UDC 550.3:551:534.8
DOI: http://doi.org/10.17721/1728-2713.98.07

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GEOLOGICAL SIGNIFICANCE OF SEISMIC REFLECTIONS IN THE SEDIMENTARY COVER OF THE EASTERN PART OF THE ABSHERON-PREBALKHAN RIDGE

(Представлено членом редакційної колегії д-ром геол. наук, ст. дослідником О.І. Меньшовим)

The Absheron-Prebalkhan tectonic zone, often called as the Absheron-Prebalkhan ridge, is a link between two large oil and gas basins of the world, which differ in the genetic level of the basement, i.e.: the South Caspian (SCB) and the Middle Caspian basins (MCB). The considered area has been completely covered by detailed seismic and gravity surveys over the past decades.

The article presents material illustrating the information content of seismic sections in different parts of the region, which are characterized by different seismogeological conditions. As a result of the analysis of the latter, the author specified and determined four seismic horizons: SH-A (Akchagyl), SH-I (tops of RS), SH-II (horizon VIII) and SH-III (lower RS) based on the dynamic expressiveness, length, and resolution of the record. The tracking quality of these horizons is not the same.

The identification of seismic intervals, which correspond to structural levels based on objectively determined seismic parameters, such as the configuration and relative position of reflections, their continuity, as well as the amplitude and frequency of seismic waves were the basis for seismic stratigraphic analysis of the wave field.

The compiled schematic structural maps show the geological structure of the red-colored strata and Akchagyl deposits and the correlation of the structural plans of the latter clearly. Comparison of complex geological and geophysical materials allows to determine the character of the distribution of lithofacies features of RS deposits.

Keywords: Absheron-Prebalkhan tectonic zone, ridge, red-colored strata, seismic stratigraphic analysis, horizon, interpretation

Articulation of the problem. A sharp jump in exploration for hydrocarbons in deep water areas has been observed over the past 10 years, which is mainly due to the risks associated with the prices of fossil fuels in the world market (*Bell et al., 2005; Skogdalen and Vinnem, 2012; Reader and O'Connor, 2014; Joye, 2015*). In this regard, it is considered very important to carry out purposeful deep drilling in places where oil and gas promising objects are located that have sufficient profitability for exploitation. Therefore, the applied task is the acquisition of high-quality seismic material and the competent interpretation of the seismic record in it, which is of great practical importance for choosing the directions and methods of geological exploration for oil and gas. The main condition for the maximum reliability of geological information is the complexity of the work and the interpretation of the materials.

The junction zone of the South Caspian (SCB) and the Middle Caspian basins (MCB), which is the main oil and gas generating component of the region, has been an object of research for more than decades. The SCB, in which the Absheron-Prebalkhan tectonic zone is developed, arose and is evolving within the Alpine-Himalayan orogenic belt. The sedimentary filling of the SCB in some places remains relatively undeformed in comparison with the neighboring Caucasian, Kopet Dag and Elburz fold-thrust complexes (Fig. 1).

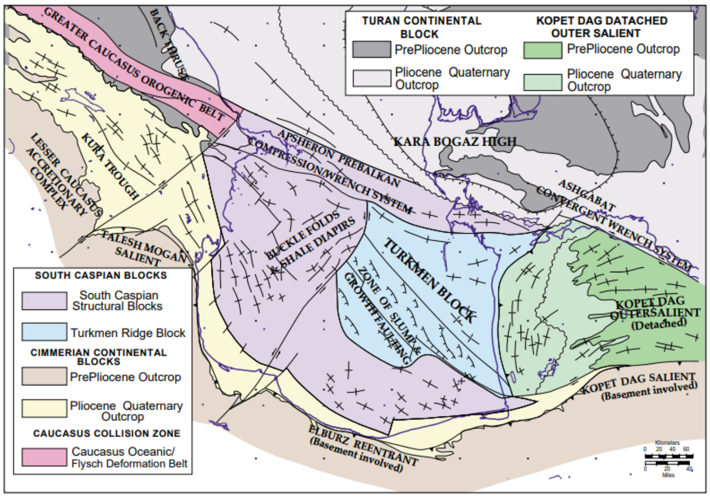

Fig. 1. Structural elements of the South Caspian Basin and adjacent areas (modified from *Philip et al., 1989; Berberian and King, 1981; Adamia et al., 1977; Nalivkin, 1976; Huber, 1978* with additions).

The section of the sedimentary cover of the convergence zone is characterized by the presence of sharply expressed in length, in-phase correlated reflections, which make it possible to mark the key horizons (dynamically most expressed, but poorly regular), which are quite long, up to many hundreds of kilometers. However, irregular (i.e. poor discontinuous, chaotic, dashed, etc.) reflections also dominate in the section of the latter. In addition, the wave field distorts reflections of a non-geological nature significantly – interference (i.e. diffraction, multiple energy, etc.), as well as reflections from fluid contacts, tectonic dislocation and developed mud volcanism. Seismic stratigraphic interpretation of the wave field by the nature of the manifestation of reflected waves on time sections is a powerful tool for establishing the genesis of geodynamic processes and deposition environment.

Seismic stratigraphic analysis is based on the assumption that seismic reflections follow depositional surfaces and erosional unconformities and therefore have chronostratigraphic significance (*Vail et al., 1977*). Based on the generalization of seismic stratigraphic analysis materials, it is assumed that the ensembles of events of reflected waves characterize the sections of sedimentary bodies and allow to assess their stereoforms ("seismic record pattern").

Diagenetic processes in sedimentary systems change the pore space and mineralogy of primary sediments significantly, thereby affecting their acoustic properties (*Eberli et al., 2003*). So, it is necessary to study the paragenetic relationship of reflections carefully to substantiate the main position of the seismic stratigraphic method a priori for any sedimentological and stratigraphic interpretation of seismic data.

Tectonics and stratigraphy of the region. The Absheron-Prebalkhan tectonic zone, which is called the Absheron-Prebalkhan ridge, has been the subject of study by many researchers for almost a hundred years. This area is of the greatest interest since it is located between the two well-known oil and gas regions of Absheron and Cheleken.

It is well known that it is necessary to find out the formation mechanism of the Absheron-Prebalkhan ridge in particular and the SCB as a whole to determine the zone of oil and gas generation correctly. Predominantly fixist views regarding the solution of this problem prevailed until the 1970s. However, the emergence of a new mobilist concept made it possible to consider this problem from new positions.

Today, there is no common idea on the geodynamic setting, time, and mechanism of site, as well as the oil and gas occurrence of the SCB. A large number of geological and geophysical works were previously carried out within the megabasin and in the mountain-fold structures surrounding it in the central segment of the Alpine-Himalayan orogenic belt, as a result of which various schemes of geodynamic and geotectonic models were developed to solve these problems from the point of plate tectonics concepts (V.P. Rentgarten, O.G. Sorokhtin, V.Y. Khain, Y.Y. Milanovsky, L.P. Zonenshain, M.G. Lomize, E.N. Khalilov, P.Z. Mamedov and others).

The study of the geological structure of the Absheron ridge was started by the classics of Russian and Soviet geology G.V. Abikh, A.F. Karpinsky, A.D. Arkhangelsky, N.I. Andrusov and others. A systematic study of the geological structure of the work area was carried out by all types of geophysical surveys, as well as exploratory and deep exploratory drilling (exploratory drilling in the offshore areas of the region has been carried out since the 40s).The Absheron-Prebalkhan ridge, which is an integral part of the Mediterranean-Alpine belt and developed in the SCB and MCB convergence zone, is characterized by a peculiar, thin consolidated crust (6-8 km) and a thickened sedimentary cover, which is built on a tectonic-mosaic geological foundation. The sedimentary series of the region, which lies on the pre-Jurassic basement, is represented by the Mesozoic and Cenozoic structural-lithological stages with a thickness of 25-32 km. The latter includes the Paleogene-Miocene and Pliocene-Quaternary structural-facies complexes.

The Absheron-Prebalkhan ridge is morphologically divided into 2 anticline belts. The first includes the Tengi-Beshbarmag and Germian mega-anticlines in the west and extends to the east, adjoins the Cheleken group of uplifts (structures: Guneshli, Chirag, Azeri, Kapaz, Magtumgulu, Diyarbekir, Turkmenabad, Cheleken gumma, etc.). The second anticline belt originates from the Gadis-Nardaran mega-anticline in the west and extends in a near-latitudinal direction (structures: Nardaran-deniz, Khali, Chilov, Hazi Aslanov, Palchig Pilpilasi, Neft Dashlari, Oghuz, Jeytun). Altiagaj-Kukrkechidag and Aladash-Yunusdag mega-anticlines form the third anticline belt like a folded ridge by stretching from west to east in a near-latitudinal direction. This belt includes the structures of Gurgan-deniz, Janub, etc. besides the western local structures located in the northern part of the Absheron Peninsula.

The stratigraphic range of sedimentary occurrences throughout the section of the Absheron-Prebalkhan ridge is filled with deposits of the Meso-Cenozoic age. It should be noted that in view of the fact that the studied region is included in the zone of interests of the two energy powers, there are discrepancies in the names of stratigraphic units.

The Mesozoic group is represented by Jurassic and Cretaceous sediments in the APR sedimentary cover, which are lithologically expressed by aspide schist with series of sandstones, siltstone, and limestone (J) and alternating gray, greenish-gray clays, marls with thin interlayers of fine-grained sand with inclusions of calcareous substances (K).

The Cenozoic group includes Paleogene, Neogene, and Quaternary sediments.

The Paleogene system is represented by three divisions: the Paleocene, the Eocene and the Maikop suite (Oligocene-Lower Miocene). The lithological composition is predominantly composed of clayey lithofacies, alternation of clays and siltstones, interlayers of dense sandstones and sands and locally marl and marl clays.

The Neogene system is represented by two divisions: Miocene and Pliocene deposits. The Miocene deposits are lithologically expressed mainly by clayey lithofacies, gray marls (Tarkhan horizon), a series of layered clays with rare interlayers of brown dolomites, hard marls (Chokrak horizon), clays with interlayers of dense dolomites and volcanic ash (Upper Miocene).

The Pliocene (lower and upper) is widely developed in the water area of the Absheron ridge. Lower Pliocene deposits, which are associated with large deposits of Azerbaijan and Turkmenistan, spread throughout the study area. They have been encountered by numerous wells here and studied for one or another thickness in almost all APR structures. The deposits of the Lower Pliocene in the Azerbaijani part of the water area are represented by the Productive series (PS), its analogues (temporary and facies) in the Turkmen part of the Caspian Sea are the deposits of the Red-colored strata (RS).

As it is known from the literature, the PS is divided into upper and lower sections.

5 formations are distinguished in the deposits of the lower part of the PS (Kalinskaya-KaS, Podkirmaki-PK, Kirmaki-KS, Nadkirmaki sandy-NKS, Nadkirmaki clayey-NKC).

KaS. They consist of sandy-clayey facies in almost all areas of the distribution range. The content of sands in KaS increases to the southeast from the Absheron Peninsula.

PK. It is more widely distributed than the underlying KaS. It is represented by a thick layer of uneven-grained quartz sands with rare interlayers of dense gray clays.

KS. It is quite thick, consistent in its lithological composition and thickness and it is a series of fine sandy-clayey alternation.

NKS. It is developed throughout the APR. It consists of a series of medium- and coarse-grained quartz sandstones and sands with thin interlayers of clays. The deposits of the NKS suite are composed of almost 90% sandy rocks.

NKC. It is an alternation of black and brown clays with inclusions of sand and fine and fine-grained, there are also interlayers of dense sandstones. The number of sand layers increases to the east of the APR.

The upper section of the PS is represented by the "break" suite, Balakhani, Sabunchu and Surakhani suites, expressed by sandy-clayey alternation.

Lower Pliocene deposits within the Turkmen shelf are represented by two sections: lower (PRS) and upper (RS). The PRS is lithologically represented by sandy-argillaceous deposits. General decreasing tendency is observed in the thickness of the PRS deposits from west to east. However, deposits of RS are all-around developed in the southeastern Caspian and its near edge zone. It consists of alternating sandy-siltstone and clayey rocks with different colors.

The Upper Pliocene is ubiquitously represented by the Akchagyl Stage, a lithologically pronounced alternation of sandy and clayey occurrences (grey, brownish, and greenish gray clays) with inclusions of volcanic ash.

The Quaternary system is also represented by two divisions: Pleistocene and Holocene. It is lithologically expressed by sandy-shell rocks and dense limestones (Absheron stage), sands, clays, and rare layers of volcanic ash. A summary correlation section is shown along the study area by illustrating the distribution area of the Cenozoic group of deposits visually within the line (I-I') of the profile below, in Figure 2.

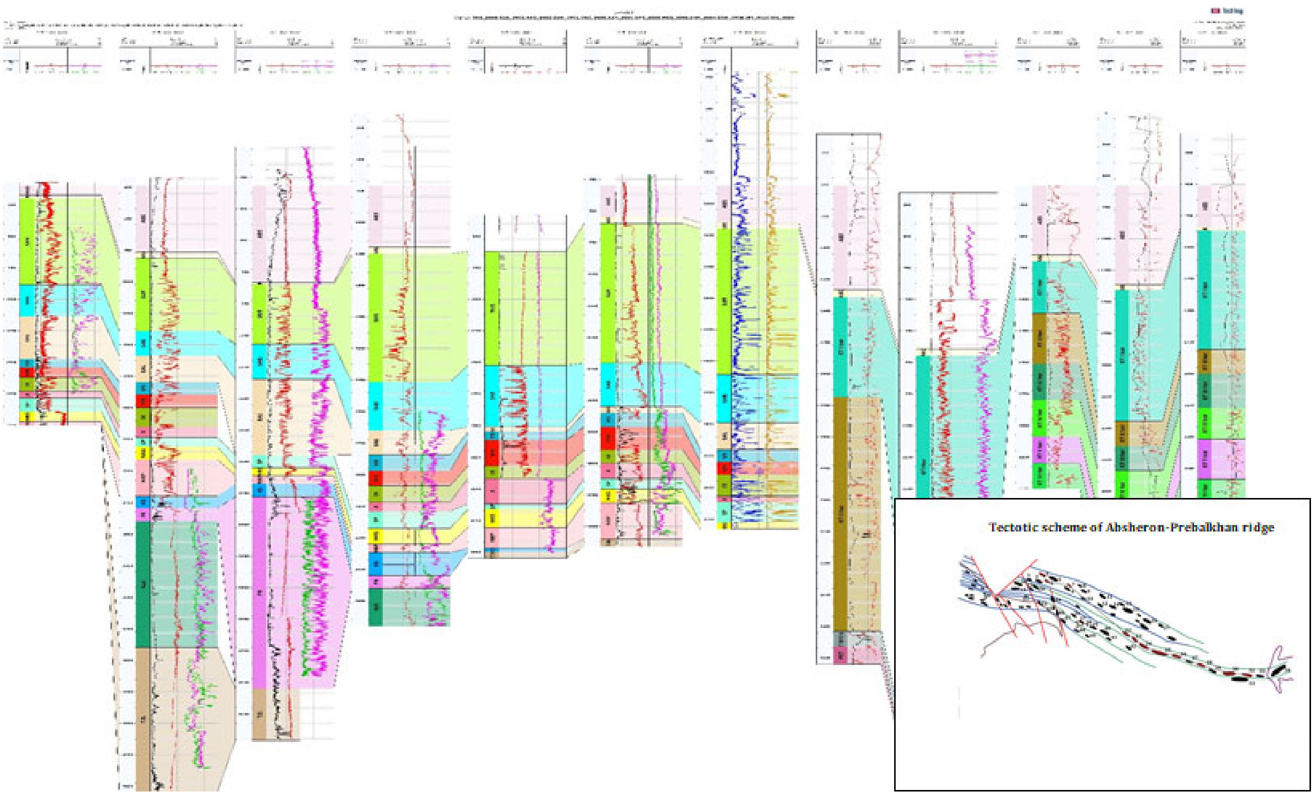

Fig. 2. Summary correlation scheme along the line (I-I')

Interpretation of seismic data. Informativeness of time sections. The study area is characterized by very complex seismogeological conditions (disjunctive folding, mud volcanism), which determines the complex character of the wave field. Apparently, the change of the character of the wave field is also associated with deep conditions – structural and lithofacies in terms of area and depth.

The wave picture reflects depositional termination in the Absheron suite, regular bedding in the RS with increasing dip angles with depth and in general, regular bedding of reflecting horizon in the sediments of underlying RS in the eastern part of the area (structures: Dostlug, Mashrikova, Magtimgulu, etc.).

Time sections according to the wave picture can be conditionally divided into three-time intervals:

1. Extended, dynamically expressed 2x-3x phase events are recorded with low-frequency recording in the interval of 0-3.0 seconds;

2. There are also clear extended, dynamically expressed reflections with a higher-frequency recording in the interval of 3-5.5 seconds;

3. As a rule, extended, low-intensity events are recorded below an interval of 5 seconds.

Basically, the multilayered structure of the section with a large number of lithological contacts determines the presence of a large number of dynamically distinctive and resolved 2-3-phase reflections with very poor slopes of the in-phase axes over the entire study area. The dynamic expressiveness of reflections increases sharply, extended seismic horizons acquire the character of key ones in some areas. As moving to the crest of the structures, the information content of the seismic picture is significantly distorted, the expressiveness and temporal resolution of the recording deteriorate, and complex interference recording is observed. Besides dynamically expressed seismic reflections, poor reflections distinguish in large numbers on the time sections obtained in the central and eastern parts of the APR. These reflections reflect the change in acoustic impedance (AI) and are associated with the age bedding of the section.

Almost all dynamically expressed reflections are of an interference character in the thin-bedded terrigenous section (Fig. 3), since they are reflected from thin-bedded series of finite thickness with layers of similar lithological features (i.e., acoustic impedance). The high-frequency components of the seismic signal decay rapidly, but the low-frequency components penetrate deeper and deeper parts of the section and provide information about deep horizon. Reflections associated with thin-bedded series carry useful geological information. The amplitudes of the total reflection are proportional to the differences of the AI at the contact of two fields.

Reflections may not occur or appear in a weakened form at a curved stretched AI gradient. On the contrary, the AI gradient will contribute to the creation of a strong reflection from a sharply appressed series. If the section consists of almost transparent intervals and dynamically expressed intervals, the character of the AI drop in the sedimentary cover is inherent in the nature of sedimentation. Thin intervals correspond to the depths of poorly differentiated sediment genesis, where AI changes occur smoothly and there are no sharp horizons. Therefore, age successive beddings are the main parameter for the occurrence of reflections. The amplitude of the traced phases is the total from each horizon in thin-bedded sections. It occurs with maximum or less compact texture and structural series at a high rate of sedimentation, i.e. high-energy environment. Dynamically poorly expressed reflections are usually associated with them.

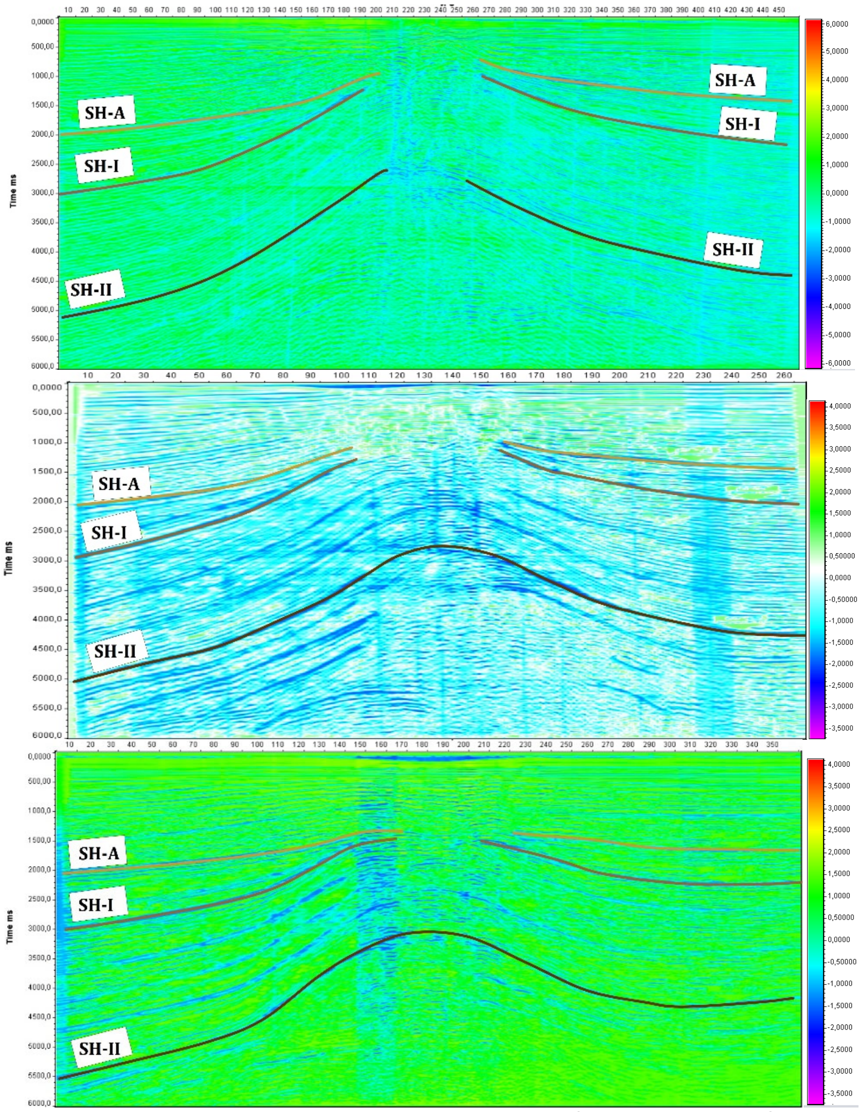

Fig. 3. Time laps seismic sections along the structures of the eastern part of the APR

The alteration of the quality of the seismic material also changes as the depth of the study increases. The material becomes more complex in depth, the number of reflections decreases, and the length of the reflecting horizons is violated.

As mentioned above, a complex deep structure: disjunctive fault, steep angles of dip of the wings, lithofacies features of the section – all these factors predetermine the formation of a complex wave field.

So, in general, a deterioration of seismic data is observed in the considered area from NW to SE, from the Dostlug structure to the Cheleken zone.

The author determined four seismic horizons: SH-A (Akchagyl), SH-I (tops of RS), SH-II (horizon VIII) and SH-III (lower RS) based on the dynamic expressiveness, length, and resolution of the record. The tracking quality of the mentioned horizons is not the same.

The stratigraphic assessment of these horizons is most reliably substantiated in areas where there are numerous data from prospecting and exploratory drilling; a small amount of seismic survey data from the TSS has been obtained for individual areas of the Pribalkhan uplift zone in recent years.

SH-A – correlated along dynamically expressed extended events at times of 1.3-2 sec. SH-A is not traced on the crest of the structures throughout the study area and in the fringes. Recording is complicated by interference, dogled of the events, diffracted waves.

SH-I – is distinguished by dynamism, length. Registration time – 2-2.7 sec. Tracing SH-I is complicated by interference in the crest position of the folds, which is a consequence of the wedging out of deposits in the Absheron.

SH-II –the horizon loses its intensity and correlates less confidently in RS deposits.

SH-III – its traceability is less confident than the first horizons. SH-III is complicated by interference, the superposition of waves arriving with different inclinations of the events increasing with depth on the wings of the area.

Structural constructions were carried out along these horizons on a scale of 1:100,000, with a contour interval of 100 m. Data of detailed and prospecting seismic works, as well as deep drilling data were involved for the compilation of consolidated structural maps. In view of the fact that most of the profiles can be considered orthogonal, the complication of structural maps was carried out in isoverticals.

Results of the Research. The results of the studies have shown that the structures of each anticline line of APR are brachs/linear anticlines with steep southwestern and gently northeastern wings, which can be explained by the fact that their southwestern wings are turned towards the South Caspian depression, which experienced the strongest warping in the Pliocene-Anthropogenic time and the Artemo-Kelkor ridge, towards which the northeastern wings of the folds are turned, did not experience such a strong warping.

The Artem-Kelkor trough is reflected as several synclines on the structural constructions made along the tops and bottoms of the RS (Fig. 4). The synclines are complicated by troughs and slightly flatten out up the RS section. The NE side of the Artem-Kelkor trough is slightly sloping to southwest and the slope angles of the layers are 7-9º, 12-14º and increase with depth to 16-18º and 24-28º.

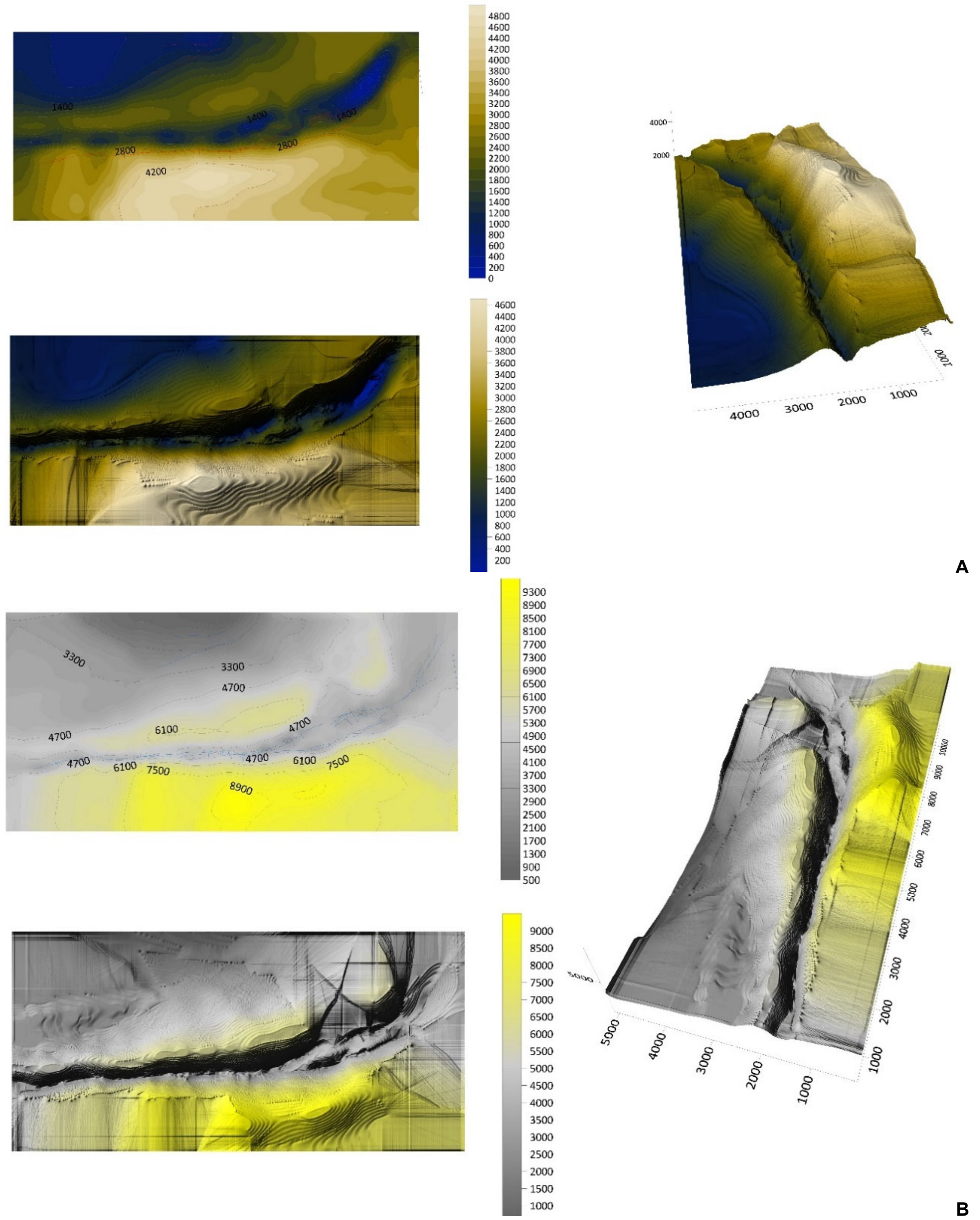

Fig. 4. Consolidated structural maps for seismic horizons SH-I (A) and SH-II (B), their representation in 2D, 3D and relief form

ISSN 1728-2713

The NE side of the Artem-Kelkor trough rises in the direction of the Kubadag ridge on all structural constructions.

Besides the abovementioned structural maps by using seismic profiles, which cover the entire study area, a map of equal thicknesses between the seismic SH-I and SH-II was compiled, which characterize the distribution of thicknesses of the RS deposits within APR (Fig. 5). The analysis of the compiled map showed that the thickness of the RS in this area varies within a fairly wide range from 1000 m in the north of the area, to 4250 m in the south (Fig. 5).

It is known that the trend of folds, as a rule, corresponds to the trend of isolines of sediment thickness, synchronous time of their growth, which provides an additional criterion for determining the age of folds (*Pishnamazov, 1982*).

Observing a similar picture in the described zone and taking into account this criterion, we can conclude that the growth of APR folds continued in the Lower Pliocene simultaneously with sedimentation. This is also evidenced by the increase of thickness from the faults to the wings of the uplifts. Notably, the greatest thickness of RS 4000-4250 m is observed on the SW wings of the uplifts, which is explained by the fact that these wings pass into the northern side of the South Caspian Basin, which underwent a long subsidence in the Lower Pliocene.

The NE wings of the uplifts of the described anticline zone pass into the side of the Artem-Kelkor syncline, which is filled with red beds, the thickness of which reaches 4000 m. The thickness of red beds decreases (up to 1000 m) to the NE of the Artemo-Kelkor syncline, gradually wedging out in the direction of the Scythian-Turan platform.

Besides the abovementioned structural constructions, the article deals with geological and geophysical profiles that provide additional information about the tectonics of the study area (Fig. 6).

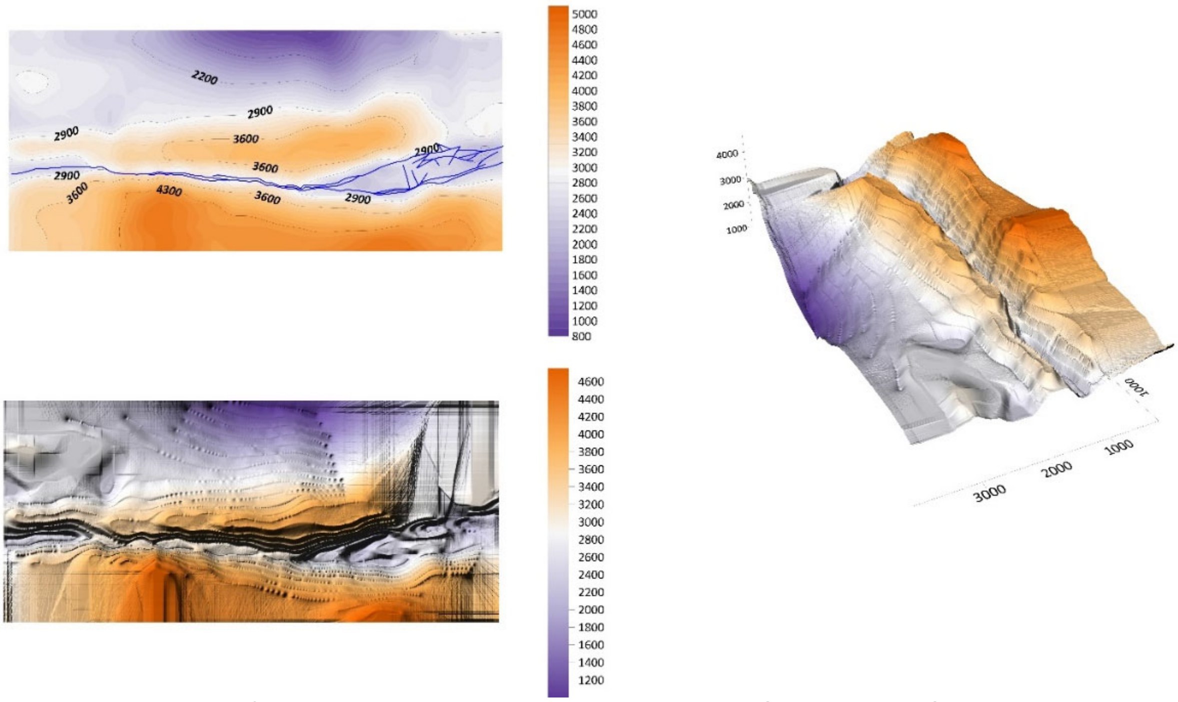

Fig. 5. Map of equal thicknesses between the seismic horizons SH-I (abow) and SH-II (below), its representation in 2D (left), 3D and relief form (right)

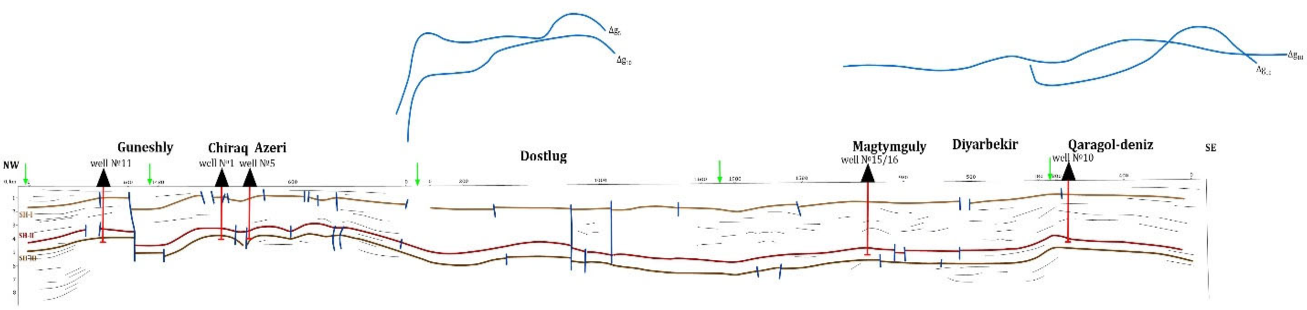

Fig. 6. Sublatitudinal geological and geophysical profile along the APR

Besides seismic surveys, the entire study area is covered with a semi-detailed gravimetric survey and certain sections of the area are covered by hydrogas surveys (*Zalova, 1982; Nasruyev, Rzayeva, 1982*). Comparing the results of seismic surveys with the data of gravimetric works (*Zalova et al, 1982*), the subordinate character of the origin and development of Pliocene structures can be emphasized. It is assumed that the formation of RS structures is to some extent associated with older structural and tectonic complications.

According to Zalova (*Zalova, 1982*), local maximums correspond to the Pliocene structures in areas where the presence of an uplifted block in the Paleogene-Mesozoic is assumed, i.e. in the areas of local maximums Magtimgulu and Diyarbekir.

So, it becomes obvious that the reflection of the Pliocene structures in the local field is subordinate to the influence of the Mesozoic. The variation of the hypsometric level of the Magtimgulu, Diyarbekir and Garagol-Deniz structures along the top and bottom of the RS coincide with the block structure, i.e. where a raised block occurs, the hypsometric level is higher there and vice versa.

The anomalies of hydrocarbonic concentrations, which are revealed as a result of hydrogas surveys, are confined mainly to the zone of uplifts in sea water. Taking into account the significant disturbance of the uplifts, the formation of gas anomalies under them can be associated with the release of hydrocarbons along the disturbances to the surface.

Conclusions.

1. As a result of the generalization of seismic data of the CDP and drilling, consolidated structural maps were compiled for the single seismic horizons SH-A, SH-I, SH-II and SH-III for the eastern part of the Absheron-Prebalkhan tectonic zone at a scale of 1:100.000. A discrepancy of the structural plans of sediment complexes of different ages was noted, regularity was determined in the displacement of the crest of structures with depth to the southeast.

2. A map of the distribution of thicknesses of red beds over the study area was compiled, where the greatest thickness of RS deposits is confined to the northern part of the zone.

3. An analysis of the CDP time sections shows that, the wave picture, as a rule, becomes more complicated with depth in the entire aquatorial area of the eastern part of the APR, the traceability of reflecting boundaries worsens, their density decreases, and the dynamic characteristics of reflected waves change.

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Надійшла до редколегії 01.04.22

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ГЕОЛОГІЧНА ПРИРОДА СЕЙСМІЧНИХ ВІДОБРАЖЕНЬ В ОСАДОВОМУ ЧОХЛІ СХІДНОЇ ЧАСТИНИ АБШЕРОН-ПРИБАЛХАНСЬКОГО ПОРОГУ

Абшерон-Прибалханська тектонічна зона, що частіше називається Абшерон-Прибалханським порогом, є сполучною ланкою двох великих нафтогазоносних басейнів світу, що розрізняються за генетичним рівнем фундаменту, а саме: Південно-Каспійського та Середньо-Каспійського басейнів. Протягом останніх десятиліть площа, що розглядається, повністю покрита детальними сейсморозвідувальними та гравіметричними дослідженнями.

Наведено матеріал, що ілюструє інформативність сейсмічних розрізів на різних ділянках регіону, що характеризуються різними сейсмогеологічними умовами. У результаті аналізу останніх, виходячи з динамічної виразності, протяжності та дозволеності запису автором уточнені та протрасовані чотири сейсмічні горизонти: СГ-А (акчагил), СГ-І (верхи ЧТ), СГ-ІІ (VІІІ горизонт) та СГ-ІІІ (низи ЧТ). Якість простеження зазначених горизонтів неоднакова.

Виділення сейсмічних інтервалів, що відповідають структурним поверхам, засноване на об'єктивно визначених сейсмічних параметрах, таких як конфігурація та взаємне розташування відображень, їх безперервність, а також амплітуда та частота сейсмічних хвиль, було покладено в основу сейсмостратиграфічного аналізу хвильового поля.

Побудовані схематичні структурні карти наочно відображають геологічну будову червонокольорової товщі та акчагильських відкладень і співвідношення структурних планів останніх. Зіставлення комплексних геолого-геофізичних матеріалів дозволяє певною мірою визначити характер поширення літофаціальних особливостей ЧТ відкладень.

Ключові слова: Абшерон-Прибалханська тектонічна зона, поріг, червонокольорова товща, сейсмостратиграфічний аналіз, горизонт, інтерпретація.