



Lithological Types of Deposit - A New Strategy for Exploration Works for Oil and Gas in Southern Mangyshlak, Kazakhstan

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Abstract

The depletion of traditional structural traps in South Mangyshlak has prompted a strategic shift toward exploring lithological and stratigraphic types of oil and gas accumulations. This article examines the formation of such traps within the Jurassic and Triassic deposits, focusing on promising sandy horizons of fluvial and deltaic facies. These horizons are often confined by pinch-outs and transitions into dense, impermeable rocks. Through lithological analysis and paleogeographic reconstructions, the study enhances the accuracy of predicting hydrocarbon-bearing zones. The application of 3D seismic surveys and modern drilling techniques enables the identification and development of new, previously unrecognized reservoirs. Findings suggest that exploration efforts should be concentrated on Jurassic wedge-out zones located along structural flanks, above basement paleo-highs, and at intersections of stratigraphic unconformities with faults—areas considered favorable for significant hydrocarbon accumulations. Middle Jurassic deposits in Southern Mangyshlak and the Caspian region contain transitional fossil complexes, including both terrestrial flora and marine fauna. The lower (Aalenian–Bajocian) part features spores, pollen, and plant remains, reflecting continental (river) conditions. Overlying deltaic and shallow-marine sediments indicate a gradual marine transgression. Delta-floodplain complexes record intense terrigenous input from Mountain Mangyshlak. By the Callovian, deepening marine conditions set the stage for Upper Jurassic carbonate deposition.

Keywords: South mangyshlak; Sedimentology; Tectonics and rifting; Deposit and facies; Oil and gas potential.

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1. Introduction

The deposits' origin is known as the proportional sediment contribution obtained from different roots, and it is specified mainly at locative scales extending from a single hillslope to a large (>10,000 km²) basin.^[1] Structural status, deposit attributes, and influence of diagenetic transaction indicate the reservoir quality.^[2-4] Sedimentary facies are the fundamental feature controlling construction and pore distribution in reservoir rocks.^[5,6] However, many of the main characteristics of carbonate reservoirs are diverse due to the effect of diagenesis.^[7,8] A facies can be qualified by many indicators that are ultimately related to the formation.^[9] Lithology, texture, depositional forms, and scorbutic content represent

these characteristics.^[10] Facies can be identified by binding all the formation processes, such as “riverine facies” or “turbidity facies”.^[3,11] A facies succession is a concatenation of facies that move gradually from one into the other and was introduced by Walther (1894).^[12] Walther’s law of facies is based on the assumption that facies lie on top of each other along with a crustal profile, and were once set up alongside each other.^[13] Estimating oil and gas prospects in sedimentary basins involves characterizing source rocks that give rise to hydrocarbons.^[14] Organic geochemical methods are a substantial issue and definitive for consolidating prospecting efficiency and improving the new oil and gas accumulation zones throughout the geological drilling, forecasting, exploration, and oil and gas development.^[15] The most appropriate drilling technique depends on the specific characteristics of the geological formation, deposition, and equipment used. It is essential to customize drilling recommendations to achieve the best possible results.^[16]

Numerous studies have been conducted in South Mangyshlak. Academician K.I. Satbayev paid special attention to the comprehensive study of the natural resources of the Mangyshlak Peninsula, including the exploration of new

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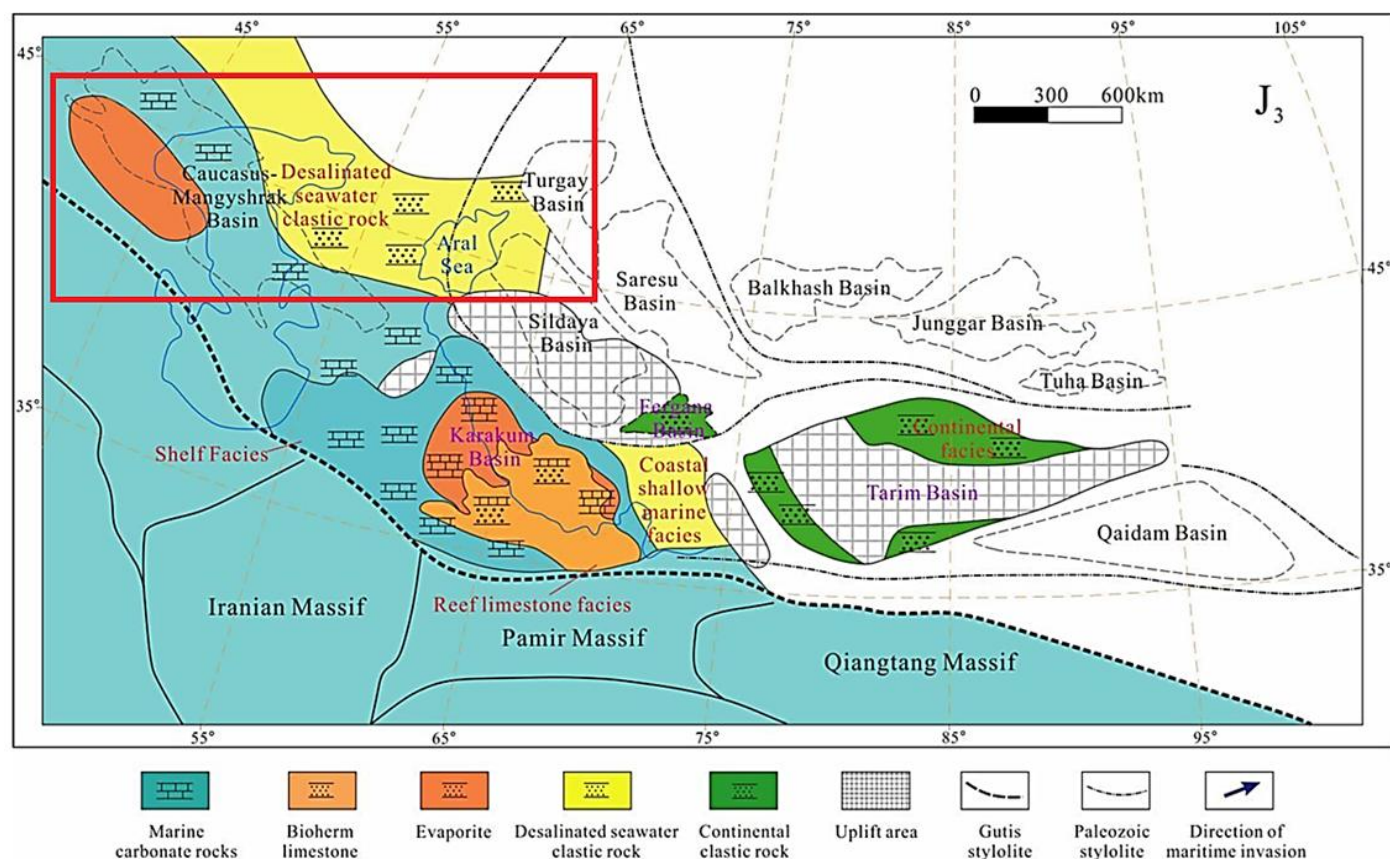


Fig. 1: Tectonic-lithofacies map of the northern margin of the West Asian section shows the late Jurassic era of Mangeshlak Basin. Reproduced from.^[28]

deposits of coal, oil, gas, and ferrous metal ores. Mirchink *et al.*, 1067 found that economic oil and gas occurrences in the Mangyshlak oil and gas-bearing region are primarily associated with Lower to Middle Jurassic terrigenous sediments. There are additional probabilities for new oil and gas detections.^[17] Sagers and Matzko in 1993 discussed the Oil Resources of Kazakhstan.^[18,19] A new integrated dissection has been sophisticated that combines static sediment modeling, microfacies analysis, and production conduct to consolidate the modulated region development regarding remaining oil.^[20,21] Rock-Eval pyrolysis was conducted on core samples from various ages of the Asar, Zhetybay, Karamandybas, Uzen, and Akkar reservoir fields in the Mangyshlak Basin to describe the source rocks and to clarify the causes for the various structures of oil biomarkers. This occurrence has given thought to a sharp decrease in the liquid hydrocarbon resources in Permian-Triassic sediments in contrast to Jurassic deposits, and an equally acute increase in the gas formation share.^[22] Kozhagulova *et al.* gave an introductory rating of the Mangyshlak Basin's geothermal energy potential by depth-temperature profiles to output the first regional division maps for temperature.^[23] The Cretaceous sequence of the Mangyshlak area is reviewed by the geological framework of Mesozoic sediments in the Kazakhstan part of the Caspian Sea, South Mangyshlak sedimentary basin, was investigated by Nurabayev (2024).^[24]

This article outlines a comprehensive strategy that utilizes 3D seismic exploration and modern drilling methods to aid in identifying and developing new deposits. The results indicated that it is advisable to concentrate searches on the wedging zones of Jurassic layers located along the sides of structures and above paleo-elevations of the basement, as well as in the zones where stratigraphic unconformities intersect with faults.

2. Geological setting

South Mangyshlak is the oldest oil and gas region of Kazakhstan, where significant hydrocarbon reserves have been discovered in sedimentary basins of the Mesozoic era.^[25] Some of the significant oil and gas fields in this region are: Zhetybai, Uzen, Tenge, Oimasha and several others. All of these fields were discovered in the 60s-70s of the last century. Oil and gas potential is associated with Jurassic and Cretaceous deposits containing up to 25 productive horizons, mainly of Upper-Middle Jurassic age.^[26,27] Thermal descent of the post-rift depression primarily occurred in the Early Jurassic, and extensive marine transgression took place in the basin. During the Middle Jurassic, a thick sequence of shallow marine clastic rocks was deposited in the basin^[21] (Fig. 1)

Three zones can be identified in the South Mangyshlak basin, which include the Mangyshlak uplift system, the South

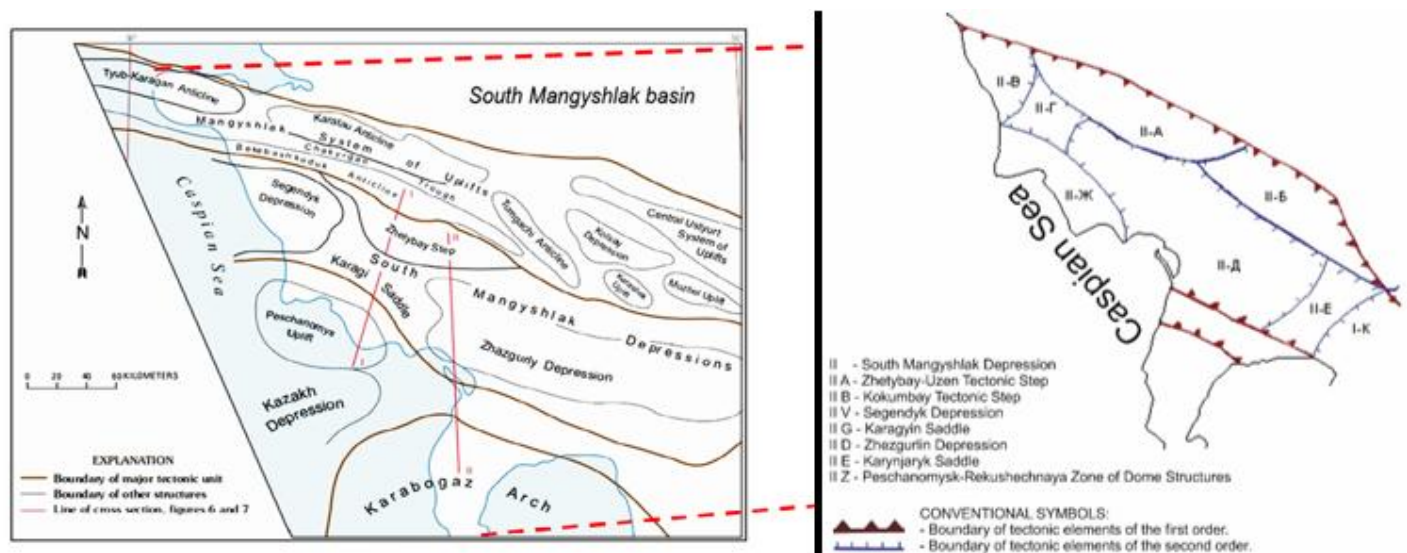


Fig. 2: Tectonic scheme of the South Mangyshlak basin. Reproduced from.^[35]

Mangyshlak depression, and the Karabogaz zone. (Fig. 2)^[29-31] All discovered and exploited hydrocarbon fields in South Mangyshlak are located within structural traps, specifically anticlines, which are considered traditional. Today, traditional structural traps in the oil and gas basin of South Mangyshlak have been largely exhausted, which makes the study of lithological deposits a relevant area of exploration. Successful identification and modeling of such traps in South Mangyshlak can contribute to increasing the resource base of the region and improving the efficiency of oil and gas production.^[32] South Mangyshlak, located in the western part of Kazakhstan, is characterized by a complex and diverse geological structure formed as a result of complex geodynamic processes in the region.^[21] The main structural elements of this area are the Beke-Bashkuduk swell, which occupies the northern part, and the South Mangyshlak trough, which covers the central and southern parts of the region.^[21] The formation of the depression is associated with late Permian-Triassic rifting, subsequent inverse uplift and active tectonics in the Mesozoic^[33] (Fig. 3). The geological section of South Mangyshlak contains deposits of various geological

periods, including Paleozoic, Mesozoic and Cenozoic rocks. of particular importance are the Triassic and Jurassic deposits, which are the main oil and gas bearing complexes of the region. Triassic deposits are represented by strata of carbonate and terrigenous rocks, in which significant reserves of oil and gas have been identified. Jurassic deposits are characterized mainly by continental facies with the development of sandstones and siltstones with good reservoir properties.^[34] The time of terrigenous sedimentation expanded from the earliest Cretaceous to the early Turonian and Neocomian succession, set up under variable Tethyan/Boreal effect. The major obstruction in marine sedimentation occurred during the early Hauterivian to Barremian period, which likely saw the deposition of continental sediments. Deposits from the Aptian to the early Turonian were formed within the European Palaeobiogeographical Region, which also experienced some Boreal invasions. The carbonate sedimentation in the "Chalk Sea" Basin of the European Palaeobiogeographic Region began in the late Turonian and continued through the Maastrichtian.^[19]

The tectonic development of South Mangyshlak has led to

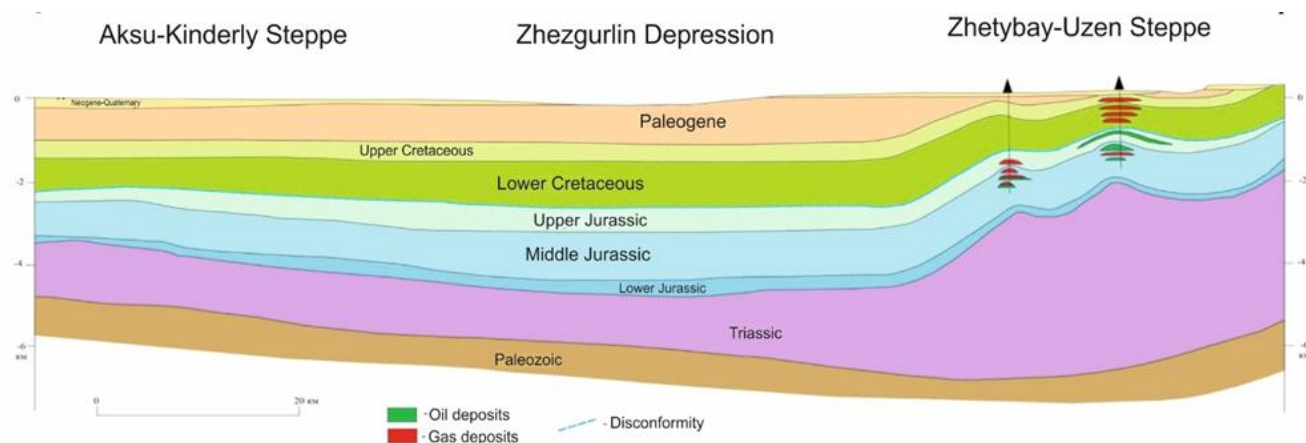


Fig. 3: Geological and geophysical section of the South Mangyshlak basin.

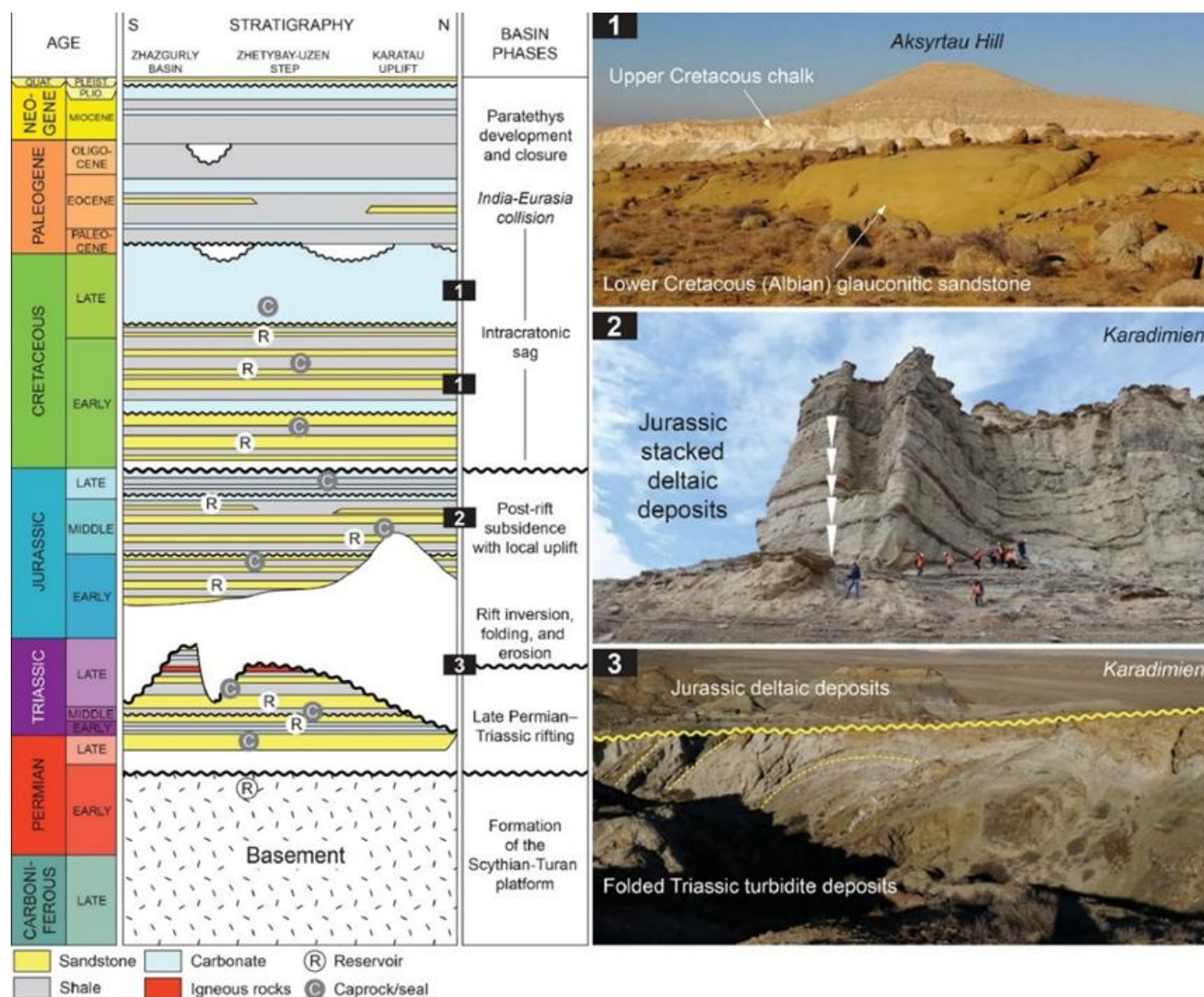


Fig. 4: Lithological-stratigraphic column of South Mangyshlak and Buzachi.

the formation of numerous folded structures, often complicated by faults. These tectonic features have contributed to the creation of favorable conditions for the formation of structural hydrocarbon traps. In particular, the region is widely distributed in anticlinal structures complicated by faults, which are the main places of accumulation of oil and gas and to which almost all previously discovered oil and gas fields are confined. However, in South Mangyshlak, in addition to structural deposits, lithological traps of oil and gas could have formed, associated with the features of sedimentation and the lithological composition of rocks.^[36] Thus, the geological structure of South Mangyshlak is a complex system, where the combination of various lithological complexes and tectonic structures creates favorable conditions for the formation and accumulation of significant hydrocarbon reserves in deposits of various types.^[37] Analysis of the Southern Mangyshlak section (Fig. 4) reflects the complex dynamics of tectonic development and sedimentation conditions in this region.

The main oil and gas complexes, as exemplified by the largest hydrocarbon deposits such as Zhetybai, Uzen, Tenge and others (Table 1), are mainly Jurassic deposits.^[38] The deposits of the Lower and Middle Jurassic were formed under conditions of continental sedimentation. These are river alluvial sandstones, coal-bearing clays, and siltstones. (Fig. 5)^[36,39-40] The facies, their features, and composition formed in continental sedimentation conditions. Eluvial, formed in weathering crusts and has a close paragenetic connection with the parent rocks, zoning: disintegration - fragments of original rocks and minerals; clay minerals - hydromica, chlorite, nontronite, etc.; Alluvial – channel alluvium formed in river beds, sharp, often with traces of erosion, sinuous, with pockets and protrusions, contact with underlying deposits, gradual contacts with overlying rocks. Mainly sandstones with layers of pebbles, gravelstones, siltstones, and clays.^[40-41] Alluvial floodplain alluvium is formed during river flooding, exhibiting paragenetic connections and gradual transitions with channel and oxbow sediments. It primarily consists of

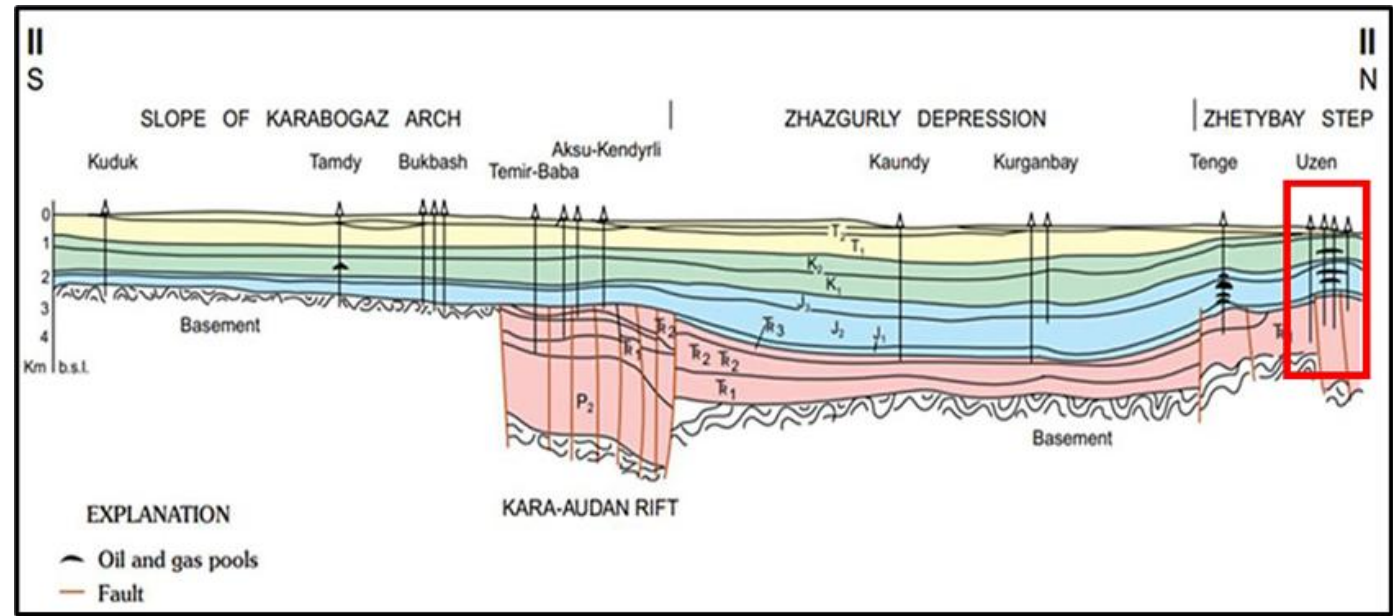


Fig. 5: Cross-section of the South Mangyshlak hydrocarbon deposits.

silty and clayey materials, with interlayers of fine-grained sandstones and soils.^[42]

Lake-marsh. Closely related to river, lake, coastal-marine (marsh swamps) facies, sandy-clayey, siliceous, and carbonate, aleuropelitic constant interbedding and alternation of siltstones and clays, interlayers of carbonaceous and sideritized clays, coal, and less often fine-grained clayey sandstones.^[43] Deluvial, formed by sheet runoff. Close connection with the lower parts of slopes, where they form inclined concave trains. Detrital fine-grained, weakly rounded, often loess-like material.^[44] Colluvial is formed by the displacement of physical weathering products along a slope due to gravity. It has a close spatial and material connection to the original rocks. The composition of colluvium varies in granulometry, ranging from large boulders to small rubble and fine materials, and its petrographic characteristics depend on the type of original rocks present.^[45] Proluvial, formed by

temporary water flows at the foot of slopes. Contacts with underlying and overlying deposits are sharp. Boulders, breccia conglomerates, conglomerate-breccias, sandstones, siltstones, clayey rocks.^[46] Aeolian sands: sandstones and coarse-grained siltstones with a sharp predominance of quartz, granite, magnetite, and other abrasion-resistant minerals; feldspars are rarely present; fragments larger than 5 mm, clay material, and micas are absent.^[47] Moraine, fluvioglacial, glacial-lacustrine facies of continental origin most likely were not formed due to the paleogeographic and paleoclimatic conditions prevailing in the Paleozoic-Mesozoic period in Southern Mangyshlak.^[48]

Geodynamic processes associated with the Hercynian folding in South Mangyshlak in the late Paleozoic led to sedimentation absent at this era. There was a long-term destruction of previously formed deposits.^[37] This stratigraphic break should be paid attention to when studying the oil and gas potential of South Mangyshlak, since this

Table 1: Indicators and petrophysical properties of the Jurassic strata for the Uzen, Zhetybai, and Karamandybas fields.

Field	Uzen	Zhetybai	Karamandybas
Indicator			
Location	North Caucasus-Mangyshlak	northwestern-trending brachy anticlinal fold	steppe part of the Mangyshlak Peninsula
depth of productive horizons		1700-2500 m	
Oil and Gas zones in the Jurassic strata	13	13	14
Gas specifications of the Middle Jurassic deposits	40-49% heavy hydrocarbons. N ₂ and CO ₂ are present	Methane 58.86-76.4%, heavy hydrocarbons - 22-37%, N ₂ 1.3-5.8%, CO ₂ 0.3-1.1%.	Methane 69.7%, heavy hydrocarbons 28.2%, N ₂ 1.9%, CO ₂ 0.2%.
Porosity	26.8-30.6%	16-22%	9-27%
permeability	0.2-0.4 μm ²	0.06-0.239 μm ²	0.05-0.3 μm ²
Oil density	844-874 kg/m ³	830-870 kg/m ³	840-861 kg/m ³
Oil Viscosity at 60 °C	3.4-4 mPa s	> 20 Centi stokes	9.4 mPa s
Oil saturation coefficient	0.53-0.73	0.55-0.65	0.44-0.71
Gas saturation coefficient	0.5-0.6	0.48-0.6	0.52



Fig. 6: The landscape of the Lower Jurassic period of Southern Mangyshlak.

circumstance can serve as a guide for identifying potential stratigraphic (non-structural) traps and hydrocarbon migration zones. Deposits can be associated with the weathering crust (eluvial) facies.^[38] Based on the analysis of the lithofacies composition of the deposits, biostratigraphic data (fossil flora and fauna), paleogeographic conditions, and features of sedimentation of the Jurassic period were identified.^[40] In the Early Jurassic, the Mangyshlak area was a lowland plain with a branched river network and episodic lakes in local depressions. The climate was warm and humid, as evidenced by coal-bearing layers and rich spore-pollen complexes of plants.^[50] The absence of marine fauna in the Hettangian-Toarcian deposits indicates the isolation of sedimentation basins from the sea and the prevalence of continental (river deltas, swamps, lakes) conditions. Small lake-swamp basins could form locally, in which thin layers of carbonaceous clays and coals accumulated among alluvial sandstones. At the end of the Early Jurassic (Toarcian Age), an increase in tectonic movements is observed (including on Karatau), which led to local breaks in sedimentation before the onset of the Middle Jurassic.^[50] Based on the actualism method, the landscape of the Lower Jurassic period of Southern Mangyshlak, with tolerances, can be presented as follows (Fig. 6).

These integrated analyses enhance reservoir characterization, support stratigraphic correlation, and contribute to accurate modeling of hydrocarbon systems,

ultimately aiding in the prediction of reservoir quality and seal effectiveness. It will benefit our country as a major oil and gas producing country.^[51-55]

3. Methodology

The new strategy involves an integrated approach: facies geologists, seismic interpreters and developers must work together. The creation of paleogeographic maps of the Jurassic period based on the results of the analysis of all wells and seismic data will allow us to identify zones of ancient river valleys, lake basins, deltas – i.e. potential lithological traps. In addition, the results of hydrodynamic studies should be taken into account: if anomalous reservoir pressures or hydrochemical anomalies are recorded in the section (for example, fresh water next to salt water), this may indicate isolated blocks of reservoirs that potentially contain hydrocarbons (the so-called hydrodynamic traps). Modern GIS (geological and geophysical information systems) methods make it possible to combine all the information – lithology, geophysics, hydrogeology – and build three-dimensional models of the distribution of reservoirs and seals.

3.1 Geological and geophysical methods, seismic stratigraphy

With technology advancements and the evolving understanding of hydrocarbon traps, exploration efforts are

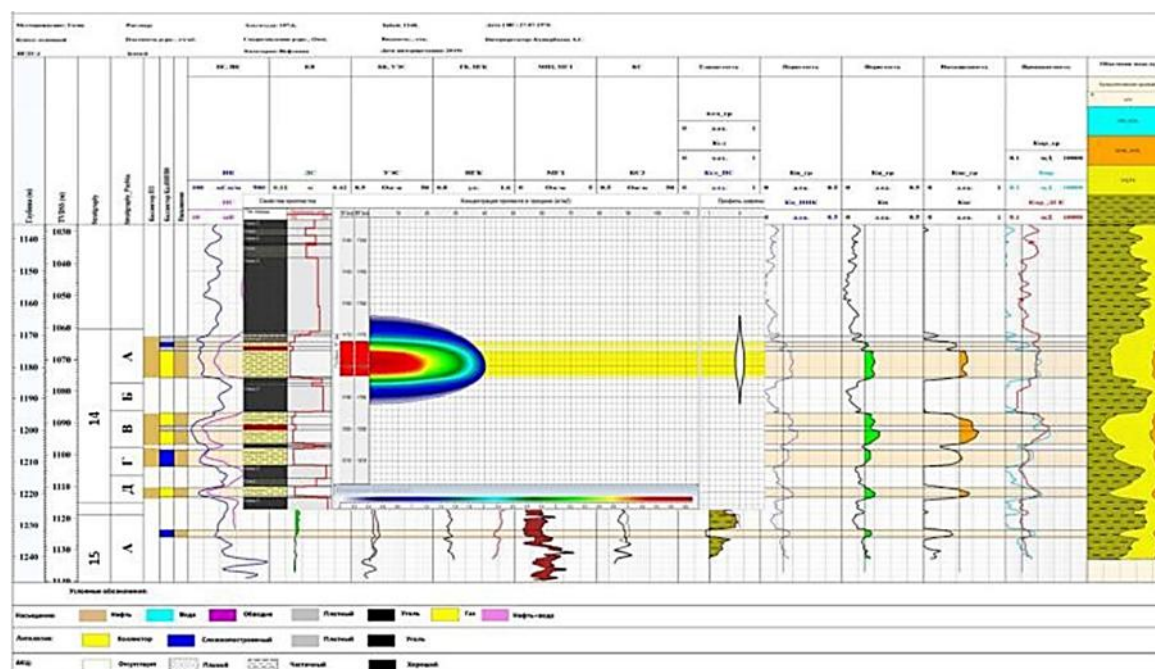


Fig. 7: Geophysical well Survey for Well-X in the area of study

increasingly focused on identifying lithological formations. High-resolution 3D seismic surveying is a crucial tool in this process. It is recommended to utilize seismic attributes that can differentiate between various facies. Attributes such as attenuation coefficient, signal phase, and impedance inversion can indicate sandstone pinch-outs within sequences rich in clay. The seismic stratigraphic approach enables the identification of seismic facies corresponding to ancient river channels, floodplains, and lacustrine expansions. This contributes to more accurate prediction of lithological boundaries—zones of pinch-outs and transitions between sandstone and argillite, which are considered prospective traps. Additionally, electromagnetic methods and scattered wave analysis was employed, as they can reveal hydrocarbon accumulations outside of classical structural settings—so-called direct hydrocarbon indicators (DHIs) within stratigraphic traps. Fig. 7 illustrates one of the geophysical well Surveys before the hydraulic fracturing process. The next step was identifying the reservoirs using a set of geophysical methods using direct qualitative features based on recording the penetration of the drilling fluid filtrate into the rocks: a decrease in the borehole diameter relative to the nominal diameter on the calipermetry and microcalipermetry diagrams; the presence of a radial gradient of specific resistance according to the probes with different research radii; a decrease in the radioactivity values relative to the host rocks. When identifying the reservoirs in well X, drilled with a weakly mineralized drilling fluid (solution resistance > 0.5 Ohm mm), the chemical element of Berkelium (BK) curve was compared with the Ionizing Radiation (IR) curve. Under

these conditions, the BK readings against reservoir beds are greater than the readings on the IR curve. In well X with mineralized drilling fluid (solution resistance < 0.5 Ohm), the BK curve was compared with the Borehole Magnetometric Resistivity (BMK) curve. Against dense, impermeable beds, the BK and BMK readings are close, against permeable oil-saturated beds.

3.2 Laboratory analyses and core studies

When moving to the search for lithological deposits, the importance of detailed studies of the core and well cuttings increase sharply. It is necessary to conduct a comprehensive lithological and stratigraphic analysis of the core: description of facies, diagnostics of rocks (grain composition, sorting, cement), paleontological analysis (spores, pollen, small mollusks) for reference to stratigraphic horizons. In the Jurassic deposits of the region, the biostratigraphy of continental strata is based on spore-pollen zones - therefore, each core intersection of carbonaceous clays should be accompanied by palynological analysis to clarify the age and correlation of layers between wells. This will help to link sand lenses identified seismically and understand whether they are a single body or several channels of different ages. Petrophysical studies of the core (porosity, permeability, capillary pressure) are needed to assess the filtration-capacity properties in different facies. For example, laboratory tests can confirm that sandstone with a certain cement structure has sufficient porosity for a reservoir, and the adjacent clay rock is essentially impermeable and serves as a seal. Mineralogical analysis of seal rocks is important (the presence of

hydromicas, montmorillonite, etc., which provide low permeability). Fluids are also studied in the laboratory - for unconventional traps, it is typical that oils can be heavier (due to proximity to the surface and biodegradation) or lighter (if migration from deep sources).^[56] In the Buzachi area, as already noted, the oils of the Jurassic and Neocomian deposits are partially biodegraded and heavy. Laboratory analysis of their composition (hydrocarbon, trace elements, isotopes) confirmed vertical migration from Paleozoic sources. This means that when searching for new traps, one can focus on geochemical anomalies – for example, increased content of light hydrocarbons in the cap rocks above a potential trap or special combinations of biomarkers indicating oil flow from underlying strata.

According to laboratory core analyses for horizons containing oil and oil and gas deposits, 513 permeability values and 561 porosity values were determined. For horizons XIII–XVIII, the number of permeability and porosity determinations was 482 and 530, respectively, and for horizons XIX–XXV, 31 permeability and porosity values. It should be noted that the lower horizons were studied by single wells, and the maximum number of porosity and permeability values was 7 cases for horizon XX. Laboratory core studies showed a fairly clear pattern of porosity decreasing with depth from 0.251 in horizon XIII to 0.139 in horizon XXV. The average porosity values determined by the GIS complex are somewhat lower than the determined porosity values by the core, the range of values fluctuates between 0.14 and 0.21 fractions of units. The maximum average absolute permeability values determined by the core are for reservoirs of horizon XIII, and the minimum value is for reservoirs of horizon XXI. The porosity and permeability values were determined by laboratory core analyses and by the results of the GIS complex, and the oil saturation values were determined only by GIS. As a rule, the permeability found by the core does not characterize the filtration properties of the formation as a whole, therefore, a method for determining permeability by GIS has been developed and is used at the field. The number of permeability and porosity values is significantly greater than by the core and is 5537 and 6951, respectively.

3.3 Analysis of the main oil and gas accumulation zones, typical deposits of the basin

In South Mangyshlak, the total hydrocarbon reserves exceed 6 billion barrels of oil equivalent (BOE), most of which (84%) are oil. Most of the hydrocarbon deposits of the Middle Jurassic terrigenous deposits are located on the Zhetybai-Uzen step to the south of the Mangyshlak folded belt (Fig. 1). The largest deposits belong to the Zhetybay-Uzen tectonic stage -

the Zhetybay gas condensate oil field and the Uzen gas and oil field. The most typical deposits are Northern Karamandybas, Tenge, Uzen, Zhetybay, Karamandybas, Asar, Turkmenoy. To date, 47 fields have been discovered in the basin, of which 32 (74%) contain oil, and 15 (9%) are gas and gas condensate. The overwhelming majority of fields (65%) are concentrated in the Zhetybai-Uzen step. The largest of them (Uzen and Zhetybai) are located here. The main role in the generation of hydrocarbons within the Mangyshlak part of the basin belongs to the clayey strata of the Lower-Middle Jurassic and Lower Cretaceous. In the Lower-Middle Jurassic deposits, the SORC content is 0.5–1%. The Lower Cretaceous strata are characterized here by strong sandiness, which reduces its oil source potential. Reservoir rocks are developed throughout the entire sedimentary filling of the basin.

Jurassic reservoirs are represented by sandstones, sometimes siltstones; in the Lower - Middle Jurassic they have a porosity of up to 25% and permeability of up to 0.003–0.005 μm^2 , and in the Upper Jurassic their porosity reaches 27%, permeability 0.034 μm^2 . The collectors in the chalk deposits are sandstones, the porosity of which reaches 27%, permeability 0.001 μm^2 . The regional seals for the productive horizons of the Triassic and Jurassic are Upper Jurassic clays; the productive horizons of the Cretaceous are screened by clayey interlayers in the middle part of the Neocomian and by a clayey pack that completes the Upper Cretaceous section (Fig. 5). Structural traps formed by anticlines and brachyanticlines and complicated by tectonic faults are widespread in the territory of the Kazakhstan part of the oil and gas basin. Non-structural traps associated with lenticular bodies of Jurassic sandstones are widespread in the northern marginal part of the basin. The initial explored reserves of the basin amounted to about 730 million tons of oil and about 214 billion m^3 of gas.

3.4 Exploration drilling strategy

Based on new geological and geophysical models, it is necessary to revise the layout of exploration wells. Previously, wells were concentrated on domes and vaults. Now it is reasonable to drill on the flanks of structures and in inter-structural zones, where, according to seismic facies analysis, wedging-out sandstones are predicted. Promising areas are near large deep faults, where tectonically screened traps or hydrodynamic types of deposits could have formed. Exploratory wells of small and medium depth on the flanks of known structures. For example, for the Uzen and Zhetybay fields, it makes sense to drill exploratory wells on the periphery of structural areas, where seismic exploration outlines a possible wedging-out of Jurassic sandstones upward along the periphery of the structures. This approach -

additional exploration "on the outskirts" of known fields – can lead to an increase in reserves due to bypass lithological traps adjacent to already developed deposits. World experience (including Western Siberia and the Volga-Urals) shows that a significant share of the growth of reserves in mature oil and gas provinces is provided by the strategy of targeted search for stratigraphic traps.^[57-59] It is also necessary to consider the risk: stratigraphic traps are usually smaller in scale than giant structures and more heterogeneous. Therefore, the drilling program should be planned with redundancy of points - drill several options at different levels of one fascial element (for example, if a river bed of 10 km in length is predicted, lay 2-3 wells in different parts of the bed to increase the chance of hitting the sandy part). If signs of oil and gas saturation are detected in one of the wells (small inflow, oil shows in the sludge, fluid-shows), it is necessary to flexibly redirect efforts to block preparation of the trap - further identify its boundaries, possibly with short laterals or additional exploratory wells.

4. Results and discussion

4.1 Lithological types of deposit in the Uzen field

13 oil-bearing and oil and gas-bearing in the Jurassic strata. Most productive horizons are multilayer. The deposits are

diverse in trap type, but mostly are sheet-like dome-shaped. In the Jurassic productive strata, sheet-like, tectonically screened deposits are found. Within the East Karamandybas dome, sheet-like dome-shaped, lithological screened deposits are noted. On the Main Dome, horizons J-XIII - J-XVII have one water-oil contact, and therefore the deposits can be classified as massive-sheet-like. The reservoirs are porous and are represented by sandstones and siltstones. The open porosity of gas-bearing horizons is 26.8-30.6%, permeability is 0.2-0.4 μm^2 . In the Jurassic strata, the highest porosity (26.5%) and permeability (0.523 μm^2) are noted in horizon XIII (Callovian stage). In other horizons, porosity is 18-25%, permeability is 0.02-0.03 μm^2 . Clays 2-60 m thick serve as seals for productive horizons (Fig. 8).

The deposit is confined to a northwestern-trending brachyanticlinal fold. Along the roof of the Jurassic horizon I (isohypses -1620 m), the structure dimensions are 22.5 x 6.5 km, the amplitude is 60 m. The dip angles of the rocks of the northern wing are up to 3°, and of the southern wing - 5°. There is a correspondence between the structural plans of the Cretaceous and Jurassic deposits and some increase in the amplitude of the uplift with depth. The relationship between the structural plans of the Triassic and Jurassic has not been fully clarified.

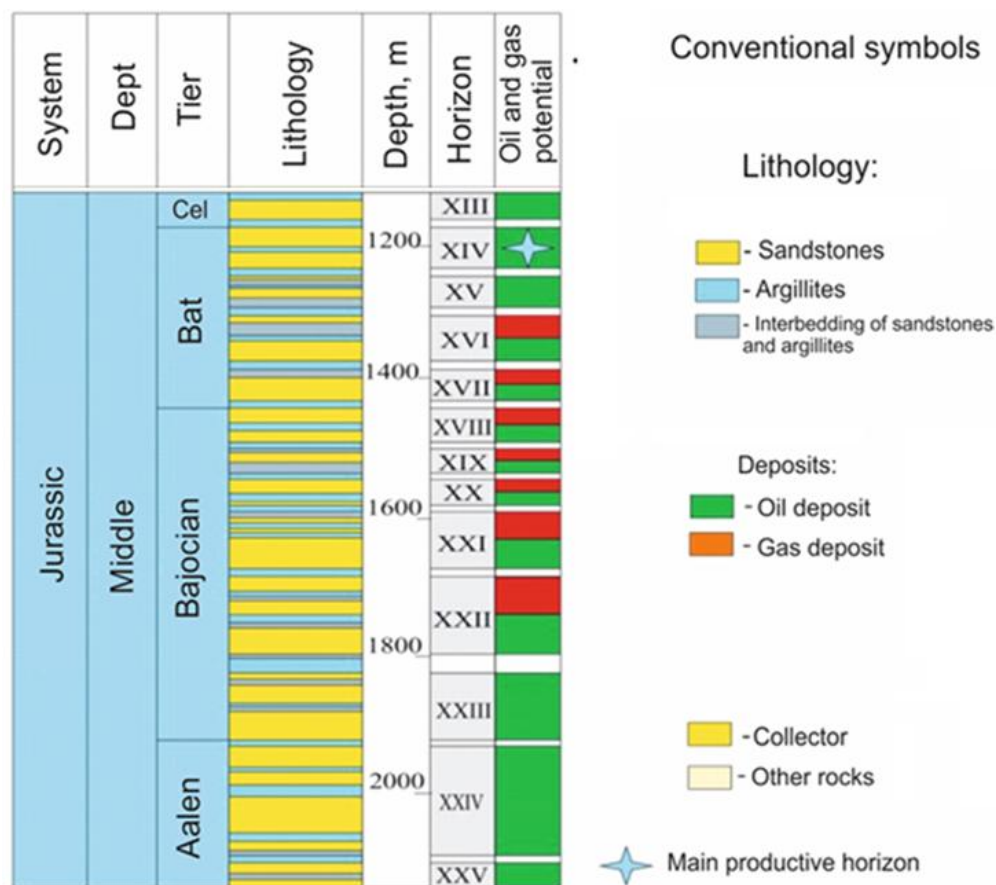


Fig. 8: Lithological of the Jurassic strata for Uzen field indicate refers to 13 oil and gas bearing zones.

4.2 Lithological types of deposit in the Zhetybai oil and gas field

The deposit is confined to a northwestern-trending brachyanticlinal fold. Along the roof of the Jurassic horizon I (isohypses -1620 m), the structure dimensions are 22.5 x 6.5 km, the amplitude is 60 m. The dip angles of the rocks of the northern wing are up to 3°, and of the southern wing - 5°. There is a correspondence between the structural plans of the Cretaceous and Jurassic deposits and some increase in the amplitude of the uplift with depth. The relationship between the structural plans of the Triassic and Jurassic has not been fully clarified. Productive deposits of the Upper and Middle Jurassic, in which 13 horizons have been identified,

represented by interbedded sandstones, siltstones and clays (Fig. 9).

The number of sandstone layers in productive horizons varies from 2 to 8. The total thickness of the productive part of the section exceeds 700 m. Productive horizons belong to: J-I – J-II to the Callovian stage, (J-III – J-VI – to the Bathonian stage, J-VII – J-XI – to the Bajocian and J-II, J-XIII – to the Aalenian. They contain two gas, 11 oil and 7 oil and gas deposits. The deposits are diverse in terms of trap type: most are sheet domed, but there are also massive-sheet and sheet, lithologically screened ones. The depth of productive horizons is 1700-2500 m.

The reservoirs are porous, with open porosity from 16-

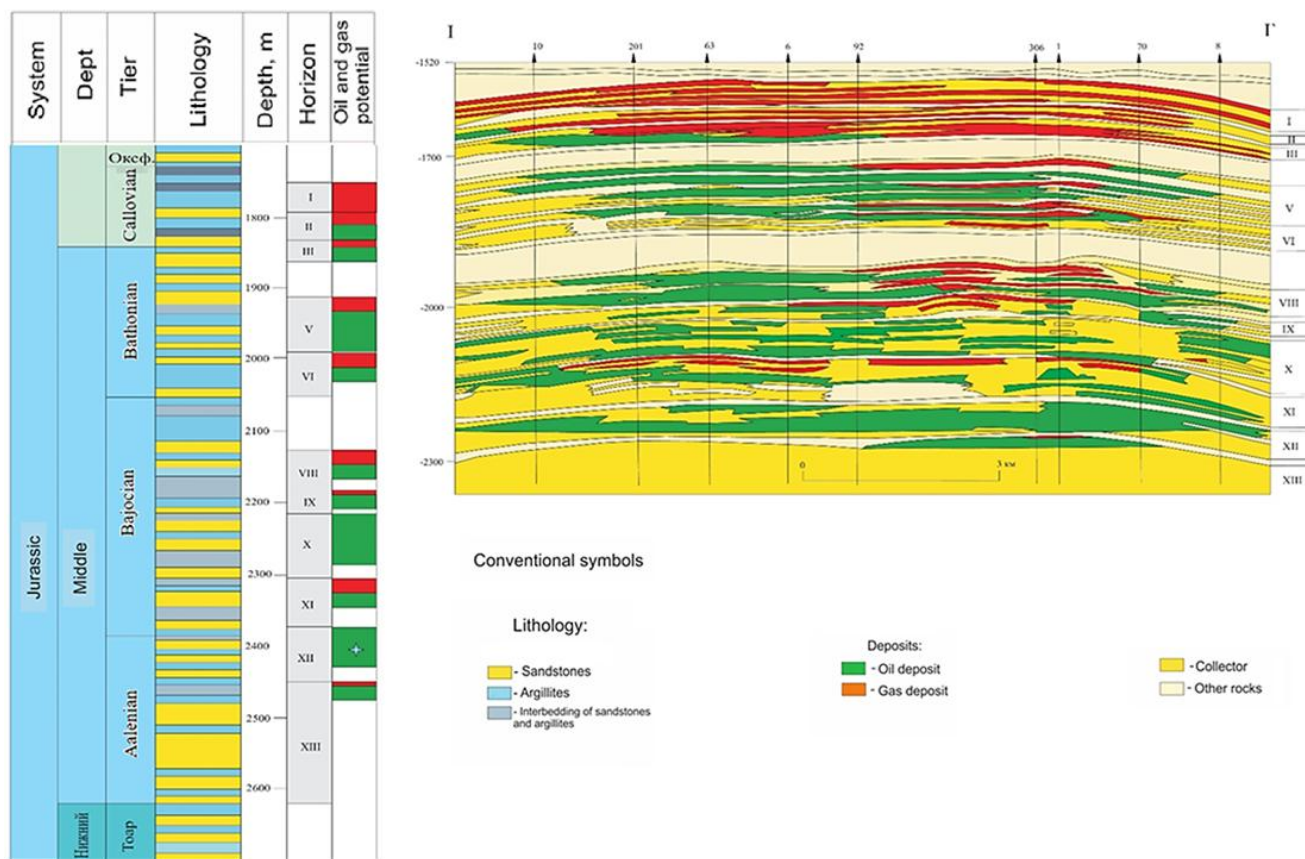


Fig. 9: Lithological of the Jurassic strata for Zhetybai field shows 13 oil and gas-bearing zones.

22%, permeability of 0.06-0.239 μm^2 . Oil-saturated thickness is 1.3-21.2 m, gas-saturated - 2-14.4 m. Oil of all horizons is light and medium in density (830-870 kg/m^3), resinous (4.53-15.5%), highly paraffinic (17.2-25%), low-sulfur (0.1-0.28%), with asphaltene content of 0.9-3.4%. Yield of fractions up to 300°C - from 25 to 42%. Composition of dissolved gas, in %: methane - 58.86-76.4, heavy hydrocarbons - 22-37, nitrogen - 1.3-5.8, carbon dioxide - 0.3-1.1. In the free gas of gas caps, the methane component reaches 78.6%, the share of heavy hydrocarbons is 11-18%. Nitrogen (up to 10.3%) is present, the concentration of which decreases with depth, and carbon

dioxide (0.23-1.2%). In the deposit of the J-I horizon, the content of stable condensate with a density of 689-704 kg/m^3 reaches 76 g/m^3 .

4.3 Lithological types of deposit in the karamandybas oil and gas field

The Karamandybas deposit is a northwestern continuation of the Uzen deposit. Against the general background of the anticlinal Uzen structure, the West-Karamandybas and East-Karamandybas domes of the second order stand out. They complicate its western pericline. The Karamandybas deposit

is located in the steppe plain part of the Mangyshlak Peninsula. In orographic terms, the territory is divided into two parts: endorheic basins in the east (Karamandybas, Asar) and the elevated plateau surrounding the basins in the south. The absolute marks of the eastern slope of the basin are over 200 m, and the western one - up to 140 m. In the geological section of the Karamandybas deposit, opened by exploratory wells to a depth of 3000 m, deposits of the Triassic, Jurassic and Cretaceous systems, clay-carbonate deposits of the Paleogene and Neogene, as well as loose Quaternary formations are distinguished. The size of the deposit is 45*10 km, the amplitude reaches 270 m.

During exploration, 13 productive horizons (XIII-XXV) were identified at the field. Currently, free gas deposits of horizons XVI-XX are being exploited at the Eastern Dome.

The Karamandybas structure was first established in 1960 by structural exploration drilling. Based on the drilling data, a structural map was constructed along the base of the Turonian stage. The opening date of the Karamandybas deposit is considered to be June 6, 1964., when an oil flow was obtained in well No. 1 during testing of horizon XIII. In 1968, exploration of the field was completed by the Mangyshlakneftegazvedka trust, and it was transferred to the Kazakhstanneft association for further work. The reservoir rocks that contain the deposit are represented mainly by arkose medium- and fine-grained sandstones. Siltstones are usually of subordinate importance. According to the structure of the void space, these reservoirs belong to the porous type.

By the nature of saturation, there were 46 oil deposits, 21 gas deposits, and 7 gas-oil deposits. It was identified that 37 of these deposits are located on the Eastern Dome, including 18 oil deposits, 15 gas deposits, and 4 deposits with gas caps. On the Western Dome, 32 deposits have been identified, of which 23 are oil deposits, 6 are gas deposits and 3 are oil and gas deposits. On the western pericline, 5 oil deposits have been identified. It can be noted that the greatest number of deposits have been identified in the XIX and XX horizons, and the XVI and XVII horizons are productive only on the Eastern Dome. Oil saturated thickness greater than or equal to 10 meters have only seven deposits - XIII (Eastern + Western), XIV (Eastern A + B + V), XV (Western, B, area of well 434), XXII (Eastern, B + V) and XXIV (Eastern, A and Western A) and XXV horizons. The minimum value of oil-saturated thickness has a small lithologically screened deposit A of the XIII horizon on the Western pericline, its value is 0.9 m. For each selected reservoir (Fig. 10), the indicators of reservoir heterogeneity characteristics were calculated: sandiness coefficients, dissection coefficients, and distribution coefficient.

For deposits XVIII B of the Western and XIX G of the Eastern domes, the reservoirs are represented by one layer.

The greatest compartmentalization of more than 5 is characteristic of the reservoirs of eight deposits XIII (Eastern + Western), XIV (Eastern A + B) and XV (Eastern A + B) XVIII (Western, G) XXII (Eastern B + V) XXIV (Eastern, A and Western B) and XXV (Western) horizons.

From analysis of the seismic records, the thickness of the platform cover of Southern Mangyshlak is from 4000 to 6000 m. The lowest part of the section, presumably attributed to the Rhaetian-Lias, according to seismic data, has a thickness of 1500-2000 m and is more dislocated than the Jurassic-Paleogene complex. The platform cover of Southern Mangyshlak is underlain by Permian-Triassic rocks, less dense and dislocated than in the Central Mangyshlak area. As one moves away from Central Mangyshlak to the Karabogazgol arch, the thickness of the Permian-Triassic complex decreases sharply. Within the arch, platform sediments lie directly on the Paleozoic folded basement.

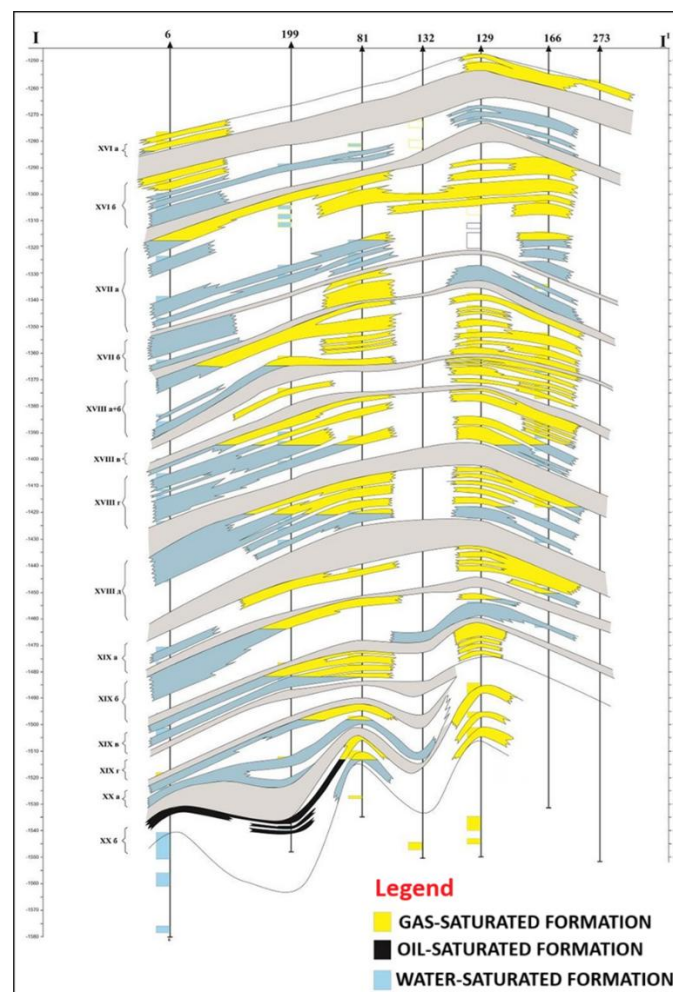


Fig. 10: Lithological section for the Jurassic strata in the Karamandybas deposits

In general, the Lower Jurassic section is composed of non-marine sediments - alluvial-deluvial sandy-siltstone strata with clay interlayers and, in places, carbonaceous material

interlayers, which indicates swampy conditions and abundant vegetation. At the base of the Toarcian stage (the end of the Early Jurassic), mainly riverbed sediments formed under a branched river network, deposits of floodplain river systems, and alluvial fans. From seismic exploration, the structure is confined to the Tenge-Tasbulat anticlinal zone of the Zhetybai-Uzen tectonic step. According to the V2ni reflecting horizon, stratified as Upper Triassic deposits, it is a brachyanticline fold of sub latitudinal strike measuring 4 x 12 km within the -3300 m isohypse. The structure is complicated by two uplifts adjacent to tectonic faults. Productive Upper Triassic deposits are represented lithologically by fine-grained sandstones with an open porosity of 13-14% and a permeability of 0.05 μm^2 . The seal is a pack of dense clays 250 meters or more thick. The deposit type is sheet, tectonically screened.

The thickness of the Lower Jurassic sediments in South Mangyshlak reaches several hundred meters. Thus, the reservoir properties of Jurassic rocks strongly depend on the sedimentation environment: the most permeable sandstones

were formed in the channels, while cap clay-carbonaceous rocks accumulated in the swampy floodplains. This lithological-facies control predetermines the placement of zones of increased capacity (reservoirs-potential deposits) and screening zones (dense barriers-seals), channel sand bodies wedging out towards floodplain clays; island dune sandstones surrounded by dense lacustrine-marsh deposits. The main role in the generation of hydrocarbons within the Mangyshlak part of the basin belongs to the clayey strata of the Lower-Middle Jurassic and Lower Cretaceous. In the Lower-Middle Jurassic deposits, the SORG content is 0.5-1%.

As a result, the Lower Jurassic deposits of Southern Mangyshlak are characterized by a favorable combination of generative and sealing factors, as the significant content of organic matter (carbonaceous rocks) makes them a source of gas and oil. In low-lying river valleys, favorable conditions developed for the formation of lithological traps associated with channel, floodplain, and lake deposits. In areas adjacent to Mountainous Mangyshlak, lens-shaped deposits were formed, related to alluvial fan (delluvial) sediments (Fig. 11).

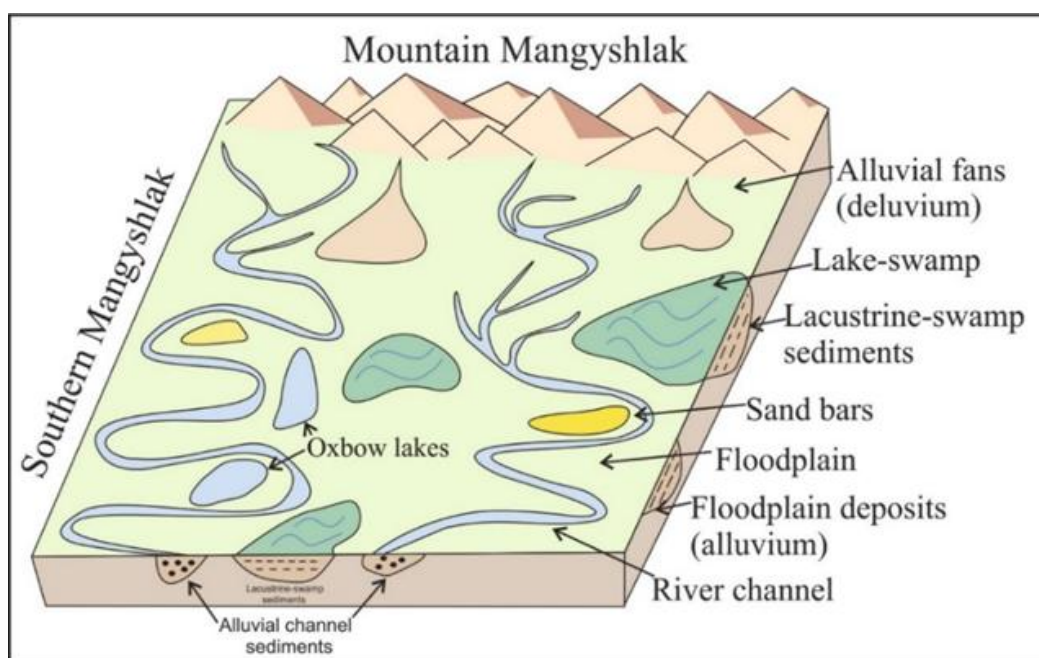


Fig. 11: Block diagram for Paleogeographic conditions of the Early Jurassic period in the Southern Mangyshlak.

These deposits often exhibit a cyclical structure with coarse-grained sand bodies at the base (typical of channel and proluvial deposits) grading upward into sediments of finer-grained materials such as siltstones and clays. Such cycles are described as “fining-upward” and reflect a deceleration of flow and a waning of sediment accumulation in floodplain environments.

The Middle Jurassic was characterized by a gradual marine transgression that began after the Aalenian age, leading to the

formation of extensive deltaic and coastal plains. This resulted in a transition of sediments from continental fluvial deposits in the lower horizons, to deltaic (transitional) deposits in the middle horizons, and shallow marine deposits in the upper horizons. The delta-floodplain complexes reflect the intense influx of terrigenous material from the adjacent landmasses (Mount Mangyshlak) (Fig. 12). By the Late Bathonian, conditions stabilized on a shallow shelf, and by the Callovian age, the sea had deepened significantly, setting the stage for

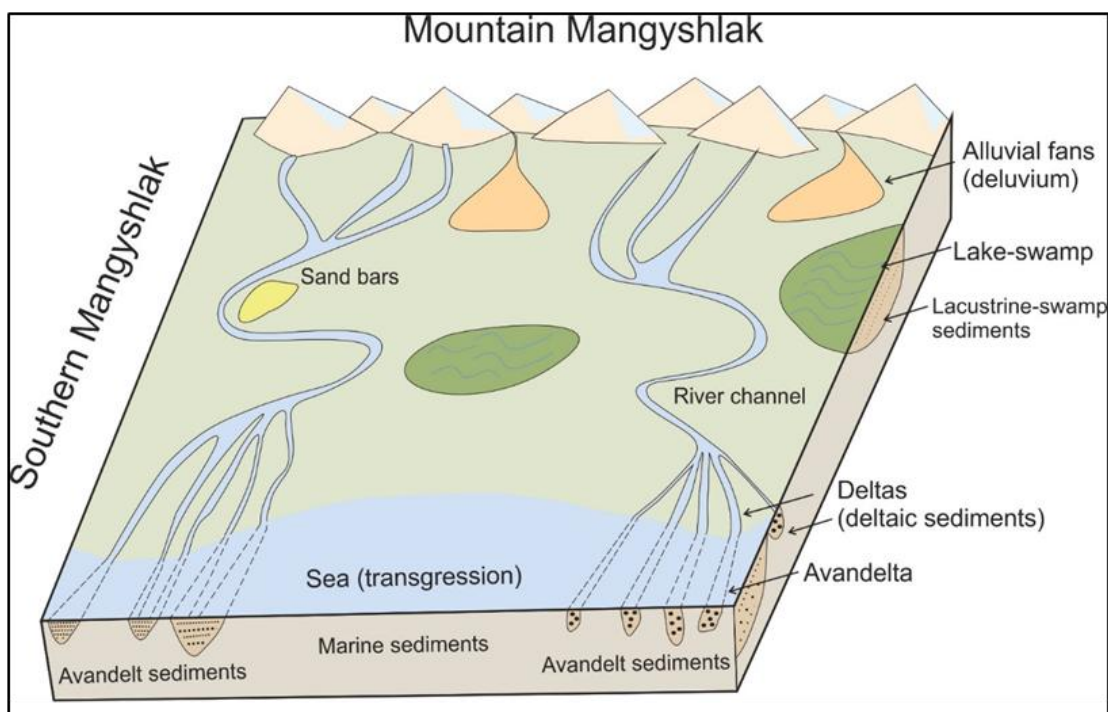


Fig. 12: Paleogeographic setting scheme of the Middle Jurassic (Aalenian–Bajocian).

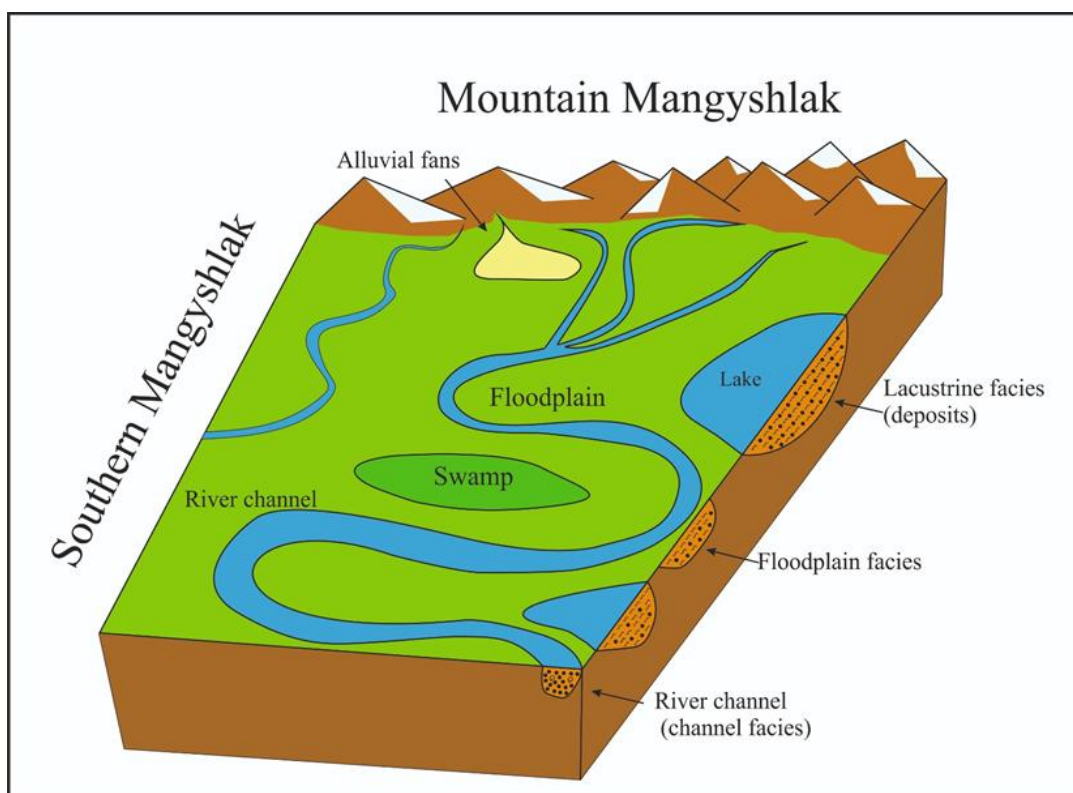


Fig. 13: Paleogeographic setting scheme during the Upper Jurassic (J3).

the accumulation of Upper Jurassic carbonates (Fig. 13).

Biostratigraphy: Middle Jurassic deposits contain transitional fossil complexes – both terrestrial flora and marine fauna. Spores and pollen of terrestrial plants similar to the Lower Jurassic complexes, as well as leaf imprints and wood, are found in the lower part (Aalenian–Bajocian). However, the

first marine organisms are already recorded in the Bajocian stage; for example, ostracods and small bivalves were found in coastal-marine layers. With the expansion of marine influence, ammonites, and belemnites appear (important index fossils for correlation) in the Bathonian stage. In particular, ammonites of the Parkinsoniidae and early Cardioceratidae

families were noted in the Bathonian rocks of Southern Mangyshlak and the Caspian region, which confidently attributes these layers to the lower Bathonian. The appearance of marine fauna in the middle Jurassic significantly facilitates biostratigraphic subdivision: the Bajocian-Bathonian horizons are already defined as parallels to the known ammonite zones of the middle Jurassic period. During the Middle Jurassic, the region experienced a gradual transgression of the sea, which began after the Aalenian. This led to the formation of broad deltas and coastal plains. The sediments of the Middle Jurassic reflect this change: the lower horizons are continental (Rivers), the middle ones are deltaic (Transition), and the upper ones are shallow-marine. Delta-floodplain complexes indicate a powerful removal of terrigenous material from nearby land (Mountain Mangyshlak) into the sea. Up the section (Late Bathonian), conditions stabilize on a shallow shelf with relatively calm sedimentation. By the end of the Middle Jurassic (Callovian), the sea had deepened significantly, preparing the conditions for the accumulation of carbonate rocks of the Upper Jurassic.

Thus, in the Middle Jurassic period there were conditions for the formation of transitional facies: facies of the above-water delta plain, facies of the underwater delta plain, facies of the lagoons. Examples of oil and gas potential in paleodeltas include the Povkhovskoye field in Western Siberia (Russia), the Kura River paleodelt (Azerbaijan), and the Amu Darya (Turkmenistan).

5. Conclusion

The development of oil and gas exploration in South is entering a stage where potential resources can only be discovered by changing the paradigm – from structure to lithology. The continental Jurassic deposits of the region, previously considered only “rock-forming”, in fact contain numerous unexplored traps of lithological and stratigraphic types. Analysis has shown that in the middle section of the Jurassic, thick sandy horizons of river and deltaic facies were formed, which are often laterally limited by wedging or transition to dense lake-marsh deposits – ideal conditions for lithological oil and gas deposits.

1. Biostratigraphic and lithological-facies data indicate the stability of these facies over large areas, which simplifies their correlation and exploration. With due attention to the paleogeographic reconstruction of the Jurassic period, it is possible to predict with a high degree of certainty the location of hidden traps. Geological and geophysical methods, primarily 3D seismic, already allow us to “see” such objects, and modern drilling technology makes it possible to effectively develop them.

2. The thickness of the platform cover of Southern

Mangyshlak is from 4000 to 6000 m. The lowest part of the section, presumably attributed to the Rhaetian-Lias, according to seismic data, has a thickness of 1500-2000 m and is more dislocated than the Jurassic-Paleogene complex.

3. From seismic exploration, the structure is confined to the Tenge-Tasbulat anticlinal zone of the Zhetybai-Uzen tectonic step. According to the V2ni reflecting horizon, stratified as Upper Triassic deposits, it is a brachyanticline fold of sub latitudinal strike measuring 4 x 12 km within the -3300 m isohypse. The structure is complicated by two uplifts adjacent to tectonic faults.

4. Productive Upper Triassic deposits are represented lithologically by fine-grained sandstones with an open porosity of 13-14% and a permeability of 0.05 μm^2 . The seal is a pack of dense clays 250 meters or more thick. The deposit type is sheet, tectonically screened.

5. According to the results, The Southern Mangyshlak experienced a gradual transgression of the sea, which began after the Aalenian during the Middle Jurassic.

6. The lower horizon sediments of the Middle Jurassic are continental (Rivers), the middle ones are deltaic (Transition), and the upper are shallow-marine. Delta-floodplain complexes indicate a powerful removal of terrigenous material from nearby land (Mountain Mangyshlak) into the sea.

7. By the end of the Middle Jurassic (Callovian), the sea had deepened significantly, preparing the conditions for the accumulation of carbonate rocks of the Upper Jurassic.

8. It is recommended to focus searches on the zones of wedging out of Jurassic layers along the sides of structures and above paleo-elevations of the basement, as well as in the zones of articulation of stratigraphic unconformities with faults. It is in such places, according to experts, that new oil and gas fields may be located, comparable in total reserves to those already.

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Data availability statement

All data generated or analyzed during this study are included in this published article.

Conflict of Interest

There is no conflict of interest.

Supporting Information

Not applicable.

CRedit Statement

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Tileuberdi: Conceptualization, Methodology, Writing – Original draft. **Ergali Auelkhan, Kuanysh Togizov, Bakytzhan Amralinova:** Data curation, Visualization. **Erlan Akbarov, Miras Sanatbekov:** Writing – Review & editing, Supervision, Funding acquisition.

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