Journal of
Marine Science and Engineering

MDPI

Editorial

High-Efficient Exploration and Development of Oil & Gas from Ocean

Mianmo Meng [1,2,*], Wenming Ji [3,*] and Guodong Cui [4,*]

[1] Hubei Key Laboratory of Marine Geological Resources, China University of Geosciences, Wuhan 430074, China
[2] College of Marine Science and Technology, China University of Geosciences, Wuhan 430074, China
[3] School of Geosciences, China University of Petroleum (East China), Qingdao 266580, China
[4] Faculty of Engineering, China University of Geosciences, Wuhan 430074, China
* Correspondence: mengmianmo@cug.edu.cn (M.M.); jiwenming@upc.edu.cn (W.J.); cuiguodong@cug.edu.cn (G.C.)

Citation: Meng, M.; Ji, W.; Cui, G. High-Efficient Exploration and Development of Oil & Gas from Ocean. *J. Mar. Sci. Eng.* **2024**, *12*, 1930. https://doi.org/10.3390/jmse12111930

Received: 17 October 2024
Accepted: 20 October 2024
Published: 28 October 2024

The ocean takes up 71% of the Earth's surface, and hosts abundant resources, such as oil/gas. At present, oil/gas exploitation from the strata under the ocean is still a challenge, especially in unconventional reservoirs. Unconventional types of oil/gas mainly include shale oil/gas, tight sandstone oil/gas, coalbed gas, and gas hydrate.

This Special Issue focuses on the highly efficient exploration and development of oil and gas, especially in relation to unconventional oil/gas resources. At present, there are still some critical problems in the exploration and development of unconventional oil and gas. Firstly, the selection of sweet points from geological perspectives is still challenging [1–3]. The use of geophysical data (wireline logs and seismic data) to identify the most favorable layers remains controversial. Secondly, prospecting well can allow for the direct recovery of the sample from the target layers, as well as determining detailed information about fluid and reservoir benefits to select the best layer for development [4]. Evaluating the hydrocarbon occurrence is also problematic, especially when investigating the movability in in situ conditions [5]. Lastly, hydraulic fracturing is a basic and widely used method to develop most types of unconventional oil/gas. However, there remain unsolved problems with generating the ideal fracture network due to the complex natural cracks and artificial fractures [6]. As for unconventional offshore oil/gas, such as gas hydrate, their highly efficient development is still challenging and attracts extensive attention. Our Special Issue concentrates on the aforementioned problems, obtaining some interesting conclusions. The main contributions of each article are presented below.

Contribution 1 focused on the organic matter (OM) accumulation mechanism of the Taiyuan and Shanxi Formations, which formed in a marine—continental transitional environment. This research pointed out that the main controlling factors for OM accumulation are redox conditions, paleoproductivity, and sedimentary rate.

Contribution 2 investigated the natural fracture properties of the Lower Jurassic shale oil reservoir in the Sichuan Basin. Natural fracture plays a significant role in shale oil migration, which is a high-throughput flow channel. It was found that the permeability sensitivity of natural fracture is obviously different among fractures with different widths.

Contribution 3 studied the influence of gravel size on the mechanical properties of conglomerate reservoirs. The samples were selected from the Triassic Baikouquan Formation in Mahu sag, Junggar Basin. With a low gravel content, the cracks are mainly controlled by stress, while a high gravel content makes the fractures more complex and discrete.

Furthermore, Contribution 4 focused on the reservoir characterization, depositional evolution, and sequence stratigraphy of the Cretaceous Mishrif Formation in South Iraq, which is located in the Mesopotamian Basin. In this formation, several facies were identified, such as deep marine, shallow marine, rudist bioherm, shoal, and lagoon. The development of the Mishrif Formation was controlled by intrashelf basinal deposits, clinoform-like shoals, and tidal channels.

Contribution 5 investigated the influence of quartz on the preservation and abundance of the organic pores of marine shale reservoirs in the Cambrian Shuijingtuo Formation, South China. It was found that early euhedral quartz benefits the preservation of organic matter (OM)-hosted pores, and late microquartz is detrimental to the organic pores.

Contribution 6 monitored oil recovery during the process of heavy water displacing the sample with saturated oil. It indicated that a high-pore-volume displacement can increase the oil recovery comprehensively. The porosity at the front end increases, while that one at the other end decreases, which is caused by particle migration.

Moreover, Contribution 7 focused on the effect of shale composition on the pore structure of marine shale. It indicated that the pore structure has a good relationship with clay minerals and organic matter. Quartz is a rigid skeleton, which is prone to retaining pores, but its influence is complicated because quartz has various origins.

Contribution 8 investigated the sequence stratigraphy of marine shale in the Sichuan Basin, which aims to analyze the sedimentary fill history. It showed that deglaciation and tectonic events lead to the special characteristic of the sequence stratigraphy of the deep Longmaxi Formation. It also indicated that the regional subsidence of the Weiyuan and Luzhou areas may lead to shale gas accumulation.

Contribution 9 appraised the properties of shale oil reservoirs in Bohaiwan Basin, which is located in the Zhanhua and Dongying Sags. Multiple methods were combined to conduct this research, which indicated that these types of reservoirs have the potential to hold vast volumes of shale oil.

Contribution 10 focused on a de-noising method for hydrocarbon exploration. Using symplectic geometry mode decomposition (SGMD) can greatly improve the signal, obtaining high-quality data. Organic matter has a positive relationship with pore structure complexity.

Contribution 11 examined the pore structure of marine shale reservoirs, mainly focusing on their heterogeneity and complexity. Deep siliceous marine shale has a complex pore structure, which is more complex than that of shallow marine shale.

Contribution 12 proposed a method to evaluate the permeability in porous samples. Usually, the permeability can be obtained using the three-dimensional reconstruction of multiple pictures. However, the two-dimensional picture can also be used to obtain the sample permeability, with good results.

Contribution 13 focused on the hydrocarbon generation characteristics and potential of marine carbonates in the Odovician Majiagou Formation, Ordos Basin. Its tested samples were selected from Nordic carbonates, which were similar to the target formation. The main experiment was a gold tube thermal simulation, which showed that when the temperature is 600 °C, it still produces methane. Hydrocarbon production is mainly related to the type of organic matter.

Contribution 14 clarified the pore structure of shale in the Upper Permian Longtan Formation, western Guizhou province, South China. Both scanning electron microscopy (SEM) and nitrogen adsorption (NA) were used as testing methods. This study indicated that OM-hosted pores are irregular polygonal variants, bubble-like, and elliptical, while the number of organic pores is lower.

Contribution 15 investigated the organic matter (OM) accumulation of the Cambrian Qiongzhusi Formation, which is located in Yangtze Platform in South China. It was suggested that a redox environment of high-quality source sediment and a lack of upwelling are good conditions for OM accumulation in the Qiongzhusi Formation.

Contribution 16 clarified the controlling factors for the poor shale gas in the Longmaxi and Niutitang Formations in northwestern Hunan. The factor accounting for the Lower Silurian Longmaxi Formation is that the evolution time of hydrocarbon generation is too short. On the other hand, the factor accounting for the Lower Cambrian Niutitang

Formation is that organic matter endures excessive evolution at a deep paleo-burial depth, which makes the organic matter approach graphite.

Contribution 17 researched the pore structure of the Jurassic Ziliujing Formation in the lower Sichuan Basin. The shales can be divided into argillaceous, mixed, and carbonate shales. The average pore size of carbonate shale is higher than that of mixed and argillaceous shale. Pores between clay mineral platelets have a great contribution to nanopores that are less than 30 nm in size, indicating that the organic matter has less influence on the pore complexity.

Contribution 18 investigated the organic matter enrichment and sedimentary environment of the Cambrian Shuijingtou Formation, South China, which was divided into three intervals. Interval I has a high TOC content, Interval II has a moderate TOC content, and Interval III has a low TOC content. Comparing all three intervals, Interval III is characterized by a lower paleoproductivity and poor preservation conditions.

Contribution 19 points out the disadvantages of existing tri-linear analytical solutions in predicting production because the uncertainty can be caused by numerical inversion and the Laplace transform. A new general analytical solution can solve this problem by combining the average pressure substitution and integral transform.

For further research about the highly efficient development of unconventional oil/gas, we suggest that more attention should be paid to the pore structure characterization, oil occurrence and mobility, artificial and natural fracture complexity, and so on.

Acknowledgments: As Guest Editors of the Special Issue "Highly Efficient Exploration and Development of Oil and Gas from the Ocean", we wish to extend our sincere gratitude to all the authors whose valuable contributions made the publication of this Special Issue possible.

Conflicts of Interest: The authors declare no conflicts of interest.

List of Contributions:

1. Wang, Y.; Cheng, X.; Fan, K.; Huo, Z.; Wei, L. The Paleoenvironment and Mechanisms of Organic Matter Enrichment of Shale in the Permian Taiyuan and Shanxi Formations in the Southern North China Basin. *J. Mar. Sci. Eng.* **2023**, *11*, 992. https://doi.org/10.3390/jmse11050992.
2. Bai, X.; Huang, S.; Wang, X.; Wang, Z.; Wang, Y.; Ma, W.; Zhu, Y.; Sun, M.; Liu, B.; Fu, X.; et al. Microscopic Analysis of Natural Fracture Properties in Organic-Rich Continental Shale Oil Reservoirs: A Case Study from the Lower Jurassic in the Sichuan Basin, China. *J. Mar. Sci. Eng.* **2023**, *11*, 1036. https://doi.org/10.3390/jmse11051036.
3. Liu, P.; Shen, Y.; Meng, M.; Luo, S.; Zhong, Y.; Cen, Q. Experimental Study of Mechanical Properties and Fracture Characteristics of Conglomerates Based on Mohr–Coulomb Criteria. *J. Mar. Sci. Eng.* **2023**, *11*, 1219. https://doi.org/10.3390/jmse11061219.
4. Zhang, L.; Zhang, W.; Li, Y.; Song, B.; Liu, D.; Deng, Y.; Xu, J.; Wang, Y. Sequence Stratigraphy, Sedimentology, and Reservoir Characteristics of the Middle Cretaceous Mishrif Formation, South Iraq. *J. Mar. Sci. Eng.* **2023**, *11*, 1255. https://doi.org/10.3390/jmse11061255.
5. Wei, S.; Hu, M.; He, S.; Shu, Y.; Dong, T.; He, Q.; Yang, W.; Cai, Q. Effects of Quartz Precipitation on the Abundance and Preservation of Organic Matter Pores in Cambrian Marine Shale in South China. *J. Mar. Sci. Eng.* **2023**, *11*, 1267. https://doi.org/10.3390/jmse11071267.
6. Liu, J.; Li, H.; Xu, J.; Liu, S.; Liu, R.; Hou, L.; Tan, Q. Exploring the Unique Characteristics of High-Pore-Volume Waterflooding and Enhanced Oil Recovery Mechanisms in Offshore Sandstone Reservoirs Using Nuclear Magnetic Resonance Technology. *J. Mar. Sci. Eng.* **2023**, *11*, 1296. https://doi.org/10.3390/jmse11071296.
7. Xu, L.; Pan, R.; Hu, H.; Meng, J. Contribution of Various Shale Components to Pore System: Insights from Attributes Analysis. *J. Mar. Sci. Eng.* **2023**, *11*, 1327. https://doi.org/10.3390/jmse11071327.
8. Xu, L.; Meng, J.; Pan, R.; Yang, X.; Sun, Q.; Zhu, B. Sequence Stratigraphy and Implications for Shale Gas Exploration in the Southern Sichuan Basin, South China. *J. Mar. Sci. Eng.* **2023**, *11*, 1393. https://doi.org/10.3390/jmse11071393.
9. Ma, C.; Fang, X.; Ma, X.; Liu, X.; Xu, B.; Ge, X. Properties and Model of a Lacustrine Shale Oil Reservoir: A Case Study of the Upper Fourth Member and Lower Third Member of the Shahejie Formation in Dongying Sag and Zhanhua Sag, Jiyang Depression. *J. Mar. Sci. Eng.* **2023**, *11*, 1441. https://doi.org/10.3390/jmse11071441.

10. Chen, Y.; Guo, Z.; Gao, D. Marine Controlled-Source Electromagnetic Data Denoising Method Using Symplectic Geometry Mode Decomposition. *J. Mar. Sci. Eng.* **2023**, *11*, 1578. https://doi.org/10.3390/jmse11081578.
11. Zhu, B.; Meng, J.; Song, C.; Pan, R.; Zhu, Z.; Jin, J. Complexity and Heterogeneity Evaluation of Pore Structures in the Deep Marine Shale Reservoirs of the Longmaxi Formation, China. *J. Mar. Sci. Eng.* **2023**, *11*, 1613. https://doi.org/10.3390/jmse11081613.
12. Lei, G.; Liu, T.; Liao, Q.; He, X. Estimating Permeability of Porous Media from 2D Digital Images. *J. Mar. Sci. Eng.* **2023**, *11*, 1614. https://doi.org/10.3390/jmse11081614.
13. Wang, Y.; Xu, Y.; Huang, J.; Shi, J.; Zhao, H.; Wang, Q.; Meng, Q. Experimental Characteristics of Hydrocarbon Generation from Scandinavian Alum Shale Carbonate Nodules: Implications for Hydrocarbon Generation from Majiagou Formation Marine Carbonates in China's Ordos Basin. *J. Mar. Sci. Eng.* **2023**, *11*, 1616. https://doi.org/10.3390/jmse11081616.
14. Zhang, M.; Hu, M.; Wei, S.; Cai, Q.; Fu, W.; Shi, F.; Zhang, L.; Ding, H. Factors Controlling the Pore Development of Low-Mature Marine–Continental Transitional Shale: A Case Study of the Upper Permian Longtan Shale, Western Guizhou, South China. *J. Mar. Sci. Eng.* **2023**, *11*, 1862. https://doi.org/10.3390/jmse11101862.
15. Zhang, Q.; Liu, E.; Pan, S.; Wang, H.; Jing, Z.; Zhao, Z.; Zhu, R. Multiple Controls on Organic Matter Accumulation in the Intraplatform Basin of the Early Cambrian Yangtze Platform, South China. *J. Mar. Sci. Eng.* **2023**, *11*, 1907. https://doi.org/10.3390/jmse11101907.
16. Miao, Y.; Wang, P.; Li, X.; Huang, H.; Jin, C.; Gao, W. Shale Gas Exploration and Development Potential Analysis of Lower Cambrian Niutitang Formation and Lower Silurian Longmaxi Formation in Northwestern Hunan, South China, Based on Organic Matter Pore Evolution Characteristics. *J. Mar. Sci. Eng.* **2023**, *11*, 1910. https://doi.org/10.3390/jmse11101910.
17. Wang, Y.; Li, W.; Wang, X.; Wang, Z.; Ma, W.; Zhu, Y.; Sun, M.; Liu, B.; Cheng, L.; Fu, X. Nanopore Structure and Multifractal Characteristics of Continental Shale Oil Reservoir: A Case Study from Ziliujing Shales in the Sichuan Basin. *J. Mar. Sci. Eng.* **2023**, *11*, 1989. https://doi.org/10.3390/jmse11101989.
18. Wei, S.; Hu, M.; He, S.; Yang, W.; He, Q.; Cai, Q.; Li, P. Sedimentary Environment Interpretation and Organic Matter Enrichment of the Lower Cambrian Shuijingtuo Shale in the Yichang Slope, South China: Insight from Sedimentary Geochemical Proxies with Major/Trace Elements. *J. Mar. Sci. Eng.* **2023**, *11*, 2018. https://doi.org/10.3390/jmse11102018.
19. Qiu, K.; Fan, K.; Chen, X.; Lei, G.; Wei, S.; Navik, R.; Li, J. A New Approach for Production Prediction in Onshore and Offshore Tight Oil Reservoir. *J. Mar. Sci. Eng.* **2023**, *11*, 2079. https://doi.org/10.3390/jmse11112079.

References

1. Wang, Q.; Li, Y.; Utley, J.E.P.; Gardner, J.; Liu, B.; Hu, J.; Shao, L.; Wang, X.; Gao, F.; Liu, D.; et al. Terrestrial dominance of organic carbon in an Early Cretaceous syn-rift lake and its correlation with depositional sequences and paleoclimate. *Sediment. Geol.* **2023**, *455*, 106472. [CrossRef]
2. Luo, Q.; Zhang, L.; Zhong, N.; Wu, J.; Goodarzi, F.; Sanei, H.; Skovsted, C.B.; Suchý, V.; Li, M.; Ye, X.; et al. Thermal evolution behavior of the organic matter and a ray of light on the origin of vitrinite-like maceral in the Mesoproterozoic and Lower Cambrian black shales: Insights from artificial maturation. *Int. J. Coal Geol.* **2021**, *244*, 103813. [CrossRef]
3. Huang, H.; Chen, L.; Dang, W.; Luo, T.; Sun, W.; Jiang, Z.; Tang, X.; Zhang, S.; Ji, W.; Shao, S.; et al. Discussion on the rising segment of the mercury extrusion curve in the high pressure mercury intrusion experiment on shales. *Mar. Pet. Geol.* **2019**, *102*, 615–624. [CrossRef]
4. Wang, Q.; Yang, W.; Li, Y.; Jiang, Z.; Wen, M.; Zuo, R.; Wang, X.; Xue, Z.; Wang, Y. In-situ fluid phase variation along the thermal maturation gradient in shale petroleum systems and its impact on well production performance. *J. Earth Sci.* **2023**, *34*, 985–1001. [CrossRef]
5. Meng, M.; Zhang, Y.; Yuan, B.; Li, Z.; Zhang, Y. Imbibition behavior of oil-saturated rock: Implications for enhanced oil recovery in unconventional reservoirs. *Energy Fuels* **2019**, *37*, 13759–13768. [CrossRef]
6. Wang, J.; Zhou, F.; Bai, H.; Li, Y.; Yang, H. A Comprehensive method to evaluate the viscous slickwater as fracturing fluids for hydraulic fracturing applications. *J. Pet. Sci. Eng.* **2020**, *193*, 107359. [CrossRef]