DOI: https://doi.org/10.68732/8b15089c0caef3c4

ISBN: 978-9989-2053-7-8

The rock mechanical background of the Praid salt mine disaster

E. Bartakovics, Á. Török, B. Vásárhelyi
Department of Engineering Geology and Geotechnics, Faculty of Civil Engineering, Budapest University of Technology and Economics, Budapest, Hungary
bartakovics.edina@emk.bme.hu
0009-0000-9272-7968, 0000-0002-5394-4510, 0000-0002-0568-1031

Abstract

The rock mechanical behaviour of salt is a less-studied field of engineering geology. Its importance became clear when a surface stream flooded the subsurface salt mine of Praid (Transylvania, Romania). When experts were planning the response to the disaster after the accident in May 2025, they faced the problem that the mechanical properties of the host rock were hardly understood. This study tries to bridge this gap by using block samples from the salt mine. The rock mechanical parameters of the Praid rock salt were analysed using non-destructive tests such as ultrasonic pulse velocity tests. Cylindrical test specimens were prepared, and strength parameters were determined. Uniaxial compressive strength (UCS) tests and Brazilian indirect tensile strength (BTS). The composition and effect of the clay content of the salts on the mechanical properties were also analysed. In addition, smaller samples were tested to see how water dissolves the rock salt of Praid. Our goal was to provide data that could help plan further defence.

Keywords

Salt, Rock mechanics, Praid, Salt mine.

1 Introduction

The Praid Salt Mine is located in the eastern part of the Transylvanian Basin (Romania) and represents one of the largest salt deposits in Europe. Salt was already mined in the area during Roman times, and in the Middle Ages salt formed the economic foundation of the Székely region, with Praid serving as the centre of regional salt mining (Horváth 2004).

The Praid disaster occurred in May 2025 (see Fig 1). Due to the large amount of precipitation, the discharge of the Korond Stream, which flows above the mine, increased significantly. As a result of the substantial rise in water discharge, the waterproof membrane installed in the streambed ruptured, allowing water to enter the mine and completely flood the underground workings. This occurred because the mine did not have adequate protection against water inrush. The inflowing water, partially dissolving the salt, caused the partial collapse of galleries and drifts. Investigations revealed that the disaster did not manifest as a single sudden collapse, but rather as a sequence of successive collapses.

The catastrophe severely affected the region and caused significant economic damage. The water inrush and the partial collapse of the mine workings not only led to structural failure within the mine but also resulted in serious environmental damage. Saline water escaping from the mine contaminated the surrounding area and endangered drinking water supplies in dozens of settlements.

During the planning of mitigation and remediation measures, experts faced the fact that the mechanical properties of the rock mass were not sufficiently known, and no comprehensive testing program had previously been conducted on the salt rock. Consequently, the exact properties of the rock salt in this deposit were not well defined. The objective of our study was to address this deficiency. For the laboratory investigations, salt blocks originating from the mine prior to the disaster were used. The obtained results may support future engineering design, including the potential opening of a new mining level.



Fig.1 The flooded area of the Praid Salt Mine.

2 Geological background

The Transylvanian Basin is an approximately circular basin located within the Carpathian arc (see Fig. 2). Subsidence began at the end of the Cretaceous and the beginning of the Paleocene in a back-arc tectonic setting (Gelencsér et al. 2024). During the Middle Miocene, as the inland sea desiccated, salt precipitated within this depression, after which a large amount of sediment was deposited above it. Sediments transported from the shoreline, such as eroded conglomerates and mica schists, were deposited between the rock salt layers and, upon incorporation into the salt mass, formed a heterogeneous rock unit.Under the load of the overlying sediments, the salt compacted and subsequently migrated toward the margins of the Transylvanian Basin. Part of the salt ascended along pre-existing fault lines, piercing through the overlying younger sedimentary sequences, while other portions were arrested at various depths (Horváth 2011). The diapiric folds formed in this way exhibit nearly vertical layering. Based on this, it can be concluded that the rock salt in this area has undergone significant plastic deformation and may also have recrystallized (Gelencsér et al. 2024).Within the salt sequence, interbedded crystalline schists, clay shales, dolomites, sandstones, and marls occur as contaminant lithologies, which may influence the quality and rock mechanical parameters of the rock salt (Horváth 2011).

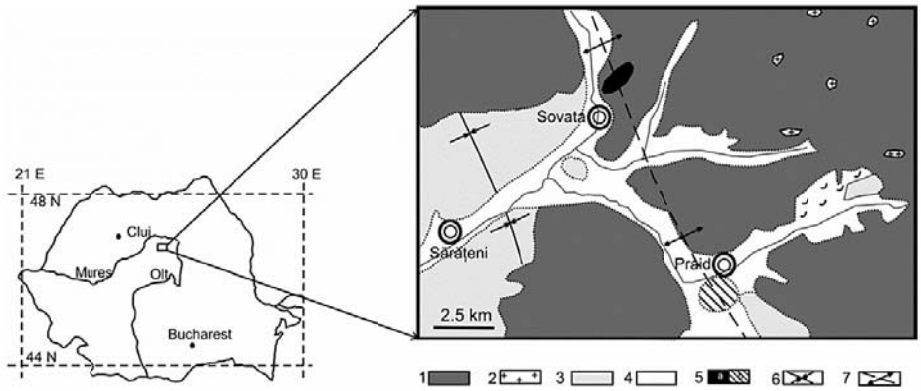


Fig. 2 The studied area and its geological map (1: Neogene volcanic breccias and agglomerates, 2: Upper Miocene amphibole andesite, 3: Upper Miocene sand, clay and conglomerate, 4: Quaternary sediments, 5: open (a) and covered (b) salt diapirs, 6: syncline, 7: anticline (Har et al 2010).

In the vicinity of the Praid salt deposit, four types of faults can be distinguished. One of the most important is the deep-seated fault, which extends from the crystalline basement to the surface and played a key role in the uplift of the diapiric fold. The second type is the boundary fault, formed during the intrusion of the salt body. The surface fault extends to the margin of the salt body and may locally penetrate into the upper zone of the salt dome. The final type consists of locally developed faults, which play an active hydrological role within the overlying rocks of the salt dome (Horváth 2010).

3 Disaster

The disaster was preceded by several warning signs, as water infiltration and minor water inrush events had occurred previously. The diversion of the Korond Stream bed had been proposed as a risk-mitigation measure for decades, because the stream flows directly above the salt deposit, and water can easily enter the mine through sinkholes and infiltration pathways developing in the streambed.

As a preventive measure, waterproof geomembranes were installed in the streambed. However, this solution proved to be only temporary. Due to heavy rainfall events, the geomembrane lining was damaged, allowing water to infiltrate into the mine. The first closure occurred on 6 May, following the detection of water leakage. Subsequently, several attempts were made to save the mine, primarily through pumping operations and concrete sealing measures. Despite these efforts, the mine was flooded on 27 May. Two days later, on 29 May, the visitor centre of the salt mine was also inundated. At the beginning of June, ground subsidence was detected above the György Dózsa mine, which required the evacuation of residents from the affected area. On 2 June, drinking water supply problems were reported in several settlements in Mureș County, as the salinity of the Târnava Mică River increased as a consequence of the Praid disaster. The losses are substantial, as the mine contains salt reserves sufficient for several hundred years of production.

4 Materials and Methods

Four salt blocks were available for the laboratory investigations. These blocks originated from the prior period to the disaster. Cylindrical specimens with a diameter of 55.4 mm were prepared from these blocks. See in Fig 3, the samples consisted predominantly of halite, but darker contaminations such as clay minerals, sand grains, and small gravel particles were also observed.

During the laboratory investigations, bulk density measurements, ultrasonic wave velocity tests, uniaxial compressive strength (UCS) tests and indirect tensile strength tests (BTS) tests were carried out according to the ISRM Suggested Methods (ISRM 2007). Twelve specimens were immersed in saturated saline solution for four days in order to investigate whether this condition influences the uniaxial compressive strength and tensile strength values. To prepare the saturated solution, 349.14 g of Praid salt was required to saturate 1 litre of distilled water.

In addition, the effect of impurity content present in the rock salt on the mechanical strength of the material was also investigated. 9 samples were tested. The contamination content in the samples varied between 1.9% and 6.1%.



Fig. 3 Praid rock salt samples.

5 Results

First, the statistical evaluation of the density, ultrasonic wave velocity parameters, uniaxial compressive strength and Brazilian tensile tests values is presented in the Fig.4, the non-destructive measurements were taken before saturation with salt water.

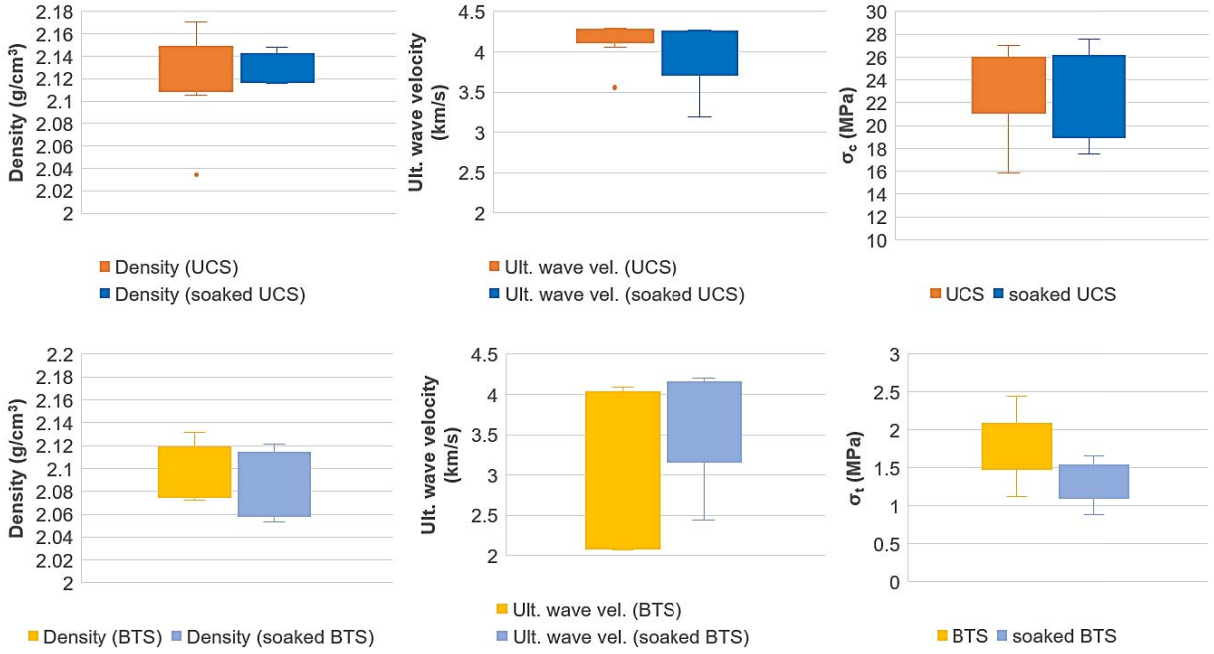


Fig. 4 Density, ultrasonic wave velocity, UCS and BTS parameters of the rock salt samples.

The results indicate that the average uniaxial compressive strength values of the specimens stored under the two different conditions show only minor differences, although the standard deviation is relatively high. This suggests that water inflow into the salt mine, after reaching saturation, likely does not cause a significant reduction in compressive strength.

The Brazilian tensile tests exhibited the highest variability, likely due to the influence of heterogeneously distributed contaminations, which is more expressed in smaller specimens. While brine saturation may slightly affect tensile strength, no drastic change was observed.

The largest dispersion of results was observed in the Brazilian tensile tests. This may be attributed to the relatively small specimen size, where the distribution of contaminations within the samples has a stronger influence on the measured values. Due to this high variability, it is less evident whether the saturated saline solution slightly affects the tensile strength, although no drastic changes were observed.

Figure 5 presents the data recorded during the uniaxial compressive strength test performed on sample 15. The ε_{axial}-$\varepsilon_{lateral}$ diagram (a) illustrates the relationship between axial and lateral strains during loading. The σ_c - Poisson's ratio diagram (b) shows a clear linear trend, indicating that lateral deformation becomes increasingly dominant with increasing applied stress. In the case of rock salt,

Poisson's ratio cannot be considered a constant rock physical parameter, as it evolves during the loading process. The load - displacement diagram (c) clearly demonstrates that the mechanical behavior of rock salt differs from that of more competent brittle rocks. The closure of pre-existing microcracks is likely to occur at approximately 7% of the peak load (≈1.5 MPa), while the onset of stable crack propagation can be identified at around 86% of the peak stress (≈17.9 MPa).

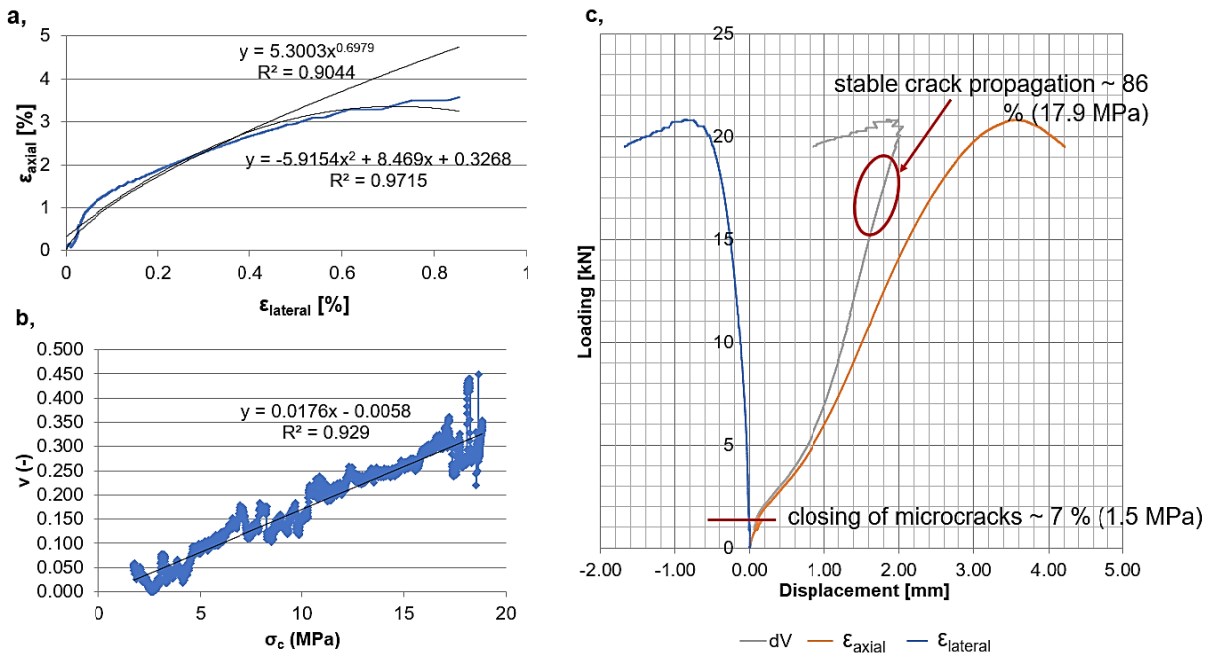


Fig. 5 Theε_{axial} - $\varepsilon_{lateral}$diagram, the σ -Poisson ration diagram (b) and the displacement-loading diagram (c).

Fig. 6 shows the relationship between contaminant content and UCS values. With a few exceptions, the strength values show a decreasing trend with increasing contamination content. The heterogeneity introduced by contamination in the rock salt generally leads to stress concentrations, and since the material is a sedimentary rock, microcracks can initiate more easily along these small internal interfaces.

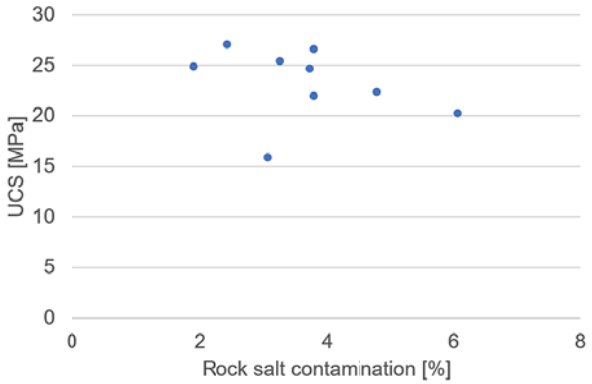


Fig. 6 The relationship between UCS-and contamination content.

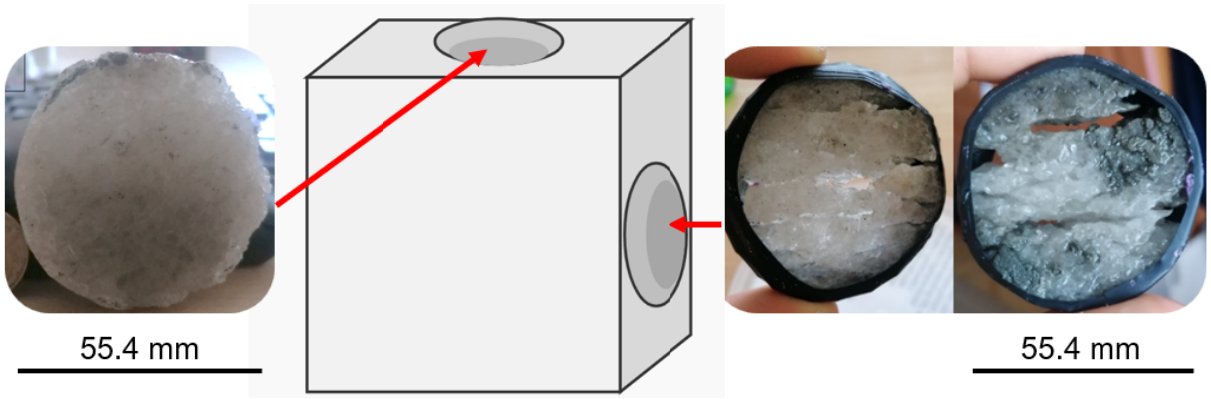


Fig. 7 Testing the penetration of water through different rock salt samples.

We examined the influence of water on failure using 1.5 cm thick disks cut from smaller specimens. One set was oriented perpendicular to bedding, the other parallel (see Fig.7). Disks parallel to bedding allowed 10 ml of distilled water to pass through in 3–6 seconds, whereas those perpendicular to bedding did not transmit water even after 1 minute. This indicates that water migration in the mine likely occurs preferentially along bedding planes, which facilitate salt dissolution.

6 Conclusion

Following the disaster that occurred in the salt mine of Praid in May 2025, the mitigation works highlighted the lack of site-specific rock mechanical data for the rock salt formation. The aim of this study was to address this deficiency and to assess the influence of water on the mechanical properties of the rock salt.

Laboratory investigations included ultrasonic wave velocity measurements, uniaxial compressive strength tests, and Brazilian tensile strength tests. Strength tests were performed on both dry specimens and specimens soaked for 4 days in saturated salt solution. The results showed only minor differences between the two conditions, indicating that water ingress, once saturated with salt, is unlikely to induce a significant reduction in the strength of the rock salt.

The influence of contamination on mechanical behaviour was also examined. An overall decreasing trend in the uniaxial compressive strength parameters was observed with increasing contamination content, suggesting that material heterogeneity plays a relevant role in the mechanical performance of the rock salt. Examination of the disk samples showed that water entering the mine primarily dissolves the salt along the bedding planes and can move forward there.

According to preliminary plans, a new mining level is intended to be opened in the Praid mine. The results obtained in this study may provide valuable input for the design and stability assessment of the planned level. From a mine safety perspective, it would be advisable to carry out regular rock mechanical testing on samples collected from predefined locations, potentially on an annual basis. Such a monitoring program would allow the detection of possible stress changes within individual rock masses and the identification of potential weakness zones.

Acknowledgment

The authors gratefully acknowledge the assistance of Gergely Jancsó and Ádám Kondás in conducting the laboratory experiments. Edina Bartakovics expresses her gratitude for the support of the Doctoral Excellence Scholarship Program (grant number DKÖP-25-1-BME-101).The financialsupport of theHungarian-Croatianbilateral project National Research, Development and InnovationFund, grant no: 2023−1.2.4.-TéT-2023-00044 is acknowledged.

References

Gelencsér O, Szakács A, Gál Á, Szabó Á, Dankházi Z, Tóth T, Breitner D, Szabó-KrauszZs, Szabó Cs, FalusGy (2024) Microstructural study of the Praid Salt Diapir (Transylvanian basin, Romania) and its implication on deformation history and hydrogen storage potential. Acta Geodaetica et Geophysica Volume 59: 343–365 p.https://doi.org/10.1007/s40328-024-00436-z

Har N, Rusz O, Codrea V, Barbu O (2010)New data on the mineralogy of the salt deposit from Sovata (Mureş county-Romania). CarpathianJournal of Earth and Environmental Sciences Volume 5, No. 2: 127-135 p.

Horváth I (2004) A székelysóbányászatrövidtörténete (A brief history of Székely salt mining), Lyra, TarguMures. (in Hungarian)

Horváth I (2010) Parajdi-medenceföldtana I. Sóvidék (Geology of the Praid basin I. Saltland) Volume II/2: 31-38 p. (in Hungarian)

Horváth I (2011) Parajdi-medenceföldtana II. Sóvidék(Geology of the Praid basin II. Saltland) Volume III/1: 30-33 p. (in Hungarian)

ISRM (2007) The complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006. Eds: R. Ulusay and J. Hudson, ISRM Turkish Nat. Group & ISRM.