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DEEP GEOLOGICAL MODELS OF THE ULTRA-DEEP WELL AREA SAATLY DW-1 BASED ON COMPLEX GEOPHYSICAL DATA

The purpose of the article is to study the reasons for the failure to achieve the scientific and geological goals set for the ultra-deep well DW-1, drilled in the Saatli region of Azerbaijan. The analysis will focus on the existing deep models built for this region, which are deemed insufficient in reflecting the truth. The paper highlights the importance of adopting a new approach to the recently created deep model and its potential benefits to the scientific community. Methodology. The technique includes a detailed comprehensive analysis of the gravitational and magnetic fields in this region, the use of local magnetic anomalies to build a model of the deep geological structure utilizing data from deep seismic sounding (DSS) and the correlation method of refracted waves (CMRW). Results. The spatial position of effusive formations in the geological section was determined using the local anomaly of the geomagnetic field in the Saatly region. At the same time, the geometric dimensions of the volcanic body were chosen in such a way that the magnetic field created by it corresponded to the observed local magnetic field. Thus, a model of the geological section up to a depth of 15 km was developed, with the display of the spatial position of the volcanic formation. In this model, unlike the previous one, the spatial position of the volcanic formation in the vertical geological section is completely different. In the newly constructed model, it turns out that there is a separate volcanic formation in the area of the Saatly DW-1. And in the previous models, it was shown that the magma came here from the Muradhanly zone, located at a distance of 25-30 km. The boundaries of the crystalline foundation and the basalt layer in the area of the DW-1 in the zone of the volcanic body are not traced. The root of the volcano narrows and goes deep into the earth. At a depth of about 15 km, the magma-producing channel has a width of 1 km. Based on the established model, it was determined that the ultra-deep well DW-1 is located on the magma-producing channel of the volcano that existed here. From the analysis of the obtained model data, it turns out that the extension of the Saatly DW-1 to depth will not allow opening the consolidated crust (crystalline foundation) and basalt layer. Because, although these layers are closer to the earth's surface in the area of the DW-1, the active volcano here has destroyed these boundaries. Orginality. Seismic survey materials were used to study the deep structures of the region, gravimagnetic data on profiles with an observation step of 250 m, and a technique was applied to construct the spatial positions of effusive formations in the geological section. Scientific novelty. It has been established that the geomagnetic field of this region is formed from three main effects - the effect of the sedimentary complex, the effect of the thickness between the basement and Curie surfaces, and the effect of local manifestations of magmatism. The sum of the first two effects quite accurately corresponds to the regional background of the observed geomagnetic field. Local positive anomalies isolated from the observed field are associated with local heterogeneities - in this region with volcanogenic formations in the sedimentary complex. Practical significance. A new geological-geophysical model was created by determining the spatial position of effusive formations in the geological section near the Saatly DW-1 well using the local anomaly of the geomagnetic field. This model has real possibilities in the direction of installation of ultra-deep wells for the study of deep layers of the earth's crust.

Key words: crystalline foundation, Saatly ultra-deep well, geological-geophysical model, gravimagnetic data.

Introduction

In 1960, the International Geophysical and Geodetic Union (IGGU) recognized the importance of drilling ultra-deep wells during its General Assembly meeting in Helsinki. These wells hold significant scientific and practical value. They allow us to study deep Earth processes, predict the location of mineral and energy resources, and understand the conditions that create strong earthquake zones.

Following this recognition, ultra-deep well drilling became a global priority by 1970. Several countries initiated projects, including Russia (Kola Peninsula, 1970), the United States (Oklahoma, 1970-1974), East Germany (1970), Austria (1977), and West Germany (1978). Notably, the Kola Peninsula well reached a record depth of 12,345 meters, while wells in Oklahoma and West Germany reached depths of 9,583 meters and 9,101 meters, respectively.

Within the former Soviet Union, drilling ultra-deep wells was considered crucial for studying the deep geological structure across various regions, including Russia, Ukraine, Azerbaijan, Kazakhstan, and Uzbekistan.

Azerbaijan joined this effort by initiating the drilling of ultra-deep well DW-1 in the Saatly district in June 1977. The well's location was chosen based on data analysis from deep seismic sounding (DSS) and the correlation method of refracted waves (CMRW). These methods indicated a shallower depth for the Mesozoic bedrock in this specific area. (Fig. 1).

Tectonic Setting and Well Objectives

The Saatly DW-1 well is located in the intermontane Kura Depression, a region identified by gravity data in the 1930s as the center of the Talysh-Vandam gravity maximum zone. Specifically, the well sits on the southern pericline (outer flank) of the Saatly uplift. This well plays a critical role in understanding the structure, composition, and geological history of the Kura Basin's crust.

To achieve these goals, a comprehensive suite of geological, geochemical, petrographic, mineralogical, hydrogeological, seismic, geophysical (nuclear, magnetic, electrical), and other measurements were conducted at the well.

The data obtained from the Saatly DW-1 well was intended to address several regional and fundamental geological questions:

- Unveiling the composition of the upper Earth's crust (sedimentary layers, volcanic rocks, and crystalline basement) within the Kura Depression.
- Determining the age and rock types forming distinct stratigraphic boundaries.
- Investigating the nature of deep-seated geological processes.
- Elucidating the origin of the mass responsible for the Talysh-Vandam gravity maximum.
- Understanding the geological basis of geophysical boundaries

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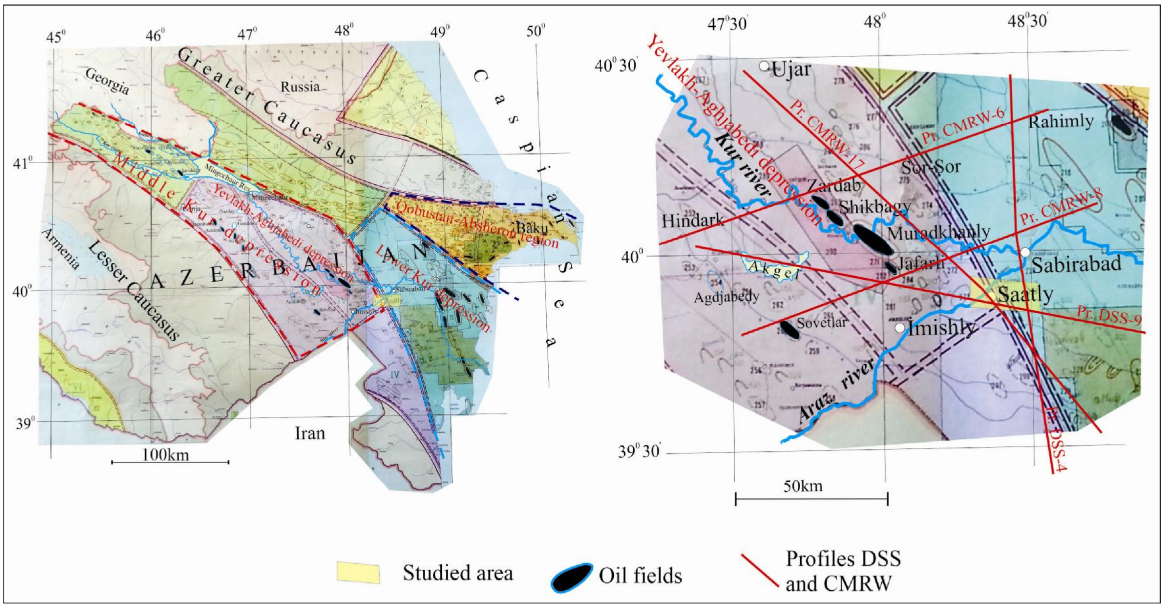

Fig. 1. Map of the study region

Results and Remaining Challenges

Drilling of the Saatly DW-1 well was completed in 1982, reaching a final depth of 8,324 meters. This endeavor yielded a wealth of material that facilitated significant scientific advancements. Notably, it provided the first opportunity to examine rocks from the Alpine folded zone at a depth exceeding 8 kilometers. Geological, petrographic, and geophysical analyses were performed to compare these rocks with those found at shallower depths.

Furthermore, the well provided new insights into the composition and structure of the deeply buried Mesozoic volcanic layer. This information proved valuable for assessing the potential role of undiscovered reservoirs within volcanic formations [Salahov, 1987].

Despite these successes, some key questions remained unanswered. For instance, the geological nature of the masses responsible for the Talysh-Vandam gravity maximum remained unclear. Additionally, the well depth was insufficient to conclusively reveal the pre-Mesozoic basement using the available seismic data.

Purpose

As part of a global initiative to study Earth's deep crust, Azerbaijan drilled the ultra-deep Saatly DW-1 well in the Saatly district. The primary goal was to investigate the upper portion of the Earth's crust, including the crystalline basement, within the Kura Basin. This exploration aimed to address several regional, fundamental, and general geological questions. However, some of the scientific and geological objectives proved elusive. For this reason, analyzing existing depth models of the area and constructing a new one becomes crucial.

Methodology

The technique includes a detailed comprehensive analysis of the gravitational and magnetic fields in this region. It uses local magnetic anomalies to build a model of the deep geological structure by utilizing data from deep seismic sounding (DSS) and the correlation method of refracted waves (CMRW).

The first gravimetric exploration work in this area was carried out by V. V. Fedinsky and L. V. Sorokin using a pendulum gravimeter in 1929-1931. As a result, a high-intensity gravitational maximum was discovered from the foothills of the Talysh Mountains to Vandam in the Greater Caucasus. Subsequent studies showed that the Talysh-Vandam maximum does not consist of one part.

In 1948, "Keshfiyatgeofizika" conducted works on general gravimagnetic planning in the central part of the Kura basin. As a result, the Talish-Vandam gravity maximum was geologically interpreted [Tsimelzon, 1965]. In the central part of this gravitational maximum, there is a separate zone of the Kurdamir-Saatly gravity anomaly. At the southern end of this zone, the local Saatly maximum is distinguished. The intensity of this gravitational maximum covering the Saatly-Sabirabad region is 40 mGal [Gadirov, 2003; Saatly superdeep..., 2000]. To the east of the Kurdamir-Saatly maximum zone, the gravity gradient reaches 4 mGal/km. A step with a relatively small gradient is also found in the west of this zone.

In the 60s and 70s of the 20th century, gravimetric and magnetometric works were carried out on seismic profiles conducted in the depression zones of Azerbaijan, as well as on the zone of the Saatly uplift, investigated by the methods of SMRW and DSS. These data were also used when creating a geological model of the Saatly area. In the following years (early 1980s), gravimetric and magnetometric observations were again carried out on the profiles of DSS 9 and CMRW 16 ("Keshfiyatgeofizika"). The error of gravimetric work performed with a step of 100 m was ±0.1 mGal, and the height determination error was ±0.32 m.

Magnetometric observations in the area of Saatly DW-1 well were carried out mainly together with gravimetric observations. The analysis of the magnetic field in the zone of Talish-Vandam maximum was conducted based on the analysis of the maps of the magnetic field ΔZ, prepared by “Azergeofizika” SRI on a scale of 1:200 000 and "Keshfiyatgeofizika" on a scale of 1:50 000. The interpretation of the magnetic anomaly of Zardab, located to the northwest of the Saatly area, showed that this anomaly is connected with magmatic masses with a magnetization of 2,000 mA/m. It was determined that the Curie border in this zone is located at a depth of 32 km [Metaxas, 1978]. The border represents the level at which magnetization disappears. .

On the Saatly area, the geomagnetic model was created based on the submeridional profile SMRW 16 and the profile DSS 9 in the east-west direction, intersecting well DW-1. Based on this, it was shown that volcanogenic magnetoactive masses belong to the Mesozoic complex.

At the beginning of the 80s of the 20th century, new magnetometric measurements were conducted by a group created at “Azergeofizika” SRI. In 1981-1983, more than 200 km of profiles with a step of 50 m were developed. The work was carried out using a quantum magnetometer M-33 with an accuracy of 1 nT. In parallel with these works, changes in the magnetic field were recorded at control points (CP) created in the villages of Mollakend, Chertayaz, and in the center of the Saatly district. The module T of the total component of the geomagnetic field at the control points was 48,640, 48,710, and 48,690 nT, respectively. 61 support points are created on processed profiles every 2-3 km.

In 1983-1984, using M-33 quantum and M-27M optical-mechanical magnetometers, planning works were carried out on the profiles cutting the Saatly area in two directions (NW-SE and SW-NE) in the volume of 150 km.

Seismic exploration work in the area of the well DW-1 was conducted both by regional DSS and CMRW, as well as by detailed RWM (Reflected Wave Method) and CDP (method common depth points). The main goal of regional seismic research was to study the surface and internal structure of the consolidated earth's crust. The DW-1 area is crossed by 6 regional seismic profiles in different directions, the development of which began in 1957.

Various types of seismic waves (reflected, refracted, diffracted) were used in the materials of the DSS and CMRW profiles. Using refracted waves, refractive boundaries were identified within the sedimentary complex and the consolidated earth's crust. Among them, we can indicate d_1^{sed} – corresponding to the surface of the Cretaceous deposits, d_2^{sed} – considered to correspond to the surface of the Jurassic complex, d^f – corresponding to the crystalline foundation, d^b – corresponding to the surface of the “basalt” layer, and d^M – the surface of Mohorovichich. Each of these boundaries is characterized by its boundary velocities [Rajabov, 1976].

There was an assumption that a thick (about 5 km) sequence of Jurassic-Lower Cretaceous volcanogenic formations was present in the Kura intermountain depression section, similar to the Mesozoic formations found in the Lesser Caucasus. [Salekhli et al., 1976]. There were other conclusions about the local distribution of volcanic rocks in the Middle Kura Depression. The evidence can be presented in two ways. Firstly, by obtaining well-traced seismic boundaries down to the basement, which demonstrates that the main bed of the sedimentary complex is the basement and not the volcanogenic rocks of the Mesozoic. Secondly, by analyzing the geomagnetic field in the region [Gadirov, 1991, 2002; Gadirov et al. 2016].

To analyze the geomagnetic field of the Middle Kura Depression, which includes the study area, we used regional profile CMRW-6, running in the SW-NE direction. It has been established that the geomagnetic field of this area is formed from three main effects - the effect of the sedimentary complex, the effect of the thickness between the basement and Curie surfaces, and the effect of local manifestations of magmatism (Fig. 2).

This result was obtained after calculating the geomagnetic effects caused by individual geological layers [Gadirov, 1991]. It is established that the sum of geomagnetic effects (curve 6) of the sedimentary layer and masses below the crystalline base (up to the Curie surface) (curves 4 and 5) fully correspond to the regional background of the magnetic field (curve 2). Then the question arises, what elements of the geological section are connected to the local components of the geomagnetic field (3)? Local magnetic anomalies on the specified profile are observed in the well-known areas of Hindark, Zardab, Sor-Sor, Rahimly (southern part), where the presence of volcanic rocks has been established by deep wells. It can be considered that local magnetic anomalies (3) are associated with the presence of local volcanic masses with high magnetic susceptibility in the section.

In the zones of local anomalies of the geomagnetic field, observed on the regional profile of CMRW-6, the spatial position of masses (11) (volcanic formations) that created these anomalies was determined with the help of D. K. Mikov's palette (see Fig. 2).

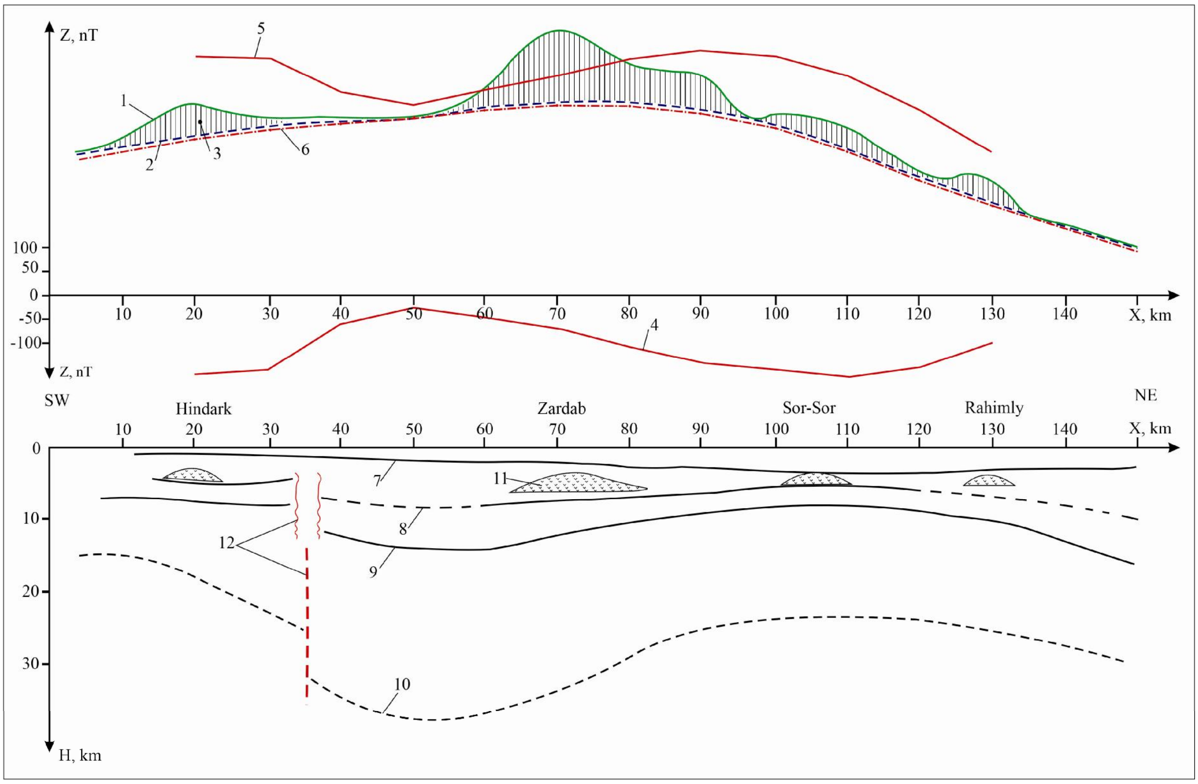

Fig. 2. Results of interpretation of the geomagnetic field (Z) along the CMRW-6 profile

1 – observed geomagnetic field Z; 2 – regional background; 3 – local magnetic maximum; 4 – calculated geomagnetic effect of the sedimentary complex; 5 – calculated geomagnetic effect of the strata below the crystalline basement; 6 – total geomagnetic effect of the sedimentary complex and crystalline basement; 7 and 8 – refractive boundaries within the sedimentary cover d_1^{sed} and d_2^{sed}; 9 – surface of the crystalline basement; 10 – Curie boundary; 11 – volcanogenic formations; 12 – deep fault identified from the materials of the DSS and C.

Thus, it became clear that the regional changes in the geomagnetic field observed within the Yevlakh-Agjabedi depression are formed by magnetic effects created by the sedimentary complex and masses from the crystalline base to the Curie surface. The observed local magnetic anomalies are associated with volcanogenic formations that arose in limited (local) areas of the section [Gadirov, 1991, 2002; Gadirov et al. 2016].

Results

In-depth analysis of gravity, magnetic, and seismic data, particularly from the Saatly DW-1 well and the DSS-9 profile, played a crucial role in refining the Earth's crust model for the Saatly region.

The initial model, built using seismic and gravity data, revealed inconsistencies. To address this, researchers transformed the model by correlating seismic wave velocities with rock densities [Rajabov, 1979; Hajiyev et al., 1984]. This approach yielded a layered-block model that incorporated both density variations and boundary velocities within the Earth's crust (Fig. 3).

The calculated gravitational field based on this new model closely matched the observed field, suggesting a good representation of the subsurface structure. The model suggests a high-density block underlying the area of the Saatly DW-1 well, coinciding with the zone of maximum gravity. This block, with a high boundary velocity (Vb = 6.7 km/sec), is interpreted as the crystalline basement and is estimated to reach a depth of around 8,000 meters according to the well data.

Below the crystalline basement, the model depicts another block with a sharp rise, attributed to the basaltic layer. This layer is further divided into three sections with distinct boundary velocities within the model.

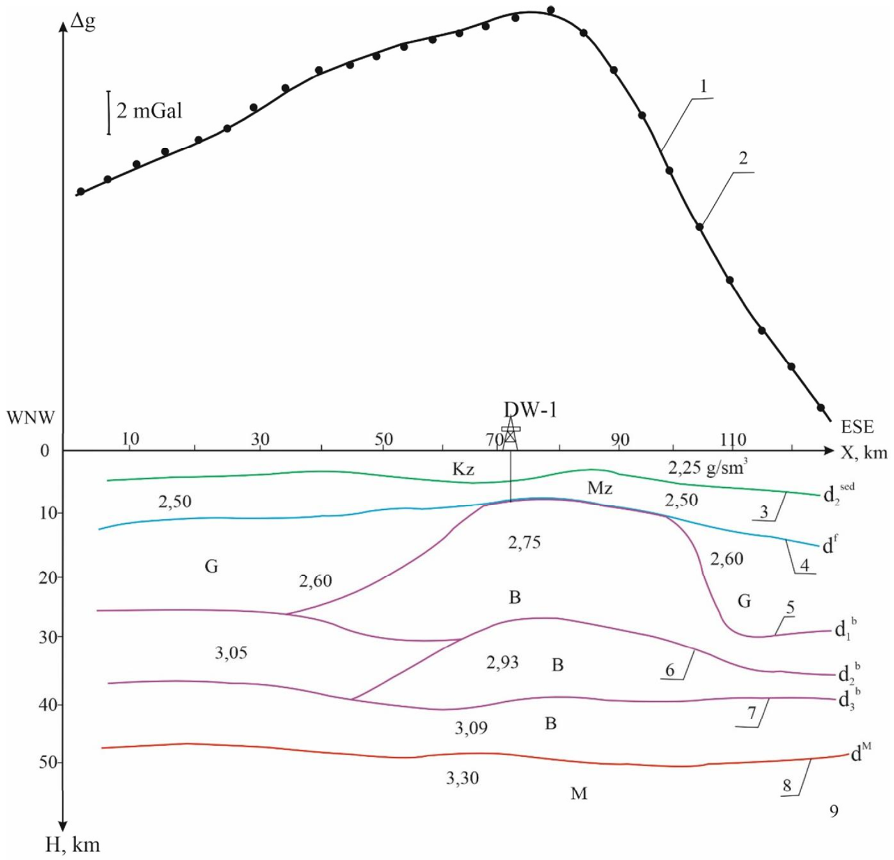

Fig. 3. Model of the Earth's crust in the area of the well Saatly DW-1 (by profile DSS-9) [Rajabov, 1979; Hajiyev et al., 1984]

1 – the observed gravity field; 2 – calculated values of gravity according to the model; 3, 4, 5 – boundaries of Mesozoic sediments, granite layer (G) and basalt layer (B), respectively; 6, 7 – boundaries in the basalt layer; 8 – boundary Mohorovichich (M).

The model proposes a basaltic layer below the crystalline basement with a sharp increase in depth. This layer is further subdivided into three sections with varying boundary velocities. The upper and middle sections are likely composed of basic basalts, while the lower section consists of denser basalt-eclogite rocks.

The Mohorovičić discontinuity, the boundary between the Earth's crust and mantle, is estimated to be at a depth of approximately 50 kilometers. The thickness of the basaltic layer varies across the profile, reaching about 40 kilometers near the Saatly DW-1 well and thinning to nearly zero in the direction of this well.

The model suggests that the high-density masses within the basaltic layer are the primary contributors to the gravitational field anomaly observed in the Saatly DW-1 well area. The upper part of the basaltic layer is thought to be composed of Upper Archean to Lower Proterozoic rocks. The middle section, conversely, is inferred to be composed of highly metamorphosed and heterogeneous rocks from the Lower Archean era [Hajiyev et al., 1984].

The layer forming the lowest part of the basalt layer corresponds to the Mohorovicic boundary and separates the upper mantle and the earth's crust from each other (see Fig. 2). This layer was first identified by M.M.Radjabov in the Caucasus and is considered one of the most important elements of the structure of the lithosphere [Rajabov, 1979].

As can be seen from Fig. 2, the surface of the granite layer (crystalline basement) in some places coincides with the boundary of the basalt layer. It is believed that the granite layer is covered with volcanic (effusive) rocks of great thickness, basic and intermediate composition.

The Saatly DW-1 well, as well as deep wells in the neighboring areas of Sorsor, Jarly, Muradkhanly, and Zardab, display widespread occurrence of effusive rocks with high magnetic properties. To determine the spatial form of the magnetically active masses involved in the formation of the observed magnetic field in this region, as well as to show the deep structure of the Saatly DW-1 well area, a new model was developed in 1984 (Fig. 4).

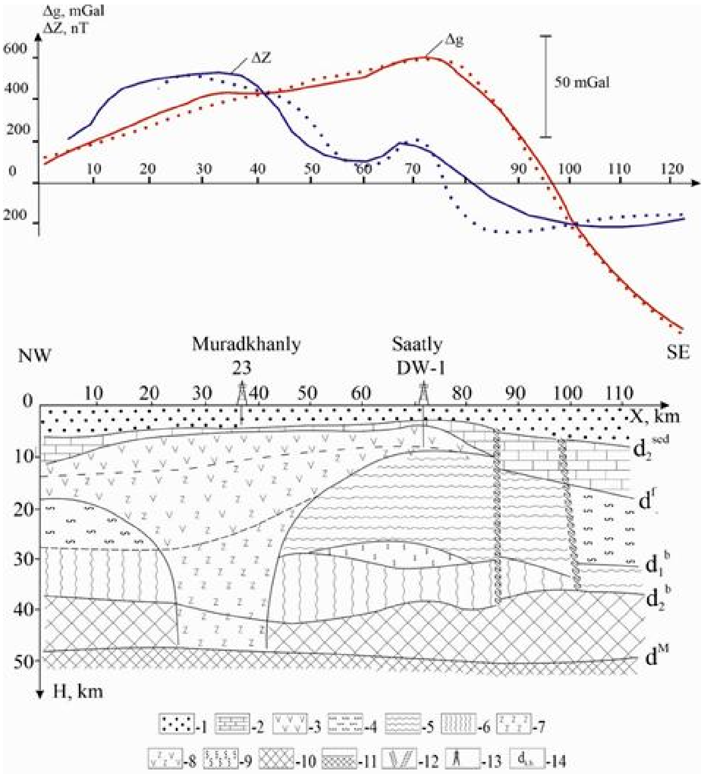

Fig. 4. Deep geological section of the area of the wells Saatly DW-1 [Hajiyev et al., 1984]

1 – Cenozoic sediments; 2 – Mesozoic sedimentary complex; 3 – Mesozoic effusive formations; 4 – metamorphic rocks (Baikal age); 5 – gneisses and marbles (before the Baikal complex); 6 – ancient gneiss-amphibolite complex; 7 – intrusive formations; 8 – effusive-intrusive complex; 9 – complex of rocks of rare density; 10 – transition complex from crust to mantle; 11 – upper mantle complex; 12 – large fault zones; 13 – deep wells; 14 – boundaries of velocities and densities and their indices: d_2^{sed}, d^f, d_1^b, d_2^b and d^M, respectively, of the Mesozoic complex, crystalline foundation, basalt layer, and upper mantle (Mohorovich boundary).

The correspondence of the calculated gravitational and geomagnetic fields of the constructed model to the observed fields gave the authors grounds to talk about the correctness of the construction of this model [Hajiyev et al., 1984]. It should be noted that already in 1982 the well was drilled to a depth of 8.324 m and its lithological and stratigraphic affiliation was known.

Based on their analysis, the authors predicted that the DW-1 well would uncover volcanic rocks up to a depth of 9 km. Beyond that, it would reveal the Talysh-Vandam gravitational maximum, which is made up of highly metamorphosed basement rocks from the Upper Archean to the Lower Proterozoic era.

From the constructed model it is clear that the volcanic rocks discovered by the DW-1 well entered this region as a result of the flow of erupted material from a central-type volcano active in the Mesozoic era in the

Muradkhanly-Zardab area. These rocks covered the crystalline basement with a thick (≈ 6 km) effusive layer. The central type volcano, described in the Muradkhanly region, stands out for its enormous size.

Thus, at a depth of 18 km, the width of the volcano is 36 km and the thickness is ≈15 km. At a depth of 30–40 km, the width of the volcano's root reaches 20 km. Thick (5–6 km) Jurassic-Cretaceous volcanic formations are widespread in the Muradkhanly-Zardab zone and adjacent areas due to the formation of the Lesser Caucasus, including the entire Yevlakh-Agjabedi depression.And, the boundaries within the sedimentary complex and the crystalline basement, marked by the DSS and CMRW, are associated with changes in the conditions for the development of magmatism within the magmatic layer [Hajiyev et al., 1984; Alekseev et al., 1988].

However, the volcano of the central type, described in the Muradkhanly-Zardab region, is surprising and unconvincing in its enormity (the width of the magma channel is 20-36 km). On the other hand, the emergence of this volcano in the Mesozoic period and the presence of marine conditions in this region at that time would not have allowed magma to flow over a distance of 35-40 km (from Muradkhanly to Saatly). The refractive boundaries marked by DSS and CMRW, within a magmatic layer with a thickness of 6 km, are also not justified from a geological point of view.

Recognizing the limitations of the 1984 model (Fig. 4), a new geological-geophysical model for the Saatly DW-1 well area was developed utilizing gravitomagnetic data (Fig. 5) [Gadirov, 1991, 2024; Gadirov et al., 2016]. This revised model incorporates data from a gravity and geomagnetic anomaly map acquired by "Keshfiyatgeofizika" and focuses on the prominent gravity and magnetic field anomalies observed in the vicinity of the Saatly DW-1 well.

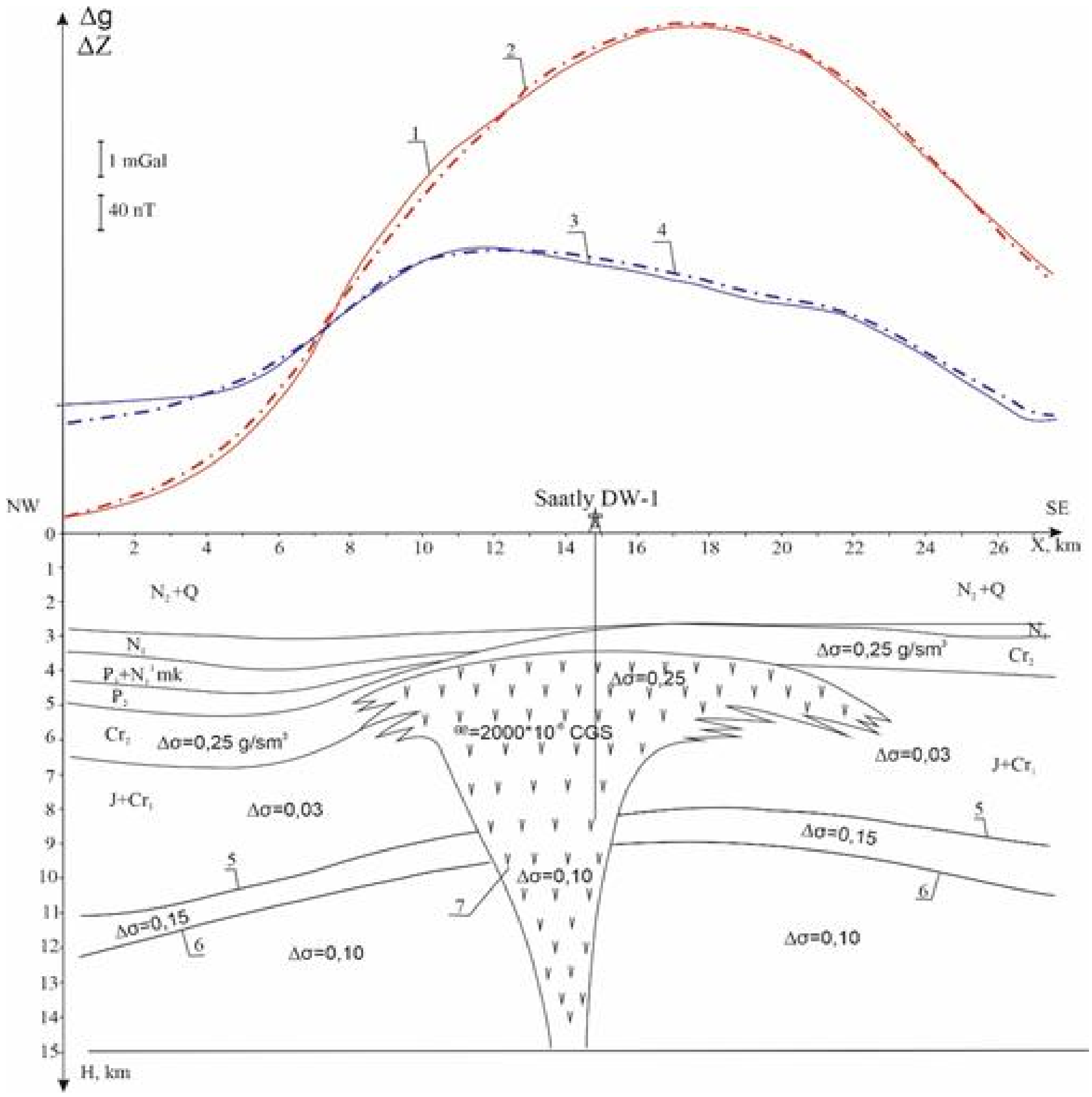

Fig. 5. Latest model of the Saatly DW-1 well area (according to V.G. Gadirov):

1 and 2 – gravity values observed and calculated by the model; 3 and 4 – geomagnetic field values observed and calculated by the model; 5 – surface of the crystalline basement; 6 – surface of the basalt layer; 7 – volcanic body.

To improve the accuracy of the new model, a correlation was established between gravity measurements and the depths of key geological horizons determined using geophysical methods or reliable well data [Gadirov, 1991, 2010, 2024; Gadirov et al., 2016]. This correlation allowed for iterative refinement of the model by adjusting the depths of the crystalline basement and basalt layer until the calculated gravitational field closely matched the observed field.

Since the gravity field extended to a height of 5 km (Δg5) better reflects the surface of the Mesozoic complex of this region, a mathematical relationship was established between these values by the method of regression analysis (Gadirov, 1991).

For this, a structural map built on the surface of Mesozoic sediments based on seismic materials was used [Hajizade, 2003]. It should be noted that due to the sparseness of the isolines on this map of the studied territory, a working formula was established that allows the calculation of the depth of the Mesozoic sediments in the following form.

$$H_{Mz} = 130.8 \cdot \Delta q^2 - 836.8 \cdot \Delta q + 4228.5$$

Using this formula, according to the gravitational field data, it is revealed that the most elevated part of the Mesozoic sediments (2900 m) covers the area of the Saatly DW-1 well. And, the calculation of the depth of the crystalline foundation is described in detail in the source [Gadirov et al., 2016].

It is assumed that the exciting source of the gravitational field in the area of the DW-1 well is the rise of a high-density basalt layer [Hajiyev et al., 1984]. Therefore, it would be advisable to establish a correlation between the depth of the surface of the basalt layer, determined by seismic exploration, and the gravitational field. For this purpose, in the area of the DW-1 well on the profile DSS-9, data on the depth of the basalt layer and the gravity values at these points were used. Then a regression relationship was established between H_{bas} and Δg in the form of a quadratic equation (Gadirov, 1991).

$$H_{baz} = -0.0519 \cdot \Delta q^2 + 1.689 \cdot \Delta q + 24.647$$

Using this formula, the depth of the basalt layer along the profile was calculated based on the observed gravity values. According to gravimetric data, this depth in the DW-1 area is about 9 km.

Unlike previous models that disregarded localized magnetic field variations, the new model incorporates these anomalies to map the spatial distribution of volcanic formations within the region. Using real materials, it was proven that volcanogenic formations in the Middle Kura basin are distributed locally with certain patterns [Gadirov, 1991, 2002]. This approach is supported by findings from DSS and CMRW studies, which demonstrate a localized distribution of volcanic formations in the Middle Kura basin, further confirmed by the presence of well-defined seismic boundaries extending down to the crystalline basement. This new understanding contradicts the notion of a continuous layer of igneous rocks throughout the basin.

The new model leverages the localized geomagnetic field anomaly observed in the Saatly region to determine the spatial distribution of volcanic rock formations within the geological section. The model incorporates realistic dimensions for these volcanic formations and assigns them an average magnetic susceptibility based on laboratory data. This iterative process resulted in a refined model of the upper 15 kilometers of the Earth's crust, accurately reflecting the placement of volcanic rocks (Fig. 5).

The calculated gravitational and geomagnetic fields generated by this new model closely match the observed field measurements. This agreement between modeled and observed values validates the overall accuracy of the refined model.

The new model presents a significantly different interpretation of the volcanic formations compared to the previous models (Fig. 2, 3) [Rajabov, et al., 1979; Hajiyev et al., 1984]. Unlike the previous suggestion of a continuous volcanic layer originating from the Muradkhanly zone, the new model proposes a distinct volcanic body located directly in the Saatly DW-1 well area. This scenario eliminates the need for unrealistic magma flow over long distances.

The new model depicts the surface of the Mesozoic complex along with the boundaries of the crystalline basement and basaltic layer. However, these boundaries are obscured within the zone of the volcanic body. The volcanic body itself extends for over 15 kilometers along the profile, with a narrowing root reaching depths of about 15 kilometers. The model suggests a wide magma channel (1 kilometer) at this depth. The thickness of the volcanic formation is substantial near the Saatly DW-1 well but thins to 1.5-2 kilometers just 4 kilometers southeast of the well.

Significantly, the new model positions the Saatly DW-1 well very close to the volcanic channel. While the well may deviate from the channel by up to 500 meters at a depth of 15 kilometers, considering model accuracy limitations, the well is likely to remain within volcanic rocks even at this depth. The model suggests that drilling the well 4-5 kilometers southeast of its current location would have had a higher chance of encountering the crystalline basement and deeper geological layers.

Analysis of the refined model (Fig. 5) suggests that further drilling of the Saatly DW-1 well is unlikely to reach the crystalline basement and basaltic layer due to the presence of the volcanic body. This volcanic body appears to have obscured the boundaries of these deeper structures in the vicinity of the well.

The new model highlights the importance of considering volcanic formations when interpreting the geological structure of the Middle Kura basin. Understanding these formations' distribution and spatial location becomes crucial for planning future exploration efforts. This knowledge can be valuable for both shallow wells targeting oil and gas reserves and ultra-deep wells aiming to study the Earth's deeper crustal layers.

Originality

The originality of these techniques is following:

- Seismic techniques (DSS and CMRW): These are well-established seismic methods used for decades to study Earth's crustal structure. While not entirely novel, their application in this specific region contributes to a more comprehensive understanding of the local geology.
- Ground-based gravity-magnetic data: Gravity and magnetic field measurements are standard geophysical techniques used to map subsurface features. The detail mentioned (observation step of 250 meters) suggests a high-resolution survey, which can be valuable for creating detailed models.
- Local magnetic field anomaly for volcanic formations: While the concept of using magnetic anomalies to detect volcanic rocks is not new, applying this technique specifically to identify the spatial distribution of volcanic formations in the Saatly region can be considered regionally innovative. This approach could be particularly useful for further studies in the Middle Kura basin.

Overall, the originality lies not in groundbreaking geophysical techniques, but rather in how these techniques are combined and applied to create a refined geological model for the Saatly DW-1 well area. This integration of various geophysical data sources with considerations for regional geological context contributes valuable insights.

Practical significance

The practical significance of the research lies in two key aspects:

1. Improved Targeting for Deep Wells: The new model provides a more accurate understanding of the subsurface structure, particularly the location and extent of volcanic formations, in the vicinity of the Saatly DW-1 well. This information is crucial for planning future deep well placements. By avoiding volcanic rock and targeting areas with a higher chance of encountering the crystalline basement and deeper crustal layers, geologists can improve the efficiency and success rate of ultra-deep well drilling for scientific studies.

2. Refined Geological Model: The research demonstrates the value of integrating various geophysical techniques (seismic, gravity, magnetic) and considering the local geological context. This approach led to a more refined geological model for the Saatly region. This model can serve as a valuable template for future geological studies in the Middle Kura basin and potentially other basins with similar geological features.

Conclusions

Here is a concise conclusion summarizing the key findings of the research.

This study combined gravity, magnetic, and seismic data, along with well information from the Saatly DW-1 well, to create a refined geological model for the Middle Kura basin in Azerbaijan. The new model revealed a previously unidentified volcanic body near the Saatly DW-1 well, significantly altering the interpretation of the deep structure compared to prior models. Due to the presence of this volcanic body, further drilling of the Saatly DW-1 well is unlikely to reach the crystalline basement and deeper crustal layers. The study suggests that drilling a well 4-5 kilometers southeast of the current Saatly DW-1 location would have had a higher probability of encountering these deeper geological targets.

This conclusion highlights the key points:

- •A new geological model incorporating various geophysical data provides a more accurate picture of the subsurface structure.
- •The model identified a volcanic body near the Saatly DW-1 well.
- •Further drilling of the existing well is unlikely to reach deeper targets.
- •A different well location might have yielded more success.

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ГЛИБИННІ ГЕОЛОГІЧНІ МОДЕЛІ РАЙОНУ НАДГЛИБОКОЇ СВЕРДЛОВИНИ SAATLY DW-1 НА ОСНОВІ КОМПЛЕКСУ ГЕОФІЗИЧНИХ ДАНИХ

Метою статті є дослідження причин недосягнення науково-геологічних цілей, поставлених для надглибокої свердловини DW-1, пробуреної в Саатлинському районі Азербайджану, щоб шляхом аналізу існуючих глибинних моделей, побудованих для цього регіону, показати, що вони не відображають істину, і показати науковому співтовариству важливість нового підходу до нещодавно створеної глибинної моделі. Методика включає детальний комплексний аналіз гравітаційного та магнітного полів у цьому регіоні, використання локальних магнітних аномалій для побудови моделі глибинної геологічної будови з використанням даних глибинного сейсмічного зондування (ГСЗ) та кореляційного методу заломлених хвиль (КМЗХ). Результати. Просторове розташування ефузивних утворень у геологічному розрізі визначено за локальною аномалією геомагнітного поля в районі Саатли. При цьому геометричні розміри вулканічної структури були підібрані таким чином, щоб створюване нею магнітне поле відповідало спостережуваному локальному магнітному полю. Таким способом побудовано модель геологічного розрізу до глибини 15 км з відображенням просторової локалізації вулканічної структури. У цій моделі, на відміну від попередньої, просторове положення вулканічної структури у вертикальному геологічному розрізі зовсім інше. У новоствореній моделі виявилося, що в районі надглибокої свердловини Saatly DW-1 існує окреме вулканічне утворення. А в попередніх моделях було показано, що магма надходила сюди із зони Мурадханли, розташованої на відстані 25-30 км. Границі кристалічного фундаменту і базальтового шару в районі DW-1 в зоні вулканічного тіла не простежуються. Корінь вулкана звужується і йде глибоко в надра землі. На глибині близько 15 км магмоутворюючий канал має ширину 1 км. На основі створеної моделі встановлено, що надглибока свердловина Saatly DW-1 розташована на магматичному каналі наявного тут похованого древнього вулкана. З аналізу отриманих модельних даних виявляється, що подальше поглиблення свердловини Saatly DW-1 не дасть можливості розкрити консолідовану кору (кристалічний фундамент) і базальтовий шар. Тому що, хоча ці шари знаходяться ближче до поверхні землі в районі свердловини DW-1, діючий тут вулкан зруйнував ці структури. Оригінальність. Матеріали сейсморозвідки та гравімагнітні дані профілів з кроком спостереження 250 м використано для вивчення глибинної будови регіону, для побудови просторових положень ефузивних утворень у геологічному розрізі застосовано спеціальну методику. Наукова новизна. Встановлено, що геомагнітне поле цього регіону формується трьома основними ефектами – впливом осадового комплексу, впливом товщі порід між поверхнями фундаменту і Кюрі та впливом локальних проявів магматизму. Сума перших двох ефектів досить точно відповідає регіональному фону спостережуваного геомагнітного поля. А виділені із спостережуваного поля локальні позитивні аномалії пов'язані з локальними неоднорідностями – з вулканогенними утвореннями в осадовому комплексі в цьому регіоні. Практичне значення. З використанням локальної аномалії геомагнітного поля визначено просторове положення еффузивних утворень у геологічному розрізі в районі свердловини Saatly DW-1 та створено їх нову геолого-геофізичну модель. Ця модель має реальні можливості в напрямку облаштування надглибоких свердловин для дослідження глибинних шарів земної кори.

Ключові слова: кристалічний фундамент, надглибока свердловина Saatly, геолого-геофізична модель, гравімагнітні дані.

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