INFILTRATION IN THE TRANSDANUBIAN MIDDLE MOUNTAINS, HUNGARY

SÁNDOR FOGARASI

Department of Climatology and Landscape Ecology, University of Szeged, Hungary

Summary

This study confirmed the deep karst character of the Transdanubian Middle Mountains. In case of the other Hungarian karst regions which have mainly shallow character, the input is followed by the output after some months. In spite of this, the Transdanubian karst system reflects the input water only with a leeway of some years. The most intensive infiltration occurred in those cases when the precipitation was >10 mm/day, snowfall, winter half-year precipitation. The water system bled its water input; first part: during 2-2.5 months, main part: 1-2 years.

Introduction

The Transdanubian Middle Mountains are situated mainly in the northeastern parts of the Transdanubian region; however, some parts extend to north and east, towards the right banks of the Danube. In morphological sense, it covers a territory of 5200 km^2 (*Fig. 1*). In the studied area, mainly Upper-Triasic limestone and dolomite can be found. The average depth of the karst strata is 2.5 km, its surface projection is around 13000 km^2. The mentioned formations - comprising one single system - reserve most of the karst waters. Special name was introduced for this type of water in the 1950s: it was entitled as „main karst water". Other, smaller closed units have to be separated from this; the age of these separate units also differs from the mineral content of the main karst. The study deals with the „main karst water" which - because of the large extension of the karst strata - belongs to the group of the „deep karsts". The extremely large capacity of the minerals causes the fact that the amount of stored water can be measured in hundreds of km^3. This

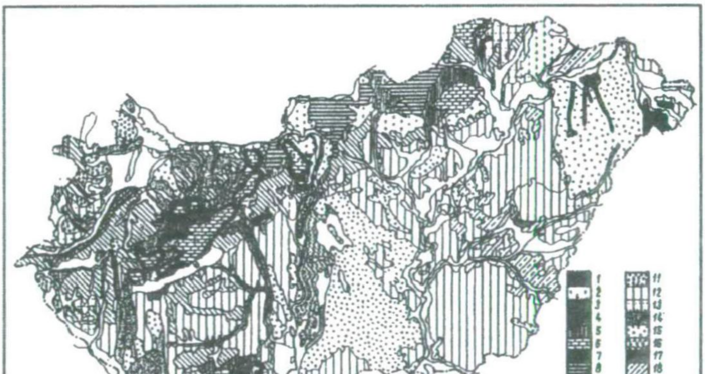

Fig. 1 Geological map of Hungary

huge quantity appears as the largest natural drinking-water body of Central Europe. Intensive exploitation of this water occurred between 1950 and 1990, which caused the 20-30 m regional decrease of the groundwater level, and the drying up of all - formerly abundant - springs of the area.

In connection with the economic decline after 1990, practically all of the significant mining activities disappeared from the area. As the very last of them, the water exploitation in Fehérvárcsurgó was halted in July, 1999. Since the only water resource of the human population of the area comes from the above-mentioned karst water, the water exploitation for human consumption has to be continued in the future. However, the amount of human consumption also decreased in the last 10 years. The intensive anthropogenic use is a good indicator of the importance of further research on karst water: the mass of natural water supply, the possible exploitation of water without the degradation of the system and also the presumable rate of regeneration of the former hydrological balance are some of the most significant and current questions in the area. (*Fig. 2.*)

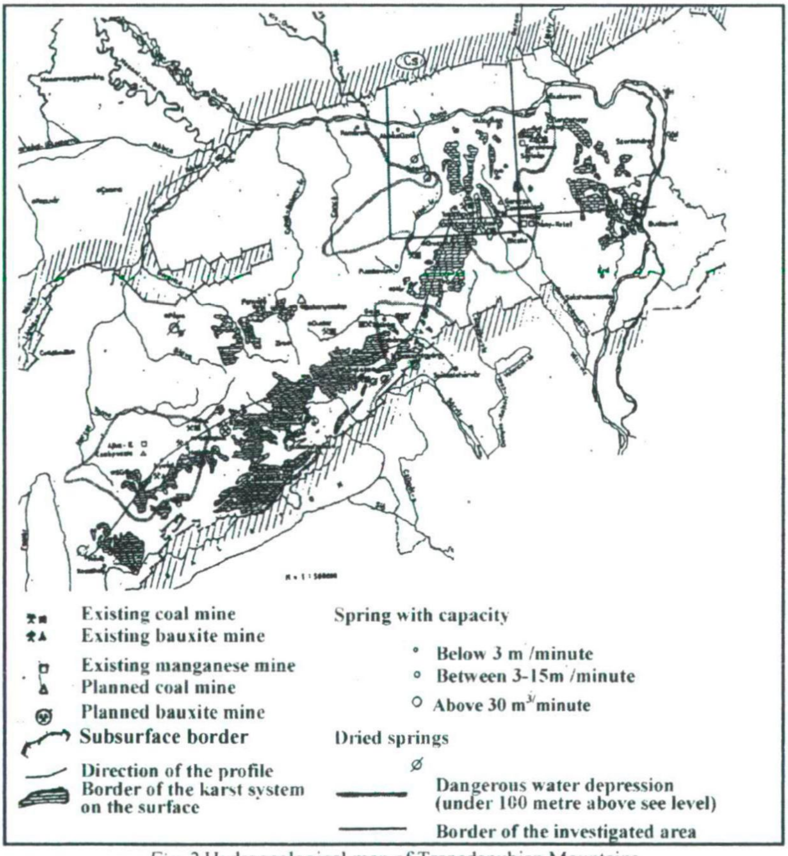

Fig. 2 Hydrogeological map of Transdanubian Mountains

The springs of the Tata area

A larger, relatively separated cell of the „main karst water" strata is the group of the springs of Tata. In this area, the original aim of the research was to present the connection between the infiltration (water input) and the runoff (water output) of the springs; and also, to draw conclusions about the functioning of the water-system. The studied springs are situated in the area of the so called „town of waters": Tata. Their runoff is around 120 m^3 in their natural conditions. The water of these springs used to be lukewarm (18-22 °C) with relatively high mineral content (H_2S, $MgCO_3$, etc.). Their curative power was well known by the Romans: even a settlement was founded by them in the close vicinity of the springs. Up to the Modern Times, springs became more and more frequently visited again, especially by tourists.

This prosperity was ended up by the new, intensive mining activity: the famous springs dried up one by one between 1949 and 1972, as the water exploitation in the area reached much larger extent then the possible infiltration. According to the changes of the last decade, from 1990, the continuous and intensive increase of the groundwater level can be followed in the area, and the renewal of the first springs will most probably occur between 2001 and 2003. Before the appearance of mining in the area, there were approximately 170 springs in and around Tata, but most of the water came from four (groups of) springs: „Nagy" (33 m^3/min), „Kis" (27 m^3/min), „Nagy-tó parti" (11 m^3/min) and the „Fényes" springs (42 m^3/min). The sustaining area of the springs was the uncovered (236 km^2) and covered (450 km^2) karst terrains in the eastern parts of the Vértes, and western parts of the Gerecse Mountains. (*Fig. 3.*)

Model

The aim of the study is to find connection between the precipitation and the runoff of the karst springs of the area (*Fig. 4*). On this way, both the input and output sides have to be counted; from their relationship, certain conclusions can be drawn about the functioning of the system.

Input side

- *precipitation*: Its quantity, intensity and the aggregate are in positive correlation with the amount of the infiltrated water.
- *vegetation overlay*: The infiltration is very much influenced by the vegetation overlay, as it decreases the runoff of the water and delays the infiltration.
- *material of the minerals*: The capacity of the pores and the rate of the cracked parts influence the infiltration (positive correlation)
- *water content of the pores*: Its task is the „pre-wetting": without this moisture, water cannot infiltrate into deeper layers.
- *Groundwater input from the surrounding areas*: In case of the cell which sustains the springs of the Tata area, water input arrives from the Bakony Mountains (15-20 m^3/min).

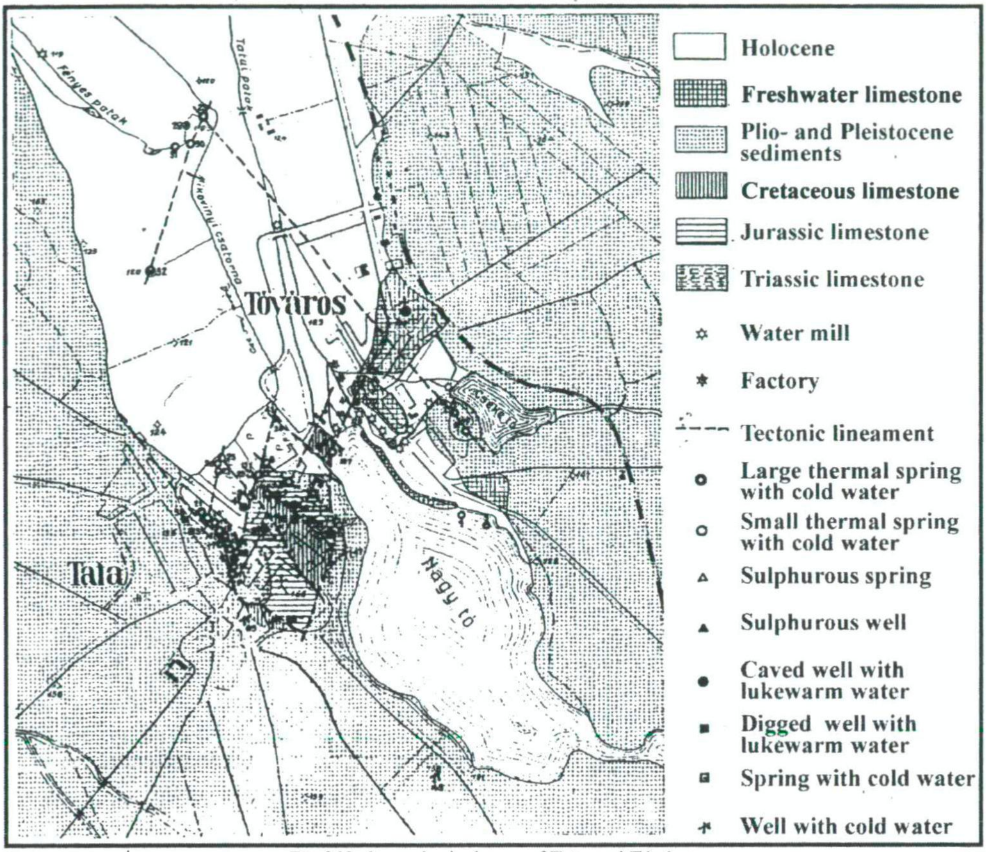

Fig 3 Hydrogeological map of Tata and Tóváros

The most important features of the present **water-system** are:

- The waterlevel is not entirely linear, but follows, more or less, the differences of the surface morphology.
- Certain rifts can be found in the mass of rock in which the watercourse is tectonically determined.
- In these rifts, the watercourse has dynamic changes: if there were significant changes in one part of the system, equalization starts immediately. For example, earlier there was a southwestern-northeastern flow in the karst system, which can be explained by the deviations of the precipitation (900 mm - 560 mm). This flow can be mentioned as an input of the studied springs.
- In spite of the uniformity of the watersystem, there exists some separated subregions such as the Tata area. This separation can be made only for some exceptional case studies: the „main karst water" comprises one solid system, and there is significant - still relatively unclear - communication between the more or less separated cells.

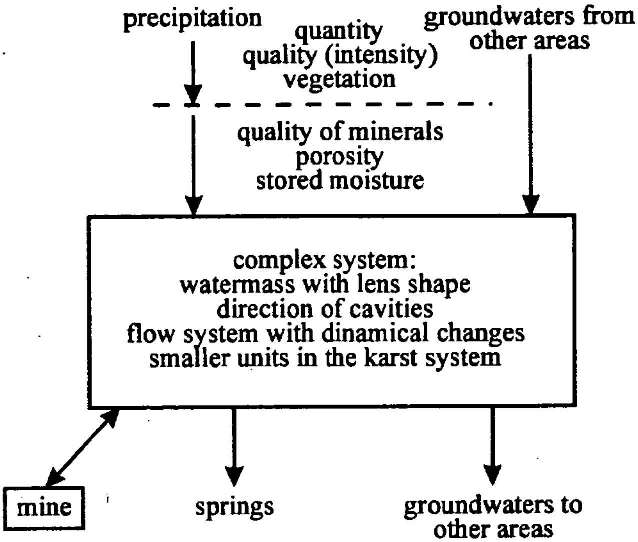

Fig. 4 The infiltration modell

Output side:

Before the foundation of mines in the region, two factors were most important:

- springs (e.g.: the springs of Tata, 175 m^3/min)
- subsurface outflow (in our case, the groundwater had its northern outflow towards the springs of Neszmély, 2 m^3/min)

Water exploitation had short history, but it was extremely influential with its 205 m^3/min consumption.

Correlation analysis:

Applied database of meteorological stations:

- fluid precipitation: Pusztamarót (340 m), Gerecse Mountains
- solid precipitation: Bakonypölöske (212 m), Bakony Mountains
- runoff of the springs: based on the data of the period between 1949 and 1954 of the afore-mentioned four springs. This period was still not influenced by the mining activity.

Linear regression:

At the beginning of the study, it was presumed that linear connection existed between the factors. Therefore, the connection between the dependent and the independent variables is y=ax+b. The statistical analysis, the linear equation of the joint line and the correlation coefficient were calculated by the application of the STATGRAPH program. (*Table 1, 2*)

Table 1 Table of calculations I.

Independent variable	Dependent variable	Correlation coefficient
1. monthly precipitation	runoff (2 months later)	0,3
2. 10 mm/day > intensity of monthly p.	runoff (2 months later)	0,4
3. 10 mm/day > int. of m. p.	runoff (3 months later)	0,1
4. 10 mm/day > int. of m. p.	runoff (1 month later)	0,0
5. winter snowfall	first runoff after melting period	0,93
6. yearly precipitation (April-April)	runoff (2 months later)	0,24
7. 10 mm/day > int. of winter p. (Oct.-May)	runoff (2 months later)	0,41
8. snowfall	runoff 2 months after melting	0,34

The following data are connected to the precipitations under 10 mm/day, fell between October and May, in the winter half-year. In case of infiltration, the winter half-year was treated as one unit, because of the organisation of the hydrological year: this begins with September, after the longer break of the summer infiltration. In case of the last precipitation data, it was compared to the two-month-later output (July is the dependent variable).

Table 2 Table of calculations II.

Independent variable	Correlation coefficient
9. previous year + two years earlier (snow 1.5*)⇒	0,67
10. previous year + two years earlier⇒	0,74
11. previous year (snow 1.5 *) + two years earlier⇒	0,74
12. previous year/2 + two years earlier⇒	0,78
13. previous year (snow 1.5 *)/2 + two years earlier (1.5 *)⇒	0,8

Conclusions

1. The correlation analysis verified the connection between the precipitation and the output of the springs only in case of winter snowfall (calculations 1-4). Stronger correlation could not be shown with the decrease of precipitation intensity or not even with the change of duration.

2.a. On the basis of one-year precipitation (calculations 5-7) the following could be concluded. The connection between the precipitation of the last year and the runoff of the springs after 2 months was also very weak. This means that the intensive precipitation did not influence the water output. As we can see, with the decreasing intensity of precipitation and the change of the measured period of precipitation, increasing connection could be indicated. On the other hand, it did not have connection with the 10 mm/day> precipitation of the winter half-year. Because of these circumstances, the precipitation database of a much longer period had to be applied for further examination.

2.b. According to the mixed database of the studied years and the database of the spring outputs 2 months after the last used precipitation data (calculations 9-13) the following could be concluded. According to the above calculations, strong correlation could be indicated only between the winter half-year and the outputs of the springs. In connection with the changes of the duration and the precipitation intensity (snowfall), much stronger correlation appeared (0.67-0.8). The strongest correlation could be indicated with the 1:1 combination of the last year precipitation and the precipitation data of the period before 2 years, also with 1.5 times counting of the snowfall data (0.8).

References

Horusitzky, Henrik: Tata és Tóváros hévforrásainak hidrogeológiája és közgazdasági jövője (Hyrogeology and economic future of Tata and Tóváros) Budapest, 1925.

Juhász, József: Hidrogeológia (Hydrogeology) Budapest, 1987.