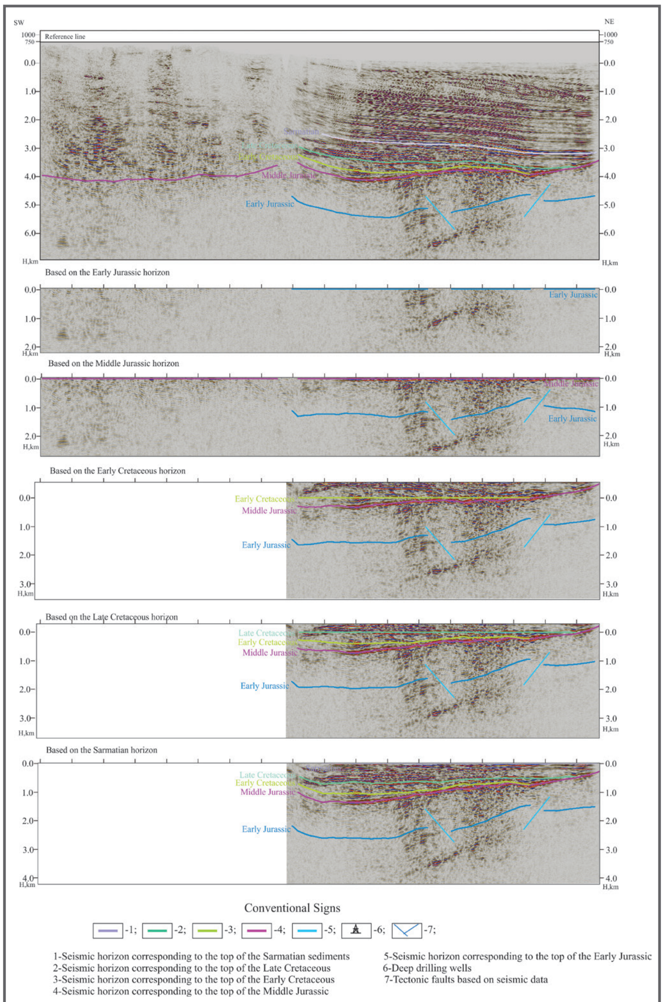

Fig. 3. Paleoseismogeological section along profile II–II (Khazaryani–Guba OGR)

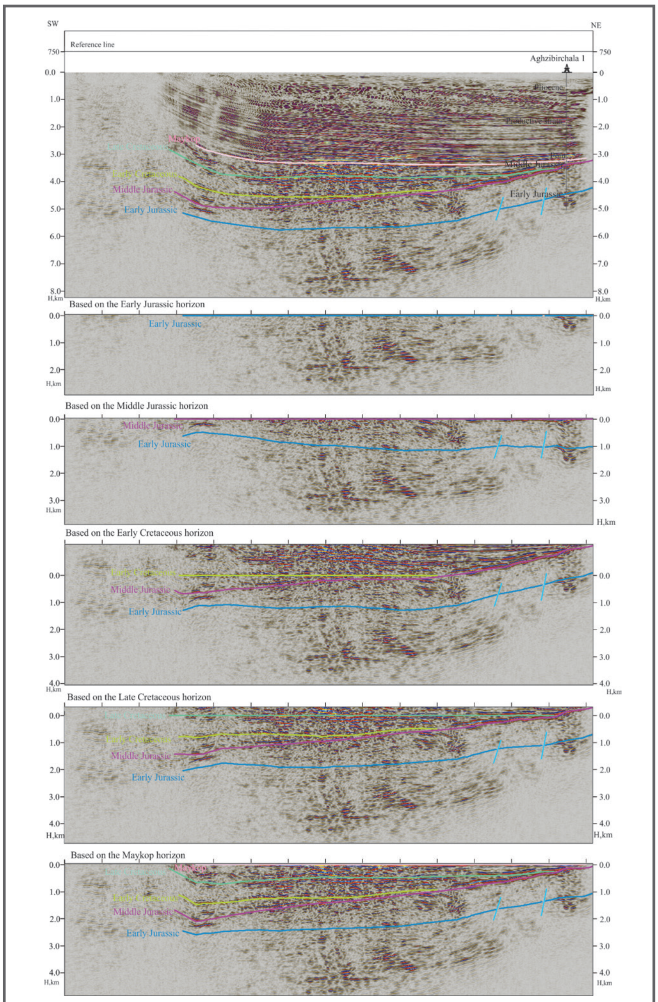

Fig. 4. Paleoseismogeological section along profile III–III (Khazaryani–Guba OGR)

processes during the Maykop time are observed.

Regional seismic profile II–II extends from the north of the Telebi structure to the south of the Aghzibirchala structure. In the paleoseismogeological section for the Early Jurassic (fig. 3), only the Middle Jurassic deposits are clearly traced up to the northeastern flank of the Gandob structure, except for minor-amplitude faults. Toward the Eastern Gandob uplift these deposits underwent tectonic subsidence and their thickness relatively decreased. During the geological development stage, the thicknesses of the Upper and Lower Cretaceous deposits decreased and wedged out into the Middle Jurassic deposits on the southwestern flank of the Aghzibirchala structure. As a result of tectonic processes, the Lower Jurassic deposits were downthrown along numerous faults.

The regional seismic profile III–III involved in the study extends from the southern flank of the Gaynarja structure and the Gandob uplift to the south of the Aghzibirchala structure. In the compiled paleosection, small-amplitude tectonic faults are observed south of the Aghzibirchala structure during the Early Jurassic (fig. 4).

During the Middle Jurassic, tectonic processes caused uplift toward the Telebi direction, and northwestward from it increased sediment accumulation is observed, indicating deep-marine conditions in the area at that time. Faults formed within the Lower Jurassic horizon continued their development during this period. Toward the Aghzibirchala uplift, gradual thinning of the deposits is clearly seen in the section, indicating the initiation of uplift processes in the northwestern Aghzibirchala uplift zone.

As seen from the paleosections, although the thicknesses of the Upper and Lower Cretaceous deposits in the Gandob uplift are 770 and 550 m respectively, they wedge out into the Middle Jurassic deposits toward Aghzibirchala.

The thickness of the Maykop deposits is 600 m on the southern flank of the Gandob structure and decreases to 200 m toward Aghzibirchala.

The compiled paleosections indicate that the Aghzibirchala–Khachmaz uplift zones existed as land areas during the Early and Late Cretaceous. These deposits wedge out onto the Middle Jurassic surface in the flank and periclinal parts of the indicated uplifts toward the northeast and north. During these periods relatively shallow-marine conditions existed within the area of the present-day Khudat uplift.

During the Late Jurassic epoch, uplift movements predominated in the geotectonic regime. Organogenic and reefal limestones formed under shallow-marine conditions in the southeastern plunge of the Greater Caucasus are considered favorable reservoirs for hydrocarbon accumulation.

Paleoseismogeological sections were compiled for the Cretaceous, Eocene and Maykop deposits within the Northern Absheron uplift zone. Along the longitudinal axis of the uplift zone, in the profile section passing through the Northern Absheron and Gilavar structures, the paleosection

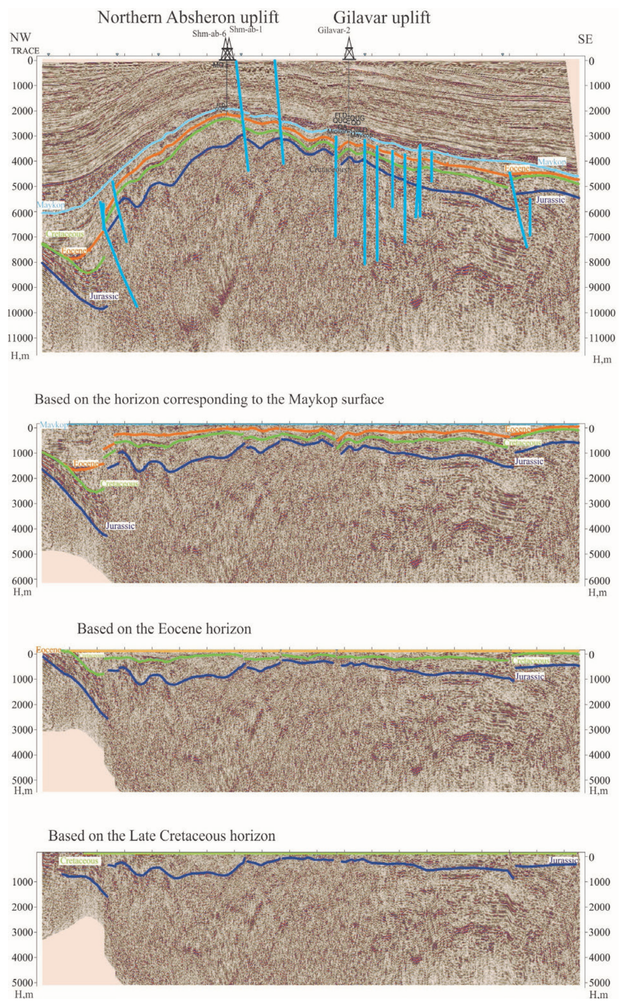

Fig. 5. Paleoseismogeological section along profile IV–IV (Khazaryani–Guba OGR)

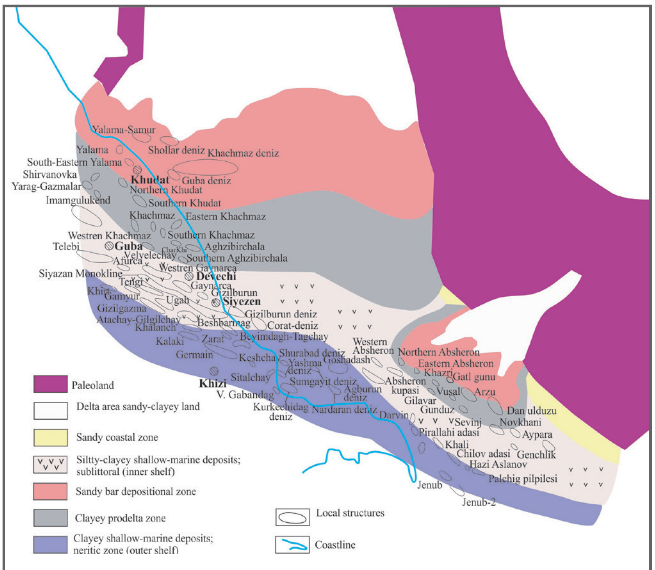

Fig. 6. Paleogeographic map of the southwestern margin of the Middle Caspian basin and the Northern Absheron uplift zone during the Aalenian

constructed on the Cretaceous surface shows that relatively deep-marine conditions existed northwest of the Northern Absheron uplift at the end of the Cretaceous. In the deepest part here, the total thickness of the Cretaceous deposits is approximately 1000 m. The deep part of this depression is complicated by uplifts at the level of the Jurassic surface. During that period an uplift existed within the Upper Jurassic deposits between the Northern Absheron and Gilavar uplifts (fig. 5). On this uplift, Cretaceous deposits about 200 m thick accumulated. Toward the southeast from the Gilavar uplift, the thickness of these deposits increased to 800 m. The most favorable conditions for sediment accumulation existed in the northwest, i.e., in the transition zone toward the Northern Absheron depression according to the present-day sediments.

Paleogeographic analyses — paleogeographic and lithofacies analyses show that during the Middle Jurassic the study area, together with the adjoining Southern Dagestan and Northern Azerbaijan territories constituted a single sedimentation basin [13, 23, 25, 26].

During this period, the maximum amount of sediment accumulation occurred in the Samur mountain ridge zone, where the thickness reaches 4000 m. Westward from the depocenter the thickness decreases to 1000 m along the Chanty–Argun River and to about 2000 m toward the southeast.

Gradual thinning of the deposits is also observed northeastward and southwestward from the basin axis. According to previous field studies conducted in Southern Dagestan, continental deposits are widely distributed there. Sand accumulations and swampy coal facies formed at river mouths within the coastal and delta plains of these areas.

In addition, thick sandstone bodies extending seaward are recorded in the Yalama–Samur area. All these indicate that during the Aalenian a large territory from the Middle Caspian basin to the Yalama–Samur structure represented land (fig. 6).

Due to the episodic desiccation of the central Caspian region, palaeorivers migrated southward, a process that led to the development of delta facies within the Yalama–Samur structural zone. Concurrently, a fall in the overall sea level of the Tethys resulted in emergence of the Karabogaz uplift, which had been present since the Paleozoic. Therefore, it is plausible that relatively small paleochannels drained from the Karabogaz uplift toward the North Absheron uplift zone and the North Absheron depression.

Below are some characteristics of the lithofacies zones in the Aalenian basin:

1. Freshwater floodplain, overbank lakes, swamps, coastal plains and delta channel zone dominated by continental sandy–clayey rocks. The deposits are mainly characterized by silty–clayey rocks with interbedded sandstones of various thicknesses. Up section, the proportion of silty–clayey rocks increases. The deposits are characterized by coal fragments. Coal-bearing layers are of small thickness and frequently wedge out and split. Coal seams of the Lower Aalenian stage are mainly confined to the deposits of this zone. Sandstones are light gray, gray, sometimes brown, fine-, medium-, coarse- and very coarse-grained and gravelly. Fine- and medium-grained sands predominate. Both well and poorly sorted rocks occur. Textures are diverse. For alluvial sandstones, multistorey, rhythmically graded, coarse, unidirectional, cross-bedding is characteristic.

Overbank deposits are characterized by wavy, curved-wavy and wavy-horizontal bedded platy and laminar sandstones. Lacustrine–swamp deposits are characterized by horizontal bedding, fine rhythmic or non-bedded texture.

Argillites are black, non-bedded or thin-bedded, poorly fissile, carbonaceous and largely represent swamp deposits. Mineral formations are characterized by siderite–pelite concretions and siderite–ankerite, siderite–calcite–pyrite compositions. In the cement of silty–sandy rocks small rhomb-shaped siderite, ankerite, kaolinite and pyrite minerals are observed. In bottom muds, geochemical conditions were determined by freshwater environment of the basin, low Eh values and neutral pH. Secondary alterations are expressed in quartz-like textural formations and accumulation of pyrite crystals and iron oxides.

2. Coastal marine and marine delta (bar, lobe) facies zone characterized by development of siltstone–sandy deposits. The deposits consist of siltstone–sand and gravelly rocks. Sandstones are unevenly distributed within the section. Their thickness ranges from 0.5 to 30 m, occurring as beds and lenses. These deposits are usually heterogeneous with argillite and siltstone interbeds and lenses. Depending on the facies characteristics of the coastal marine deposits, the following texture types occur in sandstones: thin-platy, wave-ripple marked horizontal-wavy; unidirectional, delta-type large-scale inclined sets (up to 1–2 m) with significant dip angles; coarse inclined multistorey bedding with graded terrigenous material from the lower to upper part of the section in alluvial deposits; and finally curved, unidirectional bedding characterized by changes in bedding type even of floodplain scale.

Sandstones are generally light gray, rarely gray, medium- and fine-grained, rarely coarse-grained with gravel. Sorting varies. By mineralogical composition the sandstones are polymict and monomineralic quartz (80–90%).

Siltstones occupy the second place in abundance. They are usually gray, dark gray and brown, fine- and coarse-grained. Sandy siltstones are cross-bedded, rarely massive and horizontally bedded. Cross-bedded varieties are fine and unidirectional or cross-laminated.

The texture is characterized by variation of the granulometric composition, carbonaceous–clayey material and frequent accumulation of mica flakes and carbonized plant detritus along bedding. In marine facies, ammonite remains are occasionally encountered. The rocks are characterized by numerous large carbonized plant remains and impressions of plant stems and trunks. Among minerals, siderite varieties are common, rarely calcite; ankerite, siderite, pyrite and kaolinite are characteristic in the cement.

Sedimentation occurred under freshwater conditions in a weakly reducing geochemical environment with oxidizing conditions and neutral pH. Secondary alterations are expressed by compaction of the rocks. Crystallized pyrite, iron oxides and rarely quartz are characteristic.

3. Zone of mainly silty–clayey and rarely sandy deposits developed within the shelf (subneritic zone), clayey deposits outside the shelf (neritic zone), and the distal part of the delta (prodelta zone).

Clayey rocks are gray and brown, poorly sorted, with predominance of sandy–silty material. The texture is usually spotted (lenticular) and intermittently wavy–curved bedded.

Siltstones are gray, fine- to medium-grained, weakly sorted. Clay content predominates and the mineralogical composition varies from polymict to oligomict. The texture is usually curved, unidirectional and frequently cross-cutting. Ammonite and foraminifera remains and pelecypod traces occur in the rocks. The rocks are characterized by numerous detrital carbonized plant remains and stem traces. Secondary minerals include calcite, iron oxides and widespread opal–chalcedony.

4. Facies of the deeper-water part of a shallow sea. Based on exposed Aalenian rocks, turbid deposits are characteristic. These deposits are represented by alternation of sandy and clayey rocks. Clayey rocks are dark gray, almost black, usually non-carbonate. Sorting is poor; silty clays are widespread and occasionally sandy–silty clays occur. The texture is obscurely bedded or indistinct thin-bedded, of flysch type. Sometimes clayey siltstones and occasionally sandy silts, as well-sorted rocks, are encountered. They usually form beds and interlayers within sandy rocks. Rock fragments are mineralogically polymict with poor rounding and sorting. The texture is generally massive, occasionally bedded and cross-bedded, with lenticular layers and carbonaceous clay interbeds. Mica flakes and small carbonized detritus are recorded in the beds. Ammonites, foraminifers and pelecypod traces occur in the rocks. The geochemical environment is characterized by a normal gas regime. Formation of the deposits ranges from reducing to strongly reducing conditions. Secondary alteration is expressed by compaction, hydromicatization of clay minerals and transformation of clayey rocks into argillites containing opal–chalcedony and leucoxene minerals.

Bajocian–Bathonian time. During the Bajocian, due to repeated lowering of the Tethys level below the present level of the world ocean, we assume repeated subaerial exposure of the Karaboghaz arch. Based on the thickness map of the Middle Jurassic deposits presented above, the sharp reduction in thickness in this area fully confirms this assumption. A sufficiently large land area was formed in the region. Theoretically, this land area could belong to the drainage domain of rivers flowing from northeast to southwest into the present Middle Caspian water area. It may be assumed that the marine parts of the deltas of these rivers could partly cover the northeastern part of the Northern Absheron uplift zone and partly the Northern Absheron depression (fig. 7).

The absence of Jurassic core material does not allow this fact to be stated unequivocally. At the same time, clearly expressed laterally extending layers are observed in some

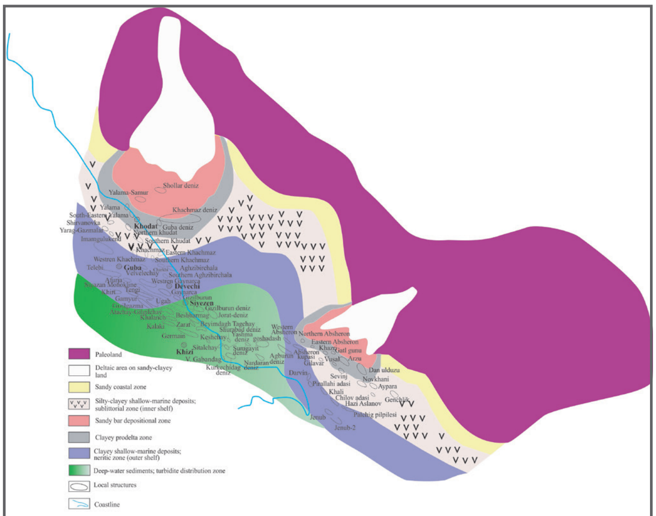

Fig. 7. Paleogeographic map of the southwestern margin of the Middle Caspian depression and the Northern Absheron uplift zone during the Bajocian

seismic profiles passing through the Arzu, Dan Ulduzu and other structures. Consequently, it may be assumed that accumulation of such sheet-like sand bodies occurred under deltaic conditions.

In addition, Bajocian sand layers identified in the section of well No. 1 in the Yalama–Samur area likely indicate their formation under avandelta conditions.

During the Bajocian the axis of subsidence slightly changes. A second southern depression, nearly submeridional in orientation, is formed. Within the depressions sediments 2000–2500 m thick accumulated. Toward the northeast from the main subsidence axis of the depression, the thickness of the deposits gradually decreases. The Middle Caspian region remains land, but according to the intensity of the gravity anomaly it is displaced somewhat northward.

Within the Northern Absheron depression and the Northern Absheron uplift zone the facies composition of the deposits is relatively homogeneous. Two facies zones are distinguished here:

1. Shallow-marine water facies zone of the outer shelf characterized by development of silty–clayey deposits. The deposits are characterized by irregular alternation of clayey and siltstone rocks with predominance of clays. Clayey rocks are dark gray and weakly sorted. The amount of siltstone material in the deposits averages 15–20%.

Siltstones are dark gray and light gray, sometimes brown, represented by clean and clayey varieties. Rock fragments are polymineralic. The texture is usually massive, occasionally cross-wavy laminated with carbonaceous–clayey material. Mica flakes and carbonized plant detritus are recorded in the beds. Ammonites, foraminifers and pelecypod traces are rarely encountered in the depositional zones. Among minerals, siderite or its dispersed crystals and pyrite are noted. The geochemical environment is characterized by a normal gas regime; muds are generally neutral in pH and reducing to strongly reducing in Eh.

Secondary alteration is expressed by compaction, hydromicatization of clay minerals and their transformation into argillite. Formation of iron oxides and opal–chalcedony is widely developed here.

2. Deep-water zone of sandy–clayey turbidite deposits. The deposits of this facies are characterized by irregular alternation of clayey and sandy rocks, with siltstones present in certain amounts. Clayey deposits are dark gray and the admixture of sandy–silty material constitutes 20–30 %. The texture is initially horizontal-bedded, often convolute-bedded or thin-bedded with light-colored siltstones. Slump (sliding) structures are typical for these rocks. Sandstones are mainly fine- and medium-grained, silty or clayey, gray to brownish-gray, weakly sorted and polymict; quartz occasionally predominates. The texture is massive or cross-bedded, the cross-bedding being related to variation in granulometric composition. Rare ammonite remains and foraminifer and pelecypod traces occur in the rocks. Individual interbeds may reach several meters in thickness.

Minerals are characterized by siderite, rare calcite and pyrite. Sedimentation occurred in a basin with a normal gas regime. The depositional environment ranged from reducing to strongly reducing at neutral pH values. Secondary alteration is expressed by compaction and hydromicatization of clay minerals and by transformation of clays into argillites with formation of opal–chalcedony and iron oxides.

Upper Jurassic time. With expansion of the transgression, the study area transformed into a shallow-marine basin. Warm and arid climate caused formation of biogenic and chemogenic rocks. The latter accumulated under extensive lagoonal conditions. Terrigenous sedimentation was practically absent. The gas regime of the basin was predominantly normal-marine.

By the end of the Callovian, supply of coarse clastic material nearly ceased. Carbonate sediments accumulated in the basin, while isolated areas of the basin formed dolomites.

During the Oxfordian, lagoonal depositional regime developed in the Dagestan territory. Unfortunately, absence of core samples from the structures of the Northern Absheron uplift zone does not allow confident interpretation of the deposits here. However, it may be assumed that homogeneous rocks accumulated within the Northern Absheron uplift zone. Increasing aridity of the climate at that time indirectly confirms this.

During the Kimmeridgian–Tithonian, the climate became even drier and warmer. Based on surface data, lagoonal depositional regime developed. Under conditions of increased water salinity, along with dolomite formation sulfate deposits were formed. Periodic salinization of lagoonal areas by marine or atmospheric waters resulted in formation of limestone–dolomite rocks containing orogenic clastic material.

Lower Cretaceous time. The Lower Cretaceous transgression began gradually with small-scale erosion. Based on gravity field intensity, northward retreat of land is observed and its size significantly decreased. As a result of retrogradational processes, more distal environments replaced proximal facies (fig. 8).

During the Valanginian the Tethys Ocean reached its lowest level, which was +75 m above the present level of the World Ocean. Naturally, this led to predominance of shallow-water and coastal-marine environments in Northeastern Azerbaijan.

Within the Khazaryani–Guba area, occasional carbonate rocks are recorded in the Valanginian section, characterized by limestones and dolomites. Thus, a lagoonal genesis of dolomite deposits and a lithofacies zone of shallow-marine limestone deposition are distinguished.

Dolomites are whitish-gray and pink, pelitomorphic and

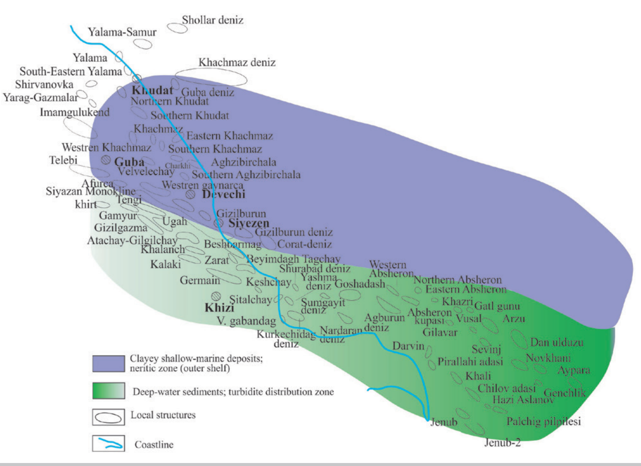

Fig. 8. Paleogeographic map of the southwestern margin of the Middle Caspian depression and the Northern Absheron uplift zone during the Lower Cretaceous

fine-grained. They are usually chemically pure or carbonate-bearing (up to 20–40% $CaCO_3$). The content of clay material varies between 10–15%.

Limestones are darker in color, micrograined and pelitomorphic in structure, dolomitic (20–30%), containing foraminifers and poorly preserved algal remains. Orogenic clastic material consists of bryozoans, pelecypods, brachiopods, echinoids, crinoids, foraminifers and others. Minor amounts of barite, celestine and pyrite minerals occur in the rocks.

Marls are scarce, whitish-gray, pelitomorphic, occasionally containing foraminifer remains and occurring in nodular form.

The geochemical conditions of formation of these facies deposits are determined by high salinity and alkalinity of waters and weakly reducing conditions in the muds. Secondary alteration is expressed by recrystallization and dolomitization of limestones. Presumably, in the Valanginian basin carbonate rocks accumulated within the Northern Absheron depression and the Northern Absheron uplift zone and analogously in the onshore area.

The Hauterivian is characterized by continuation of the Lower Cretaceous transgression. The climate remained more temperate, somewhat arid, and water salinity increased. Erosion intensified and correspondingly terrigenous sedimentation increased.

Based on investigation results of outcrops and their extrapolation to the offshore part, it may be assumed that during the Berriasian and Hauterivian outer-shelf deposits predominated in the Northern Absheron depression and are characterized by clayey rocks. The Northern Absheron area was covered by deep-water deposits where sufficiently thick sandy turbidites accumulated.

Thus, during the Neocomian the shallow-water sedimentation zone shifted northward and deep-water facies predominated within the study area. The Valanginian basin may be excluded, as carbonate rock formation was characteristic for it.

Such facies conditions also persisted during the upper half of the Lower Cretaceous. The wide distribution of turbiditic volcaniclastic sandstones in the Albian section of the Greater Caucasus confirms this. During the Albian, warm and humid climate accelerated erosion of the northern source area, and increased supply of terrigenous material was accompanied by turbidity currents, forming thick sandstone beds in the deep-water part of the basin and covering the Northern Absheron uplift zone.

Upper Cretaceous time. The presence of a warm, dry climate in the Upper Cretaceous allowed renewed accumulation of carbonate rocks formed under shallow-water conditions. Carbonate sedimentation practically covered the Northern Absheron uplift zone and the Northern Absheron depression. In the Upper Cretaceous section foraminiferal limestones dominate, whereas dolomitic rocks are limited in distribution. Their formation is mainly related to secondary dolomitization processes within limestone rocks.

Conclusions

In the study area, the Mesozoic sedimentary basins were formed under highly complex paleotectonic and paleogeographic conditions.

During the geological development stage, in the onshore–offshore transition zones of the Khazaryani–Guba OGR, the thicknesses of the Upper and Lower Cretaceous deposits decreased and wedged out into the Middle Jurassic deposits on the southwestern flank of the Aghzibirchala structure. As a result of tectonic processes, the Lower Jurassic deposits were downthrown along numerous faults.

During the Middle Jurassic, tectonic processes caused uplift toward the Telebi direction. Increased accumulation of sediments toward the northwest indicates deep-marine conditions in that area at that time. Faults formed within the Lower Jurassic horizon continued their development during this period. Toward the Aghzibirchala uplift, gradual thinning of the deposits is clearly observed in the section, indicating the initiation of uplift processes in the northwestern Aghzibirchala uplift zone.

During the Late Jurassic epoch, uplift movements predominated in the geotectonic regime. Organogenic and reefal limestones formed under shallow-marine conditions in the southeastern plunge of the Greater Caucasus are considered favorable reservoirs for hydrocarbon accumulation.

During the Early Cretaceous, the Aghzibirchala and Khachmaz uplift zones existed as land areas. The sediments accumulated during that period wedged out onto the Middle Jurassic surface in the flank and periclinal parts of the Aghzibirchala, Khachmaz and Khudat uplifts toward the northeast and north.

Within the Northern Absheron depression and the Northern Absheron uplift zone two main facies zones are distinguished:

- Shallow-marine outer-shelf facies zone dominated by silty–clayey deposits.
- Deep-water zone dominated by sandy–clayey turbidite deposits.

The deposits of this facies are characterized by irregular alternation of clayey and sandy rocks.

During the Eocene, small-scale hemianticlinal uplifts — Northern Absheron, Eastern Absheron and Khazri — separated by shallow synclines began to form within the Cretaceous deposits. These uplifts continued their development during the Maykop time.

Analysis of the sections shows that within the Northern Absheron uplift zone, during the Cretaceous up to 1000 m of sediments accumulated northwest of the Northern Absheron uplift.

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