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Geothermal energy potential assessment and utilization in the Absheron oil and gas region

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The Relevance: The Absheron oil and gas region, located in the northwestern part of the South Caspian Basin, plays a pivotal role in understanding sedimentary deposits across various geological periods. This study delves into the Lower Tabasir deposits within the key fields of the Absheron archipelago, shedding light on their lithological composition and contributing to a comprehensive understanding of the region's geological significance.

The Aim: With a primary objective of evaluating geothermal energy potential, this research centers on the Bibiheybat deposit on the Absheron Peninsula. By employing meticulous temperature and pressure measurementsand advanced modeling techniques, the study aims to analyze the distribution of the geothermal energy throughout the field.

Methods: Detailed temperature and pressure measurements and modeling using the Surfer program. Laboratory evaluations of the rock samples' thermal properties make the geothermal energy calculations evenmore precise.

Results: The findings of this study offer insights into the distribution patterns of geothermal energy within the Bibiheybat deposit. Temperature and pressure distribution maps illustrate variations across the field. The proposed conversion scheme presents an avenue for efficient geothermal-to-electricity transformation. Ultimately, this research underscores the pivotal role of geothermal resources in shaping sustainable energy strategies for the future, while promoting a more ecologically conscious approach to energy utilization.

Key words: geothermal energy, Absheron oil and gas region, Bibiheybat deposit, temperature distribution, pressure distribution, energy conversion, sustainable energy, renewable resources.

Introduction. The Absheron oil and gas region, located in the northwestern part of the South Caspian Basin, consists of sedimentary deposits from the Upper Tabasir to the Anthropogene. The Lower Tabasir deposits have been studied in exploration wells in the Xazri (area 4), Gilavar (area 2), and Arzu (area 2) fields of the Absheron archipelago, with thicknesses reaching up to 700 m. The intersected lithology mainly comprises terrigenous-carbonate sediments [Yusifov, Aslanov, 2018].

The Absheron region includes the Absheron Peninsula, the Absheron archipelago to its east, and the Baku Archipelago associated with it. The western part of the Absheron exhibits several regional-tectonic characteristics that reflect the regional-tectonic features of the South Caspian region in many aspects [Salmanov et al., 2015a].

The tectonic structure of the Southeastern Caucasus undergoes changes within the Absheron pericline area. The pericline structure is divided into the Northern Absheron and Southern Absheron anticlines [Ahmadov et al., 1958].

The Bibiheybat oil field is located on the southern-western part of the Absheron Pen-

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insula, along the coastal areas, approximately 2 km away from the center of Baku city. The southern-eastern portion of the field extends from Bayil Cape in the north to Shikhlar Cape in the south, covering the coastal area along the Caspian Sea [Salmanov et al., 2015b].

The thermal field of the Earth's near-surface layers is governed by the interaction of internal and external heat sources. The thermal energy of solar radiation reaching the surface layers is an external source of heat. Internal sources primarily include heat generated during the decay of radioactive isotopes of uranium, thorium, and potassium and the heat related to other processes inside the Earth. This last one contains potential energy released as a result of differentiation under the gravity field, latent heat linked with chemical reactions that produce or absorb heat, and tidal deformation caused by the Moon and Sun [Mukhtarov, 2018].

The release of thermal energy from tidal sources in the Earth's near-surface layers is significantly greater than the energy generated by tectonic, seismic, and hydrothermal processes. These factors contribute to the aspects of Earth's thermal field studies. Solar activity, observed on a daily, seasonal, centennial, and long-term scale, leads to cyclic changes in air temperature. The impact of these cycles becomes more profound with longer periods. For instance, daily temperature changes affect the uppermost soil layer, while seasonal variations extend to depths of 20 to 40 m, where heat is primarily transferred through molecular thermal conductivity and, in some cases, groundwater movement. At depths of 20 to 40 m, a stable layer with nearly constant annual temperature exists, generally around 3.7 °C higher than the average yearly air temperature [Mukhtarov, 1984, 2011; Frolov, 1991]. Long-term climate shifts influence temperatures at even greater depths, such as evidence suggesting temperature fluctuations during the Quaternary Period reaching depths of 3 to 4 km. However, these changes are often extremely subtle, frequently falling below the limits of measurement capabilities. Therefore, it is plausible to consider that seasonal cycles are undetectable at depths with consistent temperatures. The temperature conditions at these depths are shaped by the intricate thermal interplay between shallow and deep heat flux [Mukhtarov, 2018].

Temperature data from more than 150 wells in oil and gas-rich areas of Azerbaijan were collected, spanning depths from 100 to 6000 m. These data, including information from development wells, were used to create temperature maps. The thermal characteristics of over 3000 rock samples from Mesozoic-Cenozoic sequences in Azerbaijan were measured, [Mekhtiyev et al., 1987; Aliyev, Aliyev, 1995; Aliyev et al., 2002; Mekhdiyev et al., 2003; Mukhtarov, 2011]. The closely align with properties observed in similar regions globally [Čermák, 1979; McKenna, Sharp, 1998]. For instance, these findings played a crucial role in determining the thermal properties of the main lithological and stratigraphic formations in Azerbaijan, encompassing approximately two hundred locations.

In recent years, significant emphasis has been placed on harnessing waste heat and renewable sources of energy as a means to decrease our reliance on fossil fuels. Additionally, there is a growing global demand for energy [Sheng et al., 2013]. Renewable energy has gained prominence as a crucial supplier of energy to various industries. Unlike fossil fuels, the utilization of renewable energy sources has a lesser detrimental impact on the environment in terms of gas emissions. Geothermal energy, an abundant renewable resource, stands out as an relatively easilyaccessible option, existing beneath the Earth's surface worldwide at different depths depending on the location.

Mining this new source of affordable energy is less detrimental to the environment than mining fossil fuels [McKendry, 2002; Lurque et al., 2008]. The depletion of fossil fuel reserves necessitates the development of more sustainable energy sources such as geothermal, wind, solar, and tidal energy. As a result of this necessity, a new technology for converting tidal energy was tested [Assad et al., 2016].

Because converting geothermal energy to electrical energy is neither cheap nor simple,

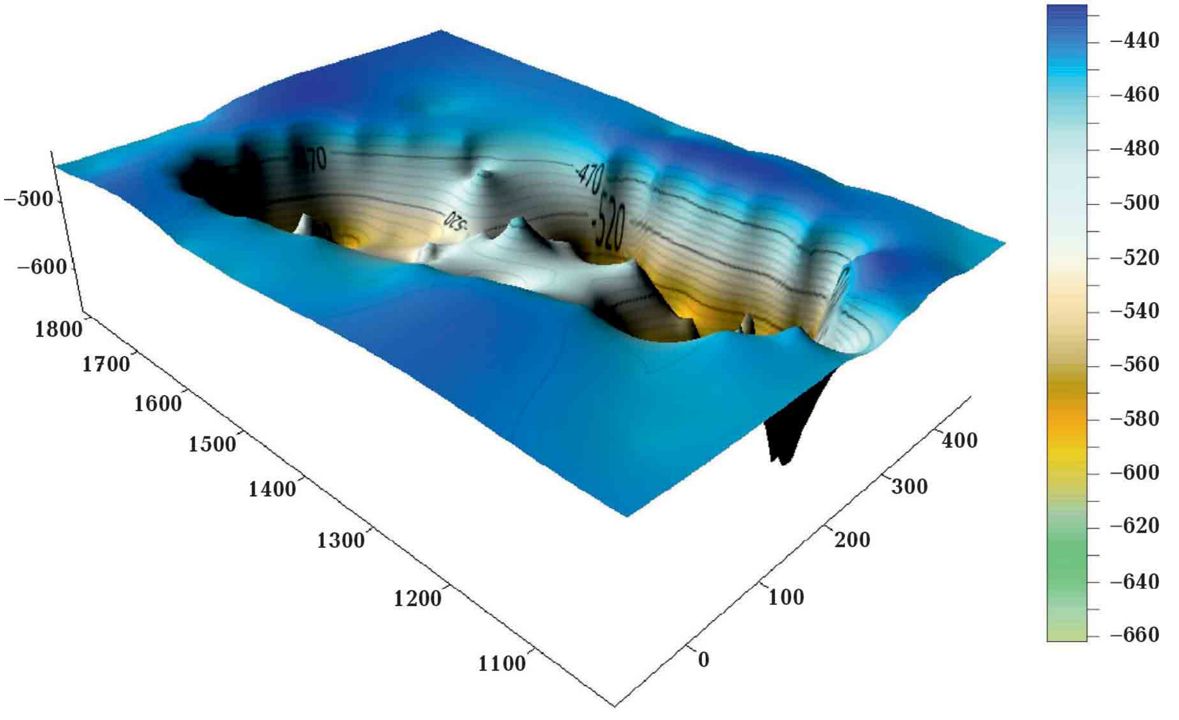

Fig. 1. Two-dimensional model of the depth structure of the Bibiheybat deposit with respect to the X stratum [Mammadov, 2021].

there is a genuine need to make efficient use of the available energy. There are now three types of geothermal power plants: (1) flash steam, (2) dry steam, and (3) binary ORC (Organic Rankine Cycle) geothermal power plants [DiPippo, 2007]. The geothermal resources, are characterized as having low, medium, or high enthalpy [Dickson, Fanelli, 2003].

Method. Utilizing geothermal energy is of significant importance alongside the exploitation of oil fields at the border. To assess the potential of geothermal energy available throughout the area, it is necessary to determine the flow rate and temperature of the fluid (oil, water, gas) exiting the wells.

Determining the distribution of pressure and temperature of the X stratum is also an important issue. In order to achieve this, it would be appropriate to first study the depth structure of the Bibiheybat deposit with respect to the X stratum.

A two-dimensional (Fig. 1)and three-dimensional (Fig. 2) models of the area were built to observe the depth structure of the

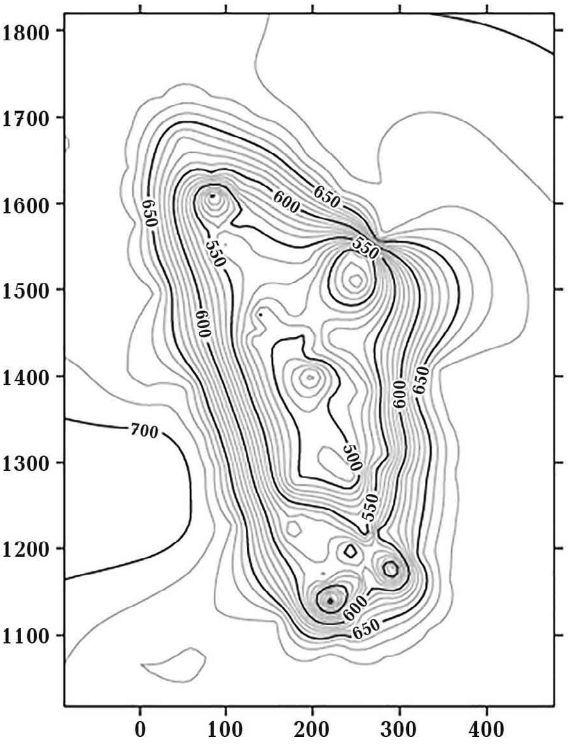

Fig. 2. Three-dimensional model of the depth structure of the Bibiheybat deposit with respect to the X stratum [Mammadov, 2021].

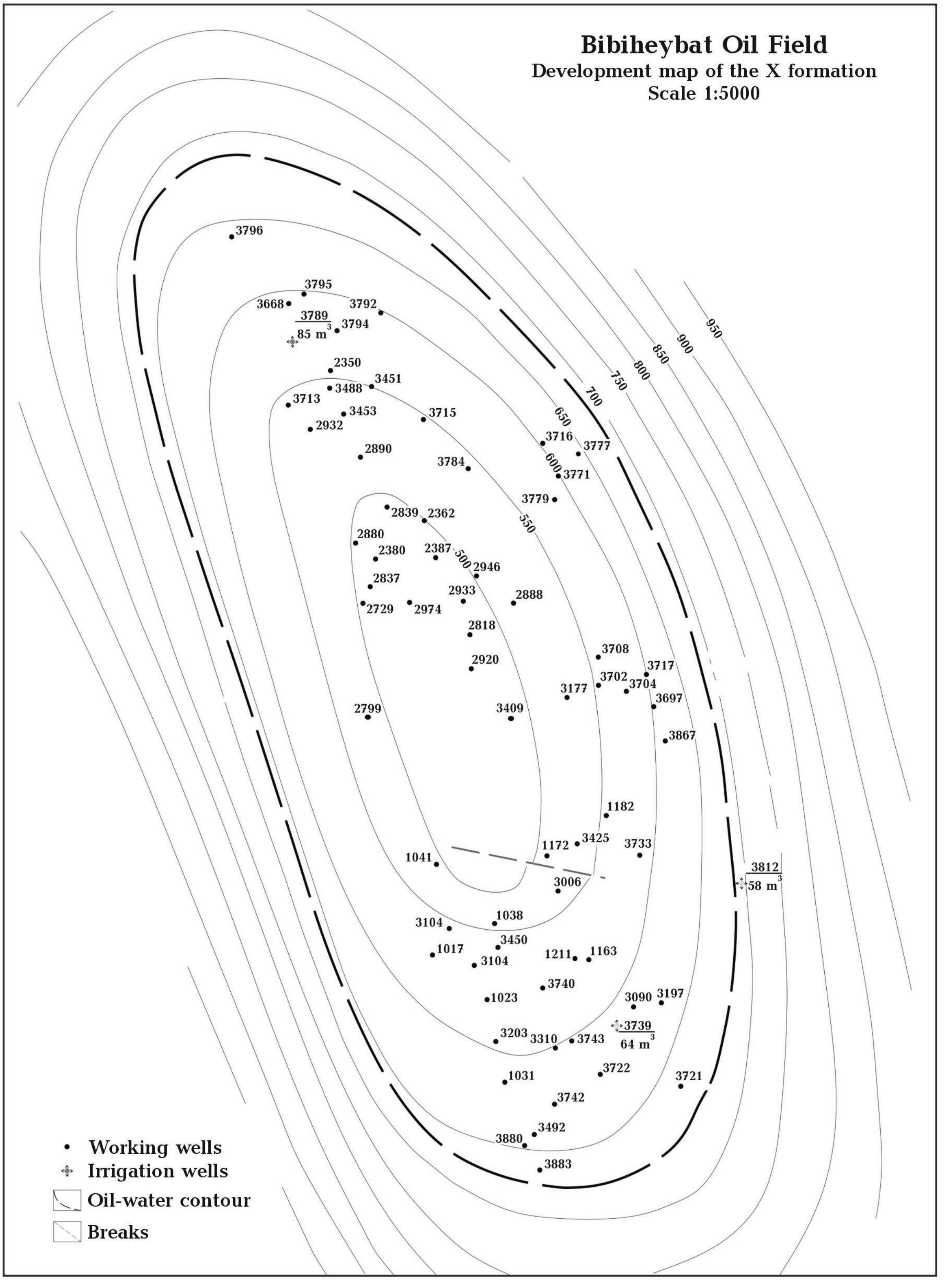

Fig. 3. Mining map of the Bibiheybat deposit with respect to the X stratum (based on the report materials of the energy department of Bibiheybat NQCI, 2021).

Bibiheybat field's X stratum.These models were built using the Surfer program after studying the coordinates and depth (in m) of the wells.

According to the two-dimensional model, the X stratum is an anticlinal fold. Likewise, with the three-dimensional model; the wells located here have depths ranging from 430 to 660 m.

According to the mining map of the X stratum, we can see that the productive oil wells are mainly located in the northern, northeast, and southern wings of the area.

In general, to calculate the potential of geothermal energy present throughout the field it is necessary to determine the flow rate and temperature of the fluid (oil, water, gas) extracted from the wells. For this, one needs the temperature and pressure for each well, which are calculated and recorded in the monthly reports of the Research and Production Department of Bibiheybatneft (Fig. 3).

The measurement works are carried out in the following sequence.

1. Setting Up.

Manometer with Thermometer: This is a pressure gauge designed to work in conjunction with a thermometer. It can be a combined instrument or have separate sensors for pressure and temperature.

Specific Program: This refers to specialized software used to record and analyze the well data. The project name within the program reflects the specific well being measured.

2. Data Acquisition.

Lowering the Manometer: The manometer, along with any necessary protective housing and cables, is carefully lowered into the wellbore.

Continuous Measurement: As the manometer descends, it constantly records pressure and temperature data at specific intervals throughout the well's depth.

3. Data Analysis.

Data Transfer: Once the manometer reaches the bottom and finishes measurements, the collected data is transferred to the dedicated program.

Pressure & Temperature Graphs: The program analyzes the pressure and temperature data at different depths. It then generates graphs that visualize how these parameters change as you go deeper into the well. These graphs can reveal important information about the well's characteristics, such as fluid properties and potential pressure variations.

4. Reporting.

Monthly Report: After analyzing the data,

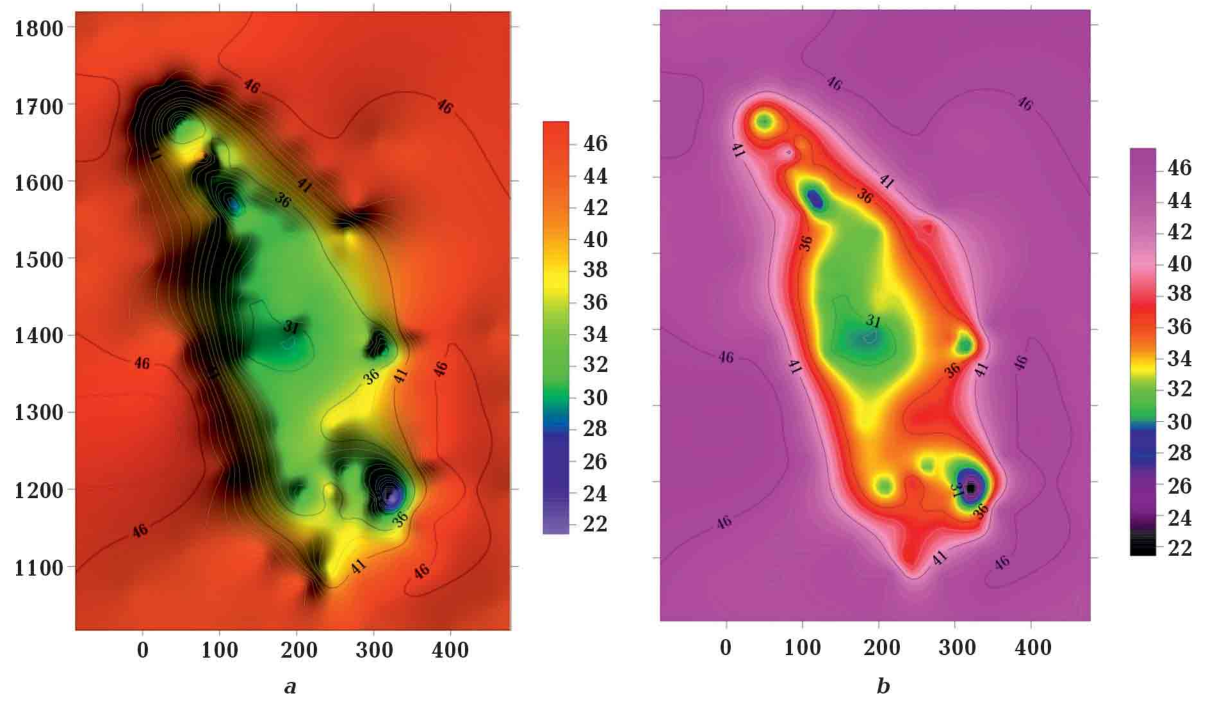

Fig. 4. Temperature distribution models in the X stratum of the Bibiheybat field [Mammadov, 2021].

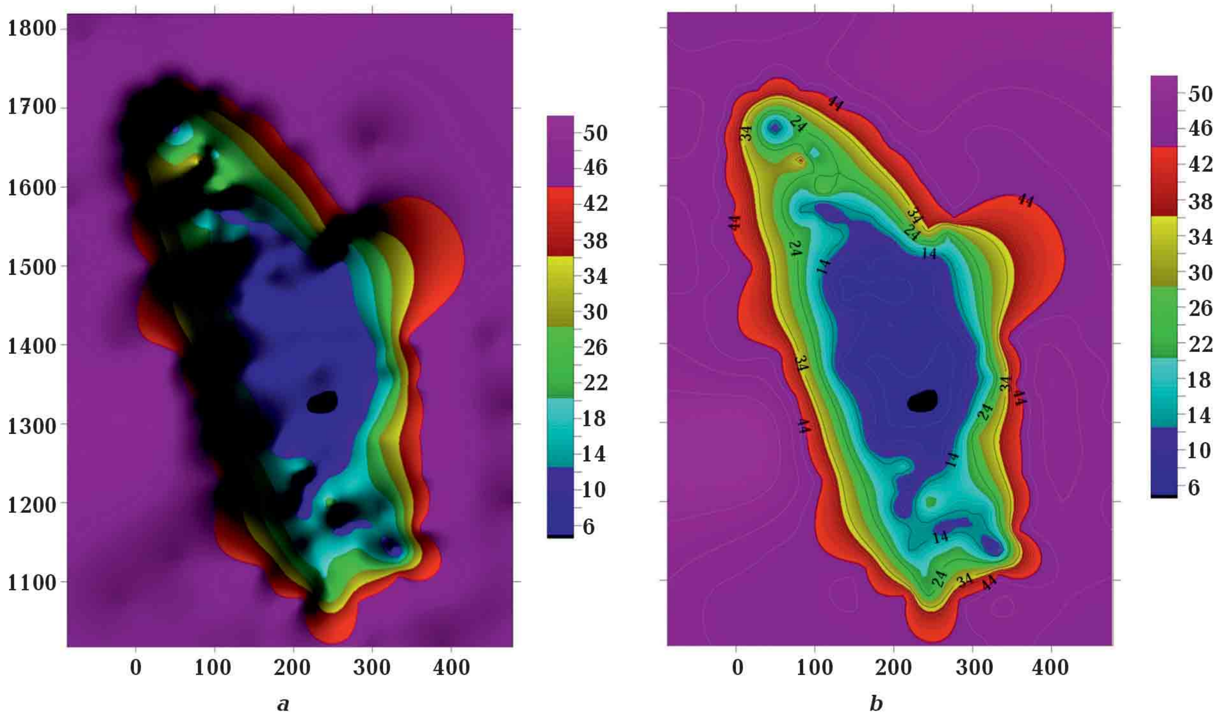

Fig. 5. Pressure distribution models in the X stratum of the Bibiheybat field [Mammadov, 2021].

key pressure and temperature readings from various depths are documented in a monthly report. This report allows for tracking changes over time and helps in understanding the overall well behavior.

In addition to the measurement works mentioned earlier, we also measured temperature of the fluid that comes through the wells and exits through the pipes. It is known that as the fluid moves along the wellbore and is influenced by the surrounding environment, it cools down. The purpose of conducting these measurements was to determine the temperature difference between different points.

Afterwards, special software is used to create a temperature distribution model for the X stratum of the Bibiheybat deposit. This model shows the distribution of temperature across the field (Fig. 4).

In the first model (Fig. 4, *a*), the temperature distribution map in the X stratum is depicted. The temperature in the producing wells throughout the field ranges from 46 to 22 °C. It decreases towards the center and increases towards the wings. Particularly, at the injector wells 3812, 3739, and 3789 the temperature drops sharply.

In the second model (Fig. 4, *b*) as well, we observe that the temperature increases from the center towards the wings in the X stratum.

Distribution maps were also constructed for pressure (Fig. 5).

If we look at the first model (Fig. 5, *a*), we can observe that the pressure decreases from the wings towards the center. Along the X stratum, the pressure ranges from 50 to 6 atm.

In the second model (Fig. 5, *b*), we can mainly note that the pressure increases from the center towards the wings.

The potential of geothermal energy in the Bibiheybat deposit is of interest. The objective is to calculate the geothermal energy potential of the Bibiheybat deposit and determine the distribution law of energy throughout the field.

For this purpose, it would be appropriate to first know the flow rate and temperature of the wells in that region. The thermal energy that wells bring to the earth's surface from the ground is estimated according to the discharge at the exit. If we express the flow rate as $q=m/t$, the fluid of mass m will bring as much energy as $m=qt$. The amount of heat is $Q=mc\Delta T$ and we can express it as $Q=qtc\Delta T$. Here you

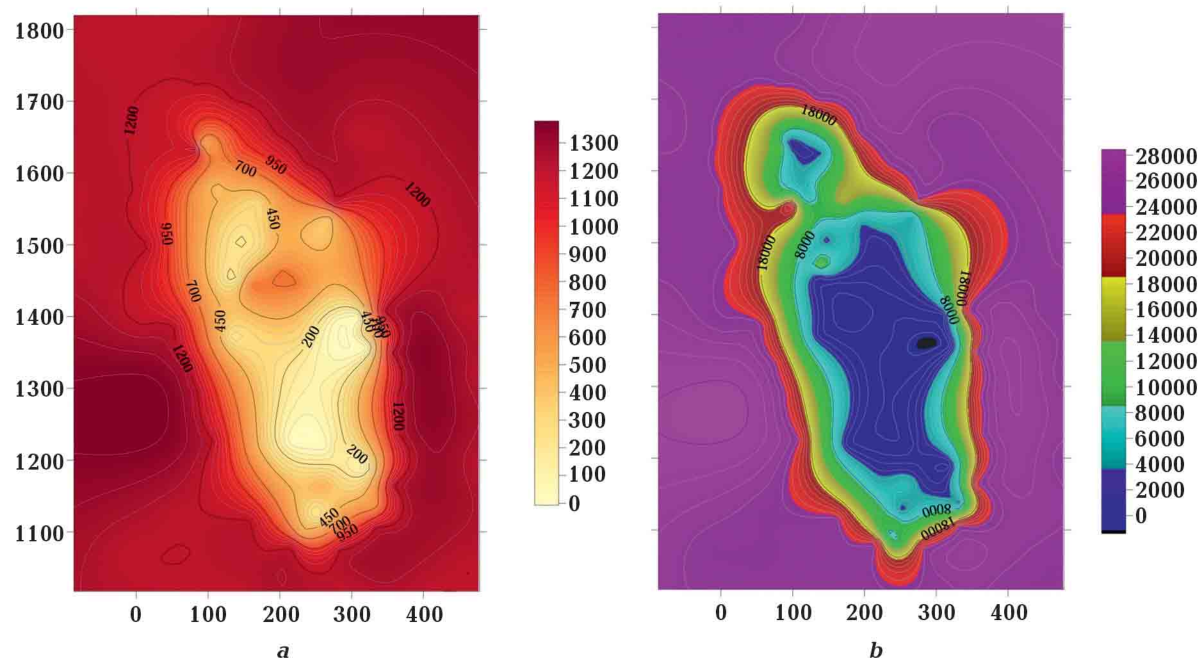

Fig. 6. Geothermal energy potential distribution models in the X stratum of the Bibiheybat field (*a* — for oil, *b* — for water) [Mammadov, 2021].

can find the amount of heat (heat power) that oil wells bring per unit time: $W=Q/t==qc\Delta T$ [Mammadova, 2016].

After determining the flow rate and temperature of each well, the geothermal energy (for oil and water) is calculated by the formula $W=Q/t=qc\Delta T$ [Mammadova, 2016]. After the calculations were completed, models were built using the Surfer program to observe the distribution of geothermal energy throughout the field (Fig. 6).

In the first model (Fig. 6, *a*), the geothermal energy obtained from the oil produced from the wells in the X stratum increases from the center towards the wings. The intensity of geothermal energy is represented by various shades of red and ranges from 100 to 1300 Wt/hour.

In the second model (Fig. 6, *b*), the same pattern is repeated. The increase in geothermal energy towards the wings is due to the high flow rate of the wells located there and the higher temperature compared to the central region.

Results. As a result, the total geothermal energy power for the 45 wells is calculated to be 207239.9 Wt/hour or approximately 207 kWt/hour on average. This energy consists of 15565.5 Wt/hour (15 kWt/hour) from oil and 191674.4 Wt/hour (191 kWt/hour) from water.

After evaluating the geothermal energy for the X stratum of the Bibiheybat deposit, one of the important issues to consider is the calculation of the electrical energy that can be obtained from this energy.

As we know, in order to convert the geothermal energy here into electricity, a scheme of special devices (heat exchangers, gas turbine, generator and etc) needs to be built. The proposed scheme is as follows: (Fig. 7).

First, a heat exchanger radiator will be connected to each well, and these radiators will be supplied with fluids boiling at high pressure and low temperature. The fluid coming from the well and having a certain temperature will boil this fluid, and the high-pressure steam obtained will be transported to the gas turbine through the steam pipes. This gas turbine will be connected to an electric generator and will convert the geothermal energy into electrical energy.

In general, the overall efficiency of this scheme can be up to 35 %. In other words, it

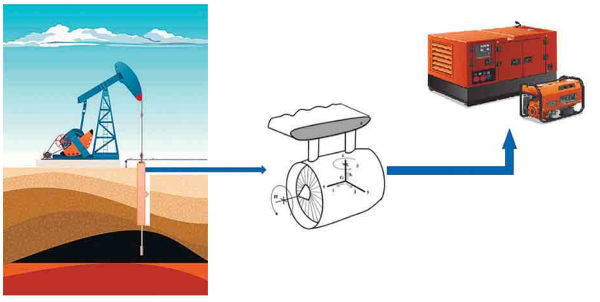

Fig. 7. Scheme of special devices for converting geothermal energy into electrical energy [Mammadov, 2021].

is possible to convert 35 % of the calculated geothermal energy into electrical energy. For the calculated geothermal energy of 207239.9 Wt/hour or approximately 207 kWt/hour for the 45 wells, we can obtain approximately 72533.965 Wt/hour (72 kWt/hour) of electrical energy using this scheme. The calculated electrical energy of 5447.925 Wt/hour (5 kWt/hour) corresponds to the share of geothermal energy transported to the surface through oil, and 67086.04 Wt/hour (67 kWt/hour) corresponds to the share of geothermal energy transported to the surface through water.

Table presents the amount of electricity consumption (in manats) in Bibiheybatneft Oil Company. Overall, the energy consumption per well is 24.53 kWt/hour. With this calculation, the energy consumption for the 45 wells in the X stratum is 1104.03 kWt/hour.

With the proposed scheme, it has the potential to supply 3 active wells in the mine, all offices and equipment in the production area, as well as 345 residential apartments with a consumption of 150 kWt/h located near the Bibiheybat deposit.

Distribution of electrical energy in Bibiheybatneft Oil Company in March 2020 (Based on the report materials of the energy department of Bibiheybat NQCI, 2021)

Number	Fields	The amount of active electricity is 0.07627₼ (manat) per 1 kWt/hour
1	NQÇS 1	270000
2	NQÇS 2	320000
3	NQÇS 3	340000
4	NQÇS 4	305000

Conclusion. This study investigated the geothermal energy potential of the X stratum within the Bibiheybat oil field in Azerbaijan. Utilizing 3D and 2D depth structure models, temperature and pressure distribution maps, and geothermal energy potential models, the researchers were able to assess the viability of harnessing geothermal energy for electrical power generation.

Key findings include:

– the X stratum exhibits an anticlinal fold structure, with well depths ranging from 430 to 660 m;

– productive oil wells are primarily located in the northern, northeastern, and southern wings of the field;

– temperature varies throughout the field, ranging from 46 to 22 °C, with higher temperatures observed in the wings and lower temperatures towards the center;

– pressure also exhibits spatial variation, decreasing from the wings towards the center and ranging from 50 to 6 atm;

– geothermal energy potential is highest in the wings due to higher flow rates and temperatures.

The total geothermal energy power for the 45 wells is estimated to be 207239.9 Wt/hour (207 kWt/hour), with 15565.5 Wt/hour (15 kWt/hour) from oil and 191674.4 Wt/hour (191 kWt/hour) from water;

– utilizing a conversion scheme with an efficiency of 35 %, approximately 72533.965 Wt/hour (72 kWt/hour) of electrical energy can be generated;

– this generated electrical energy has the potential to power 3 active wells in the mine, all offices and equipment in the production area, as well as 345 residential apartments with a consumption of 150 kWt/hour located near the Bibiheybat deposit.

In conclusion, the X stratum of the Bibiheybat oil field demonstrates significant potential for geothermal energy utilization. Implementing the proposed conversion scheme could provide a sustainable and clean source of electrical power for various operations within the field and the surrounding area. Further research and development are warranted to optimize the conversion process and maximize the energy output.

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Оцінювання потенціалу та використання геотермальної енергії в Абшеронському нафтогазоносному регіоні

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Актуальність. Нафтогазоносний район Абшерон розміщується у північно-західній частині Південнокаспійського басейну і відіграє ключову роль у розумінні осадових відкладів різних геологічних періодів. Дане дослідження присвячене нижньотабаширським відкладам на ключових родовищах Абшеронського архіпелагу, що проливає світло на їх літологічний склад і робить внесок у комплексне розуміння геологічного значення регіону.

Мета. Основна мета дослідження — оцінювання потенціалу геотермальної енергії, що фокусується на Бібі-Ейбатському родовищі Абшеронського півострова. За ретельного вимірювання температури та тиску у поєднанні з передовими методами моделювання детально досліджено розподіл геотермальної енергії в межах всього родовища.

Методи. За багатоаспектного підходу дослідження включає детальні вимірювання температури і тиску, доповнені складним моделюванням за допомогою програми Surfer. Лабораторне оцінювання теплових властивостей зразків гірських порід додатково підвищує точність розрахунків геотермальної енергії.

Результати. Отримано вичерпне уявлення про закономірності розподілу геотермальної енергії на Бібі-Ейбатському родовищі. Карти розподілу температури та тиску наочно демонструють зміни в межах усього родовища. Запропонована схема перетворення є суттєвим шляхом для ефективного перетворення геотермальної енергії в електрику. Це дослідження підкреслює центральну роль геотермальних ресурсів у формуванні стратегій сталої енергетики у майбутнє, що сприяє більш екологічно свідомому підходу до використання енергії.

Ключові слова: геотермальна енергія, Абшеронський нафтогазоносний район, Бібі-Ейбатське родовище, розподіл температури, розподіл тиску, перетворення енергії, стійка енергія, відновлювані ресурси.