Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

Country Update of the Slovak Republic

Marian Fendek and Miriam Fendekova

Department of Hydrogeology, PRIF UK, Pavilon G, Mlynska dolina, 842 15 Bratislava, Slovakia

fendek@fns.uniba.sk, fendekova@fns.uniba.sk

Keywords: hydrogeothermal structures, prospective areas, heat flow density, geothermal wells, geothermal waters, geothermal energy utilization

ABSTRACT

Geothermal energy sources belong to the second place when ranking renewable energy sources included in the Energetic conception of the Slovak government. They are represented by geothermal waters bound mainly to Triassic carbonates and sands, sandstones and conglomerates of Neogene age, less often to neovolcanic rocks. Geothermal wells are located mostly in the intra-mountainous depressions or in lowlands bordering the Slovak territory in its southern part.

Geothermal waters were proven by 159 geothermal wells with the depth of 9 m to 3 616 m. The temperature on the well head ranges from 18 to 129 °C, yields reach up to 70 l/s. Water is mostly of Na-HCO_3-Cl, Ca-Mg-HCO_3 and Na-Cl chemical type with the TDS value of 0.4 – 90.0 g/l. The total amount of thermal energy potential of geothermal waters in prospective areas represents 6653 MW_t.

Geothermal waters are widely used for recreational purposes, mostly in very popular aquaparks in many places of Slovakia. Space heating, greenhouses and fish farming belong to other ways of geothermal energy utilization.

1. INTRODUCTION

Geothermal energy is one of the renewable energy sources which are able to solve two basic problems of the mankind further development – energy supply and environmental pollution.

European Parliament noted in its Resolution on climate change (14 February 2007, http://www.europarl.europa.eu) that energy policy is a crucial element of the EU global strategy on climate change, in which renewable energy sources and energy efficient technologies play an important role. The Parliament supported the proposal of a binding target to increase the level of renewable energy in the EU energy mix to 20 % by 2020.

According to Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 (2009), each member state shall adopt a national renewable energy action plan and notify them to the Commission by 30 June 2010. Slovak national overall target for the share of energy from renewable sources in gross final consumption of energy in 2020 shall make 6.7 % in 2005 and 14 % in 2020. The highest potentials on renewable energy production have biomass with 46.7 %, geothermal energy with 17.5 % and solar energy with 14.5 % (Decree of the Slovak Government No. 282/2003). The renewable energy sources for electricity production targets are 31.0 % for 2010; however, no electricity is expected to be produced from geothermal energy sources.

2. GEOLOGY BACKGROUND

The Western Carpathians are the Alpine mountain range stretching across the Slovak territory. According to the age of development of the Alpine nappe structure they are classified as the Outer – with Neo-Alpine nappes and the Inner with Paleo-Alpine – Pre-Paleogene nappe structure. The Klippen Belt marks the boundary between the two (Figure 1). The structure of the Western Carpathians is characterized by zoning. The Outer Carpathians are made up of Tertiary series of rootless nappes with the typical flysch-like character. The Klippen Belt, a dividing unit between the Outer and the Inner Western Carpathians, has a typical klippen-fashioned tectonic pattern represented by lenses of Jurassic-Early Cretaceous limestone which penetrate the Cretaceous and Paleogene marlstones and flysches. The formations of the Inner Western Carpathians, arrayed in a series of arcuate belts, are vertically stratified into a nappe complex (consisting mostly in a Paleozoic crystalline rock basement, Late Paleozoic formations and Mesozoic complexes) overlain by post-nappe Cretaceous to Neogene sedimentary and volcanic formations (Biely Ed. 1996).

The geological structure and favorable geothermic conditions create a suitable setting for the occurrence of geothermal energy resources in the Slovak territory. However, the geological setting is favorable for the occurrence of geothermal waters with temperature higher than 20 °C only in the Inner Western Carpathians. Geothermal waters are largely associated with Triassic dolomites and limestones of the Krizna and Choc nappes (Fatricum and Hronicum units), less frequently with Neogene sands, sandstones, conglomerates, andesites and related pyroclastics. Lately, geothermal aquifers were proven also in Mesozoic nappe structures in the Silicicum unit occurring in the southern parts of Slovakia.

3. GEOTHERMAL RESOURCES AND POTENTIAL

Geothermal research on the territory of the Slovak Republic started in 70-thies of the last century. Results gained during more then 20 years were for the first time evaluated and summarized in the Atlas of geothermal energy of Slovakia (Franko, Remsik and Fendek eds., 1995). Knowledge on geothermal resources of selected parts of Slovakia became a part of the Atlas of geothermal resources in Europe (Hurter and Haenel eds., 2002).

The latest graphical review of geothermal and mineral water occurrence in Slovakia was published in 2002 as a map in the scale 1:500,000 under heading “Geothermal and mineral water sources” (Fendek et al., 2002), which is a part of the Landscape Atlas of the Slovak Republic (Landscape atlas, 2002). The map shows geological structure of the area, main geothermal aquifers, prospective areas or structures of geothermal waters, yields and temperatures of respective sources, as well as thermal power of geothermal waters in respective areas.

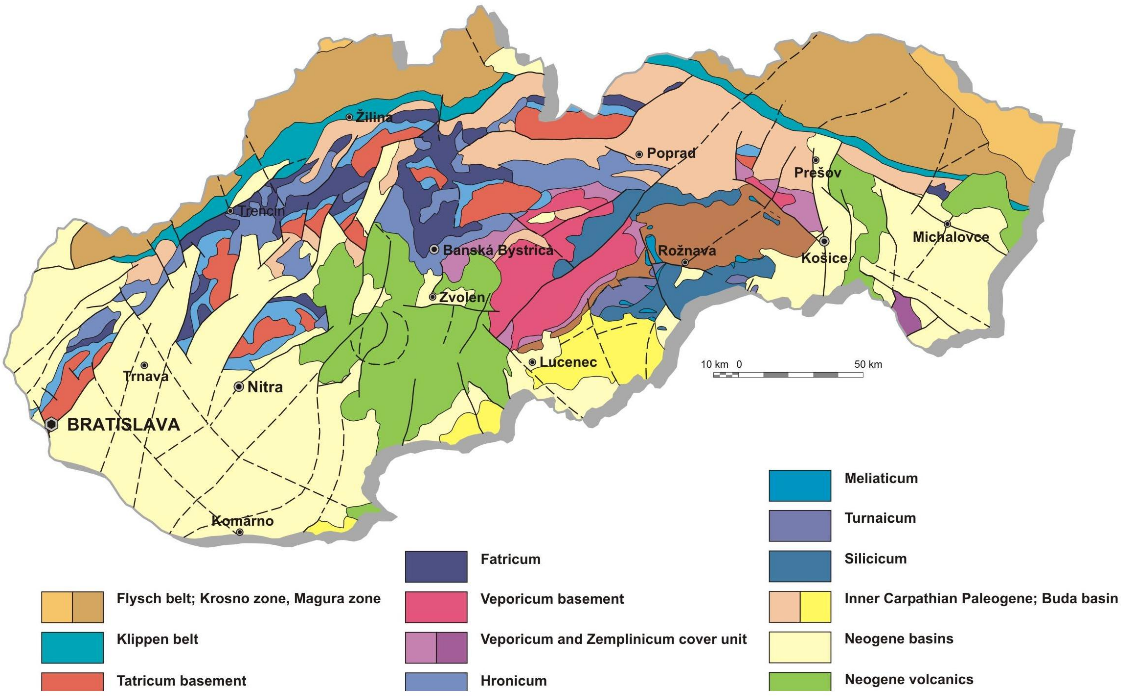

Figure 1: Tectonic sketch of the Slovak Republic (Biely Ed., 1996)

3.1 Results of the hydrogeothermal evaluation

Hydrogeothermal research in the end of nineties of the last century and beginning of the 21st century was done according to the Conception proposal for utilization of geothermal energy in the Slovak Republic"(Decree No. 861/1996 adopted by the Slovak Government), which was later on further elaborated within the Conception of renewable energy sources utilization (2003).

Altogether 27 hydrogeothermal areas or structures (Figure 2) were distinguished in the Slovak territory. Several areas were investigated in the past (until 2000), being represented by Central depression of the Danube Basin, Vienna Basin, Komarno elevated block, Komarno marginal block, Levice block, Skorusina depression, Turiec Basin, Liptov Basin, Levoca basin W and S part (partially in Poprad Basin), Dubnica depression and Kosice Basin (restricted to Durkov area). After 2000 the geothermal investigation was focused on Ziar Basin – Central Slovakian Neogene volcanics – NW part, Horna Nitra Basin, Topolcany embayment and Banovce Basin, Humenne Ridge and Rimava Basin. In some geothermal areas the hydrogeothermal investigation by geothermal drillings has not been done yet (Trnava embayment, Trencin Basin, Ilava Basin, Zilina Basin, Komjatice depression, Central Slovakian Neogene volcanics SE part, Upper Strhare-Trenc depression, Levoca Basin – NE part, Besa-Cicarovce structure).

The hydrogeothermal investigation is systematic, aiming to examine all geothermal areas in Slovakia. This investigation (usually using a geothermal borehole) is realized by means of regional hydrogeothermal evaluation of particular hydrogeothermal areas, being financed by the Ministry of Environment of Slovak Republic from the state budget. The regional hydrogeothermal evaluation of particular areas is done by methodology used in similar evaluation of regions in other countries of European Union presented in Atlas of geothermal sources of Europe (Hurter and Haenel, eds. 2002).

New results were reached by hydrogeothermal investigation in the Ziar Basin, Horna Nitra Basin, Banovce Basin and Topolcany embayment, Humenne Ridge, Rimava Basin, Lucenec Basin and Poprad Basin since 2004.

3.1.1 Ziar Basin

In the geothermal area Central Slovakian Neogene volcanics - NW part only the regional hydrogeothermal evaluation in the Ziar Basin was done (Remsik et al., 2000). The Ziar Basin represents the Inner Carpathian depression located among Neogene volcanic mountain ridges (Vtacnik Mts., Pohronsky Inovec Mts., Stiavnicke vrchy Mts. and Kremnicke vrchy Mts.), being filled in with products mainly of andesite and rhyolite volcanism (Badenian – Sarmatian) as well as Pannonian to Quaternary sediments with maximum depth of pre-Tertiary basement (Ziar nad Hronom – Lovca) around 3500 m beneath the sea level. The pre-Tertiary basement in SE and NW part of the territory is built by Triassic limestones and dolomites of Hronicum and in middle part of the territory by Ipoltica Group (melaphyre series – shales, sandstones).

Ziar Basin can be characterized as an active area from the geothermic point of view. The temperatures in the depth of 1000 m reach 55 – 60 °C, the heat flow density varies from 80 to 100 mW/m^2 with characteristic value of 95 mW/m^2. The central part of the pre-Tertiary basement of the basin is characterized by the temperatures of 100 °C and higher at the depth of -2100 m a.s.l. and deeper. The highest temperatures are present in the central part of the basin in partial depression between Lovca and Ziar nad Hronom, where in the depths of -3400 to -3500 m a.s.l. the temperature reaches app. 130 °C.

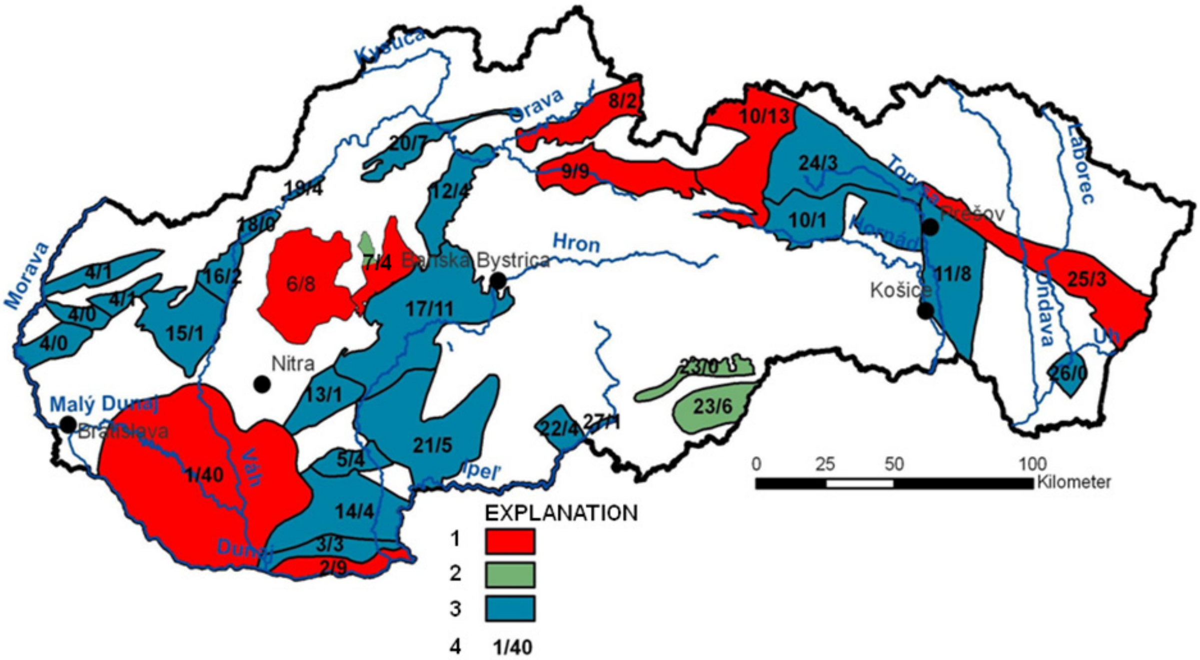

Figure 2: Potential geothermal areas and structures in the territory of the Slovak Republic: Explanation: 1 – prospective areas with geothermal water verified by geothermal wells, 2 – prospective areas geologically assessed for the purpose of prospecting and exploration of geothermal waters, 3 – prospective area with assumed occurrence of geothermal waters (based on general knowledge of geological conditions) 4 – serial number of the prospective area or structure/number of drilled geothermal wells,. List of prospective areas: 1-Danube Basin central depression, 2-Komarno high block, 3-Komarno marginal block, 4-Vienna Basin, 5-Levice marginal block, 6-Banovce Basin and Topolcany embayment, 7-Upper Nitra Basin, 8-Skorusina Basin, 9-Liptov Basin, 10-Levoca Basin (W and S parts), 11-Kosice Basin, 12-Turiec Basin, 13-Komjatice depression, 14-Dubnik depression, 15-Trnava embayment, 16-Piestany embayment, 17-Central Slovakian Neogene volcanics (NW part), 18-Trencin Basin, 19-Ilava Basin, 20-Zilina Basin, 21-Central Slovakian Neogene volcanics (SE part), 22-Horne Strhare – Trenc graben, 23-Rimava Basin, 24-Levoca Basin (N part), 25-Humenne ridge, 26-Besa – Cicarovce structure, 27 – Lucenec Basin

Geothermal water in the area is known from 11 springs and two boreholes (ST-1, 2) in the Sklene Teplice village (yield of 0.1 – 22.3 l/s, water temperature 24 – 53 °C, mineralization 2.4 – 2.6 g/l), from boreholes ST-4 and ST-5 in the neighborhood of Sklene Teplice (yields of 16.13 l/s and 4.4 l/s, water temperatures 57 °C and 46.3 °C), in Vyhne – Vyhnianka spring in a mine adit and borehole H-1 (yield of 5.3 and 5.0 l/s, water temperatures 33 and 36 °C, mineralization around 1 g/l), from Lukavica borehole LKC-4 (yield of 10.0 l/s, water temperature 35 °C, mineralization of 0.37 g/l), Zlatno borehole R-3 (yield of 10.0 l/s, water temperature 35 °C, mineralization 4.5 - 5.0 g/l). Chemical composition of geothermal water is dominated by Ca-Mg-SO_4, and Ca-Mg-SO_4-HCO_3 type, respectively, with mineralization of 3 – 5 g/l and CO_2, event. H_2S contents (Remsik et al., 2007).

The geothermal borehole RGZ-2, realized in the town of Ziar nad Hronom to the depth of 2 500 m, did not reach geothermal aquifers (Triassic carbonates). Instead of them, the subsurface volcanic body was found.

The natural amount of geothermal water with temperature of 60 °C (the Sklene Teplice structure) and 110 °C (Ziar structure) represents 65.3 l/s, corresponding to prognostic amount of geothermal energy of natural sources 22.296 MW_t. The prognostic amount of geothermal energy of the natural resources in the whole area of the Central Slovakian Neogene volcanics is evaluated to 109.0 MW_t (Franko, Remsik and Fendek, eds., 1995).

3.1.2 Horna Nitra Basin

The Horná Nitra Basin represents the intra-mountainous depression surrounded by core mountains of Strazovske vrchy Mts., Tribec Mts., Ziar Mts. and a volcanic mountains of Vtacnik. The depression is filled by Paleogene, Neogene and Quaternary rocks. The pre-Tertiary basement is formed by the rocks of Ipoltica Group (Paleovolcanics) in the southern part of the basin, by carbonates of Choc nappe (Hronicum) in the central part, by carbonates of Krizna nappe (Fatricum) and Mesozoic of Tatricum in northern part. The depth range of Mesozoic rocks varies from the north to south from 1000 to 3500 m.

Maximum temperature values in the Horna Nitra Basin are reached in the central part of the basin between Novaky and Prievidza towns. They get lower towards the basin margins. Temperatures in the depths of 500 m reach 22.5 – 32.5 °C, in depth of 1000 m 35 – 50 °C, in depth 1500 m 50 – 65 °C, in depth 2000 m 60 – 80 °C, in depth 2500 m 70 – 90 °C and in depth 3000 m beneath surface they will reach values 80 – 100 °C. The heat flow density in the Horna Nitra Basin represents values in the range 70.2 – 84.4 mW/m^2 with statistic mean 79.2 ± 4.6 mW/m^2. The supreme values above 75 mW/m^2 are typical for the central part of the basin between Novaky and Prievidza towns.

The geothermal water in the Horna Nitra Basin is known from springs and wells. They are connected to carbonates of Fatricum and Hronicum units, which is reflected also in their chemical composition. Water from carbonates of

Hronicum unit is of $Ca(Mg)\text{-}HCO_3$ type with total mineralization up to 1 g/l and water from Fatricum unit of the $Ca(Mg)\text{-}SO_4$ type with total mineralization 1.31 g/l. Temperatures in the area of Bojnice high elevated block vary in the range 30 – 51.2 °C, in the central part in the well S1-NB II it is 63 °C, at Chalmová village around 39.5 °C. In geothermal well FGHn-1 at Handlova the temperature was 19.4 °C.

The thermal-energy potential of the territory of the Horna Nitra Basin was determined to 29.12 MW_t, representing the sources of geothermal water with the total yield of 140 l/s at average temperature of geothermal water of 60 °C (Fendek et al., 2004).

3.1.3 Banovce Basin and Topolcany embayment

The geothermal area, representing the northern spur of the Danube Basin, is surrounded by mountain ranges of Povazsky Inovec Mts., Strazovske vrchy Mts. and Tribec Mts. The dominant morphotectonic structures of the territory are represented by the Banovce depression in the northern part (covering the central part of the Banovce Basin, with 2800 – 2900 m thickness of the Paleogene and Neogene rocks) and by a distinct elevation – Zavada-Bielice block in the southern part of the territory (with the thickness of Tertiary rocks from several meters up to 1200 m). The pre-Tertiary basement is built by Paleozoic – Mesozoic rocks of the Choc nappe and Krizna nappe.

The temperatures at the depth of 1000 m beneath the surface in the Banovce Basin and in the northern part of the Topolcany embayment vary between 25 and 45 °C, at depth of 1500 m between 35 – 55 °C, at the depth of 2000 m between 45 – 70 °C, at the depth of 2500 m in the range 60 – 85 °C and at the depth of 3000 m under the surface they range in the extent 75 – 95 °C. The anomaly with increasing temperatures in the central area of the Banovce Basin in depths of 1500 – 2500 m beneath the surface (in the territory between villages Svinna and Drzkovce) probably relates to the large thickness of Tertiary sediments in this part of the basin. Heat flow density in the territory is represented by values of 55.1 – 74.2 mW/m^2 with an average value of 63.5 ± 7.6 mW/m^2. Geothermal water occurrence is known from springs and boreholes. It is associated prevailingly with Triassic carbonates of Choc nappe (Hronicum unit). Chemical composition of geothermal water is represented by $Ca\text{-}Mg\text{-}HCO_3$ type with mineralization between 0.48 and 0.78 g/l.

Geothermal borehole FGTz-2 was drilled to the depth of 998 m at the town Partizanske. The pumping rate of geothermal well reached 12.5 l/s of geothermal water with the temperature of 33 °C (Fendek et al., 2004a). The natural amount of geothermal water in Banovce structure was accounted to 64 l/s and corresponds to geothermal energy of 6.653 MW_t. The natural amount of geothermal water in the Zavada-Bielice structure represents 77.7 l/s and corresponds to total amount of geothermal energy of 5.816 MW_t.

The total amount of geothermal water of 141.7 l/s was accounted for both structures corresponding to total amount of geothermal energy of 12.469 MW_t, by the reservoir temperature of water of 35 – 42 °C and well head temperature of 33 – 40 °C (reference temperature of 15 °C) (Remšík et al., 2007a).

3.1.4 Humenne ridge

The structure is built by the strip of Mesozoic rocks (Fatric Triassic-Cretaceous sediments) of the NW-SE direction, mainly in the basement of Tertiary rocks, coursing along the Klippen Belt from the Levoca Basin in the territory north of Presov through towns Humenne and Sobrance to state boundaries with Ukraine, continuing on its territory. The Mesozoic sequences are owing to intensive compression significantly faulted with lensoidal setting and alternation of carbonates and pelitic rocks.

The heat flow density increases from the Klippen belt towards the basin from 75 to 90 mW/m^2. Similar picture is offered also by the temperature field – temperature in the depth of 1000 m increases from 45 to 55 °C, in the depth 2000 m from 75 to 95 °C. This picture is deformed only in the area of Humenske vrchy Mts. with the temperature minimum of 40 °C at the depth of 1000 m, resp. 70 °C at the depth of 2000 m, which is not observable at the depth of 3000 m. The average temperature gradient in the interval 0 – 1000 m is ca 39 °C/km, in interval 1000 – 2000 m it is app. 36 °C/km. Geothermal water, bounded to Triassic dolomites and limestones of Krizna nappe (Fatricum unit) is known preferably from wells. At the town Sobrance (with present natural outflows) the geothermal water with temperature 19.5 – 29.5 °C was registered by wells deep 100 – 400 m and verified by the 823 m deep well TMS-2. In the well MLS-1 in the Podskalka area the geothermal water in the depth 896 – 1719 m was found. The geothermal well GTH-1 Kaluza (Bajo et al., 2007), 600 m deep, found water with temperature of 34.4 °C, being hosted by Triassic carbonates. The pumping rate reached 2.0 l/s. Chemical composition of the water from the borehole MLS-1 (Podskalka) is characterized as mixed Ca-(Mg)-$Na\text{-}SO_4\text{-}HCO_3\text{-}Cl$ type with mineralization of 0.83 g/l, geothermal water in both wells GTH-1 Kaluza and TMS-2 Sobrance was of Na-Cl type with mineralization of 4.7 and 10.56 g/l.

Six partial hydrogeothermal structures have been distinguished within the Humenne Ridge, namely: Kapusany, Zlatnik, Mernik-Oreske, Kaluza, Sobrance and Sejkov (Bajo et al., 2007). All of them are formed by uplifted or sinked blocks of Mesozoic rocks. The geothermal water aquifer is represented by Triassic carbonates with variegated thickness ranging from 880 to 1100 m. The depth of the surface of Triassic carbonates varies in the wide range from the superficial occurrence (Humenske vrchy Mts.), down to depth of 2250 m. There are assumptions that 1700 – 3000 m deep geothermal wells would be able to find geothermal water with temperature of 60 – 100 °C, well yield of 10 – 16 l/s and mineralization of 5 – 10 g/l. The total volume of geothermal water with above stated temperatures (Bajo et al., 2007) is accounted on 341 l/s. The total amount of geothermal water represents 237 l/s. The thermal energy potential of the Humenne Ridge is 750.5 MW_t.

3.1.5 Rimava Basin

The Rimava Basin forms eastern part of the South-Slovakian Basin being filled with Tertiary rocks. The pre-Tertiary basement is built mainly by Mesozoic elements of Silicicum, locally also Meliaticum and Turnaicum units. In the easternmost part it is built by Middle to Upper Triassic limestones and dolomites sinking here from the Slovak Karst Mts. The majority of pre-Tertiary basement consists of Lower Triassic variegated shales containing infolded Middle Triassic limestones and dolomites in tight synclinal zones. Geothermal activity of the territory is standard. The heat flow density increases from the northern margin of the Rimava Basin towards southeast to town Tornala from 60 to 65 mW/.m^2 and in the southwestern direction to Hajnacka village up to 80 mW/m^2. The temperature field in the depth of 1000 m differs, temperature increases from the north towards south from less than 35 °C to more than 50 °C. The temperature at the depth of 1500 m, in which the Triassic carbonates of Silica nappe (Silicicum unit) can occur, increases from the north southward in the range 45 – 70 °C.

The geothermal water is bound to Triassic limestones and dolomites of Silica nappe it in the basement of Tertiary rocks. The water temperature in shallow boreholes varies in the range 17 – 45 °C, the well yields in Kralik and Tornala reached the range 17 – 23 l/s and at the village Hrnciarske Zaluzany the value of 2.7 l/s. The small amount of water was verified by the wells BC-2 in Cakov and RKZ-1 in Batka.

Geothermal water was found also by the wells deep 158 – 1022 m, their yields ranged between 3.3 and 45.0 l/s, with the water temperature from 18°C to 33 °C. Chemically it represented by Ca-Mg-HCO_3 type with mineralization or 1.7 – 5.9 g/l. The regional hydrogeothermal exploration is going on recently in the Rimava Basin, supported by the geothermal well FGRk-1 Ivanice with the depth of 1050 m (Fendek, 2005). Predicted resources of geothermal energy in the Rimava Basin associated with Triassic carbonates of the Silica nappe is evaluated to 26 MW_t (Franko, Remsik and Fendek, Eds., 1995).

3.1.6 Lucenec Basin

The Lucenec Basin is a new geothermal structure (No. 27 in Figure 2) which was proven by the geothermal well GTL-2 in Rapovce (finished in April 2007). The well penetrated the Quaternary cover, the whole Cenozoic sedimentary fill and reached the pre-Tertiary basement built by Triassic carbonates of the Silicicum Unit. The Cenozoic sedimentary fill of the Lucenec Basin has a pelitic character. It is created by impermeable layers of clays and claystones inter-bedded by permeable sandy layers. The Filakovo formation (drilled through up to 45 m depth in the well), Lucenec formation, Szecseny schlier and Panice layers (up to the well depth of 606 m) and Ciz formation with basal Blh, Lenartovce and Rapovce layers (Upper Kiscellian to Upper Rupelian ages; up to the 775 m of well depth), were confirmed. The well GTL-2 has a depth of 1501.5 m and was finished in Mesozoic limestones and dolomites of the Middle to Upper Triassic ages belonging to the Silicicum nappe. Triassic carbonates were reached at the depth of 755 m and were not drilled through. The free outflow from the well reached 17 l/s, the recommended exploitation yield is 11.25 l/s. Dominant gas in geothermal water in the well GTL-2 Rapovce was CO_2 (up to 95 %) (www.developmentnews.sk/rr08/17_vas.ppt). Temperature of the geothermal water is 38.1 °C on the wellhead; water is of Na-HCO_3 type with the mineralization of 12.55 g/l (Vass et al., 2008). Thermal potential of the well represents 1.039 MW_t.

3.1.7 Poprad Basin

The area is filled by Paleogene sediments of the podtatranska unit (alternation of sandstones and claystones, with basal conglomerates on the base of the unit).Under the Mesozoic carbonatic rocks of the Choc and Krizna nappe are developed under the Paleogene filling of the basin. Two geothermal wells were finished in the Poprad Basin in the last period. The well GVL-1 is located at Velka Lomnica village. Hydrodynamic tests performed in March 2006 proved the free outflow of 54.9 l/s of geothermal water with the temperature of 61.8 °C. The recommended yield is 35 l/s, mineralization of geothermal water is 3.24 g/l (Decision of the Ministry of Environment of Slovakia, 2006). Thermal potential of the well represents 6.88 MW_t.

Another geothermal well, VSC-1 Velky Slavkov was finished in the Poprad Basin in 2006, however the first drilling started already in 1993. Then the well was conserved and in 2006 it was deepened up to the final depth of 2400 m. Hydrodynamic tests and chemical analyses of geothermal water proved the pumping rate of 27 l/s of geothermal water with the temperature of 56.9 °C on the well head. Geothermal water is of Ca-Mg-HCO_3 chemical type with the mineralization of 3.5 g/l. The main gas present in geothermal water is CO_2 (ca 94 %). Thermal potential of the well represents 4.74 MW_t.

4. GEOTHERMAL UTILIZATION

The total amount of thermal-energy potential of geothermal waters in prospective areas (proven, predicted and probable) represents 6,653.0 MW_t (Table 1.). This amount consists in 708 MW_t of geothermal resources and 5,945 MW_t of reserves.

Geothermal energy utilization is distributed non-equally on the territory of Slovakia. The highest number of geothermal installations is located in the Nitra County (southwest of the central Slovakia), where 19 localities in utilization are placed (Table 2). The total amount of 382.1 l/s of geothermal water is used in the Nitra County, which is equivalent to 39.65 MW_t of geothermal energy. The highest utilized thermal power is used in Trnava County (Western Slovakia) in 13 localities, represented by 199.7 l/s of geothermal water and 45.84 MW_t of geothermal energy. The smallest number of geothermal installations is located in the Eastern part of Slovakia – in Kosice County, where geothermal energy is used only in 5 localities representing 44.9 l/s of geothermal water with the thermal energy potential of 1.24 MW_t. On the other hand, the Kosice depression is one of the most prospective areas of Slovakia with possibilities to accumulate geothermal waters with the highest temperature to be used for electricity production in the future.

TABLE 1. THERMAL–ENERGY POTENTIAL OF GEOTHERMAL WATERS IN SLOVAK REPUBLIC

Resources [MW_t]			Reserves [MW_t]		
proven	predicted	probable	proven	predicted	probable
218	**390**	**100**	**147**	**805**	**4,993**
708			**5,945**		
Total amount: **6,653.0 MW_t**					

TABLE 2. DISTRIBUTION OF UTILIZED GEOTHERMAL ENERGY SOURCES IN COUNTIES OF THE SLOVAK REPUBLIC (TILL 30.06.2009)

County	Number of localities in utilization	Yield [l/s]		Thermal power [MW_t]	
		Total yield	Utilized yield	Total thermal power	Utilized thermal power
Bratislava	1	30.8	12.0	4.12	1.71
Trnava	13	369.2	199.7	83.01	45.84
Nitra	19	617.5	382.1	89.65	39.65
Trencin	10	140.8	111.1	12.48	10.89
Zilina	14	388.3	268.4	39.91	32.12
Banska Bystrica	13	211.9	151.8	18.84	13.33
Presov	7	267.8	172.3	36.09	19.08
Kosice	5	241.6	44.9	80.82	1.24
Total amount	82	2,267.9	1342.3	364.92	163.86

In Slovakia, geothermal water is not used for electricity production (Summary tables – Table 1.). It is utilized for direct use in agriculture (G), for individual space heating (H) and district heating (D), for fish farming (F) and for recreational purposes (B).

Geothermal water in agriculture provides possibilities to heat greenhouses and glasshouses, as well as the soil, enabling early production of vegetables and flowers out of the normal vegetation season. All together, 11 localities use the geothermal water for agricultural production (Summary tables – Table 3.). The geothermal heat with the capacity of 17.59 MW_t, which is equivalent to energy use of 461.11 TJ/yr, is primarily used for greenhouses in nine localities. In the rest of localities, greenhouses are heated in the end of the cascade heating system (Summary tables – Table 3, 5).

Lately, an important increase was reached in utilization of geothermal energy for space heating – either for individual (19 installations) or for district heating (2 installations). Geothermal energy is used for space heating in 21 localities (Summary tables – Table 3, 5), among them for heating of blocks of flats and hospital in Galanta, for hotels in Besenova, Podhajska, Sturovo and Velky Meder, for dressing rooms and air heating in brown coal mine in Novaky, and for service buildings heating in many localities.

The majority of localities where geothermal water is utilized, are oriented on utilization of geothermal water for bathing in open-air and/or indoor swimming pools. In Slovakia, there are 59 localities using geothermal water for recreational purposes. In some of them, the combined utilization for greenhouses, district heating and bathing has been developed, for instance in Topolniky and Podhajska (Summary tables – Table 3.).

Geothermal water is utilized for fish farming in Vrbov, and in Turcianske Teplice.

5. FUTURE DEVELOPMENT AND INSTALATIONS

At present, hydrogeothermal investigation is being done in Handlova area, belonging to the Upper Nitra Basin and in Rimava Basin.

A lot of individual projects, funded from the private sector financial sources, are ready, or under preparation, to find and utilized geothermal waters for district heating (Velky Meder, Sered, Sala, Trstena, Dolny Kubin, Michalovce, and Presov). Some of the projects are oriented on the new bathing and swimming facilities construction (Bardonovo, Zuberec, Bobrovec, Fiacice, Demanova, Liptovska Kokava, Velka Lomnica and others).

REFERENCES

Bajo, I., Franko, O., Grexova, S., Kral, M., Mlynarcik, M., and Pramuk, V.: Regional hydrogeothermal evaluation of the Humenne Ridge, *Manuscript*, GEO Slovakia, s.r.o., Košice, (2007), 1-114.

Biely, A. ed.: Geological map of Slovakia, 1:500,000, Ministry of Environment – Geological Survey of Slovak Republic, (1996).

Conception of renewable energy sources utilization, Ministry of Environment of Slovakia, (2003).

Decision of the Ministry of Environment of Slovakia: Environmental impact assessment of the activity: Abstraction and utilization of the geothermal water from the well GVL-1 Velka Lomnica, (2006), from: http://eia.enviroportal.sk/detail/odber-vyuzivanie-geotermalnych-vod-z-vrtu-gvl-1-velka-lomnica

Decree of the Slovak Government No. 282/2003, to Conception of renewable energy sources utilization, 23 April 2003.

Decree of the Slovak Government No. 861/1996, to Conception proposal of geothermal energy sources utilization, 10 December 1996.

Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 On the promotion of the use of energy from renewable sources and amending and subsequently repealing directives 2001/77/EC and 2003/30/EC, *Official Journal of the European Union*, L 140/16, 47 p.

European Parliament Resolution on climate change, P6_TA(2007)0038, Strasbourg, 17 February 2007, http://www.europarl.europa.eu.

Fendek, M., Havrila, M., Simon, L., Hok, J., Zecova, K., Michalko, J., Bajtos, P., Obernauer, D., Fendekova, M., Zenisova, Z., Kral, M., Grand, T., Dzuppa, P., and Komon, J.: Regional hydrogeothermal evaluation of the Horna Nitra Basin, *Manuscript*, archive of the Geological Survey of Slovakia, Bratislava, (2004).

Fendek, M.: Project of geological task. Change No. 1: Hydrogeothermal evaluation of the Topolcany embayment, *Manuscript*, archive of the Geological Survey of Slovakia, Bratislava, (2004).

Fendek, M.: Project of geological task: Hydrogeothermal evaluation of the Rimava Basin, *Manuscript*, archive of the Geological Survey of Slovakia, Bratislava, (2005).

Franko, O., Remsik, A., and Fendek, M., eds.: Atlas of geothermal energy of Slovakia, Geological Survey of Slovakia, Bratislava, (1995), 1-268.

Hurter, S., and Haenel, R., eds.: Atlas of Geothermal Resources in Europe, Publ. No.: EUR 17 811 of the European Commission, L-2985, Luxembourg, European Communities, (2002), 1-182.

Landscape Atlas of the Slovak Republic, 1st edition, Ministry of Environment of Slovak Republic, Bratislava, (2002), 344 p.

Remsik, A., Konecny, V., Fendek, M., Kral, M., Lexa, J., Hok, J., Madar, D., Grand, T., Weis, K., Sefara, J., Vika, K., and Drozd, V.: Regional hydrogeothermal evaluation of the Ziar Basin, *Manuscript*, archive of the Geological Survey of Slovakia, Bratislava, (2000).

Remsik, A., Malik, P., Bajtos, P., Rapant, S., Bottlik, F., Bacova, N., Michalko, J., Benkova, K., Krcmova, K., Fendek, M., Marcin, D., Cernak, R., Helma, J., Simon, L., Mrosko, J., Moravska, A., Madar, D., Weis, K., Grand, T., Ujpal, Z., Sivo, A., Richtarikova, M., Janosik, E., Kovacik, J., and Daricek, A.: Neogene volcanites of the northern slopes of Stiavnicke vrchy Mts. – hydrogeological exploration, *Manuscript*, archive of the Geological Survey of Slovakia, Bratislava, (2007).

Remsik, A., Polak, M., Fordinal, K., Boorova, D., Vanekova, H., Bajtos, P., Malik, P., Bodis, D., Michalko, J., Cernak, R., Fendek, M., Dzuppa,P., Grand, T., Varga, G., Sefara, J., Kral, M., Sivo, A., Perunsky, I., Brichta, R., Ujpal, Z., and Hodak, L.: Hydrogeothermal evaluation of the Topolcany embayment, *Manuscript*, archive of the Geological Survey of Slovakia, Bratislava (2007a).

Vass, D., Sotak, J., Dzurik, J., Halasova, E.: New knowledge on Cenozoic filling of the Lucenec Basin, *Mineralia Slovaca*, 40 (2008), 17-24.

www.developmentnews.sk/rr08/17_vass.ppt

SUMMARY TABLES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2009	-	-	3,237	9,259	1,653	4,782	2,640	17,026	7,530	31,067
Under construction in December 2009	-	-	-	-	-	-	180	1,073	180	1,073
Funds committed but not yet under construction in December 2009	-	-	70	200	-	-	940	5,602	1,010	5,802
Total projected use by 2015	6	40	4,437	12,690	1,727	4,993	3,760	24,249	9,929	41,972

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF DECEMBER 2009

Lokality	Type	Maximum Utilization			Capacity (MWt)	Annual Utilization		
		Flow Rate (l/s)	Temperature (°C) Inlet	Temperature (°C) Outlet		Ave. flow (l/s)	Energy (TJ/yr)	Capacity Factor
Senec	B/H	12.0	49	28	1.05	10.5	29.084	0.875
Piestany	B	2.0	69	30	0.33	1.8	9.259	0.900
Koplotovce	B	14.5	24	15	0.55	7.8	9.259	0.538
Diakovce-2	G/H	12.0	68	26	2.11	10.5	58.168	0.875
Galanta-2	D/B	25.0	77	28	5.13	15.7	101.471	0.628
Galanta-3	D/B	25.0	80	25	5.75	18.0	130.581	0.720
Galanta-1	B	10.8	62	28	1.54	6.8	30.495	0.629
Cilizska Radvan	G	6.0	82	32	1.26	4.8	31.656	0.800
Velky Meder (Calovo)-1	G/H	10.0	79	26	2.22	9.6	67.111	0.960
Velky Meder (Calovo)-2	B	18.2	57	26	2.36	16.2	66.240	0.890
Topolniky	G/H/B	23.0	74	18	5.39	18.6	137.387	0.808
Dunajska Streda-2	B	23.0	55	22	3.18	15.5	67.467	0.674
Dunajska Streda-1	G/H	15.2	91	35	3.56	13.4	98.978	0.881
Cilistov	B/H	15.0	52	16	2.26	12.5	59.355	0.833
Belusske Slatiny	B	6.0	22	15	0.18	3.8	3.509	0.633
Trencianske Teplice	B	12.1	40	27	0.66	10.8	18.519	0.892
Banovce n. Bebravou	B	17.0	40	21	1.35	8.6	21.552	0.506

Lokality	Type	Maximum Utilization			Capacity (MWt)	Annual Utilization		
		Flow Rate (l/s)	Temperature (ºC)			Ave. flow (l/s)	Energy (TJ/yr)	Capacity Factor
			Inlet	Outlet				
Chalmova	B	13.4	33	18	0.84	7.6	15.037	0.567
Chalmova	H	5.0	39	20	0.40	3.8	9.523	0.760
Kos	H	22.0	59	38	1.93	16.3	45.149	0.741
Partizanske	B	18.8	20	15	0.39	9.6	6.331	0.510
Male Bielice	B	8.5	40	22	0.64	7.4	17.569	0.870
Velke Bielice	G	8.3	39	19	0.69	4.9	12.926	0.590
Topolcany	B	2.0	55	33	0.18	1.5	4.353	0.750
Zeliezovce	G	13.5	18	15	0.17	6.7	2.651	0.496
Santovka	B	10.0	27	18	0.38	5.2	6.173	0.520
Kaliniakovo	B	36.0	25	19	0.90	22.7	17.965	0.630
Vlcany	G/H	10.0	68	38	1.26	6.1	24.138	0.610
Diakovce-1	B	4.0	38	18	0.33	3.6	9.497	0.900
Diakovce-3	B	15.0	19	15	0.25	13.4	7.070	0.893
Obid	B	5.8	21	15	0.15	2.7	2.137	0.465
Sturovo	B/H	70.0	40	22	5.27	53.1	126.070	0.758
Podhajska	H/B/G	53.0	80	34	10.20	33.6	203.865	0.634
Tvrdosovce	B/G	20.0	70	38	2.68	11.2	47.273	0.560
Surany	B	3.5	49	35	0.21	2.4	4.432	0.685
Patince	B	103.5	26	17	3.90	32.5	38.581	0.314
Virt	B	10.0	26	18	0.33	7.2	7.597	0.720
Virt	B	18.3	24	15	0.69	8.9	10.565	0.486
Zlatna na Ostrove	G	7.5	51	21	0.94	7.1	28.095	0.946
Oravice	B/H	65.0	56	26	8.16	52.9	209.325	0.814
Rajecke Teplice	B/H	9.0	37	22	0.56	7.7	15.234	0.855
Stranavy	B	22.0	24	18	0.55	8.7	6.885	0.395
Liptovsky Jan	B	30.0	29	15	1.76	16.8	31.023	0.560
Liptovsky Trnovec	B/H	31.0	60	28	4.15	27.8	117.338	0.896
Besenova FBe-1	B	22.0	26	15	1.01	15.4	22.344	0.700
Besenova ZGL-1	H/B	27.0	62	26	4.07	25.8	122.509	0.955
Lucky	B	35.0	32	18	2.05	31.5	58.168	0.900
Turcianske Teplice	F/H	12.4	54	18	1.87	8.5	40.361	0.685
Turcianske Teplice	B	15.0	44	18	1.63	12.1	41.496	0.806
Tornala	B	45.0	18	15	0.56	18.2	7.202	0.404
Vyhne	B	5.0	36	22	0.29	3.1	5.724	0.620
Sklene Teplice	B	16.0	57	21	2.41	12.3	58.405	0.768
Kremnica	B	23.2	47	23	2.33	11.4	36.088	0.491
Kovacova	B/H	30.0	48	18	3.77	26.4	104.465	0.880
Sliac	B	4.0	33	15	0.30	3.6	8.547	0.900
Sielnica	B	3.6	33	15	0.27	3.0	7.123	0.833
Dudince	B	9.0	28	15	0.49	7.7	13.203	0.855
Vinica	B	10.0	21	15	0.25	4.6	3.640	0.460
Dolna Strehova	B	1.5	29	15	0.09	0.8	1.459	0.526
Dolna Strehova	B	2.5	35	15	0.21	1.2	3.166	0.480
Slovenske Klacany	B	2.0	38	18	0.17	1.0	2.638	0.500
Vysne Ruzbachy	B/H	49.8	23	12	2.29	29.2	42.366	0.586
Poprad	B/H	61.2	48	15	8.45	58.4	254.198	0.954
Vrbov-1	F/B	28.3	56	22	4.03	18.3	82.068	0.646
Vrbov-2	F/B	33.0	59	15	6.08	25.6	148.572	0.775
Trstene pri Hornade	B	10.0	18	15	0.13	6.1	2.414	0.610
Trstene pri Hornade	B	14.3	21	15	0.36	7.5	5.936	0.524
Valaliky	B	11.7	21	15	0.29	6.3	4.986	0.538
Kosice (Tahanovce)	B	4.9	26	15	0.23	2.3	3.337	0.469
Sobrance	B	4.0	29	15	0.23	3.5	6.463	0.875
TOTAL		**1,342.3**			**130.63**	**914.89**	**3,053.770**	

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2009

Locality	Ground or water temp. (°C)	Typical Heat Pump Rating or capacity (kW)	Number of Unites	Type	COP	Equivalent Full Load Hr/Year	Thermal Energy Used (TJ/yr)
Podhajska	40	20	1	W	3.8	3360	0.153
Bojnice	38	40	1	W	4.2	4350	0.273
V.Ruzbachy	19	778	2	W	3.7	8250	6.845
Gbelany	9	23	1	W	4.0	4550	0.115
Raj. Teplice	34	489	3	W	4.5	7600	4.725
Piestany	45	43	2	W	5.4	5600	0.208
Senec	40	106.8	2	W	5.5	7900	0.729
Cilistov	38	43	2	W	5.6	4750	0.176
Rabca	19	81.2	2	W	5.9	3800	0.266
TOTAL		**1,624**	**16**			**50,160**	**13.490**

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2009

	Installed Capacity [MW_t]	Annual Energy Use (TJ/yr)	Capacity Factor
Individual Space Heating	16.7	381.1	0.723
District Heating	10.8	232.0	0.681
Air Conditioning (Cooling)			
Greenhouse Heating	17.6	461.1	0.831
Fish Farming	11.9	271.0	0.722
Animal Farming			
Agricultural drying			
Industrial Process Heat			
Snow Melting			
Bathing and Swimming	73.6	1,708.5	0.736
Other Uses [specify]			
Subtotal	130.6	3,053.7	0.741
Geothermal Heat Pumps	1.6	13.5	0.267
Total	**132.2**	**3,067.2**	**0.733**

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINET USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2005 TO DECEMBER 31, 2009.

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration	**(all)**	-	4	-	-	3.558
Production	**>150 °C**	-	-	-	-	-
	150-100 °C	-	-	-	-	-
	< 100 °C	-	6	-	-	9.815
Injection	**(all)**	-	1	-	-	1.994
Total		-	**11**	-	-	**15.367**

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2005	5	2	3	-	1	13
2006	4	2	3	-	2	15
2007	4	2	5	-	4	18
2008	4	2	6	-	4	18
2009	4	2	6	-	4	19
Total	**21**	**10**	**23**	**-**	**15**	**83**

(1) Government (4) Paid Foreign Consultants
(2) Public Utilities (5) Contributed Through Foreign Aid Programs
(3) Universities (6) Private Industry

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2009) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995 – 1999	6.25	0.75	3.00	-	95	5
2000 – 2004	3.72	1.32	3.60	-	82	18
2005 – 2009	4.27	14.4	48.59	-	95	5