Status and Prospect Analysis of Global Gas Hydrate Exploration and Development Technology

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Abstract: Natural gas hydrate mainly exists in the unconsolidated sediments in the sea area as a solid state. It is a kind of green and clean energy with large reserves and high unit calorific value. It is another potential strategic alternative energy after tight sandstone gas, shale gas and coalbed methane. Based on the extensive investigation of the research results of natural gas hydrate at home and abroad, this paper expounds the current situation of global hydrate investigation and production test, defines the potential distribution of global hydrate, discusses the key problems to be solved in the commercial development of hydrate, and analyzes the secondary disasters caused by hydrate development. Finally, some policy suggestions and technical direction of exploration and development are given.

1. Introduction

Natural gas hydrate, commonly known as combustible ice, also known as methane hydrate, is a cage like crystalline compound formed by methane and water molecules in the sea floor or land permafrost under low temperature and high pressure environment, mainly white ice like solid. Natural gas hydrate can be ignited in case of fire and the products of combustion are water and carbon dioxide. The combustion value of 1 m3 natural gas hydrate is equivalent to that of 163 m3 methane, so natural gas hydrate is a new type of energy with large calorific value, high reserves, clean and pollution-free. According to the estimation of WEA, the global gas hydrate reserves are about 9 400-20 000×1012m3, which is about 100 times of the remaining conventional natural gas resources[1,2,3,4]. 99% of gas hydrates are distributed in marine sediments, which is a very important strategic alternative energy after tight sandstone gas, shale gas and coalbed methane. So it has high research value. In addition, methane greenhouse gas effect caused by natural gas hydrate leakage is 20 times of that of carbon dioxide, which is a very important greenhouse gas[5,6]. Improper development may cause very serious climate problems. In view of the huge potential of natural gas hydrate resources and its potential impact on the environment, governments and energy experts in many countries began to pay attention to the investigation and research of natural gas hydrate since the end of the 20th century. The United States, Canada, Germany, Norway, Japan and South Korea have formulated long-term research plans for natural gas hydrate, and the geological

exploration, experimental exploitation and supporting environmental impact assessment work are deepening[7,8,9]. At present, the exploration and production of natural gas hydrates are mainly concentrated in the MALLIK delta of Canada and Alaska of the United States in the Arctic tundra, and the Gulf of Mexico, the coast of India, the northern South China Sea and the sea of Japan in the sea area, which have successively broken through the gas production threshold of hydrate[11,12,13,14,15]. The pattern of "one land, four seas" has been initially formed in the investigation and production of natural gas hydrate.

The natural gas hydrate resources in China are huge, and the prospective resources are about 110 × 1012m3, which is about twice of the conventional natural gas resources in China. 65% - 85% of gas hydrates in China are distributed in the northern part of the South China Sea, and 25% - 35% in the Qinghai Tibet Plateau and the Mohe permafrost. At present, the hydrate survey work in China's sea area mainly focuses on Dongsha, Shenhu, Xisha and Qiongdongnan in the northern slope of the South China Sea(Fig.1)[16,17,18,19]. According to the survey results, 11 hydrate enrichment areas have been delineated. Based on the hydrate cores obtained from the enrichment area, the potential gas hydrate resources are estimated to be about 63 × 1012m3. Although the work of hydrate exploration and production in China started late, the technology of hydrate exploration and production has reached the leading level in the world, which provides technical support for commercial trial production of hydrate[20].

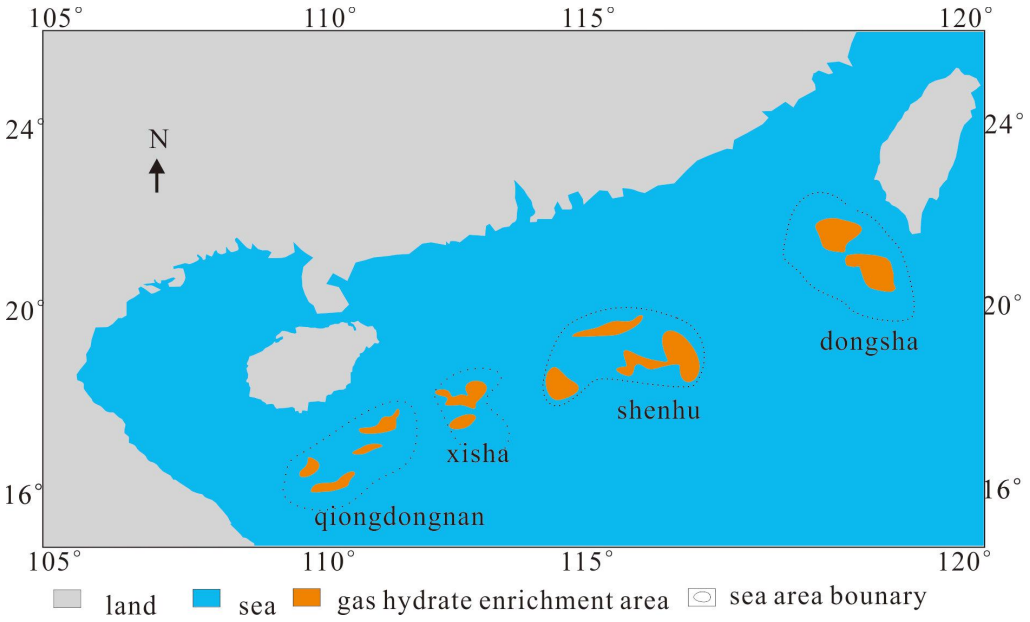

Figure 1: Distribution of hydrate accumulation in the northern South China Sea(Modified from Xinghe Yu et al, 2019).

2. Progress of Global Exploration and Production Test

Natural gas hydrate exists in the seafloor loose sediments in solid form, similar to coal-bed gas and shale gas. In the process of exploitation, natural gas hydrate can be decomposed into free natural gas by changing the stable temperature and pressure conditions. At present, the main mining methods are depressurization method, heat injection method and chemical agent method, and nitrogen injection / carbon dioxide replacement method is still under exploration.

2.1. Progress of Exploration and Production Test Abroad

Early marine gas hydrate survey was mainly carried out by ODP, DSDP and IODP related projects. In 1995 and 2002, ODP carried out hydrate drilling and coring at Blake platform off the east coast of the United States and the continental margin of cascade in the Western Pacific of the United States, respectively, to study the migration and accumulation mechanism of hydrate and the characteristics of porosity and permeability parameters. In 2005 and 2017-2018, IODP studied the Hydrate Occurrence Mechanism and the stability of hydrate ore bodies in the northeast Pacific continental margin of Canada and the continental margin of the east coast of New Zealand by drilling and logging[21].

The United States is one of the earliest countries in the world to carry out hydrate investigation and research. As early as 1972, it obtained hydrate samples by drilling in Alaska. In 2005, 2009 and 2017, the United States carried out hydrate drilling and logging while drilling in the northern Gulf of Mexico, and conducted in-depth research on the potential resources, types and occurrence characteristics of hydrate in the northern Gulf of Mexico[22]. The investigation of natural gas hydrate in Japan started in 1999, and a set of comprehensive evaluation methods for exploration of hydrate resources, including drilling, logging, seismic and core testing, have been formed. In 2002, Japan successively drilled more than 30 wells and identified various types of natural gas hydrate. In 2012, Japan became the first country in the world to drill and produce hydrate in sea area. In 2013 and 2017, Japan carried out two trial production experiments of hydrate in the sea area. The first trial production was conducted by depressurization method, with a total production of 1.2×104m3 for 6 days. The second trial production was conducted for 24 days, with a total gas production of about 20×104m3 and an average daily production of more than 8 000 m3. In addition, India and South Korea have also conducted a large number of marine hydrate surveys. India has carried out two cruises of hydrate survey, drilled more than 30 holes, and identified a large-scale and high saturation hydrate mineral in coarse-grained sandy sedimentary strata of Krishna-Godawari basin, which has delineated a target area for subsequent trial production. South Korea has carried out two cruises of hydrate investigation and research in Yulong basin, and delineated three hydrate rich sedimentary strata, providing candidate sites for hydrate production[23].

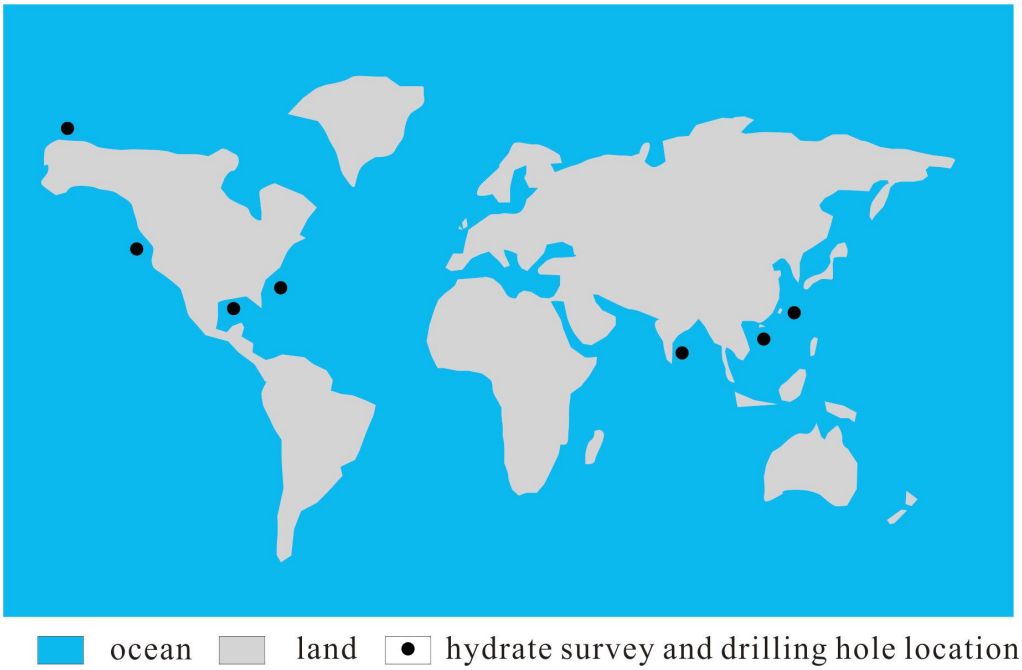

Figure 2: Global hydrate survey and drilling hole location (Modified from U.S. Energy Administration).

2.2. Current Situation of Exploration and Production Test in China

The research on the investigation and exploration evaluation of natural gas hydrate in China's sea area began in 1995. It has gone through four stages: investigation and pre research, marine geological investigation evaluation and exploration research, exploration evaluation and comprehensive research, exploration evaluation and exploratory and experimental production. The hydrate survey in China is mainly concentrated in the northern part of the South China Sea, and the related work is mainly led and undertaken by Guangzhou Marine Geological Survey Bureau of China Geological Survey. Since 2007, GMGS-1, GMGS-2, GMGS-3 and GMGS-4 have been investigated for four times. More than 80 wells have been drilled and well logging. Massive geophysical and geochemical survey data and core samples have been obtained in the northern South China Sea, and hydrate potential resource distribution areas in Qiongdongnan, Xisha Shenhu and Dongsha have been delineated[24,25,26,27,28,29,30,31].

On March 28, 2017, Guangzhou Marine Geological Survey conducted a vertical well slotted completion hydrate production test in the Shenhu sea area, and successfully extracted natural gas hydrate gas from the soft clay silty sand reservoir of about 200-280 m below the seabed with a water depth of 1266 m[32,33]. This is the first time in China and the first time in the world that the gas hydrate in the unconsolidated argillaceous silty sediment reservoir has been successfully exploited in the deep sea[34]. The trial production lasted for 60 days with an average daily output of 5000 m3, creating a double world record of maximum production of 3.5×104 m3/d and cumulative gas production of 30.9×104 m3[35,36,37,38]. The second hydrate production test was conducted from February 17, 2020 to March 17, 2020. The production test was conducted by casing completion and staged fracturing of horizontal wells. The gas production was stable for 30 days. The cumulative total gas production reached 86.1×104 m3 and the daily average gas production was 2.9×104 m3, creating two new world records of total gas production and daily average gas production of natural gas hydrate[39,40,41].

3. Prospect Analysis

Natural gas hydrate is a kind of strategic alternative energy. Although there are huge potential resources, marine hydrate is still in the stage of experimental exploration because of its physical properties, mechanical parameters and environmental risks in the process of development. It is a worldwide scientific and technological challenge to find safe, efficient and economic exploitation methods to realize commercial exploitation at present and in the future Research and development focus of cutting-edge innovative technology. The cost of hydrate investigation and production test is very expensive and the cycle is long. Therefore, it is necessary to formulate a plan for the research and development of natural gas hydrate as soon as possible from the national level and strategic height, and issue corresponding policy support to ensure the continuity of relevant technology research. The commercial development and utilization of hydrate resources is of great significance to adjust China's energy structure, alleviate the shortage of energy supply and effectively solve the increasingly serious environmental crisis.

4. Conclusions

Through the analysis of the results of hydrate investigation and production test at home and abroad, the latest progress of hydrate investigation and production test is fully understood. Although the phased results have been achieved, there is still a long way to go before the realization of commercial development. It is suggested to strengthen the technical research, from the aspects of hydrate selection evaluation, development technology, monitoring technology means, indoor test simulation and hydrate development, which may lead to serious problems In order to realize the safe and efficient development of natural gas hydrate as soon as possible.

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