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GEOLOGICAL AND GEOCHEMICAL FEATURES OF AN OIL FIELD OF PRECASPIAN REGION

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This article highlights the geological and geochemical features of the oil field of the Caspian region of the territory of Kazakhstan. The ways of hydrocarbon migration, which were carried out in the direction of the southern steeper part of the Arystanov stage, are described. All the studies carried out over the previous years have shown that the composition of dispersed organic matter (kerogen) contained in Jurassic and Triassic sediments has a predominantly mixed, mixtinite composition. The factor causing long-range migration may be faults, including a high-amplitude fault in the junction zone of the Kosbulak trough with the Akkulkovsko-Bazaysky ledge and the Aral-Kyzylkum fault, to which the deepest parts of the Kosbulaksky and Barsakelmessky bends are confined, and rock fractures in various porous and permeable reservoir rocks can also serve. The presence of significant reserves of dry methane gas deposits in the Paleogene of the Akkulkovsko-Bazaysky ledge and the established manifestations of gas in the northern half of the Kyzyloysky shaft in Upper Cretaceous sediments are associated with their vertical and lateral migration within these ledges, including vertical along the faults. The unconformity surface at the foot of the Lower Jurassic sediments

provides the development of organic life, plant growth, and clay residues deposited above these unconformities become good source rocks. According to all geochemical indicators, the Middle Jurassic rocks are oil-producing that are located in a favorable middle zone of mesocatagenesis. The main volumes of oil reserves discovered on the territory of Northern Ustyurt were found in the sediments of the Middle Jurassic. The results of geochemical studies in the future will allow basin modeling to be carried out with greater accuracy.

KEY WORDS: *Precaspian basin, geochemical, dispersed organic matter, hydrogen index*

КӨМІРСУТЕКТЕРДІ ӨНДІРУ АЙМАҚТАРЫН ЖӘНЕ КӨШІ-ҚОН ЖОЛДАРЫН МОДЕЛЬДЕУ, КАСПИЙ МАҢЫ ӨҢІРІНІҢ МҰНАЙ КЕН ОРНЫНЫҢ РЕСУРСТАРЫН БАҒАЛАУ

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Бұл мақалада Қазақстан аумағындағы Каспий өңірі мұнай кен орнының геологиялық және геохимиялық ерекшеліктері қамтылады. Арыстанов ярусының Оңтүстік тік бөлігі бағытында жүзеге асырылған көмірсутектердің көші-қон жолдары сипатталған. Алдыңғы жылдары жүргізілген барлық зерттеулер Юра және триас шөгінділеріндегі дисперсті Органикалық заттардың (кероген) құрамы негізінен аралас, микстинит құрамына ие екенін көрсетті. Үлкен қашықтықтарға көші-қонды тудыратын фактор ақаулар болуы мүмкін, оның ішінде Қосбұлақ доғасының Ақкөл-Базай доғасымен және Арал-Қызылқұм жарылысымен қосылу аймағындағы жоғары амплитудалық ақаулық, оған Косбұлақ және Барсакелмес иілімдерінің ең терең бөліктері шектелген, сондай-ақ әртүрлі кеуекті және өткізгіш тау жыныстарындағы ақаулар.коллекторлық жыныстар да қызмет ете алады. Ақкөл-Базай жотасының палеогенінде құрғақ метан шоғырларының едәуір қорының болуы және Қызылой үйіндісінің солтүстік жартысындағы жоғарғы бор шөгінділеріндегі газдың анықталған көріністері олардың осы кемерлер шегінде, оның ішінде сынықтар бойында тік және бүйірлі көші-қонымен байланысты. Төменгі Юра шөгінділерінің етегіндегі сәйкессіздік беті органикалық тіршіліктің дамуын, өсімдіктердің өсуін қамтамасыз етеді, ал осы сәйкессіздіктердің үстінен жиналған саз қалдықтары барлық геохимиялық көрсеткіштер бойынша жақсы бастапқы жыныстарға айналады. Солтүстік Үстірт аумағында табылған мұнай қорының негізгі көлемі орта Юра шөгінділерінен табылған. Геохимиялық зерттеулердің нәтижелері болашақта бассейндерді үлкен дәлдікпен модельдеуге мүмкіндік береді.

ТҮЙІН СӨЗДЕР: *Каспий маңы ойпаты, геохимиялық, дисперсті органикалық зат, сутегі индексі*

ГЕОЛОГИЧЕСКИЕ И ГЕОХИМИЧЕСКИЕ ОСОБЕННОСТИ НЕФТЯНОГО МЕСТОРОЖДЕНИЯ ПРИКАСПИЙСКОГО РЕГИОНА

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В данной статье освещаются геологические и геохимические особенности нефтяного месторождения Каспийского региона территории Казахстана. Описаны пути миграции углеводородов, которые осуществлялись в направлении южной более крутой части Арыстановского яруса. Все исследования, проведенные за предыдущие годы, показали, что состав рассеянного органического вещества (керогена), содержащегося в юрских и триасовых отложениях, имеет преимущественно смешанный, микстинитовый состав. Фактором, вызывающим миграцию на большие расстояния, могут быть разломы, в том числе высокоамплитудный разлом в зоне соединения Косбулакского прогиба с Аккульковско-Базайским выступом и Арало-Кызылкумским разломом, к которому приурочены наиболее глубокие части Косбулакского и Барсакельмесского прогибов, а также разломы горных пород в различных пористых и проницаемых коллекторах. Наличие значительных запасов залежей сухого метана в палеогене Аккулковско-Базайского выступа и установленные проявления газа в северной половине Кызылойского вала в верхнемеловых отложениях связаны с их вертикальной и боковой миграцией в пределах этих уступов, в том числе вертикальной вдоль разломов. Поверхность несогласия подошвы нижнеюрских отложений обеспечивает развитие органической жизни, рост растений, а глинистые остатки, отложенные над этими несогласиями, становятся хорошими материнскими породами. По всем геохимическим показателям среднеюрские породы являются нефтепродуцирующими породами, которые расположены в благоприятной средней зоне мезокатагенеза. Основные объемы запасов нефти, обнаруженных на территории Северного Устюрта, были выявлены в отложениях средней юры. Результаты геохимических исследований в будущем позволят проводить бассейновое моделирование с большей точностью.

КЛЮЧЕВЫЕ СЛОВА: *Прикаспийский бассейн, геохимический, РОВ, водородный индекс.*

INTRODUCTION. The relevance of using effective innovative methods in the search and exploration of hydrocarbon (HC) deposits is currently growing due to the emerging trend of depletion of a large number of exploited oil and gas fields [1]. The southern framing of the Precaspian basin is a complex of various structures: the Precaucasian zones of the Scythian plate, the Donbass-Tuarkyr trough of post-drift immersion, the shelf of the Northern Ustyurt of the Turanian plate [2]. The triangular-shaped North Ustyurt basin is located between the Caspian Sea and the Aral Lake in Kazakhstan and Uzbekistan and extends offshore both on the west and east [3]. Ustyurt was formed on a cratonic microcontinental block that accreted to the north in the East European platform in Visean or Early Permian time [4]. In 1965, Nevolin N.V. [5], considering the question of the

deep geological structure of Western Kazakhstan, identified 5 complexes within Ustyurt: Archean-Lower Proterozoic, Riphean-Ordovician, Silurian-Eiffel, Zhivet-Lower Triassic and Upper Triassic-Paleocene. In the publications of the 1970s by S.M. Ozdoev, on the basis of a comprehensive analysis of the material composition of rocks and hydrogeological indicators, the zoning of the territory of Northern Ustyurt was carried out according to the prospects of oil and gas potential [6] [7]. Within the Kazakh part of the territory of the North Ustyurt sedimentary basin, industrial oil accumulations have been discovered in Jurassic sediments on the Komsomolskaya, Kultukskaya, Arstanovskaya and Karakudukskaya, Koshkaratinskaya mulda areas in the Shalkar trough (*Figure 1*) [8]. The basement at the Northern Ustyurt Block is located at 5–11 km [9]. In 1996, A.A. Abidov and F.G. Dolgopolov identified 2 paleorift systems of collision type in the Paleozoic complex of Ustyurt [10]. According to other authors, within the Arystanovsko-Mynsualmassky system of geomagnetic anomalies, the depth of immersion of the foundation varies in the range of 8.5–12.5 km [11]. According to the Upper Triassic-Lower Jurassic deposits, the East Shoshkakol graben also meets these conditions, where the depth of the sole of these deposits is estimated to 3.5–4 km according to the preliminary stratification of the reflecting boundaries.

Accumulation of hydrocarbons in traps can occur both in the generation zones and in the marginal, most elevated parts and separating ledges in the presence of favorable conditions for lateral migration of hydrocarbons.

The formation of accumulations of the Komsomolskoye, Karakuduk (and Arystanovskoye) deposits occurred due to the thermal transformation of kerogen from the Middle Jurassic deposits accumulated in the bent zones of the Koltyk and possibly Kulazhatskaya mulds.

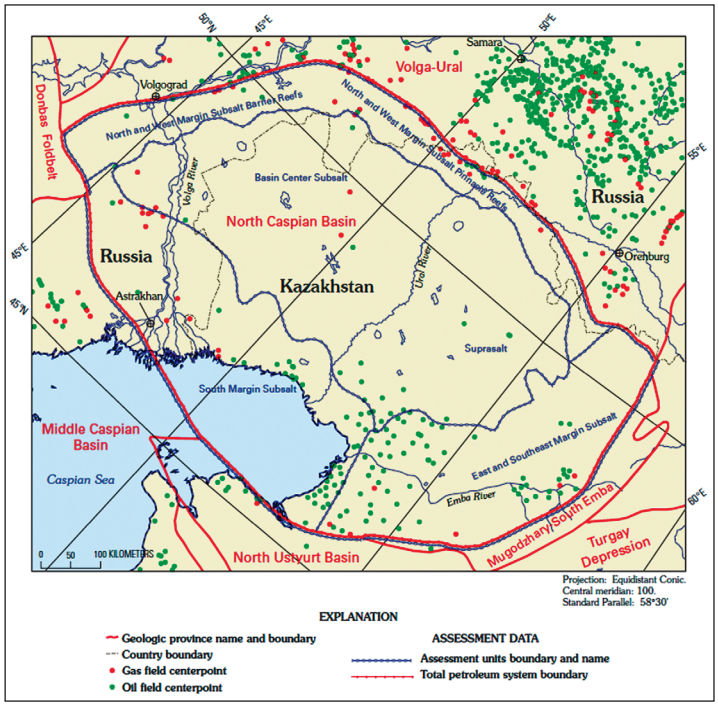

Figure 1 – **Petroleum system and assessment units of North Caspian basin.** *(by Ulmishek G., 2001)*

The migration of newly formed hydrocarbons probably occurred to the south, towards a steeper side – the Arstanov stage, which occupied an elevated position, where accumulations formed in the Jurassic productive complex. There is widely held opinion that further source-rock potential may be provided by Carboniferous deep-water facies in the adjacent North Caspian basin through lateral migration of hydrocarbons into the adjacent North Ustyurt basin [12].

In the relief of the surface of Paleozoic deposits, the Kosbulak and Samsky bends are isolated at depths of 5.5–6.5 and 6.5–7.5 km, respectively, and the Kultuk depression up to 7.0–8.0 km [13]. The distribution of thickness and facies shows that the North Ustyurt depression remained the main synclinal structure of the region, along which the waters of all Miocene transgressions were spread [14]. The proposed oil-producing complex of Triassic age includes formations of the Upper Triassic and, possibly, the Lower Jurassic, formed in shallow coastal-marine and marine conditions that existed only in the west of the territory, mainly in the most bent zones of the Kultuk mulda. The migration of hydrocarbons from the Triassic sediments occurred mainly in the vertical direction. The realization of the generation potential of this complex could cause the formation of clusters within the Kultuk zone.

The most significant changes in the facies conditions of accumulation of source rocks are observed in the latitudinal direction. They were caused by the spread of marine transgressions in the eastern direction, both in the Triassic and Jurassic periods. More significant changes are noted for the Jurassic stage of precipitation accumulation, since the territory was more differentiated structurally and tectonically. All the studies carried out over the previous years have shown that the composition of dispersed organic matter (kerogen) contained in Jurassic and Triassic sediments has a predominantly mixed, mixtinite composition (*Figure 2*).

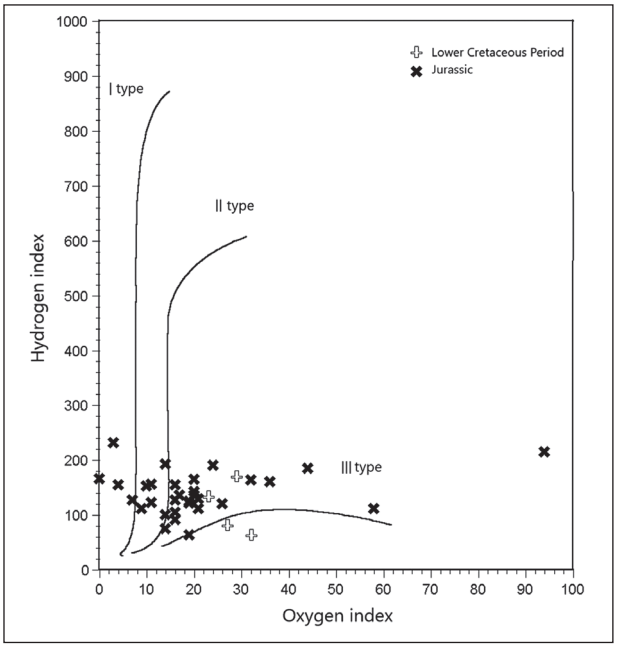

Figure 2 – **Characteristics of the types of dispersed organic matter by the ratio of oxygen and hydrogen indices**

Moreover, the ratio of micro-components of kerogen experiences changes in accordance with the change of facies conditions.

Spatially Jurassic deposits are traced in the time relations of Early Mesozoic rifting. The accompanying geodynamic and tectonic processes are inextricably linked with the historical and genetic model of the formation of hydrocarbon accumulation zones.

The factor causing long-range migration may be faults, including a high-amplitude fault in the junction zone of the Kosbulak trough with the Akkulkovsko-Bazaysky ledge and the Aral-Kyzylkum fault, to which the deepest parts of the Kosbulaksky and Barsakelmessky bends are confined, and rock fractures in various porous and permeable reservoir rocks can also serve. Zones of oil and gas accumulation are inversion uplifts, areas of rock wedging and faults of tectonic shielding, and side sections of grabens of lateral migration of hydrocarbons.

At the same time, the presence of significant reserves of dry methane gas deposits in the Paleogene of the Akkulkovsko-Bazaysky ledge and the established manifestations of gas in the northern half of the Kyzyloysky shaft in Upper Cretaceous sediments are associated with their vertical and lateral migration within these ledges, including vertical along the faults. The latter is proved by the presence of faults that cut through the entire sedimentary cover and affect Paleogene deposits, which were established by the latest work on the Akkulkovsky ledge.

In accordance with this, the main positive structural elements of the platform type, along with the side parts of the depression, are the most likely zones of oil and gas accumulation along the deposits of the platform cover and the Upper Triassic-Lower Jurassic. The lithological factor is favorable for lateral migration -the presence of alternating bundles of sand reservoirs and clays in the Middle-Upper Jurassic section.

METHODOLOGY. The prospects of oil and gas potential depend on three main criteria for the formation of generation potential and accumulation of hydrocarbons: the volume of oil and gas-producing strata, their entry into the main catagenetic zones of oil and gas formation and the reliability of screening of oil and gas-bearing rock complexes. There is a sufficient volume of sediments of Jurassic strata in the Kosbulak trough. They lie at sufficient depths up to 5 km, which, together with the anomalous geothermal regime of the subsurface, caused them to undergo the processes of oil and gas formation.

The history of the development of the Ustyurt sedimentary basin from the Kultuk Bay to the Aral Sea shows the consistent and uniform passage of Jurassic sediments in the grabens of the Kultuk, Samsky and Kosbulak bends of the main oil and gas formation zone.

Geochemical studies of the material composition of organic matter and bitumoids indicate that the Jurassic deposits have fully realized their generation capabilities. Dynamics of development of deep-submerged grabens of the North Ustyurt shows that optimal conditions for the mass generation of liquid hydrocarbons of Jurassic rocks were created in them already in the Cretaceous, on uplifts in the Paleogene.

The conducted studies of the Jurassic strata from the standpoint of a new approach to the theory of rift structures made it possible to determine the formed potential of oil and gas complexes and to outline areas for the prospects of oil and gas exploration.

The regionally widespread and most studied Jurassic deposits in the sedimentary cover are oil and gas bearing in the sedimentary basins of Kazakhstan. Within the territory

of Ustyurt, they lie on the eroded surface of Paleozoic, Lower Triassic rocks, and in places - Middle and Upper Triassic with hiatus and unconformity. The most ancient of them belong to the lithologically difficult-to-separate thickness of the Shoshkakol series of the Upper Triassic and Lower Jurassic. On the Northern Ustyurt cliff, they are opened by several wells and are represented by mudstones, which are layered with sandstones and siltstones of gray tones. According to the thickness distribution of dark mudstones, Kosbulak sag, Sudochi sag and Barsakelmes sag were preferable hydrocarbon-generation sags [15]. The uncovered thickness of the rocks of the Shoshkakol series reaches 1000 m. Such rock thickness and lithology are characteristic near the Shoshkakol anticline in the north-west of Ustyurt. In other places of the studied territory such capacities are not met, which indicates the intensive subsidence of some and the rise of other Ustyurt blocks at this time. The Ancient Cimmerian folding phase is observed here, which affected the preservation of Lower Jurassic deposits in bends and on positive structures.

Where the deposits of the Lower Jurassic are uncovered by wells on the structures of the Northern Ustyurt that are distant from each other, they indicate a sufficient concentration of organic matter in them capable of generating hydrocarbons (*Figure 3*). The unconformity surface at the foot of the Lower Jurassic sediments provides the development of organic life, plant growth, and clay residues deposited above these unconformities become good source rocks. According to the accepted gradation of the stages of oil and gas formation, the Lower Jurassic deposits are located at the depth of the lower phase of mesocatagenesis. This interval is considered the most favorable for oil formation and preservation of oil deposits. Due to the sporadic distribution and low thickness, the Lower Jurassic deposits could produce a limited amount of hydrocarbons. This is evidenced by open oil fields with average reserves.

The Middle Jurassic deposits of regional distribution lie with stratigraphic and angular disagreement on the underlying rocks. They are represented by three tiers: Aalensky, Bayosky and Batsky. The Aalensky tier of sporadic distribution is conditionally distinguished in sections of wells drilled at the Arstanovsky stage and in the Barsakelmessky trough. Widespread deposits of the Bajocian and Batsky tiers are confirmed by many paleontological data. Lithologically, the deposits of the Middle Jurassic are composed of overlapping sandstones, clays, siltstones containing numerous charred plant remains. The clays are argillite-like, silky, colored in gray, dark brown and black tones. Siltstones are light gray, thinly layered, clayey. The sandstones are fine-grained, light gray, silky. There are separate differences of calcareous sandstones with carbonaceous detritus, gravel, polymictic, thin-layered sections. The thickness of the Middle Jurassic ranges from complete wedging in the extreme northwest of Ustyurt in the area of the Zhaksybutash block uplift and up to 980 m in the trough. This Middle Jurassic volume of rocks is the main supplier of hydrocarbon compounds. A characteristic feature of the indicators of the analysis of geochemical studies of rocks of the Middle Jurassic is the spread of a large content of organic substances over the territory.

The dividing boundary of the two areas of the quantitative content of hydrocarbon indicators is the rift zone, tectonically confined to the North Ustyurt trough. It stretches latitudinal from the Komsomolets Bay of the Caspian Sea to the Aral Sea. Within the area of the territory located north of the rift zone, the content of hydrocarbon compounds increases

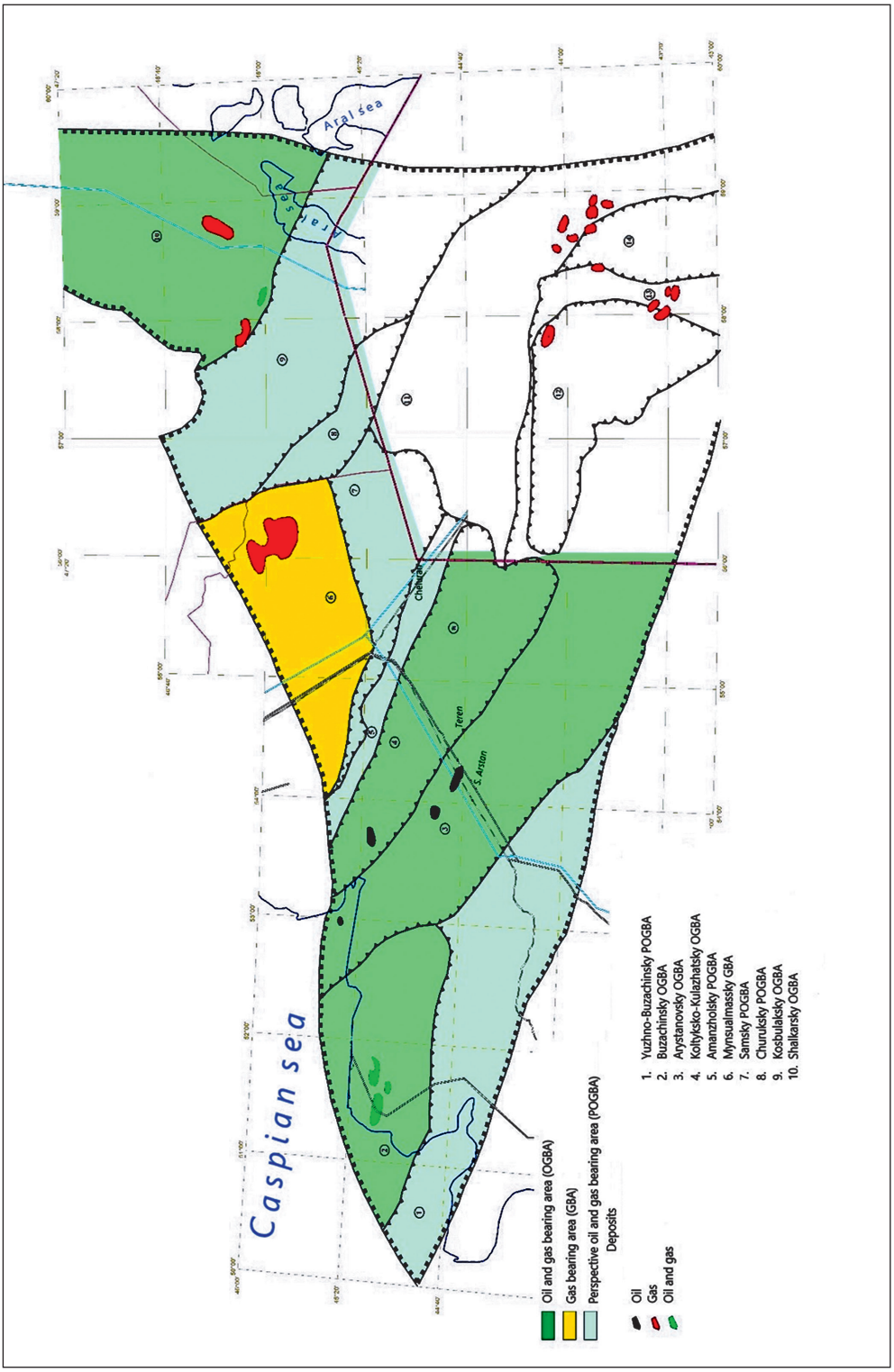

Figure 3 – **Oil and gas geological zoning scheme**

from west to east. While in the territory located south of the rift zone, geochemical indicators of hydrocarbon compounds are increasing from east to west.

RESULTS. According to all geochemical indicators, the Middle Jurassic rocks are oil-producing rocks that are located in a favorable middle zone of mesocatagenesis. The main volumes of oil reserves discovered on the territory of Northern Ustyurt were found in the sediments of the Middle Jurassic.

Upper Jurassic deposits have been uncovered in many areas of the territory of Northern Ustyurt. They lie with stratigraphic unconformity on rocks of the Bajocian tier. Lithological features in combination with paleontological remains and field geophysics data make it possible to dissect the Upper Jurassic deposits into the Kellovian, Oxford, Kimeridgian and Volga tiers. The Kelloway-Oxford deposits are represented by a thickness of dark green, greenish-gray mudstones with interlayers of greenish-gray medium-grained sandstones and siltstones. On the waterworn surface of the Kelloway-Oxford formations, the Kimeridge-Volga formations are deposited, represented mainly by carbonate rocks: dark gray, greenish-gray sandstones, organic limestone-shells, mudstone-like clays, siltstone clay with a shell fracture and remnants of fauna. The layering of clay and carbonate deposits of the Upper Jurassic, whose thickness reaches 100-400 m, makes it possible to consider this thickness a good seal for the underlying oil and gas producing rocks. The Upper Jurassic sediments subjected to geochemical studies showed a characteristic increase in the concentration of bitumoids from the northeast to the southwest of the territory of Northern Ustyurt.

In the marginal rift zones and at the Arystanov stage, a group of structures according to geochemical factor are favorable for the formation of gas-oil deposits in the Upper Jurassic sediments, which is proved by well-known oil deposits. Thus, taking into account the regional distribution with a total thickness of up to 1500 m, geological and structural factors and analytical data, we can conclude about the degree of prospects of the territory of Northern Ustyurt for Jurassic deposits.

DISCUSSION. Industrial accumulations of oil and gas in the Jurassic sediments have been identified and are being exploited in a number of areas. The high content of organic matter, bitumoids, and reducing sedimentation conditions that existed in the Jurassic period make it possible to highly evaluate their prospects for oil and gas. At the same time, the degree of prospects of the Jurassic section as a whole according to geochemical data increases from east to west. Analytical data indicate that there are still undisclosed prospects for the discovery of new oil and gas fields in the territory of Northern Ustyurt.

CONCLUSION. In the marginal rift zones and at the Arystanov stage, a group of structures according to geochemical factor are favorable for the formation of gas-oil deposits in the Upper Jurassic sediments, which is proved by well-known oil deposits. Thus, taking into account the regional distribution with a total thickness of up to 1500 m, geological and structural factors and analytical data, we can conclude about the degree of prospects of the territory of Northern Ustyurt for Jurassic deposits.

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