Transboundary geothermal resources of the Mura-Zala basin

Joint thermal aquifer management of Slovenia and Hungary

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The growing energy demand of the world, restricted reserves of fossil fuels, efforts to reduce the emissions of greenhouse gases, thus contributing to the mitigation of global climate change made clear that within 20-30 years a significantly growing proportion of energy has to come from renewables. In March 2007, EU leaders endorsed an integrated approach to climate and energy policy that aims to reduce energy consumption and greenhouse gas emission by 20% and increase the proportion of renewables by 20% by 2020. This ambitious goal is manifested in the 2009/28/EC Directive on the promotion of the use of energy from renewable sources which, among other types of renewables, defines geothermal energy as "the energy stored in the form of heat beneath the surface of the solid Earth".

La demande mondiale croissante en énergie, les réserves limitées en combustibles fossiles, les efforts entrepris pour réduire les émissions de gaz à effet de serre, contribuant ainsi à la réduction du changement climatique global, indiquent que dans les 20 à 30 prochaines années, une partie significative et croissante de l'énergie devra provenir de sources renouvelables. En Mars 2007, les Chefs d'Etats européens ont approuvé une approche intégrée associant climat et politique énergétique dont le but est, d'une part, la réduction de 20% de la consommation d'énergie et de l'émission de gaz à effet de serre et, d'autre part, une augmentation de 20% des énergies renouvelables, à l'horizon 2020. Cet objectif ambitieux est clairement exprimé dans la Directive 2009/28/EC concernant la promotion de l'utilisation de l'énergie provenant de sources renouvelables qui, parmi d'autres sources renouvelables, définit l'énergie géothermique comme l'énergie stockée sous forme de chaleur, sous la surface de la Terre.

La creciente demanda de energía del mundo, las restricciones de las reservas de combustibles fósiles, los esfuerzos para reducir las emisiones de gases de efecto invernadero contribuyendo a la mitigación del cambio climático global, indica que dentro de 20 o 30 años una proporción creciente de la energía deberá proceder de fuentes renovables. En marzo de 2007, los líderes de la UE aprobaron un enfoque integrado a la política climática y energética que tenía como objetivo reducir el consumo de energía y las emisiones de efecto invernadero en un 20% y aumentar la proporción de energías renovables en un 20% para 2020. Estos objetivos ambiciosos se pusieron de manifiesto en la Directiva 2009/28/EC sobre la promoción del uso de energía procedente de recursos renovables que, entre otros tipos de renovables, define la energía geotérmica como "la energía almacenada en forma de calor bajo la superficie de la Tierra"

Geothermal energy is restricted to areas with appropriate geological conditions: heat source (high geothermal gradient), hot permeable rock volume at depth (fractured or porous reservoir) and carrying medium (deep circulating groundwater flows that extract and transport heat). The geothermal flow system is governed by convection. Heated fluids expand and have lower density, therefore they rise and are replaced by higher density cold water recharging the system along the margins. The recharge areas typically lie in mountain regions,

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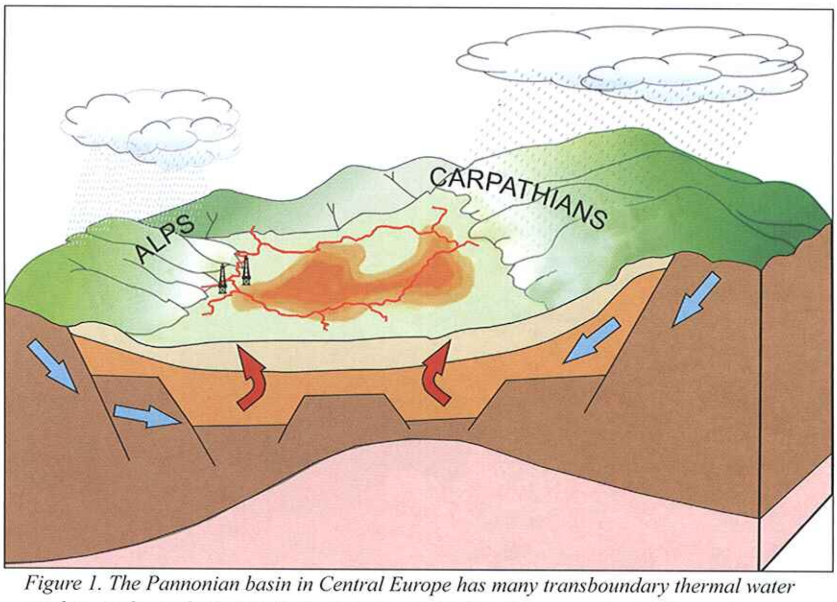

Figure 1. The Pannonian basin in Central Europe has many transboundary thermal water aquifers, as the geological-hydrogeologial units hosting deep groundwater flow systems are cut by state borders

then infiltrating water follows geological structures towards the basin and discharges as thermal water from deeply buried reservoirs. Although the different sections of these large geothermal systems are connected in geological-hydrogeological terms, they are often cut cross by state-borders, and various parts of these integrated systems are shared by neighbouring countries, such as the Pannonian basin in Central Europe (Fig. 1). When neighbouring counties exploit the same geothermal aquifer, water extraction at a national level without cross-border harmonized management strategies may cause negative impacts (depletion or overexploitation) leading to economic and political tensions between countries. Therefore only a transboundary approach and the establishment of a multinational management system can handle the assessment of geothermal resources and their sustainable use, rational water use and integrated river basin management plans as set up in the Water Framework Directive (2000/60/EC). This can only be based on joint research and evaluation of available information on the entire geothermal system, regardless of state borders. The T-JAM project (Thermal Joint Aquifer Management: Screening of geothermal utilization, evaluation of thermal groundwater bodies and preparation of joint aquifer management plan in the Mura-Zala basin) running in the frame of the Slovenia-Hungary Operational Programme 2007-2013 aims to provide such a complex assessment with harmonized data and tools for decision makers in the transboundary region of Pomurje, Podravje (Slovenia) and Vas and Zala (Hungary) at the southwestern part of the Pannonian basin (Figs 2, 3, 5).

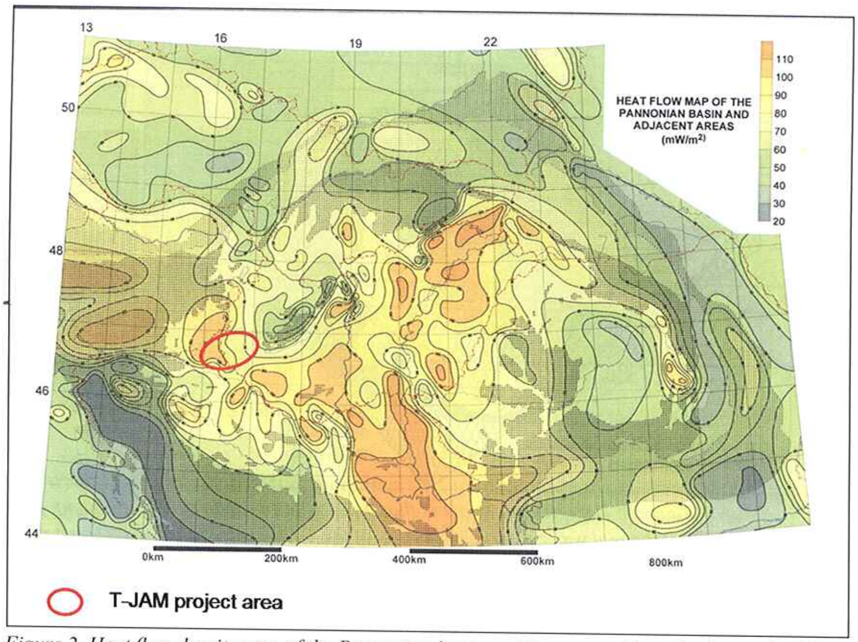

Figure 2. Heat flow density map of the Pannonian basin and its surroundings (Lenkey et al., *2002)*

Geology and geothermics of the Pannonian basin

The Pannonian basin in Central Europe lies on a characteristic positive geothermal anomaly, with heat flow ranging from 50 to 130 mW/m² with a mean value of 100 mW/m² (Fig. 2) and geothermal gradient of about 45 °C/km. This increased heat flux is related to the Middle Miocene back-arc style extension (rifting) of the Pannonian basin, coeval with the thrusting of the Carpathian belt, when the lithosphere thinned and the hot astenosphere got closer to the surface (Horváth and Royden, 1981). During the post-rift thermal subsidence of the basin in the Late Miocene, a single large depression developed, which was occupied by the brackish to freshwater Lake Pannon. The uplift and erosion of the surrounding Alpine-Carpathian mountain belt supplied a significant amount of sediments via large fluvio-deltaic systems into the Lake Pannon (Bérczi and Phillips, 1985; Juhász, 1994) resulting in the accumulation of a 5000-7000 m thick sedimentary succession. River deltas that entered the basin from the northwest and northeast prograded to the south, so that, by the Pliocene, the lake basin was filled (Magyar *et al.*, 1999) (Figs 3, 4).

This vast porous basin fill complex is the main reservoir of geothermal fluids (heated groundwater recharging from the surrounding Alpine and Carpathian mountain belts), as well as many hydrocarbon accumulations. Within this several thousand meters thick sedimentary succession, the best reservoirs are those large sand bodies which once deposited on the front of the delta-systems filling up the basin (Fig. 4). These 50-300 m thick sand bodies with an aerial extent of 200-2000 km² have good connectivity due to the continuous delta progradfrom 50-70 °C (Dövényi and Horváth, 1988) and are considered as the main thermal-water bearing aquifers. Basin floor turbiditic sands (Fig. 4) were deposited during distinctive slumping events on the delta slopes, and are, therefore, thinner individual bodies with less connectivity; however they are also considered as good thermal water aquifers at some locations. In addition to these porous reservoirs, the karstified zones of the Palaeozoic-Mesozoic carbonates in the basement, as well as fractured zones along main regional tectonic faults in the crystalline rocks, are also very good thermal water reservoirs. At

*Figure 3. Gradual filling up of Lake Pannon during the Neogene (*after *Magyar* et al., *1999)*