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The hydrogeothermal potential of the Vardar zone and Serbo-Macedonian mass and energetical valorization of the available geothermal resources at the territory of the Republic of Macedonia

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ABSTRACT

The hydrogeothermal explorations in the Republic of Macedonia intensively started to conduct after 1970, after the first effects of the energy crisis. As a result of these explorations, more than 50 springs mineral and thermomineral waters with a total yield of more than 1000 l/sec., were registered, and proved exploatation reservoirs with temperatures higher than the medium year seasons hesitations for this part of the Earth in boundaries of 20 - 79°C, with significant quantities of geothermal energy.

This paper will shortly present the hydrogeothermal potential of the Vardar zone and Serbo-Macedonian mass end energetical valorization of the available geothermal resouces at the territory of the Republic of Macedonia acording to the results of previous explorations with especial retrospect of the last few years. In this paper will pesent short descriptions of the hydrogeothermal resources, the degree of exploration, the prognosisis dimensions of the hydrogeothermal systems and theirs reservoir environments dimesions where the hydrogeothermal fluids occur as well as the quantity of geothermal energy that they contain.

1.INTRODUCTION

Republic of Macedonia is situated in the central part of the Balcan Peninsula and covers a surface of 25713 km^2., along the very favourable geothermal zone that starts in Hungary to the north and Itali to the West, and stretchest through Grece down to Turkey and beyond to the East. The earth's crust in this region suffers poliphase structural deformations, which as a result gives different structural features. Unfortunatately, its is one of the rare European countriest which has not systematically measured terrestrial heat flow.However, existing natural springs and exploration results illustrates that it is one of the countries with richest low-entalpy geothermal energy resources.

Several geothermal regions have been distinguished including the Macedonian region,which is connected to Vardar tectonic unit. This region shows positive geothermal anomalies and is hosting different geothermal systems.The hydrogeothermal systems, at the moment,are the only ones that are worth for investigation and exploitation.

All thermal waters in The Vardar zone andSerbo-Macedonian mass are of meteoric origin. Heat sources in The Vardar zone and Serbo-Macedonian mass is about 100 mW/m^2 and crust thickness 32 km

2. SHORT DESCRIPTION OF THE GEOLOGIKAL AND GEOTECTONIC CHARACTERISTICS OF THE TERRAIN IN MACEDONIA

The geotectonic situation of the territory of the Republic of Macedonia is conditioned of its location. It belongs to the Alpine-Kaukaus - Himalyan geosynclinnian belt where the history of creation of the terrain is connected with the former geosynclinian Tethis and Alpine orogeny, but also with the primary position of the prime lithosphere of this regions, as with the effect of the pre-alpine orogeny. Many reserchers were involved with the tectonic zonation of Macedonia throught examination of the tectonic complex of the whole Alpine-Himalaya orogen or onli of the Balcanian peninsula. As a consequence of the many exsting geotectonic concept, there are many geotectonic zonations of Macedonia and its surrouding territories.

Generaly speaking, in the division of the Alpine orogen, the territory of Macedonia belongs to the two tectonic systems:the west part of Macedonia including the Vardar area, belongs to the Dinarides(Helenide), while the east Macedonian mountain terrain and valley depression are segments of the Serbo-Macedonian massif. Along the bondary with Bulgaria, a separate zone known as Karpato-Balkanides has been distinguished.

According to this geotectonic regionization, the basic part of the territory of Macedonia, in the west of the line Dojran - Strumica - Zletovo - Kumanovo, refers to the Dinaric system in which four geotectonic units are distinguished: the Vardar zone, the Pelagonian horst-anticlinorium, the western Macedonioan zone and the Korab zone known as Cukali-Krasta zone. In the eastern part of the already mentioned line, the Macedonian massif occurs, which unites with the Rhodope mass through the Ograzden complex. In the bordery part with Bulgaria, in the north from Berovo, Pehcevo, sediments from the Karpato-Balcanides occur as a wedge within the old Rhodope mass, distinguished as Strumica zone (Krajshtides- according to E.Bonchev). Each distinguished unit is a separate structural-facies wholeness, which is characterized by a special geological development, including the specific processes of the tectonic deformations as well as the manifestations of the magmatic differentiation (Fig.1.)

The terrain which forms the territory of Macedonia,ind the geological past suffered numerous large tectonic alterations. Nearly all types of rocks have been

represented, starting from the oldest to the youngest formations, from the Precambrian matamorphic rocks, with high crystallinity to the youngest Neogene and Quaternary sedimentary complexes. Also, very often, large areas and eruptive rock masses occur, starting from the ultrabasites to the extreme acid and alkaline magmatic rfocks. As a result of it, different structural formations with rather specific geological, hydrogeological and geomorphological

Fig. 1 Main geothermal areas in theRepublic of Macedonia and regional tectonicsetting(Arsovski,1998)

characteristics were formed. Because of such heterogeneity of the geological-lithological composition and the tectonic structure of the terrain, as well as the different geomorphological and its climatic characteristics, different types of aquifers have been formed. (Fig.2). Usually in the mountainous parts of the terrain, there are aquifers being of fractured type, with free level and with the level under pressure (artesian aquifers), while thermal and mineral water occur within the seismically active fault and tectonic zones, i.e. the hydrogeothermal resources.

Geothermal investigations have mainly concentrated in two major geotectonic units:

Serbo-Macedonian geotectonic unit, where around 17 hot spring and other surface manifestations are found, located mainly in geotectonic depressions, such as: Kocani-Vinica valley, with the hot springs at Podlog, Banja and Istibanja; and Strumica valley with the natural hot springs at Bansko locality(Fig.1).

Vardar Zone: the main geothermal springs are located in Gevgelija valley with Smokvica, Negorska Banja and Gornicet localites; Skopje valley with the natural springs at Katlanovo and Volkovo; and Kumanovo geothermalarea with the geothermal springs at Proevci and Strnovec(Fig.1)

3. NEOTECTONIC CHARACTERISTICS IN THE TERRITORY OF MACEDONIA

The terrotory of Macedonia, as a part of the Balcan region, belongs to the mediteranian orogene area which has been exposed to intensive tectonic disturbances being reflected by significant blocky modelling of the earth crust. The deformations of the terrains of Macedonia primarily refer to

the vertical mechanism of the blocks movement that have differentiated the territory into morphostructures of uprising and siubsidence. Fig.2 (Jancevski).

The manifestations of these movements havent been happening along the whole territory equally, so that various morphostructural units have been formed. The terrains in the

water tempearture of 64-68°C, and dynamic reserves of 25 l/sec.

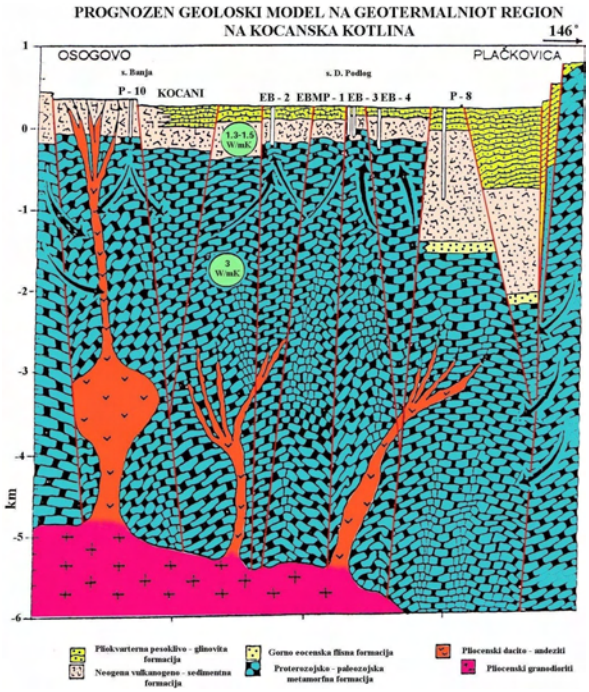

Fig. 3 Predicted geological model of the geothermal region of the Kocani valley

4.2.Hydrogeothermal system in Strumica valley

The Strumica hydrogeothermal system is of fractured type. The reservoir of this system is built of granites stone. The granites stones are originating from Paleozoic age, which have transformed into granite-gneiss. The granites, which are the basement of the valley, are covered with thick Tertiary sediments (thickness up to 1300 m). The reservoir of this system is drained through several natural springs with temperatures between 60 to 73 °C. There are also some exploitation drillings, such as B-1 in Bansko village with water temperature of 70 °C and capacity of 50 l/sec, D-2 in Drvosh-Baldovci with water temperature of 29 °C and capacity of 51 l/sec. Fig

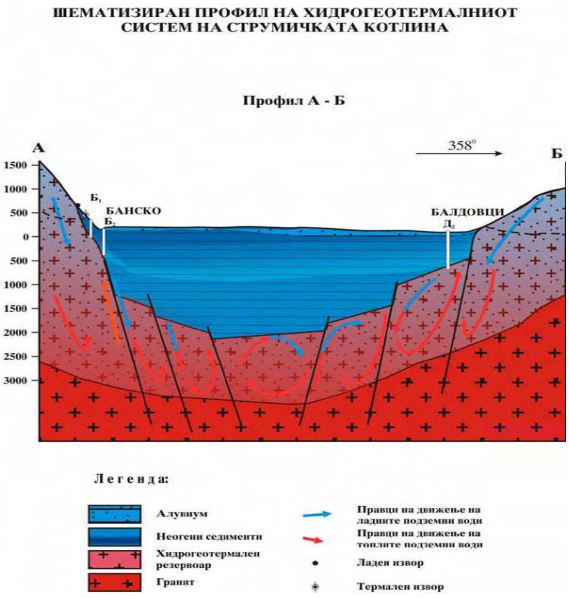

Fig.5 Schematic profile of the hydrogeothemal system on the Strumica valley

The water recharge of the reservoir is through the granite rocks on the southern side (Belasica Mountain) and northern side (Ograzhden Mountain) of the valley. This hydrogeothermal system is open, covered with Tertiary sediments, located in neotectonic depression (so called ditch structure). This neotectonic depression is located between Belasica and Ograzhden mountains. The estimated area of the reservoir is 100 km2, with estimated thickness of about 1000 m, and depth of 1 - 3 km, deep into the granito-gneiss of Belasica Mountain. The depth of the reservoir underneath the Tertiary sediments is estimated to be 1000 to 1500 m. The chemical analysis shows that these waters are of sodium-sulfate type with total mineralisation of 1157 mg/l, while the estimated temperature is between 90 to 120 °C (measured with quartz and Na-K geothermometers).

4.3 Hydrogeothermal system in Gevgelija valley

The hydrogeothermal system of Gevgelija Valley is discharged through several surface thermal springs near Gornichet village as well as through exploration drillings and wells in Negorska Banja and Smokvica. The water recharge of this reservoir is from fault strucutres, Jurassic volcanic rocks, diabase, spillite and Triassic limestone from Kozhuf Mountain and Paleozoic marbles on the boundary of Valandovo Valley, northern of Valandovo and Bogdanci. The hot fluids circulate through the deep fault structures, which are allocated in form of zones near the Smokvica Field and Negorska Banja. This kind of circulation enables the direct hydraulic connections between the hydrogeological structures in Smokvica and Negorska Banja, but at the same time provides direct mixing of the thermal fluids with the cold groundwater, which reduces the temperature of the thermal fluids on the surface. The hot fluids circulate through the deep fault structures, which are allocated in form of zones near the Smokvica Field and Negorska Banja. This kind of circulation enables the direct hydraulic connections between the hydrogeological structures in Smokvica and Negorska Banja, but at the same time provides direct mixing of the thermal fluids with the cold groundwater, which reduces the temperature of the thermal fluids on the surface.

4.4 Hydrogeothermal system Kezhovica - Shtip

The hydrogeothermal system Kezhovica - Ldzhi is located near the Kezhovica Spa, Novo Selo in Shtip region. The structure of this reservoir is built up from Jurassic fractured granite. Great deal of these granite masses are covered with Tertiary sediments of Ovche Pole and Lakavica basin. The Kezhovica Spa uses water from two wells with capacity of 4.5 l/sec and water temperature 63 °C. The water recharge of the reservoir is from the granite structures southern of Shtip. The chemical analysis show that the reservoir is partially recharged from the flysch sediments of Ovche Pole. This system belongs to the group of semi-open hydrogeothermal systems. The waters are Na-Cl type, and estimate of water temperature is 100-115 °C.

4.5. Hydrogeothermal system Kratovo – Zletovo volcanic area

In the Kratovo-Zletovo area, so far we have registered significant geothermal systems: Strnovec near Kumanovo, Zrdavevci near Kratovo and Poglog-Banja in KochaniValley.The hydrogeothermal systems "Zdravevci" and "Strnovec" are still in phase of investigation, while the hydrogeothermal system “Podlog-Banja” is in a phase of exploitation. The following text gives the main features of each of the three systems.

4.6. Hydrogeothermal system Strnovec

This hydrogeothermal system is located near Strnovec village in Kumanovo region. This system covers the northwest part of the Kratovo-Zletovo volcanic area, in the vicinity of Pchinja River, near Staro Nagorichane village. The structure of this system consists of Paleozoic marbles. The waters of this system belong to the Eocene carbonate structures. The estimate area of this system is 10 km^2, with thickness of 300m. In the previous investigations, we have drilled 13 exploration wells : 4 wells with depth of 50 m, 6 wels with depth of 200 m. One of the drillings already become exploitation well PEB - 1 with depth of 172 m. The investigation drilling ST-5 have given the source of water with capacity of 17 l/sec. The water temperature of about 40°C. The exploitation well which is located near the drilling, has the capacity of 47 l/sec.

4.7. Hydrogeothermal system Zdravevci – Kratovo

The hydrogeothermal system Zdravevci is located in the central part of the Kratovo-Zletovo volcanic area, covering the territory western of Kratovo in Povishnica River basin, in the region of former Pirolevsi Krater. This system is drained through several investigation drilllings in the valley of Povishnica River, near Zdravevci village, with total capacity of 20 l/sec and tempeartures 20 - 50 °C. The analysis show that the waters from this hydrogeothermal system belong to the carbonate type. The reservoir consists of Tertiary limestone. But in the deeper structure, the Paleozoic carbonate schist are creating the hydrogeological reservoir. The hydogeological reservoir, consisting of Eocene limestone, has estimated depth about 2000 m, while the reservoir of the Paleozoic carbonate schist and marbles is estimated to be much deeper. The water recharge of the system comes from the springs from porous rock and through fault zones i Kratovo-Zletovo volcanic area

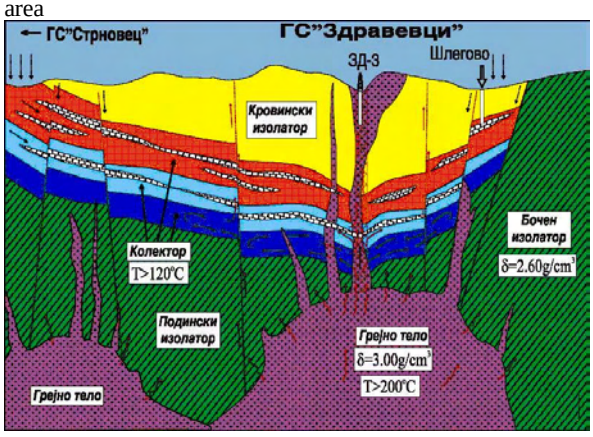

Fig. 5 Predicted geological model of the Kratovo – Zletovo volcanic area

4.8.Hydrogeothermal system in Skopje valley

The Geothermal system of Skopje Valley is karst-fractured type of geothermal system. The substratum has block structure, on the bottom of thick Tertiary sediments. The basic characteristics of Skopje Valley geothermal system are:- Thermomineral water sources are appearing only in Katlanovska Banja. These sources have very small capacity, with average temperature of 27 to 54.4 °C.- The investigation drilling in the area of Volkovo have shown that there are resources of thermal water, rich with CO_2 and temperature of 25°C. Other areas in Skopje Valley, such as Matka, Svilari, Kisela Voda, Brnjarci, Markova River and others, also have mineral water resources with temperature of 14 to 20 °C.

- The geothermal fluids are vadose waters which are warmed inside the earth by the conductive manner of energy transmission. The recharge of the water resources is implemented through the water reservoirs beneath the rocks, which are located by the edge of the valley itself. These rocks are: limestone, Paleozoic schist, marble layers in the northern part, marble limestone in the north-western part of the valley, Precambrian limestone in the western and south-eastern part of the valley.- The analysis of the chemical properties of thermal waters from Skopje Valley, as well as the big reserves of CO_2 gas are good indicator of the ground structure in this region. According to this, there is a carbonate reservoir of thermal fluids.

5. ENERGETIC VALORIZATION OF THE GEOTHERMAL RESOURCES IN THE VARDAR ZONE AND SERBO-MACEDONIAN MASS

According to the present findings about the geothermal potentials of the Vardar zone and Serbo-Macedonian mass an attempt for their actual energetic value was made and in accordance with the available technologies for an application in our country and in the world. The maximal available 154 MWt (table 1) illustrate a perspective and justification for large investment in further explorations, but at the same time a real possibility for significant participation in the energetic balance in the Republic. The real energetic potential of the geothermal resource in the Republic of Macedonia is in direct correlation with the technical/technological possibilities for its use.

The effective valorization of a geothermal resource is possible only if we have data for compensation of its users. Each separately causes temperature area of use and possibilities for creating a cascade chain for optimal use of the available temperature level.

In table 2. we may see the valorization of the available heat power of all exploitation geothermal resources in the Vardar zone and Serbo-Macedonian mass. We obtained total maximal available heat power of 154 MWt, or a capacity for annual production of 1.349.040MWh/year (K. Popovski, 1995) which in the overall geothermal potential of the Republic take part with 88 %..

As it has been already mentioned, the estimations are on the basis of present available flows and temperatures of the exploitation springs and drillholes in the Vardar zone and Serbo-Macedonian mass. In a period of 5-6 years the available heat power can be doubled by minimal investments in the exploration. If the strategy of systematic development of the geothermal resource is adopted by opening of detailed explorations and programmed dealing at great depths, in Europe ranges of course, it is real to expect very higher temperatures and flows, as well as increasing the power of the energetic resources and widening the possible field for application (introducing the electric power production).

The experience in the use of geothermal energy in Macedonia exists more than 30 years. There are more than 15 projects for construction of green houses, drying of agricultural products, heating of objects (facilities), building of pools, preparation of sanitary hot water, application in industry etc. The annual energy production used from the available geothermal resource in Macedonia participates with 0.5 % in order to satisfy the overall needs of energy of Macedonia (K.Dimitrov, 1995). Three of the projects for direct application of geothermal energy in the Republic of Macedonia are of special interest and importance. They are: the geothermal project of Kocani, the geothermal project in Gevgelija-Valandovo and the integral geothermal project

Bansko-Strumica, with total yield of 611 l/sec and temperatures from 65-75^{o} C which in the overall geothermal potential of the republic take part with 66 %.

No	Geothermal field (Location)	Flow capacity	Temp.	Heat power (MWt) For different outlet temperatures						
		l/s	^{o}C	15^{o}C	20^{o}C	25^{o}C	30^{o}C	35^{o}C	40^{o}C	45^{o}C
01	D.Podlog-Kocani	300	75	75.4	69.1	62.8	56.5	50.2	44.0	37.7
02	Istibawa-Vinica	73	65	15.3	13.8	12.2	10.7	9.2	7.8	6.1
03	Povishnica-Kratovo	20	48	2.8	2.4	1.9	1.5	1.1	0.7	0.3
04	Strnovec-Kumanovo	46.71	40	4.9	3.9	2.9	1.9	1.0	-	-
05	Kumanovska banja	4	31	0.3	0.2	0.1	-	-	-	-
06	Dobrevo-Zletovo	8	28	0.4	0.3	0.1	-	-	-	-
07	Bansko-Strumica	50	70	11.5	10.5	9.4	8.4	7.3	6.3	5.2
08	Smokvica-Gevgelija	120	65	25.1	22.6	20.1	17.6	15.1	12.6	10.0
09	Negorska banja	80	50	11.7	10.1	8.4	6.7	5.0	3.4	1.7
10	Kezovica-Shtip	20	60	3.8	3.4	2.9	2.5	2.1	1.4	1.3
11	Raklesh-Radovish	1	26	0.1	-	-	-	-	-	-
12	Topli dol i Mrezichko-Rzanovo	2	27	0.1	-	-	-	-	-	-
13	Katlanovo-Skopje	13	50	1.9	1.6	1.4	1.1	0.8	0.5	0,2
14	Volkovo-Skopje	20	25	0.8	0.4	-	-	-	-	-
15	Gornicet	5	24	-	-	-	-	-	-	-
	VKUPNO	752.71		154.1	134,7	122.2	106.9	95.8	76.8	62.5

Table 1. Temperatures, flows and available heat power of geothermalresourcesin Macedonia

CONCLUSION

The Republic of Macedonia is one of the rare countries in Europe which has not undertaken the systematic investigation on thermal waters. According to the,explorations, Macedonia is rich with low-temperature resources. We have recorded more than 50 sources of thermal and thermomineral water with total capacity exceeding 1400 l/sec, and available water quantities exceeding 1000 l/sec. The temperature range is 20-75°C.

The results of the newest hydrogeothermal investigations in the Republic of Macedonia, which are now undertaken actively in Kratovo-Zletovo volcanic area, Dojran regions are giving satisfactory guarantee for continuing researches and increasing the hydrogeothermal potential of the country in the future.

The future investigations in the Republic of Macedonia should be carried out in the regions with registered potentials, such as Kratovo-Zletovo volcanic area, Vardar Zone and Serbian-Macedonian mountain massive

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