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Serbian Spas as a Base for Tourism Development

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ABSTRACT

Serbia is a relatively small country. Its total surface area is 88.000 km^2, but the geological compositions are very complex. Due to this complexity, 250 natural springs and 100 wells with thermal water are situated in the territory of Serbia. Reservoirs of this water vary as do the chemical compositions of the rocks. The pH values of thermomineral waters vary from 2.5 (hyperacid) up to 12 (hyperalcaline). The TDS values vary from 0.2 gr/kg to 20 gr/kg. The maximum temperature of natural springs is 96 ^{o}C. The maximum temperature of thermal waters from wells is 111 ^{o}C. According to geothermometers, the maximum expected temperature of geothermal water is 150 ^{o}C. The total amount of thermal waters discharged from natural springs and wells is 5.000 l/s. Utilization of thermomineral water, about 20 percent, is mainly for balneotherapeutic purposes and tourism in 46 spas.

1. INTRODUCTION

Serbia is a former Yugoslavian country situated in the western part of the Balkan Peninsula (Fig.1.) The Balkan Peninsula is located in southeastern Europe and geographically represents its largest section. Serbia covers a relatively small surface area (about 88.000 km^2) but its geology is quite complex. The upper part of the earth's crust in Serbian territory has a very complex geological composition. The hydrogeological and geothermal characteristics are very complex and interesting. Serbia has 250 natural springs. Various archaeological proofs confirm that the use of geothermal waters started with the Romans and before. The Romans built large spas and used thermal waters for balneotherapy, recreation and space heating. Serbia has 46 spas. The thermal and mineral waters in these spas is used mainly for healing and other purposes. Serbia produces bottled water at 11 localities. This paper shows the main characteristics of the thermomineral waters of Serbia, such as yield, temperature, chemical content and utilization.

2. REGIONAL GEOTECTONICS AND GEOLOGICAL OVERVIEW

Most Serbian thermal springs are located in the Inner Dinarides, situated in the southern periphery of the Pannonian Basin. The area ranges from Belgrade in the east to Sisak in the west and from the Sava River to the north toward the cities of Banja Luka and Sarajevo (Fig. 2). The Inner Dinarides represents the northern branch of the Dinaric Formations, which are the largest geotectonic unit of the Balkan Peninsula. According to conventional tectonic concepts, the Dinaric Formations represent the central part of the former large geosyncline inside the Alpine Orogeny, which also encompasses the following large geotectonic units: the Serbian-Macedonian Massif, Carpatho-Balkanides and Pannonian Basin and a small part of the Mesian Platform (Grubic, 1980). According to the latest interpretations of the tectonics of the Balkan Peninsula, which are the result of the applied "global tectonic" theory, the Earth's crust in the territory of former Yugoslavia consists of terranes (Keppie & Dallmeyer, 1990).

The terranes in the central and western parts of the Balkan Peninsula are the consequence of subduction that occurred during the Jurassic Period (Karamata & Krstic, 1996). According to these authors, the hydrogeothermal system of the Inner Dinarides is situated in the extreme southern section of the Pannonian Basin and the following Dinaric terranes: the Dinaric Ophiolite Belt terrane (DOBT), the Central Bosnian Mts. terrane (CMBT), the Jadar Block terrane (JBT), and the Vardar Zone composite terrane (VZCT). The distribution of the terranes is given in Fig. 2. The Pannonian Basin, or its south part in Serbia and Bosnia and Herzegovina, consists of Paleogene, Neogene and Quaternary sediments with a total maximum thickness of about 4000 meters.

The Dinarides occupy the largest part of Serbian and Montenegro territory and they consist of the following terranes: VZCT, JBT, DIT, DOBT, CMBT, EBDT and DHCT (Fig. 2.). The Dinarides are built mainly of Mesozoic rocks, most significantly the thick deposits of karstified Triassic limestones and dolomites, a Jurassic ophiolitic melange and Cretaceous flysch deposits.

The Serbian-Macedonian Massif (SMM), (Fig. 2), is composed of very thick Proterozoic metamorphic rocks: gneisses, various schists, marbles, granitoid rocks, etc. The Proterozoic complex of the Serbian-Macedonian Massif extends across eastern Macedonia and northern Greece into Turkey and further eastward. This Massif includes magmatic, or intrusive-granitoid and volcanic rocks of Tertiary age. The Carpatho-Balkanides (ESCBCT on Fig. 2.) were formed in the Mesozoic as a carbonate platform separated from the Dinarides by the Serbian-Macedonian Massif. This unit is dominanted by Triassic, Jurassic and Cretaceous limestones. The Pannonian Basin, or its southeastern part in Serbia, consists of Paleogene, Neogene and Quaternary sediments with a total maximum thickness of about 4000 meters.

3. MAIN CHARACTERISTICS OF THERMOMINERAL WATER

The total flow of all natural thermomineral springs is about 5,000 kg/s. The highest flows are from thermomineral springs draining Mesozoic karstified limestones, and the next highest are those from Tertiary granitoids and volcanic rocks. The greatest numbers of thermomineral springs are in the Dinarides, the Carpatho-Balkanides, and the Serbian-Macedonian Massif. The lowest numbers—only one in each—are in the Pannonian Basin and the Mesian Platform. Considering the present state of our knowledge of the geologic composition and hydrogeothermal properties of rocks to a depth of 3000 m, there are 70 convective hydrogeothermal systems in Serbia. Of this number, 40 are in the Dinarides, 18 in the Carpatho-Balkanides, 5 in the Serbian-Macedonian Massif, and 7 in the Pannonian Basin under Tertiary sediments.

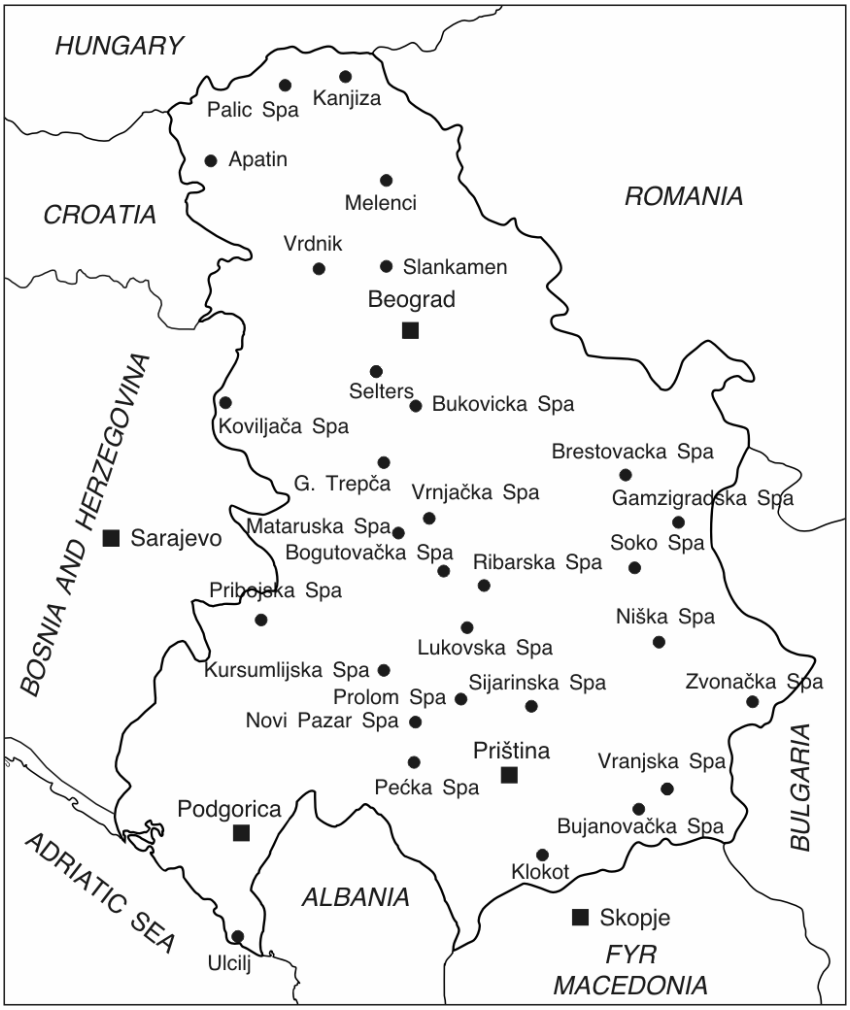

Figure 1. The locations of major spas in Serbia and Montenegro.

Conductive hydrogeothermal systems are developed in basins filled with Paleogene and Neogene sedimentary rocks. The majority of these are in the Pannonian Basin in Vojvodina, northern Serbia. The other 14 systems are less interrelated and less important.

Pannonian Basin. Within this geotectonic unit comprising a complex hydrogeothermal conductive system with a number of separate reservoirs, four groups of reservoirs are individualized by depth. The first group of reservoirs has a maximum depth of 2000 m. The highest water temperature in the reservoirs is 120 ^{o}C. The average flowing-well yield is 1-13 kg/s. Total mineralization of thermal waters is 1-9 g/kg, mostly 3-5 g/kg. Chemically, thermal waters are of the HCO_3-Na type. Water temperatures at wellheads are mostly 40-55 ^{o}C, maximum 82 ^{o}C (Tonic et al., 1989). The second group of reservoirs are in the Lower Pliocene and Pannonian sediments, composed of sandstones with a porosity lower than the aquifers of the first group. Thermal waters in this reservoir are of the HCO_3-Cl-Na type and the mineralization rate is 4-20 g/kg, mostly 5-12 g/kg. The maximum expected water temperature in this reservoir group is up to 160 ^{o}C. Average yields of flowing wells are 2.5 to 5 kg/s, and the wellhead water temperatures are 50-65 ^{o}C, on average. The third group of reservoirs are those at the base of Neogene or Paleogene sediments. These are Miocene limestones, sandstones, basal conglomerates, and basal breccias. Thermal water contained in these rocks is highly mineralized (to 50 g/kg) and its chemical composition is of the HCO_3-Na type. Average well yields are 5-10 kg/s and water temperatures at the wellheads range from 40-50 ^{o}C. The fourth group of reservoirs are in Mesozoic and Paleozoic rocks under Paleogene and Neogene sediments. The most important reservoirs of this group—and of the entire Pannonian hydrogeothermal system in Serbi—are Triassic karstified and fractured limestones and dolomites. Similar reservoirs extend beyond the Yugoslavian border in the Pannonian Basin in Hungary, Romania and Slovakia. Far from the basin's margin, at depths exceeding 1500 m, thermal waters in Triassic limestones are of the Cl-Na type.

In the marginal zone of the basin, where Neogene sediments are 1000 m deep over Triassic limestones and where water exchange is active, thermal waters are of the HCO_3-Na type and have mineral contents of up to 1 g/kg. Average well yield is 12 kg/s, or 40 kg/s from reservoirs near the basin's margin. Water temperatures at wellheads are mostly 40-60 ^{o}C.

Figure 2. Geotectonic map and locations of major spas in Serbia and Montenegro.

Dinarides. Hydrogeothermal systems in this geothermal province differ in their types, kinds of reservoirs and their extents, etc., as a result of varying geology. Rocks that have the largest distribution are Mesozoic in age: (1) karstified Triassic limestones and dolomites; (2) ophiolitic melange including large Jurassic peridotite massifs; (3) Cretaceous flysch; (4) Paleozoic metamorphic rocks; (5) Paleogene and Neogene granitoid and volcanic rocks, and (6) isolated Neogene sedimentation basins.

Hydrogeothermal systems have formed in terrains of: (1) Neogene sedimentation basins with reservoirs in Triassic limestones below them; (2) peridotite massifs and ophiolitic melange with reservoirs in Triassic limestones; (3) granitoid intrusions and respective volcanic rocks with reservoirs in the same rocks; and (4) Paleozoic metamorphic rocks with reservoirs in marbles and quartzites. The best aquifers are Triassic limestones, as the thermal water contained has low mineral content (<1 g/kg) of HCO_3-Na or HCO_3-Ca-Mg type. Spring flows are very high, up to 400 kg/s, and well yields are up to 60 kg/s. Maximum temperatures of waters at wellheads are 80 ^oC. The second most important reservoirs are those in granitoid intrusions and their marginal thermometamorphosed fracture zones. The contained thermal waters also are low in total mineralization (>1 g/kg), are of the HCO_3-Na type, and the maximum yield reaches 15 kg/s. The highest water temperatures at wellheads are 78 ^oC. There are few occurrences of thermal waters in Paleozoic metamorphic rocks. Such springs have low flows (< 1 kg/s), low water temperatures (<20 ^oC), mineralization rates of 5-7 g/kg, HCO_3-Na water types and high concentrations of free CO_2 gas.

Serbian-Macedonian Massif. There are two types of hydrogeothermal systems in this geothermal province. One is the type formed in the Proterozoic metamorphic complex, with the reservoir in marbles and quartzites up to 1500 m in thickness. Thermal waters in this reservoir have a total mineral content of 5-6 g/kg. Their chemical composition is of HCO_3-Na-Cl water with a high concentration of free CO_2. The gas is formed by the thermolysis of marble at temperatures above 100 ^oC in the presence of water, as verified by isotopic studies (Milivojevic, 1989). Thermal water temperatures at springs are 24-72 ^oC and spring flow is the gas-lift type due to the high CO_2 gas content.

The second type of hydrogeothermal system was formed in contact with and in the marginal zones of the Neogene granitoid intrusions. The reservoir rocks are granitoids, metamorphic and contact-metamorphic rocks, heavily fractured as a result of heating and cooling. The thermal springs of Vranjska spa belong to this system type and have the warmest waters in Serbia, 80-96 ^oC. Their mineral contents vary from 0.1 to 1.2 g/kg. The water type is HCO_3-Na-SO_4-Cl. Spring flows reach 80 kg/s.

Carpatho-Balkanides. This geothermal province has many hydrogeothermal systems, most formed in regions of isolated Neogene sedimentary lake basins. Reservoir rocks are karstified Triassic, Jurassic or Cretaceous limestones. Thermal karst springs have flows of 60 kg/s, with water temperatures reaching 38 ^oC. Total mineralization is 0.7 g/kg and the water type is HCO_3-Ca. Another type of hydrogeothermal system in this geothermal province was formed in the Upper Cretaceous paleorift of Eastern Serbia,

where Mesozoic limestones were penetrated and thickly covered with andesitic lavas and pyroclastics. The mineralization of these contained water are up to 0.8 g/kg and the water is of the SO_4-Na-Cl type, or HCO_3-Na-SO_4-Cl.

4. UTILISATION OF THERMOMINERAL WATER IN SPAS

The commonest uses of thermomineral waters in Serbia are the traditional ones: balneology and recreation. Certain archaeological evidence indicates similar uses by the ancient Romans in the localities of the presently known spas: Niska spa, Vrnjacka spa, Gamzigradska spa and Vrnjacka spa. There are today in Serbia and Montenegro 60 thermal-water spas used for balneology, sports and recreation and as tourist centers. Thermal waters are also bottled by 10 mineral-water bottling companies. The direct use of thermal energy for space heating or power generation is in its initial stage and very modest in relation to its potential capacity. In the hydrogeothermal system of the Pannonian Basin, thermal water is used from 23 wells. This direct use began in 1981. Water from two wells is used for heating greenhouses, from three wells for heating pig farms, from two for industrial processing in leather and textile factories, from three for space heating, and from 13 wells for various uses in spas and for sport and recreational facilities. The total heat capacity of the wells presently in use is 24 MW (Tonic et al., 1989). Thermal waters outside of the Pannonian Basin region are used for heating in several localities. Space-heating started in Vranjska spa 40 years ago. Thermal water is used there to heat flower greenhouses, a poultry farm, a textile workshop, the premises of a spa rehabilitation center and a hotel. A large hotel and rehabilitation center with a swimming pool is heated in Kursumlijska spa. In Niska spa and Prolom spa, a heating system, including heat pumps, is installed for the hotel and rehabilitation centers. Thermal direct use in Sijarinska spa is for heating the hotel and recreation center. A similar use is practiced in Ribarska spa. Thermal water in Lukovska spa is used in the carpet industry. Carbo-gaseous springs are used for production of bottled mineral water. Serbia has eight factories that produce bottled mineral water.

5. POSSIBILITIES FOR INTENSIVE DEVELOPMENT OF TOURISM IN SERBIAN AND MONTENEGRO SPAS

The total discharge amount of thermomineral water in Serbian spas is about 1200 l/s, an indicator of favorable hydrogeological characteristics up to a depth of 2000 m. Thermomineral water can be utilized for balneotherapeutic purposes from aquifers at the depth of 3000 m.

The total extent of aquifers with thermomineral water is very different. It varies from several kilometers up to several thousand kilometers. The thickness varies from several meters up to 2000 meters maximum. Because of this, the total volume varies significantly, from several hundreds up to several millions m^3.

Isotopic investigations of thermomineral waters from Serbian spas show that water ages vary from 1,350 years in the Prolom Spa—the youngest—up to 40,000 years in the Bujanovacka spa—the oldest. (Milivojevic, 1989, 2003). Results of the completed hydrogeological exploration show possibilities for increasing the discharge amount of thermomineral water from two to ten times, generally four to five times.

According to the current hydrogeological investigations, it is possible to increase the temperature of the thermomineral water type when it is in limestone. Water temperatures at thermal springs reach 43 ^oC, and spring flows reach 10 kg/s from present springs. Geothermometers, temperature logging and terrestrial heat-flow measurements show that the maximum temperature at a depth of 2000 m should be 100 ^oC. The expected thermomineral water temperature in Vrnjacka spa is 120 ^oC, in Mataruska spa 100 ^oC, in Josanicka spa 135 ^oC, in Ribarska spa 130 ^oC, in Novopazarska spa 110 ^oC, in Pribojska spa 60 ^oC, in Koviljaca spa 40 ^oC, in Ovcar spa and Bogutovacka spa about 60 ^oC, in Bukovicka spa about 100 ^oC, in Mladenovac spa about 90 ^oC, in Trepca spa about 50 ^oC, in Prolom spa 60 ^oC, in Vranjsak spa about 150 ^oC, in Kursumlijska spa about 120 ^oC, in Sijarinska spa about 100 ^oC in Niska spa and Soko spa up to 50 ^oC, in Brestovacka spa up to 100 ^oC and in Gamzigradska spa up to 50 ^oC.

Present results show possibilities for significantly increasing the temperatures of thermomineral waters in Serbian spas. The geothermoenergetic potential for thermomineral water could be increased by several times according to present geothermal indicators—it could be at least 1.200 MWt.

Recent hydrogeological investigations discovered several aquifers of thermomineral waters with favorable possibilities for balneo-tourism.

Thus Serbia has favorable balneo- and hydogeothermal-resources that, with other geologic and tourist resources, could develop the tourist economy significantly.

REFERENCES

Grubic, A., "An Outline of Geology of Yugoslavia", 26th Internat. Geological Congress, Paris, Guide book, 49.

Keppie, J.D. & Dallmeyer, R.D., 1990; Introduction to terrane analysis and the tectonic map of pre-Mesozoic terranes in circum-Atlantic Phanerozoic oreogens. Abstract, IGCP Meeting 233, 24, Goettingen.

Karamata, S. & Krstic, B., 1996. Terranes od Serbia and neighbouring areas. In: Terranes of Serbia (Eds: Knezevic, V. & Krstic, B.), Fac. of Mining and Geology & Committee for Geodynamics of Serb. Acad. of Sci. and Art., Belgrade, 25-40.

Milivojevic, M., "Assessment of Geothermal Resources of Serbia Excluding Autonomous Provinces" (Doctor thesis), University of Belgrade, Belgrade, (1989), 458 (in Serbian).

Milivojevic, M., "Assessment of The Geothermal Resources of Serbia", Geothermal Resources Council Transactions, Vol. 14, Part II, (1990), 933-936.

Radovanovic, S., "Ground Waters: aquifers, springs, wells, thermal and mineral waters", Serbian Books Assosiation 42, Belgrade, (1897), 152, (in Serbian).

Ravnik, D., Kolbah, S., Jelic, K., Milivojevic, M., Miosic, N. and Tonic, S., "Yugoslavia. In: Geothermal Atlas of Europe" (Editors: E. Hurtig, V. Cermak, R. Haenel and V. Zui), GeoForschungsZentrum Potsdam, Publication No. 1, Potsdam, (1992), 102-105.

Tonic, S., Milosavljevic, S., Vidovic, S., and Agatonovic, V., "Results of exploration and utilization of geothermal water in Vojvodina. Journ. of YU Committ. of The World Petroleum Congr., Nafta (40), No. 10, Zagreb, (1989), 593-600, (in Serbian).