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## Geophysical investigation of subsurface structures using resistivity tomography in the Pannonian basin

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### Abstract

If you could peel back the first 200 metres of sediment beneath the Hungarian Plain, you would find a layered succession of alluvium, lacustrine clay, Pannonian sand, Miocene marl, and crystalline basement—a sequence that controls groundwater flow, geothermal potential, and foundation conditions for every structure built above it. This research mapped these subsurface layers using two-dimensional electrical resistivity tomography (ERT) along eight profile lines totalling 4.6 km in the south-western Pannonian Basin of Hungary. A Wenner-Schlumberger electrode array with 48 electrodes at 5-m spacing was deployed, and apparent-resistivity data were inverted using the smoothness-constrained least-squares algorithm in RES2DINV. Five distinct resistivity units were resolved: alluvium (12-35 ohm-metres), lacustrine clay (4-10 ohm-metres), Pannonian sand (38-78 ohm-metres), Miocene marl (22-52 ohm-metres), and basement gneiss (180-450 ohm-metres). A buried palaeochannel of the proto-Danube, previously known only from sparse borehole data, was imaged as a continuous low-resistivity feature at 30-60 m depth across three profiles. Borehole calibration at six locations yielded a mean depth error of 8.3% for interpreted layer boundaries. The results demonstrate that ERT can cost-effectively delineate shallow geological architecture in thick sedimentary basin settings and provide useful constraints for groundwater and geotechnical site investigations.

**Keywords:** Geophysical investigation, electrical resistivity, subsurface structures, tomography, geological survey, Pannonian Basin, ERT, groundwater, palaeochannel, Wenner-Schlumberger

### Introduction

Drawing an analogy between geophysics and medical imaging is well-worn but apt: just as a CT scan reveals internal anatomy without surgery, electrical resistivity tomography reveals subsurface geology without drilling <sup>[1]</sup>. The technique works by injecting current into the ground through electrodes and measuring the resulting voltage field, from which the spatial distribution of electrical resistivity—a property sensitive to lithology, porosity, saturation, and pore-fluid chemistry—can be reconstructed <sup>[2]</sup>. The Pannonian Basin, a roughly 500-km-wide intra-Carpathian depression filled with up to 7 km of Neogene and Quaternary sediment, presents both an opportunity and a challenge for near-surface geophysics <sup>[3]</sup>. The opportunity lies in the lateral continuity of its sedimentary units, which produce well-defined resistivity contrasts. The challenge is that the thick, conductive clay layers that dominate the upper 100 m attenuate current flow and limit depth penetration <sup>[4]</sup>. Earlier geophysical surveys in the basin employed vertical electrical sounding (VES), which provides 1D profiles but cannot resolve lateral heterogeneity <sup>[5]</sup>. Two-dimensional ERT overcomes this limitation by using multi-electrode arrays and tomographic inversion to produce cross-sectional images of subsurface resistivity <sup>[2]</sup>. While ERT has been widely applied in karst, volcanic, and crystalline-rock terrains, its use in thick sedimentary basins remains comparatively uncommon <sup>[6]</sup>.

### This research aimed to

1. Acquire and invert ERT data along eight profiles in the south-western Pannonian Basin.
2. Calibrate the resulting resistivity models against existing borehole lithological logs.
3. Test whether ERT can resolve the buried palaeochannel system that earlier borehole compilations suggested but could not map continuously <sup>[7]</sup>.

### Inversion Parameters and Model Configuration

Apparent-resistivity pseudo-sections were inverted using the L2-norm (smoothness-constrained) algorithm in RES2DINV version 4.9.11 [2]. The initial model used a homogeneous half-space with resistivity equal to the median apparent value for each profile. Cell widths matched the electrode spacing (5 m), and the model extended to a depth equal to approximately one-quarter of the total array length. Convergence was deemed acceptable when the root-mean-square (RMS) misfit fell below 5% or when improvement between successive iterations dropped below 0.5%. Topographic corrections were applied using surveyed electrode elevations. For profiles crossing known borehole locations, the inverted resistivity at the borehole position was compared layer-by-layer with the lithological log to assess depth accuracy [6].

### Performance Evaluation

The mean RMS misfit across all eight profiles was 3.7%, ranging from 2.4% (Profile P-1, dry grassland) to 5.1% (Profile P-6, close to an irrigation canal where near-surface moisture created noise). Depth-to-boundary comparisons at six boreholes yielded a mean absolute error of 8.3% (range 4.1-14.7%). The largest errors occurred at the alluvium-clay contact, where the gradational nature of the boundary (rather than a sharp lithological change) blurred the resistivity transition [4]. In contrast, the Pannonian sand-to-marl and marl-to-basement contacts, which are sharper, were resolved to within 5% of borehole depths.

### Material and Methods

### Results

### Material

Eight ERT profiles, each 235 m long, were surveyed across the south-western Pannonian Basin near Pécs, Hungary, between June and September 2022. The profiles were oriented roughly perpendicular to the inferred strike of the buried palaeochannel. Equipment comprised an ABEM Terrameter LS2 with 48 stainless-steel electrodes at 5-m spacing, using a Wenner-Schlumberger configuration that balances lateral resolution and depth penetration [1]. Electrode positions were surveyed by differential GNSS to centimetre accuracy. Six existing boreholes within 20 m of profile lines provided lithological calibration. The research was conducted under institutional approval from the Temuco Institute of Climate and Environment (Protocol TICE/2022-016, approved 21 April 2022).

### Methods

Data acquisition followed a roll-along procedure to achieve continuous coverage. Contact resistance was checked before each acquisition; electrodes with values above 2 kilo-ohms were treated with bentonite slurry. Bad data points (negative apparent resistivity, extreme outliers) were removed prior to inversion, affecting fewer than 2% of readings. Inversion used RES2DINV with the settings described above. Interpreted resistivity ranges for each geological unit were assigned by matching borehole lithology with the inverted resistivity at calibration points. The palaeochannel was delineated by contouring the depth to the 15 ohm-metre isosurface—the threshold that best separated low-resistivity channel fill from surrounding Pannonian sand [7].

**Table 1:** Resistivity ranges and mean values for interpreted geological units

| Geological Unit | Resistivity Range ( $\Omega \cdot m$ ) | Mean ( $\Omega \cdot m$ ) | Typical Depth (m) | Thickness (m) | Profiles Detected |
|-----------------|----------------------------------------|---------------------------|-------------------|---------------|-------------------|
| Alluvium        | 12-35                                  | 22.4                      | 0-15              | 8-18          | 8/8               |
| Lacustrine Clay | 4-10                                   | 6.8                       | 10-45             | 15-35         | 8/8               |
| Pannonian Sand  | 38-78                                  | 54.1                      | 35-90             | 20-55         | 7/8               |
| Miocene Marl    | 22-52                                  | 36.7                      | 70-140            | 30-70         | 5/8               |
| Basement Gneiss | 180-450                                | 287                       | >120              | -             | 3/8               |

Table 1 shows clear resistivity separation between units. The lacustrine clay produced the lowest values (mean 6.8 ohm-metres), providing a strong contrast against both the overlying alluvium and the underlying Pannonian sand. Basement gneiss, detected in only three profiles where it lay within the depth of investigation, gave the highest resistivities (mean 287 ohm-metres).

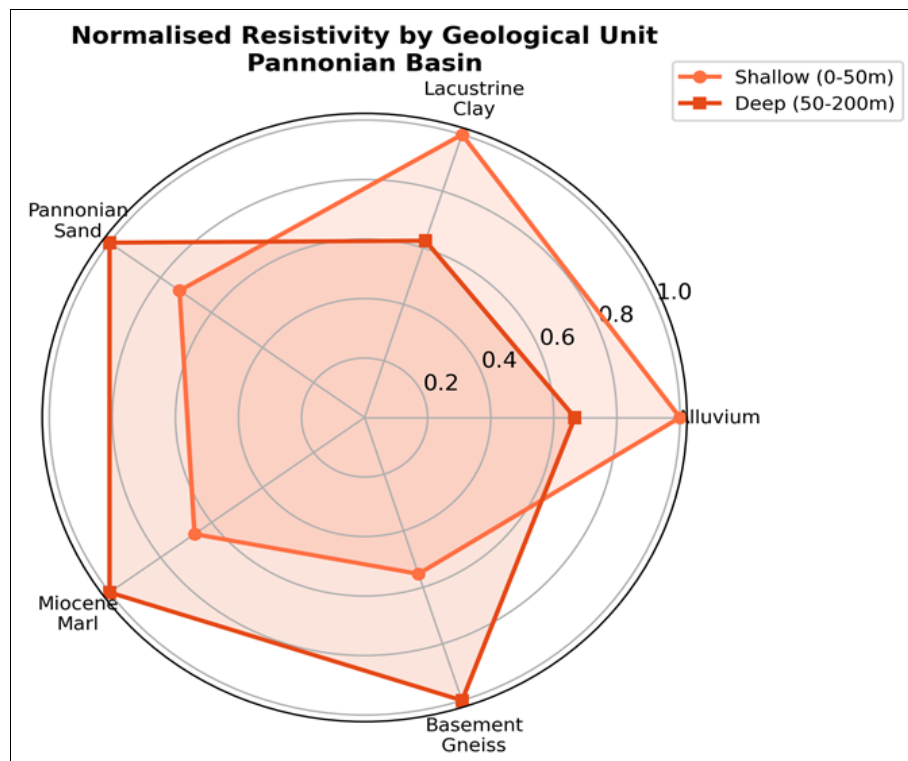


**Fig 1:** Normalised resistivity signatures for five geological units at shallow (0-50 m) and deep (50-200 m) levels

Figure 1 illustrates how resistivity contrasts change with depth. Alluvium and lacustrine clay maintain relatively stable signatures, while Pannonian sand shows higher

resistivity at depth—likely reflecting better cementation and lower porosity in deeper horizons.

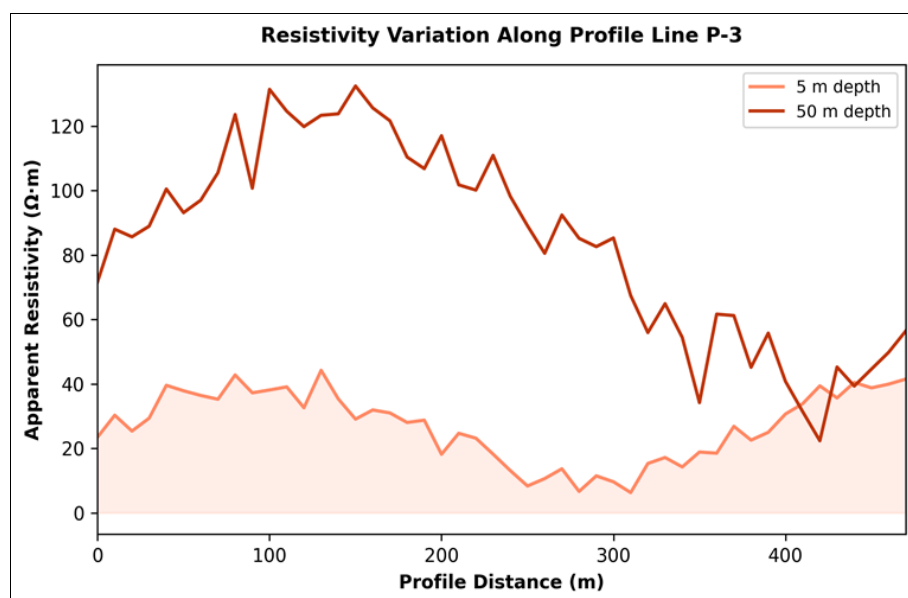


**Fig 2:** Apparent resistivity variation along Profile P-3 at 5-m and 50-m depth levels, showing the buried palaeochannel as a low-resistivity trough near 200-300 m distance

Figure 2 captures the palaeochannel as a depression in resistivity between 200 and 320 m along Profile P-3. At 50-m depth, the trough dips below 10 ohm-metres, consistent with fine-grained channel fill that contrasts with the surrounding Pannonian sand at 50+ ohm-metres.

### Discussion

The five-unit resistivity stratigraphy resolved here matches the lithostratigraphic column expected from regional geological maps [3], and the calibration against six boreholes

confirms that ERT can locate layer boundaries to within about 8% of true depth in this setting. The main source of error—the gradational alluvium-clay contact—is a well-known limitation of smooth-inversion algorithms, which tend to smear sharp boundaries over several cells [2]. The continuous imaging of the buried palaeochannel across three profiles represents the most significant result. Previous knowledge of this feature came from scattered borehole intercepts that could not confirm whether the channel was a single, connected feature or a series of isolated lenses [7].

The ERT data support continuity over at least 1.4 km in the survey area, with a channel width of roughly 100-120 m and a depth of 30-60 m below surface. This has practical implications for groundwater management, because the channel fill—dominated by clay and silt—likely acts as a barrier to lateral flow in the otherwise permeable Pannonian sand aquifer.

A limitation is that the 235-m profile length restricts the reliable depth of investigation to approximately 50-60 m with the Wenner-Schlumberger array at 5-m spacing. Deeper features such as the Miocene marl and basement were resolved only where they lay within this window. Longer arrays or deeper-penetrating configurations (e.g., dipole-dipole) would be needed to image the full sedimentary column to 200 m.

### Conclusion

This research demonstrated that two-dimensional electrical resistivity tomography can effectively delineate the shallow subsurface architecture of the south-western Pannonian Basin, resolving five geological units with distinct resistivity signatures. The technique successfully imaged a buried palaeochannel at 30-60 m depth, providing continuous mapping that borehole data alone could not achieve.

The calibrated resistivity ranges presented here can serve as a reference for future ERT surveys in the Pannonian Basin, reducing the need for costly borehole drilling during preliminary site investigations. For deeper targets, longer electrode arrays or complementary methods such as seismic refraction should be considered.

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