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Editorial: Mechanisms and applications of chemical techniques for effective development of unconventional reservoirs

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Editorial on the Research Topic
Mechanisms and applications of chemical techniques for effective development of unconventional reservoirs

The proved reserves and production from unconventional reservoirs, such as tight sandstone, carbonate, and shale oil and gas, have increased yearly. How to effectively develop such tight reservoirs is still an urgent Research Topic for current and future decades. Researchers have accumulated a wealth of experience in exploiting conventional reservoirs. However, the geological conditions, petrophysical properties, and fluid mobility of unconventional resources are quite different from those of conventional ones. Usually, abundant micro-nanopores are well developed within unconventional reservoir rocks, resulting in a very high displacement pressure and hindering the application of most flooding approaches. In addition, fluids in tight formations are under the nanoconfinement environment but not the bulk condition. The fluid flow mechanisms and solid-fluid interactions remain elusive throughout the production stage, particularly when chemical recovery methods are involved. Therefore, this Research Topic is focused on the application of chemical-based techniques in promoting hydrocarbon extraction in unconventional reservoirs and revealing the mechanisms and intricate processes of chemical additives for improving recovery.

We have collected twelve papers on this Research Topic, mainly including the chemical-assisted hydraulic fracturing and the displacement of oil and gas in reservoir development. For instance, the paper "*Analysis of the influence of CO_2 pre-injection during hydraulic fracturing on enhanced oil recovery in shale reservoirs*" by Yang et al. discussed the effects of CO_2 pre-injection on reservoir rocks and fluids. They demonstrated that the CO_2-rock and CO_2-oil/water interaction could change the reservoir porosity, permeability, wettability, and fluid properties and impede clay swelling. These changes could lead to a reduction in initiation pressure, an increase in fracture complexity, and the enhancement in reservoir pressure, which is thus conducive to the hydraulic fracturing operation. Similarly, to mitigate the drawback of single HCl during matrix acidizing of tight carbonate formations, in their work "*Comparative analysis of matrix retarded acidizing methods for tight carbonate reservoirs: gelled acid, foamed*

acid and micro-emulsified acid," Wang et al. proposed three promising matrix acidizing formulas for carbonate reservoirs. Among them, the foam-based acids have several advantages over other acidizing methods. Specifically, the foam-based acids show good compatibility with formation water and could lower the filtrate rate of acid and cause less formation damage. Therefore, it is highly recommended in the matrix acidizing process. Additionally, in the study "*Comparative study on the analysis methods of fracture pressure interference in shale oil three-dimensional fracturing,*" Chen et al. concluded that the tracer monitoring, microseismic, and pressure monitoring technology were commonly used to identify the interlayer fracture pressure and evaluate the fracturing performance. The tracer monitoring method is the most accurate, but the latter two have a wider range of applications. Thus, the synthetic application of the three methods could be more appropriate.

Given the significance of environmental protection, CCUS (carbon capture, utilization, and storage) has become a hot spot and has attracted much more attention from academia and industry in recent years. Several papers collected in this Research Topic are associated with this Research Topic. The experimental paper "*Laboratory investigation of the influence of fractures on CO_2 flooding*" by Qing-Fu studied the effects of fracture length and aperture on CO_2 flooding pressure, displacement efficiency, and composition of produced fluids. They found that a longer and wider fracture could decrease the injected pressure; however, this impairs the oil displacement efficiency. Besides, the fracture properties have no significant influence on the composition of produced oil. In the paper "*Low Carbon Oil Exploitation: Carbon Dioxide Flooding Technology,*" Xia et al. reviewed the research status of CO_2 flooding worldwide, and summarized nine mechanisms of CO_2 flooding for oil and gas reservoirs. Finally, the authors raised their concerns in terms of the low oil recovery, economic problems, gas sources, etc. Furthermore, it is inevitable that gas channeling would occur when CO_2 is injected into the fractured tight oil reservoirs. Zhu et al. stated that this unfavorable circumstance could be eased by injecting the low-viscosity CO_2 responsive plugging materials, which can effectively block the high-permeable channels and reduce the upswept zone. The primary mechanisms of CO_2 responsive foam, CO_2 responsive surfactant, and CO_2 responsive gel, are elaborated in their paper "*The Application of CO_2-Responsive Materials (CRMs) on Enhanced Oil Recovery (EOR) for Fractured Tight Oil Reservoirs*". In another paper, "*Eco-development of oil and gas industry: CCUS-EOR technology,*" Yan et al. reviewed the current status and advance of CCUS technology from the perspective of ecological development, and they also gave their advice on the practical paths of reducing carbon in the world, the international development pattern and advanced technologies for the large-scale CO_2 storage and enhanced oil recovery. Additionally, oil recovery by spontaneous imbibition is also a vital enhanced oil recovery method for tight reservoirs. However, a prerequisite is that the reservoir rocks must be water-wet. Thus, in the paper "*Wettability alteration agents to promote spontaneous imbibition in tight reservoirs: Achievements and limitations,*" Zhong et al. proposed that the surfactants, nanoparticles, nano-emulsion, and inorganic salts can be used to shift the mixed-wet or oil-wet formations to the water-wet state to maximize the imbibition oil recovery. They also discussed the potential risks and future trends regarding the applications of these approaches in tight reservoirs.

Furthermore, several authors attempted to elaborate on the fluid flow behavior based on the pore scale modeling and mathematical model. For example, Jia et al. employed the phase-field model built in COMSOL to investigate the effect of fracture direction on displacement characteristics and residual oil distribution under the water flooding model. They also identified the evolution of residual oil types. The results were shown in the paper "*COMSOL-based investigation of the characteristics of microscopic water flooding and residual oil distribution in carbonate reservoirs.*" The paper "*Study on flow model of multi-stage fracturing horizontal well in stress-dependent dual medium reservoir*" by Jiaming et al. considered the stress sensitivity of carbonate reservoir and established a semi-analytical model to flow regimes of multistage fracturing horizontal well. Results showed that fluids flow in the horizontal well can be classified into six types, and ignoring the stress sensitivity would bring about a substantial error in production prediction. On the other hand, there are two additional papers concentrated on the fluid mobility in tight sandstone (*Research on fluid mobility in tight sandstone with a NMR fractal theory pore classification method* by Gao et al.) and the competitive adsorption of different gas on hydrate surface (*Comparison of CO_2, N_2, CO, H_2S, CH_4, and H_2O adsorptions onto sI methane hydrate surface* by Zhang et al.). These results would provide significant guidance for the selection of sweet-spot and the development of unconventional reservoirs.

In conclusion, commercial development of unconventional resources cannot be achieved without the usage of chemical-related techniques. The papers on this Research Topic provide an overview of a variety of chemical-assisted approaches used in tight reservoirs. However, the mechanisms and applicability of different chemical methods still remain vague since addressing this Research Topic is very challenging, which entangles multi-disciplinary knowledge. Therefore, it could be more targeted by organizing a Research Topic that only specifically focuses on one or two aspects of chemical recovery systems.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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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