Bulletin d'Hydrogéologie No 17 (1999)
Centre d'Hydrogéologie, Université de Neuchâtel
EDITIONS PETER LANG

Geological setting of the Kosice Basin in relation to geothermal energy resources

by Miroslav Pereszlenyi, Anna Pereszlenyiova & *Peter Masaryk

Slovak Gas Industry - VVNP Research Oil Company, Votrubova 11/A, 825 05 Bratislava, Slovak Republic. E-mail: masaryk@vvnp.sk

ABSTRACT

In the Slovak Republic there are at present delimited at ahout 30 prospective areas aimed at the utilisation of geothermal energy. Mesozoic rocks of the underlier of the Kosice Basin Tertiary sediments represents one of the most prospective areas for the geothermal energy.

Knowledge on geological setting, temperature of field and geothermal waters are derived from six older exploration wells for oil and natural gas, three new geothermal wells, and approximately 100 km of seismic sections. It is possible to gain geothermal water with a reservoir temperature of 120" to 155° C from a depth interval between 2,200 to 3,200 m.

From theoretical view point of complete utilization of this geothermal resource for practical aims of household heating and electrical energy production, it is possible to gain up to 700 MW of heat energy.

KEYWORDS

West Carpathians, Triassic dolomites, geothermal waters

1. Geological setting

The Kosice Basin from geological viewpoint represents north-eastern promontory of the Pannonian Basin aggregate (Fig.1). The Kosice Basin is of a longitudinal north-south trending form with the southern part twisted south-westwards and transiting to Hungary. Total acreage represents approximately 1,500 km^2. Geological structure of the Kosice Basin is relatively complex and formed during more stages.

Present shape was formed during the accumulation of Neogene sedimentary formations. In the northern part of the Kosice Basin Neogene sediments are underlain by Paleogene sediments and underlying pre-Tertiary complex in the whole basin is represented by different Palaeozoic- Mesozoic rocks.

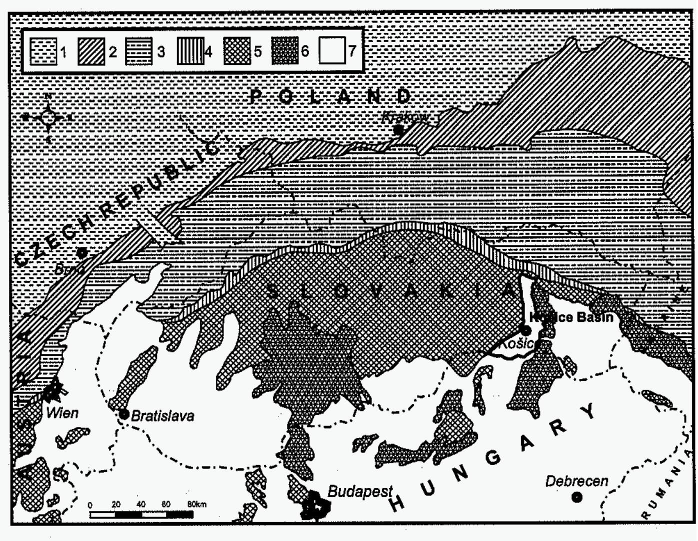

Figure 1 : Position of Košice Basin within the West Carpathians. 1 - European Platform, 2 - West Carpathians and Alpine Foredeep, 3 - Alpine – Carpathian Flysch Belt, 4 - Pienny Klippen Blet, 5 - Inner Alpine – West Carpathian Units, 6 - Late Cainozoic volcanic Rocks, 7 - Neogene Basins

1.1 Pre-Tertiary underlier

In pattern of the Kosice Basin Tertiary sediments underlier take part different geological units of the Inner West Carpathians (Fig.2).

Low metamorphosed Palaeozoic complex of the Gemeric Unit has the largest areal extension within the underlier of Tertiary sediments in the southern and south-western part of the Kosice Basin. Oil exploratory Ca-1 well within interval from 1,175 to 1,197 m penetrated through Devonian green amphibolites, These amphibolites are overlain by Carboniferous rocks. Within interval from 1,123 to 1,175 m there are rhythmically alternating dark phyllitic shales with light gray quartzy phyllitic shales. A layer of a few metres of coarse grained quartzites to fine grained metaconglomerates appears within interval from 1,044 to 1,123 m of dark quartzy phyllitic shales. Sequence of dark monotonous phyllitic shales is developed within interval from 715 to 1,044 m. From depth of 715 m practically to surface, there are sandy-shaly sediments of Badenian and Sarmatian age, except a few last tens of metres of Quaternary gravels.

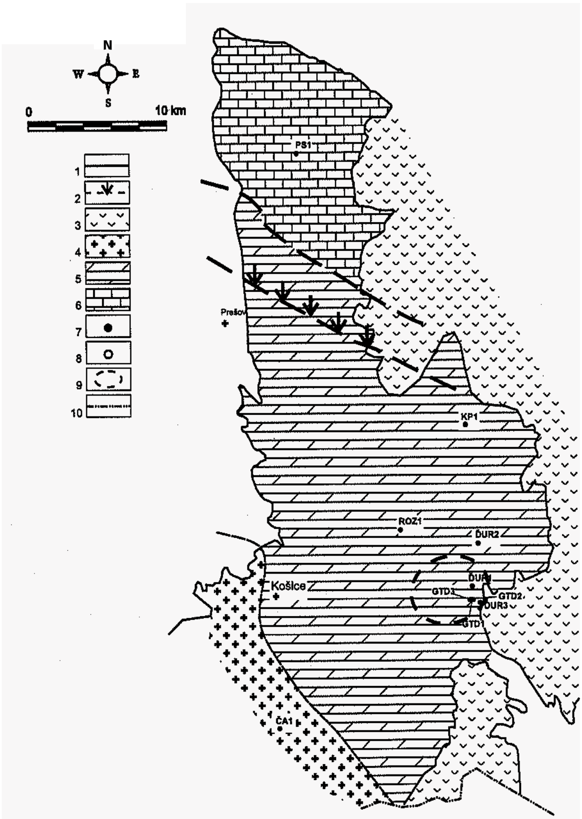

Figure 2 : Schematic distribution of the geologic – tectonic units in the Košice basin underlier. 1 - Neogene sediments boundary, 2 - Paleogene sediments boundary, 3 - Neovolcanic rocks, 4 - Phytithic shales and amfibolites of Gemeric Palaeozoic, 5 - Triassic dolomites of the Veporic unit, 6 - Triassic dolomites of the Tatric unit, 7 - Oils wells, 8 - Geothermal wells, 9 - Geothermal structure Durkov, 10 - State boundary

Palaeozoic complex lithology of the Gemeric Unit indicates low water saturation of rocks and low temperature follows from a shallow burial depth. For this reasons the southern part of the Kosice Basin is more or less uninteresting from geothermal energy viewpoint. Palaeozoic-Mesozoic complex of the Veporic Unit represents underlier of Tertiary sediments in the central part of the basin. Granites, granodiorites to high metamorphosed Old Palaeozoic rocks are overlain by isolated remnants of Young Palaeozoic - Permian sequence of violet shales and sandstones to conglomerates, probably in autochthonous position.

This complex is overlain by Mesozoic sedimentary sequence of Triassic age in parautochthonous position. The Triassic sequence starts with Werfenian shales and quartzy sandstones, continuing by dolomitic limestones to dolomites of Anisian - Ladinian age and at some places preserved remnants of slaty limy claystones with layers of dolomites, evaporitic siltstones and anhydrites of Carpathian Keuper. Mesozoic sequence was penetrated by oil exploratory Roz-1, KP-1, Dur-1,2,3 wells and by geothermal GTD-1,2 and 3 wells (Fig.3). This sequence is overlain by shaly-sandy and volcanoclastic sediments of Karpatian, Badenian and Sarmatian age.

Fractured Anisian - Ladinian dolomites, reaching in the vicinity of Slanske vrchy Mts. thickness above 1,000 m, are the most important from geothermal energy viewpoint. These dolomites are highly saturated by water and high burial depth results also in a relatively high temperature of geothermal waters. The high prospectivity of this region was confiied by drilled geothermal GTD-1,2 and 3 wells.

Based on Ps-1 well results a large Palaeozoic-Mesozoic complex of Tatric Unit in the northern part of the Basin is supposed. Ps-1 well penetrated in Paleogene sediments underlier at depth of 2,810 to 3,010 m into slaty dolomitic claystones and brecciated dolomites of Carpathian Keuper overlain by gray organogenic-muddy limestones of Rhaetian and Liassic age. Shaly-sandy sequence of Paleogene (Eocene and Oligocene) forms interval from 1,575 to 2,810 m. Shaly-sandy sediments with evaporites and coarse grained clastics interlayers of Eggenburgian and Karpatian age of the uppermost interval from 1,575 m to surface.

Even though, no fractured Anisian - Ladinian dolomites were up to now drilled in this part of the basin, we can assume their presence helow Carpathian Keuper sequence. For this reason the area is considered as prospective from viewpoint geothermal energy.

1.2. Tertiary sediments

Distinctive nature of Tertiary sediments, both of Paleogene and Neogene age is alternation of different varieties of claystones, tuffaceous claystones, tuffs with sandstones, tuffaceous sandstones and conglomerates. Considering their unsuitable properties as reservoir rocks they have no significance from viewpoint of geothermal energy.

In harmony with progressive north-southward trending inversion of relief during Tertiary in the northern part of the basin there are Paleogene and Lower Miocene sediments, in the

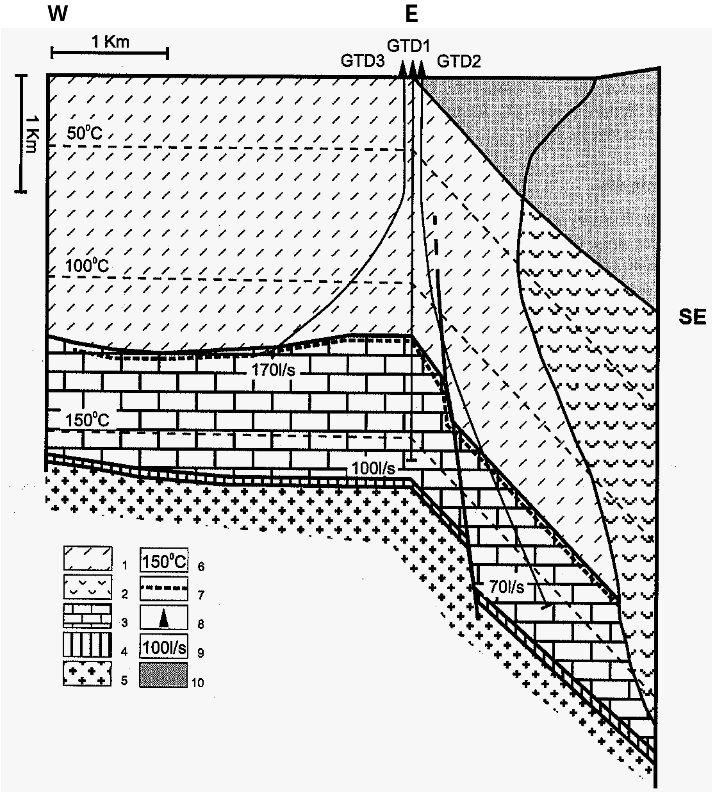

Figure 3 : Schematic geological cross section along wells GTD - 1,2,3, on Durkov structure. 1 - Neogene sediments, 2 - Neovolcanics, 3 - Anisian and Ladinian dolomites, 4 - Werfenian shales, 5 - Palaezoic crystaline rocks, 6 - Stabilized temperatures, 7 - Major reservoir rock of geothermal water – cellular dooimites, 8 - Wells heads, 9 - Reservoir rock of geothermal water discharge, 10 - Surface

central part, namely Lower and Middle Miocene sediments, while in the southem part of the basin there are only Middle and Upper Miocene sediments. Eastem margin of the basin is formed by subsequent Neogene volcanic mountain range of Slanske vrchy Mts. Initial stage of the basin inception and development during Lower Miocene was accompanied by predominantly explosive rhyolite and dacite volcanism. Major volcanic activity, represented above all by andesite volcanism, dominated during more advanced to closing stage of the basin development, i.e. during the Upper Badenian to Lower Pannonian. Products of this stage in Slanske vrchy Mts. form a range of morphologically separated smaller and larger andesite stratovolcanoes.

1.3. Tectonics

Basin pre-Tertiary rocks are folded, imbricated and frequently in a nappe position. Within the major stage of the West Carpathian folding, during Upper Cretaceous and Paleogene, those sediments underwent an intensive denudation, continuing in the central and southern part of the basin till to Lower Miocene. For this reason there are no preserved Jurassic and Lower Cretaceous sediments, even though they would be undoubtedly developed here. On the other hand an intensive erosion caused fracturing and weathering of Triassic carbonate complexes till to 100 to 200 m of depth, which represents an important reservoir of geothermal waters.

Less known Paleogene tectonics has a normal fault nature with strike-slip attributes.

Three major fault systems are characteristic for Neogene tectonics. The oldest fault system of north-westem - south-eastern trending have been opening the basin during Lower Miocene. Another fault system of north-north-eastern - south-south-westem trending functionated during Lower and Middle Badenian sedimentation. The last group of faults is of west-north-westem - east-south-eastem trending functionating namely during Upper Badenian and partly also Upper Miocene. During Neogene predominated synsedimentary and epigenetic normal faults, showing in some cases strike-slip attributes. Rotation of extensional and compressional components of the paleostress field during Neogene distinctly influenced development of sedimentary environment in the basin and depocenter migration from north-southwards.

Sedimentary development and Tertiary tectonics influenced burial depth of Triassic carbonate reservoir rocks. Burial depth and vicinity of neovolcanics are closely connected with geothermal water temperature.

2. Hydrogeological and geothermal setting

Inflow of salt geothermal waters from tectonically disturbed and fractured Triassic carbonates, underlying Tertiary sediments with total mineral content of **16** to **33** g/l, was identified both by old oil wells and new geothermal wells. These waters are predominantly of sodium-chloride type. Salt waters are also accompanied by gas with the main component of CO_2 up to 99%. Watersí mineralization is of marine nature what means that these waters infiltrated into sea floor namely during Lower Miocene. For this reason these waters have practically no direct connection with rock environment of their present position. New geothermal wells verified that from Triassic carbonates it is possible to gain waters production by overflow of 70 to 170 l/s/ from three different wells *(see* Fig. 3).

Depth of surface of Triassic carbonates increases from east westwards from a few hundreds of metres over more than 2,200 m simultaneously with thickness approximately from 300 to 1,200 m. Heat flow density varies from 75 mW/m^2 in the western part of the basin to 110 mW/m^2 in the eastern part (Franko et al. 1995). Mean thermal conductivity of Triassic carbonates equals 3.4 V/mk.

Geothermal gradient in the eastern part of the basin in Tertiary sedimentary fill varies from 46.3' to 50.3° C/km and within underlying Mesozoic rocks equals approximately 32.3' C/km (Franko et al. 1996).

Presumable thermo-energetic potential of utilizable amount of geothermal energy was evaluated for exploitation by injection system and represents 1,276 MW_t for thermal gradient from 119° **C** to reference temperature of 15° **C** (Franko et al., 1995). From theoretical viewpoint there is a possibility to gain approximately 700 MW of thermal energy by full utilization of this geothermal resource for practical purposes of household heating and electric energy production. However, actual practical utilization would be lower, approximately 300 MW (Franko et al., 1996).

3. Geothermal resources utilization

Considering the fact that it is a case of closed structures, during the first stage of execution of the geothermal energy project there is presumed drilling of 6 to 8 exploration and 6 to 8 injection wells. Total production of the geothermal water by overflow is presumed to reach 360 to 480 l/s and temperature at well head would vary between 115° to 130° C.

During this stage geothermal energy would be utilized only for heat production for Kosice town. Total input would represent 100 - 110 MW (Franko et al., 1996).

Electric energy production and waste heat utilization is planned for the second stage.

We can conclude that whole area of the Kosice basin is from viewpoint of geothermal energy a very active one, what is evidently connected with adjacent neovolcanics of Slanske vrchy Mrs. To minimize the geological risk, and this way to prepare basic assumption for successful project execution, our attention is concentrated on 3D seismic survey and qualitative interpretation of geological, geophysical and geochemical documentation.

Result of first wells (GTD1-3, Fig.3) on Durkov structure overstepped expectation. Wellís discharge, according to above presented Fig. 3 varies from 70l/s to 170l/s with wellhead temperature of 125° C.

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