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Research article

3D seismic survey data processing and interpretation by use of latest tools applied for discovery of new traps in Pleistocene deposits of Hovsan field

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Abstract: The paper is devoted to outlining of hydrocarbon traps in Absheron suite by use of seismostratigraphy, standardless classification, taxonomy and attribute analysis. The paper gives a brief description of area under the study, its geographical position and research history. Correlation of seismic horizons traced within interval of seismic record embracing Absheron suite has been analyzed in detail. It has been noted that Absheron suite is rich with oil and gas deposits, which has been evidenced by discovery of fields located near to the study area. Six seismic horizons were picked off within the limits of target deposits.

The described methodology of study reveals the essence of applied standardless classification and taxonomy. Analysis of dynamic parameters of seismic record led to outlining of amplitude anomalies related to zones of development of stratigraphic traps attributed to unconformity surfaces. Three such zones have been outlined. Classification and taxonomy cubes have been designed for the interval of Absheron suite. The internal structure of studied series is well traced in sections of "Classification" and "Taxonomy". Classification results allowed to outline traps characterized by abnormal grouping of some classes. Three "bright spot" anomalies are outlined in the Absheron deposits.

Seismic anomalies are well correlated with sedimentation environment favorable for evolution of stratigraphic traps. The area of anomalies is 10.1 sq.km in summary. Burial depth of these anomalies is 450–950 m. Earlier drilled wells did not recover studied anomalies.

Keywords: seismic survey; standardless classification; taxonomy; attribute analysis, seismostratigraphy

1. Introduction

Zykh-Hovsan area is located in Surakhany region of the south-western part of Absheron peninsula immediately neighboring the eastern outskirts of Baku, Azerbaijan Republic (Figure 1). The study area is densely populated: Zykh village, Guneshli and Hovsan settlements are located to the west and south-east of the region.

The area of interest has been covered by studies applying various geological and geophysical techniques starting from 30-ies and 40-ies of the last century. Drilling in Zykh-Hovsan area started in 30-ies of the XX century [1]. Discovery and production from Zykh field dates back to 1935. In 1936–1940-ies the oil accumulations were identified in suites of the lower part of Productive Series (PS) of Lower Pliocene (Nadkirmakinskaya sand—NKP, Kirmakinskaya—KC, Podkirmakinskaya—PK, Kalinskaya suite—KaC). Of 235 wells drilled in the field, 80 wells are exploration wells (1 offshore well), 154 production wells and 1 appraisal well. By the date of 1.01.2011 in total 199 wells have been abandoned, of these 93 wells due to geological reasons and 106 wells due to the technical reasons. The largest portion of drilling works goes back to 40-ies and 50-ies of the XX century. 9 wells have been drilled in the field in the 90-ies. By 2001 the number of production wells was 10.

Through the period of 1932–1935 a large number of exploration wells were drilled in Hovsan area by "Azneftkeshfiyyat" trust. Acquired data made it possible to derive monoclinal burial of layers. Well 1308 drilled in 1948 down to Kalinskaya suite of Productive Series led to discovery of Hovsan field with further produtcion of oil from this field. In total 83 exlploration and production wells were drilled across the field: 3 appraisal wells, 20 exploration and 45 production wells. 45 wells were terminated by the date of 1.01.2001, including 24 wells due to geological reasons and 21 due to the technical reasons. 11 wells have been drilled in the field in 90-ies. The number of production wells by 2001 was 11 and 2 wells were registered as uncompleted. Production from the field is only onshore since its marine margines are not definitely outlined for the reason of insufficiency of studies.

 - the area covered by 3D CDP

Figure 1. Contour of the area covered by 3D CDP on the image from space.

To study velocity model of the environment the seismic logging was applied in well 60 in Garachukhur area, through the period of 1949–1950 in wells 156 and 191 in Zykh area and wells 1310 and 1508 in Hovsan area. VSP was performed in wells 1856 and 1867 of Hovsan area.

At present, development of two deposits in KaC-2 and KaC-3 (in the western part) layers are underway in Hovsan field. KaC-1 layer is not developed. These three deposits in layers KaC-1, KaC-2 and KaC-3 and Absheron suite (Pleistocene) have significant perspectives in the eastern part of the field [2].

It should be noted that available deep drilling and seismic data do not allow to define detailed geological model of oil traps for Kalinskaya suite of Hovsan area. Oil accumulations is supposedly tied to lateral-facies alterations and small amplitude faults [3].

In the area under the study, we have derived the time cube within 0–6 sec interval. Geological data and analysis of wave pattern enabled us to carry out the seismostratigraphic division of the section in the study area. Based on the nature of the wavefield the entire interval is conditionally divided into three seismostratigraphic megaunits (SSMU): Miocene, Pliocene and Pleistocene (Figure 2). Within the Miocene SSMU we have outlined SH-VI, which separates the regular seismic record from the chaotic record, tied presumably to the clay diapirs. SH-VI represents the dynamic reflection in the north-central part of the area. The Pliocene is overlaid by Pleistocene, which in its turn is overlaid by Eopleistocene—Absheron suite, which is the target of our study.

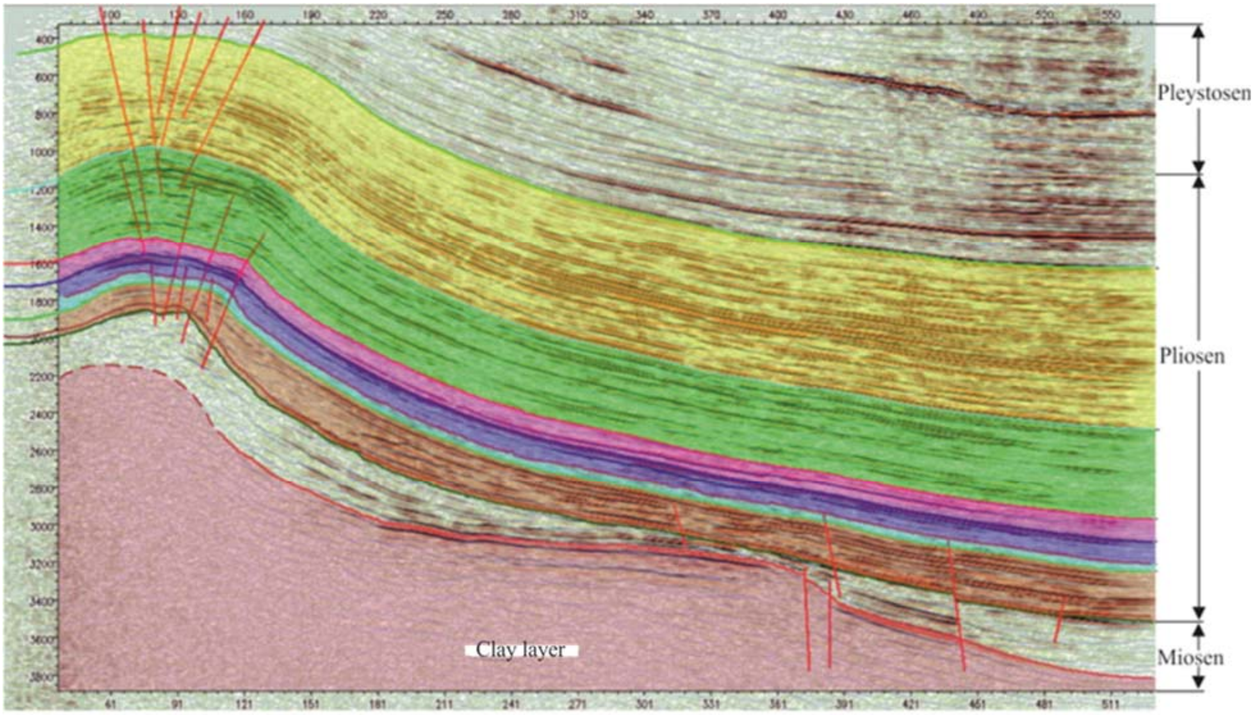

Figure 2. Miocene, Pliocene and Pleistocene seismic-stratigraphic megaunits.

The target interval of seismic record is within the limits of 1150 msec and includes deposits of Eopleistocene-Absheron suite. (Figure 3). Absheron suite is represented by irregular alternation of sandstones, sand, aleurites, siltstone and clay with rare interlayers of white limestone. Wave field of this seismostratigraphy unit is characterized by variable dynamic display and is represented by medium- and poor intense seismofacies, diverging, with pinching of some phases towards the west, and represented by wide diversity of forms in seismic records and reflections varying from parallel to torn ones with entrances and intensification of time thickness.

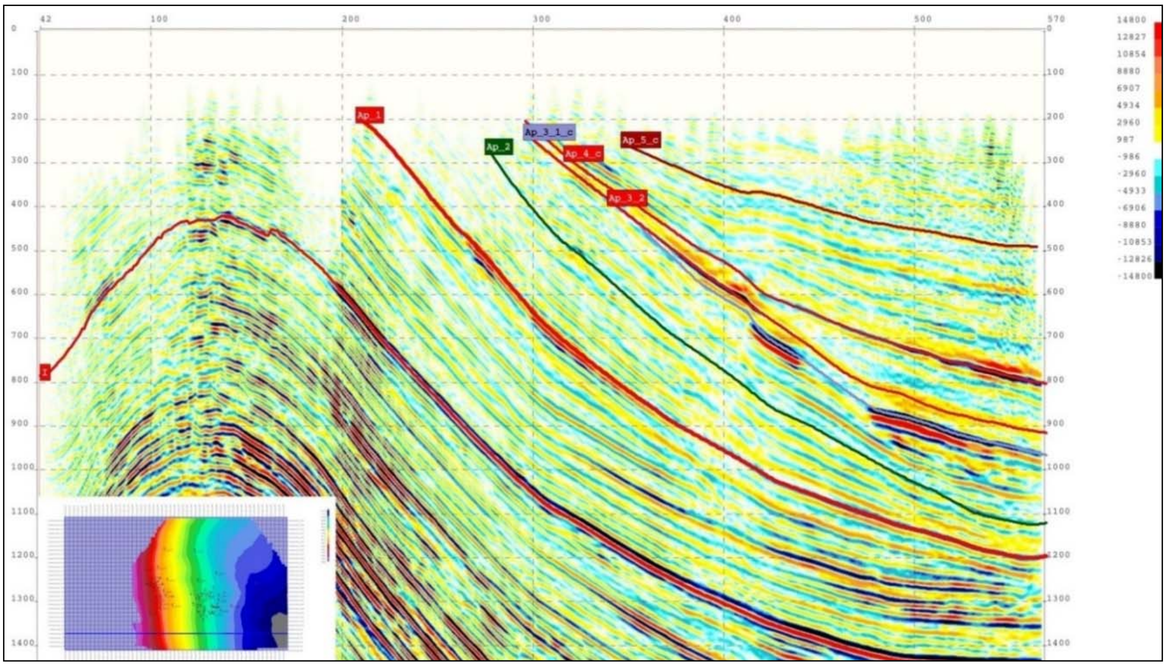

Figure 3. Correlation of seismic horizons in Absheron suite along the 3D seismic survey line.

Correlation of seismic horizons within interval of Absheron deposits has been done by use of automatic and "manual" tracing of reflection horizons by time cubes applying cubes of seismic attributes and dynamic parameters [4,5].

Reflection horizon Ap_1 is correlated for the center of positive phase within 170–1220 msec time interval. The reflection is not clearly traced due to fragmentary nature of positive phase and unstable amplitude. Fragmentary drop of amplitude intensity to a degree of its disappearance is also observed.

Reflection horizon Ap_2 is tied to the Anomaly №1 location and traced along the central part of positive phase within 250-1200 msec time interval. Correlation of this horizon is complicated due to the same reasons as Ap_1.

Reflection horizon Ap_3_1 is tied to the Anomaly №3 and correlated for the center of positive phase within 200–1000 msec time interval. Correlation of this horizon is not univocal due to the presence of high interference and unstable amplitude zones.

Reflection horizon Ap_3_2 is tied to the Anomaly №2 and attributed to the center of positive phase and within 190–990 msec time interval. Picking of this horizon is not clearly traced due to the strong interference.

Reflection horizon Ap_4 is picking in the center of positive phase within 160–880 msec time interval. Picking of this horizon is also complicated by high interference and instable seismic signal position.

Reflection horizon Ap_5 is the reflection with picks in the center of positive phase within 230–520 msec time interval. Correlation is complicated due to chaotic wave field and is characterized by instable amplitude and phase along horizon line.

Positions of picked seismic horizons are shown in Figure 3.

2. Problem statement

It can be derived from all the said above that in the Hovsan field the major production targets is within the lower part of Productive Series, which resources are gradually depleted. Hovsan field is located in the surroundings of Baku, has developed infrastructure and therefore the exploration works targeted to other stratigraphic level as Absheron suite of Pleistocene with proven oil and gas presence is quite substantiated, as currently the commercial oil is produced from fields of Absheron peninsula and nearby areas.

Some figures related to the fields discovered within Absheron suite must be given here. Fields similar to each other: Kurovdag, Karabaghly, Kyursanga, Qalmas, Neftchala, Balakhany-Sabunchu-Ramany, Surakhany [2]. Fluid composition: oil, gas, gas + oil, oil + gas-condensate, burial depth: 8–2600 m, the total thickness of the layer: 45–180 m, porosity: 15–33%, permeability: 13–492 mD, formation pressure: from hydrostatic to +10%, gas factor: 4.4–80 m^3/t, oil output −2.0–20 m^3/day, gas output—150 thousand m^3/day. Another advantage is that the Pleistocene deposits are buried at relatively small depths.

Analysis of available geological and seismic data shows that it would be expedient to explore for traps of non-anticline type at the target stratigraphic level within this field. Analysis of schemes of underwater objects, channels, alluvial cone of terrigeneous deposits displays that such models are most suitable for our exploration models making it possible to correctly outline anomalies of seismic wave field of Absheron suite and identify sand reservoirs. According to the accepted sequence-stratigraphy model the evolution of sand reservoirs is attributed to the cycles of the low sea level and shallow shelf environment. Figure 4 [6–8].

3. Aim of the study

Application of standardless classification, taxonomy and attribute analysis with seismic stratigraphy for outlining and tracing of non-anticline oil and gas traps in Absheron suite.

4. Methodology

The basis for outlining of perspective classes are results of standardless classification and taxonomy. Taxonomy cube is derived by use of ReView-Pangea software package. We describe in brief the procedures of standardless classification of seismic attributes in cube, which done within the framework of "Taxonomy" and "Classification" (Figures 5 and 6). Standardless classification of targets in multidimensional data space is done by dividing into cuts of sections similar by their physical and geological characteristics.

"Taxonomy" and "Classification" software resolves the problem of standardless classification of units within multidimensional space. Both software search for some homogeneous areas in multidimensional space of attributes and regard such areas as classes (taxon). However, there are essential distinction in the algorithms of these software.

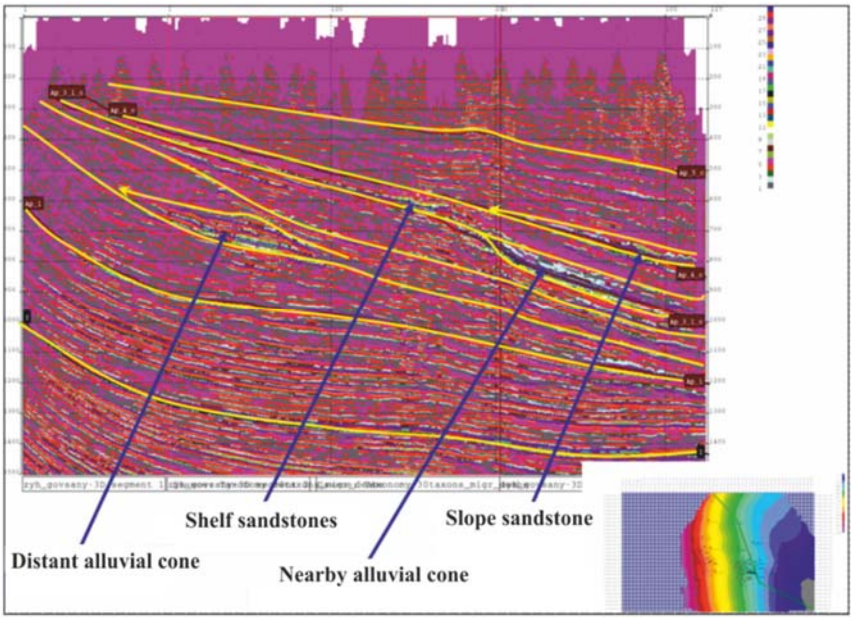

Figure 4. Types of stratigraphic traps in Absheron suite of Hovsan area.

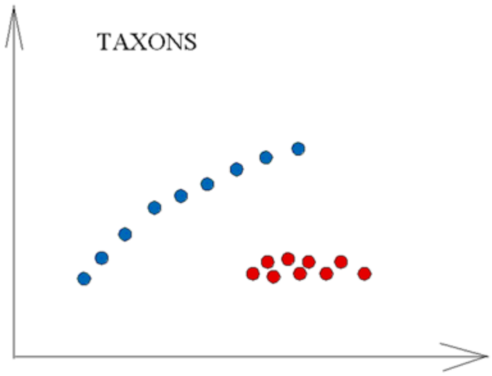

Figure 5. Illustration of work done by "Taxonomy" software.

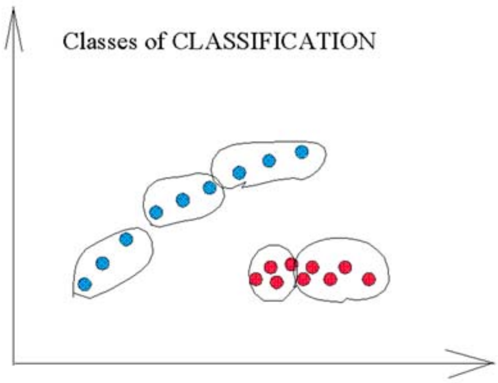

Figure 6. Illustration of work done by "Classification" software.

"Taxonomy" software designs the so-called minimal unclosed graph. Points in multidimensional space of attributes are considered as close ones if chain of close neighbors tying these two points are present. "Classification" software works in the other way. It uses a traditional Euclidean distance as a measure of distance and therefore considers two points as close points if the distance between them is not higher than some figure. Therefore, some conclusions can be made.

"Taxonomy" prefers to trace horizons with quite significant variation of the signal (graph of neighboring).

"Classification" in distinction to the "Taxonomy" usually cuts horizons in places with variation of record nature.

Figure 7 is the graph for the "Classification" procedure, in which the applied seismic attributes are shown.

Figure 8 displays the section of type designs of "Classification" procedure along the cross-line 170. Performing analysis of division of section into 30 classes, it can be noted that the section is significantly inhomogeneous both along the lateral and vertical directions.

This is also can be seen while analysis of section of typification derived by use of Taxonomy (Figures 9 and 10). However, for more detailed research there is a need to divide the section in small portions and apply these procedures within those portions. This is one of infrequent case when results of "Taxonomy" and "Classification" coincide.

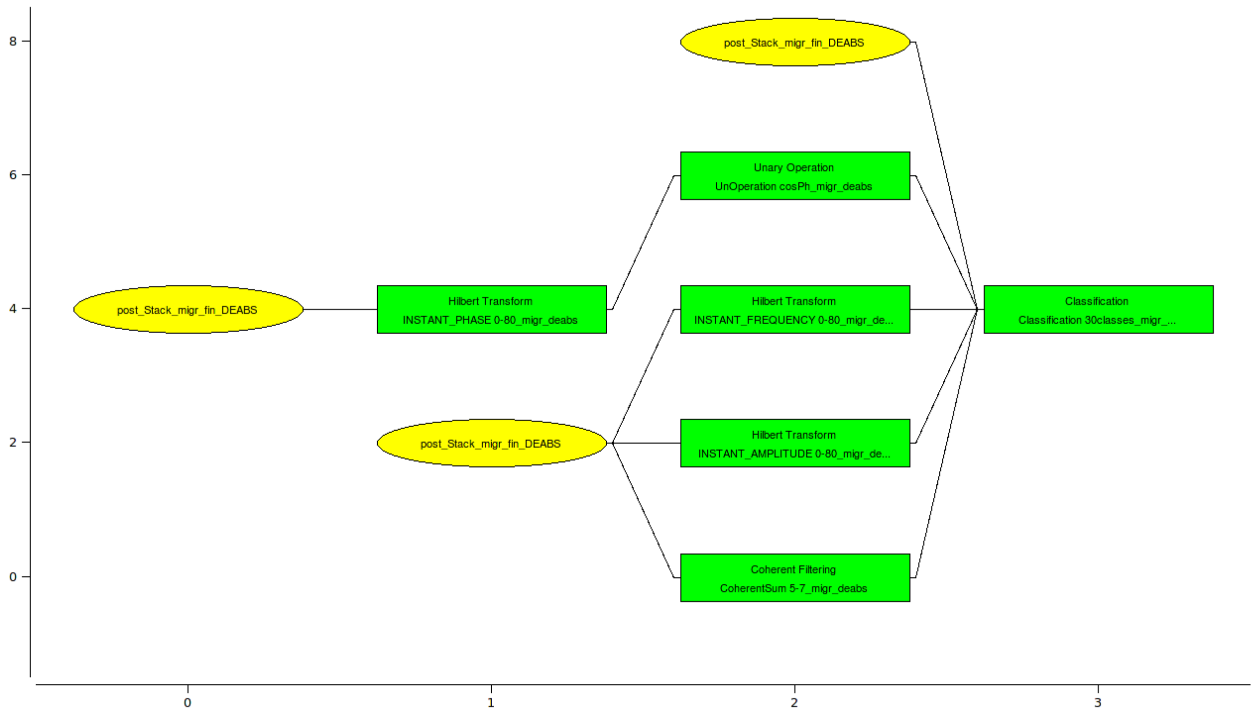

Figure 7. "Classification" procedure.

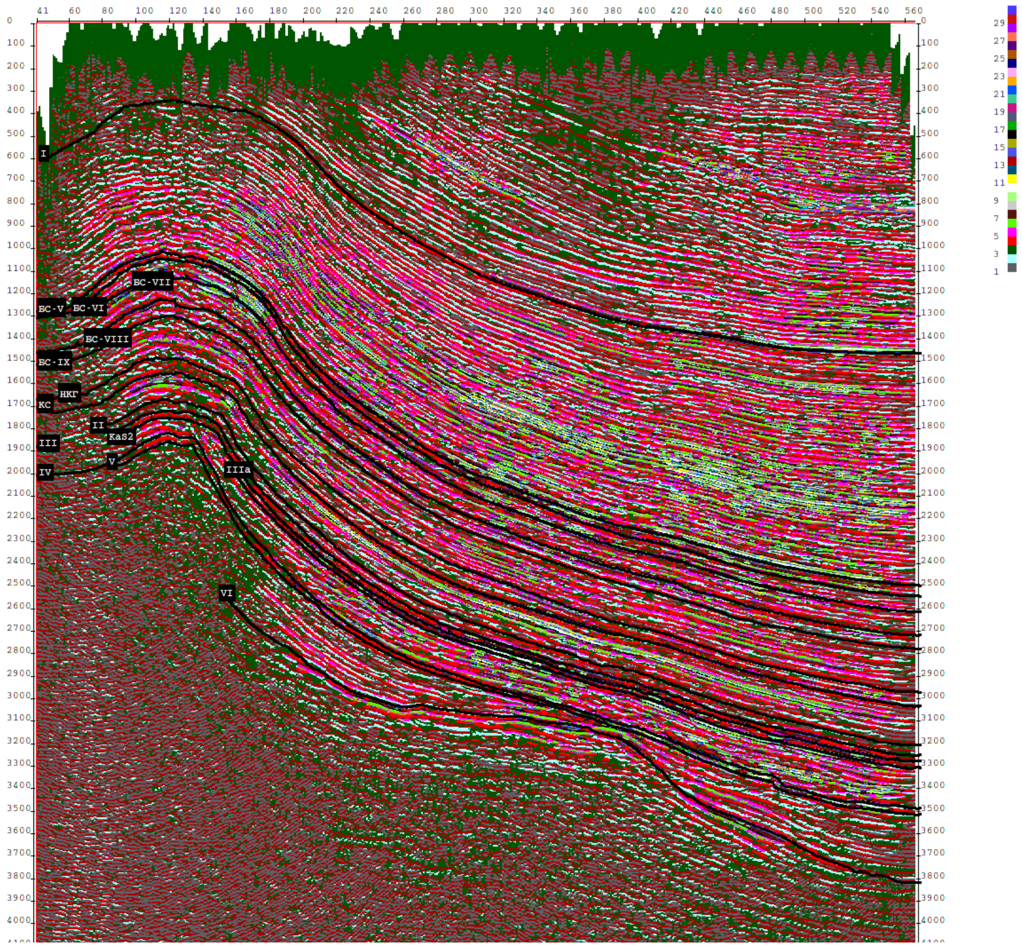

Figure 8. Section of typification along the cross-line 170 (“Classification” procedure).

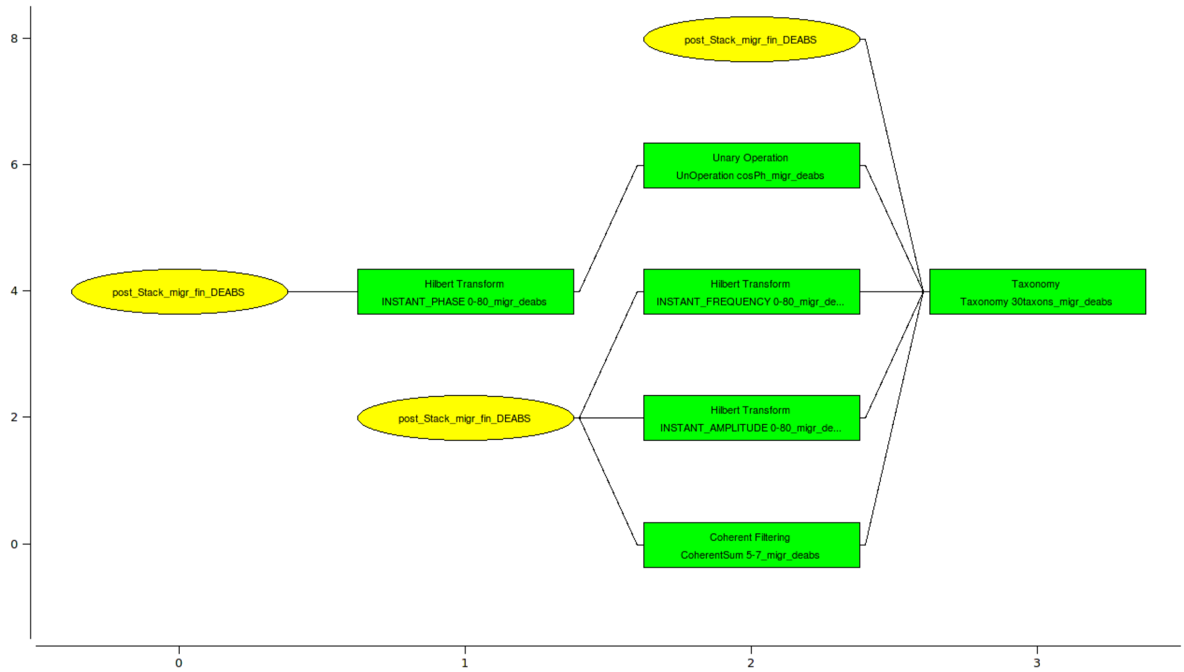

Figure 9. “Taxonomy” procedure.

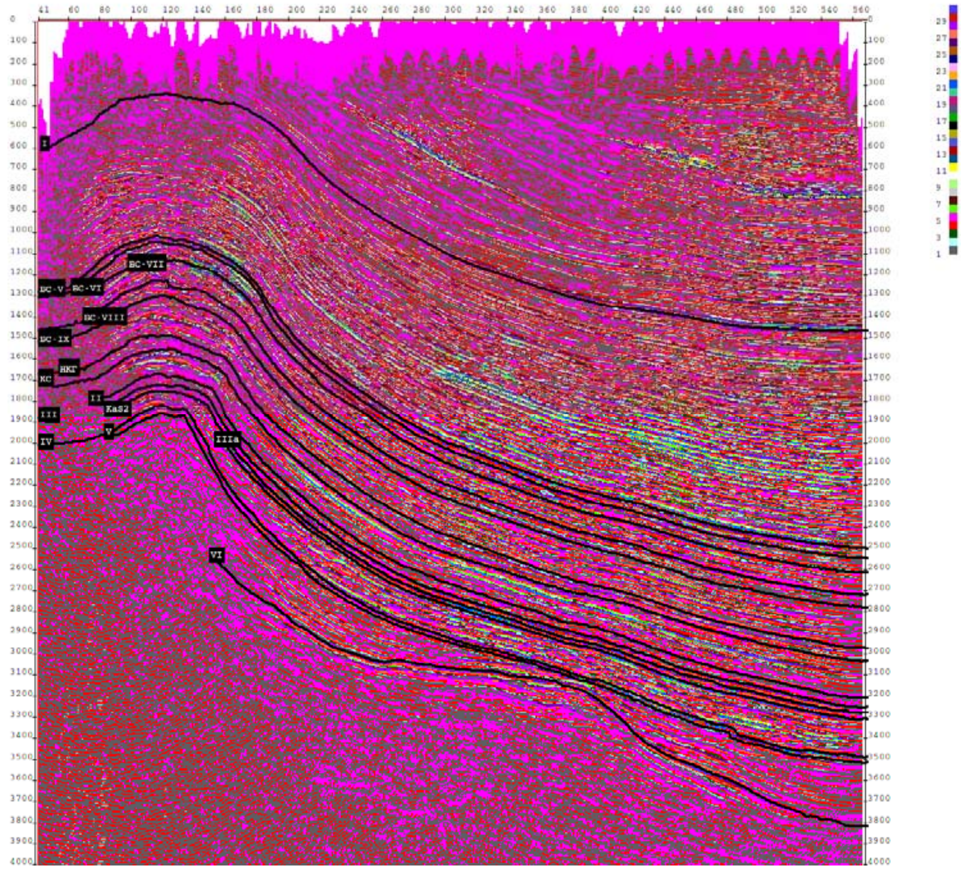

Figure 10. Section of typification along the cross-line 170 (“Taxonomy” procedure).

5. Results

As a basis to study dynamic peculiarities of intervals of productive deposits, we have used the cubes of typification calculated by “Classification” and “Taxonomy” software. By sections of “Classification” of lines crossing directly the wells with reservoirs outlined by well log data, in the each well site we have outlined classes corresponding to reservoir locations. Visualization of time thicknesses of these outlined classes restricts the portions of the study area, in which wavepattern coincides, to a some degree, with a wavepattern characteristic for reservoirs burial intervals.

Analysis of dynamic characteristics of seismic record allowed to identify the amplitude anomalies, which in our point of view are attributed to the zones with traps of stratigraphic type tied to the unconformity surfaces. Three such zones have been outlined. The section of amplitude anomalies with outlined zones are shown in Figure 5. Amplitude anomalies of seismic record are well corresponding to anomalous sets of classes derived by the procedure of standardless classification of seismic attributes in the cube.

Additional studies enabled us to design classification and taxonomy cubes for the interval of Absheron suite. Initial data for design of classification and taxonomy included the following attributes: cube of instantaneous amplitudes, cube of cosines of the phase, cube of instantaneous frequency, additional processing of initial data—application of coherent filtration for improved tracing of phases, the number of classes given in advance is 30.

Applying “Classification” software the cubes of classes have been calculated and for each class the images have been drawn. In one case the standardless classification was done on the basis of 4 abovementioned parameters, in the other case the parameter of cosines of the phase was excluded and this allowed to exclude unnecessary extension of phases in sections.
Standardless classification cubes were designed in the interval: upper border—constant time 200 msec, the lower border—along the Ap_1 reflection boundary.

In sections derived by “Classification” and “Taxonomy” the inner structure of studied series is well observed [9]. Classification results made it possible to substantiate the outline of traps featured by abnormal grouping of some classes [10,11].

To analyze derived classes, the classes images are used (Figure 11). It must be noted that informative classes are characterized by low amplitude and low frequency. Substantiated outlining of trap, geometry, calculation of the area, recommendations for the first well by use of seismic attributes are shown in Figure 12.

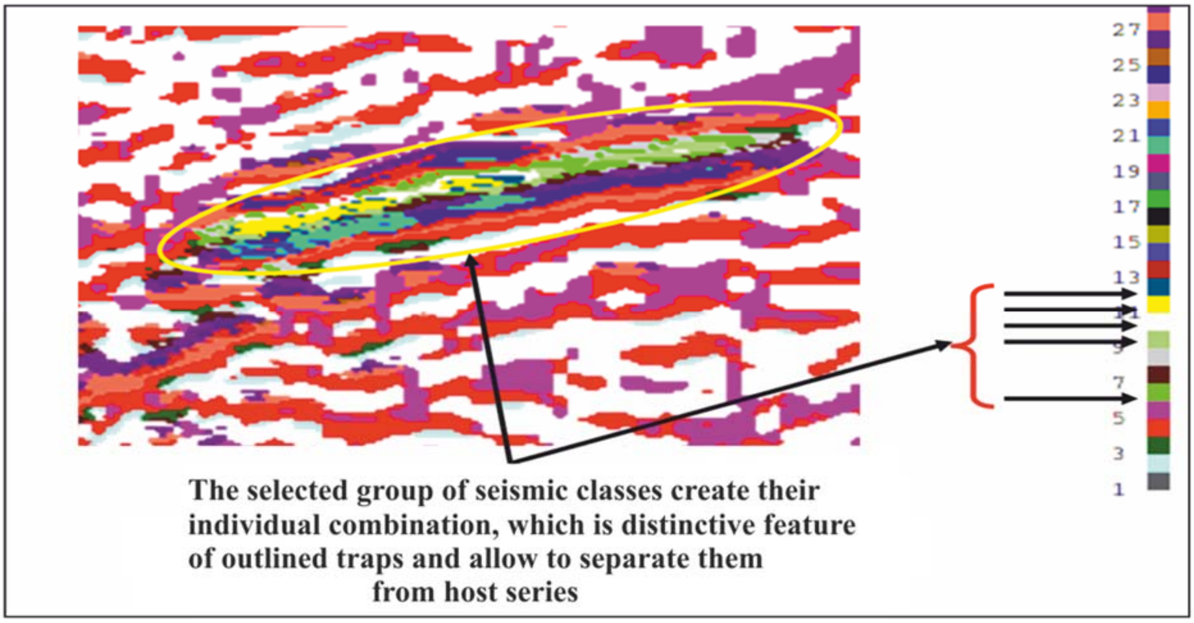

Figure 11. Perspective classes 6-9-10-11-12.

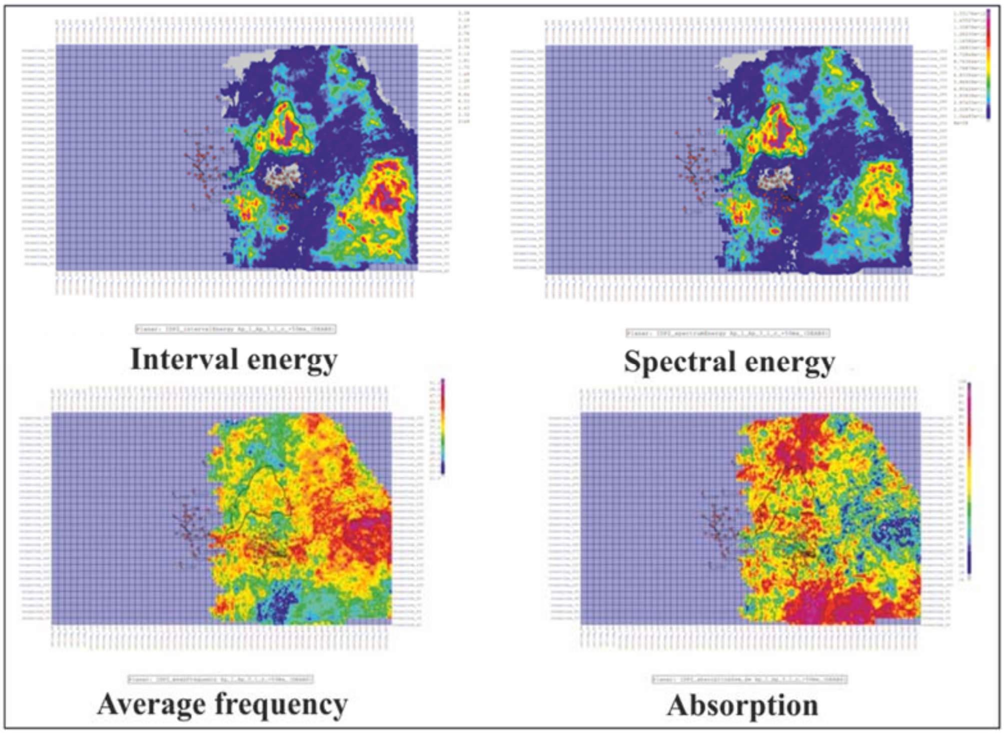

Figure 12. Seismic attributes within Ap-1–Ap-3-1 interval.

To select the informative seismic classes reflecting geological setting of supposed productive series in the Absheron suite the cubes of classification and taxonomy have been designed (Figures 13 and 14). The initial data applied for design of classification and taxonomy cubes included the following attributes: cube of instantaneous amplitudes, cube of phase cosines, cube of instantaneous frequency [12–14].

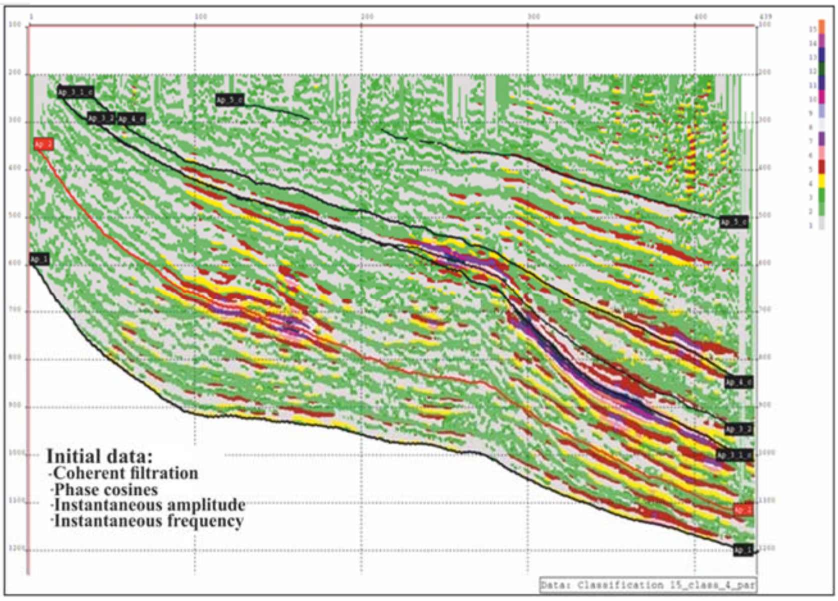

Figure 13. The section of classification within the interval of Absheron suite, 200 msec—reflection boundary Ap_1 (number of classes 15).

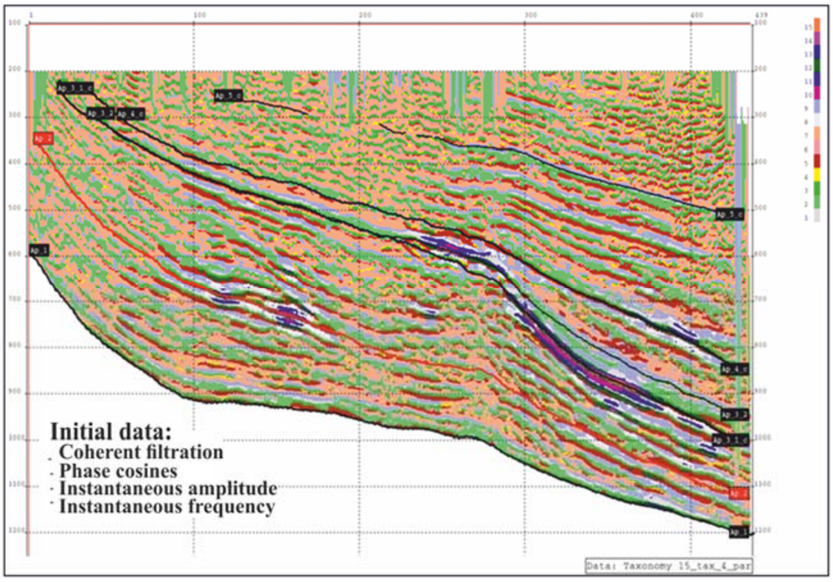

Figure 14. The section of taxonomy within the interval of Absheron suite, 200 msec—reflection boundary Ap_1 (number of classes 15).

The coherent filtration (additional processing of initial data—applying the procedure for coherent filtration for improvement of tracing of phases) has been done. The number of classes given in advance is 30, the interval: the upper border—constant time 200 msec; the lower border—along the reflection border Ap_1.

As a result, of this study the taxonomy with 15 taxons and classification with 15 classes can be recommended as the most informative cubes. Selected informative seismic classes we identify as the term "seismic facies" [15]. Thus, constructed cubes of taxonomy and classification reflect the geometry and spatial distribution of seismic facies. To perspective seismic facies we attribute seismic facies of the nearby and far shelf.

6. Paleoreconstruction and tectonic history of evolution

Reconstruction of tectonic and sedimentation mode of deposition [16–18] is shown in Figure 15. Within the interval of Absheron deposits 3 anomalies of "bright spot" type have been outlined.

6.1. Anomaly I. North Hovsan trap

Substantiation of trap outline, geometry, calculation of its area, substantiation of the first-priority well drilling, evaluation of resources by Monte-Carlo technique are shown in Figures 16 and 17. The status of the project well: secondary, dependent.

6.2. Anomaly II. The North-Eastern Hovsan

Substantiation of trap outline, geometry, calculation of its area, substantiation of the first-priority well, evaluation of resources by Monte-Carlo technique are shown in Figures 18 and 19. The status of the planned well: first-priority, independent.

6.3. Anomaly III. The South Hovsan trap

Substantiation of trap borders, geometry, calculation of its area, substantiation of the first-priority well, evaluation of resources by Monte-Carlo technique are shown in Figures 20 and 21. The status of the project well: first-priority, independent.

Spatial location of all three outlined anomalies is shown in Figure 22.

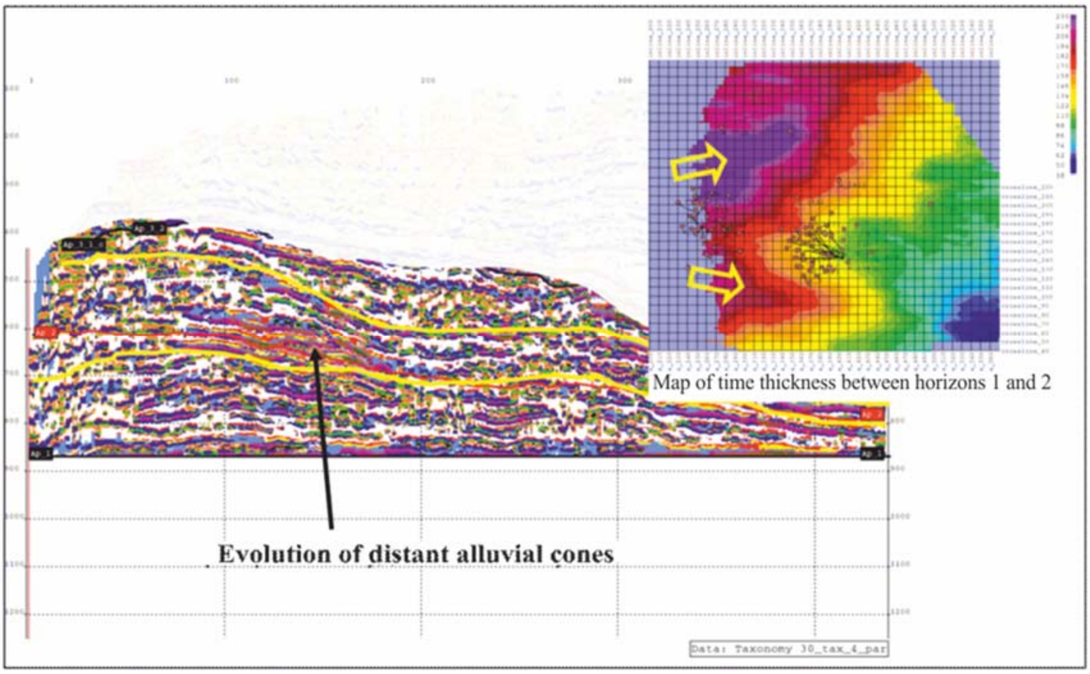

Figure 15. Assumed planation surface Ap-1 and map of time thicknesses between horizons 1 and 2.

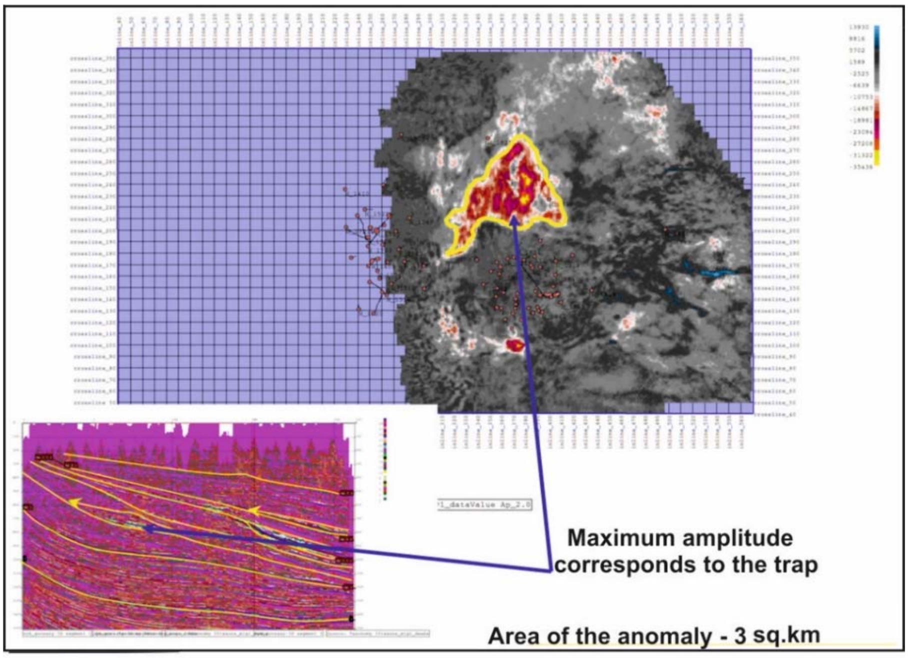

Figure 16. Anomaly I. The North Hovsan trap.

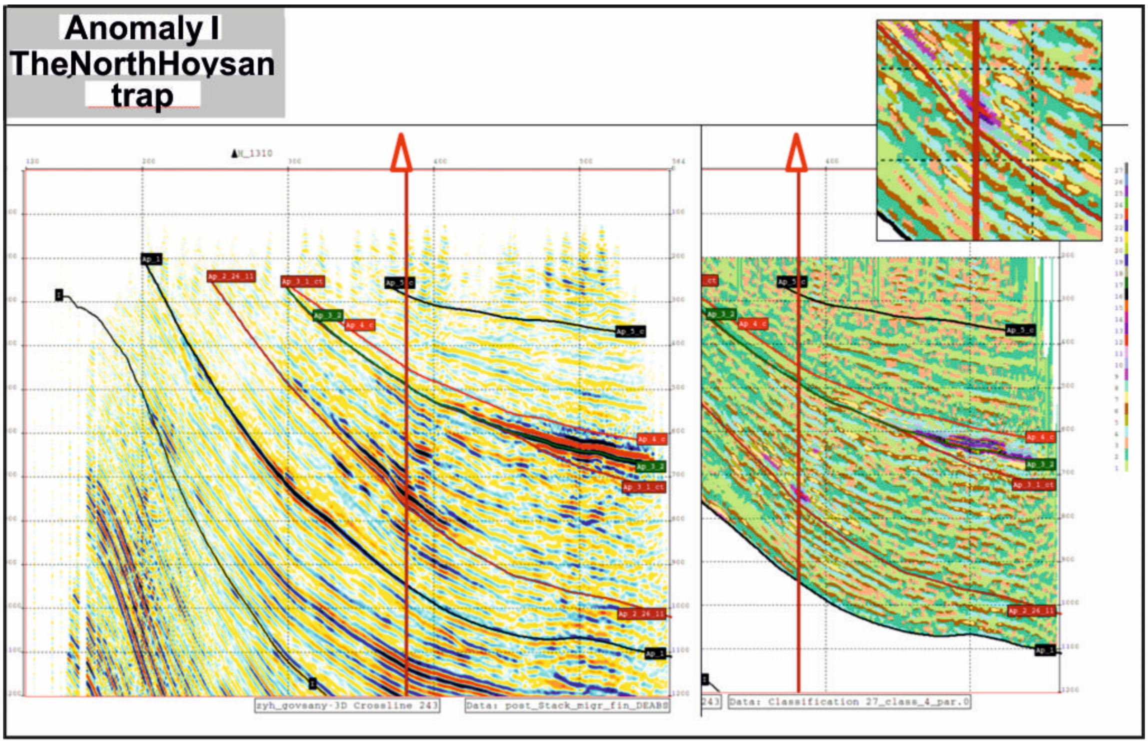

Figure 17. Substantiation of the project well 1

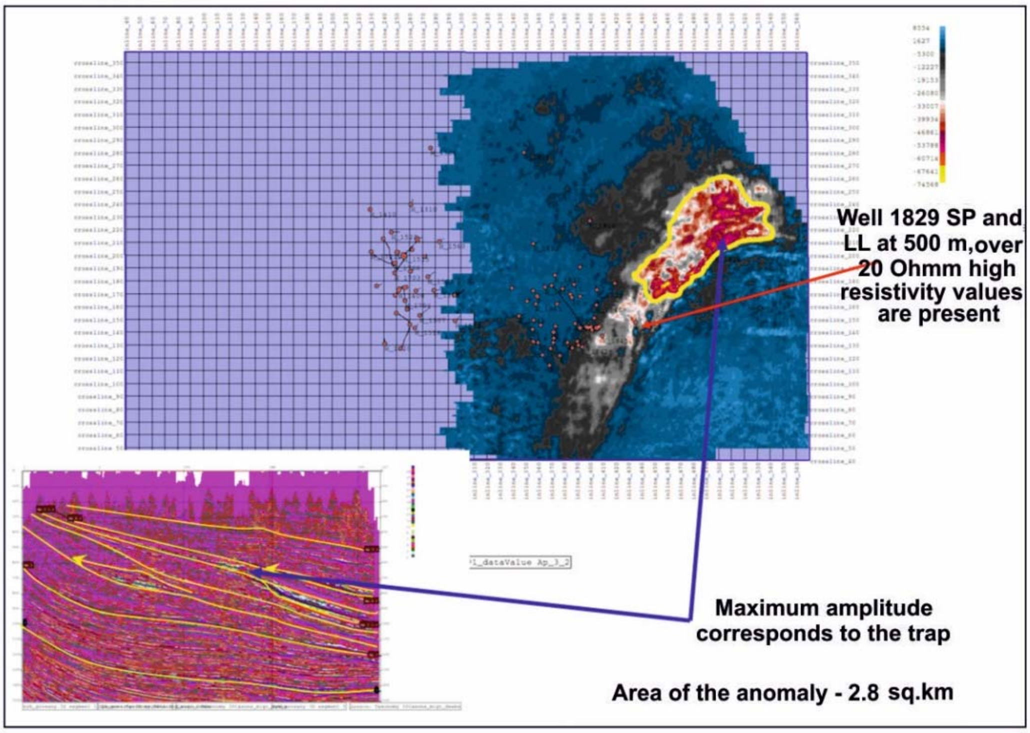

Figure 18. Anomaly II. The North-Eastern Hovsan trap.

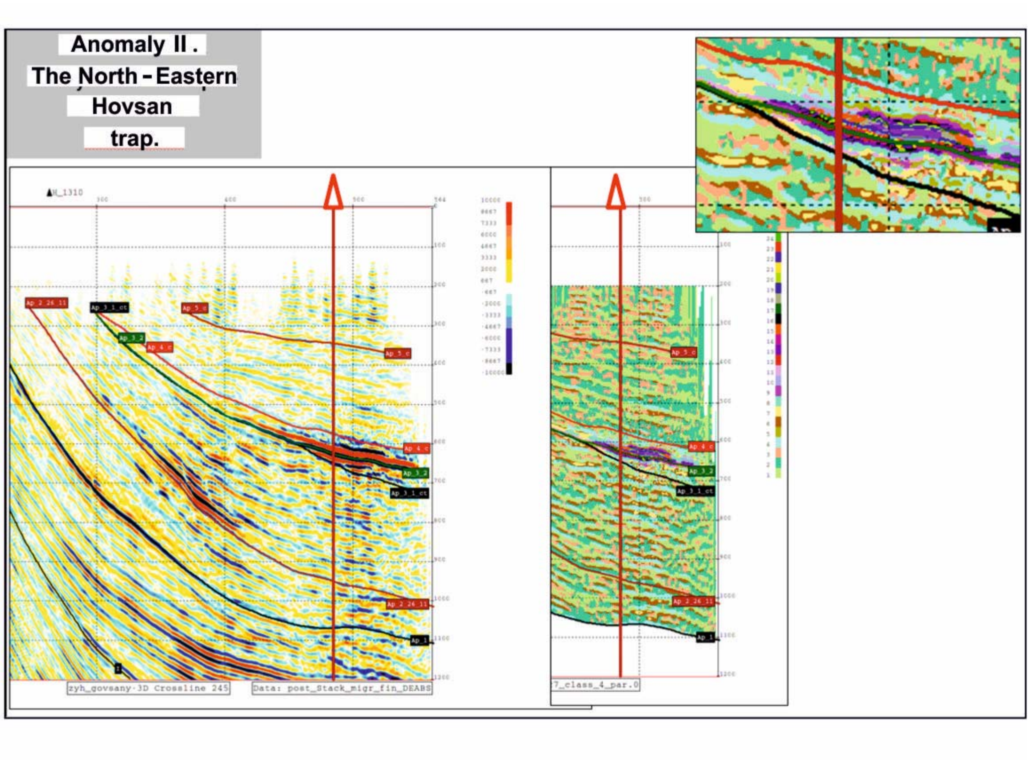

Figure 19. Substantiation of drilling of the project well 2.

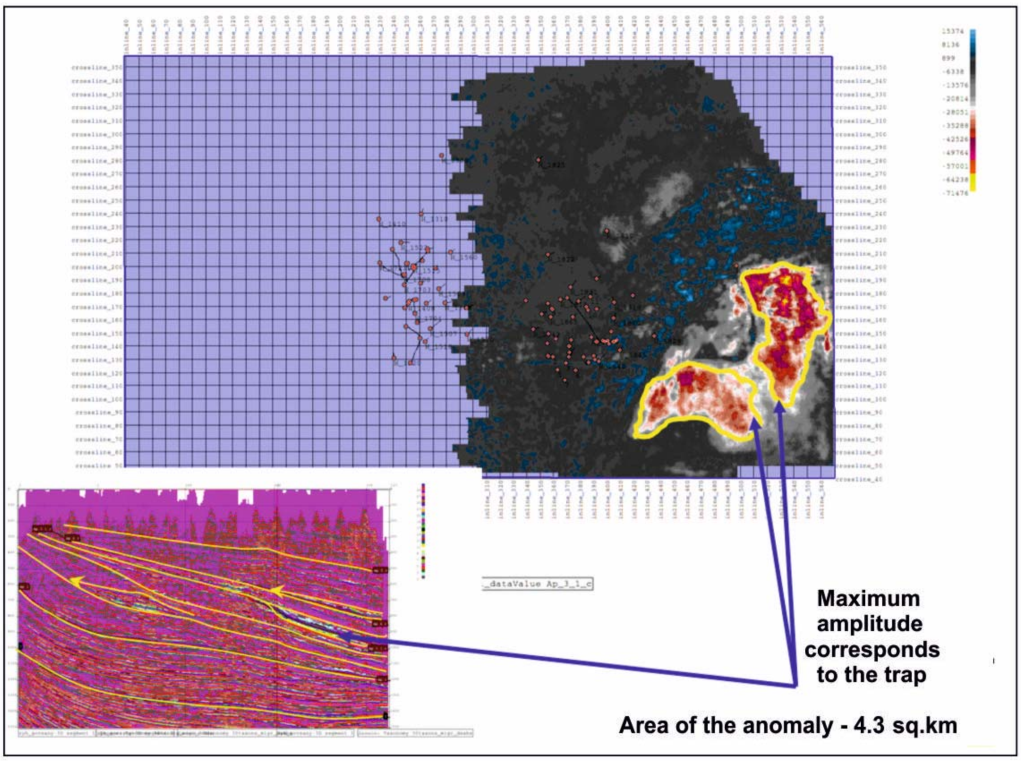

Figure 20. Anomaly III. The South Hovsan trap.

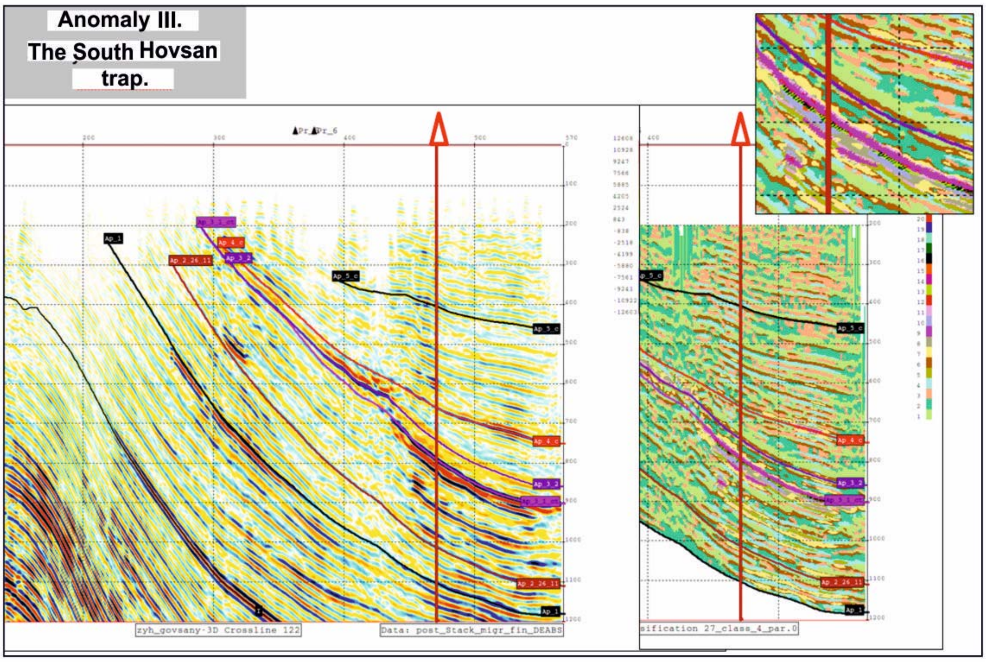

Figure 21. Substantiation of the project well 3.

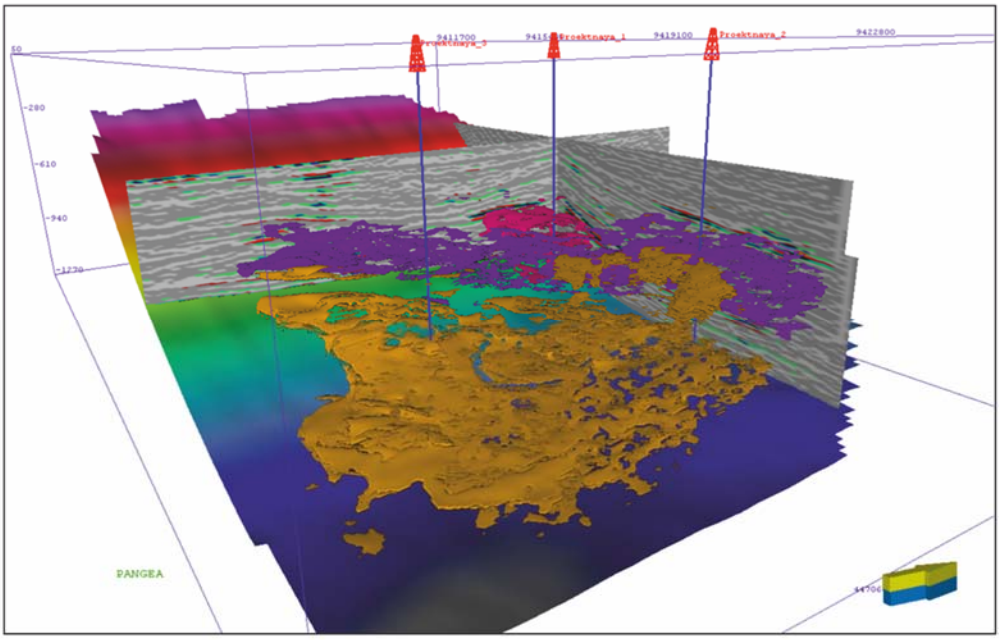

Figure 22. Spatial position of three anomalies outlined within Absheron suite.

7. Conclusions

The study area is within the South Caspian Basin (SCB), where the clay diapirism and mud volcanoes are widely developed. Presence of clay diapirism are most frequently tied to tectonic activity and alteration of sedimentation mode, which stipulated development of quasi-synchronous seismostratigraphic units (QSSU) and subunits.

Each subunit of seismostratigraphy is divided by unconformity surfaces and hiatus and this is very important for generation of stratigraphic traps. Seismic anomalies are in good correspondence with the environment and deposition features favorable for generation of stratigraphic traps. The area of anomalies in total is 10.1 sq.km. The interval of depths of these anomalies varies within 450–950m. Wells drilled earlier did not recover the studied anomalies.

The North Hovsan trap (Anomaly I) can be covered by the program of drilling in the northern part of Kalinskaya suit, currently the major oil target under exploitation. The traps of the North—Eastern Hovsan (Anomaly II) and the South Hovsan (Anomaly III) will require the individual drilling program down to Absheron deposits. The condition for favorable closure of trap and their infill by hydrocarbons is the unity of trends of sedimentation and hydrocarbon migration.

Since Absheron suite deposits does not bear oil source rocks it can be supposed that hydrocarbon migration is occurred due to the vertical and lateral movements of oil from the lower deposits, most probably from the Miocene.

Conflict of interest

The author declares no conflicts of interest in this paper.

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