GEOTHERMAL WATERS OF THE LIPTOV BASIN

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Abstract: The Liptov Basin represents an intramontaneous depression in the core mountain belt of the Western Carpathians. Results from four geothermal wells 1,987 – 2,500 m deep were used for evaluation of geological structure, geothermic and pressure conditions, hydraulic parameters of aquifers, spatial distribution and chemical composition of geothermal waters and their thermal-energy potential. Triassic dolomites and limestones represent aquifers of geothermal water in Liptov Basin with the fissure-karst permeability, which were documented by geothermal wells at depths of 1,255 – 1,625 m. The geothermal field activity varies considerably, geothermal gradient ranges from 18 to 32 °C/km and the heat flow density from 44 to 77 mW/m^2. Chemical composition of these waters is mainly of the Ca-Mg-HCO_3-SO_4 and Ca-Mg-HCO_3 types respectively, with mineralization of 0.4 – 5.1 g/l. Thermal-energy potential of the Liptov Basin was estimated by distributed parameter model at 34.589 MW_t.

Key words: geothermal field, geothermal wells, geothermal waters, hydraulic parameters, thermal-energy potential

1 INTRODUCTION

The Liptov Basin belongs to the important areas of the Slovak Republic as far as the possibilities of geothermal water – source of the geothermal energy obtaining, is concerned. This 611 km^2 large basin is located in the north-western part of Slovakia (Figure 1). It is elongated in the E-W direction and fringed by the Nizke Tatry, Zapadne Tatry, Chocske vrchy and Velka Fatra Mts. The possibilities of obtaining and utilization of the geothermal waters in Liptov Basin were manifested in the past by a number of natural springs of mineral waters.

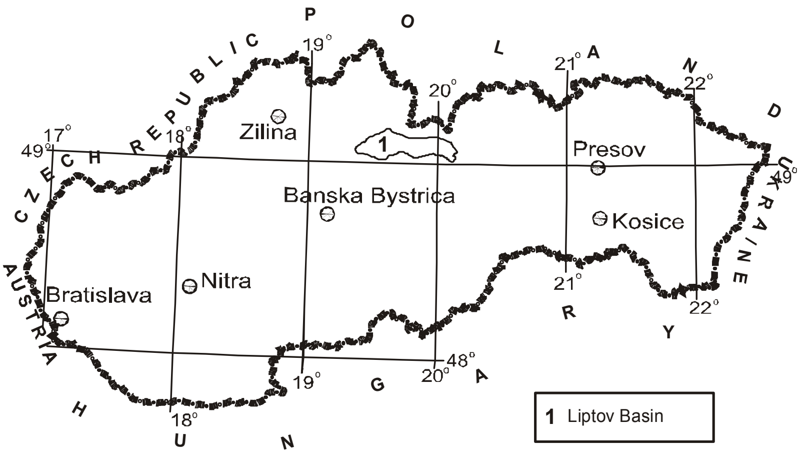

Figure 1 Location of the Liptov Basin

The first hydrogeothermal evaluation of the Liptov Basin, oriented on research of the geothermal resources, was done for Demanova area [1], followed by drilling of the first geothermal borehole FGL-1 in Pavcina Lehota [2]. Research of geothermal resources of the

Liptov Basin has continued by project of the partial research work of the development of science and technique [3]. In the frame of the project, the whole area of the Liptov Basin was assessed (based on knowledge of geological, geophysical, hydrogeological, geothermic and geochemical conditions) and drilling of three research boreholes in Besenova, Liptovska Kokava and Liptovsky Trnovec was proposed. Separate projects for drilling of these boreholes were elaborated [4, 5, 6]. Boreholes were drilled in 1986 – 1991. After finishing of drilling works, complex evaluation of them was done and results were summarised in reports [7, 8, 9, 10].

Based on the results of these four geothermal boreholes, but also other research boreholes and works performed in the Liptov Basin [11, 12, 13], the complex evaluation of the hydrogeothermal conditions in Liptov Basin was performed.

All the above mentioned research works enabled to obtain basic data for evaluation of the pressure conditions, hydraulic parameters and amounts of geothermal waters of the Liptov Basin.

2 HYDROGEOTHERMAL CONDITIONS

The Liptov Basin is an intramontane depression in the Inner Western Carpathians. It is filled with Paleogene sediments whose thickness ranges from 100 m (Besenova) to 1,700 m (Liptovska Mara). The substratum consists of the Choc and Krizna nappes, which form elevated and sunken morphostructures (Figure 1).

The activity of geothermal field is very variable, mainly as a result of hydrogeological processes. Temperatures at different depths are as follow in Table 1.

Table 1 Temperatures at different depths in the Liptov Basin

Depth [m]	500	1,000	1,500	2,000	2,500
Temperature [ºC]	17 – 28	29 – 46	37 – 62	46 – 76	54 – 87

Geothermal gradient in wells 2,000 to 2,500 m deep varies from 18 to 32 ºC/km and heat flow density ranges from 55 to 77 mW/m^2. The lowest values of the geothermal parameters have been noted in the eastern (Kokava depression – well ZGL-3) and southern (well FGL-1) parts of the basin while the highest ones occur in the west (wells ZGL-1, ZGL-2/A). Convective heat transfer in the Kokava depression (negative anomaly – well ZGL-3) and Besenova elevation (positive anomaly – well ZGL-1) disturbs the thermal field of the basin.

Geothermal waters in the Liptov Basin are discharged through natural springs and wells. In the deeper nappe structure beneath the Paleogene there may be one to three hydrogeothermal structures positioned one above another in which geothermal waters are mostly associated with Triassic dolomites and limestones ("carbonates" throughout the following text) of the Choc and Krizna nappes and possibly also of the Tatric envelope unit. These hydrogeological structures are largely open (having recharge area on adjacent slopes of surrounding mountains, as well as transit-accumulation and discharge areas) or semi-open (discharge area is missing). The Triassic carbonate aquifers with geothermal waters are from 300 to 1,200 m thick.

Geothermal waters occurring in the Choc nappe Triassic carbonates at depths 500 – 2,800 m have the temperature of 20 – 90 ºC hot while those in identical rocks of the Krizna nappe at depths of 900 – 4,000 m could be 25 – 125 ºC hot. The temperature of geothermal waters occurring in Triassic carbonates of the envelope unit at depths of 2,500 – 5,000 m might amount to 70 – 150 ºC.

3 RESULTS OF HYDROGEOTHERMAL RESEARCH

Geothermal wells were situated in elevations (ZGL-1) as well as in depression (e.g. ZGL-3) of the pre-Paleogene substratum. They tapped geothermal waters in Triassic carbonates of the Choc (FGL-1, ZGL-2/A) and Krizna nappes (ZGL-1, ZGL-3) at depths ranging from 1,315 to 2,486 m.

Set of hydrodynamic tests was performed on all geothermal wells in the basin. Courses of selected hydrodynamic tests are showed in Figure 2. The absolute transmissivity coefficient of the Triassic carbonates varies from $2.4*10^{-12}$ m^3 (FGL-1) to $1.1*10^{-10}$ m^3 (ZGL-3) and permeability from $3.8*10^{-14}$ m^2 (ZGL-1) to $9.1*10^{-13}$ m^2 (ZGL-3), both parameters decreasing from the east to the west. Well discharges range between 6 and 31 l/s and water temperature at the well head between 32 – 62 ºC (Table 2). Controlled by the discharge and temperature, the thermal power of wells attains 0.4 – 5.9 MW_t (water temperature drops to 15 ºC during exploitation).

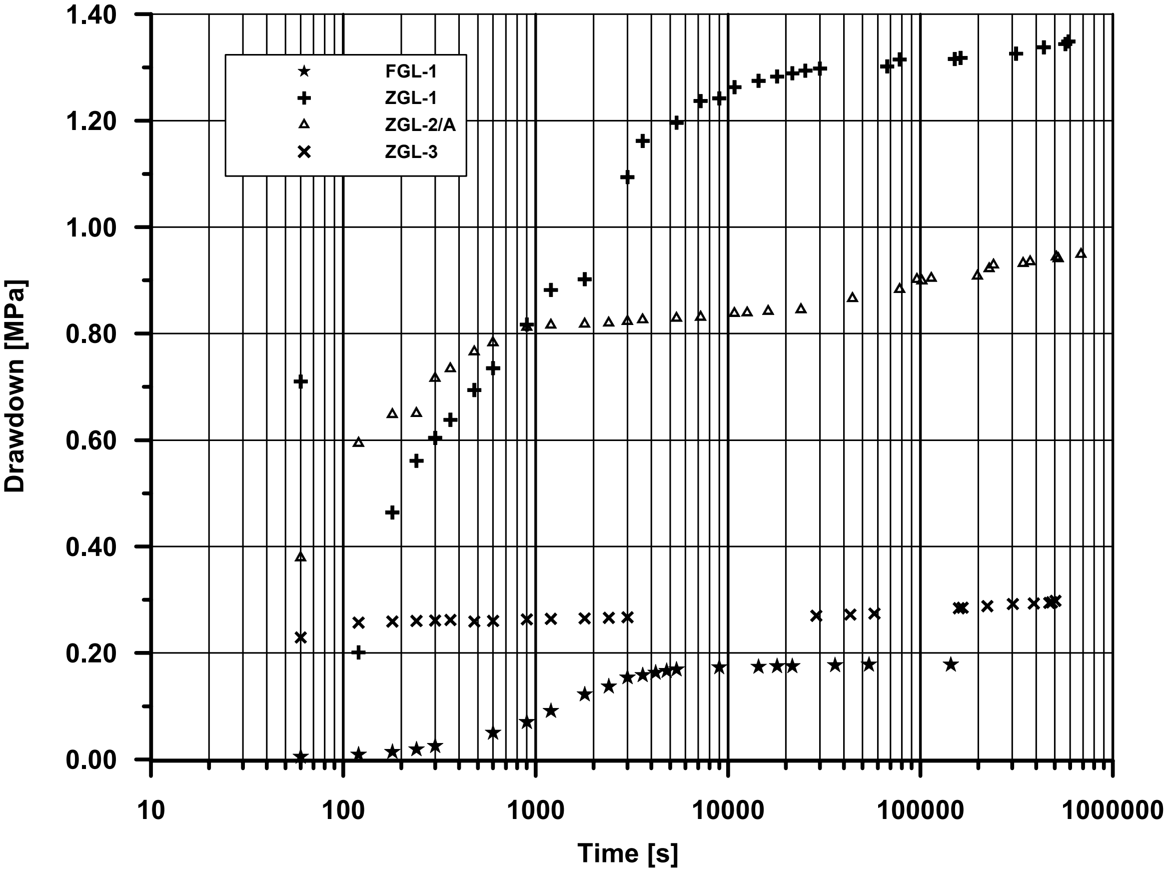

Figure 2 Course of selected hydrodynamic tests on geothermal wells

The depth of bubble points for geothermal wells in Liptov Basin varies in the interval 162 – 225 m. The maximal depth of the bubble point was estimated for the well ZGL-2/A. According to the positioning of the bubble points it can be claimed that its utmost depths can be expected in the northern and north-eastern part of the Liptov Basin. In these parts of the basin, the influence of the gaslift (free gas content) on the density of geothermal waters during their exploitation will be the greatest. Also higher contents of gases could be expected, which is connected with the possible technological problems (scaling, corrosion) during exploitation of the geothermal water.

Table 2 Data from research geothermal wells

Well Locality	Aquifers	Perforated interval [m]	Discharge [l/s]	Water temperature [ºC]	Thermal power [MW_t]	T.D.S. [g/l]	Chemical type of water
FGL-1 Pavcina Lehota	Triassic limestones and dolomites[1]	1,315-1,570	6.0*	32.0	0.42	0.4	$Ca\text{-}Mg\text{-}HCO_3$
ZGL-1 Besenova	Triassic dolomites[2]	1,420-1,964	27.0**	62.0	5.30	5.3	$Ca\text{-}Mg\text{-}SO_4\text{-}HCO_3$
ZGL-2/A Liptovsky Trnovec	Triassic dolomites and limestones[1]	1,624-2,486	31.0**	60.7	5.89	5.9	$Ca\text{-}Na\text{-}Mg\text{-}HCO_3\text{-}SO_4$
ZGL-3 Liptovska Kokava	Triassic limestones and dolomites[2]	1,475-2,365	20.0**	43.5	2.42	2.4	$Ca\text{-}Mg\text{-}HCO_3\text{-}SO_4$

[1] Choc nappe, [2] Krizna nappe, * pumping, ** free outflow

In accordance with the preceding claim, the highest values of the gaslift were estimated for boreholes ZGL-2A and ZGL-3 (Table 3), in which they represent 50 – 83 % of the measured drawdown. The percentual ratio of the gaslift and thermolift on the measured drawdown in boreholes showed that for geothermal boreholes in the Liptov Basin are the gaslift values in 5 – 71 % higher than values of the thermolift. At the same time, the influence of the free gas content and the water temperature represent 18 – 95 % of the measured drawdown and as a result of their influence on the boreholes exploited by the free outflow the bettering of the borehole discharge occur. It means that without these influences, the value of the free outflow on geothermal boreholes ZGL-1 and ZGL-2/A would be only 27 – 70 % of the values measured during pumping tests.

Table 3 Comparison of gaslift and thermolift values with the measured depression p_{me} for geothermal boreholes in Liptov Basin

Locality	Well	Depression	Gaslift		Thermolift	
		p_{me} [MPa]	MPa	% from p_{me}	Mpa	% from p_{me}
Pavcina Lehota	FGL-1	0.186	-	-	0.033	17.7
Besenova	ZGL-1	1.349	0.238	17.6	0.172	12.7
Lipt. Trnovec	ZGL-2/A	0.949	0.476	50.1	0.218	22.9
Lipt. Kokava	ZGL-3	0.298	0.247	82.9	0.035	11.7

Spreading of piezometric levels for geothermal wells and selected boreholes tapping mineral waters of the Liptov Basin showed that the dominant element forming the probable groundwater flow direction under natural conditions is placed in the north-eastern part of the Liptov Basin. The course of hydroisopiezes (Figure 3) is in the southern part of the basin formed by the influence of water recharge in the area to the south-west of Liptovsky Jan (well B-2) and Demanova valley. In the northern part it is formed by the influence of water recharge in the area to the north of villages Jalovec and Konska. Evident diminishing of the piezometric level slope can be observed in the area to the north of villages Liptovska Anna and Kvacany. The point of the lowest piezometric tension is located in the south-western part of the basin between the villages Liptovska Stiavnica (well LSH-1) and Vysny Sliac (well VSH-1). Another potential area of the cold water infiltration is to the south-east of the connecting line between boreholes LSH-1 and VSH-1.

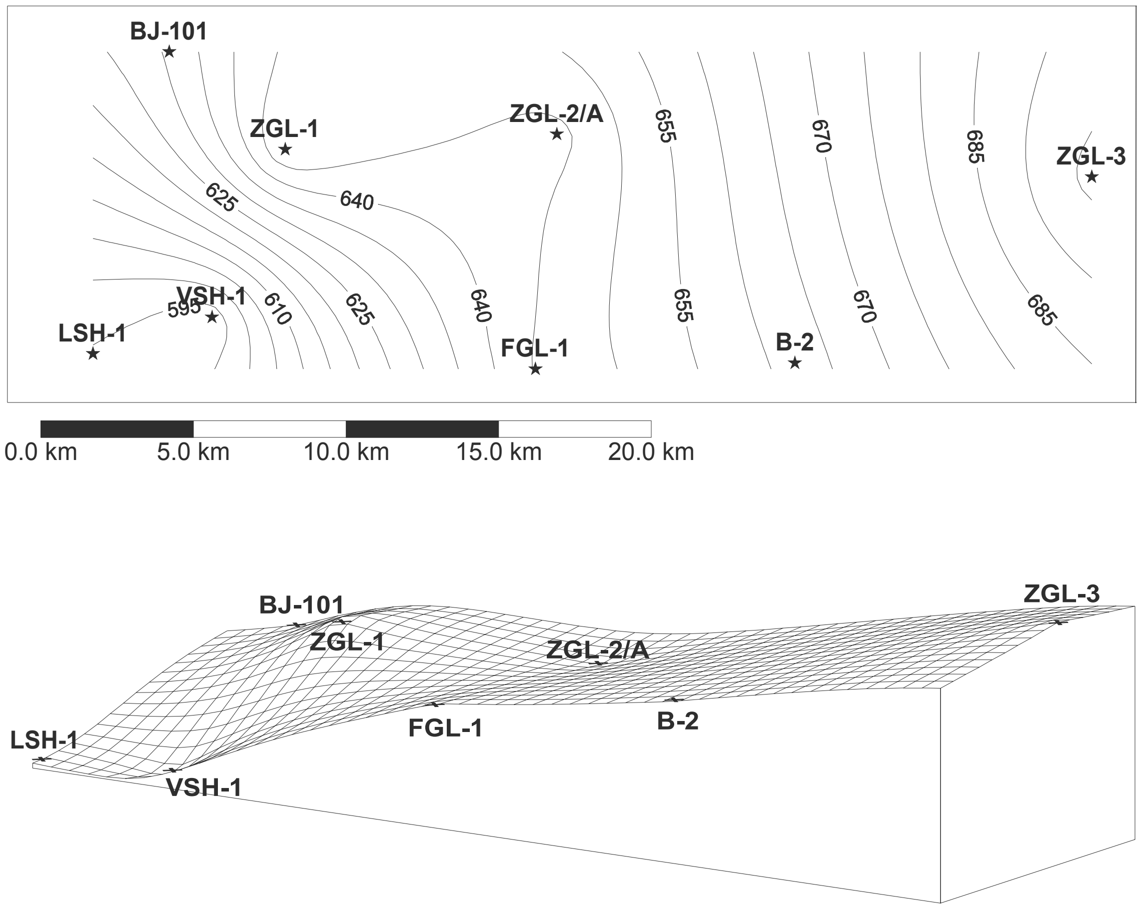

Figure 3 Geothermal water piezometric levels of the Liptov basin

The average value of the hydraulic conductivity coefficient in the area was estimated on $5.645*10^{-6}$ m/s, corresponding by the piezometric gradient of the $2.94*10^{-3}$ to the filtration velocity of $1.66*10^{-8}$ m/s. According to this, taking into account the value 0.1 for the coefficient of the filtration cross-section effectiveness of geothermal water aquifers, the value of the estimated average effective geothermal water flow velocity is $1.66*10^{-7}$ m/s, which represents 5.2 m per year.

The main Ca-Mg-HCO_3-SO_4 type of mineralization amounts to about 0.4 – 5.0 g/l, while gases are represented mainly by CO_2. Sulphates in geothermal waters [13] came largely from Lower Triassic formations with evaporites ($\delta^{34}S$ = 23.3 – 27.1 ‰); the isotopic composition of oxygen in geothermal waters shows that they are of meteoric origin (precipitation).

The thermal-energy potential (TEP) of geothermal waters in the Liptov Basin was evaluated by the thermal balance method and mathematic modelling using AQUA programme [14], both techniques yield similar results. The prognostic TEP of geothermal water natural resources amounts to 34.6 MW_t (248 l/s of water with temperature 27 – 70 ºC). From the total amount, 14 MW_t (84 l/s of water with temperature 32 – 62 ºC) can be classified as a verified TEP (Table 2) while further 20.6 MW_t (152 l/s of water with temperature 30 – 70 ºC) still remain to be verified by further investigations.

4 CONCLUSIONS

The Liptov Basin is a typical intramontane depression in the Inner Western Carpathians where geothermal waters are associated with Triassic Carbonates of the Inner Carpathian tectonic units (largely Choc and Krizna nappes) overlain by Paleogene sediments. Estimated geothermal parameters allowed dividing of the basin into two geothermally different parts, whereby the western one can be characterized by a higher geothermal activity.

Geothermal waters with the temperature of 20 – 150 ºC occur beneath the Paleogene at depths of 500 – 5,000 m. With regard to their temperature, geothermal waters can be classified as low-temperature (T < 100 ºC) and medium-temperature (T = 100 – 150 ºC). As far as their chemistry is concerned, geothermal waters here are represented by Ca-Mg-HCO_3-SO_4 type containing CO_2. Their T.D.S. ranges from about 0.4 to 5.0 g/l. Genetically, they are mostly waters with carbonate and sulphate mineralization. Geothermal waters occur in open and semi-open hydrogeological structures (their recharge areas lie in the adjacent mountain ranges), which implies that they and their TEP are renewable in time and space. The prognostic TEP of geothermal waters amounts to 34.3 MW_t, 14 MW_t of which have already been confirmed by drilling. This energy source is a significant contribution to the energetic potential of the Liptov Basin. It is particularly valuable because of its renewability.

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