

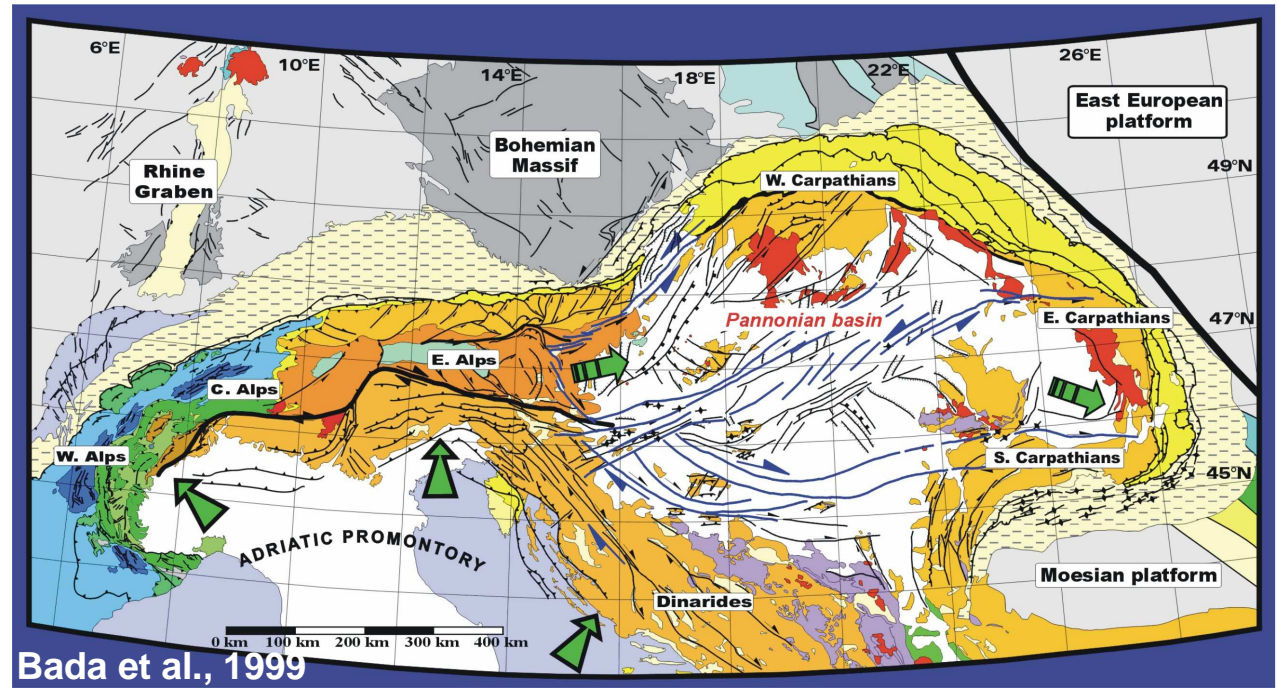
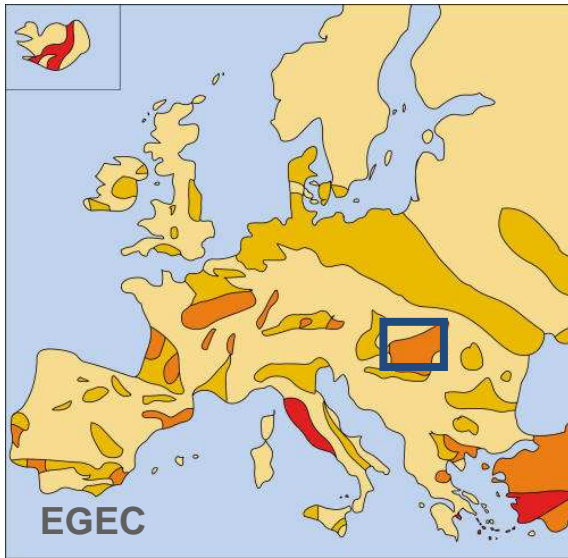


On-going transboundary geothermal exploration projects in the Pannonian Basin

Annamária Nádor

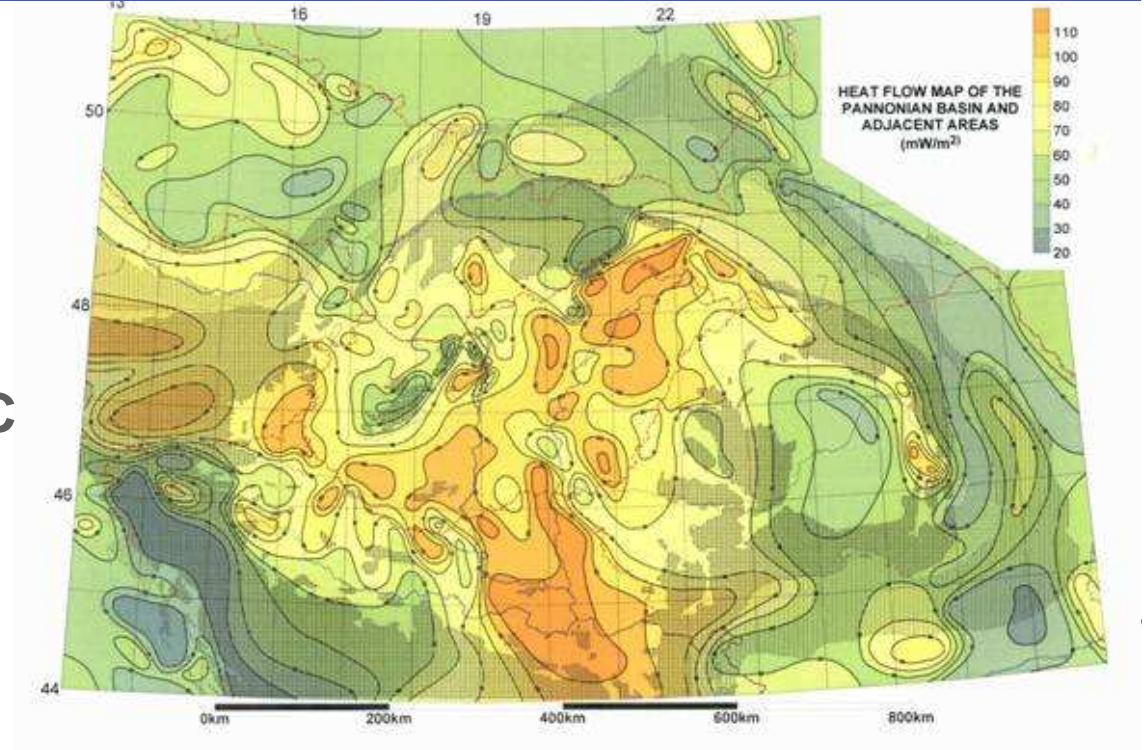
Geological Institute of Hungary

Pannonian basin

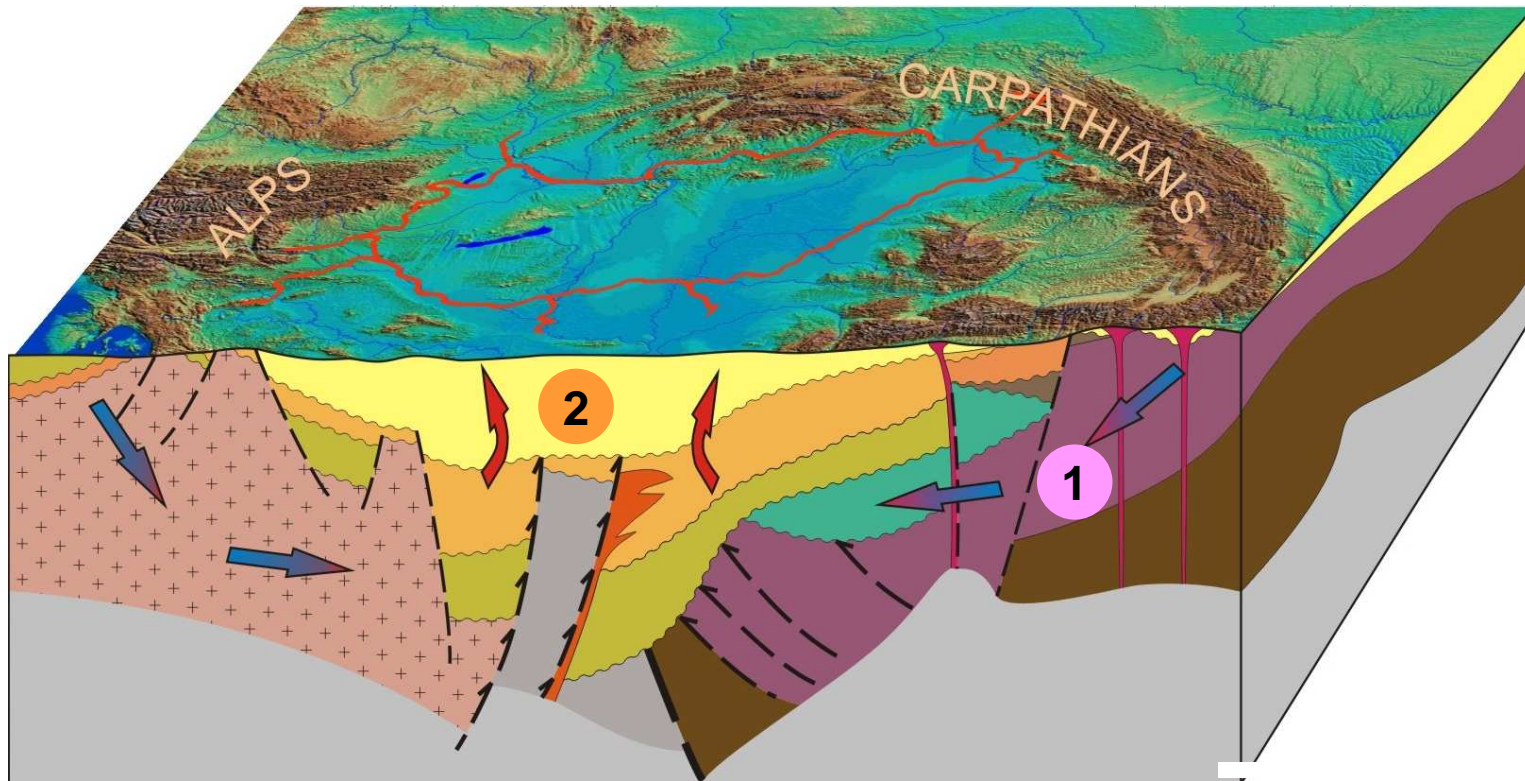


Average terrestrial heat flow: 100 mW/m^2

Geothermal gradient: $45 \text{ m/}^\circ\text{C}$

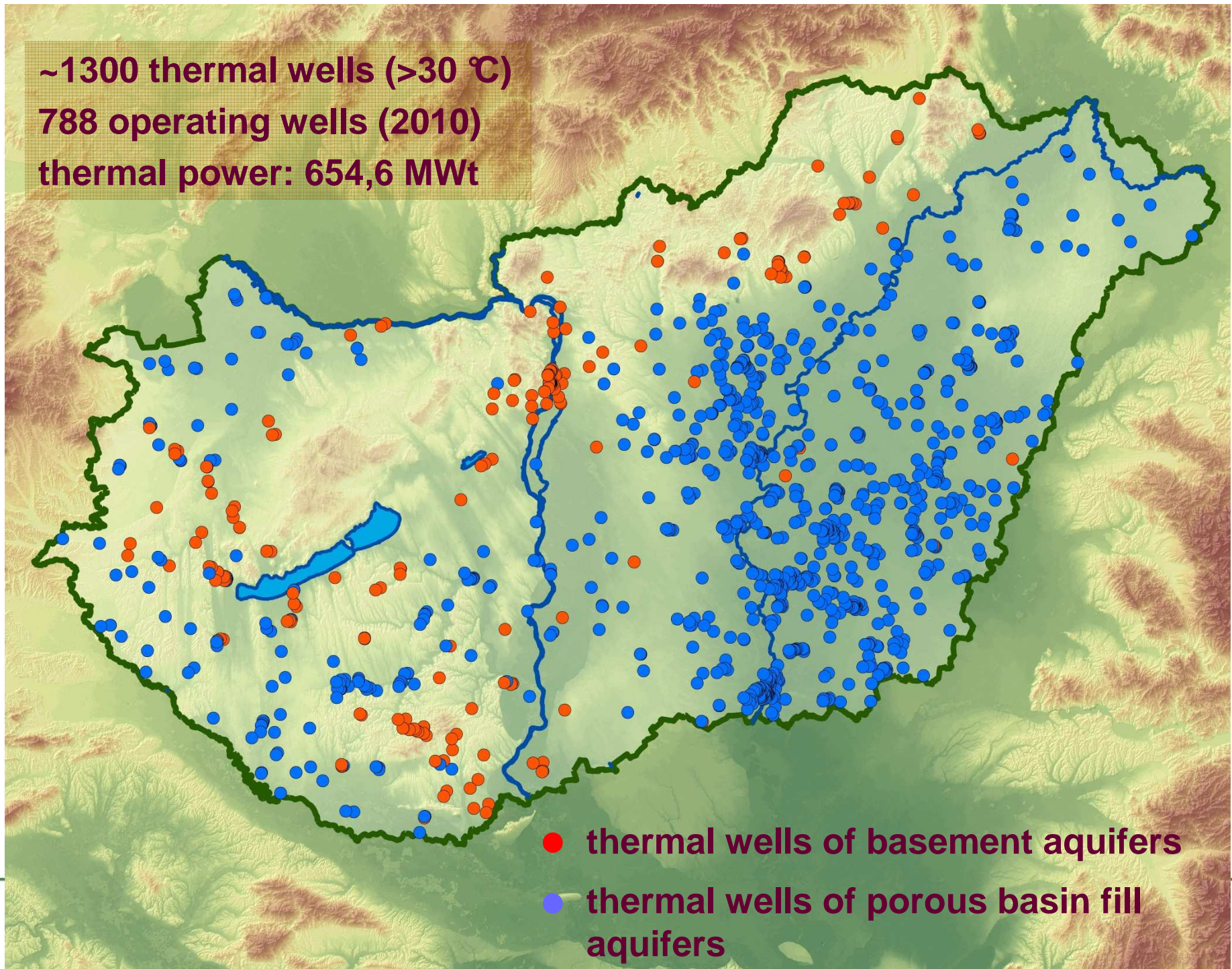


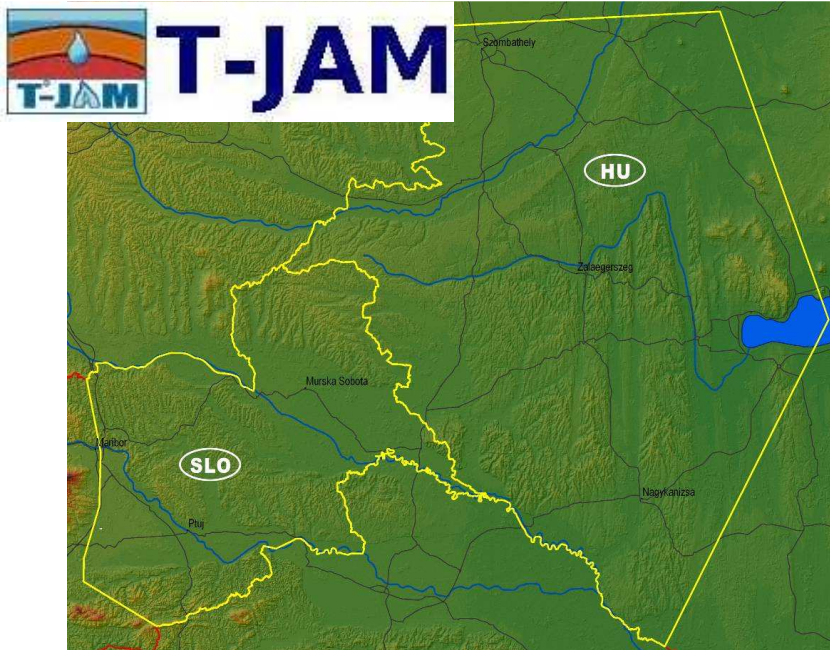
Lenkey et al., 1999



| | | |
|-----------------------------------|--|---|
| Main geothermal reservoirs | 1. fractured, karstified basement rocks (Palaeozoic-Mesozoic) | 2. porous multi-layered sandstones, shales (Upper Miocene-Pliocene basin fill) |
| thickness | 80-100 m (upper part) | 200-300 m |
| depth, temperature | >2500 m, >100-120 °C | 800-2000 m, ~60-70 °C |
| porosity | < 5% | 20-30% |
| permeability | 500 -1500 mD | 500 -1500 mD |

**~1300 thermal wells (>30 °C)
788 operating wells (2010)
thermal power: 654,6 MWt**



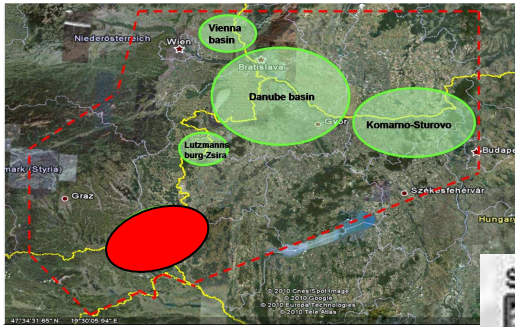


Joint evaluation of **transboundary hydrogeothermal systems**, recommendations for sustainable utilization and management

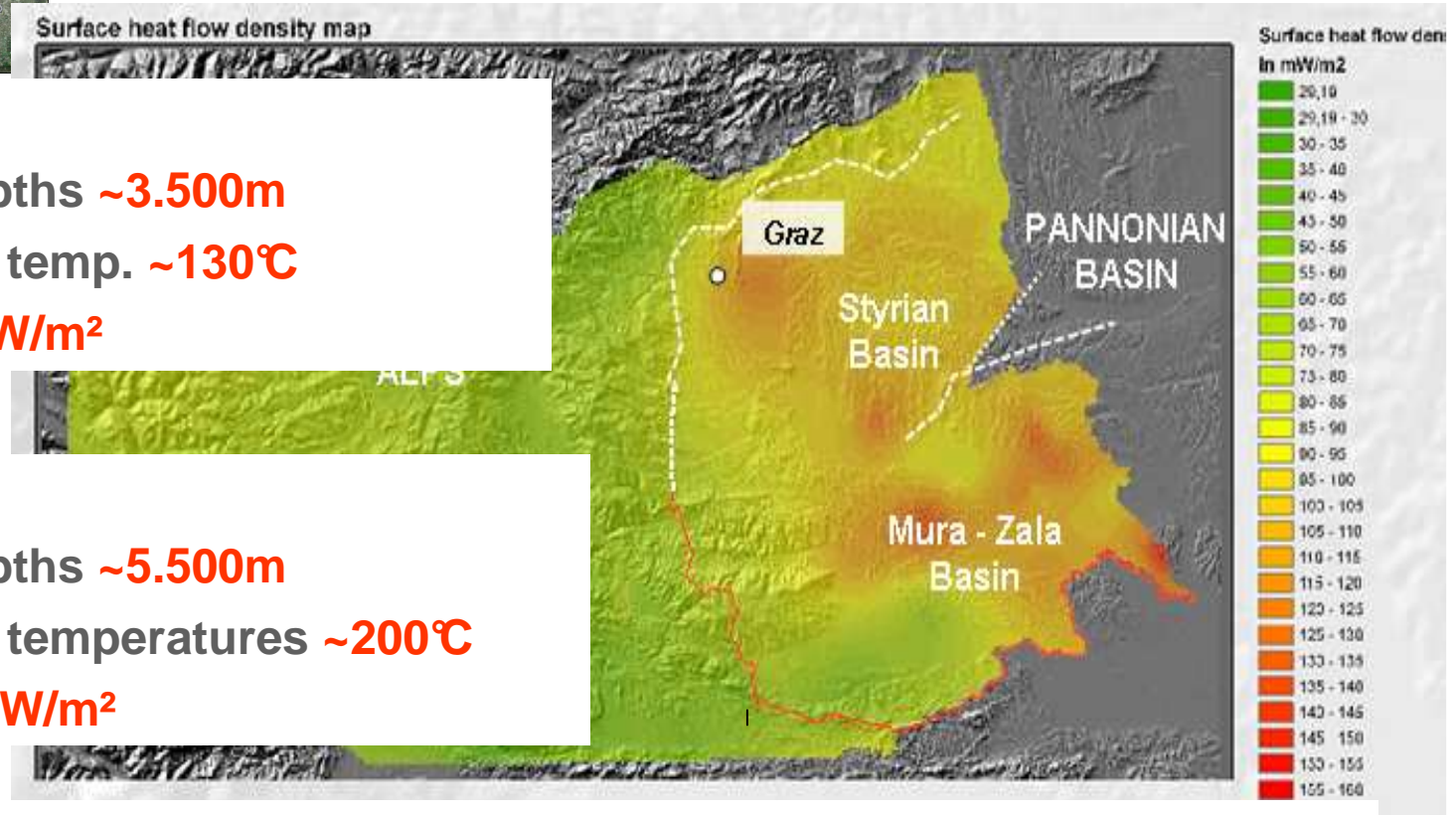
- focus on Upper Pannonian hydrogeothermal reservoirs
- shallow geothermal (heat pumps) also included
- single-well concept: to determine amount of extractable thermal water
- delineate joint SI-HU porous thermal groundwater body

- focus on porous basin AND basement reservoirs
- no shallow geothermal
- single AND double-well concept: focus on energetic utilization
- steady state and scenario models for cross-border pilot areas
- web-based decision support tool

SLO-A-HU cross border region



Surface heat flow density map



Styrian Basin

Maximum basin depths **~3.500m**

Maximum reservoir temp. **~130°C**

Heat flow **70-130 mW/m²**

Mura-Zala basin

Maximum basin depths **~5.500m**

Maximum reservoir temperatures **~200°C**

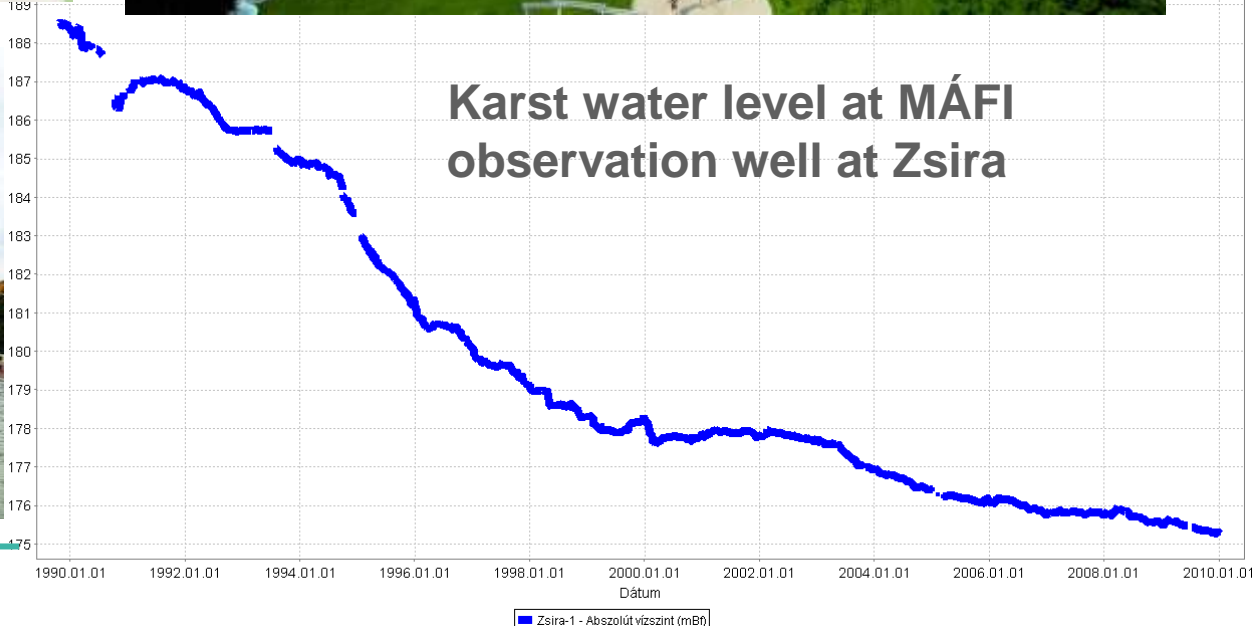
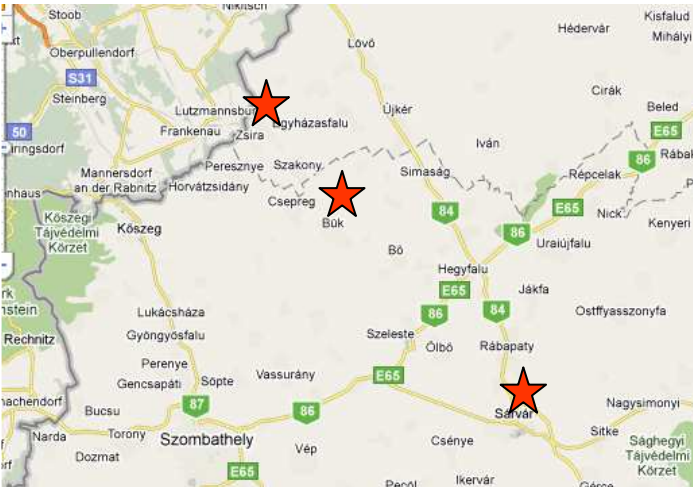
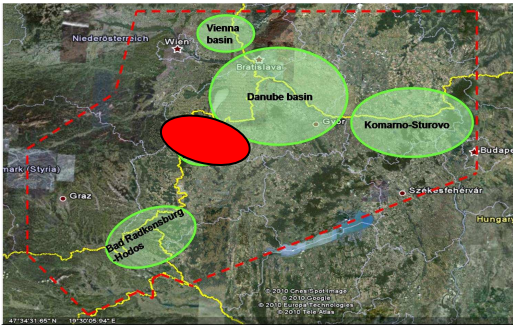
Heat flow **60 -150 mW/m²**

Questions addressed:

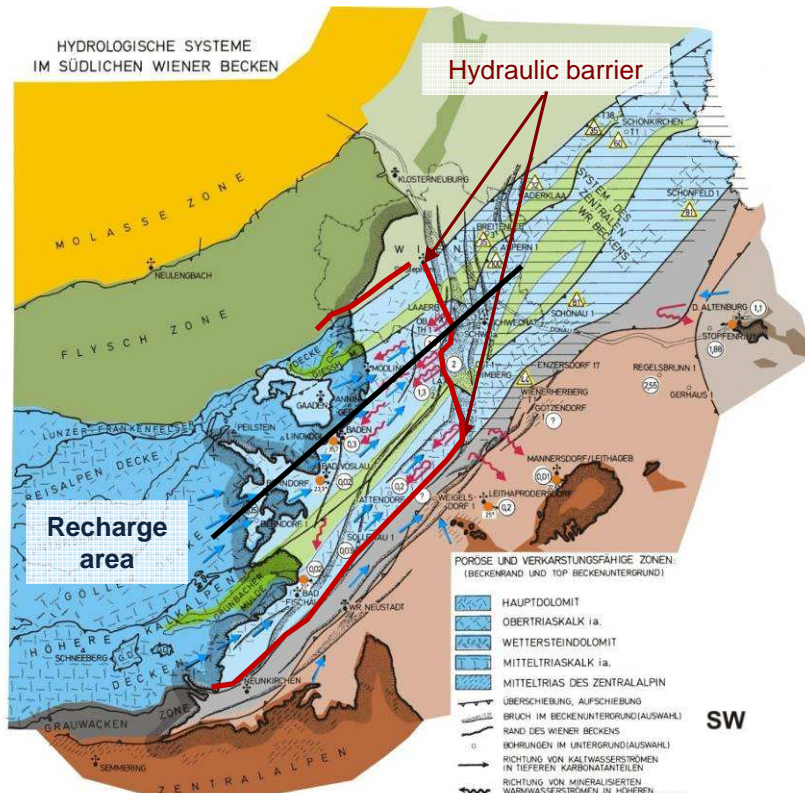
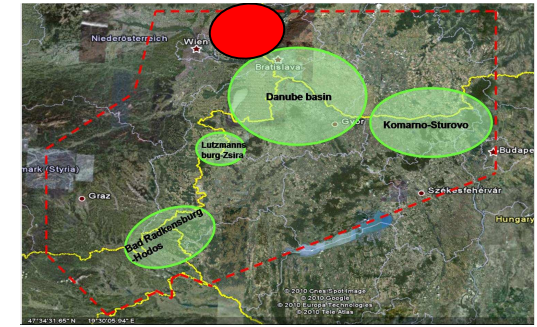
- preneogene carbonate reservoir of the Radgona-Hodos area – role of hydraulic barriers on possible recharge
- modelling of a narrow fissured aquifer (Rába fault zone)
- cross-border utilization problems (Bad Radkensburg and vicinity)

A-HU cross-border region: Lutzmannsburg Zsira

Maximum basin depths **~2.000m**
 Maximum reservoir temp. **~70°C**
 Heat flow **70-110 mW/m²**



A-SK cross-border region: Vienna basin



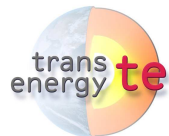
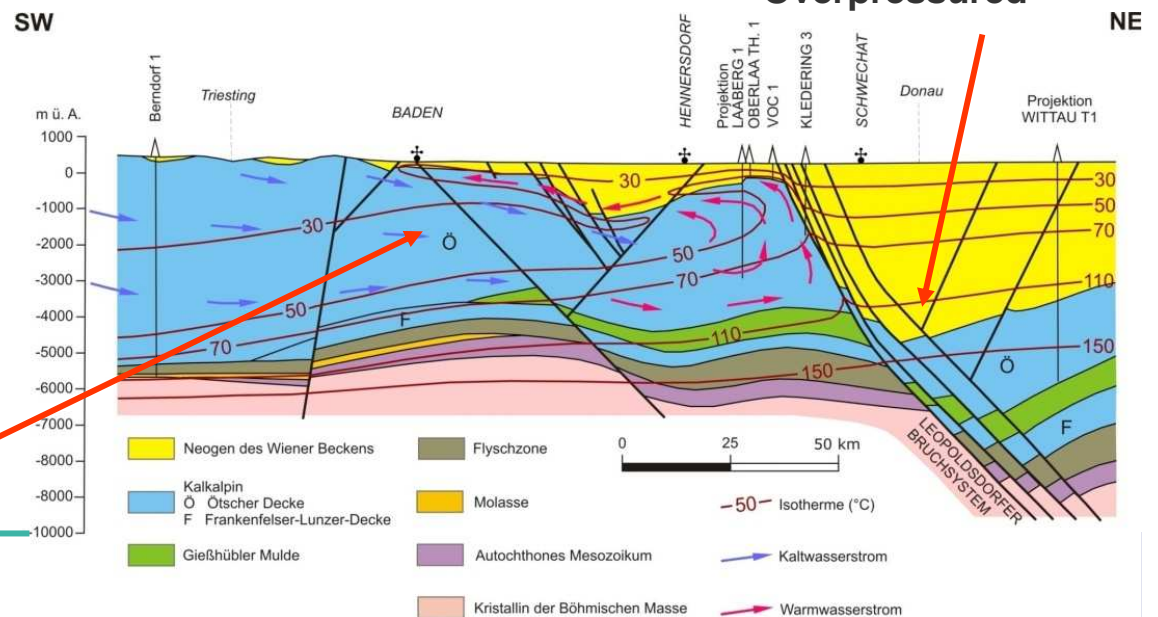
Questions addressed:

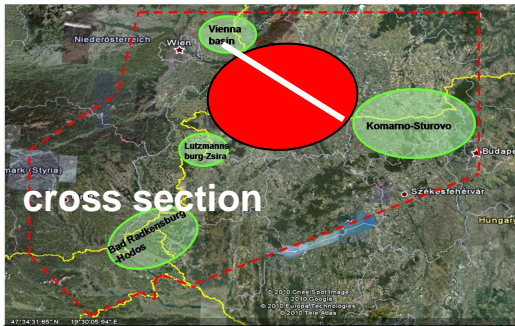
- conflicts with hydrocarbon exploration
- promote hydrogeothermal utilization in the central depression

Maximum basin depths ~7.000m
 Maximum reservoir temp. ~200°C
 Heat flow 40-90 mW/m²

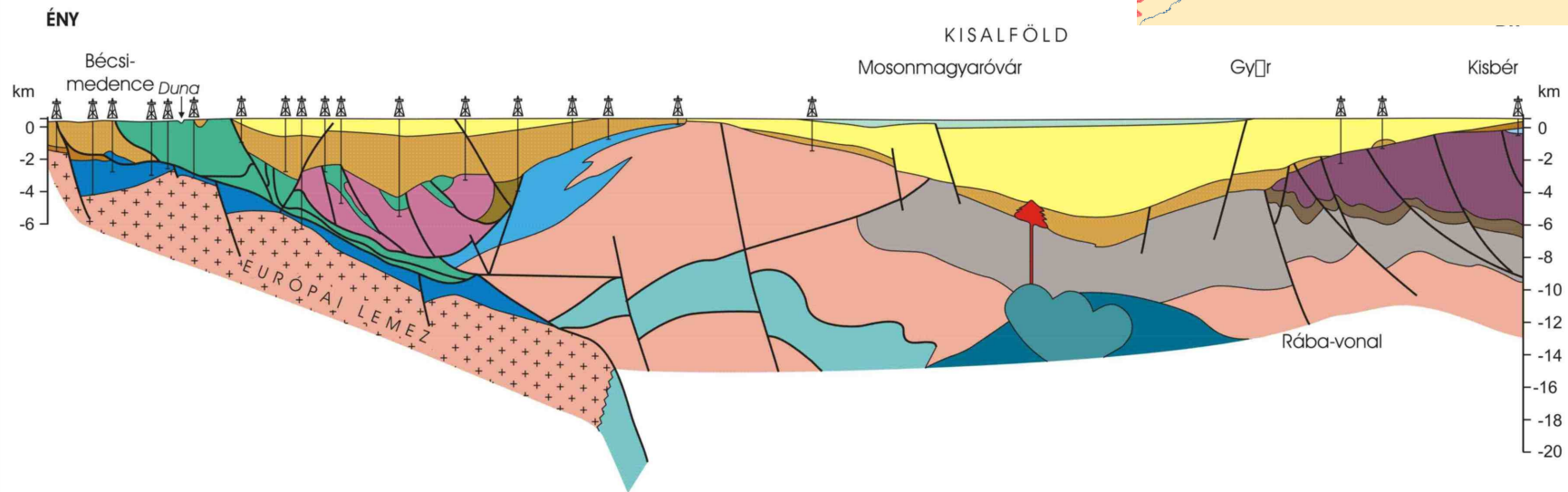
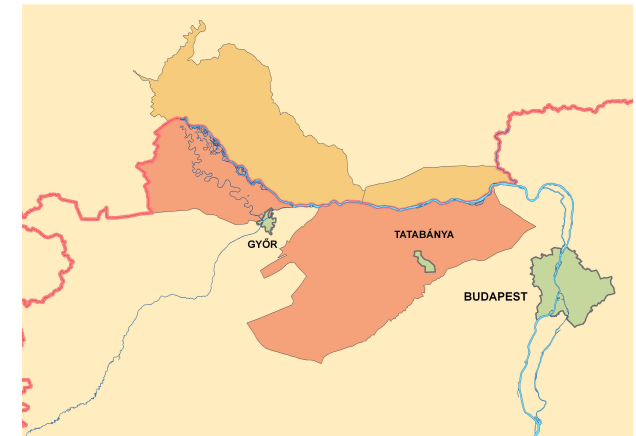
High mineralization
 Connate
 Overpressured

Low mineralization
 Active recharge
 Temperature anomalies





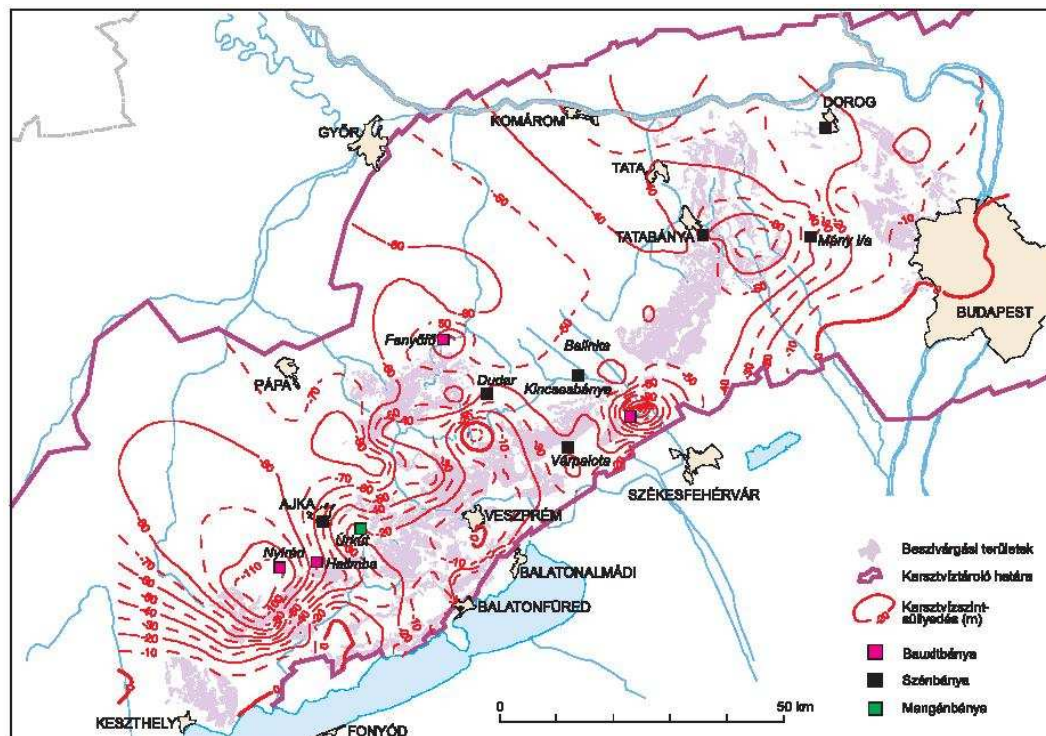
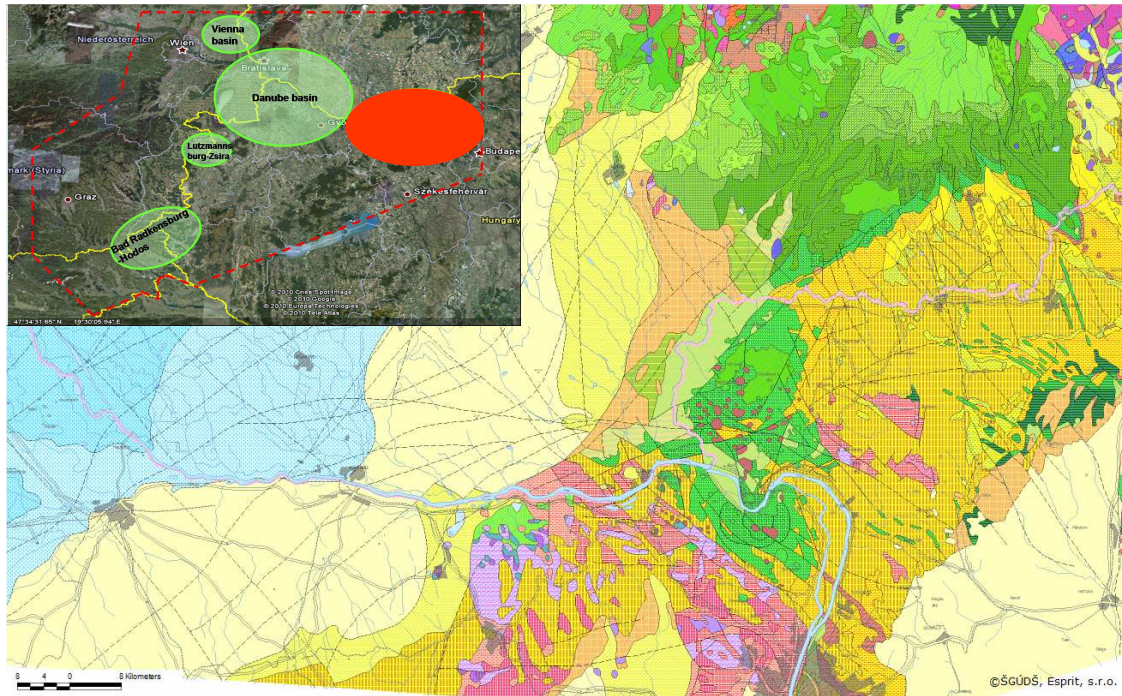
A-HU-SK cross-border region: Danube basin



- | | | |
|---------------------------------|---|--|
| Kvarter korú folyóvízi üledék | Jura korú homokkő és mészkő | Kristályos aljzat |
| Pannóniai korú tavi üledék | Mezozoós kőzetekből álló mészkő takarók | Cseh masszívum kristályos aljzata |
| Miocén korú tengeri kőzetek | Metamorfizált mezozoós kőzetek | Óceáni kéreg bazaltja |
| Miocén korú vulkáni kőzetek | Triász korú mészkő, dolomit, márga | Nagy mágneses anomáliájú aljzat (benyomult magmás kőzetek) |
| Paleogén korú tengeri kőzetek | Perm korú folyóvízi homokkő | Nagy sűrűségű aljzat (benyomult magmás kőzetek) |
| Kréta-paleogén, tengeri kőzetek | Felső-paleozoós kőzetek | Szerkezeti vonal |
| Jura-kréta tengeri mészkő | Alsó-paleozoós kőzetek | A kontinentális és az óceáni kéreg határa |



SK-HU cross-border region: Komarno-Sturovo



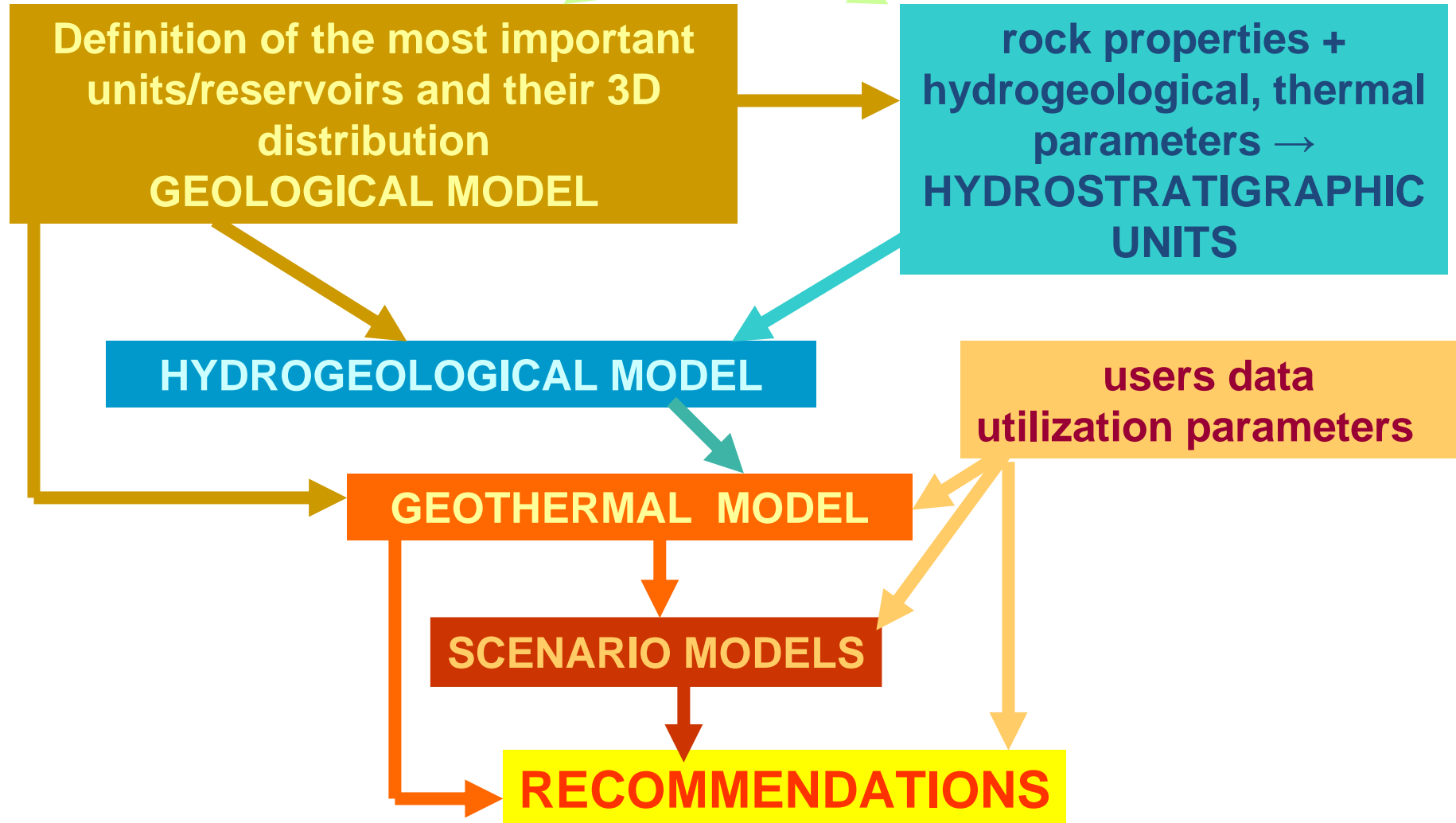
Questions addressed:

- mining related karstwater withdrawal vs. hydrogeothermal systems
- possible utilization according to different withdrawal scenarios

depression in karst water level 1990's

<http://transenergy-eu.geologie.ac.at>

**harmonised geological, hydro-geological, geothermal datasets
multi-lingual JOINT DATABASE**



Multi-lingual joint database (MS-Access)

basic data (name, coordinates, depth, screened intervals, etc.)

purpose of drill (hydrogeological, geothermal, oil prospection, reinjection)

utilization (heating, balneology, agriculture, reinjection, no, etc.)

geology (lithology from-to, facies, etc.)

hydrogeology (permeability, porosity, pressure logs, etc.)

geothermics (BHT, T-outflow, thermal conductivity, etc.)

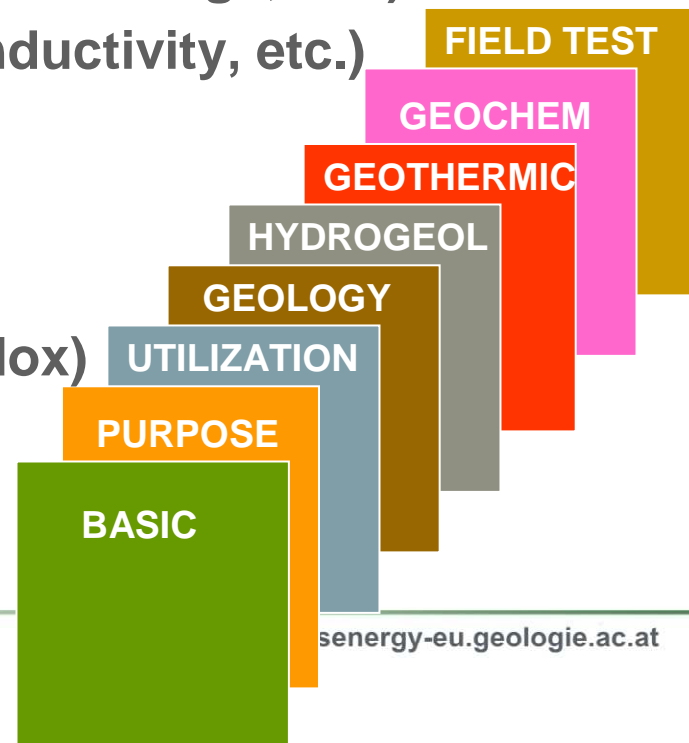
isotopes (O, C, Rn, Ra, noble gases)

organic components

trace elements

field measurements (pH, conductivity, redox)

pumping test (yield, level)



| Hungary | | Slovenia | |
|---------|--------|----------|--------|
| Expert | Public | Expert | Public |
| 792 | 158 | 404 | 99 |

www.t-jam.eu

The screenshot displays the T-JAM borehole database web application. The browser window title is "T-JAM borehole database - Windows Internet Explorer". The address bar shows the URL: http://akvamarin.geo-zs.si/t-jam_boreholes/Default.aspx. The page header features logos for T-JAM, SI, HU, and various regional agencies including the Ministry of Regional Development and Infrastructure of Slovenia and the Regional Development Agency of the Pomurje region.

The main content area shows a map of a region with green circular markers representing boreholes. A legend on the left lists the following results:

- 0 (T-JAM project area) 613273.4
 - 0
- 0 (T-JAM project area) 646504.1
 - 0

A pop-up window shows details for a selected borehole:

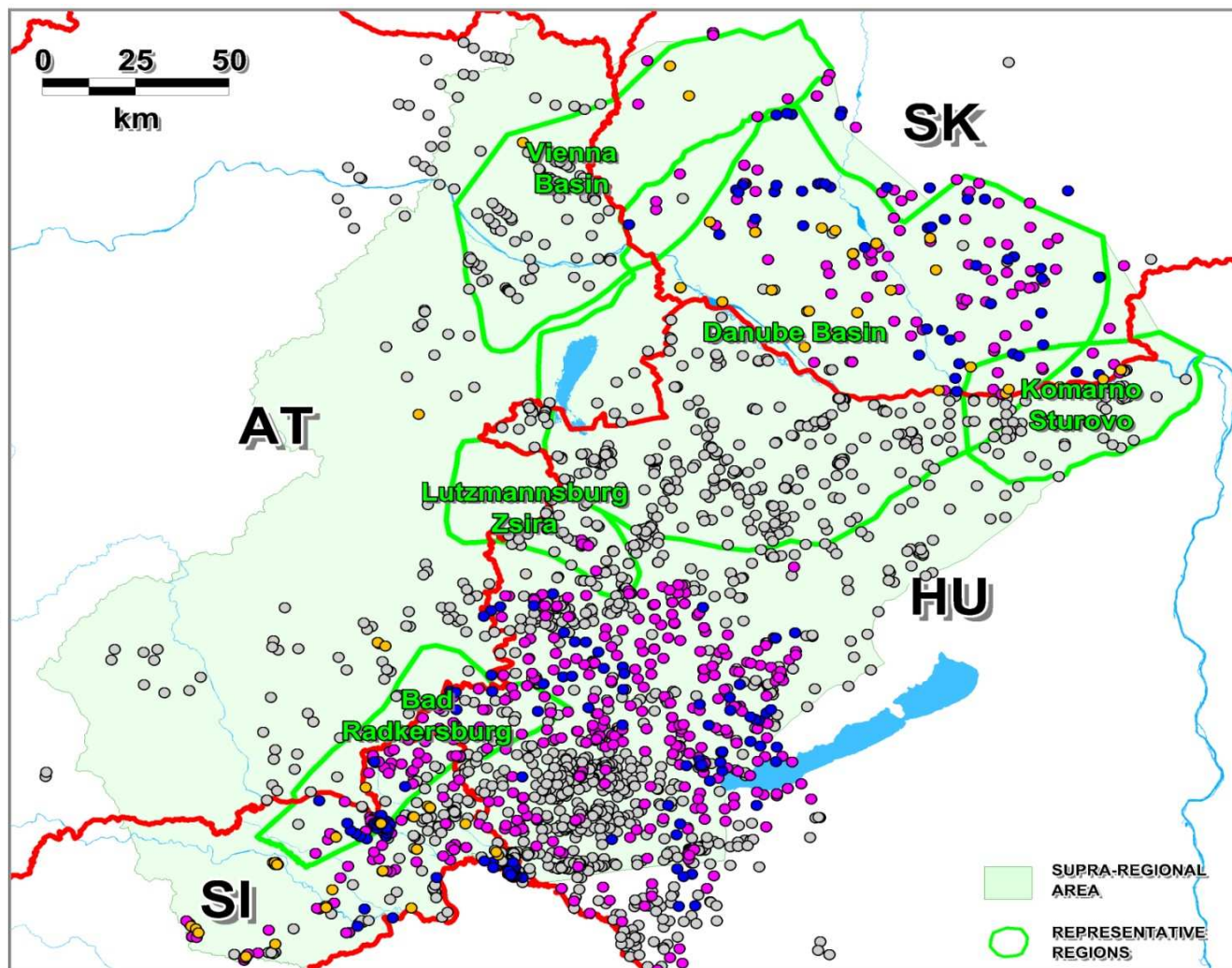
- 0 (T-JAM project area)
 - FID: 0
 - OID: 0
 - T-JAM_boreholes > T-JAM project area
 - [Add to Results](#)

The map shows a region with a red boundary and a yellow line. The X, Y coordinates are 688431.92, 176544.71. The source of topographic layers is listed as:

- Vector layers: ArcGIS 9.2 ESRI Data&Maps Europe basemap
- Raster layer: Void-filled seamless SRTM data V1, 2010, International Centre for Tropical Agriculture (CIAT), available from the CGIAR-CSI SRTM 90m. Database: <http://srtm.csi.cgiar.org>

© GeoZS, MAFI, Februar 2011

The browser window also shows the Windows taskbar with various open applications and the system tray showing the time as 19:16.



Number of boreholes
(March 31, 2011)

SK: 284

SLO: 455

AT: 223*

HU:1797

SUM: 2759

○ BOREHOLE
NON-ClassIFIED

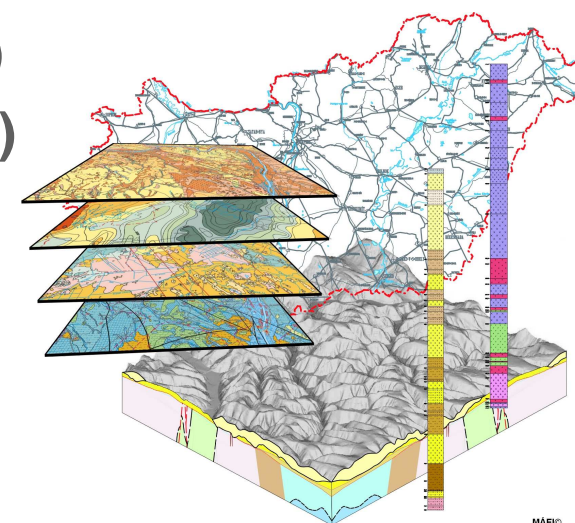
● HYDROGEOLOGICAL
BOREHOLE

● GEOTHERMAL
BOREHOLE

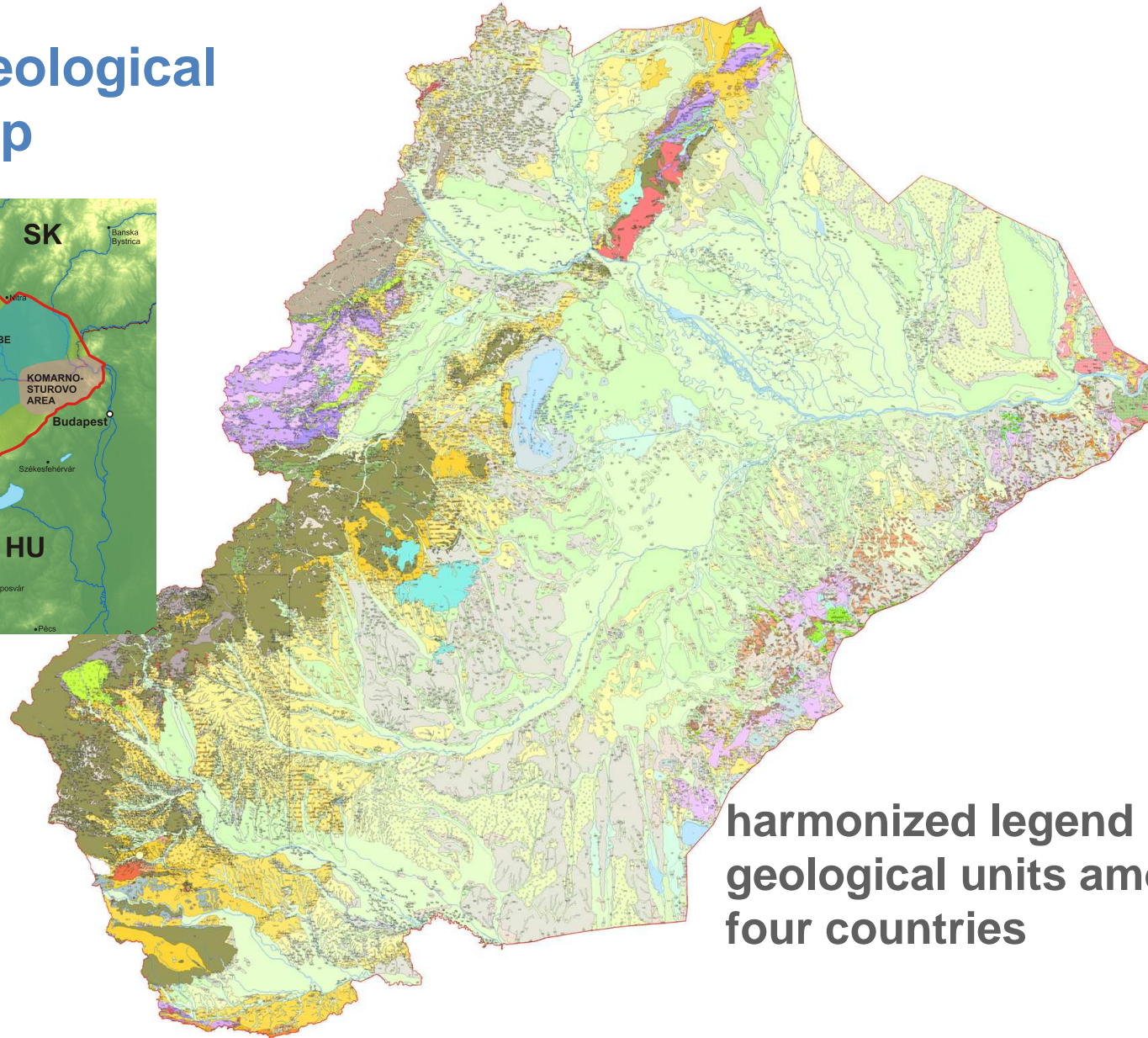
● STRUCTURAL
BOREHOLE

Geological model: bounding surfaces of hydrostratigraphic units

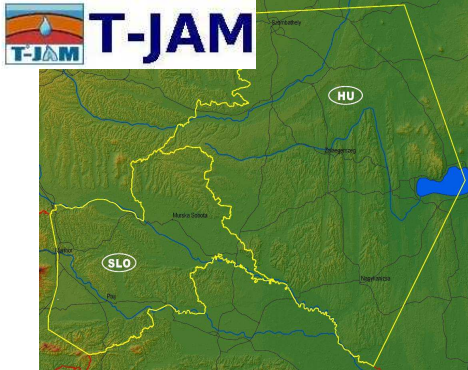
- Quaternary covered (surface) geological map
- Base of the Quaternary formations (Pre-Quaternary)
- Base of the Upper Pannonian formations (base of delta front sands)
- Base of the Lower Pannonian formations (Pre-Pannonian)
- Base of the Sarmatian formations (Pre-Sarmatian)
- Base of the Badenian formations (Pre-Badenian)
- Base of the Neogene formations (Pre-Neogene)
- Base of the Cenozoic formations (Pre-Cenozoic)
- Base of Cretaceous formations (Pre-Cretaceous)
- Surface of basement formations



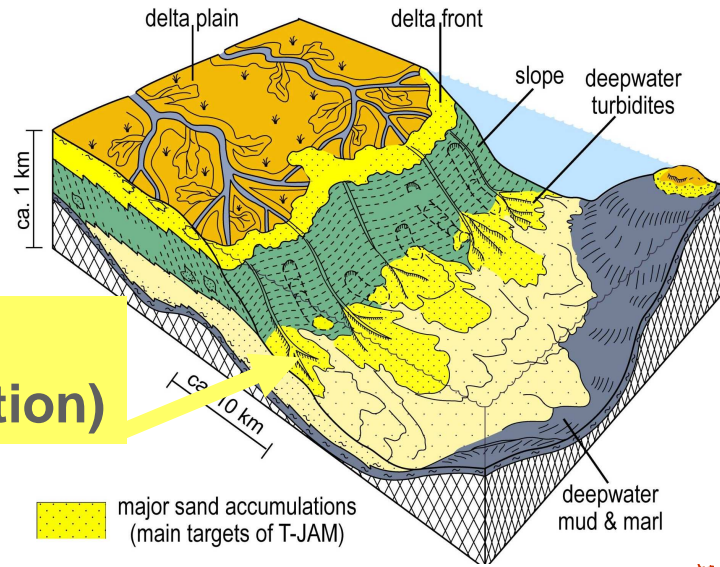
Surface geological map




harmonized legend of geological units among four countries

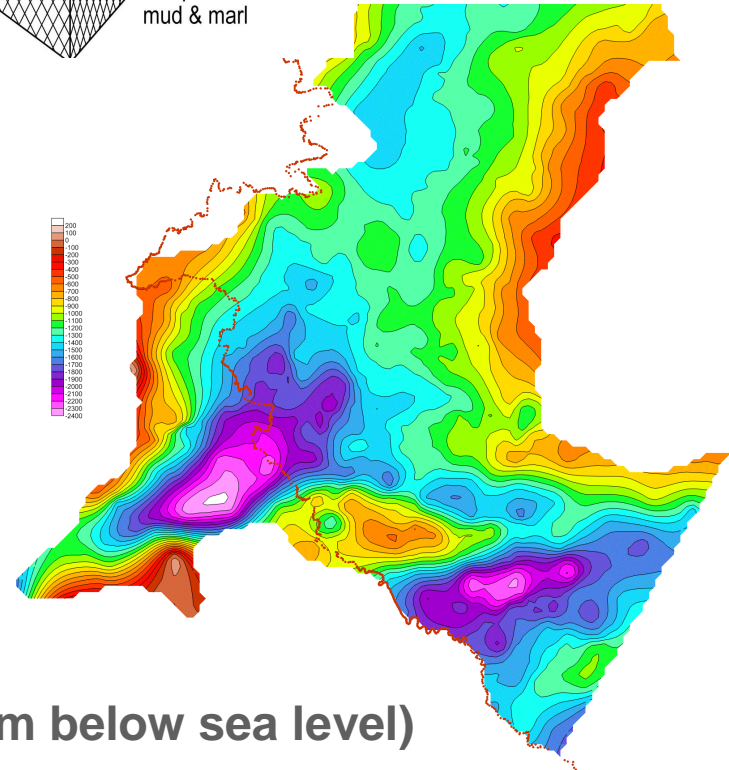
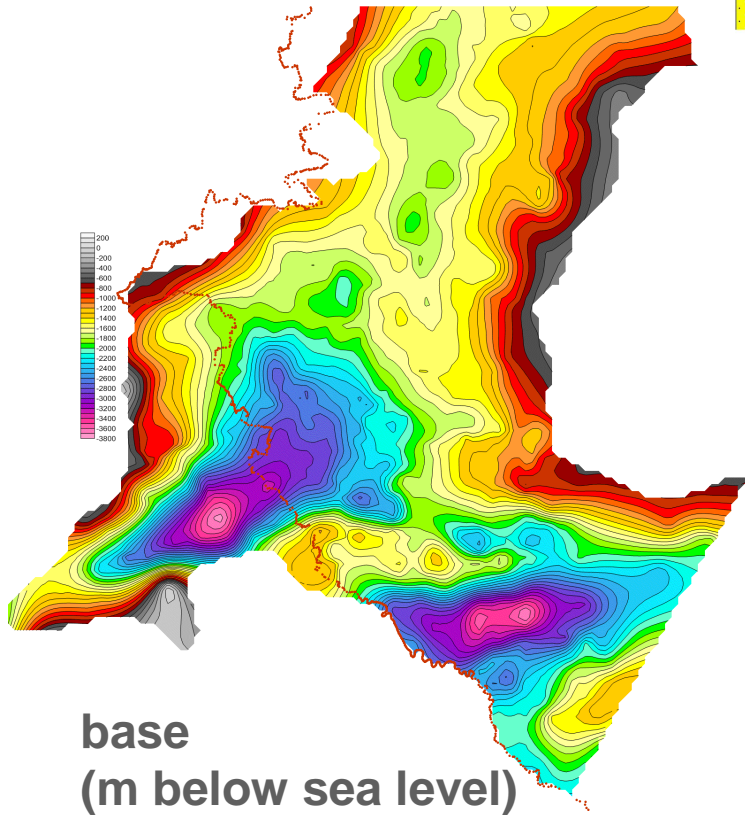


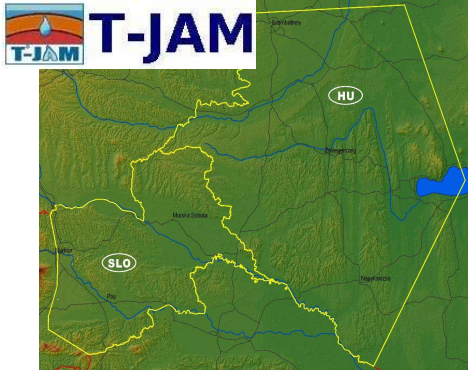
Late Miocene palaeoenvironment



Pannonian turbidites (Szolnok / Lendava Formation)

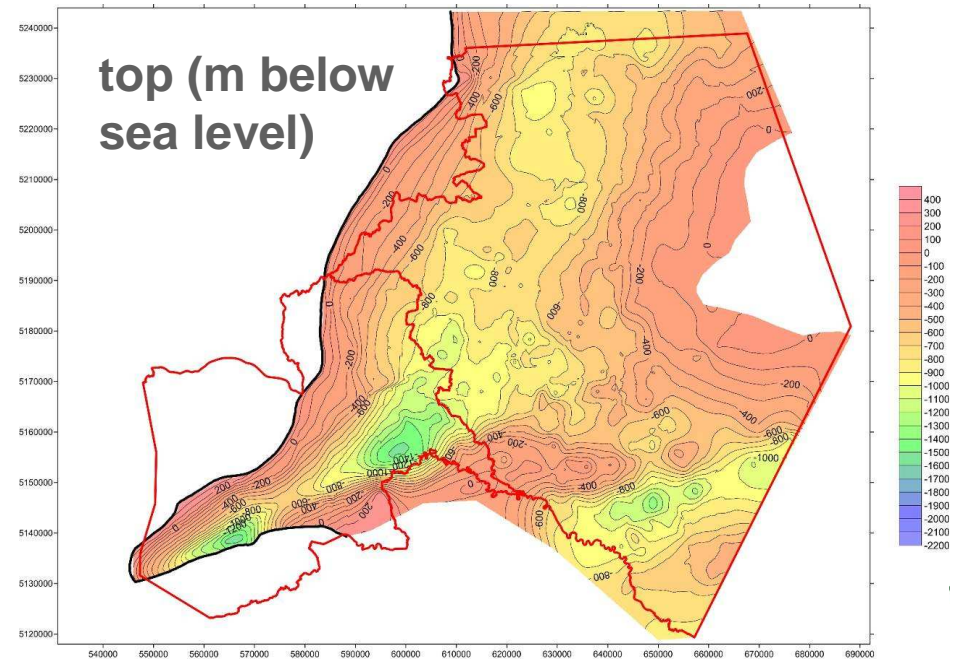
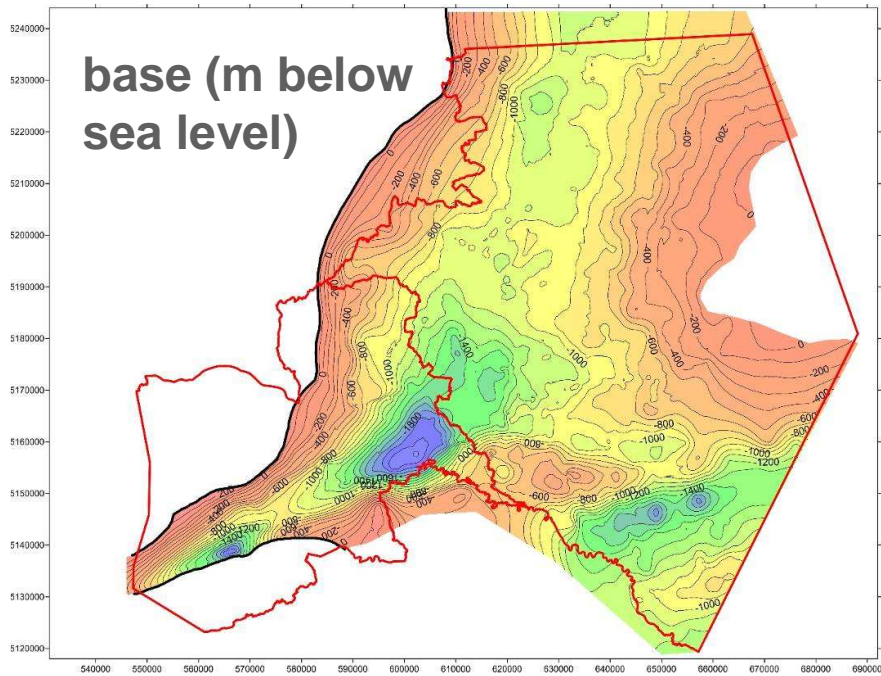
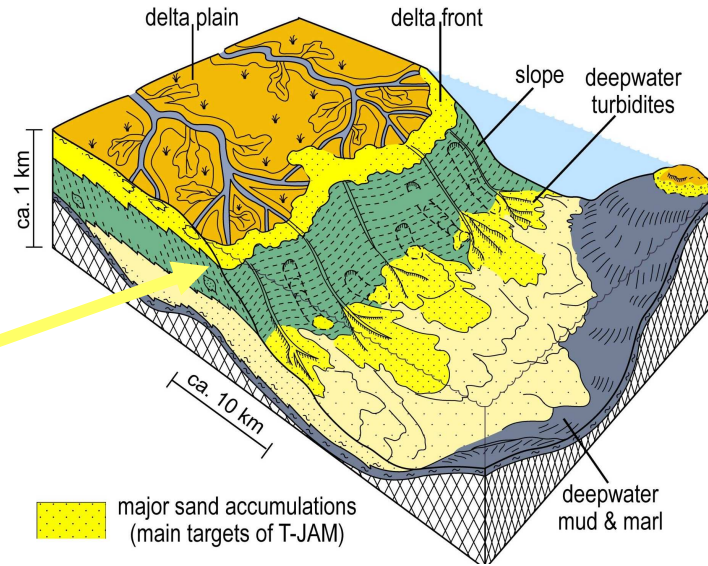
 major sand accumulations (main targets of T-JAM)

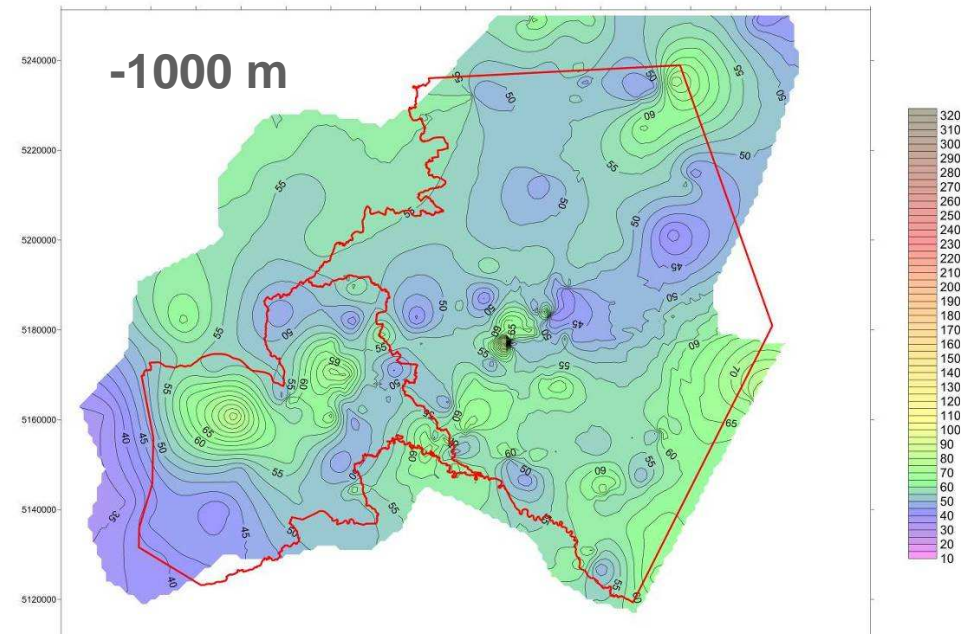
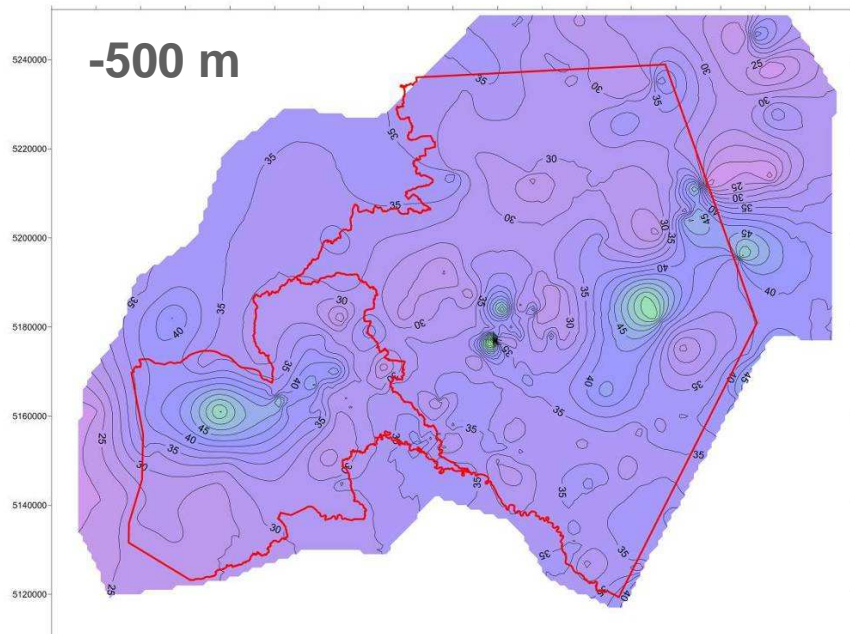




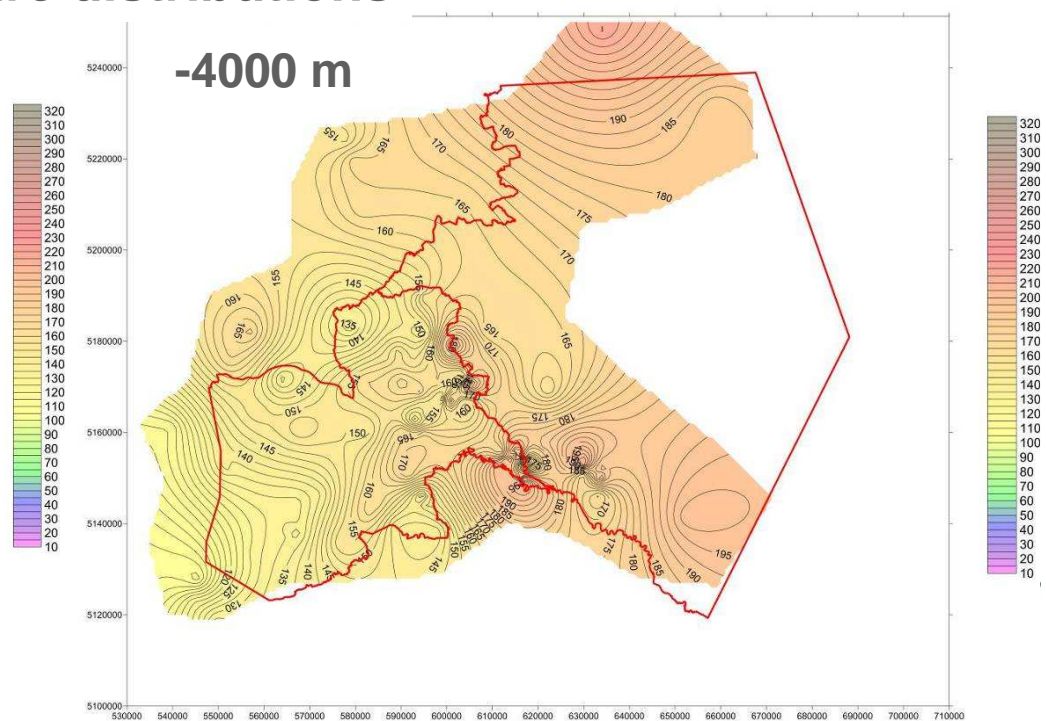
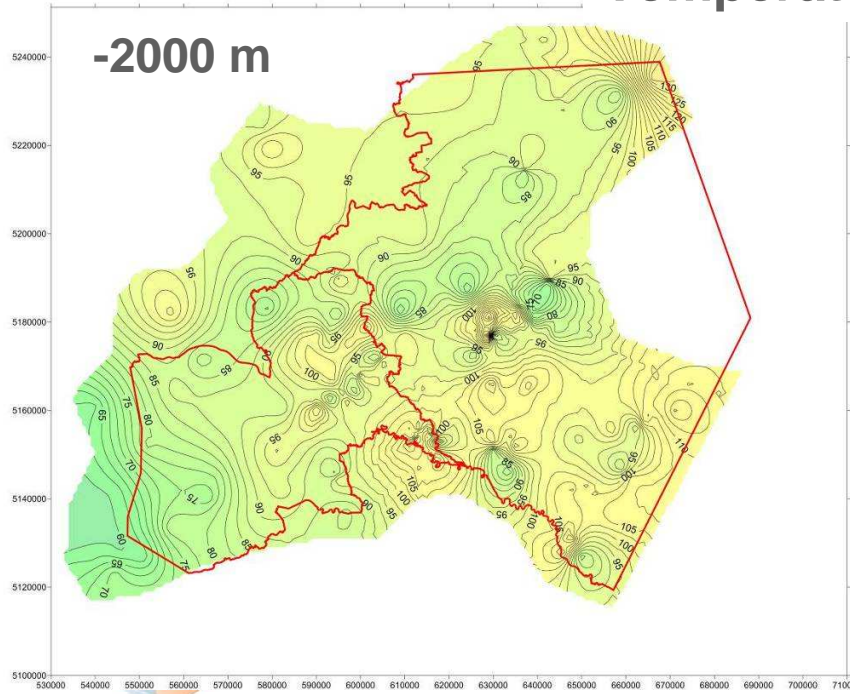
Pannonian delta-front sands Újfalu / Lower Mura Formations

Late Miocene palaeoenvironment

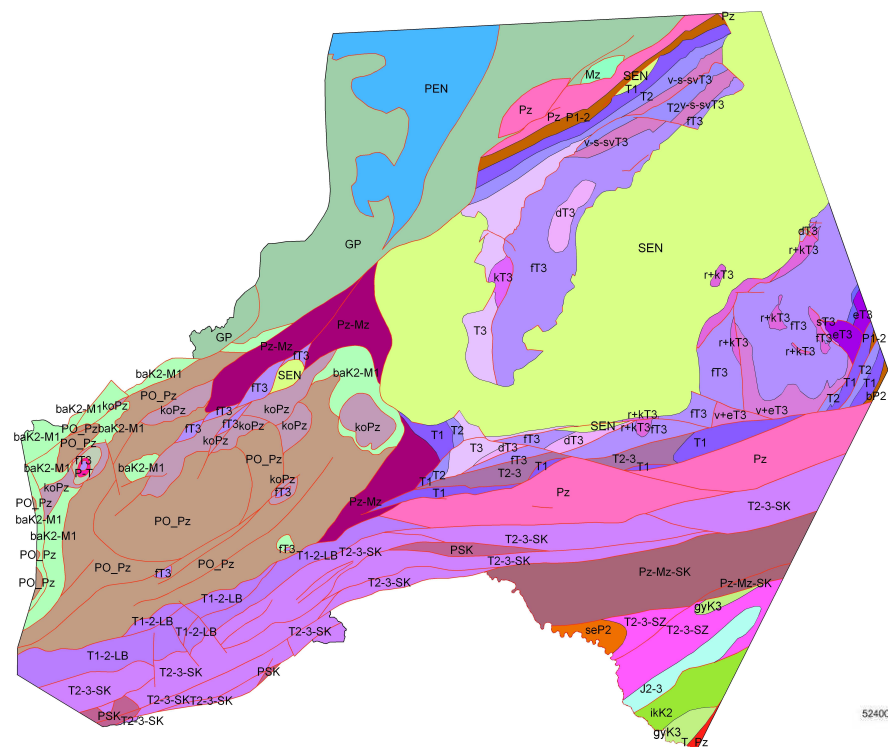
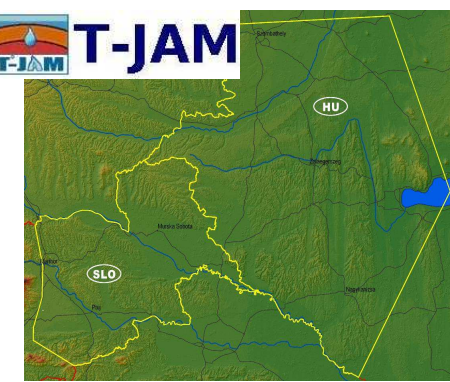




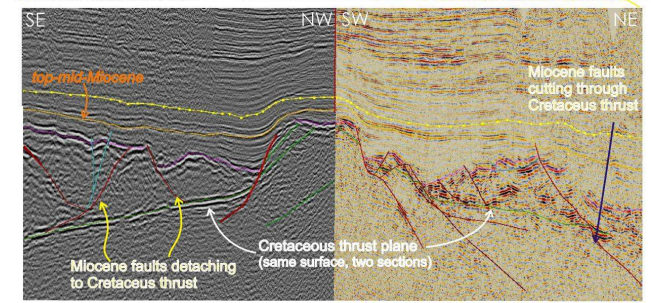
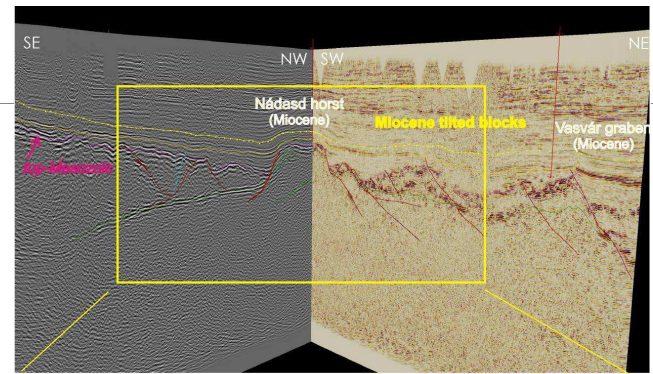
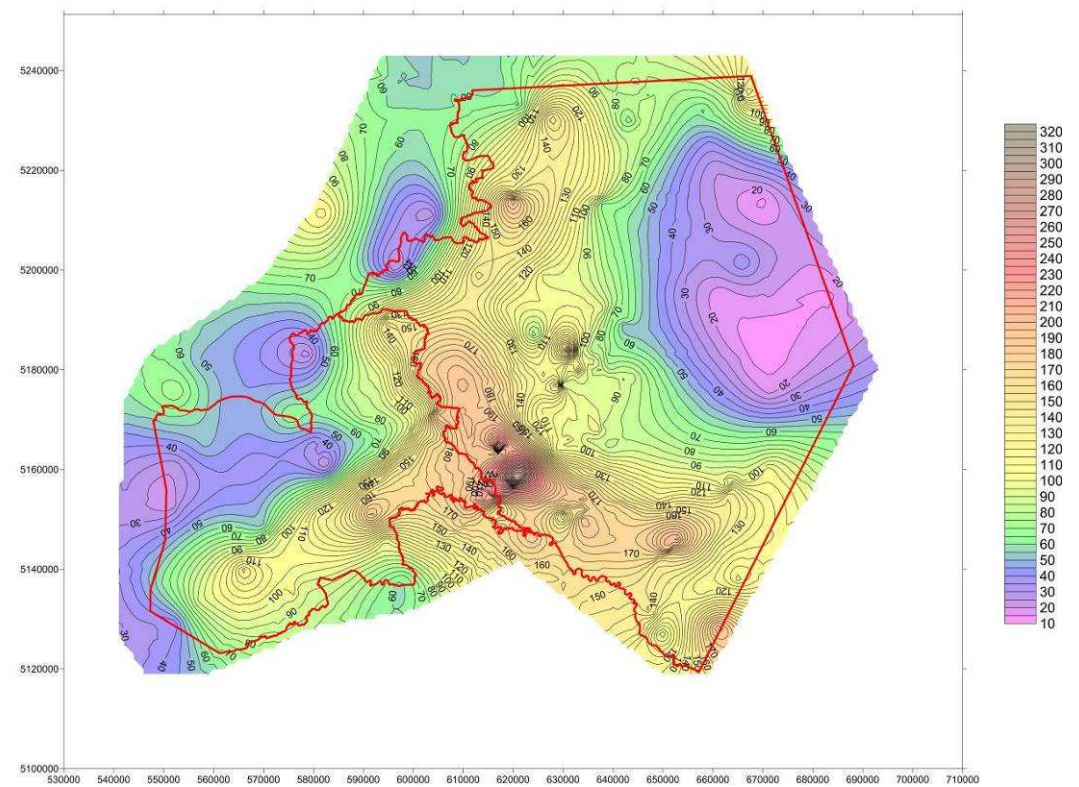
Temperature distributions



Pre-tertiary basement map

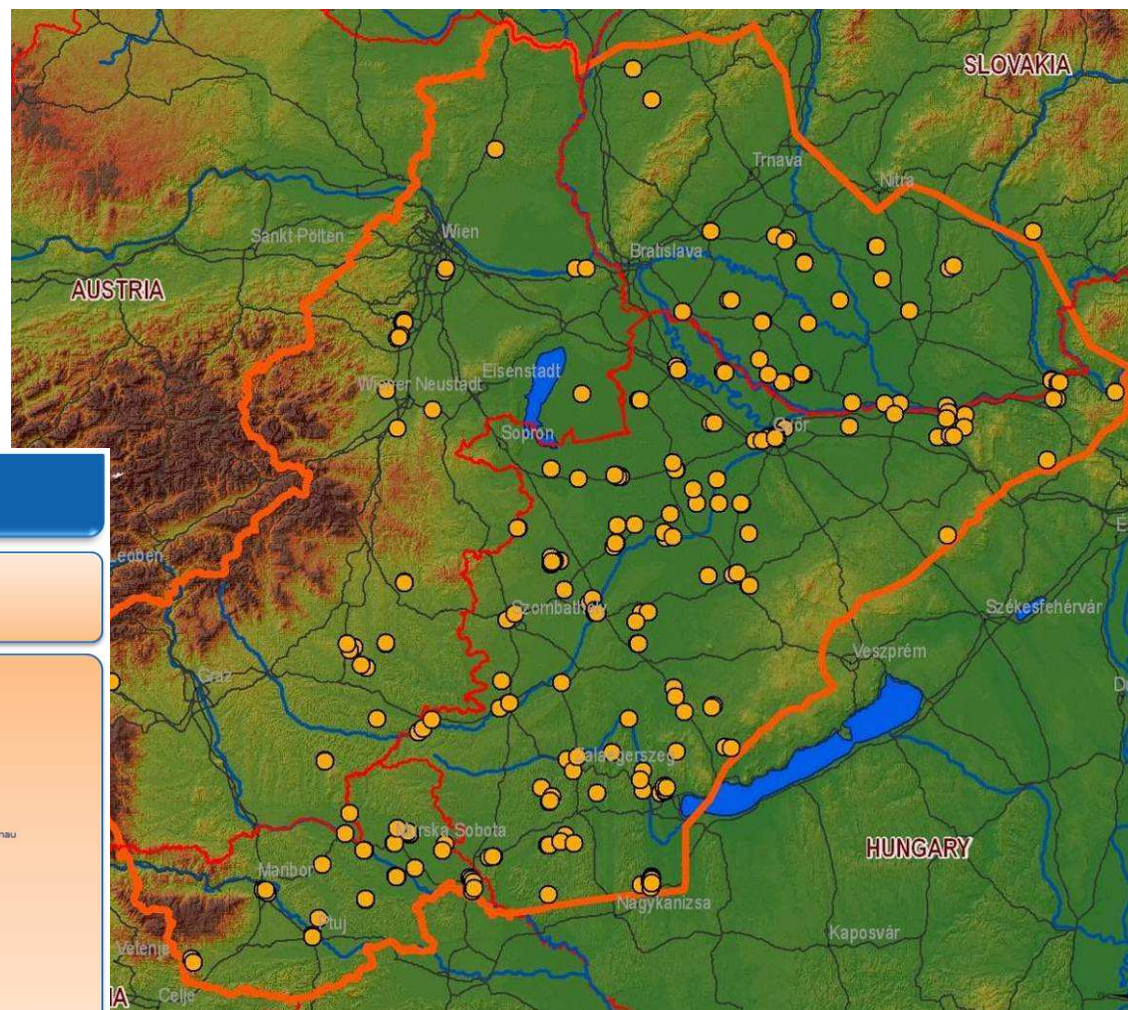


Temperature distribution at the pre-tertiary basement



Location of the geothermal users identified in the TRANSENERGY project area

| | Organizations | Formations | Boreholes |
|--------------|---------------|------------|------------|
| SLO | 23 | 27 | 35 |
| SK | 28 | 31 | 39 |
| AT | 20 | 26 | 50 |
| HU | 104 | 131 | 184 |
| Total | 175 | 215 | 308 |

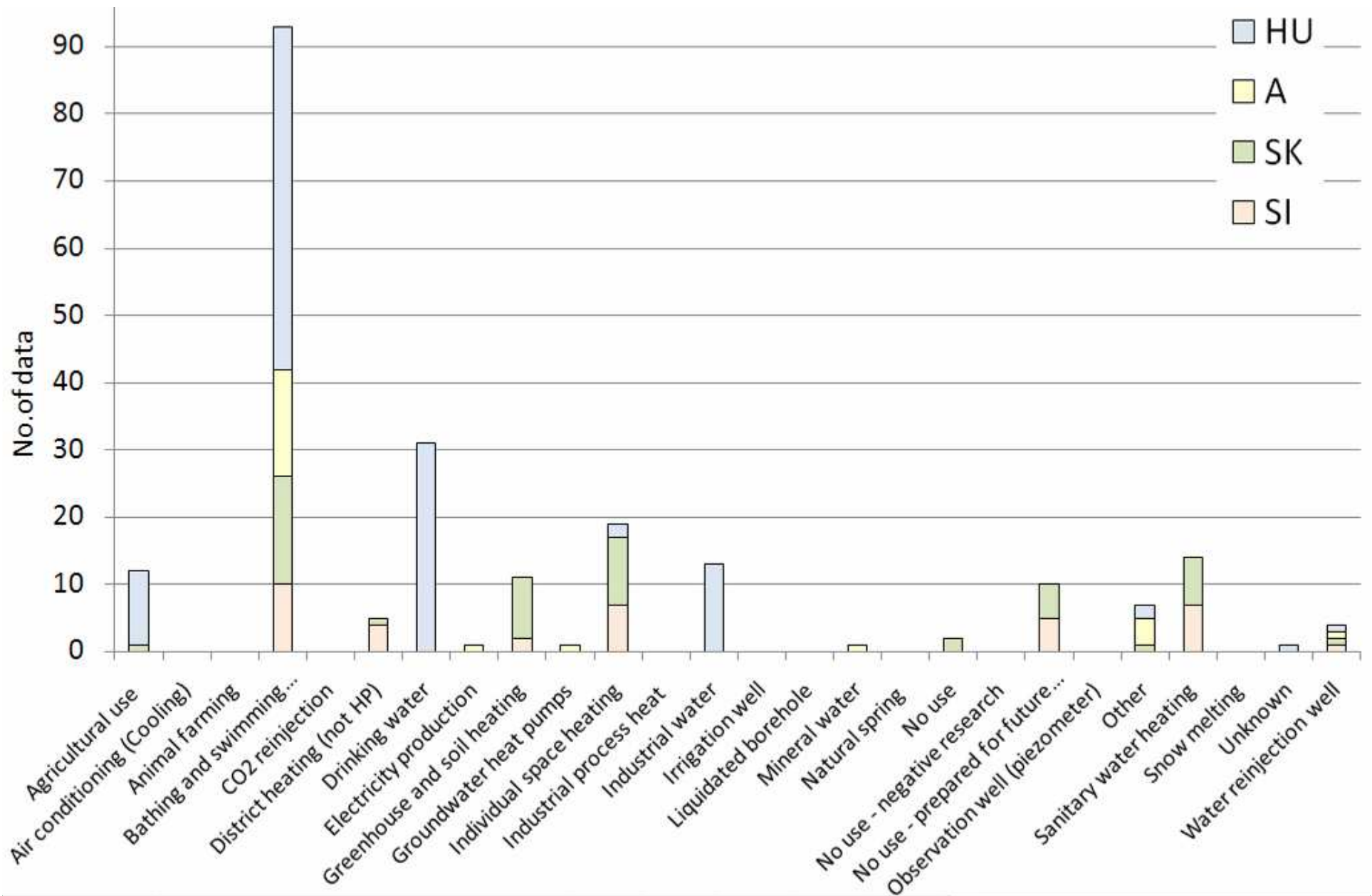


Country: Austria

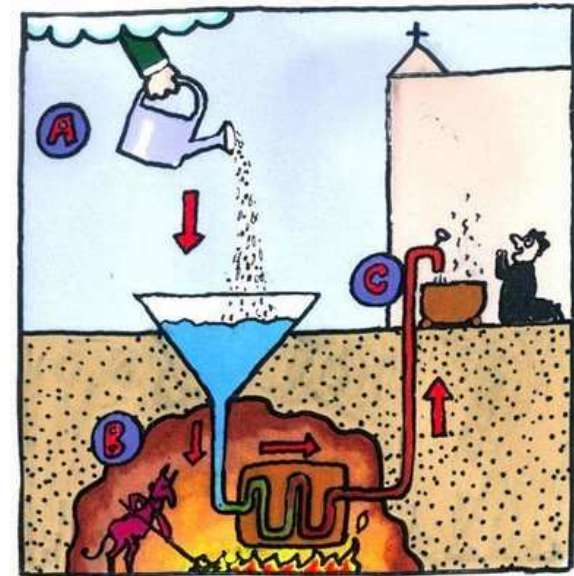
Users: Spa Terme Blumau Betriebs GmbH

| ORGANIZATION INFORMATION: | | PRODUCED WATER MANAGEMENT: | |
|--------------------------------|--------------------------------|--------------------------------|---|
| Commercial name | Rogner Bad Blumau | User status | active production |
| Country | Austria | Water use | bathing and swimming (including balneology) |
| Location | Bad Blumau | | electricity production |
| Level | local | | groundwater heat pumps |
| Organization (Original) | Spa Terme Blumau Betriebs GmbH | | water reinjection well |
| Organization (English) | Spa Terme Blumau Betriebs GmbH | Water sources | Blumau 1/1a, Blumau 2, Blumau 3 |
| Web address | http://www.blumau.com | MIN. water temp. (°C) | 32,00 |
| Address | Nr. 100 | MAX. water temp. (°C) | 109,00 |
| Postcode | 8283 | WASTE WATER MONITORING: | |
| Post name | Bad Blumau | Quantitative monitoring | no data |
| Telephone | +43 (0)3383 510 00 | Chemical monitoring | no data |
| Fax | +43 (0)3383 5100 808 | Temperature monitoring | no data |
| Organization group | | Waste water temp. (°C) | 35,00 |
| Comment | | Waste water treatment | seepage purifying plant |
| | | Place of water release | channel Fürstenfeld, reinjection from Blumau 2 well to 1/1a |
| | | Comment | |

<http://transenergy-eu.geologie.ac.at>



Only harmonized, multi-national management strategies can lead to sustainable utilization of transboundary geothermal resources



Results (*uploaded continuously according to the progress of the projects*) are available at:

www.t-jam.eu

<http://transenergy-eu.geologie.ac.at>