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Investigation of the Durkov geothermal structure for utilisation of geothermal energy

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ABSTRACT

Within investigation of geothermal structure in Durkov three geothermal wells were drilled - GTD-1, GTD-2 and GTD-3 focused on possible geothermal energy utilisation in central heating system in town Kosice. Technical parameters of vertical geothermal well GTD-1 and two directional geothermal wells GTD-2 and GTD-3 prepared them for production and reinjection. Testing of wells proved existence of geothermal reservoir with average free flowrate of wells is 65 l/s, wellhead temperature of geothermal water is 125°C and TDS 30 g/l . The source of geothermal water is located in Mesosoic dolomites in depth 2100 - 3200 m. Hydraulic parameters of aquifer and chemical composition of water suggest the prospective geothermal structure which seems to be hydrogeologically and geochemically confined and its utilisation is possible exclusively by reinjection. High TDS (31g/l) and pressure - temperature conditions suggest scaling and corrosion problems during operation. Geothermal heat will be used via heat exchangers in 4 centres and heat will be delivered to central heating system in Kosice. For the realisation of the whole project with heat output 100 MW 8 production and 8 reinjection wells are needed.

KEYWORDS

Geothermal energy, geothermics, chemistry, water technologic properties, Mesozoic reservoir, Kosice basin

1. Introduction

The project for utilisation of geothermal energy in Kosice basin which is the biggest planned geothermal heating project in Central Europe for an expected heat output of 100-110MW of heat. Project requires drilling and completion of 8 production and 8 reinjection wells. Geothermal reservoir is located about 15 km east of Kosice in the depth 2000 – 3500 m in Mesozoic dolomites aquifer. The geothermal water of 125 - 130 °C delivered from production wells after heat exchange to secondary loop fresh water will be reinjected back to the aquifer. Because of geological conditions and chemical properties of the geothermal water the **reservoir** can be used just with the reinjection system. High TDS content **in** the geothermal water restrain its discharge into adjacent brooks or rivers. The heat will be delivered to TEKO Kosice by pipeline from heat centre in Kosicke Olsany where the heat will come from well sites heat exchangers in Bidovce, Durkov, Slanec and Ruskov. From TEKO Kosice by network already built in the town **the** heat from geothermal wells will be supplied to the dwellings of the town Kosice. To c o n f m reservoir properties **three** geothermal wells GTD-1 – 3 were drilled during 1998 and at beginning 1999. Results of wells exceeded expected parameters.

2. Geological settings and hydrogeologic conditions

Kosice basin is situated **in** eastern Slovakia between ***Ore** Mts.* on western side and Slanskevrchy Mts. on eastern side (figure **1).** Basin is fulfilled by Quaternary sediments, Neogene sediments – Sarmatian (clays, thickness about 500-1000 m), Badenian (calcareous sandy clays, thickness up to 1300m). clays, thickness *up* to 1300 m), Karpatian (calcareous claystones, conglomerates on base, thickness about 400 m). Thickness of Mesozoic rocks which form underlying layers of Neogene rocks rise eastward from 300 to 1000 m , depths of Mesozoic dolomites are more shallow in western part and deeper on east. Kosice basin is folded by 3 main fault **zones** Karpatian direction **(NW-SE),** transversal direction (SW-NE) and Hornád direction (N-S). Faults cut basin into smaller structures, mainly Karpatian and transversal directions **are** important. **One** of the structures is Durkov geothermal structure located in **SE** part of Kosice basin, restricted by Slanske vrchy Mts. on east side. Slanske vrchy Mts. **are** formed by Neovolcanic rocks – andesites and pyroclastic rocks.

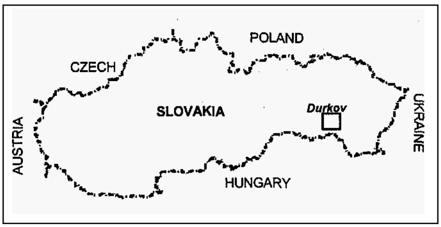


Figure 1:* Durkov *geothermal structure location

Investigation wells GTD-1, GTD-2 and GTD-3 are located in Durkov geothermal structure and proved existence of geothermal water reservoir (figure 2). Wells orientation is showed in table 1.

Table 1: Wells *orientation*

WELL	GTD-1	GTD-2	GTD-3
Azimuth	0 (vertical)	140°	264°
Angle	0	38°	39°
TVD (m)	3 210	3 151	2 252
TMD (m)	-	3 730	2 625

Lithology (KOVAC et al. 1998 and 1999) and well test characteristics (FENDEK 1998, GIESE 1998 and 1999) are documented in figure 3 and tables 2 and 3. Short well tests on wells were performed because of environmental problems with discharging water. Interference measurements showed very good communication between GTD-1 and GTD-3 and poor interference between GTD-1 and GTD-2. Fault zone occur between these two wells and therefore Mesozoic reservoir dolomites are more than 300 m deeper. For proving or excluding of impervious fault zone properties new interference measurements will be run.

Table 2: Well data in dynamic conditions

WELL	GTD-1	GTD-2	GTD-3
T_{wh} (°C)	125	124	123
P_{wh} (MPa)	0,92	0,2	2,20
T_b (°C)	144	154	131
P_b (Mpa)	29,3	27,4	21,9
Q (l/s)	56	70	65

Table 3: Hydraulic parameters

WELL	T (m^2/s)	K_f (m/s)	Inflow TVD (m)	Bubble point
GTD-1	$2{,}089 * 10^{-4}$	$4{,}471 * 10^{-7}$	2150 – 2500	750 m
GTD-2 prod	$8{,}16 * 10^{-5}$	$9{,}44 * 10^{-8}$	2750 – 2920	1070 m TVD
GTD-2 inj	$1{,}34 * 10^{-4}$	$1{,}55 * 10^{-7}$	-	-
GTD-3	$3{,}41 * 10^{-4}$	$8{,}50 * 10^{-6}$	2223 - 2246	1146 m TVD

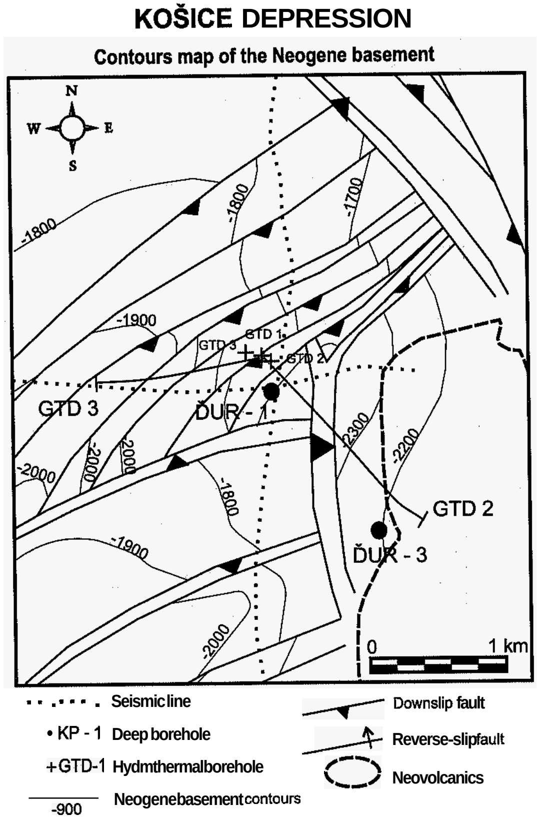
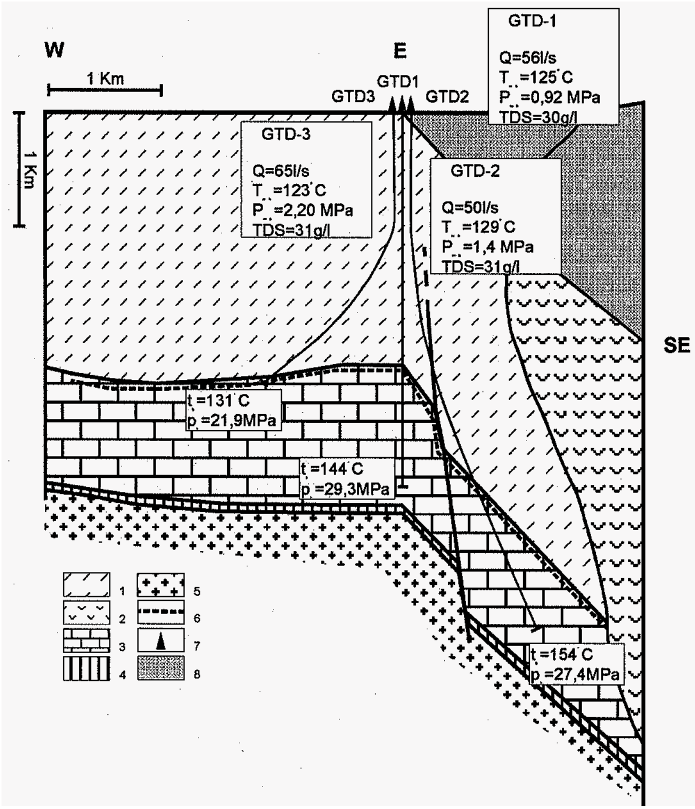


Figure 2. Wells view in structural map of Neogene basement



1-Neogene sediments, 2-Neovolcanics, 3-Triassic dolomites, 4-Werfenian shales, 5-Palaezoic crystalline rocks, 6-Main inflow zone. 7-Well heads, 8-Surface

Figure 3: Schematic hydrogeological cross section through Durkov geothermal structure

3. Chemistry and technological properties of water

During hydrodynamic tests of all three wells also physical and chemical analyses of geothermal water were performed including determinations of Ca, Mg, HCO_3^-, pH etc. at the sampling site. The physical and chemical properties of GTD-2 and GTD-3, which are intended for production, are almost identical. They are characteristic by their increased mineralization consisting especially from higher amounts of chlorides (16.6 $g.l^{-1}$ to 17.1 $g.l^{-1}$ in GTD-2 and 3, sodium (10.85 up to 11.78 $g.l^{-1}$), HCO_3^- (1653 - 2135 $g.l^{-1}$) and sulphates and potassium. Typical is high content of dissolved gas varying from 12.7 to 20 m^3 of gas per m^3 of water, 98% of which is CO_2. Compared with other geothermal sources in Slovakia, there is an interesting amount of arsenic (20 to 50 $mg.l^{-1}$), boron (about 1000 $mg.l^{-1}$ as HBO_2), lithium and in GTD-2 also bromides and iodides.

The calcium carbonate system is very sensitive to the changes of pressure (and consequent degassing) and temperature. The results of chemical equilibria model computations revealed that under partial degassing, when pH rises to more than 5.57 at GTD-3 wellhead (pCO_2 2.2 MPa, 125°C), the water tends to form scaling and depending on the amount of gas loss the scaling rate can reach considerable values. For instance free Ca^{2+} ions supersaturation at GTD-3 wellhead, compared with the relevant equilibrium concentration is 61 $mg.l^{-1}$ at pH 6.4 (pCO_2 0.373 MPa, 125°C) and when degassed more severely (pH 7.0 or higher) the free Ca^{2+} ions (scale forming) supersaturation reaches 173 $mg.l^{-1}$ (pCO_2 0.079 MPa, 70°C) (DROZD 1999). On the other hand, when the water would be kept under pressure high enough to maintain a sufficient amount of CO_2 dissolved, serious corrosion takes place due to the increased contents of Cl^-, SO_4^{2-}, NH_4^+, CO_2-HCO_3^- etc. The required partial CO_2 pressure to maintain the calcium ions in solution reaches app. 2.1- 2.2 MPa for GTD-2 and GTD-3 wells (DROZD 1998 and 1999). The wellhead pressure at GTD-3 under free outflow condition is 2.2 MPa, which is enough, but at GTD-2 well the pressure is only 1.7 - 1.8 MPa i.e. a submersilbe pump will be needed to raise the pressure at the wellhead and consequently in the heat exchanger system, too.

These results were confirmed by coupon check, too. During the hydrodynamic test the steel coupons (plates) were mounted at the wellhead, behind gas separator and at the discharge from the system. At GTD-3 the scaling occured during the hydrodynamic test only between separators, at the wellhead and outflow from the system corrosion was observed, which can be explained by high pressure at the wellhead. The corrosion rate reached around 5 $mm.y^{-1}$, the scaling rate was 0.9 $mm.day^{-1}$ (GTD-2). The dependence of free Ca^{2+} ions oversaturation on partial CO_2 pressure and temperature is in graphic form on figure 5 and figure 6 for GTD-2 and GTD-3 wells respectively.

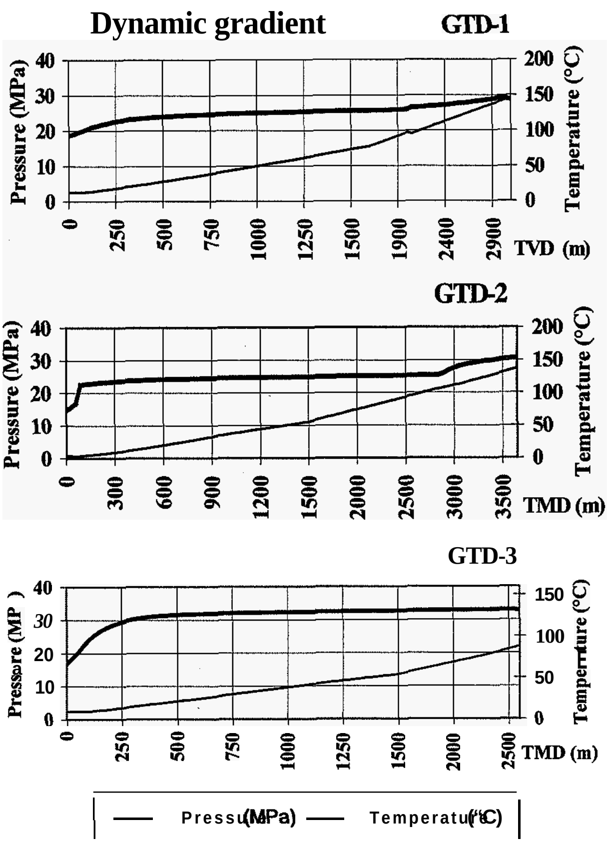


Figure 4: Pressure – temperature gradients of GTD-I, 2 and 3

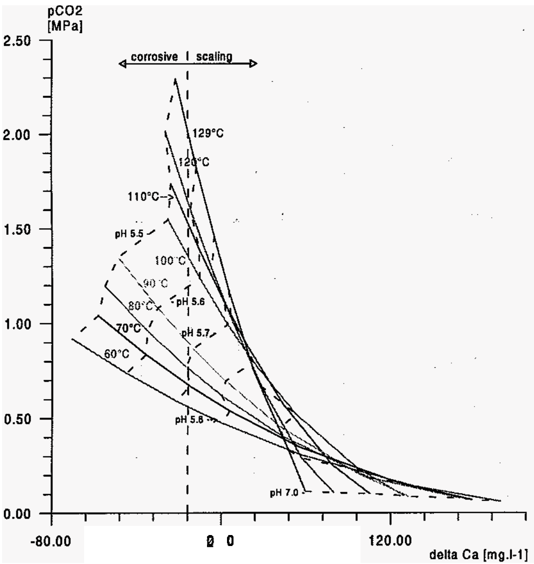


Figure 5: Well GTD-2: dependence of free $Ca^{(2+)}$ ions oversaturation on partial CO_2 pressure and temperature. If delta Ca>0, the water is scaling, if delta Ca<0, the water is corrosive.

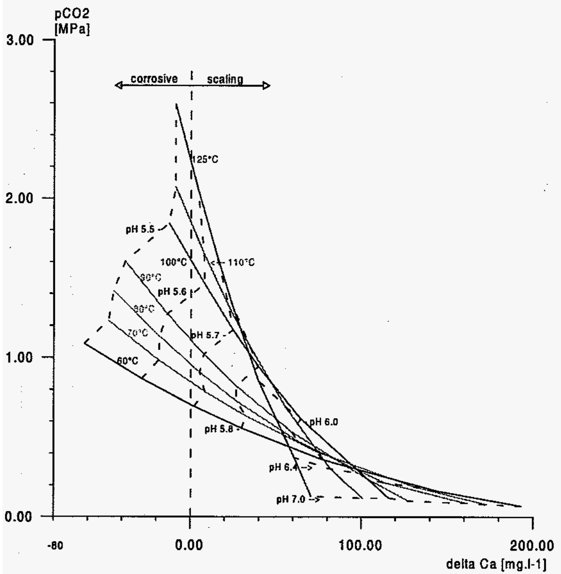


Figure 6: Well GTD-3: dependence of free $Ca^{(2+)}$ ions oversaturation on partial CO_2 pressure and temperature. If delta Ca>0, the water is scaling, if delta Ca<0, the water is corrosive.

The analyses of scale deposits proved the scaling consists in the main part from $CaCO_3$, with small amounts of SiO_2 and $FeCO_3$. With respect to the other mineral phases, the majority **of** saturation indices are negative or within the range 0 to 0.5, which means only a few compounds have saturation index above 0.5 (goethite, diaspore) under wellhead condition (125°C, 2.2 MPa, pH 5.7). Under different condition (partial degassing and correspondingly higher pH, lower temperatures) except calcite the water is oversaturated also by caolinite, quartz, dolomite and strontianite, which will coprecipitate. The heavy metals concentrate in scaling, too (e.g. **As** in sandy deposits from tanks).

With respect to these results the treatment of water by inhibitor will be necessary for its longterm utilisation, except, as a matter of course, careful handling of pressure and other auxiliary precautions . The inhibitor will be of a composite **type** with protection against scaling as well as against corrosion (its composition is already known). The best solution is the dosage of inhibitor downhole at the aquifer depth of production well, to protect the whole system - both the casings and beat exchangers with pipelines, too. The dosage **of** inhibitor will also enable to **use** lower pressures in the heating system.

4. Technical solution for heating

Geothermal energy heating project with total installed heat output 100 – 110 MW plans to drill 8 production and 8 reinjection wells. According to the well data **of** GTD-1 – 3 heat output of one well will be about 15 MW which is more than previously calculated. Centre in Durkov **offer** a good possibility for construction of one beat exchange centre for heat delivery in TEKO Kosice. TEKO Kosice is beat distribution company with central beating network to consumers, our company is supposed to deliver beat into this network with intent of heating 60 000 flats. Pumping station for beat delivery to TEKO will be located in Kosicke Olsany. Study with location of other beat exchange centres count with locations in Bidovce, Durkov, Slanec and Ruskov. Geothermal water heating secondary water in heat exchangers will be delivered to TEKO Kosice (figure 7). Utilised geothermal water from 125°C to 60°C will be reinjected back to reservoir. Payback time for project as the whole is 7 years and system is supposed to operate during 30 years.

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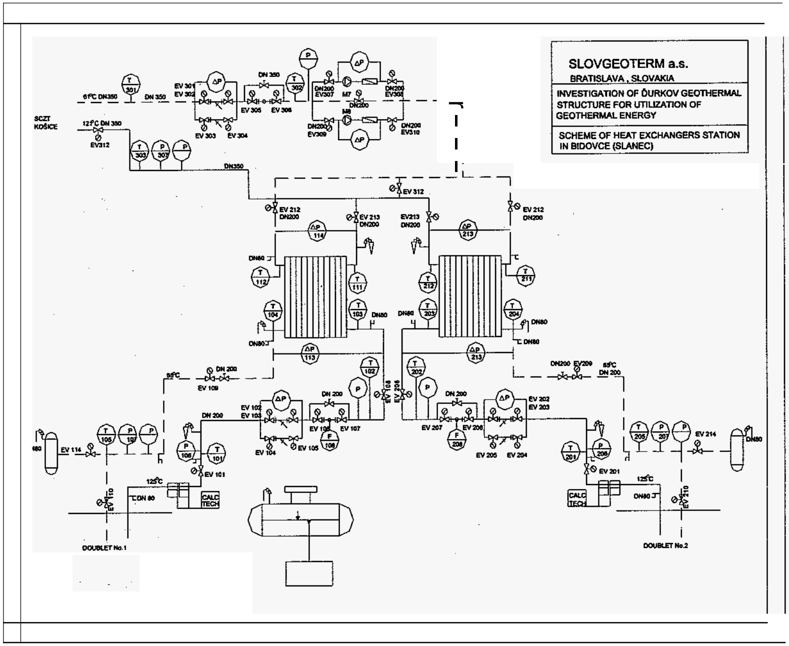

Figure 7: Scheme of heat exchangers station in Bidovce

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