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GEOTHERMAL RESOURCES AND UTILIZATION OF GEOTHERMAL ENERGY IN BULGARIA

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ABSTRACT

Bulgaria has natural conditions, traditions, experience and nation-wide interests to carry out broad and complete geothermal studies. The geological territory of the country contains plenty of convective and conductive hydrothermal systems that tap and reproduce great quantities of thermal waters with temperatures in some places, reaching 110°C. The attached Table 1 comprises information about the main properties of 54 important hydrothermal occurrences in the country.

Bulgaria is a small country of about 111000 km^2 and population of about 8 million inhabitants. It is poor on fossil and hydraulic energy. The production of electricity and heating energy is based on the following sources: nuclear power station; thermal power stations (using mainly lignite coal and having no significant importance); some hydropower plants; and many heating stations (using derivatives of imported oil and gas).

In order to improve the energy situation in future, some steps have to be taken in the next years for more efficient utilization of all types of produced power in the country. Therefore, a considerable attention has to be paid on the geothermal production for everyday life, as well as in the major sectors - agriculture and industry.

1. INTRODUCTION

There are many active magmatic centres in the country and related to them occurrences of geothermal energy with high enthalpy. Bulgaria is mostly rich in thermal waters with temperatures between 25 and 105°C, formed in relatively normal geothermal conditions: heat flow 50-90 mW/m^2 and geothermal gradient 2,5-4,0°C/100m.

Thermal waters are tapped and reproduced in various geological aquifers in accessible depths; to be more specific - in many stratified, unstratified and conjugated hydrothermal systems with different genesis, geometry, structure and hydrodynamic properties. In South Bulgaria, some of those systems manifest on the surface as impressive natural thermal springs, that have been used for spas, recreation and heating since ancient times. Therefore, we may even say that utilization of geothermal waters in our lands has begun in the remote past and is an old tradition.

Direct and contemporary use of geothermal potential in Bulgaria has been carried out for the last 30 years or so. Until 1960 more than 200000 m^2 of geothermal greenhouses and about 10 heating systems for spas have been built. But the low oil prices at that time did not stimulate the use of geothermal waters for heating, thus many projects had been canceled. The energy crisis in the 70's gave birth to some new ideas, but just few were realized. There were various reasons for this, but the most important was the restriction (for the lack of hard currency and ability) to purchase modern foreign technologies (submersible pumps, heat-exchangers, heat pumps, etc.). Lucky enough, all those obstacles did not discourage the Bulgarian researchers as to go deep into investigations of geothermal sources in the country and collect data about their genesis, type, flow rate, distribution and stratification in the accessible depths (3000-4000 m).

2. GEOLOGICAL BACKGROUND OF THE GEOTHERMAL PANORAMA IN BULGARIA

The small size of the country does not mean that its geothermal scene is not complicated enough. The territory presents a complex geological mosaic of platforms and orogenic structures, cut with deep tectonic faults, lithofacial and magmatic contrasts with different behaviour in the contemporary geo-dynamic processing. The geostructural picture of the country includes half of the Moesian platform with its southern active margin; the Balkan orogen belt; parallel to it - the Upper Cretaceous Reef Zone (Srednogorie); and large part of the Rodopian median massif. In some of the faulted zones in the Rodopian massif and in the Srednogorie Zone as well, post-orogenic grabens are presented, filled with continental terrigenous-clastic deposits.

The Moesian platform has a Caledonian-Hercynian basement and a cover of Upper Paleozoic and Mesozoic sediments. Its eastern part presents a tectonic arch with reduced sedimentary cover mass. In the western part, a depression has been developed with deposit's thickness at about 6000-7000m. The main geothermal reservoirs in this platform are tapped in the carbonate stratigraphic floors of the Malm-Valanginian (J_3 - K_1), Middle Triassic (Anisian) and Upper Devonian (Givetian). Those are thick (up to a hundred meters) artesian aquifers of limestone and dolomites, strongly fractured and with high permeability. This has been the result of ancient and contemporary karstification, and/or by secondary dolomitization. Those aquifers (excl. Valanginian) can be found in the Balkan Foreland with strong dislocations and depths up to 3000-4000m and more.

The Balkan orogen belt, including the lineament granitoid bodies in the western part, do not have any geothermal perspectives, so they are not viewed in details in this report.

The Srednogorie Zone is a heterogeneous hydrothermal region with unstratified (fault-fractured), stratified and conjugated hydrothermal systems presented. Stratified systems are formed in all deeper bodies of Mesozoic carbonate rocks and the Neogene's deposits. Unstratified hydrothermal systems could be found in the massifs of the ancient granites, metamorphittes and the larger bodies of the Alps' granites. Hydrothermal aquifers with mixed (stratified and vein) circulation and accumulation are presented in the Upper Cretaceous volcano-sedimentary depressions and perhaps most strongly - along the Black Sea coastal line, where the ancient silhouette of the Upper Cretaceous reef system is outlined.

A remarkable place in the Bulgarian geothermal panorama and in the Balkans holds the *Rodopian Massif*. The main part of it is built by ancient metamorphittes and granites, cut off and dislocated by a dense system of active and seismic faults. In this geological area some impressive unstratified hydrothermal systems are formed and are still active. They reproduce a significant part of the low mineralized thermal water resources with meteoric genesis and temperatures up to 105°C. According to some estimates by Shterev (1989), a single autonomous unstratified system covers areas up to a hundred square kilometres and depths up to 3-3,5 km below the base erosion level. The average hydrothermal production from an area of about 1 km^2 of such system is between 0,1-0,4 dm^3/s of thermal water and 20-80 kW convective geothermal energy. The hydrothermal flow for a whole system of that type is usually distributed and discharged by several autonomous drainage centres (hydrothermal occurrences) with production between 5 and 100 dm^3/s. The discharge is normally achieved through faults, fault-units, or/and permeable contact zones of dikes, veins, sills, etc.

In the eastern part of the Rodopian Massif there are some Paleogene volcano-tectonic depressions. In their old caldera and dike structures, deep circulation of meteoric thermal waters is also carried out. In the middle and southern parts of the massif the metamorphic substrate contains large bodies of marble that occasionally play an important role as primary or secondary hydrothermal reservoirs. The same could be said about the permeable terrigenous-clastic deposits in the deep Neogene and Paleogene grabens.

3. HYDROTHERMAL PROVINCES AND RESERVOIRS

A general view, concerning distribution, stratification, type of the hydrothermal resources within depths of 3 km, as well as some of the most important hydrothermal occurrences in Bulgaria, can be obtained from the attached scheme (Fig.1).

In the *Moesian Platform and the Balkan Foreland,* the artesian carbonate aquifers of Malm-Valanginian, Middle Triassic (Anisian) and Upper Devonian (Givetian) contain large commercial geothermal resources.

The Malm-Valanginian reservoir contains fresh thermal waters with temperatures 25-55°C (around the tectonic arch of the platform), as well as some highly mineralized thermal waters with temperatures up to 75°C (in its western parts). It is the largest and most easily accessible accumulator of low enthalpy geothermal energy, covering an area of over 15000 km^2 and depths between 800 and 2000m. The productivity of the wells is quite remarkable and in some places reaches 100-400 m^3/h. Along the Black Sea coast line (up to +25m above the sea level) all wells are running on free flow. The production of geothermal energy in the western part (with highly mineralized waters, covering an area of more than 10000 km^2) can be carried out only by conjugated geothermal doublets - production and injection wells. In those reservoirs, hundreds (or even more) of such doublets could be implanted, for use in various agricultural, industrial and public projects.

The Triassic (Anisian) aquifer in the platform is a pure conductive hydrothermal system with highly mineralized thermal waters (100-140g/kg) and even some brines with temperatures up to 100°C. It lays deeper and is less productive, so it is not so attractive for commercial utilization for the moment. There is a slight exception however - an autonomous part in the anticlinal structure of the Balkan Foreland seems to be quite perspective.

The Devonian (Givetian) reservoir contains also highly mineralized thermal waters and brines with temperatures reaching 100°C. It could be accessed only in the eastern and far western parts of the platform.

In *the Srednogorie Zone and the Rodopian Massif* the geothermal resources are tapped and reproduced in convective systems of unstratified, stratified and mixed type. Based on certain conditions, they can be divided into 4 hydrothermal provinces: a) granitoids and siliceous metamorphittes (unstratified systems); b) volcano-tectonic depressions (Upper Cretaceous and Paleogene); c) carbonate bodies and massifs (karst aquifers); d) terrigenous-clastic reservoirs. In all provinces and systems the thermal waters have exclusively meteoric genesis, very low mineralization (usually below 1g/kg), contain nitrogen, and their temperatures vary between 25 and 100(110)°C. The composition of the rocks very much reflects the geochemistry of the thermal waters. In smaller areas, streams of endogene CO_2 are effecting the systems. The studied occurrences from all 4 provinces are about 120. Most of them manifest on the surface with natural thermal springs, but the exploitation comes mainly through wells with depths 100(200)m - 1000(1300)m. The overall production from the Rodopian massif and Srednogorie Zone at present is about 2000 dm^3/s - that is only 25% of the whole potential reproduction of the thermal waters in the bowels in South Bulgaria.

4. SOME QUANTITATIVE EVALUATIONS AND FORECASTS

The evaluations of the geothermal potential in Bulgaria are not complete and in some cases - rather complicated, but never-the-less some approximate figures can be presented.

The convective hydrothermal systems in the Rodopian Massif, Srednogorie Zone, Balkan Foreland and the eastern part of the Moesian platform (Malm-Valanginian aquifer) reproduce about 12 m^3/s of thermal water with average temperature 40-45°C. We may also add some 6 m^3/s of subthermal karst waters with average temperature 17°C, that can be only used for heat extraction by heat pumps. As a result, the resources of low enthalpy energy from the convective geothermal systems are estimated about 1000-1200 MW, with only 8-10% utilized at present.

Much higher is the potential of the *conductive hydrothermal systems* in North Bulgaria. In future, they could ensure the development of hundreds of geothermal projects with total heat capacity over 4000 MW. It could be produced from hundreds of conjugated well doublets that yield about 150-180 m^3/h thermal water with average temperature 60-65°C. The power of the present projects does not exceed 30 MW.

5. UTILIZATION OF GEOTHERMAL ENERGY

Direct and indirect utilization of the geothermal energy in the country is achieved so far in spas, swimming pools, heating systems and hot water supply for recreation needs, geothermal heating of greenhouses and other activities. We estimate that the total utilization effect of the geothermal energy in the country per year is equivalent of 90000 tons of oil - a modest figure, compared with the actual geothermal potential of Bulgaria.

6. OUTLOOK

In North Bulgaria we are aiming at 2 goals: 1) total utilization of the geothermal potential along the Black Sea coast line for heating and hot water supply for various needs in the city of Varna and its northern outskirts (additional power of 100 MW); 2) construction of hundreds of hectares of geothermal greenhouses and municipal heating systems in the Danube Valley between Iskar and Yantra rivers (additional power of 400-500 MW).
In South Bulgaria we need a full investigations for utilization of the potentials in the high enthalpy (80-100^{o}C) convective systems around Struma Valley, Sofia Basin and some other geothermal fields in the Rodopian Massif and Srednogorie Zone (total additional power - 150 MW).

Table 1. Geothermal occurrences in Bulgaria

No	Occurrence	Miner.	T	Flow rate
-	-	g/kg	^{o}C	dm^3/s
1.	Sofia-Centrum	0,3	49	16
2.	Sofia Basin	0,9	64-80	40/80
3.	Kjustendil	0,6	74	35/50
4.	Sapareva Bania	0,7	97-100	14/20
5.	Blagoevgrad	1,0	63	15/20
6.	Simitli	0,6	63	27/35
7.	Sandanski	0,6	83	20/30
8.	Levunovo	0,9	85-90	15/20
9.	Marikostinovo	1,0	63	20/30
10.	Rupite	2,3	73-76	30/45
11.	Guliina Bania	0,3	54-59	60/80
12.	Eleshnitza	0,3	55	27/35
13.	Ognianovo	0,2	41	70/100
14.	Velingrad	0,5	47-87	130/200
15.	Draginovo	0,7	94	15/25
16.	Varvara	0,7	72-90	20/30
17.	Dolna Bania	0,6	65	25/40
18.	Ptchelin	1,0	73	12/15
19.	Momin Prohod	1,0	64	15/20
20.	Devin	0,3	44	30/40
21.	Beden	1,8	76	12/20
22.	Erma Reka	1,1	90-100	100/?
23.	Haskovo	1,6	55-60	30/50
24.	Simeonovgrad	0,8	57	15/20
25.	Panagjurishte	0,6	48	5/8
26.	Streltcha	0,3	56	15/20
27.	Krasnovo	0,3	55	14/20
28.	Hissar	0,3	45-52	45/60
29.	Bania-Plovdiv	0,4	46-50	30/40
30.	Pavel Bania	0,6	60-63	16/25
31.	Ovoshtnik	0,6	45-75	35/50
32.	Yagoda	0,6	40-46	8/20
33.	Korten Bania	0,9	56-60	12/20
34.	Sliven Bania	1,9	48	17/25
35.	Straldja	1,1	77	12/20
36.	Aitos	0,4	50	20/30
37.	Burgaski Bani	0,6	41	30/50
38.	Varna-South	0,6	55	100/200
39.	Varna-City	0,6	50-55	250/400
40.	Varna-Droujba	0,6	39-49	315/500
41.	Varna-Zl.Piasatzi	0,6	30-37	100/200
42.	Albena	0,6	30	100/150
43.	Kavarna	0,6	30	120/200
44.	Rusalka	1,1	32	50/80
45.	Shabla	3,5	39	150/200
46.	Marash	7,0	63	10/30
47.	Krushuna	11,0	57	18/40
48.	Svishtov	2,0	49	42/100
49.	Resen	4,6	55	20/60
50.	Chiflik	0,3	51	33/40
51.	Pleven	18,5	64	70/120
52.	Dolni Dabnik	20,0	65	75/150
53.	Dolni Lukovit	25,0	73	35/50
54.	Vidin	57,0	50	30/50

Flow rate: 100/150 dm^3/s - present/potential

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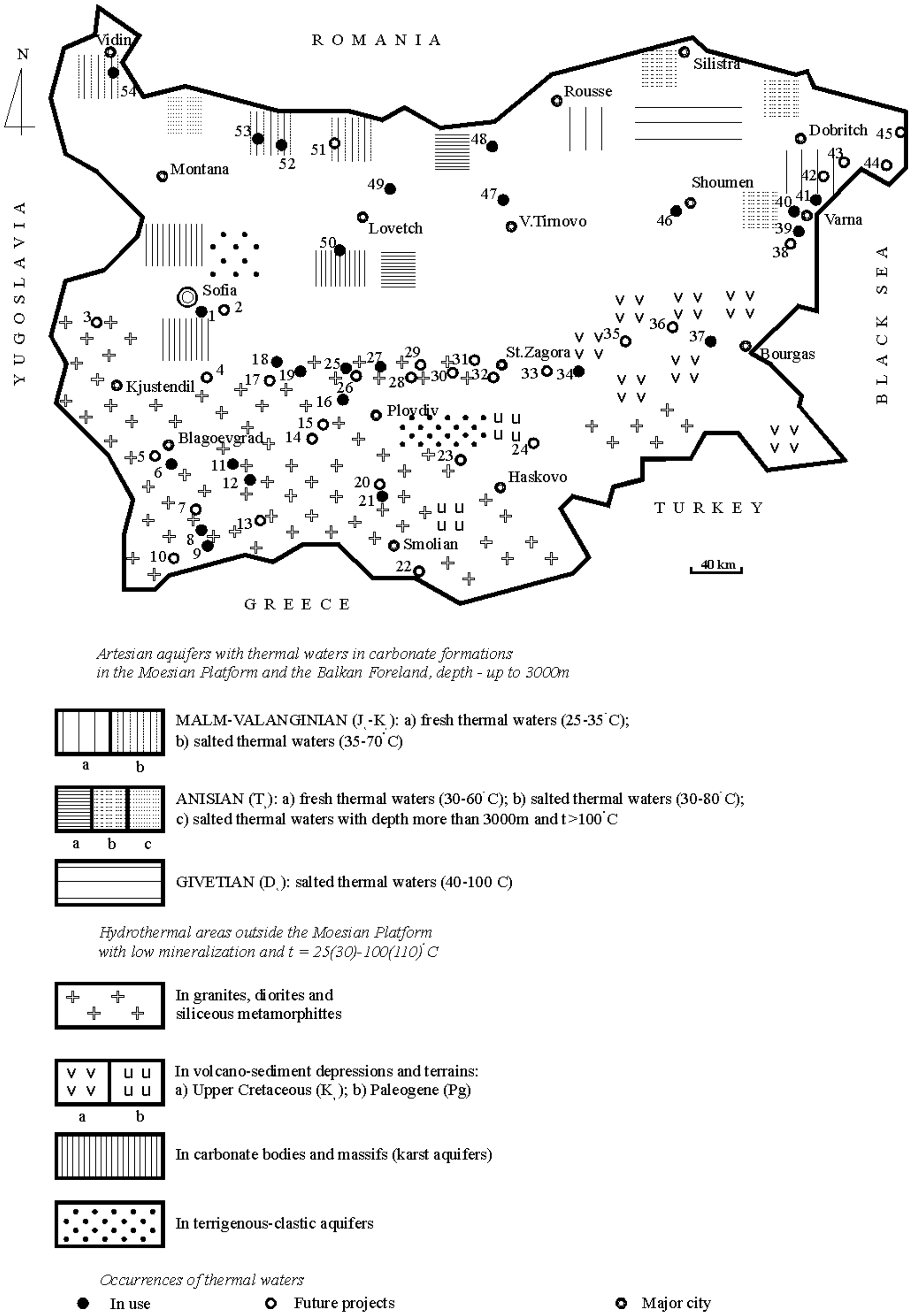

Figure 1. Hydrogeothermal areas, aquifers and occurrences in Bulgaria