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Methane Hydrate: Fuel of the Future - A Literature Review

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A B S T R A C T

Gas hydrates or Methane hydrates are white, ice-like solids that consist of methane and water. The methane molecules are enclosed in microscopic cages composed of water molecules. Methane gas in essence is produced by the micro-organisms which live in deep sediment layers and gradually turn organic matter into methane. These organic materials are the residue of the planktons that resided in the ocean in the past, sank to the bottom of the ocean, and were eventually incorporated into the sediment layers. Methane hydrate is not stable at the normal sea level pressure and temperature conditions, which is the main reason that it is a challenge to study. In this paper, we have done a review of methane hydrates discussing where they are found, how to recover them and how they can be utilized in the future.

Keywords: Methane, Hydrates, Plankton, Organic Matter.

Introduction:

The world is very much dependent on hydrocarbons, and it's easy to see why – they are economical, abundant, and easy to mine, they represent an energy source to fuel industrial development in the world. The side-effects, however, can be devastating - burning fossil fuels emits CO2 which is linked to global warming. As reservoirs of oil, gas, and coal become difficult to access, governments are trying even harder to find other sources, not just to produce energy, but to help achieve energy independence. Some have discovered a potential savior, locked away under deep ocean beds and vast swathes of permafrost. The trouble is it's a hydrocarbon, but it’s different from the other hydrocarbon that we know of. Although many gases form hydrates in nature, methane hydrate is by far the most common. Figure 1 shows the gas hydrate structure. Methane is the most common natural gas found in nature[1]. The conditions necessary for gas hydrates to form and remain stable are a low enough temperature and sufficiently high pressure, a region known as the gas hydrate stability zone[2]. Sediment containing gas hydrates is found within certain pressure-temperature conditions that occur in permafrost regions and beneath the sea in continental margins[3]. Methane hydrates constitute a very concentrated form of methane gas, 1m^3 of methane hydrate contains 0.8 m^3 of water and more than 160 m^3 of methane at standard temperature and pressure conditions[4].

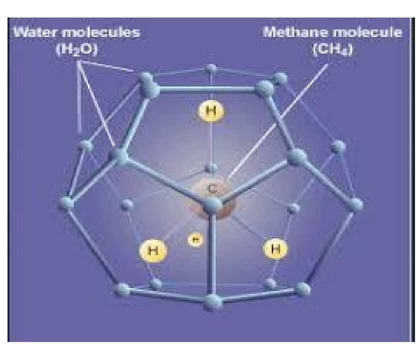

Fig. 1 - GAS HYDRATES STRUCTURE
(Image Source: Kvenvolden, 2003)

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The volume of carbon contained in methane hydrates worldwide is roughly calculated to be twice the amount contained in all fossil fuels on Earth. Estimates of the global resources of natural gas hydrate range from 100,000 to almost 300,000,000 trillion cubic feet (TCF)[1]. Now either we can extract it and use it for our future or wait for it to naturally come out and become a major cause for global warming. The problem with recovering this source of energy is that the fuel is in solid form and cannot be extracted using conventional gas and oil recovery techniques[5]. The utilization of the methane contained in natural gas hydrate will ensure the adequacy of the world's energy resources.

Where Are Gas Hydrates Found?

Methane hydrates are methane containing substance which looks like ice and are found in permafrost areas such as Canada, the North Slope of Alaska and offshore continental margin surroundings in the world including the East and West Coasts of the United States and the Gulf of Mexico [6].

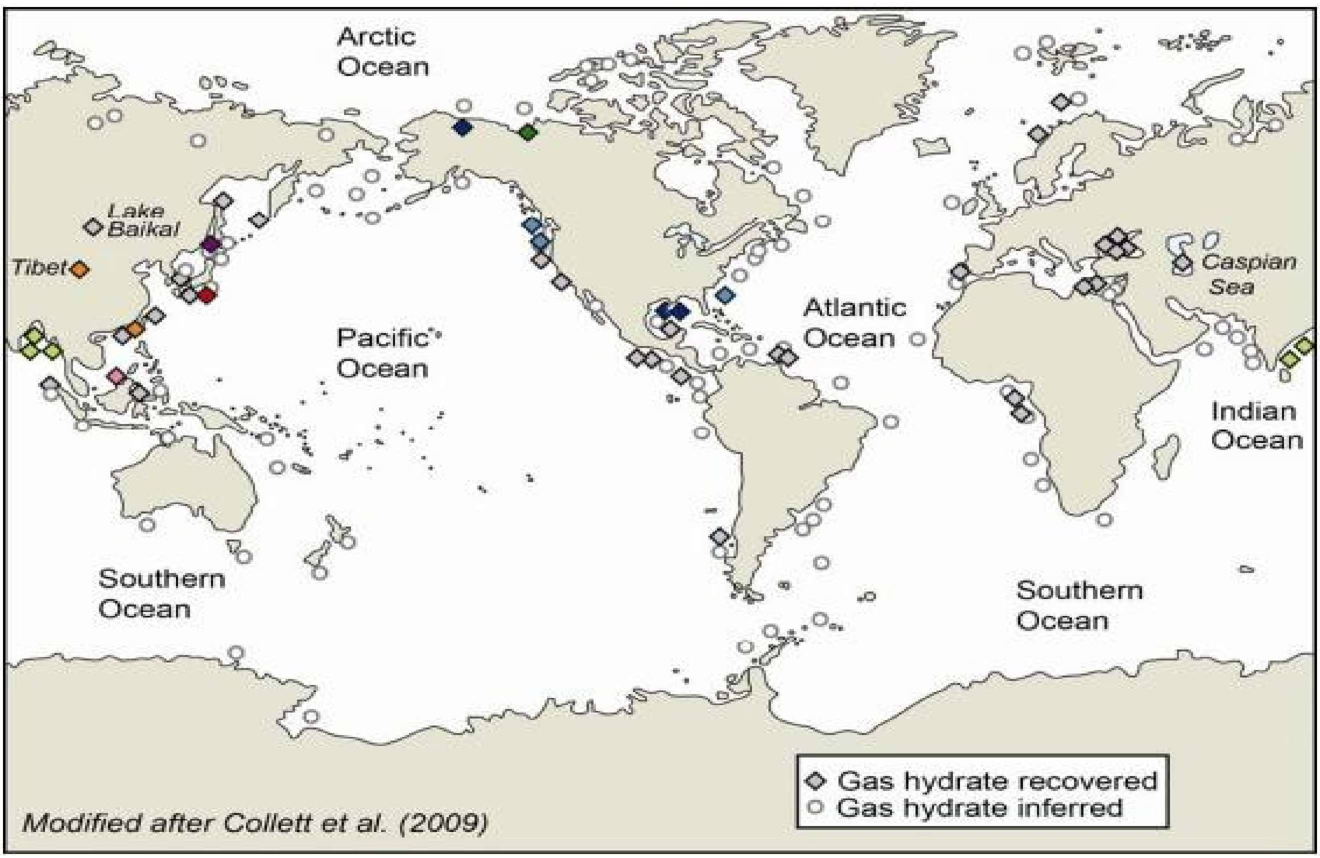

Fig. 2 - GAS HYDRATES GLOBAL MAP

(Image Source: Ruppel C, Collett Et. Al., 2009)

Questions are raised about the economic and commercial viability of methane hydrates as unconventional gas is playing a more eminent part in the total gas mix. After recent tests, Japan is expecting commercializing hydrate-extracting technology as early as 2023, and China is also preparing to begin commercial production of hydrates by 2030[7]. Commercial-scale production of methane hydrates can be revolutionary for few countries. Japan has a vast industrial sector but it's very much dependent on LNG imports, for Japan, methane hydrate resource offers a chance to decrease its dependence on imported fuels.

Moreover, as the fight against climate change is in progress, this resource can become a welcomed replacement for other high carbon-emitting fuels for countries like China which is trying to mitigate the pressure on decreasing its carbon emissions, and treat its serious air pollution issues in urban areas, especially Beijing whose air quality is very bad. In other places, reasons to exploit the gas commercially are less critical, for now. Russia has vast natural gas reserves The US is in the middle of a shale gas boom and Canada also has abundant shale resources, In fact, Canada has postponed any funding and has put its research into methane hydrate on hold[8]. China and India, with their huge demand for energy due to their high population, are well behind in their endeavors to develop methane hydrates[9]. Till-date only a few minor projects have been finished and many elements are presently contributing to making the resource uneconomical. Dissociating the methane from the hydrates is technologically challenging, and thus is very expensive. Figure 2 shows a global map of inferred and recovered gas hydrates[10]. Here, the color-coding refers to the drilling programs focused in the gas hydrates research timeline shown in Figure 3.

 International Journal of Research Publication and Reviews Vol (2) Issue (6) (2021) Page 45-49

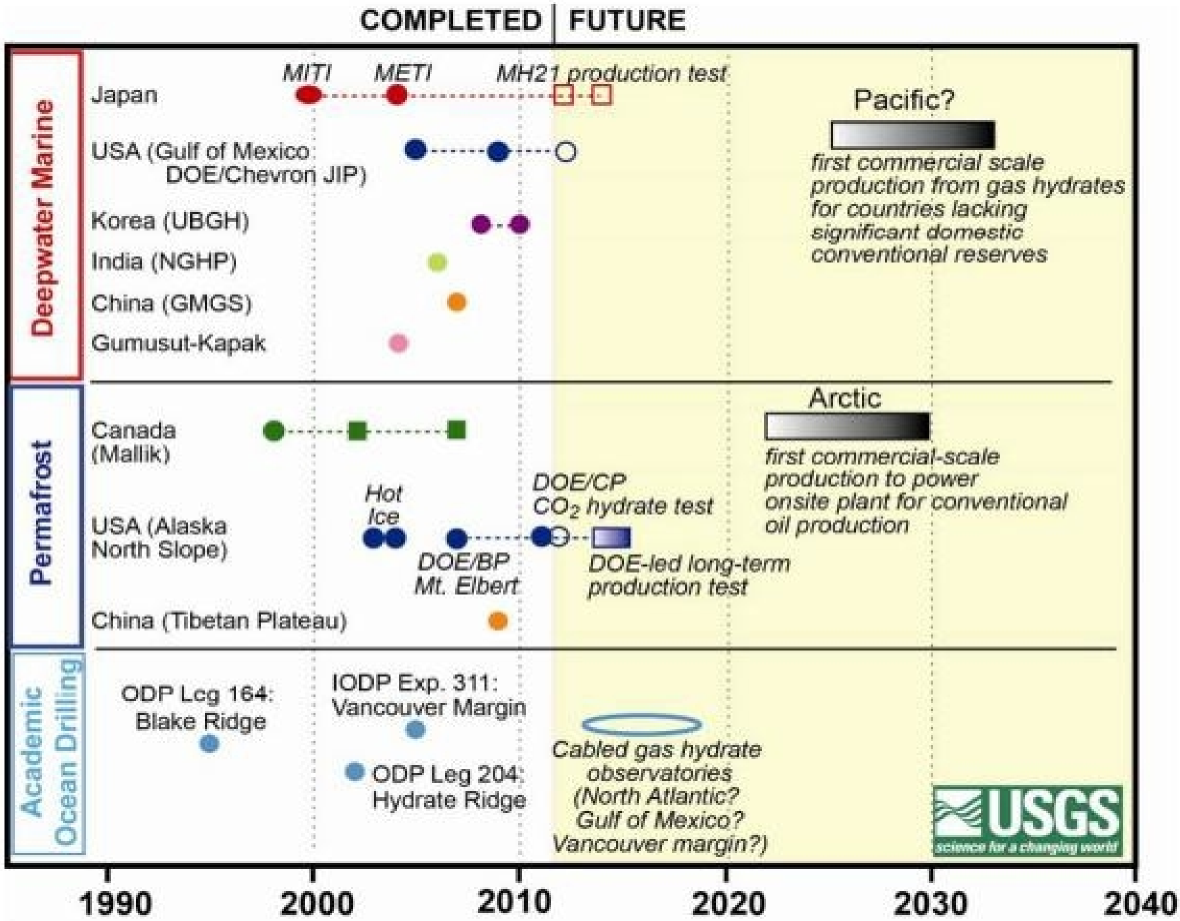

Fig. 3 - GAS HYDRATE TIMELINE

(Image Source: USGS)

Gas Hydrate Resources:

The hydrate resource pyramid is depicted in Figure 4, it shows the distribution of sequestered methane between the major kinds of global gas hydrate deposits. The pyramid also shows that only a small part of these deposits is supposed to be regarded viable as a source of commercial quantities of natural gas. The pyramid is an agreeable way to acknowledge the expected chronology for the evolution of gas hydrates as a resource[11].

Arctic Sand Reservoirs:

At the peak of the pyramid lies highly permeable sediments in permafrost areas. Despite the comparatively less amount of gas hydrate

in these environments globally, permafrost-associated gas hydrates will likely be the foremost to be commercialized, especially in areas with well-developed base for conventional hydrocarbon extraction (e.g., Alaskan North Slope). The gas produced in these settings would most likely be used to meet on-site power needs[12].

Marine Sand Reservoirs:

The permeable marine sediments come below the permeable permafrost-associated sands on the gas hydrate pyramid and they are thought to be the goal for the long-term development of gas hydrates as a resource. Resource category gas hydrate accumulations are classified depending on reservoir quality and saturation. Extremely permeable marine sands with average gas hydrate saturation are perceived to be the best targets for large-scale resource development. Recent logging while drilling programs in the Gulf of Mexico have found geologic units with inferred hydrate saturations as high as 80[13].

Non-Sand Marine Sediment:

The non-sand marine sediment slightly below the marine sands within the gas hydrate resource pyramid is often best interpreted as less permeable sediments which may host gas hydrate in fracture-related permeability[14]. Such sediments may not have a high average saturation of gas hydrate taken in bulk, but targeted production within the fractures could theoretically yield significant gas from the gas hydrates. The fractures themselves may additionally be exploited as conduits for rapidly extracting gas through otherwise low permeability sediments similar to shale gas.

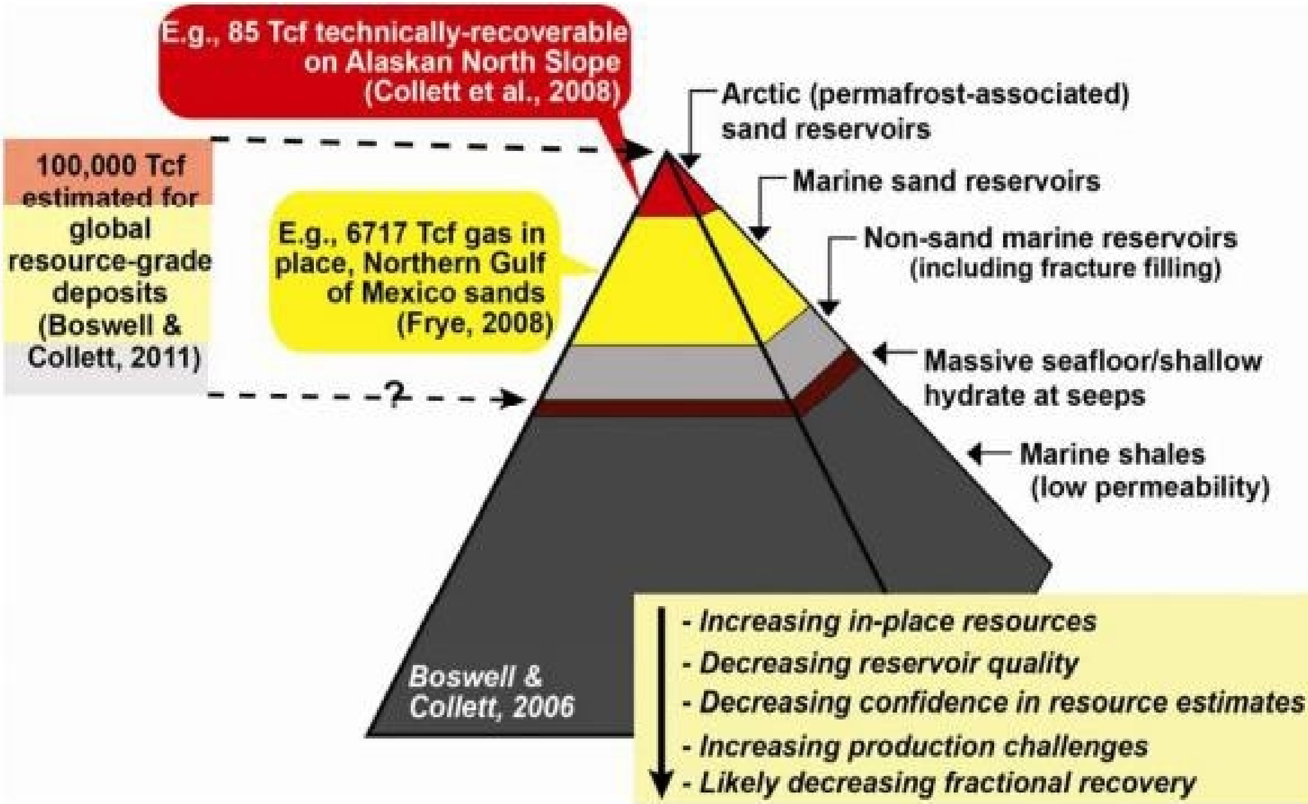

Fig. 4 - GAS HYDRATES RESOURCE PYRAMID

(Image Source: Boswell R, Collett T, 2006)

Low Permeability Marine Sediments:

At the bottom of the resource pyramid lies the permeable marine sediments. As noted above, In methane hydrates, such sediments carry most of the worldwide gas in place (GIP) and are very less likely to become a target for commercial production of gas from methane hydrates.

Recovering The Gas From The Hydrate:

The massive amount of methane hydrates globally can be a possible resource of remarkable prolificacy. Our comprehension of these resources, yet, is basic. methane hydrates provide great potential if an economically attainable production technique can be recognized. Now, we contemplate each of the primary production techniques:

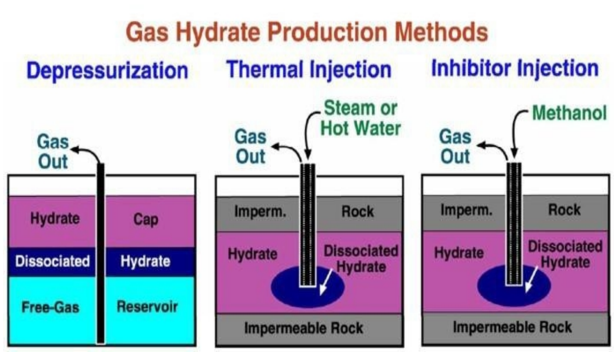

Fig. 5 - GAS HYDRATES PRODUCTION METHODS

(Image Source: IITB)

i) Depressurization: It has come out as the favored and more economical method of producing gas from methane hydrates through most of the well's life. It can be used to drive dissociation of a notable volume of gas hydrate quite swiftly and does not need great energy expenditure.

ii) Thermal Stimulation: It refers to heating the formation by the injection of high-temperature fluid or the direct heating of the formation. This process is very energy exhaustive, if the warmer pore fluids don't mobilize and expand the volume of the formation exposed to higher temperatures then it will lead to comparatively slow dissociation of gas hydrates. In terrestrial surroundings, this method must be precisely managed to reduce permafrost thawing, which can lead to unplanned environmental consequences and change the permeability seal for the underlying gas hydrate deposits[15].

iii) Chemical Inhibition: This technique utilizes the fact that the hydrate stability is reserved in the presence of a few definite organic (glycol) or ionic (seawater or brine) compounds. Seawater and other inhibitors could be required through some phase of production of gas from methane hydrate deposits, but it cannot be the primary method of dissociating gas hydrate nor it can be used for an extended period or on a large scale.

Conclusion:

The use of natural gas will increase far into the 21st century thanks to the increasing demand for cleaner-burning fuels and greater use within the transportation sector. The government policy responding, for instance, to growing concern about global climate change, also will influence the development of methane hydrates. In the past, government subsidies have driven the development of other unconventional natural gas resources, including coal-bed methane. Despite all the apparent obstacles to the development of gas hydrate resources, it is good to remember that extraordinary technological developments in the petroleum industry such as 3-D seismic strategies, horizontal drilling, and secondary recovery techniques have led to the exploitation of resources once thought to be unavailable. Natural gas hydrates may also become economically extractable.

Natural gas, essentially methane, is a great fuel for combustion for a variety of reasons. Methane produces less CO_2 per mole than the other fuel when it's used as fuel. Thus, it can reduce the amount of emission of carbon dioxide gas, which may cause a greenhouse effect. In addition, the quantity of fuel in hydrate form is approximately twice as large as altogether other fossil fuels combined. Thus, methane gas hydrate has the potential to be widely used as a replacement energy source.

Exploration campaigns and production tests have shown that gas-hydrate deposits in sand-bearing sediments could be extracted using existing technologies. Continued investment in R&D, along with the execution of prolonged production tests, will help to assess the long-term economics of gas-hydrate production and to address environmental and safety concerns.

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