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Editorial: Unconventional resources: provenance analysis, sediment transport, reservoir evaluation, geo-energy

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Editorial on the Research Topic
Unconventional resources: provenance analysis, sediment transport, reservoir evaluation, geo-energy

With the progress of theoretical understanding, exploration, and development techniques, the community has made significant efforts in unconventional oil and gas resources. Global unconventional oil and gas production is proliferating, and its role in global energy supply is increasingly prominent. Given the rich unconventional oil and gas resources, it is necessary to conduct in-depth research on provenance analysis, sediment transport, reservoir evaluation, and geo-energy. This Research Topic aims to provide operational evaluation ideas for unconventional resource prediction through reservoir provenance analysis, sediment transport, reservoir evaluation, and geo-energy, and ultimately improve oil and gas exploration practice. This Research Topic contains 28 papers related to the provenance analysis, sediment transport, reservoir evaluation, and geo-energy of unconventional resources. These 28 papers are as follows:

The modelling of unconventional reservoirs is mainly aimed at reservoirs, which are originally tight reservoirs and generally have no profitable output and demand artificial stimulations. A large number of horizontal wells, branch wells, and other technologies are targeted at enhancing production. Wang et al. proposed a fracture-vuggy carbonate reservoir modeling method based on multiple geological information fusion. Different from the traditional method, the four kinds of reservoirs are characterized in a fusion model. More reservoir development factors, for example, fault factor, depth factor, and wells interpretation are taken into consideration. The model result is closer to the real data. Wang et al. proposed a fracture grading modeling method based on geological information fusion. This method utilizes fracture development control factors and seismic attribute information as constraints for fracture modeling to establish a discrete fracture network model. This approach enhances the accuracy of fracture prediction and provides a basis for the exploration of ultra-deep low-porosity sandstone reservoirs. Song et al. carried

out experiments including fluid inclusion tests, and C–O isotope tests, which revealed the densify mechanism of the Upper Paleozoic sandstone reservoirs in the Daniudi gas field, and divided the tight gas reservoirs into two types: self-sourced and near-source accumulations. The study provided a new understanding of the formation process of tight sandstone gas reservoirs and a reference for the exploration and development of the same type of gas reservoirs. Li et al. reveal that micropores (<7 nm) do not contribute to the storage and percolation but contribute significantly to contrasting specific surface area, that mesopores only contribute to total porosity but not to permeability. The macropores (>300 nm) contribute to both porosity and permeability, which demonstrate that the content and heterogeneity of macropores are key indicators for the quality of the Chang 7 tight sandstones.

Wu et al. studied the diagenetic alterations and distribution of high-quality reservoirs within deltaic distributary channel facies. A concept model about favorable lithofacies with high reservoir quality was proposed. This model revealed favorable lithofacies in deltaic sand bodies could form lithologic traps, which have important exploration and development value for lithologic hydrocarbon reservoirs.

Shi et al. proposed an improved stacked model with a gate network module to predict the permeability of tight sandstone reservoirs. The GNS model can automatically evaluate the impact of various logging parameters and significantly improve the prediction accuracy, which helps to enhance the reliability of tight reservoir evaluation parameters.

He et al. established a data-driven fracture propagation model and fracture channeling identification method, successfully explains the reason for cross-well fracture channeling, and its conclusion aligns with the actual monitoring results.

Shi et al. proposed a method to characterize the regional distribution of complex multi-layer migration pathways for oil and gas in the paleo-slope zone outside petroliferous basins' source kitchens. This study established a method creatively for determining the threshold for oil and gas migration along sandbodies and faults, and it improves the exploration efficiency of petroleum in areas with similar geological conditions like eastern basins in China.

Zhang et al. study the dynamic loss process and the molecular changes of hydrocarbons in preserved shale samples exposed in open air for different time, and reveal that there is a large amount of oil loss of about 42%–78% for samples with maturity %Ro between 1.01 and 1.53. The oil loss is mainly contributed by free oil, while adsorbed oil remains unchanged. NMR T1–T2 mapping can be an important method to estimate *in situ* fluid saturation without sample crushing.

Dong et al. employed nuclear magnetic resonance (NMR), X-ray micro-computed tomography (micro-CT), and mercury injection capillary pressure (MICP) to analyze the descriptive topological and geometric features of carbonate samples from the Gaoshitti-Moxi area of the Sichuan Basin, compared the corresponding experimental results, and developed a novel comprehensive characterization approach for its parameters, which is conducive to characterizing the pore structure of carbonate rock.

Zhao et al. characterized the source rocks and the structural evolution history is restored by using 2D-Move software. The characteristics of reservoirs and caps are clarified, and the controlling factors of reservoir formation are summarized. The sandstone reservoir has fracture and dissolution porosity, which provide storage space for oil accumulation. Faults and unconformities provide pathways for oil migration. The dense basalt is a good cap layer to preserve the reservoir. The research results are of great significance to guide future oil and gas exploration in the Liaohe Basin.

Li et al. revealed the main controlling factors of reservoir heterogeneity in the Jiaxian area through thin rock sections, scanning electron microscopy, high-pressure mercury intrusion, and conventional property analysis. The multi-stage metamorphic hydrocarbon expulsion process in coal seams enriched the organic-inorganic interactions in coal-bearing strata, adding some reservoir capacity.

Zhang et al. proposed a new method for dynamic monitoring of hydraulic fracturing of shale gas by borehole-to-surface Transient Electromagnetic Methods (BSTEM). By combining field-based shale gas fracturing monitoring models, the response patterns of the borehole-to-surface transient electromagnetic field under different fracturing stages are analyzed, which can guide importance for the application of borehole-to-surface transient electromagnetic methods in monitoring hydraulic fracturing of shale gas.

Wang et al. constructed a three-dimensional model using hydraulic fracturing software based on the discrete lattice theory and synthetic rock mass method. The effect of a relatively short cluster spacing (5 m or less) on fracture propagation behavior was investigated through a series of case studies, considering operational parameters (injection rate, the number of fractures) and reservoir parameters (reservoir Young's modulus, stress anisotropy, principal stress direction).

Wang et al. employed a well-seismic fusion method, incorporating RGB seismic attribute fusion technology, to classify and detail the sedimentary architecture of thin-layer beach-bar sand bodies in Niger's G oilfield. By integrating seismic attributes and well-logging data, it identifies the spatial distribution and connectivity of sand bodies, presenting a comprehensive architecture classification. These findings enhance the fine characterization of thin-layer beach-bar reservoirs, supporting efficient reservoir development and offering an important methodological reference for similar geological settings.

He et al. explored the necessity of switching from water injection to natural gas injection in the fault-controlled fracture-cavity reservoir in Shunbei. They studied the optimization of natural gas injection parameters and methods, analyzed the natural gas displacement mechanism, optimized well pattern layout and injection-production parameters, and constructed an evaluation system for natural gas injection. This improves reservoir development efficiency and oil production rate, reduces the risk of gas channeling, and provides technical support for oil and gas field development.

Li et al. based on a systematic study of the noble gas and stable isotope characteristics of normally-pressured shale gas samples, revealed the origin of noble gas from normally-pressured shale gas reservoirs and discussed the accumulation and expulsion mechanisms of normally-pressured shale gas in the tectonically complex margin of the southeastern Sichuan Basin. The result can provide insights into the enrichment mechanism of shale gas reservoirs and the prediction of shale gas production capacity in other structurally complex regions of the world.

Wang et al. analyzed the Carboniferous Dawuba and Cambrian Niutitang shales in the Upper Yangtze Platform, South China, revealing their paleoenvironmental conditions and gas potential. Dawuba shales formed in warm, arid, reducing conditions, while Niutitang shales experienced cooler, arid climates. Both have high gas generation

potential, with Dawuba featuring Type II2 kerogens and Niutitang Type I. Despite low gas content, promising exploration areas include the Qiannan Depression's Shangyuan and Zongdi regions.

Fu et al. investigated the influence of extensional strike-slip fault systems on hydrocarbon accumulation in the Bohai Bay Basin's Huanghekoudong and Miaoxi'nan sub-sags. Utilizing three-dimensional seismic data, new sequence stratigraphic frameworks, and advanced analysis techniques, they develop a model detailing how these systems shape sub-sag evolution and trap formation. This research enhances understanding of structural trapping dynamics, providing crucial insights for exploration strategies in similar geological settings globally.

Yuan et al. proposed a method for the identification of complex lithology of tight marl reservoir based on logging data. Lithological identification of 2D and 3D plots is established using sensitive GR, DEN, and RT. Corresponding identification standards are built in two hierarchies. The lithological characteristics of vertical, horizontal, and plane are discussed in the research area, which may aid in understanding the complex marl reservoir in the Leikoupo Formation 32 Submember of the Sichuan Basin, China.

Meng et al. found that the factors that influence the CO_2 injectivity are CO_2 injection rate, reservoir pressure, formation water saturation, and permeability, respectively. The oil recovery is mainly influenced by CO_2 injection rate and formation permeability, and the influences of reservoir pressure and water saturation on oil recovery are smaller. To improve the CO_2 injectivity, the threshold values for radial perforation and fracture half-length are 25 m and 50 m.

The different provenance controls the distribution of sedimentary facies in the vertical and lateral directions, which in turn controls the spatial distribution of the grain size and clastic composition. The study of provenance analysis and sediment transport can integrate tectonics, climate, provenance lithotypes, transport dynamics, and burial diagenesis, which can provide a comprehensive understanding of unconventional reservoirs. Wang et al. studied the seasonal deltaic deposits in the Cretaceous red bed of the Tarim Basin. As seasonal deltaic deposits were still not well studied in previous research, a concept depositional model about seasonal deltaic deposits was proposed in this research. This model revealed different types of distributary channels in Cretaceous arid paleoclimate, which have important value for both delta sedimentology and deltaic hydrocarbon reservoir exploration. Lan et al. used the Jurassic asphalt found in the QD1 well, combined with the source rocks of drilling cores and outcrops, and explored the possible hydrocarbon source and forming process in the Ruoqiang Sag using oil-source correlation and hydrocarbon accumulation geochronology methods. Peng et al. analyzed beach-bar reservoirs in Qinghai Lake, NW China, linked to unconventional hydrocarbon reservoirs. It highlights the influence of lake-level fluctuations, wind wave dynamics, sediment provenance, and terrain gradient on beach bar formation and morphology. Large-scale fluctuations set initial conditions, while small-scale ones refine features. Wind dynamics define depth zones, affecting morphology. Beach bars are categorized by sediment provenance: bedrock, alluvial fan, and braided river systems. Terrain gradients under 0.7° favor formation, aiding hydrocarbon exploration and sedimentary geology. Wang et al. spectral analysis and wavelet transform are used to study the high frequency Milankovitch sedimentary cycle in Fengcheng Formation. A high resolution astronomical age scale is established, and the 2-stage sedimentary cycle and 8-layer sweet spot are identified. Qi et al. take the Chang 6 lobate delta in the Wuliwan area of the Jing'an Oilfield in the Yishan Slope of the Ordos Basin as an example, this study sets parameters including sediment grain size, hydraulic conditions, and slope gradient similar to those underground to simulate the evolution of the shallow-water delta in the research area through flume experiments, dissect its internal configuration characteristics, establish a sedimentary model, and provide guidance for water flooding adjustments in the oilfield. Dong et al. based on the observation and description of drilling cores, carbon and oxygen isotope tests, inclusion analysis, logging data analysis, and seismic data interpretation, they depict the filling architecture, analyze the stages of collapse–filling, and discuss the differential evolution process and associated filling mechanism of typical paleounderground rivers.

Machine learning and artificial intelligence are of great value to the research of unconventional reservoirs. Wei et al. presented a hybrid feature selection method that integrates hyperspectral data with machine learning for precise estimation of dolomite content in carbonate rocks. This non-destructive approach improves the accuracy of field-based mineral identification and facilitates more detailed geological surveys, offering practical significance for oil resource assessment and exploration.

Author contributions

WW: Supervision, Validation, Visualization, Writing–original draft, Writing–review and editing. XW: Writing–original draft, Writing–review and editing. YC: Writing–original draft, Writing–review and editing. CL: Writing–original draft, Writing–review and editing. YZ: Writing–original draft, Writing–review and editing.

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Conflict of interest

The 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.

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

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