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Electrical Resistivity Tomography as a Tool for Geological-Engineering Assessment of the Benkovski-2 Tailings Storage Facility

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Abstract: Geophysical methods, and in particular electrical resistivity tomography (ERT), have proven to be highly suitable for investigating tailings storage facilities (TSFs) and addressing a wide range of engineering–geological problems. Their ability to delineate subsurface structures and identify zones with contrasting physical properties makes them an effective tool for monitoring the internal stability and hydrogeological conditions of such complex anthropogenic systems. A geophysical survey based on two-dimensional electrical resistivity tomography (ERT) was carried out at the "Suludza Dere" tailings storage facility (TSF). The objective was to determine the specific electrical resistivity distribution within a section of the TSF and to determine the spatial distribution of materials with varying resistivity, reflecting differences in composition and structural characteristics. Within this context, the 2D ERT survey was conducted to provide a detailed subsurface cross-section and identify zones with contrasting resistivity properties. The results serve as a basis for better understanding of the internal structure and hydrogeological conditions of the TSF, supporting its sustainable monitoring and safe operation.

Keywords: Mine saste, Geophysics, Electrical tomography, Monitoring

Introduction

A shallow, non-destructive geophysical technique, electrical resistivity tomography (ERT), is one of the most widely applied methods for subsurface imaging. Over the past three decades, it has been successfully employed in mineral prospecting, hydrological exploration, environmental investigations, civil engineering, and archaeological mapping. The popularity of ERT is due to its ability to generate high-resolution two-dimensional and three-dimensional models of the subsurface by measuring the spatial variability of electrical resistivity, a physical parameter that is highly sensitive to lithology, porosity, water content, and fluid chemistry.

In the broader context of Industry 4.0 and the digital transformation of mining and geotechnical systems, the implementation of intelligent technologies for monitoring and risk management has become a fundamental component of sustainable resource extraction (Nikolov, 2023; Nikolov & Koleva, 2025). The increasing use of artificial intelligence (AI) and data-driven models in industrial and educational systems highlights both the potential and the associated risks of automation and human–machine interaction (Koleva, 2024; Koleva & Nikolov, 2025). These technological frameworks provide a valuable foundation for integrating advanced geophysical monitoring tools, such as ERT, within smart decision-support systems for mine safety and stability assessment (Nikolov & Koleva, 2025).

Numerous studies have documented the significant environmental impacts associated with mining activities, particularly those resulting from leakages or failures of tailings storage facilities. As Dimitrov stated, the storage of tailings always is one of the major challenges (Dimitrov et al., 2023). The extraction of valgenerateeral

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resources inevitably generates substantial quantities of waste material, most notably tailings-mixtures of finely ground rock particles and residual process fluids produced by milling, washing, or concentration operations after the recovery of economically important metals, minerals, or fuels (Yankova, 2021; Farjana et al., 2019; Kossoff et al., 2014). These fine-grained residues are typically stored in large impoundments or tailing dams to prevent their release into the environment. Efficient and safe disposal of the waste generated in the mining activity is one of the most important things in the mining industry (Dimitrov & Grigorova, 2023). Keeping the tailings pond safe and stable is the most challenging task in the entire mining process (Lyu et al., 2019).

Many authors highlighted that electrical resistivity tomography (ERT) is a promising technique for monitoring various subsurface processes (Loke et al., 2013, Binley et al., 2015, Slater and Binley, 2021, Dimech et al., 2022). In the field of waste management, ERT has emerged as a particularly valuable tool for investigating tailings storage facilities (TSFs). It allows for the determination of the geometry of pond bases, the thickness and distribution of tailings, and the delineation of zones with contrasting material properties. More importantly, resistivity measurements can be used to detect early-stage processes such as anomalous seepage, internal erosion, or preferential flow pathways. These features, if not properly identified and controlled, may compromise the stability of tailings dams, leading to environmental hazards and severe socio-economic consequences (Aleksandrova et al., 2017). Compared to conventional geotechnical methods, ERT offers the advantages of being non-invasive, cost-effective, and capable of covering large areas with minimal disturbance to the facility. Recent studies have demonstrated its utility in assessing the integrity of TSF embankments and monitoring temporal changes in moisture and porewater distribution.

The Benkovski-2 TSF, located in Bulgaria, serves as a deposition site for flotation tailings generated by the concentrator plant processing ore from the Elatsite porphyry copper deposit. Copper is the primary industrial element, accompanied by gold and molybdenum as secondary components. The tailings are transported as slurry through a hydro-transport system and separated via hydrocycloning, whereby coarse sands are used to build the supporting dam walls, while the finer fractions are deposited in the impoundment basin. The facility is divided into two sectors, “Ai Dere” and “Suludza Dere,” where dam walls are successively raised with hydrocycloned sand. A combined drainage system beneath both sectors ensures overall structural stability by directing drainage waters outside the dam walls and into a pumping station, from which they are returned to the concentrator plant water cycle.

Description of the Technology

A geophysical survey employing 2D ERT was carried out in the Suludza Dere sector of the Benkovski-2 TSF. The survey was conducted with the primary goal of characterizing the electrical resistivity distribution within a section defined by predetermined coordinates. It aimed to generate a detailed subsurface cross-section, highlighting zones of contrasting resistivity, and to outline the spatial variability of materials whose differing responses reflect variations in composition, grain size, and structural characteristics. The measurements are acquired using specific electrode configurations (e.g., Wenner, Schlumberger, or dipole–dipole), which determine the depth of investigation and the sensitivity to lateral and vertical variations. By systematically shifting and expanding the electrode spacing along a survey line, a dense dataset of apparent resistivity values is obtained. These data are then processed through inversion algorithms that minimize the difference between measured and calculated responses, producing two-dimensional resistivity models of the subsurface. Such models allow the detection of zones with contrasting physical properties, which in tailings facilities may correspond to variations in grain size, moisture content, saturation levels, or seepage pathways. As noted from many authors, the potential of this method is higher when the contrast in resistivity between the objects is important (Scapozza & Laigre, 2014, Baines et al., 2002). The results are expected to enhance understanding of the internal structure and hydrogeological regime of the TSF, thereby supporting its effective monitoring, safe operation, and sustainable management.

Electrical resistivity tomography (ERT) is a non-invasive geophysical method that images the subsurface by measuring the apparent resistivity of the ground. The technique is based on the injection of a direct electrical current into the subsurface through a pair of electrodes and the simultaneous measurement of the resulting potential differences at other electrodes positioned along a survey line (Lesmes & Friedman, 2005). By systematically varying the spacing and position of the current and potential electrodes, a large dataset of apparent resistivity values is collected, reflecting the electrical properties of the subsurface at different depths and lateral positions.

The measured resistivity values are strongly influenced by factors such as lithology, porosity, water saturation, and pore fluid chemistry. Through inversion algorithms, the apparent resistivity data are converted into two-dimensional (or three-dimensional) models that represent the true resistivity distribution of the subsurface. These models allow the identification of geological structures, stratigraphic variations, and zones of differing material properties.

The method is widely recognized for its ability to resolve subsurface contrasts in a cost-effective and non-destructive manner, making it particularly suitable for monitoring tailings storage facilities. In such environments, ERT can provide information on dam wall construction materials, pond base geometry, tailings thickness, seepage pathways, and internal erosion processes-critical factors for assessing structural stability and hydrogeological conditions.

Field Measurements and Results

On the field survey at the Suludza Dere sector of the Benkovski-2 TSF, a multi-electrode resistivity system was employed, consisting of ZZ Universal 96, with 96 stainless-steel electrodes connected via multicore cables and an automatic switching unit. The electrode spacing was set to 10 m, allowing coverage of a profile length of 960 m. Position of the ERT line follows the drainage system on site, as it is presented in Figure 1.

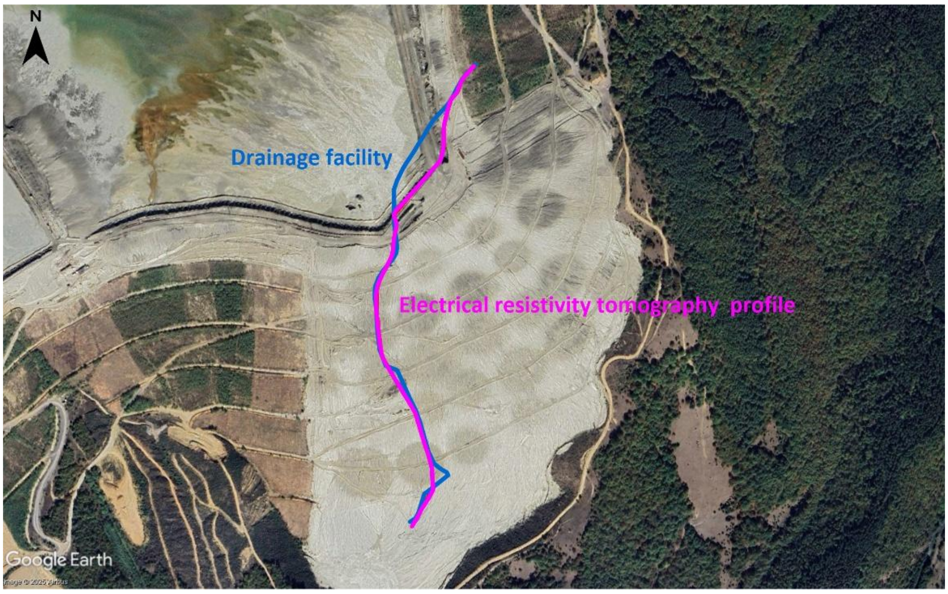

Figure 1. Field situation

The resistivity measurements were carried out using the Schlumberger configuration (Figure 2), which provides a balance between vertical resolution and depth penetration, making it suitable for imaging layered structures and detecting lateral variations in tailings deposits.

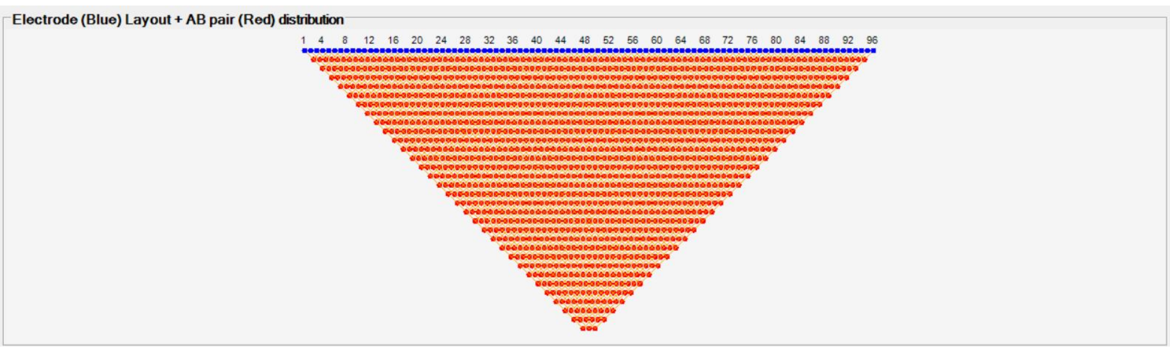

Figure 2. 96 channel data-acquisition layout

The apparent resistivity dataset was processed using a standard least-squares inversion algorithm implemented in RES2DINV (Loki, 2001), which iteratively minimized the difference between measured and calculated data.

The resistivity model generated from the ERT survey was further refined and adjusted to reflect the site-specific geological conditions of the study area. This process involved the integration of several complementary datasets. First, general geological information, including the lithological, facies, tectonic, and hydrogeological framework of the region, was considered to place the geophysical results into a broader geological context. Second, reference values of the specific electrical resistivity for different rock types were used to constrain the interpretation of zones with contrasting resistivity responses. The combined use of these datasets ensured that the resulting resistivity sections were both geophysical consistent and geologically meaningful, thereby improving the reliability of the interpretation (Figure 3). Upon completion of the inversion process, the resulting resistivity model provides a distribution that best fits the observed data. This model is considered an approximation of the true subsurface resistivity structure, while recognizing that it is influenced by inherent limitations such as prior assumptions, data quality, modelling uncertainties, resolution constraints, and the non-uniqueness of the inversion results (Whiteley et al., 2019).

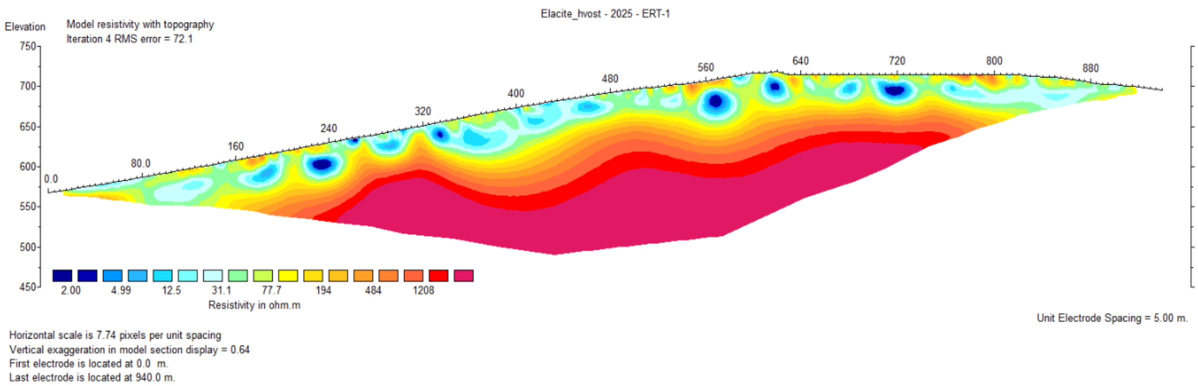

Figure 3. Electrical tomography line

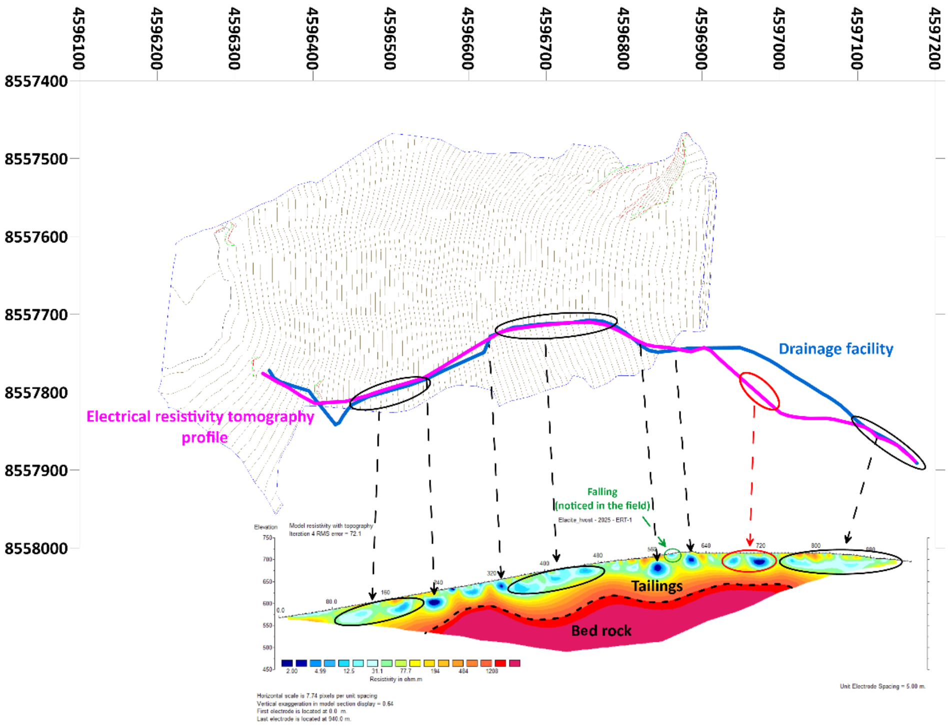

Figure 4. Comprehensive examination of the measured ERT profile and the location of the investigated drainage system

The analysis of the ERT results provides several important insights into the subsurface conditions of the Suludza Dere sector. The resistivity distribution along the geoelectrical profile is well defined, with values ranging widely between approximately 2 Ωm and more than 2000 Ωm. The depth of investigation reached about 200 m, allowing the identification of two main geoelectrical domains: a low-resistivity zone in the shallow section, interpreted as hydrocycloned tailings deposits, and a high-resistivity zone at greater depths, corresponding to the natural bedrock. Zones with elevated resistivity values in the range of 500–2000 Ωm are most likely associated with the underlying natural terrain, whereas areas with lower resistivity, between 2 and 200 Ωm, are indicative of the tailing's material. The contact between these two units is gradual rather than abrupt, reflecting the penetration of tailings into surface irregularities of the natural terrain and their integration with the upper soil layer as it is shown on Figure 4. The contact zones between the embankment and natural media, although not sharply defined, provide valuable information on the embedding of tailings material in terrain and its interaction with the surface soil layer.

The drainage system beneath the embankment is clearly distinguishable on the resistivity profile, where drained material is characterized by very low resistivity values (2–30 Ωm) compared to the overlying tailings (50–200 Ωm) and the natural foundation (>200 Ωm). At locations where the profile intersects the drainage system transversely, round-shaped resistivity anomalies are observed, while elongated anomalies are recorded where the profile runs parallel to the system. Additionally, detected resistivity anomalies that do not correspond to the known drainage system indicate the presence of other underground installations or structural elements such as a pipeline or auxiliary drain. (mark with red on the Figure 4). Particular attention should be paid to the low-resistivity surface anomaly observed in the 560–640 m interval, which coincides with a subsidence detected in the field. This finding highlights the significance of ERT methods not only for structural and lithological interpretation but also for early detection of potential geotechnical issues.

Conclusion

The conducted 2D electrical resistivity tomography (ERT) survey in the "Suludja Dere" section of the "Benkovski – 2" tailings storage facility (TSF) confirms the high effectiveness of electrical tomography as a tool for geotechnical and engineering-geological applications. The results clearly demonstrate the differentiation of geological media based on their electrical resistivity, enabling reliable discrimination between tailings deposits and drainage systems (characterized by low resistivity values) and the bedrock of the natural terrain (with high resistivity values). In a broader context, the results of this study demonstrate that electrical tomography constitutes a reliable tool for integrated assessment of the stability and functionality of tailings storage facilities. It provides complementary information to traditional engineering-geological investigations and is applicable for developing strategies for sustainable management and monitoring of mining waste.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

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References

Aleksandrova, E., Sokolova, E., & Topalova, M. (2017). Study of the type and nature of the main sources of pollution in the Rhodope Mining Basin. In *National Scientific Conference with International Participation "Science and Society"* (pp. 534-537).

Baines, D., Smith, D. G., Froese, D. G., Bauman, P., & Nimeck, G. (2002). Electrical resistivity ground imaging (ERGI): A new tool for mapping the lithology and geometry of channel-belts and valley-fills. *Sedimentology, 49*(3), 441-449.

Binley, A., Hubbard, S. S., Huisman, J. A., et al. (2015). The emergence of hydrogeophysics for improved understanding of subsurface processes over multiple scales. *Water Resources Research, 51*(6), 3837-3866.

Dimech, A., Cheng, L. Z., Chouteau, M., Chambers, J., Uhlemann, S., Wilkinson, P., Meldrum, P., Mary, B., Fabien-Ouellet, G., & Isabelle, A. (2022). A review on applications of time-lapse electrical resistivity tomography over the last 30 years: Perspectives for mining waste monitoring. *Surveys in Geophysics, 43*, 1699-1759.

Dimitrov, L., & Grigorova, I. (2023). Improved tailings consolidation using dewatering agents: A step towards safer and sustainable mining waste management. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 23*, 225-231.

Dimitrov, L., Grigorova, I., & Yankova, T. (2023). Possibilities to construct combined mine waste dump facility with better operational sequence. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 23*, 42-49.

Koleva, N. (2024). Human in cooperation with AI - Next level of intelligent man-machine interaction. *Proceedings of World Multi-Conference on Systemics, Cybernetics and Informatics (WMSCI)*.

Koleva, N., & Nikolov, B. (2025). Main risks caused by the application of artificial intelligence in educational institutions in Bulgaria. *American Institute of Physics*.

Kossoff, D., Dubbin, W., Alfredsson, M., Edwards, S., Macklin, M., & Hudson-Edwards, K. (2014). Mine tailings dams: Characteristics, failure, environmental impacts, and remediation. *Applied Geochemistry, 51*, 229–245.

Lesmes, D. P., & Friedman, S. P. (2005). Relationships between the electrical and hydrogeological properties of rocks and soils. In Y. Rubin & S. S. Hubbard (Eds.), *Hydrogeophysics* (pp. 87–128). Springer.

Loke, M. H. (2001). *Tutorial: 2-D and 3-D electrical imaging surveys* (Course notes). USGS Workshop "2-D and 3-D Inversion and Modeling of Surface and Borehole Resistivity Data".

Loke, M., Chambers, J., Rucker, D., et al. (2013). Recent developments in the direct-current geoelectrical imaging method. *Journal of Applied Geophysics, 95*, 135-156.

Lyu, Z., Chai, J., Xu, Z., Qin, Y., & Cao, J. (2019). A comprehensive review on reasons for tailings dam failures based on case history. *Advances in Civil Engineering, 2019*, 1-18.

Nikolov, B. (2023). Main pillars building up the risk frame of Industry 4.0 implementation in the enterprises in Bulgaria. *Economic Studies (Ikonomicheski Izsledvania), 32*(7), 77–92.

Nikolov, B., & Koleva, N. (2025). Risks in managing smart factories. *Proceedings IMCIC - International Multi-Conference on Complexity, Informatics and Cybernetics*.

Scapozza, C., & Laigre, L. (2014). The contribution of electrical resistivity tomography (ERT) in Alpine dynamics geomorphology: Case studies from the Swiss Alps. *Géomorphologie: Relief, Processus, Environnement, 20*(1).

Slater, L., & Binley, A. (2021). Advancing hydrological process understanding from long-term resistivity monitoring systems. *Wiley Interdisciplinary Reviews: Water, 8*(3), e1513.

Whiteley, J., Chambers, J., Uhlemann, S., et al. (2019). Geophysical monitoring of moisture-induced landslides: A review. *Reviews of Geophysics, 57*(1), 106-145.

Yankova, T. (2021). Mining-damaged landscape reclamation study. In O. Trofymchuk & B. Rivza (Eds.), *21st International Multidisciplinary Scientific GeoConference SGEM 2021* (Vol. 21, No. 1.1).

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