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Guest Editor: M. Dobróka

POTENTIAL THERMAL WATER EXPLORATION IN THE TOKAJ AND SZERENCs AREA

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1. Introduction

The area around Szerencs lies in the border of many landscape contacts, so it is characterised by morphological diversity. The city of Tokaj lies on the southern part of the Tokaj Mountains. The region lies between the Bodrog River and the Nagy Kopasz Hill, built up from andesite, and is therefore a geologically complex unit. Both sides of Nagy Kopasz Hill are volcano tectonically and geomorphologically structured lines.

In the paper mainly Szerencs and Tokaj will be analyzed within their administrative boundaries, but also the wider environment will be mentioned. The area is bordered by Abaújdevcser to the north, Nyíregyháza to the east, Tiszaújváros to the south and Szikszó to the west (Figure 1).

In the wider environment hundreds of wells and geological exploration drilling units have been installed. The 74 wells in which effluent water is over 20°C provide the main information for thermal water research. We collected many parameters of the wells (code, EOV coordinates, depth, temperature, filtering, etc.). From these data we made the basic database. The major lukewarm and hot water wells are illustrated in Figure 1.

From the wider environment we located a narrower area, where we made detailed research for Szerencs and Tokaj. This area is bordered by Tállya to the north, Prügy to the south, Mád to the east and Megyaszó to the west. On this map we marked the preliminary results of geophysical investigations, including the structural and the tectonic lines.

Szerencs and Tokaj are in a hydrogeologically disadvantageous environment. In spite of this fact, we attempt to mark the places with hot water potential, which can be used for long-term hot water supply.

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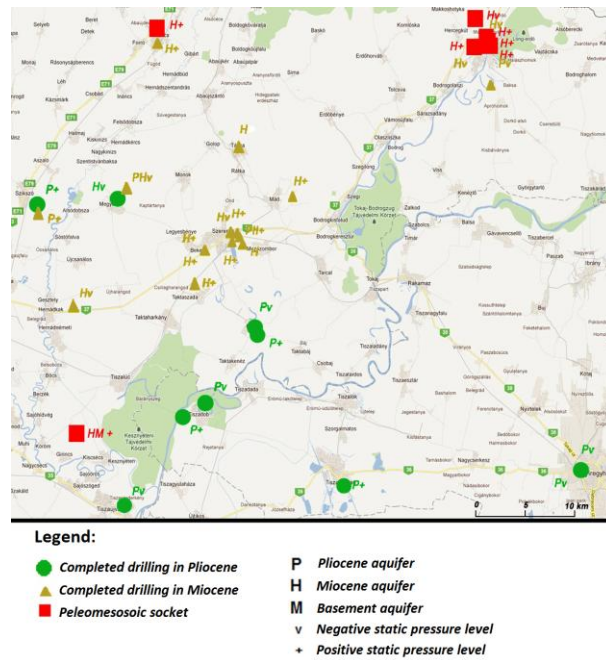


Figure 1. Map of the regional area with the warm and hot water wells

2. Geomorphological characterization of the Szerencs area

We have wide knowledge from the geological documentation, but precise depth parameters of the basement are insufficient. The depth and the material of the basement have not yet been identified (Table I).

The tectonic and structure lines of the basement maps are approximately parallel [2] [3] [4] [5] [6] [11]. The lines of three basement maps from the six we used coincide, and this line lies next to Szerencs in North-South direction. This line is probably the Hernád tectonic line, from which transverse fractures may permit hot water updraft.

Table I. Suspected materials of the basement under Szerencs

Year	Author(s)	Material of basement
1967	Viktor Dank, József Fülöp	Trias
1987	József Fülöp, Viktor Dank	Unknown material
1989	K. Brezsnýánszky, J. Haas	Unknown material
1990	Viktor Dank, József Fülöp	Unknown material
1990	János Tanács, R. Lászlóné	Unknown material
2010	János Haas	Unknown material

Different rocktypes are formed due to the updrafting solutes: hydrothermal quartz, geyserite and sweetwater quartz [8]. These rocktypes imply to postvolcanic activity. Mád and Szerencs are bounded by two faultlines: North-Southern and the East-Western direction. is the faultlines intersect at Aranka

Mountain. On higher levels the peaks are covered with hydrothermal quartz, while the valleys are covered with sweetwater quartz [1] [7].

We measured the potential temperature values of the depth from the effluent water's temperature to fill in the missing geothermal data of the depth. From this we defined the geothermal gradient, which is $7.1^{\circ}\text{C}/100\text{ m}$, which we then used as a constant in this area.

3. Summary of geothermal research activity in Szerencs

In Szerencs's surroundings there is a North-Eastern hydrothermal zone. It can be seen on the surface: Fekete Hill – Aranka Mountain – Árpád Mountain to the North and also to the South at the Bocskai church (Figure 2). Further to the South it tends to the deep and can only be traced in the drills' stratigraphical lines. The filtering of the transversing drills through the hydrothermal quartz is on this layer, because of its high permeability. (Table II).

Table II. Comparison of warm water anomalies in wells of Szerencs

Well name	Sign	Static water level [maB]	Outlet temp. [°C]	Yield [l/min]
Bakery	K-43	99.8	20	270
Chocolate factory-III	Cs-III	102	25	1,500
Motel Fridez	K-60	100	24.8	1,300

The Chocolate factory drill (Cs-III) has the highest static water level, effluent temperature and yield. With these conditions we can assume in the depth there is a plentiful yield of warm water from the aquifer layer, due to the drainage capacity of the hydrothermal quartz's zone.

Approaching the centre of the Taktaköz Basin the hydrothermal quartz formation's dip increases, so the temperature of the water increases. The tectonic breccia is intersected by disaggregated hydrothermal quartz and fractured siliceous rhyolitic tuff at a depth of approximately 220-230 m. Water with a temperature of approximately 28°C can potentially be found at this depth. If we assume $0.5^{\circ}\text{C}/100\text{ m}$ updraft cooling, the fissure's temperature is still around at least 26.5°C . When further geophysical experiments show the hydrothermal quartz's continuation to the depth (around 360 m at the periphery border), the base temperature may be about 39°C . In this case the effluent water's temperature is around 37°C . Surface investigations should be carried out in Vince Tanya (a dairy farm) to the south of Szerencs, in the area of Mád and Ond.

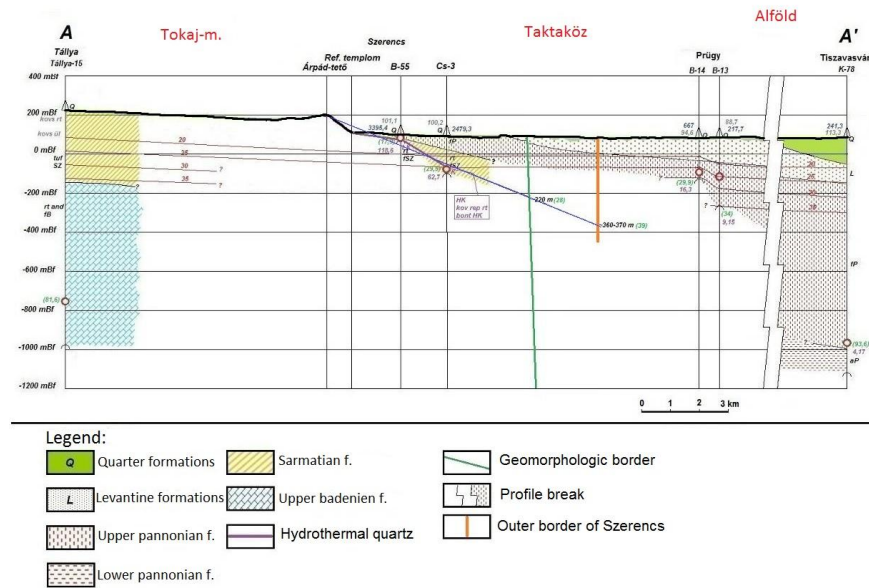


Figure 2. North-South hydrogeological profile

4. Geomorphological characterization of the Tokaj research area

In the environment of Tokaj there are many shallow drillings and wells, but these only tell us the near-surface geological structure and hydrogeological conditions. Without deep drillings, we do not have enough knowledge about the deeper layers. As far as thermal water research is concerned, only the environment of the Sárospatak-Véghardó Spa has been sufficiently examined, due to kaolin mining, uranium exploration and subsequent spa well drillings [9].

In Table III we can see the most likely rock material of the basement under Tokaj and its estimated depth according to several studies [2] [3] [4] [5] [6] [11].

Table III. Material and depth of basement under Tokaj

Year	Author(s)	Material of basement	Depth
1967	Viktor Dank, József Fülöp	Supposed Perm	-1500 m
1987	József Fülöp, Viktor Dank	Unknown basement	-900 m
1989	K. Brezsnyánszky, J. Haas	Unknown basement	-1000 m
1990	Viktor Dank, József Fülöp	Unknown basement	-900 m
1990	János Takács, R. Lászlóné	Badenien formations	-900 m
2010	János Haas	Unknown basement	-900 m

As can be seen from the table, our knowledge about the consistency of the basement and its depth is uncertain. On the southern part of the Tokaj Mountains there is an andesitic volcano-tectonic line and along this volcanic material erupted onto upper Tortonian and lower Sarmatian formations. After the end of

volcanic periods huge tensile stresses affected the solidified lava. On the edges of the mountain the taper volcanic matter became less resistant to the emerging tension, thus it was cut and dropped, made the pair of structural lines [10] (Figure 3).

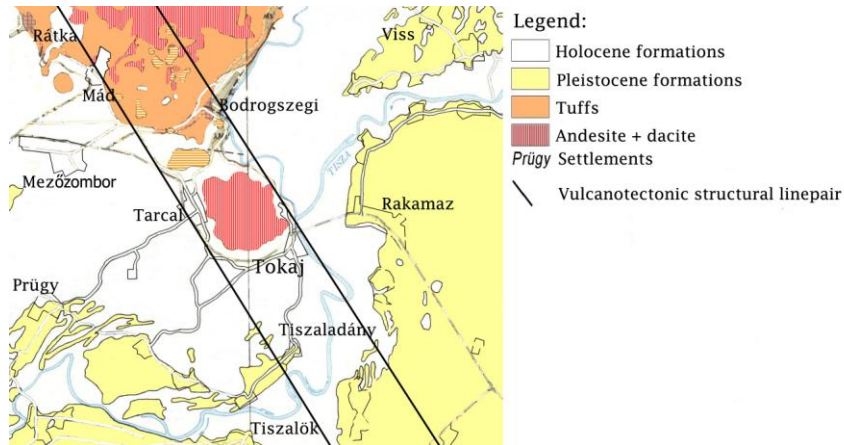


Figure 3. Pair of structural lines of Tokaj

A more detailed picture of the previously shown structural lines can be seen in Figure 4. It shows the depth's geological structure between the geothermal well at the Tokaj synagogue and the well in Viss settlement. Drilling into the structural line at sufficient depth results in inflowing hot water. Further geophysical experiments are needed to define the precise location and depth.

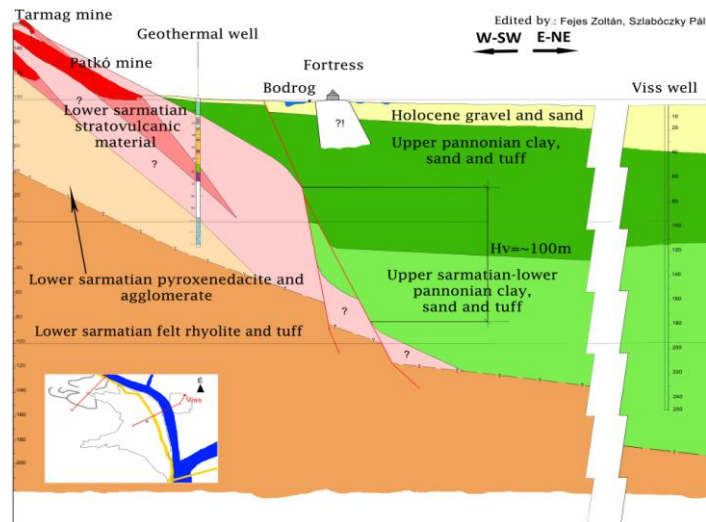


Figure 4. Conceptual hydrogeological profile

5. Conclusion

Recently the hot water supply of Szerencs and Tokaj has become more important. We used the previous research results, a thermal well database and the complex geology of the area for our exploration. In this territory the hot water providing basement is at a great depth, so it cannot be a target of thermal water research.

The highest chance of hot water updraft is in the occurrences of structural lines and layers formed by the post-volcanic activities that can be found in this area. To clarify these locations, further geophysical experiments are required in this region.

Acknowledgements

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INFILTRATION TESTS ON IRRIGATED AGRICULTURAL AREAS

LÁSZLÓ KOMPÁR¹, PÉTER SZÜCS², ZOLTÁN FEJES³, LÁSZLÓ PALCSU⁴, JÓZSEF DEÁK⁵

1. Introduction

The Duna-Tisza ridge is one of the largest recharge areas in Europe. There is an international project, which is coordinated by the International Atomic Energy Agency (IAEA) to investigate the natural groundwater recharge at some test sites in Europe. In Hungary a special research group carries out this interesting research program at two sampling sites named Méntelek and Kecskemét Szv II. The aim of the research is to build flow and transport models for the sample sites, which are based and calibrated on tritium isotope measurements in order to derive local recharge values. In earlier papers the research work at Méntelek has been presented [1]; we showed our model simulations and the results. Now in this work another test site, which was irrigated for agricultural purposes earlier, has been investigated close to Kecskemét.

2. Materials and method

³H is the radioactive isotope of hydrogen. The only difference between the ³H and the hydrogen is the number of the neutrons. Tritium is formed in the upper atmosphere during – β decay. It has a half life of 12.4 years, during which tritium decays to ³He.

The main aspects of selection of sample area were the followings:

- on the site there was sewage disposal for at least 5 years,
- the site was used for agriculture ,
- the sites must be on the Hungarian Great Plain,
- the depth and the quality of the groundwater must be suitable to model the movement of sewage components.

The choice was based on these parameters, so for a test site Kecskemét was chosen [2].

Kecskemét can be found near Méntelek in the Duna-Tisza ridge (Méntelek was the base of the previous studies (Figure 1)). The test site in Méntelek operates just for research; only a meteorological station works on the site. This test site in Kecskemét was installed in 1944 for research purposes on an agricultural area. At that time there was a plan to join the Danube and the Tisza rivers through a canal. At the station in Méntelek the decreasing of groundwater level would have been monitored, but this plan was never realised.

The wells in Kecskemét were installed in loess and sand bedrock on the Duna-Tisza ridge. This area has a moderately warm and arid climate. The average annual precipitation was about 550 mm/year in the last 70 years. The soils of the site were investigated before the study began. The test site is physiologically heterogeneous; there are several soil types on the area [3].

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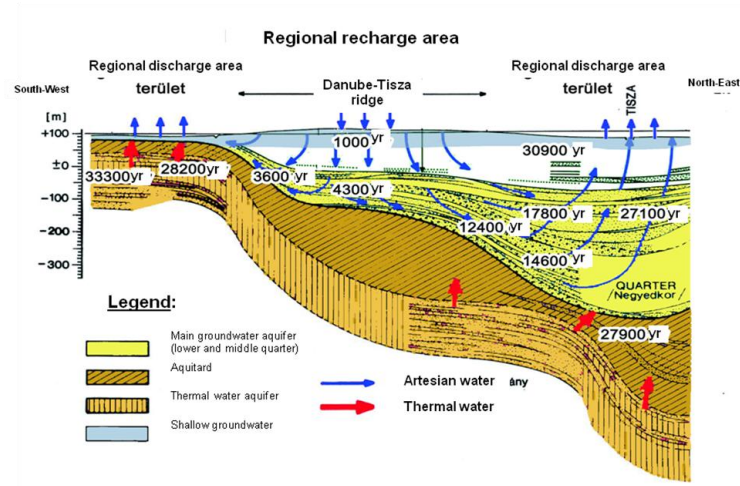


Figure 1. The Duna-Tisza ridge is the main recharge area of Hungary

The test site, as in Mentelek, is a typical recharge area. The groundwater flow is nearly vertical. This is the reason for its selection as a test site. The tritium profile was measured in 2001 at 6 different depths under the surface from groundwater, because at that time 6 wells were drilled (Figure 2). A numerical transport model was created covering the period between 1951 and 2010, like for Mentelek. The tritium content of the Hungarian precipitation was estimated for this period using precipitation data since 1972, wine samples of 1960 to 1977 and GNIP data of Vienna and Ottawa.

The framework of the model is the same as in the model of Mentelek: a column model was built, which works with just vertical flow involving recharge. The hydrodynamic model is similar to the other model; while the groundwater level is different, the geological parameters are the same. These geological parameters were determined from the boreholes from 2001.



Figure 2. The 6 wells near Kecskemét

MODFLOW is a U.S. Geological Survey modular finite-difference flow model. This computer code can solve the groundwater flow equation. The governing partial differential equation solved numerically in MODFLOW is given in the following form:

$$\frac{\partial}{\partial x} \left(K_{xx} \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left(K_{yy} \frac{\partial h}{\partial y} \right) + \frac{\partial}{\partial z} \left(K_{zz} \frac{\partial h}{\partial z} \right) + W = S_s \frac{\partial h}{\partial t}$$

where K_{xx} , K_{yy} , and K_{zz} are the values of the hydraulic conductivity along the x, y, and z coordinate axes (L/T), h is the hydraulic head (L), W is the volumetric flux per unit volume representing the sources and sinks of groundwater, for which the negative values mean extractions while the positive values mean injections (T^{-1}), S_s is the specific storage of the investigated aquifer (L^{-1}), and t is time (T). This program is widely used throughout the world by hydrogeologists to simulate the flow of groundwater through aquifers. The code is a free software, written in the FORTRAN language, and can be compiled and run on the DOS, Windows, or UNIX operating systems. Since its original development in the early 1980s [4], the USGS have released four major versions of this code, and it is now considered to be the de facto standard industrial code among groundwater specialists for aquifer simulation. Currently, there are many actively developed commercial and non-commercial graphical user interfaces for MODFLOW.

Commercial MODFLOW programs are typically used by governments and consultants for practical applications of MODFLOW to real-world groundwater problems. The applied PMWIN-Pro may be considered as a professional commercial version of MODFLOW. A three-dimensional flow model considering 44 layers was implemented with the help of the MODFLOW-2000 module in the current project work. This model was used to characterise

the nearly vertical groundwater flow of the investigated area in Kecskemét, which is a main recharge region on the Hungarian Great Plain. The required input data for the flow model were readily available from an earlier geological and hydrogeological prospecting activity.

Besides the flow model, a transport model was also built to investigate tritium concentration distribution under the surface due to the groundwater recharge from precipitation. The tritium transport movement investigations were carried out in the field-study by the module MT3DMS, where MT3D means Modular 3-dimensional transport model, and MS means the multi-species structure to model several components simultaneously. MT3DMS has a comprehensive set of options and capabilities for simulating the advection, dispersion, diffusion, radioactive decay and chemical reactions of contaminants in groundwater flow systems under general hydrogeologic conditions. MT3DMS was developed for use with any finite-difference flow model such as MODFLOW, and is based on the assumption that changes in the concentration field (Figure 3) will not affect the flow field appreciably.

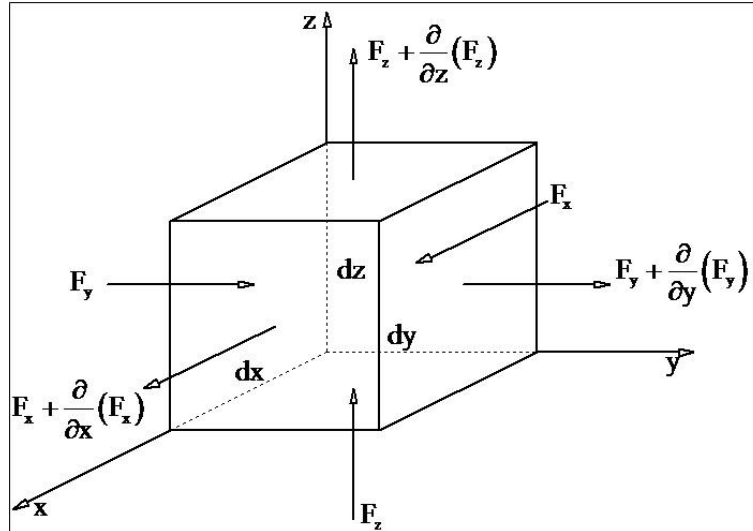


Figure 3. The balance of tracer of elementary space

The partial differential equation describing the fate and transport of chemical components or contaminants of the species k in a three-dimensional space in transient groundwater flow systems can be written as follows:

$$\frac{\partial(\phi C^k)}{\partial t} = \frac{\partial}{\partial x_i} \left(\phi D_{ij} \frac{\partial C^k}{\partial x_j} \right) - \frac{\partial}{\partial x_i} (\phi v_i C^k) + q_s C_s^k + \sum R_n$$

where ϕ means porosity of the aquifer, dimensionless, (fraction), C_k is the dissolved concentration of species k , (M/L^3), t is time (T), $x_{i,j}$ is distance along the respective Cartesian coordinate axis (L), $D_{i,j}$ is the hydrodynamic dispersion coefficient tensor (L^2/T), v_i is the seepage or linear pore water velocity based on the Darcy equation (L/T), q_s is the

volumetric flow rate per unit volume of aquifer representing fluid sources and sinks ($1/T$), C_s^k is the concentration of the source or sink flux for species k (M/L^3), and $\sum R_n$ is the chemical reaction term ($M/L^3/T$).



Figure 4. Water sampling for tritium measurement

3. Results

Water samples were collected on the test site close to Kecskemét in 2012 (Figure 4). The model of Kecskemét shows the same results as the model of Méntelek. We obtained a tritium profile from the transport model (Figure 5). The red line was constructed from data of 2001, when the wells were drilled, and the groundwater was sampled during drilling. From these drillings the largest TU value was established at 9.5 m. The figure simulates 2 peaks, which is an interesting thing: the researches started in 1971 on this site, during 10 years of sewage disposal, when the splashed water had a TU value, which was 0 TU (the deep groundwater has 0 TU tritium content). After the research work the tritium content of the precipitation appeared in the shallow groundwater, this look likes the second peak at 13.6 m below the surface. The blue line shows the calculated values. These model values need to be clarified and calibrated, as the obtained line is an adducing result. However, it can be seen that the model works in an acceptable manner, and it shows the character of the red curve.

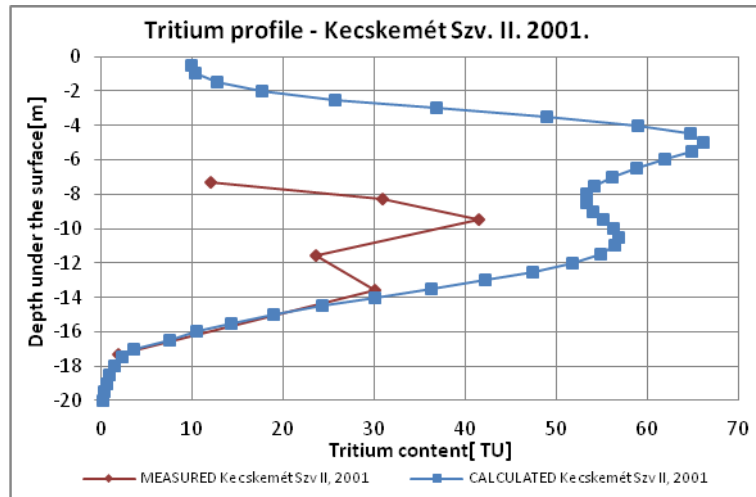


Figure 5. The tritium profiles of Kecskemét

4. Conclusion

Nowadays isotopes are very important tools for hydrogeology. Numerical transport modeling is also a useable tool for defining some problems in earth science and engineering. In this case study we determined that isotope hydrology and transport modeling applied together is a possible tool for investigating the natural recharge from precipitation.

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