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Editorial

Formation, Exploration, and Development of Natural Gas Hydrates

Hongsheng Dong [1], Lunxiang Zhang [2,*] and Jiaqi Wang [3,*]

[1] Dalian National Laboratory for Clean Energy, Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian 116023, China
[2] Key Laboratory of Ocean Energy Utilization and Energy Conservation of the Ministry of Education, School of Energy and Power Engineering, Dalian University of Technology, Dalian 116024, China
[3] College of Power and Energy Engineering, Harbin Engineering University, Harbin 150001, China
* Correspondence: lunxiangzhang@dlut.edu.cn (L.Z.); jiaqiwang@hrbeu.edu.cn (J.W.)

1. Introduction

Currently, natural gas hydrates (NGHs) have been proposed as promising and environmentally friendly carbon-based energy sources that are beneficial for mitigating the traditional energy crises [1]. NGH is an ice-like crystal composed of methane molecules enclosed in a water lattice under low temperature and high pressure, and it is mainly enriched in deep marine reservoirs or permafrost zones [2]. The energy density of NGH is extremely high because 1 m^3 NGH can disassociate into 164 m^3 methane at standard temperature and pressure. In addition, the amount of organic carbon contained in NGH is twice that of other traditional hydrocarbon reservoirs, according to the resource's assessment [3]. Therefore, studying the formation, exploration, and development of NGH at a greater depth is imperative for promoting the commercial production and utilization of NGH.

The exploration, exploitation, and further application of NGH are interrelated. Understanding the NGH's formation and dissociation is the foundation of its exploration, development, and applications. The exploration serves as a connecting link between formation and development. The exploration is highly dependent on understanding the formation characteristics and provides references for selecting development sites and methods. The development directly tests the theories and practices of the formation and exploration and advances NGH to commercial production. Although some pilot productions of NGH have been carried out in some countries and regions, some unforeseen problems still remain, which limit its commercial exploitation [4,5]. The comprehensive research on the properties and formation of NGH is paramount for guaranteeing its efficient and effective exploration and development. An in-depth study of the fundamental properties of NGH formation and dissociation can provide significant guidance for its exploration and development [6]. The practices on the exploration and development, in turn, can also provide helpful insights into its formation and dissociation. The Special Issue of *Energies* on the subject area of "Formation, Exploration and Development of Natural Gas Hydrate" aims to collect the latest research outputs on the theory and practice in basic properties, novel exploration technology, and highly efficient development process. We hoep that this Special Issue can spur advancements and provide a more effective strategy for the field production of NGH.

2. Formation and Exploration of Natural Gas Hydrate

Distinct from conventional oil and natural gas deposits, marine NGH is widely enriched in argillaceous low-permeability sediment reservoirs, which are characterized by non-diagenesis and weak cementation. The basic physical characteristics of marine hydrate reservoirs and their spatial-temporal evolution are the decisive factors for understanding

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the reservoirs, which transform and realize the development of hydrate resources. Although the phase equilibrium [7], structural properties [8], mass transfer mechanism [9], heat transfer analysis [10], growth kinetics [11,12], and phase change parameters [13] of NGH have been well-studied in the past, a need for a fundamental and thorough understanding of NGH formation and occurrence still remains. In particular, developing high-precision, multi-dimensional, and comprehensive exploration technologies are the future direction of deep-sea NGH exploration [14]. The advancement in this field will be conducive to ascertaining the geological condition, revealing the reservoir-forming mechanism, proving the NGH reserve, and disclosing the NGH distribution. This Special Issue plans to collect the latest advancement in the formation mechanism and exploration technologies of NGH and provides a basis for screening NGH's sweet spots.

3. Dissociation and Exploitation of Natural Gas Hydrate

NGH is considered the most promising potential clean energy source for substituting traditional energy sources [15]. Many countries, including Russia, Canada, the USA, Japan, and China, have launched pilot field productions of NGH and have made rapid and important progress [16]. The development of NGH has moved from early field surveys and laboratory tests into field production, and it is at the transitory stage of commercial production [17]. Although some technologies, including depressurization [18], heat injection [19], CO_2 replacement [20], and other novel methods [21], have been widely studied, these technologies are still immature because of their low yields, high costs, and low efficiencies. In addition, the spatial-temporal variation and multiple-time-scale characteristics of heat, fluid, stress, structure, and distribution in NGH reservoirs are unknown, impeding the large-scale production of NGH. The joint development of hydrate and oil and gas with multi-type, different occurrence forms, and various depths will be the critical points of future deep-sea hydrate development strategies. This Special Issue will focus on the recent advancement of the highly efficient exploitation method of NGH and drive the large-scale and commercial development of NGHs.

4. Flow Assurance of Hydrate Blockage

Safe and efficient development has always been a central topic in the oil and gas industry. Since 2000, significant oil and gas discoveries have been made in deep waters around continental edges. Compared to onshore development, offshore development safety issues are more prominent because of (i) more expensive offshore facilities and (ii) marine ecological disasters caused by oil leakage and geological disasters by hydrate blockage [22]. Continuous accidents due to hydrate blockages were reported, such as Statoil Tommeliten-Gamma, Norway, Wyoming Werner-Bolley, America, Jinzhou 20-2, China, Roncador Field, Brazil, Marlim Field, Brazil, and others. Therefore, the flow assurance of hydrate blockage management attracts increasing investigations from both scientists and engineers. Extensive efforts have been made for accurate predictions as well as detection, effective prevention, and functional remediation [23]. This Special Issue provides accounts of recent concepts and technologies in flow assurance, and some novel methods such as interfacial modification and green inhibitors would help the management of hydrate blockage.

5. Further Applications of Gas Hydrate

In recent years, hydrate-based technologies have been considered as promising alternatives for solving numerous energy- and environment-related issues, such as H_2 storage and separation [24], CO_2 geological sequestration [25], refrigerant as suitable cold storage [26], heavy metal separation and desalination [27], and others [28]. Extensive efforts have been dedicated to optimizing the hydrate growth rate and the application efficiency across various scales. The latest research studies reported impressive experimental results and functions with great promise; however, this field is still far from industrial application and is limited by effective rapid formation methods and suitable adjustable systems. Thus, this

Special Issue also pays attention to the new discovery of well-controlled hydrate phase changes and development to promote the further application of gas hydrates.

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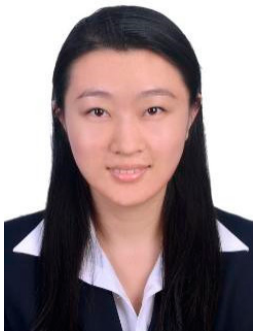
Short Biography of Authors

Dr. **Hongsheng Dong** is an assistant professor at the Dalian Institute of Chemical Physics, CAS. He received his Ph.D. degree in Engineering Thermophysics from Dalian University of Technology. His research interests include gas hydrates, phase change material, and thermal energy storage. He has published more than 50 peer-reviewed journal papers. As a visiting researcher, he spent one year at the University of Edinburgh.

Dr. **Lunxiang Zhang** is a lecturer at Dalian University of Technology. He received his Ph.D. degree in Engineering Thermophysics from Dalian University of Technology in 2019. His research areas focus on safe and high-efficiency exploitation of NGH, flow assurance of oil and gas, carbon dioxide capture and utilization, and green hydrate-based applications. He has published more than 60 peer-reviewed journal papers and has nearly 1000 citations.



Dr. **Jiaqi Wang** is an associate professor at Harbin Engineering University. She received her Ph.D. degree in Engineering Thermophysics from Dalian University of Technology. Her research areas focus on marine gas hydrate exploitation technology, hydrate-based technology application, and seepage and heat and mass transfer in porous media. She has authored or co-authored about 30 peer-reviewed journal papers and has nearly 600 citations.