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Prospects for exploration of the non-anticlinal traps of Hovsan shallow water area by geophysical methods

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Abstract. The paper analyzes the complex geophysical (seismic, gravimetric) and downhole geophysical survey (DGS) of the SW part of the Hovsan Shallow Water area, specifying the lithofacies composition of Pliocene sediments, predicting oil and gas potential, identifying promising areas in the Turkan and Gala areas related to non-anticlinal traps, substantiating the directions of search and exploration work for these types of traps, predicting favorable conditions for hydrocarbon accumulation, and predicting oil and gas potential.

At the Hovsan oil and gas field, research work was carried out on the temporal sections of the seismic profile of two common depth points developed in 2004.

Based on the obtained amplitude and energy diagrams, a comparative analysis of anomalies in the zones of minimum values of dynamic parameters of tested and reflected waves at oil and gas facilities of profiles No. 030808 and 030908 was carried out.

As a result, as can be seen from scheme of the seismic profiles in the Hovsan shallow water field, it was assumed that during the migration of oil and gas, the border of this local change in lithology plays the role of local change in lithology, due to the fact that the borders of these local change in lithology diverged due to the approximate overlap with the borders of two small tectonic faults, which are observed at a sufficient distance, based on numerous downhole and seismic data.

Taking into account the complex topography of the area, we have chosen such an observation system, in which field on the Hovsan area is exposed to 2 directions (Shah dili and Gala field island). Here, it was possible to detect trap type anomalies in the same places by radiating the area from different directions. By choosing such a mutual observation system and radiating the same area from different directions, the location of trap type anomalies was determined.

The main purpose of the complex geophysical studies carried out on subjects No. 091-96 and 165-2000 was the predicting and analysis of oil and gas deposits at the Hovsan-Deniz field as a result of the combined use of the seismic exploration method with refracted and reflected waves with high-precision gravimetrical exploration, and determination of formation boundaries in plan and the depth of the section based on trap type anomalies obtained in geophysical areas. Comparative analysis of the trap type anomaly overlapping obtained in 1996 and 2000 on both subjects was conducted and issues related to the non anticlinal trap were examined. The following conclusions and recommendations were made based on the direct exploration of oil and gas fields using complex geophysical methods:

1. In seismic exploration works carried out in the Hovsan area, direct methods of searching for oil and gas fields due to changes in the amplitudes of refracted and reflected waves were used to determine a connection with a lithological fault-bounded non-anticlinal trap, corresponding to different depths (depths of 3600-4200 m) and sediments (related to horizons Lower Girmaki Suite 2 and Lower Girmaki Suite 3) and a formation anomaly was identified;

2. As a result of reservoir-type anomaly, discovered on the basis of a comparative analysis of complex geophysical works carried out in the area No. 165-2000 slightly west of Cape Hovsan, wells No. 1700, 1701, 1703, 1704, 1705, 1706, 1707, 1708, 1709 were drilled and from horizons Lower Girmaki Suite 1, Lower Girmaki Suite 2, Lower Girmaki Suite 3 industrially important oil was produced.

Keywords: Productive Series, oil and gas contour, sediment accumulation process, transgression, regression, konsedimentasion and postsedimentasion, diagenesis, katagenesis, gipergenesis and tektogenesis

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Introduction. Since the 1930s, seismic, gravimetric, electrical exploration and magnetometric works have been carried out in the Hovsan shallow water area, located in the eastern part of the Absheron Peninsula, and as a result of the geophysical work carried out, it was found that there is a monocline uplift due to the surface of the productive series. In the 1950s and 1960s, in order to study the tectonics of the productive series and the sediments beneath it, a number of works were

carried out using the reflection method and refraction correlation method of seismic exploration, and the location of wells to be drilled for oil and gas was determined [1, p. 17].

In the Hovsan Shallow water area, exploration work was carried out in 1994-1995 to predict oil and gas reservoirs in the productive series sediments based on vertical seismic sounding with reflected waves and precise gravimetric methods, and additional promising areas for oil and gas exploration were identified [1, p. 17].

Considering the complex terrain of the area, we have chosen an observation system in which the field in the Hovsan area is irradiated from 2 directions (Shah Dili and Gala field island) (Figure 1). Here, it was possible to detect the trap type anomaly from the same places by irradiating the area from different directions. By choosing such a mutual observation system and irradiating the same area from different directions, the location of the trap type anomaly was determined (Figure 1).

Research was conducted on the time sections of 2 common depth point seismic profiles developed in 2004 for the Hovsan oil and gas field (Figure 2) [3, p. 17].

Observations were carried out in the WE direction of the field on seismic profile No. 030808 [3, p. 46]. Seismic exploration works were carried out in the field by “Azneftgeofizika” Trust, the top and bottom of the Girmaki suite, Lower Girmaki suite, Lower Girmaki suite Pont layer were monitored, the wave information was evaluated and specified based on well data (Figure 2) [3, p. 47].

As can be seen from the figure, the top and bottom of Girmaki suite are accompanied by high-amplitude intense waves and are well monitored (Figure 3). Here, the wave pattern of the Girmaki suite is observed to be chaotic, slightly transparent trace, which is associated with the clay formation. Intensive, fairly reliable monitoring of the wave landscape is also observed in the upper part of Lower Girmaki suite . Due to the rather complex design, it was possible to trace the top and the bottom of the Lower Girmaki suite by conducting additional studies and using borehole data (Figure 3). The figure shows that the main boundaries are represented by high-amplitude intense waves [3, p. 47].

In addition to the lithological composition of the sediments, other factors are also involved in changing the wave landscape of the Lower Girmaki suite (thickness 300 m), which is considered the main oil and gas facility in the Hovsan Shallow water area [3, p. 76]. These factors can be mainly due to the replacement of oil-saturated reservoirs with water bearing ones, minor tectonic faults, paleomorphological conditions, and other geological processes involved in the formation of Lower Girmaki suite. If we carefully consider the paleo-reconstructed sections, we can see that the roof of Lower Girmaki suite$_1$ and Lower Girmaki suite$_3$ in both sections was washed away (Figure 4). Here, the change in the thicknesses of Lower Girmaki suite$_1$ and Lower Girmaki suite$_3$ in area and cross-section is more clearly visible [3, p. 76]. For this reason, we see that the thickness indicated in section No. 030808 is less in the middle part of the section. The thickness of the Lower Girmaki suite$_2$ horizon varies less than Lower Girmaki suite$_1$ and Lower Girmaki suite$_3$ and is quite stable (Figure 5) [3, p. 80].

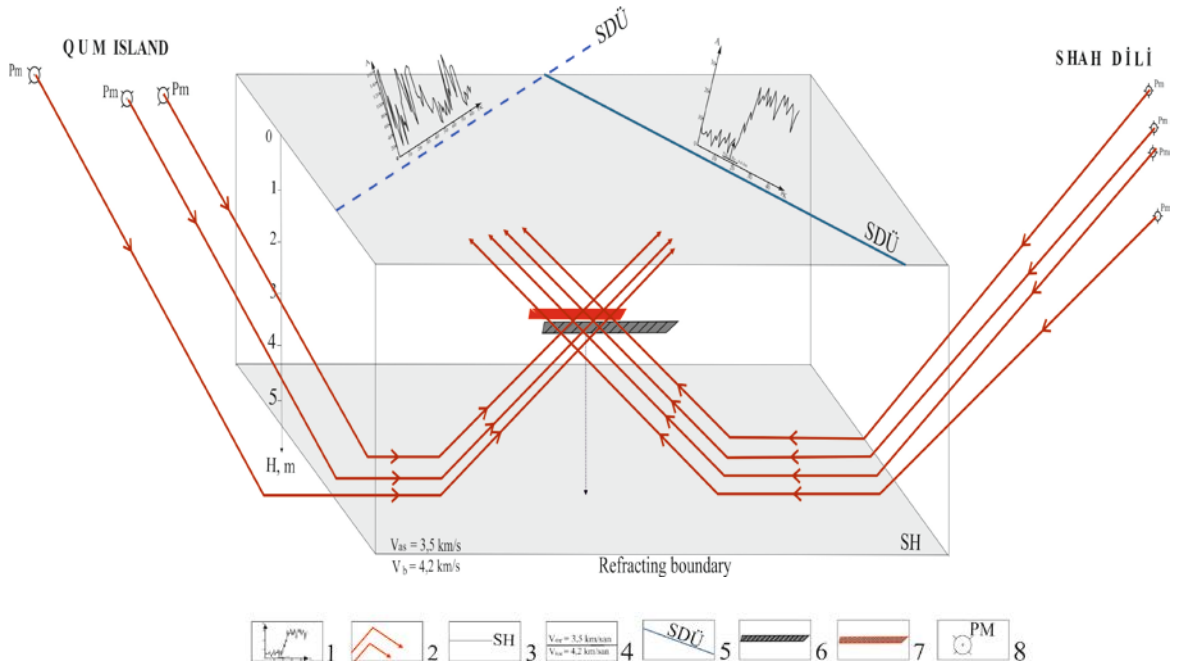


Figure 1. Forecasting of the oil and gas field in the Hovsan area from different directions
Legends:
1 – Amplitude curve; 2 – path of the refracted wave ray; 3 – refracting boundary; 4 – boundary velocity; 5 – profile (refracted waves method); 6 –trap type anomaly of 1996; 7 –trap type anomaly of 2000; 8 – Explosion point.

Seismic profile No. 030908 was developed intersecting seismic profile No. 030808 in the NE-SW direction of the field (see Figure 2). The wave pattern of both profiles is practically the same. As can be seen from the figure, the description of high-amplitude waves characterizes the complexities in the section (figure 6).

Oil and gas facilities have been predicted in the section based on seismic data. It can be assumed that the increase in the thickness of the lower Girmaki suite in the eastern direction of the section is related to the conditions of sedimentation and the exposure of some boundaries to washing [20, p. 54].In the seismic section, productive facilities are attributed to the lower Girmaki suite 1 and lower Girmaki suite 2 horizons. Here, oil and gas reservoirs (the first 170-460 trass) are observed at a 3100-3700 m depth interval, and their thickness is 40-100 m (Figure 6).

Oil and gas facilities were predicted in the seismic dynamic depth section [3, p. 73]. In the seismic section, productive facilities are attributed to the lower Girmaki suite 2 and lower Girmaki suite 3 horizons. Here, oil and gas reservoirs (the first 90-450 trass) are observed at a 3500-4000 m depth interval, and their thickness is 80-90 m (Figure 7).

Thus, formations with reservoir properties were separated on the dynamic depth sections of both profiles involved in the research, and their oil and gas content was predicted. As a result,

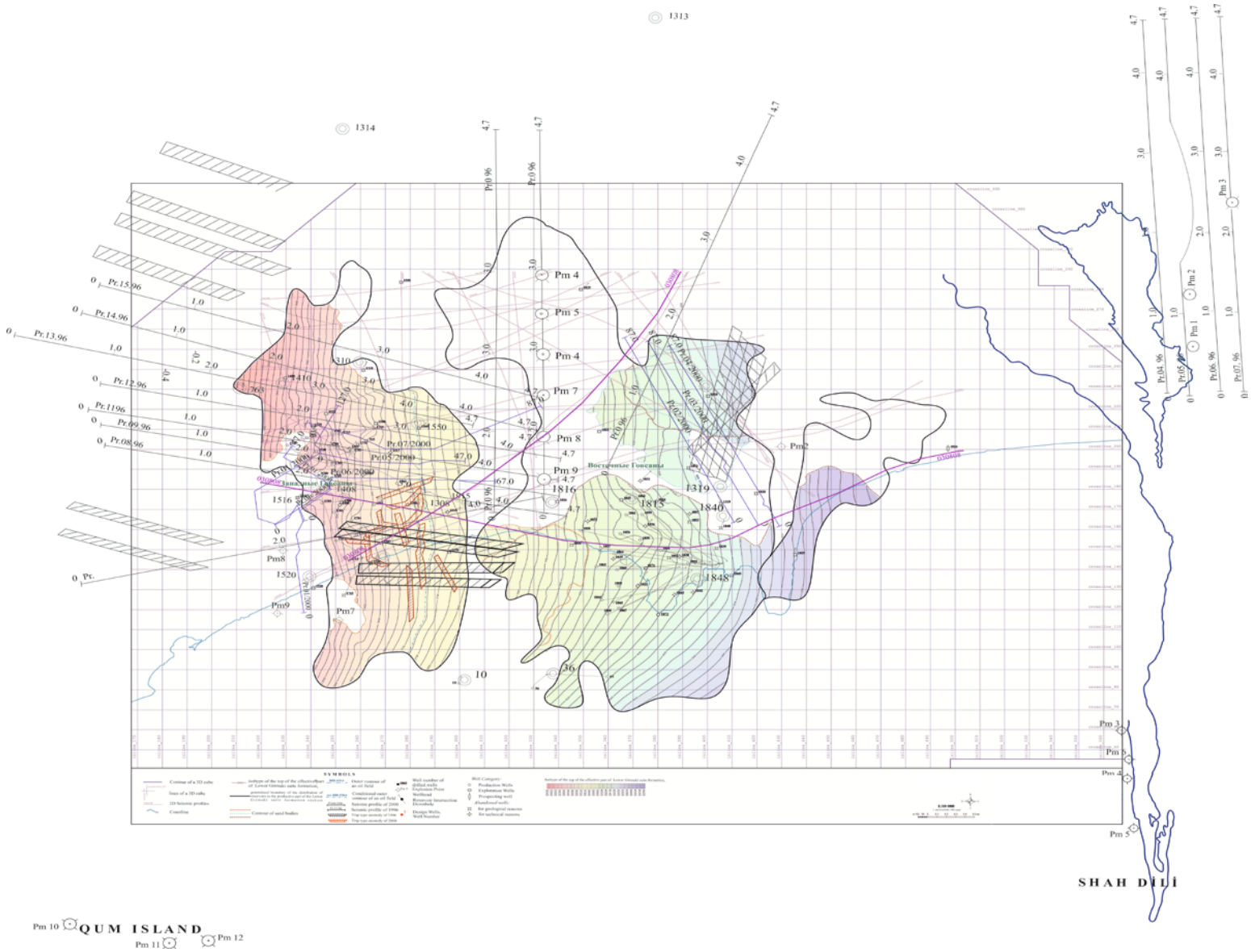


Figure 2. Location map of seismic profiles in the Hovsan Shallow water area [1; 2; 3; with addition by M. Huseynova].

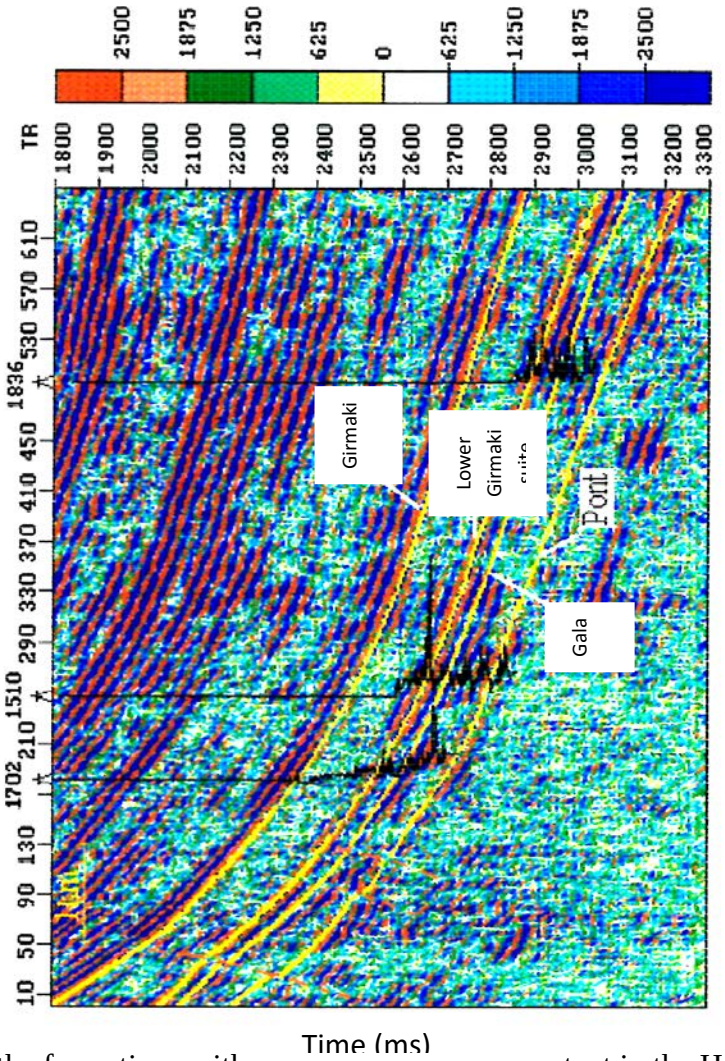


Figure 3. Selection of research facilities in seismic time-section.

the formations with negative oil and gas content in the Hovsan area are found in the section between two small tectonic faults that are traced over a long distance, intersecting the area in the SE-NE directions on the structural map based on well data. These faults can be one of the factors preventing the migration of oil and gas to the reservoirs located between them (see: fig. 2, 9) [3, p. 73].

As a result of the joint analysis of the sections, which reflect the amplitude and energy graphs, seismic dynamic cross sections, well data, and the distribution of petrophysical parameters, two oil-gas regions separated by a supposed "screen" were predicted [3, p.84]. It is predicted that the oil and gas reservoirs, which are attributed to non-anticlinal traps, located in the southwest of the area and the width of the assumed local change in lithology separating them is approximately 1200-1400 m (See: Figure 4, 8) [3, p. 84].

The depths and distribution areas of stratigraphic units in the lower productive series sediments were specified and traced along seismic sections by jointly processing and interpreting seismic profiles 030808 and 030908 and well data located close to them [3, p. 83]. In addition, the lithofacies characteristics of the formations were evaluated, amplitude and energy graphs were calculated, and on the basis of the joint analysis with the correlation scheme established by the well data, a local change in lithology preventing the migration of oil and gas was predicted, trap-type anomalies were identified, and log and seismic data were adapted. Another interesting pattern observed in the paleosections is that the existence of presumed lenticular structures is manifested in the form of local change in lithology and as a result of the sediment accumulation process, the formation of lithological non-anticlinal trap is observed (see: fig. 4, 8) The seismic wave pattern of these structures, separated by elliptic curve in the sections, and the local change in lithology, which is observed to be related to small-amplitude tectonic faults, play an important role in the distribution of oil and gas reservoirs across the section and area [3, p. 80].

As a result, as can be seen from the layout of seismic profiles in Hovsan Shallow Water area (see: fig. 2, 9), due to the approximate overlapping of the borders of two small tectonic faults, which are traced at a sufficiently large distance by numerous wells and seismic data it is assumed that the borders of these separated local change in lithology act as local change in lithology during oil and gas migration (see: Figure 7, 8) [3, p. 80].

Thus, as can be seen from the paleoreconstructed section of seismic profile 030808 (see: Figure 4), it is assumed that there is a local change in lithology with a width of approximately 1370 m, attributed to lower Girmaki suite 1, lower Girmaki suite 2 and lower Girmaki suite 3 intersecting the SE direction of the area, in seismic profile 030908 (see: Figure 8), it is assumed that there is a local change in lithology with a width of approximately 1200 m, attributed to lower Girmaki suite 1, lower Girmaki suite 2 and lower Girmaki suite 3 intersecting the NE direction of the area [3, p. 80].

As a result, the seismic exploration data of the Hovsan area were evaluated, the wells drilled in the area and the seismic exploration data were comprehensively processed and interpreted in order to separate small thickness formations and predict their probable oil and gas content, the research interval was defined, the sections were traced and dynamic analyses (instantaneous amplitude, frequency, phase, etc.) were conducted on them [3], the geological structure was specified according to the lower productive series sediments, it was determined that the trap type anomaly was related to non-anticlinal traps (lithological and tectonic screened traps) discovered in the SE part of the area, and criteria were developed for separating the traps.

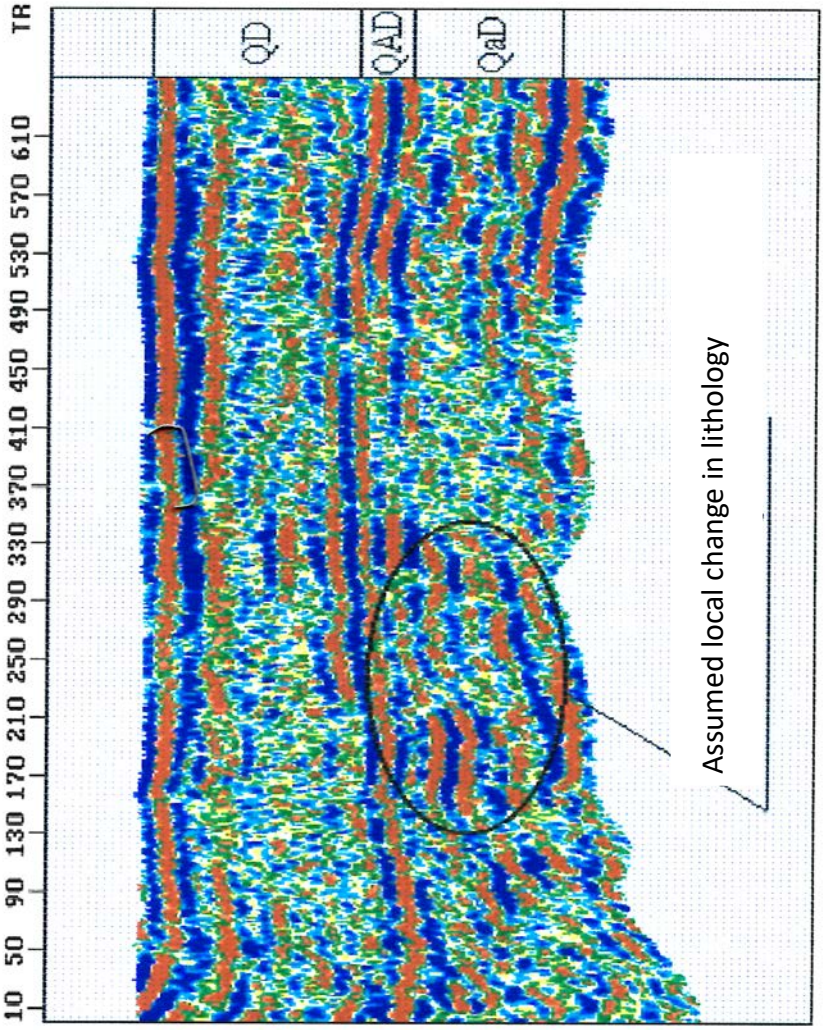


Figure 4. Paleoreconstructed section of seismic profile.

PR 030808 [3, p. 78]

Transverse seismic profiles 01.96 – 07.96 developed in the Hovsan Shallow Water area are located west of the Hovsan region and the exploration points are located 6-7 km east of the profiles.

Processing and interpretation of the materials of transverse seismic profiles No. 01.96.-07.06 was predicted oil and gas content under the Hovsan region (See: Figure 9) [1, p. 26].

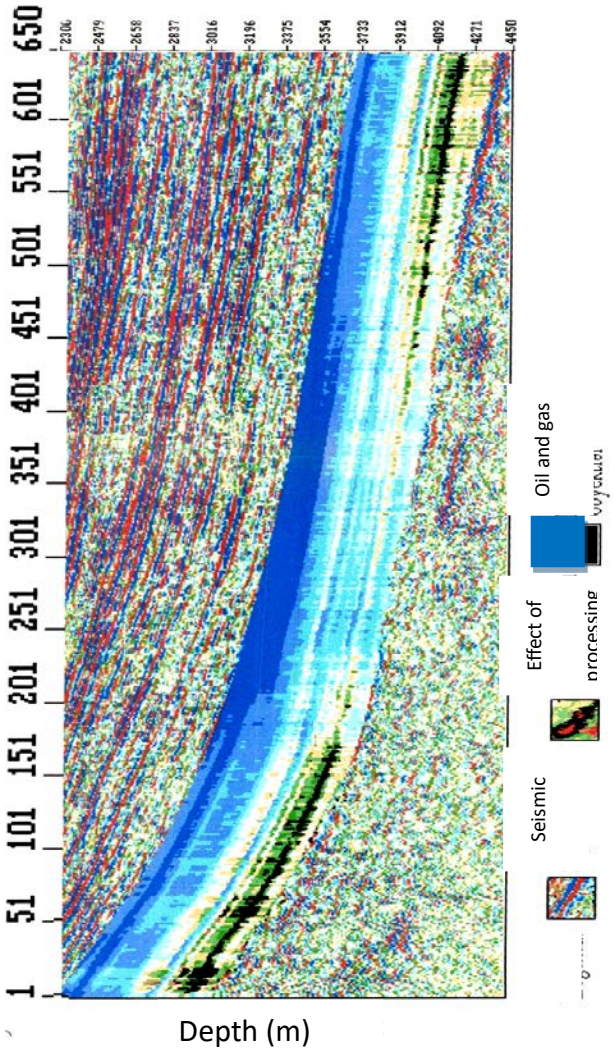


Figure 5. Distribution of assumed oil and gas facilities by depth section.

Exploration Point. 030808. [3, p. 61].

The results of the cross-sectional seismic profiles numbered 02.96 and 03.96 are shown in Figure 10. [1, p. 26]. At the beginning of both profiles, between stakes 0-20, a Trap Type Anomaly characteristic of an oil-gas field was observed, with the seismic boundary depth determined to be 4800 m, and the depth of the presumed oil-gas reservoir established at 4200 m. These depths correspond to the upper part of the Miocene deposits and the productive series deposits of Lower Girmaki Suite 1, Lower Girmaki Suite 2, and Lower Girmaki Suite 3. [1, p. 28].

Profiles numbered 09.96, 10.96, 12.96, and 14.96 are located in the northern part of the field. The distance from the profiles to the explosion points is 4.5 – 5.0 km, and the distance between the explosion points is 0.5 km. Amplitude anomalies characteristic of the oil-gas field have been observed in each profile (PK 0-12). Here, the seismic boundary depth is between 3700-4000 m, while the depth of the presumed oil-gas reservoir is estimated to be around 3250 m. (See: figure 9, 11) [1, p. 32].

The location of the Trap-Type Anomalies detected in the Hovsan Sea area has been specified on the plan. (See: figure 8). As can be seen, the presumed oil-gas reservoir beneath the Hovsan settlement extends towards the sea in the southwest direction. (figure 9) [1, p. 32].

Based on the structural map constructed according to the surface of the Miocene deposits, it can be inferred that the tectonic structure of the Miocene deposits may play a key role in the formation of the identified oil and gas reservoirs in the Hovsan Sea area. Thus, the observation of a buried volcano at the Miocene surface in the Zıgh and Qum island- offshore areas (Figure 9) could be a key factor in the formation of oil and gas reservoirs. "The structures formed by the buried volcanoes, such

as the Bibi-Heybat and Qum island-offshore fields, are large oil and gas reservoirs of significant industrial importance." [1, p. 47].

Field seismic exploration in Hovsan shallow sea area was carried out by recording waves refracted and reflected in transverse profiles by direct search method. The profiles were located on the shore, while the explosion points (EP) were used on Qum Island, the Turkan field, and cape of Shah dili (figure 9, 12, 13) [1, p. 18].

In the seismic records obtained along the transverse seismic profiles processed from wave sources No. 3, 4, 5, 6 in the areas of Gum island, Turkan and Shah dili several correlated seismic waves were observed, amplitude and energy plots of their dynamic and kinematic parameters were plotted along the profile, as a result of which local anomalies were identified and it was analyzed that these oil and gas zones belong to non-anticlinal traps (see Fig. 9, 12, 13).

Based on the obtained amplitude and energy plots on the profiles, the zones of maximum and minimum values of dynamic parameters of tested and reflected waves were selected. The characteristic minima were compared, and oil and gas objects were forecasted based on the technique of direct search in the graphs (see: Figs. 10, 12, 13) [1, p.19].

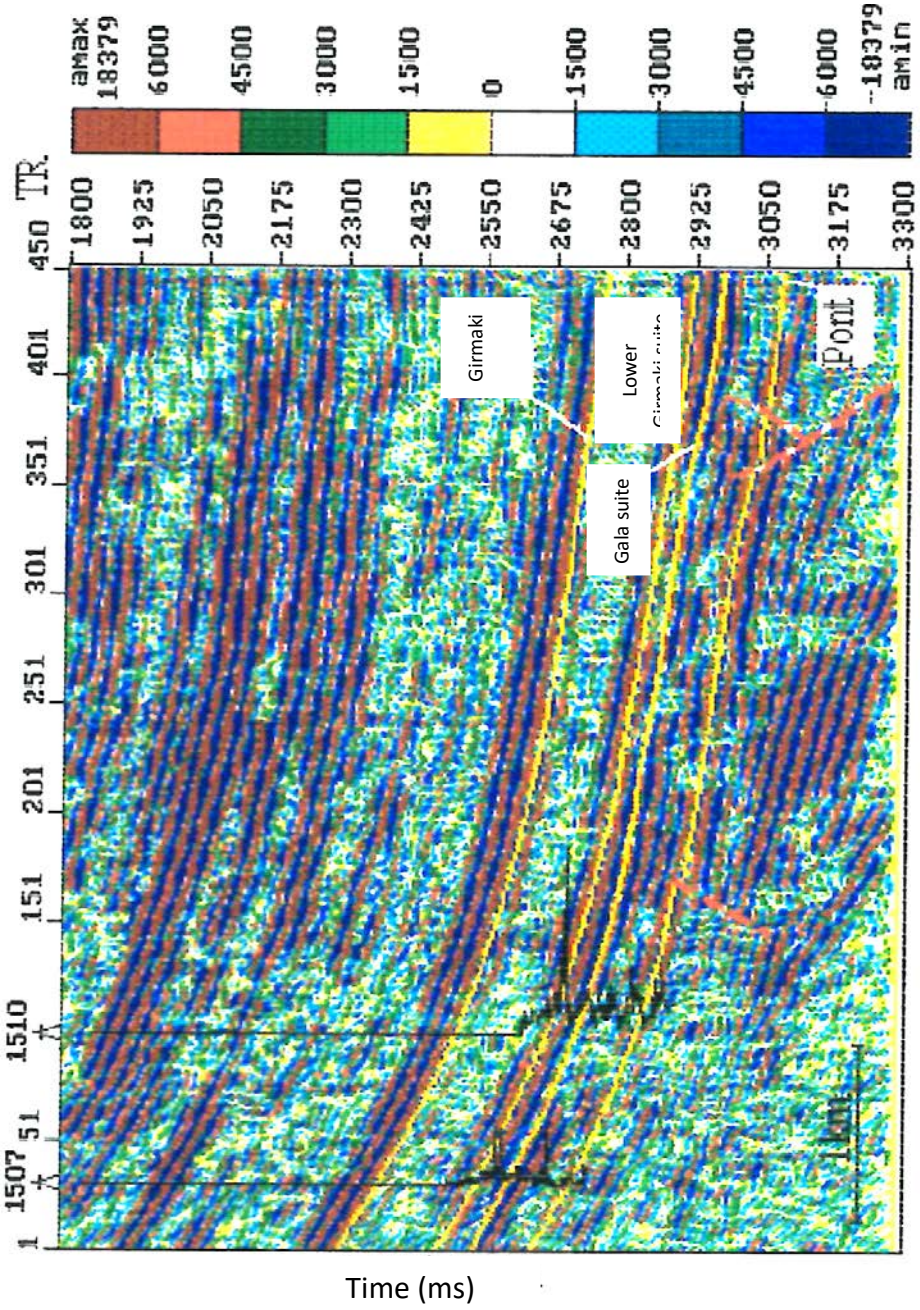


Figure 6. Selection of research facilities in seismic time-section.

Exploration Point 02008 [3, p. 63]

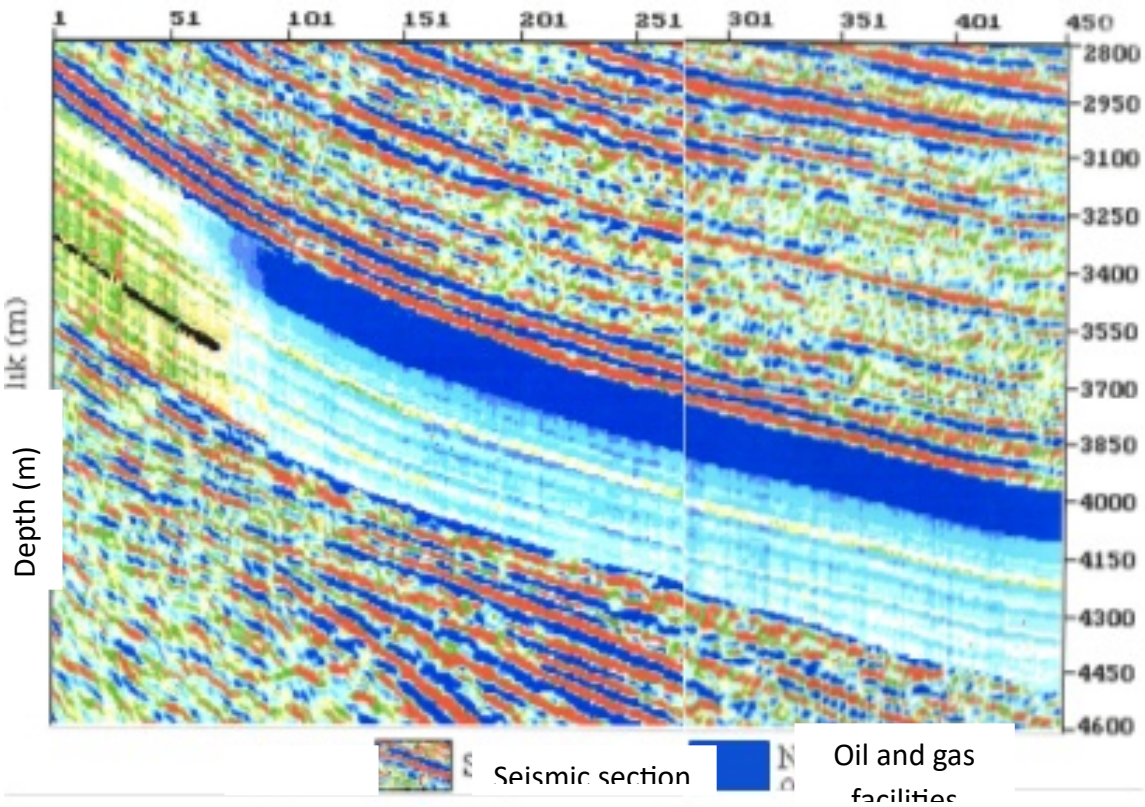


Figure 7. Distribution of assumed oil and gas facilities by depth section. Exploration Point 030908 [3, p. 75].

Assumed local change in lithology

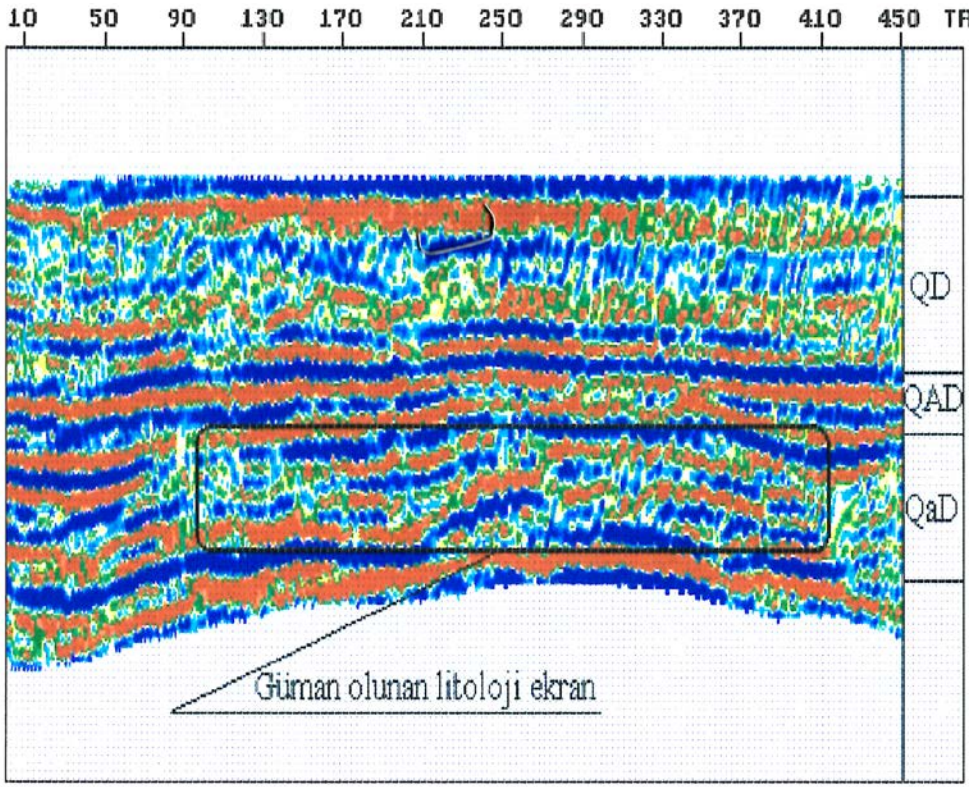


Figure 8. "Paleo-reconstructed section of the seismic profile."

PR 030908 [3, p. 79].

Figure 9. Location scheme of the profiles involved in the study and the Trap Type Anomaly based on seismic data [1, p. 49; 2, p. 44; with the additions of M. Huseynova].

At Hovsan-Deniz field other profiles - profiles Nos. 01/2000 and 01A/2000 in the South-West - North-East direction, as well as profiles Nos. 02-04/2000 in the South-East - north-West direction are developed according to the form close to reciprocal profiles. Profile No. 01/2000 is completely reworked from explosives-1,2,5,6 and partially from explosives 3.4. Profiles 02-05/2000 are processed from explosives -7,8 and profiles 06-08/2000 are processed from explosives -7,9 (see: Figure 9, 12, 13).

Based on the geophysical and well surveying data (WSD) in the Hovsan Shallow Sea area, seismic boundaries related to the productive series sediments and lower ones have been established in the south-north direction, and it has been observed that the depth boundaries lie unconformably towards the coast (from sea to land) and there is an uplift (See: Figure 9, 10, 11, 12, 13) [1; M. Huseynova].

Considering the minima of the dynamic parameters of seismic waves recorded at different arrivals, trap-type anomalies (PTA) were detected and the nature of these minima indicates certain complications (such as fractures), leading to the disruption of the formation's integrity across the area. The proposed field is expected to belong to the Lower Girmaki Suite 1, Lower Girmaki Suite 2, and

Lower Girmaki Suite 3 horizons at depths of 3600m to 4200m (see Figures 9, 10, 11, 12, 13) [1; M. Huseynova].

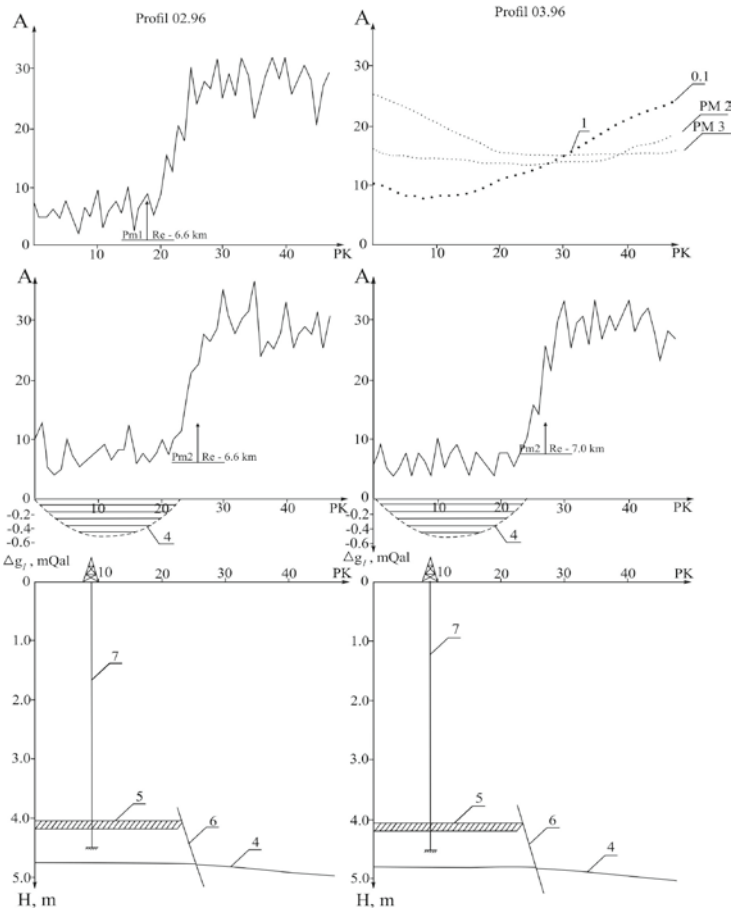


Figure 10. Results obtained on seismic profiles 02.96 and 03.96. [1, c. 24].

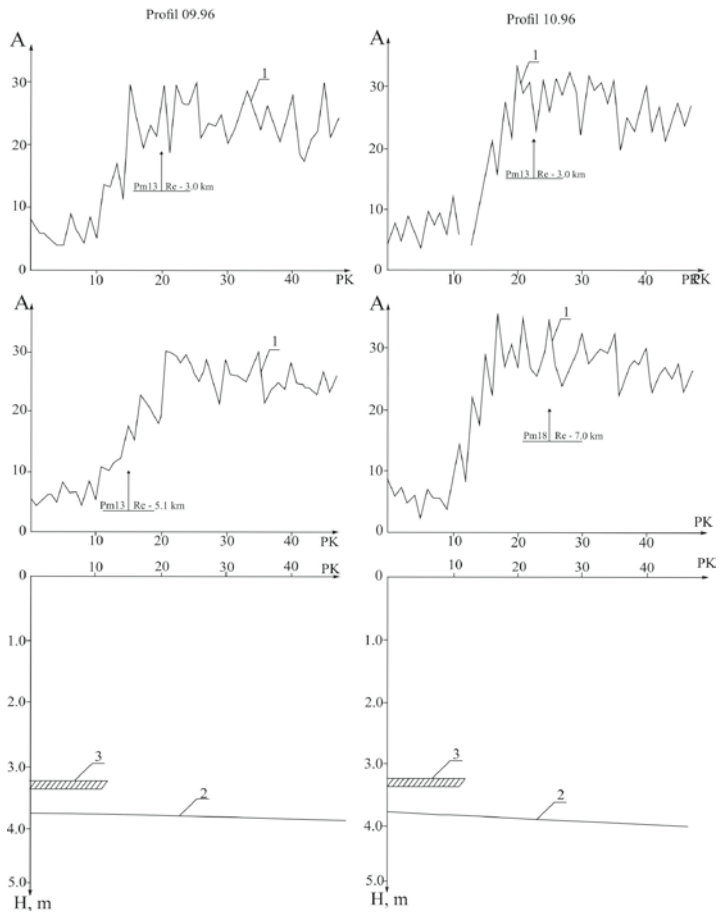


Figure 11. Results obtained on seismic profiles 09.96 and 10.96. [1, c. 33].

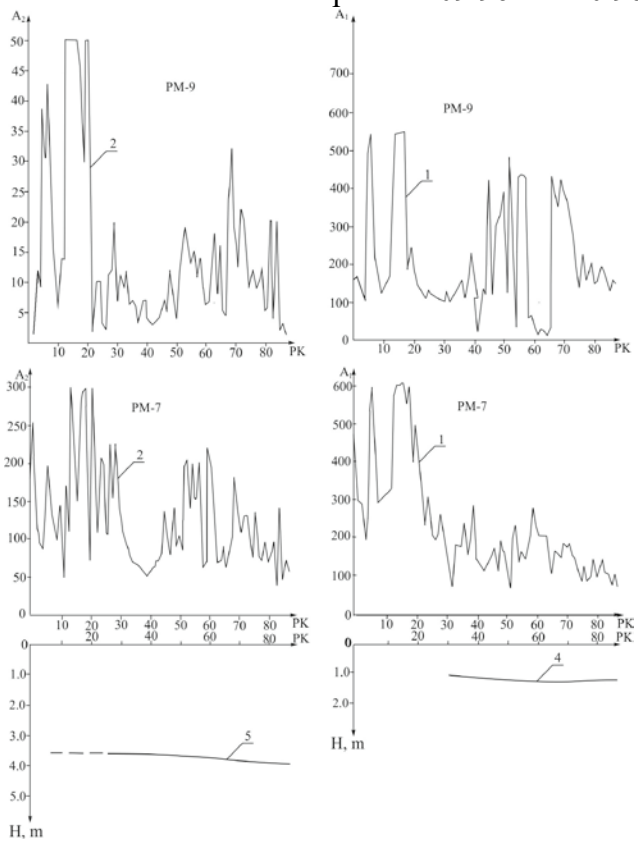


Figure 12. Results obtained on seismic profile No. 06/2000.

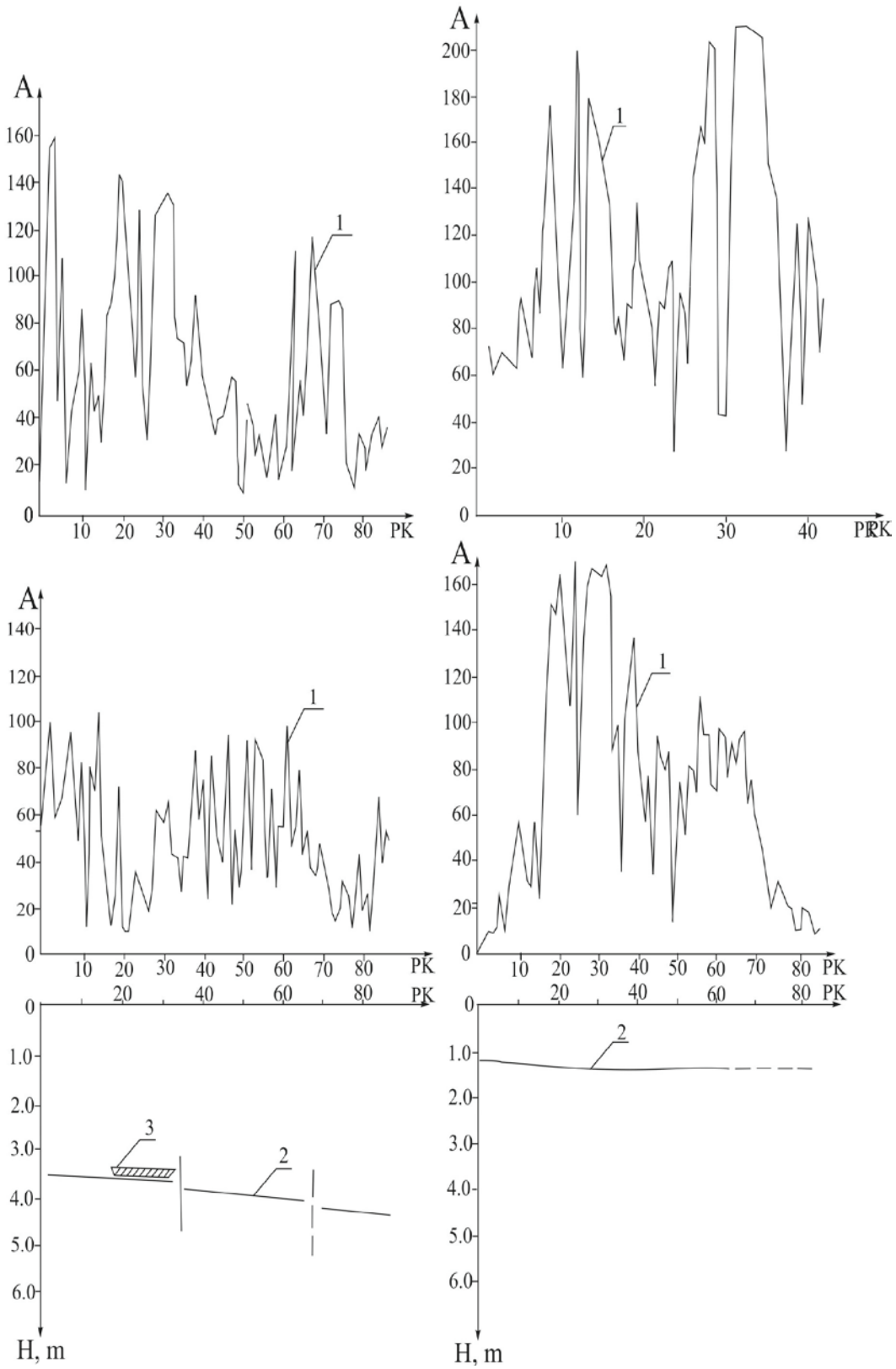
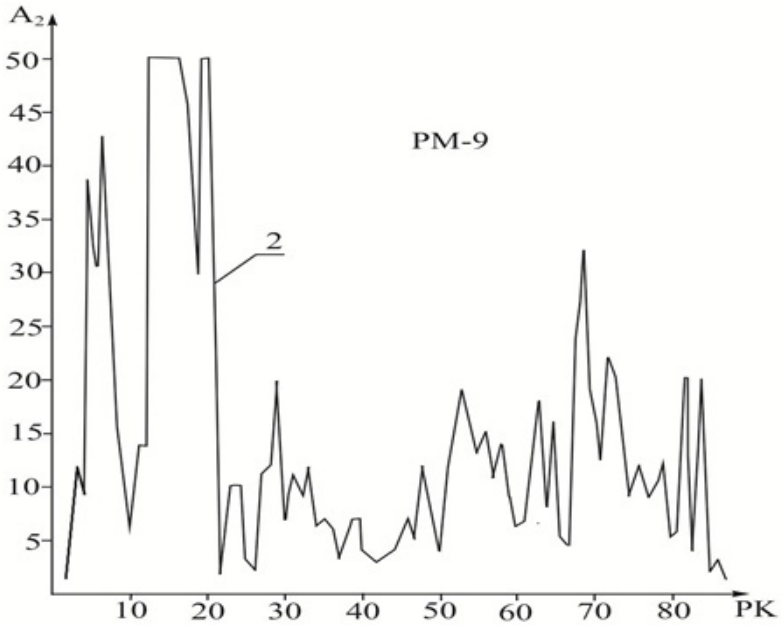


Figure 13. Results obtained on seismic profile No. 07/2000.

Based on the obtained amplitude and energy graphs, a comparative analysis of anomalies was performed at oil and gas bearing objects of profiles No. 030808 and 030908, and in the zones of minimum values of the dynamic parameters of refracted and reflected waves (Figures 14, 15). As can be seen from the graphs, characteristic minima were compared, and oil and gas objects were predicted using the direct search method. This also shows that, according to seismic sections (profiles No.

030808 and 030908), findings from both the refracted wave method and the reflected wave method suggest and confirm the presence of anomalies in the same zone (see Figures 2, 14, 15). Data obtained from amplitude and seismic sections were plotted in one column and comprehensively interpreted.

As a result of an observed decrease of 3.5-4 times in amplitude intensity between stakes 21 and 51 derived from the refracted wave amplitude graph recorded on profile No. 06/2000 (with the depth of the trap type anomalies approximately 3500m to 4000m) and a decrease in amplitude intensity of 3.5-4.2 times between stakes 10 and 45 derived from the refracted wave amplitude graph provided on profiles No. 07/2000 (with the depth of the trap type anomalies approximately 3500m to 4200m) taken from the North, wave sources No. 7 and 9, evidence suggesting the presence of oil and gas was revealed in the Lower Girmaki Suite 2 and Lower Girmaki Suite 3 horizons. On profiles No. 030808 (route No. 201-501) and 030908 (route No. 10-450), with the application of the common depth point (CDP) method, indications of the presence of oil and gas prospects were identified in the same zones (see Figures 2, 14, 15).



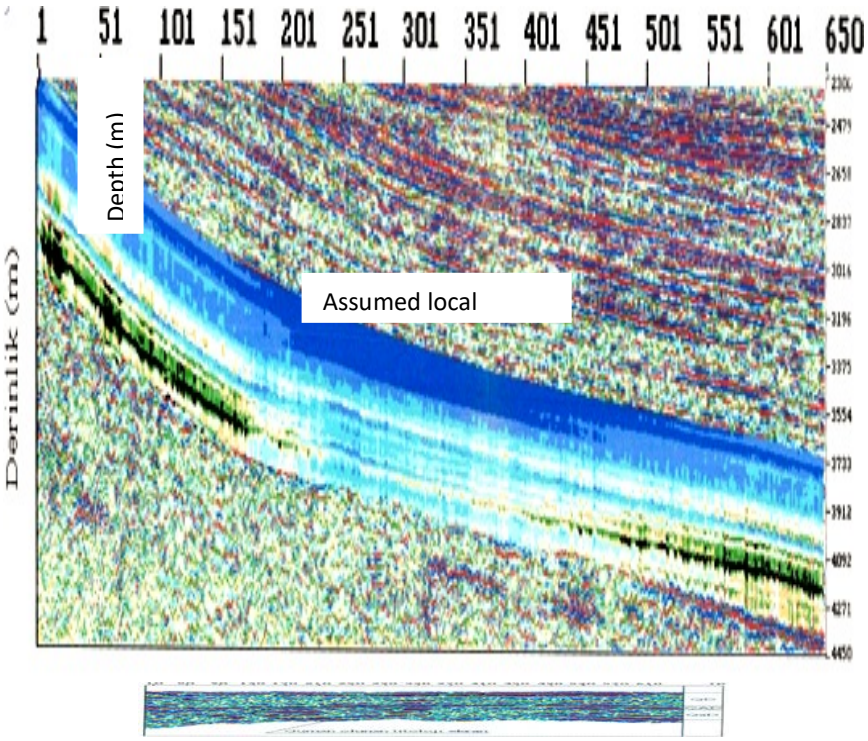


Fig 14. Results obtained on seismic profile No. 06/2000 and seismic dynamic depth section No. 030808 [3, p. 61, 78; with additions by M. Huseynova].

Based on the data from profiles No. 030808 and 030908, with the applied CDP method, sections were built in the Petrol software (instantaneous amplitude, instantaneous frequency, instantaneous phase [3, pp. 50, 65], amplitude, energy, hodograph). The graph and the sections were plotted in the same column to compare the sections. As a result of a comparative analysis of the data obtained using refracted and reflected wave methods, the correspondence of these indications with the oil and gas-bearing objects was confirmed (see Figures 14, 15).In 2000, it was recommended to drill wells based the results of scientific studies conducted with my participation.

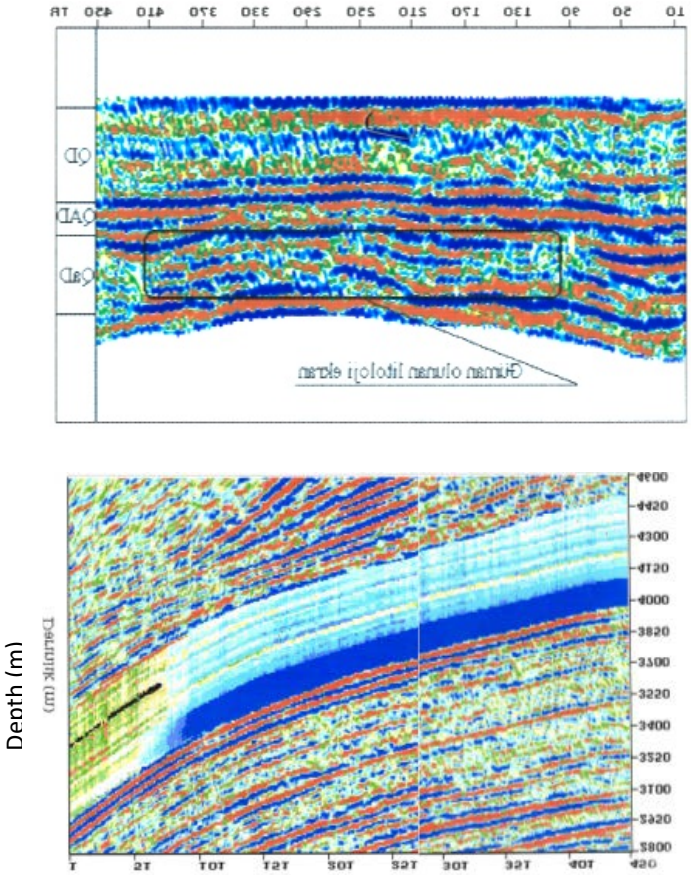


Fig 15. Results obtained on seismic profile No. 07/2000 and seismic dynamic depth section No. 030908 [3, p. 75, 79; with additions by M. Huseynova].

In 1996-2000, as a result of works on these zones, drilling of wells No. 1700-1709 was recommended and positive results were obtained. In the following years Azneft PU achieved positive results within the anomalies in this zone.

In 2000, research work on new profiles was again carried out in this area and trap type anomaly was obtained for this area. Based on the results obtained, it was decided to confirm each other as a result of comparing the results of the work carried out in 1996 with the data obtained.

As a result, the main purpose of the complex geophysical studies carried out on subjects No. 091-96 and 165-2000 was the predicting and analysis of oil and gas deposits at the Hovsan-Deniz field as a result of the combined use of the seismic exploration method with refracted and reflected waves with high-precision gravimetrical exploration, and determination of formation boundaries in plan and the depth of the section based on trap type anomalies obtained in geophysical areas. [10, p. 48; 13; M. Huseynova]. A comparative analysis of overlapping of trap type anomalies obtained in 1996 and 2000 on both subjects was carried out, and their connection with non-anticlinal traps was considered. The following conclusions and recommendations were made based on the direct exploration of oil and gas deposits using complex geophysical methods [1, p. 48; 13; M. Huseynova]:

1. The seismic trap type anomaly detected as a result of comparative analysis of complex geophysical subjects conducted on topics 091-96 and 165-2000 in the Hovsan Shallow Water area largely coincides and confirms each other. In the CQ part of the study area, the trap type anomalies obtained for both subjects overlapped and were determined to be attributed to lithologically and fault-bounded non-anticline traps. Here, the presumed oil and gas field (lithologically and fault-bounded non-anticline traps) is attributed to Lower Girmaki Suite 1, Lower Girmaki Suite 2 and Lower Girmaki Suite 3 and is located at a depth of 3500-4200 m.

2. As a result of reservoir-type anomaly, discovered on the basis of a comparative analysis of complex geophysical works carried out in the area No. 165-2000 slightly west of Cape Hovsan, wells No. 1700, 1701, 1703, 1704, 1705, 1706, 1707, 1708, 1709 were drilled and from horizons Lower

Girmaki Suite 1, Lower Girmaki Suite 2 and Lower Girmaki Suite 3 industrially important oil was produced. The depth of the suspected deposit (including parts with non-anticlinal traps) is about 3500-4200 m.

In this part of the thesis work, as a result of the analysis of complex geophysical (seismic) works and downhole geophysical survey (DGS) in the Hovsan shallow water area, the lithofacies composition of Pliocene deposits was clarified, oil and gas potential was predicted, parts of potentially productive areas were determined, especially those related to non-anticlinal traps, to these types traps, the directions of exploration operations were substantiated, a repeated analysis of the presence of favorable conditions for hydrocarbons accumulation and the prospects for oil and gas extraction was carried out.

Here, seismic work needs to continue offshore to fully define the boundaries of the field.

Conflict of interest

The author declare that they have no conflict of interest in relation to this research.

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