The hydrogeological relations of the thermal karst of Bükk Mountains (Northern Hungary)

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Zusammenfassung: Die Bükk-Region befindet sich in Nordungarn. Das Gebiet des kalten Karstwasserkörpers beträgt ungefähr 823 km^2 und das Gebiet des warmen Karstwasserkörpers 4286 km^2 (gemäss EU-Normen).

Die wasserreichste kalte Quelle des Bükk-Gebirges entspringt in Miskolctapolca 127 Meter über dem Baltischen Meer. Der höchste Karstwasserspiegel in den Jahren zwischen 1983 und 2012 lag auf 550 Meter ü. M. Die „technische“ Grenzfläche zwischen dem kalten und warmen Karstwasser (30 °C-Isotherme) im Bükk-Gebirge befindet sich in 900-1400 Meter Tiefe. Dieser Wert senkt sich am Rande des Gebirges. Im Vergleich zum Quellniveau auf 127 m.ü.M. beträgt der Wasserdruck im Bükk-Gebirge maximal 420 Meter (42 bar). Die Bewegung des Karstwassers im Bükk-Gebirge wird von diesem Druckunterschied bestimmt.

Ein Teil des kalten Karstwassers fließt aus den Quellen am Gebirgsrand aus. Der andere Teil des Wassers entfernt sich vom Bükk-Gebirge durch die unter der wärmeisolierenden Schuttschicht liegende verkarstete Zone, wo er sich aufwärmt. Das Thermalwasser wird durch Bohrungen erschlossen, die tiefste ist mehr als 2500 Meter tief.

In unserem Artikel analysieren wir die wichtigsten hydrogeologischen Eigenschaften (Wasserstand, Wasserdruck und Wassertemperatur) des Thermalkarstwassers und seine Beziehung mit dem kalten Karstwasser.

Introduction

The cold karst water area of the Bükk Mountains (Northern Hungary) is surrounded by a significantly extended thermal karst water area (yielding karst water with temperatures exceeding 30 °C) by east, west and south (Fig. 1; LIEBE, 2002). About two dozens of karst springs and thermal wells are located at the rim of the mountains or the surrounding area, yielding tepid or warm (springs), or even warm or hot thermal water (wells). (Fig. 2; based on the map of LEXA et al, 2000: LÉNÁRT, 2012) The area around the mountains is covered with a sediment layer. The water catchment areas of these objects are situated on the limestone areas of Bükk. The cold karst water system of the Bükk is treated as a unified system. The data presented by Nv-17 karst water monitoring well is accepted to represent typical karst water levels. In present paper we are concerned with the relations of the open and covered karst in the area with regards to karst waters.

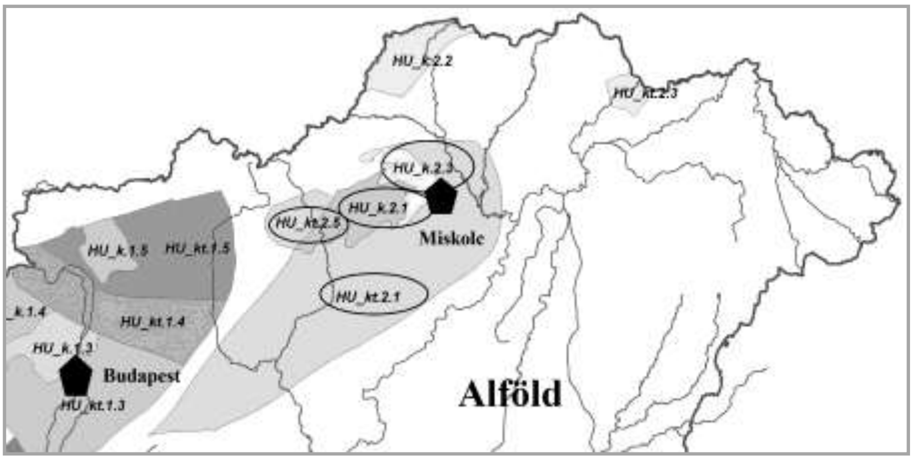

Fig. 1:

The karstic water bodies of Northern Hungary represented by the grey areas (LIEBE, 2009).

k: cold karst; kt: thermal karst;

k.2.3 = Bükk eastern karst;
k.2.1 = Bükk western karst;
kt.2.1 = Bükk thermal karst;
kt.2.5 = Recsk-Bükkszék thermal karst.

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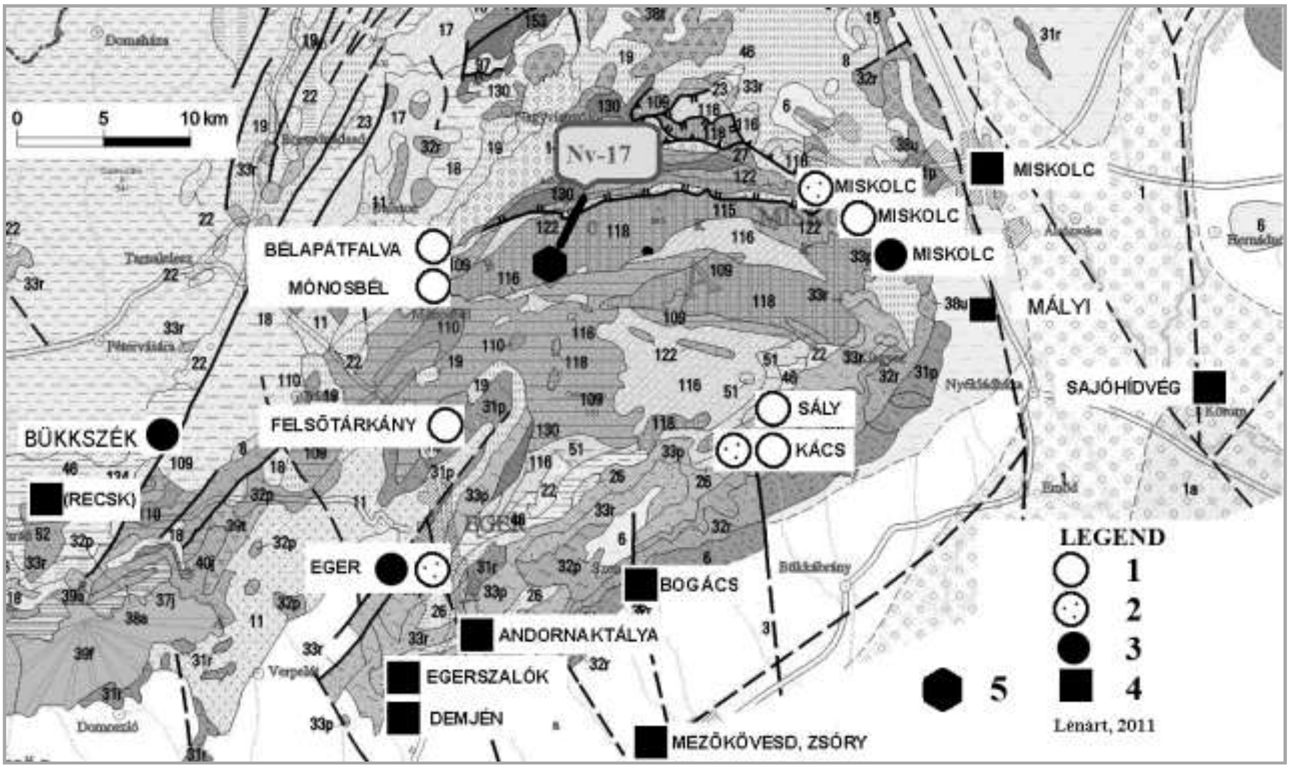

Fig. 2: The thermal karst draft of the Bükk region with location of the Nv-17 cold karst water monitoring well [based on the map of LEXA et. al, 2000; LÉNÁRT, 2012]
1: cold tepid karst water, 10-16 °C;
2: warm tepid karst water, 16-25 °C;
3: warm karst water, 25-37 °C;
4: hot karst water, above 37 °C;
5: Nv-17: Bükk, Nagy-fennsík, standard level measurement site of cold karst water.

The geological and hydrogeological overview of the Bükk region

The size of the unconfined (open) karst system is about 207 km^2 (marked by numbers 116; 118; 130; 134 on Fig. 2) and stretches from east to west in patches. This means that the line of bearing of Carboniferous-Permian (134; 141) and Triassic-Eocene (116; 118; 130) carbonate rocks is east to west. (The most significant faults are also oriented from east to west but at the rim of the mountains faults perpendicular or at an angle to it are also found.)

The precipitation falling on the open (unconfined) karst of the Bükk infiltrates the karst, and either leaves it through springs, or moves toward the Alföld (Great Plain) region through the limestone layers stretching beneath the Cenozoic sediment layer, due to the pressure differences of the karst water relief of the Bükk.

Due to ground heat (convection) the cold karst water warms up along the flowpaths. (Note: the convection value 100 mW/m^2 measured at the Great Plain (Alföld) gradually decreases as it reaches the rim of the mountains. At the middlemost area of the Bükk it is as low as 40 mW/m^2 (DÖVÉNYI & HORVÁTH, 1988). In Hungary, for technological reasons, the dividing line between cold and warm (karst) water is drawn at temperature 30 °C. (In my opinion Nature doesn't allow for such sharp line to be set but for technological and legal reasons let us accept this value as the dividing line.) This latter clearly reflects that the 30 degrees Celsius isotherm is located under the Bükk Mountains in the depth of 900-1400 m. Its depth is rapidly decreasing towards the rims. There is no possibility to exploit the thermal karst water in the Bükk, it could only take place on the covered karst, further away from the Bükk's rim. The reason is because the thermal karst water is in great depths, and it has direct hydrological connection to cold karst water. Caves containing thermal karstic formations are found at the brim of the Bükk. These formations had been created by upwelling karst water. Despite this, the thermal karst genetics remains questionable for many scientists.

The largest karst spring of the Bükk (cold and warm water spring group) is at Miskolctapolca. The location of thermal karst water springs and wells are specified on Figure 2. The Miskolctapolca spring group is located at 127 m aBs (above Baltic Sea) level. The maximum karst water level at the Bükk Plateau (Nv-17) has been measured to be at 550 m aBs level. The average of karst water level between 1992 and 2012 was 530 m aBs level. It means that since the karst water level at Miskolctapolca at 127 m aBs, and the average and maximum water level of the open karst water system in the Bükk area is at much higher level, it generates a 40-42 bar pressure difference, thus causing the water to flow (LÉNÁRT, 2010).

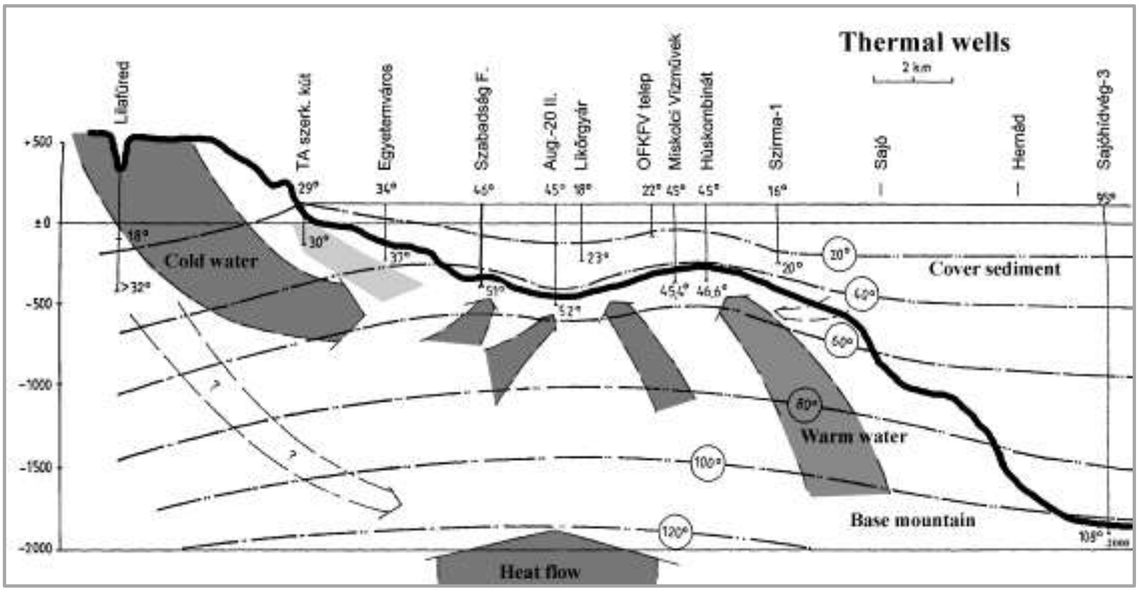

Fig. 3: The overview of the thermal karst system in Miskolc surroundings, E to W (SZLABÓCZKY, 1974).

The large open karst is “well karstified” from surface to 300 m underground. The cold water infiltrating the large open karst is moving in the upper zone of the karst limestone layer which stretches under the sediment layer in the Miskolc pilot area of the Bükk (Fig 3; SZLABÓCZKY, 1974). The thickness of the “well karstified” zone is probably about the same in the case of covered (confined) karst but drillings did not penetrate to deeper than 100 meters. The carbonate layers are located at more and more depth. Around Köröm (Sajóhídvég), the base temperature exceeds 100 °C at a depth 2000 m below Baltic sea level. The 30 °C isotherm is not marked on the Figure. The presentation of values 20 and 40 °C was based upon, among others, the published data of the Pávai Vajna well which is highly debated even today. In order to determine the exploitability of karst water it is very important to have more accurate data, but based on data of karst water monitoring wells, caves and springs, we can conclude that the 30 °C isotherm is located in more depth even on the area marked than it is shown on the Figure 3. The drilling at Mályi in 2010 reached 2300 meters depth. It is not shown on the relevant figure as the investor treats the official data of the drilling confidential The temperature measured in the drill are very similar to the values measured in the monitoring well at Köröm.

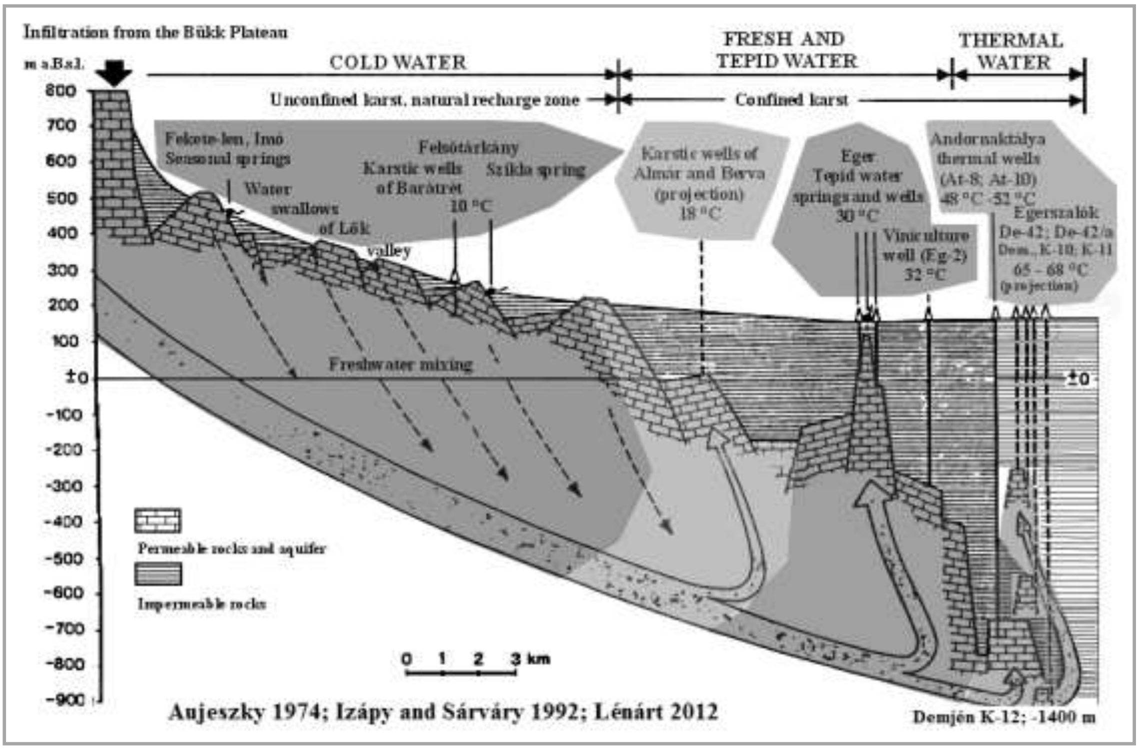

Fig. 4: Overview of the thermal karst system in Eger surroundings, without Demjén K-12, NE to SW (based on AUJESZKY, 1974; IZÁPY & SÁRVÁRY, 1992; LÉNÁRT, 2012).

The open karst water catchment area of Eger (including Egerszalók and Demjén) is neither as large nor as unified as the Miskolc aquifer. Due to heavily tectonized structure and significant karsting, the karst water warms up in the depth and moves along the faults (Fig. 4; IZÁPY & SÁRVÁRY, 1992). The temperature of the karst water reaching the surface is almost the same whether it is coming from depths of 300 or 900 m below Baltic Sea level (65-68 °C). At the mountain brim, some wells yield water colder than this. The well K-12, drilled in 2011 in Demjén, is 1514 m deep. The highest temperature measured in the K-12 well is 79 °C, and karst water that reaches the surface is 73 °C. The water cools 6 degrees on its way. In the Miskolc area, from the depth of 400-500 m below Baltic Sea level, the temperature of the karst water is 40-45 °C.

Thermal Karst Water Exploitation

Figure 5 shows the fluctuation of the annual volume of water, exploited in the surroundings of the Bükk and discharging at mountain brim springs.

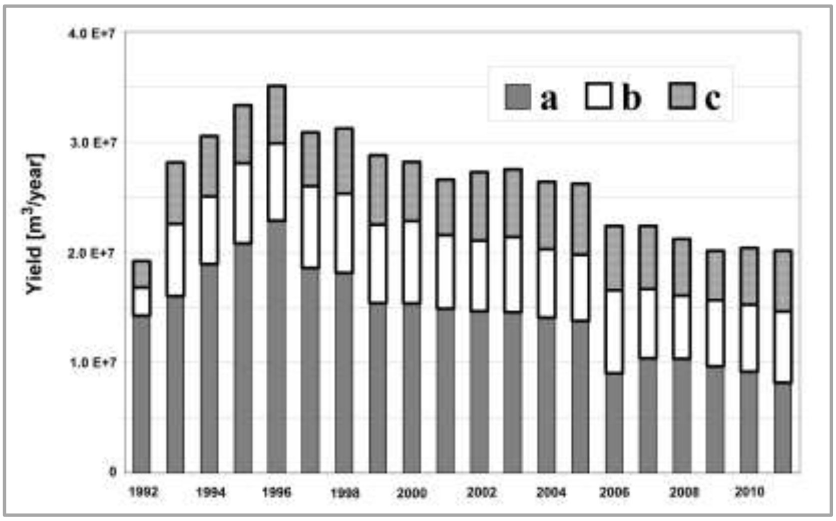

Fig. 5: The karst water exploitation of Bükk by temperature [LÉNÁRT 2012; a: cold; b: warm tepid; c: warm and hot].

The water is mostly used for medicinal and bath purposes in the region, but the communal use is also significant. At certain places it is also sold as drinking water. The greatest possibility for development is for energy production. Most of the bath establishments cool the water using heat exchangers, but the use of wasted heat for energy production is still very limited. Drillings have been done in Mályi and Kistokaj in order to support the central heating system of Miskolc city but the system is not yet completed.

Hydraulic relations of the thermal and cold water aquifers

The closest relationship is considered to be the one between the water levels of Nv-17 and the Termál spring (Fig. 6). (On Fig. 2 the Thermal spring is marked as "Miskolc warm karst water".) One of the reasons for this is that the distance of the cold and warm spring at Miskolctapolca is about 80 m, and between them limestone and mountain rim gravel layer is situated. Also, the flood overflow of the warm spring (Termál spring) is located only less than one meter above the flood overflow of the cold spring. It means a tight spatial relationship. (About 100 years ago there were many dozens of cold, tepid and warm springs but in order to concentrate the water yields, for water exploitation reasons, the number of springs basically decreased to two.) Also, above all the water yielding objects under examination, the Termál spring is situated closest to the karstic feeding area (LÉNÁRT, 2005a, 2005b; KOVÁCS et al, 2006; MÁDAI et al, 2010). The sole most important use of the water of the Termál Spring is to supply water to the Cave Spa (Barlangfürdő).

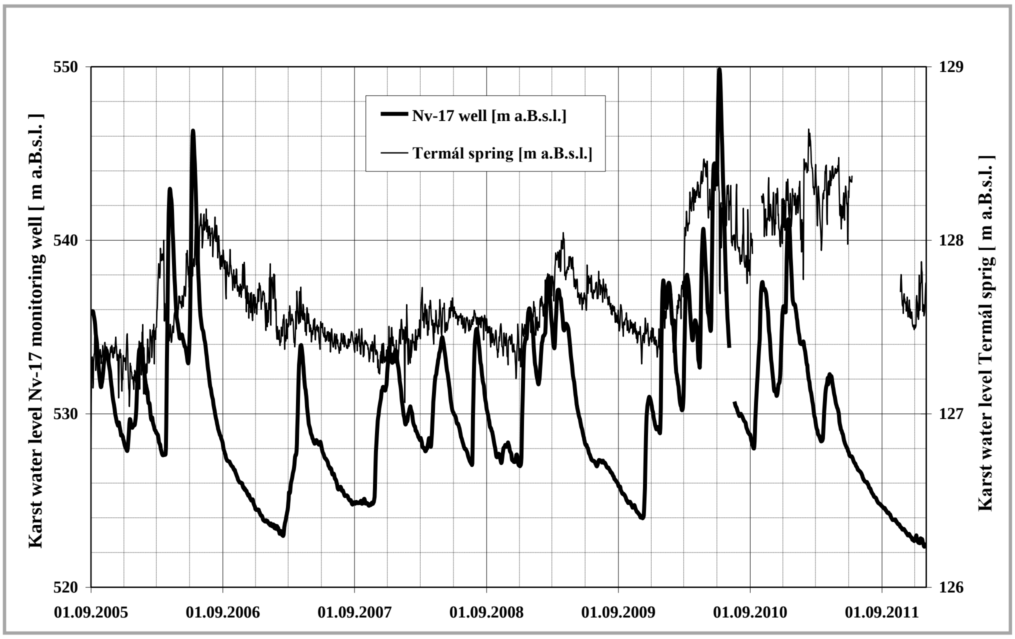

Fig. 6: Comparison of the water levels recorded at the Nv-17 karst water monitoring well and the Termál spring of Miskolctapolca (LÉNÁRT 2012).

We consider the relationship very tight (Fig. 7) between the pressure levels of Nv-17 and the Vizmű and Selyemréti I thermal well of the water company. (These two thermal wells are under “Miskolc thermal water” on Fig. 2, and their distance is about 1 km.) Both thermal wells basically react immediately the same way and for longer durations when the cold karst water pressure level is on its peak. (Naturally due to the fluctuation of water exploitation it is not possible to follow the changes of smaller magnitudes.) They are situated at a greater distance from the feeding area, and they yield the water moving in the limestone layers that are the subsurface extensions of the east to west patches of the open karst aquifer.

The relationship is much looser in case of the Nv-17 and the wells of Egerszalók and Demjén (Fig. 8). For one thing, these are located much further away from the feeding area, and also situated perpendicular to the carbonate patches stretching east to west. (These are shown on Fig. 2 as “Egerszalók, Demjén thermal karst water”. The distance between the two wells of Demjén is 1 km. The distance between the wells of Egerszalók – De-42 and De-42a – is about 15 meters.) Well De-K-11 is closest to the Mátra. Mátra is a mountain range whose surface is non-karstic rock. The abovementioned Demjén K-12 well is the deepest in the area, with its depth of 1514 meters. During its test run it effected the Demjén K-10 and Demjén K-11 wells the most.

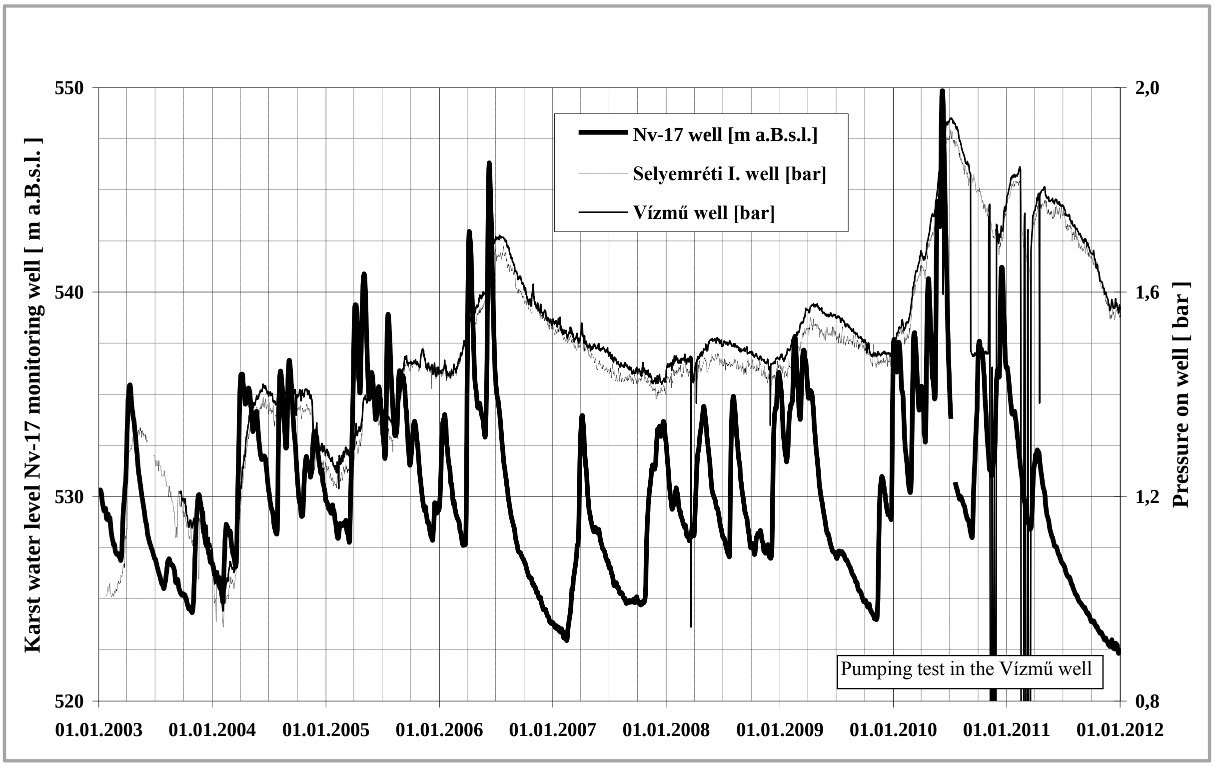

Fig. 7: The relationship of the Nv-17 karst water monitoring well and 2 thermal karst water wells of Miskolc (LÉNÁRT, 2012).

Summary

The following statements can be drawn:

- The relationship between the cold karst water level and warm karst water level (pressure level) is clear but its tightness differs, because
  - more significant exploitation quickly creates drops in the increases,
  - the tightness of the relationship grows in case of wells situated in the east-west carbonate patches, but it weakens in case of wells situated perpendicular to such patches.
- The temperature of thermal karst water increases when moving further away from the mountain rims,
  - evenly with the depths in the Miskolc area,
  - more independently of the depths due to the horst structure in the Egerszalók and Demjén area.
- The thermal karst water moves in the karstic zones that can be connected to the onetime open (unconfined) karst surfaces (Miskolc area), or along tectonic zones (Egerszalók, Demjén area).
- The cold karst water of the Bükk with its 42 bar pressure forces the 30 °C isotherm into deep layers – 900-1400 m – , therefore it is not reasonable to attempt examinations in order to exploit thermal karst water in the Bükk and its rims, because
  - the zone with the necessary temperature is at great depths,
  - in such depths the porosity of conductive layers is very low
  - in case there was adequate porosity, (for instance a known cave passage), the cold karst water would flow into the area surrounding the well and it would cool off the thermal karst level.

- In case of exploiting more thermal karst water than the optimum, the cold karst water would flow into the area, and the temperature of the thermal karst water would decrease. (Optimum is considered the long term water exploitation that corresponds to the long term water replacement applied to the mountain or the area.)

Acknowledgements

The described work was carried out as part of the TÁMOP-4.2.1.B-10/2/KONV-2010-0001 project in the framework of the New Hungarian Development Plan. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

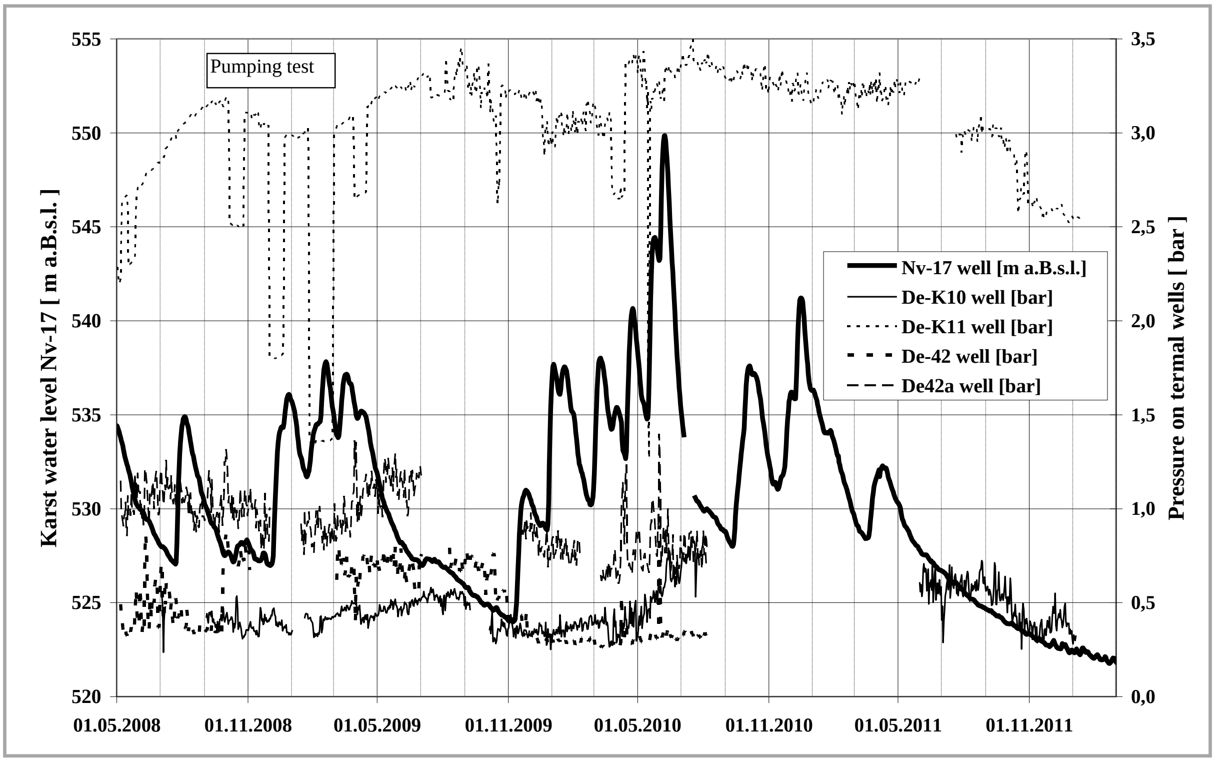

Fig. 8: The relationship of the Nv-17 karst water monitoring well and 4 thermal karst water wells of Egerszalók-Demjén (LÉNÁRT, 2012).

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