The Ice that Burns

Can methane hydrates fuel the 21st century?

By RICHARD MONASTERSKY

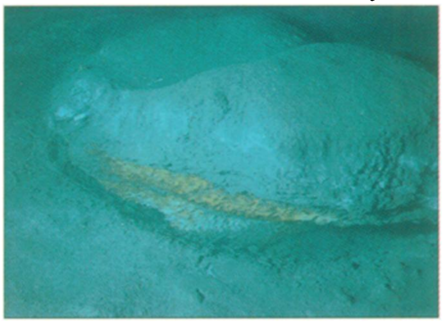
In October of next year, the Japan National Oil Corp. will send a ship to a spot about 60 kilometers off a cape called Omae zaki, not far from Mount Fuji. Its crew will lower a drill through 950 meters of water and then start cutting a circular hole the width of a dinner plate into the seafloor. At first, the bit will slice through fine silt as soft as birthday cake. Then, at a depth not yet known, the diamond-tipped drill will breach a hard icelike layer and, in the process, reach into the postpetroleum future.

The frozen substance is called methane hydrate, a name that has been increasingly echoing off the walls of Congress, university research offices, and oil company conference rooms around the world. Found under the ocean floor and polar permafrost, methane hydrates are a crystalline combination of natural gas and water, locked together into a substance that looks remarkably like ice but burns if ignited. Until recently, the natural gas industry considered it only a nuisance, something that occasionally plugs up pipelines. Now, some scientists view methane hydrates as the resource that may power the 21st century, and governments are scrambling to explore its promise.

"Methane hydrates are a potentially enormous natural gas resource," declared a U.S. presidential commission last year in its report on future energy research. "It may be that [natural] gas can be produced economically from the methane hydrates on the continental shelf, and this may prove to be a very large new source globally, particularly for some developing countries such as India as well as for the United States," concludes the report.

With some geologists predicting that oil supplies will tighten in the next 15 years (SN: 10/31/98, p. 278), the prospect of vast new fossil fuel deposits has fired the imagination of energy experts. According to some estimates, the energy locked within methane hydrates amounts to more than twice the global reserves of all conventional gas, oil, and coal deposits combined (SN: 11/9/96, p. 298). The U.S. Geological Survey (USGS) estimates that the methane hydrates hidden beneath U.S. waters alone hold some 200 trillion cubic feet of natural gas, enough to supply all the nation's energy needs for more than 2,000 years at current rates of use.

Lured by such a vast resource, Congress is currently considering a bill that would establish a national methane hydrates research program. At the same time, the U.S. Department of Energy is proposing a plan aimed at making it possible to extract methane commercially from hydrates in less than 20 years. Canada, India, Korea, and Norway have all joined Japan by initiating their own hydrates research programs.



Charles Fisher/Pennsylvania State Univ.

Untapped potential: Deposits of methane hydrates often lie well below the seafloor, but this sediment-covered hydrate mound sits on the ocean bottom in the Gulf of Mexico.

Such hopes may be little more than drill-pipe dreams, though. At this point, no company or government has demonstrated how to pull natural gas out of methane hydrates deposits without pouring a tremendous amount of money down the borehole.

"The bottom line is there is a lot of gas hydrate. There's probably more gas hydrate than all other resources. But because we have no sense of how much gas hydrate is actually recoverable, we have to be careful," says Timothy S. Collett, a geologist who studies methane hydrates at the USGS in Denver. "It may be totally irrelevant to any resource issue," he says.

Japan has taken the lead on methane hydrates exploration because its geologic heritage has left it with few options. "We don't have many energy resources near Japan, so we mainly import oil and gas from foreign countries," explains Arata Nakamura, assistant project director at the Japan National Oil Corp. (JNOC), a quasi-governmental company headquartered in Tokyo. "JNOC is very interested in conducting research to develop methane hydrates," he says.

Just how deep that interest runs is a matter of some secrecy. Like other oil and gas companies, JNOC considers many exploration issues proprietary. In 1994, Japan's Ministry of International Trade and Industry established a 5-year methane hydrates research plan, culminating in the offshore-drilling project slated for next year. Nakamura declined to specify exactly how much the plan will cost but said it will total more than $60 million.

In a preview of next year's program, JNOC funded a drilling operation in February and March of this year at an inland site in the Mackenzie Delta of northwest Canada. Working with the Geological Survey of Canada, a Japanese team bored a well 1,150 m deep into the Arctic permafrost, where methane hydrates are common.

Using a hollow drill, they pulled up cores of sandy sediment that formed the ocean bottom many millennia ago. This once-soft sand was as solid as concrete. In places, methane hydrates filled almost all the space between the sand grains, cementing the sediment into frozen layers located between 900 m and 1,100 m below the surface.

The main purpose in drilling the well, called Mallik 2L-38, was to measure how much hydrates hide in the sediments, says Scott Dallimore of the Geological Survey of Canada in Ottawa, who coordinated the scientific research at Mallik. "Methane hydrates occur in very high concentrations in the Mallik well, much higher [concentrations] than have been observed anywhere else," he says.

In sand, explains Dallimore, the grains occupy only about 65 percent of the total space, leaving a network of pores that take up the rest of the volume, much like the gaps between the nuts in a jar of cashews. At Mallik, methane hydrates fill 55 percent of the pore space surrounding the sand grains. So, roughly 20 percent of each coreful of the cemented sand was methane hydrates. That percentage exceeds the concentration found even in the richest known deposits under the seafloor, says Dallimore.

The Japanese team chose to drill onshore at Mallik because it is easier to work on land than under the ocean. When it comes to searching for domestic methane hydrates, however, JNOC must move underwater. Japan has no permafrost of its own.

The lair of most methane hydrates lies far from shore and deep below the waves. There, in water depths of at least 600 to 800 m, low temperatures and extreme pressures in the sediments combine to squeeze methane and water into a crystalline structure. Each molecule of methane gets trapped within a cagelike lattice of frozen water molecules, an arrangement that greatly concentrates a large amount of methane into a small space. Hydrates also go by the name of clathrates, a term derived from the Latin word for lattice.

The methane in most hydrate deposits originally comes from bacteria living beneath the seafloor. As they consume bits of plant and animal remains in the sediment, the bacteria excrete methane, a process still going on today. "It's the same thing as swamp gas or sewer gas," says Roy D. Hyndman of the Geological Survey of Canada in Sidney, British Columbia. When conditions are cold and the pressure is high, the bacterial gas gets locked up into hydrates.


Takashi Uchida, Japan Petroleum Exploration Co.

A drilling project in the permafrost of arctic Canada pulled up this gritty sample of methane hydrate.

In some deposits, the source of the gas lies much deeper, in sediments warmed by Earth's internal heat. Several kilometers below the seafloor, the temperature in the sediment rises so high that it cooks the buried organic debris. This slow simmer produces petroleum and hydrocarbon gases, which leak upward toward the seafloor. As the gases reach cooler sediments, they can form hydrates containing a mixture of hydrocarbons.

Or so the theory goes. Methane hydrates lie so deep beneath Earth's surface that geologists are uncertain about even the most basic details concerning the deposits. "We have to understand where they occur and why they occur," says Collett. The Energy Department, in its plan for a 10-year research program, puts the top priority on resource characterization—in other words, determining how much is out there and how to locate the richest deposits.

The same methane locked up in hydrates also comes out of the rear ends of cows and sheep, but the gas industry is not bursting down barn doors to collect the flatus of farm animals. Each animal produces only a little methane, and companies would go bankrupt trying to collect sizable quantities of gas. Likewise, most methane hydrate deposits are probably uneconomical because the gas is not concentrated in large-enough amounts, says Arthur H. Johnson, a geologist with Chevron USA Production Co. in New Orleans.

"While the published estimates of methane hydrate abundance are enormous, it is likely that most of the hydrate occurs in low concentrations and has no commercial potential. Our goal is to be able to find locations where the methane hydrates are sufficiently concentrated to warrant commercial production," Johnson testified at a hearing of the House Energy and Environment Subcommittee in September.

To spot underwater hydrate deposits, geologists rely principally on a technique routinely used by companies searching for petroleum. Blasts set off near the ocean surface send out sound waves that reflect off deep geologic structures and then return to the ocean surface, where they are recorded.

This process, called seismic reflection profiling, sometimes picks up a distinct band in the sediments that parallels the contour of the seafloor. Geologists call these "bottom simulating reflectors." The band marks the bottom of a hydrate deposit, where bubbles of methane gas in the sediment have become trapped below the impermeable frozen layer.

A related technique spots hydrates by estimating the speed of the sound waves as they penetrate the seafloor. In places where hydrates have stiffened up the otherwise soft sediment, sound travels much faster, says Hyndman. He and his colleagues at the Geological Survey of Canada recently used these techniques to pinpoint the potential locations of hydrate deposits off the coast of India.

People in both India and Japan pay three to four times as much for natural gas as do consumers in the United States. The steep price provides an incentive for these countries to pursue methane hydrates, whereas countries with domestic sources of hydrocarbons currently find hydrates far too expensive to seek.

In next year's drilling, Japan plans primarily to extract cores of methane hydrate, which will help in assessing the richness of the deposit, according to Nakamura. The company says it does not intend to "produce" the hydrate, a term engineers use to mean pulling commercial quantities out of the ground.

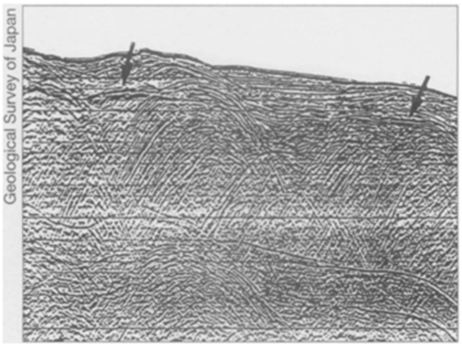
Nonetheless, U.S. geologists believe that Japan is taking steps toward that goal. At a meeting last year in England, a JNOC official said that after next year's drilling, the company hopes to take the commercially significant step of classifying some of the hydrate resource as energy reserves, says Michael D. Max, a geologist with the Naval Research Laboratory in Washington, D.C. "What that means is [the resource] changes from a possibility to a certainty. That means they would be able to put some recovery numbers on it, and they can start looking at the commerciality and the costs," says Max.

Right now, the costs of producing methane hydrates remain a big question mark because nobody has tried to extract this resource, with the possible exception of the operators of a controversial well in Siberia. Solid hydrates won't come out of the ground as easily as oil and so-called conventional gas, which can flow through rock pores and then up through the drill pipe.

One way to pry hydrates loose would be to release some pressure on the deposit, which would cause the methane and water to split apart, or dissociate. The advantage of this technique is that it would be relatively cheap, says Collett. To relieve pressure, a drill crew could tap the methane gas that often accumulates underneath and pushes up on the deposit. Unfortunately, this process might work too slowly, he says. As hydrates dissociate, they cool down, which stabilizes them and prevents more hydrate from melting.

To speed up the process, crews could drill far below the methane hydrates and pump hot water upward into the deposit, thereby melting the hydrates. Or, they could inject antifreeze from the surface to spur dissociation. "But when you look at the total balance sheet of the issue," says Collett, "the minute you start looking at enhanced techniques, you're putting energy and money into the project, and gas is not a real expensive commodity. So, you end up with the problem that you're putting more money in than you're going to get out in the form of gas."

Even though hydrates remain uneconomical at present, U.S. policy makers see other reasons for researching these deposits. Oil-drilling operations in the Gulf of Mexico are now moving into water more than 1,000 m deep and are



A sound picture: Geologists rely on seismic waves to locate hydrate layers, shown by arrows in this image taken off the coast of Japan.

A map of Japan shows suspected fields of methane hydrates. Next year, the Japan National Oil Corp. will drill into region number 4.

starting to drill through methane hydrate layers more frequently, raising safety concerns. A drill spinning through the hydrate can cause it to dissociate, and each liter of melted hydrate releases 160 liters of gas, says Robert S. Kripowicz, acting assistant secretary for fossil energy at the U.S. Department of Energy.

The freed gas can explode out of the hole, causing the drilling crews to lose control of the well, a costly problem to solve.

"Offshore operators are increasingly reporting problems of drilling through hydrates," Kripowicz told the House energy subcommittee.

Engineers are exploring whether unstable hydrate layers could give way beneath oil platforms or even play a role in triggering tsunamis (SN: 10/3/98, p. 221). Climate researchers have also grown concerned about hydrates because global warming could melt some shallow methane deposits, releasing millions of tons of this potent greenhouse gas into the air.

With so little known about methane hydrates, energy experts say that it is hard to predict whether society will ever tap into these deposits as a fuel source. Still, the Japanese initiative has spurred other oil companies to take an active interest. At a meeting last month in Chiba City, Japan, a group from Shell International Exploration and Production, B.V., discussed its analysis of exploiting methane hydrates. "Our consensus is there are no show stoppers. There is nothing that we cannot handle technically. If we encountered a good accumulation of natural gas hydrates, we could develop it with the existing technology," says Wim J. A. Swinkels, a member of Shell's gas hydrate team. The only issue standing in the way right now, he says, is economics.

Yet, the days of plentiful oil and gas are numbered, and countries will require new energy sources to keep the wheels of progress spinning. "We're enjoying a wonderful economy right now, largely because of the very low cost of energy," said Rep. Vernon J. Ehlers (R-Mich.) at the recent hearing on methane hydrates. "I'm very worried about what's going to happen when the cheap oil is gone, and we're not paying enough attention to it." □

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for self-importance through power. The young are especially vulnerable because adolescence is a period of wide vacillation between self and other—the stage in which we try each bias, testing our wings as independent decision makers. Their need for security can be intense.

M.M. Kramer
Wausau, Wis.

Although every anecdote of violence in the article "Incriminating Developments" quite appropriately describes the actions of boys, the article makes no mention of the possible role of gender in juvenile violence. It is a wonder that so many learned professionals can apparently ignore the fact that about 90 percent or more of all violent conduct is the conduct of boys and men. If we ever hope to understand these terrifying events, we must first ground our inquiry in reality by asking about the roots of aggression and violence in boys.

Judith A. Ferry
Kingston, N.Y.

Researchers have long noted the surplus of male violence, although the rate for females is now rising. —B. Bower

More experts on experts

The sooner we figure out how experts make decisions, the better. Gary Klein, a psychologist, calls the experts' process "naturalistic decision making" as opposed to whatever it is the rest of us rely on ("Seeing through Expert Eyes," SN: 7/18/98, p. 44). Patricia Benner, a nurse, proposed a similar concept about nurses' decision making (*From Novice to Expert*, 1984, Addison-Wesley).

Sandy Oestreich
North Redington Beach, Fla.

A colleague and I were both surprised that you could write such a long article without mentioning case-based reasoning once.

It was developed primarily by Janet Kolodner at Georgia Tech about 10 years ago and has been the basis for a wide range of expert systems that have been used to recognize situations and apply and tailor solutions to them. There are several commercial systems based on the technology.

An area for future research along these lines would be areas like sports officiating. Sports officials first have to learn the laws of their respective games and then learn how to recognize situations and react appropriately. Usually, events happen far too quickly to be able to reason out whether a foul has occurred. Very often, judgment enters into decisions when it is necessary to gauge the impact of an action. The World Cup presented many of these opportunities recently.

Ivan Mann
Birmingham, Ala.