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Satbayev University

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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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CONDITIONS FOR THE FORMATION OF CLINOFORMS IN THE MIDDLE AND SOUTH CASPIAN MEGABASIN

Abstract. The paper considers sedimentation process and objects of lateral development in deep-water uncompensated and shallow-water – epicontinental paleobasins developed at various evolution stages of South-Caspian and Middle-Caspian basins. The South Caspian megabasin is a great tectonic crustal element and a highly prospective sedimentary basin in the central segment of the Alpine-Himalayan mobile belt. The role of boundary structures of Scythian-Turan platform in the Middle Caspian (such as South-Caspian land and Karaboghaz arc) and avalanche sedimentation on the continental shelf in development of sedimentation units and specific shape objects of lateral development in many kilometers long sedimentary cover of South-Caspian basin has been shown. According to interpretation of seismo-stratigraphic data the inflow of paleodeltaic, avandelatic and turbidite objects of lateral development for infill of the Early Pliocene basin has been proved. Seismo-stratigraphic analysis, using other analyses (e.g. study of morphostructure of palaeorelief and thicknesses of the units and formations) and GSW, enabled the genesis of deposits in the underlying PS formations to be clarified from a new perspective and the favourable zones of formation of large lithological and stratigraphic traps for oil and gas accumulations to be identified.

Key words: sedimentary basins, South Caspian basin, clinoform, Miocene, Early Pliocene, Absheron, Quaternary deposits.

Introduction. Analysis of regional seismic stratigraphy data acquired from the South Caspian and Middle Caspian basins display that at the various phases of their evolution the uncompensated sedimentation mode is common for this area. It must be noted that 50% of sediments in the south part of Middle Caspian basin and sediments in South Caspian basin consist of uncompensated laterally accumulating objects in deep water basins, which further form clinoform type sedimentary sequences. These objects and sequences were accumulated during the periods of sharp sea level drop and intensification of activity of paleoriver, underwater flows and channels and in areas of erosion of wide shelf zones. River deltas were generating progradation type sedimentary objects in coastal zones and shelfs while the output cones of underwater channels generated the same on the continental slopes and abyssals. Layers making up these sequences are characterized by inclined sigmoidal and clinoform type layer boundaries (figure 1). Layers thickness does not characterise syncronous vertical tectonic motions. In this respect, techniques such as “thickness analysis” and “hidden thicknesses restoration”, as well as some other tools, such as borders extrapolation and intrapolation techniques could not be applied for paleotectonic restoration of uncompensated basins. Seismic stratigraphy analysis of regional lines shows that at the all stages of basin evolution the uncompensated mode was dominating.

Geodynamic, tectonic and seismic stratigraphy studies performed for the last 2-3 decades evidenced that South Caspian basin is the relict of marginal (behind the arc) sea (Caucasus-Caspian – Kopetdag marginal sea) recovered in Middle Jurassic across the northern active flank of Meso-Tethys and developed over the oceanic crust. It has been identified that the platform cover was evoluted on shelfs and slopes of embracing continental areas in Mesozoic and Paleogene of Middle Caspian, while in Neogene the epicontinental – forebasins was developing (including North Absheron basin) [1,2].

Interpretation of data acquired in the South and Middle Caspian by use of 16-20 sec. ultra-deep seismic Common Depth Point technique displays consolidated crust of South Caspian basin as thin and oceanic type (~6 - 10 km) and its subduction below the Scythian-Turanian platform to the north-east [3,4]. Based on seismic stratigraphy studies 10 seismic stratigraphy units – sedimentation sequences are outlined in sedimentary cover of high thickness (>25 – 27 km) limited by seismic horizons and uncomformity surfaces [5].

Geodynamic processes, tectonic motions and sea level fluctuations in the region generated various types of tectonic and morphological sedimentary basins. Seismic stratigraphy outlines two types of morphological sedimentary basins: deep water (uncompensated) basins and shallow epicontinental basins [6-9] (figure 1).

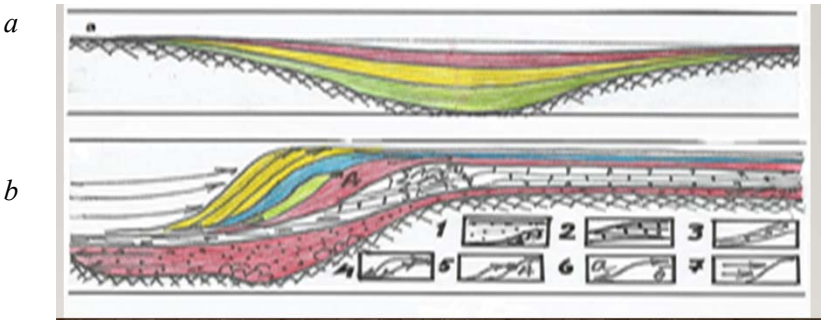

Figure 1 – Morphological types of sedimentary basins:
a – shallow consedimentation epicontinental basin; *b* – deep-water uncompensated basin:
1 – laterally filled (reverse) clinoform; 2 – carbonate (direct) clinoform; 3 – depression sediments;
4 – progradation clinoform; 5 –layers onlapping the steep slope; 6-laying over the foot (a) and top (b); 7 – onlapping the foot

The former are the basins recovered as a result of riftogenesis (horizontal stress and vertical sedimentation) and developed over the oceanic crust. In some cases they are named as “sedimentation traps” or “topodepression”. The latter are the basins developed over the platform or in intermountain areas [10-14]. Great Caucasus – South Caspian marginal sea outcropped as a result of riftogenesis in Jurassic extended and deepened to Oligocene and was not compensated by sediments. Despite subduction and tension started from Oligocene the marginal sea and its relict- the South Caspian Basin were an areas of constant subduction. Presence of terrigeneous laterally accumulating sedimentary objects in the northern part of South Caspian basin and fore-platform transition zones on continental slopes, as well as presence of carbonate clinoforms on shelf margins are evidencing deep water nature of this basin. Seismic stratigraphy makes it possible to outline lateral sedimentation (reverse clinoform), carbonate (direct) clinoform, progradation clinoform and depression sediments attributed to deep water seas existed in the South Caspian basin at various time periods. (figure 2).

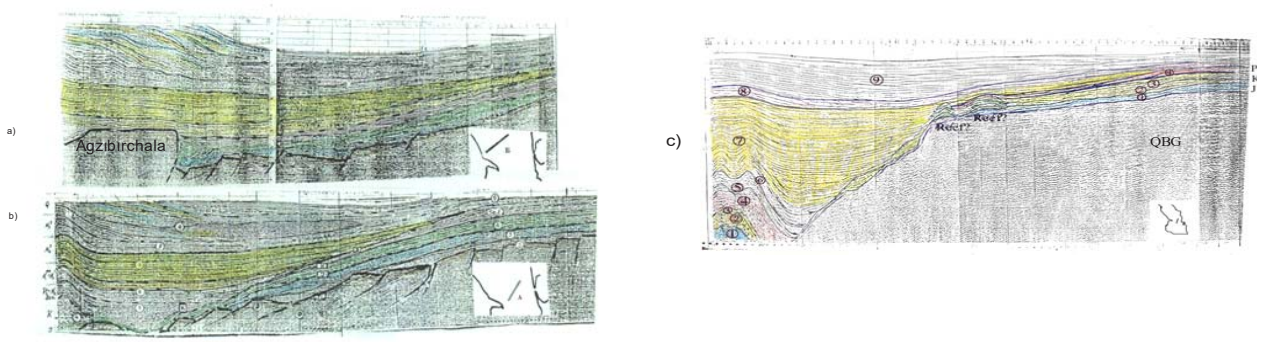

Figure 2 – Image of laterally accumulated terrigeneous and carbonate objects (sequences) in regional profiles

Lateral sedimentation is generated by terrigeneous material incoming from shelf, covering the bottom and relatively gentle slope (<10^0) creating reverse clinoform. This sequence consists of gently-sloping parallel layers onlapping the slope foot.

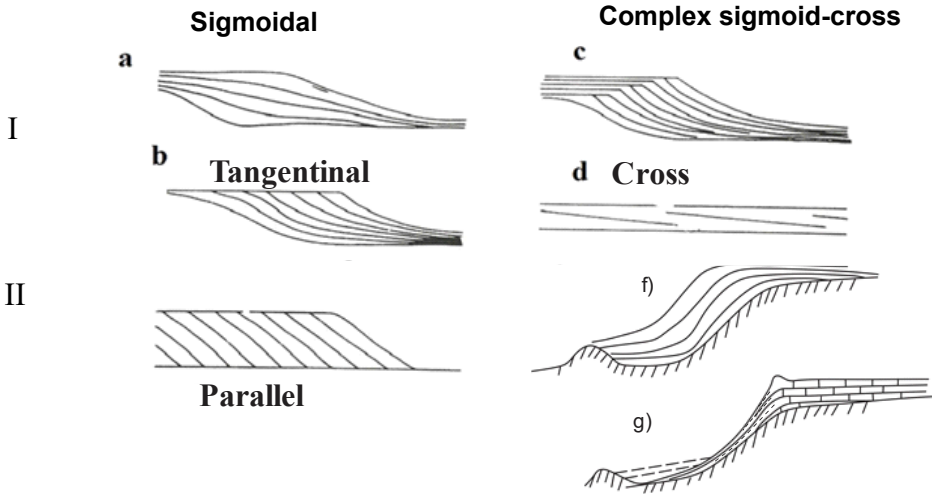

Figure 3 – Image of laterally accumulated sedimantary objects in seismic time sections:
I – scheme of laterally accumulated sedimentary objects;
II – progradation terrigeneous clinoform (f), carbonate clinoform (g) and elements of deltaic sequence

Carbonate clinoform is generated in areas with no erosion on passiv shelfs and far distance of sedimentation sources and replaced by depression facies at the foot of the slope. In case of abnormal amount of brought detritus the sedimentary sequence accumulated laterally on the gentle slopes creates terrigeneous clinoform (figure 3). On relatively steep ($>15^0$ - 20^0) slopes sediments brought from shelf serve as a transit along the slope and laterally cover foot of the slope. Progradation type clinoforms are observed also in areas far from avandelta and gentle slopes.

Applying backstripping analysis for reconstruction of the South Caspian basin subduction to the large depths [8] and seismic stratigraphy analysis it has been derived that the South Caspian basin always was a deep-water basin. At the divergence (extension) stage the depth was 3-5 km, at the convergence (compression) stage the depth was 2 - 1 km. In both cases the basin was not fully compensated.

It must be noted that even in the Early Pliocene basin considered as a shallow-water the deep-water lake existed in fore-Elbrus trough and deltaic and avandeltaic sediments were accumulating on its shelf and slopes due to sediments brought by large rivers (Paleo-Volga, Paleo-Uzboy, Paleo-Kur) and tens of small rivers. As a result, the lake was extended, however not fully compensated. Identification of seismo-facies units laterally accumulated and onlapping the slopes in Late Pliocene and Pleistoceine in the central part of South Caspian are the pivotal indicators of the deep-water basin presence in this area through all time periods.

Clinoforms are generated by joint impact of sea level fluctuations and sedimentation rate, while they have poor relation with tectonics. Studies of laterally accumulated sedimentary objects makes it possible to derive comprehension of paleotectonic and paleogeographic sedimentation environment in the basin. Paleotectonically these objects display uncompensated sedimentation mode of negative (subsided) relief. Paleogeographically these units by their form, configuration and dip of reflection surfaces allow to derive denudation areas locations, erosion direction, erosion basis and sedimentation areas. Finally, from oil and gas exploration point of view the clinoforms deserve the interest for prediction of coarse detrital and sand lenses presence [15-16].

Seismic stratigraphy makes it possible to outline and map paleogeographic zones playing a major role in generation of sedimentation cover in ancient continental margins in Caspian section of Scythian-Turanian platform during Mesozoic and Cenozoic.

In highly informative seismic time sections of Middle Caspian the wide continental shelfs (100-120 km) of Mesozoic –Paleogene basins the gentle ($<1^0$ - 5^0) and relatively steep (>20°) slopes are reflected (Figure 4). These shelfs and slopes for a long period of time (from Late Jurassic to the Middle Miocene) were morphological and structural units of regional scale on continental margins of Meso-Tethys (Neo-Tethys) marginal sea. In transition zone from the southern flank of Scythian-Turanian platform to the Alpian active zone several sedimentation units developed under the environment of sea

level fluctuations and tectonic processes, they were limited by layer boundaries and unconformity surfaces: vertically developing (aggradation), laterally developing (progradation), accumulative, massive, sediments filling exogenic relief and faults. In the South Caspian basin the clinoform type clastic sedimentary sequenc are widely distributed. These evidences lateral infill by sediments brought from continental margin of deep-water basin. On seismic sections of sedimentary sequences of various age in Middle Caspian and South Caspian basins the laterally developing units can be clearly seen (figure 4). In these basins the laterally developing and clinoform sequences were identified in Paleogene (Oligocene, in particular), Miocene, Early Pliocene, Absheron and Quaternary deposits.

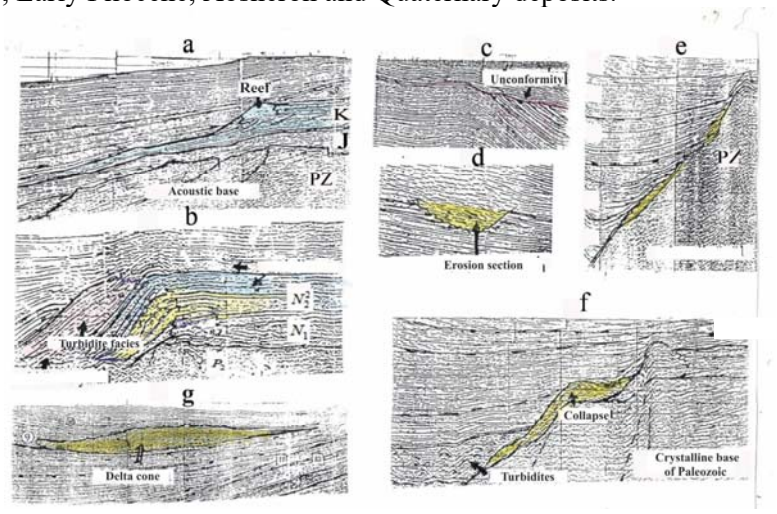

Figure 4 – Fragments of time sections dispalying lateral objects covered shelfs (b, c, g), gentle slopes (a) and steep slopes (e, f) and filled up the erosion sections (d)

The real mechanism of terrigeneous sedimentogenesis on continental margins is clearly displayed by flow-type sedimentation concept [17-18]. Modern concepts on eustatic and relative fluctuations of sea level gives us the logical explanation of huge amount of sediments in these zones. According to flow-type sedimentation concept while the low sea level the sediments are moved to the slope foot from deltas and shelfs by water flow and dense flow (gravities). Deltas, shelfs and slope foot are the major places where laterally accumulating sedimentation masses are developed. Seismic stratigraphy shows that in some cases the gentle continental slopes are areas favorable for generation of laterally accumulating objects.

Analysis of morphological features of northern near-flank structures of Mesozoic-Paleogene paleobasins in transition zone reflect that the zone corresponds to the classical model of continental margins of marginal seas in modern oceans. Here the specific features of transition from continent (platform) to deep-water marginal sea (the South Caspian basin as its relict after the Miocene) are the major indicators of the South Caspian basin being of marginal sea origin. Thus, transition structures of Epi-Paleozoic platform in the Middle Caspian play an exceptional role in generation of sedimentary units of various age and laterally developing objects of specific shape in sedimentary cover of South Caspian basin.

One of the major results of paleogeographical and facies analysis is the conclusion that sedimentary cover of high thickness (>20 – 25 km) was formed due to detrital and erosion materials brought mainly from the north – Scythian -Turanian platform and neighboring mountain ridges by river flows, mudflows and underwater flows.

Sediments of high thickness (>27 – 30 km) were accumulated on the northern flank of South Caspian basin – at the threshhold of Absheron-Balkhanyani (after closure of Great Caucasus and Kopetdagh segments of marginal sea in Miocene). On seismic sections they are mostly were traced in the northern flank of South Caspian basin - at the threshold of Absheron-Balkhanyani and adjacent areas. Mesozoic-Paleogene deposits of high thickness (~10 – 15 km) were uplifted and currently they can be identified at 1.0 – 3 km depths in some structures of North Absheron uplift zone (Absheron kupasi, Shargi Gilavar, etc.). A huge amount of sediment accumulation in the northern flank of South Caspian basin and uplifting of ancient (Mesozoic – Paleogene) deposits was previously supposed as related to geosynclinal processes in the region.

However, for the last years, based on interpretation of ultra-deep seismic data it became obvious that in the northern part of South Caspian basin the major reason of complicated folding, high thickness and uplifting of Mesozoic-Paleogene deposits is cutting and deformation of sediments during subduction of oceanic type of crust in the basin and development of overthrust type structure within its accretionary wedge. Seismic stratigraphic analysis of acquired data provides accurate data on laterally developing objects and tectonic and morphological elements in fluvial-deltaic zones of Middle and South Caspian, ancient continental shelfs, slopes and slope foot. To study laterally developing objects in these paleogeographic zones the known diagnostic techniques of seismic stratigraphy are applied [19-20].

The role of fluvial-deltaic sequences was significant in evulotion of sedimentary sequences on the northern continental border of marginal sea – in the southern flank of Scythian-Turanian platform. During the periods of low sea level the sediments were eroded from continental shelfs and slopes by underwater flows and dense mudflows down to the slope foot where they created huge cone outcrops.

In the South Caspian the origin of the major hydrocarbon bearing target – Productive Series of Early Pliocene is related mainly to three large rivers (Paleo-Volga, Paleo-Uzboy and Paleo-Kur) and paleodelta of several small rivers. At the end of Pontian during regional "Messinian Salinity Crisis" (5.1 mln. years ago) the sharp decrease (700 m) of erosion basis led to transportation of a huge amount of fluvial-deltaic, sandy-clay (detrital) sediments into the small lake on the south of the Caspian through Paleo-Volga and other rivers (figure 5), riverbeds, channels, ravines and underwater valleys.

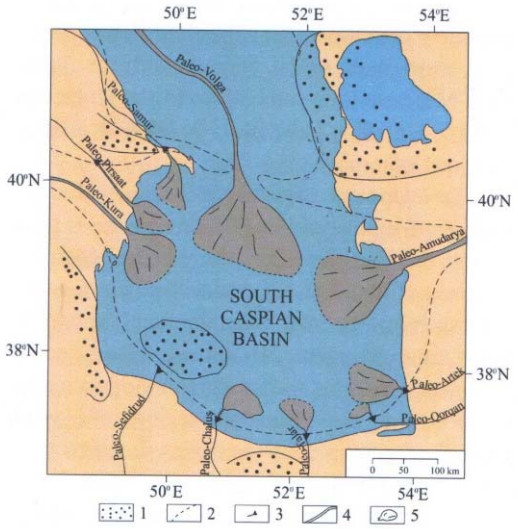

Figure 5 – Riverbeds and deltaic systems in the Early Pliocene basin:
1 – relative uplifts; 2 – basin limits; 3 – riverbeds; 4 – large riverbeds and underwater ravines; 5 – deltas

Deltaic and avandeltaic units of Paleo-Volga and Paleo-Uzboy were mentioned in many papers. The huge deltaic system of Paleo-Volga was developing from the end of Miocene to the south for 150 - 200 km (to the center of South Caspian basin) and moved for 200 km to the north (to the center of Middle Caspian) during basin transgression at the end of Early Pliocene (figure 6). The wide deltaic system of Paleo-Volga developed in the Early Pliocene in transition zone from Middle Caspian to the South Caspian, around the Absheron threshold in particular, has played a crucial role in development of oil and gas bearing Productive Series. Avandeltaic clinoforms of Paleo-Uzboy can be clearly traced in Early Pliocene section in the north-east of South Caspian basin (figure 6). These clinoforms were developing through the whole paracycle (apprpximately 500 thousand years) of relative sea level fluctuations in the narrow area (50 - 60 km). Stacked clinoforms consist of initial clinoforms (a), the cover made of conformable layers (b) and cross bedding (c). According to seismic sections the I – stacked clinoforms cover by 15-20 km laterally and by 100-200 m vertically the initial topographic trough. As a result, new sedimentary slope was developed, which after a long period of hiatus (approximately 300 thousand years) was covered by a new – II clinoform (figure 6). This clinoform covered new slope laterally by 30-40 km and vertically by 300 m. Currently this clinoform is buried at 4.5 – 7 km depths.

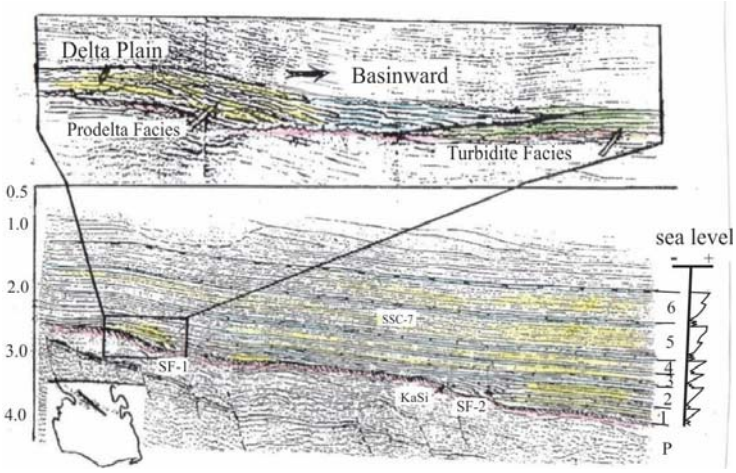

Figure 6 – Delta and avandelta systems of large rivers in the Early Pliocene
and delta-avandelta systems and turbidites in pinching out zones of Gala suite

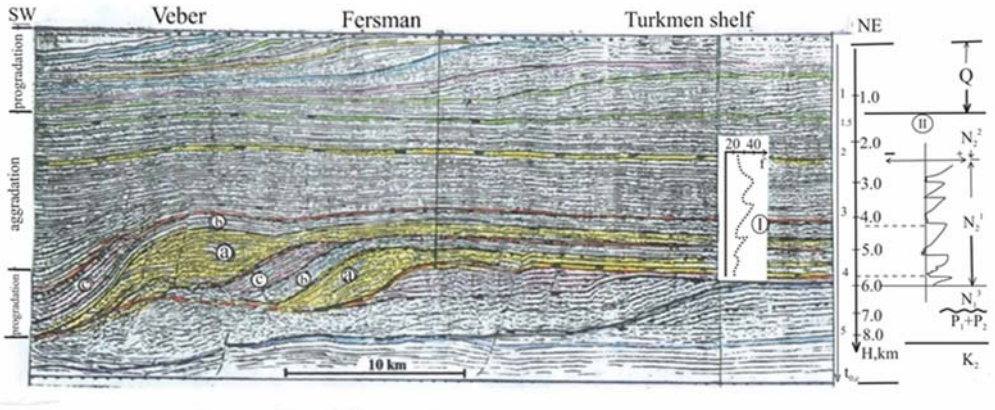

Figure 7 – Chronostraigraphic section displaying relative sea level fluctuations
and hiatus in accumulation of Paleo-Uzboy avandeltaic sequence in the South Caspian basin

The special attention should be paid to turbidites in deep-water basin of Early Pliocene across the South Caspian basin. In the USA large hydrocarbon accumulations have been discovered namely in such deposit types (turbidites). From the Ventura field only 120 mln.t of oil and 60 mln.m^3 meters of gas were produced from turbidite deposits. In the Mexican gulf also the oil and gas bearing sequence with alternation of high quality reservoirs and pelagic deposits has been attributed to turbidites [21-22]. They have been accumulated in areas far from frontal parts of deltas and avandeltas and in underwater cones. In the central portion of South Caspian several large structures (Umid, Babek, Inam, etc.) have been discovered by seismic survey. These are mainly located in the areas of turbidites accumulations in underwater cones of frontal parts of large and small rivers deltaic systems (Paleo-Kur, Paleo-Volga, Paleo-Uzboy, etc.) in the Early Pliocene basin (figure 7).

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ОРТА ЖӘНЕ ОҢТҮСТІК КАСПИЙ МЕГАБАЗИНІНДЕГІ СЫНА ПІШІНДЕРІН ҚАЛЫПТАСТЫРУ ШАРТТАРЫ

Аннотация. Мақалада тұнбаға түсу процесі және Оңтүстік-Каспий және Орта Каспий бассейндерінің эволюциясының әр түрлі кезеңдерінде пайда болған терең сулы компенсацияланбаған және таяз-эпикон-тинентальды палеобазиндердің бүйірлік өсу объектілері қарастырылған. Оңтүстік Каспий мегабазині – жер

қыртысының үлкен тектоникалық элементі және Альпі - Гималай жылжымалы белдеуінің орталық сегментіндегі болашағы зор шөгінді бассейн. Скиф - Тұран платформасының шекаралас құрылымдарының Орта Каспийдегі рөлі (Оңтүстік Каспий ойпаты және Қарабоғаз доғасы) және континентальды қайраңдағы қар көшкінінің тұнбалары шөгінді кешендермен көпқабатты жанама аккреция сандарының даму рөлі көрсетілген. Оңтүстік Каспий ойпатының шөгінді жабыны көрсетілген. Басқа талдау деректерін қолдана отырып сейсмостратиграфиялық талдау (мысалы, палеорельефтің морфоструктурасын және мүшелер мен түзілімдердің қалыңдығын зерттеу) және ұңғымаларды геофизикалық зерттеу жаңа қабаттардан өнімді қабаттардың төменгі қабаттарындағы шөгінділер генезисін жарықтандыруға мүмкіндік берді және мұнай мен газды жинақтауға арналған үлкен литологиялық-стратиграфиялық тұзақтарды қалыптастыру үшін қолайлы аймақтарды анықтау.

Түйін сөздер: шөгінді бассейндер, Оңтүстік Каспий бассейні, клиноформалар, миоцен, ерте плиоцен, абшерон, төрттік шөгінділер.

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УСЛОВИЯ ФОРМИРОВАНИЯ КЛИНОФОРМ В СРЕДНЕ- И ЮЖНО-КАСПИЙСКОМ МЕГАБАССЕЙНЕ

Аннотация. В статье рассмотрены процесс седиментации и объекты латерального наращивания в глубоководных некомпенсированных и мелководно-эпиконтинентальных палеобассейнах, сформировавшихся на различных стадиях эволюции Южно-Каспийского и Средне-Каспийского бассейнов. Южно-Каспийский мегабассейн – крупный тектонический элемент земной коры и высокоперспективный осадочный бассейн в центральном сегменте Альпийско-Гималайского подвижного пояса. Показана роль пограничных структур Скифо-Туранской платформы на Среднем Каспии (Южно-Каспийская впадина и Карабогазская дуга) и лавинной седиментации на континентальном шельфе в развитии осадочных комплексов и объектов специфической формы латерального наращивания в многокилометровом осадочном чехле Южно-Каспийской впадины. Согласно интерпретации сейсмостратиграфических данных доказано поступление палеодельтаовых, авандельтовых и турбидитных объектов латерального наращивания для заполнения раннепилиоценового бассейна. Сейсмостратиграфический анализ с использованием других данных анализа (например, изучения морфоструктуры палеорельефа и мощностей пачек и свит) и ГИС позволил осветить генезис отложений в подошвенных свитах ПТ с новых позиций и выявить благоприятные зоны формирования крупных литолого-стратиграфических ловушек для скопления нефти и газа.

Ключевые слова: осадочные бассейны, Южно-Каспийский бассейн, клиноформы, миоцен, ранний плиоцен, Абшерон, четвертичные отложения.

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