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HYDROGEOLOGICAL AND GEOTHERMAL CHANGES IN KARSTIC RESERVOIRS DUE TO MINE DEWATERING

by

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Abstract

Lowering of the piezometric-head due to pumping to protect mines from water-inrushes can create an extensive cone of depression. As a result of this, the directions of ground water flow in the surrounding aquifers can be changed, which can be sensitively indicated by the changes in water-temperature. In the bauxite deposits of Hungary the regular temperature measurements in the piezometric boreholes and observation wells, makes it possible to monitor, in combination with other methods, the hydrological structure of the surrounding rock mass.

Introduction

In the Transdanubian Range of Hungary significant brown coal and bauxite deposits are found. The coal mining at the beginning of the century and the bauxite mining since 1950 confronted with the water-inrushes of main karstic water forming a unified hydraulic system (Figure 1). Since the bauxite deposits lie directly on the surface of the Triassic basement the karstic water is mostly managed by sinking the water-head below the level of the mine workings. Because of this, natural depressions were occurring and the flow conditions became different (Figure 2). It is well known that in the territory of Hungary arising from its basin character the terrestrial heat flow shows a positive anomaly. It is so for the territory of the Transdanubian Range too, where the heat flow data of the areas being not or slightly disturbed by the motion of water, are very high (Val, Barszentmihalyfa). At the same time especially on the territories of the open karst, the cooling effect of the intensive infiltration (200-300 mm/year) deprives or considerably modifies a significant part of the terrestrial heat flow in the temperature field according to the direction of the filtration. Thus the influence of the hot springs emerging at the margins of the mountain regions on the temperature fields is already well known long time ago. The above statements are rather qualitative since our knowledge concerning the underground water flow conditions have become sufficiently exact only in the last decades. While the water movements in natural condition are existing permanently for a long time and are forming a quasi balanced geothermic field, creating in great areas negative and around the hot springs small concentrated positive anomalies, at the Nyirad-Csabpuszta region studied by the authors in consequence of the mine dewatering the flow conditions have significantly changed, transforming also the temperature field. In the centre of the thus formed depression as a result of intensive water pumping with flow rates of about 200-300 m^3/min for 20 years the water-head had sunk approximately 100 m, having an influence on the whole western part of the mountain range.

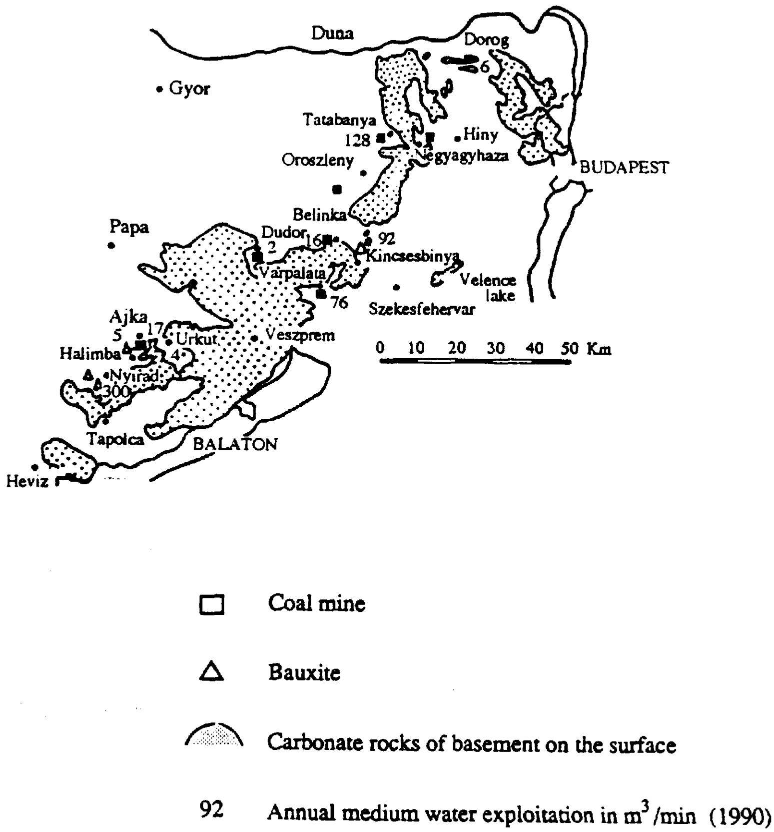


Figure 1 Mines in the Transdanubian range being endangered by water inrushes.

The rapid decrease of the water pumping in the last year marks the beginning of a new change of conditions, resulting the re-charge of the depression, however the undisturbed natural flow conditions will not completely restore, because in the area, although to a smaller extent, the water use for communal and technical purposes will remain. The changes in the geothermic conditions created by the influence of the considerable intervention in the natural flow conditions are followed and with the aid of the collected data an attempt has been made to describe more precisely the flow conditions of the area.

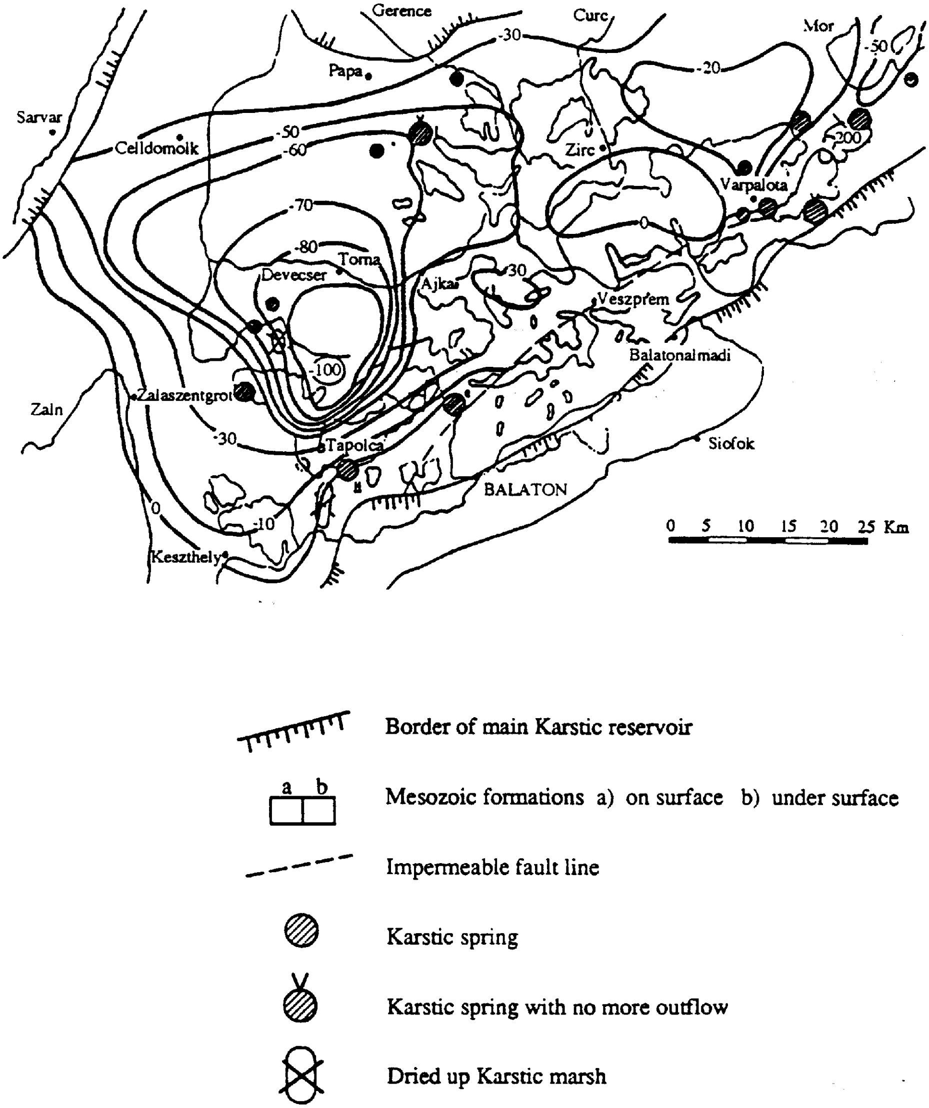


Fig. 2. The extent of water-head depression at the western and medium part of the Transdanubian range.

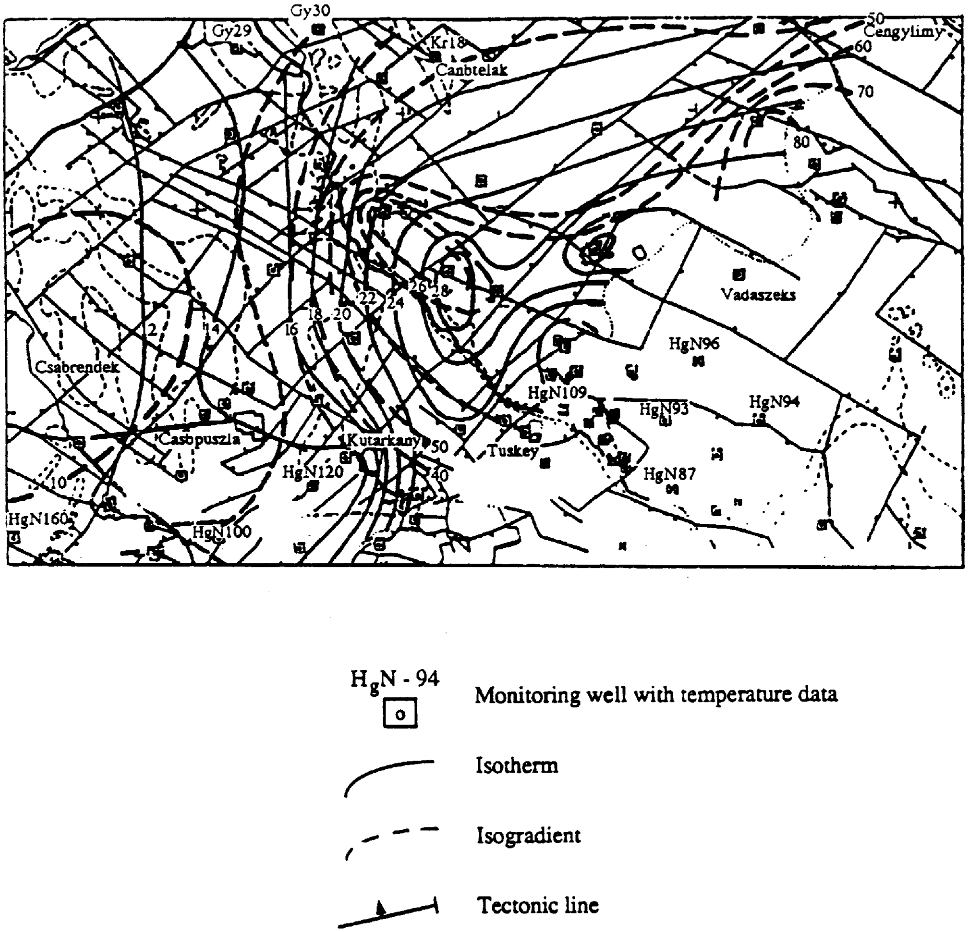
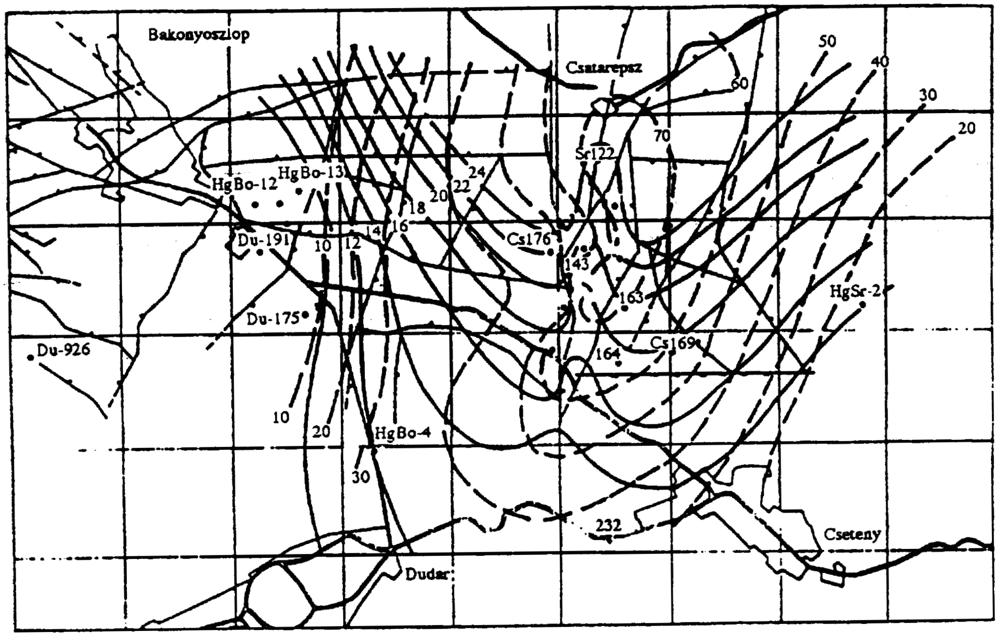


Fig. 3. Isotherms and isogradients related to the upper Cretaceous surface at Csabuszta area.



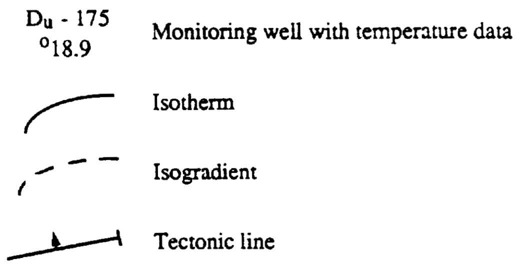
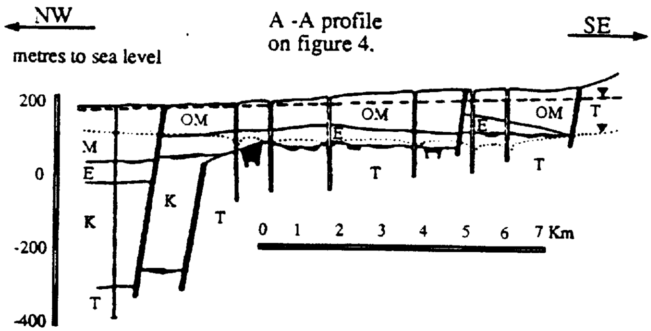


Fig. 4. Isotherm and isogradient map of the Triassic basement at Bakonyoszlop-Cseteny.



OM Oligocene - Miocene formations: conglomerate, clay

E Eocene formations: limestone, marl, clay

Bauxite

K Upper Cretaceous formations: limestone, marl

T Upper Triassic formations: dolomite, limestone

Original main Karstic water-head

Main Karstic water-head at the end of 1990

Dewatering well

Borehole

Fig. 5. Schematic section of Csabpuszta area.

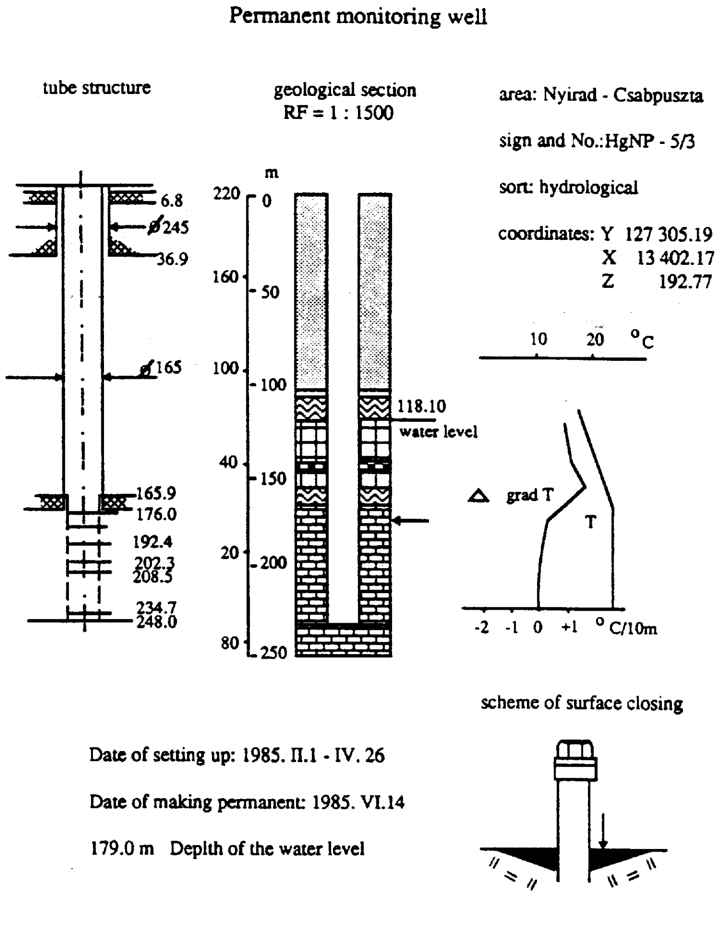


Fig. 6. One of the monitoring wells involved in the geothermal logging.

Sites of thermo-measurements and their geological structure

The measurements were performed at two sites, the area of the re-charge of depression at Nyirad and the territory of Cseteny-Bakonyoszlop where significant bauxite reserves are found but by now only small quantities of water had been pumped out for experimental purposes, thus it can be considered as a practically untouched territory from artificial water drainage. At Nyirad more than two hundred permanent monitoring wells are available mostly on Triassic main dolomite and at Bakonyoszlop there are about 50 measuring the water-head of the same aquifer (Figures 3 and 4). The wells are partly manually measured generally once in two weeks, and partly provided with automatic water registering instruments, making possible a continuous operation (one measurement in every half an hour).

All wells are not suitable for the thermo-measurements either because of their shallow depth or other reasons. Therefore, first of all those wells were chosen which deepened properly in the rock basement and by the evidence of the examinations made at their boring have crossed zones with required water conductivity. At Nyirad first of all those wells were taken into account which have crossed the upper Cretaceous Ugod Limestone Formation, since it was already known that here geothermic anomalies have existed already before the mining has begun. Within the area of occurrence of the limestones even a small hot spring existed. Here on the karstified surface of the limestones are bauxite layers of industrial quality just like on the surface of the deeper situated Triassic deposits and the hydraulic communication between the aquifer of the Cretaceous limestones and the flow system of the main karst in dolomites is a problem referring to the security of mines.

On the schematic section of the Csabpuszta area (Figure 5) it can be seen that the Ugod limestone is sinking gradually in northern direction and is covered with Eocene and Oligocene layers of more and more thickness having a worse regional transmissibility of several orders. At Bakonyoszlop-Cseteny similarly to Nyirad-Csabpuszta on the border of a Triassic infiltration area, the rock basement is also sinking more and more deep. Here the Triassic layer is covered with a limestone having a good permeability, too. It is the Szoc Limestone Formation where the layers of the upper cover are also of bad hydrogeological parameters. In spite of Csabpuszta no hot springs can be found here, and the infiltrated water wells up the surface in the springs of the east mountain-margin.

The method and extension of thermo-measurements

In the time of investigations within October 1989 and August 1990, 79 temperature loops have been installed in 68 wells. A thermoscope having a platinum sensor with 0.1^{o}C accuracy was used for measurements which operated first with a length of 170 m then 400 m shielded cable. The registration of logs was executed by point measurements at every 10 m interval. In some cases where it seemed reasonable, smaller intervals were chosen. The maximum depth in the best case was the bottom of the borehole, except those wells, where for some reason the scope got stuck before reaching the bottom or it was deeper than the maximum length of the cable.

Evaluation of thermologs

As a primary evaluation of the measured data for all boreholes has been made, diagrams of geothermal gradient were derived from the depth. These curves were practical to place on the registry sheet of the monitoring wells in the same measures as the other data. The Δ grad T values were counted in o^{C}/10 m dimension due to the most frequent measuring interval and related to the bottom of the interval. Thus the measured log can clearly be compared with the geological section, the tube structure and the filter (Figure 6).

As a result of the further elaboration the isotherm and isogradient maps were drawn of the both areas related at Nyirad on the Cretaceous, and at Bakonyoszlop on the Eocene limestone and beyond the margin of these deposits on the Triassic basement. The temperature of the surface in most of the logs could be determined by interpolation. At those wells, where the surface of the basement was out of the measured interval but the distance was less than 10 m, the temperature was estimated by extrapolation, what is shown on the maps too (Figures 3 and 4). At the drawing of the isogradient map, data from the literature (Dovenyi et al., 1983) was also taken into consideration, showing that the surface temperatures at Nyirad can be taken for 10.5^{o}C and at Bakonyoszlop 9^{o}C. The gradient data are represented in the commonly used mK/m dimension, where the total cover thickness was considered.

Results and Conclusions

Although the data collected are rather imperfect and the examined area was not ideal, it can be established that at the sites of dewatering wells the rock temperature has increased, in comparison to the sites not drained as a result of changes in the flow system.

At the Csabpuszta region the temperature changes occurred first at the central territories where the characteristic increase of rock temperature at the surface was 1 to 1.5^{o}C, but this trend was true for the whole of Nyirad-Csabpuszta region.

The shape of the iso-gradient lines (Figure 3) (i.e. long outstretched) shows a tectonically defined zone, where the upflow of the warm water from the places of the previous natural outcomes (spring at the monitoring well No. HgN-63 and the springs at Gyepukajan) had transferred. It can be seen from the isotherms that at the territory of the infiltration where the wells exist, the temperature increases in the whole territory intensively and uniformly. It means that the extent of the infiltrating cold water having a great specific heat, flows so slowly, that it can receive from the warm flow medium so much heat, which is enough for the warming up.

This means that in the Cretaceous formation, the horizontal water flow is limited which is in agreement with the hydrogeological model formed on the basis of previous tectonic and lithologic assumptions. The uniform isotherms in the Eastern part of the territory shows the absence of the horizontal water flow. This further provides evidence that the Cretaceous formation is a located reservoir and in it the pressure conditions of the main karstic water above are equalized.

The rather small territory warmed up by the upflow which coincides almost properly with the situation of the group of dewatering wells having the greatest volumes, shows that the artificial uplift has a great influence on the heat flow and its ceasing calls for the subsequent cooling down of the convection system to the original natural conditions. At the Bakonyoszlop-Cseteny region (Figure 4) the dewatering will start only at the time of the beginning of mine works. Recently the natural flow system is only insignificantly influenced by some dewatering at great distance like the Dudar coal mines, having by now less than 1 m^3/min. water demand, or the activity of some water works situated nearby.

As it is seen from the isogradient lines the geothermic scheme has a lot of features similar to the territory of Csabpuszta. First of all the outstretched positive anomaly following a tectonic line, however do not have hot springs either now or in the past. The outflow of the warm water is occurring under the surface in the well karstified Eocene limestones.

There also appears a strong heat anomaly altering in the direction of the infiltration territory, where geothermic gradient is approaching zero. So the experience of Csabpuszta are making possible to make a model of the influence of geothermic field of the mine dewatering. So much the more because the centre of the dewatering will also be near to the recent natural upflow creating the anomaly the same way as at Csabpuszta. It can be already assumed from the recent data that the temperature in the middle of the depression will increase about 2 to 3°C and according to the character of the convective field it will get a shape outstretched to the east.

Valuable data will be received also from the measurement having begun in Nyirad-Csabpuszta region where the re-charge of depression has started. From the further thermolog data in Csabpuszta, received in the time of the recharge of the reservoir the original thermal conditions will return gradually and as a result the reappearance of the natural karstic springs.

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