REPUBLIKA SRBIJA
AUTONOMNA POKRAJINA VOJVODINA
POKRAJINSKI SEKRETARIJAT ZA ENERGETIKU I MINERALNE SIROVINE

REPUBLIC OF SERBIA
AUTONOMOUS PROVINCE OF VOJVODINA - PROVINCIAL SECRETARIAT FOR ENERGY AND MINERAL RESOURCES

ATLAS PRIREDILI (ATLAS PREPARED BY)

Departman za hidrogeologiju, Rudarsko - geološkog fakultata iz Beograda - Department of Hydrogeology, Faculty of Mining and geology

Geološki Institut Srbije iz Beograda - Geological Institute of Serbia

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GEOTERMALNI ATLAS VOJVODINE

GEOTHERMAL ATLAS OF VOJVODINA

BEOGRAD - NOVI SAD
2010. godine

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INTRODUCTION

Geothermal atlas of Vojvodina is a graphical presentation of knowledge, obtained so far, on geothermal characteristics and hydro-geothermal potentials of the Earth crust at a depth of 2000 m for the territory of the AP of Vojvodina. It is a result of a much broader venture under the title “Study of Knowledge and Assessment of the Geothermal Energy Resources of the AP of Vojvodina” that was funded by the Provincial Secretariat for Energy and Mineral Resources (2006-2008). It is consisted of 10 maps and one tracing, scale 1:300.000, accompanying text – legend and associated data base. The data base contains over 120 descriptive and numerical indicators and parameters for each of the 78 hydro-geothermal boreholes, where relevant detailed (hydro) geological and geophysical researches and explorations were performed. Spatial position of the boreholes is shown on the **Map No. 1**; the data base is available on the site of the Provincial Secretariat for Energy and Mineral Resources - www.psemr.vojvodina.gov.rs. Aside from these data, other relevant data on over 200 “oil and oil-gas” boreholes were used for creation of certain maps.

GENERAL GEOLOGICAL AND HYDROGEOLOGICAL CHARACTERISTICS OF VOJVODINA

Generally speaking, there are three great complexes of Vojvodina geological structure: (**1**) main highlands, (**2**) complex of neogene formations and (**3**) quaternary sediments that originated prior, during the emergence and existence and after the “withdrawal” of the Pannonian Sea (Paratetisa) from the areas. The oldest formation of the main highlands are composed of granite and gneiss of the Precambrian age; crystalline schist of the Palaeozoic age covered by sediments (in flysch faces: conglomerates, sandstones, marlstones and shales that alternate in succession, then limestones, dolomitic limestones and dolomites) and magmas (serpentinite, diabase, trachite) of the Mesozoic age. The Neogene complex, which is over 3000 m thick (**Map No**. **2**), in some Vojvodina region places, mostly is comprised of sandstone, shale, marlstone, oolitic limestone, clay, sand and gravel, whereas magmatic and volcanic rocks (dacites, andesites and basalts), as well as their pyroclastic equivalents, occur in subordinate amounts. Quaternary sediments are consisted of aeolian (sand and loess) and fluvial (sandy-clay alevrites, clays, sands and gravel) layers. **Image No. 1** illustrates two characteristic geological profiles, while **Tracing No. 4** shows detailed geological columns of characteristic hydro-geothermal boreholes, which aside from the lithological composition and age, describe the depths of the tapping intervals that is very significant for understanding of the hydro geological characteristics of certain area.

In the territory of Vojvodina, which also represents a separate geothermal province (Milivojević, 1989) and a complex conductive hydro-geothermal system with several separated reservoirs, four hydro geological systems were defined according to the depth, they are:

The first hydro geological system encompasses sediments from the surface to the basement of the upper Pontian. It is developed across the entire surface of Vojvodina, except from Fruška gora and Vršački breg. Its thickness amounts 2000 m in the North Banat and reaches several dozen meters in the bordering zones of the Pannonian basin (**Map No. 3**). The collectors are sands and gravel of various granulation and intergranular porosity, whereas clays are insulators. Layer temperatures higher than 120 °C are not anticipated in this system, and the average temperatures at the mouth of the borehole are around 60 °C. The results obtained so far show the maximum abundance of 28.3 l/s, while it most often amounts between 6.7-13.3 l/s. Great initial abundances have been obtained from the upper Pontian sandy deserts (max. 28 l/s) and paludine sands (max. 12 l/s). Water mineralization amounts 1-9 g/l, and most frequently 3-5 g/l. Composition of gas in water varies from 0.04 to 2.2 m^3/m^3. *This system is of the greatest economic importance due to its distribution and low water mineralization* (Milosavljević, 1997).

The second hydro geological system is located immediately under the first one and is consisted of the lower Pontian and Pannonian rocks. The collectors in this system are sandstones, the spreading of which is limited without or with very small possibilities of recharging. The insulators are marlstones, marls and clays. Aqueous layers are of small abundance that vary from 2.5-5 l/s, and maximum to 7.3 l/s. The water abundance obtained from the lower Pontian sand deserts is the smallest (cca 3 l/s). The exit water temperatures start at 82 °C, whereas the most frequently they start at 50-65 °C. Mineralization most frequently is 5-12 g/l, and reaches 20 g/l. *Due to low abundance, this system is not of greater economic importance.*

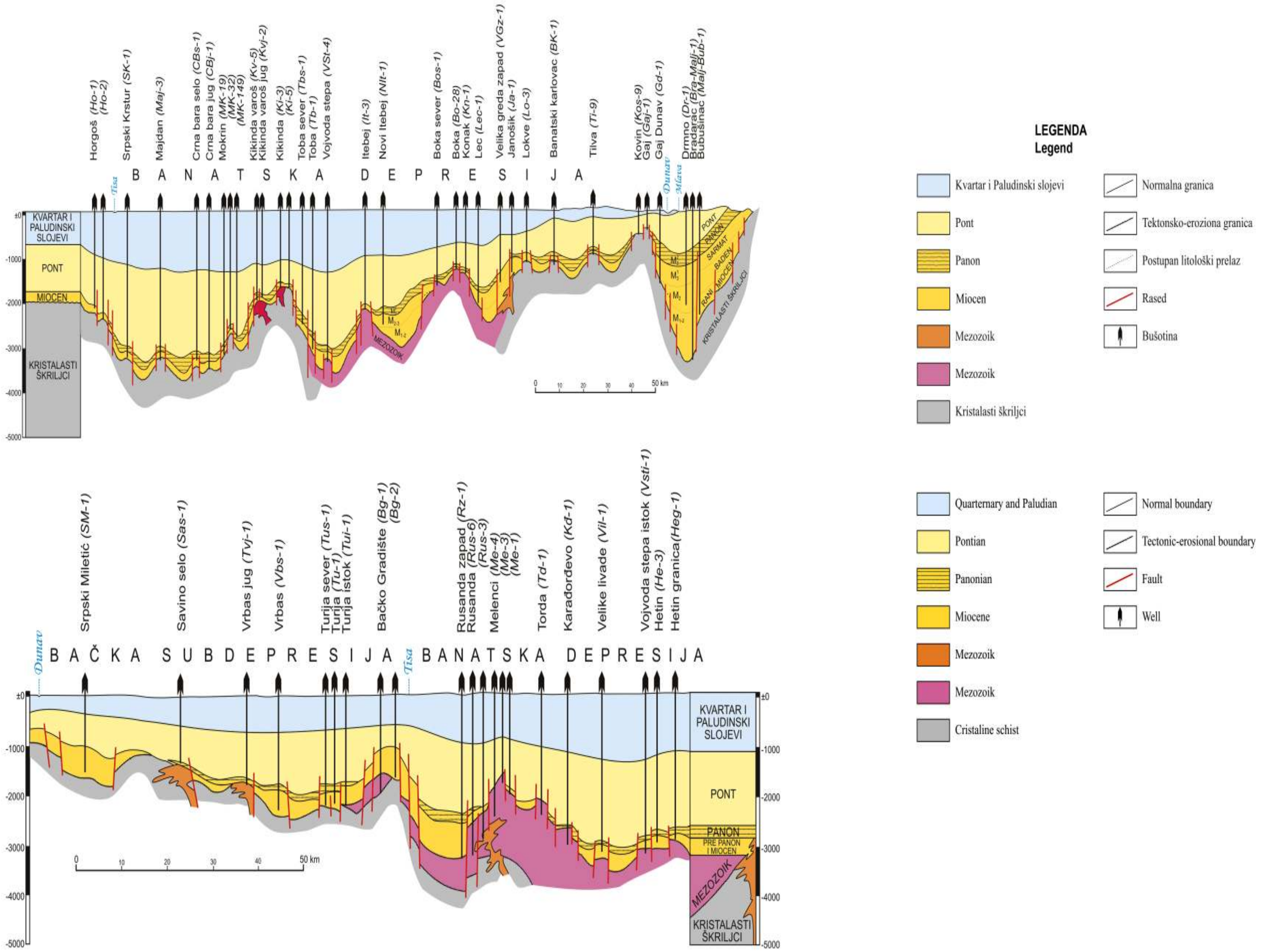


Image 1. Regional geological profiles Horgoš-Drmno, Srpski Miletić-Hetin, (Aksin, i dr., 1991)

The third hydro geological system encompasses Miocene, Paleogene Jurrasic and Cretaseous rocks. The collectors are sandstones, conglomerates, limestones and breccia, while the insulators are marls, marlstones and clays. The abundance of the boreholes is up to 25 l/s, and most often between 5 and 10 l/s. The great initial abundances have been obtained from Miocene sands, sandstones and limestone (max. 25 l/s). The exit water temperature varies up to 54 °C, whereas most frequently from 40 °C to 50 °C. Waters are characterized by high mineralization, up to 50 g/l. The problems with utilisation of the waters are in resolving their aggressiveness and encrustation. *Economic aspect of this system utilisation is not of great importance.*

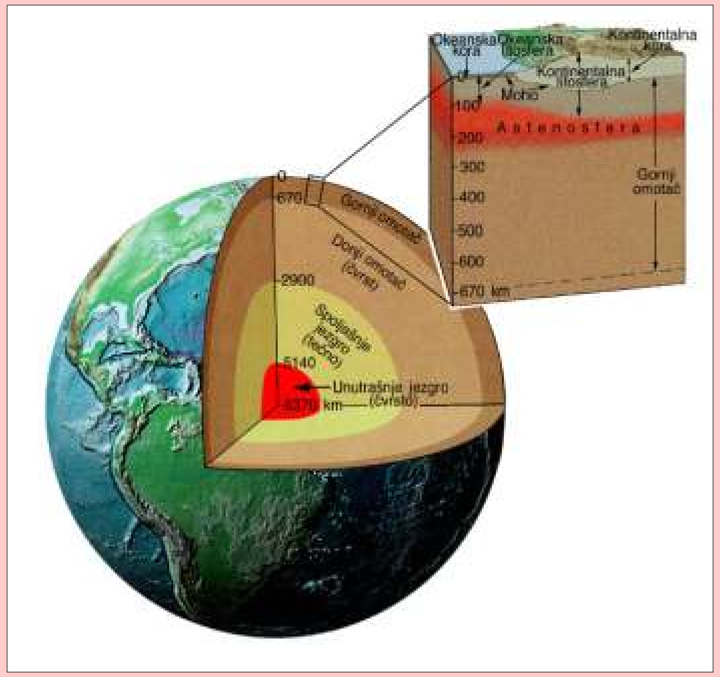
The fourth hydro geological system encompasses magmatic, metamorphic and sedimentary rocks of the Triassic and Paleozoic age. The most significant collectors are cracked Triassic limestones and dolomites, particularly due to their great abundance and relatively small content of dissolved salts. The abundance of the boreholes varies up to 47 l/s, and most frequently from 8 to 17 l/s. The greatest initial abundance has been registered at the borehole "Kup-1" (Kupinovo) in South Srem, in karstified dolomite limestones of Triassic age (41,6 l/s), while the abundance of the disintegrated crystalline schists varies from 2-4 l/s. The exit water temperatures vary up to 82 °C, and most frequently from 40-60 °C (Tonić and others, 1989). Almost all boreholes operate as self- effusive, it is a result of the increased bearing pressure or the phenomenon in gas-lift system, that is, the composition of the gasses dissolved in water. Total mineralization amounts from 0.5 g/l to 50 g/l and is mainly in the function of stratigraphic division of the accumulative rocks and the intensity of water exchange. The composition of the dissolved gases is 0.04-2.2 m^3/m^3. It is predominantly methane (80-95 %) with traces of carbon-dioxide and nitrogen. *The system has not been explored enough, and it would not be possible to estimate its actual significance*.

VOJVODINA GEOTHERMAL CHARACTERISTICS

Geothermal characteristics of the Earth vary greatly from place to place. They are determined by specific "local" geological conditions and activities that have taken place in those areas during 4 billion years of the Earth history. The thickness and the lithological composition of the crust and the lithosphere, the character, type and the age of the tectonic movements and magmatism have crucial impact on the composition of radioactive elements of the rocks, particularly uranium, thorium and potassium, and on the seismic and hydro geological nature of the terrain, which on the other side determines directly or indirectly, in smaller or greater degree, geothermal characteristic of certain area.

Vojvodina region, being an integral part of the Pannonian basin, as regards geological and geothermal characteristics has all attributes of this specific geotectonic unit. Among the geological characteristics, as a specific feature we should primarily emphasize small thickness of the crust that amounts "only" 25.5 to 29 km at the territory of Vojvodina (Dragašević, 1989), and small thickness of the lithosphere that ranges from 60 to 100 km in the area of the Pannonian basin. The smallest anomalous thickness of the crust of 25.5 – 26 km, at the entire territory of the former SFRY, is registered in the direction SW-NE from Ripanj near Belgrade, across the Uljm to Vršac and further towards Romania. Small thickness of the crust and lithosphere that is result of various geodynamic movements that took place approximately 23 to 10 million years ago, during the lower and middle Miocene (Lenkey,1999) make (among other things) Pannonian basin, and thereby the region of Vojvodina, the most perspective geothermal regions in Europe (Stegena and others, 1975). The average values of the geothermal gradient and teresstic heat flow that are significantly higher than characteristic values of the same parameters for the whole continent of Europe, also indicate that the geothermal characteristics of Vojvodina are favourable.

Geothermal gradient in the territory of Vojvodina – is determined on the basis of the data on temperatures measured in 70 hydro-geothermal boreholes and 126 boreholes drilled for the needs of oil and gas research. Considering the fact that temperature measurements were performed in various phases of borehole construction (in most cases under "unsteady conditions") such as: during the borehole construction; following the completion of the borehole, usually 3 to 12 hours upon the termination of drill-in fluids' circulation or after two to three days; immediately before the derivation trial (more representative data) and during self - effusion, or thermal water pumping, all data are firstly analysed in details, and then appropriate corrections are made based on the need, so that the actual data could be obtained under the steady conditions. The corrections are performed through the application of Horner's method or "inter", or, "extra polarisation". Representative data are used for determination of the actual temperature values at the depth of 500, 1000 and 2000 m.



Crust is the part of the Earth above Mohorovičič (or Moho) discontinuity which separates it from the mantle. Moho discontinuity is located under the ocean's floor at the depth of 2 km to 12 km, whereas it reaches 20 km and even up to 80 km under the continents.

Lithosphere is the part of the Earth above the asthenosphere, which is composed of the crust and the upper part of the upper mantle. It is considered that the boundary of the lower part of the lithosphere and asthenosphere is represented by the isotherm at approximately 1200 C.

According to the mineral composition, structure and physical-mechanical characteristics, there are oceanic and continental lithospheres. The thickness of the oceanic lithosphere varies from 50 to 125 km, and the continental from 80 to 200 km.

Image 2. The Internal Structure of the Earth (Milovanović, D., Boev, B., 2001)

The rate at which the Earth's temperature increases with depth is called the ***geothermal gradient***. Every geological environment has specific geothermal gradient, but the average increase of temperature in the continental parts of the Earth is approximately 30 C per kilometre of depth (C/km). The highest geothermal gradient is in the area of ocean reef, where the temperature increases even over 100 C per kilometre of depth, and indicates that the asthenosphere is located at a very low depth. There are differences in the ratio between depth and temperature in the ocean and continental crusts and the upper part of the upper mantle, however the geothermal gradients of the various geological environments equalize at a depth of approximately 200 km.

Temperatures at the depth of 500 m in the territory of Vojvodina ranges between 34,2 °C and 43,6 °C, the average temperature being 38,2 °C. The highest temperatures have been registered in the wider area around Subotica and Kupinovo, while the lowest temperature has been recorded in the wider area of Uljma (**Map no. 5**).

Temperatures at the depth of 1000 m. Temperature at the depth of 1000 m was calculated on the basis of inter- and extrapolation of data pertaining to the previously mentioned boreholes. The temperature at the depth of 1000 m in the territory of Vojvodina ranges between 57,5 °C and 73,5 °C. The highest temperatures have been recorded around Prigrevica, reaching 73,5 °C. In the area of Kupinovo, the temperature at the depth of 1000 m is 71,5 °C (**Map no. 6**).

Temperatures at the depth of 2000 m. The temeprature map at the depth of 2000 m was prepared on the basis of deep research boreholes drilled for the purposes of oil and gas research. The temperature at the depth of 2000 m in the territory of Vojvodina ranges between 95 °C and 120 °C. The highest temperatures, reaching above 118 °C , have been registered to the west of Kanjiža, while the lowest ones (below 96 °C) have been registered in the wider area of Inđija (**Map no. 7**).

Based on the obtained values, geothermic gradients were calculated, differing according to depth. Therefore, for the 0 m - 500 m interval, it is 0.056 °C/m, for the 500 m – 100 m interval, it is 0,052 °C/m, while for the 1.000 m - 2.000 m interval, it is 0,050 °C/m. The average value of the temperature gradient (in the 0 m – 200 m interval) for the entire Vojvodina is 0,0526 °C/m, meaning it is much higher than the average value recorded in the continental Europe, which is cca 0,03 °C/m. The highest average values of the geothermic gradient in Vojvodina, established in the area of Northern Bačka, are over 0,062 °C/m, while the lowest ones, established in the area of south-eastern Banat, are below 0,046 °C/m (**Map no. 8**).

Density of Terrestrial Heat Flow – The density of the terrestrial heat flow in the territory of Vojvodina is established on the basis of average geothermic gradient and average heat permeability of sediments located around hydro-geothermal boreholes, reaching 1,6 W/m °K for clay and marl and 2,8 W/m °K for limestone, sandstone, marlstone and shale (Milivojević, 1989) and are very similar to those used in the neighbouring Hungary, based on the following formula:

$$q = \lambda * \frac{T_2 - T_1}{z_2 - z_1}$$

where:

- q - terrestrial heat flow (mW/m^2)
- λ - heat permeability (W/m°K)
- T_1 - temperature at the depth z_1 (°C)
- T_2 - temperature at the depth z_2 (°C)
- z_1 - depth at which T_1 (m) temperature was measured
- z_2 - depth at which T_2 (m) temperature was measured

Heat energy created in the Earth's interior is «transferred» towards its surface that is much colder. The amount of heat (mW) passing in a time unit (s) through a surface unit (m^2) is called **density of terrestrial heat flow** (mW/m^2). Its distribution at the surface of the Earth is very irregular and depends on a range of factors, but first of all on the geotectonic position and heat permeability of rocks forming the Earth's crust at a particular spot. Depending on all these factors, its average value on continents is 65 mW/m^2, while in oceans it is 101 mW/m^2. Based on several thousands of measurements, Pollack (Pollack i dr., 1993) has estimated that the global, average density of terrestrial heat flow on the Earth is 87 mW/m^2.
To compare, in a geothermal field (Larderello), where the first geothermal system for electrical energy production was constructed in 1904, the density of terrestrial heat flow exceeds 200 mW/m^2, while in the area of southern Hungary, known for intense exploitation of geothermal energy, typical values of the terrestrial heat flow range from 80 mW/m^2 to 110 mW/m^2.

The heat flow ranges from 83 mW/m^2 to 111 mW/m^2. The lowest values of the heat flow have been recorded in the Southern Banat – wider ara of Uljma (borehole Ulj-1/H), while the highest values have been recorded in the area around Subotica, (borehole S-1, **Map no. 9**).

GEOTHERMAL RESOURCES OF VOJVODINA

Researched geothermal resources (or reserves) – A lot of data on geological, geothermal and hydro-geothermal features of Vojvodina, collected during the twenty years (1949-1968) of systematic geological research of oil and natural gas, have provided the opportunity to initiate, in 1969, the first targeted researches of **hydro-geothermal resources** of Vojvodina. Within these researches, in the period from 1969 to 1996, the total of 72 boreholes were drilled, while in the period from 1997 to 2008 another six boreholes were drilled. The greatest number of boreholes has been drilled in Bačka (44) and Banat (18), while the least number of boreholes has been drilled in Syrmia (16). Basic information about these 78 boreholes, such as their depth, temperature, water flow and its heat power have been presented in **Table 1**, while the physical and chemical characteristics of thermal waters are specified in **Map no. 10.** All other relevan data, necessary for the assessment of hydro-geothermal potentials of particular boreholes and areas in the entire Vojvodina may be found in the data base mentioned earlier.
The heat power of available **hydro-geothermal resources** from particular boreholes is calculated using the following formula:

$$Q = m * (T_2 - T_1) * 0{,}004184$$

where:

- Q - heat power (MW_t)
- m - mass (kg)
- T_2 - water temperature (°C)
- T_1 - reference temperature (20 °C)

and their sum represents the total available heat power of the hydro-geothermal resources researched so far (from the 78 boreholes) in the territory of Vojvodina, which is **72.606 MW_t** (**Table 1**).

Geothermal resources, in the widest sense, represent the total quantity of the Earth's interior heat, accumulated in its solid, liquid and gaseous phase, which is categorised accordingly, as: **hydro-geothermal resources** (in free underground thermal waters and hot steams), **litho i.e. petro-geothermal resources** (in warm and hot dry rocks) and **magma-geothermal resources** (in magma and volcanic lava).
The total geothermal resources of the Earth, given the average temperature around surface of 15 °C, have been estimated to be $12{,}6 \times 10^{24}$ MJ, while those of the crust appear to be 4×10^{21} MJ (Armstead, 1983). Out of this gigantic amount of heat energy, given the current level of technological development, only a small portion, i.e. the one found in the first ten kilometres of the Earth's crust, is available to humans, in a narrow sense representing a geothermal recource. However, even this „small“ portion has a great potential, because, in global terms, theoretically available geothermal resources are estimated to be $41{,}743 \times 10^6$ EJ, i.e. technically 718,4 EJ/per year and 75,674 EJ/per year in terms of economy (Lund, 2010), which makes a little over 15% of the total world consumption of all energy sources in 2009 (cca 472 EJ).

Utilisation rate of the researched geothermal resources – The modern utilisation of hydro-geothermal resources in AP Vojvodina started back in 1978, when the first of the total of 24 hydro-geothermal systems constructed so far, was made operative (all systems were constructed prior to 1990). The systematic monitoring of production has been conducted since 1987. Until 31/12/2009, these systems produced the total of 23,153. 000 m^3. The greatest annual production was recorded in 1990, reaching cca 1.600.000 m^3 of thermal water. This period was followed by a gradual decrease in production, and later by exclusion of certain systems from the production process (**Diagram no.1**). The lowest number of systems (10) operated in 1997 and 2007, while the lowest production was achieved in 2009, when the 12 active systems (**Map no. 11)** produced 739.149 m^3. The total heat power of the available hydro-geothermal resources from the systems that were operative in 2009 was 26 MW_t (for 180 workdays), while the produced quantity of thermal water was a little less than 6 MW_t., implying that the **utilisation rate** of the available hydro-geothermal resources from these systems reached **23 %**. The situation is even worse if this parameter is considered in relation to the geothermal resources researched so far, whose total available heat power is 72.606 MW_t , as the utilisation coefficient in this case reaches **8 % only.**

Potential geothermal resources – According to the available information, the potential geothermal resources in the territory of Vojvodina have not been subject to specific assessments. The calculation, made as part of the implementation of the previously mentioned study and preparation of this atlas, has included the overall (litho + hydro) potential geothermal resources of Vojvodina until the depth of 1200 m, with a separate calculation of potential hydro-geothermal resources until the same reference depth. The calculation was made by applying the volumetric method, using the following parameters as a starting point: surface and thickness of acquifer, porosity, density of rock masses, density of water, specific rock heat, specific water heat. Based on these parameters, it was calculated that **the total potential geothermal resources** in the territory of Vojvodina, until the average depth of 1200 m, are **13,6 EJ** or cca 325M_{toe}, while **the total potential hydro-geothermal resources** are **3,95 EJ** or 94 M_{toe}.

According to the experience criteria, only cca 25 % of potential geothermal resources may be used in practice, therefore, the **potential available hydro-geothermal resources** in the territory of Vojvodina, until the depth of "only" 1200 m are cca **1 EJ** (≈24 M_{toe}). The fact that best illustrates the amount of potentials is the average annual consumption of energy sources **in Serbia** in the last five years, which was cca **0,63 EJ** or approximately cca 15M_{toe}.

WORLDWIDE UTILISATION OF GEOTHERMAL RESOURCES IN LATE 2009

a.) direct utilisation of geothermal resources – including the use of heat pumps (Lund et all., 2010):

- 78 countris in the worls utilise geothermal resources in this manner (in 2005 – 72; in 2000 – 58; in 1995 - 28);
- the total power of installed capacities is **50.583 MW_t**, which is by almost 79% higher than in 2005, and the largest percent – a bit less than 69,7% or 35.236 MW_t is related to geothermal heat pumps;
- the total amount of generated heat energy is **438.071 TJ/per year** (121.696 GWh/per year), which is by cca 60% higher when compared to 2005, and the largest percent, a bit over 49% or 214.782 TJ, is related to heat pumps;
- in this way, **46, 200.000$_{toe}$** (total consumption of all energy sources in Serbia in 2009 was less than 15,000.000$_{toe}$) of mainly fossil fuels has been replaced, which prevented the emission of 46,6 million tons of carbon and 148,2 million tons of CO_2 in the athmosphere;
- „Top five countries" when it comes to the total installed capacities are: USA, China, Sweden, Norway and Germany (60% of the total installed capacity in the world);
- from the perspective of the number of inhabitantsu, (MW/inhabitant), the leading countries are the following: Iceland, Sweden, Norway, New Zealand and Switzerland. When it comes to the size of a country, (MW/km^2) the leading ones are: Denmark, Holland, Iceland, Switzerland and Hungary;
- the greatest progress in installed capacities in he past five years has been achieved in the following countries: Great Briatain, Korea, Ireland, Spain and Holland;
- the number of equivalent units of 12 kW (usually found in USA ann Western Europe households) using the heat pumps has increased by more than four times when compared to the year 2000, now being 2,940.000;
- geothermal energy is used for the purpose of district heating in 27 countries (the leading countries include Iceland, China, Turkey, France and Russia), while in 24 countries it is also used for individual purposes (the leading countries include Turkey, Italy, USA, Japan and Georgia);
- 34 countries (in 2005 – 30 of them) have used geothermal energy for the purpose of heating greenhouses (when compared to 2005, installed capacities have increased by 10%, being 1.544 MW, while the production of heat energy has increased by 13 %, being 23.264 TJ/per year.). Top five countries are the following: Turkey, **Hungary** , Russia, China and Italy.

b.) Production of electrical energy (Bertini, 2010):

- in the period from 2005 to 2009, the number of countries producing electrical energy from geothermal resources (24) has remained unchanged, but the installed capacities have increased from 8.933 MW to **10.715 MW**, i.e. by cca 20%, as is the case with production of electrical energy, from 55.709 GWh to **67.246** GWh, i.e. by cca 21 % (total annual consumption of electrical energy in Serbia is cca 32.000 GWh);
- - the greatest installed capacities may be found in the USA (3.093 MW), followed by Philippines (1.904MW), Indonesia (1.197 MW), Mexico (958 MW) and Italy (843 MW);
- the largest producers of electrical energy, according to the installed capacities, are the following: USA (16.603 GWh), Philippines (10.311 GWh), Indonesia (9.600 GWh), Mexico (7.047 GWh) and Italy (5.520 GWh), whose total amount is 34.081 GWh, i.e. a bit more than half of the total worldwide production of electrical energy from geothermal resources;
- the greatest number of installed capacities for production of electrical energy is still based on the use of high-temperature hydro-thermal fluids (above 180 °C), but in recent years, however, owing to the development of new technologies, such as binary and «flash» (single and double) systems, the use of hydro-geothermal fluids using lower temperatures (below 100 °C) has gradually increased.

Temperature and content of mineralisation are practically no longer a restiction factor when it comes to the use of hydro-geothermal resources – a combined system for heating (6 MW_t) and electrical energy production (210 kW) in Neustadt – Glewe (Germany), uses the hydro-geothermal fluid, whose temperature is 98 °C, with the total mineralisation being 227 g/l.

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Table 1 - Key features of hydro-thermal boreholes and wells in Vojvodina

Red. Broj No. num.	Lokacija Location	Naziv bušotine Identifier of borehole	Dubina bušotine Depth of borehole (m)	Temp. (°C)	Proticaj Flow rate (l/s)	Termalna snaga Thermal power (MWt)
1	Subotica	S-1	1453.80	36.0	-	-
2	Subotica, Dudova šuma	DŠ-2/II	650.00	35.0	3.58	0.225
3	Palić jezero	Pj-1/II	701.00	48.0	12.20	1.429
4	Palić jezero	Pj-2/H	750.00	48.0	9.51	1.114
5	Kanjiža	Kž-1/H	1147.00	45.0	2.69	0.281
6	Kanjiža	Kž-2/II	1123.00	65.0	9.20	1.732
7	Kanjiža	Kž-3/II	1140.00	72.0	18.9	4.112
8	Bajmok	Bajmok1-/II	678.00	47.0	1.60	0.181
9	Novi Knežcvac	NK-5	1250.00	69.0	6.58	1.349
10	Vrbica	Vbc-1/H	2520.00	82.0	16.6	4.306
11	Bezdan	Bezdan	1305.50	-	-	-
12	Zobnatica	Zob-1/II	543.00	37.0	3.60	0.256
13	Mokrin	Mk-1/H	950.00	51.0	10.5	1.362
14	Bačka Topola	BT-1/H	886.00	22.0	1.0	0.008
15	Bačka Topola	BT-2/II	541.00	37.5	10.90	0.798
16	Kikinda, Šumice	Šm-1/H	950.00	50.0	2.03	0.255
17	Kikinda	Ki-2/H	1200.00	51.0	15.20	1.972
18	Banatsko Veliko Selo	VS-1/H	925.00	43.0	17.70	1.703
19	Banatsko Veliko Selo	VS-2/II	895.00	45.0	11.60	1.213
20	Kupusina	Kps-1/H	1600.00	72.0	3.30	0.718
21	Prigrevica banja	Pb-1/H	701.70	53.0	20.5	2.830
22	Prigrevica banja	Pb-2/II	800.00	59.0	6.88	1.123
23	Prigrevica banja	Pb-3/II	711.70	56.0	21.4	3.223
24	Prigrevica	Prg-1/H	590.00	43.0	2.70	0.260
25	Prigrevica	Prg-2/H	478.00	33.0	2.75	0.150
26	Kikinda	Ki-4/H	1203.00	57.0	4.80	0.743
27	Srpska Crnja	Cr-5	2052.00	75.0	18.30	4.211
28	Sonta	So-1/II	923.00	43.0	2.33	0.224
29	Kula	Kl-1/H	750.00	50.0	9.50	1.192
30	Kula	Kl-2/H	787.40	51.0	8.40	1.090
31	Kula	Kl-3/II	602.00	38.0	3.73	0.281
32	Kula	Kl-4/II	820.00	51.0	8.47	1.099
33	Bečej	Bč-1/H	503.00	33.0	10.70	0.582
34	Bečej	Bč-2/H	1020.00	65.8	24.90	4.772
35	Kucura	BKc-1/GTE	996.50	56.0	8.83	1.330
36	Vrbas	Vrb-1/II	1033.00	37.2	3.70	0.266
37	Vrbas	Vrb-2/H	932.00	51.0	4.37	0.567
38	Vrbas	Vrb-3/H	947.00	56.0	11.30	1.702
39	Srbobran	Sr-1/II	1207.00	63.0	11.60	2.087
40	Srbobran	Sr-2/II	950.20	54.0	5.50	0.782
41	Turija	Tus-1/H	1175.00	54.0	5.95	0.846
42	Turija	Tus-2/H	500.00	34.0	10.50	0.615
43	Melenci	Me-1/II	850.00	33.0	10.30	0.560
44	Bačko Dobro Polje	DP-1	1659.00	57.0	14.60	2.260
45	Žitište	Ži-1/H	1002.00	44.0	3.70	0.372
46	Bački Petrovac	BP-1/H	803.00	46.0	19.20	2.089
47	Bački Petrovac	BP-2/II	800.00	45.0	9.75	1.020
48	Temerin	Te-1/II	914.00	42.0	15.50	1.427
49	Zrenjanjin	Zr-1/H	870.00	48.0	3.96	0.464
50	Zrenjanjin	Zr-2/II	503.25	24.0	3.67	0.061
51	Neuzina	Ne-1/II	1163.00	-	-	-
52	Neuzina	Ne-1a/II	866.00	47.0	3.94	0.445
53	Bačko Karađorđevo	Kdj-1/H		-	-	
54	Bačko Karađorđevo	Kdj-2/H	500.00	34.0	5.67	0.332
55	Bačko Karadordevo	Kdj-3/II	484.30	-	-	-
56	Bačko Karadordevo	Krdj-1/II	1075.00	36.0	3.00	0.201
57	Celarevo	Ce-1/II	1134.00	32.0	13.70	0.688
58	Novi Sad	NSb-1/H	300.50	23.3	17.1	0.236
59	Novi Sad	NS-1/H	573.00	39.0	4.40	0.350
60	Novi Sad	NS-2/II	809.90	38.0	-	-
61	Novi Sad	NS-3/H	824.00	36.0	6.85	0.459
62	Šajkaš	Šaj-1/H	801.00	39.0	8.28	0.658
63	Novi Ledinci	NL-1/H	808.00	20.0	6.05	0.000
64	Sremski Karlovci	SK-1/II	498.20	23.0	5.20	0.065
65	Janošik	Ja-1/H	742.00	35.0	9.57	0.601
66	Erdevik	Er-1/H	352.00	16.0	-	-
67	Ležimir	Lež-1/II	350.00	21.0	1.10	0.005
68	Mala Remeta	MR-1/H	412.00	25.0	-	
69	Vrdnik	Vrd-1/H	600.00	32.0	1.00	0.050
70	Šid	Šid-1/H	850.00	35.0	-	
71	Indija	Ind-1/II	975.00	57.0	13.40	2.074
72	Indija	Ind-3/II	1594.80	43.0	0.20	0.019
73	Banatski Karlovac	BK-1/H	509.74	26.0	15.90	0.399
74	Uljma	Ulj-1/H	1420.00	68.0	1.83	0.368
75	Devojački bunar	Db-1/II	600.00	25.0	11.30	0.236
76	Platicevo	Pt-1/II	1207.20	26.0	1.00	0.025
77	Kupinovo	Kup-1/II	644.00	51.0	24.50	3.178
78	Kupinovo	Kup-2/H	663.00	44.0	9.70	0.974
					UKUPNO:	72.606

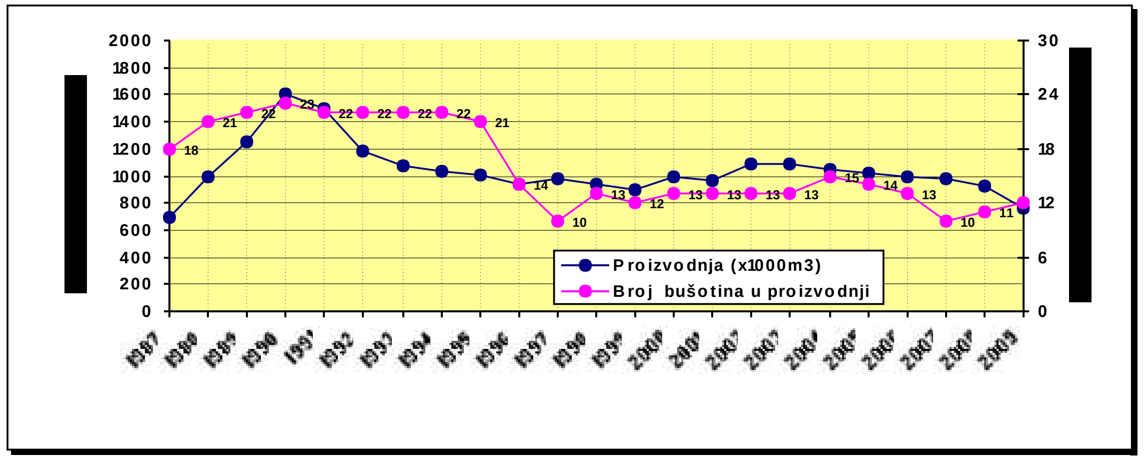

Table 2. Factors used for energy unit conversion in international statistics

from:	to:	TJ	Gcal	M_{toe}	Mbtu	Gwh
Terajoule	**TJ**	1	238.8	2.388×10^{-5}	947.8	0.2778
Gigacalory	**Gcal**	4.1868×10^{-3}	1	10^{7}	3.968	1.163×10^{-3}
Mtoe *	**M_{toe}**	4.1868×10^{4}	10^{7}	1	3.968×10^{7}	11630
Milion **Btu**	**Mbtu**	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
Gigawatt hour	**Gwh**	3.6	860	8.6×10^{-5}	3412	1

One ton of oil equivalent ($_{toe}$) is 41,868 GJ or 11,630 MWh of electrical energy, 2 tons of stone coal or 5,586 tons of raw lignite.

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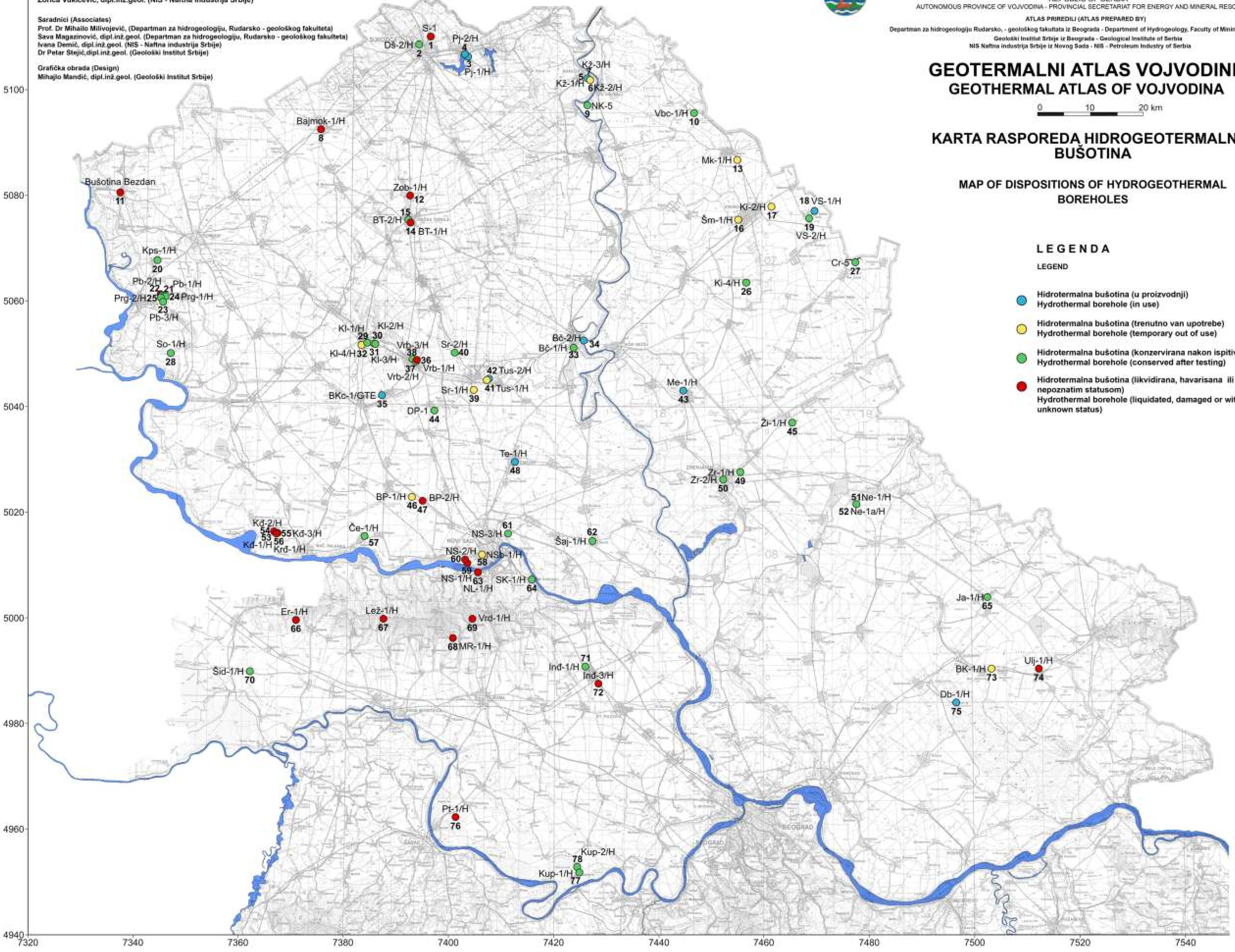
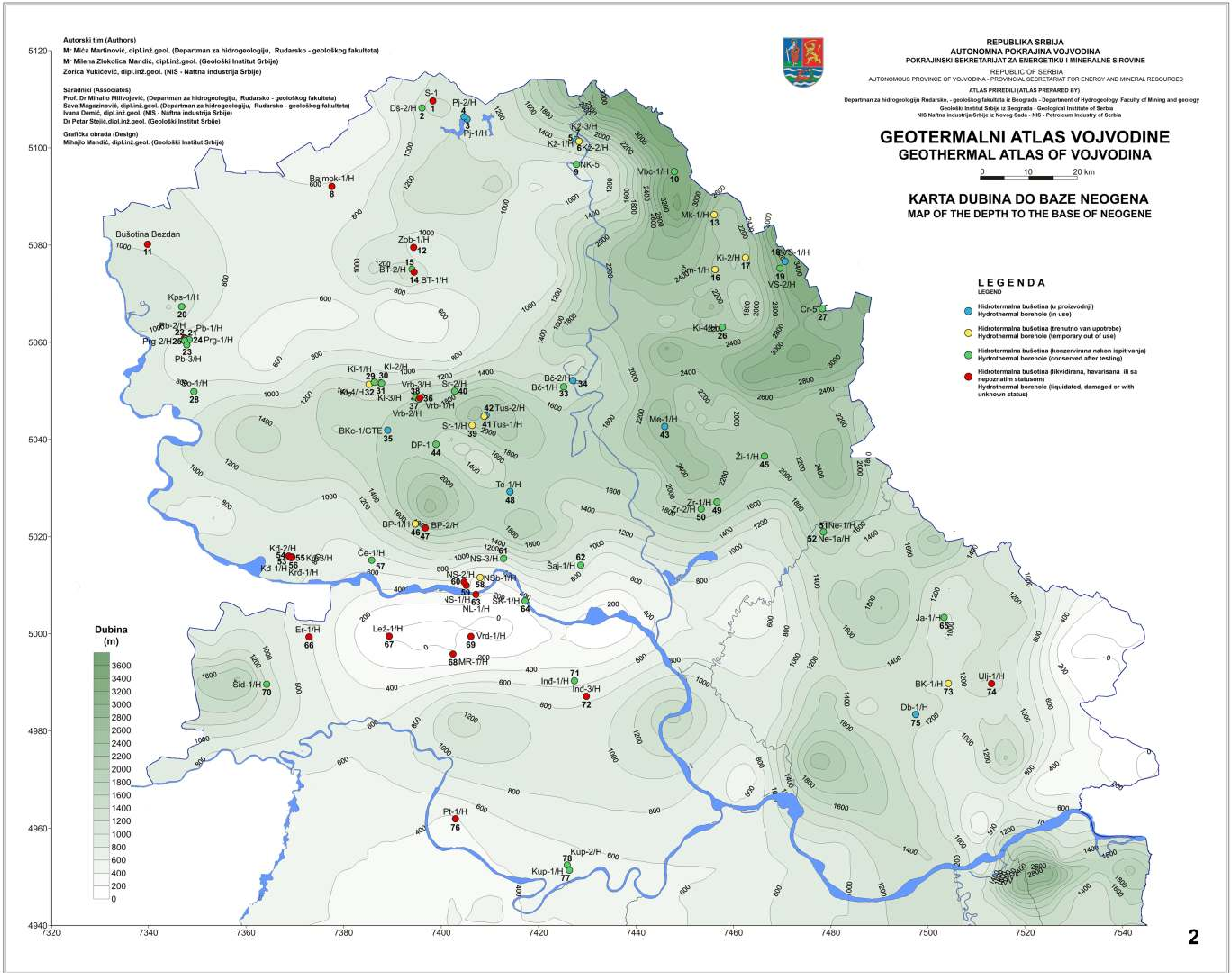
GEOTERMALNI ATLAS VOJVODINE
GEOTHERMAL ATLAS OF VOJVODINA

KARTA RASPOREDA HIDROGEOTERMALNIH BUŠOTINA

MAP OF DISPOSITIONS OF HYDROGEOTHERMAL BOREHOLES

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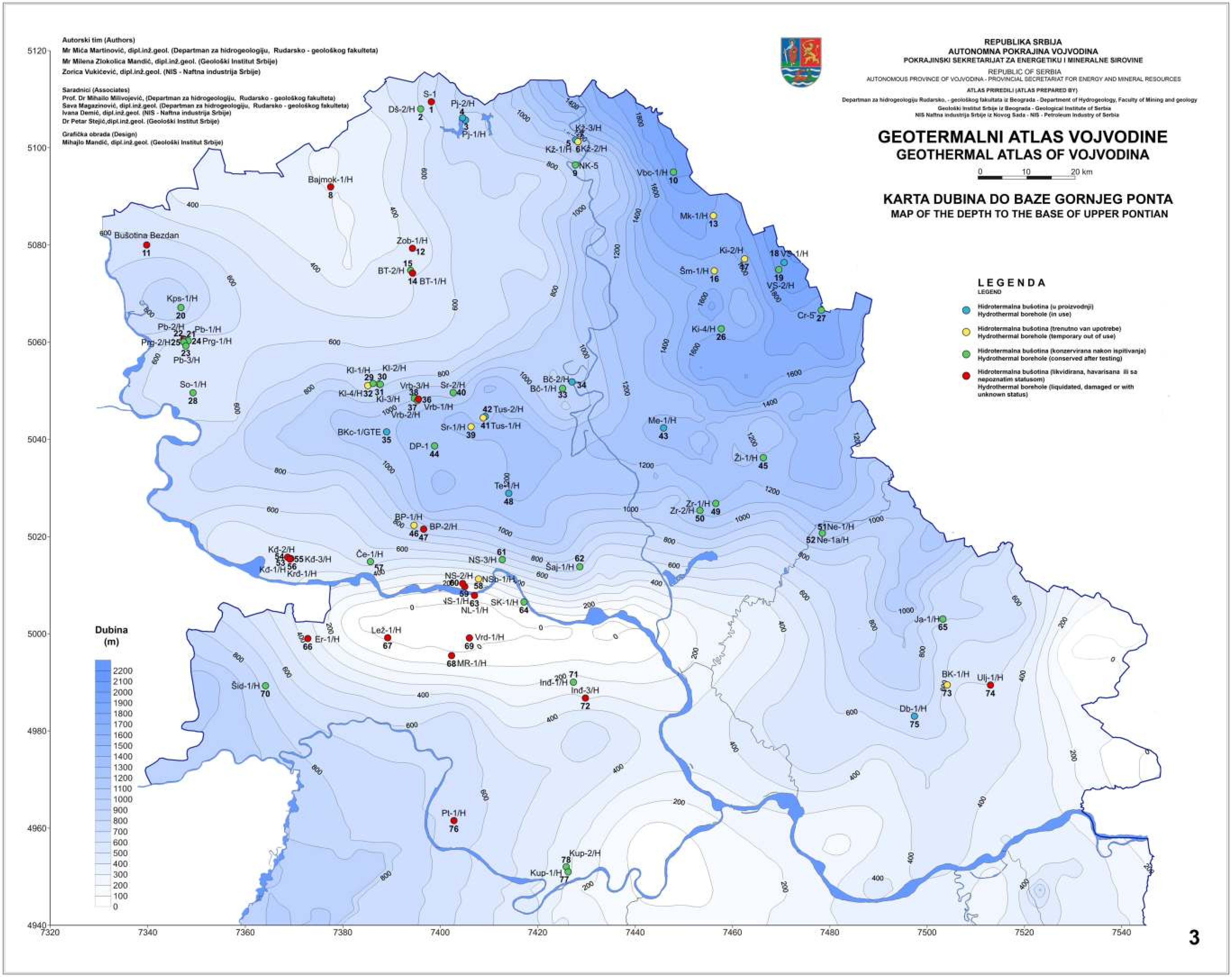
GEOTERMALNI ATLAS VOJVODINE
GEOTHERMAL ATLAS OF VOJVODINA
0 10 20 km
KARTA DUBINA DO BAZE NEOGENA
MAP OF THE DEPTH TO THE BASE OF NEOGENE
LEGENDA
LEGEND
Hidrotermalna bušotina (u proizvodnji)
Hydrothermal borehole (in use)
Hidrotermalna bušotina (trenutno van upotrebe)
Hydrothermal borehole (temporary out of use)
Hidrotermalna bušotina (konzervirana nakon ispitivanja)
Hydrothermal borehole (conserved after testing)
Hidrotermalna bušotina (likvidirana, havarisana ili sa nepoznatim statusom)
Hydrothermal borehole (liquidated, damaged or with unknown status)
Dubina (m)
3600 3400 3200 3000 2800 2600 2400 2200 2000 1800 1600 1400 1200 1000 800 600 400 200 0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GEOTERMALNI ATLAS VOJVODINE
GEOTHERMAL ATLAS OF VOJVODINA
0 10 20 km
KARTA DUBINA DO BAZE GORNJEG PONTA
MAP OF THE DEPTH TO THE BASE OF UPPER PONTIAN
LEGENDA
LEGEND
Hidrotermalna bušotina (u proizvodnji)
Hydrothermal borehole (in use)
Hidrotermalna bušotina (trenutno van upotrebe)
Hydrothermal borehole (temporary out of use)
Hidrotermalna bušotina (konzervirana nakon ispitivanja)
Hydrothermal borehole (conserved after testing)
Hidrotermalna bušotina (likvidirana, havarisana ili sa nepoznatim statusom)
Hydrothermal borehole (liquidated, damaged or with unknown status)
Dubina (m)
2200 2100 2000 1900 1800 1700 1600 1500 1400 1300 1200 1100 1000 900 800 700 600 500 400 300 200 100 0
S-1 1
Dš-2/H 2
Pj-2/H 4
3
Pj-1/H
Kž-3/H
Kž-1/H 5 6 Kž-2/H
NK-5 9
Vbc-1/H 10
Bajmok-1/H 8
Mk-1/H 13
Bušotina Bezdan 11
Zob-1/H 12
Ki-2/H 17
18 VS-1/H
Šm-1/H 16
19 VS-2/H
BT-2/H 15
14 BT-1/H
Kps-1/H 20
Cr-5 27
Ki-4/H 26
Pb-2/H 22 21 Pb-1/H
Prg-2/H 25 24 Prg-1/H
23 Pb-3/H
Kl-1/H 29
Kl-2/H 30
Kl-4/H 32 31
Kl-3/H
Vrb-3/H 38 36
37 Vrb-1/H
Vrb-2/H
Sr-2/H 40
Bč-2/H 34
Bč-1/H 33
So-1/H 28
42 Tus-2/H
41 Tus-1/H
Sr-1/H 39
Me-1/H 43
BKc-1/GTE 35
DP-1 44
Ži-1/H 45
Te-1/H 48
Zr-1/H 49
Zr-2/H 50
BP-1/H 46
BP-2/H 47
51 Ne-1/H
52 Ne-1a/H
Kđ-2/H 54 55 Kđ-3/H
53 56
Kđ-1/H
Krđ-1/H
Če-1/H 57
NS-3/H 61
Šaj-1/H 62
NS-2/H 60
NSb-1/H 58
59
NS-1/H 63
NL-1/H
SK-1/H 64
Ja-1/H 65
Er-1/H 66
Lež-1/H 67
Vrd-1/H 69
MR-1/H 68
Šid-1/H 70
Inđ-1/H 71
Inđ-3/H 72
BK-1/H 73
Ulj-1/H 74
Db-1/H 75
Pt-1/H 76
Kup-2/H 78
Kup-1/H 77
5120 5100 5080 5060 5040 5020 5000 4980 4960 4940
7320 7340 7360 7380 7400 7420 7440 7460 7480 7500 7520 7540

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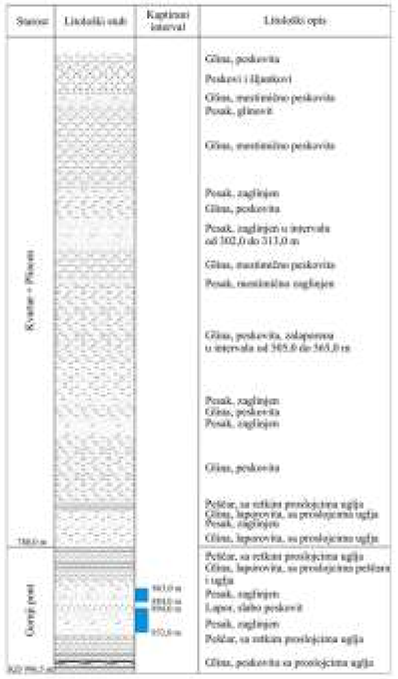
GEOTERMALNI ATLAS VOJVODINE
GEOTHERMAL ATLAS OF VOJVODINA

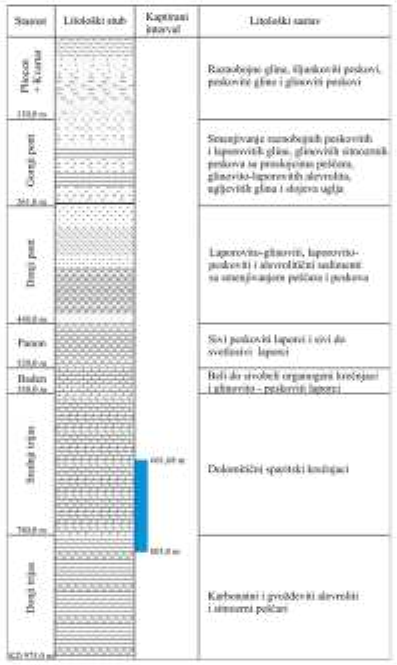
PROFILI HIDROGEOTERMALNIH BUŠOTINA

CROSS SECTIONS OF SELECTED HYDROGEOTHERMAL BOREHOLES

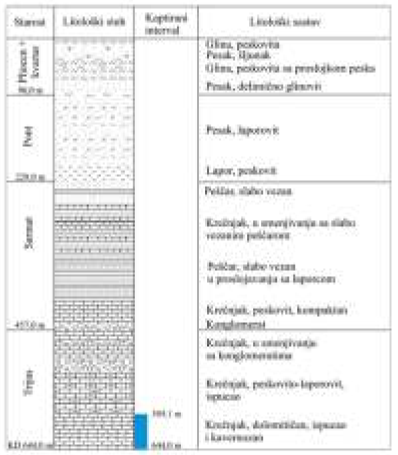
BKc-1/GTE



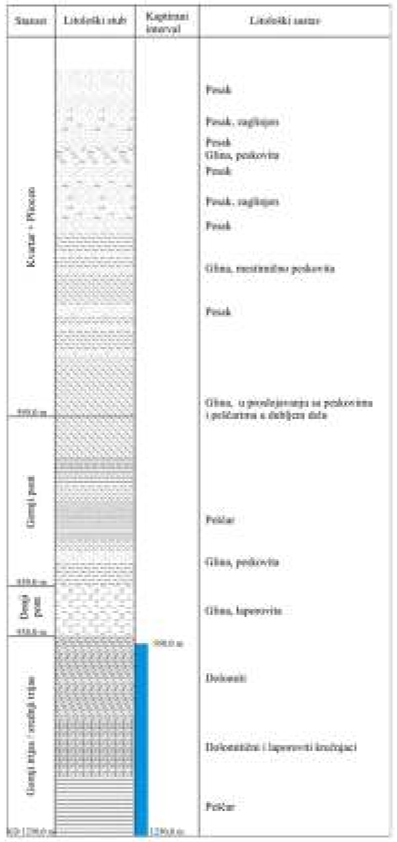
Inđ-1/H



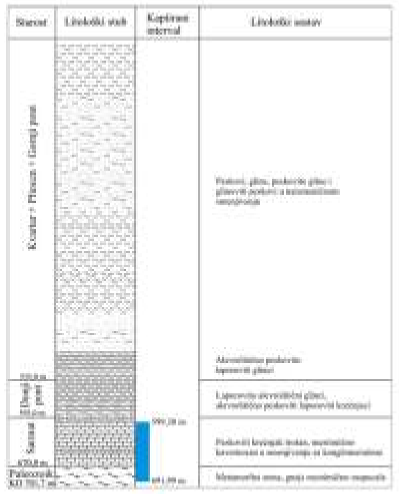
Kup-1/H



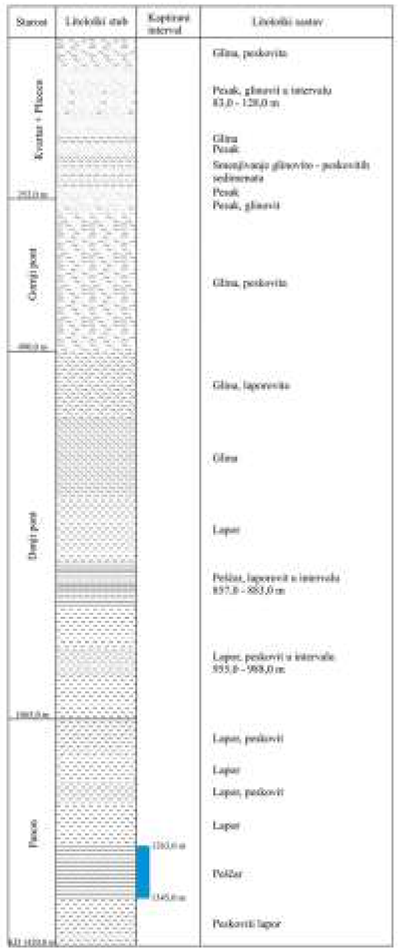
NK-5



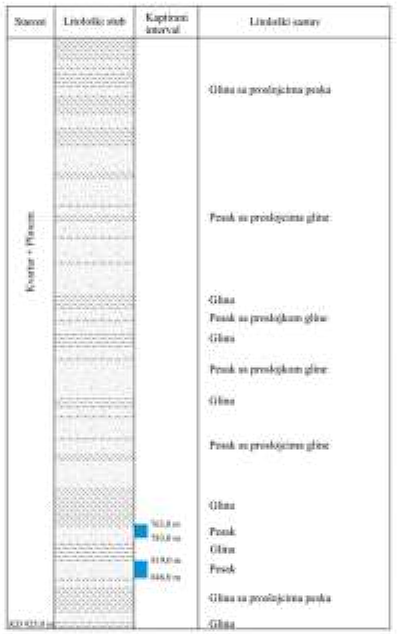
Pb-1/H



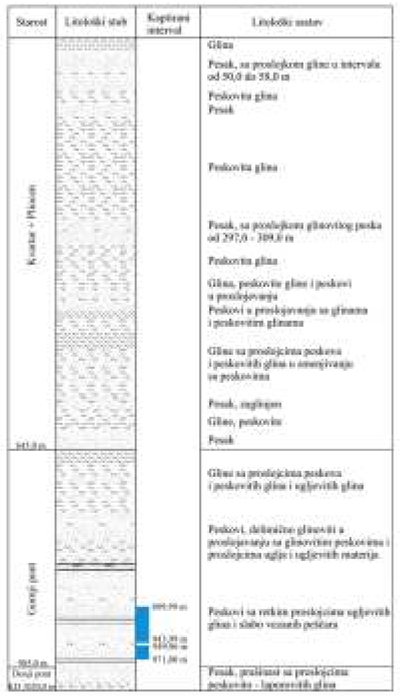
Ulj-1/H



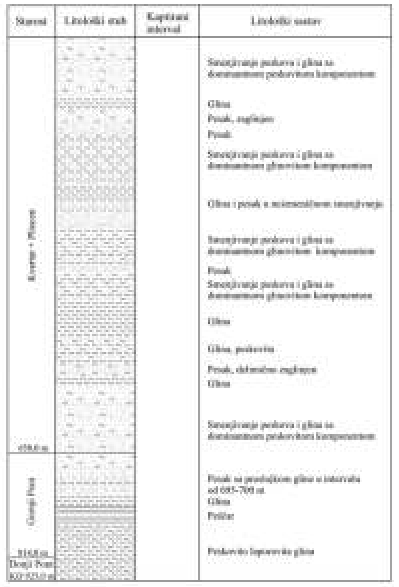
VS-1/H



Bč-2/H



Šid-1/H



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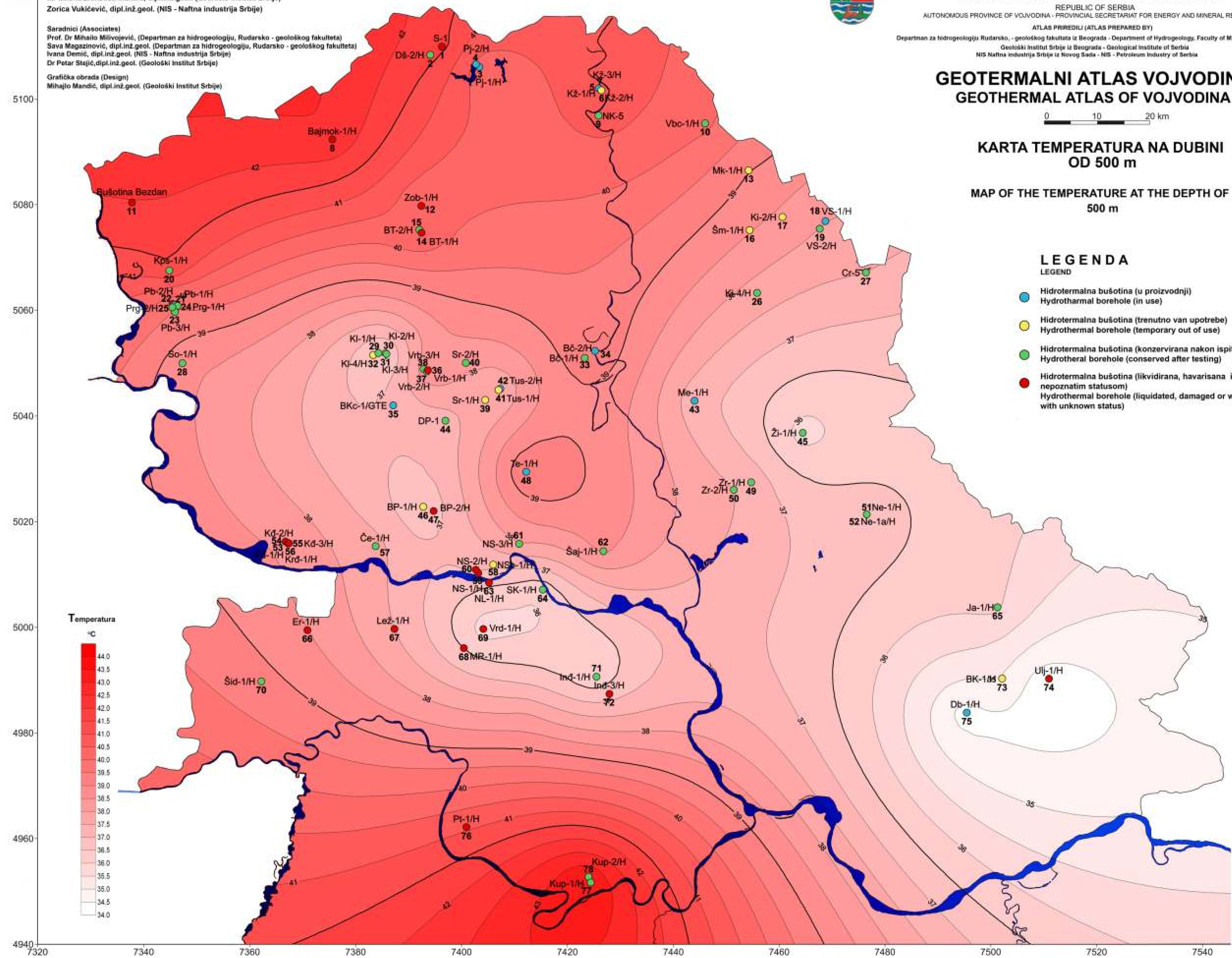
KARTA TEMPERATURA NA DUBINI OD 500 m

MAP OF THE TEMPERATURE AT THE DEPTH OF 500 m



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ATLAS PRIREDILI (ATLAS PREPARED BY)
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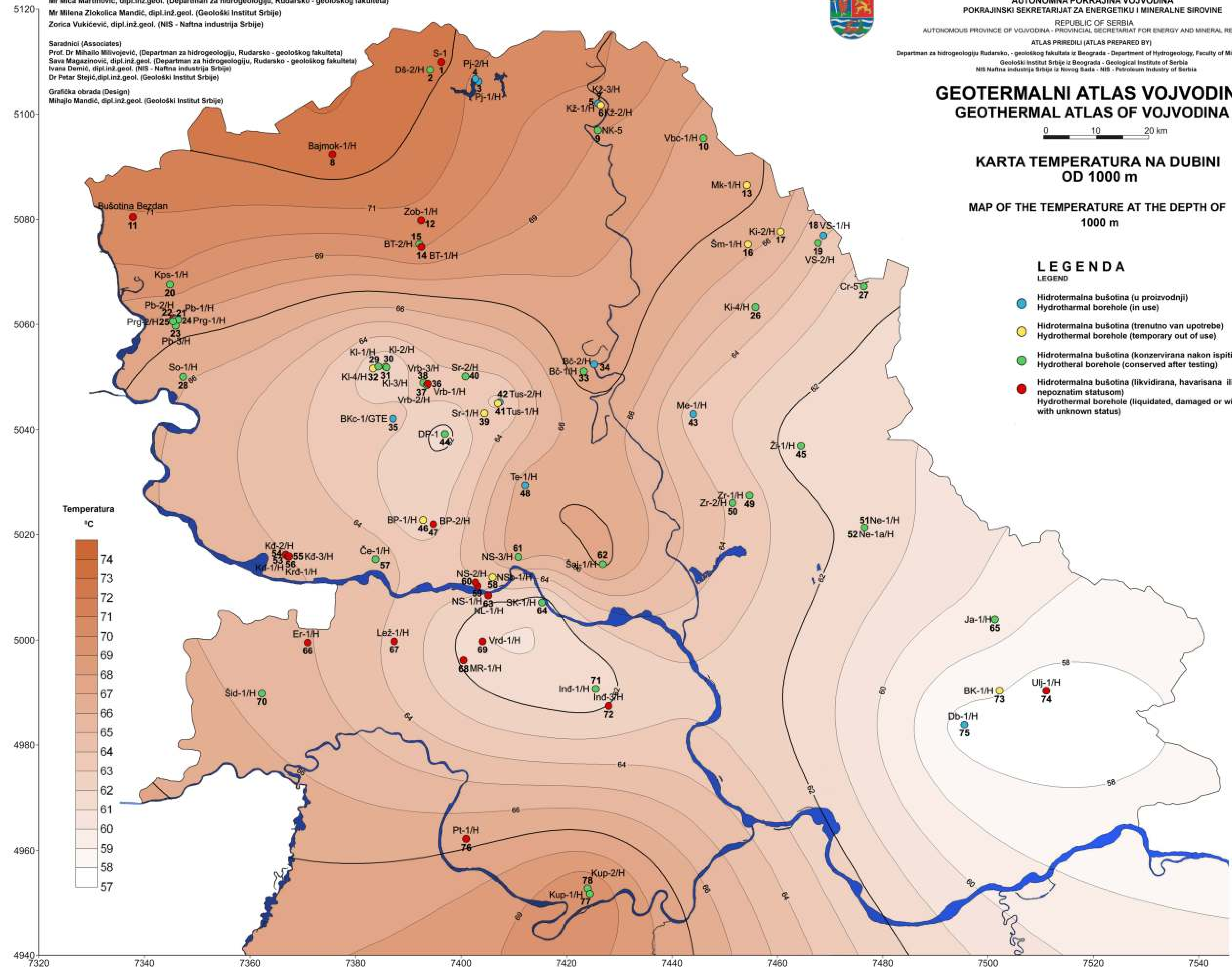
GEOTERMALNI ATLAS VOJVODINE
GEOTHERMAL ATLAS OF VOJVODINA

KARTA TEMPERATURA NA DUBINI OD 1000 m

MAP OF THE TEMPERATURE AT THE DEPTH OF 1000 m



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GEOTERMALNI ATLAS VOJVODINE
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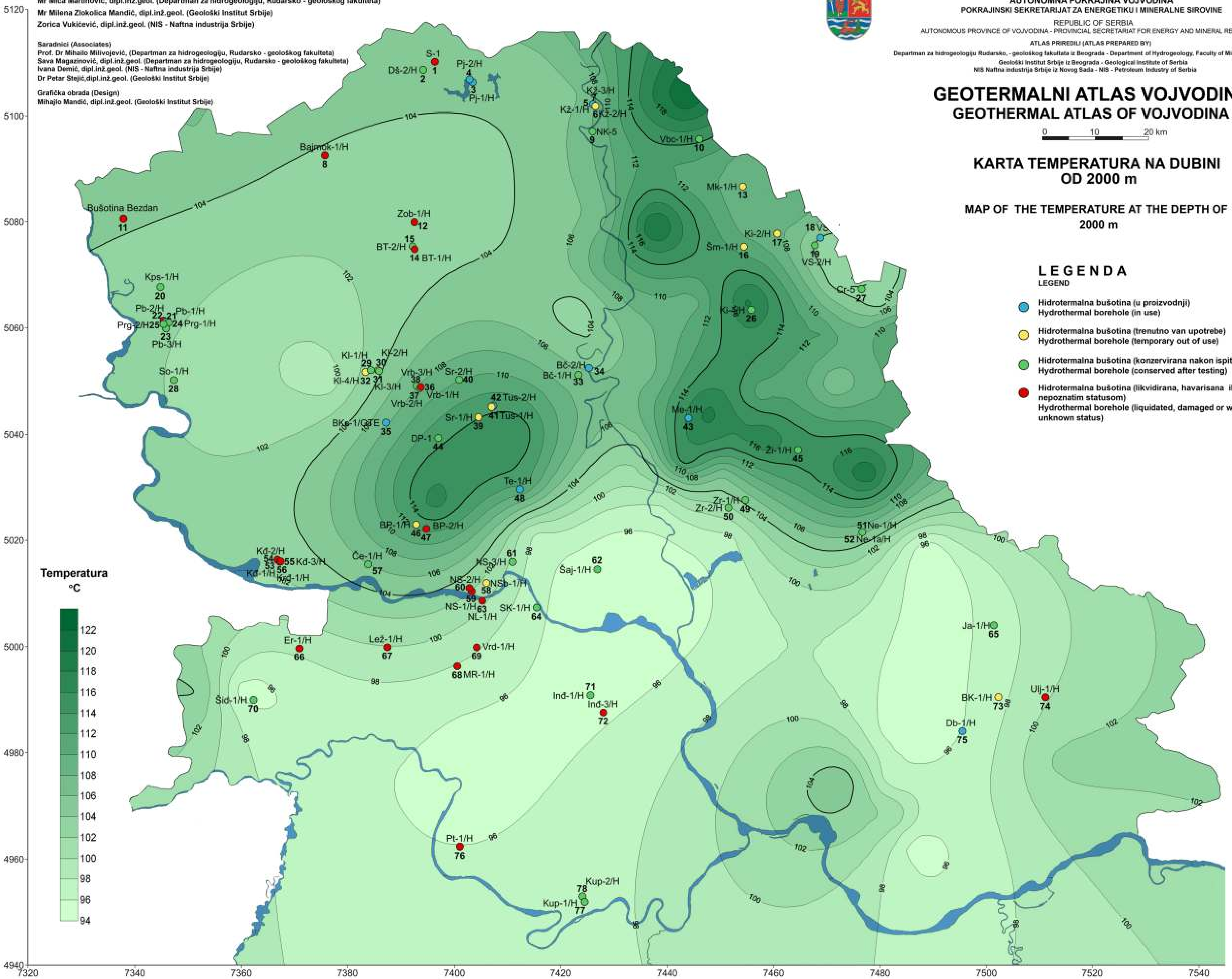
KARTA TEMPERATURA NA DUBINI OD 2000 m

MAP OF THE TEMPERATURE AT THE DEPTH OF 2000 m



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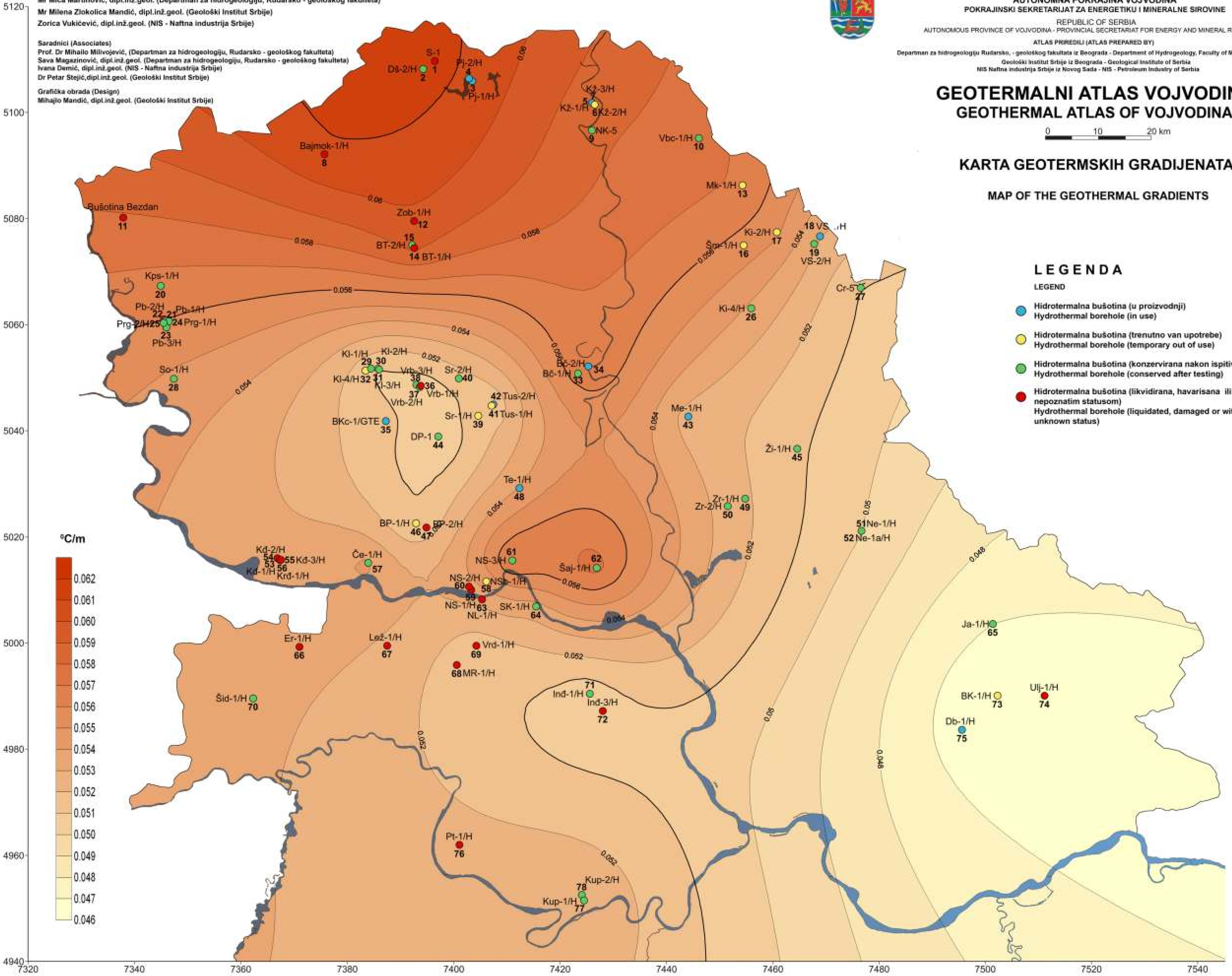
KARTA GEOTERMSKIH GRADIJENATA

MAP OF THE GEOTHERMAL GRADIENTS



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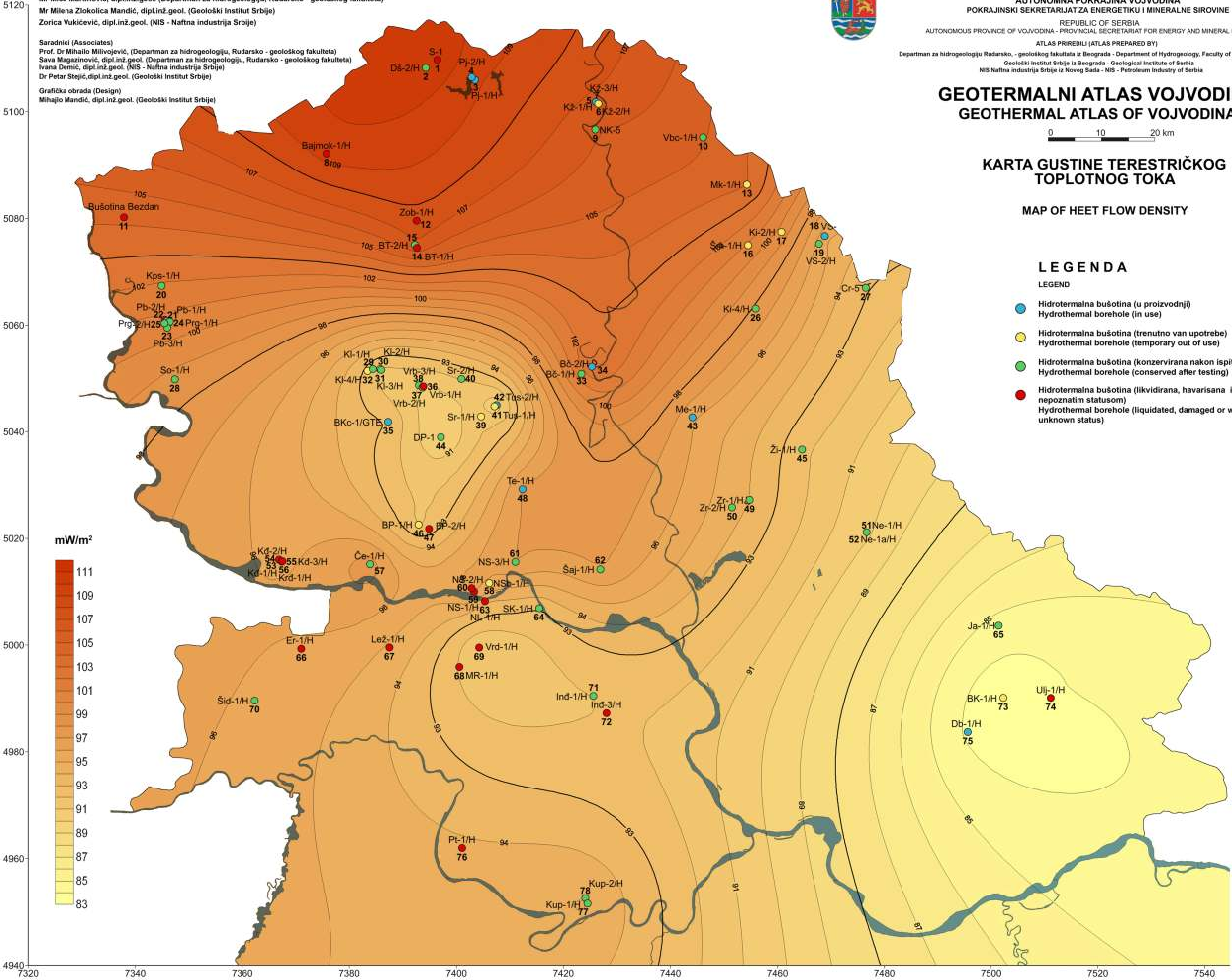
GEOTERMALNI ATLAS VOJVODINE
GEOTHERMAL ATLAS OF VOJVODINA

KARTA GUSTINE TERESTRIČKOG TOPLOTNOG TOKA

MAP OF HEET FLOW DENSITY



LEGENDA
LEGEND

- Hidrotermalna bušotina (u proizvodnji) / Hydrothermal borehole (in use)
- Hidrotermalna bušotina (trenutno van upotrebe) / Hydrothermal borehole (temporary out of use)
- Hidrotermalna bušotina (konzervirana nakon ispitivanja) / Hydrothermal borehole (conserved after testing)
- Hidrotermalna bušotina (likvidirana, havarisana ili sa nepoznatim statusom) / Hydrothermal borehole (liquidated, damaged or with unknown status)

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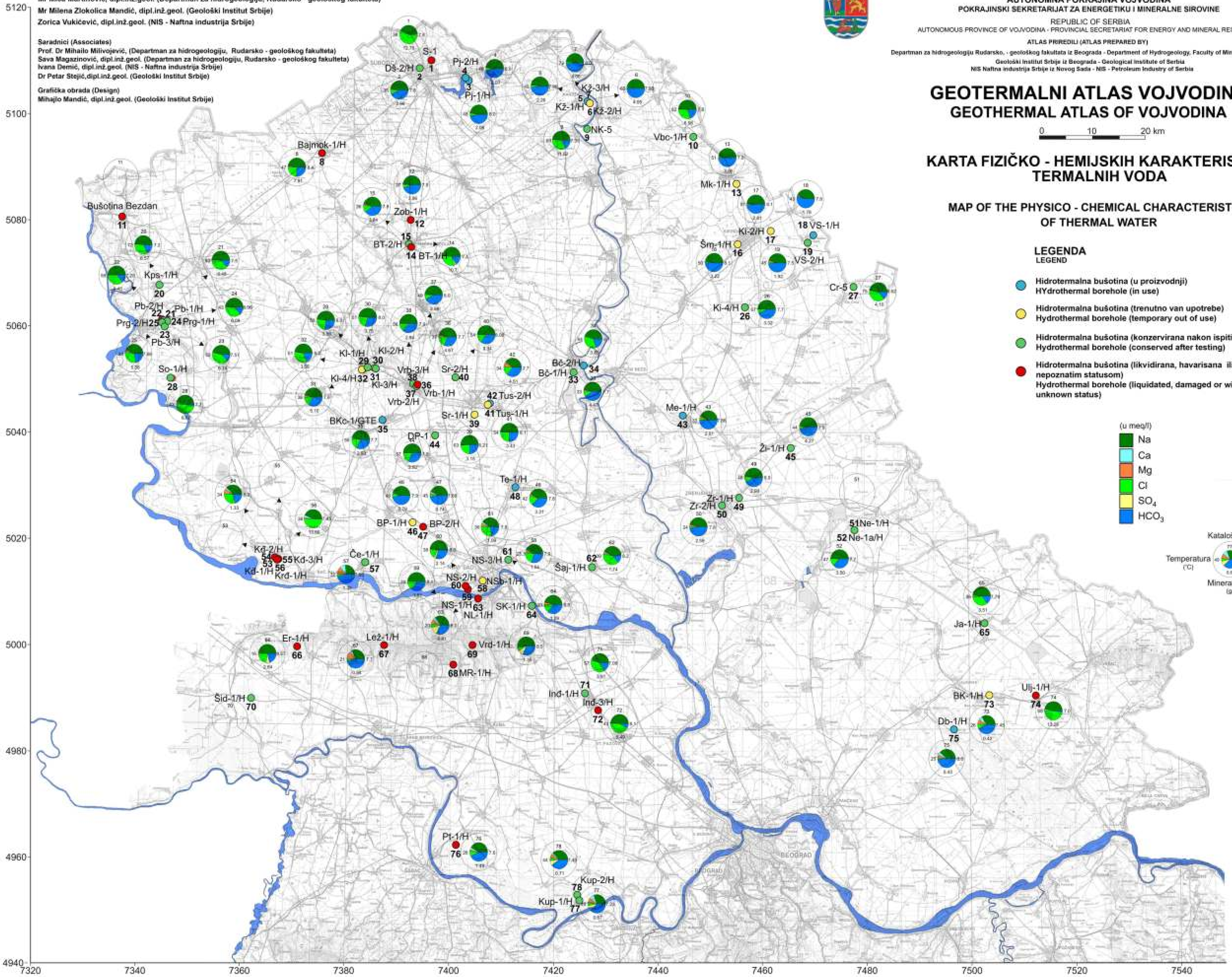
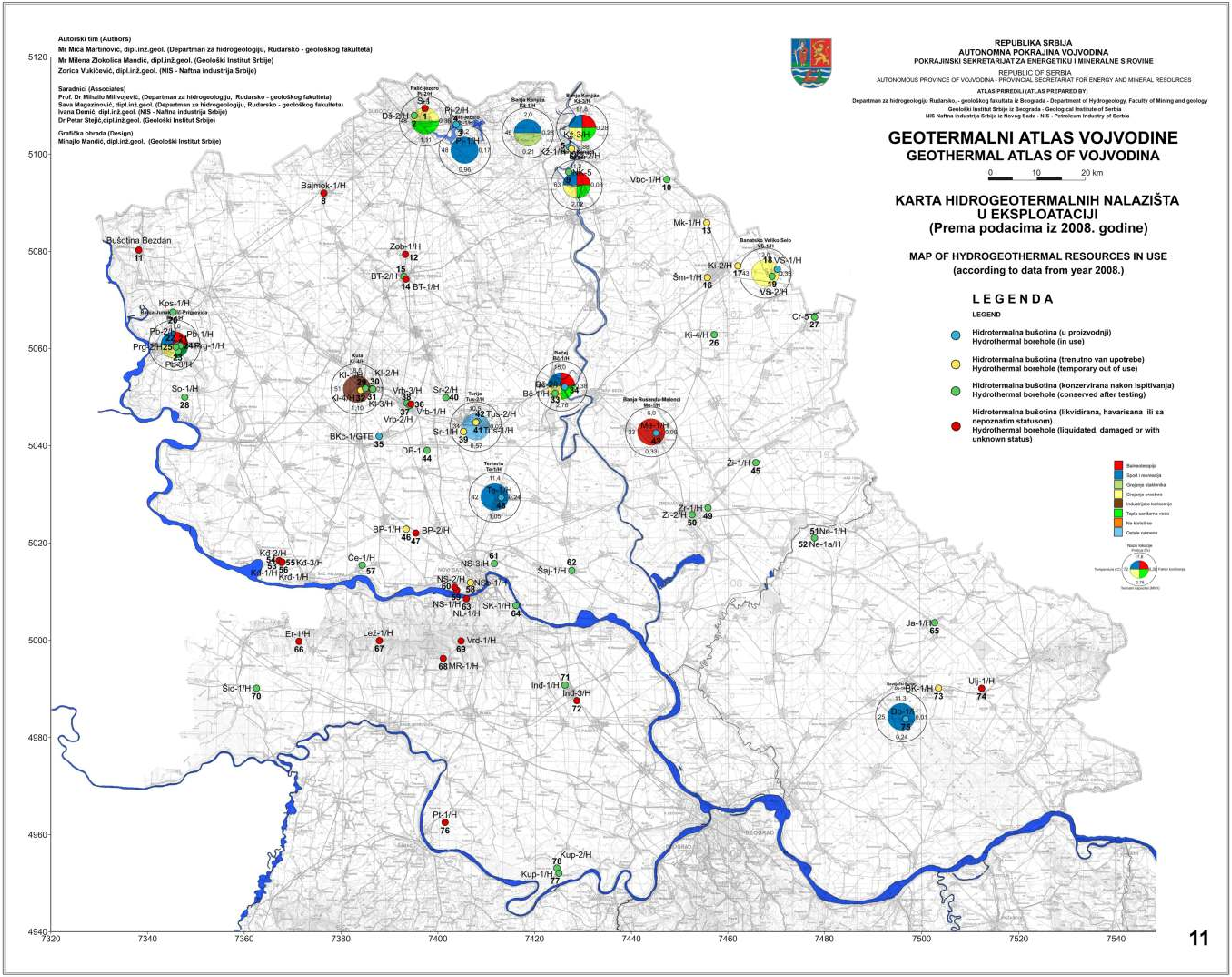
GEOTERMALNI ATLAS VOJVODINE
GEOTHERMAL ATLAS OF VOJVODINA

KARTA FIZIČKO - HEMIJSKIH KARAKTERISTIKA TERMALNIH VODA

MAP OF THE PHYSICO - CHEMICAL CHARACTERISTICS OF THERMAL WATER

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GEOTERMALNI ATLAS VOJVODINE
GEOTHERMAL ATLAS OF VOJVODINA
0 10 20 km
KARTA HIDROGEOTERMALNIH NALAZIŠTA U EKSPLOATACIJI
(Prema podacima iz 2008. godine)
MAP OF HYDROGEOTHERMAL RESOURCES IN USE
(according to data from year 2008.)
LEGENDA
LEGEND
Hidrotermalna bušotina (u proizvodnji)
Hydrothermal borehole (in use)
Hidrotermalna bušotina (trenutno van upotrebe)
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Hydrothermal borehole (conserved after testing)
Hidrotermalna bušotina (likvidirana, havarisana ili sa nepoznatim statusom)
Hydrothermal borehole (liquidated, damaged or with unknown status)
Bajmok-1/H
Bušotina Bezdan
Zob-1/H
BT-2/H
BT-1/H
Vbc-1/H
Mk-1/H
Ki-2/H
Šm-1/H
VS-1/H
VS-2/H
Cr-5
Ki-4/H
Kps-1/H
Pb-1/H
Pb-3/H
So-1/H
Kl-2/H
Kl-3/H
Vrb-3/H
Vrb-1/H
Vrb-2/H
Sr-2/H
Tus-2/H
Tus-1/H
Sr-1/H
Bč-1/H
Me-1/H
BKc-1/GTE
DP-1
Ži-1/H
Te-1/H
Zr-1/H
Zr-2/H
BP-1/H
BP-2/H
Ne-1/H
Ne-1a/H
Kđ-2/H
Kđ-3/H
Kđ-1/H
Krd-1/H
Če-1/H
NS-3/H
Šaj-1/H
NS-2/H
NS-1/H
NL-1/H
SK-1/H
Ja-1/H
Er-1/H
Lež-1/H
Vrd-1/H
MR-1/H
Šid-1/H
Inđ-1/H
Inđ-3/H
BK-1/H
Ulj-1/H
Db-1/H
Pt-1/H
Kup-2/H
Kup-1/H
5120
5100
5080
5060
5040
5020
5000
4980
4960
4940
7320
7340
7360
7380
7400
7420
7440
7460
7480
7500
7520
7540