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HIGH PRESSURE AND TEMPERATURE (GEOPRESSURED) GEOTHERMAL RESERVOIRS IN HUNGARY

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ABSTRACT

Hungary is in a favorable geothermal position because of its geological conditions. The reason for this is the doming of the crust and the lithosphere, i. e. the tectosphere, located under the Pannonian basin. As a result, the heat flow density and geothermal gradient are higher than the world average. The Basin areas of the country are filled with Neogene sediments with low thermal conductivity. They insulate relatively well the base of the basin, which consists of higher thermal conductivity Precambrian-Paleozoic-Mesozoic rocks underlying them at depths, in some places, of 7000 m. At the boundary of the two formations the temperature increases sharply. The temperature is not the same in the same depth. The temperature and the geothermal gradient depend mainly on the depth of the tectosphere, the local heat flows, and the thermal conductivity of the rocks. It is a characteristic of the thermal conditions of the base of basin that the geothermal gradient is higher in the more outlying areas than under the deep basin. Where the rocks of the base of basin have appropriate productivity and permeability, it is possible to achieve wet steam production even from a relatively shallow depth. In such reservoirs the formation pressure can be more than twice the hydrostatic pressure. Such reservoirs were mainly formed in karstified carbonate rocks or brittle rocks by tectonic and hydraulic breccia formation. The breccia reservoirs are connected to the main tectonic feeder with wrench faults of the Pannonian Basin in the direction of the NE-SW strike or local reverse fault zones. Three such reservoirs have been identified by deep drilling but, on the basis of theoretical considerations, there can be several others. The deep wells which discovered these reservoirs are described below. On the basis of magnetotelluric and SiO_2 temperature measurements, it appears that the high temperature fluids flow into the reservoirs from deeper formations than those explored by the boreholes.

INTRODUCTION

In Hungary, high-enthalpy hot-water reservoirs can be found in Precambrian-Paleozoic-Mesozoic rocks. In these rocks - regardless of depth - a considerable part of the primary porosity can remain, and a significant secondary storage capacity can develop by karstification, tectonic and hydraulic brecciation processes. This type of reservoir can be found mainly along the high tectonic belts. We have crossed three such areas like this by wells so far.

1. Álmosd. The Álmosd -13 well was drilled in 1981, and entered a tectonic zone in the metamorphic rocks between 3278-3280 m. It produced 360 m^3/d water (93°C) and some gaseous-steam. The diameter of choke was 7.4 mm. The gas-to-steam ratio could not be determined. Calculating separately, the amount of steam (relative density 0.622) was 2 990 m^3/d and the amount of gas (relative density 0.995) was 24 100 m^3/d. The production pressure was 12.9 MPa and the pressure in the reservoir was 48.035 MPa. During production the temperature of the fluid was 143°C at the depth of 2500 m. The diaphthorised, cataclastic, brecciated variations of metamorphic rocks are hydrocarbon reservoirs in several fields of Hungary. Their reservoir capacity is 2-8%, the permeability is minimal and their heterogenity is fairly great. These metamorphites have reservoir capacity generally near erosion unconformity surfaces and along tectonic belts, where they can also have good permeability. The metamorphic reservoir in Álmosd is the reverse fault zones and the brecciated rocks in their surroundings.

2. Fábiánsebestyén. The Fábiánsebestyén-4 well was drilled in 1985, near to a major tectonic zone. During the drilling, steam blew out from the opened section (3698-4239 m). The blowout happened at 4.25 p.m., 16 December 1985, and continued until 19.15 p.m., 31 January 1986. It produced hot water (161°C) with steam (20%). The amount of fluid was 5000-8500 m^3/d. The production pressure at the surface was 36.0-37.5 MPa, occasionally 40.0 MPa. The estimated pressure at the bottom of the hole was 76.3 MPa and the reservoir temperature 200-210°C. The water-steam fluid entered from the section between 3750-4034 m. It was a Middle Triassic brecciated dolomite intercalated with dolomite-marl. This part of the well went wrong during the blowout, so we could not study and measure the capacity of the reservoir. But this type of rock is well-studied in some zones of Szeged and Üllés fields: mean reservoir capacity was calculated on the basis of electric logs 3.9-7.3%, the mean of all values is 5.33%. In Szeged field the permeability is 7-846x10^{-3} μm^2, mean value on the basis of hydrodynamic measurements in ten wells is 261x10^{-3} μm^2. The reservoir qualities do not depend on the depth. For this reason the dolomite and the carbonate rocks can be considered the best high-enthalpy geothermal reservoirs in Hungary. Locations of carbonate reservoirs which have temperatures higher than 150°C can be found in Fig. 1.

3. Nagyszénás. Nagyszénás-3 well is situated about 12 km from Fábiánsebestyén-4. We received during the well test wet-steam inflow with high temperature and high pressure from the opened section, between 2922-3500 m. The crossed layers and the well construction can be seen in Fig. 2. In the studied section the rocks differ in their ages and compositions. On the basis of the production test it is supposed that the inflow had happened from 3165 m. In other areas the porosity of the Lower Triassic sandstone is 2-6% and the permeability is minimal at this depth, but in the case of Nagyszénás -3 well it was found that the reason for the extremely good inflow is not only a simple fissure, but a considerably fractured reservoir. The permeability of the reservoir surrounding the well (within 400m-radius) is 11.28x10^{-3} μm^2. The line of the pressure build-up curve shows that the reservoir is inhomogeneous, and beyond 400 m the permeability is higher than 11.28x10^{-3} μm^2 . During the productivity test, the best volume rate of water was 1891 m^3/d and the gas was 10 060 m^3/d. This time the temperature of the wellhead was 171°C. The highest temperature (185.47°C) was measured at 3006 m when the well produced through a 10 mm in diameter choke. When shut-in, the temperature decreased to 177.79°C and later to 169°C. On the basis of these data the temperature was 190°C at 3165 m and the pressure was 63.8 MPa. The above-mentioned changing of temperature means that the water flows into the well along the fissure from a deeper layer. This is also demonstrated by SiO_2 temperature measurements. In the Fábiánsebestyén-4 well the bottom-hole (4239 m) temperature was 202°C, but the SiO_2 temperature was higher - 254°C. This suggests that the produced water migrated partly from 5-6 km depths. In the case of Nagyszénás-3 well, the SiO_2 dissolved in the water at 193-199°C. To research the faults and geothermal reservoirs in the surroundings of Nagyszénás-3 and Fábiánsebestyén-4, magnetotelluric measurements were carried out. The results of measurements proved that there were geothermal reservoirs which were connected to tectonic zones and went down to 9-10 km depths. Fig. 3 shows the potential geopressured reservoir near Nagyszénás-3. The temperature data, which were measured in the surrounding wells, can be seen in table 1.

FUTURE PROSPECTS

In Hungary, the high pressure and high temperature geopressured reservoirs can be used for power generation. The utilization of geothermal energy has to be solved in multistage energy cascading system, including power generation and direct use. After power generation and direct use the salt removal and balneological utilization can be considered. Before the feasibility stage of the project, detailed geophysical measurements have to be carried out for the determination of the features of the geopressured reservoir.

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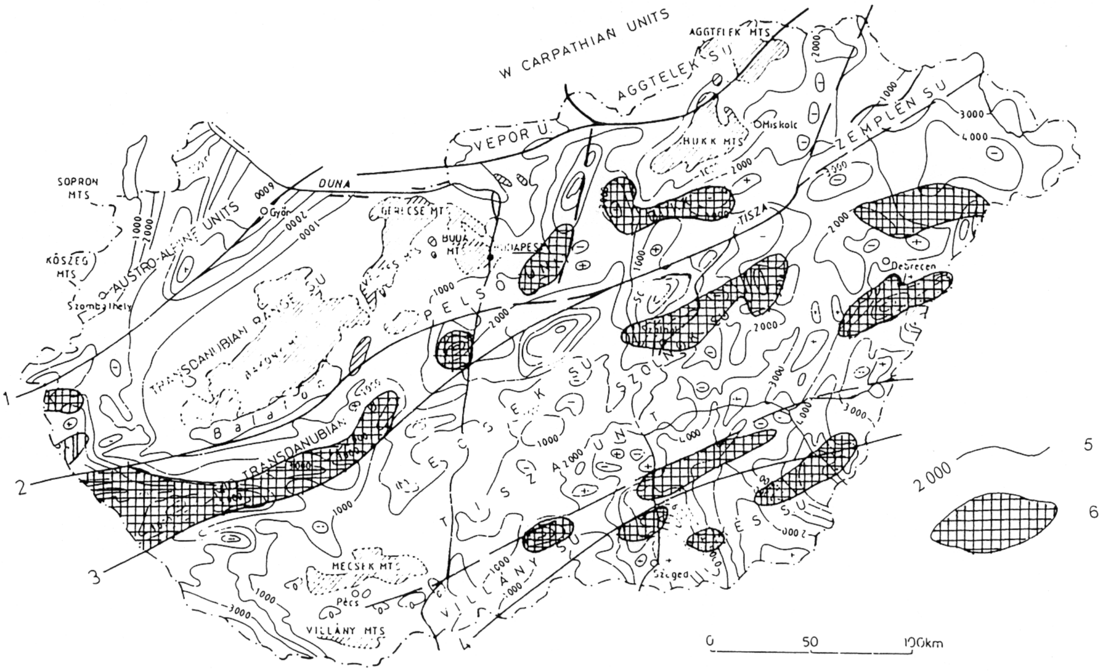

Legend : 1. Rába line 2. Balaton line 3. Hungarian lineament 4. Békés line 5. Bottom of Neogene below sealevel in metre
6. Karstified and/or tetonically fractured rocks with temperatures higher than 150 °C

Figure 1. Basement depthmap of Neogene sequence and karstified and/or tectonically fractured carbonate rocks as high enthalpy geothermal reservoirs.

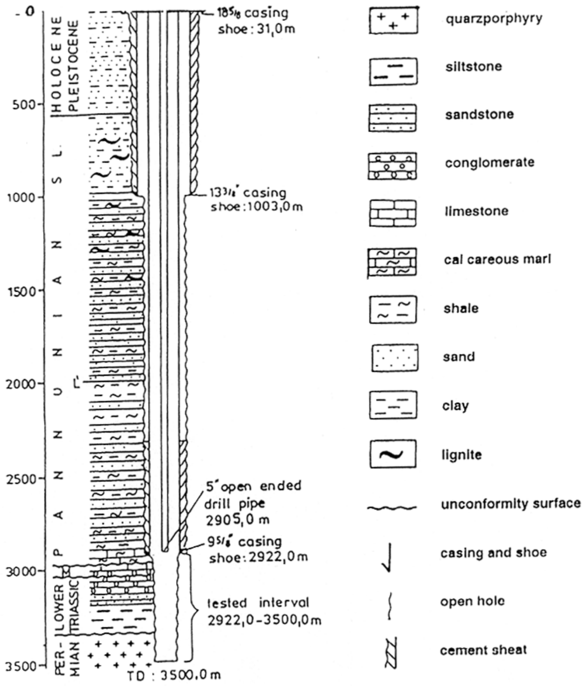

Figure 2. Geological sequence and wellstructure of the Nagyszénás-3 well at steam production

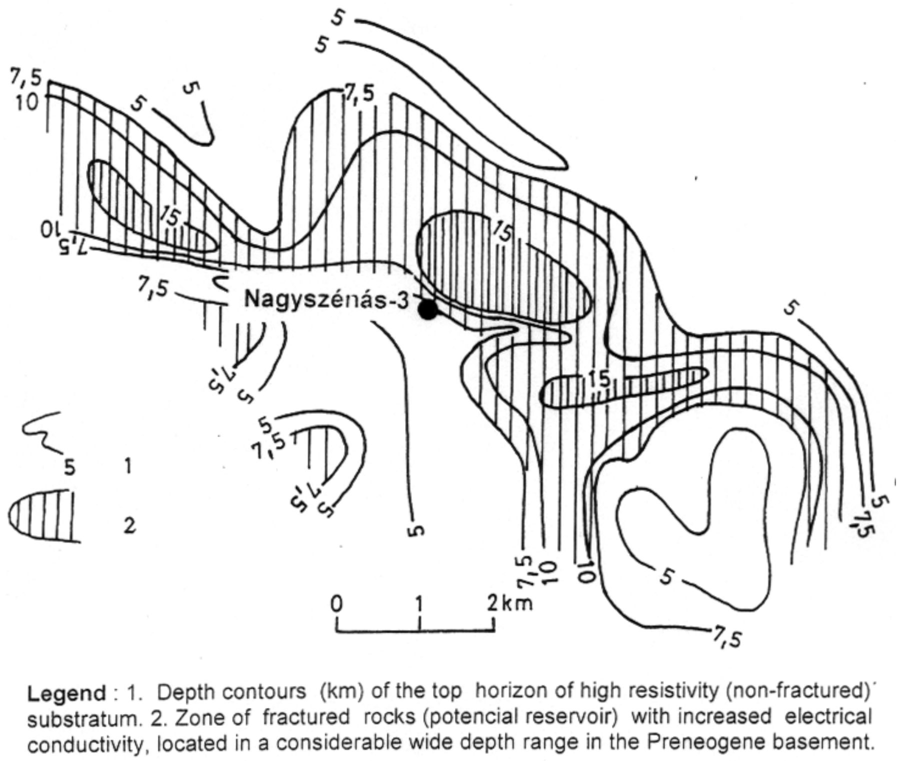

Figure 3. Nagyszénás geothermal field. Map of the potential geothermal reservoir on the basis of MT survey.

Well	**Depth** **m**	**Temperature** **C°**	**Geothermal gradient** **C°/km**	**Age**
Szentes-ÉK-1	**2975**	**143,4**	**44,8**	**Pannonian**
	3400	**160**	**44,1**	**Upper Cretaceous**
Fáb-2	**3259**	**162**	**46,6**	**Miocene**
Fáb-4	**3160**	**166,4**	**49,5**	**Upper Cretaceous**
	3864,5	**190,5**	**46,7**	**Middle Triassic**
Nsz-2	**2911**	**165**	**53,3**	**Pannonian**
Nsz-3	**3200**	**169**	**49,7**	**Lower Triassic**
	3500	**176**	**47,4**	**Permian**
Oros-1	**2610**	**142,2**	**50,6**	**Pannonian**
	2800	**149**	**49,6**	**Precambrian**
Oros-2	**2810**	**162**	**54,1**	**Miocene**
Oros-3	**2771**	**160**	**54,2**	**Pannonian**
	2942	**167**	**53,4**	**Precambrian**

Table 1. Temperature data in the Pannonian Basin and in the region of Fábiánsebestyén-Nagyszénás