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Editorial

Marine Gas Hydrate: Geological Characterization, Resource Potential, Exploration, and Development

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Natural gas hydrate is critical for its tremendous potential to impact the energy supply field, accelerate global warming if methane reaches the atmosphere, and affect the safety of deep-sea oil and gas production. In recent decades, research into natural gas hydrate has greatly advanced in the areas of natural gas hydrate formation, geological characteristics, resource potential assessment, and exploration and production technology. Commercial gas production from gas hydrate reservoirs is the most critical target for related research and industrial activities. This Special Issue reports on the latest research results on hydrate formation and occurrence, hydrate saturation estimation via geophysical methods including acoustic waves and electrical resistivity, new ideas to improve gas production, and potential issues that could be encountered during gas production. In addition, a contribution focusing on flow assurance and the impact of global warming on methane fate in sediments via its influence on micro-bio activities enriches the content of this Special Issue.

A good understanding of the natural hydrate system is a prerequisite for gas production or evaluating its environmental impacts. Biogenesis sources very often account for more than 90% of the methane gas in gas hydrate, and hydrate formation from microbial methane is essential to understanding hydrate formation in natural sediments. Guan, et al. [1] show a case study of a stratigraphic-diffusive type of gas hydrate system in Dongsha slope sediments. Their deposition production model emulated the vertical and lateral seabed morphology of the sediments. Uneven hydrate distribution can be explained by the coexistence of hydrate formation and decomposition in different parts of the sediments. Their results also verify that the residual methane could overflow into the seawater. Su, et al. [2] approach this problem from a different perspective. A Monte Carlo probability-based volume method is applied to assess the hydrate distribution and resource potential in the South China Sea. Heat flow, deposition rate, and total organic carbon content are the critical parameters in the analysis. The estimated gas hydrate resource density in this area is typical, and the total gas hydrate stored is expected to be equivalent to around 74.4 billion tons of oil. Mud volcanoes have been an enduring mystery with a lot of unknown characteristics. Wan, et al. [3] explore the thermal effect of mud volcanoes on the occurrence of gas hydrates. They consider the relatively more active heat transfer near the volcano, which could shift the temperature profile and affect the stability boundary of gas hydrate as well as the formation dynamics.

Analyses at a large scale provide a big picture of the resource potential, but these studies cannot tell us where exactly gas hydrate is located. Geophysical methods are thus a good complement to large-scale analyses. The acoustic detection of gas hydrate is effective as gas hydrate significantly increases the stiffness of sediments, and the coexistence of free gas under the hydrate stability zone could result in a bottom simulating reflector. However, the precision of such practices heavily relies on the assumed correlation between hydrate saturation and acoustic wave velocities, which is largely determined by hydrate

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pore habits. Bu, et al. [4] solve this problem by combining the micro-CT technique and acoustic measurements. Similarly, Archie's law relates hydrate saturation with electrical resistivity. However, as an empirical equation, the saturation exponent is also determined by the actual pore habit. It is wise to apply the micro-CT technique to visualize the 3D pore structure and evaluate its effect on the measured electrical resistivity [5]. Chen, et al. [6] infer that the resistivity change of pore-filling gas hydrate is affected by sediment lithology and hydrate saturation based on a summary of global resistivity logging and experimental studies' results; fracture-filling hydrate reservoirs have strong anisotropy and show higher resistivity variation. Clay minerals are an important factor restricting the accurate estimation of gas hydrate saturation from in situ resistivity measurements.

Gas production is the third step after the assessment of gas hydrate resource potential and hydrate saturation detection with geophysical methods. The efficiency of gas production is closely related to the seepage in hydrate-bearing sediments. Li, et al. [7] investigate the effects of three key parameters, permeability, hydrate saturation, and porosity, on gas production efficiency. Their multi-physics coupled analysis reveals the complexity of gas production and suggests that the combined effect of seepage, heat transfer, and hydrate content should be fully considered. As hydrate dissociation is an endothermic process, fast gas production may induce ice formation and block the flow paths within sediments. Heat transfer towards the hydrate dissociation front limits the gas production rate. Ye, et al. [8] present a novel heat transfer device that can transfer heat from the lower reservoir to the wellbore wall without external energy injection to accelerate hydrate dissociation. Sand production is another severe issue preventing continuous gas production and is believed to be the main reason for failures in previous gas production trials. Lu, et al. [9] utilize cryo-SEM to visualize the microcosmic characteristics of hydrate formation and dissociation with an emphasis on different particle sizes. Crustal stress, the sputtering process, and the relative size between sand particle and hydrate particles are the key factors determining the sand screen design. The geomechanics of the hydrate-bearing sediments during gas production affect the wellbore stability and seafloor settlement. Dong, et al. [10] investigate the failure mechanisms during the shearing process of reconstituted hydrate-bearing clayey-silt samples from the South China Sea from both macro and micro perspectives. Strength parameters, including both failure strength and Young's modulus, are predicted based on the proposed empirical models, which can be used for parameter estimation in natural gas hydrate development.

Flow assurance issues and the environmental impact caused by gas hydrate are also important topics besides gas production. As a major hydrate reservoir, the marine environment facilitates hydrate formation within oil and gas pipelines, and hydrate formation could clog the pipes and cause catastrophic disasters. Flow assurance is vital for the safety of oil and gas transport in marine environments, which has been inhibited by hydrate formation within pipelines at earlier stages, meaning that the formed hydrate particles should be prevented from attaching with each other. Fang, et al. [11] present the latest result on cohesive force between cyclopentane hydrate particles and suggest that the selection and concentration of surfactant can help the mitigation of blockage risks. Li, et al. [12] examine the temperature effects on the activity of methanotrophs and conclude that these microbes show strong temperature sensitivity. These features should be considered during the evaluation of the biodegradability of methane.

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