Geothermal Resources Council, TRANSACTIONS, Vol. 8, August 1984

PRESENT STATUS OF GEOTHERMAL RESOURCE ASSESSMENT IN HUNGARY

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Abstract

Earlier geothermal resource assessment of Hungary was made assuming traditional production technology without reinjection. Production with reinjection makes possible the more effective heat extraction from both the water and the reservoir rock. Using borehole data /depth, reservoir, thickness, porosity, temperature etc./ geothermal energy reserve is computed for the so-called upper Pannonian aquifer. Reserve recovery factor is also determined.

Introduction

Anomalous geothermal conditions of Hungary are known since Roman age. Thermal springs of Budapest have been used since that time for balneological purposes. Artificial production of thermal water has developed since the end of the last century. The 970 m deep hot water well in Budapest was drilled in 1877 as Europes deepest borehole of its time. Drilling activity for oil and gas provided a great number of borehole temperature data from the Pannonian Basin. These data together with observed temperatures in deep coal mines by Boldizsár /1944/ have shown a high geothermal gradient and an intensive terrestrial heat flow in almost the whole country.

In the course of this systematic exploration activity great thermal water reserves were discovered mainly in the sandy strata of the neogenic sedimentary rocks. Since the fifties more than a hundred wells were drilled directly for thermal water. The number of non-electric utilization of low enthalpy thermal water is steadily increasing in the country.

Thus there is an increasing need to revise geothermal resource assessment respecting to the rapidly changing technology and economics. Traditional production technology is based on the elasticity of the aquifer, reacting to the decreasing pressure of the reservoir fluid. This technology cannot be sustained for a long time. The redistribution of reservoir pressure makes possible a replenishment of the aquifer from other nearby aquifers or recharge from meteoric water. For deep aquifers such recharge can be very limited. The flow rate at the wellhead is reduced in spite of the increasing reservoir pressure drop. The water level of thermal wells has radically fallen after several years of production in the areas of Hajduszoboszló, Debrecen and Szolnok.

This phenomenon makes it necessary to reinject cold water through other wells in order to maintain the reservoir pressure and the yield of production wells. The primary goal of this production technology is the more effective heat extraction from the geothermal reservoir. Not only the enthalpy of the water, but partly the enthalpy of the permeable rock mass can be extracted by this way. There is another reason to reinject cooled-down water: geothermal brine is usually highly saline and can induce harmful effects on the natural environment.

The first geothermal resource assessment of Hungary was made by Boldizsár /1978/. The extractable amount of energy was determined by the volume method. Thermal energy stored in the upper three kilometers of the Pannonian Basin was obtained by him to be equal to 5,5x10 KJ.

Basic definitions

In the present paper following the terminology and method elaborated by Muffler and Cataldi /1977/ the geothermal resource base /GRB/ is obtained as the total sum of thermal energy content above the local mean annual temperature in the crust beneath the country's surface. It can be expressed by the integral:

$$GRB = A \int_{0}^{H} \varrho\, c\, /T-T_0/\, dz ,$$

where A is the surface area, ϱ is the average density, c the heat capacity, T is the temperature depending on z, T_o is the surface temperature, H is the average thickness of the crust /28 km/. This GRB value, for Hungary is 2,52x10 KJ. This is a huge amount of energy, but its greater part is inaccessible in the foreseable future. It may serve primarily as a theoretical limit for any assessment of geothermal energy potential in Hungary.

That fraction of the accessible resource base that can be extracted economically at some reasonable future time is the geothermal resource. This geothermal resource is divided into an identified and an undiscovered part.

The geothermal reserve is the identified part of the geothermal resource, which can be extracted today at a cost competitive with other energy sources. This quantity of geothermal energy is having practical importance.

The estimation of geothermal resources and reserves of Hungary should be founded on a three-dimensional basin model modified as much as possible to the regional geological framework.

Geological Framework

Under the Pannonian Basin thermal mantle diapirism caused a relatively thin /average thickness of 28 km/ crust. The intensive subcrustal erosion led to the isostatic subsidence of the region, forming a basin. This has filled with sediments, mainly of Neogene and Quaternary age.

The granite crust is covered with Mesozoic and Paleozoic dolomite, limestone or sandstone. The Miocene sediments are deposited on these older bedrocks. Upper Miocene sediments are called Pannonians, having a great thickness /2-4 km/. The sandy, clayey and silty strata of Pannonian sediments form a sedimentary sandwich. Isopach map /after Somfai/ of Pannonian sediments is shown in Figure 1. Its layers have mainly horizontal structure. Lower Pannonian sediments are mainly impermeable, but the upper Pannonian formations include a huge porous and permeable system the so-called upper Pannonian hot water reservoir.

FIGURE 1.

TOPOGRAPHY OF THE BOTTOM OF THE UPPER PANNONIAN AQUIFER

Its structure and dimensions are satisfactorily known from a great number of exploratory drilling well data. In these formations the individual sandy layers having a thickness of 2-30 m are interconnected forming an extended aquifer. Its total volume is about 10,000 km³. These upper Pannonian sandy strata are proved as formations bearing economically extractable geothermal energy. Thus their energy content can be regarded as geothermal energy reserve.

Carbonate rocks, mainly of Triassic age are present in the basement, and form a fractured-fissured karstic aquifer with great dimensions and a sufficient secondary porosity and permeability. This deep karstic aquifer in Western Hungary is not so well explored yet as the sedimentary basin. Its energy content can be regarded as geothermal resource mainly in the undiscovered category.

Determination of geothermal energy reserve

As already noted, geothermal energy reserve is the economically extractable part of identified resource. Thus reserves depend on the degree of exploration, type of production technology and economic circumstances. In order to compute geothermal energy reserve of Hungary we must restrict our attention to the sufficiently hot, porous and permeable sandy strata of the upper Pannonian formations. The production technology chosen for our assessment is the closed-loop recirculation system. The investigated area is more than 40,000 km². The sandy layers have a reasultant thicknes varying from 60 to 400 m. Their porosities are from 20 to 35 per cent, permeabilities are from 0.20 to 1.45 Darcy. Thus the geothermal energy reserve under the investigated area can be expressed by the integral:

$$GER = \int_A \left\{ \int_{z_u}^{z_L} \left[(1-\phi)\, \varrho_R c_R + \phi\, \varrho_w c_w \right] (T-T_o)\, dz \right\} dA ,$$

in which ϕ is the porosity, z_L and z_u are the lower and the upper boundaries of the aquifer /at a given place/, the indices R and w refer to the rock and the water. T is the measured temperature in a given depth, A is the surface area. The region of interest was divided into a mesh. Nodal points of the mesh usually do not coincide with points where borehole data were measured. In such cases interpolation is required. Interpolated isotherms of the upper-Pannonian aquifer at the bottom and at the roof are shown in Fig.2. and Fig.3. In this way the integral can be determined numerically. The final result for the geothermal reserve of the upper Pannonian reservoir is 1,835.10 KJ.

A further major problem is the determination of the reserve recovery factor it is known the environment of reinjecting wells is cooled down by recirculated cold water. This cold front will extend toward the producing wells. Therefore the reservoir of a recirculation system can be regarded as a heat source with diminishing intensity. Some mathematical models are known for the computation of the lifetime of such a system. This lifetime is limited by the temperature drop occurring in the producing well, which makes the geothermal energy utilization uneconomic.

This temperature limit was assumed the value of 50°C. That part of geothermal reserve, that can be really extracted during the lifetime of the system /i.e. till the outflow temperature will be higher than 50°C/ can be expressed as:

$$(GER)_R = \int_0^{t_L} N\dot{m}c\,(T_{out} - T_o)\, dt ,$$

where t_L is the lifetime of the system, T_{out} is the outflowing water temperature at the wellhead, $\dot{m}$ is the mass rate of a producing well, N the number of the wells.

We can determine the geothermal recovery factor as the ratio of extractable heat during the lifetime of a recirculation system /measured at the wellhead/ to the total thermal energy contained originally in the given subsurface volume of rock and water:

$$GRR = \frac{(GER)_R}{GER}$$

The geothermal reserve recovery factor can only be subjectively estimated. It depends on many variables, the most important of which seem to be

- the shape and dimensions of the reservoir
- physical properties the rock and the fluid
- the configuration of producing and reinjecting wells
- the intensity of production
- the heat extraction technology
- reservoir temperature
- reinjected water temperature

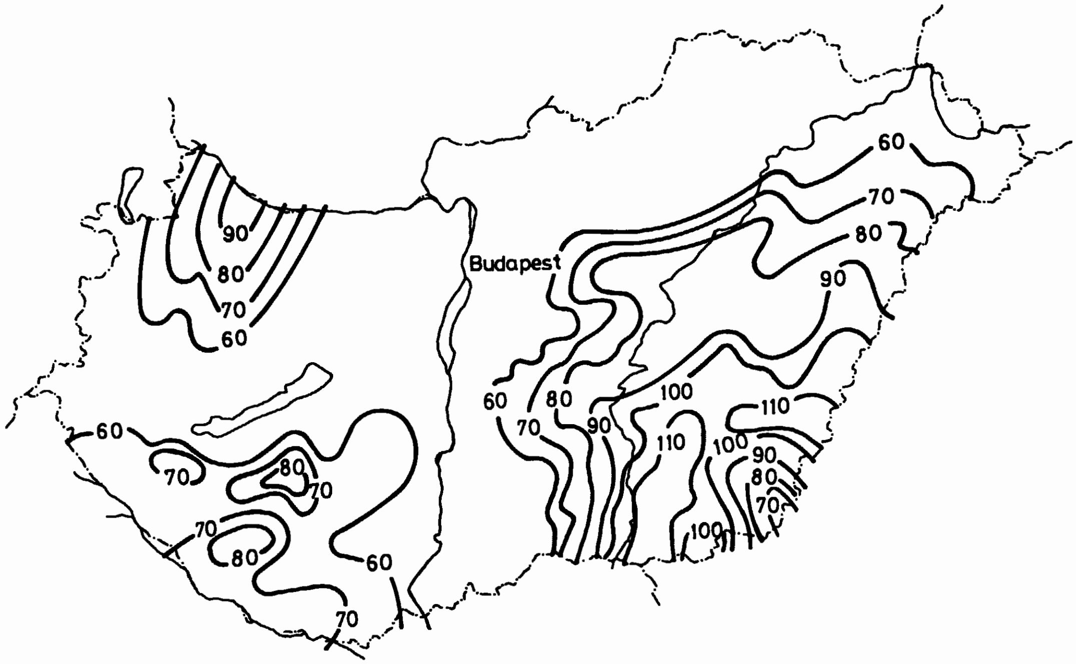

FIGURE 2.

ISOTHERMS AT THE BOTTOM OF THE UPPER PANNONIAN AQUIFER

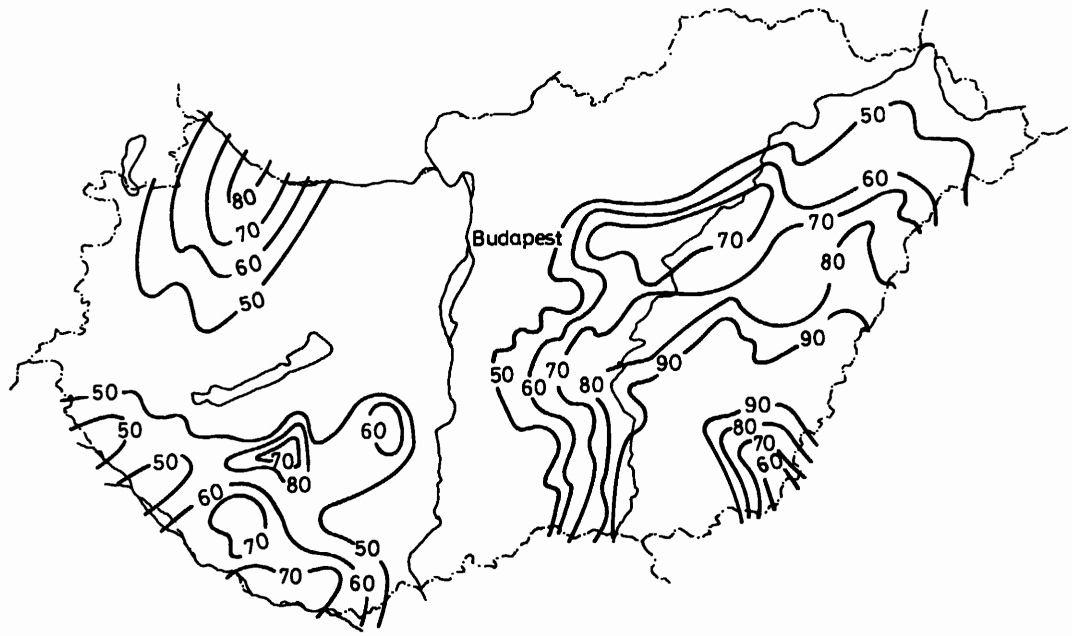

FIGURE 3.

ISOTHERMS AT THE ROOF OF THE UPPER PANNONIAN AQUIFER

- heat loss in producing wells

The uncertainties of such estimates originate from many causes. The first of these is the relatively little number of adequate data. Another problem is the subjectivity of some future data such as the number and configuration of wells, production rate, heat extraction technology etc.

Thus the evaluated recovery factor refers to an ideal situation: uniform well spacing, constant rate of production, constant reinjection temperature, and an ideal heat-extraction technology.

Finally, the value of the geothermal reserve recovery factor of the upper Pannonian hot water aquifer was determined as 42 per cent. This is a quite high value relative to the estimated 25 per cent by Nathenson and Muffler /1975/.

Our assessment seems to be more detailed and realistic than earlier estimations of Hungarian geothermal potential. The present production and utilization is quite far from the determined possibilities.

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