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**Water Rock Interaction [WRI 14]**

# Hydrogeochemistry in transboundary thermal water management

Teodora Szocs[a]*, György Tóth[a], Nina Rman[b], Gerhard Schubert[c], Radovan Černák[d]

[a]*Geological and Geophysical Institute of Hungary, Stefánia út 14, Budapest 1143, Hungary*
[b]*Geological Survey of Slovenia, Dimičeva ulica 14, Ljubljana 1000, Slovenia*
[c]*Geological Survey of Austria, Neulinggasse 38, Wien 1030, Austria*
[d]*Geological Survey of Slovakia, Mlynská dolina 1, 817 04 Bratislava 11, Slovakia*

**Abstract**

This study gives a brief and general overview of the hydrogeology and hydrogeochemistry of the transboundary geothermal resources in the western part of the Pannonian Basin, carried out within the framework of a joint Hungarian, Slovenian, Slovakian and Austrian project (TRANSENERGY). Chemical and isotope data were used to describe the different flow systems, to calculate the groundwater ages along both the flow paths and the main discharge zones, and to help calibrate the hydrogeological flow and transport models used as input for a sustainable transboundary thermal water management scheme.


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*Keywords*: Pannonian Basin; thermal water; geothermal; transboundary; water management; isotope.

## 1. Introduction

The increasing exploitation of geothermal resources in regions close to National boundaries in Central Europe requires extensive cooperation and joint, transboundary management in order to avoid the risk of conflicts due to unequal exploitation of resources, or adverse effects on the resources of neighbouring countries.

Previous bilateral projects focused on establishing and evaluating the transboundary nature of aquifers in the western part of the Pannonian Basin (Götzl et al. [1], 2008, Nádor and Lapanje, 2010 [2], Szocs et

* Corresponding author. Tel.: +36-309-600-710.
*E-mail address:* szocs.teodora@mfgi.hu.


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al., 2012 [3]). The TRANSENERGY project, presented here, carried out by the Geological Surveys of Hungary, Slovenia, Slovakia and Austria, investigates the transboundary aquifers of four countries, simultaneously applying a common geological, hydrogeological, hydrogeochemical and geothermal methodology, contributing to the identification of both the possible transboundary intergranular and karstic aquifers. The main hydrogeochemical and isotope characteristics of these groundwaters presented in this paper help to delineate and characterize the transboundary groundwater bodies, provide independent parameters for calibrating the hydrogeological numerical model, and support setting up a sustainable transboundary thermal water management scheme.

## 2. Hydrogeology-hydrogeochemistry of the transboundary regions

The Pannonian Basin developed as the result of Early-Middle Miocene back-arc style extension related to subduction along the Carpathians and lies on a positive geothermal anomaly, with an average geothermal gradient of about 5°C/100m (Dövényi et al., 1983 [4]). Due to the high geothermal gradient and increased heat flow, large thermal groundwater resources are available in the Basin in both the intergranular and karstic aquifers.

The western part of the Pannonian Basin investigated here is surrounded by the eastern margin of the Alps, the western margin of Carpathians, the Transdanubian Mid-mountains and the Slovenske Gorice (Figure1). Between these mountains, there are some lowland regions separated by hilly territories and smaller inselbergs. The entire survey area forms part of the Danube River Basin. All the rivers are connected to two main river networks, the Danube and the Drava. This investigation covers the whole project area (Figure 1) focusing on 5 pilot areas, namely the Bad Radkersbug-Hodoš, Lutzmansburg-Zsira, Vienna Basin, Danube Basin and Komarom-Šturovo.

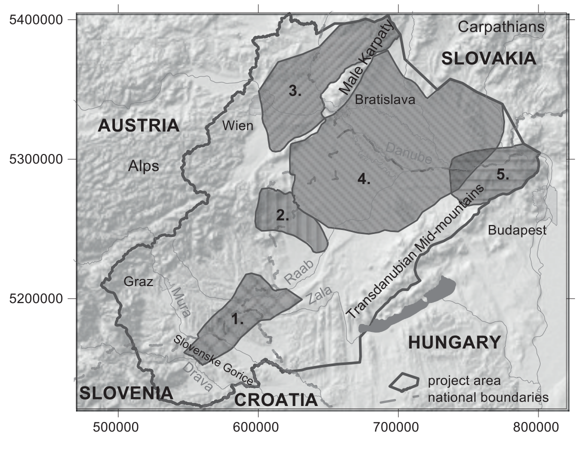


Fig. 1. Location of the project area with the five pilot areas in the western part of the Pannonian Basin, Central Europe. 1. Bad Radkersbug-Hodoš; 2. Lutzmansburg-Zsira; 3. Vienna Basin; 4. Danube Basin; 5. Komarom-Šturovo.

The mountain regions at the edges of the area (Alps, Male Karpaty, Carpathians, Transdanubian Mid-mountains) represent the groundwater divide, the natural boundaries of the groundwater flow system and serve as the main recharge areas. The mountains are formed mainly from crystalline or carboniferous basement rocks. Part of the infiltrated precipitation returns to the surface along short flow paths forming local flow systems, while other part infiltrates towards deeper zones and enters the regional flow systems. Where fault zones have high vertical permeability and are of a large vertical extent there is a possibility that they form so called geothermal heat chimneys along which groundwater can move upward.

A hydrogeochemical evaluation was carried out based on existing archival data, complemented by data from additional samples collected from areas where the lack of information was considered critical.

In the Quaternary and Pliocene aquifers a Ca-Mg-HCO3 water type prevails. In the upper part of the Upper Pannonian (Figure 2), calcium to sodium cation exchange is typical of the longer residence time of groundwater, resulting in an evolution towards a Na-HCO3 water type at deeper levels. The deeper Upper Pannonian aquifers store alkaline Na-HCO3 thermal water, which locally can be enriched in chloride or sulphate anions, mostly due to mixing. Chloride enrichment comes from the Na-Cl type brines, which locally may be overpressured or like sulphate can be due to in-well mixing with other water from Miocene formations. Water stored in the marly, clayey Lower Pannonian Formations is a rather isolated brine of Na-Cl type. In contrast, the sand bodies of the turbidites in the Lower Pannonian Formations store water which is less isolated from its surroundings and is often mixed with other groundwater from Miocene aquifers, therefore anions show a wide range of values. The Middle Miocene Formations store different waters depending on their burial depth. Where layers outcrop, the infiltrating Ca-Mg-HCO3 water is observed, while towards deeper parts the longer residence time, cation exchange, mixing, dissolved gas and other geochemical processes modify its composition, so Na-HCO3 to Na-Cl types prevail. Some of the thermal water aquifers both in the intergranular Neogene sediments and in the basement have no active recharge and store brine-type Na-Cl waters. Most of the Mesozoic carbonate aquifers are of Ca-Mg-$HCO_3$ type with active recharge and low TDS content, but with longer residence times waters of Na-$HCO_3$, Na-Mg-$HCO_3$-Cl and Na-Cl-$HCO_3$ types can also be detected. The Palaeozoic metamorphic rocks usually do not represent important geothermal aquifers, and their water can be highly mineralized.

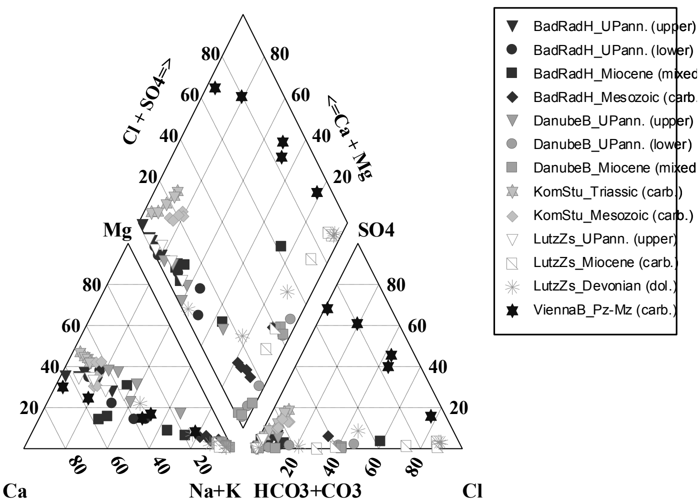


Fig. 2. Anion and cation distribution of groundwaters from different formations in the four countries.

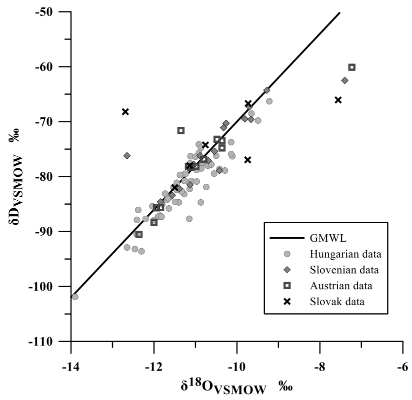


Fig. 3. $\delta^{18}O$ versus δD distribution of groundwaters from different formations in the four countries.

Groundwater ages were calculated based on stable ($\delta^{18}O$, δD, $\delta^{13}C$) and radioactive isotope ($^{14}C$) analyses. Where tritium data were available, those were also used as markers of fresh (last 60 years) infiltrations. Stable isotopes of ($\delta^{18}O$, δD were used to differentiate between the cold (Pleistocene) and warm (Holocene or older than Pleistocene) infiltrations. All available data are shown in figure 3. Based on the available data we can assume that most of the data represent infiltration of precipitation origin with data point (Figure 3) plotted close to the Global Meteoric Water Line (GMWL). While most of the samples that plot in the evaporation zone represent groundwater that went through evaporation, some of the archive data may represent samples that incorrectly plot in the evaporation zone due to too long and/or improper sample storage. Very depleted waters (not all shown in the ($\delta^{18}O$, δD plot) in the upper 200-300 meters of the Neogene sediment succession in the Danube Basin suggest a very slow groundwater flow rate in this succession. The very low $^{14}C$ values also support this assumption.

The age calculations were performed with simple $^{14}C$ decay and with carbon-13 correction as well. The age calculations with carbon-13 correction cannot be applied when the $\delta^{13}C$ values are shifted towards the positive direction due to water-rock (gas) interactions.

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