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5. Mineral and Geothermal Waters of the Podunajská Rovina Flat

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Abstract: In the Podunajská rovina Flat (Danubian Flat) there are mineral water sources on its western edge in Svätý Jur. These sources contain water of chemical type Na-Cl-HCO_3 with mineralization of 867.9 mg.l^{-1} and H_2S content of 2.82 mg.l^{-1}, which was used in the past for spa treatment. Geothermal waters of the Danubian Flat are widespread mainly in the area of the Central Depression of the Danube Basin and the Dubník Depression, where the sediments of the Neogene with predominant intergranular permeability above the fissure are found. In the Central Depression of the Danube Basin, the geothermal water reaches in the depth range of 1,050 – 2,500 m a temperature of 42 – 91 °C, a mineralization of 1.5 – 8.3 g.l^{-1} and a chemical type of water is Na-HCO_3, Na-HCO_3-Cl to Na-Cl-HCO_3. In the eastern part of the Danubian Flat, the geothermal water of the Dubník Depression has a temperature of 50 °C, a mineralization of 5.3 g.l^{-1} and a chemical type of Na-Cl at a depth of 975 – 1,321 m. Geothermal water is found in the Mesozoic aquifers with karst-fissure permeability in the Komárno Marginal Block. In the area of Komárno the geothermal water in the depth interval of 1,140 – 1,900 m reaches a temperature of 42 – 64 °C, a mineralization of 2.2 – 3.1 g.l^{-1} and a chemical type ranges from Na-Ca-Mg-SO_4-HCO_3-Cl, Ca-Na-Mg-SO_4-Cl-HCO_3 to Ca-Na-Mg-SO_4-Cl. The vast majority of geothermal wells in the Danubian Flat are used for recreation and in agriculture and, to a lesser extent, for heating.

Key words: porous aquifers, karst-fissure aquifers, chemical and isotopic composition of waters, installed capacity of boreholes

5.1 Introduction

The Danubian Flat is not rich in the occurrence of natural groundwater outlets. However, its potential due to the nature of the geological setting of the area is hidden in depth, where there are significant aquifers of geothermal water verified by drilling.

In the Danubian Flat, mineral water sources are found only in Svätý Jur (St. George), which began to be used in local spas since the beginning of the 17th century. The mineral water of the Svätý Jur Spa has the character of cold sulphur water (12.8 °C) of chemical type Na-Cl-HCO_3 with total mineralization (TDS) of 867.9 mg.l^{-1} and H_2S content of 2.82 mg.l^{-1}. This water has been used to treat rheumatism, gout, female diseases and nerve inflammation (Krahulec et al., 1978). According to Hensel (1941), mineral water taken from four captured springs was used for drinking treatment and two sources were used for balneologic treatment. According to the registration of mineral resources of Slovakia (Vandrová et al., 2015), two springs with registration numbers BA-001 (U troch pilotov – At three pilots) and BA-002 (Kúpeľný prameň – Spa Spring) are currently known. The spring BA-001 has disappeared, the spring BA-002 is located on the southern outskirts of Svätý Jur in the former Svätý Jur Spa between the railway and the Šúrsky kanál (Šúr Channel). The facility later served as the Institute for Disabled Youth. The initial yield of the Spa Spring was 0.21 l.s^{-1}. Mineral water is captured by a well with a diameter of 2.5 m and a depth of 2.0 m. The well is walled into a dome shape to a height of 1.4 m above the terrain. At present, the spa area and the mineral water spring are in a devastated state.

There are three geothermal groundwater bodies in the Danubian Flat – the Central Depression of the Danube Basin (SK300240PF), the Dubník Depression (SK300250PF) and the Komárno Marginal Block (SK300020PF) – (Fig. 5.1). The first work on hydrocarbon exploration of the Danubian Flat documented the presence of geothermal waters in Bernolákovo (Be-1, Homola, 1956), Diakovce (Di-1, Homola, 1960), Kráľová nad Váhom (Kr-1, Gaža, 1966e) and Kolárovo (Kolárovo-2, Gaža, 1966a; Kolárovo-3, Gaža, 1967; Kolárovo-4, Gaža, 1970). The Di-1 well was later converted to a geothermal well. Within the framework of the research and exploration of geothermal waters, 38 geothermal boreholes were realized in the area of the Danubian Flat in the period 1966 – 2010 (Figs. 5.1, 5.2, 5.3 and Tab. 5.1).

5.2 Central Depression of the Danube Basin

The Central Depression of the Danube Basin is the largest geothermal water body in Slovakia. This body of geothermal water, as a hydrogeothermal structure, has a bowl-like brachysyncline structure and is filled with Pannonian to Quaternary sediments (clays, sandstones, sands, gravel). The geothermal water reservoir is spatially delimited between Bratislava and Komárno so that it is bounded from above by a plane at a depth of 1,000 m, with a relatively impermeable subsoil – an bowl-shaped aquiclude from the sides and from below till 3,400 m depth – Gabčíkovo area (Franko et al., 1984a).

There are geothermal waters with a temperature of 42 – 92 °C, which are mainly bound to Tortonian to Zanclean sandstone and sand to a large extent. Hydrogeologically, it is a structure with interlayer flow, intergranular permeability and a regime with a confined water level. From a structural point of view, it is a semi-open structure of mineral waters with a natural infiltration and accumulation area, but without an outflow area. Water supply is provided both through a reservoir of ordinary groundwater in Quaternary – Piacenzian sediments and also through Neogene sediments emerging at its northern edge (Senec – Sereď – Šurany).

A characteristic feature of the structure pattern is the alternation of aquifers (sands, sandstones) and aquicludes (clays) in the vertical direction and their mutual lateral wedging-out. Spatially, the aquifers are distributed in such a manner that the highest percentage (40 – 50%) is in the marginal part.

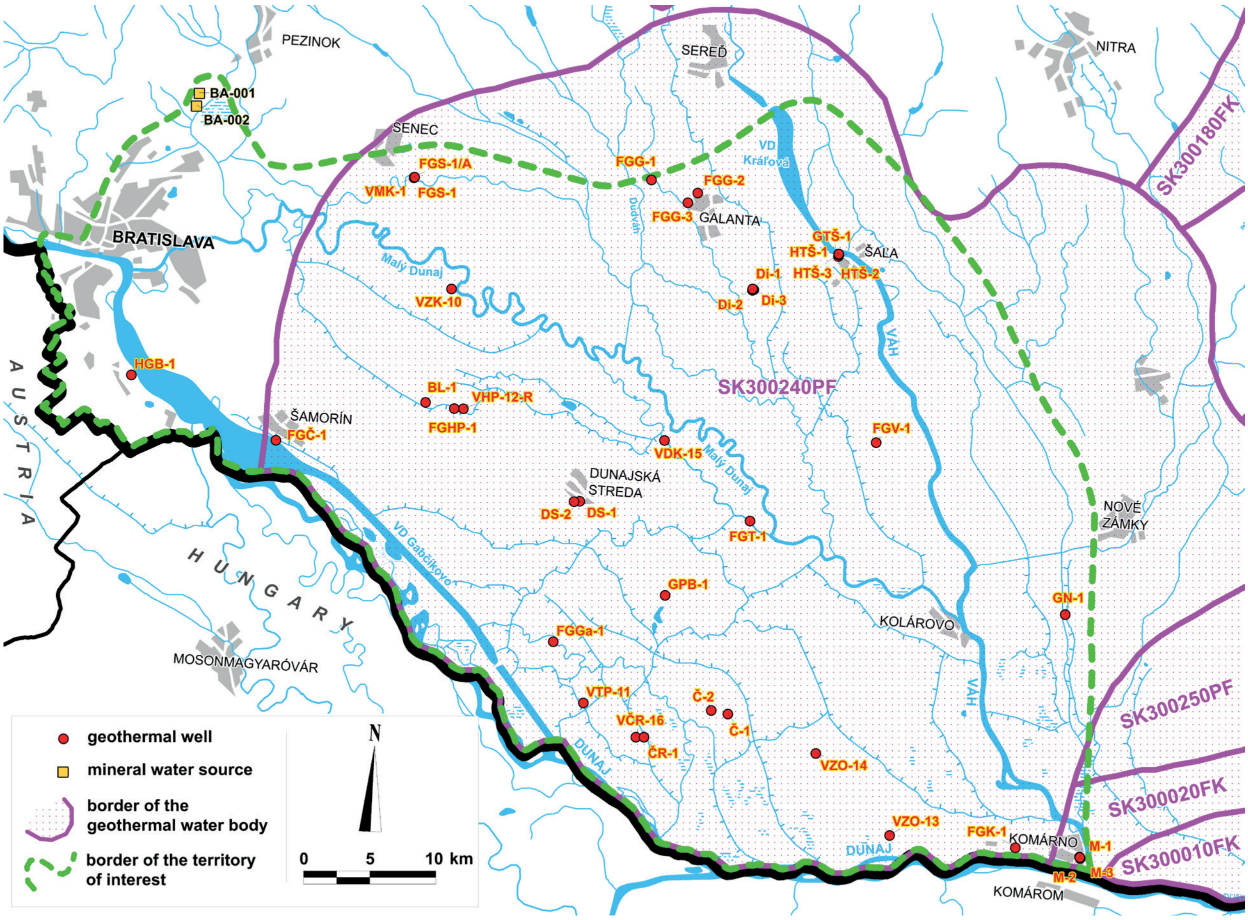

Fig. 5.1 Geothermal water bodies of the Danube Flat

In the centre of the depression, the proportion of the aquifers decreases to 20 – 30%, which is related to the disappearance of the aquifers with increasing depth. According to lithology, there are 6 hydrogeological units in the reservoir and in its overburden, which form certain complexes with different proportion of aquifers and aquicludes (e.g. complex with approximately equal representation of aquifers and aquicludes, complex of aquicludes, complex with aquicludes predominating over aquifers, etc.). Hydrogeological units do not respect the stratigraphy of the Neogene stages due to the vertical alternation and horizontal wedging out of aquifers and aquicludes.

In the temperature field of the depression to the depth of 1,000 – 1,500 m, two positive anomalies occur at the NW and SE edge of the depression caused by elevation of subsoil. In the middle part of the depression, a decrease in the temperature caused by the infiltration of water can be observed. The geothermal gradient in depression in the depth range of 0 – 2,500 m ranges from 34.1 to 43.7 °C.km^{-1} with an average of 39 °C.km^{-1}. The average temperature at 1,000 m is 48 °C, at 2,000 m at 87 °C and at 3,000 m at 125 °C. The density of the Earth's heat flux is in the range of 67.7 – 87.0 mW.m^{-2} with an average value 76 mW.m^{-2} (Franko et al., 1995).

The chemical composition of the geothermal waters of the Central Depression of the Danube Basin is closely related to lithostratigraphy and paleosalinity of the environment. Its regular depth changes are reflected in the increase in the mineralization and Na-Cl proportion of the S_1 component (Cl) and in the decrease in the Na-HCO_3 component (A_1) and the HCO_3/Cl ratio with depth.

Geothermal waters according to chemical type and mineralization belong to five hydrogeochemical types of waters (Bodiš in Fendek & Bodiš, 1992):

1. Type Na-HCO_3 with mineralization up to 1 g.l^{-1}; Component A_1 above 60 eq.%, HCO_3/Cl – ratio above 10 (characteristic of Zanclean and Messinian aquifers).
2. Type Na-HCO_3 with mineralization 1 – 5 g.l^{-1}; Component A_1 above 60 eq.%, HCO_3 Cl 3 – 10 ratio (characteristic of the aquifers of the Zanclean and Messinian, or well-washed Tortonian aquifers).
3. Type Na-Cl with the presence of component A_1 above 30 eq.% Na-HCO_3 or type with the

presence of a component S_1(Cl) above 30 eq.% with a mineralization of 3 – 8 $g.l^{-1}$; HCO_3/Cl ratio predominantly 1 – 2 (typical especially for Messinian aquifers).

4. Distinct type Na-Cl with mineralization 5 – 8 $g.l^{-1}$; HCO_3/Cl ratio max. 0.3 (typical for Messinian and Tortonian aquifers).
5. Significant Na-Cl type with mineralization above 10 $g.l^{-1}$ (10 – 36 $g.l^{-1}$); HCO_3/Cl ratio very low, below 0.3 (typical for Tortonian to Langhian aquifers).

Fig. 5.2 Collar of one of the most valuable geothermal wells of the Central Depression of the Danube Basin – well FGT-1 in Topoľníky (photo: D. Marcin, 2010)

The isotopic composition of the geothermal waters of the Central Depression of the Danube Basin is characterized by $\delta^{18}O$ values from -13.8‰ (Di-1 Diakovce) to -9.8‰ (Č-1 Veľký Meder) and $\delta^{2}H$ values from -96‰ (Di-1 Diakovce) to -68.2‰ (Č-1 Veľký Meder), which represent waters of meteoric origin. The value of $\delta^{18}O$ and $\delta^{2}H$ increases with the depth of the built-in sections of Di-1 Diakovce (open section 720 – 810 m) and Č-1 Veľký Meder (open section 2,284 – 2,389 m). In the Danubian Flat in the Kolárovo K-3 structural borehole in the cadastral area of the village Nesvady with water of chemical type Na-Cl and in the geothermal DS-1 borehole Dunajská Streda with water of chemical type Na-Cl-HCO_3 typical for marine (to a certain degree a desalinised) water, namely $\delta^{18}O$ = -1,98‰, or $\delta^{18}O$ = -7.31‰). The $\delta^{18}O$ values in other documented geothermal waters are within this range and document the evolution of infiltration degradation of seawater and its progressive replacement with meteoric water (Kantor et al.,1985; Michalko, 1998; Franko et al., 2000; Franko, 2001).

Based on ^{14}C dating the residence time of geothermal waters in the Neogene sediments of the Danubian Flat (Franko et al., 1994b; 2000; Franko, 2001) ranges from 26,000 years (Di-1 Diakovce, Č-1 Veľký Meder) to 42,000 years (FGHP-1 Horná Potôň, FGS-1/A Kráľová pri Senci, FGG-1 Sládkovičovo – Vincov Les).

Until 2017, geothermal boreholes to a depth of 290 – 2,800 m were implemented in the area, of which one well (GBP-1 Boheľov) served for geothermal observation. Geothermal waters were captured by boreholes at depths of 73 – 2,482 m, the yield was 0.1 – 25.0 $l.s^{-1}$, with a water temperature of 18.0 – 92.9 °C, water mineralization of 0.5 – 18.6 $g.l^{-1}$ and with a borehole installed capacity of 0.01 – 6.8 MW_t. The verified total yield of wells in the formation is 488.3 $l.s^{-1}$, which corresponds to a installed capacity of 101.96 MW_t.

The total exploitable amount of geothermal water from the Galanta Depression substructure was determined by a mathematical model (Fendek in Franko et al., 1984b). The total abstraction of geothermal water from the area in question together with the geothermal wells realized so far represents 176.0 $l.s^{-1}$, which corresponds to 39.77 MW_t of thermal energy. Comparing the results of the mathematical model and the geothermal balance documented a very good match of results (Remšík et al., 2011).

Currently 30 geothermal wells are used with a total annual consumption of approx. 2.8 mil. $m^3.year^{-1}$ (approx. 100 $l.s^{-1}$). Most used are geothermal boreholes Č-2 Veľký

Fig. 5.3 Geothermal borehole M-3 Komárno in the Komárno Marginal Block (photo: K. Benková, 2017)

Tab. 5.1 Geothermal wells in the territory of Danubian Flat

Designation	Cadaster/Site	Year of implementation	Well depth (m)	Active section (m)	Aquifer age and lithology	T ($m^2.s^{-1}$)	Q ($l.s^{-1}$)	T_{water} at collar (°C)	Installed capacity (MW)	TDS ($g.l^{-1}$)	Chemical type of water	Utilisation	Data source
SK300240PF Danube Basin Central Depression													
GPB-1	Boheľov	1982	2,800.0									GT	1
Č-1	Veľký Meder (Čalovo)	1972	2,502.0	1,573 – 1,791	Messinian; sands	$1.1.10^{-4}$	4.5	79	2.59	1.1	$Na\text{-}HCO_3$	R, V	2
Č-2	Veľký Meder (Čalovo)	1983	1,503.0	1,037 – 1,439	Messinian; sands	$6.9.10^{-3}$	10.50	57	3.2	0.9	$Na\text{-}HCO_3$	R, V	3
FGČ-1	Čilistov	1979	2,500.0	1,195 – 1,549	Tortonian; sandstones	$4.1.10^{-3}$	15.0	52	2.32	6.9	$Na\text{-}HCO_3\text{-}Cl$	N	4
ČR-1	Čiližská Radvaň	1986	2,513.0	1,614 – 2,430	Messinian – Tortonian; sands	$1.4.10^{-4}$	6.0	82	3.3	1.6	$Na\text{-}HCO_3\text{-}Cl$	P	5
VTP-11	Čiližská Radvaň / Ňárad (Topoľovec)	1988	2,500.0	1,533 – 2,482	Messinian – Tortonian; sands	$7.2.10^{-4}$	14.6	74	3.6	1.2	$Na\text{-}HCO_3\text{-}Cl$	P	6
VČR-16	Čiližská Radvaň	1990	1,800.0	1,390 – 1,745	Messinian; sands	$1.5.10^{-3}$	14.5	65	2.93	0.8	$Na\text{-}HCO_3$	N	7
Di-1	Diakovce	1962	3,303.0	720 – 810	Zanclean; sands		4.0	38	0.39	0.5	$Na\text{-}HCO_3$	R	8
Di-2	Horné Saliby/ Diakovce	1982	1,551.0	1,416 – 1,536	Messinian – Tortonian; sands	$1.2.10^{-3}$	6.7	68	2.66	2.1	$Na\text{-}HCO_3\text{-}Cl$	R, V	9
Di-3	Horné Saliby/ Diakovce	1983	306.0	215 – 275	Zanclean; sands	$5.7.10^{-3}$	7.0	19	0.25	0.6	$Ca\text{-}Na\text{-}HCO_3$	R	10
DS-1	Dunajská Streda	1971	2,500.0	2,183 – 2,432	Messinian; sands	$3.9.10^{-4}$	15.2	91	5.82	6.9	$Na\text{-}Cl\text{-}HCO_3$	P	11
DS-2	Dunajská Streda	1986	1,600.0	1,190 – 1,549	Zanclean – Messinian; sands	$2.3.10^{-3}$	23.0	55	3.85	1.6	$Na\text{-}HCO_3$	R	12
VDK-15	Dunajský Klátov	1991	2,240.0	1,425 – 2,222	Messinian – Tortonian; sands	$5.8.10^{-4}$	15.4	74	3.75	2.4	$Na\text{-}HCO_3\text{-}Cl$	N	13
VZK-10	Eliášovce/ Zlaté Klasy	1987	1,800.0	1,331 – 1,457	Messinian; sands	$3.2.10^{-4}$	12.5	65	2.6	8.3	$Na\text{-}Cl\text{-}HCO_3$	N	14
FGGa-1	Gabčíkovo	1982	2,582.0	1,122 – 1,926	Messinian; sands	$1.4.10^{-3}$	10.0	52	1.64	1.1	$Na\text{-}HCO_3$	N	15
FGG-1	Sládkovičovo (Vincov les)	1975	1,990.0	1,212 – 1,670	Messinian; sands	$7.1.10^{-4}$	10.8	62	2.13	3.2	$Na\text{-}HCO_3\text{-}Cl$	R	16
FGG-2	Galanta	1983	2,101.0	1,706 – 2,032	Tortonian; sands	$2.6.10^{-3}$	25.0	80	6.8	4.9	$Na\text{-}HCO_3\text{-}Cl$	V	17
FGG-3	Galanta	1984	2,102.0	1,731 – 1,999	Tortonian; sands	$4.9.10^{-4}$	25.0	77	6.49	5.9	$Na\text{-}HCO_3\text{-}Cl$	V	18
FGHP-1	Horná Potôň	1980	2,500.0	1,394 – 1,804	Messinian; sands	$1.2.10^{-3}$	20.0	68	4.43	4.7	$Na\text{-}Cl\text{-}HCO_3$	P	19
VHP-12-R	Horná Potôň	1987	2,100.0	1,380 – 1,832	Messinian; sands	$1.7.10^{-3}$	22.3	68	4.94	4.3	$Na\text{-}HCO_3\text{-}Cl$	P	20
M-2	Komárno	1971	1,060.0	771 – 1,025	Messinian – Tortonian; sands		4.5*	42	0.51	3.9	$Na\text{-}HCO_3\text{-}Cl$	R	21
FGK-1	Komárno (Nová Stráž)	1976	1,970.0	904 – 1,082	Messinian – Tortonian; sands	$9.2.10^{-5}$	4.0	45	0.5	2	$Na\text{-}HCO_3\text{-}Cl$	P	22

Tab. 5.1 – continue

Designation	Cadaster/Site	Year of implementation	Well depth (m)	Active section (m)	Aquifer age and lithology	T ($m^2.s^{-1}$)	Q ($l.s^{-1}$)	T_{water} at collar (°C)	Installed capacity (MW)	TDS ($g.l^{-1}$)	Chemical type of water	Utilisation	Data source
FGS-1	Kráľová pri Senci	1974	810.0	430 – 570	Messinian; sands	$1.0.10^{-4}$	0.3	23	0.01	3.6	Na-Mg-HCO_3	N	23
FGS-1/A	Kráľová pri Senci	1974	1,500.0	910 – 1,370	Messinian – Tortonian; sands	$7.4.10^{-4}$	13.0	52	2.01	7.7	Na-HCO_3-Cl	N	24
VMK-1	Kráľová pri Senci	1992	804.5	439 – 572.5 601 – 784	Messinian; sands	$1.5.10^{-4}$	1.2	30	0.07	2.8	Na-Mg-HCO_3	N	25
BL-1	Lehnice	1985	1,500.0	1,031 – 1,455	Zanclean – Messinian; sands	$2.1.10^{-3}$	12.0	54	3.78	2.2	Na-HCO_3	N	26
GN-1	Nesvady	2008	1,505.0	1,283 – 1,494	Messinian; sands, sandstones	$1.3.10^{-4}$	2.7	60	0.5	2.9	Na-HCO_3	N	27
HGB-1	Rusovce	1975	1,493.0	1,067 – 1,493	Langhian – Serravalian; andesites		0.1	28		18.6	Na-Cl	L	28
HTŠ-1	Šaľa	1982					0.2*	22				L	29
HTŠ-2	Šaľa	1983	1,200.5	880 – 1,169	Messinian; sands	$3.0.10^{-4}$	3.1	42	0.36	1.5	Na-HCO_3	L	30
HTŠ-3	Šaľa	1983	290.0	73 – 282	Zanclean; sands	$5.5.10^{-4}$	3.0	18	0.06	0.5	Na-HCO_3	L	31
GTŠ-1	Šaľa	2010	1,800.0	1,481 – 1,786	Tortonian; sands, sandstones		15*	69	3.39	4.9	Na-HCO_3-Cl	V	32
FGT-1	Topoľníky	1975	2,503.0	1,394 – 2,487	Messinian; sands	$1.6.10^{-3}$	23.0	74	5.68	2.2	Na-HCO_3-Cl	P, R	33
FGV-1	Vlčany	1982	2,500.0	1,244 – 1,852	Messinian; sands	$1.8.10^{-4}$	10.0	68	2.22	2.1	Na-HCO_3	P	34
VZO-13	Zlatná na Ostrove (Ontopa)	1990	1,780.0	1,089 – 1,625	Messinian - Tortonian; sands	$2.8.10^{-4}$	7.5	51	1.25	7.5	Na-Cl	P	35
VZO-14	Zlatná na Ostrove/Zemianska Olča	1990	1,908.0	1,555 – 1,839	Messinian; sands	$3.2.10^{-4}$	10.0	74	2.51	2.7	Na-HCO_3-Cl	P	36
SK300020FK Komárno Marginal Block													
M-1	Komárno	1966	1,224.0	1,140 – 1,221	Mesozoic; limestones, dolomites		1.6	42	0.18	2.2	Na-Ca-Mg-SO_4-HCO_3-Cl	R	37
M-3	Komárno	1979	1,184.0	1,139 – 1,184	Jurassic – Triassic; dolomitic limestones	$1.4.10^{-4}$	5.0	51	0.75	3.1	Ca-Na-Mg-SO_4-Cl-HCO_3	R	38
FGK-1	Komárno (Nová Stráž)	1976	1,970.0	1,710 – 1,900	Triassic; limestones, dolomites	$1.5.10^{-4}$	3.3	64	0.67	2.9	Ca-Na-Mg-SO_4-Cl	N	22

Notes: GT – observation of geothermal parameters over time; P – agriculture; N – out of operation; V – heating; R – recreation; L – well discarded; T – coefficient of transmissivity; Q – well yield; TDS – total dissolved solids, 0,2 * – yield at pumping

Data source: 1 – Fendek et al., 1984; 2 – Čermák & Gaža, 1972; Franko, 1976; 3 – Šindlář et al., 1985; 4 – Franko et al., 1981; 5 – Bondarenková et al., 1986a; 6 – Bondarenková et al., 1991b; 7 – Bondarenková et al., 1991b; 8 – Homola, 1960; 9 – Šindlář et al., 1982; 10 – Valíček et al., 1983; 11 – Bondarenková, et al., 1984a; 12 – Bondarenková et al., 1986a; 13 – Bondarenková et al., 1991c; 14 – Bondarenková et al., 1988 ; 15 – Franko et al., 1984a; 16 – Franko & Mateovič, 1977; 17 – Franko et al., 1985; 18 – Bondarenková et al., 1985a; 19 – Franko et al., 1980; 20 – Bondarenková et al., 1991b; 21 – Trávniček, 1971; 22 – Remšík & Franko, 1978; 23 – Bondarenková et al., 1980; 24 – Bondarenková et al., 1980; 25 – Dzúrik et al., 1992; 26 – Bondarenková et al., 1985; 27 – Hlavatý, 2008; 28 – Bondarenková et al., 1977; 29 – Bondarenková et al., 1984 ; 30 – Bondarenková et al., 1984; 31 – Bondarenková et al., 1984; 32 – Halás et al., 2010; 33 – Franko & Mateovič, 1978; 34 – Remšík et al., 1984; 35 – Dzúrik et al., 1991; 36 – Dzúrik et al., 1991; 37 – Pagáč & Čermák, 1976; 38 – Franko & Račický, 1979.

Meder, FGG-2 and FGG-3 Galanta, GTŠ-1 Šaľa, Di-2 Horné Saliby and BS-1 Senec.

5.3 Dubník Depression

The geothermal water body termed as Dubník Depression reaches only marginally in the area of the Danubian Flat in the east. The depression is filled with Neogene sedimentary rocks, which reach the thickness of more than 3,000 m in the central and western part of the depression. The geological structure of the pre-Tertiary underlayer consists of Palaeozoic granitoids and Palaeozoic and older rocks of Veporicum (crystalline schists, phyllites, mica, gneiss, migmatites). Geothermal activity of the area is slightly increased to increased. The image of the heat and thermal fields has a similar pattern. The temperature at a depth of 1,000 m ranges from 45 to 70 °C, at a depth of 2,000 m to 80 to 100 °C, at a depth of 3,000 m to about 105 to 125 °C and rises in the direction from south to north. The temperature on the pre-Tertiary underlayer ranges between 50 – 100 °C and increases in the west and also towards the centre of the depression, which is related to the depth of the pre-Tertiary underlayer. The heat flux density ranges from 70.0 – 90.0 $mW.m^{-2}$ and rises from south to north.

Geothermal waters in the Dubník Depression are bound to Neogene sands, sandstones and basal conglomerates, or breccia. In the Dubník Depression, 4 boreholes to a depth of 350 – 1,927 m were located outside the Danubian Flat. The closest to the Danubian Flat at a distance of about 4 km is the borehole PGT-11 Svätý Peter, which reached a depth of 1,856 m. The borehole documented the presence of geothermal water with a temperature at the mouth of the well 50 °C and a mineralization of 5.3 $g.l^{-1}$ in the depth interval 972 – 1,321 m (Neogene sediments – sands). The well yield during the pumping test was 6 $l.s^{-1}$ and the water was Na-Cl chemical type. The installed capacity of the well is 0.88 MW_t (Franko et al., 1995).

5.4 Komárno Marginal Block

The Komárno Marginal Block extends into the area of the Danubian Flat near Komárno. In this area, the sediments of the Mesozoic (Triassic limestones and dolomites) of the Transdanubian Mountains descend from the Gerecse Mountains below the sedimentary fill of the Danube Basin. The Komárno Marginal Block is bordered by the Komárno fault system in the west and the Hurbanovo fault in the north.

The geothermal waters bound to the Komárno Marginal Block are accumulated as static reserves, probably in a closed hydrogeothermal structure (without infiltration and outflow area).

The water temperature in the Komárno Marginal Block reaches a value from 40 °C to 68 °C, which was documented in 4 geothermal wells with a depth of 1,184 – 1,970 m (Tab. 5.1). The geothermal gradient is in the range of 32.2 – 35.8 $°C.km^{-1}$ for a depth interval of 0 – 2,000 m. The coefficient of absolute transmissivity (T_p) of carbonates at depths of 700 – 2,000 m is $1.9.10^{-12}$ – $2.1.10^{-11}$ m^3 and decreases with depth.

From the chemical point of view, it is a mixed type of geothermal water with a predominance of $Ca\text{-}SO_4$ component and an increased content of Na-Cl with a mineralization of 2.7 – 5.9 $g.l^{-1}$ and an HCO_3/Cl ratio of less than 1. It is a mixture the sulphato-carbonatogenic waters of the Mesozoic and the infiltration of significantly degraded marinogenic waters of the overlying Miocene, which seeped into the carbonate complexes mainly in the early phase of its marine transgression. The higher presence of sulphates in waters in the Komárno region indicates their contact with gypsum (Remšík et al., 1992).

The isotopic composition of the geothermal waters of the Komárno Marginal Block carbonates occurring in the Danubian Flat (Kantor et al., 1985; Michalko, 1998; Franko, 2001) is characterized by $\delta^{18}O$ -12.58‰ (M-3 Komárno) and $\delta^{18}O$ -12.0‰ (M-1 Komárno). The results document a significant degradation of seawater, with infiltrating water coming from precipitation in a colder period.

5.5 Conclusion

In the Danubian Flat, mineral water sources are located only on its western edge in Svätý Jur. Geothermal waters of the Danubian Flat are located in three bodies of geothermal waters – the Central Depression of the Danube Basin (SK300240PF), the Dubník Depression (SK300250PF) and the Komárno Marginal Block (SK300020PF).

The aquifers of mineral and geothermal waters of the Danubian Flat are Neogene sediments (sands, gravel, sandstones, conglomerates) with prevailing intergranular permeability over the fissure one, which occur in the Central Depression of the Danube Basin and in the western part of the Dubník Depression. Mesozoic sediments (Triassic limestones and dolomites) with karst-fissure permeability form the geothemal water reservoir in the Komárno Marginal Block.

Coefficient of transmissivity of the Neogene sediments of the Central Depression of the Danube Basin reaches parameters from $9.2.10^{-5}$ to 1.10^{-4} $m^2.s^{-1}$. For the Mesozoic sediments of the Komárno Marginal Block in the Komárno region, its value is around the value $1.5.10^{-4}$ $m^2.s^{-1}$.

Mineral water in Svätý Jur has the character of sulphuric and cold water of chemical type $Na\text{-}Cl\text{-}HCO_3$ with TDS 867.9 $mg.l^{-1}$ and H_2S content 2.82 $mg.l^{-1}$. In the Central Depression of the Danube Basin, the geothermal water reaches in the depth range of 1,050 – 2,500 m a temperature of 42 – 91 °C, a TDS of 1.5 – 8.3 $g.l^{-1}$ and a chemical type of water is $Na\text{-}HCO_3$, $Na\text{-}HCO_3\text{-}Cl$ to $Na\text{-}Cl\text{-}HCO_3$. In the eastern part of the Danubian Flat, the geothermal water of the Dubník Depression has a temperature of 50 °C, a TDS of 5.3 $g.l^{-1}$ and a chemical type of Na-Cl at a depth of 975 – 1,321 m. Geothermal water reaches 42 – 64 °C in the western part of the Komárno Marginal Block at a depth of 1,140 – 1,900 m, TDS of 2.2 – 3.1 $g.l^{-1}$ and the chemical type ranges from $Na\text{-}Ca\text{-}Mg\text{-}SO_4\text{-}HCO_3\text{-}Cl$, $Ca\text{-}Na\text{-}Mg\text{-}SO_4\text{-}Cl\text{-}HCO_3$ to $Ca\text{-}Na\text{-}Mg\text{-}SO_4\text{-}Cl$.

The isotopic composition of the geothermal waters of the Central Depression of the Danube Basin documents its precipitation origin, whereas in its deeper parts (1,500 – 2,000 m below the ground) it is possible to observe the degradation of marine origin by infiltrating rainwater in the colder period.

The largest quantities of geothermal water are exploited from the Central Depression of the Danube Basin, where the most abundant geothermal wells are located in Galanta (FGG-2, FGG-3), Topoľníky (FGT-1), Dunajská Streda (DS-1) and Horná Potôň (FGHP-1, VHP-12-R).

Geothermal water of the Danubian Flat is taken through geothermal boreholes and used mainly for recreation (aqua parks, thermal pools), agricultural activities (greenhouses) and, to a lesser extent, for heating purposes.

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Slovak Geol. Mag., 18, 2 (2018), 89 – 96

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