Method of determining the location of the pinch point using seismic survey in some areas of the Absheron Peninsula

T. R. Ahmadov

ABSTRACT

The article is devoted to determining the exact position of the point of pinching sediments by 2D and 3D seismic. It is noted that industrial oil and gas production has a nearly two-century history and the main developed fields are concentrated in anticlinal traps that have already exhausted their resources. At present, there is an intensive search for non-anticline hydrocarbon traps both in the Absheron Peninsula and beyond; most traps are associated with wedging out sediment complexes. It is emphasized that the study of seismic pinch-out zones in Azerbaijan does not meet difficulties, and the situation of studying determining the position of the pinch point is different. Three methods for determining and clarifying the position of the pinch point are proposed: a - using attribute analysis or instantaneous dynamic characteristics of the wave field; b - the method of determining the quality of the recording according to the Vertical Seismic Profiling (VSP); c - with spectral analysis of seismic records based on Fourier transform. All three methods were tested on different seismic and geological conditions, gave good results, and showed high geological efficiency.

Key words: 2D and 3D seismic, anticlinal and non-anticlinal traps, hydrocarbons, Vertical Seismic Profiling (VSP); quality factor, spectral analysis, pinch point.

*Azerbaijan State University of Oil and Industry (16/21 Azadlig Avenue, Baku, Azerbaijan). akhmedov.tofik@bk.ru ORCID: https://orcid.org/0000-0003-0634-5600

Recibido: 04/02/2019 Aceptado: 20/04/2019

Методика определения положения точки выклинивания сейсморазведкой на некоторых площадях Апшеронского полуострова

АННОТАЦИЯ

Статья посвящена определению точного положения точки выклинивания отложений сейсморазведкой 2D и 3D. Отмечается, что промышленная добыча нефти и газа имеет почти двухвековую историю и основные разработанные и разрабатываемые месторождения сконцентрированы в антиклинальных ловушках, которые уже исчерпывают свои ресурсы. В настоящее время идет интенсивный поиск не антиклинальных ловушек углеводородов как в Апшеронском полуострове, так и за его пределами, среди которых большинство составляют ловушки, связанные с выклиниванием комплексов отложений. Подчеркивается, что изучение зон выклинивания сейсморазведкой в Азербайджане не встречает трудностей, а что касается определения положения точки выклинивания, то здесь дело стоит иначе. Предлагается три способа определения и уточнения положения точки выклинивания: а - с применением атрибутного анализа или мгновенных динамических характеристик волнового поля; б - методикой определения добротности записи по данным Вертикального Сейсмического Профилирования (ВСП); в – со спектральным анализом сейсмических записей на основе Фурье преобразования. Все три способа опробованы на разных сейсмогеологических условиях и дали хорошие результаты и показали высокую геологическую эффективность.

Ключевые слова: сейсморазведка 2D и 3D, антиклинальные и не антиклинальные ловушки, углеводороды, Вертикальное Сейсмическое Профилирование (ВСП); добротность, спектральный анализ, точка выклинивания.

Método para determinar la ubicación del punto pinch utilizando la encuesta sísmica en algunas áreas de la Península de Absheron

RESUMEN

El artículo está dedicado a determinar la posición exacta del punto de pellizco de sedimentos mediante sísmica 2D y 3D. Se observa que la producción industrial de petróleo y gas tiene una historia de casi dos siglos y que los principales campos desarrollados se concentran en trampas anticlinales que ya han agotado sus recursos. En la actualidad, hay una búsqueda intensiva de trampas de hidrocarburos no anticlínicas tanto en la Península de Absheron como fuera de ella; la mayoría de las trampas están asociadas con la eliminación de complejos de sedimentos. Se enfatiza que el estudio de las zonas de pellizco sísmico en Azerbaiyán no encuentra dificultades, y la situación de estudiar la determinación de la posición del punto de pellizco es diferente. Se proponen tres métodos para determinar y aclarar la posición del punto de pellizco: a - utilizando el análisis de atributos o las características dinámicas instantáneas del campo de onda; b - el método para determinar la calidad de la grabación de acuerdo con el Perfil Sísmico Vertical (VSP); c - con análisis espectral de registros sísmicos basados en la transformada de Fourier. Los tres métodos se probaron en diferentes condiciones sísmicas y geológicas, dieron buenos resultados y mostraron una alta eficiencia geológica.

PALABRAS CLAVE: sísmicas 2D y 3D, trampas anticlinales y no anticlinales, hidrocarburos, perfiles sísmicos verticales (VSP), Factor de calidad, análisis espectral, pinch point.

Introduction

The Absheron peninsula of Azerbaijan is one of the main oil and gas regions. The history of the industrial production of hydrocarbons in the peninsula goes back about two centuries; the first well was drilled using a percussion method to a depth of 21 m under the direction of V.N. Semenova in 1846 near Baku, in the village of Bibi Eybat (now it is almost the city of Baku). The main objects of exploitation in the Absheron Peninsula and the Azerbaijan sector of the Caspian Sea are still separate formations of the productive stratum

(PT), which for a long time belonged to the Middle Pliocene, but according to the latest research, it is confined to the Lower Pliocene (Mamedov, 2018; Abdullaev et al, 2012). All deposits, which are still in operation at Absheron, are anticline. The resources of anticlinal traps are drying up both around the world and in Azerbaijan, including on the Absheron peninsula, therefore the center of gravity of the search and exploration of hydrocarbon deposits (HC) is shifting towards non-structural traps.

1. Purposes and goals

The main purpose of these studies is to show the geological effectiveness of seismic prospecting when searching for and prospecting non-structural pinch-type traps, since one of the most common types of non-structural traps in Azerbaijan are pinch-out zones of individual sediment complexes. Analyzing the results of interpretation of seismic data in Azerbaijan, it can be stated that seismic CDM does not encounter insurmountable obstacles in identifying and tracking pinch zones at different stratigraphic levels. Refining the position of the pinch point remains the only problem, which, as is well known, is of great practical importance in determining the location of the deep drilling well.

2. Research methods

We used several approaches to clarify the position of the pinch point: 1 - the use of attribute analysis, i.e. instantaneous dynamic characteristics of the wave field; 2 - taking into account the effect of inelastic absorption according to VSP; 3 - spectral analysis using Fourier transform.

Zones of pinch-out sediments are found in many oil and gas regions of Azerbaijan, but we have examined them in some areas of the Absheron Peninsula. For example, on alleged non-anticlinal traps of sediments of the Lower Pliocene and Miocene of the Lokbatan-Puta-Kushkan area of the south-west of this peninsula. The following seismic profile (Fig. 1) revealed several pinch zones, the shallowest of them being attributed to the seismic horizon SH-IV, timed to the underlying PT sediments, which is adjacent to the horizon SH-V, belonging to the tops of the diatom At depths of approximately 2,800−3,800 m, several pinching zones are distinguished in the underlying diatom sediments. A more detailed and detailed study of the internal structure of these pinch zones may be the subject of further research. It is assumed that these pinned sediments belong to Oligocene sediments (Bochkarev, 2002; Markov, 1973).

A careful analysis of the wave pattern of the dynamic deep seismic section, extending in the north-south direction, reveals that the seismic horizons that lie below the SH-V horizon belonging to the tops of the diatom are outlined at depths of 1500-2000 m. The total thickness of the pinned-out sediments in the syncline part of the section is 800–900 m, while the deep interval is approximately 2500– 3000 m. The reservoir properties and lithofations of the Lower Pliocene and Miocene deposits of the Western Absheron were studied on the basis of seismic survey data and well logs (Aliyev, 2011).

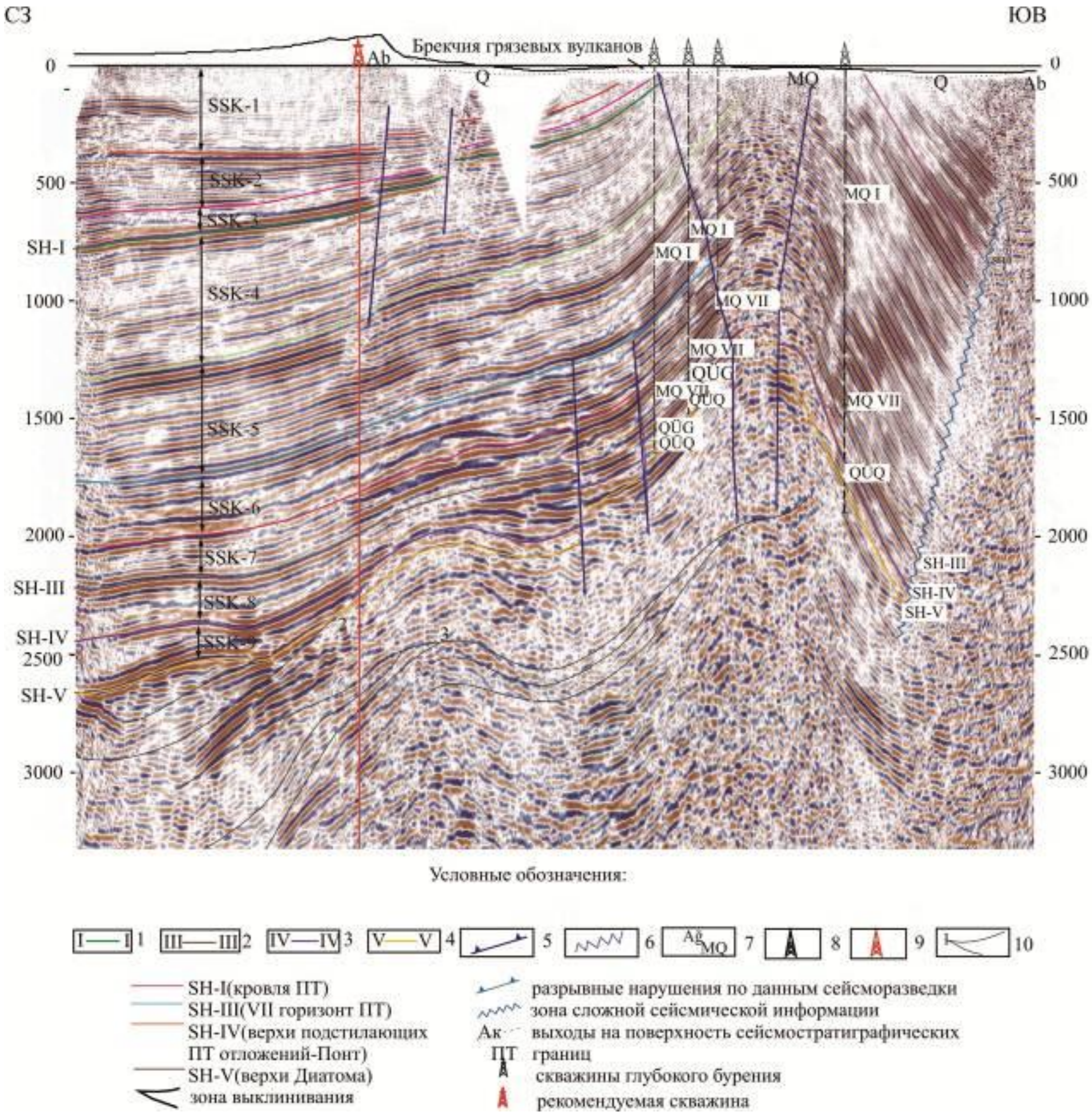

Fig.1. Zones of wedging on the section of South-Western Absheron

Attempts to study the same properties with instantaneous dynamic characteristics (MDC) led to interesting results: sections of instantaneous amplitudes turned out to be quite informative, and it was found that nonstructural oil and gas traps can exist in the pinch points of the Lower Pliocene and Miocene deposits. For example, a section of instantaneous amplitudes along profile No. 090103 shows that the amplitudes of seismic waves are not distinguished by high values at time intervals of 0.0–1.2 sec, covering the deposits of the Quaternary (anthropogenic) and the upper parts of the PT, while the waves reflected from the underlying sediments and recorded at times

1.2 - 2.2 seconds are characterized by relatively high intensity (Fig. 2). The highest amplitudes are observed in the pinch zones (Levyant, 2006). Most of the high values of the instantaneous amplitudes observed on the section are connected on the one hand by the interference of "adjoining", and on the other hand by the change in the layering and lithological variability of the rocks in the adjacent strata. Such variability is observed throughout the section. Reflected waves related to seismic horizons, traced inside the pinching deposits, in the pinching direction, are first characterized by a weak instantaneous amplitude, and their amplitudes increase near the pinch point. This can also be considered as an indirect sign of the existence of sandy deposits here.

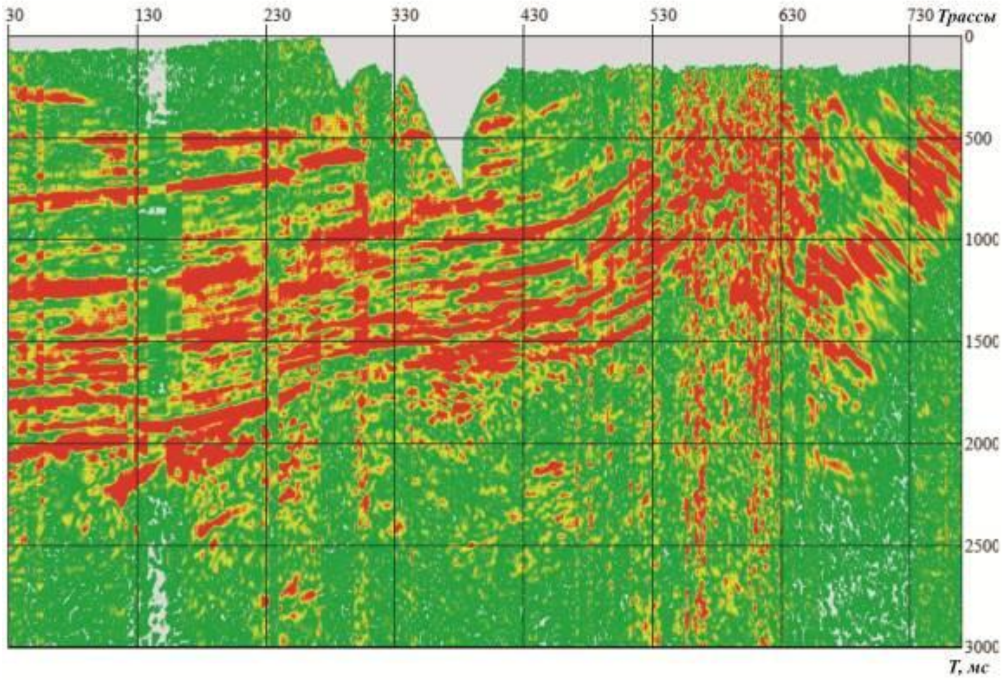

Fig.2. The cut of the instantaneous amplitudes

In the section of the instantaneous phases, the wedged out seismic horizons are well traced, and the pinch point is clearly distinguished (Fig. 3). In the section of instantaneous frequencies (Fig. 4), it is clearly seen that with an increase in the time of registration of reflected waves, the values of instantaneous frequencies decrease, and the correlation of horizons improves.

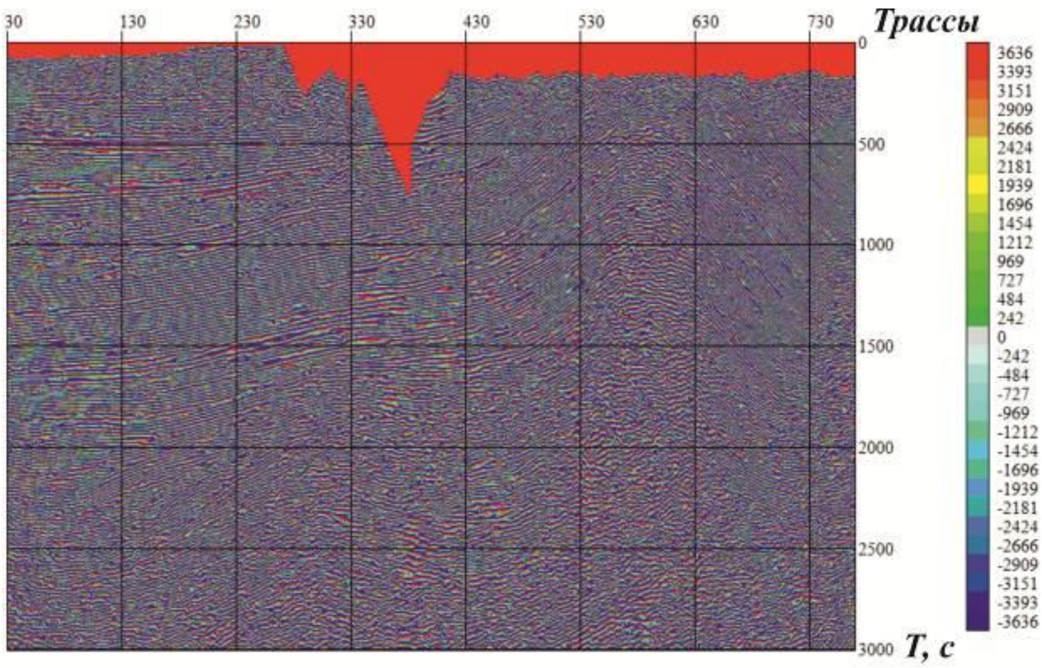

Fig.3. The cut of the instantaneous phases

Due to the change in layering in the direction of the pinch point in the direction of the rise or uprising of the pinch deposits, a strong change in the frequency composition of the oscillations is observed. Such a change in frequencies can be caused by both the stratification of the section and the oil and gas content of the sediments: it is impossible to perform an unambiguous interpretation of the data.

Accounting for inelastic absorption allows to increase the resolution of seismic, which was carried out according to the vertical seismic profiling (VSP). It was decided to determine the parameter of inelastic absorption of the medium, also known as Q of Q. The main value of this parameter is that Q-filtering can be performed in order to restore the frequency components absorbed by the geological medium and to increase the resolution of the data on the ground and borehole seismic. In the best way, the quality factor is determined from the data of the vertical VSP profile, and then used in the processing of ground seismic surveys.

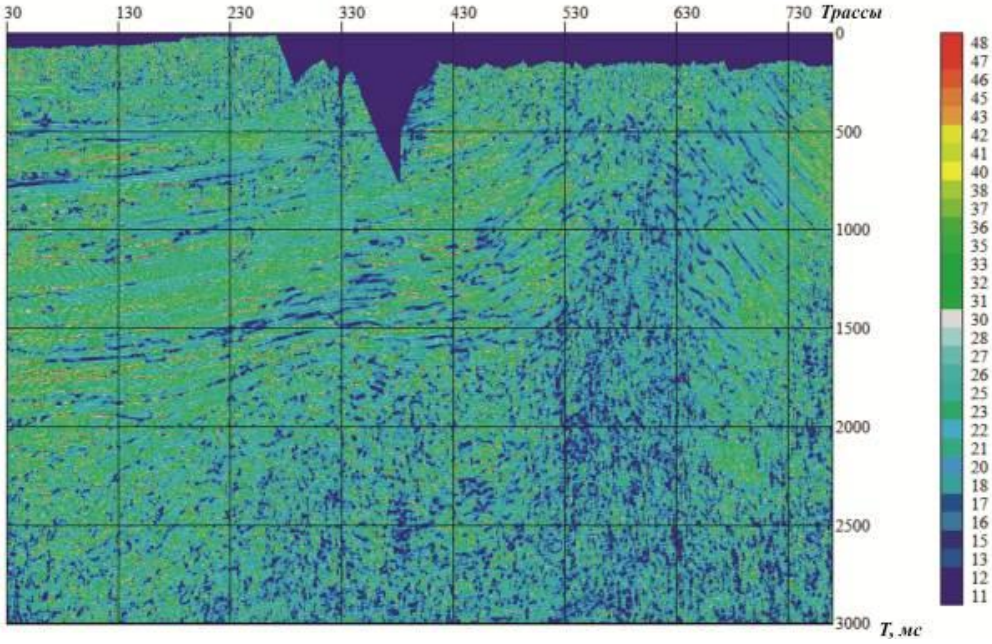

Fig.4. The cut of the instantaneous frequencies

On the area of the southeast of Absheron, Hovsany-Zykh, the method of determining the quality of recording using Vertical Seismic Profiling (VSP) data was applied (Akhmedov et al, 2012). The basis for determining the quality factor is the analysis of the measured amplitudes of the incident longitudinal wave at different levels. It should be noted that the ratio of recorded amplitudes is a complex function of the mass conditions (Shilov and Jafarov, 2011). Therefore, the numerical value of the determined quality factor Q is rather a mathematical parameter than a physical one, which could be measured in "laboratory conditions". That is why the values of the quality factor Q, determined for the same horizons within the same field, may differ significantly (Buryakovsky, 1991). However, their value lies in the fact that the use of calculated mathematical parameters to compensate for inelastic absorption gives correct and adequate results in terms of increasing the resolution of seismic sections. To balance the amplitude-frequency spectrum, as well as to take into account the absorption of the medium, the total cube was performed using the inverse Q-filtering or deabsorption procedure (Fig. 5). The average effective Q value of Q = 145 was used to reconstruct the attenuated frequency components in the time sections of 3D seismic surveys. The Q-filter results show a significant improvement in the resolution of seismic sections, which clearly demonstrates the effective possibilities of using some VSP parameters in the processing of ground-based seismic surveys. Also, it should be noted that the application of good quality can be carried out at different stages, which is often determined experimentally. Here it is shown that by improving the resolution of the deep dynamic section, it was possible to clarify the position of the pinch point (Fig. 5, b).

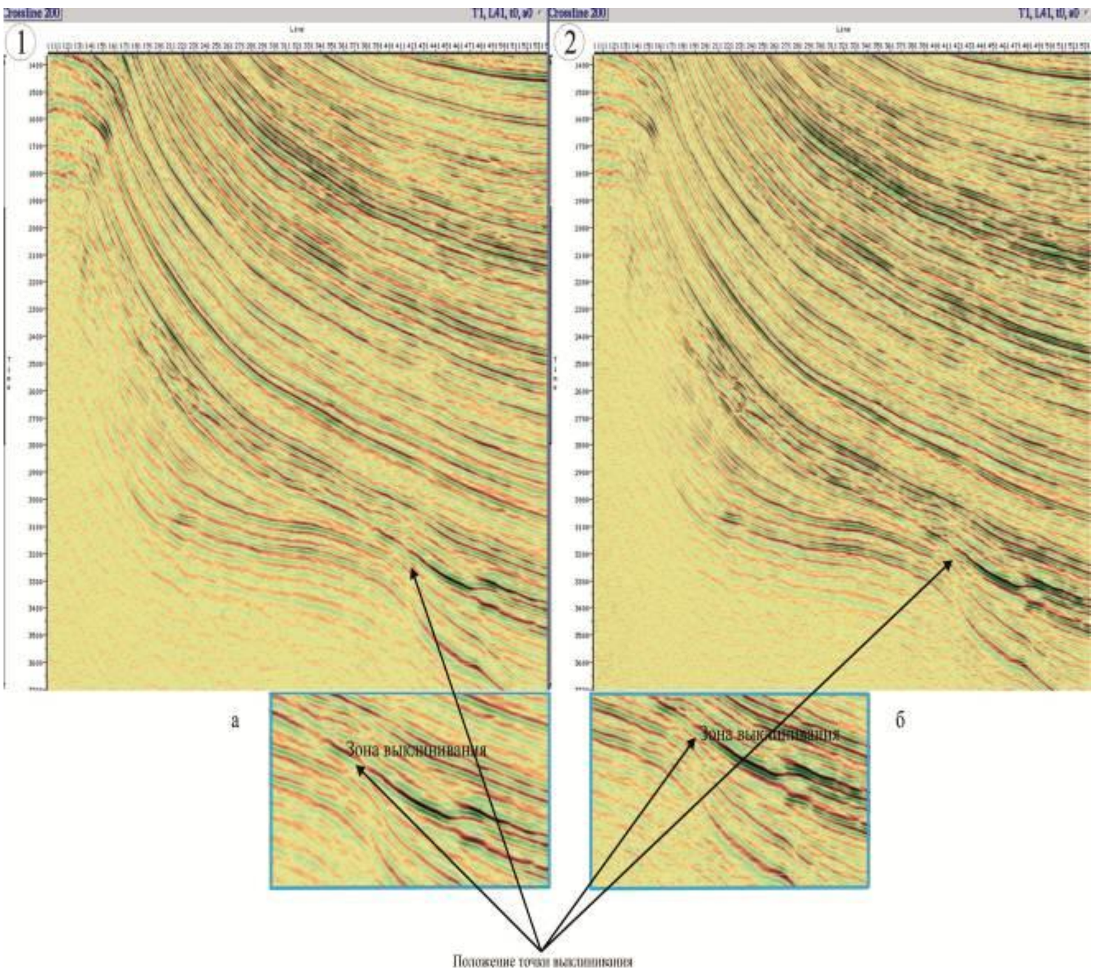

Fig.5. Comparison of the result of the procedure of reverse Q-filtering on the total crossline section 200: a) before; b) after

We used another way to clarify the position of the pinch point. The spectral analysis of seismic records based on the Fourier transform, which gave good results, was tested. It is known that when the seismic horizons approach each other in the direction of the pinch point, an "abutting" interference zone is formed, one of the horizons falls out of the cut after this zone, and the nature of the layering changes naturally and, therefore, the frequency composition of the seismic vibrations around the pinch zone (4). Obviously, using the direct Fourier transform, calculating the amplitude and phase spectra of each trace before and after the pinch point, including the path at this point, the disappearance point of one of the paths can be determined, which will give us the location of the pinch point. We were not able to conduct such an analysis, therefore we made an analysis of groups of neighboring tracks, i.e. within processing windows. Thus, three sites and four processing windows of the same length were chosen for studies on time or dynamic depth sections (Fig. 6). Spectral analysis was performed on a section obtained after the final amount (final stack), therefore, due to the application of the necessary procedures (frequency filtering, summation, etc.) that change the frequency composition of oscillations, the frequency of oscillations covers a certain band. Despite this, the amplitude spectra (or power spectra) of each of the processing windows have their own distinctive features (Bochkarev, 2002).

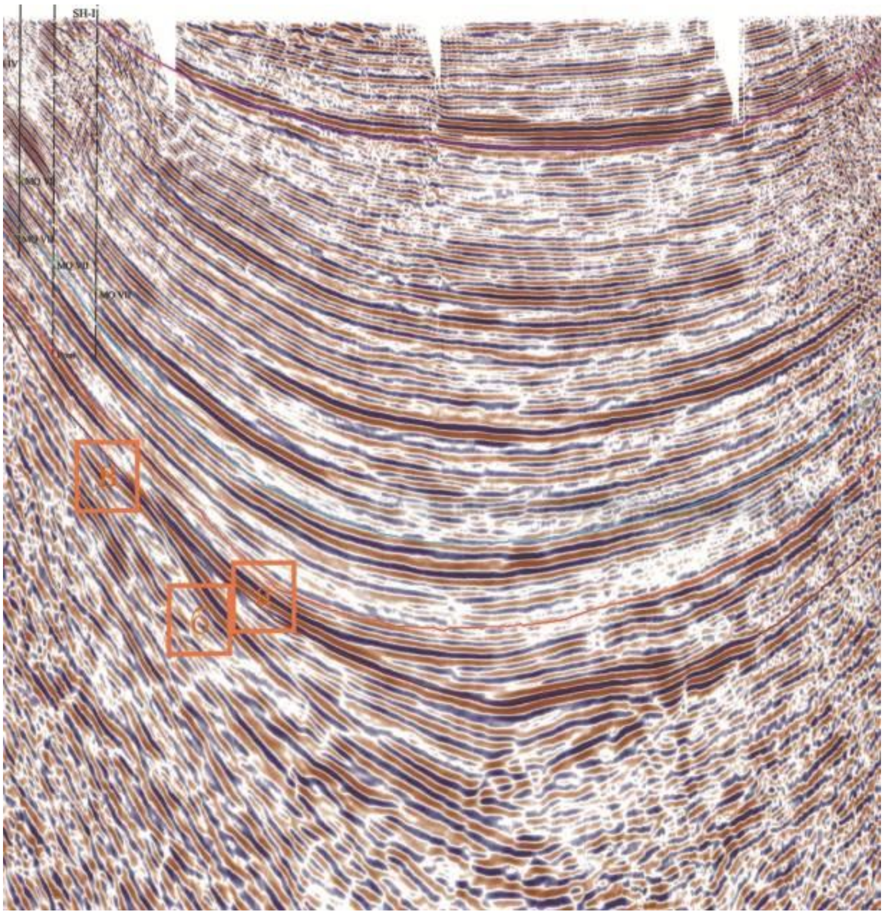

Fig.6. Fragment of time section (positions of processing windows in which the spectral analysis is carried out)

To the zone of pinching out, a single peak at a frequency of 25 Hz characterizes the amplitude spectra (Fig. 7) of both seismic horizons. The slopes of the spectra characterizing the low-frequency components are very steep, whereas the slopes in the direction of the high-frequency components are sloping and more jagged and the upper seismic horizon is rich in high-frequency components (Fig. 7a).

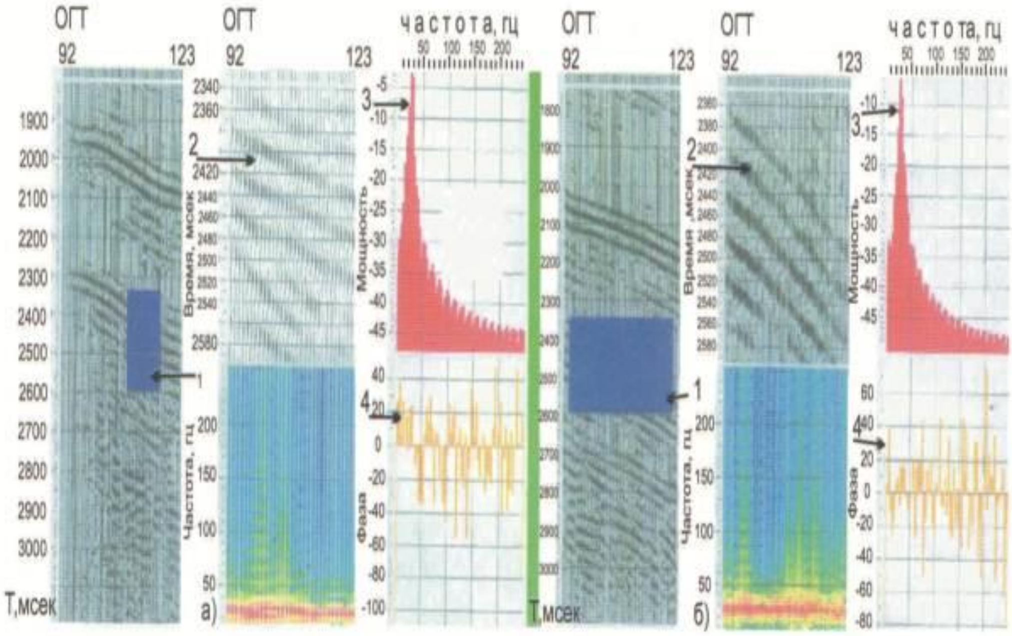

Fig.7. Spectral analysis to the wedging zone: a-upper seismic horizon; b-lower horizon; 1 - position of the processing window; 2-wave pattern in the processing window (on a larger scale); 3-amplitude spectrum; 4-phase spectrum

Directly above the pinch point, spectral analysis was not carried out, since it is obvious that due to the change in layering, the oscillatory process here is complex: the amplitude spectrum of this part of the section would have noticeable differences from the previous ones (these differences can be assessed visually).

The results of the spectral analysis after the transition of the pinch point are discussed further (Fig. 8).

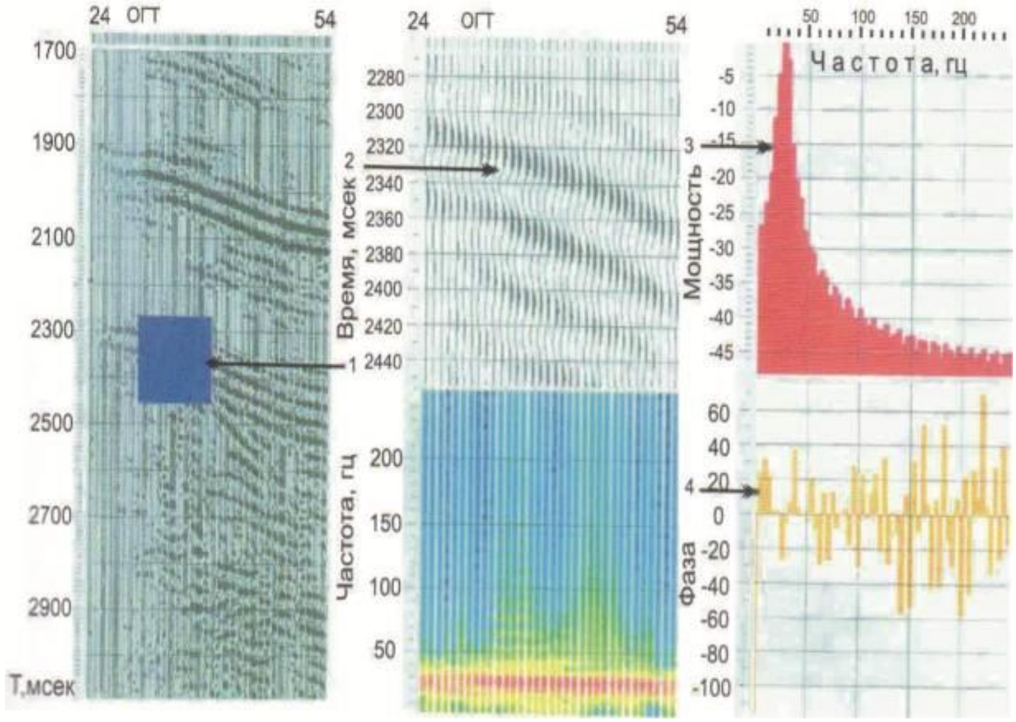

Fig.8. Spectral analysis (after the wedging zone along the upper seismic horizon): symbols – see Fig.7

Comparison of the amplitude spectrum of this segment of the time section with the amplitude spectrum of the first window (Fig. 7a) shows their similarity, with the exception of some insignificant differences, which are most likely caused by the influence of the variability of the character of the thinly layered section. This means that the lower seismic horizon has disappeared from the section.

All this shows that with the help of spectral analysis it is possible to clarify the position of the point of pinching out of sediments. Naturally, more accurate results would have been obtained if spectral analysis would be carried out for the needs of the day. For a more unambiguous and confident interpretation, in addition to the spectral analysis, it is necessary to calculate the mutual correlation functions of the segments of the paths within the same processing windows.

3. Research results

The deposits of the Pliocene and Miocene of the western part of the Absheron Peninsula are mainly sandy-clay and clay-sandy rocks. This is commonly observed especially in pinch zones. It can be concluded that non-anticlinal traps of oil and gas can form in the zones of pinching out of the Lower Pliocene and Miocene deposits.

On the Absheron Peninsula, especially in its western part, the reservoirs of the Middle and Upper Miocene have a limited areal distribution and here fluid accumulations can be associated with non-anticlinal traps. These accumulations or deposits are related by lithological factors; clay strata are formed in areas that are rich in sandy-aleritic materials and non-anticlinal traps are located near the water parts of the structures, on the wings of the anticlines and synclines separating them.

Thus, in conclusion, it can be said that 4 pinch zones were identified and traced on the northeastern wings and pericline structures in the considered anticlinal zones of Western Absheron.

Conclusions

The results obtained allow us to conclude that the applied all three methods of determining the position of the pinch point are highly efficient and can be used in solving such problems in appropriate seismic and geological conditions.

Funding

The study was carried out with the financial support of the Foundation for the Development of Science under the President of the Republic of Azerbaijan – **Qrant №EİF-KETL-2-2015-1(25)-56/33/2.**

References

Abdullayev, N. R., Riley, G. W., Bowman, A. P. (2012). *Regional controls on sandstone reservoirs: the Pliocene of the South Caspian basin*. In: O. W. Baganz, Y. Bartov, K. M. Bohacs, D. Nummedal (eds.). Lacustrine sandstone reservoirs and hydrocarbon systems. Tulsa; American Association of Petroleum Geologists Memoir.

Akhmedov, T. R, Akhundlu, A. A., Giyasov, N. Sh. (2012). On some results of surface and borehole seismic surveys at the Hovsaninskoye field. *Karotazhnik. Scientific Technical Bulletin* 6(216).

Aliyev, E. G., Aliyev, C. C., Huseynov, D. A, Babaev, Sh. A., Mamedov, R. M. (2011). *Sedimentary conditions for sediments of the lower section of the productive unit and their natural radioactivity*. Baku.

Bochkarev, V. A. (2002). *Estimation of the initial geological and recoverable oil reserves in the Zikh and Hovsany fields. Determination of residual oil reserves*. LLC "LUKOIL-VolgaNIPImorneft". Volgograd.

Buryakovsky, L. A. (1991). *Petrophysics of oil and gas reservoirs of the productive stratum of Azerbaijan*. Baku.

Levyant, V. B. Ampilov, Yu. P. (2006). *Methodological recommendations on the use of seismic data (2D, 3D) for the calculation of oil and gas reserves*. Moscow, Nedra.

Mamedov, P. Z. (2018). *Productive stratum of Azerbaijan*. Moscow, Nedra.

Markov, N. I. (1973). *Paleogeographical foundations of oil and gas searches*. Moscow, Mir.

Shilov, G. Ya., Jafarov, I. S. (2011). *Genetic models of sedimentary and volcanogenic rocks and the technology of their facies interpretation based on geological and geophysical data*. Moscow, Nedra.