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Editorial

Focus on research advances in the natural gas hydrate resource evaluation: Introduction to papers in the special section of Evaluation of Natural Gas Hydrate Resource Potential in the South China Sea

The continental hydrocarbon generation theory has opened a new field of oil and gas development and once solved the oil and gas shortage problem in China. Since then, geological theories of coalbed methane accumulation, foreland basin oil and gas accumulation, carbonate rock oil and gas accumulation, superimposed basin, and deep oil and gas accumulation have contributed to relieving the pressure of oil and gas shortage in China. Even so, ***Science*** has listed the energy shortage as one of the 125 biggest challenges facing humankind in the new century (D. Kennedy & C. Norman, 2005).

Globally, there are still abundant oil and gas resources available for human development and utilization. However, most of them are unconventional, deep-formation, and deep-water oil and gas reserves, which are difficult to exploit; that is, the era of easy oil and gas exploitation has basically ended. Unconventional natural gas resources mainly include shale gas, tight gas, coalbed methane, and natural gas hydrate (NGH), etc., which have the essential characteristics of "large quantity, low grade and difficult to exploit". Among which NGH is a kind of low-carbon and clean "solid" energy, which is primarily distributed in deep ocean water and frozen soil, making it more difficult to extract (Gao, 2020). It has attracted global attention and is considered a solution to the shortage of energy in future since 1973 (Arthur, 2011; Wadham et al., 2012), when the former Soviet Union scholars first evaluated the global resource as high as 3×10^{18} m^3 (Trofimuk and Cherskiy, 1973). Since then, the United States, Canada, Japan, South Korea, and China have organized large-scale geological surveys and researches successively in the 21st century. In the past 50 years, at least 29 groups of scientists have assessed the global NGH resources, but the estimates vary significantly with up to 10,000 times. Based on the mode values and average values of these evaluation results far more significant than those of conventional oil and gas resources, some scholars believe that the development potential of NGH is enormous. In contrast, some scholars believe that the development prospect is not optimistic based on their decreasing trend (Pang et al., 2020a,b).

Supported by the National 973 Project and through nearly 10 years of exploratory research, Chinese scientists have revealed the correlation between conventional and unconventional oil and gas and established the distribution model of oil and gas resources controlled by hydrocarbon threshold (Pang et al., 2020a,b). Furthermore, it is recognized that NGH is only one of many fossil energy sources in the global oil and gas system, and the quantitative relationship between NGH resource potential and conventional oil and gas resource potential is established. Then, based on the principle of material balance and Monte Carlo simulation, it is estimated that the global recoverable resources of NGH are less than 5% of the total recoverable resources of conventional oil and gas. For the first time, the Chinese scientists proposed a new understanding that "the global natural gas hydrate is unlikely to constitute the main energy resource for human beings in the future" and published it as a cover paper in ***Petroleum Science*** (Pang et al., 2020a,b, 2021). Obviously, in the process of exploring new energy resources, both "discovering new fields" and "identifying trap areas" should be valuable contributions to global energy innovation and development.

The evaluation results of NGH resources potential from 29 groups of scientists in the world show a general trend of decreasing. It is found that they can only form in the phase equilibrium zone of high pressure and low temperature (Sloan, 2003; Chong et al., 2016), and are dispersed in mudstone with low saturation, which cannot constitute realistic resources (Boswell, 2009; Boswell and Collett, 2011). Besides, the NGH recovery factor obtained by simulation experiment studies is only about 30% (Konno et al., 2014). All these imply a limited development potential of NGH resources in the future. However, in the past 20 years, the evaluation results of the potential NGH resources in the South China Sea from 35 groups of scientists have remained almost unchanged, reaching a range of 60–90 billion tons of oil equivalent, which is more than twice the total amount of conventional oil and gas resources in the South China Sea, showing a great development potential. In addition, 7 of the 10 (70%) major government-led NGH research projects worldwide focus on the resource potential, while among the 24 key and major projects on NGH in the South China Sea, there is barely any project focused on that of NHG resources. In this case, it is of great significance to adjust the exploration and development layout of the NGH resources in the South China Sea.

Why is there such a big difference between China and foreign countries in the NGH resources potential evaluation? What is the real potential of NGH exploitation in the South China Sea? These questions are of great concern not only to scientists but also to government policymakers. To figure out these questions, the department of the Chinese Academy of Sciences has set up a major consulting project of "Strategic Research on the Comprehensive Development of Oil and Gas in the South China Sea", including a particular topic of "Strategic Studies on the Comprehensive Development of Natural Gas Hydrate in the South China Sea". Funded by this project, the research group led by Prof. Pang has jointly conducted the in-depth studies with relevant scientists at home and

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abroad. By detailed analyzing the reasons for the continuous reduction of global NGH resources, a comprehensive evaluation of NGH resources in the South China Sea was conducted based on the new theory and method; the recoverable NGH resources estimated by four methods are 0.8×10^{12} m^3–6.5×10^{12} m^3, with an average of 3.3 billion tons of oil equivalent, accounting for only 5.5% of the previous estimates. Therefore, it is confirmed that "NGH resource is incapable of being the major energy in future". This understanding deserves the attention of relevant experts and scholars and in-depth discussions. It also requires the relevant government departments of my country to carefully consider and make decisions on large-scale investment in the exploration and development of natural gas hydrate resources in the South China Sea, and timely adjust the relevant strategic layout and investment priorities.

Petroleum Science published the related papers written by Prof. Pang and other scholars in the special section of Evaluation of Natural Gas Hydrate Resource Potential in the South China Sea of which the primary purpose is to deepen the understandings of the NGH resource potential, strengthen the NGH resource evaluation studies, guide relevant academic exchanges and debates, and provide a scientific basis for revising relevant development strategies. This special section includes five papers, the first one of which describes the reasons for the continuous decreases of global NGH resources, confirms the key controlling factors and evaluates the influence of each factor quantitatively, and finally makes an overall evaluation of the resource potential in the South China Sea with the new theory and method; the second one describes the progress and challenges of the NGH resources evaluation in the South China Sea, recognizing that the current estimates are controversial and challenging to guide the layout of the NGH exploration and development. The others evaluate the NGH resource using the volumetric method, trend analysis method, and mass balance method, respectively, and illustrate that the recoverable NGH resource on average is only 18.7% of the total recoverable resources of conventional oil and gas in the South China Sea.

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