

GEOPHYSICAL METHODS FOR EFFECTIVE PLANNING AND OPTIMISATION OF MINERAL RESOURCE EXTRACTION IN THE CONTEXT OF CIRCULAR ECONOMY AND SUSTAINABLE RISK MANAGEMENT

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ABSTRACT. This paper examines the role of geophysical methods in the efficient planning and optimisation of mineral resource extraction within the framework of circular economy and sustainable risk management. The main geophysical methods are analysed as non-destructive tools for subsurface investigation, providing reliable information on geological structures and the physical properties of the rock mass. The study demonstrates that the integration of geophysical data into mine planning improves the accuracy of deposit modelling, supports selective mining, reduces investment costs, and limits the generation of mining waste. Special attention is given to the application of geophysics in managing geological, geomechanical, hydrogeological, and environmental risks through continuous monitoring and early detection of potentially hazardous processes. The relationship between geophysical methods and circular economy principles is also discussed, including the re-evaluation of tailings storage facilities and mining waste in order to enhance resource efficiency. Examples from the Bulgarian mining practices are presented, highlighting the importance of geophysics as a strategic tool for improving operational efficiency, safety, and the sustainable development of the mining sector.

Key words: Applied Geophysics, circular economy, mine planning.

ГЕОФИЗИЧНИ МЕТОДИ ЗА ЕФЕКТИВНО ПЛАНИРАНЕ И ОПТИМИЗАЦИЯ НА ДОБИВА НА ПОЛЕЗНИ ИЗКОПАЕМИ В КОНТЕКСТА НА КРЪГОВАТА ИКОНОМИКА И УСТОЙЧИВОТО УПРАВЛЕНИЕ НА РИСКОВЕТЕ

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РЕЗЮМЕ. Настоящата статия разглежда ролята на геофизичните методи за ефективно планиране и оптимизация на добива на полезни изкопаеми в условията на кръгова икономика и устойчиво управление на рисковете. Анализирани са основните геофизични методи като инструменти за неинвазивно изследване на подземната среда и за получаване на надеждна информация за геоложкия строеж и свойствата на скалния масив. Показано е, че интегрирането на геофизични данни в минното планиране повишава точността при моделирането на находищата, подпомага селективния добив, намалява инвестиционните разходи и ограничава количеството генерирани отпадъци.

Особено внимание е отделено на приложението на геофизиката при управлението на геоложки, геомеханични, хидрогеоложки и екологични рискове чрез мониторинг и ранна диагностика на потенциално опасни процеси. Разгледана е връзката между геофизичните методи и принципите на кръговата икономика, включително повторната оценка на хвостохранилища и минни отпадъци с цел по-пълноценно използване на ресурсите. Представени са примери от българската миннодобивна практика, които доказват значението на геофизиката като стратегически инструмент за повишаване на ефективността, безопасността и устойчивото развитие на минния сектор.

Ключови думи: Приложна геофизика, кръгова икономика, минно планиране.

Introduction

Mining industry occupies a key position in the economy of the Republic of Bulgaria, providing strategic raw materials for various industrial sectors (BCMG, 2024). At the same time, exploration and extraction activities are associated with significant geological, technological, and environmental risks (Hartman & Mutmanský, 2002). In the context of increasingly strong European and national policies for sustainable development and circular economy, there is a need to implement scientifically grounded, highly efficient, and environmentally friendly methods for resource management (European Commission, 2015).

Geophysical methods have established themselves as an indispensable tool for non-destructive investigation of the subsurface, supporting informed decision-making in the planning, operation, and closure of mining sites, while reducing risk, costs, and environmental impact (Lowrie, 2007; Reynolds, 2011).

Theoretical foundations of geophysical methods

Seismic methods

Seismic methods use the dispersing of elastic waves to map

geological structures and ore bodies (Telford et al., 1990). They allow determination of the shape, depth, and spatial distribution of deposits, which is critical for efficient planning for the mining operations (Lowrie, 2007).

Electric and electromagnetic methods

These methods measure variations in electrical conductivity and electromagnetic properties of rocks. They are used in the search for sulphide ores, metallic bodies, and in monitoring groundwater contamination (Reynolds, 2011), as well as for engineering-geological assessment and monitoring conditions of tailings facilities and water retention in a mining waste storage facility (Kisyov, 2025; Kisyov et al., 2025; Milenkovic, 2025; Tomova & Kisyov, 2025a, b; Tomova et al., 2025).

Gravimetric and magnetic methods

Gravimetric and magnetic analyses are useful for regional exploration of structures with anomaly of density and magnetic properties (Lowrie, 2007). These techniques reduce the need for expensive drilling by identifying promising zones (Telford et al., 1990).

Ground penetrating radar (GPR)

The GPR method is suitable for shallow investigations and control by time of exploitation, including such activities as

detecting cavities, assessing slope stability, and monitoring infrastructure around mining sites (Everett, 2013).

Application of geophysical methods in mine planning and optimisation of mineral resources

The role of geophysical data in mine planning

Mine planning is a complex multi-stage process that includes exploration, design, operation, and closure of mining sites (Hartman & Mutmanský, 2002). The quality of decision-making in this process is directly dependent on the availability of reliable and detailed information about the geological structure, the physical-mechanical properties of the rock mass, and the spatial distribution of ore bodies (Lowrie, 2007). In this context, geophysical methods play a key role, as they provide the opportunity for non-destructive and relatively rapid investigation of the subsurface environment (Table 1).

Table 1. *Fundamental geophysical methods and their application in mining planning*

Geophysical method	Physical parameter studied	Main application in mining	Contribution for optimisation
Seismic method	Speed of propagation of seismic waves	Identification of faults and structural disturbances	Increased safety and stability
Electrical resistivity method	Electrical resistivity	Mapping of ore bodies and aquifers	Selective mining and water control
Electromagnetic method	Electrical conductivity	Distinguishing mineral bodies	Waste reduction
Gravimetric method	Density	Regional study of structures	Optimization of investment costs
Geomagnetic method	Magnetic susceptibility	Search for ore anomalies	Directing detailed research

Geophysical data are used even in the early stages of exploration to delineate prospective zones, which allows for a significant reduction in the number of required drillings and optimisation of investment costs (Reynolds, 2011). At more advanced stages, they are employed in building geological and geomechanical models that support the selection of optimal mining technologies and the placement of mining activities.

The integration of geophysical results with drilling data and geological observations leads to the creation of three-dimensional models of deposits (Everett, 2013). These models form the basis for both long-term and short-term mine planning, resource estimation, and prediction of rock mass behaviour during exploitation. In this way, geophysics becomes not only a tool for exploration but also a strategic instrument for the management of mineral resources.

Optimisation of extraction through geophysical methods

The optimisation of mineral extraction is associated with achieving maximum economic efficiency while minimising environmental impact and ensuring occupational safety. Geophysical methods contribute to this optimisation by increasing the accuracy in defining ore body boundaries and by improving the understanding of the internal structure of deposits.

Seismic methods allow detailed tracking of fault zones and structural disturbances, which have a significant influence on the stability of the rock mass (Telford et al., 1990). Their timely

identification enables the adaptation of project solutions and the selection of safer routes for mine workings. This leads to a reduction in loss caused by accidents and interruptions in the production process.

Electrical and electromagnetic methods, on the other hand, are particularly effective in distinguishing ore bodies with different physical properties (Lowrie, 2007; Reynolds, 2011). They support selective mining, in which material with higher concentrations is extracted, while unnecessary costs for processing low-grade ores are limited. This approach is essential for improving resource efficiency and reducing the amount of generated waste.

Gravimetric and magnetic studies contribute to the optimisation by covering large areas at a regional scale and identifying anomalies that guide subsequent detailed investigations. In this way, a balance is achieved between the level of detail and the economic feasibility, which is a key factor for the sustainable development of mining enterprises.

Geophysical methods for managing geological and technological risks

Mining is associated with a range of risks, including collapses, flooding, gas occurrences, and ground surface deformations. The effective management of these risks requires timely information about the condition of the rock mass and the dynamics of ongoing processes. Geophysical methods provide the opportunity for early diagnosis of potentially hazardous zones and for monitoring during operation.

Seismic monitoring is used to record microseismical events, which may serve as indicators of stress accumulation within the rock mass. The analysis of these data allows for the prediction of possible collapses and the implementation of preventive measures.

Ground-penetrating radar (GPR) investigations are particularly useful for shallow zones and for controlling the stability of slopes and underground workings.

Hydrogeological risks associated with sudden inflows of groundwater can also be assessed using electrical and electromagnetic methods. These methods allow the tracking of aquifers and zones with increased water saturation, which is essential for the safe operation of underground mines.

Bulgarian examples of the application of geophysical methods

In Bulgarian mining practices, geophysical methods are widely applied both during the exploration stage and throughout the exploitation of deposits (Dimovski et al., 2017, 2023; Grigorova et al., 2017; Ivanov et al., 2017; BCMG, 2024; Kisyov, 2025; Kisyov et al., 2025; Tomova & Kisyov, 2025a, b; Tomova et al., 2025). Particularly illustrative are the examples from the copper mining sector, where the complex geological structure imposes the use of an integrated approach.

In enterprises such as Assarel-Medet, geophysical data are used for long-term planning of open-pit mining, for assessing slope stability, and for managing geomechanical risks. Through the integration of seismic, magnetic, and electrical surveys, more accurate modelling of ore bodies is achieved, along with optimisation of production processes.

In the coal mining sector, geophysical methods are applied to identify fault zones and gas-bearing layers, contributing to increased safety and reduced risk of accidents. In quarries for inert materials, ground-penetrating radar (GPR) and electrical

prospecting are used for raw material quality control and for optimal planning of extraction fronts.

These examples demonstrate that geophysical methods significantly contribute to improving the efficiency and sustainability of the mining sector in Bulgaria, while also supporting the implementation of best practices in resource management.

Geophysical methods in the context of the circular economy and sustainable development policies

The concept of circular economy and its importance for the mining sector

The circular economy represents an economic model aimed at the efficient use of resources through extending the life cycle of products, reusing materials, and minimising waste (European Commission, 2015; Sabri, 2023). Unlike the linear model “take–produce–dispose,” the circular approach seeks to close material loops and reduce pressure on natural resources (Figure 1).



Fig. 1. The role of geophysical methods as a connecting element in the circular economy model in the mining sector (“Figure from ‘Lean Circularity mogelijk maken met Smart Factory oplossingen.’ ” Novotek Group, 2025. <https://www.novotek.com/be/insight/lean-circularity/>).

The mining industry is traditionally regarded as a sector with high resource and energy intensity and significant environmental impact. For this reason, it occupies a key position in the transition to a circular economy. The main challenges facing the mining sector include the depletion of high-grade deposits, the increasing volume of mining waste, and the growing environmental and social requirements. In this context, the application of circular principles becomes a necessity rather than a choice.

Geophysical methods contribute to this transition by providing the information necessary for more efficient resource utilisation, re-evaluation of waste storage facilities, and reduction of the environmental footprint of mining activities (Table 2).

Table 2. Link between geophysical methods and principles of circular economy

Principles of circular economy	Role of geophysical methods
Efficient use of resources	More accurate determination of ore boundaries
Reuse	Tailings and waste assessment
Waste reduction	Selective mining
Prevention of environmental damage	Geophysical monitoring

European policies for the circular economy and the sustainable use of raw materials

The transition to a circular economy is among the leading priorities of the European Union. Over the past decade, a number of strategic documents have been adopted that directly affect the mining sector and the management of raw materials.

Among the key policies, the Circular Economy Action Plan stands out, emphasising sustainable resource management, waste reduction, and the promotion of innovation. Within this framework, mining waste and secondary raw materials are regarded as potential sources of valuable materials rather than as final waste for disposal.

Of particular importance is also the European Critical Raw Materials Strategy, which aims to reduce import dependency and increase domestic extraction and recycling. In this context, the re-evaluation of old deposits, tailings storage facilities, and waste dumps is considered a strategic opportunity (European Commission, 2020). Geophysical methods play a key role in identifying residual resources and assessing their economic feasibility.

European policies also impose strict environmental protection requirements, including those related to groundwater, the stability of tailings facilities, and the reclamation of disturbed land. This further increases the importance of geophysical monitoring as a tool for preventing environmental risks and ensuring long-term sustainable management.

Bulgarian policies and regulatory framework in the context of the circular economy

The national policy of the Republic of Bulgaria in the field of the circular economy is closely aligned with European strategic documents. The main document in this direction is the National Circular Economy Strategy, which sets objectives for improving resource efficiency and reducing the amount of waste (MOEW, 2022).

The mining sector occupies an important place in the national economy, which imposes the application of a balanced approach between economic development and environmental protection. Legislation in the field of mineral resources and waste management requires the implementation of environmental impact assessments, the monitoring of mining sites, and the application of reclamation measures.

In this context, geophysical methods are applied both in the initial planning of extraction and in the subsequent management of mining waste. Bulgarian practices show a growing interest in the re-evaluation of tailings storage facilities for the purpose of extracting residual quantities of metals, which is fully consistent with the principles of the circular economy.

The role of geophysical methods in the reuse of resources and mining waste management

One of the key aspects of the circular economy in mining is the reuse of resources contained in mining waste. Tailings storage facilities and waste dumps often contain significant quantities of valuable elements that were not economically recoverable at the time of initial extraction.

Electrical and electromagnetic geophysical methods enable the spatial mapping of waste masses and the identification of zones with increased metal content. This supports decision-making for selective reprocessing and reduces the need for large-scale destructive activities.

Geophysical investigations are also used to monitor the stability of tailings storage facilities, which are of particular

importance in the context of environmental risks and public safety. Through continuous monitoring of the physical parameters of these structures, accidents can be prevented and their sustainable management can be ensured (Tomova & Kisyov, 2025; Tomova et al., 2025).

Geophysical methods as a medium for the sustainable development of the mining sector

The integration of geophysical methods into circular economy strategies contributes to achieving several key objectives: improving resource efficiency, reducing environmental impact, and enhancing public perception of the mining industry.

Through more precise mine planning and the reuse of available resources, the need for developing new deposits and disturbing additional land areas is reduced. This is fully consistent with European and national policies for sustainable development and the conservation of natural capital.

Geophysical methods are increasingly recognised as a bridge between scientific research, industrial practice, and sustainable development policies. Their application enables the adaptation of the mining sector to new economic models and allows maintaining its competitiveness under increasingly stringent regulatory requirements.

Sustainable risk management in mining through geophysical methods

The nature of risk in mining activities

Mining activities are associated with a high degree of uncertainty and risk, arising from the complex geological structure of deposits, the dynamic processes within the rock mass, and the impact of human activity on the natural environment. Risk in mining can be defined as the probability of an adverse event that leads to economic, environmental, or social loss.

The main groups of risks include geological, geomechanical, hydrogeological, environmental, and technological risks. Their management requires a systematic and integrated approach based on reliable data and continuous monitoring. In this context, geophysical methods are established as a key instrument for the early identification, assessment, and control of risks (Hartman & Mutmanský, 2002; Everett, 2013; Stoyanov et al., 2024) (Table 3).

Table 3. Main risks in mining and applicable geophysical methods

Risk type	Manifestation	Geophysical method	Management effect
Geomechanical	Collapses, landslides	Seismic, GPR	Early diagnostics
Hydrogeological	Floods	Electro-reconnaissance	Water control
Ecological	Pollution	Geophysical monitoring	Prevention
Technological	Deformation	Microseismic	Safe mine operation

Geological and geomechanical risks

Geological and geomechanical risks are among the most significant in mining, as they are directly related to the stability of the rock mass and the safety of mine working. They include

collapses, landslides, fault ruptures, and unexpected changes in the lithological composition (Table 4).

Table 4. Examples of the application of geophysical methods in Bulgarian deposits

Enterprises	Type of mining	Applied geophysical methods	Main goal	Practical effect
Asarel-Medet	Copper ores (open pit)	Seismic, Magnetic, ERT, Magnetotelluric Borehole geophysics	Assessment of slope stability, Modeling of the copper bodies, Faults and water bearing zones	Geo-mechanically reducing risks, Mining optimisation, Increased safety
Ellatzite-Med	Copper ores (open pit)	ERT, Magnetic, EM	Modelling of the copper bodies	Mining optimisation
Chelopech Mine	Underground copper-gold mine	ERT, IP, EM, Magnetic, Magnetotelluric, Gravity Borehole geophysics	Modelling of copper bodies, Faults and water bearing zones	Mining optimisation, Increased safety
Mines Maritsa-Iztok	Coal	Seismic, ERT	Faults and water bearing zones	Increased safety
Kaolin-Senovo	Kaolin	GPR, ERT	Quality control (QC)	Selective mining
Aggregate quarries	Inert raw materials	GPR	Front control	Loss reduction

The electrical resistivity tomography (ERT) and Seismic geophysical methods allow detailed mapping of fault zones and structural disturbances, which represent potential sources of instability (Ivanov, 2017; Kisyov et al., 2024). Microseismic monitoring provides information on stress accumulation within the rock mass and enables the prediction of critical conditions.

Ground-penetrating radar (GPR) investigations are applied in shallow mine workings and open-pit mines, where they are used to detect cavities, zones of reduced density, and unstable slopes. Through timely interpretation of these data, preventive measures can be implemented, which significantly reduce the risk of accidents.

Hydrogeological risks and water management

Hydrogeological risks are associated with the presence and movement of groundwater and may lead to flooding, erosion, and deterioration of rock mass stability. Sudden water inflows, as well as the presence of suffusion zones (Dimovski et al., 2013), pose a serious threat both to the production process and to the life and health of mining personnel.

Electrical and electromagnetic geophysical methods are particularly effective in investigating aquifers and zones with increased water saturation. They enable spatial mapping of groundwater and assessment of its interaction with mine working. By integrating these data into mine planning, drainage systems can be optimised and hydrogeological incidents can be prevented.

Environmental risks and sustainable monitoring

Environmental risks in mining are associated with impacts on soil, water resources, and atmospheric air, as well as with the stability of tailings storage facilities and waste disposal sites. Disruption of the ecological balance may have long-term consequences for the environment and local communities.

Geophysical methods are used for contamination monitoring, controlling the infiltration of polluted water, and

assessing the stability of tailings facilities. Continuous geophysical monitoring enables early detection of adverse processes and the implementation of corrective measures, which is consistent with the principles of sustainable development and risk prevention.

Integrated approach to sustainable risk management

Effective risk management in mining requires the integration of geophysical data with geological, hydrogeological, and engineering analyses. By applying a systematic approach, greater reliability of predictions and better coordination between the different stages of mine planning can be achieved.

Geophysical methods not only reduce the likelihood of accidents but also contribute to cost optimisation and increasing public trust in the mining industry. This makes them an essential component of sustainable risk management.

Conclusion

The present study was devoted to investigating the role of geophysical methods in the effective planning and optimisation of mineral resource extraction within the context of the circular economy and sustainable risk management. Under the conditions of increasing pressure on natural resources and growing environmental and social requirements, this topic has gained particular relevance at both European and national levels.

The research established that geophysical methods represent a key tool for non-destructive investigation of the subsurface environment, significantly improving the quality of mine planning. Through the integration of geophysical data with drilling and geological information, more accurate models of deposits are created, leading to more efficient resource utilisation, cost reduction, and mitigation of technological and environmental risks.

The analysis demonstrated that geophysical methods make a substantial contribution to sustainable risk management in mining. They enable early identification of geological, geomechanical, and hydrogeological risks, as well as effective monitoring of tailings storage facilities and mining waste. This creates conditions for preventing accidents and improving occupational safety and environmental protection.

Particular attention was given to the role of geophysical methods in the context of the circular economy. It was found that through the re-evaluation of mining waste and tailings facilities, additional resource opportunities can be identified, which is in line with European and Bulgarian policies for sustainable use of raw materials. In this sense, geophysics is established not only as a technical tool but also as a strategic factor for the transition to a more sustainable model of mining development. The study provides a foundation for future scientific research, including the use of primary field data and the quantitative assessment of the effectiveness of different geophysical approaches.

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Literature

- Bulgarian Chamber of Mining and geology. (2024). Activity of the mineral and raw materials industry in Bulgaria. Impact on the national economy and the regions. Sofia. (In Bulgarian). https://bmgk.bg/wp-content/uploads/2024/11/Mining-sector-impact_IME_July_2024-V4.pdf
- Dimovski, S., Stoyanov, N., Kisyov, A., & Tzankov, Ch. (2017). Application of electrical resistivity tomography for studying fissure-karst water-bearing complexes. 9th Congress of the Balkan Geophysical Society, Antalya, Turkey.
- Dimovski, S., Stoyanov, N., Tsankov, C., & Kisyov, A. (2017). Geophysical approach for mapping old mine workings and deconsolidated zones in coal mining areas. *Annual of the University of Mining and Geology "St. Ivan Rilski"*, 60(1), 99–103 (In Bulgarian).
- Dimovski, S., Stoyanov, N., Kisyov, A., & Kolev, S. (2023). Application of the ERT method for three-dimensional mapping of geological objects. *XI National Geophysical Conference*, 1–4. ISSN 1314-2518. (In Bulgarian) <https://doi.org/10.48368/BGS-2023.1.N13>.
- Dimovski, S., Stoyanov, N., Kisyov, A. & Yankova, M. (2013). Application of electrotomography for mapping suffusion zones. *Annual of the University of Mining and Geology "St. Ivan Rilski"*, 56(1), 135–141 (In Bulgarian).
- Everett, M. E. (2013). *Near-surface applied geophysics*. Cambridge University Press.
- European Commission. (2015). Closing the loop – An EU action plan for the circular economy. Brussels. https://ec.europa.eu/commission/presscorner/detail/en/ip_19_1480
- European Commission. (2020). Critical raw materials resilience: Charting a path towards greater security and sustainability. Brussels. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0474>
- Grigorova, M., Tzankov, Ch, Kisyov, A, Koprev, I, Dimovski, S. (2017). Complex geophysical prospection – electrical resistivity tomography and geomagnetic survey for detecting limestone inclusions in Mini Maritsa Iztok EAD. *3rd International Scientific Conference GEOBALCANICA 2017*, 31–37.
- Grigorova, M., Tzankov, Ch., Kisyov, A., Koprev, I., & Dimovski, S. (2017). Complex geophysical prospection – electrical resistivity tomography and geomagnetic survey for detecting limestone inclusions in Mini Maritsa Iztok EAD. *3rd International Scientific Conference GEOBALCANICA 2017*, 31–37.
- Hartman, H. L., & Mutmansky, J. M. (2002). *Introductory mining engineering* (2nd ed.). Wiley.
- Ivanov, Y., Kisyov, A., Tzankov, C., & Nikolov, S. (2017). Application of electrical resistivity tomography for investigation of landslides. *Проблемы недропользования. Международный форум-конкурс молодых ученых, Санкт-Петербург*, 62–65. ISBN 978-5-94211-781-8.
- Kisyov, A. (2025). Risk assessment in integrated mining waste storage facility with geophysical methods. In N. Dobrinkova & S. Fidanova (Eds.), *Environmental Protection and Disaster Risks (EnviroRisks 2024)*. Lecture Notes in Networks and Systems (Vol. 883). Springer, Cham. https://doi.org/10.1007/978-3-031-74707-6_23
- Kisyov, A., Milenkovic, B., & Stoyanov, N. (2024). Application of the ERT method for mapping old landfills and the groundwater pollution caused by them. *Review of the*

- Bulgarian Geological Society*, 85(3), 293–296.
<https://doi.org/10.52215/rev.bgs.2024.85.3.293>
- Kisyov, A., Tomova, M., & Koprev, I. (2025). Geophysical methods for optimising mining waste management. In N. Dobrinkova & S. Fidanova (Eds.), *Environmental Protection and Disaster Risks (EnviroRisks 2024)*. Lecture Notes in Networks and Systems (Vol. 883). Springer, Cham. https://doi.org/10.1007/978-3-031-74707-6_22
- Lowrie, W. (2007). *Fundamentals of geophysics* (2nd ed.). Cambridge University Press.
- Milenkovich, B. (2025) Geophysical Monitoring for Sustainable Mining: Case Studies Using Electrical Resistivity Tomography. *Annual of the University of Mining and Geology “St. Ivan Rilski”*, 68, 35 - 39, ISSN 2738-8808
- Reynolds, J. M. (2011). *An introduction to applied and environmental geophysics* (2nd ed.). Wiley-Blackwell.
- Sabri, A. (2023). Sustainable development of industrial enterprises (dissertation). “D. A. Tsenov Academy of Economics”, Svishtov (In Bulgarian).
- Stoyanov, N., Dimovski, S., Panayotova, M., Bratkova, S., Angelov, A., & Kisyov, A. (2024). *Assessment and forecasting of groundwater pollution from natural and anthropogenic sources*. Sofia: Avangard Prima. ISBN 978-619-279-017-2 (In Bulgarian).
- Strategy for the transition to a circular economy 2022 – 2027. Ministry of environmental and water (MOEW) (In Bulgarian).
- Telford, W. M., Geldart, L. P., & Sheriff, R. E. (1990). *Applied geophysics* (2nd ed.). Cambridge University Press.
- Tomova, M. & Kisyov, A. (2025a). Geophysical evaluation of water drainage and containment in a mine waste storage facility: A comparative ERT study. *Annual of the University of Mining and Geology “St. Ivan Rilski”*, 68, 61–64. <https://doi.org/10.5281/zenodo.17155179>
- Tomova, M. & Kisyov, A. (2025b). Electrical resistivity tomography as a tool for geological-engineering assessment of the Benkovski-2 tailings storage facility (TSF). *The Eurasia Proceedings of Science, Technology, Engineering, and Mathematics*, 38, 682–687. <https://doi.org/10.55549/epstem.1265>
- Tomova, M., Kisyov, A., & Tsankov, C. (2025). Geophysical monitoring of Chelopech tailings storage facility conditions using electrical resistivity tomography. *Review of the Bulgarian Geological Society*, 86(3), 147–150. <https://doi.org/10.52215/rev.bgs.2025.86.3.147>