Proceedings of the 21st ICSMGE, Vienna, Austria, 14 – 19 June 2026. Pistrol, Adam & Schweiger (eds.)
Published by: ÖGG, Austrian Society for Geomechanics, Salzburg, Austria, ISBN 978-3-9503898-4-5
https://doi.org/10.53243/ICSMGE2026-183

About geotechnical investigations for difficult soils conditions consisting in a salt dome in the foundation ground of a motorway

Emilia Milutinovici
Mega Mühendislik Muşavirlik Anonim Sirketi, Bucharest Branch, Romania, emiliamilutinovici@gmail.com

Gürtan Doğu, Evren Güneşoğlu
Mega Mühendislik Muşavirlik Anonim Sirketi, Ankara, Turkey

Bahadır Boztepe, Erbil Balıkaya
Makyol Construction Industry Tourism and Trade Co. Inc., Sibiu Branch Office, Romania

ABSTRACT: The EU's trans-European transport network policy, the TEN-T policy, aims to develop a more efficient and high-quality transport infrastructure across the EU. Romania has the privilege to develop during this period many infrastructure projects to ensure the implementation of the TEN-T framework on its territory. These projects are in different stages of implementation, from feasibility studies to design and execution. In the southern part of Transylvania, in-situ investigations were carried out for the design of a motorway sector. The section is known to be an area with a good foundation ground, comprising a covering formation made up of alternating fine or coarse stiff, uncohesive deposits, and a marly bedrock. Following the site investigations, a body of salt was identified underground that extends along the length of the highway for about 500 m. The salt body occurs at depths between 17.00 and 23.00 m, down to depths of 40.00-45.00 m. It is much thicker in its eastern part, of about 20.0 m, thinning to the west, where its thickness is reduced to 5.00 m. Salt does not appear over as a massive body and is dispersed with in the marly formation that constitutes bedrock. Considering the fact that this salt body is part of the foundation ground of a future viaduct, whose project involved indirect foundation, on piles, it became extremely important to know the geometry and its properties, in order to choose a feasible foundation method. The in-situ investigation program involved geotechnical drilling, in-situ tests (penetration and presyometric tests) and geophysical investigations. The result of the interpretations of field and laboratory investigations will lead to the choice of a design solution that will ensure the stability and integrity of the future construction.

KEYWORDS: Salt dome, geotechnical investigations, deep foundations.

1 INTRODUCTION

This study focuses on the geotechnical and geological conditions in the area of the Mârșa River, located along the Sibiu–Făgăraș motorway in central Romania. The Mârșa River, a right tributary of the Olt River, flows through the southern edge of the Transylvanian Basin. During early-stage geotechnical and geophysical investigations, an underground salt body was identified extending beneath the motorway alignment for approximately 500.00 m.

To better understand the geometry, extent, and composition of this salt body, additional and more detailed investigations were carried out. These included geotechnical drilling, geophysical measurements, and a suite of in-situ tests such as DPSH, CPT, CPTu, and Menard pressiometry.

The presence of the salt body is associated at the surface with sinkhole-type depressions and problematic soils, including organic-rich deposits and loose sands with potential for liquefaction. Because both the structural foundations and the salt-bearing formations form part of the foundation ground for a complex system of structures crossing the Mârșa River and the nearby railway—including a viaduct, two bridges, and large embankments of significant height—it became essential to determine the geometry and engineering properties of these formations.

The main objective of this paper is to highlight the geotechnical challenges arising from the presence of underground salt deposits, and to emphasize that such deposits, their associated evaporitic rocks, and the related morphological features should be classified as problematic foundation soils.

2 LITERATURE REVIEW

Salt deposits are part of the evaporitic group of rocks, known geologically as halite. They are sedimentary in origin and form exclusively through chemical precipitation from hypersaline waters as evaporation increases (Anastasiu, 1998). Such processes typically occur in arid environments with limited freshwater inflow, such as lagoons and bays.

In Romania, approximately 200 rock salt masses have been identified, formed within three major marine sedimentary basins: the Peri-Carpathian Depression (Subcarpathians), the Transylvanian Depression (Basin), and the Maramureș Depression. These basins functioned either as elongated deposition zones or as smaller, localized lagoonal basins.

Within the Transylvanian Basin, salt accumulation occurred both centrally and along the basin margins. Central accumulations are thick—up to 1,000 m—whereas lagoonal zones typically contain thinner deposits. Salt migration occurred both vertically and laterally, moving toward basin margins under tectonic and sedimentary influences.

The studied area is located at the southern edge of the Transylvanian Basin, where salt formed in a lagoonal environment. Here, the deposits are typically interlayered, heterogeneous, and thinner than those found in the central parts of the basin. Dissolution defects and recrystallization features are common.

Previous studies (Closson & Karaki, 2009; Frydman et al., 2014) have shown that salt bodies exhibit upward (diapiric) or lateral movement, characterized by plastic flow that cannot be prevented. These movements generate associated formations such as salt breccia—more permeable than massive salt—and may alter groundwater circulation, leading to localized dissolution.

Surface morphological changes, such as sinkholes, are often related to the dissolution of underground salt or limestone layers. They occur when unsaturated groundwater replaces saline groundwater, dissolving the salt and causing the overlying strata to collapse. Such features can create serious geotechnical and foundation challenges (Hayashi et al., 2018).

In addition to the salt itself, the overlying soils—often organic-rich, silty, or loose sands—can also pose geotechnical risks, including settlement, liquefaction, and reduced bearing capacity.

The investigation of the foundation ground in the studied area was a long-term process, carried out in several stages—one main stage and four additional stages. The necessity for additional investigation stages was due to understanding the phenomena, their extent, and anticipating their effects over time. As results were obtained, it became necessary to apply new and different methods to ensure the most comprehensive understanding possible.

The investigations and tests targeted both the salt body and the overlying strata. Regarding the salt body, the aim was primarily to determine its geometry, depth and horizontal extent, the type of salt it is composed of, and any possible cavities or cracks/faults. For the strata above the salt body, the purpose was to identify and classify the category of difficult soil they belong to and to determine their geotechnical parameters.

3 METHODS

3.1 *Overview of the Investigation Program*

The investigation of the foundation ground in the study area was a multi-stage process, including one main and four supplementary investigation stages conducted between 2019 and 2025. Each stage expanded upon previous results to improve understanding of the subsurface phenomena and their potential effects on long-term stability.

The investigations targeted both the salt body and the overlying strata. Objectives included determining the salt's geometry, thickness, composition, and any associated voids or faults, as well as characterizing the overlying soils and their geotechnical parameters.

3.2 *In-situ Geotechnical Investigations*

3.2.1 *Geological and Geomorphological Mapping*

A total of 48 geotechnical boreholes were drilled between 2019 and 2025, in two primary and three supplementary stages, to depths between 10.00 and 80.00 m. Both disturbed and undisturbed soil samples were collected, and groundwater levels were recorded where encountered.

3.2.2 *Geological and Geomorphological Mapping*

In the studied area, geological and geomorphological mapping was carried out to identify morphological structures associated with the presence of the salt body. Apart from the collapse area at the location of the viaduct's eastern ramp, two or three similar structures were identified. A drone was used to identify such structures over a larger area. A total of 16 sinkhole-type structures were identified, nearly circular, all with vegetation typical of swamp/marshland, some containing water. The water present in these structures is fresh, unsaturated with salts, indicating that it is not in contact with the salt deposit.

3.2.3 *Geotechnical Boreholes*

A total of 48 geotechnical boreholes were drilled between 2019 and 2025, in two main stages and three supplementary stages. Borehole depths ranged from 10.00 to 80.00 m. Disturbed and undisturbed samples were taken from the boreholes, and groundwater levels were measured where encountered.

Table 1. In-situ geotechnical and geomorphological investigations

Investigation type	Depth of investigation (m)	Level of investigation purpose
Geological and geomorphological mapping	*surface*	Difficult structure associated with underground salt body
Boreholes	*0-80*	Presence and geometry of the salt body and associated difficult soils
SPT (standard penetration test)	*0-30*	Qualitative strengthens and estimation of the geotechnical parameters
DPSH (dynamic penetration super hard)	*0-20*	Qualitative strengthens and estimation of the geotechnical parameters for associated difficult soils
CPTu	*0-30*	Estimation of the geotechnical parameters for associated difficult soils; liquefaction characterization
Menard pressiometry	*0-30*	Estimation of the geotechnical parameters
Seismic geophysical investigation	*0-40*	Estimation of dynamical parameters
Vertical electric sounding	*0-50*	Geometry of the salt body

3.3 *In-situ tests and trials*

In all boreholes, SPT dynamic penetration tests were carried out. Additionally, four DPSH tests, eleven CPTu tests (with pore water pressure measurement), and three Menard pressiometry tests were performed.

3.4 *Geophysical investigations*

Geophysical investigations included seismic refraction and MASW surveys, as well as electrical resistivity soundings (VES). Three longitudinal and twelve transverse seismic refraction profiles, and thirty-two vertical electrical soundings were carried out. VES depth of investigation was up to 50 m, arranged along three longitudinal profiles—one along the motorway axis, and the other two parallel to it at 100 m to the left and right.

3.5 *Laboratory investigations*

The disturbed and undisturbed samples were analyzed in the laboratory. Tests were carried out for all the analyzed layers. These consisted of: analysis of particle size distribution, determination of plasticity, density and porosity, natural moisture, free swelling, shear strength parameters determined by direct shear test, in unconsolidated – undrained, consolidated –undrained, consolidated–drained conditions, compressibility, monoaxial compression strength and point loading tests. All tests were carried out in compliance with European standards of method.

4 RESULTS

4.1 *Geometry and Extent of the Salt Body*

Initially identified during the feasibility study, the salt body was known to be present in the foundation ground of the future motorway for about 550 m, between km 13+200 and km 13+750, at depths of 16.0–20.0 m from natural ground level, with a thickness between 0.10 and 24.0 m.

Starting from the 23 boreholes drilled initially during the feasibility study, the investigation expanded to 48 boreholes in total. Borehole depths ranged from a minimum of 6.0 m to a maximum of 80.0 m.

The salt body was identified in 20 of the boreholes, extending under the future motorway for at least 1.2 km, from km 13+000 to km 14+233. The roof of the salt body occurs at depths between 12.40 m and 35.0 m, and the base between 18.7 m and 52.0 m. In the eastern part, the salt base is deeper than in the west. In the west, the geometry is relatively uniform and tabular; in the east, it is irregular with variable depths. Thickness is asymmetric: in the west it ranges from a few centimeters to 10 m; in the east, it varies between 17.0 and 27.4m.

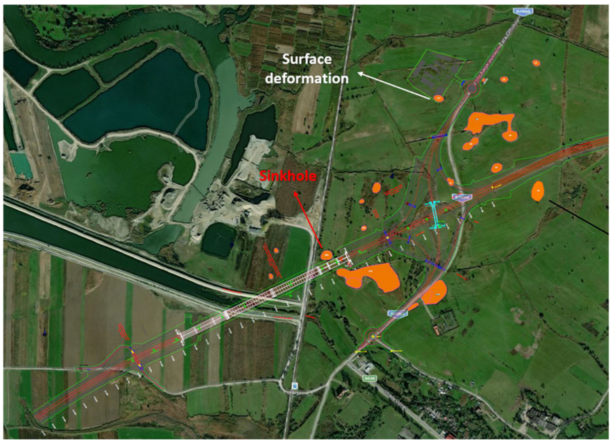


Figure 1: Sinkholes distribution

The geotechnical investigation carried out through drilling was complemented by a geophysical survey—vertical electrical soundings performed along longitudinal and transverse profiles—with the aim of determining the extent of the salt body. Following the geophysical investigations, the shape of the salt body was determined, and a 3D image of it was produced. In the quasi-central area, where salt had not been identified in the boreholes, the geophysical investigations indicated the existence of a possible fault system, which had allowed the circulation of fresh, unsaturated groundwater. This had affected the salt body in areas where the protective clay cover had been damaged by tectonic movement. The southern and western boundaries of the salt body were able to be delineated; however, the northern and eastern boundaries could not be precisely identified. The geophysical survey also revealed a high variability of shape in the eastern part and an almost tabular uniformity in the western part of the salt body. In addition, in the quasi-central part there was an area where the salt body was not identified, confirming the information obtained from the geotechnical study.

In determining the outline of the salt body, surface morphological structures sinkholes, also played an important role. These were identified either through direct geomorphological mapping or with the help of topographic images obtained by drone. Sixteen such semicircular structures were identified, varying in size, some containing water (freshwater), others dry but with vegetation typical of wetland areas. Considering the mode of formation of these structures, it was concluded that throughout the area where these structures are distributed, the salt body would be found at depth. This assumption was later confirmed by the geotechnical and geophysical investigations carried out.

But the most important information obtained from all the investigations carried out is the mapping of the new lithological profile along the alignment of the bridge complex over the Mârșa River. Thus, on the new lithological profile it was possible to outline the longitudinal extent of the salt body, as well as its thickness, the presence or absence of the impermeable clay protective layer, the areas where the salt is dissolved and recrystallized, as well as the areas where the salt is more massive or where salt breccia occurs. A direct correlation was observed between the presence of the impermeable protective clay layer and the quality of the salt body.

Figure 2: Sinkholes, details (Balikaya & Milutinovici, 2025)

Highly relevant for understanding the behavior of the salt and the occurrence of morphological changes at the surface was the case of borehole BH13_6b. This borehole was drilled precisely on the site of the largest depression area in the site—a sinkhole—in order to investigate what is happening at depth in that area.

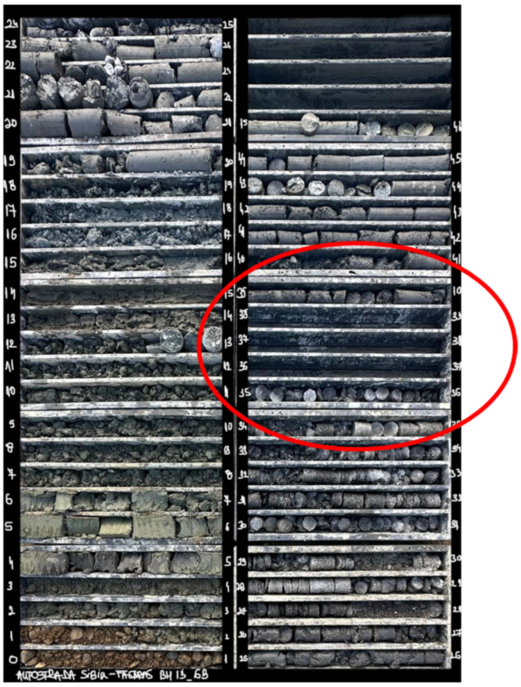


Figure 3: Interlayered salt and gap in the layers, borehole 45m depth (Milutinovici, et al., 2024)

The drilling revealed that, at a depth between 39.00 m and 42.00 m, there is an underground void; during drilling, the drill rods descended under their own weight without encountering any obstacle. Salt was encountered between depths of 25.00 m and 42.00 m. Between 25.00 m and 36.00 m, the salt is altered, with dissolution voids present, and between 39.00 m and 42.00 m, the salt is interbedded with marly clay, forming salt breccia. Above the salt layer, there is an impermeable clay layer that protects the salt from infiltration of fresh groundwater, but beneath the salt layer, the breccia zone has high permeability and can hold unsaturated groundwater, which dissolves the upper salt layer and forms underground cavities. Under the weight of the overlying rock packages, collapse eventually occurs, leading to the formation of the characteristic surface depression (in this case, the widening or deepening of the existing depression). This behavior fits well with the mechanisms that lead to the formation of sinkhole-type morphological areas.

The salt deposit generally appears as finely disseminated salt mixed with marly clay, but there are also areas where it appears as massive, crystallized salt with centimeter-thick layers of marl, slightly inclined relative to the horizontal. In the western part, the salt shows a migrated nature, recrystallized on the bedding surface. From a permeability perspective, there are permeable zones with salt resulting from dissolution processes, as well as zones where the salt behaves as a rigid body. Compared to diapir-type salt bodies found in the Transylvanian Depression—which are characterized by large thicknesses, sometimes on the order of thousands of meters, and by massive, plastic salt deposits with generally acceptable geotechnical characteristics and without intercalations of other material types—the salt in the studied area, located at the margin of the former Transylvanian sedimentary basin, formed in a lagoonal environment and occurs over larger areas with relatively small thicknesses (when compared to diapir-type salt), on the order of meters to tens of meters (Institutul Geologic al României, 1926). These deposits are interbedded and interlayered with clayey materials, with areas showing dissolution and with typical salt breccia zones. Although interbedded with clay or marly clay, the salt retains its upward or lateral migratory character; therefore, salt breccia formations can appear both in the roof of the salt deposit and laterally relative to it. Fault zones may also occur, as identified through the geophysical measurements conducted to determine the geometry of the salt body.

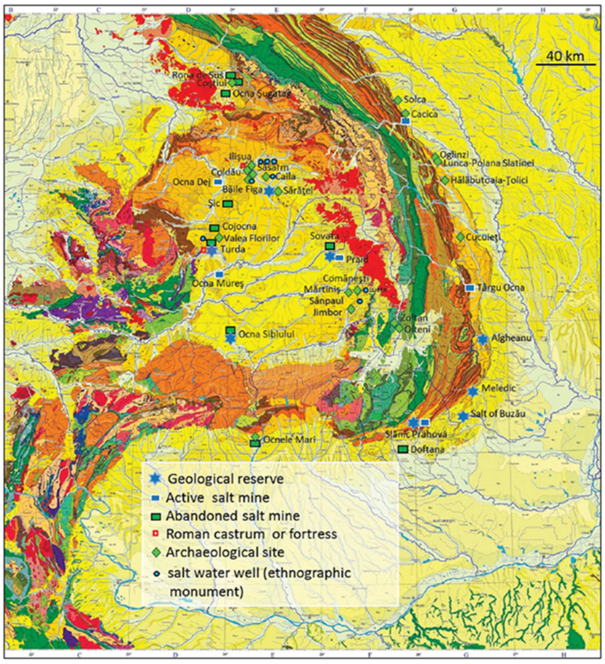


Figure 4: Salt deposits in Transilvania Basin (Codarcea & Stancu, 1968), (Seghedi, et al., 2021)

4.2 *Extension of organic, fine, and liquefiable deposits*

Associated with the salt body, in addition to sinkhole-type collapse structures, there were also problematic organic, fine, and liquefiable soils identified in the roof zone of the salt. With meter-scale thicknesses, these were found in 13 of the executed boreholes. They generally occur at depths between 0.20 m and 4.70 m, extending down to depths between 2.20 m and 15.00 m. They are represented by organic soils, muds, peats, and loose sands.

4.3 *Hydrogeological Conditions*

Groundwater was encountered at depths between 2.00 and 5.00 m, fluctuating seasonally. In areas above the salt-bearing strata, local artesian conditions were recorded due to confined groundwater within the overlying clayey layers.

Water chemistry analyses indicated elevated chloride content, suggesting partial dissolution of the salt body and upward migration of saline water through fissures and weak zones within the marl. The interaction between groundwater and salt contributes to the development of subsidence features and potential sinkhole formation at the surface.

4.4 *Geophysical Results*

The vertical electrical soundings (VES) and seismic refraction profiles confirmed a distinct resistivity anomaly corresponding to the salt body. Resistivity values exceeded 1,000 Ω·m, compared to 30–100 Ω·m for the surrounding marly soils.

The interpretation of longitudinal and transverse profiles revealed an irregular geometry of the salt body, with local bulging and thinning. These variations align with areas where surface subsidence or small sinkholes have been mapped, confirming the correlation between dissolution features and the salt geometry.

4.5 *In-situ Testing Results*

SPT, DPSH, and CPTu results indicated generally medium to dense sands and stiff to very stiff clays above the salt-bearing layer. However, zones of reduced penetration resistance were identified near the contact with the salt, suggesting localized weakening due to dissolution or remolding.

Menard pressiometer tests showed modulus values (Em) varying between 15 and 40 MPa in the upper layers, decreasing to 10–15 MPa near the salt zone. These results demonstrate that the overlying soils exhibit variable stiffness, influenced by groundwater conditions and proximity to the halite-bearing strata.

5 DISCUSSION

5.1 *Engineering Implications of Salt Presence*

The identification of a discontinuous salt body beneath the motorway alignment significantly influences the geotechnical and structural design of the planned viaduct and associated embankments. Salt deposits are inherently unstable under long-term loading and may undergo creep, dissolution, or recrystallization when exposed to groundwater flow (Closson & Karaki, 2009).

In this context, the main engineering risks include:

- Progressive dissolution leading to local loss of support and settlement of foundation piles;
- Creep deformation of salt under sustained load;
- Changes in groundwater regime accelerating salt dissolution; and
- Formation of voids and collapse structures that can propagate to the surface.

These processes can induce differential settlements and compromise the stability of deep foundations and embankments if not properly addressed.

5.2 *Foundation Design Considerations*

Following the feasibility study, the proposed foundation method for the bridge complex over the Mârșa River was indirect, using piles with their base at least 5.0 m above the salt layer.

However, bearing capacity calculations showed that the pile length would need to be between 25 m and 30 m, meaning that many piles would either extend beyond the salt layer or be founded directly within it. This solution could not remain as the final choice, as it was concluded that the foundation method specified in the feasibility study would carry very high risks—both material and human—due to the unpredictable behavior of the salt mass.

In this situation, the following options were considered for the foundation of the bridge complex over the Mârșa River:

- Changing the route to avoid the salt body;
- Crossing the salt body with a single, very long structure;
- Indirect foundation of the structures using bored piles that would go beyond the salt body and be founded in the marly soil identified from the boreholes;
- A composite alternative solution: removing the eastern half of the viaduct and replacing it with two smaller bridges and an embankment made of lightweight geoBLOCK material (expanded polystyrene).

Because the salt body's boundaries could not be fully determined, and due to morphological constraints north of the route, the presence of the Olt River with its embanked banks, expropriation limitations, and most importantly the design stage restrictions that did not allow route changes, the option of modifying the alignment—although the simplest from an engineering perspective—was not possible.

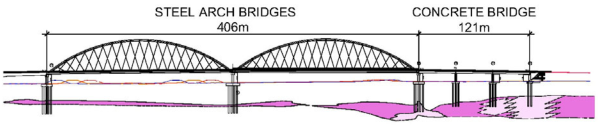
Regarding the option of building a single structure to cross the entire salt body, the large length of the salt body (approximately 1.3 km), the existing design constraints due to the presence of the Avrig junction at the eastern part of the route, and the fact that such a solution would also impact the start of Lot 2 of the Sibiu–Făgăraș Motorway led to the conclusion that it was not feasible or applicable.

As for the option of indirect foundation with piles passing through the salt layer, it was concluded that the required pile length—in some areas over 50 m—was practically impossible due to technological challenges (very large length, excavation difficulty) and high costs. Moreover, passing through large thicknesses of salt would irreversibly damage the piles through deterioration of concrete and reinforcement. Penetrating the salt layer with hundreds of piles (271 piles were planned in the feasibility study) would also compromise the integrity of the salt body by allowing fresh groundwater from the aquifer above it to infiltrate, leading to dissolution and irreversible degradation of the salt. This solution was therefore considered not only too costly but also too risky for the operational safety of the future structure.

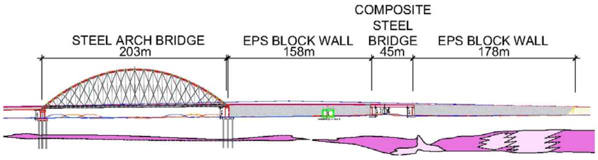
In the end, the chosen foundation solution was a composite one: the eastern arch of the viaduct over the Mârșa River was eliminated and replaced with a combination of smaller bridges and a lightweight embankment. Considering the two identified states of the salt—more massive in some areas, more dissolved and degraded in others—it was decided that small-span bridges with direct foundations could be used, along with a new box underpass with an 11.0 m span for a local road beneath the motorway, and a new mixed-structure bridge over the railway with a span of 46.60 m (Borbeli & Pușculiță, 2025).

Between these two bridges, and across the entire area of the second viaduct arch, a lightweight geoBLOCK embankment will be built. This fill material offers several advantages (Ciortan, 2025):

- Prevents excessive loads on the foundations of the bridge over the railway, allowing for direct foundations without piles;
- The construction technology for lightweight fills allows vertical slopes, keeping the existing expropriation limits;
- The lightweight fill will not generate additional vertical loads on the salt layer where it is at the surface, nor on the ground above the salt that has been identified as problematic organic soil with low compressibility.



a. feasability study design solution



b. final design solution, after detailed geotechnical investigation

Figure 5: New foundation solution for Mârșa structure (in magenta salt body with massive or interlayered structure; in pink dissolute salt, recrystallized salt)

At the base of the geoBLOCK fill, geogrids will be used to minimize the impact of differential settlements, and on top of these a reinforced concrete slab will be placed to prevent the occurrence of significant local differential settlements. The advantages of using lightweight fills and foundations in areas where organic soils are encountered include simple construction technology, reduced volumes of earthworks, and low loads transmitted to the ground. As a result, settlements are reduced, which also minimizes the impact on the groundwater flow regime (Aminu, Asadi, O'Kelly, Huat, & Reul, 2019). The use of expanded polystyrene blocks instead of conventional solutions reduces the time of installation, construction costs, reduces the volume of filling material that must be excavated, transported, stored and placed in the work. The density of polystyrene blocks represents approximately 1% of the density of compacted filling soil, approximately 2-3.5 kg/m3 (Austrotherm, 2025) compared to 1700-2000 kg/m3 for cohesive and non-cohesive materials, has low water absorption and is chemically resistant under normal conditions.

5.3 *Broader Implications for Infrastructure Design*

This case study underlines the importance of integrating geophysical and geotechnical data in areas with potential evaporitic formations. The combination of electrical and seismic methods proved particularly effective in delineating the salt body, while in-situ tests provided essential mechanical parameters for design.

Moreover, the study highlights that salt-bearing formations should be classified as problematic foundation soils, due to their susceptibility to dissolution, creep, and high variability in stiffness. The results from Mârșa demonstrate that even in regions traditionally considered geotechnically stable, hidden salt layers can pose significant engineering challenges.

6 CONCLUSIONS

The comprehensive geotechnical and geophysical investigation carried out along the Sibiu–Făgăraș motorway, in the Mârșa River area, led to the identification of a discontinuous underground salt body within the marly substratum, extending approximately 500 m along the motorway alignment. The salt was found at depths between 17.00 and 23.00 m, with thicknesses varying from about 5.00 m in the western area to 20.00 m in the eastern part.

The presence of this salt deposit represents a significant geotechnical hazard, as halite-bearing strata are prone to dissolution, creep, and deformation under the influence of groundwater and sustained loads. These processes can generate voids, localized subsidence, and differential settlements, which pose major risks to deep foundation systems and overlying structures.

Geophysical investigations (seismic refraction and vertical electrical sounding) provided a reliable delineation of the salt body's geometry and internal heterogeneity. When correlated with borehole and in-situ testing results, these data allowed the development of an accurate geotechnical model for foundation design.

The selected foundation solution—deep bored piles anchored into competent marl beneath the salt—was based on integrated analysis of geological, geotechnical, and geophysical information. This design minimizes the potential effects of salt-related instability on the viaduct and associated structures.

From an engineering perspective, this study demonstrates that even areas traditionally classified as favorable for construction may conceal complex subsurface conditions with substantial implications for infrastructure stability. Consequently, salt-bearing and evaporitic formations must be systematically considered problematic foundation soils during all stages of geotechnical investigation and design.

Future monitoring of groundwater chemistry, settlement, and deformation is recommended to ensure the long-term safety of the structures and to provide further insight into the behavior of salt-influenced foundations under real loading conditions.

7 AKNOWLEDGMENT

Special thanks to Prospect Technical Studies SRL team and Mr. Dan Mihăilescu for their dedication in carrying out the in-situ geotechnical investigations and laboratory analyses.

8 REFERENCES

Aminu, I. et al., 2019. Ultralightweight foundation system for peaty ground. *Enviromnental Geotechnics ICE Publishing*, 18 01, pp. 12-21.

Anastasiu, N., 1998. *Sedimentologie și petrologie sedimentară - ediție adăugită.* București: Editura Universității din București.

Austrotherm, 2025. *Austrotherm geoBLOCK.* [Online] Available at: https://www.austrotherm.ro/

Balikaya, E. & Milutinovici, E., 2025. *Evaluarea geotehniă a condițiilor de fundare în zona depozitului de sare, între km 13+000 și 14+233, Autostrada Sibiu - Făgăraș,* București: Mega Muhendislik.

Borbeli, C. & Pușculiță, I., 2025. *Prezentare DTAC Autostrada Sibiu - Făgăraș; Tronson 1: Boița (autostrada Sibiu-Pitești) și Avrig - Mârșa (DJ105G) km 0+000-14+253,* București: Mega Muhendislik.

Ciortan, R., 2025. *Expertiză geotehnică preliminară asupra lucrărilor din cadrul proiectului "Autostrada Sibiu-Făgăraș, lot 1: Boița (Autostrada Sibiu-Pitești) și Avrig - Mârșa (DJ105G), km 0+000-14+253",* București: Asocierea Makyol Inșaat Sanayi Turizm ve Ticaret A.Ș..

Closson, D. & Karaki, N. A., 2009. Salt karst and tectonics: sinkholes development along tension cracks between parallel strike-slip faults, Dead Sea, Jordan. *Earth Surface Process and Landforms,* pp. 1408-1421.

Codarcea, M. D. & Stancu, J., 1968. *Harta geologică scara 1:200.000, foaia 27_Sibiu.* București: Comitetul de Stat al Geologiei, Institutul Geologic.

Frydman, S., Carrach, J. & Goretsky, I., 2014. A geotechnical study of evaporitic, lacustrine sediments in the saline environment of Dead Sea area. *Elsevier. Engineering geology 181*, 16 september, pp. 309-322.

Hayashi, H., Yamanashi, T., Hashimoto, H. & Yamaki, M., 2018. Shear modulus and damping ratio for normally consolidated peat and organic lay in Hokkaido area. *Geotechnical and Geological Engineering 36*, 21 March, pp. 3159-3171.

Institutul Geologic al României, 1926. Discuțiune relativă la vârsta sării. In: *Dări de seamă ale ședințelor, volumul VIII (1919-1920).* București: Tipografiile Române Unite, S.A., pp. 4-18.

Jiang, D. et al., 21012a. Similar experimental study of cavity building using large-size molded salt rock. *Chin J Rock Mech Eng 31 (9),* pp. 1746-1755.

Jiang, D. et al., 2012b. Experimental study of mechanical characteristics of molded salt rock with weack interlayer. *Chin J Roch Mec Eng,* pp. 1797-1803.

Milutinovici, E. et al., 2024. *Studiu Geotehnic, autostrada Sibiu Făgăraș, Lotul 1, revizia 3,* București: Prospect Technical Studies.

Milutinovici, E. et al., 2025. *Studiu Geotehnic; Autostrada Sibiu-Făgăraș, Lot 2, revizia 3,* București: Prospect Technical Studies.

Oz, I. et al., 2016. Salt dissolution and sinkhole formation: Results of laboratory experiments. *Journal of Geophysical Research: Earth Surface,* pp. 1-17.

Seghedi, A., Rădan, S. & Briceag, A., 2021. Salt-relatde geological and cultural heritage in Romania. *Geo-Eco-Marina 27*, pp. 153-182.

Xing, W. et al., 2014. Experimental study of mechanical and hydraulical properties of bedded rock salt from the Jintan location. *Acta Geotechnica*, pp. 145-151.