



# Application and Prospects of Emerging Technologies in Petroleum Geological Exploration

Aifeng Li<sup>1,2</sup>, Feng Wang<sup>2</sup>, Luyao Gao<sup>2</sup>, Bingquan Ai<sup>2</sup>, Xiu Li<sup>2</sup>

<sup>1</sup> Xi'an Shiyou University, Xi'an, Shaanxi, China

<sup>2</sup> Jingbian Oil Production Plant of Yanchang Oilfield Co., Ltd., Yulin, Shaanxi, China

DOI: 10.32629/aes.v4i2.1226

**Abstract:** With the rapid development of technology, emerging technologies have become the focus of attention in various fields. In the field of natural resources, petroleum geological exploration has always been a challenging and important area. Petroleum, as the backbone of modern industry, is crucial for the development of human society. However, traditional petroleum exploration methods face many difficulties in the face of declining conventional oil resources and complex geological conditions. This article aims to explore the application and prospects of emerging technologies in petroleum geological exploration. By providing an overview of relevant technologies and case studies, the role of these technologies in solving exploration challenges and optimizing the exploration process will be deeply analyzed. In addition, the future development trends of these technologies will be discussed, and the prospects of their application will be explored.

**Keywords:** emerging technologies, petroleum geological exploration, application

## 1. Introduction

### 1.1 Importance of Petroleum Geological Exploration

Petroleum is a key energy source for modern industry and social development, occupying a crucial position in international economics and politics. Petroleum geological exploration is a critical stage in the search for petroleum resources, and it plays a significant role in ensuring energy supply, supporting economic development, and promoting the sustainable development of the petroleum industry. With the gradual depletion of global petroleum resources, the difficulty of petroleum geological exploration has been increasing, and the development of new petroleum resources has become an urgent need for the industry. In this context, emerging technologies bring great potential and new opportunities to petroleum geological exploration by improving exploration efficiency, reducing exploration costs, and providing strong support in the search for more petroleum resources.

### 1.2 Impact of Emerging Technologies on Petroleum Geological Exploration

With the continuous development of science and technology, emerging technologies are being widely applied in the field of petroleum geological exploration. These emerging technologies include drone and remote sensing technology, artificial intelligence and big data, new developments in geophysical exploration techniques, and 3D geological modeling and visualization technology. The application of these technologies not only improves the accuracy and efficiency of geological exploration but also enables geological exploration work to be carried out in more complex and extreme environments, expanding the boundaries of the exploration field.

(1) Optimizing exploration efficiency: The application of emerging technologies greatly improves the efficiency of geological exploration work, reducing the exploration cycle and shortening the time for petroleum resource development.

(2) Enhancing exploration accuracy: Emerging technologies have significant advantages in geological data analysis and interpretation, enabling more accurate prediction of the distribution and reserves of petroleum resources.

(3) Reducing exploration costs: Emerging technologies can reduce the investment of manpower, material resources, and financial resources in the geological exploration process, thereby lowering exploration costs and improving the economic benefits of resource development.

(4) Improving exploration methods: Emerging technologies provide more advanced and diverse means for geological exploration, allowing exploration work to be conducted in more complex and extreme environments, thus increasing the success rate of exploration. [1]

In summary, emerging technologies have had a profound impact on petroleum geological exploration, bringing immense potential and opportunities for the search and development of petroleum resources. In future petroleum geological exploration, emerging technologies will play an even more important role, driving the rapid development of the petroleum

geological exploration industry.

## 2. Application of Emerging Technologies in Petroleum Geological Exploration

### 2.1 3D Seismic Survey Technology

3D seismic survey technology is an advanced seismic exploration method that involves deploying a large number of seismic receivers on the ground and seabed, and generating artificial seismic waves through seismic sources. These seismic waves propagate through the subsurface, and their reflections and refractions are recorded by the receivers. By processing this data, a three-dimensional structural model of the subsurface can be generated. Compared to traditional 2D seismic surveys, 3D seismic survey technology offers the following advantages:

(1) Higher spatial resolution: 3D seismic survey technology provides more detailed information about the subsurface structure, enabling more accurate identification of the distribution, thickness, and morphology of petroleum reservoirs.

(2) Better data continuity: 3D seismic survey technology can provide continuous coverage of the entire exploration area, avoiding data gaps caused by large line spacings in 2D seismic surveys.

(3) Stronger noise suppression capability: 3D seismic survey technology utilizes data recorded by a large number of receivers and performs multiple stackings of seismic signals, thereby improving the signal-to-noise ratio and enhancing the clarity of subsurface structure identification.

(4) More effective solution to complex geological problems: 3D seismic survey technology can reveal the spatial distribution and morphology of complex geological structures such as faults, folds, and salt bodies, providing strong support for petroleum exploration in complex geological areas. [2]

The application of 3D seismic survey technology in petroleum exploration has achieved significant results. For example, in the North Sea petroleum exploration project, the use of 3D seismic survey technology has led to the discovery of multiple new petroleum reservoirs, greatly improving the exploration success rate. Additionally, 3D seismic survey technology is widely employed in onshore and offshore petroleum exploration, becoming an important tool in modern petroleum geological exploration.

### 2.2 Geophysical Data Processing and Interpretation Techniques

Geophysical data processing and interpretation techniques are crucial components of petroleum geological exploration. They involve the processing, analysis, and interpretation of geophysical data to provide insights into the distribution and characteristics of subsurface petroleum reservoirs. With the rapid development of computer technology, geophysical data processing and interpretation techniques have made significant progress.

(1) Advancements in data processing techniques: Geophysical data processing techniques encompass operations such as filtering, noise removal, signal enhancement, and stacking. With the development of computer technology, these operations have become more efficient and precise. For example, random noise in geophysical data can be efficiently eliminated, thereby improving the quality of seismic signals. Furthermore, geophysical data processing techniques may also incorporate technologies such as artificial intelligence and deep learning in the future to further enhance seismic data processing.

(2) Advancements in data interpretation techniques: Geophysical data interpretation techniques aim to extract information about petroleum reservoirs from processed geophysical data. The progress in computer technology enables geophysicists to employ more complex mathematical models and algorithms for data interpretation. For instance, seismic tomography imaging techniques can reconstruct the velocity structure of the subsurface based on the propagation characteristics of seismic waves, revealing the distribution of petroleum reservoirs.

In practical exploration projects, the application of geophysical data processing and interpretation techniques has yielded significant results. For example, a potential ultra-deepwater oil reservoir was discovered in the Gulf of Mexico, primarily due to advancements in geophysical data processing and interpretation techniques. By efficiently processing and interpreting geophysical data, geologists can more accurately predict the location and characteristics of petroleum reservoirs, thereby improving the success rate of exploration.

In conclusion, geophysical data processing and interpretation techniques play a crucial role in petroleum geological exploration. With the continuous advancement of computer technology, these techniques will continue to provide more accurate and efficient support for petroleum exploration, contributing to meeting global energy demands.

### 2.3 Machine Learning and Artificial Intelligence

Machine learning and artificial intelligence (AI) technologies have tremendous potential in the field of petroleum geological exploration. They can assist geologists in analyzing vast amounts of geological, geophysical, and geochemical data

more effectively, thereby improving the accuracy of exploration decisions.

(1) Reservoir identification and prediction: Machine learning models can analyze large volumes of geophysical data to automatically identify seismic response characteristics of petroleum reservoirs, thus predicting their potential distribution. This helps geologists conduct more targeted exploration work and improves the success rate of exploration. [3]

(2) Production forecasting: By analyzing historical production data, machine learning models can predict the production of new petroleum reservoirs, providing a basis for development planning. For example, in shale oil development projects in Texas, USA, machine learning technology has successfully predicted oil production and development benefits.

(3) Drilling optimization: Machine learning models can analyze drilling parameters, geological conditions, and other factors to provide optimization recommendations for drilling plans. This helps reduce drilling costs and improve drilling success rates.

(4) Risk assessment: Machine learning models can evaluate the risks of exploration and development projects based on geological, engineering, and economic data. This is crucial for decision-makers to formulate reasonable investment strategies.

(5) Automated seismic interpretation: By utilizing advanced algorithms such as deep learning, geophysicists can automatically identify geological structures, such as faults and stratigraphic interfaces, in seismic profiles. This improves the efficiency and accuracy of seismic interpretation.

With the continuous development of machine learning and AI technologies, their applications in the field of petroleum geological exploration will become increasingly widespread. By leveraging these advanced technologies, geologists can make exploration decisions more accurately and efficiently, contributing to meeting global energy demands.

## 2.4 Unmanned Aerial Vehicles (UAVs) and Remote Sensing Technology

The application of unmanned aerial vehicles (UAVs) and remote sensing technology in the field of petroleum exploration is of great significance. They can provide geologists with a wealth of information about surface geological structures, sedimentary environments, and other aspects, thereby assisting in exploration decision-making.

(1) Geological structure analysis: High-resolution remote sensing imagery can clearly display surface geological structures such as faults, folds, and structural lines. Geologists can analyze these structures in detail to infer the distribution of underground petroleum reservoirs.

(2) Sedimentary environment research: Remote sensing technology can help geologists study the formation and evolution of sedimentary basins and reveal the characteristics of sedimentary environments. This is important for predicting the types, distribution, and scale of petroleum reservoirs. [4]

(3) Geomorphological analysis: UAVs and remote sensing technology can capture information about surface elevation, slope, and other geomorphological features. This information is crucial for evaluating drilling site selection, designing routes, and other engineering considerations.

(4) Environmental monitoring: UAVs and remote sensing technology can provide real-time monitoring of the environmental conditions in petroleum exploration areas, such as vegetation coverage and water distribution. This is important for assessing the impact of exploration activities on the environment and formulating environmental protection measures.

(5) Emergency response: With the assistance of remote sensing technology and UAVs, geologists can respond quickly to emergencies in exploration areas. For example, monitoring geological hazards and responding to oil spills and other urgent situations.

In an oil exploration project in Africa, remote sensing technology and UAVs successfully assisted geologists in discovering a highly prospective oil and gas exploration area. This clearly demonstrates the important role of UAVs and remote sensing technology in the field of petroleum exploration. As these technologies continue to evolve, they will provide more accurate and efficient support for petroleum exploration, contributing to meeting global energy demands.

## 2.5 Molecular Biogeochemical Techniques

Molecular biogeochemical techniques have important applications in the field of petroleum exploration. They can help geologists gain a deeper understanding of the formation, migration, and storage processes of oil and gas reservoirs. Here are some specific application scenarios:

(1) Oil source comparison: By comparing the biomarkers in different oil and gas reservoirs, geologists can determine whether the oil and gas come from the same or different source rocks. This helps to understand the source of oil and gas and provides a basis for exploration decision-making.

(2) Oil and gas genesis research: Molecular biogeochemical techniques can analyze the variations of biomarkers during the generation process of oil and gas, thereby inferring their origins. This is important for predicting the distribution of oil

and gas reservoirs.

(3) Analysis of oil and gas migration paths: By studying the distribution changes of biomarkers during oil and gas migration, geologists can reveal the migration paths of oil and gas. This helps optimize exploration strategies and improve exploration success rates.

(4) Reservoir evaluation: Molecular biogeochemical techniques can analyze the biomarkers in reservoirs to evaluate their physical properties, reservoir conditions, etc. This helps geologists assess the oil and gas potential of the reservoir.

(5) Paleoenvironmental reconstruction: By analyzing the stable isotopic composition of biomarkers, geologists can reconstruct the paleoenvironment during the formation of source rocks. This is important for understanding the depositional conditions and oil and gas generation potential of source rocks. [5]

In a deepwater oil and gas exploration project in Brazil, molecular biogeochemical techniques successfully guided the exploration team in discovering a significant oil and gas reservoir. This demonstrates the enormous potential of molecular biogeochemical techniques in the field of petroleum exploration. With the continuous development of this technology, it will provide more accurate and efficient support for petroleum exploration, contributing to meeting global energy demands.

## 2.6 Digital Rock Technology

Digital rock technology has significant applications in the field of petroleum exploration, as it can help geologists gain a more accurate understanding of the reservoir characteristics and permeability of oil and gas reservoirs. Here are some specific application scenarios:

(1) Analysis of rock microstructures: Digital rock technology enables high-resolution scanning of core samples, revealing their pore structures, fractures, and other features. This helps geologists evaluate the reservoir conditions and permeability of oil and gas reservoirs.

(2) Property simulation: By digitally processing core samples, geologists can simulate the physical properties of rocks, such as porosity and permeability. This is important for assessing the potential of oil and gas reservoirs and optimizing exploration strategies.

(3) Reservoir modeling: Digital rock technology provides more accurate information about the microstructures of rocks for reservoir modeling. This helps geologists construct more realistic reservoir models and improve prediction accuracy.

(4) Evaluation of oil recovery effects: By simulating rock microstructures and properties, geologists can evaluate the effects of different oil recovery methods on oil and gas reservoirs. This helps optimize oil recovery strategies and improve oil and gas recovery rates.

(5) Research on enhanced oil recovery techniques: Digital rock technology provides strong support for geologists to study new enhanced oil recovery techniques. For example, by simulating the effects of enhanced measures such as acidization and fracturing on rock microstructures, the enhancement plans can be optimized.

In a oil sands project in Canada, the application of digital rock technology significantly improved the success rate of exploration and the accuracy of production forecasts. This clearly demonstrates the importance of digital rock technology in the field of petroleum exploration. With the continuous development of this technology, it will provide more accurate and efficient support for petroleum exploration, contributing to meeting global energy demands.

## 3. Prospect Outlook of Emerging Technologies in Petroleum Geological Exploration

### 3.1 Integration of Multiple Emerging Technologies in Exploration Methods

In the future, petroleum geologic exploration will leverage interdisciplinary research and collaboration to integrate various emerging technologies. This will help improve the accuracy and efficiency of exploration and provide technological support for the sustainable development of the petroleum industry. For example, by combining techniques from geophysics, geochemistry, and biogeology, a more comprehensive and detailed evaluation of oil and gas reservoirs can be achieved. Furthermore, the utilization of big data, cloud computing, artificial intelligence, and other technologies can enable efficient processing and analysis of massive geological data, further enhancing the scientific basis of exploration decisions.

### 3.2 Continuous Development and Optimization of Existing Technologies

With the acceleration of technological iteration and innovation, existing exploration technologies will continue to develop and optimize to reduce exploration costs and minimize environmental impacts. For instance, improvements in geophysical exploration methods can lead to higher-resolution data acquisition at lower costs. In terms of drilling technology, the development of unmanned and environmentally-friendly drilling techniques can reduce the environmental footprint of drilling operations. Additionally, the development of new materials and equipment can enhance the safety and efficiency of

exploration operations.

### 3.3 Cultivation of a New Generation of Talents and Technical Teams

To address the technological challenges in future petroleum geologic exploration, it is necessary to train a new generation of talents and establish research and development teams focused on technological innovation. This requires strengthening education and training in the field of petroleum geology exploration and encouraging young talents to join the research workforce. At the same time, the establishment of interdisciplinary and cross-industry collaboration platforms promotes technological exchange and application, facilitating the continuous innovation and development of petroleum geologic exploration technologies.

### 3.4 Adapting to Changes and Challenges in the Global Energy Market

In response to challenges such as energy supply and demand balance and environmental policies, the development of petroleum geologic exploration technologies needs to be coordinated with the advancement of alternative energy sources to adapt to changes in the global energy market. Specifically, petroleum exploration companies should focus on technological advancements in the field of renewable energy and actively participate in renewable energy projects to achieve energy structure diversification. Efforts should also be made to improve the efficiency and environmental performance of petroleum geologic exploration, minimizing its impact on the environment. Moreover, closely monitoring factors such as international oil prices and energy policies, and flexibly adjusting exploration strategies, allows petroleum exploration companies to respond to market uncertainties.

## 4. Conclusion

The outlook for emerging technologies in petroleum geological exploration is highly promising. By integrating various technologies, continuously developing and optimizing existing techniques, cultivating a new generation of talent and technical teams, and adapting to changes and challenges in the global energy market, petroleum exploration technology will continue to advance, providing reliable support for global energy demands. In this process, the field of geological exploration will face numerous opportunities and challenges, requiring collective efforts to drive technological innovation and application in order to achieve sustainable development of the petroleum industry and global energy security.

## References

---

- [1] Peng, X. (2020). Application of new technologies in petroleum geological exploration. *Chemical Management*, 579(36), 195-196.
- [2] Hu, J., Gao, S., Yang, X., & Sun, K. (2020). Application of new technologies in petroleum geological exploration. *Chemical Design Communication*, 5(2), 152-160.
- [3] Jiang, B. (2022). Innovation and development of petroleum geological exploration technology. *Small and Medium-sized Enterprise Management and Technology*, 673(04), 172-174.
- [4] Jiao, F. (2022). Research on petroleum geological exploration technology. *Petrochemical Technology*, (04), 79-82.
- [5] Li, Y. (2022). Application of new technologies in petroleum geological exploration. *Small and Medium-sized Enterprise Management and Technology*, (04), 31-35.