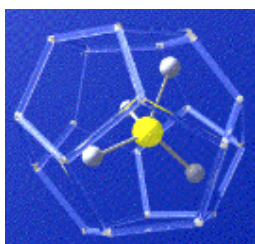


Gas Hydrates

T. Ramprasad

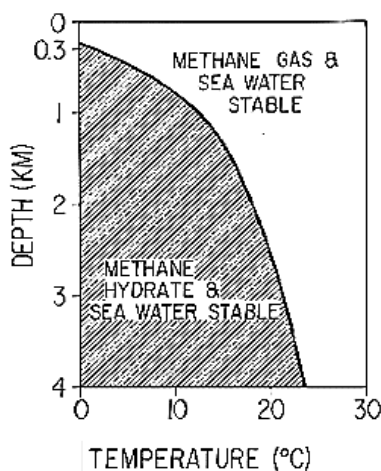
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A gas hydrate is a crystalline solid; its building blocks consist of a gas molecule surrounded by a cage of water molecules. Thus it is *similar to ice*, except that the crystalline structure is stabilized by the guest gas molecule within the cage of water molecules. Many gases have molecular sizes suitable to form hydrate, including such naturally occurring gases as carbon dioxide, hydrogen sulfide, and several low-carbon-number hydrocarbons, but most marine gas hydrates that have been analyzed are methane hydrates.

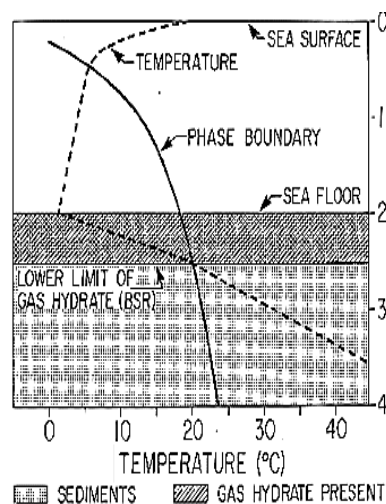


Although gas hydrates contain hydrocarbons that are colorless, not all of them are white like snow. Some hydrates from the deep Gulf of Mexico are richly colored in shades of yellow, orange, or even red. The ice-like masses are beautiful, and contrast with the dull gray of deep sea muds. Hydrates from the Blake-Bahamas Plateau in the Atlantic Ocean can be gray or blue. Why hydrates show these colors is still to be answered. A number of different factors, including oil, bacteria, and minerals, are probably at play in producing the rainbow hydrates.

Where is Hydrate Stable?



Pressure and temperature are two of the major factors controlling hydrate formation.



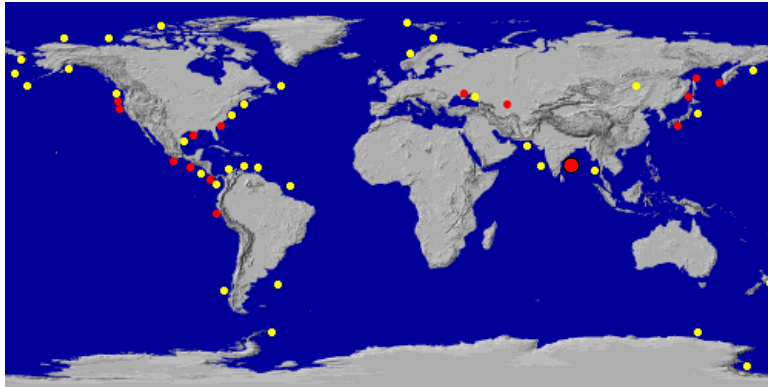
The diagram to the above shows where the same stability curve above crosses the temperatures of ocean sediments

Capacity to Trap Gas

Hydrate forms as cement in the pore spaces of sediment as well as in layers and nodules of pure hydrate. Hydrates also seem to have the capacity to fill sediment pore space and reduce permeability, so that hydrate-cemented sediments act as seals for gas traps. Gas hydrates are stable at the temperatures and pressures that occur in ocean-floor sediments at water depths greater than about 500 meters, and at these pressures they are stable at temperatures above those for ice stability. Gas hydrates also are stable in association with permafrost in the polar regions, both in offshore and onshore sediments. Gas hydrates bind immense amounts of methane in sea-floor sediments. Hydrate is a gas concentrator; the breakdown of a unit volume of methane hydrate at a pressure of one atmosphere produces about 164 unit volumes of gas. The worldwide amount of methane in gas hydrates is considered to contain at least 1×10^{14} gigatons of carbon (in a very conservative estimate). This is about twice the amount of carbon held in all fossil fuels on earth.

Gas hydrate concentration occurs at depocenters, probably because most gas in hydrate is from biogenic methane, and therefore it is concentrated where there is a rapid accumulation of organic detritus (from which bacteria generate methane) and also where there is a rapid accumulation of sediments (which protect detritus from oxidation).

Where Gas Hydrates found?



Since the 1970's, naturally occurring gas hydrate, mainly methane hydrate, has been recognized worldwide, where pressure and temperature conditions stabilize the hydrate structure. It is present in oceanic sediments along continental margins and in polar continental settings. It has been identified from borehole samples and by its characteristic responses in seismic-reflection profiles and oil-well electric logs. Beneath the ocean, gas hydrate exists where water depths exceed 500 meters (depending on sea bottom temperature), and it can occur within a layer of sediment as much as hundreds of meters thick directly beneath the sea floor; the base of the layer is limited by geothermal gradient (increasing temperature). At high latitudes, it exists in association with permafrost.

Need for study of gas hydrates

Gas hydrate is an important topic for study for three reasons:

1. It contains a great volume of methane, which indicates a potential as a future energy resource.

When hydrate fills the pore space of sediment, it can reduce permeability and create a gas trap. Such trapping of gas beneath hydrate may cause the formation of the most concentrated hydrate deposits, due to the presence of a reservoir of gas below the hydrate zone. The gas can continually migrate upwards to fill any open pore spaces. This process, in turn, causes the trap to become more effective, producing highly concentrated methane and methane hydrate reservoirs.

Gas from hydrate might become a major energy resource if economically profitable techniques could be devised to extract its methane.

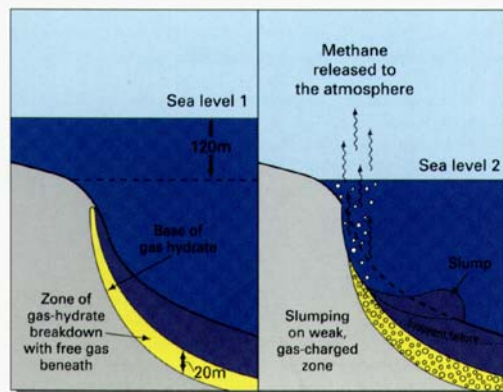
2. It may function as a source or sink for atmospheric methane, which may influence global climate.

Methane from the hydrate reservoir might significantly modify the global greenhouse, because

methane is ~20 times as effective a greenhouse gas as carbon dioxide, and gas hydrate may contain three orders of magnitude more methane than exists in the present-day atmosphere. Because hydrate breakdown, causing release of methane to the atmosphere, can be related to pressure changes caused by glacial sea-level fluctuations, gas hydrate may play a role in controlling long-term global climate change.

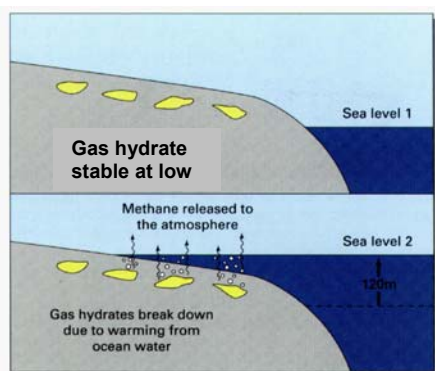
3. It can affect sediment strength, which can initiate landslides on the slope and rise.

Gas hydrate apparently cements sediment, and, therefore, it can have a significant effect on sediment strength; its formation and breakdown may influence the occurrence and location of submarine landslides. Such landslides may release methane into the atmosphere, which may affect global climate.



Changes in water pressure due to sea level changes may generate landslides by converting the hydrate to gas plus water, causing significant weakening of the sediment, and generating a rise of pore pressure. Conversely, sea-floor landslides can cause breakdown of hydrate by reducing the pressure in sediments. These interacting processes may cause cascading slides, which would result in

breakdown of hydrate and release of methane to the atmosphere.



Sea-level rise causes relatively warm ocean water to cover cold hydrate strata resulting in breakdown of stable gas hydrates within sediments and release of gas to atmosphere

How Gas Hydrates studied?

Interpreted Seismic Profile

Although gas hydrate has been recognized in drilled cores, its presence over large areas can be detected much more efficiently by acoustical methods, using seismic-reflection profiles. Hydrate has a very strong effect on acoustic reflections because it has a high acoustic velocity (approximately 3.3 km/s - about twice that of sea-floor sediments), and thus grains cemented with hydrate produce a high-velocity deposit due to the mixing of hydrate with the sediment.

The BSR

The contrasts in velocity created by the hydrate-cemented zone produces a strong reflection called the bottom simulating reflection (BSR). Lower velocities below the hydrates occur because underlying water saturated sediments have lower velocities (water velocity is about 1.5 km/s) and often contain gas trapped by the overlying, less porous hydrate-cemented sediments. This contrast produces a strong reflection. Because the base of the gas-hydrate stable zone occurs at an approximately uniform sub-bottom depth throughout any small area, the well-defined seismic reflection from the base of the zone roughly parallels the sea floor (hence "bottom simulating").

Blanking

A second significant seismic characteristic of hydrate cementation is called "blanking". Blanking is the reduction of the amplitude (strength) of seismic reflections that apparently is caused by cementation by hydrate of the strata that form reflectors. The blanking effect occurs throughout the entire hydrate-cemented zone and can be quantified to estimate the amount of gas hydrate that is present.

Over large areas the thermal field may be distorted and even the pressure field and the chemistry of pore water may vary unpredictably; all are factors that affect the phase stability of hydrate. Therefore the variation in depth to the base of the gas-hydrate stable zone can indicate a great deal about sub-sea-floor conditions.

Laboratory Studies

Laboratory studies are necessary to understand the processes by which gas hydrate may be concentrated on the continental margin and to develop tools (such as acoustic models) that facilitate recognition and resource analysis of these offshore hydrate deposits. The USGS has begun using a computer-controlled test system in which gas hydrate is formed and decomposed in sediment samples under simulated in-situ (deep-sea or arctic) conditions.

Possible mechanisms of natural concentration are also simulated, including: 1. an accumulating sediment column, 2. cyclic sea-level change, 3. faulting and fluid migration, and 4. trapping of free gas beneath a hydrate seal. Experiments are being conducted to assess the impact of gas hydrate on sediment behavior, particularly with respect to slope failure and other potential geohazards, and to estimate the amounts and rates of release of methane into the atmosphere in response to geological phenomena.

Currently, groups of scientists in the U.S., Canada, Norway, Great Britain and Japan are working to try to understand gas hydrate and the role it plays in the global climate and the future of fuels. Russia, Japan, Nigeria, Peru, Chile, Pakistan, Indonesia, Korea, etc are various countries who are perusing the gas hydrates studies as a future resource for fuel.

Indian Initiative for gas hydrates research

Gas hydrate research in India is in a nascent stage, and a modest beginning has been made under the aegis of National Gas Hydrate Programme (NGHP), conceived by the Ministry of Petroleum & Natural gas, Government of India. The fundamental research being undertaken on gas hydrates may ultimately have a significant impact on energy policy.

The offshore sedimentary basins are filled with the early Cretaceous to Recent sediments (0.5 to <8 Km). Several offshore sedimentary basins explored by oil industry show the presence of higher order hydrocarbons at the deeper depths. It is envisaged the existence of source gas for gas hydrate formation at such deeper depths. The low-density gas migrates through the pathways and under low temperature - high pressure (1-2°C and 8-30 MPa) conditions in to the shallow layers, and then forms the gas hydrate deposits. Realising the significance of these new energy resources and, the preliminary indications from the existing seismic data, an

expert committee was constituted by Secretary Ministry of Petroleum and Natural Gas (MOP & NG), Government of India in 1996 to recommend the steps to be taken for identification and development of gas hydrate resources in Indian offshore. National Gas Hydrate Programme (NGHP) was formulated based on the recommendations of the expert committee. The NGHP is monitored by a Steering Committee headed by Secretary, MOP & NG with ONGC, GAIL (India) Limited, OIL, DGH, NIO & NGRI as members. The NGHP prepared the Road map for exploration of the gas hydrates. The Ministry of Earth Sciences, MoES (erstwhile Department of Ocean Development), Government of India and the Council of Scientific & Industrial Research (CSIR) recognized the importance of these offshore hydrate deposits and their potential. Accordingly, NGHP and the then DOD have organised the workshops, brainstorming sessions and invited the experts from abroad. The Workshop in 2000 on gas hydrates under International Long Term Programme (ILTP) on Science and Technology between India and Russian conceived a programme that leads to exploration of gas hydrates in the continental margins of India.

Simultaneously, the CSIR initiated the in house R&D Programme at its constituent laboratories National Institute of Oceanography (NIO) and National Geophysical Research Institute (NGRI) under new millennium projects. The programme is aimed to develop expertise through experience for better understanding of the formation and occurrences of the gas hydrates and their resource potential in Indian continental margins.

Prior to the multidisciplinary investigations, NIO at the behest of GAIL (India) limited generated the Gas Hydrate Stability Zone thickness map in 1997 using methodology of Peter Miles (1995). The available bathymetry, seabed temperatures, and heatflow data were used as the basic input. This map served as precursor in predicting as well as confirming BSRs on the multichannel seismic reflection records. Meanwhile, the NGHP, under the aegis of DGH undertook multidisciplinary scientific investigations through NIO during 2002-'03, and integrated the findings with the inferred BSRs from 2D and 3D seismic data and planned for drilling to establish the occurrence of gas hydrates in the eastern offshore, Andaman Sea. The preliminary analysis of these data sets facilitated in identification of proxies in support of the observed BSRs. Based on the geoscientific studies supplemented by the BSRs identified on the 2D and 3D seismic reflection records, more than ten locations were selected by the NGHP Technical Committee for drilling and deployed the ODP drillship JOIDES Resolution during May-Aug 2006 and recovered gas hydrate samples from the eastern margin of India. Figure shows the massive gas hydrate samples recovered from the eastern offshore.



Gas hydrate sample from the eastern offshore of India

Future exploration technology trends

The Ministry of Earth Sciences (erstwhile DOD) of India entrusted the project "Gas hydrate exploration and Technology development for its exploitation to NIO, NGRI and NIOT. This is currently an ongoing project that was initiated by the erstwhile DOD.

Seismic data acquisition and processing

New seismic data (2D and 3D) and OBS data are to be acquired to characterize the gas hydrate bearing strata and quantification of gas hydrates. Once a BSR is identified, the amount of hydrate, its mobility and recoverability (i.e. permeability and formation strength) has to be estimated. The key to extracting this information from seismic data is knowledge about rock physics. Amplitude Variation with Offset (AVO) is a petro-physical imaging tool and this analysis reduces risk. The reflection coefficient variation with offset is dependent on changes in medium P-wave velocity (V_p), S-wave velocity (V_s), and density (ρ), thereby providing the theoretical basis for AVO analysis.

High resolution seismic or Deep Towed Acoustic Geophysical System

New experiments need to be conducted using the high resolution seismic systems such as the Deep Towed Acoustic Geophysical System, which is well suited to provide high resolution mapping of sub bottom structures in deep water and to map the shape and structure of the BSR for methane gas exploration. Source and receiver array are towed between 200-300 m above the sea floor to have data to resolve sediment structural details < 5 m in thickness within the upper 600-700 m of sediments.

Acquisition of Long cores (>15 to 60m)

Long cores need to be acquired and studied to understand the behaviour of geochemical proxies such as methane concentration, Chloride anomalies, and Sulfate-methane interface.

Microbiological proxies

The microbiological studies elsewhere reveal the presence of Sulfate Reducing Bacteria SRB_r (reducers) and SRB_f (fermenters) in appreciable quantities in the

bottom layers of the core probably vouching for a continuous supply of methane from the subsurface layers. Integration of geophysical, geological, geochemical and microbiological data results suggests that KG basin is highly conducive for gas hydrate occurrence. Recent drilling results in the Krishna-Godavari and Mahanadi offshore by various public/private sector units indicated the presence of natural gas at deeper depths, and the well log data of supports presence of considerable thick gas hydrate zones in the eastern offshore.

Stable isotope studies

Laboratory study for stable isotopes ratios is an important component. This facility needs to be augmented to assess the genesis of hydrates and other hydrocarbons. Since Gas hydrate research is in the infant stage at India, and the anticipated benefits are several folds, the research activity should be continued and necessary infrastructure including the ship time, laboratory facility with the state of the art equipment, trained and dedicated manpower, sample storage facilities are to be developed.

ODO Drilling Results

Processing, analysis, interpretation of the gas hydrate cores recently collected onboard JOIDES Resolution in the Indian offshore will be undertaken and the preliminary results would appear in the draft initial report on the Indian Gas Hydrate Drilling Programme by the 1st quarter of 2008. DGH is the coordinating agency for this task.

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