# Assessment of the Hydrocarbon Potential of the Salatin and Alekperli Structures Using the Frequency–Resonance Processing of Satellite Images

## Abstract

The paper presents the results of a regional assessment of the hydrocarbon potential of the promising Salatin and Alekperli structures located in the Azerbaijani sector of the Caspian Sea. The study was carried out using a frequency–resonance method for processing satellite imagery and vertical electric resonance sounding (VERS). The Umid gas-condensate field, which has been thoroughly studied by drilling and is under commercial development, was used as a reference object for method calibration.

Based on the processing of a Landsat 8 satellite image at a scale of 1:250,000, ten anomalous zones were identified within the study area and interpreted as potentially gas- and gas-condensate-bearing. It was established that the anomalous zones corresponding to the Salatin and Alekperli structures are comparable in terms of area and intensity characteristics to the reference Umid field, indicating their prospectivity. The Alekperli structure is particularly notable, as the area and intensity of its anomaly are close to those of Umid.

The results of vertical electric resonance sounding performed for the Umid field and the Salatin structure made it possible to conduct a comparative analysis of their deep geological structure and to identify anomalously polarized intervals interpreted as potentially productive reservoirs. For the Salatin structure, a limited number of promising intervals were identified, mainly within the depth range of up to 6,200–6,300 m, which makes it possible to recommend optimization of exploratory drilling depths.

It is concluded that the applied set of methods is an effective tool for preliminary (screening-level) forecasting of oil and gas potential at the regional stage. The results obtained substantiate the feasibility of further detailed studies and the initiation of exploration activities on the Salatin and Alekperli structures using larger-scale surveys and integrated interpretation of seismic and geoelectric data.

**Keywords:** South Caspian, gas-condensate fields, frequency–resonance method, satellite imagery, anomalous zones, vertical electric resonance sounding, geological exploration.

## Introduction and objectives of the study

The Caspian Sea within the jurisdiction of Azerbaijan is among the well-studied oil and gas provinces. Since the Soviet period, a significant volume of seismic surveys and exploratory drilling has been carried out in this area, resulting in the identification of a number of promising structures and the discovery of large hydrocarbon fields. The main oil and gas reserves are associated with the Middle Pliocene Productive Series (PS), including the Pereriva Suite. The discovery and development of new fields along the western and eastern margins of the basin within Middle Pliocene deposits emphasise the high resource potential of this stratigraphic interval ( Javadova A and Hauk M ., 2000). In much of the South Caspian region, Paleogene–Miocene and Mesozoic formations occur at great depths. The hydrocarbon potential of the southern part of the Baku Archipelago is also mainly associated with the Productive Series and, to a lesser extent, with Paleogene–Miocene deposits. The patterns of thickness distribution and lithofacies of the Productive Series are similar to those observed in adjacent onshore areas, particularly in the Lower Kura oil and gas province. Structures such as Umid, Babek, Salatin, and Alekperli are of particular interest, as their offshore extensions coincide with known oil fields, including Neftchala, Babazanan, and Kyurovdag. In recent decades, large gas-condensate fields such as Umid and several others have been discovered and brought into production in the offshore part of the area.(Javadova, 2021)

The Salatin and Alekperli structures are located on the Azerbaijani shelf in the southwestern part of the South Caspian Basin and form an undrilled structural trend extending in the NW–SE direction (according to seismic data, approximately 80 km long and 15 km wide), comprising several structures. In this study, these two closely spaced structures are considered as a single exploration unit referred to as the Salatin Block. The block covers an area of about 910 $km^2$ and is located east of 49°40′ E and south of 39°20′ N, in offshore waters with depths ranging from 50 to more than 500 m.(Javadova, 2000)

According to regional seismic interpretation, structural closures within the Salatin Block are identified at several stratigraphic levels: the top of the Pliocene (roof of the upper part of the Productive Series), a level close to the top of the Pereriva Suite (near the base of the upper part of the Productive Series), and the base of the Pliocene.(Javadova, 2019)

The main reservoir section of the Salatin Block is represented by Middle Pliocene sandstones of the Productive Series, a widely distributed alternation of sands and clays transported into the Kura and South Caspian basins by the paleo-Kura and paleo-Volga rivers and deposited in a complex regressive–transgressive environment as fluvial-deltaic and/or turbiditic sediments (Figure 1).

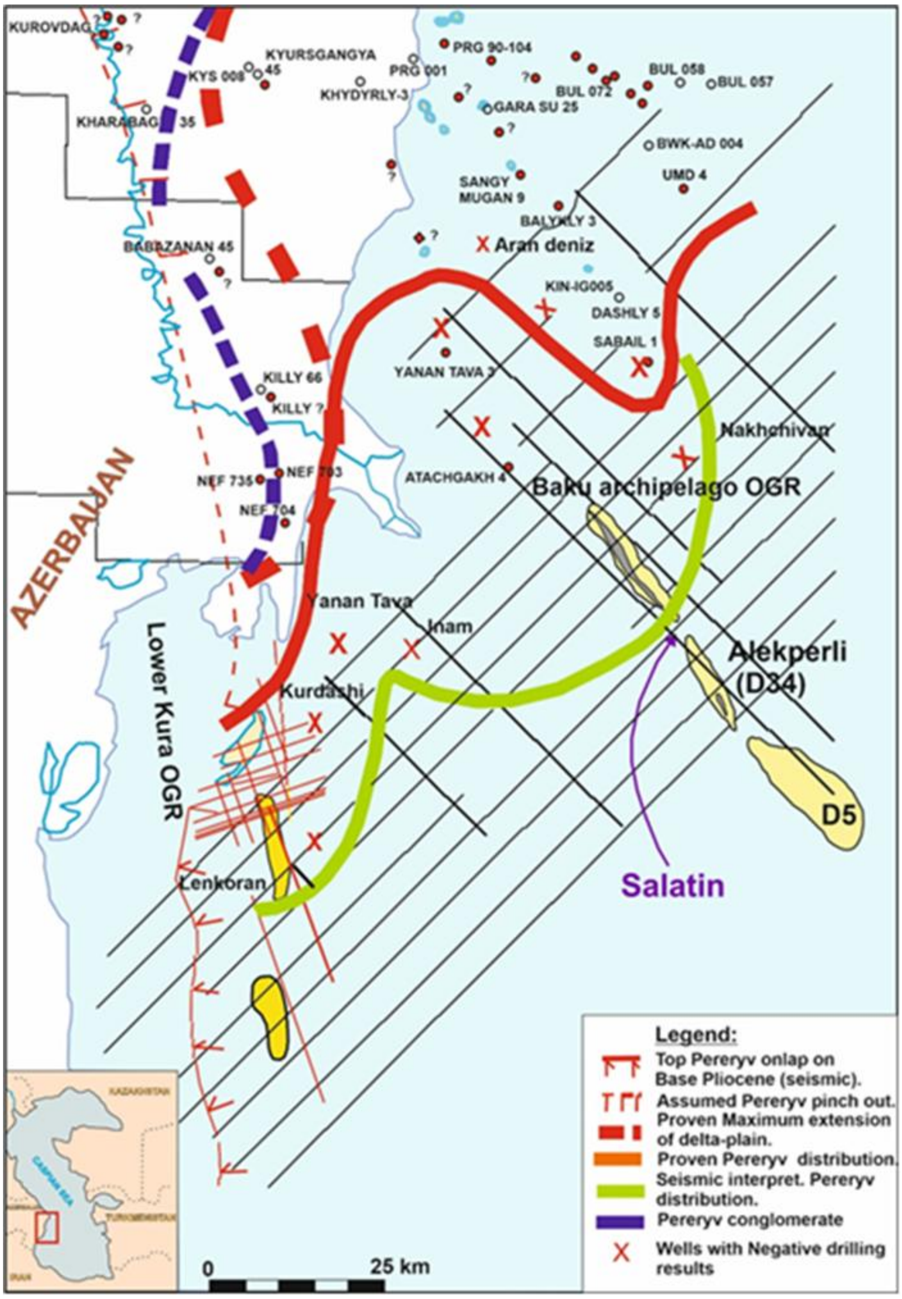


**Fig. 1**. **Schematic map showing the regional location of the Salatin and Alekperli structures.**

**The objective of the present study** is to assess the hydrocarbon potential of two promising seismically identified structures—Salatin and Alekperli. These structures are interpreted as anticlinal structural traps confirmed by seismic profile data; however, no exploratory drilling has been carried out on them to date.

## Research methodology

To evaluate the oil and gas prospectivity of the Salatin and Alekperli structures, a frequency–resonance method for processing satellite imagery developed by Geoprom was applied. The method is based on the detection of anomalous responses associated with the presence of hydrocarbon-saturated reservoirs and is comparative (relative) in nature. (Levashov etc, 2006)

The Umid field was selected as the reference (calibration) structure because:
• Its structure has been confirmed by drilling.
• the field is under commercial development;
• gas and gas condensate are being produced;
• Reliable data are available on depths, productive horizons, and reservoir pressures.

Using the Umid structure as a reference made it possible to calibrate the method and determine characteristic resonance frequencies for gas-condensate fields of this type, followed by a comparable analysis of the Salatin and Alekperli structures.

**Input data and scale of work**

For processing, a single satellite image sheet at a scale of 1:250,000 was prepared, covering:
• the Umid and Babek structures;
• wells located within the sheet area (including Nakhchivan, Sabail, and several others).

A Landsat 8 satellite image dated 10 October 2025 was selected for processing (https://doi.org/10.5066/P9OGBGM6),
LANDSAT_PRODUCT_ID = "LC09_L2SP_166033_20251009_20251010_02_T1".

It should be noted that the 1:250,000 scale represents the maximum regional scale for solving oil and gas prospectivity assessment tasks. At this scale, the spatial resolution of the method is approximately 2.5 km per 1 cm of the image, which defines the expected positioning error of anomalous zones. Accordingly, the contours of the identified anomalies may be displaced within this distance.

It is important to emphasize that when transitioning from a regional scale to a more detailed one (1:100,000 and larger), the sizes of anomalous zones generally decrease due to changes in the focusing area and refinement of anomaly boundaries.(Levashov etc, 2008)

**Method calibration**

The input data used to calibrate the technique included:
• coordinates and depths of wells at the Umid field;
• well logging data;
• information on productive horizons;
• parameters of gas-condensate saturation and reservoir pressures.

Based on these data, resonance frequencies characteristic of a gas-condensate field of the Umid type were determined. These frequencies were subsequently used to process the entire image sheet shown in Figure 2.

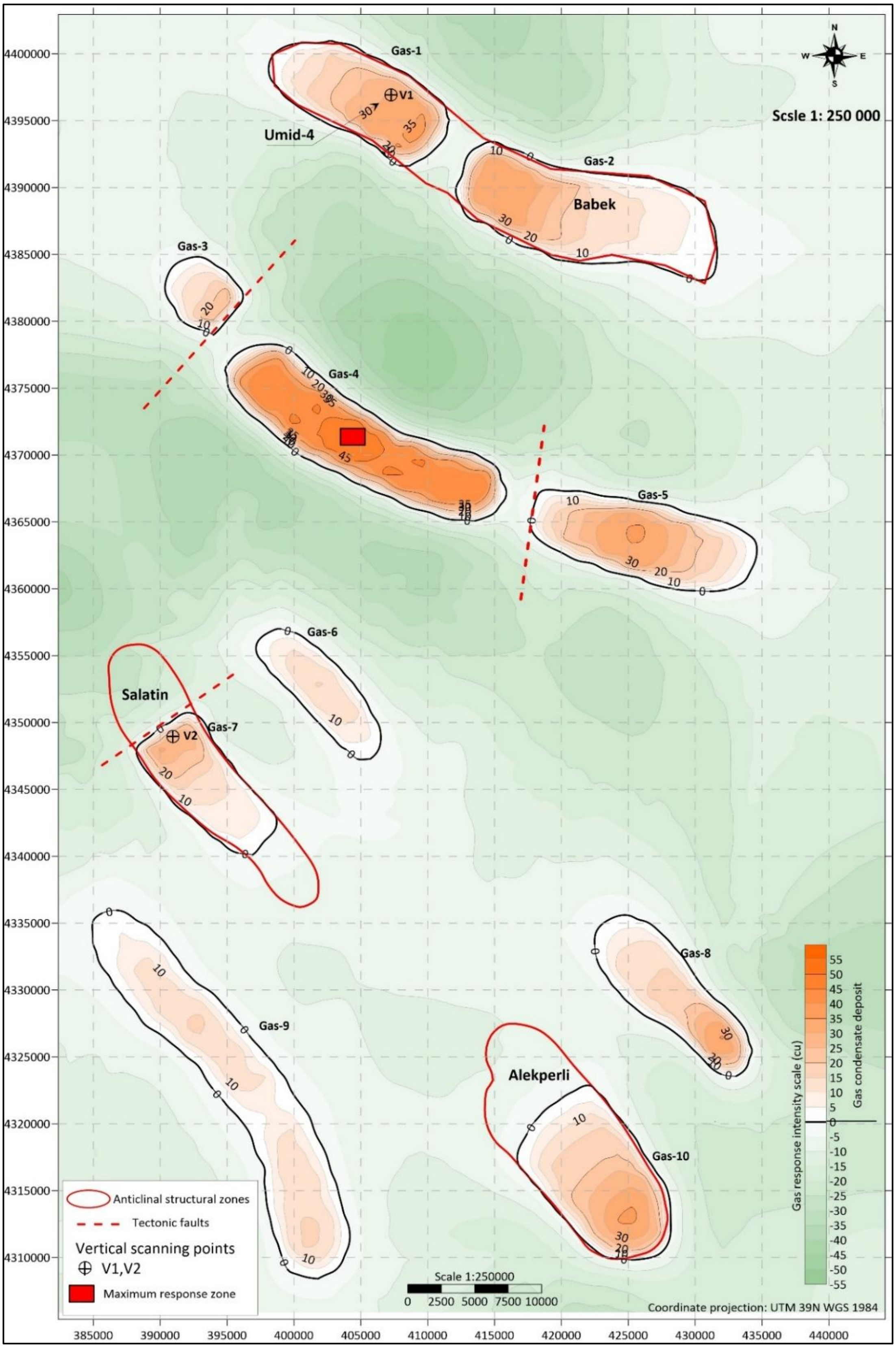


**Fig.2. Map of anomalous geoelectric zones of the " Gas condensate deposit" type in the South Caspian Sea according to frequency-resonance interpretation of space images**

**Processing results**

As a result of frequency–resonance processing, ten anomalous zones were identified within the study area, conventionally designated as Gas-1 to Gas-10.

• The Gas-1 and Gas-2 anomalies spatially coincide with the Umid field and the prospective Babek structure.
• The Gas-3, Gas-4, and Gas-5 anomalies represent a continuation of a single elongated structure.
• The Gas-6 anomaly is characterized by relatively small dimensions.
• The Gas-7 anomaly corresponds to the Salatin structure.
• The Gas-10 anomaly corresponds to the Alekperli structure.
• In addition, an elongated, low-intensity Gas-9 anomaly is noted.

All anomalies are expressed in relative units reflecting the response intensity compared to the reference Umid field. Given the known parameters of Umid, including anomalous reservoir pressure values, these relative units can be interpreted in an applied geological exploration context.

In addition, several tectonic zones were identified within the study area. The configuration of the Gas-7 (Salatin) anomalous zone and the position of a tectonic fault may be interpreted as a structural seal favorable for trap formation.

**Comparative characteristics of anomalies**

Table 1 presents the main parameters of the identified anomalous zones—their areas and maximum values of relative field intensity.

• The most intense anomalous zone is Gas-4, located in the vicinity of the Nakhchivan well. Its maximum intensity is 49 relative units (r.u.), with an area of 114 km².
• For the Umid field, the area of the anomalous zone is 73 km², with a maximum intensity of 36 r.u.
• For the Salatin structure, the anomalous zone covers an area of 55 km², with a maximum intensity of 30 r.u., which is lower than the Umid indicators.
• For the Alekperli structure, the anomalous zone area reaches 94 km², exceeding that of the Umid anomaly, while the maximum intensity is 35 r.u., virtually matching the Umid level.

**Table 1.** The main parameters of the identified anomalous zones—their areas and maximum values of relative field intensity.

| Anomaly Name | Area km2 | Max intensity |
|---|---|---|
| **Gas-1 (Umid)** | **73** | **36** |
| **Gas-2 (Babek)** | **122** | **36** |
| **Gas-3** | 23 | 20 |
| **Gas-4** | **114** | **49** |
| **Gas-5** | 85 | 35 |
| **Gas-6** | 41 | 15 |
| **Gas-7 (Salatin)** | 55 | 30 |
| **Gas-8** | 63 | 35 |
| **Gas-9** | 150 | 15 |
| **Gas-10 (Alekperli)** | **94** | **35** |

Based on these results, it can be concluded that the Salatin and Alekperli structures, according to frequency–resonance interpretation of satellite imagery, are promising targets for the discovery of gas-condensate fields.

**Vertical electric resonance sounding**

The next stage of the work involved vertical electric resonance sounding (VERS). This type of investigation can be considered an analogue of a "virtual well," in which the presence and properties of anomalously polarized layers are interpreted from the frequency–resonance characteristics of the response, including their inferred lithology and type of fluid saturation.

The Umid field was used as the reference object for interpreting the VERS results, as confirmed drilling data are available for it, along with information on productive intervals, lithological composition, and the nature of fluid saturation (gas and gas condensate). Vertical scanning was carried out at locations of drilled wells at the Umid field in order to compare the virtual well responses with the known geological model.

An important methodological limitation should be noted: the regional scale of investigation (1:250,000) used at the previous stage implies that the results of vertical scanning reflect averaged characteristics of the geological section within an area on the order of 1 km or more around the scanning point. For this reason, direct comparison of VERS results with actual data from a specific well, which is a point object of small diameter, is not correct. Thus, vertical scanning data are informational and indicative in nature and are intended primarily for comparative analysis between different structures.

**Scanning at the Umid field**

Vertical scanning at the Umid field was performed at point V1 (the locations of points V1 and V2 are shown in Figure 2). The scanning interval ranged from 4,000 to 7,500 m. It is known that the actual drilling depth at the Umid field reached 6,700 m, and in 2025–2026 new wells are planned to be drilled to depths of approximately 7,000 m.

As a result of VERS, 15 anomalously polarized intervals were identified at this point, interpreted as layers saturated with gas, gas condensate, or water. The scanning results are presented in Table 2, where for each interval the following parameters are given:

- average depth of occurrence;
- thickness of the interval;
- interpretation of fluid type (gas, condensate, water);
- characteristics of the resonance response (including propane frequencies);
- relative response intensity;
- estimated anomalous reservoir pressure;
- final assessment of prospectivity.

**Table 2. Results of scanning of each interval at the Umid field.**

| № | Depth (m) | Thickness (m) | Gas, (Propane) Condensate (Transparent) Water | Response intensity (c.u.) | Pressure MPa | Note |
|---|---|---|---|---|---|---|
| 1 | 4081-4082 | 1 | Gas | 5 | 41.4 | Not promising |
| 2 | 4130-4131 | 1 | Condensate | 6 | - | Not promising |
| 3 | 4488-4489 | 1 | Condensate | 12 | - | Not promising |
| 4 | 4963-4966 | 3 | Gas | 10 | 50.9 | Not promising |
| 5 | 4994-4999 | 5 | Condensate | 15 | - | Not promising |
| 6 | 5195-5197 | 2 | Gas | 9 | 52.3 | Not promising |
| 7 | 5695-5696 | 1 | Gas | 5 | 57.0 | Not promising |
| 8 | 5967-5969 | 2 | Gas | 10 | 59.6 | Not promising |
| 9 | 6187-6195 | 8 | Condensate | 24 | - | Poorly promising |
| 9a | 6195-6198 | 3 | Water | -- | - | --- |
| 10 | 6225-6234 | 9 | Condensate | 35 | - | Promising |
| 10a | 6234-6242 | 8 | Water | - | - | -- |
| 11 | 6587-6595 | 8 | Condensate | 33 | - | Promising |
| 11a | 6595-6597 | 2 | Water | - | - | |
| 12 | 6659-6674 | 15 | Gas | 49 | 68.3 | Max Promising |
| 12a | 6674-6683 | 9 | Water | - | - | |
| 13 | 6763-6777 | 14 | Gas | 53 | 69.9 | Max Promising |
| 13a | 6777-6790 | 13 | Condensate | 45 | - | Max Promising |
| 13b | 6790-6701 | 11 | Water | - | - | - |
| 14 | 7019-7034 | 15 | Gas | 60 | 71.4 | Max Promising |
| 14a | 7034-7044 | 10 | Condensate | 55 | -- | Max Promising |
| 14b | 7044-7054 | 10 | Water | - | - | |
| 15 | 7260-7280 | 20 | Gas | 72 | 72.9 | Super Promising |
| 15a | 7280-7298 | 18 | Condensate | 60 | - | Super Promising |
| 15b | 7298-7311 | 13 | Water | -- | - | |

**Anomalous reservoir pressure** was considered a key criterion of prospectivity:
• when values exceeded hydrostatic pressure, the reservoir was regarded as potentially prospective;

• when values were equal to or lower than hydrostatic pressure, it was considered non-prospective.

The analysis showed that within the Umid field section, seven intervals (9, 10, 11, 12, 13, 14, and 15) are identified and interpreted as the most prospective gas- or gas-condensate-bearing reservoirs.

A graphical representation of the VERS results in the form of a virtual well column is shown in Figure 3. The analysis indicates that:
• two intervals (conventionally designated as layers 1 and 12) are located within the depths already reached by drilling;
• the three most prospective intervals (layers 13, 14, and 15 according to the adopted numbering) lie below the depths achieved by drilling to date.

This suggests that further deepening of drilling at the Umid field may lead to the discovery of new productive horizons and an increase in resource potential. A more detailed representation of these intervals is provided in Figure 4.

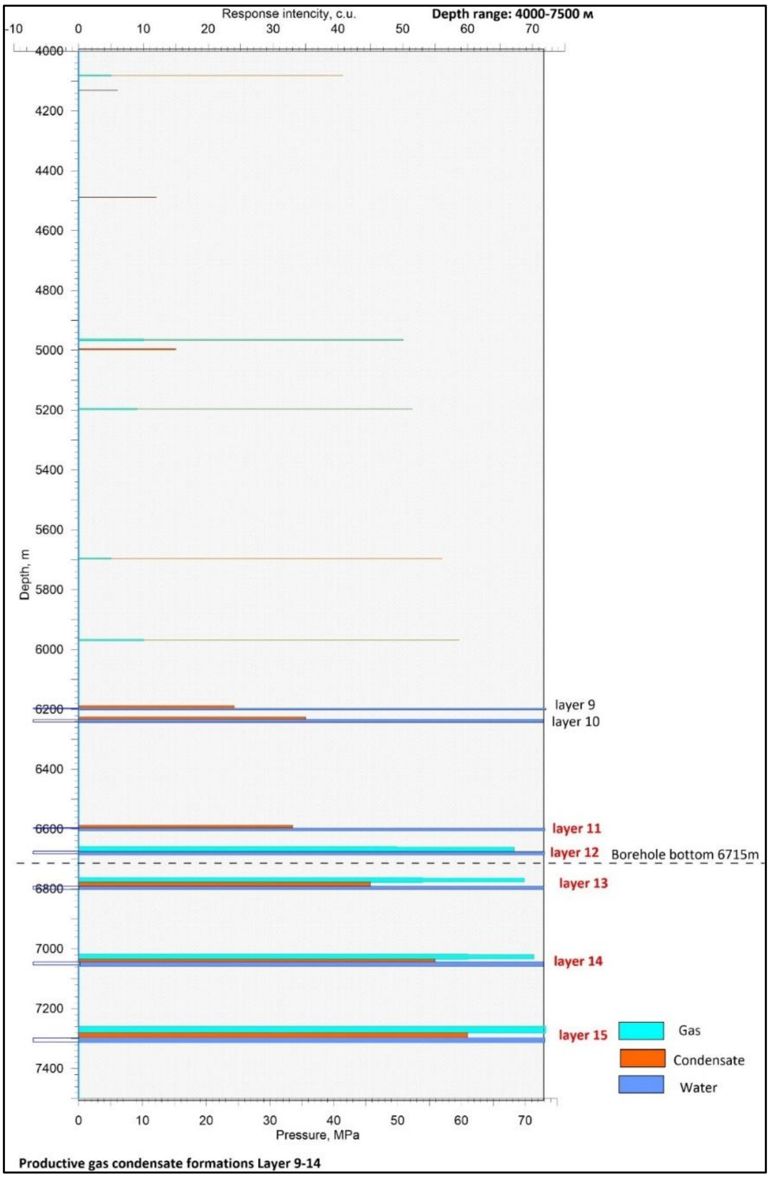


**Fig 3. Results of vertical frequency-resonance scanning in the area of the well Umid-4, Point V1, depth range 4000-7500 m.**

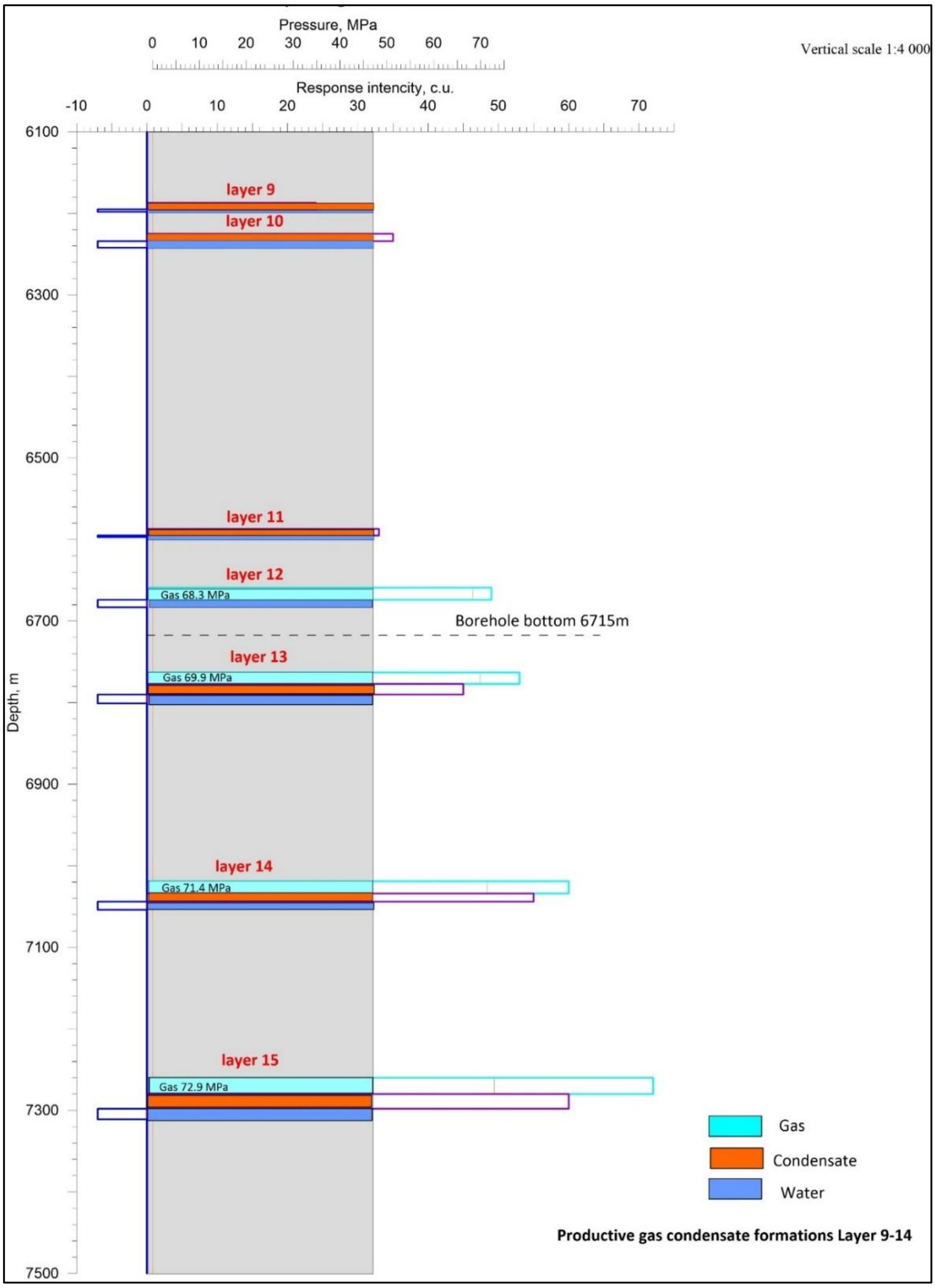


**Fig. 4. Results of vertical frequency resonance scanning in the area of the Umid gas condensate field, Point V1, Depth range 6100-7500 m. Vertical scale 1:4000**

**Vertical scanning of the Salatin structure**

For the Salatin structure, vertical electrical resonance scanning was carried out over the depth interval from 2,000 to 7,500 m. Similar to the results obtained for Umid, about 15 anomalously polarized intervals were identified; however, most of them, based on the combination of features, are interpreted as non-prospective or weakly prospective. Table 3.

**Table 3. Vertical electric-resonance scanning of the Salatin structure performed over the depth interval from 2000 to 7500 m.**

| № | Depth (m) | Thickness (m) | Gas, (Propane) Condensate (Transparent) Water | Response intensity (c.u.) | Pressure MPa | Note |
|---|---|---|---|---|---|---|
| 1 | 2167-2168 | 1 | Gas | 4 | | Not promising |
| 2 | 2581-2584 | 3 | Gas | 1 | | Not promising |
| 3 | 2709-2711 | 2 | Gas | 1 | | Not promising |
| 4 | 2918-2919 | 1 | Gas | 2 | | Not promising |
| 5 | 3038-3041 | 3 | Gas | 6 | 29.2 | Not promising |
| 6 | 3372-3376 | 4 | Condensate | 9 | | Not promising |
| 7 | 3517-3523 | 6 | Condensate | 9 | | Not promising |
| 8 | 3829-3832 | 3 | Condensate | 8 | | Not promising |
| 9 | 3971-3975 | 4 | Gas | 11 | 39.7 | Poorly promising |
| 9a | 3975-3978 | 3 | Condensate | 10 | - | Poorly promising |
| 9b | 3978-3981 | 3 | Water | | | |
| 10 | 4070-4074 | 4 | Gas | 63 | 42.9 | Promising |
| 10a | 4074-4078 | 4 | Condensate | 55 | - | Promising |
| 10b | 4078-4081 | 3 | Water | | | |
| 11 | 4457-4460 | 3 | Condensate | 16 | | |
| 12 | 4588-4593 | 5 | Condensate | 22 | | |
| 13 | 4689-4694 | 5 | Condensate | 30 | | |
| 14 | 5087-5089 | 2 | Condensate | 43 | | |
| 15 | 6217-6225 | 8 | Gas | 70 | 65.3 | Max Promising |
| 15a | 6225-6236 | 11 | Condensate | 75 | | Max Promising |
| 15b | 6236-6243 | 7 | Water | | | |

**The most promising interval** is interval 10, occurring at depths of 4,070–4,074 m, and is characterized by:

- elevated anomalous formation pressure;
- a strong resonance response;
- a thickness of approximately 4 m.

The next most promising are intervals 15 and 15A, located at depths of around 6,200 m. It should be noted that during scanning down to 7,500 m, no significant prospective intervals were identified below depths of 6,200–6,300 m.

The obtained results are recommended for use:

- in the interpretation of seismic data;
- for correlation with prospective stratigraphic units and reflecting horizons identified on seismic sections;
- in planning further geological exploration activities.

Based on the VERS data, it can be concluded that exploratory drilling on the Salatin structure deeper than 6,300 m appears to be impractical.

A graphical representation of the results of vertical scanning for the Salatin structure is presented in Figures 5, 6, and 7, where anomalous intervals are shown as a virtual well column.

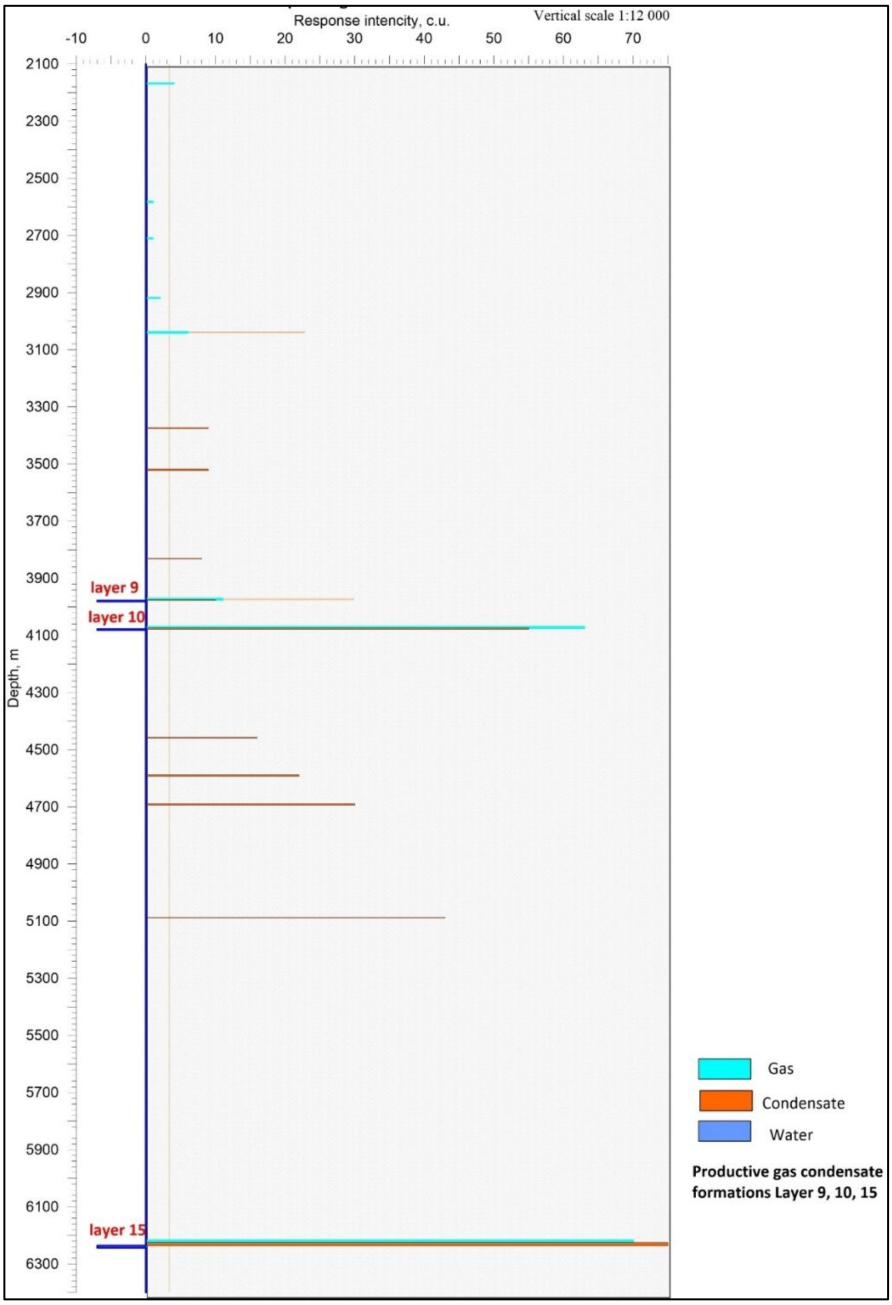


**Fig. 5. Results of vertical frequency resonance scanning in the area of the Salatin structure, Point V2, depth range 2100-6400 m, Vertical scale 1:12000**

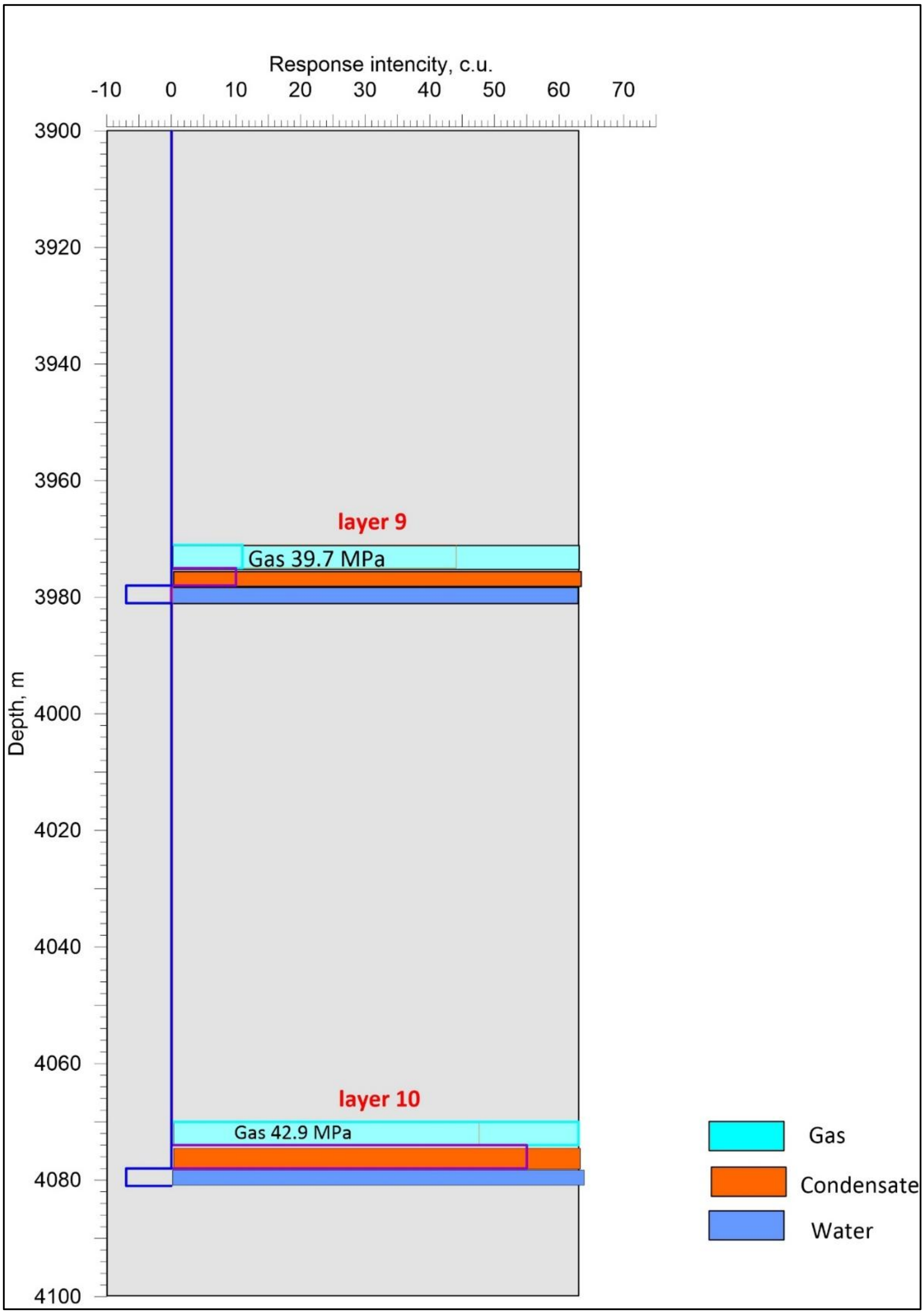


**Fig. 6. Results of vertical frequency resonance scanning in the area of the Salatin structure, Point V2, depth range 3900-4100 m**

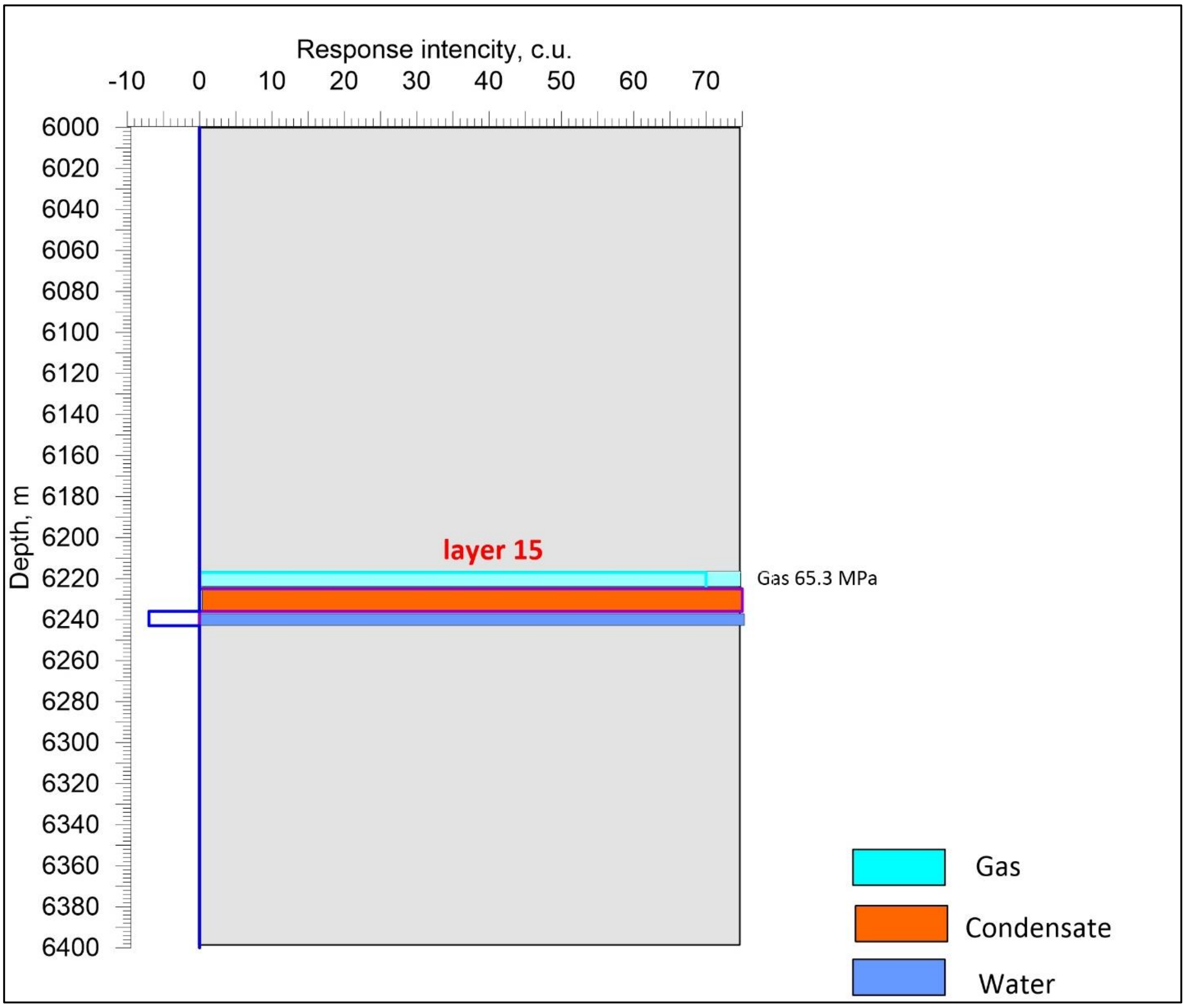


**Fig 7. Results of vertical frequency resonance scanning in the area of the Salatin structure, Point V2, depth range: 6000-6400 m, Vertical scale 1:3000**

## Conclusions and Recommendations

Based on the results of the work performed, the following main conclusions can be drawn.

1. The frequency–resonance processing of satellite images demonstrated that this method is an effective tool for regional assessment of hydrocarbon potential over large areas. Based on a comparative analysis of anomalous responses obtained for an already explored and confirmed structure (in this case, the Umid field), the method makes it possible to carry out a preliminary assessment of the potential of other structures located within the same map sheet.
2. Using the Umid field as a reference object made it possible to calibrate the technology and obtain comparable relative characteristics of anomalous zones for the Salatin and Alekperli structures. As a result of areal interpretation, sufficiently significant values of anomalous zone areas and response intensities were obtained for both structures, indicating their potential oil and gas potential.
3. At the same time, the results of vertical electrical resonance scanning performed for the Salatin structure and compared with similar data for the Umid field showed that:

    - in terms of depth characteristics and the degree of expression of anomalously polarized layers, the Salatin structure is inferior to the reference Umid field;
    - nevertheless, the Salatin structure retains a positive anomalous characteristic, and intervals interpreted as potentially gas-bearing or gas-condensate-bearing are identified in its geological section.

   Thus, the Salatin structure should be considered a promising object for further study, including exploratory drilling aimed at confirming the obtained results, as well as for integrated interpretation of seismic exploration data taking into account frequency–resonance analysis materials.

4. The limitations associated with the use of the regional scale of 1:250,000 primarily relate to:
    - the accuracy of delineating the boundaries of anomalous zones;
    - the accuracy of depth correlation of anomalously polarized intervals;
    - the averaged nature of interpretation due to the large area covered by a single analysis point.

   In this regard, the current stage should be regarded as preliminary (screening).

## Recommendations for Further Work

To increase the reliability and level of detail of the obtained results, the following set of further studies is proposed:

1. Perform detailed frequency–resonance processing of satellite images separately for each prospective structure:
    - Salatin structure;
    - Alekperli structure;
    - if there is interest, other anomalous zones identified within the map sheet, including the zone coinciding with the area of the Nakhchivan well drilling.
2. Increase the scale of studies to 1:50,000 and larger, which will make it possible to:
    - refine the boundaries of anomalous zones;
    - improve the accuracy of spatial and depth interpretation;
    - reduce positioning errors of anomalies.
3. At each prospective object, carry out series of vertical electrical resonance scanning points located:
    - along the strike of the structure;
    - across the strike of the structure.

   This will allow the construction of geoelectrical profiles of anomalously polarized layers, comparable in informativeness to structural models obtained from seismic data interpretation.

4. The use of vertical scanning data, especially at the periphery of anomalous zones, may allow:
    - evaluation of trap geometry;
    - preliminary estimation of the volume of traps potentially containing gas and gas condensate;
    - if prior information on reservoir petrophysical properties is available, estimation of resources.

5. It should be noted that at the current stage of work, vertical scanning of the Alekperli structure was not carried out. However, given its similarity to the Salatin structure based on areal interpretation results, conducting similar depth investigations for Alekperli appears justified and is recommended at the next stage of work.