frontiers | Frontiers in Earth Science

TYPE Editorial
PUBLISHED 22 May 2025
DOI 10.3389/feart.2025.1625168

OPEN ACCESS

EDITED AND REVIEWED BY
Valerio Acocella,
Roma Tre University, Italy

*CORRESPONDENCE
Yifan Li,
liyifan@cugb.edu.cn

RECEIVED 08 May 2025
ACCEPTED 13 May 2025
PUBLISHED 22 May 2025

CITATION
Li Y, Li Z, Zhang J, Qiu Z, Kontakiotis G, Peng J and Wang Y (2025) Editorial: Fine-grained sedimentary rocks: sedimentary processes, diagenesis, geochemistry and their relationship with critical geological events. *Front. Earth Sci.* 13:1625168.
doi: 10.3389/feart.2025.1625168

Editorial: Fine-grained sedimentary rocks: sedimentary processes, diagenesis, geochemistry and their relationship with critical geological events

Yifan Li[1]*, Zhiyang Li[2], Jianguo Zhang[1], Zhen Qiu[3], George Kontakiotis[4], Junwen Peng[5] and Youwei Wang[6]

[1]School of Energy and Resources, China University of Geosciences, Beijing, China, [2]School of Engineering, Texas A&M International University, Laredo, TX, United States, [3]Research Institute of Petroleum Exploration and Development (RIPED), PetroChina, Beijing, China, [4]Department of Historical Geology and Paleontology, Faculty of Geology and Geoenvironment, School of Earth Sciences, National and Kapodistrian University of Athens, Athens, Greece, [5]Oklahoma Geological Survey, University of Oklahoma, Norman, OK, United States, [6]Department of Environmental Sciences, University of Virginia, Charlottesville, VA, United States

KEYWORDS

sedimentary process, sedimentary geochemistry, diagenenesis, shales and mudstones, unconventional reservoir, geological event

Editorial on the Research Topic
Fine-grained sedimentary rocks: sedimentary processes, diagenesis, geochemistry and their relationship with critical geological events

Fine-grained sedimentary rocks are increasingly studied for their complex depositional processes, high organic content, reservoir potential, metal enrichment, and geochemical records of paleoenvironments (Ettensohn et al., 1987; Wignall, 1994; Stow et al., 2001; Aplin et al., 2011; Shahzad et al., 2024). Once seen as homogeneous suspension-settled deposits, flume experiments and sedimentological studies have revealed that they can form under high-energy conditions, influenced by floods, storms, and bottom currents (Schieber et al., 2007; Bohacs et al., 2014; Macquaker et al., 2014; Li et al., 2022; Mehmood et al., 2023). Additionally, finegrained sedimentary rocks may receive sediments of various origins and can be characterized by a complex composition comprising clay minerals, quartz, carbonates, feldspars, sulfides, biogenic debris, and organic matter (Taylor and Macquaker, 2002; Macquaker and Adams, 2003; Milliken, 2014; Camp et al., 2015). Diagenesis in these rocks is governed by mass-balance, fluid transport, and organic-inorganic interactions (Morad et al., 2000; Cobbold et al., 2013; Liang et al., 2018). Geochemical proxies link their formation to major tectonic and environmental events, including rifting, glaciation, volcanism, anoxia, mass

extinctions, and hydrothermal activity (Algeo et al., 2012; Trabucho-Alexandre et al., 2012; Li et al., 2015; Qiu et al., 2022; Shen et al., 2025; Derkowski et al., 2013). These insights are vital to sedimentary and diagenetic theory—especially unconventional petroleum sedimentology (Qiu et al., 2020; Zou et al., 2022)—and to understanding Earth's sphere-system evolution.

This Research Topic comprises ten papers presenting advances in the study of fine-grained sedimentary rocks from three perspectives: depositional processes, diagenetic mechanisms, and geochemical characteristics. Rocks focused in this volume encompass both marine and continental mudstones and shales, spanning strata from the Cambrian to the Eocene, and therefore are broadly representative. Through these case studies, we aim to further enrich the theoretical framework surrounding fine-grained sedimentary rocks.

Sedimentary processes

Wen et al. investigated the Beipiao Formation in western Liaoning, Northeast China, and identified lithofacies formed under the influence of volcanic activities and sediment-gravity flows. Three depositional environments—shallow lake, semi-deep/deep lacustrine, and fan delta—were defined, with basin evolution transitioning from fan delta to deep lake and back, interbedded with volcanic deposits. Volcanism enhanced nutrient supply and organic matter preservation, while gravity flows transported plant fragments to deep lakes, leading to the enrichment of Type III kerogen.

Feng and Zhang analyzed the ShangGanchaigou Formation in the western Qaidam Basin, Northwest China, and identified seven architectural elements (distributary channels, bars, algal mounds, etc.) and three facies belts (proximal delta front, middle isolated lobes, distal algalmarl complexes). Short-term base-level cycles were documented as the dominant factor producing frequent facies variations. Reservoir connectivity was documented to decrease lakeward, revealing challenges in predicting heterogeneous reservoirs.

Diagenesis

Zhang et al. examined coevolution of minerals in lacustrine mudstones from Bohai Bay Basin, East China. Fibrous calcite/ankerite precipitated in primary laminar fractures during peak organic-acid release, with elements supplied by early carbonate dissolution and smectite–illite transformation. Clay alteration led to the formation of microcrystalline quartz, feldspar dissolution, and the increase in pH allowed authigenic albite to form. Authigenic carbonates and colloidal pyrite regulated pore-fluid chemistry, while variations in organic matter governed pore pressure, acid levels, and diagenetic pathways.

Yuan et al. studied tight sandstones of the Jurassic Lianggaoshan Formation in the eastern Sichuan Basin, Southwest China, and identified various facies associated with subaqueous distributary channels and mouth bars. Strong compaction/cementation led to reduction of porosity, while chlorite coatings and weak dissolution preserved pores. Five diagenetic facies were classified, with Type III (chlorite-coating) and IV (weak dissolution) in coarse-grained channels showing high AC, low GR/DEN/RT as optimal reservoirs.

Lin et al. studied analcime formation in Middle Permian reservoirs in the Jinan Sag, Junggar Basin, Northwest China. Analcime was originated from early alkaline hydrolysis of volcanic debris under specific conditions, forming low-silica, Al-rich, Na-poor varieties. Cementation reduced primary porosity, but acidic fluids from oil/gas charging dissolved analcime, generating secondary pores via albitization. Reservoir quality was enhanced by formation of intragranular pores through dissolution of analcime, feldspar or lithic fragments.

Guo et al. investigated glutenite compaction using a self-designed diagenetic simulation system, addressing the lack of quantitative studies on complex rock fabrics. Experiments revealed segmented logarithmic relationships between porosity and depth during mechanical compaction, with larger grains aiding in pore preservation. A 30% sand content in gravel formed stable secondary structures optimizing pressure-bearing capacity, while high heterobase content reduced primary pores.

Ge et al. examined Niutitang shale gas across four palaeouplifts in the Sichuan Basin, Southwest China, showing that structural preservation, thermal maturation, and sedimentary subfacies control enrichment and that thrust-nappe lower plates and deepwater trough facies were recognized as prime exploration targets.

Geochemistry

Lu et al. investigated Qiongzhusi Formation shale from three wells in southern Sichuan Basin, Southwest China, by analyses of lithofacies, mineralogy, TOC, trace elements, and isotopes. They defined two depositional end-members in a fault-controlled, moderately restricted setting: (1) organic-rich black shale formed under anoxic-suboxic conditions during periods of low chemical weathering, cold-arid climate, and high productivity; and (2) organic-lean grey shale deposited under suboxic-oxic conditions during periods of similarly low weathering intensity and aridity but reduced productivity.

Gao et al. analyzed fine-grained floodplain deposits in the Greater Green River Basin, southwestern Wyoming, United States of America. They used paleosol morphology, bulk organic $\delta^{13}C$, leaf-wax $\delta^{13}C$ and δD, and CIA-K–derived MAP to reconstruct LPEE continental hydroclimate. They identified the PETM by a ~4‰–5‰ negative carbon isotope excursion and a 30‰–50‰ leaf wax n-alkanes δ Dn-alk increase. Paleosols indicate generally humid–warm conditions with transient drying during the PETM, with pCO_2 of 600–900 ppm reconstructed through the integration of δ^{13}Corg with carbonate $\delta^{13}C$.

Wang et al. reconciled Qingshankou Formation mud/silt stratigraphy in the southern Songliao Basin, Northwest China, by linking gamma/density logs to astronomical cycles, and developed a high-resolution, isochronous framework. They showed that tectonics and orbital climate paced rhythmic sand–mud progradation and proposed a "synchronous heterotopy" lake-delta

model with overfilling strata lagging eccentricity peaks, whereas balanced - filling strata coinciding with them.

Author contributions

YL: Writing – original draft, Writing – review and editing. ZL: Writing – original draft, Writing – review and editing. JZ: Writing – review and editing. ZQ: Writing – review and editing. GK: Writing – review and editing. JP: Writing – review and editing. YW: Writing – review and editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This work was supported by the National Natural Science Foundation of China (Grants 42272173, U24B6001), and the National Key Research and Development Program of China (Grant Nos. 2023YFF0804300, 2023YFF0804302).

Conflict of interest

Author ZQ was employed by Petrochina.

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

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

References

Algeo, T. J., Morford, J., and Cruse, A. (2012). New applications of trace metals as proxies in marine paleoenvironments. *Chem. Geol.*, 306: 160–164. doi:10.1016/j.chemgeo.2012.03.009

Aplin, A. C., and Macquaker, J. H. S. (2011). Mudstone diversity: origin and implications for source, seal, and reservoir properties in petroleum systems. *AAPG Bull.* 95 (12), 2031–2059.

Bohacs, K. M., Lazar, O. R., and Demko, T. M. (2014). Parasequence types in shelfal mudstone strata—Quantitative observations of lithofacies and stacking patterns, and conceptual link to modern depositional regimes. *Geology*. 42 (2), 131–134. doi:10.1130/g35089.1

Camp, J., Roberts, M., Maclachlan, C., Wallace, E., Hermanson, L., Brookshaw, A., et al. (2015). Seasonal forecasting of tropical storms using the Met Office GloSea5 seasonal forecast system. *Q. J. R. Meteorological Soc.* 141 (691), 2206–2219. doi:10.1002/qj.2516

Cobbold, P. R., Zanella, A., Rodrigues, N., and Løseth, H. (2013). Bedding-parallel fibrous veins (beef and cone-in-cone): Worldwide occurrence and possible significance in terms of fluid overpressure, hydrocarbon generation and mineralization. *Mar. Petroleum Geol.* 43, 1–20. doi:10.1016/j.marpetgeo.2013.01.010

Derkowski, A., Bristow, T. F., Wampler, J. M., Środoń, J., Marynowski, L., Elliott, W. C., et al. (2013). Hydrothermal alteration of the Ediacaran Doushantuo Formation in the Yangtze Gorges area (South China). *Geochimica Cosmochimica Acta*. 107, 279–298. doi:10.1016/j.gca.2013.01.015

Ettensohn, F. R. (1987). Rates of relative plate motion during the Acadian orogeny based on the spatial distribution of black shales. *J. Geol.* 95 (4), 572–582.

Li, Y., Fan, T., Zhang, J., Zhang, J., Wei, X., Hu, X., et al. (2015). Geochemical changes in the Early Cambrian interval of the Yangtze Platform, South China: Implications for hydrothermal influences and paleocean redox conditions. *J. Asian Earth Sci.* 109, 100–123. doi:10.1016/j.jseaes.2015.05.003

Li, Z., and Schieber, J. (2022). Correlative conformity or subtle unconformity? The distal expression of a sequence boundary in the upper cretaceous mancos shale, Henry mountains region, Utah, USA. *J. Sediment. Res.* 92 (7), 635–657.

Liang, C., Wu, J., Jiang, Z., Cao, Y., and Song, G. (2018). Sedimentary environmental controls on petrology and organic matter accumulation in the upper fourth member of the Shahejie Formation (Paleogene, Dongying depression, Bohai Bay Basin, China). *Int. J. Coal Geol.* 186, 1–13. doi:10.1016/j.coal.2017.11.016

Macquaker, J. H. S., and Adams, A. E. (2003). Maximizing information from fine-grained sedimentary rocks: An inclusive nomenclature for mudstones. *J. Sediment. Res.*, 73(5): 735–744.

Macquaker, J. H., Taylor, K. G., Keller, M., and Polya, D. (2014). Compositional controls on early diagenetic pathways in fine-grained sedimentary rocks: Implications for predicting unconventional reservoir attributes of mudstones. *AAPG Bull.* 98 (3), 587–603. doi:10.1306/08201311176

Mehmood, M., Naseem, A. A., Saleem, M., Rehman, Ju, Kontakiotis, G., Janjuhah, H. T., et al. (2023). Sedimentary Facies, Architectural Elements, and Depositional Environments of the Maastrichtian Pab Formation in the Rakhi Gorge, Eastern Sulaiman Ranges, Pakistan. *J. Mar. Sci. Eng.* 11, 726. doi:10.3390/jmse11040726

Milliken, K. (2014). A compositional classification for grain assemblages in fine-grained sediments and sedimentary rocks. *J. Sediment. Res.* 84 (12), 1185–1199. doi:10.2110/jsr.2014.92

Morad, S., Ketzer, J. M., and De Ros, L. F. (2000). Spatial and temporal distribution of diagenetic alterations in siliciclastic rocks: implications for mass transfer in sedimentary basins. *Sedimentology* 47, 95–120. doi:10.1046/j.1365-3091.2000.00007.x

Qiu, Z., and Zou, C. (2020). Controlling factors on the formation and distribution of "sweet-spot areas" of marine gas shales in South China and a preliminary discussion on unconventional petroleum sedimentology. *J. Asian Earth Sci.* 194, 103989.

Qiu, Z., Zou, C., Mills, B. J., Xiong, Y., Tao, H., Lu, B., et al. (2022). A nutrient control on expanded anoxia and global cooling during the Late Ordovician mass extinction. *Commun. Earth and Environ.* 3 (1), 82. doi:10.1038/s43247-022-00412-x

Schieber, J., Southard, J., and Thaisen, K. (2007). Accretion of mudstone beds from migrating floccule ripples. *Science* 318 (5857), 1760–1763. doi:10.1126/science.1147001

Shahzad, A., Kontakiotis, G., Adatte, T., Ahmed, K. S., Riaz, M. T., Janjuhah, H. T., et al. (2024). Multi-Elemental Chemostratigraphy, Sequence Development, Depositional History, and Environmental Importance of Early Eocene Red Beds (Kuldana Formation) in NW Himalayas, Pakistan. *J. Earth Sci.* 35, 349–375. doi:10.1007/s12583-023-1860-6

Shen, B., Lang, X., Wang, R., Liu, Y., Zhang, S., Huang, T., et al. (2025). Resolving the Snowball Earth conundrum: the role of marine dissolved organic carbon pool. *Bull. Sci.*, doi:10.1016/j.scib.2025.03.056

Stow, D. A. V., Huc, A. Y., and Bertrand, P. (2001). Depositional processes of black shales in deep water. *Mar. Petroleum Geol.* 18 (4), 491–498. doi:10.1016/s0264-8172(01)00012-5

Taylor, K. G., and Macquaker, J. H. S. (2002). "Early diagenetic pyrite morphology in a mudstone-dominated succession," in *The lower Jurassic Cleveland Ironstone formation, eastern England*.

Trabucho-Alexandre, J., Hay, W. W., and De Boer, P. L. (2012). Phanerozoic environments of black shale deposition and the Wilson Cycle. *Solid earth*. 3 (1), 29–42. doi:10.5194/se-3-29-2012

Wignall, P. B. (1994). *Black shales*. Clarendon Press.

Zou, C., Qiu, Z., Zhang, J., Li, Z., Wei, H., Liu, B., et al. (2022). Unconventional petroleum sedimentology: Unconventional Petroleum Sedimentology: A Key to Understanding Unconventional Hydrocarbon Accumulation key to understanding unconventional hydrocarbon accumulation. *Engineering* 18, 62–78. doi:10.1016/j.eng.2022.06.016