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Assessment of energy potential in the Khizi tectonic zone of the Caspian-Guba research region (on the example of the Bayimdagh-Tekchay field)

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This study assesses the energy potential of the Khizi tectonic zone within the Caspian-Guba research region, focusing on the Bayimdagh-Tekchay field. Given Azerbaijan's increasing emphasis on alternative energy sources, geothermal energy emerges as a viable and sustainable option. The region's geothermal resources, mainly concentrated in the Greater and Lesser Caucasus, the Talysh-Lankaran zone, and the Kur-Araz basin, remain underutilized due to Azerbaijan's rich oil reserves.

Thermal waters in the Caspian-Guba region have been analyzed based on stratigraphic data, geothermal measurements, and hydrogeological studies. The Siyazan monocline, a key tectonic feature, separates various geological formations and influences temperature variations with depth. Temperature distribution analyses in the Bayimdagh-Tekchay zone reveal a correlation between rock age, dip angles, and geothermal gradients. The Productive layerformation, predominantly consisting of conglomerates, gravels, and clays, plays a crucial role in subsurface heat retention.

Experimental findings indicate that the region possesses significant thermal water reserves, exceeding 30,000 m^2/day in certain areas such as Khachmaz, Khudat, and Nabran. The study also highlights the potential for repurposing abandoned oil wells for geothermal energy production. Injected water, upon heating through rock contact, can be extracted to supply local heating networks, industrial facilities, and even power generation using the Organic Rankine Cycle or Kalina Cycle technologies.

An economic feasibility analysis demonstrates that energy extracted from selected wells in Bayimdagh-Tekchay could meet the heating requirements of hundreds of households. This underscores the importance of further investment in geothermal infrastructure to optimize energy recovery and enhance sustainability. The research ultimately advocates for a transition towards green energy in Azerbaijan, emphasizing geothermal energy's role in reducing reliance on conventional fossil fuels while promoting environmental conservation.

Key words: geothermal energy, thermal parameters of rocks, energy evaluation.

Introduction. In recent times, the efficiency of alternative energy sources' use and the demand for them have been growing. These types of energy allow us to save on them, reducing the use of other energy sources that have been used for a long time and are not environmentally friendly, in some cases.

In order to develop and increase the prospects for the use of wind, solar, and geothermal energy, which are practical for Azerbaijan,

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the necessary work is currently being done in our country. Large financial resources are allocated for its expansion. The advantages of geothermal energy sources allow us to devote more space to them in the article. Geothermal energy sources in the republic are mainly located in the Azerbaijani part of the Greater and Lesser Caucasus, the Talysh-Lankaran zone, and many oil and gas provinces of the Kur-Araz basin (Fig. 1). The study of thermal waters in these zones began in the 1970s. However, to this day their use as an energy source cannot be considered satisfactory. This is most likely due to the fact that Azerbaijan is an oil country.

Geothermal energy potential of the Caspian-Guba zone. The study area, which covers the southeastern part of the northeastern slope of the Greater Caucasus, is shaped like an irregular trapezoid. The Siyazan monocline, located in the central part of the Caspian-Guba region, stands out as the largest free tectonic element. Thus, the monocline separates the Gusar-Devachi depression, the Tengi-Beshbarmag anticlinorium from its northeastern flank, and is characterized by a steep dip of the layers in the northeast direction. However, in some areas it results in the overthrusting of the Upper Cretaceous and Paleogene-Neogene sediments in the north-northeast direction. The length of the Siyazan monolith stretches for more than 70 km along the northeastern foothills of the Greater Caucasus, from the coast of the Caspian Sea (in the southeast — from the village of Chorat) to the Velvelachai River in the northwest.

The stratigraphy of the sediments constituting the geological structure of the study area was studied based on the data from numerous drilled wells, natural rock outcrops, and eruption products of mud volcanoes [Geology..., 2008].

The geological structure of the Caspian-Guba region is composed of Middle Jurassic-Quaternary sediments [Mokhammed, 1986], listed in Table.

The Productive layer (Lower Pliocene) sediments cover most of the Caspian-Guba oil and gas region. The Productive layer is characterized by thick coarse-grained sediments in the Gusar-Devachi derivative depression and is composed of conglomerate,

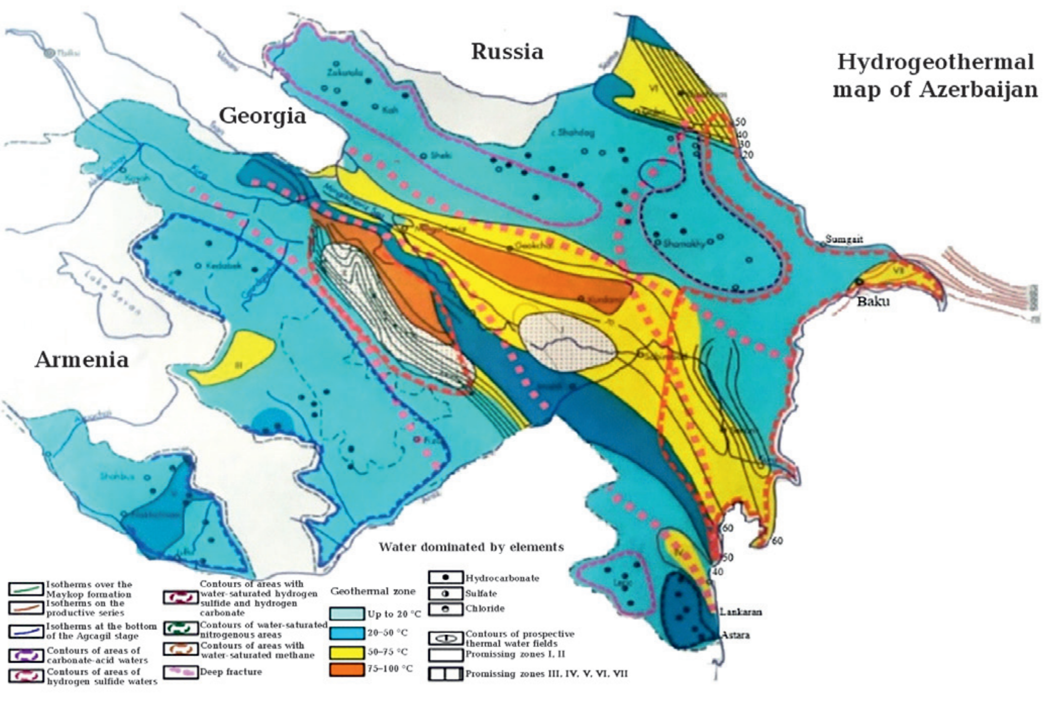

Fig. 1. Hydrogeothermal map of Azerbaijan [Ali-zadeh, 1998].

Characteristics of sediments in the Caspian-Guba region [Ali-zadeh, 2005; Geology..., 2008]

Stratigraphic units	Thickness, m	Lithofacies	Absolute heights of terraces, m
Holocene	6—7 m	sands, gravels, organic limestones	26 21—22
Khvalınhorizon	Up to 30 m	sands, gravels, clays	16—17 10—11 2—3 19—20 45—50
Khazar horizon	From 10 m up to 280—330 m	clays, sands, gravels	45—50 60—70 85—90 125—130 150—180 180—190
Baku horizon	From 30 m up to 280 m	clays, sands, gravels, small pebbles	200—210 220—240 250—400

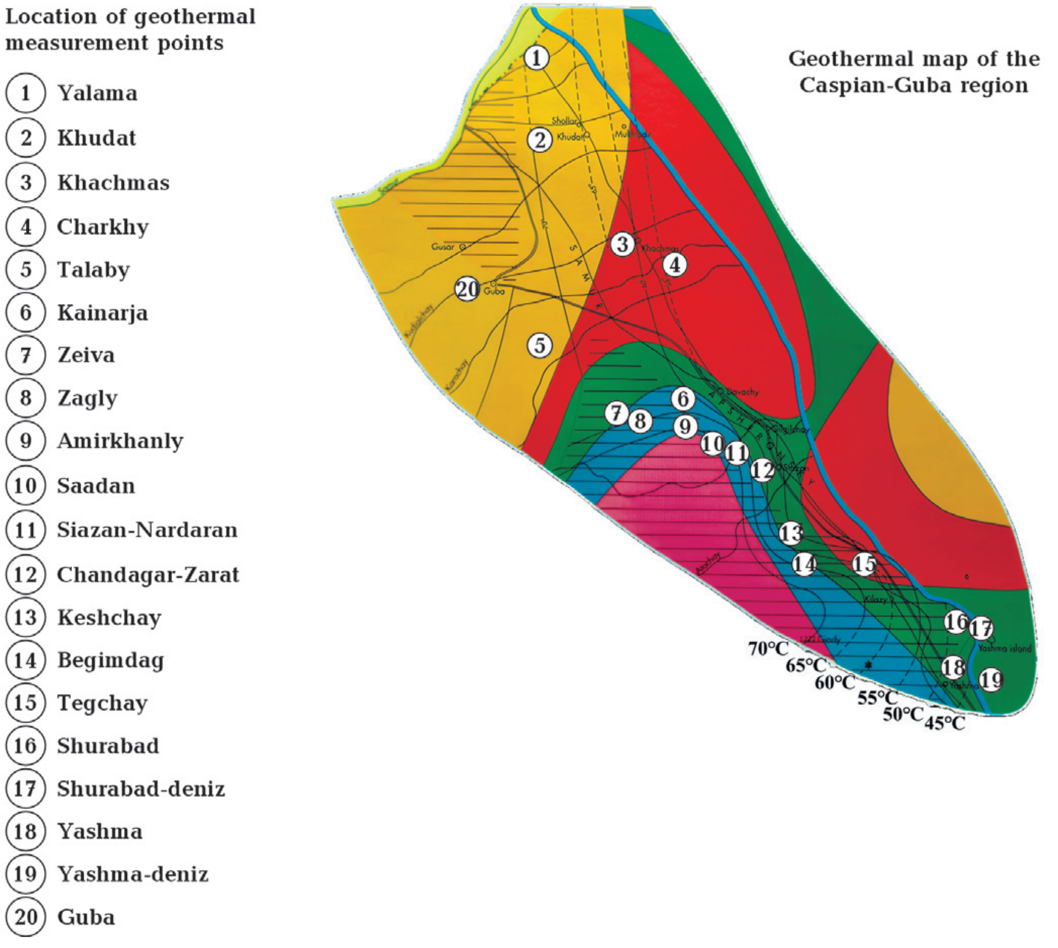

Fig. 2. Geothermal map of the Caspian-Guba region.

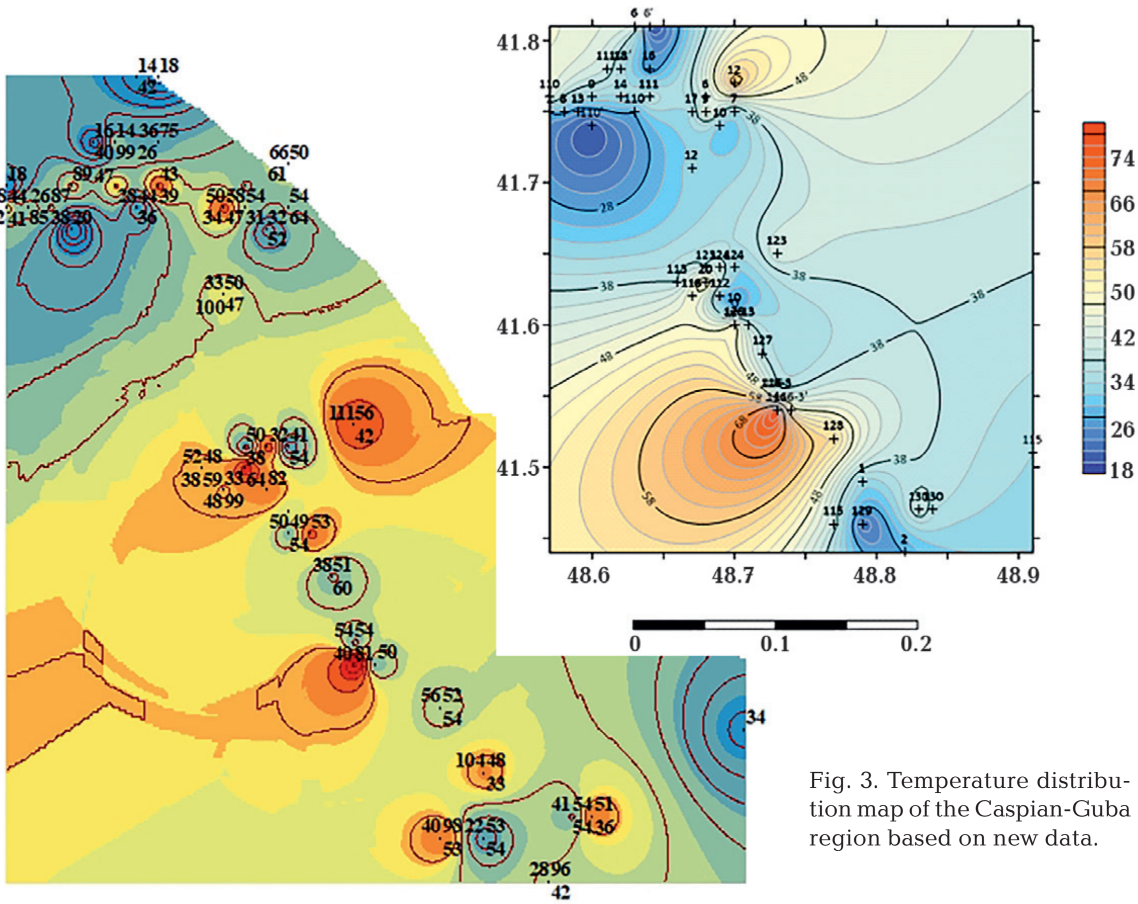

Fig. 3. Temperature distribution map of the Caspian-Guba region based on new data.

gravel, gravelly sand, clay, and sandy-clayey sediments according to its lithological composition.

As a long-term outcome of the geothermal research, extensive data have been collected on the characteristics of the thermal field, and a heat flow map of the Caspian-Guba region has been developed (Fig. 2).

From a geothermal perspective (Fig. 3), most of the Caspian-Guba region is characterized by relatively low heat flow, with the values of this parameter generally not exceeding 30 mW/m^2. In the Siazan monocline (located in the southwestern part), however, the heat flow reaches 50 mW/m^2. The Siazan regional fault crosses the boundary at the transition between the geosynclinal flexure zone of the Greater Caucasus and the foredeep zone. According to S.A. Aliyev, the observed increase in heat flow values toward the east and southwest in the regional context is associated with this fault [Mukhtarov, 2004; Gojayev, 2009].

The use of thermal waters in the studied region as a source of thermal energy in relatively large areas such as Khudat and Khachmaz, as well as in other settlements, would contribute to saving electricity, firewood, coal, oil, and gas while also reducing environmental damage.

The estimated exploitable reserves of thermal waters (Fig. 4), a source of thermal energy, as well as the identified medicinal mineral waters categorized as A, B, and C_1, exceed 30000 m^2/day in the Khachmaz, Khudat, and Nabran areas within the Upper Productive Series aquifer complex [Muradov, Salahov, 1998].

Based on the results of studies conducted in 2019—2020 to monitor thermal water sources [Muradov, Mammadov, 2020] and assess their industrial usage potential in the Guba-Khachmaz Economic-Geographical region, the temperature distribution was mapped.

As a result of hydrogeological testing

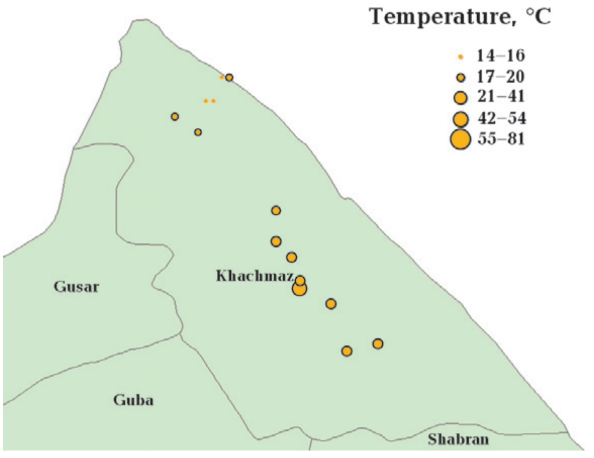

Fig. 4. Temperature distribution map based on the results of work carried out in 2019—2020 to monitor thermal water resources in the Guba-Khachmaz Economic-Geographical Region and study the prospects for their use in industry.

conducted in wells drilled in the specified areas, high-flow and high-temperature underground thermal and mineral waters were discovered within the Middle Jurassic, Upper Cretaceous, and Upper Productive Series aquifer complexes [Tagiyev, Babayev, 2010].

The analysis results confirmed that the underground waters possess various medicinal and therapeutic properties. Additionally, the exploitable reserves of thermal waters in the Upper Cretaceous and Productive Series aquifer complexes have been estimated at 20000 m^2/day for the C_1 and C_2 categories.

The data obtained as a result of research conducted in the Caspian-Guba region by N.N. Muradov, Y.D. Mammadov, T.D. Muradov, S.Sh. Salahov in 1998—2000, 2009—2011, 2019—2020 were.

The increase in rock temperature with depth in the Bayimdagh-Tekchay area of the Siyazan monocline is associated with the age of the rocks that form the structure, in contrast to other areas of the monocline, where this trend is influenced by the dip angle of the layers. In other words, the rocks in this region are older than those in other parts of the monocline. The variation in temperature with depth was analyzed in several wells within the Bayimdagh-Tekchay zone (Fig. 5).

A linear variation in temperature is observed along the well cross-section. Such distribution is associated with the passage

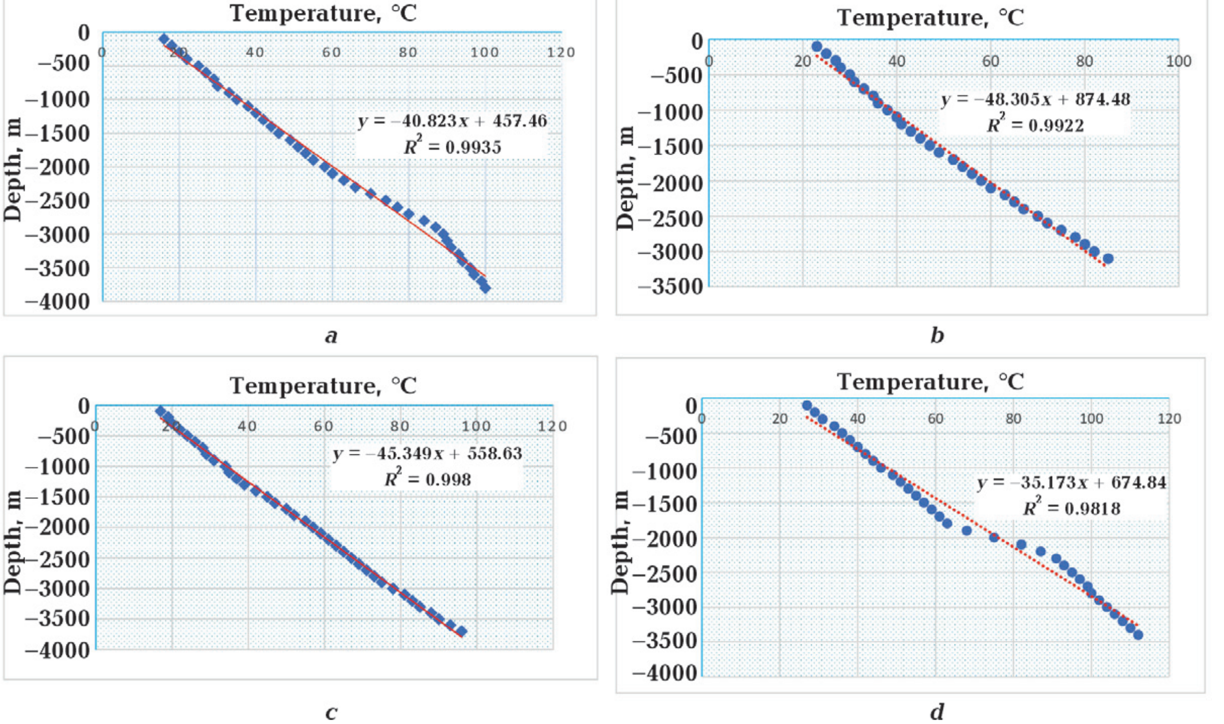

Fig. 5. Temperature variation with depth in wells 10 (*a*), 1 (*b*), 6(*c*), 15 (*d*) in the Bayimdagh-Tekchay zone.

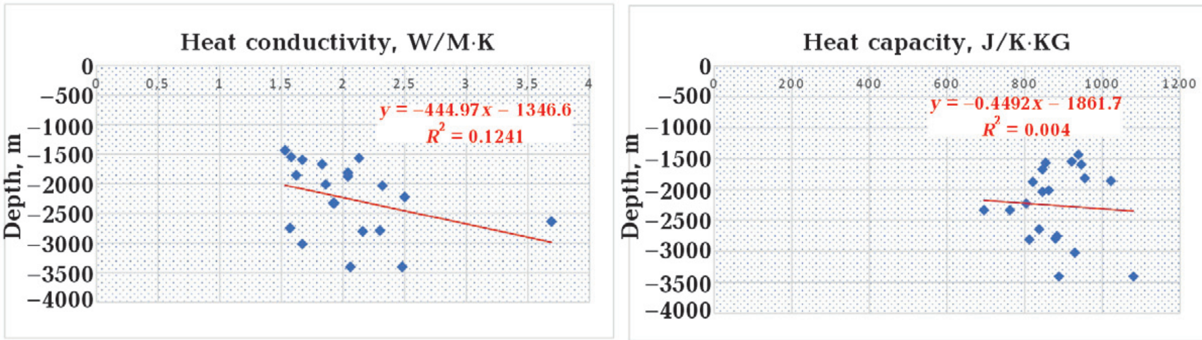

Fig. 6. Variation of thermal conductivity and heat capacity with depth based on studies conducted in several wells in the Bayimdagh-Tekchay area.

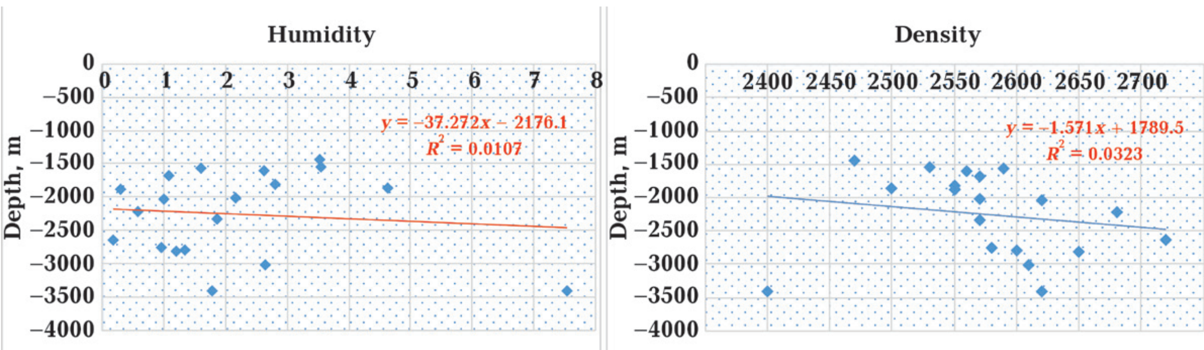

Fig. 7. Variation of humidity and density with depth in the Bayimdagh-Tekchay area.

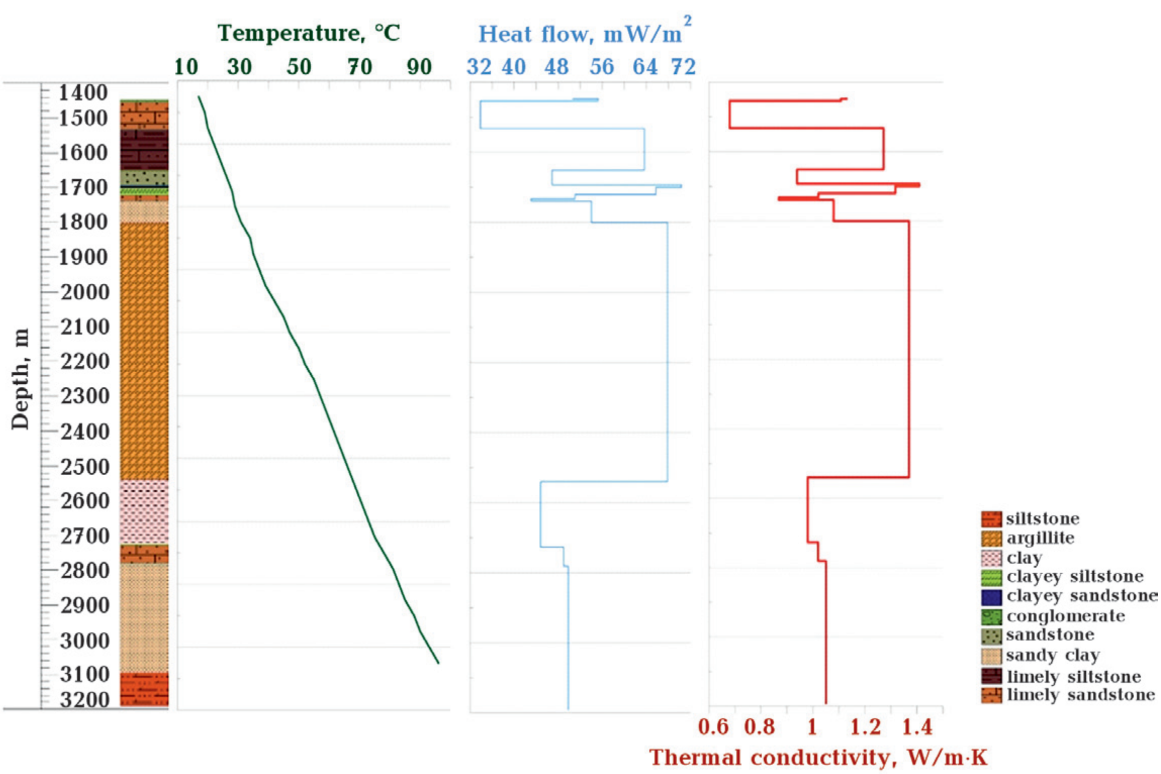

Fig. 8. Changes inthermal parameters in well N1 in the Bayimdagh-Tekchayarea.

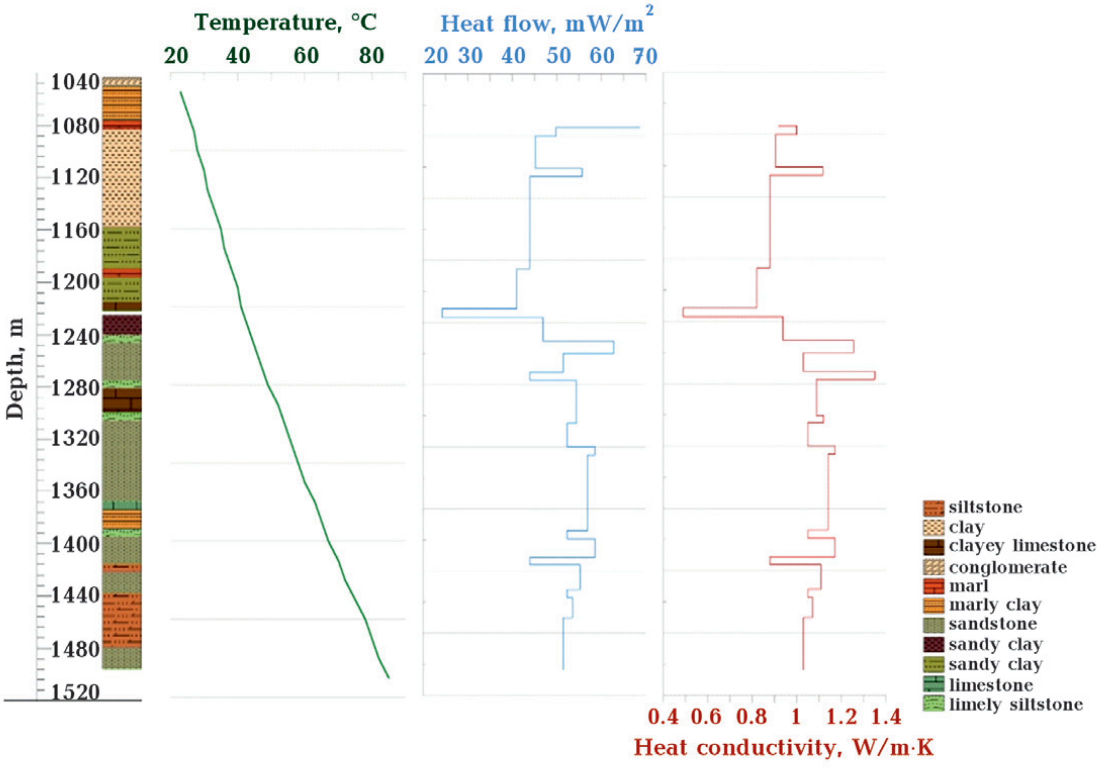

Fig. 9. Changes inthermal parameters in well N6 in the Bayimdagh-Tekchayarea.

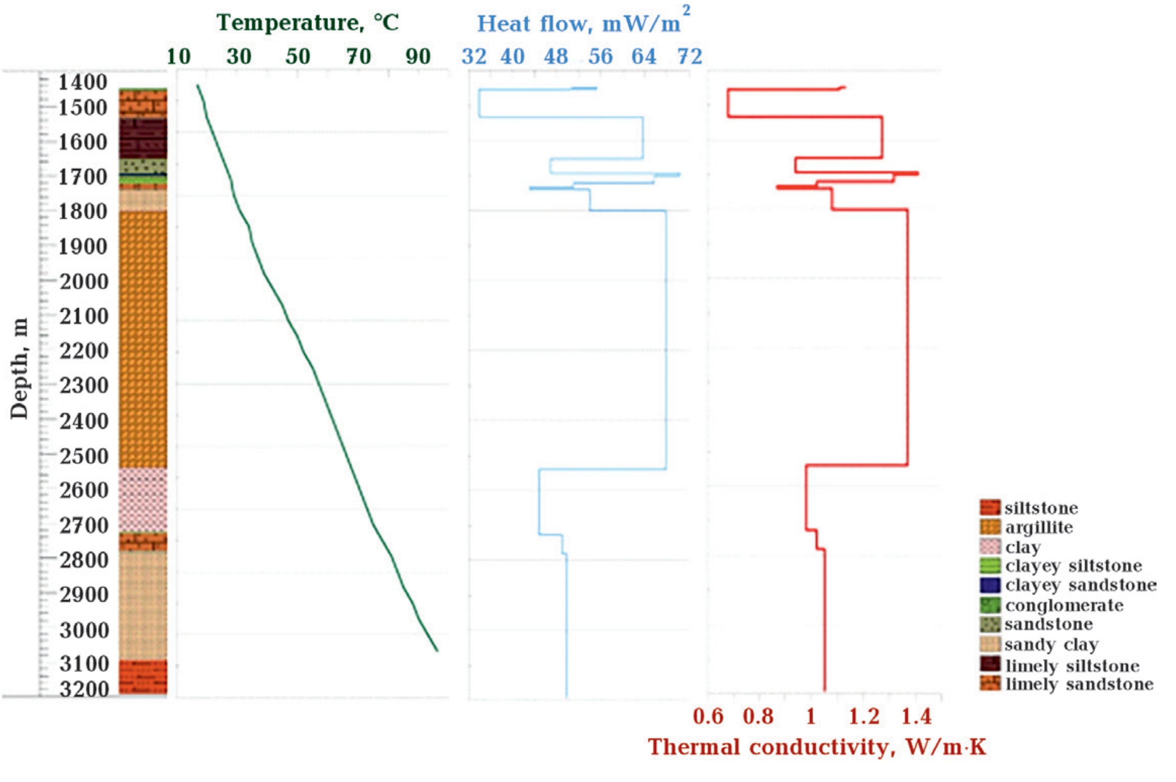

Fig. 10. Changes inthermal parameters in well N10 in the Bayimdagh-Tekchayarea.

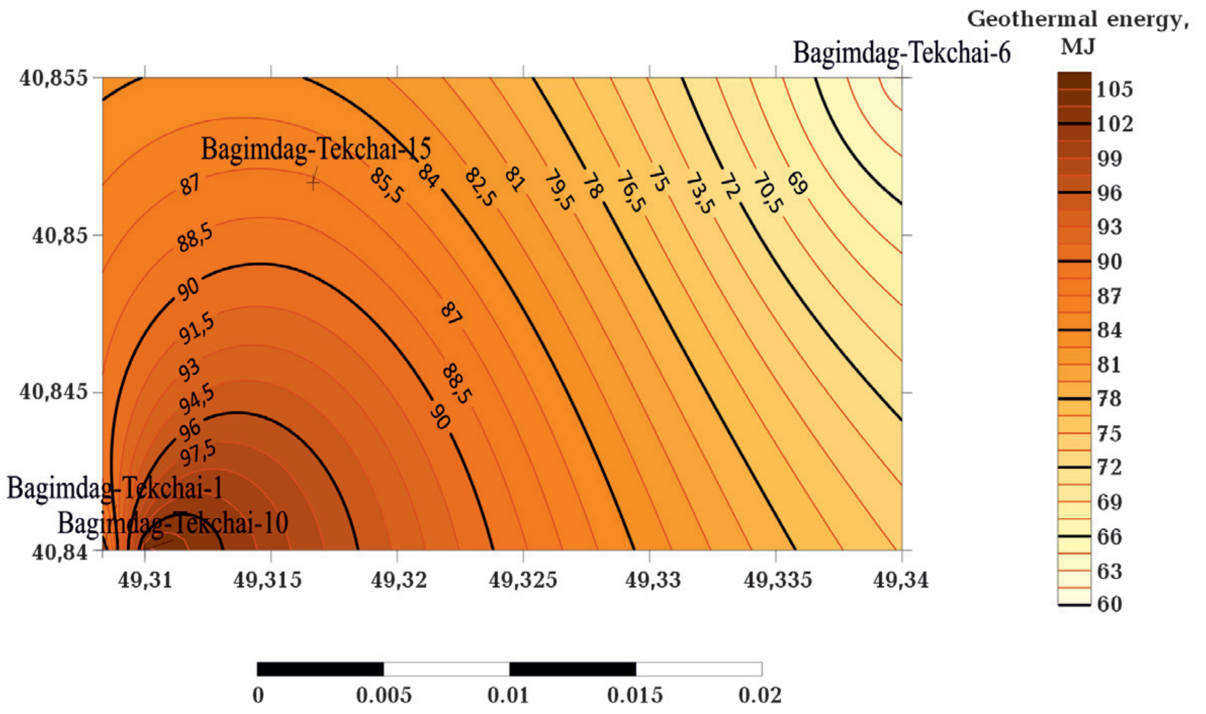

Fig. 11. Distribution map of calculated energy potential for wells 1, 6, 10 of the Begimdagh-Tekchai field.

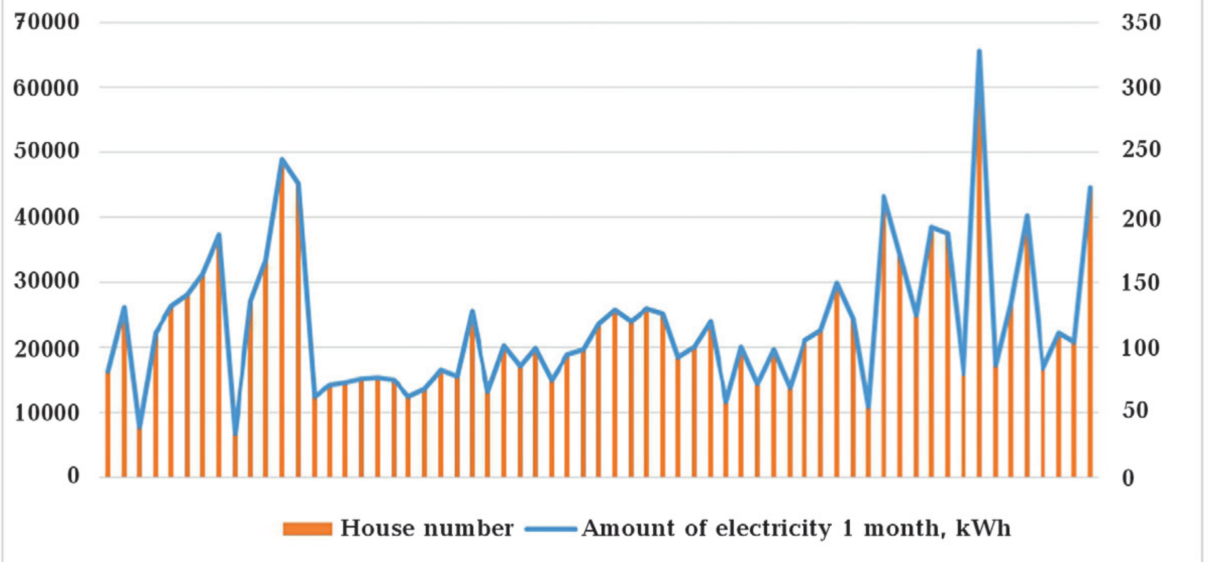

Fig. 12. Graph of the dependence of the calculated amount of energy on the number of houses in the Begimdag-Tekchai zone.

of sediments through homogeneous layers [Mukhtarov, 2011].

The horizons exposed in the Bayimdagh-Tekchay area of the Khizi tectonic zone of the study region correspond to the Bayos-Bat strata; these horizons are composed of shaly clays, sandstones and siltstones [Abbasova, 2022]. Based on the data obtained of Mukhtarov A.Sh., the regularity of changes in the physical parameters of the Bayimdagh-Tekchay area, the range of temperature variations, lithology, and the effect of

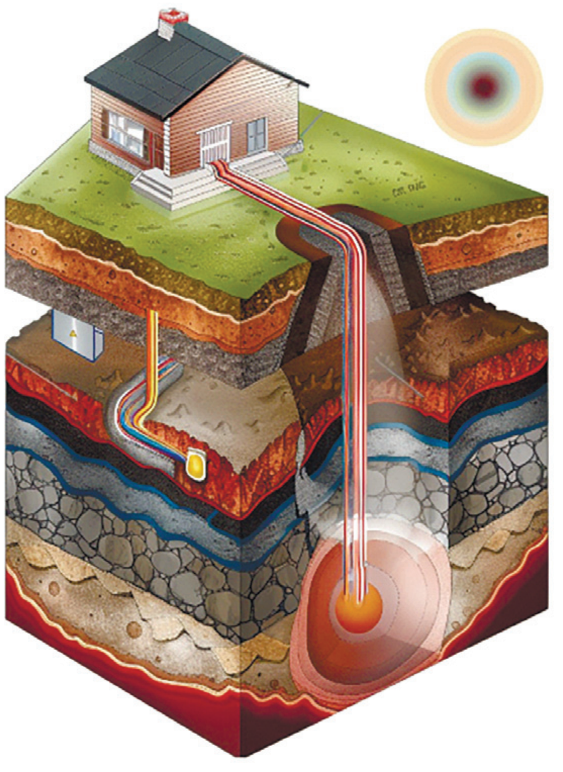

Fig. 13. Geothermal Energy System — Using Underground Heat.

lithological characteristics on temperature were studied (Fig. 6).

Based on the data obtained from wells drilled in the Bayimdagh-Tekchay field (Fig. 7), we observe that the physical parameters of the rocks (density, humidity, heat capacity, thermal conductivity) increase with increasing depth. These parameters directly indicate an increase in temperature with depth. At the exploration depth, limestone, clay, argillite, shale, sandstone, and other rock types are mainly encountered.

It known that temperature changes (Figs. 8—10) are directly related to structural, lithological, hydrogeological, and other factors. For example, an increase in clay content in the section leads to a decrease in temperature, while an increase in sand, on the contrary, leads to an increase, which is also related to the rocks' thermal conductivity. Filtration of surface waters leads to a decrease in temperature, and a rise in the level of deep waters leads to its increase [Mukhtarov, 2011].

When considering the energy potential of the Caspian-Guba region, we take into account both the heat generated by natural thermal waters and the heat obtained as a result of geothermal research conducted in oil wells that have already been decommissioned. Thus, it is possible to highlight the economic efficiency of the energy collected in several wells in the Bayimdagh-Tekchay field in the Khizi tectonic zone. Since there is a Bayimdagh-Tekchay oil well here, the temperature of the rocks forming the cut to the depth is taken as the basis. Water injected into the well at high pressure, penetrating the rocks and moving down, comes into contact with high-temperature rocks and is heated. The heated liquid is pumped back to the surface. The heat obtained in this way can be used in the local heating network or directly for heating resorts, industrial facilities, and greenhouses. The conversion of heat into electrical energy is possible at temperatures above approximately 80 °C using additional technologies, such as the Organic Rankine Cycle or Kalina devices [Kalina, 1984; Ibrahim, 1996]. The energy distribution map was constructed by calculating the energy potential of the dry rock mass. However, we must take into account that this is only the energy calculated for a total of 3 wells of one field and for certain depth intervals. This energy potential constitutes a very small percentage of the energy potential of the entire field (Fig. 11)

The following formula is used to calculate the amount of thermal energy stored in underground rocks and the recoverable portion of it. In other words, it determines the extractable heat by considering the heat capacity of rock and water, temperature differences, and the recovery factor:

$$H_1 = H_0 R_0 ,$$

$$H_0 = [(1-P)\rho_m c_m + \mathrm{P}\rho_{\text{water}} C_{\text{water}}] \times$$
$$\times [T_t - T_0] A \Delta Z ,$$

$$R_0 = \frac{0.33(T_t - T_r)}{T_t - T_0} ,$$

where H_0 is the heat stored in rocks; R_0 is the coefficient of recovery; T_r — water injection temperature, °C (25 °C) [Mukhtarov, 2011].

Economic efficiency. As we have mentioned, the energy obtained is suitable for direct or indirect use. If we assume that the average monthly energy consumption of a house is 150 kW, then 150/30(day)=5 kW, 5/24h=0.21 kW/h. In this case, 10278/0.21=49 (house); 14722/0.21=70 (house); 37222/0.21= =177 (house); 40000/0.21=191 (house); 92777/ 0.21=442 (house); 94166/0.21=448 (house) (Figs. 12, 13).

Thus, the energy potential calculated for the wells can meet the energy needs of a different number of houses for 1 hour.

Proposal. The territory of the republic has sufficient potential for green energy production. The transition to green energy is an important step for protecting the environment on a global scale and building a healthier future for people. By supporting green energy, governments and individuals can contribute to the harmonious development of nature and the economy.

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Оцінка енергетичного потенціалу Хизинської тектонічної зони Каспійсько-Губинського дослідницького регіону (на прикладі родовища Байимдаг-Текчай)

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У дослідженні оцінюється енергетичний потенціал Хизинської тектонічної зони в межах Каспійсько-Губинського дослідницького регіону з фокусом на родовище Байимдаг-Текчай. З огляду на зростаючу увагу Азербайджану до альтернативних джерел енергії, геотермальна енергія постає як перспективний і сталий варіант. Геотермальні ресурси регіону, переважно зосереджені у Великому і Малому Кавказі, Талишсько-Ленкоранській зоні та Кура-Аразькому басейні, залишаються маловикористаними через багаті запаси нафти в Азербайджані.

Термальні води Каспійсько-Губинського регіону були проаналізовані на основі стратиграфічних даних, геотермальних вимірювань і гідрогеологічних досліджень. Сіязанська моноклiналь як ключова тектонічна структура відокремлює різні геологічні утворення та впливає на температурні коливання з глибиною. Аналіз розподілу температур у зоні Байимдаг-Текчай виявляє взаємозв'язок між віком порід, кутами падіння та геотермальними градієнтами. Продуктивний шар, який переважно складається з конгломератів, гравію та глин, відіграє важливу роль у збереженні тепла в надрах.

Експериментальні результати свідчать про наявність значних запасів термальних вод у регіоні, що перевищують 30 000 $м^2$/добу в окремих районах, таких як Хачмаз, Худад і Набран. У дослідженні також підкреслюється потенціал повторного використання покинутих нафтових свердловин для виробництва геотермальної енергії. Вода, закачана в надра і нагріта при контакті з породами, може бути вилучена для забезпечення місцевих теплових мереж, промислових об'єктів, а також виробництва електроенергії з використанням технологій органічного циклу Ренкіна або циклу Каліни.

Економічний аналіз доцільності показує, що енергія, отримана зі свердловин у Байимдаг-Текчай, може задовольнити потреби в опаленні сотень домогосподарств. Це підкреслює важливість подальших інвестицій у геотермальну інфраструктуру з метою оптимізації вилучення енергії та підвищення сталості. Дослідження в цілому закликає до переходу на «зелену» енергію в Азербайджані, наголошуючи на ролі геотермальної енергії у зменшенні залежності від традиційних викопних палив і сприянні збереженню довкілля.

Ключові слова: геотермальна енергія, термальні параметри порід, оцінка енергетики.