Proper identification of pore space in rocks is crucial for several significant reasons. Firstly, accurate characterization of rock porosity and permeability is essential in the exploration and production of hydrocarbons, where understanding the porous structure of the reservoir affects the efficiency of oil and gas extraction. Additionally, in the context of geothermal technology development, knowledge of the pore system and fluid flow capabilities in rocks directly impacts the efficiency and economic viability of geothermal energy extraction. Furthermore, in Carbon Capture and Storage (CCS) projects, precise pore space analysis is necessary to assess the potential for storing carbon dioxide in underground geological formations, which is vital for reducing greenhouse gas emissions and combating climate change.

In this project, the focus is on the Miocene formations of the Carpathian Foredeep, recognized as particularly challenging yet promising. The thin-layered Miocene complexes are characterized by a complex lithological structure and the presence of layers of varying thickness, including those rich in clay minerals. These features make the study of these formations challenging but also open up broad opportunities for various industrial and ecological applications. The primary problem in investigating Miocene formations is their thin layering, with a significant proportion of silt-clay layers. These are characterized by a high specific surface area and swelling capacity. These properties affect the availability and distribution of pores, complicating measurements made with individual methods. Clay minerals tend to form very small pores, which can be difficult to detect and analyze with standard techniques. Methods such as Mercury Injection Capillary Pressure (MICP) and Nuclear Magnetic Resonance (NMR) have their limitations in studying clay-rich materials. MICP, although effective in analyzing small pores, may not fully penetrate micropores in clayey rocks. NMR, while providing information on total porosity, may struggle with very small pores and interactions between water and clay minerals.

To overcome the limitations of individual techniques, it is necessary to combine various measurement methods. Nitrogen adsorption (BET) allows for detailed analysis of micropores and mesopores, providing precise data on specific surface area and pore volume. The BET technique is particularly useful in determining the surface characteristics of clay minerals, which tend to adsorb large amounts of gases due to their high specific surface area. Computed Tomography (CT) enables three-dimensional imaging of the internal structure of the rock, which is crucial for understanding pore distribution on a larger scale. CT allows for non-invasive examination of the rock's internal structures and can provide information on pore and fracture distribution, which is crucial for understanding fluid flow within the reservoir. Scanning Electron Microscopy (SEM) provides very high-resolution surface images, allowing detailed examination of the microstructure and chemical composition of clay materials. SEM allows visualization and analysis of pore structures at the nanoscale, which is important for understanding interactions between clay minerals and fluids in the reservoir. Combining these methods allows for a comprehensive picture of the pore space by integrating data from different scales.

The final step in accurately characterizing rock porosity involves integrating laboratory results with geophysical logging. Geophysical logging provides data along the borehole, enabling the transition from microstructure to macrostructure of the reservoir. Integrating geophysical logging data with laboratory results allows for the creation of three-dimensional models of the reservoir that incorporate fine details of the porous structure and its distribution across the entire study area. This enables more accurate determination of formation parameters. These models can be used for simulating fluid flow within the reservoir, which is crucial for resource management and planning extraction operations, but also for CCS and geothermal energy extraction. Moreover, new geometrical parameters of the pore network developed based on laboratory results will be important not only from a geological perspective but also in applications for porous materials such as porous polymers, porous ceramics in biotechnology, and cells in the clean energy sector.