

FROZEN HEAT

A GLOBAL OUTLOOK ON METHANE GAS HYDRATES

VOLUME ONE

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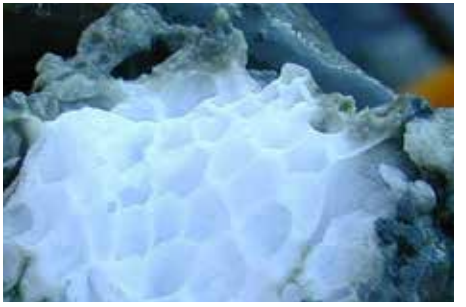

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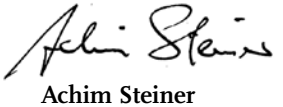
FOREWORD

Growing energy demands, uncertainty about supplies, and the urgent need to reduce emissions of greenhouse gases mean that the world faces an uncertain energy future. Many countries have begun to explore alternative energy sources, including so-called unconventional fossil fuels such as natural gas hydrates.

Gas hydrates generally occur in relatively inaccessible polar and marine environments, which is why they have not been extensively studied until recently. Research about naturally occurring gas hydrates has increased markedly over the past two decades, however, and understanding about where hydrates occur and how they might be exploited is growing rapidly. Japan has recently tested offshore production of natural gas from a hydrate reservoir located more than 1,300 metres below the sea's surface and other countries are also actively exploring production potentials.

Continuing a tradition of identifying emerging issues, the Global Outlook on Methane Gas Hydrates is the result of a rigorous assessment process designed to ensure the availability of scientifically credible and policy-relevant information. This assessment format brings together diverse strands of knowledge and is a key mechanism through which science informs decision-making.

This report provides a basis for understanding how gas hydrates occur and the emerging science and knowledge as to their potential environmental, economic, and social consequences of their use. The intention of this publication is to enable sound policy discourse and choices that take into account a number of important perspectives.



Achim Steiner
UN Under-Secretary General
and Executive Director of UNEP

PREFACE

Methane gas hydrates are solid, ice-like combinations of methane and water (Fig. I.1) that are stable under conditions of relatively high pressure and low temperature. Gas hydrates contain most of the world's methane and account for roughly a third of the world's mobile organic carbon. Because gas hydrates tend to occur in relatively inaccessible and harsh polar and marine environments, they were not studied extensively until recently. For more than a century after their first creation in the lab by scientists in the early 1800s, gas hydrates were considered an academic curiosity, with no meaningful occurrence in nature. In the 1930s, they were recognized as an industrial hazard forming blockages in oil and gas pipelines. In the late 1960s, scientists in Russia inferred their occurrence in nature. However, it wasn't until after a series of deep-ocean scientific drilling expeditions in the late 1970s and early 1980s that the abundance of gas hydrates in the natural environment was widely recognized.

Figure I.1: Gas hydrate nodules. Nodules (white) recovered while coring in the East Sea (Sea of Japan) (Courtesy Korea Institute of Geoscience and Mineral Resources)

Growing energy demands and climate concerns have brought increased attention to the potentially immense quantity of methane held in natural gas hydrates. The result has been a significant acceleration of the investigation of gas hydrates over the past two decades (Fig. I.2), and the pace of scientific discovery about naturally occurring gas hydrates continues to increase.

Although industry remains focused primarily on mitigating unwanted gas-hydrate formation in production and transport infrastructure, it is beginning to invest in understanding the hazards that naturally occurring gas hydrates pose to deepwater and Arctic energy development. Academia, supported by national programs, is making significant progress in understanding the basic physics and chemistry of gas hydrates, as well as their impact on the physical properties of sediments. This research furthers our understanding of the role of gas hydrates in global environmental processes, including natural geohazards, long-term carbon cycling and – given that methane is a potent greenhouse gas – global climate change. However, the primary driver for much of the current interest is the prospect of utilizing gas hydrates as an energy resource. For a world in which energy demands are increasing steadily and future energy supplies are uncertain, the widespread occurrence of potentially immense gas resources is motivating intensive investigations in many countries.

Gas hydrate research is shifting from the level of individual scientists to coordinated national research programs. As a result, policy makers, business leaders, and private citizens are now engaged in a discussion about the most appropriate directions for gas hydrate research, as well as about management and funding issues. The large quantities of naturally occurring gas hydrates distributed around the globe give rise to numerous societal and scientific concerns.

To facilitate decisions that must often rely on highly technical and multidisciplinary information, this comprehensive summary of current issues in global gas hydrate research and de-

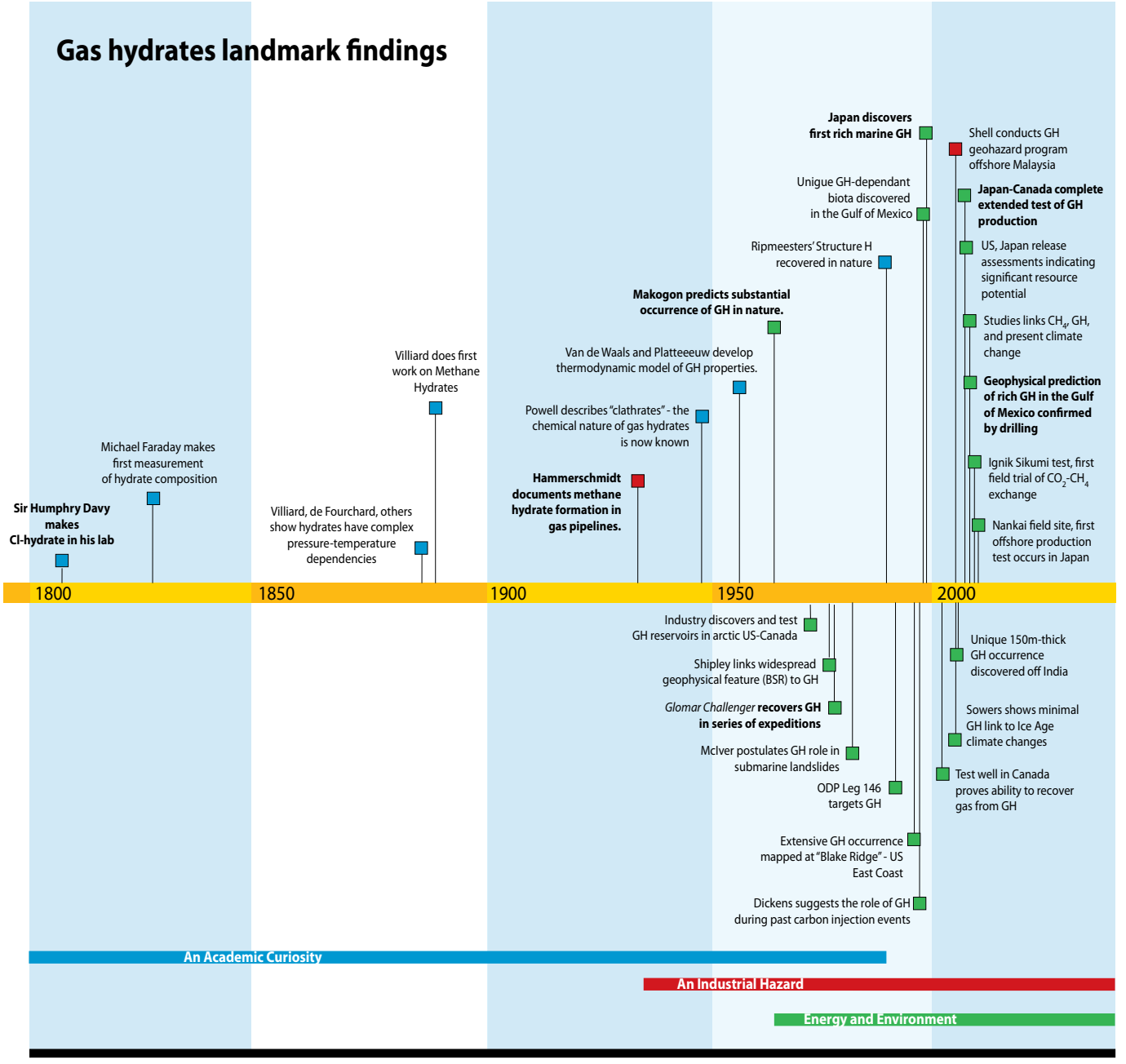


Figure 1.2: Timeline of major milestones in gas hydrate (GH) research.

velopment has been compiled: Frozen Heat: A global outlook on methane-gas hydrates. Frozen Heat is a two-part review that covers the role of gas hydrates in natural systems (Volume 1) and the potential impact of gas hydrates as a possible new and global energy resource (Volume 2).

Volume 1 Summary

As a basis for understanding how gas hydrates occur and evolve in nature, Chapter 1 describes the crystal structures of gas hydrates, their stability requirements, and the environmental settings in which gas hydrates commonly occur. It also gives estimates of the global quantity and distribution of gas hydrates. These gas hydrate basics provide a context for the central message in Chapter 2: gas hydrates are a key part of the global carbon cycle, storing and releasing vast quantities of methane in response to changing environmental conditions. Chapter 2 summarizes how methane is generated, moved into and out of gas hydrates, and gets consumed. Chapter 2 also discusses the link between gas hydrates and deep marine ecosystems. For example, much of the methane released by gas hydrates into these ecosystems is consumed by microbes in the upper sediment layers and water column and never reaches the atmosphere.

Understanding the behaviour of gas hydrates over long time periods is an important step in understanding how Earth works. As discussed in Chapter 3, the breakdown of gas hydrates due to natural events, such as long-term increases in bottom-water temperature, could release large volumes of gas from marine sediments, potentially transferring significant amounts of methane into the oceans and, to a lesser degree, into the atmosphere. Chapter 3 considers models of past climing events. Chapter 3 notes that, in the near term, the direct contribution of methane from gas hydrates to Earth's climate warming will likely be of minor significance. Despite the tremendous quantity of methane contained in gas hydrates globally, only a small fraction occurs in environments that will warm sufficiently over the next century to release methane capable of reaching the atmosphere. A more significant near-term result of methane release, particularly in the ocean, may be the oxygen depletion and acidification of the deep ocean that occurs when methane is broken down by microbes. Baseline monitoring studies will be important for understanding the extent of these environmental degradation issues.

Volume 2 Summary

The central message in Volume 2 is that gas hydrates may represent both an enormous potential energy resource and