RESEARCH OF THERMAL AND MINERAL WATERS FORMATION CONDITIONS IN THE AZERBAIJAN PART (KARABAKH AND NAKHCHIVAN) OF THE SOUTH CAUCASUS

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Abstract

The risk of exhausting the oil and gas resources used by the countries of the world for many years is increasing over time. Also, considering that the oil and gas sector is one of the main causes of climate change, it is necessary to move away from this type of fuel. In this case, there is a need to use alternative and renewable energy sources in the world. Addressing climate change requires a shift away from fuels such as hydrocarbons to renewable energy sources such as solar, wind, hydro and geothermal. Renewable energy sources are carbon-free and produce fewer emissions, making them an important component in reducing greenhouse gas emissions. Overall, the transition to renewable energy sources is critical to addressing climate change and ensuring a sustainable future for the planet. The favorable geographical position and climatic conditions of the Azerbaijani part of the Lesser Caucasus allow the wide use of ecologically clean alternative (renewable) energy sources. The article describes the perspective of using the thermal water deposits in the Azerbaijani part of the Lesser Caucasus as an alternative energy source. The analysis of fund and printed materials on thermal water deposits of the research area shows that the energy resources collected in this area can be considered as alternative energy and are of great importance for the future economy of the region. Studies show that the water temperature is high in the zones where the tectonic faults spread directly. As you move away from these zones, the water temperature decreases and the zones without lavas are characterized by natural outlets of cold mineral waters. Mineral water resources are also considered useful for the development of balneological, sanatorium-health complexes.

Keywords: geothermal, percent of mineralization, natural hazards, climate change, renewable energy

I. İntroduction

The Azerbaijani part of the Lesser Caucasus occupies the territory between the Kura in the northeast and the Araks rivers in the southeast and borders with the Republic of Armenia in the southwest.

The rift consists of separate blocks bounded by micro- and macro-tectonic faults with a very complex geological-tectonic structure, mineral and thermal water deposits are widespread on the micro-macro-tectonic faults at the contacts of separate rock masses [1]. There are numerous natural outlets of mineral and thermal water deposits in carbonate sandstones and clayey rocks, which are products of intrusive and effusive magmatism and have a special layering structure. For example, river valleys and terraces with complex structure, different formation features and ancient geological development history have caused the formation of fault and fault lines that have caused the fragmentation of separate geological blocks along the Lesser Caucasus

megaanticlinorium. Carbon dioxide, hydrocarbonate, chloride-hydrocarbonate-sodium type sediments are found in the Devonian, Upper Jurassic (Oxford-Kimmerian-Tithonian), Upper Cretaceous (Campanian-Maastrichtian) and Paleogene (Middle Eocene) sediments in the central part of the Lesser Caucasus, especially in the area of Nakhchivan MR, where thick carbonate rocks are accumulated mineral waters are widespread [2] (Fig. 1).

As a whole, Quaternary lavas are characterized by high-temperature thermal waters. Studies show that the water temperature is high in the zones where the tectonic faults spread directly. As you move away from these zones, the water temperature decreases and the zones without lavas are characterized by natural outlets of cold mineral waters. For example, the total discharge of natural thermal water outlets in Yukhari Istisu, Ashagi Istisu, Bagirsag and Tutkhun areas in Kalbajar region, which is characterized by volcanic eruptions that occurred in Paleogene-Neogene (Upper Eocene and Miocene) Pliocene and Anthropogenic periods in the Lesser Caucasus, is more than 100 m^3/day [3]. The consumption of individual wells dug here at a depth of 300-400 m was 300-1000 m^3/day (temperature 28-700C). It is estimated that there is a great possibility of obtaining thermal water with a temperature of 100^0C through wells with a depth of 900-1000 in these areas.

A very famous sanatorium-health complex operated during the USSR in an area rich in Istisu springs in Kalbajar region. This field is considered analogous to Karlovy Vary in Czech Republic.

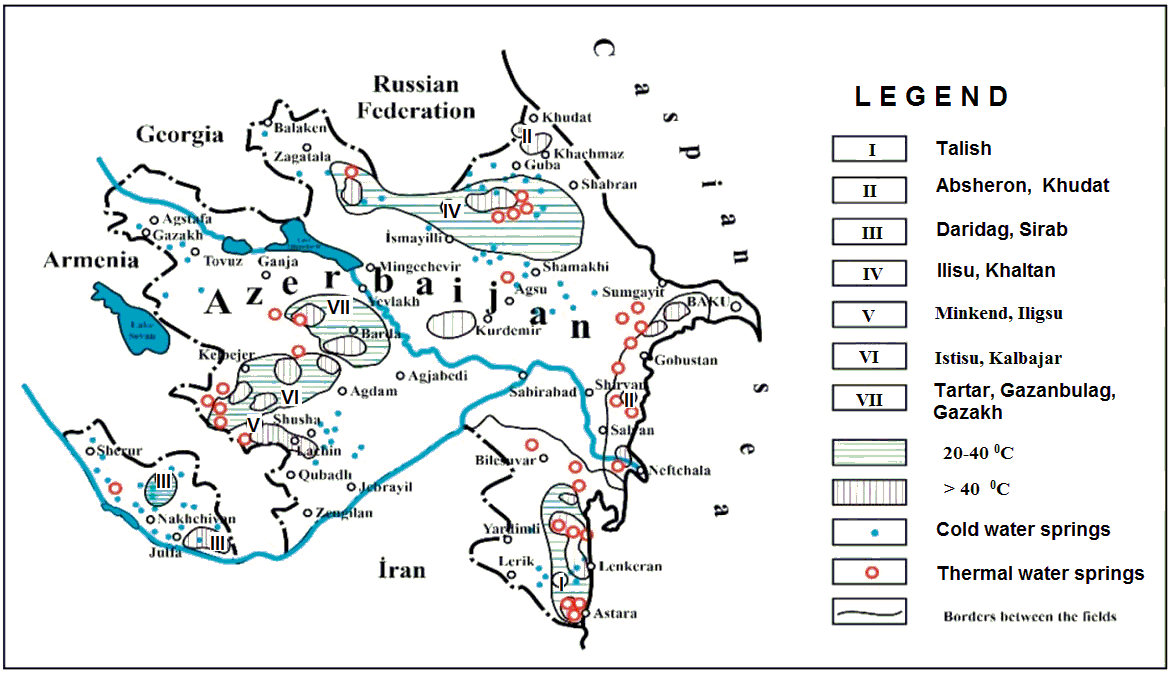

Figure 1: *Mineral-thermal waters map of Azerbaijan*

II. Methods

The amount of mineral salts contained in the mineral and thermal water deposits distributed throughout the territory of the Lesser Caucasus is much higher than that of ordinary drinking water, and these waters are rich in active chemical and specific components and gases (Table 1).

Carbon dioxide waters have great industrial and economic importance. In the territory of Azerbaijan, these waters are widespread only in the regions of the Lesser Caucasus mountain ranges and in the territory of Nakhchivan AR (Nakhajir, Istisu, Badamli, Turshsu, Daridag, etc.).

Along with Istisu and Tutkhun deposits, the Minkend-Ahmadli and Turshsu-Shirlan hydrochemical zones were studied in Kalbajar region (Fig. 2).

Table 1: *Some indicators of the main mineral and thermal water deposits distributed in the Kalbajar fold area of the Lesser Caucasus*

Name of field	Degree of mineralization, g/l	The formula of the ionic composition	Specific components	Water temperature, ^{0}C	pH	Consumption, 10^3 l/day
Gashtak	3,6-7,6	$\underline{HCO_370(SO_418)}$ Na86(Ca10)	Ba, Cu, Sr	21,0-52	7,1	50
Shaplar	2,2-2,6	$\underline{HCO_379(SO_413)}$ Na71Ca21	Ba, Cu, Sr	11,0-21,5	8,7	30
Kalbajar	4,2-6,7	$\underline{HCO_378(SO_416)}$ Na80(Ca15)	Ba, F, Cr	12,0-25,0	6,6	25
Tutkhun	4,8	$\underline{HCO_385(SO_49)}$ Na64Ca27	Ba, F, Cr	33,0	6,3	120
Turshsu	2,1	$\underline{HCO_386(Cl12)}$ Mg45Ca37	Fe^{2+}, Cu, Ni	9,5	7,0	40
Shirlan	1,3-3,3	$\underline{HCO_393(Cl7)}$ Mg68Ca29	Fe^{2+}, Zi, Ba	10,0	7,2	600
Agbulaq	3,6	$\underline{HCO_388(SO_411)}$ Ca68 Mg26	Ba, Sr	10,0	6,2	90
Ahmadli	1,6	$\underline{HCO_372Cl21}$ Na39Ca31 Mg30	Pb, Ag, Ti	47,0	5,6	300
Gushlu gaya	1,9	$\underline{HCO_352Cl41}$ Na65Mg22	Cr, Ba	16,0	5,6	30
Iligsu	1,6	$\underline{HCO_367Cl25}$ Na40Mg34Ca26	Ag, Sr	28,5	6,2	200
Nuraddin	3,6	$\underline{HCO_387(SO_413)}$ Ca65 Mg29	Fe^{2+}, Ag	18,0	6,2	150
Minkand	5,0	$\underline{HCO_366Cl27}$ Na40Mg34Ca26	Fe^{2+}, Ag	43,0	5,8	300
Saloglu	4,4	$\underline{HCO_354SO_437}$ Ca45Na37	Ba, Mn, Cr	14,0	8,2	10
Salahli	5,9	$\underline{Cl79HCO_321}$ Ca45Na33Mg22	Ba, Pb, Cu	50,0	8,1	21
Kazımli	1,2	$\underline{HCO_391(SO_49)}$ Na46Ca40	Ba, Ti, Ni	12,5	5,6	11
Shinikh	1,1	$\underline{HCO_397(SO_43)}$ Na47Ca48	Ba, Ti, Sr	7,0	5,8	10
Slavyanka	2,7	$\underline{HCO_379(SO_418)}$ Na45Ca32Mg23	Fe^{2+}, Br, J, HBO_2	12,5	7,6	30

Since the mineral water group of the intestinal area comes out through the granitoids, their contents are enriched with radium element, and their radioactivity gradually decreases as they move away from the dykes [4].

The above-mentioned Tutkhun mineral water field is characterized by a large amount of carbon dioxide mineral water outlets in the Tutkhun river valley (Gotursu, Garasu, Mozchay, Galatalig, Zulfugarli, Oruclu water groups) [5,6,7].

In general, in this zone, the Cenomanian tuffogenic-clastic rocks, characterized by conglomerate and tuffaceous sandstones, are considered more watery. Limestones and andesites (Eocene age) with vertical cracks, which create infiltration conditions, play the main role in ensuring the hydration of these rocks [8,9,10].

Turshsu-Shirlan zone is one of the most interesting mineral water deposits in the Lesser Caucasus. These deposits were discovered in the deep valleys of Gargarchay River (Turshsu) and Khalfalichai River (Shirlan) 16 km from Shusha region. Here, as a result of the Middle Jurassic volcanogenic layer sliding over the sediments characterized by lower Cretaceous shaly sandstones and crushing them, it created conditions for the formation and movement of mineral waters.

Figure 2: *Mineral-thermal water outlet in Kalbajar*

The mineral water deposits distributed in the Nakhchivan fold area of the Lesser Caucasus are divided into hydrochemical zones along 3 lines.

A number of mineral water deposits (Badamli, Vaykhir, Sirab, etc.) were studied along the 1st line. Badamli and Sirab mineral water sources are closely related to rocks characterized by Upper Cretaceous, Paleocene and Eocene age marls, sandstones, conglomerates, andesite and their tuffs and tufobreccias. The chemical composition of mineral waters is hydrocarbonate-chlorine-sodium.

The 2nd line of mineral waters of the territory passes through the border zone with Armenia in the southwest direction of Nakhchivan. In this zone, there is a zone of tectonic tension accompanied by fractures, cracks and disjunctive dislocations.

The 3rd line of mineral water sources of the area passes through Daridag water sources. These water sources are collected in a large anticlinal fold zone extending in the northwest direction in connection with the Upper Cretaceous and Eocene marly-sandstone rocks. The mineral waters of this zone are chlorinated-hydrocarbonate-sodium based on their chemical composition.

In total, there are more than 200 natural mineral water springs in the area of Nakhchivan folds. The mineral water deposits of this area resemble a hydrochemical museum with their diversity (Table 2).

When the mineral waters of the Lesser Caucasus come to the surface, they form many sediments in various forms (argonite, stalatite, stamite, etc.). For example, argonites formed in the area of Sirab village in Babak district of Nakhchivan are used as an excellent type of marble.

"Daridag" mineral water deposits in Julfa region are used to buy CO_2.

There are 2 types of mineral water in the "Sirab" mineral water field:

1. "Barjomi" type waters; operational reserve is more than 200000 l/day.
2. "Narzan" type waters; operational reserve is more than 500000 l/day.

Table 2: *Some indicators of natural water outlets of the main mineral and thermal water deposits distributed in the Nakhchivan fold area of the Lesser Caucasus*

Name of field	Gas composition	Degree of mineralization, g/l	The formula of the ionic composition	Specific components	Water T, ^{0}C	pH	Consumption, 10^3 l/day
Shakhtakhti	H_2S	2,8	$\underline{SO_4 67(HCO_3 10)}$ Ca58Na30	H_2S+HS	21,0	6,2	70
Bakharsu	CO_2	3,9	$\underline{HCO_3 86(Cl11)}$ Mg62Na36	H_2SiO_3	18,0	6,9	150
Sharur	CO_2	4,4	$\underline{HCO_3 75Cl21}$	-	18,0	7,5	900

			Mg58Na41				
Bashnorashen	H_2S	5,8	$\underline{SO_4 79Cl21}$ Ca66Na32	H_2S+HS	19,5	6,3	500
Gushchu	CO_2	4,1	$\underline{HCO_3 58Cl37}$ Mg65Na29	-	16,8	6,7	300
Dahna	CO_2	6,9	$\underline{SO_4 50Cl29HCO_3 21}$ Na47Ca31Mg22	H_2SiO_3	17,5	6,9	150
Gomur	CO_2	3,2	$\underline{HCO_3 76(SO_4 17)}$ Ca45Na33Mg22	H_2SiO_3	16,0	6,4	150
Badamlı	CO_2	2,1-3,2	$\underline{HCO_3 74(Cl17)}$ Na23Ca37Mg21	As, Cu, Zn, F, Br, J, Pb	16,0-20,5	6,4	50
Sirab I	CO_2	6,6	$\underline{HCO_3 72(Cl18)}$ (Na+K)60Ca32	As, Cu, Ni, Fe^{2+}, Br, J	24,2	6,4	1330
Sirab II	CO_2	29,0	$\underline{Cl54HCO_3 45}$ (Na+K)94(Mg3)	Cu, As, Cd, Ni, Br, J, Fe^{2+}	28,0	6,9	150
Sirab III	CO_2	2,6	$\underline{HCO_3 78(SO_4 17)}$ Ca56(Na+K)25	Ni, Cu, Br	20,0	6,4	180
Vaykhir I	CO_2	6,1	$\underline{HCO_3 53Cl39}$ (Na+K)60Ca30	As, Br, J, Fe^{2+}	22,0	6,5	125
Vaykhir II	CO_2	31,8	$\underline{Cl63HCO_3 32}$ (Na+K)93(Mg5)	As, Cu, Zn, Fe^{2+}, Br, J	20,4	6,5	175
Vaykhir III	CO_2	4,6	$\underline{HCO_3 75(SO_4 14)}$ (Na+K)61	As, Cu, Fe^{2+}, Br, J	30,1	6,5	280
Kalbagil	CO_2	3,4	$\underline{HCO_3 80(SO_4 15)}$ Ca48Na37	Cu, Fe^{2+}, Br, J	20,0	6,4	2000
Gakhab	CO_2	6,2	$\underline{HCO_3 35SO_4 33Cl32}$ Na61Ca26	Cu, Zn, Rn, Br	22,0	6,8	900
Gizilvank	CO_2	5,7	$\underline{SO_4 71Cl22}$ Na40Mg31Ca29	Fe^{2+}, Br, J	16,0	7,7	300
Ahangagil	CO_2	3,9	$\underline{HCO_3 46Cl41}$ Na76(Ca15)	Fe^{2+}, Br, J	20,0	6,3	110
Daridag	Co_2	21,1	$\underline{Cl64HCO_3 29}$ (Na+K)92(Ca5)	As, Ni, Pb, Zn, Br	40,0	6,6	922
Daridag	CO_2	19,5	$\underline{SO_4 58Cl30}$ (Na+K)69Mg30	As, Pb, Br, J, Zn, Cu	42,0	6,4	2800
Daridag	CO_2	1,5	$\underline{HCO_3 42SO_4 35Cl23}$ (Na+K)45Mg29Ca25	As, Pb, Br, J, Zn	52,0	6,5	835
Nakhajir	CO_2	5,5	$\underline{Cl56HCO_3 38}$ Na91(Ca8)	Fe^{2+}, Br	17,0	6,5	200
Cuga	CO_2	4,2	$\underline{HCO_3 57SO_4 36}$ Ca47Mg28Na25	Fe^{2+}, Br, Ni	14,0	6,1	300
Lokotak	CO_2	1,6	$\underline{HCO_3 92(SO_4 6)}$ Ca76Mg21	Cu, Co, Ni	13,0	6,5	700
Aravsa	CO_2	4,3	$\underline{HCO_3 87(SO_4 11)}$ Na57Ca22Mg21	Mn, Cu, Br	14,5	6,3	250
Bashkand	CO_2	2,9	$\underline{HCO_3 85(SO_4 11)}$ Ca50 Na26Mg24	Ni, Cu, Br	16,0	7,6	100
Gevi	CO_2	2,6	$\underline{HCO_3 79(SO_4 11)}$ Ca58Na38	Ni, Pb, Zn	11,5	6,6	90
Darasham	CO_2	3,3	$\underline{Cl41SO_4 38HCO_3 21}$ Na40Ca38Mg22	Pb, Br, J	23,0	6,6	55
Coshgun	CO_2	3,4	$\underline{HCO_3 76(SO_4 16)}$ Na45Ca41	J, Br, Zn	18,0	6,4	75
Teyvaz	CO_2	7,6	$\underline{HCO_3 67Cl21}$ Na65Ca22	Ni, Pb, Br	21,0	6,2	50

Khoshkeshen	CO_2	5,6	$\underline{Cl38HCO_335\ SO_427}$ Na78(Mg15)	Pb, Zn. J, Br	29,0	6,1	35
Saldash	CO_2	4,1	$\underline{HCO_384(SO_410)}$ Ca36Na35Mg29	Ni, Pb, Zn	14,8	6,4	50
Gulustan	CO_2	3,4	$\underline{HCO_377(Cl16)}$ Na38Ca37Mg25	Ni, Zn, Br	21,0	6,4	28
Nasirvaz	CO_2	1,5	$\underline{HCO_368SO_424}$ Ca36Na35Mg29	Ni, Fe	14,3	6,1	350
Katam	CO_2	1,9	$\underline{HCO_391(SO_46)}$ Ca85(Mg9)	Cu, Ca, Ni	14,5	7,7	250
Tivi	CO_2	4,4	$\underline{HCO_376(SO_415)}$ Ca55Mg33	Ni, Mn, Br	10,0	5,7	200
Paraga	CO_2	1,7	$\underline{SO_487(HCO_311)}$ Ca77Mg22	Ni, Cu, Br	16,5	6,6	120

In the Ordubad region of Nakhchivan, the Ordubad-Araz hydrochemical zone passes along the axis of the anticlinal uplift, around the fault zone and through the outer part of the intrusive.

The main mineral water deposits are:

1. The natural mineral water outlet in the Dasta area comes out of the gravel and gravel sediments on the ground. These waters belong to the Narzan type, the chemical composition belongs to the hydrocarbonate-sulfate-calcium type. Water discharge is 5000 l/day, water temperature is 19 ^{0}C, mineralization rate is 1.4 g/l, carbon dioxide (CO_2). Among the specific components – Ni, Pb, Zn were determined in the water. An exploratory exploitation well with a depth of 395 m was dug in this area. Mineral water-bearing rocks consist of fissured sandstones. The flow rate of the well is 300000 l/water, the degree of mineralization is 18.2 g/l, the chemical composition is chlorinated-hydrocarbonate-sodium, Fe (iron) and Br (bromine) have been determined in the water as specific components.

2. The Nasirvaz area spring emerges from small-grained Cognac-Sectonian sandstones. The discharge of the spring is 350,000 l/day, the degree of mineralization is 1.5 g/l, the water temperature is 14.3 0C, specific components Ni and Fe are determined in its content, it is carbon dioxide.

3. The Ketam area has a natural mineral water outlet, which comes out of the Cretaceous sandy-marly, calcareous sediments. The flow rate of the water is 250 thousand l/day, the degree of mineralization is 1.9 g/l, the chemical composition of the water is hydrocarbonate-sulfate-calcium, it contains Cu, Ni.

4. The Tivi area consists of an alternation of chalky marly, sandy, and limestone rocks. The flow of water is 200,000 l/day, the temperature is 100C, it belongs to carbon dioxide, hydrocarbonate-sulphate-calcium type.

5. Paraga emerges from the delluvial sediments to the earth's surface. Water discharge is 120 thousand l/day, mineralization rate is 1.7 g/l, water temperature is 16.5 ^{0}C. It contains specific components such as nickel, copper, and bromine. The chemical composition is sulfate-hydrocarbonate-calcium.

6. The flow of water in Alyagi area is 80000 l/day, it comes from delluvial sediments, the degree of mineralization of water is 3.6 g/l, the temperature is 19.5^{0}C with carbon dioxide, and the chemical composition belongs to the hydrocarbonate-sulfate-sodium type. Specific components of water include iron and bromine.

7. The flow of water in the Belav area is 40 thousand l/day, the temperature is 18.5 ^{0}C, the degree of mineralization is 2 g/l, and the chemical composition belongs to the hydrocarbonate-sulfate-sodium type. Among the specific components, water contains copper, bromine, iodine and carbon dioxide.

8. Bist area - delluvial sediments, water discharge 25 thousand l/day, water temperature 180C, mineralization rate 3.9 g/l, chemical composition belongs to hydrocarbonate-sulfate-calcium type. Carbon is gaseous, it contains copper, bromine and iodine as specific components.

9. Specimen area - delluvial sediments, water discharge 10 thousand l/water, mineralization rate 0.8 g/l, refers to carbon dioxide, hydrocarbonate-sulphate-calcium waters. Specific components of water include nickel, copper, and bromine.

10. Geyenza area - delluvial sediments, water discharge 12 thousand l/day, mineralization rate 5.6 g/l, carbon dioxide, water temperature 15 ^{0}C. Specific components of water include nickel and bromine.

III. Results

During the long geological period, mountain folding of the Lesser Caucasus, which continued with varying intensity in connection with the Alpine folding in the Caucasus, occupied a large area and participated in the formation of geochemical and geothermal characteristics of the geostructural zones on the right bank of the Kura basin. The Lesser Caucasus mega-anticlinorium has complex geological-tectonic conditions characterized by alternation of carbonate, sandstone and clayey rocks and tectonic faults, which are products of intrusive and effusive magmatism.

Analysis of geological materials shows that carbonic acid (H_2CO_3) acts on layers above magma, turning them into carbonate rocks. Free sulfuric acid is formed when sulfides, especially pyrite, are oxidized. That acid chemically reacts with limestone and other rocks to convert carbonates into sulfates. Carbon dioxide (CO_2) is compressed and remains free, and in some cases dissolved in water.

Due to the constant interaction with the mountain rocks in the research object, the degree of mineralization of the waters increases as a result of the dissolution of the rocks and the reaction of individual particles. The degree of mineralization is formed depending on the lithological composition of the rocks, the temperature and pressure of the substance in which the water moves.

Effective use of mineral and thermal water deposits of the Lesser Caucasus has been highly appreciated, especially in the Istisu, Tutkhun, Minkend, Ahmadli hydrothermal zones, according to the results of the search and exploration works conducted in these regions. The temperature of thermal waters in these zones is 54-74 ^{0}C, the total mineralization rate ranges from 4.2-7.9 g/l, and their chemical composition belongs to the hydrocarbonate-chlorine-sulfate type.

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