International research project on gas hydrates: Hydrates in Oceans — Programme of Exploration (HOPE)

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A b s t r a c t . Global warming caused by increased emissions of greenhouse gases (especially carbon dioxide) to the atmosphere can be accelerated by release of additional amounts of methane from gas hydrates. These specific chemical compounds (clathrates) consisting of water and hydrocarbons exist as solids under a narrow range of conditions. The methane hydrates occur naturally mainly in the ocean bottom worldwide, as well as on lands in the permafrost zone. The last decade of the 20th century expanded our knowledge on areas of occurrence, potential resources, environmental conditions of gas hydrate formation and their stability. Increasing average temperature of the Earth changes the conditions of gas hydrate stability and may result in release of methane into seawater and then atmosphere. This may intensify the greenhouse effect. Thus, international research centres should urgently develop an integrated effort towards studying the origin and areas of occurrence of the gas hydrates, as well as feasibility of their commercial exploitation. Such integration could be coordinated by the International Sea Bed Authority within the proposed Project HOPE (Hydrates in Oceans — Program of Explorations).

Key words: *gas hydrates, clatrathes, global warming process, International Sea Bed Authority, methane, ocean explorations, greenhouse gases*

The accelerated pace of civilization development, especially in the second half of the 20th century, offered new technical abilities to humankind. At the same time, the existence of biological realm became endangered. Only after dramatic appeals by scientists and politicians made people aware of inevitable events that would occur if no coordinated actions are undertaken to eliminate or reduce the risks. Constraints due to physically limited natural resources, causes and effects of "acid rains", systematic increase of atmospheric emissions of CO_2 and resulting global warming, formation of the ozone hole — all these problems are now much better understood. The knowledge about their existence and patterns of change allowed to introduce substantial countermeasures; hopefully, the chances of avoiding global ecological disaster are growing. The international community of scientists and politicians had many times shown prudence and farsightedness in service of understanding the Earth natural system and its processes. Since many years especially active is the international scientific community of geophysicists. Thanks to them, many fruitful projects were launched, such as the International Geophysical Year (1957–1958), project MOHOLE, Polonaise Project '97 (Grad et al., 2003), Deep Sea Drilling Project, DSDP (1968–1975), International Programme of Ocean Drilling, IPOD (1975–1983).

Of similar importance were influential political initiatives, including the UN Secretary General U Thant's report "Man and His Environment" of 1969, publishing "The Limits to Growth" by the Club of Rome in 1972, report by Gro Haarlem Brundtland "Our Common Future". A special role was played by the Arvid Pardo address at the UN General Assembly in 1967, pointing at the need of regulating the open seas and their resources as "common heritage of mankind" (Art. 137 of the UN Convention on the Law of the Sea). Such initiatives mobilized the international public and forced the governments to undertake integrated actions in order to postpone the global ecological disaster (e.g., "The Asahi Glass Foundation" since 1992, or "State of the World" reports by the Worldwatch Institute). The reports provide assessments presented by experts from various countries, like in, e.g., "Questionnaire of Environmental Problems and the Survival of Humankind" (Hiromichi Seya, 2003). Greenhouse gases, and especially carbon dioxide and methane are accelerating the global warming (average temperature on Earth increased by 0.4–0.7 °C during the last hundred years). Of course, changes in Earth temperature are nothing exceptional in the geological history of our planet. Actually, the climate fluctuations can be regarded a natural process with varying dynamics and frequency. However, the rate of temperature changes observed in recent decades provokes urgent questions: Is a natural process of periodic global warming accelerated by human activity? and: Has the mechanism of Earth's climate self regulation been seriously affected?

In this context, it should be noted that the Earth (especially the seas) abound in potentially enormous accumulations of gas hydrates, which are stable within a limited range of pressure and temperature parameters. Increase of the average temperature of the Earth changes the stability conditions for these compounds and results in intense release of methane to seawater and then to the atmosphere. Thus an international research project HOPE (Hydrates in Oceans — Programme of Exploration) should be launched as soon as possible, to determine the places of occurrence and possibilities of exploitation of gas hydrates, both from terrestrial and marine deposits. The most suitable international institution to coordinate such a project is the International Seabed Authority (ISBA) affiliated by the United Nations, or the newly organized agenda: the United Nations Global Marine Assessment (GMA).

Basic information about gas hydrates

It is generally acknowledged that the first gas hydrates (specific combination of water and gas molecules) in the laboratory conditions were obtained by Sir Humphrey Davy in 1810 (chlorine hydrate). Later, the potential of hydrate formation was demonstrated also for other gases, such as H_2S, CH_4, C_2H_6, C_2H_4, C_2H_2 or N_2O. Outside the

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lab, first occurrences of gas hydrates were found in the 1920s in US gas pipelines (technogenic gas hydrates). They formed inside the pipes, blocking gas flow. In 1934, an American chemist, E.G. Hammerschmidt, first identified the hydrate of methane in frozen ice that was obstructing the flow of gas in natural gas pipes in Russia (Hammerschmidt, 1934). Presence of hydrates in natural (albeit specific) geological conditions was confirmed only in 1967 during prospecting work in Siberia (Messoyakhi hydrocarbon field) and Yakutia (Viliuisk field) and in 1968 in the American Byrd Polar Station in the Antarctic (at the depth of 2164 m) (Makogon, 1997).

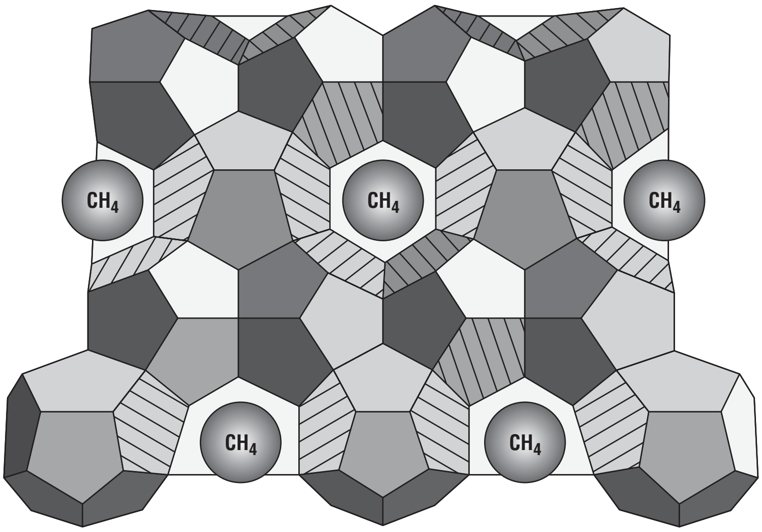

Fig. 1. Structure of type I gas hydrate. Rigid cages made of water molecles connected with hydrogen bonds; each cage in this section, both cut open and hidden, could carry a methane molecule. Average cage is 8 Ĺ across. After Hitchon (1974) modified

Natural gas hydrates are solid substances named clathrates (cage structures). Their internal structure consists of water molecules arranged into a rigid framework of cages, many of which are occupied by a molecule of methane (Kvenvolden et al., 1993) (Fig. 1). Gas hydrates are stable in specific narrow ranges of pressure and temperature (Fig. 2). Gas hydrates occur when 90% of space in clathrate is filled with gas. It is estimated that a 1 m^3 of gas hydrate contains 164 m^3 of gas and 0.8 m^3 of water.

The deep-sea pressures (at depth >500 m) and intrasediment temperatures (increasing with depth) determine the gas hydrate stability. At depth in the sediment where the temperature becomes too high for hydrate to be stable, the abrupt change of physical properties inherent with free gas in the sediment pore spaces generates a seismic reflection — the Bottom Simulating Reflector (BSR) (ISA, 1998). Since late 1960s there is a growing interest in gas hydrates (their prospecting, revealing their origin and developing usage possibilities). Especially

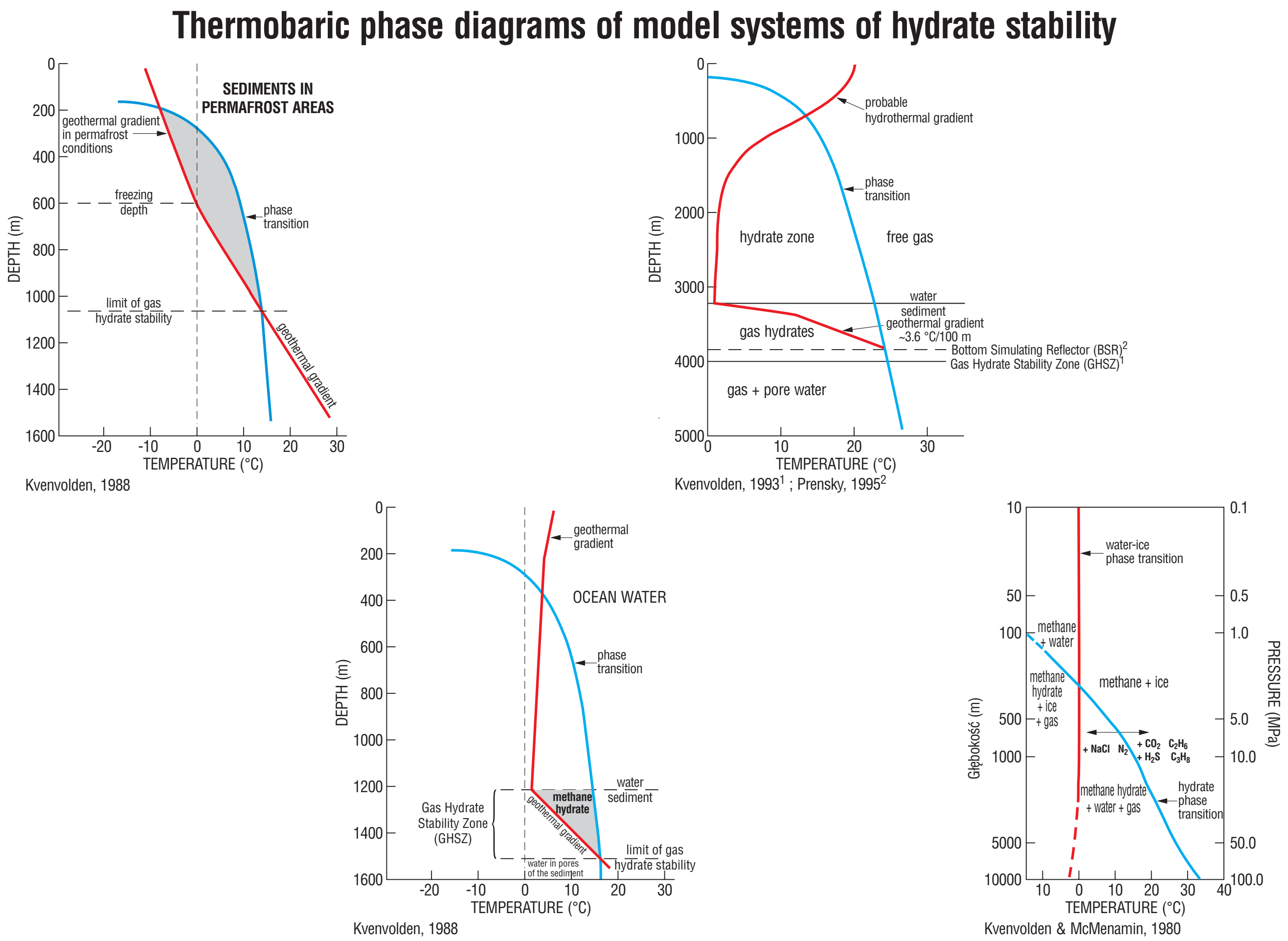

Fig. 2. Stability diagrams of gas hydrates occurrence, after: Kvenvolden, 1988, 1993; Kvenvolden & McMenamin, 1980; Prensky, 1995

intense gas hydrate studies during 1990–2000 resulted in many monographs published on that topic. By 1993, there were 57 places worldwide with known occurrences of gas hydrates in the sediments (Kvenvolden et al., 1993).

Only a few years later, 64 sites were identified. Most of the presently known gas hydrate deposits is related to the world oceans (42 out of 64) (Makogon, 1997; Cherkashev & Soloviev, 2002) (Fig. 3). The progress in prospecting is substantial but still insufficient, given the potential climate hazards due to methane releases.

Current estimates of total global resources of gas hydrates vary from 1.8×10^{14} to 7.6×10^{18} m^3. It seems that like was the case with the first estimates on polymetallic nodules on the seafloor (Mero, 1965), closer, more detailed studies will verify the resources at slightly lower level. The idea that the initial calculations of gas hydrate resources were overestimated is gaining popularity, their amount should be closer to $1.8 \times 10^{14} – 1 \times 10^{15}$ m^3 (Cherkashev & Soloviev, 2002).

Natural gas hydrates may be of biogenic origin (as a result of decay of organic matter and methane formation — methanogenesis) or thermogenic. A clue about the origin may by found in their structure (biogenic gas hydrates reveal type known as structure I, while thermogenic hydrates have structures II and H) or their stable isotope content.

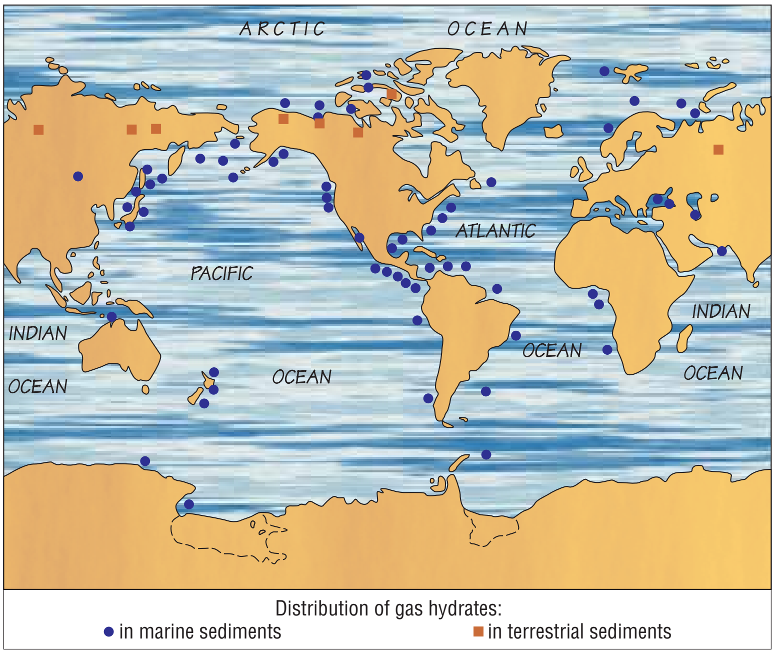

Fig. 3. Distribution of gas hydrates in terrestrial (squares) and marine (circles) sediments (Makogon, 1997)

Currently the most popular and most useful way of prospecting for gas hydrates is to use geophysical methods. Among them of special importance is the reflective seismic method. In timelogs, layers with anomalously high sound wave velocity (up to twice that of recorded in adjacent sediment layers) are recorded. Such irregularities are known as the BSR (Bottom Simulating Reflector) or a "false bottom" reflector. The presence of BSR is a useful signal to identify hydrates, although other seismic characteristics also occur.

HOPE Programme

The International Seabed Authority (ISBA) was established in 1994, as a result of ratifying and adoption of the UN International Convention on the Law of the Sea in 1982. In Part XI of the Convention, in Art. 137–141, al resources found in the international "Area" of the world ocean are defined as "common heritage of mankind".

Several countries and economic organisations conducted large scale prospecting for polymetallic concretions to document their deposits in the world ocean. After transferring the results of their documentation research to the ISBA, seven investors (IOM, COMRA, DORD, IFREMER-AFERNOD, YUZHMORGEOLOGIYA, KORDI, India) were granted status of a Registered Pioneer Investor. Currently, research focus on preparing for exploitation of the polymetallic nodules. It is estimated that the exploitation can begin within about ten years. The ISBA developed a widely accepted procedure and methods of seafloor research. Besides the deposit documentation and processing technology, also marine environmental studies were conducted (Kotliński & Szamałek, 1998). They involved environmental impact assessment of submarine exploitation of nodules, especially on the benthic fauna (BIE — Benthic Impact Experiment), DISCOL, INDEX, NAVABA, DOMES, etc.

Given its international status and experience, the ISBA could become the coordinating body for international research on submarine gas hydrates. It would be justified also by the fact that a large part of known resources of gas hydrates occurs below 300 m depth, and is structurally related to the continental slope and its base. The open sea area, under jurisdiction of the ISBA, shall soon attract intense research. Thus, an integrated international research program in urgently needed; such an initiative was postulated by the author during the Special Session of the Assembly of the ISBA (Szamałek, 2004). The stability of gas hydrates in natural conditions is not yet sufficiently understood. Available results suggest that marine hydrates occur in various climatic zones.

The activity of the ISBA concerning propsecting for polymetallic nodules and their documentation demonstrated that the organisation is able to create, coordinate and supervise integrated international operations. For the ISBA it is an indication that hydrates should now be under serious consideration when formulating rules and regulations for management in the Area.

Intense research on conditions of occurrence and distribution of gas hydrates are conducted by the USA, Japan, India, Canada and Russia. After drilling documentation well near Hokkaido in 1999, Japan plans to commence commercial exploitation of gas hydrates in 2010. Extraction of about 1/10 of documented deposits should satisfy the country's demand for many years.

So, what should be aim of the Project HOPE? First, the regions and conditions of occurrence of gas hydrates

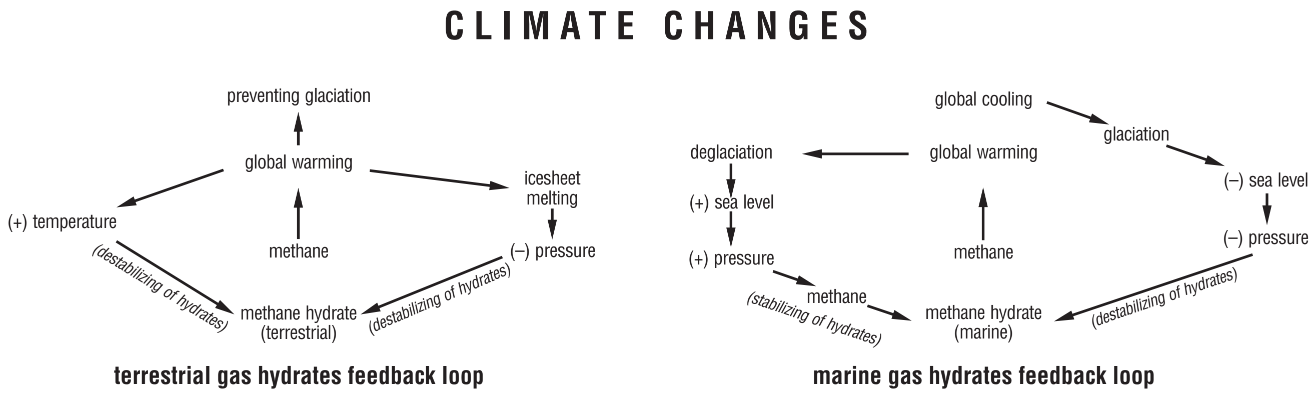

Fig. 4. Influence of climate warming on gas hydrate occurrence and its potential impact on natural environment (modified after Desa, 2000)

should be determined in more detail. New discoveries of gas hydrates still suffer from being largely accidental, and not stem from systematic studies. Internationally coordinated marine research should yield faster and more reliable results. Precise identification of the distribution of gas hydrates will allow a better estimate of the total amount of methane they contain. This estimate should in turn allow to reveal the amount potentially released to the atmosphere, and so to calculate the dynamics of influence of released methane on the greenhouse effect (Fig. 4). It should be noted that a large increase of atmospheric CO_2 and methane concentrations was observed in the last quarter of the 20th century (Lorius, 1991).

Of high priority is determination of the applicability of possible method of exploiting the methane from gas hydrates. The sooner the methane resources are managed, the sooner humanity would follow the path of sustainable development.

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