frontiers | Frontiers in Earth Science

TYPE Editorial
PUBLISHED 19 January 2024
DOI 10.3389/feart.2024.1347462

Check for updates

OPEN ACCESS

EDITED AND REVIEWED BY
David R. Lentz,
University of New Brunswick
Fredericton, Canada

*CORRESPONDENCE
Qian Zhang,
amadozhang@pku.edu.cn

RECEIVED 30 November 2023
ACCEPTED 08 January 2024
PUBLISHED 19 January 2024

CITATION
Zhang Q (2024), Editorial: Organic matter accumulation in organic-rich shales.
Front. Earth Sci. 12:1347462.
doi: 10.3389/feart.2024.1347462

COPYRIGHT
© 2024 Zhang. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

Editorial: Organic matter accumulation in organic-rich shales

Qian Zhang*

Institute of Energy, School of Earth and Space Science, Peking University, Beijing, China

KEYWORDS

organic-rich shale, accumulation, deposition, shale oil, shale gas

Editorial on the Research Topic
Organic matter accumulation in organic-rich shales

Shale oil and gas have been regarded as alternative resources for conventional petroleum in recent decades. The exploration and development of shale oil and gas are, however, confronted with dilemmas. One of the most striking challenges for petroleum geologists is the "sweet spot identification", for which the assessment criteria are not fully clearly. Nevertheless, it is widely accepted that the "sweet spot" of shale oil and gas is a comprehensive embodiment of multiple optimal parameters, including desirable organic matter type, appropriate thermal maturity, excellent petrophysical and rock mechanical properties, and so on (Littke et al., 1991; Bechtel et al., 2002; Sachsenhofer et al., 2003; Bechtel et al., 2012; Rippen et al., 2013; Sun et al., 2013; Ghazwani et al., 2018; Zhang et al., 2019; Zhang et al., 2020; Cai et al., 2022; Deng et al., 2022; Zheng et al., 2022; Zheng et al., 2023a; Zheng et al., 2023b). These properties are largely controlled by the processes of organic-rich shale formation. Consequently, a better understanding of the organic matter accumulation in organic-rich shales is vital for successful shale oil and gas exploration and extraction.

Yang et al. numerically simulated three-dimensional characteristics of cracked shale based on CT technology. The finite element software RFPA-3D was employed to create a three-dimensional non-uniform numerical model, which can be used to present the meso structure of rock mass. The results showed that prefabricated fractures and quartz content will significantly affect the tensile strength and weaken the destructive strength of shales. The crack initiation angle was supposed to be controlled by the angle of prefabricated crack. The modes of shale damage were divided into four categories. This study helps for revealing the mechanisms of fracture initiation and propagation in the hydraulic fracturing process.

Pastor-Chacón et al. analyzed the sweet spot areas for shale oil and shale gas plays in the Upper Cretaceous rocks of the Middle Magdalena Valley, Colombia, using basin modeling approaches. A three-dimensional basin model for three Upper Cretaceous source rocks within the Middle Magdalena Valley Basin has been established in this study. The results showed that the sweet spot areas in the studied basin primarily reply on porosity, thermal maturity, gas-oil ratios, and retained oil and gas volumes, and they may also be affected by natural fractures and pore pressure conditions. This study helps in sweet spot identification in the study area and probably offers insights in shale oil and gas exploration in other basins and areas.

Liu et al. studied the physical properties of shale oil in the Dongying Sag, Bohai Bay Basin, eastern China. The Dongying Sag has experienced decades of conventional petroleum exploration and development, and it contains several sets of high-quality source rock formations. Integrated petrographic and geochemical approached were adopted to analyze the organofacies and thermal maturity proxies of the Eocene Es3 and Es4 formations, which were linked to the physical properties of crude oil. The results showed that crude oil physical and geochemical properties can be ascribed to the differences in organofacies and thermal maturity. This study is likely helps in screening beneficial facies and thermal maturity stages for the sweet spots of shale oil formations.

Liu et al. reconstructed the sedimentary framework of the world's oldest alkaline lake during the Late Paleozoic period when the Fengcheng Formation in the Mahu Sag, Junggar Basin, China was formed using astronomical methods. The results showed that a period of 405 kyr eccentricity played a key role in dividing and correlating the high-frequency sedimentary sequences in lacustrine shales. The lake levels reached their highest value during the deposition of the second member of Fengcheng Formation. The spatial distribution of lithofacies in the Fengcheng Formation was proved within the isochronous cycle framework under the constraints of long eccentricity cycles. These findings are beneficial for characterizing alkaline lacustrine sequences and forecasting favorable areas for shale oil exploration with higher accuracy.

Liu et al. characterized the distribution pattern of natural fractures in the Fengcheng Formation in the Mahu Sag, Junggar Basin, China. The results showed that transformational shear fracture, intraformational open fracture and bed-parallel shear fracture were observed in the Fengcheng Formation, among which the intraformational open fracture is the most developed type. The abundance and extent of fracture were primarily controlled by lithology and brittle mineral content. These fractures are closely related to fault activity and are caused by regional stress fields. Gaining knowledge on the spatiotemporal distribution of natural fracture in shale could help in shale oil and gas exploration and extraction.

Bai et al. analyzed source-reservoir rock assemblages and hydrocarbon accumulation models in the Middle-Lower Jurassic of eastern Sichuan Basin, China. The results demonstrated that a range of reservoir rocks were developed in the Jurassic strata of eastern Sichuan. Among those several sets of rocks, the Da'anzhai, Dongyuemiao, and Liangshan shale formations should be the primary exploration targets, especially the parts deposited in the synclines of semi-deep lake. Then, the Liangshan and Shaximiao sandstone formations could be the secondary exploration targets, particularly in the anticline areas with better sealing conditions. Limestone formations only distributed in limited areas, and those with high and steep fractures are preferable for petroleum exploration.

Fang et al. investigated the distribution lacustrine shale and primary controls of organic matter accumulation in the Middle Jurassic Lianggaoshan Formation in the Sichuan Basin, southwestern China based on seismic interpretation, core observation, high-frequency geochemical analysis. The results showed that the migration of depocenters plays a key role in the distribution of lacustrine organic-rich shale. Organic matter accumulation in first and second Members of organic-rich shale was controlled by paleoproductivity and preservation condition caused by lake-level rise. In contrast, the primary controls of OM accumulation in the third Member are the joint effects of terrestrial OM input and the preservation condition created by rapid deposition.

Ni et al. studied the distribution characteristics of organic matter in the Fengcheng Formation in Mahu Sag, Junggar Basin, China. Mineralogical, organic geochemical and petrographic methods were adopted to characterize the abundance, type, and bio-precursors of organic matter, as well as mineral composition. The results suggested that the Fengcheng Formation can be divided into three zones based on alkaline mineral assemblages, namely, the inner zone dominated by sodium carbonate minerals, the transitional zone containing of higher borosilicate mineral content, and the marginal zone hosting abundant calcite. Lamalginite and telalginite were observed in both the inner and transitional zones, while a certain amount of terrigenous input, mainly inertinite were identified in the marginal zone. The slight variation in pre-cursors resulted in tiny difference in organic matter type in the three zones.

Hong et al. assessed the source to sink of Early-Middle Jurassic strata and revealed its tectonic significance in northeastern Sichuan Basin. Several formations mainly comprise of detrital sediments, lacustrine and fluvial-delta deposits. The orogenesis on the periphery of the basin, e.g., the uplifting of Micangshan Mountain, Dabashan Mountain and Qinling Mountain, were thought to control the sedimentary environment and source property.

Tang et al. carried out cyclostratigraphical and sedimentological analysis of the Lower Permian alkaline lacustrine deposits in the Mahu Sag, Junggar Basin, China. A detailed astronomical cycle and an astronomical time scale, as well as an isochronous sedimentary framework of the Lower Permian Fengcheng Formation in the northern Mahu Sag were constructed by using different wells based on cyclostratigraphy. The spatio-temporal variation in the lithofacies within the Fengcheng Formation was reconstructed based on lithofacies identification.

In summary, this Research Topic collected research articles primarily involving the formation conditions of organic-rich shales. A few of them offer us the physical properties of both rock and crude oil. It is obviously that, although the 10 papers have various research focuses, the Research Topic of articles in this Research Topic helps in gaining new knowledge in this research area and enriching the datasets in the different study blocks. Hopefully, this Research Topic brings some novel insights into shale oil and gas exploration and development.

Author contributions

QZ: Writing–original draft.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This work was supported by National Natural Science Foundation of China (Grant No. 42090025) and China Postdoctoral Science Foundation (Grant No. 2021TQ0003).

Acknowledgments

The reviewers are acknowledged for their constructive and valuable comments that improved the published papers. Guest editors' supports in organizing this Research Topic are much appreciated.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Bechtel, A., Jia, J., Strobl, S. A., Sachsenhofer, R. F., Liu, Z., Gratzer, R., et al. (2012). Palaeoenvironmental conditions during deposition of the Upper Cretaceous oil shale sequences in the Songliao Basin (NE China): implications from geochemical analysis. *Org. Geochem.* 46, 76–95. doi:10.1016/j.orggeochem.2012.02.003

Bechtel, A., Sachsenhofer, R. F., Kolcon, I., Gratzer, R., Otto, A., and Püttmann, W. (2002). Organic geochemistry of the Lower Miocene Oberdorf lignite (Styrian Basin, Austria): its relation to petrography, palynology and the palaeoenvironment. *Int. J. Coal Geol.* 51 (1), 31–57. doi:10.1016/s0166-5162(02)00079-4

Cai, Y., Zhu, R., Luo, Z., Wu, S., Zhang, T., Liu, C., et al. (2022). Lithofacies and source rock quality of organic-rich shales in the cretaceous qingshankou formation, songliao basin, NE China. *Minerals* 12 (4), 465. doi:10.3390/min12040465

Deng, E., Zhang, Q., Jin, Z., Zhu, R., Yan, Z., Jiang, B., et al. (2022). Non-overmature equivalents confirmed a high initial hydrocarbon generation potential of the Permian Longtan Shale in southern China. *Int. J. Coal Geol.* 259, 104043. doi:10.1016/j.coal.2022.104043

Ghazwani, A., Littke, R., Gaus, G., and Hartkopf-Fröder, C. (2018). Assessment of unconventional shale gas potential of organic-rich Mississippian and Lower Pennsylvanian sediments in western Germany. *Int. J. Coal Geol.* 198, 29–47. doi:10.1016/j.coal.2018.08.008

Littke, R., Leythaeuser, D., Rullkötter, J., and Baker, D. R. (1991). Keys to the depositional history of the posidonia shale (toarcian) in the hils syncline, northern Germany. *Geol. Soc. Lond. Spec. Publ.* 58 (1), 311–333. doi:10.1144/gsl.sp.1991.058.01.20

Rippen, D., Littke, R., Bruns, B., and Mahlstedt, N. (2013). Organic geochemistry and petrography of Lower Cretaceous Wealden black shales of the Lower Saxony Basin: the transition from lacustrine oil shales to gas shales. *Org. Geochem.* 63, 18–36. doi:10.1016/j.orggeochem.2013.07.013

Sachsenhofer, R. F., Bechtel, A., Reischenbacher, D., and Weiss, A. (2003). Evolution of lacustrine systems along the Miocene Mur-Mürz fault system (Eastern Alps, Austria) and implications on source rocks in pull-apart basins. *Mar. Petroleum Geol.* 20 (2), 83–110. doi:10.1016/s0264-8172(03)00018-7

Sun, P., Sachsenhofer, R. F., Liu, Z., Strobl, S. A., Meng, Q., Liu, R., et al. (2013). Organic matter accumulation in the oil shale-and coal-bearing Huadian Basin (Eocene; NE China). *Int. J. Coal Geol.* 105, 1–15. doi:10.1016/j.coal.2012.11.009

Zhang, Q., Grohmann, S., Xu, X., and Littke, R. (2020). Depositional environment and thermal maturity of the coal-bearing Longtan Shale in southwest Guizhou, China: implications for shale gas resource potential. *Int. J. Coal Geol.* 231, 103607. doi:10.1016/j.coal.2020.103607

Zhang, Q., Littke, R., Zieger, L., Shabani, M., Tang, X., and Zhang, J. (2019). Ediacaran, cambrian, ordovician, silurian and permian shales of the upper yangtze platform, south China: deposition, thermal maturity and shale gas potential. *Int. J. Coal Geol.* 216, 103281. doi:10.1016/j.coal.2019.103281

Zheng, T., Grohmann, S., Arysanto, A., Baniasad, A., Zhang, Q., and Littke, R. (2023a). Petrographical and geochemical investigation on maturation and primary migration in intact source rock micro-plugs: insight from hydrous pyrolysis on Woodford Shale. *Int. J. Coal Geol.* 266, 104170. doi:10.1016/j.coal.2022.104170

Zheng, T., Zhang, Q., and Deng, E. (2023b). Applications of low molecular weight polycyclic aromatic hydrocarbons (PAHs) and diamondoids ratios/indices on the maturity assessment of coal-bearing source rock: insight from mature to overmature Longtan Shale. *Int. J. Coal Geol.* 269, 104209. doi:10.1016/j.coal.2023.104209

Zheng, T., Zieger, L., Baniasad, A., Grohmann, S., Hu, T., and Littke, R. (2022). The shahejie Formation in the dongpu depression, Bohai Bay Basin, China: geochemical investigation of the origin, deposition and preservation of organic matter in a saline lacustrine environment during the Middle Eocene. *Int. J. Coal Geol.* 253, 103967. doi:10.1016/j.coal.2022.103967