# Re-Assessment of the Geothermal Potential of Tbilisi Region: The Hydrodynamic Digital Model Project

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**Abstract:** Owing to its geological location, Georgia has considerable resources of middle and low temperature thermal water (33 – 108 ºC) that presently are only for heat supply. Most of the geothermal wells are middle depth and non-operating. On the other hand the economic development of the country relies to a great extent to energy production. Geothermal potential of Georgia exhibits a promising resource that might be available for energy production. This requires an extensive study to re-assess the geothermal potential of the country. Several projects were implemented and some others are underway to achieve this purpose. This paper summarizes the geothermal potential of Georgia based on existing data and outlines one of the major projects that have already been implemented to assess the potential of Tbilisi geothermal field using the hydrodynamic digital modeling approach.

**Keywords**: energy, hydrodynamic digital model, geothermal resources, Georgia, Tbilisi

## 1. Introduction

Taking into account the world-wide spread energy crisis, search and rational use of cheap and ecologically pollution-free renewable energy sources is extremely important. Among these sources earth depth heat is a noted subject with great potentialities. The renewable sources that are already in use in Georgia for power generation are hydropower plants and to a lesser extent wind plants. The use of geothermal and biomass is limited to heat generation while solar energy is not used at all. Georgia has a high potential of geothermal sources, some have been in use since ancient times. The major areas of utilization are balneologic resorts, local heating systems, processing industry and greenhouse. Searching and boring researches carried out in the 70s of the last century and conducted up-to-date, revealed that Georgia abounds in geothermal resources, concentrated in 44 deposits (thermal waters of Georgia). According to preliminary estimations, their heat power is 420 megawatts, and elaboration of thermal energy is maximum 2.7 million megawatt/hour/year. However, the most of the existing 50 geothermal wells in Georgia are of medium depth and supply water at temperatures ranging between 40 to 60 °C. It also should be noted that most of these wells are non-operational. None of the wells are used for power generation. The Georgian energy sector uses only 730,000 $m^3$ per annum of the geothermal water mainly to supply hot water to the Saburtalo district of Tbilisi while other systems are damaged or remain in testing stage [1]. Therefore, a re-assessment of the geothermal potential of Georgia is of major importance from the standpoint of economic development of the country based upon renewable, ecological cleaner energy source.

## 2. Regional Geography and Geology

Georgia is a country in the Caucasus region of Eurasia. Situated at the juncture of Western Asia and Eastern it is bounded to the west by the Black Sea, to the north by Russia to the south by Turkey and Armenia, and to the east by Azerbaijan. Georgia covers a territory of 69,700 ka². The climate in Georgia varies significantly, and ranges from subtropical conditions on the Black Sea coast to continental with cold winters and hot summers in the east. The cold air from the north is prevented by the Greater Caucasus range. On the other hand, warm and moist air from the Black sea moves into the coastal lowlands, where the annual precipitation ranges between 1000 and 2000 mm, often exceeds 2000 mm on the coast, whereas the eastern part receives precipitation between 400 and 1600 mm during spring and autumn. The mean temperature in winter is 5 °C and in summer 22 °C [1].

Geologically, the territory of the Republic of Georgia is located in the Central and Western parts of the Trans-Caucasus and lies between the Euro-Asiatic and Afro-Arabian plates. This area marks the junction of the European and Asiatic branches of the Mediterranean, also known as the Alpine-Himalayan fold belt. The geologic evolution of Georgia is controlled, to a great extent, by the development of the whole Caucasus segment of the Mediterranean belt. The present structure of the ophiolithic rock associations suggests that several oceanic basins were generated and developed during the period between the Precambrian and early Mesozoic as a consequence of the horizontal movements of the ancient East European and African platforms, and some certain litho-stratigraphic plates within the Mediterranean belt [2]. Apart from the Precambrian and Paleozoic formations that cover a smaller area, Mesozoic and Cenozoic rock assemblages mainly build up the geological structure of Georgia. Three major tectonic units can be distinguished according to the geologic evolution of Georgia: 1) Fold system of the Greater Caucasus which represents a marginal sea in the geological past, 2) Trans-Caucasus inter-mountain area which marks the northern part of the Trans-Caucasus island arc, 3) Fold system of the Lesser Caucasus, the southern part of the ancient Trans-Caucasus island arc. Closely related to the geological evolution, Georgia whose about two third of territory is occupied by mountains is characterized by rough topography. The country lies between the Greater Caucasus in the north and the Lesser Caucasus range in the south. The intermountain area that extends between these two mountain ranges is divided by the Likhi ridge into the Kolkheti (Rioni) and Lueria (Kura) lowlands. The Meskheti and Trialeti ridges together with the volcanic highlands in the south make up the major geographic units in Georgia.

## 3. Geothermal Regions of Georgia

Owing to the high geothermal potential in the South Caucasus and particularly in Georgia, a confirmed total reserves of 90,000 $m^3$/day, corresponding to a heat potential of 500,000 tones of equivalent fuel annually, has been recorded [3]. The amount of thermal flow for the main parts of Georgia can be listed as follows: 1) The south flank of Caucasus Mountains - 100 $mWm^{-2}$; 2) Plate of Georgia; a) For the west zone 40 $mWm^{-2}$ b) for the east zone 30$mWm^{-2}$; 3) Adjara-Trialeti folded system a) Central part 90 $mWm^{-2}$ b) the east zone 50 $mWm^{-2}$ ; 4) Artvin- Bolnisi platform 60 $mWm^{-2}$. Figure 1 shows the main geothermal fields in western Georgia where the reservoir formations are fractured karstic limestone’s of the Upper Cretaceous in the sedimentary trough and at the southeast where the reservoir formations are volcanic and sandstones of Paleocene-Middle Eocene in the fold system. Thus we see the following pattern in the distribution of heat flow: the maximum heat flow is observed for the central zone of folded part of Georgia and the minimum for the plate. As to heat flow for Adjara-Trialeti folded system, is characterized by the middle range. The temperature condition of Paleocene- middle Eocene thermal water bearing complex is better investigated for Tbilisi region. This investigation revealed that temperature condition of this complex is influenced by depth of lay of high thermal resistivity upper Eocene rocks as well as their thickness. From the surface of Volcanic-sediment formation of middle Eocene the temperature of rocks increases to all direction from 20 $^0$ C till 100$^0$C. To the north-east the increase of temperature is less then to other direction because of nearness of the plate. On the contact of Cretaceous – Eocene temperature has remarkable variation: to the farthest west, where upper Cretaceous is raised till 500 m. we have temperature variation from 100 till 160 $^0$C, when to the North and East, where the Cretaceous deeps till 600 m we have temperature about 240 $^0$C.

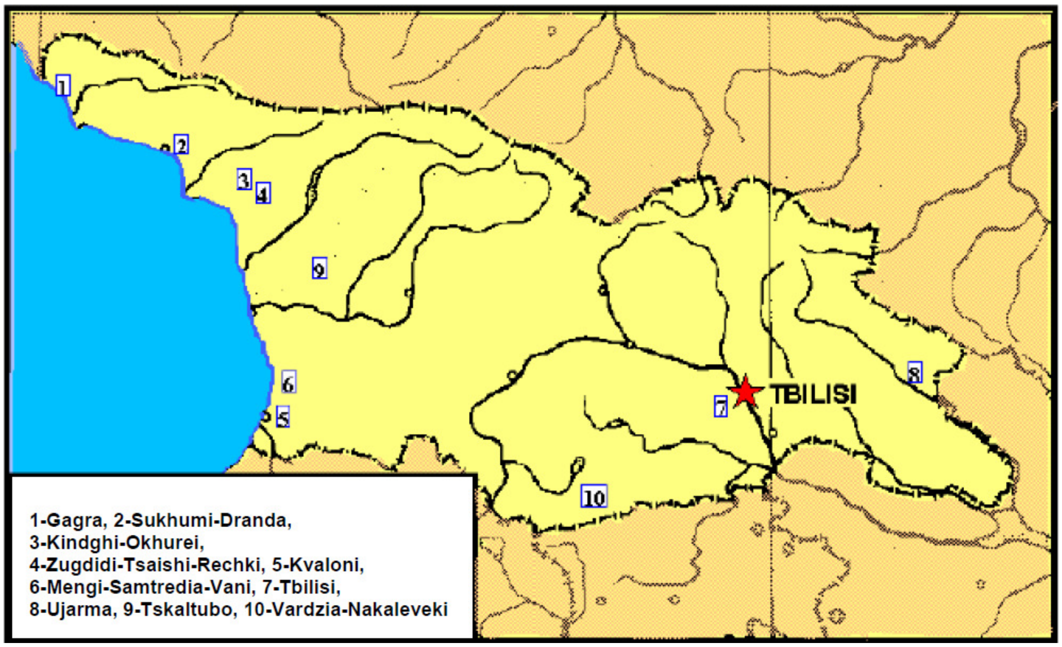


Figure 1. Main geothermal fields in Georgia (from [1])

Complete development of this energy will allow to save up to 500 000 tons of conventional fuel (TCF) per year and reduce $CO_2$ emission level in the atmosphere by 1.22 million tons. Launching the rational regime of deposits exploitation recommended in this proposal may considerably increase these parameters. If we take into account that Georgia has no organic fuel resources of its own and after the 90s political collisions, the country's heat supply system has been completely destroyed, it will be clear how important it is to develop local renewable resources. To connect the cheap and ecologically clean geothermal energy to the country's common heat and cold supply system, it is necessary to calculate geothermal resources, the thickness and the potentialities of individual deposits, to introduce up-to-date progressive technologies and to chart rational schemes.

**4. Specificities of Tbilisi Geothermal Field**

Thermal mineral waters (sulppur springs) of Tbilisi hydrothermal field, were of great importance during the 15- century history of city. The word TBILI means worm and because of that Tbilisi-worm waters was built this city as well as the name was given. The waters are hot, 40.50$^0$ C and due to the presence of suppurated hydrogen, have healing properties; now days a balneal resort based on this springs. Drilling on the site on the north- west part of Tbilisi hydrothermal field, reveals sulphur-hydrogen thermal water with the temperature 62-70$^0$C. At 30 km to the north-east from, the oil field has been revealed. The intensive oil production disturbs the regime of the central hydrothermal deposit and causes decreasing and desalination of spring in 80- s. Later, after stopping of intensive extraction, the regime of hydrothermal field was recovered. Besides, some disturbances of water level were discovered before and after local seismic events. Thus, it is evident that the regime of thermal waters is subjected to the influence of many factors: exogenous (precipitation, atmospheric pressure, tides) and the endogenous (earthquakes, creep, tectonic strain, oil production) impacts. Comparison of responses of these impacts can be used for the revealing the degree of interconnectivity of aquifers in various parts of THF in order to design the numerical hydrogeological model and to find optimal conditions for sustainable exploration of thermal waters and oil. From the geological point of view the region belongs to the Sartichala sup-zone of Ajara-Trialeti folded system of the Lesser Caucasus. This is delineated by the seismoactive tectonic faults. A geological map showing the main tectonic units along with the major faults of the eastern part of the Ajara-Trialeti area is depicted in Figure 2. From the North, South and East the region is delineated by deep fault and one fault that is still disputable, crosses the center of the city, following the valley of the river Mtkvari Kura, The destructive Tbilisi earthquake of M=4.5 is very probably generated by that fault. The most part of underground waters in Tbilisi, as it was mentioned above, are thermal. Structural and hydrogeological data allow to single out two main units of THF: Saburtalo and Tbilisi central thermal water basins. The operations at the Sartichala-Teleti oil field also affect the thermal water regime.

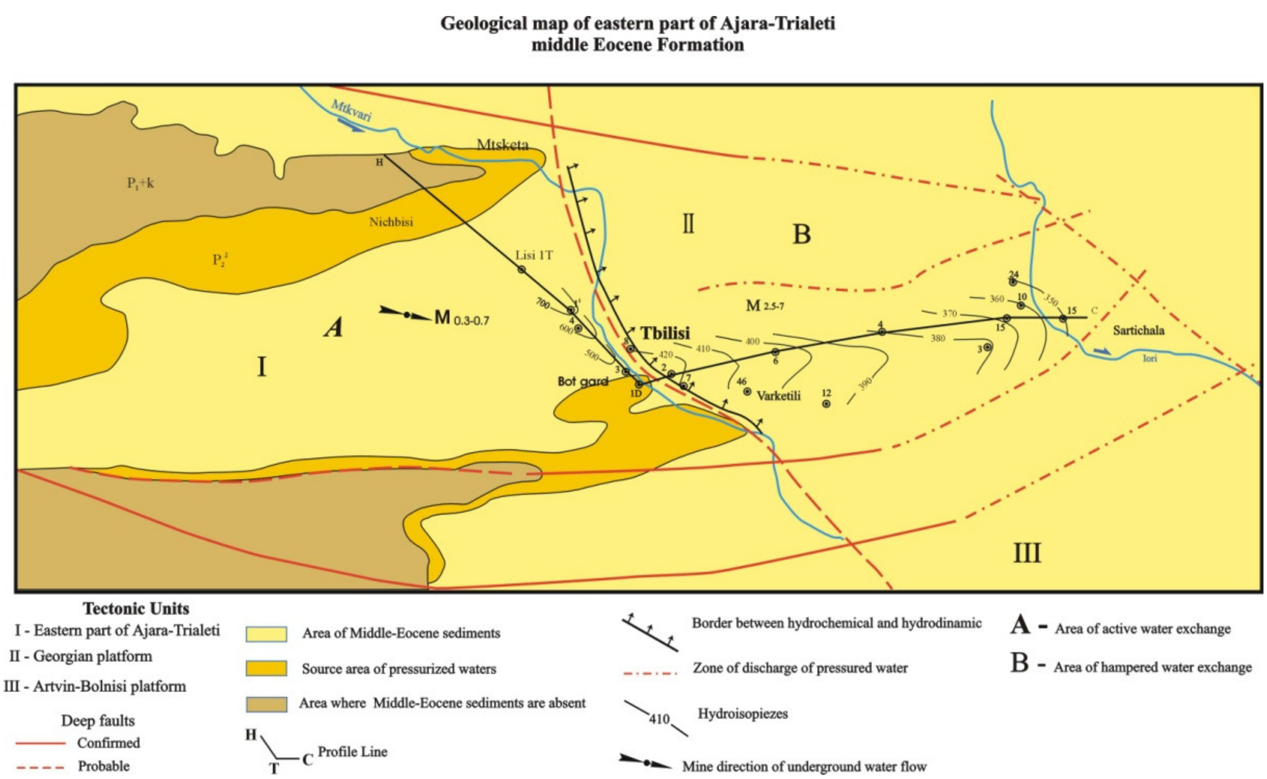


Figure 2. Geological map of the eastern part of the Alajara-Trialeti middle Eocene Formation

## 5. The Hydrodynamic Digital Model of Tbilisi Thermal Region and Regularities of Thermal Field Distribution Project

Urban centre Tbilisi is of a particular importance with its multilateral and dimensioned consumer existence, thermal waters resources, unlimited perspective of development and 1.5 million populations. Tbilisi thermal waters' deposit as a result of historical and research works' chronology, conditionally has been divided in 3 exploitation sections: central or balneology resort and baths section, Lisi-Saburtalo section and Samgori-Sartichala oil section which is related to the same Middle Eocene thermal water horizon, unlike two previous ones. Up-to-date hydrodynamical relations on these 3 regions (Lisi, Central and Oil) are not entirely investigated, and it is impossible to conduct ecologically and rationally proved exploitation of balneological and thermal waters without detailed regime monitoring. Use of heat energy of ground hydrothermal resources for therapeutic and heating aims is traditional worldwide, although detailed research into hydrodynamical and hydrochemical characteristics of this area is significant. Commonly, for such hydrothermal resource three dimensional model construction not only hydrodynamical, but also thermal features are used. It is considered, that three dimensional digital modeling, hydrodynamical and thermal gradients' selection is of big importance for estimating low thermal-consisting hydrothermal pools' proper regime and ecologically proved exportation conditions determination. At the same time, not having geothermal anomalies, during ground water hydrodynamical regime modeling, three dimensional model is often substituted for more simple two dimensional one. It does not include hyrothermal pools, where existing strains determine ground water flow nourishment and its movement conditions. As a rule, in such environment, ground water flow is related not only to the hydrodynamical gradient, but to the temperature gradients as well, which can govern density changes in the flow and its movement. Pool's geological peculiarities are anticipated. The modeling studies will utilize data obtained and to be obtained from boreholes. Locations and related information of boreholes under observation and those to be observed in the future are given in Figure 3 and Table 1 respectively.

Table 1. Some basic information on boreholes in Saburtalo, Tbilisi central and Oil thermal water fields

| # of borehole | Depth of horizon | Age of rock | Q $m^3$ /day | $^0C$ | P kg./$sm^2$ | Mineral developm ent | Notice |
|---|---|---|---|---|---|---|---|
| 3-tech. | 3075-3286 | P | 86 | 33 | - | 0.44 | det.1978 |
| 4-tech. | 1050-2685 | P | 680 | 70 | 13.1 | 0.22 | 16.09.90 |
| 5-tech. | 1086-1878 | P | 3400 | 62 | 2.87 | 0.28 | - " - |
| 6-tech. | 1921-2771 | P | 340 | 66 | 24.1 | 0.41 | - " - |
| 7-tech. | 2118-3702 | P | 425 | 62 | 4.16 | 0.30 | - " - |
| 8-tech. | 1740-2529 | P | 155 | 46 | 5.20 | 0.35 | -" - |
| 1-sab. | 2140-2867 | P | 370 | 66 | 16.28 | 0.25 | -" - |

Up to present, thermal waters in Georgia has been used in a primitive way: the well → consumer → sewerage. The changes of the deposits' hydrodynamic parameters have not been monitored in time.

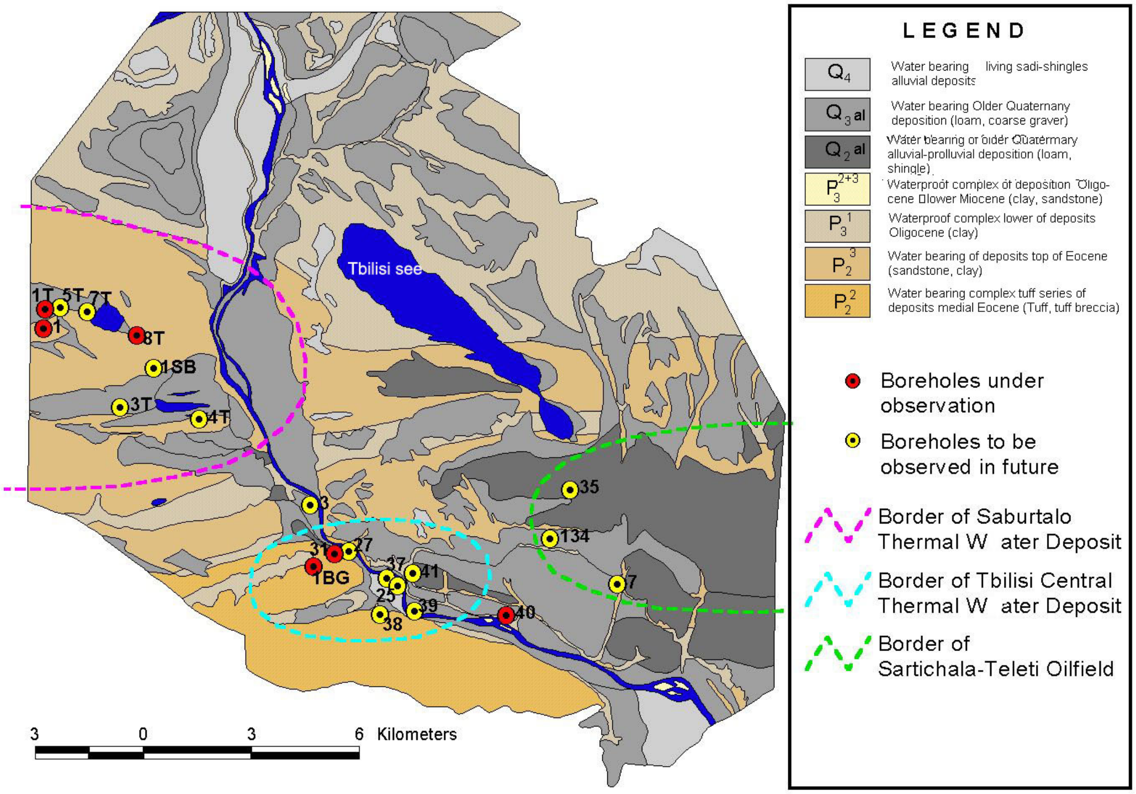


Figure 3. Location map of observation boreholes in Saburtalo, Tbilisi central and Oil thermal water fields

This has resulted decrease of single wells’ flow and in some cases, artificial increase of one section exploitation, affected the second section and the deposits stopped existing. Wells’ exploitation regime and researches of wells’ and sections’ hydrodynamical interactions are not monitored, that effects in a negative way on exploitation conditions. To preserve pressure in the water-bearing horizon and to prolong the deposit’s life, the world practice is pumping the wastewater into the layer (reinjection). Thereby, an artificial geothermal circulation system (GCS) is created.

In order to organize Geothermal Circulation System in Tbilisi area prepared the current project “Hydrodinamical Digital Model of Tbilisi Thermal region and Regularities of thermal field distribution” will be able to give more detailed and complete information about Tbilisi Thermal field. The Goals and Objectives of Research are: 1-Creation of the region hydrodynamical model; 2-Determination of interactions between separate regions; 3- Estimation of thermal water supply using computer program; 3-Work out scientifically based rational regime taking into account the water re-flow (reinjection). This will protect the deposit from extinction and prolong its usage within indeterminate term. The substitution of city traditional water supply for the geothermal one will considerably reduce $CO_2$ emission and preserve the city and its recreation zones from pollution. 4-Starting of thermal waters hydrodynamical and micro temperature monitoring. Thereby, digital model development of pool is a significant stage of research plan, which aims study of Tbilisi section using geological, hydrogeological and geophysical methods.

Realization of objectives and demands accomplishment of tasks as follows:

1. Study of lithologic composition, geological construction of water bearing horizon and creation of the database
2. Hydrodynamical and hydrochemical regime determination with organization of multi parametrical monitoring
3. Study of Tbilisi thermal field
4. Determination of hydrodynamical parameters (filtration coefficient, water loss etc.)
5. Determination of the investigation regions' boundary conditions and creation of a conception model
6. Implementation of digital modeling in order to determine origin of interactions between separate wells and sections and estimate thermal water supply
7. Establishment of recommendations for ecologically proved Tbilisi deposit exploitation

There are serious prerequisites for the successful implementation of the project: in the field of Tbilisi thermal waters deposit research has been obtained a great amount of facts that should be processed and analyzed at the present-day level. This project will be completed in December 2009.

## 6. Need For Further Research and Future Projects

There is prepared another project. The region of our interest is thermal waters of the west Georgia, Zugdidi-Tsaishi region. The goals of the project are: to avert the depletion of producing geothermal fields in Georgia and to prolong their life for a long time by substituting the traditional fuel for the geothermal one. To preserve pressure in the water-bearing aquifer and to prolong the field's life, the world practice has been pumping wastewater back underground (re-injection). Thereby, an artificial geothermal circulation system (GCS) is created. To create GCS, it is necessary to know hydrodynamic parameters of the wells and aquifers. The project provides for calculations of parameters needed for creating GCS using mathematical modelling and for determining scientifically rational operation regime for geothermal fields in the Zugdidi-Tsaishi area.

Among the thermal deposits available in Georgia, Zugdidi-Tsaishi deposit is of special importance due to its numerous exploitation and reinjection wells, considerable amount of tapped resources, favourable conditions and numerous consumers. The history of using thermal waters as a source of energy in Georgia also begins in this region. In 1951 the trust "Saknahshirdzieba" drilled Well #1 in the Tsaishi area. A water with temperature $82^0$C tapped by the well was used for heating a small greenhouse. In 1963-1973 a 3728m deep well #1-on and 2400 m deep well #3 were drilled in the same area of the village of Tsaishi to explore for oil and gas. They tapped thermal water. From 1979 the "Sakburggethermy" began prospecting the Zugdidi-Tsaishi deposit. By 1992 18 wells were drilled there. (See the Catalogue). From the depth of 1272-2820m water with temperature $83^0$-$98^0$C welled up from the Lower Cretaceous intensively fractured, karsted limestones and dolomites. The explorations allowed to establish that the above mentioned thermal aquifer favourable within the deposit as the Senaki-Tsaishi tectonic fracture has been ruptured by a 1500m amplitude and that there is no favourable c connection between its up-thrown and downthrown sides. The wells drilled in the up-thrown side are relatively shallow (1272-2661m) and consequently, waters tapped here are characterized by low mineralization (0,87 g/L-1,6 g/L) and temperature ($82^0$C-$90^0$C). In the downthrown side the water is of relatively high mineralization (2,4 g/L) and temperature ($95^0$C – $98^0$C). In 1984 operational reserves were confirmed in the amount of 14300 $m^3$/day on the basis of general exploration of the wells (1-on, 1-T, 2-T, 8-T) drilled on the up-thrown side. Later additional thermal water reserves were tapped by numerous wells drilled both on the up-thrown and downthrown sides of the thermal aquifer. In Zugdidi region, until political collisions in 1991-1992, communal sector of the city (newly constructed blocks of flats, hospital, schools), agricultural enterprises (poultry and animal farms, tea factory), and famous Tsaishi resort for thermal and healing pools were heating with geothermal water and supplied with hot water. Owing to the abovementioned political situation, geothermal industry was completely destroyed. Nowadays, boreholes are repaired and are in observatory and exploitation condition. To rationally use a geothermal potential of the Zugdidi will be tested the boreholes which are located as follows: production - #2-T and #3-T Zugdidi. In the former water temperature is $86^0$C and discharge 117 $m^3$/h and in the latter water temperature is $97^0$C and discharge 125$m^3$/h. And reinjection boreholes - #24-T and #31-T. To connect the cheap and ecologically clean geothermal energy to the country’s common heat and cold supply system, it is necessary to calculate geothermal resources, the thickness and the potentialities of individual deposits, to introduce up-to-date progressive technologies and to chart rational schemes, which can be carried out basing on the proposed project.

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