REDEVELOPMENT OF MATURE HYDROCARBON FIELDS USING RESERVOIR CHARACTERISATION

REDEZVOLTAREA ZĂCĂMINTELOR MATURE DE HIDROCARBURI PRIN CARACTERIZAREA |ROCILOR REZERVOR

Ion FOIDAȘ[1] , Adrian Cristian MIHĂILĂ[2],

Abstract: *Natural gas plays its role in the energy transition as a low-carbon alternative to traditional fossil fuels such as coal and oil. The majority of gas production comes from mature fields that have passed their production peak and are now in decline. This paper aims to address the issue of redeveloping mature fields by reservoir characterization, particularly by modeling sedimentary facies to identify undeveloped isolated zones, a discipline that has evolved continuously with geophysical investigation techniques.*

Keywords: redevelopment, mature fields, facies modelling.

Rezumat: *Gazele naturale își au rolul lor în tranziția energetică ca alternativă low-carbon pentru combustubilii fosili clasici, cărbunii și țițeiul. Majoritatea producției de gaze provine din câmpuri mature, care au trecut de vârful de producție și se află într-*un declin. *Această lucrare își propune să abordeze problema redezvoltării câmpurilor mature prin caracaterizarea rocilor rezervor, în special modelarea faciesurilor sedimentare pentru identificarea zonelor izolate nedezvoltate, o metodă care a evoluat continuu o dată cu tehnicile de investigare geofizică.*

Cuvinte cheie: redezvoltare, câmpuri mature, modelare de facies.

1. Introduction

The advances in geology and geophysics, along with high-resolution seismic processing capabilities, have led to continuous improvements in our ability to construct quantitative 3D geological models for reservoir

[1] Lecturer, Dept. of Industrial Engineering and Management, “Lucian Blaga” University from Sibiu, Romania, e-mail: ion.foidas@ulbsibiu.ro / Head of the Production Dept. S.N.G.N. ROMGAZ S.A., Romania, e-mail: ion.foidas@romgaz.ro
[2] Eng. Geologist, S.N.G.N. ROMGAZ S.A., Romania, e-mail: adrian.mihaila@romgaz.ro

performance simulation and volumetric calculations. All these advancements have largely emerged due to the increased focus on improving the hydrocarbon recovery factor from known, mature fields, and unconventional reservoirs [3].

A significant contribution to the understanding of mature fields has been made by 3D reflection seismics. 3D seismic technology can capture fine-scale stratigraphic and structural features that previously went unnoticed through well-based modeling. As it can be seen in the case of the 2D line in figure 1, we can observe the discontinuity of reflectors and the uncertainty of the fault position, while on the 3D line, these issues are resolved through 3D migration due to the regular grid in which the information was recorded. These fine features are visible in the amplitude domain only in ideal cases. To observe them, data often undergo additional processing and interpretation stages, including seismic attribute analysis. A seismic attribute is a parameter extracted or derived from seismic data that can be analyzed to enhance information that might be more subtle in a traditional seismic image, leading to a better geological or geophysical interpretation of the data.

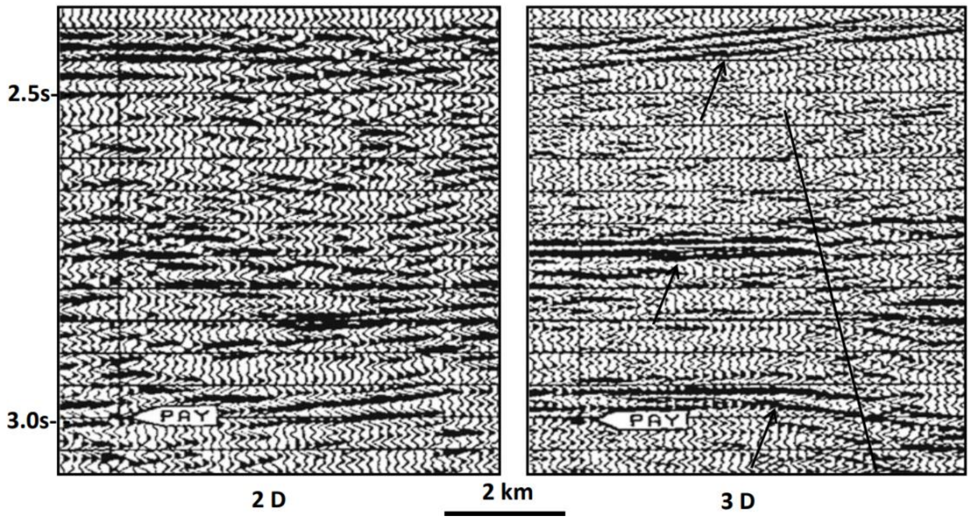

Figure 1. Reflection seismics on the same segment [2]

Reservoir characterization began as a purely engineering discipline, based on production data and hydrodynamic studies. In classical models, reservoirs were considered simple alternations of sandstones and clays, and a purely lithostratigraphic correlation was used between wells. Later, as more seismic data became available and processing advanced, reservoir compartmentalization proved to be the rule rather than the exception. Thus, in both the initial and final stages of characterization, we should assume that any field will be compartmentalized and segmented at scales too small to be recognized with usual investigation technologies between wells.

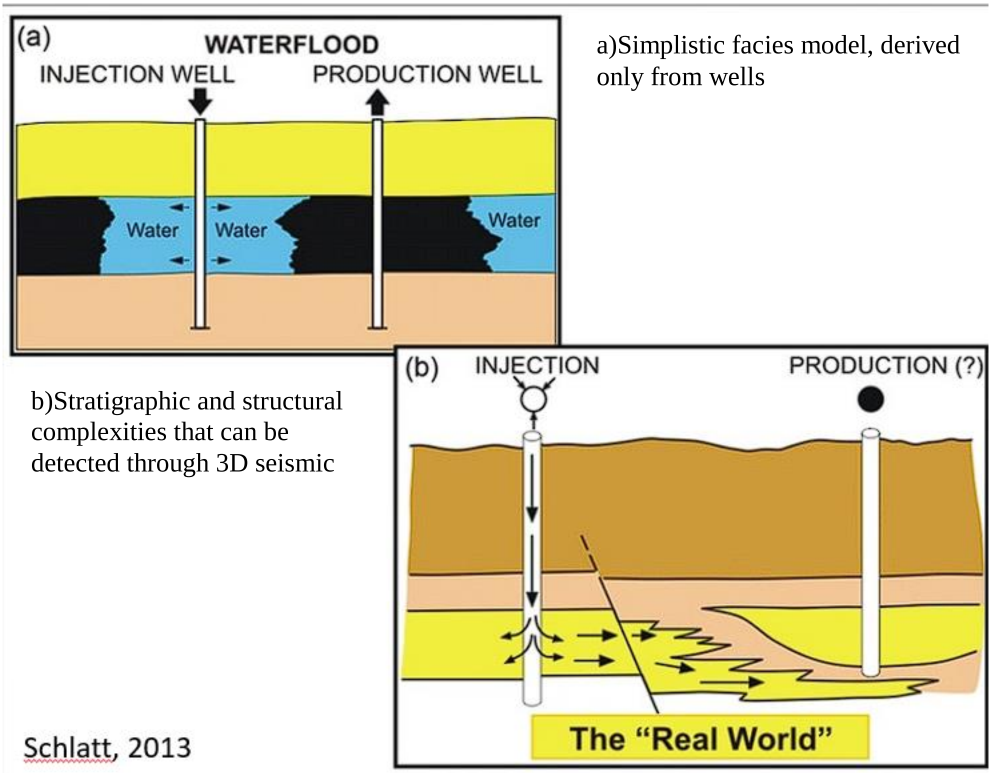

Figure 2. Comparison between a simplistic facies model and one that takes reservoir compartmentalization into account. [3].

Reservoir compartmentalization is a consequence of geological processes acting on the reservoirs from the time of sediment deposition up to the period of exploitation. Generally, the compartments of a field are delineated by stratigraphy, structural discontinuities, or a combination of both. While it is difficult to determine the sealing nature of faults, stratigraphy is clearer. In regional depositional environments, there are both fine-scale stratigraphic architectural elements that can act as seals and elements that can act as reservoirs.

2. Actual situation of mature hydrocarbon fields

Currently, hydrocarbons still hold approximately 60% of the global energy mix. Even though the demand for natural gas is projected to decline in the medium to long term, this decrease will mainly be due to the efficiency improvements in industrial processes and could even be offset by the production of hydrogen from natural gas.

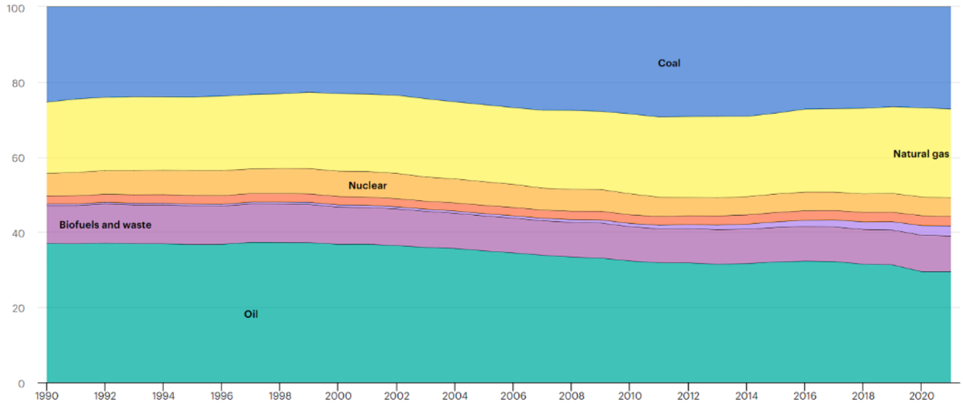

Figure 3. Global energy mix for 1990-2024 [5].

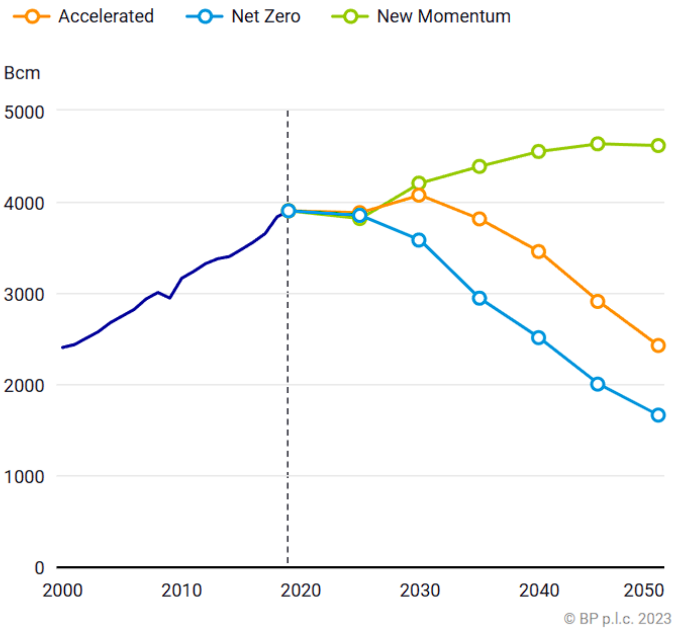

Figure 4. Evolution of natural gas demand through to 2050, based on 3 scenarios [4].

The discovery of new fields is an important component in maintaining and increasing global hydrocarbon production. Impacted by the Covid-19 pandemic and low oil prices, the investment strategy in exploration by oil companies in 2021 remained conservative, and exploration projects and well drilling generally slowed down and decreased in number. In 2021, 1,235 exploration wells were drilled, recording an annual decrease of 39. There were only 644 wildcat exploration wells, recording an annual decrease of 26[1].

Therefore, the redevelopment of mature fields remains the most economical measure to maintain or increase hydrocarbon production in the short term, with much lower investments compared to those required for an exploration project. In this process, reservoir characterization, particularly facies modeling, plays an important role by discovering and developing resources that were previously unnoticed because identifying isolated stratigraphic bodies was difficult or nearly impossible without high-quality 3D seismics. The added value of reservoir characterization increases as the fields become more mature. Thus, enhanced reservoir modelling can, depending on how far in it's lifecycle a given field is, contribute to lowering development costs through optimization of well design and placement and of surface facilities. Another important aspect of geological modelling, especially if done early in the field's lifecycle, is the reduction of well numbers, which leads to lowered emissions related to drilling and subsequent leaks, lowering the total environmental impact of the lifecycle of the field.

3. Compartmentalization of hydrocarbon reservoirs and modelling

Reservoir compartmentalization refers to the fact that hydrocarbon deposits are often segmented into multiple hydrodynamically isolated stratigraphic bodies. These isolated zones arise due to sedimentary processes that form the reservoir sedimentary rocks. Reservoir heterogeneities range from the microscopic level, related to the sorting and grain size of clasts, to the regional level, depending on the continental or marine environment in which the sediments were deposited. For example, in a fluvial system, the first order is considered the regional depositional environment, such as continental or transitional. The second order represents the classification of deposits as belonging to the fluvial environment. The third order is the type of river, such as meandering, braided, or anastomosing, and the fourth order consists of detailed stratigraphic elements: point bar, cutbank, overbank, floodplain, and levee[3].

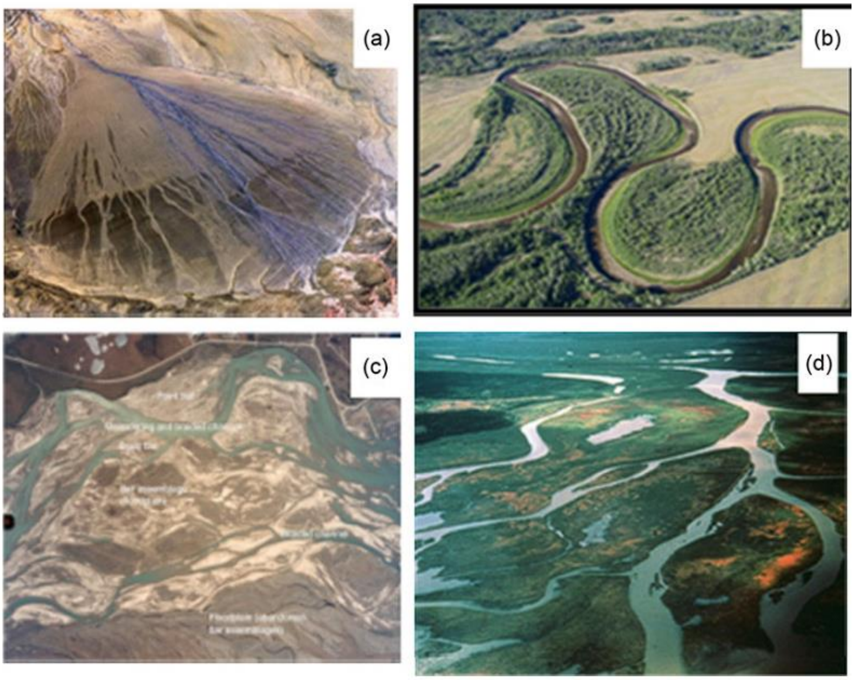

Figure 5. Example of a fluvial depositional environment (third order) and second-order environments, each with sedimentary characteristics:
(a) Alluvial fan, (b) Meandering river, (c) Braided river, (d) Anastomosing river [3].

Lithological contrasts between fourth-order elements are rarely visible on conventional reflection seismics. For their modeling, there are two approaches: stochastic modeling or deterministic modeling.

Stochastic modeling follows a purely statistical approach to facies distribution. It requires percentage values for each facies we want to model, which can be calculated from a facies log based on well log data. Statistical analysis of how values vary in space to determine possible directions of anisotropy is necessary. The results provided by this approach are sometimes uncertain because they depend on the quantity and quality of the input data. However, when data are scarce or their quality is uncertain, this type of model is preferred. Stochastic models can be improved using data driven, machine learning approaches but caution should be taken that data is cleaned up before being fed to a model. Because of the effect of depth or logging tool calibration, the correlations between different well log values can be misleading. Therefore, machine learning can be a valuable tool for this type of modelling, but always supervised so that results can be guided to make geological sense.

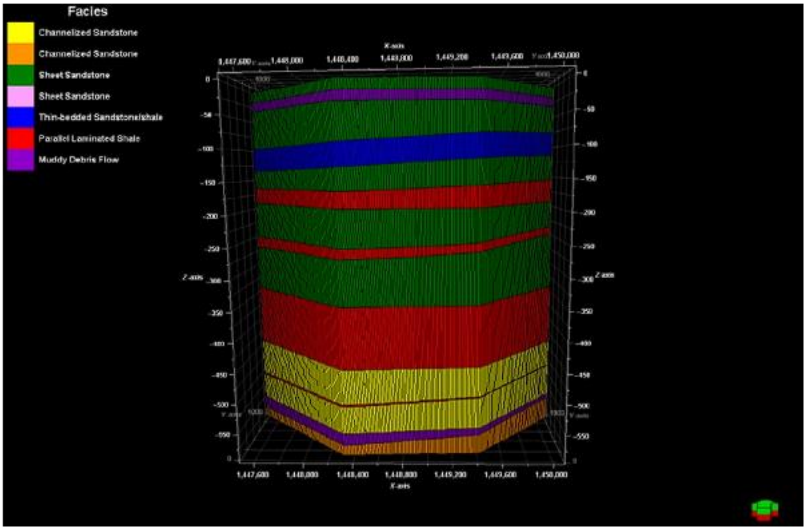

Figure 6. Example of stochastic modeling where fine stratigraphic elements are missing or difficult to identify [3]

The second type of modeling is deterministic modeling. It is used when the quantity of data is larger and their quality is good. The following subjects are most suitable for deterministic modeling: geological interpretation from seismic data, including the geometry of main sedimentary facies, and geological structures from 3D seismic data. Seismic attributes are used to improve seismic interpretations. Some useful seismic attributes include: Coherence, which checks the similarity between seismic traces, RMS (Root Mean Square), the square root of the sum of the squared values of amplitude, Instantaneous Frequency. By using these visualization methods, fourth-order stratigraphic elements can be visible, better outlining the reservoirs.

Once the fourth-order elements are identified, they can be integrated into a 3D model and assigned petrophysical properties based on core data and petrophysical interpretations of well logs. The deterministic model provides a better understanding of the reservoir and can lead to improved development and exploitation of a reservoir. The detailed modelling of the reservoir opens multiple redevelopment strategies. Better reservoir delineation and subsequent modelling of mechanical rock properties can improve the selection process of candidate wells for stimulation operations such as acid injection, gas injection or hydraulic fracturing, and better pinpoint the selection of perforation intervals. Thus, reservoir modelling and alternative recovery techniques are complimentary processes that go hand in hand when considering field development strategies.

Figure 7. A meandering fluvial system observed on 3D seismic.
Visible fourth-order elements include point bars, oxbow lakes, and river channels. [3].

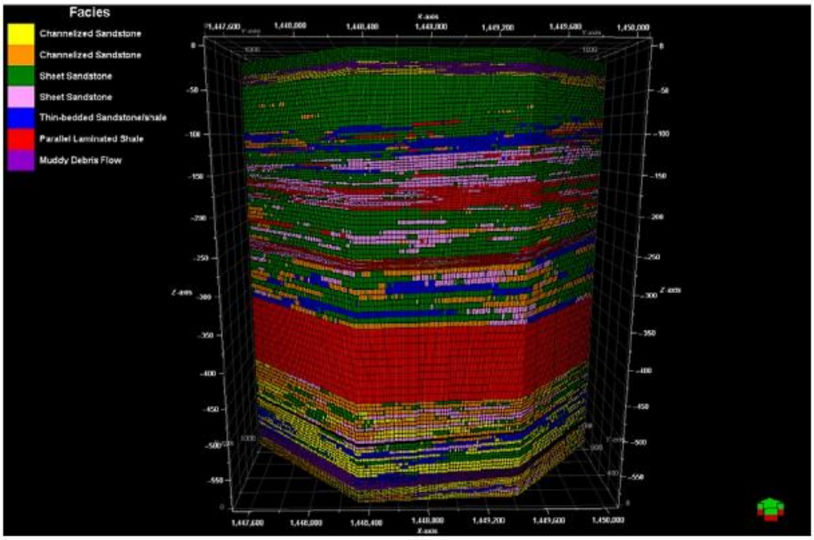

Figure 8. Same model as in Figure 8, approached deterministically
to observe the fourth-order stratigraphic elements[3].

4. Case study – Eastern Transylvanian Basin

The Transylvanian Basin is a sedimentary basin superimposed on the Carpathian orogeny. Within it, operates a Mid-Miocene biogenic petroleum system. The basin and its fields are considered mature, with the first discovery dating back to 1909. The structure under investigation is located in the eastern part of the basin, where the main deformation mechanism is represented by salt tectonics, and it consists of an anticline with a fault on each flank. At the time of discovery and delineation, wells were drilled along the anticline. The previous geological model has been reinterpreted due to significant differences in flow rates at the same target level.

Following the analysis of seismic attributes, a fluvial channel system was determined at the level of the studied target. The channel system was deterministically integrated into the old model, and the wells intercepting it were identified. The direction in which the channel system develops is perpendicular to the direction of the anticline, leading to the reclassification of the trap at this target as a combined structural-stratigraphic trap. Perforating the target on a well already positioned on the channel resulted in over a 50% increase in production from the structure and confirmed the previous hypothesis that the channel system is charged.

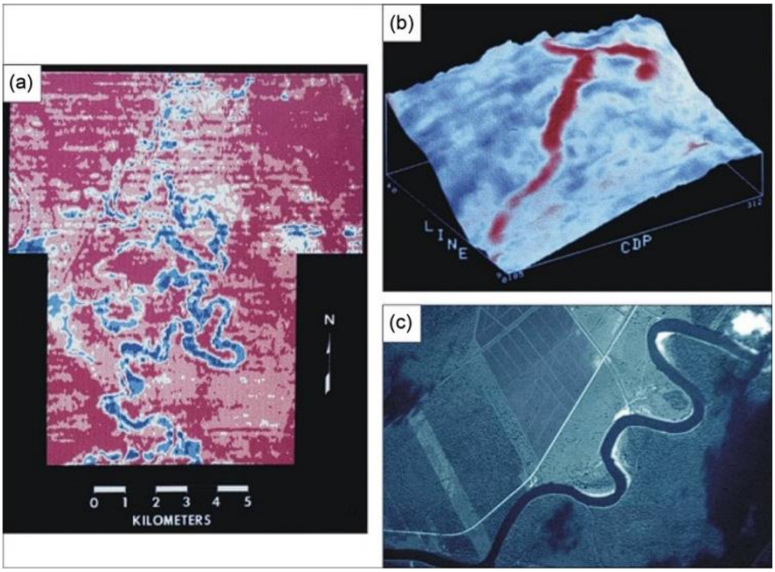

Figure 9. (a) and (b) depict fluvial channel systems on the seismic attribute RMS, similar to the structure in the Eastern Transylvanian Basin under study. (c) represents a modern analog (image from [3]).

5. Conclusions

In conclusion, adequate reservoir rock characterization is crucial for maintaining and optimizing hydrocarbon production globally. This characterization allows for a detailed understanding of the geological and petrophysical properties of rocks, providing essential information for identifying production potential zones and developing efficient exploitation strategies. By employing advanced reservoir characterization methods, data on porosity, permeability, fluid composition, and distribution within the rock can be obtained.

These informations are fundamental for decision-making regarding drilling, operating, and maintaining oil and gas wells, ultimately leading to more efficient and sustainable hydrocarbon production.

In a global context where the need to extract hydrocarbon resources remains essential for the economy and energy, reservoir characterization remains an important discipline for the oil and gas industry in ensuring the continuity and growth of production.

R E F E R E N C E S

[1] DOU Lirong, WEN Zhixin1, WANG Jianjun, WANG Zhaoming, HE Zhengjun, LIU Xiaobing, ZHANG Ningning, PETROL. EXPLOR. DEVELOP. „Analysis of the world oil and gas exploration situation in 2021", Volume 49, Issue 5, October 2022

[2] Niranjan C. Nanda, „Seismic Data Interpretation and Evaluation for Hydrocarbon Exploration and Production. ", Volume 2, 2021

[3] Roger M. Slatt, Stratigraphic Reservoir Characterization for Petroleum Geologists, Geophysicists, and Engineers, Developments in Petroleum Science, Volume 61, 2013

[4] bp Energy Outlook: 2023 edition

[5] IEA, World Energy Balances, IEA, Paris https://www.iea.org/data-and-statistics/data-product/world-energy-balances

Acknowledgements

The authors would like to extend their sincere gratitude to SNGN ROMGAZ SA for granting access to essential information and facilitating the research necessary for the completion of this paper.

Authors' biographies

Ion FOIDAȘ holds a Ph.D. in Engineering Sciences, in the Mine, Oil and Gas domain, has a Master's Degree in Management in the Oil Industry and a Master's Degree in Environmental Science and has graduated "Institutul de Petrol și Gaze" from Ploiești as an engineer specialised in Drilling Wells and Exploitation of Oil and Gas Fields. He currently works as head of the Production Department within S.N.G.N. ROMGAZ S.A. and Head of Works in the Department of Industrial Engineering and Management at the Faculty of Engineering of the "Lucian Blaga" University from Sibiu.

Email: ion.foidas@romgaz.ro

Adrian Cristian MIHAILA holds a bachelor's degree in Geological Engineering and is a reservoir geologist at SNGN ROMGAZ SA. He graduated from the University of Bucharest in 2023.
His research topics include Geological Modelling, Structural Geology, Petroleum systems, Sedimentology.

Email: adrian.mihaila@romgaz.ro