METHANE FROM MARINE GAS HYDRATES

Gas hydrates are a solid form of gas combined with water. They naturally occur on the seafloor and in subsurface sediments in water depths of 300 m and beyond, and their volume far exceeds all conventional energy reserves. Because of their potential role as an energy resource, an agent of climate change or as a geohazard, methane hydrates have attracted increasing interest over the past three decades. As with other unconventional energy resources, the challenge is to first understand the resource and assess possible environmental impacts before developing viable production strategies.

What are gas hydrates?

Gas hydrates are solid compounds consisting of cage-like structures of water molecules that enclose natural gas molecules (Figure 1). They resemble ice or wet snow in appearance and can form at water depths ranging from 300m to more than 4000m, where the temperature and pressure conditions allow gas hydrate to be stable (known as the hydrate stability zone).

Gas hydrates can form from a variety of natural gases produced by the decay of organic matter or as a by-product of microbial activity. Methane hydrates are the most common, and they represent a highly concentrated form of methane: one cubic metre of methane hydrate can contain more than 160 m^3 of gas at atmospheric pressure and temperature. In a process known as dissociation (the breakdown of the hydrate molecule), this huge amount of gas, along with a smaller amount of water, can be released very quickly if the temperature increases or pressure decreases beyond the limits of the hydrate stability zone.

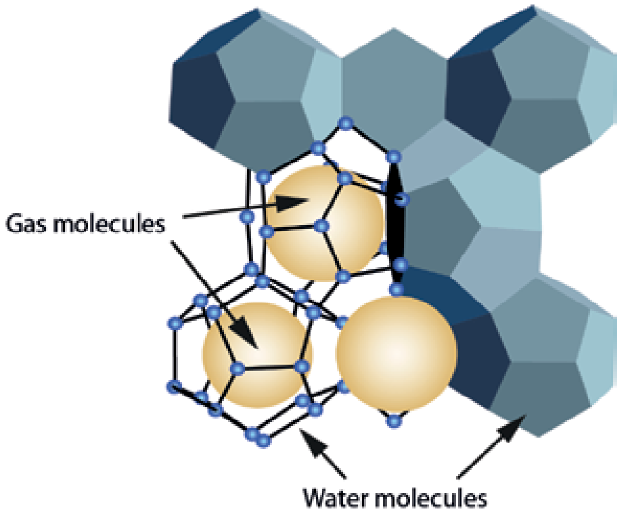

Figure 1: The molecular structure of gas hydrate.

Where and how do they accumulate ?

Gas hydrate accumulations occur in three distinct types: seafloor hydrate, hydrate filling fractures in clay-rich sediments and hydrate filling the pore spaces between sand grains. On the seafloor, hydrates form pavements or mounds commonly associated with methane seeps, which support unique and complex communities of tube worms, mussels and associated species (Figure 2). Deeper in the subsurface, gas migration and hydrate growth combine to force fine sediment grains apart, forming pure veins, lenses or nodules of hydrate. In sand deposits where porosity and permeability is high, large quantities of hydrate may accumulate between sediment grains, filling 60 - 90% of the pore spaces and can cement the grains together.

The discovery of concentrations of gas hydrates in the Gulf of Mexico and in the Nankai Trough (offshore Japan), along with a number of accumulations yet to be fully quantified, suggests that the global volume of gas trapped in gas hydrate-bearing sands is in the order of 3 to 6 × 10^{14} m^3 (equivalent to about double the organic carbon found in all fossil fuels).

Figure 2: A gas hydrate seafloor mound (white matter in the centre) supporting a chemosynthetic community of Bathymodiolid mussels, Siboglinid tubeworms and Alvinocaris shrimps at 3160 m water depth offshore Gabon (image courtesy of Ifremer from WACS cruise 2011).

Extraction challenges

To date, gas hydrate accumulations in sand deposits have been considered the most suitable for extraction and production technologies. The high permeability of sand deposits means that the necessary temperature and pressure changes required to transform solid hydrate to free gas are easily transmitted from a borehole through the deposit, which allows the gas to flow to the surface for extraction.

Concerns over operational safety and environmental issues led to the recognition that the most favourable targets will be the most deeply buried gas hydrate-bearing sand deposits. In such a setting, gas production would be isolated from the seafloor and subsea facilities by consolidated sediments with sufficient sealing capacity and mechanical strength to prevent unwanted leaks and seafloor failure (landslides). Deep burial may also be a factor in preventing gas hydrates from dissociating in response to temperature increases due to climate change.

Those concepts have been applied to developing plans for exploration and production drilling of methane hydrate in the Nankai Trough, offshore Japan. This research programme in deep water (around 1000 m) sought to depressurise a gas hydrate accumulation trapping about 0.57 million cubic metres of methane. Field evaluation of the feasibility of this production method occurred in March 2013. Although about 120,000 m^3 of gas was produced in six days, the experiment had to be stopped because of operational problems caused by significant sand flow into the borehole. This was due to the loss of mechanical strength in the sediment during gas hydrate dissociation, resulting the sand behaving as a gassy slurry.

Figure 4: Methane hydrate from the seafloor. Image courtesy MARUM Center for Marine Environmental Sciences, University of Bremen.

Following this pilot production programme, it is fair to conclude that the development of ocean gas hydrates as a resource requires sustained efforts to assess and mitigate the potentially adverse consequences of the depressurisation method on the integrity and stability of the borehole, the associated subsea facilities and surrounding sediments. Vertical and horizontal seafloor deformation, landslide development, fault reactivation and unintended gas leakage are key issues to tackle (Figure 3).

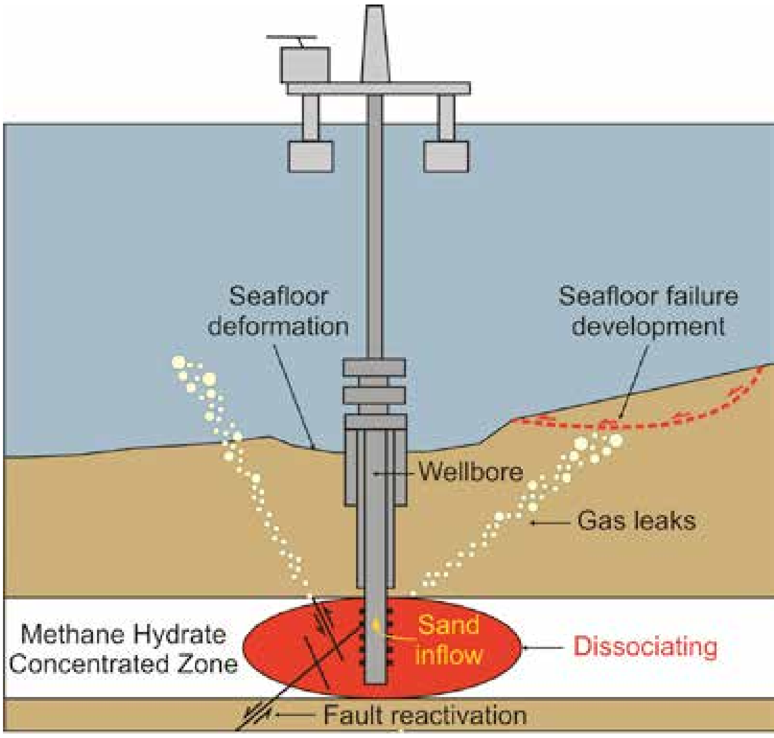

Figure 3: Illustration of the hazards associated with the depressurisation of gas hydrates (Yamamoto et al., 2015).

Research is currently underway to evaluate whether some of these issues may be avoided by injecting carbon dioxide into sediments containing methane hydrates, as an alternative to the depressurisation method. The technical merit of this novel method, which relies on the replacement of methane hydrate by carbon dioxide hydrate, is that it would keep reservoirs mechanically stable whilst trapping a greenhouse gas. Hydrate extraction raises environmental concerns as hydrate-bearing sediments are associated with slow-growing, bacterial communities and consortia that consume methane and toxic hydrogen sulphide before they reach the overlying water column. The bacterial communities themselves could add great value to methane gas extraction from hydrates due to their potential for biotechnological application.

Yamamoto, K., Nakatsuka, Y., Sato, R., Kvalstad, T. J., Qiu, K., & Birchwood, R. (2015) Geohazard risk evaluation and related data acquisition and sampling program for the methane hydrate offshore production test. Frontiers in Offshore Geotechnics III, 173.

Ruppel, C. (2011) Methane hydrates and the future of natural gas. MITEI Natural Gas Report, Supplementary Paper on Methane Hydrates, 4, 25.

MIDAS has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under Grant Agreement No. 603418. For more information please visit our website: www.eu-midas.net