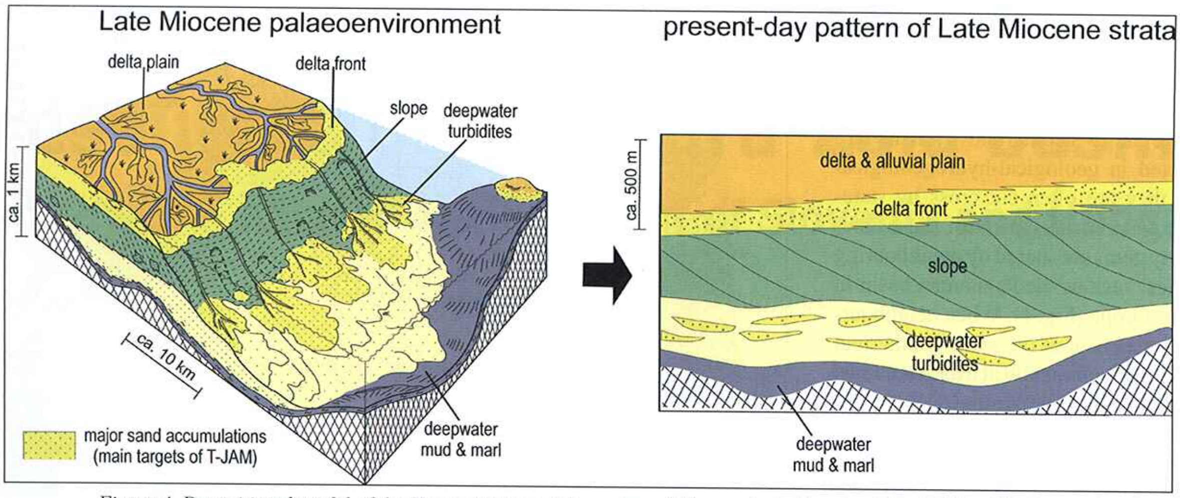

Figure 4. Depositional model of the Upper Miocene delta systems filling up Lake Pannon (after *Juhász, 1994*). *Best thermal water reservoirs (targets of the T-JAM project) are delta sands and to a less extent turbiditic sands*

this depth (on average 2,000 m or more) temperature can exceed 100 °C, reaching 120-140 °C in some areas (Dövényi and Horváth, 1988).

Transboundary geothermal resources of the Mura-Zala basin

The Mura-Zala basin is one of the deep sub-basins in the south-western part of the Pannonian basin. The pre-neogene basement is built up of Palaeozoic low-grade metamorphic crystalline rocks and non-metamorphic Permo-Mesozoic carbonates belonging to various alpine nappe systems and is bounded by two large tectonic lines (Fodor *et al.*, 2003) (Fig. 5). The basement is overlain by Lower and Middle Miocene clays, clayey marls, calcareous sandstones and limestones which crop out on the surface in Slovenia. The prograding delta systems of Lake Pannon reached the area about 8-9 Ma ago from the north (Fig. 3) (Uhrin *et al.*, 2009) and deposited a Late Miocene-Pliocene basin fill up to 2,500-3,000 m thickness (Fig. 5).

The heat-flow map (Fig. 2) shows that the eastern part of the Mura-Zala basin (Hungarian part) forms a transitional zone between the karstic block of the Transdanubian Central Range, where heat flow is as low as ~50 mW/m^2 as a result of the cooling effect of recharging cold karstic waters. Towards the west, a positive heat-flow anomaly with ~100 mW/m^2 characterizes the Slovenian part of the Mura-Zala basin. This is also reflected by the temperature distribution at various depths: it is about 60-70 °C at -1,000 m and 100-120 °C at a depth of 2,000 m in the north-easternmost part of Slovenia (Ravnik *et al.*,1995) with lower values in the Hungarian parts of the basin, 40-60 °C at -1000 m and 90-100 °C at -2,000 m (Dövényi and Horváth, 1988).

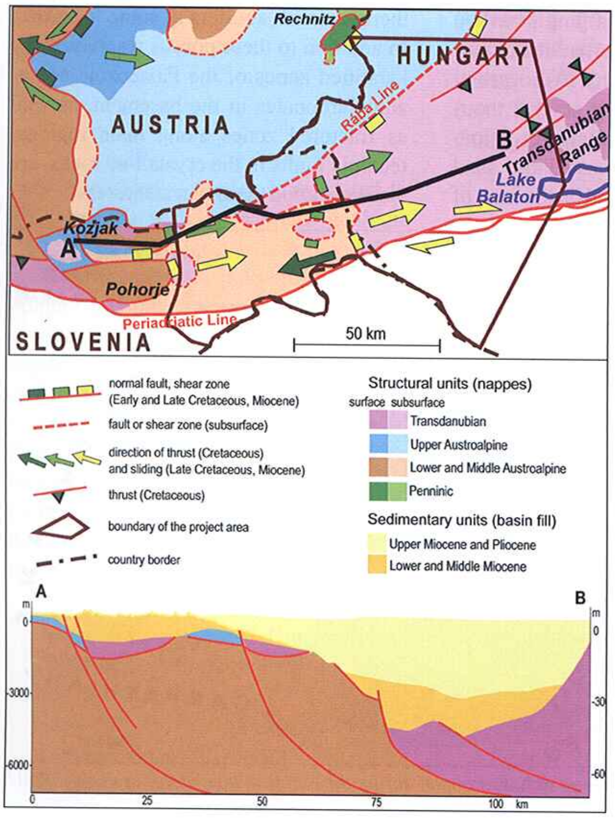

*Figure 5. Geological setting of the Mura-Zala basin and a simplified cross-section (*after *Fodor* et al.*, 2003)*

As a result of these favourable geothermal conditions, the Mura-Zala basin is rich in thermal waters which are stored both in the karstified basement rocks (mostly in the Hungarian part) and the porous Late Neogene sandstone reservoirs. The recent use of geothermal resources has been surveyed by the T-JAM project based on questionnaires following the methodology of the International Geothermal Association. At the moment, thermal water is used for balneological purposes, as well as for heating and combined use with no electricity generation (Table 1). However these preliminary results show that the proportion of utilization is quite different in the two countries. While in Hungary the overwhelming majority of thermal water is used for balneological purposes, in Slovenia more than a half of the installed thermal capacity is used for heating. The distribution of spas clearly shows that many of them utilize the same aquifer in the transboundary area. Water temperature (measured at well-head) ranges between 30-55 °C on average in Hungary with a few wells providing water as hot as 70°C while in Slovenia it is 40-70 °C with a maximum produced temperature of 82 °C (Rajver *et al.*, 2010). The temperature of the abstracted thermal water depends on several factors, such as reservoir temperature, discharge rates and cooling. These temperature values are solitary measurements and therefore represent single production situations. Although time series of different parameters (e.g. yield, temperature) would reflect dynamic changes of the reservoir (e.g. effects of production) and would be essential for a sustainable and harmonized use of geothermal resources in

Use	Installed capacity (MWt)		Annual energy use (TJ/yr)	
	NE-Slovenia	SW-Hungary	NE-Slovenia	SW-Hungary
Individual space heating	11.69	1.76	131.55	12.46
District heating	3.29		43.98	
Air conditioning (cooling)	0.13		2.04	
Greenhouse heating	7.06		25.59	
Bathing & swimming (incl. balneology)	16.38	65.17	176.52	591.03
Subtotal	**38.55**	**66.93**	**379.68**	**603.49**
Geothermal heat pumps at thermal spa centers (used to raise water temperature for further use)	**0.26**		**4.75**	
Total - direct use without ground-source GHPs	**38.81**	**66.93**	**384.43**	**603.49**
Geothermal (ground-source) heat pumps (estimated number)	10	no data	50	no data
TOTAL	**48.81**	**66.93**	**434.43**	**603.49**

Table 1. Summary of geothermal utilization in the Mura-Zala basin (preliminary results of questionnaire survey of the T-JAM project)

the neighbouring countries, they are unfortunately missing at the moment. The acquisition of such further parameters is one of the key goals of the T-JAM project and will be implemented in the summer of 2010 by sampling 24 wells in both countries with hydrodynamic testing in 5 key-wells.

The preliminary results of the utilization (Table 1) highlighted the problem of lack of information on heat pumps, especially in Hungary. In Slovenia, heat pumps are either used to raise water temperature for further utilization (swimming pools, sanitary water, etc.) at spa centers (usually of greater capacity), or as ground-source heat-pumps. However there is no information on the exact number of the latter and their types (open-loop, closed-loop, dry systems), so their installed capacity and energy use is just an estimation (Table 1) (Rajver *et al.*, 2010). Nevertheless in Hungary even such estimations are missing at the moment. Therefore the T-JAM project aims to promote heat-pump technology in both countries by installing a demonstration heat-pump with the monitoring equipment in Martjanci near Murska Sobota, organizing workshops and preparing information leaflets for the stakeholders in the region.

What T-JAM project can offer?

The final aim of the T-JAM project is to provide decision makers and stakeholders of the region with up-to-date information on future perspectives of sustainable use of geothermal resources in the Mura-Zala basin, to help to enhance cooperation between strategic thermal water users on both sides of the border. The project intends to delineate a joint thermal groundwater body in the border zone, which hasn't been done so far and which would serve as the basis for future joint management strategies. It will prepare guidelines for the rational utilization and joint monitoring of thermal aquifers in the transboundary area and will also prepare a critical evaluation of the existing legislation (Slovenian, Hungarian and EU) on geothermal energy. To achieve these goals, partners establish a joint multi-lingual database and elaborate geological-hydrogeological and geothermal models for the entire project area. Results of the project can be followed on the *www.t-jam.eu* website.

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