

Literature Statistical Analysis of Gas Hydrate Research in China

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Abstract

Gas hydrate is a new clean energy with considerable reserves, commonly known as "combustible ice". Since the 1980 s, the study of gas hydrate has gotten more and more attention in China. In this paper, based on super-star discovery system, analyzed the literature statistical data of gas hydrate in the literature quantity, subject classification, mechanism, related knowledge and other aspects; The study found that the study and attention of gas hydrate is on the rise in China, and the research mainly focused on the both of subject, earth science and astronomy; In the institutions which engaged in the gas hydrate research, research institutes and universities rank top, and they are the main force that gas hydrate research continues to move forward in the future; The research has focused on the basis of the research direction, such as the analysis of accumulation function and geological environment, resource prospection, research review, etc., and the future study of gas hydrate will have the great development space.

Keywords: gas hydrate; Super-star discovery system; literature statistical analysis

INTRODUCTION

Gas hydrate is a solid crystalline material, formed by the combination of combustible gas and water molecules, and has the advantages of using conveniently, high combustion value, no pollution and so on, and it is a new type of clean alternative energy sources in the future. Environmental pollution is more and more serious caused by the burning of fossil fuels at present, and China's energy shortage is very prominent, for the exploration of new energy, especially for clean energy research is getting more and more attention. Gas hydrate as a new type of clean energy, its study on economic, environment, and even has important meaning for the development of the country. China began to research gas hydrate in the 1980s, the ministry of land and resources of China launched the resources survey of gas hydrate in 1999, and obtained a very clear evidence of the existence of gas hydrates in the north slope of the South China Sea^[1]. In 2002 the state council approved to set up the gas hydrate

resource investigation of China marine^[2]. Later, China geological survey set up multiple research projects, for the permafrost regions of China, especially in the cryolithozone of the Qinghai-Tibet Plateau, and carried out more detailed investigation in many aspects. In 2007 and 2009, China firstly and successfully obtained samples of gas hydrate in the area and cryolithozone respectively^[2]. In June 2016, China first found active cold seepage with huge distribution area in the western slope of the north of the South China Sea^[3]. The policy introduced by China, the corresponding research platform and the technical support provided, to a great extent, promoted the research and development process of gas hydrate. After decades of research and development, domestic researchers has obtained the certain research results and the corresponding literature in terms of gas hydrate. Based on the super-star discovery system, this paper makes a statistic analysis on the literature of gas hydrate, and further discusses the research process and development trend of gas hydrate.

STATISTIC ANALYSIS OF LITERATURE DATA OF GAS HYDRATE

In 1996-2016, the change of the total of literature related to gas hydrate and published in China as shown in figure 1. From figure 1, the literature numbers of gas hydrate is mainly on the rise, and in 1998, 2000 and 2016, rising sharply. The reason is closely related to China gas hydrate exploration process. In 1998, China completed the topics called "China Marine gas hydrate exploration research", and joined the ocean drilling project^[1]. In 1999, China ministry of land and resources integration of the domestic various aspects advantage, and officially launched the gas hydrate resources investigation^[1]. And in June 2016, China first found active cold seepage, "haima cold seepage", with distribution area of about 618 square kilometers in the western slope of the north of the South China Sea^[3]. These discoveries promote the development of

China gas hydrate research.

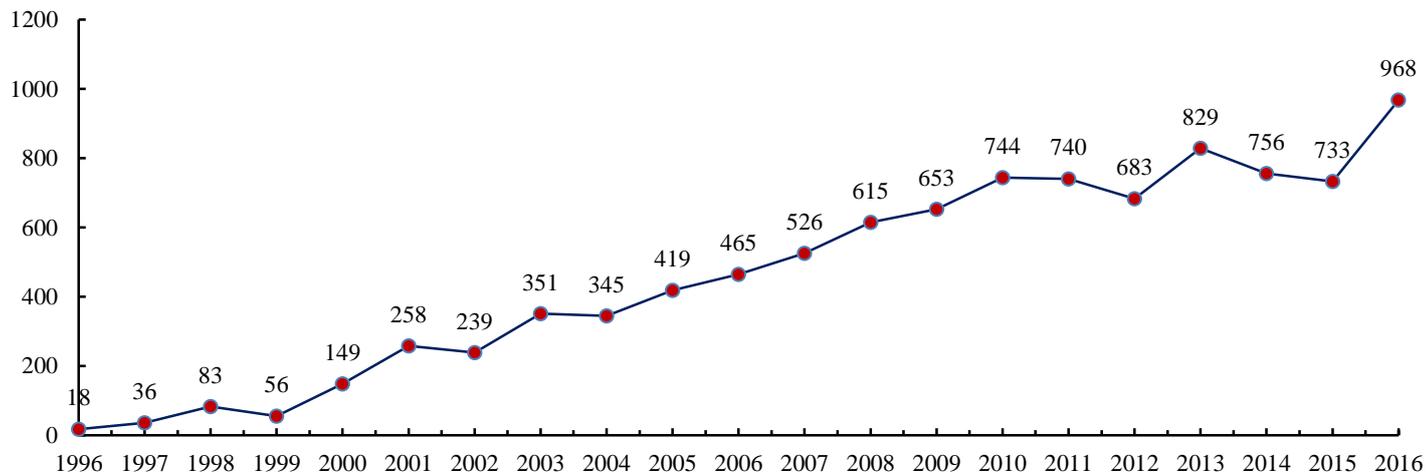


Figure 1. The development trend of literature number of gas hydrate

Development trend of journal literature number of gas hydrate is shown in figure 2. Figure 2 shows, since records began in 1975, by 1996, the literature about gas hydrate is very few, and only 73. Since 1996, the number of journal articles increases dramatically, and only in the three years of 1999 to 2001, the number is from 41 to 220. In this three year, Song haibin, yinxia fang et al. carried on the preliminary study to submarine gas hydrates, especially the South China Sea, and they analyzed the formation and distribution of gas hydrate, and discussed the seismic identification and inversion technique of submarine gas hydrates^[4,5]. Fan shuanshi, kaihua guo et al. made study of gas

hydrate phase equilibrium, and analyzed the generation and storage and transportation of gas hydrate from the Angle of geochemistry^[6,7,8]. Jianming gong et al. analyzed geological conditions and formation and prospect of gas hydrate from the Angle of geophysics^[9,10]. Since then, the number of journal articles is rising. 266 journal articles was published in 2005, 444 in 2009, 556 in 2013. The development trend of journal articles suggests that it gets more and more attention on the study of gas hydrate and becomes booming.

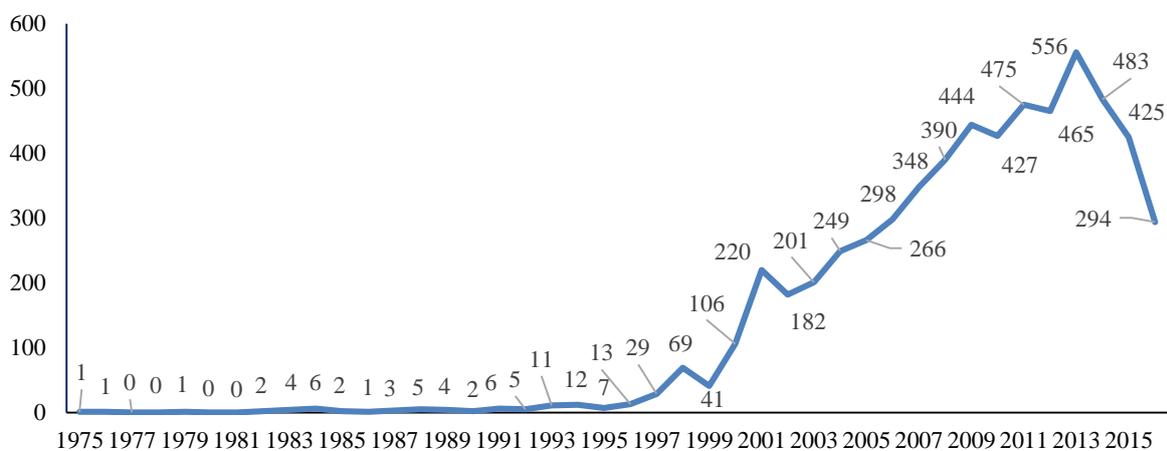


Figure 2. The development trend of journal literature number of gas hydrate

From institution distribution of important journals literature about gas hydrate, the institutions mainly concentrate in the Chinese Academy of Sciences, Chinese Academy of Geological Sciences, China University of Petroleum (east China), China University of Geosciences and Guangzhou Marine Geological Survey. However, generally, the top six institutions are the Chinese Academy of Sciences, Guangzhou Marine Geological Survey, Qingdao Institute of Marine Geology, China University of Geosciences, Chinese Academy of Geological Sciences and Southwest Petroleum University, and the number of papers is respectively 1467, 410, 265, 263, 249 and 238. Therefore, research institutions and universities are on the top in natural gas hydrate research, and they are the main force of gas hydrate research to move forward in the future.

The keywords of gas hydrate mainly focus on the research progress, experimental research, north of the South China Sea, and numerical simulation, accounted for 25% of the total, and also involve in geochemistry, phase equilibrium, exploration and development, and so on. And the review articles are majority in the research of gas hydrate. Related knowledge of gas hydrate research as shown in table 1. In the analysis of research progress, based on outlined the experimental study, technical research, the research status, the research process is summarized and prospected. The study of gas hydrate is more in the South China Sea area, and the number of this literature reached the knowledge is up to more than four hundred articles. In addition, in recent years, numerical simulation technology is more and more mature. Using the corresponding numerical software for simulating the formation and exploitation of natural gas hydrate, and to understand the physical and chemical characteristics of natural gas hydrate and optimize the mining technology, which is one of the hot spot of the gas hydrate research. The research about gas hydrate also includes the formation conditions, resource prediction, environmental geochemical characteristics and the influence of inhibitors on hydrate formation and so on.

Table 1. Statistics of the knowledge related to gas hydrate research

The correlation order	The relevant knowledge
1	the north of the South China Sea, research progress, present research situation, experiment research, technology research
2	numerical simulation, phase equilibrium, porous media, saturation, mathematical model
3	prospection and exploitation, mining, drilling fluid, shale gas, coalbed methane, unconventional natural gas
4	geochemical, carbon dioxide, inhibitors, decomposition
5	geophysics, formation conditions, Marine geology, sediment, prediction, dynamic

RESEARCH PROGRESS AND PRESENT SITUATION ANALYSIS

Since the 1980s, China gas hydrate research from scratch. And in the process of decades of development so far, there has been a lot of research results and literature. Through the analysis of literature data of gas hydrate research, the process of its research will be roughly divided into, starting, exploration, development, the three stages.

Start-up stage (1980-1997): China is on the basis of study for gas hydrate at this stage, including the internal structure of gas hydrate, the analysis of the forming process and exploration technology. In 1988, Du ya and tianmin guo respectively made the analysis for the gas hydrate formation conditions prediction of excluding inhibitor system and the methanol injection system, and they discussed the application method of electronic computer prediction and described the molecular thermodynamic model of generating conditions^[1]. In 1990, China permafrost engineering laboratory first synthesized methane hydrate, the gas hydrate, in the domestic, through the cooperation with Moscow state university^[1]. In 1992, "the foreign research progress of gas hydrate" published by resources and environment information center, Chinese academy of sciences^[1], and the book promotes the exchange of abroad and domestic research achievements and the research

process at home. Since then, the research mainly focuses on the resources and reservoir exploration and analysis of the generating conditions of gas hydrate.

Exploratory stage(1998-2009): At this stage, gas hydrate had been attracted the attention of the country and the scientific community, and a lot of research work were started. In 1998 China officially joined the ocean drilling project at sixth membership, in the same year, in June, the 21st energy science development strategy seminar held in domestic, the theme of "the prospect of research and development of gas hydrate"^[1]. At this point, the study of gas hydrate was further and deeper. Liao jian and Tianmin Guo et al. analyze the research progress of phase equilibrium of gas hydrates, and summarize the experimental and theoretical model of the phase equilibrium conditions, and put forward the main research direction of phase equilibrium^[12]. Shi dou et al. discuss the seismic pattern of formation of gas hydrate, including low temperature mode, "transgression" mode and diagenesis model, etc^[13]. In 1999, China for the first time found the earthquake sign of gas hydrate in northern South China Sea, and the first domestic gas hydrate conference organized by the organization of the lanzhou geology institute in this year^[1]. Since then, many experts and scholars analyzed the prospect on the study of gas hydrate, and generally had high hopes on it as a new energy. Besides, Song haibin, yinxia Fang et al. analyses gas hydrate of northern South China Sea research, using the seismic data, well logging and geothermal^[14]. Shui biyuan makes the evaluation for the application research and development of storage technology of gas hydrate, and thinks the NGH technology has great potential for application and development, and China should strengthen the study of NGH application technology^[15]. In 2002 the state council approved the special of China Marine gas hydrate resources survey, and China geological survey set up a multiple research projects, and carry out the resources survey of gas hydrate to the investigation in qinghai-tibet plateau regions in China^[2]. Among them, Huang peng, Guitang Pan et al. analyze the possibility of hydrate formation and its position of qinghai-tibet plateau from several aspects, according to onshore gas hydrate formation conditions, and think that the most favorable area is the outcrop area of petroleum-bearing basin reservoir in the northern Tibet^[16]. Chen duofu et al. establish a new method of dynamic evaluation of seepage type hydrate resources, and the hydrate forming process of undersea gas leakage formation is analyzed^[1].

China successfully sampled for the first time in the north of the South China Sea in 2007, and it confirmed the existence of rich gas hydrate resources in the northern South China Sea^[1]. This cross promoted the research process for China gas hydrate. Wu nengyou, zhenquan Lu, Yang shengxiong et al. conduct a preliminary study to gas hydrate reservoiring system of shenhu area of the South China Sea waters, and analyze its fluid migration system, and they think that gas hydrate are mainly distributed on a certain depth range above the bottom of the stability zone on the longitudinal bounded in the study area, and migration system consists of the diapirs, high angle fracture and vertical fracture system^[17]. Accordingly, at this stage, China gas hydrate research is deeper and wide, and makes some breakthrough in technology and theory.

Developing stage (2010-2016): Since 2010, the study of gas hydrate has been further development, and the amount and cited number of literature reaches 5166 and 8206 respectively, and the research direction also further develops into deeper. In this phase, the formation conditions of gas hydrate, reservoir characteristics, gathering mechanism and key technology are introduced in the book, "unconventional oil and gas geological", by Zou caineng et al.^[18]. Zhu youhai, Zhao shengmin and Lu zhenquan analyze the prospecting districts and resource potential of gas hydrates in China cryolithozone, and think the qiangtang basin is the best area of the forming conditions and the prospecting prospect^[19]. And they estimate the gas hydrate resource in China cryolithozone, about $38 \times 10^{12} \text{m}^3$, and there is a huge resource potential. Moreover, numerical simulation technology is also gradually applied in this area. Li gang and Li xiaosen establish stratified geological model and make the numerical simulation for the single well huff and puff thermal production of gas hydrate of the shenhu area in the South China Sea, and the results show that the obvious brine concentration and dilution effect are produced in the heat injection stage and production stage, and a single horizontal well huff and puff thermal production is not cost-effective^[20]. Hu litang et al. carry on the numerical simulation research on gas hydrate thermal depressurization mining of the area, and they discover that the distribution range of low hydrate saturation increases with time and temperature, and compared with the pure heat injection mode, thermal depressurization mining is improved substantially^[21]. Xiao yu et al. analyze the discrete element numerical simulation for the deep energy soil of considering simplified cementation model, and they compare the biaxial

simulation results and triaxial test results, and suggest that the model can better simulate the micro cementation mechanical behavior of hydrate^[22]. Wang Xiaoxing, Wu Nengyou et al. study the multiple field coupling problems in the development process of enhanced geothermal system, including the temperature field, seepage field, stress field and the field^[23]. And they discuss any two field interaction, and point out the focus which should be considered in three field coupling and which is not perfect in four field coupling. Ruan Xuke, Li Xiaosen et al. use numerical simulation to analyze the secondary generation and permeability variation of gas hydrates on the influence of step-down mining, and the research shows that second generation will lead to gas rate greatly reduced and the system pressure increased dramatically, but the accumulative gas production is not affected^[24].

In the actual investigation, China Geological Survey drilled and sampled in the east China sea of pearl river mouth basin in 2013, and get a large amount of gas hydrate samples^[2]. In the same year, Qilian mountain gas hydrate resources exploration project successfully drilled for the sample of gas hydrate which its single-layer thickness is more than 20 meters in Tianjun County of Qinghai Province^[25]. These breakthroughs not only confirm the preliminary understanding for metallogenic factors and formation mechanism of the gas hydrate, and also verify the effectiveness of multidisciplinary comprehensive prospecting methods. Furthermore, in June 2016, China first found active cold seepage with huge distribution area in the western slope of the north of the South China Sea^[3]. This discovery not only is the breakthrough of domestic gas hydrate exploration, but also further promotes the research and development of gas hydrate.

CONCLUSION

Gas hydrate is an important part of new energy system in the future, and with development and present situation in China, the research of the field is still a long way to go. From the perspective of the literature statistical analysis of super-star discovery system, gas hydrate research focuses on the basic research direction, for example, the analysis of the accumulation function and geological environment, resources prediction, prospecting and exploitation technology of application, overview and so on. From the future development of gas hydrate research, as a result of the strong sound reflection effect of gas hydrate and free gas beneath, The prospecting technology will continue to give priority to with the seismic

method. In the way of its mining technology, there still need further study for the field coupling analysis and gas hydrate phase change in the process of mining, and so on. In addition, the methane will produce the greenhouse effect in gas hydrate, and it may lead to submarine landslide formation collapse etc. in the exploitation process. In the later research, the researcher should strengthen the study on the influence of geological environment.

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