*Romanian Journal of Petroleum & Gas Technology*
*VOL. VI (LXXVII) • No. 2/2025*

# SEDIMENTARY BASINS AND HYDROCARBON RESOURCES ON A GLOBAL SCALE: INSIGHTS FROM ROMANIA

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**DOI: 10.51865/JPGT.2025.02.10**

## ABSTRACT

Global economies and infrastructure still depend heavily on petroleum-based products. Despite significant initiatives aimed at transitioning to renewable energy, the oil and gas sector continues to play a key role in shaping both the global economy and political landscape. Organizations like the U.S. Energy Information Administration, the U.S. Geological Survey, and the BP Statistical Review of World Energy have gathered extensive data reflecting this ongoing reliance. Oil reserves are not uniformly distributed across the globe. The Middle East holds the majority of the world's confirmed reserves, followed by countries such as United States and the Canada, as well as regions in Latin America, Africa, and the former Soviet states.

Hydrocarbon deposits of a basin, or even part of it, led to the concept of an oil province that is mainly based on the analysis of geological setting. The defining of a petroleum system or province considers several criteria: geographic criteria (especially the extent and volume of rocks of interest); geological criteria (type of basin and its classification, stratigraphy) and petroleum criteria (potential and volume of discoveries, type of reservoir). After classifying giant oil fields according to basin and tectonic setting, several conclusions were drawn and a hierarchy was established: passive continental margins facing large ocean basins host of about 31% of giant deposits; continental rifts and overlying sag basins contain about 30% of the world's largest oil fields; the final collision belts between two continents form major basin that contains for approximately 24% of global giant fields; and continental arcs at convergent plate boundary, strike-slip systems, and subduction margins together host 15% of the world's giant fields.

Looking ahead, the direction of oil exploration will be influenced not only by the quantity and type of resources available in the mentioned areas, but also by geopolitical dynamics and technological advances. Improved seismic imaging and detailed reservoir analysis are expected to play a greater role, especially in the development of unconventional resources such as tight oil, tight gas and shale formations.

Romania can be considered the second largest oil producer and the third largest gas producer in the EU. Most known oil and gas fields in Romania have reached maturity, but the exploration of deeper structures has led to several recent discoveries. Current research techniques based on high-resolution seismic images correlated with a complex geophysical well investigation are expected to reveal new hydrocarbon accumulations both onshore areas (in orogenic or foreland type basins) and offshore in the western Black Sea basin.

In order to have a clear picture of the development directions for oil and gas fields, this study analyzed data and statistics provided by specialized institutions and literature, synthesizing them in a clear and suggestive way possible according to the diagram below. The paper represents a first step in guiding future exploration efforts.

**Keywords:** petroleum provinces, oil and gas exploration, global resources, Romania's oil and gas, future areas of interest.

## INTRODUCTION

Hydrocarbon resources have been the subject of many published research projects. The analyses began with the distribution of source rocks for oil and gas and continued with their relationship to reservoir rocks capable of storing commercially quantities of oil or gas. New technologies will be able to provide a more accurate correlation between seismic survey profile and rock parameters rocks, allowing thus a better characterization of reservoir quality. The analysis of economic risks will thus become a necessary and easily achievable object.

Having a view of resource distribution allows us to know the possibilities of each country to have its own resources, or to head towards the most favorable ones in the geographical or geopolitical area to which they belong.

Romania is a privileged country. We had and still have resources that ensure our economic independence. Today our country can be considered the second largest oil and third largest gas producer in the European Union. The future direction of exploration in Romania is focused on deep, complex geological structures, but also towards the rehabilitation of mature oil fields, (re-evaluation of the geological models and increasing the final recovery).

In order to establish the areas with the greatest prospects in future hydrocarbon exploration, in this paper, we have tried to include the essential aspects that allow the evaluation of current resources and, more importantly, to identify areas with high potential, capable of providing the necessary resources for future energy demands and economic development.

## METHODS

This study analyzed data and statistics provided by specialized institutions (U.S. Energy Information Administration, the U.S. Geological Survey, and the BP Statistical Review of World Energy, the International Energy Agency, Oil & Gas Journal, Tulsa, Oklahoma, etc.) and data from the specialized literature regarding the classification criteria, the geographical and geological extent of the sedimentary basins and oil provinces on a global scale, establishing the perspective areas both on a global and local scale (for Romania), areas that would ensure the best results in the future exploration activity.

## CRITERIA FOR CLASSIFYING PETROLEUM PROVINCES AND SYSTEMS

The way of associating hydrocarbon deposits of a basin, or only a part of it, led to the notion of oil province that is mainly based on the analysis of the geological setting. Several criteria are taken into account in the analysis a petroleum system or province:

- geographic criteria (especially the extent and volume of rocks of interest);
- geological criteria (type of basin, its classification and stratigraphy);
- petroleum criteria (potential and volume of discoveries and type of habitat).

Hydrogeological conditions control the depositional environment and paleogeography, while hydrocarbon migration generally follows the path of decreasing pressure gradient. High pressures in the overlying layers provide significant protection for the hydrocarbons.

In stable basins, with low subsidence, or in young basins with high subsidence, the hydrogeological zones favorable to hydrocarbon migration are located in the central area. In young basins, with deep, under compacted layers, the favorable hydrogeological zones are generally in the transition areas located above the over pressurized sequences.

Sedimentological criteria refer to the distribution of rock types during sedimentation: lateral facies variations, (such as the transition from source rock to reservoir rock); superposition of strata and unconformities and sedimentary organization (for example, porous mega sequences overlain by fine, impermeable sequences, as well as the frequency of transgressions and regressions).

The evolution of a basin can be characterized by the juxtaposition and succession in time of positive and negative structural areas. Regional sea level determines the presence of subsidence zones productive for source rocks, depositional environments favourable to the appearance of protective rocks, the degree of burial favourable to the compaction and maturation of source rocks. The subsidence and sedimentation rates, the environmental and lithological conditions, geothermal gradient and the geochemical properties ~~character~~ of basin waters define the characteristics of source rocks and the volume of hydrocarbons generated throughout the Earth's evolutionary history.

A petroleum province is defined as a sedimentary basin, or a sector thereof, characterized by relatively uniform general conditions for the formation, accumulation, and preservation of hydrocarbons in the different stages of geological development. It is a geo-structurally controlled system, influenced by sedimentation, lithification, organic diagenesis and trap formation [5]. Petroleum provinces can occur in all types of sedimentary basins [5], but the architecture of the basin largely determines the potential of a province, with richness typically governed by significant subsidence and moderate tectonic activity.

Foredeep basins represent the most characteristic configuration, with the majority of giant discoveries in these settings being gas fields, except for those in passive margin environments such as West Africa, the Gulf of Mexico, and Brazil [19]. Approximately 53% of the hydrocarbon resources in giant fields are located within fold belts, forelands, and foredeeps.

After classification of giant oil fields according to basin and tectonic setting, several key conclusions were reached [6]:

1. Passive continental margins that face large ocean basins are the hosts of about 31% of giant deposits (fig. 1-1). Most of these consist of wide, low amplitudes folds. Source rocks are abundant throughout the depositional sequences, while reservoir rocks include sands and carbonates in the early stages of oceanic opening, and turbidites in later stages. Traps are primarily structural, horst - related or associated with salt and clay tectonics.

2. Continental rifts and overlying sag basins account for approximately 30% of the world's giant oil fields (fig. 1-2). Hydrocarbons accumulations are found in rifting phases, where the heat flow control the maturation of source rocks, and in post-rifting sag phases, which are characterized by long-term subsidence and marine sedimentary infill.

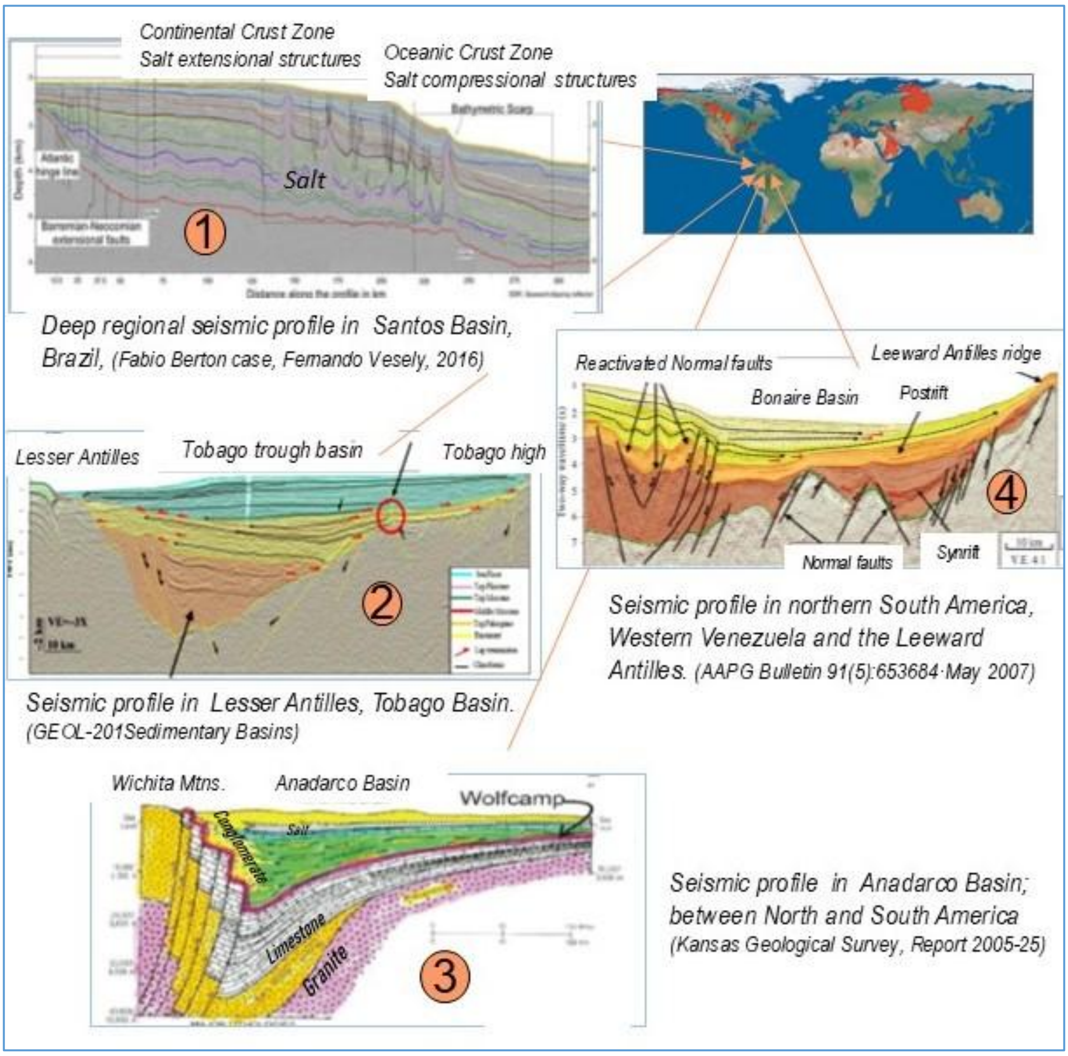


***Figure 1**. Examples of seismic profiles from the northern part of South America (onshore/offshore), suggestive for the types of major provinces* [3], [6],[8].
*1-Continental passive margins fronting major ocean basins. (Santos Basin, Brazil);*
*2-Continental rifts and overlying steer's head sag basins.( Tobago Basin, southeastern Caribbean Sea);*
*3-Terminal collision belts between two continents,(Anadarko Basin, between North and South America);*
*4-Arc/continental collision margins, strike-slip margins. (Western Venezuela and the Leeward Antilles)*

3. The final collision belts between two continents form major basin that contains about 24% of the world's oil giant oil fields (fig. 1-3). The continent-continent collision culminate in the development of orogenic belts, providing a large volumes of sediments.

4. Continental arcs at collision margins, strike-slip margins, and subduction zones together form the framework for 15% of the world's giant fields. These regions are associated with areas of large wrench faults systems (fig. 1-4). The echelon

folds formed in contact zones are good traps during the subsidence, although tension faults, can compromise their integrity. They have a short formation time, high thermal conditions, rapid sedimentation, and are characterized by detrital reservoir rocks or turbiditic in deeper areas.

The main oil provinces in the world classified by geological criteria(fig. 2) are as follows:

- North America: *1-Alaska; 2-Rocky Mountain foreland; 3-Southern California; 4-Permian and Anadarko basins; 5-Gulf of Mexico*;
- South America: *6-Northern South America; 7-Brazil; 8-North Africa; 9-West Africa*;
- Africa-Asia: *11-Arabian Peninsula / Persian Gulf*;
- Europe-Asia: *10-North Sea; 12-Black Sea; 13-Caspian Sea; 14-Ural Mountains; 15-West Siberia; 16–Siberia*;
- Asia-Australia *17-China; 18-Sunda; 19-Australia; 20-Bass Strait/Australia/ Tasmania.*

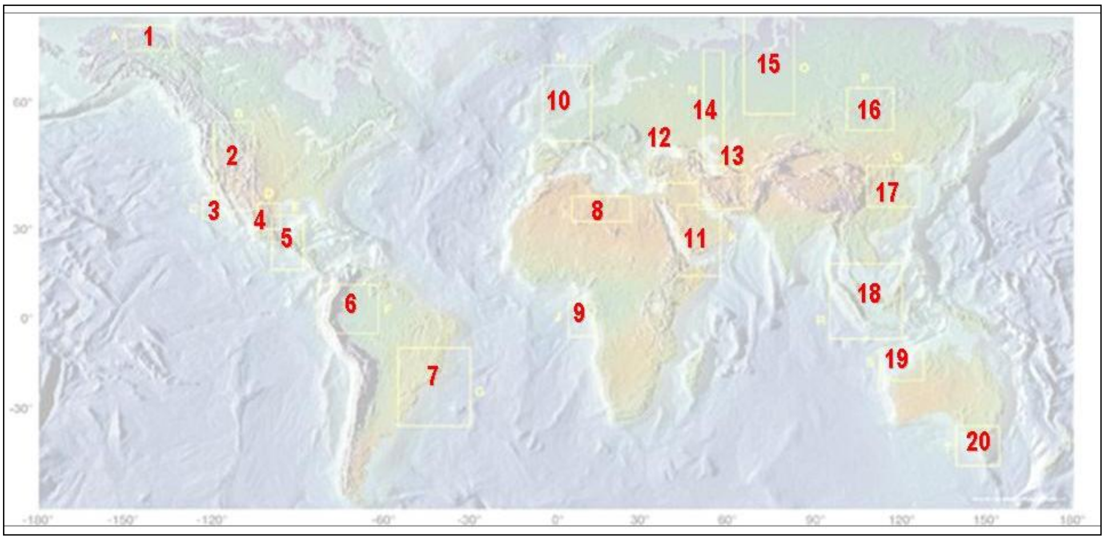


***Figure 2.*** *Location of the world's giant oil fields* [6]

## OIL ON THE GLOBAL SCALE

The world's dependence on oil and gas continues to grow, with global economies and infrastructure remaining heavily dependent on petroleum products. Despite massive efforts to increase the use renewable energy source, the oil and gas industry continues to exert a major influence on international economics and geopolitics. There are over two hundred oil and gas companies in the world. In recent years, traditional multinational companies have faced strong competition from numerous national oil companies that need more exclusive rights to major local oil reserves [7].

Numerous statistics and assessments on a global scale have been produced by companies such as the U.S. Energy Information Association, the International Energy Agency (Oil Market Report), the U.S. Geological Survey, and the BP Statistical Review of World Energy [12,13,14]. Among the world's largest companies in this sector are Sinopec (China), Saudi Aramco (Saudi Arabia), China National Petroleum, Royal Dutch Shell (UK/Netherlands), BP (UK), ExxonMobil (USA), Total (France), Valero (USA), Gazprom (Russia), Phillips 66 (USA), Kuwait Petroleum Corporation (Kuwait), Lukoil (Russia), Eni (Italy), Pemex (Mexico), Chevron Corporation (USA), and the National Iranian Oil Company (NIOC). For about fifty years, world supremacy has been held by countries such as the United States, Russia, Saudi Arabia while Iran, Mexico, Canada were in fourth position (fig. 3).

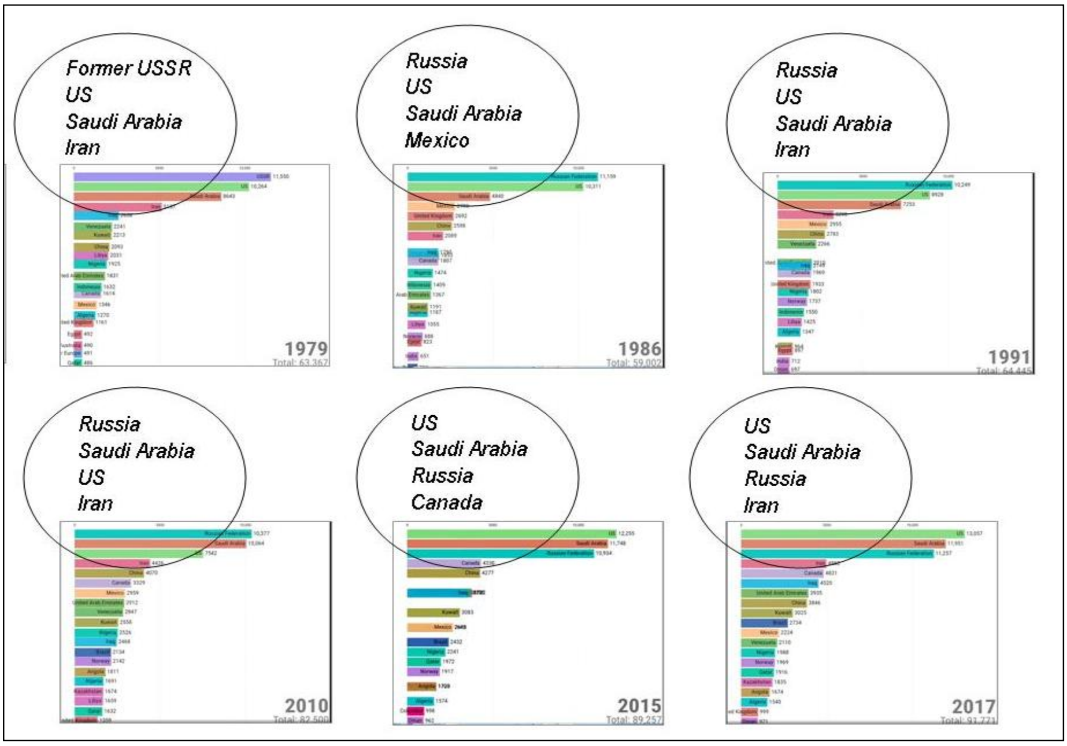


***Figure 3***. *The word leading for the past 50 years (conventional / unconventional oil LNG)* [13].

Oil resources are distributed unevenly across the planet. The Middle East holds the majority of the world's confirmed oil reserves, possessing more crude oil than all other regions combined. North America, particularly the United States and Canada, ranks second, followed by Latin America, Africa, and the territories of the former Soviet Union. Each of these regions contains less than 15 percent of the world's proven reserves, a term that refers to both actively exploited fields and those explored sufficiently to allow for future development [4].

Proven oil reserves are defined as those with a reasonable certainty of being recoverable under existing economic and political conditions, with existing technology. The volume of oil extracted from a region does not necessarily correspond to the size of its confirmed reserves. Although the Middle East possesses more than half of the world's proven oil reserves, it contributes only around 30 percent of global production. In contrast, the United States, with less than five percent of these reserves, generates approximately 15 percent of global output (U.S. Energy Information Administration).

Since the beginning of systematic oil exploration in the 1860s, an estimated 50,000 oil fields have been identified worldwide. However, the vast majority, over 90%, have had minimal influence on global production levels. A relatively small number of exceptionally large fields account for most of the world's oil supply, whereas smaller fields are numerous but less productive. As exploration activities expand within a region, the average size of newly discovered fields tends to decline, along with the quantity of recoverable oil per well. Typically, the largest and most productive fields are identified during the early stages of exploration [7].

The two major classes of fields are supergiants, fields with more than 5 billion barrels of ultimately recoverable oil, and world-class giants, fields with 500 million to 5 billion barrels of ultimately recoverable oil. More than 40 supergiant oil fields have been discovered worldwide, but they contain about half of all the oil discovered to date. The Arabian-Iranian sedimentary basin in the Persian Gulf region contains two-thirds of these supergiant fields, and the remaining supergiants are spread across countries such as the United States, Russia, Mexico, Libya, Algeria, Venezuela, and China. Less than 5 percent of known fields provide an initial reserve of about 95 percent of global oil [6].

A global geographic distribution of giant fields has been marked by numbers on the bathymetric topographic map of the world generated from satellite gravity measurements by the Institute for Geophysics, University of Texas at Austin (fig. 4).

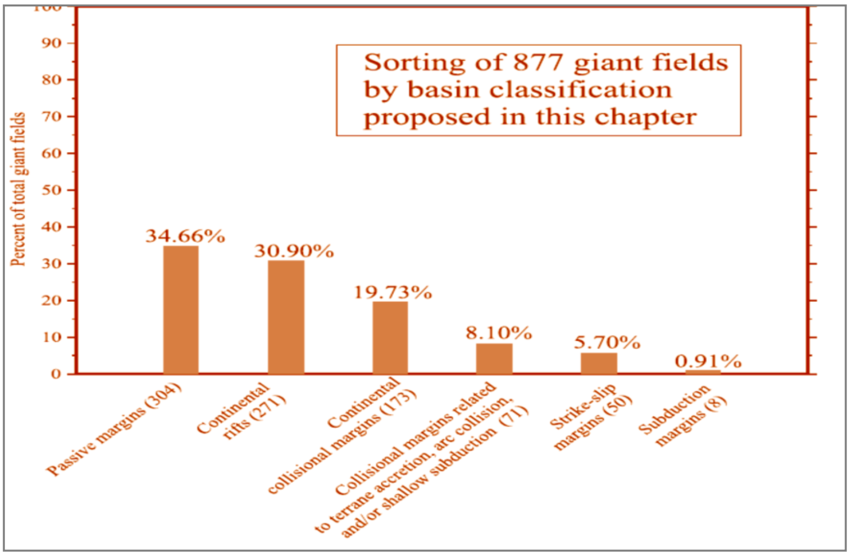


***Figure 4.*** *Participation of basin types in the supply of hydrocarbon resources on a global scale* [6].

## FUTURE TRENDS IN GLOBAL OIL AND GAS EXPLORATION

The most important discoveries of 2019/2020 mentioned by the *Oil & Gas Journal*, Tulsa, Oklahoma are (fig. 5):

- **Gas:** Offshore Australia (PTTEP), Sakakemang, Indonesia (Repsol), Offshore Cyprus (ExxonMobil), Yamal Peninsula, Arctic Russia (Gazprom), Humberside, England (Rathlin Energy Ltd., Beverley), Urengoyskoye horizontal drilling, Perth Basin, Australia (Strike Energy), West Erregulla (Strike Energy), Offshore Otway, Western Australia (Cooper Energy) Browse Basin, Western Australia (Shell), Otway, South Australia (Lakes Oil NL), Northern Morocco (SDX Energy Plc), Emirates and Abu Dhabi (ADNOC), Tierra del Fuego region, Chile (GeoPark).
- **Gas and condensate:** center of the North Sea (CNOOC), Outeniqua Basin, South Africa (Total), Offshore Vietnam, offshore Angola and the Niger Delta (Eni), offshore Mahani, UAE (SNOC, Eni SPA), Central North Sea (Total SA).

- **Oil:** Offshore Ghana (Aker Energy), Utsira High (Lundin Norway AS), near the Oseberg field, North Sea (Equinor), Santander, Middle Magdalena, Columbia (Ecopetrol), Alvheim field, North Central Sea (Aker BP), Goddo prospect, North Sea (Lundin), Barents Sea (light oil, Equinor), Llanos Block 34, Colombia (GeoPark), offshore Guyana to Suriname (Apache and Total), Pikka East Block, northern Alaska (Oil Search Ltd), offshore Mexico (Eni), Rhine Valley, Germany (Neptun Energy), Azerbaijan (SOCAR, Equinor), Alaska (Oil Search), offshore Suriname (Oil Search).
- **Oil and gas:** Western Australia (Santos Ltd. & Carnarvon Petroleum), Northern Norwegian Sea (Equinor), Norwegian part of the North Sea (MOL Norge).
- **Minor discoveries** were made near Balder, North Sea (ConocoPhillips), offshore Guyana (ExxonMobil), and in Magdalena Valley, Colombia (Parex and Frontera) [18], [23].

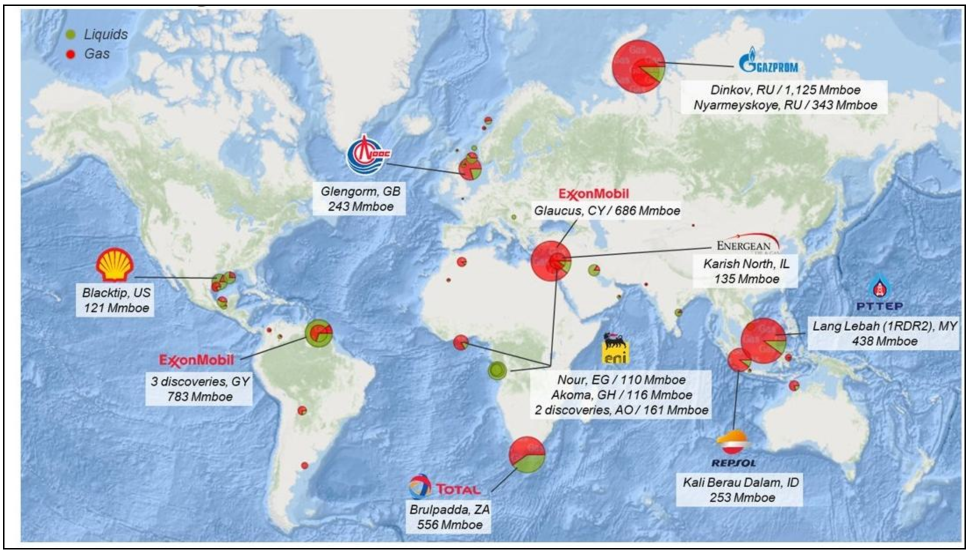


***Figure 5.** The most important discoveries of conventional resources of 2019* [24].

Geological investigations and preliminary exploration efforts have demonstrated that there are still areas with undiscovered hydrocarbon accumulations. (fig. 6, fig. 7)

Important factors that will influence the future of exploration, in addition to the type and volume of resources, are related to geopolitical aspects and the evolution of technology. Particular care will be given to the management and reduction of the impact on the environment [2]. High-resolution seismic images and a high-performance reservoir analysis will be extended to unconventional plays (tight oil, tight gas, shale oil).

The analysis of seismic attributes, especially fluid mobility attributes, can help identify shale gas reservoirs, including their spatial distribution, thickness, and structural configuration, having thus a characterization of gas-bearing shales before drilling.

Another key objective is to integrate the geological and mechanical properties of the rocks to understand the impact of stimulation technology and to improve the yield capacity of the reservoir. Modeling the basin and the petroleum system is as important as the technology for acquiring, processing and interpreting seismic data on which providing an accurate geological picture depends [2].

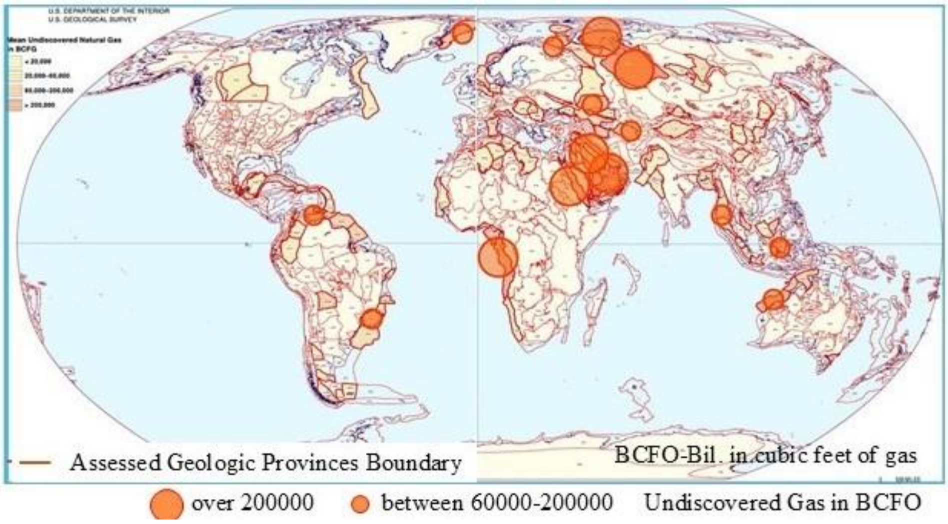


***Figure 6***. *The main estimated undiscovered gas reserves at geologic provinces level* [15]

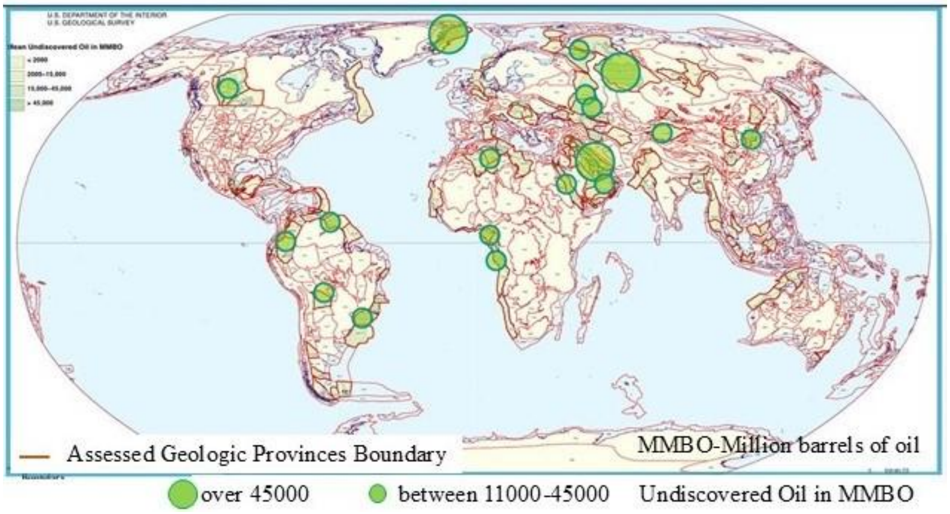


***Figure** 7. The main estimated undiscovered oil reserves at geologic provinces level* [15].

Continued exploration in established areas, augmented by novel technologies and perspectives, has represented a significant paradigm shift, effectively arresting production declines in regions such as the United States. The resource prospects of the Arctic region can be seen in the Kara Sea area, in untested basins belonging to Russia and Canada.

The North Sea remains a region of major economic interest in the oil industry, for countries such as United Kingdom, Norway, Denmark, Germany and the Netherlands.

Today, deepwater areas have become the focus of global exploration, representing some of the most important opportunities for increasing oil and gas production [1]. The deepwater discoveries so far are mainly distributed along five groups of deep-water basins [20].

- Deepwater basins of the Atlantic Ocean,
- Deepwater basins along the continental margin of East Africa;
- Deepwater basins in the Western Pacific Ocean;

- Deepwater basins in the Neo-Tethys region, particularly on the northwest shelf of Australia and in the eastern Mediterranean area;
- Deepwater basins surrounding the Arctic Pole.

A series of offshore seismic surveys bring information on the presence of gas hydrates on the seabed (fig. 8). These hydrates, associated with certain slope characteristics can be dangerous for drilling hazard but also considered a potential energy resource of biogenic or thermogenic origin.

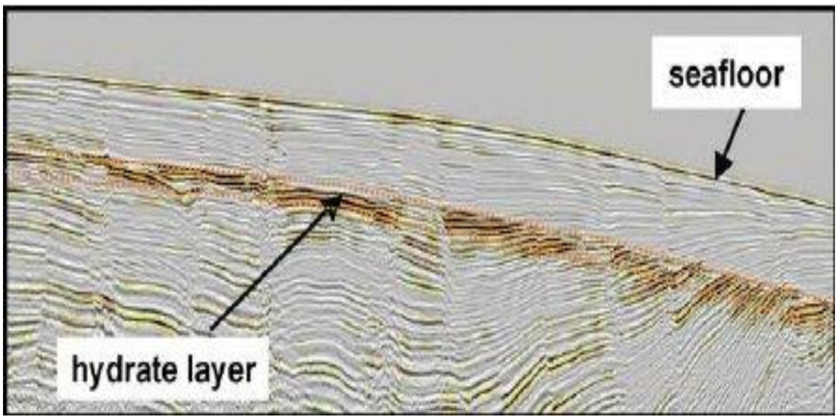


***Figure 8**. Seismic reflection image of a bottom-simulating reflector representing a methane hydrate layer beneath the ocean floor,. at approximately 80 ms TWTT (two way travel time)* [25]

A fundamental requirement for the accurately evaluating prospects is achieving a strong correlation between well data and seismic information. This correlation is also essential for accurately estimating the depth and characteristics of subsurface formation but also for effectively guiding the drilling process through the targeted geological layers. Seismic investigation using real time waveform while drilling gives us the image of reflectors (layer surfaces) before the drilling bit reaches them (fig. 9).

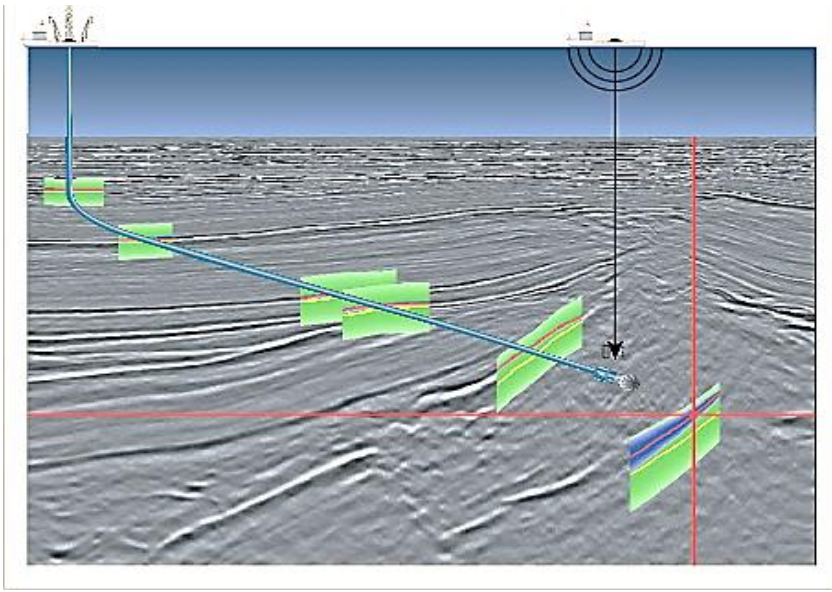

***Figure 9.** Schlumberger's seismic-while-drilling service uses real-time waveforms to image reflectors ahead of the drill bit while drilling* [26].

*Romanian Journal of Petroleum & Gas Technology*
*VOL. VI (LXXVII) • No. 2/2025*

Crude oil continues to serve as a fundamental component of the global energy framework, exerting a significant influence across sectors such as transportation, industrial production, international relations, and national security. As global energy demand continues to evolve and the transition to alternative sources accelerates, identifying the geographic distribution of the world's largest proven oil reserves is essential for planning prospective supply networks, anticipating market behaviour, and assessing geopolitical dynamics.

Nations endowed with the most extensive verified crude oil reserves play a decisive role in shaping the trajectory of the international energy landscape. Venezuela holds the largest proven crude oil reserves globally, estimated at approximately 303 billion barrels as of 2024. These reserves are predominantly located in the Orinoco Belt, which contains extra-heavy crude oil that requires advanced extraction technologies. However, Venezuela’s oil production has faced significant challenges due to economic instability, infrastructure limitations, and international sanctions (fig. 10) [21].

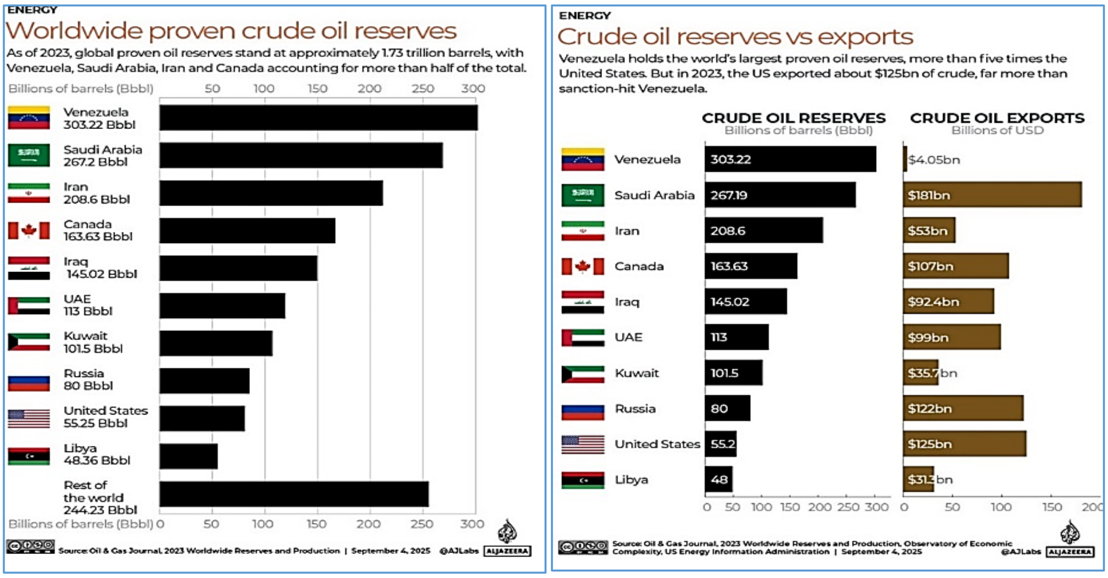


***Figure 10.*** *Today wordwide reserves and exports* [21].

Saudi Arabia holds the world’s second-largest proven crude oil reserves, estimated at approximately 267 billion barrels as of 2024. Most of these reserves are concentrated in the Eastern Province, which hosts the largest onshore oil field on the planet. The nation’s petroleum sector is administered by Saudi Aramco, the state-owned enterprise responsible for managing production and exports. Through strategic operations, Aramco has maintained Saudi Arabia’s status as a dominant global oil supplier. In 2023, the company’s daily output averaged around nine million barrels, with the majority of exports directed toward markets in Asia.

Canada occupies the fourth position globally in terms of confirmed crude oil reserves, amounting to roughly 171 billion barrels in 2024. An estimated 97% of these reserves are located within Alberta’s oil sands, particularly in the Athabasca, Peace River, and Cold Lake regions. Canada’s petroleum industry operates a hybrid system, combining private-sector investment with regulatory oversight at both federal and provincial levels. Major energy corporations play a significant role in extraction and production, reinforcing Canada’s position as the fourth-largest crude oil producer in 2023. While the United

States remains the primary destination for Canadian oil exports, there is increasing commercial interest in expanding trade with Asian markets.

Iraq possesses the world's fifth-largest volume of confirmed crude oil reserves, exceeding 145 billion barrels as of 2025. The majority of these resources are situated in the southern part of the country, encompassing major fields such as Rumaila and West Qurna, both classified as supergiant deposits.

The United Arab Emirates (UAE) ranks sixth in terms of verified crude oil reserves, which were estimated at approximately 113 billion barrels in 2024. Most of these reserves are concentrated within the emirate of Abu Dhabi, the main centre of the nation's hydrocarbon industry. Oversight of exploration, production, and export operations is conducted by the Abu Dhabi National Oil Company (ADNOC), which places strategic emphasis on technological advancement and operational efficiency. As of 2024, the UAE's crude oil production capacity was projected to expand to nearly 3.5 million barrels per day by 2028, reflecting the country's strategic objective of strengthening its role in global energy markets.

The spatial distribution of global crude oil reserves exerts a profound impact on both energy markets and geopolitical relations. Countries such as Venezuela, Saudi Arabia, and Iran possess extensive hydrocarbon resources that play a decisive role in determining global supply patterns and pricing structures. Concurrently, countries including Canada, Iraq, and the United Arab Emirates (UAE) are actively advancing the development of their reserves while contending with diverse economic, technological, and environmental challenges. A comprehensive understanding of the location management of these reserves is essential for policymakers, industry leaders, and investors seeking to navigate the complex dynamics of international oil production, trade, and consumption [15].

The contemporary energy industry is undergoing a phase of accelerated technological advancement, supported by strong cash flows and solid financial stability, indicators that suggest continued growth and resilience in the near future. To sustain this positive trajectory, several strategic priorities have emerged:

- Adopting advanced technologies such as generative artificial intelligence (genAI) and machine learning (ML) to enhance operational efficiency, reduce expenditures, and minimize risk exposure;
- Implementing comprehensive decarbonization strategies to align industrial processes with global sustainability objectives;
- Integrating sophisticated market intelligence platforms that offer real-time access to essential data, including regulatory and geopolitical developments, competitive analysis, and expert assessments, thereby enabling informed and adaptive decision-making [17].

## ROMANIA'S RESOURCES IN THE CONTEXT OF GLOBAL EXPLORATION

Romanian's hydrocarbon fields are distributed across five main onshore basins and one offshore basin: the Pannonian Basin (in the West), the Transylvanian Basin (Central Romania), the foreland of the Moldavian Platform (in the East), the Moesian Platform (in the South), the external area of the Carpathian Orogen (East and South), and the Black Sea Basin (Southeast) [9]. The hydrocarbon generation possibilities are met in all Romanian sedimentary basins and in every stratigraphic level, the distribution of source rocks and their degree of maturation controlled by the geothermal gradient and subsidence patterns specific to each basin (fig. 11). The description of the depositional systems based on the seismic stratigraphy principles opens new opportunities for identifying and delineating both source rocks and reservoir rocks (fig. 12) [9].

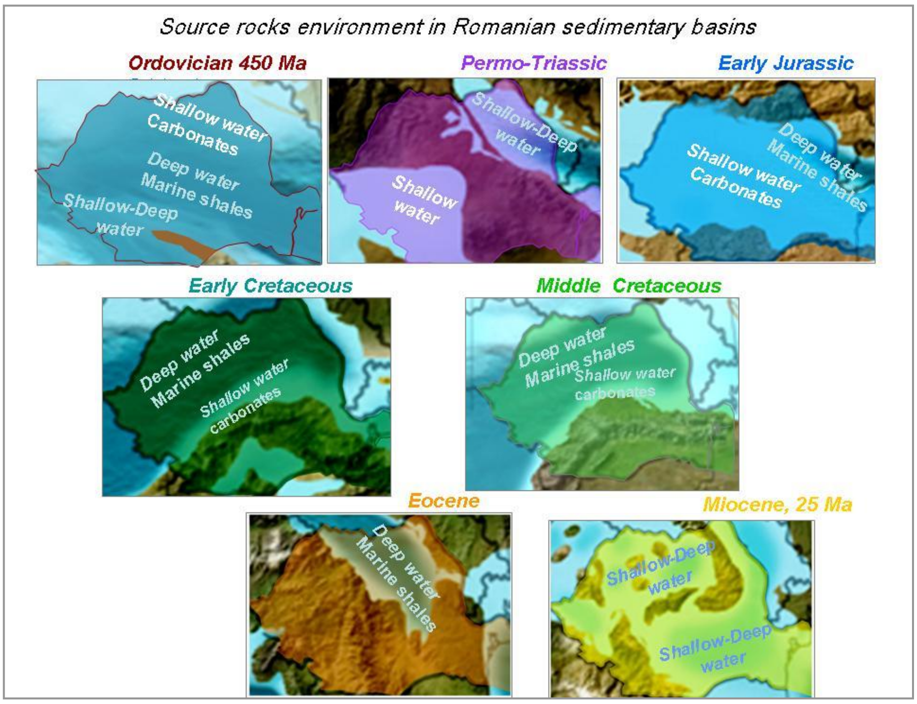


***Figure 11.*** *The territory of Romania; the geological periods in which it was covered by deep water (most favourable for source rock)* [9].

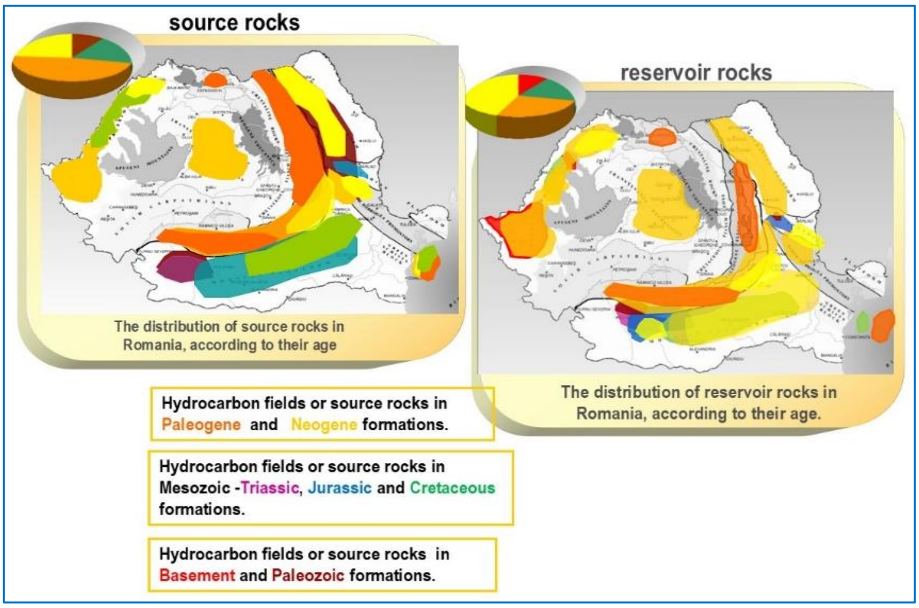


***Figure 12.*** *The distribution of source rocks on the Romanian territory, from Neogene to Paleozoic in some areas they overlap, with the chances of forming hydrocarbons of different types* [9].

The oil and gas industry in Romania dates back to 1857, when the country drilled one of the world's first commercial oil wells. Production peaked at 300,000 barrels per day in 1978 for crude oil and 39 billion cubic meters per year for natural gas in 1982. Today, Romania can be considered the second largest oil producer and the third largest gas producer in the European Union, and has the highest number of active wells in Europe. The first offshore commercial oil field was discovered in 1979, and production began eight years later [27].

In 2012, OMV Petrom and ExxonMobile announced a major natural gas discovery in the deep waters of the Romanian sector of the Black Sea, within the Neptun Block. The estimated reserves were approximately 84 billion cubic meters (bcm) of natural gas, making it the largest discovery in the region to date. Various studies estimate that the total unexploited natural gas reserves in the Black Sea amount to between 170 and 200 billion cubic meters (bcm).

Romania's known oil and gas fields have reached a mature stage of development. However, recent exploration targeting deeper geological structures has led to new discoveries. In 2016, Petrom and Hunt Oil discovered a new oil and gas field at a depth of 2,500 meters, while Romgaz made a major discovery after testing formations at a depth of around 5,000 meters in the eastern basin of the Moesian Platform.

Recent seismic research has identified new hydrocarbon prospects in the country's most geologically complex regions. Since 2015, approximately 16,000 $km^2$ of 3D seismic data have been acquired, but they cover only 10% of the surface of Romania's total sedimentary basins aera. Most of the seismic prospecting has focused on targets up to 3,500 meters deep, leaving deeper structures relatively underexplored.

Romania benefits from a well-developed energy infrastructure, currently undergoing modernization projects. The refining capacity is also high, although it is not fully utilized. Hydrocarbon production comes from approximately 400 fields, of which almost 90% are classified as mature. The decline in production is attributed to the maturity of these fields; however, they still represent a significant resource base that can be revitalized through enhanced oil recovery (EOR) techniques aimed at maximizing the extraction of the remaining reserves. OMV Petrom is the principal operator in this field in Romania. Enhanced oil recovery techniques are applied to improve the flow in oil and gas fields, both onshore and offshore.

On the global map of proven oil reserves, Romania is categorized among countries with reserves ranging between 100 and 1,000 million barrels of oil (fig. 13). In terms of natural gas reserves on a global scale, Romania ranks among the countries possessing approximately 00 billion cubic meters (bcm) of proven reserves (fig. 14).

According to the *BP Statistical Review of the World Energy* (2017), Romania's oil consumption per capita range between 0.5 and 1 tonne per person (fig. 15). In terms of natural gas consumption per capita, Romania ranked between 0.5 and 1 tonne of oil equivalent (toe) in 2017, on a scale ranging from 0 to 2.0 toe (fig. 16).

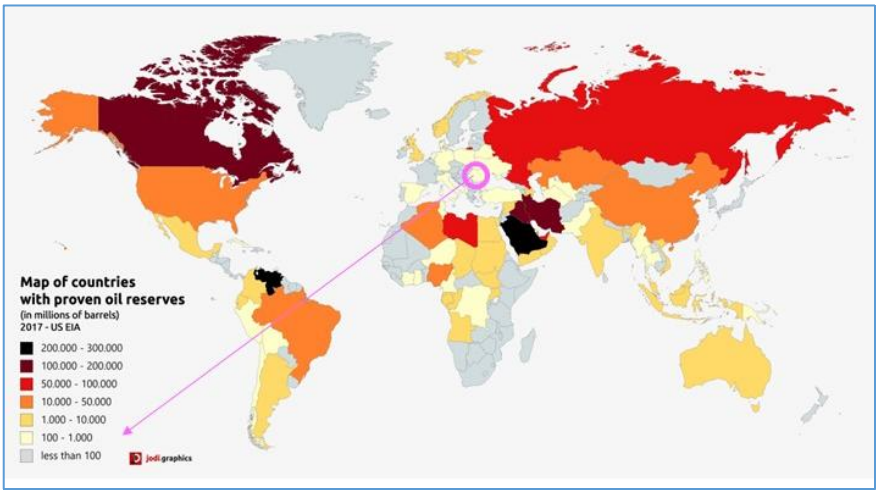


***Figure 13.*** *Romania's position in terms of proven oil reserves, compared to the global distribution in echelon of values in 2017* [13].

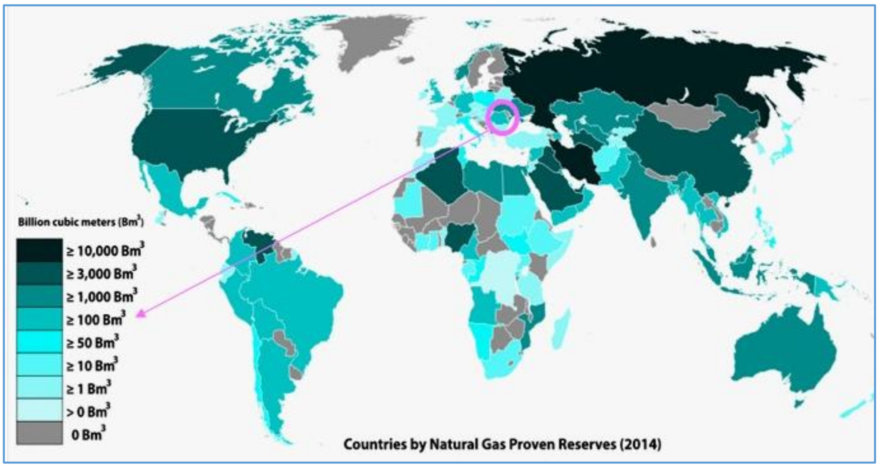


***Figure 14.*** *Romania's position in terms of proven gas reserves, compared to the global distribution in echelon of values.* [13]

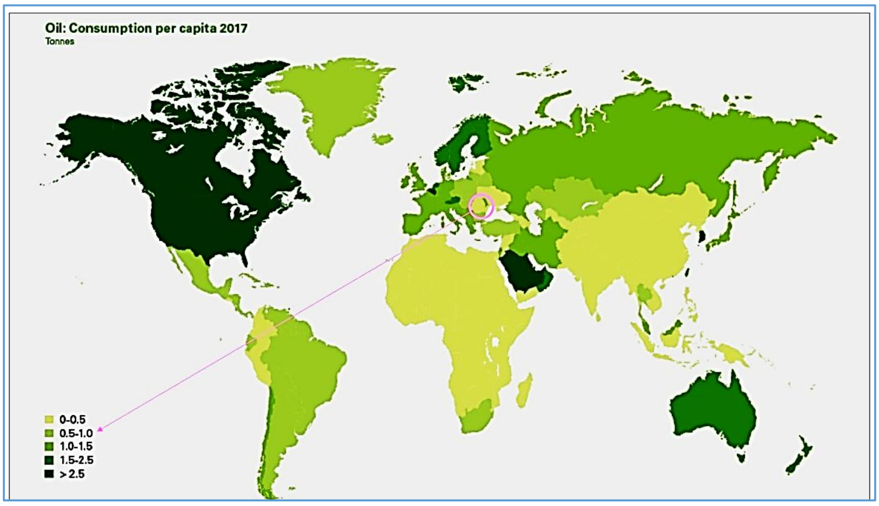


***Figure 15.*** *Romania's position in terms of oil consumption in 2017, compared to global consumption in echelons of values* [13].

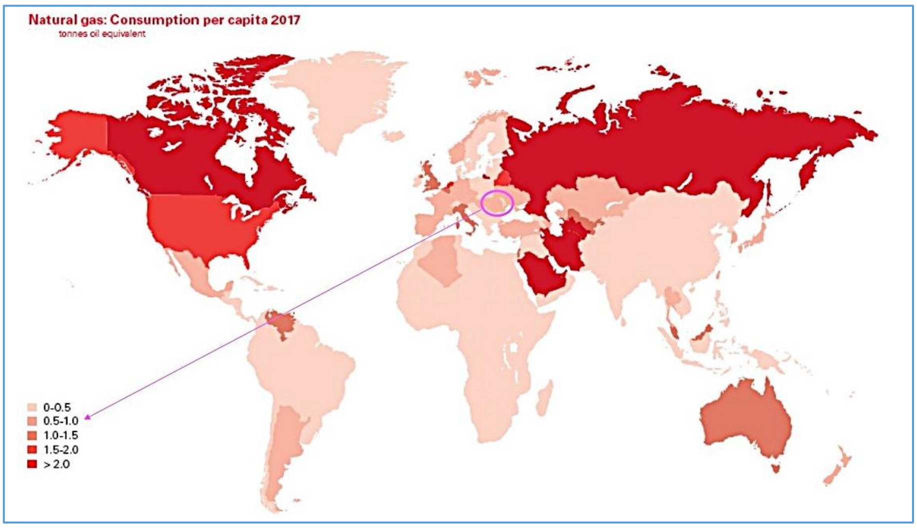


***Figure 16.*** *Romania's position in terms of gas consumption in 2017, compared to global consumption in echelons of values* [13].

The future direction of oil and gas exploration in Romania is shifting toward deeper zones characterized by complex geological formations and more profound structural settings. Hydrocarbons can be found across all major geological units of the country - both onshore and offshore - and are associated with either thermogenic or biogenic petroleum systems. In some areas, hydrocarbon accumulations are vertically stacked, although each stratigraphic layer may be associated with distinct source rocks and formation conditions. As a result, Romania continues to hold significant untapped hydrocarbon potential in the following regions (fig. 17):

1 - Basement of the Pannonian Basin (below 1 500 m in the North and 5 000 m in the South)

2 - Pre - Saliferous sequence of the Transylvanian Basin (below 2 500 m);

3 - Pre-Tertiary sequence of the Moldavian Platform (below 4 000 m);

4 - Pre-Tertiary sequence of the Moesian Platform (below 5 000 m).

5 - Paleogene deeper anticlines of the Getic Depression or Mesozoic (below 5 000 m).

6 - Considerable exploration potential also exists in the deeper offshore of the Black Sea Basin [8].

Unconventional gas or subtle traps in carbonate sediment can be found in the Moesian Platform. Facies variations in carbonates (such as reefs, karst phenomena, dolomitizations), along with mixed structural-diagenetic traps, are very important in the central and southern parts of the Moesian Platform for future hydrocarbon reserves. Hydrocarbon accumulations may also be present in the Paleogene deeper anticlines of the Getic Depression or in the Mesozoic foreland sequences.

The West Black Sea Basin located in the offshore area of Romania, has a complex structure and a highly dynamic evolution. It hosts oil systems related to sedimentary sequences ranging in aged between the Cretaceous and Pliocene.

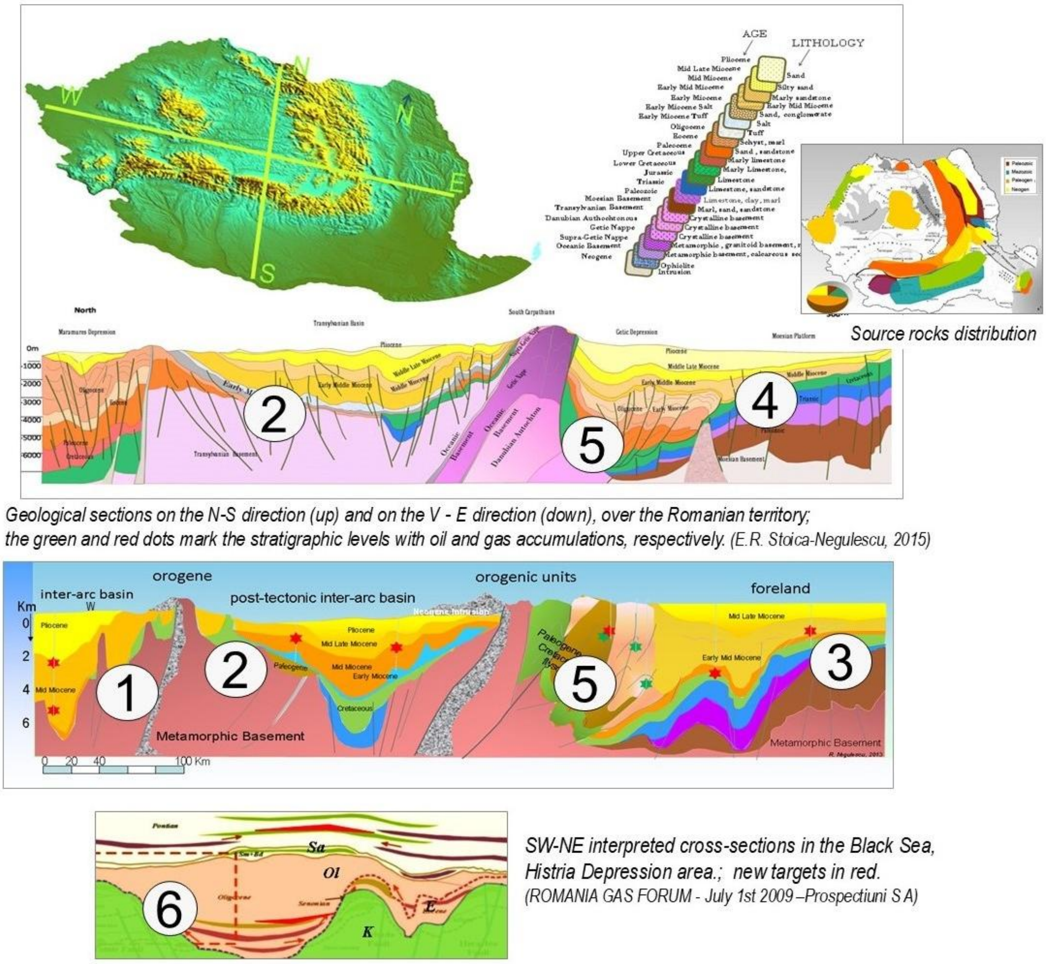


***Figure 17***. *Romania's hydrocarbon potential* [9].
*1- The Basement of Pannonian basin; 2 – Pre-Saliferous sequence from the Transylvanian Basin; 3- Pre-Tertiary Sequence from the Moldavian Platform; 4 - Pre-Tertiary Sequence from the Moesian Platform. 5 - Paleogene deeper anticlines of Getic Depression or in the Mesozoic. 6 - Considerable exploration potential for oil and gas also remains in the deeper offshore of the Black Sea basin.*

According to data published in *Word Oil* (2024-2025), OMV Petrom made important discoveries in several areas of the Moesia Platform. Natural gas and condensate were confirmed in the first exploration well near Craiova [15], [22]. A large oil field was discovered in Oltenia, near other productive fields, having thus all facilities for rapid production. In the Targoviste exploration block, an oil deposit discovered a year earlier is ready for exploitation. In the northern part of the Moesia Platform, within-the South Carpathian foredeep - Târgu Jiu exploration block, a large natural gas field was discovered and is being prepared for exploitation.

In recent years, the exploration strategy has focused mainly on discovering new fields in areas where the infrastructure is already in place, in order to have a chance of putting into production as quickly as possible. The potential of Romanian's offshore Black Sea remains one of the most important objectives. Following seismic surveys and geological studies, OMV Petrom started drilling the first well in the Neptun area for gas exploitation. Next to the Neptun Deep area, the company Sell continues its prospecting and exploration activities [16].

The description of depositional systems based on the seismic stratigraphy principles (fig 18) opens new opportunities to identify and delineate the presence and extent of source rocks and reservoir rocks. Using seismic stratigraphic analysis in the Pontian of the Romanian Black Sea shelf, we demonstrate the transition from one system tract to another. This observation is very important for the characterization of reservoir rocks, particularly the sand and turbidite deposits of the Lower Pontian lowstand system tract (SP2, fig. 18, point 1) and the sand sequences located the top of highstand system tract of the Mid-Upper Pontian (SP3, fig. 18, point 2) [10].

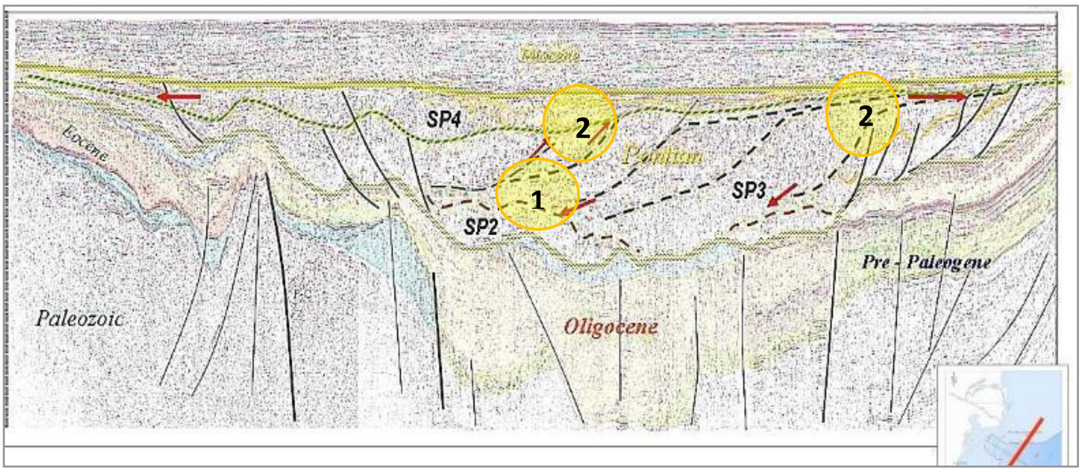


***Figure 18.*** *SW-NE interpreted cross-sections in the deeper part of Histria Depression area* [10]

High quality seismic data are essential for a reassessment of geological models and reservoir parameters, supporting ongoing efforts to rehabilitate mature fields through techniques aimed at increasing the ultimate recovery factor. The upcoming licensing rounds will provide both large and small oil companies with opportunities to participate in the competition for new hydrocarbon discoveries within Romanian territory.

## DISCUSSIONS

The systematic classification of petroleum provinces and systems provides a structured approach to understanding the distribution, characteristics, and potential of hydrocarbon resources globally. Clear and consistent classification criteria allow for more reliable predictions of resource locations and facilitate comparisons between both well-explored and frontier basins.

Petroleum provinces are adapted to all types of sedimentary basins. The structural architecture of the basin determines the character hydrocarbon potential (“richness”) of its petroleum province. Stable platform basins are generally less productive, with hydrocarbon dispersed habitat, whereas unstable platform basins tend to be more prolific, characterized by concentrated accumulation zones.

Passive continental margins bordering major ocean basins account for approximately 31% of the world’s giant oil fields. Continental rifts and their overlying sag basins host about 30% of the global giant oil fields. Collision belts formed by the final convergence of two continental plates constitute another major basin type, containing roughly 24% of the world’s giant oil accumulations. The remaining 15% are associated with continental arcs at collision margins, strike-slip margins, and subduction-related settings.

Future exploration strategies are expected to include the re-evaluation of onshore and shallow-water basins; however, the principal focus of global hydrocarbon exploration will shift toward deep-water environments—currently among the most promising areas for increasing oil and gas production.

Five main groups of deep-water basins are expected to attract particular attention: deep-water basins of the Atlantic Ocean; the deep-water basins on the continental margin of East Africa; the deep-water basins of the western Pacific Ocean; the deep-water basins along the northwest shelf of Australia and in the eastern Mediterranean region and the deep-water basins surrounding the Arctic Pole region.

Future technological advances will aim to obtain exceptionally high-quality seismic data, enabling more accurate interpretation of subsurface geometries and petrophysical parameters. Mature fields, will increasingly depend on advanced technologies and digital tools designed to extend productive lifespans.

When considering Romania’s ranking in oil resources (42–43) (Table 1) and production (29) (Table 2), especially in relation to its surface area (ranked 81st) and population size, it becomes clear that the country holds a relatively strong position - potentially outperforming several other nations. In terms of natural gas reserves, Romania's standing may be even more favorable [11].

Potential thermogenic accumulations of oil and gas occur in the deeper, faulted anticlines of the Badenian and Cretaceous age, while biogenic gas accumulation be present within the deltaic formations of the Sarmatian in the Moldavian Platform. The Bârlad Depression, representing the Romanian part of the Scythian Platform, still contains unexplored structures within Triassic, Jurassic, and Cretaceous sequences.

In the Transylvanian Basin, the Mesozoic and Paleogene formations underlying the extensive salt layers, as well as channels and depositional fans fan systems along the northeastern slope, warrant further investigation. In the Pannonian Basin, the areas of interest are associated with structural or stratigraphic traps within the deeper Miocene, paleo-deltaic systems, and roll-over structures associated with the Upper Miocene-Pliocene.

***Table 1.*** *Romania's place in terms of proven oil reserves* [14]

| Country | Rank | Reserves | Rank |
|---|---|---|---|
| Argentina | 33 | 2185 | 31 |
| Columbia | 34 | 2002 | 34 |
| Gabon | 35 | 2000 | 33 |
| Australia | 36 | 1821 | 26 |
| Congo (Brazzaville) | 37 | 1600 | - |
| Chad | 38 | 1500 | - |
| Brunei | 39/40 | 1100 | 35 |
| Equatorial Guinea | 39/40 | 1100 | - |
| Ghana | 41 | 660 | - |
| **Romania** | **42/43** | **600** | **-** |
| Turkmenistan | 42/43 | 600 | 36 |
| Uzbekistan | 44 | 594 | 37 |
| Italy | 45 | 557 | - |
| Denmark | 46 | 491 | 38 |
| Peru | 47 | 473 | - |
| Tunisia | 48 | 425 | - |

*Table 2. Romania's place in the list of oil-producing; Its position in the global list by area* [14].

| | Country | Oil Production (bbl/day) | Oil Production per capita (bbl/day/million people) |
|---|---|---|---|
| 1 | USA | 15,043,000 | 35,922 |
| 2 | Saudi Arabia (OPEC) | 12,000,000 | 324,866 |
| 3 | Russia | 10,800,000 | 73,292 |
| 4 | Iraq (OPEC) | 4,451,516 | 119,664 |
| 5 | Iran (OPEC) | 3,990,956 | 49,714 |
| 6 | China | 3,980,650 | 2,836 |
| 7 | Canada | 3,662,694 | 100,931 |
| 8 | United Arab Emirates (OPEC) | 3,106,077 | 335,103 |
| 9 | Kuwait (OPEC) | 2,923,825 | 721,575 |
| 10 | India | 2,515,459 | 554 |
| 11 | Venezuela (OPEC) | 2,276,967 | 69,914 |
| 12 | Mexico | 2,186,877 | 17,142 |
| … | ………… | ………….. | ……….. |
| **29** | **Romania** | **504,000** | **25,469** |
| 30 | Egypt | 490,000 | 5,166 |

| | Country | | | |
|---|---|---|---|---|
| 77 | Guinea | 245,857 (94,926) | 245,717 (94,872) | 140 (54) |
| 78 | United Kingdom | 242,495 (93,628) | 241,930 (93,410) | 1680 (650) |
| 79 | Uganda | 241,550 (93,260) | 197,100 (76,100) | 43,938 (16,965) |
| 80 | Ghana | 238,533 (92,098) | 227,533 (87,851) | 11,000 (4,200) |
| **81** | **Romania** | **238,397** (92,046) | **231,291** (89,302) | **7,100** (2,700) |
| 82 | Laos | 236,800 (91,400) | 230,800 (89,100) | 6,000 (2,300) |
| 83 | Guyana | 214,969 (83,000) | 196,849 (76,004) | 18,120 (7,000) |
| 84 | Belarus | 207,600 (80,200) | 202,900 (78,300) | 4,700 (1,800) |
| 85 | Kyrgyzstan | 199,951 (77,202) | 191,801 (74,055) | 8,150 (3,150) |

The continental shelf of the Black Sea presents favorable conditions for biogenic gas accumulation within Upper Miocene (Pontian) sands, as well as in argillaceous sandstone located in broad anticlines and stratigraphic traps, including turbiditic and paleo-valley systems.

Overall, the direction of petroleum exploration in Romania is moving toward deeper targets. This trend is supported by advanced prospecting techniques such as high-resolution 3D seismic surveys and emerging 4D and 4C technologies, complemented by modern interpretive methods aimed at identifying subtle and structurally intricate traps.

## CONCLUSIONS

Future research efforts should focus on achieving a deeper understanding of regions characterized by complex geology and deeply buried structural features. Ongoing technological advancements will continue to emphasize the acquisition of high-resolution seismic data, which is essential for accurate interpretation of both structural geometry and petrophysical properties.

Significant attention is also directed toward the revitalization of mature oil fields through updated geological interpretations and the implementation of advanced recovery techniques aimed at maximizing production. Throughout these processes, environmental responsibility and effective resource management will remain key priorities.

Romania continues to hold substantial potential for hydrocarbon exploration, both within established producing areas and in new, deeper onshore and offshore regions that remain insufficiently explored. Advanced technologies currently applied worldwide for the rehabilitation of mature fields can likewise be successfully implemented in Romania.

This study has identified the geological and geographical parameters that should guide future oil and gas exploration activities. The practical application of emerging technologies and the detailed assessment of results that validate their effectiveness warrant further investigation, which should be addressed in a dedicated follow-up study (fig. 19).

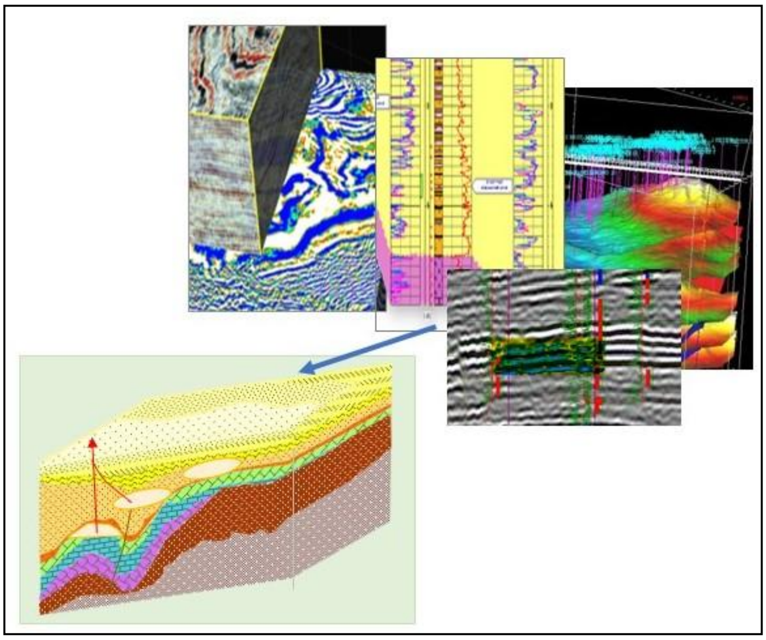

***Figure 19****. Evaluation of the geological model using the incredible possibilities of seismic interpretation software.*

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Received: October 2025; Revised: November 2025; Accepted: November 2025; Published: November 2025