Combination of basin-scale data analysis and numerical simulations for the interpretation of the coexistence of thermal water and hydrocarbon accumulations

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Introduction

FACT

In the surrounding area of Ebes-Hajdúszoboszló, there is biogenic gas accumulation and Thermal water exploration

HYPOTHESIS

The groundwater flow is responsible for its secondary migration and accumulation

Can we prove the connection between the effect of groundwater flow and the secondary migration and accumulation of biogenic gas in the Ebes-Hajdúszoboszló area?

Objectives and methods

The groundwater flow

Understanding the regional groundwater flow regimes based on measured hydraulic data and hydrostratigraphy.

Transport and entrapment

Their role in the transport and the entrapment of hydrocarbons were analyzed in the study area.

Numerical simulations

2 D numerical simulations of a cross-section across the study region for a better understanding of the processes.

1. Study area
2. The approach
3. Basin-scale data evaluation: hydrostratigraphic units (Szabó et al., 2018)
4. Hydraulic evaluation:
    - Pressure vs. elevation [p(z)] profiles
    - Tomographic fluid-potential maps [h(x,y)]
    - Cross section
5. 2D numerical simulations.
6. Results and conclusion.

1. Study area

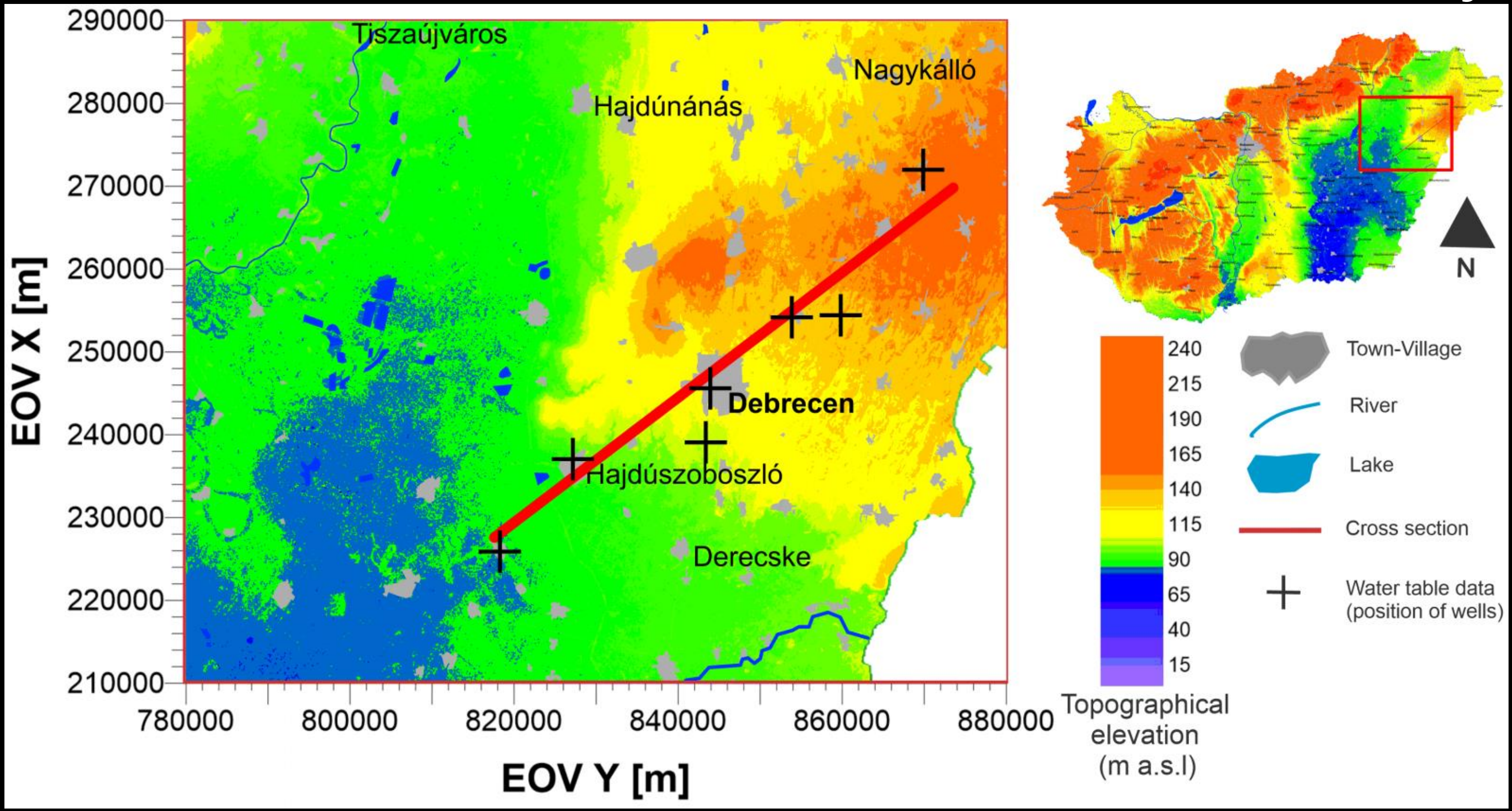
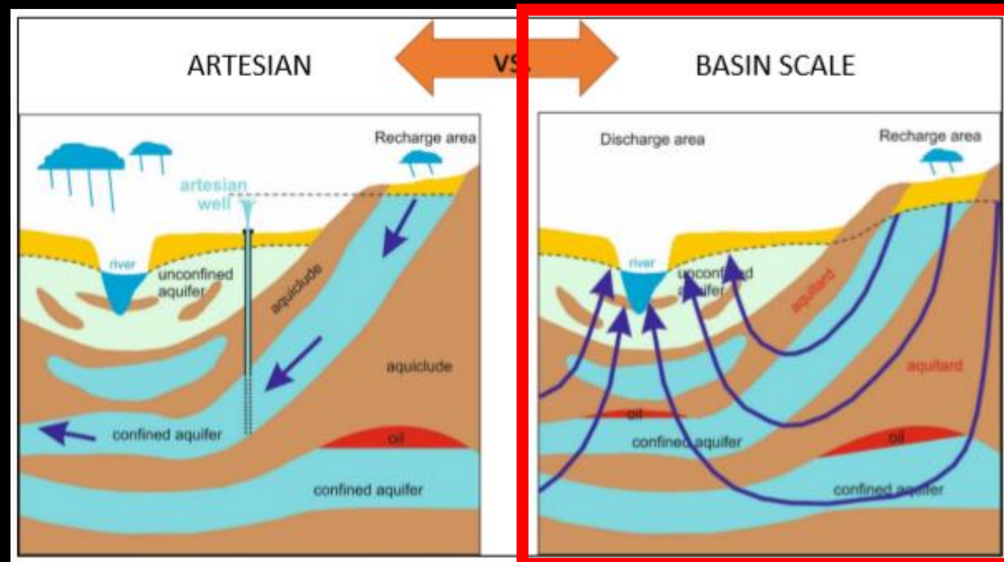


Fig. 1: Location of the study area

The Ebes-Hajdúszoboszló area is located in the Eastern Part of the Great Hungarian Plain. Hungary is located in Central Europe, geologically in the Pannonian Basin. It is a back-arc basin almost surrounded by the Alpine-Carpathian-Dinaric orogens. Extensional formation of the basin started in the early Miocene, whereas its structural reactivation (inversion) has been taking place since Late Miocene to recent times (Horváth, 1990).

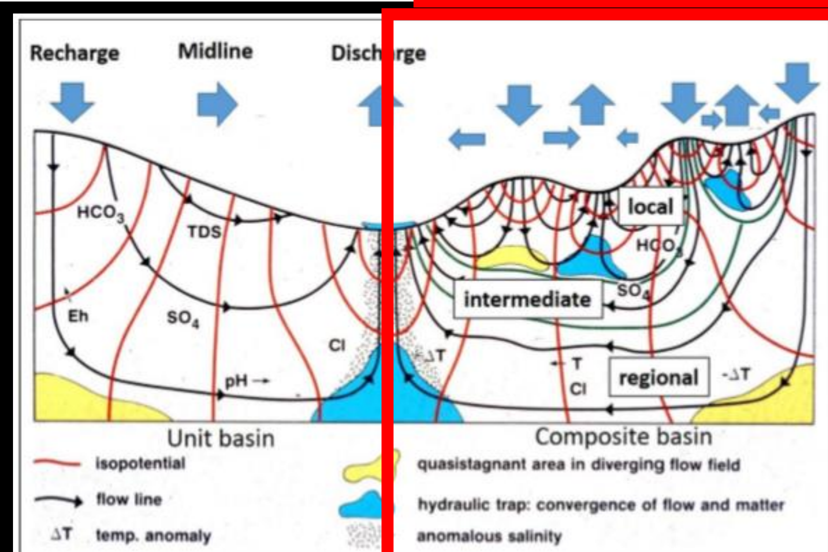
2. The approach

- A significantly larger area is taken into consideration, in order to apply the hydrogeological methods and provide a wide picture of the basin-scale groundwater flow systems.



- Using the principles of "basin-scale or modern hydrogeology" (Tóth, 2009). Where the hydraulic continuity was supposed (Tóth, 1995), no aquicludes, or impermeable rocks.

- the theoretical Unit basin, which has a linearly dipping land surface, in Composite basins the undulation of land surface results in hierarchically nested flow systems, namely, local, intermediate and regional scale nested flow systems.



3. Basin-scale data evaluation

Lithostratigraphic units	*Hydrostratigraphic units*	*Hydraulic conductivity (Kx)*	*Hydraulic conductivity (Kz)*	*Porosity (%)*
Quaternary and Ujfalu, Zagyva formations	Great Plain aquifer	10^{-5} m/s	10^{-6} m/s	24.6
Algyo Formation	Algyő aquitard	10^{-8}m/s	10^{-11}m/s	11
Pre-Pannonian formations	Pre-Pannonian aquifer	10^{-5} m/s	10^{-8} m/s	5.6
Pre-Neogene formations	Pre-Neogene aquifer	10^{-6} m/s	10^{-10} m/s	2.7

Table 1: Hydrostratigraphy of the study area (modified based on Tóth and Almási, 2001, Czauner and Mádl-Szőnyi, 2013)

4. Hydraulic evaluation

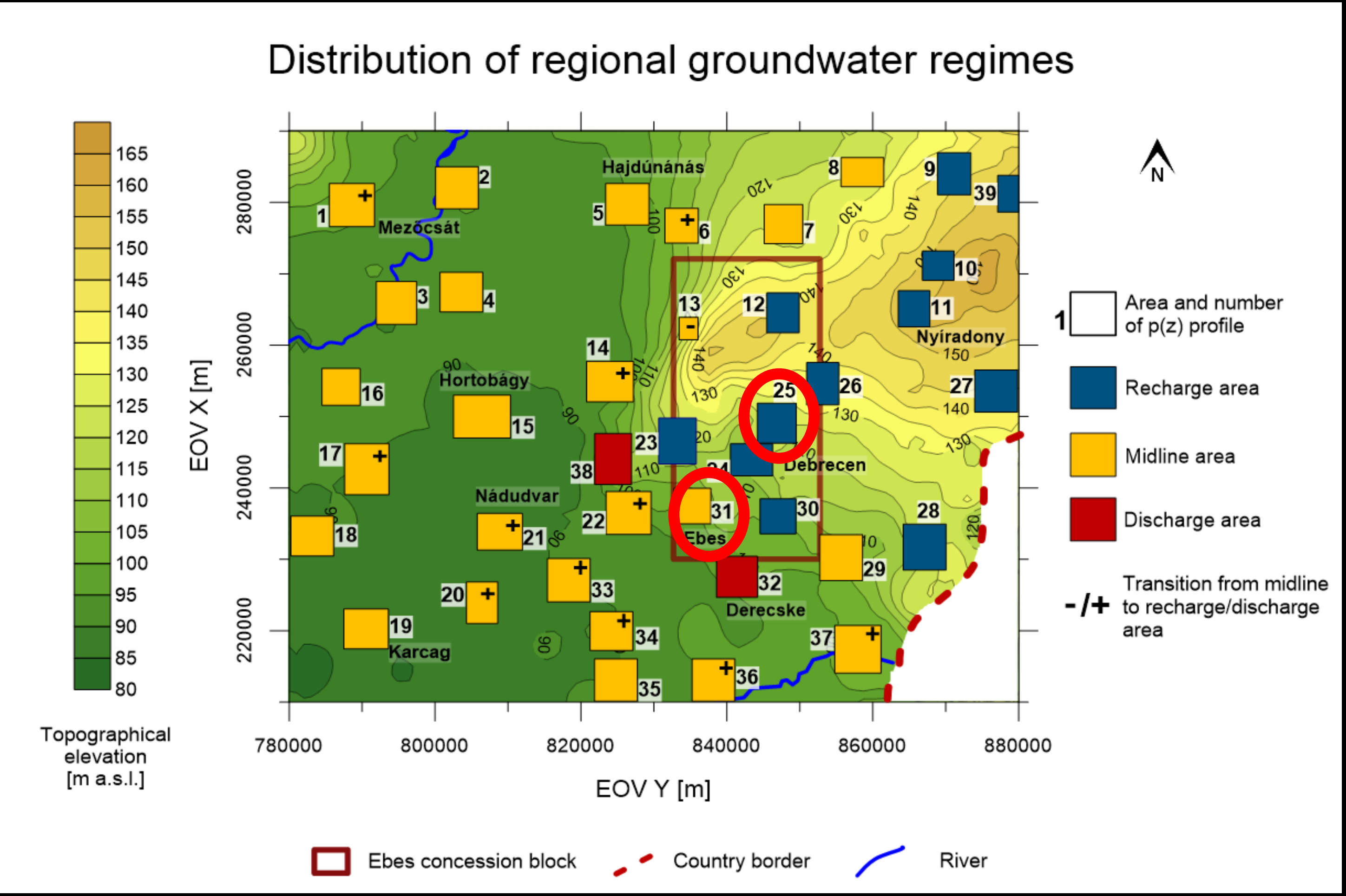


Fig.3: Vertical flow directions of the shallow (near-surface) gravitational flow system in the areas of p(z) profiles. Recharge area: downward flow, Midline area: horizontal (no vertical) flow, Discharge area: upward flow. The transition from horizontal to upward/downward flow is also indicated (Szabó 2018).

4. Hydraulic evaluation

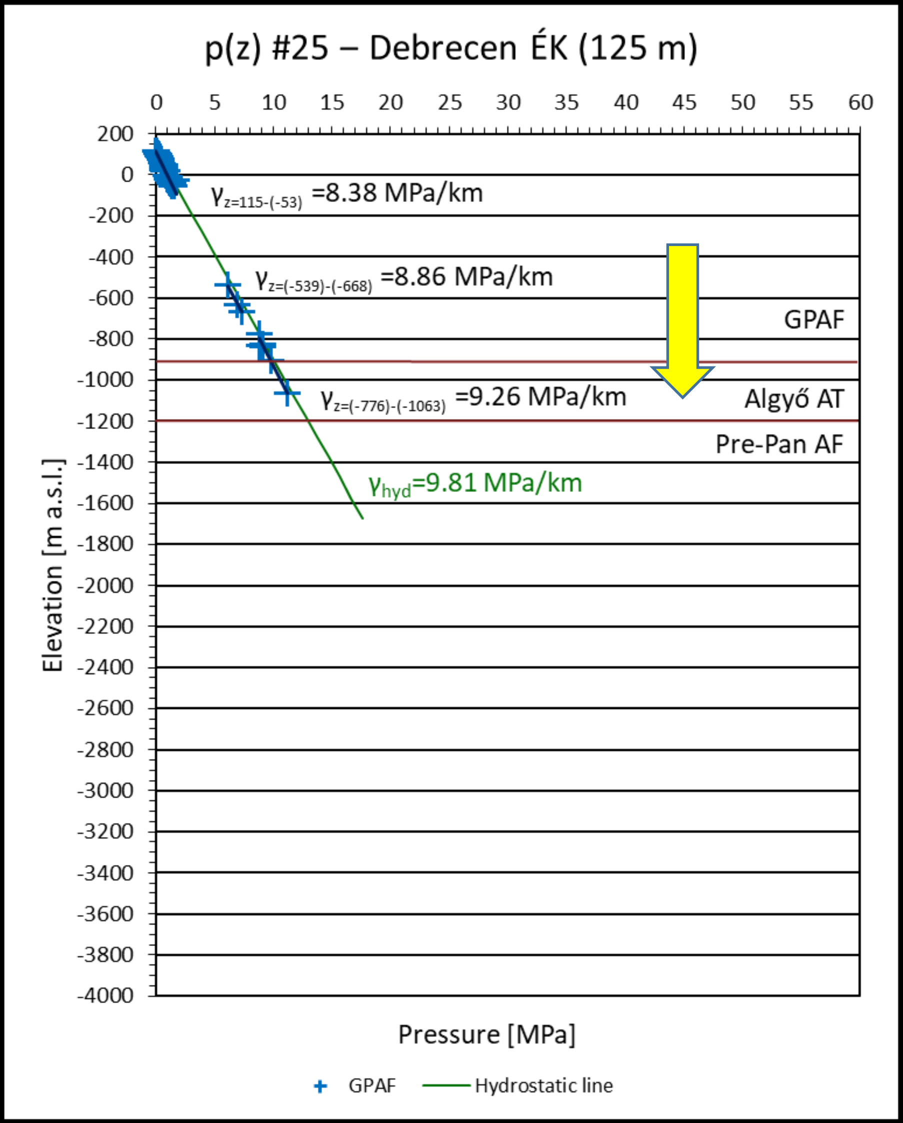


Fig.2: P(z) profile (Szabó 2018)

The p(z) profiles allows the examination of the vertical component of fluid flow directions by comparing the vertical pressure gradient to the ideal hydrostatic one.

Based on the subhydrostatic vertical pressure gradients of the data groups (γ=8.38, 8.86 and 9.26 MPa/km), downward flow conditions could be determined down to about z= (-1100) m asl.

4. Hydraulic evaluation

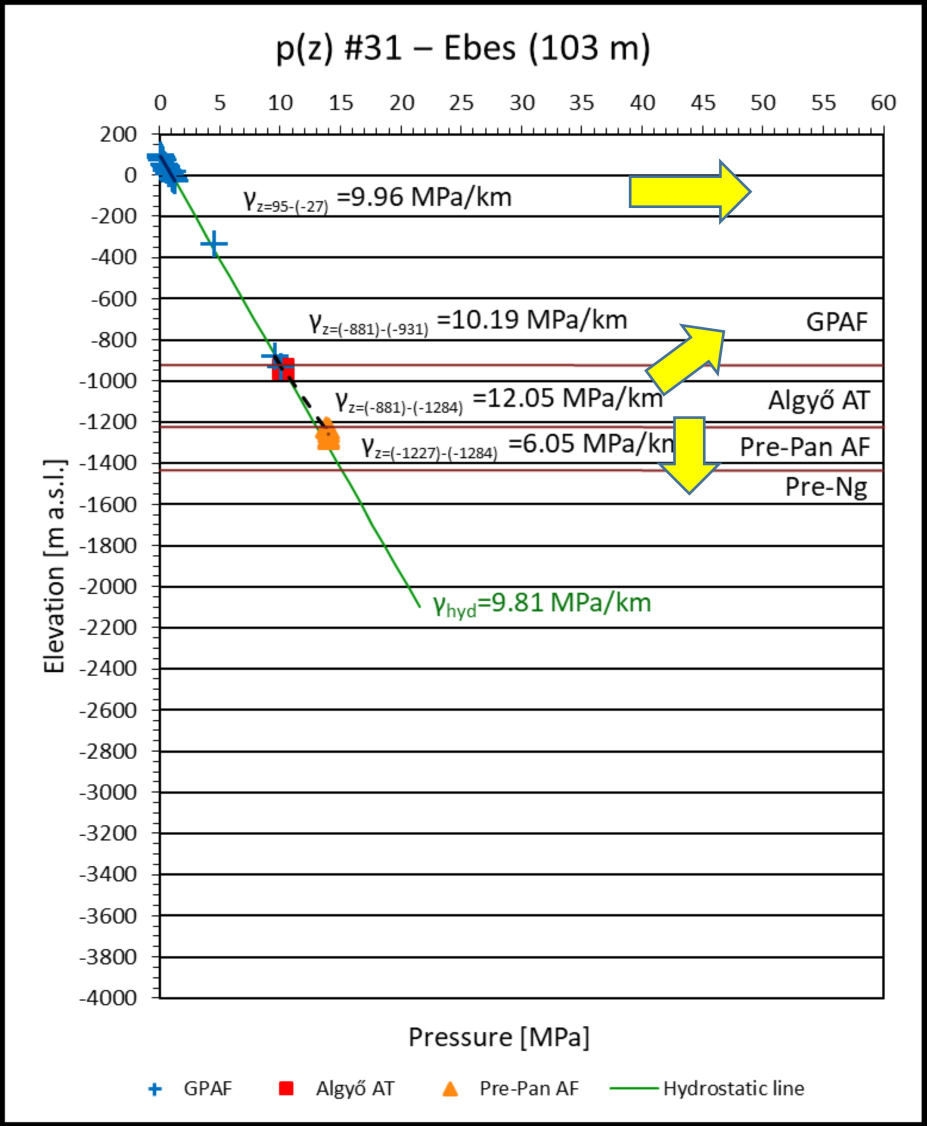


Fig. 3: p(z) profile (Szabó 2018)

- Based on the hydrostatic vertical pressure gradient of shallow data (γ=9.96 MPa/km), horizontal flow conditions could be determined.

- Between z= (-800) -(-1000) m asl, (γ=10.19 MPa/km), thus horizontal flow with the transition toward slight upward flow.

- The Pre-Pannonian data seemingly show 3-7% overpressure and subhydrostatic vertical pressure gradient (γ=6.05 MPa/km), which could rather be caused by the gaseous data (since in hydrostatic case γ depends only on the density of the fluid ($\gamma=\rho g$), and $\rho_{water} > \rho_{oil} > \rho_{gas}$, therefore $\gamma_{water} > \gamma_{oil} > \gamma_{gas}$).

- Between z= (-800) -(-1300) m asl, the vertical pressure gradient is slightly superhydrostatic (γ=12.05 MPa/km).

4. Hydraulic evaluation

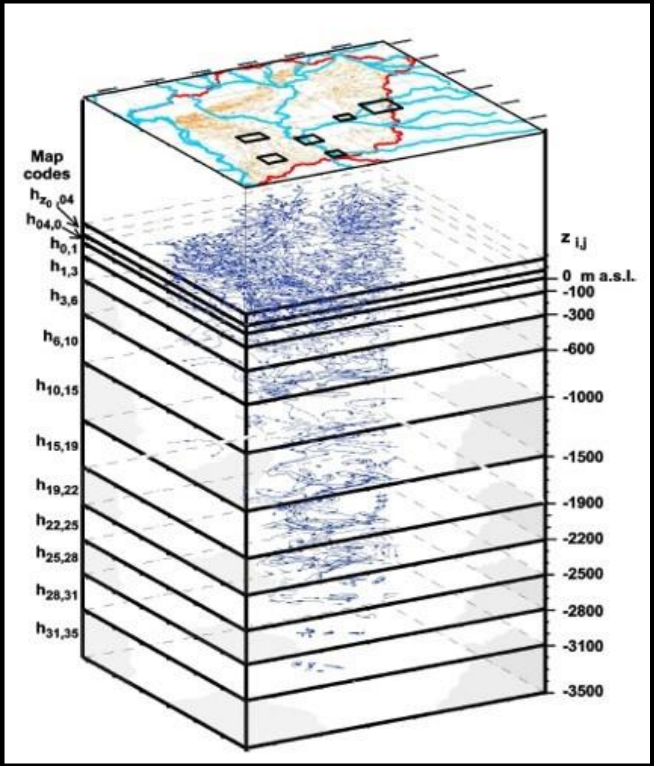


Fig.4: Theory of tomographic fluid-potential map construction (Almási, 2001).

Tomographic fluid-potential maps [h(x,y)] for successive elevation intervals, were made to show the direction of the horizontal component of fluid flow in each map, and the vertical flow direction can be interpreted by comparing the different maps.

4. Hydraulic evaluation

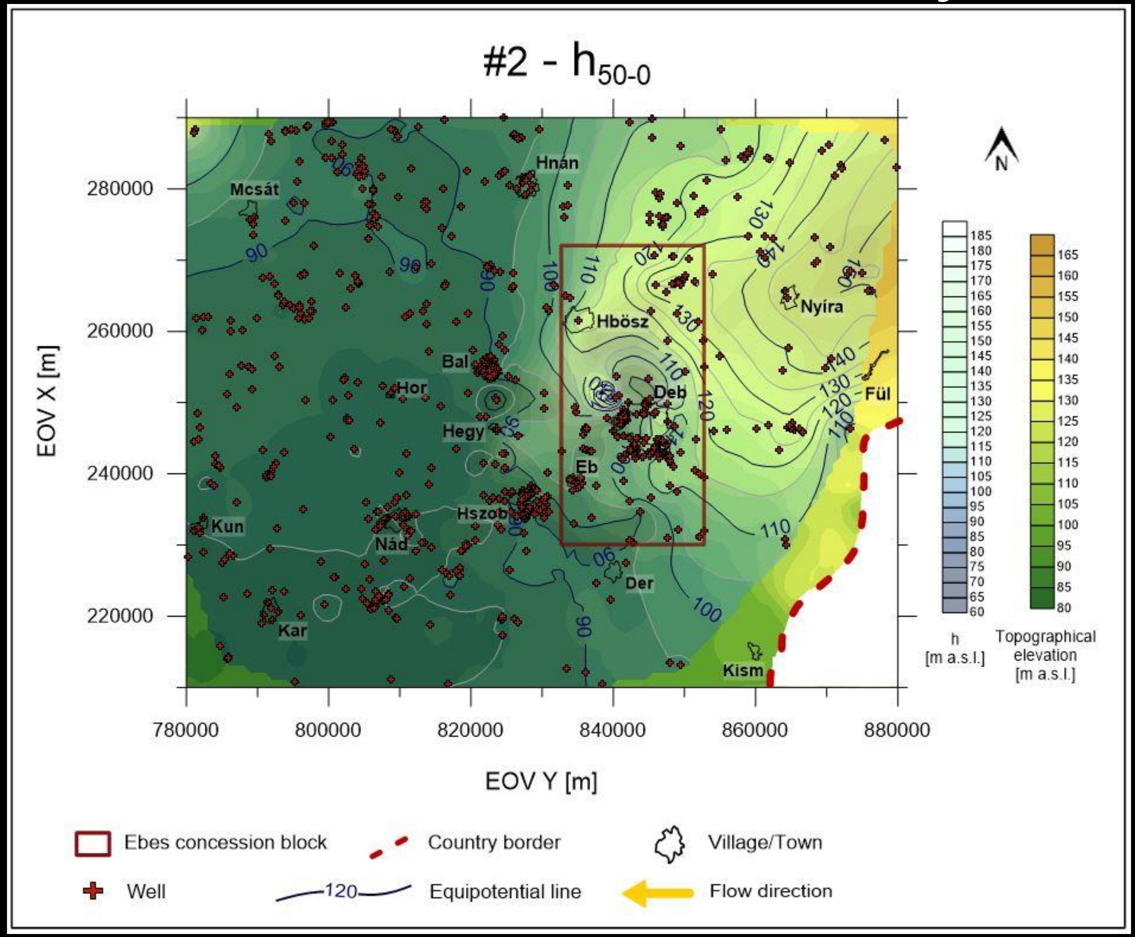


Fig. 5: Tomographic fluid-potential map #2 for elevation interval z=50-0 m asl. Background: topographical maps (Szabó 2018).

The groundwater flow directions basically reflect the effect of the topography, thus represent gravitational flow systems.
The regional fluid flow direction tends toward W-SW.

4.Hydraulic evaluation

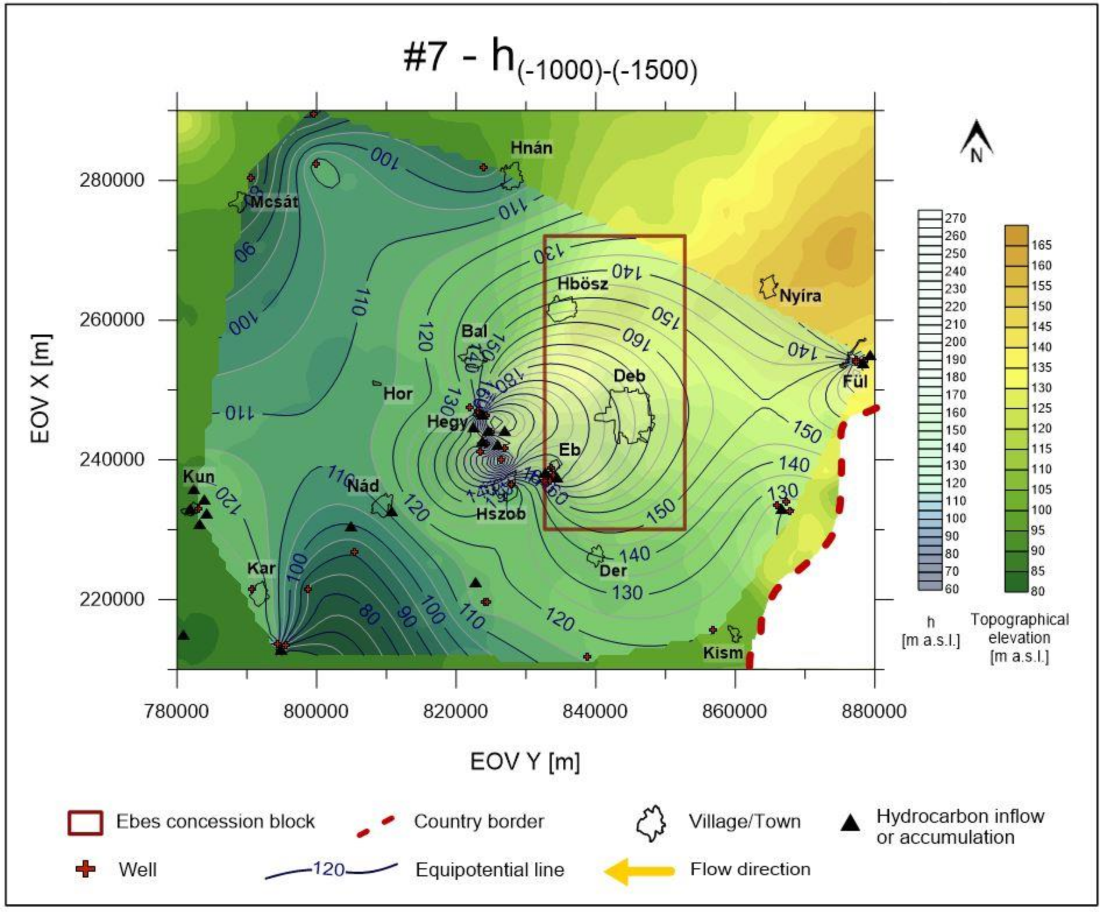


Fig. 6: Tomographic fluid-potential map #7 for elevation interval z= (-1000) -(-1500) m asl. Background: topographical maps (Szabó 2018).

Down to z=(-1500)m asl, positive anomalies around Hajdúszoboszló and Ebes gas fields which represent an upward flow condition in the gravity-driven flow systems for the Ebes and Hajdúszoboszló gas fields.

From z=(-1500)m asl represent the overpressured flow system.

4. Hydraulic section

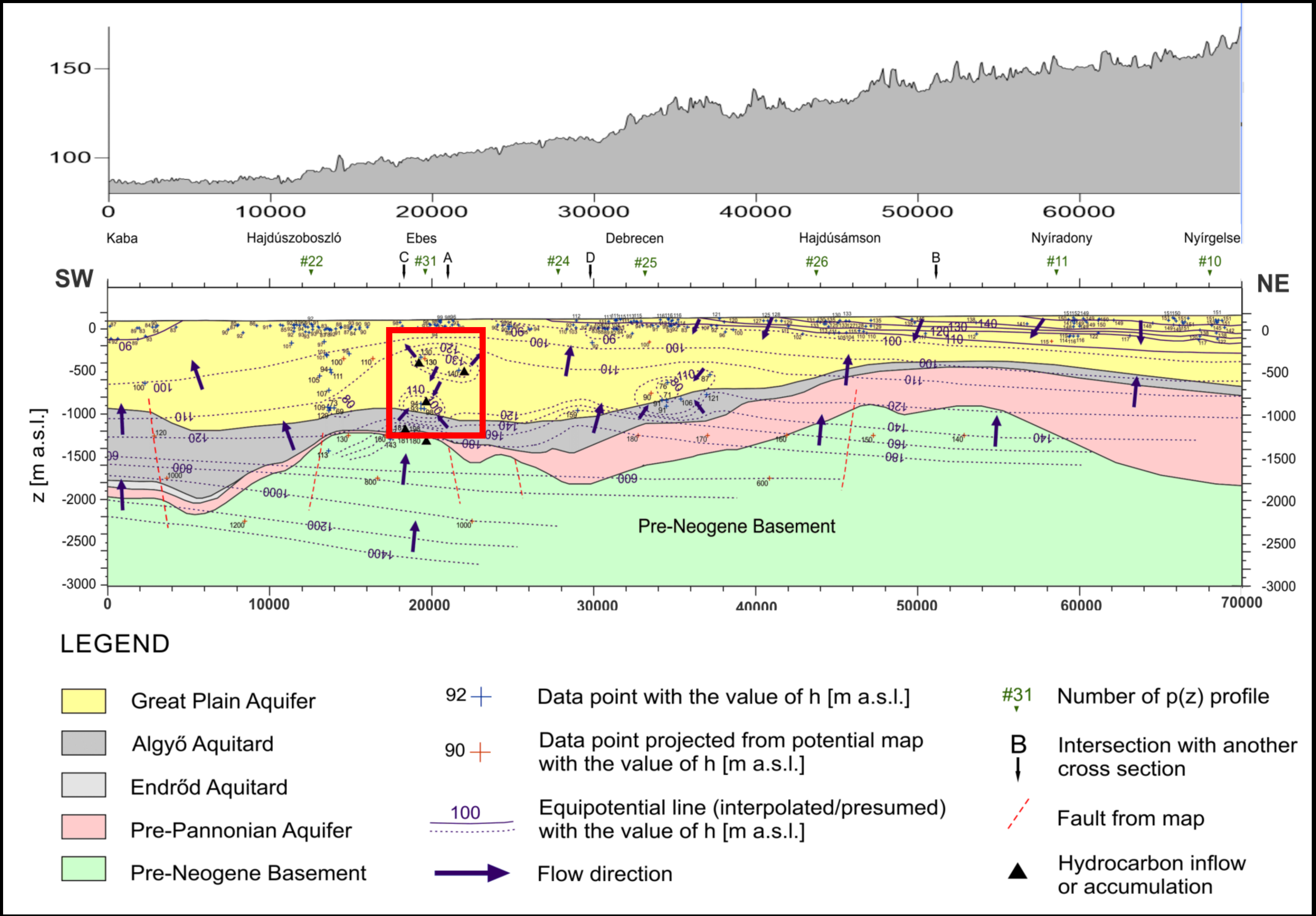


Fig. 7: NE-SW cross-section of the area (Szabó 2018)

5. 2D Numerical simulations

The boundary conditions	
Left boundary	Outflow towards the SW with the rate of 10^{-12} m/s (calculated from the equipotential lines of the cross section).
Upper boundary	An increasing slope of the water table from 88 m asl in Kaba (SW) into 150 m asl in Nyírgelse (NE).
Right boundary	No flow from the NE, it is the highest topography area so-called catchment, recharge or water divide area.
Lower boundary	Set in 1200m deep and represents the flux incoming flow across the bottom which is 10^{-12} m/s

Tab.2: The boundary conditions of the cross section

5. 2D numerical simulations

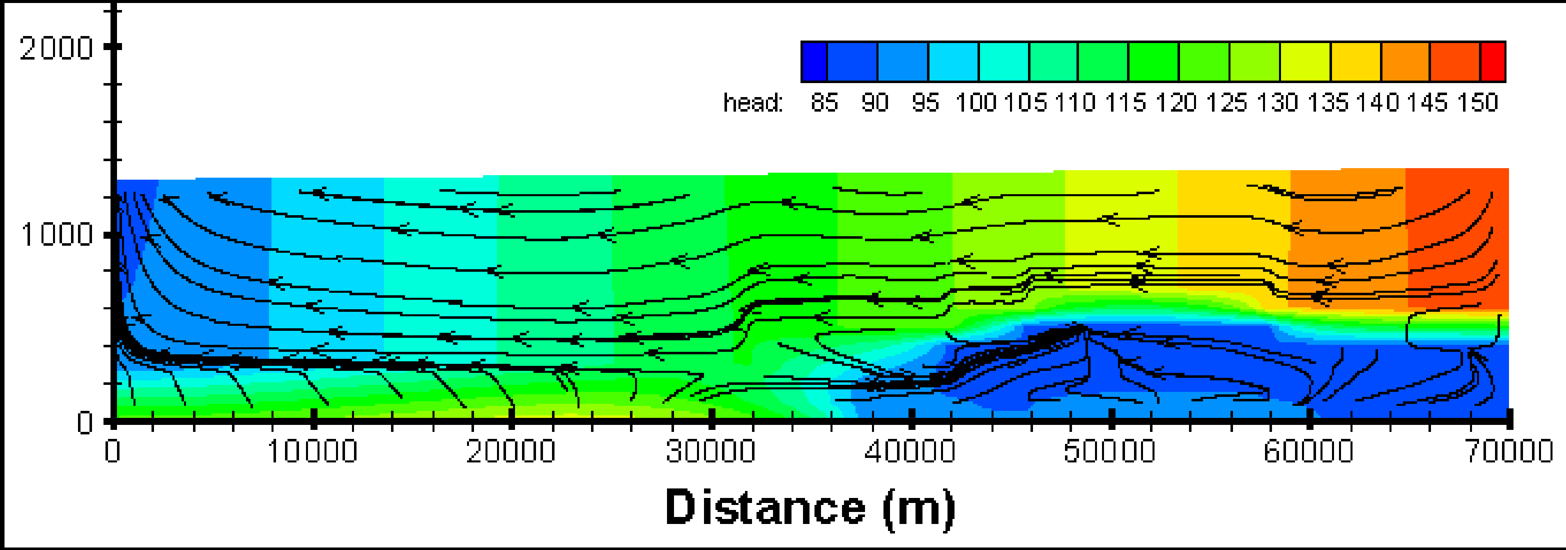


Fig.8: The numerical simulation result of the NE-SW cross-section.

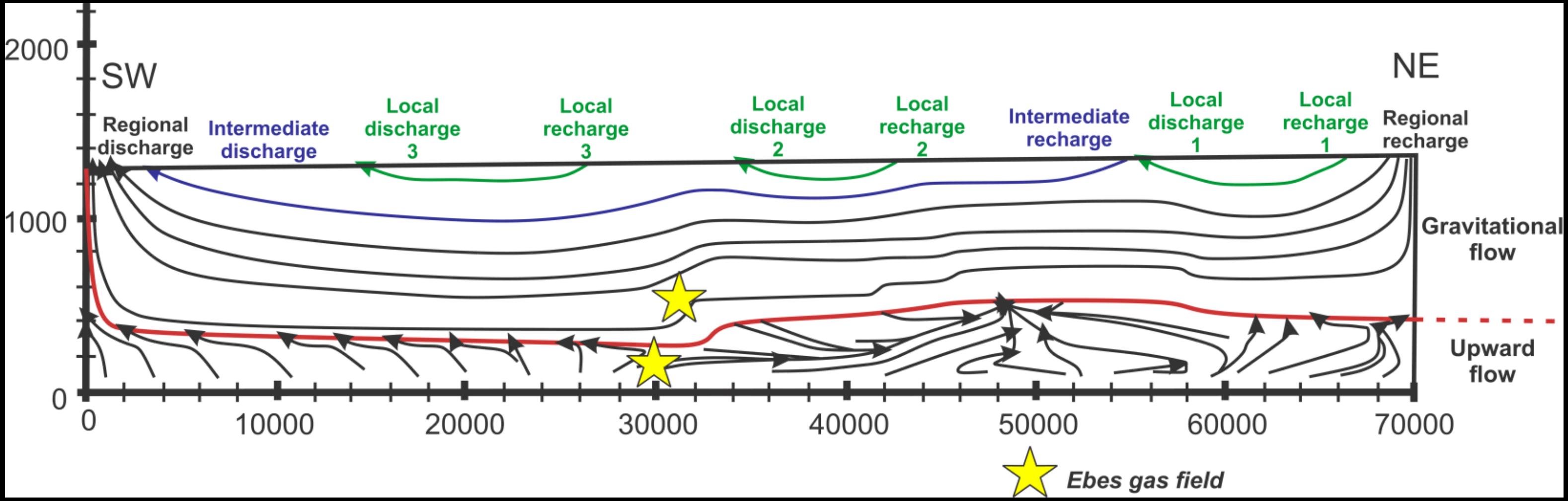


Fig.9: The interpretation of the fluid flow system of the numerical simulation.

5. 2D numerical simulations

The modeling results showed

A nested flow system, containing three local, an intermediate and a regional scale nested flow system

Two different and separated flow systems the gravitational and the overpressure → confirm the measurement results

The Ebes-Hajdúszoboszló gas field could not be seen or interpreted in the simulations result → Seismic interpretation of 3D seismic cubes is needed for more detailed hydrostratigraphy interpretation

6. Results ans conclusion

- ✓ The near hydrostatic (gravitational) and the overpressured flow system below were distinguished within the study area in good accordance with previous studies (e.g. Tóth and Almási, 2001, Mádl-Szőnyi and Tóth, 2009; Czauner and Mádl-Szőnyi, 2013)

- ✓ The study based on the field measurements could show the connection between the effect of groundwater flow and the secondary migration and accumulation of hydrocarbons and the coexistence of thermal water in the Ebes-Hajdúszoboszló area.

- ✓ The lithosratigraphy set into the model was simplified, containing a large-scale layers, however, in reality and in a smaller scale, the geology of the region is much more heterogeneous and anisotropic with a complex geometry and influenced by tectonics. Thus, for a better understanding of the process of the hydrocarbon accumulation, it is necessary to make a detailed hydrostratigraphy, to have more detailed simulation, containing a visible gas field, it is necessary to study in details the lithostratigraphy on a relatively small scale.

Thank you for your attention! Questions?