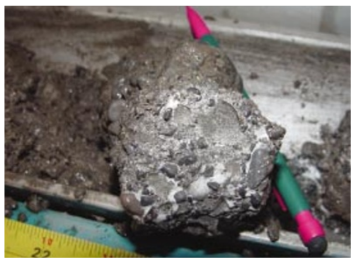
Fire from ice

Natural gas is in great demand, and researchers know where vast amounts are hidden — in icy crystals called hydrates. But getting it out is another matter, as David Adam finds out.

T. COLLETT/US GEOL. SURVEY



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What a gas: researchers at Mallik Field, Canada, used a drilling rig (top) to mine methane from buried hydrate crystals (above).

It's unlike fossil-fuel companies to ignore an untapped energy resource. Yet from the Arctic tundra to the Indian Ocean, huge reserves of methane lie undisturbed, trapped in strange, ice-like crystals. Estimates of the extent of these deposits vary wildly, but they could contain more than twice as much methane as known conventional gas reserves[1]. If just a fraction of this could be recovered, the deposits would be a viable energy source.

The energy companies' reticence is understandable, however. Extracting methane from the crystals, which are known as hydrates, is costly. The deposits are also considered a nuisance by many. Catastrophic releases of gases from hydrates disrupt attempts to drill for oil, and a few researchers have speculated that they could lie behind the mysterious disappearance of some ships.

But things could be changing. The US National Petroleum Council, a government advisory body, estimates that shifting from coal- and oil-fuelled power stations to cleaner, methane-powered alternatives, together with increased use of natural gas in homes and industry, will push up US demand for methane by 40% over the next 15 years. And as the importance of secure energy sources grows, prompted in part by continued instability in the Middle East, so does the need for more hydrates research.

The deposits form when high pressure causes water in sediments to freeze at higher temperatures than normal, giving rise to a solid containing unstable cavities rather than typical ice. As the temperature continues to fall, the cavities collapse, forming normal ice. But in some sediments, bubbles of methane rise up from underlying reservoirs and fill the cavities, preventing them from collapsing. The result — methane hydrate — looks like normal ice but burns if touched by a flame.

Fuelling progress

In the past decade, several countries have set up research programmes focused on hydrates — Japan, for example, hopes that hydrates could contribute to its energy production within a couple of decades. Estimates of the amount of gas that could be extracted are encouraging, and tentative drilling experiments have been successful. Earlier this year, researchers successfully tapped subterranean deposits for the first time. "As long as energy supplies are not threatened, people can always find cheaper fuel than hydrates," says Bahman Tohidi, head of the Centre for Gas Hydrate Research at Heriot-Watt University in Edinburgh, UK. "But now the political situation is not so stable, methane hydrates begin to look more attractive."

Hydrates form only within a narrow range of pressure and temperature (see chart, overleaf), so they are restricted to certain locations. Some deposits are hundreds of metres beneath the sea floor, in areas where the water is more than half a kilometre deep. Similar conditions cause hydrates to build up around a kilometre below the Arctic tundra. But although geologists now find it relatively easy to locate hydrate deposits, extracting the methane is another matter.

Additives such as methanol can be used to release the methane in a controlled manner, but most experts fear that the chemicals could, in some locations, pollute nearby aquifers. Reversing the conditions that led to the hydrates' formation is one alternative. Most extraction schemes involve heating hydrate deposits, reducing the pressure on them, or a combination of the two — but each technique comes with problems.

Using hot water to release the gas requires large amounts of energy. Reducing the pressure on the deposits also releases methane but, although less energy-intensive, this method cools the surroundings, perhaps enough to make the hydrates reform. Brad Tomer, head of the US Department of Energy's (DOE) National Methane Hydrates Program at the Strategic Center for Natural Gas in Morgantown, West Virginia, thinks this could be avoided by continuing to reduce the pressure, but admits that long-term tests would be needed to evaluate this idea.

Attempts to compare these methods began last January. Most usable hydrate

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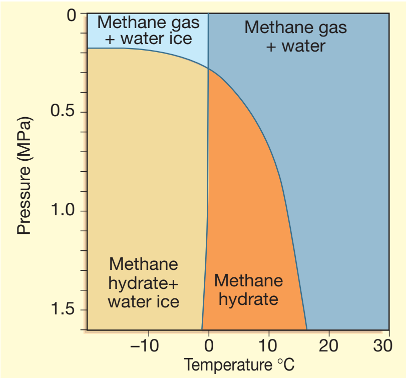

Phase chart for a mixture of methane and water; pressure increases with subterranean depth.

deposits probably lie offshore, but it is cheaper to begin with those beneath the Arctic. One of the most promising sites lies in Mallik Field in Canada's Northwest Territories. As well as abundant hydrates, the site has similar geology and reservoir conditions to many offshore deposits, making it an ideal and accessible testing ground.

Last winter, a group of researchers from Canada, Japan, India, Germany and the United States began probing the hydrates. The bulk of the researchers' experiment, led by the Geological Survey of Canada, involved drilling into the hydrates, circulating warm water for several days and measuring the amount of gas produced. They also carried out pressure-reduction trials by carefully sucking out residual water.

Turn on the flare

Those involved say that they were encouraged by the amount of methane produced — enough to ignite a flare similar to those seen burning over oil rigs. But whether the yellow flame is symbolic or a genuine step forwards remains to be seen. The researchers are confident that they will get more energy out than they put in, but that alone will not make extraction economically worthwhile. It might be financially viable to power an on-site turbine, for example, but not to pipe it to a power station. Exact details of the results are being kept under wraps until 2004, when confidentiality agreements with energy companies that helped to fund the work expire.

M. NIXON/GEOL. SURVEY CAN.

Low risk: Timothy Collett (far left) is confident that hydrate mining is not unduly dangerous.

DOE-funded researchers will begin examining a different — and potentially more promising — production technique this winter in Alaska. Many hydrate deposits lie above conventional methane reservoirs. Draining this gas could reduce the pressure on the hydrates, causing them to melt and allowing the escaping gas to top up the reservoir. "It's likely that the first production from gas hydrates will be made economically viable by free gas below," says Timothy Collett, a hydrates researcher with the US Geological Survey in Denver, Colorado.

The Indian and Japanese governments agree — both are attempting to produce methane from offshore deposits in this way. In Japan's case, the focus is the Nankai Trough off the country's southern coast. Tetsuo Yonezawa, who heads the hydrates programme of the Japan National Oil Corporation's Technology Research Centre in Makuhari, hopes to begin commercial extraction within 15 years.

No one has proved that this method will work, but a natural methane reservoir topped up by dissociating hydrates may already exist. Methane was extracted from the Messoyakha gas field in Siberia from 1969 to 1985, but the pressure drop in the field was less marked than expected. A layer of methane hydrate is thought to overlie part of the reservoir, and many experts argue that it is producing replacement gas and so helping to maintain the pressure. Not everyone agrees, however. Methane reservoirs do not release gas at constant pressure, and others argue that the pressure change is within normal variability[2].

The issue might become clearer if researchers can find out exactly how big the Messoyakha deposits are, but hydrates are hard to identify remotely. Engineers can use seismic waves to identify the presence of hydrates, but cannot deduce how much methane they contain. Drilling for samples can confirm whether hydrates actually exist, but the deposits occur both as relatively large layers and as smaller nuggets, so it is difficult to build up a big picture in this way.

By a landslide

This makes it difficult to know how much gas can be exploited by draining an underlying reservoir. But the uncertainty also gives researchers other worries. Hydrates could lend mechanical strength to the sediment. Removing them might make the sea floor fail, producing underwater landslides and enormous uncontrolled gas releases. Massive releases of methane in the geological record are, for example, associated with the collapse of seafloor slopes[3]. Right now, this is a worrying possibility that hydrates researchers simply have to live with. "You always keep in mind that the extreme is possible," says Collett. "But the likelihood of it happening is pretty low. After all, we probably drill into hydrates somewhere in the world every day."

The possibility of such events is behind

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Brad Tomer is optimistic that hydrates can be tapped by reducing the pressure on the deposits.

one of the most enduring stories about hydrates: that sudden releases of gas could sink ships by making the water below the vessel less dense. Some researchers have speculated that an escape of methane could have sunk the *Gaul*, a trawler that went down in the Barents Sea in 1974. The loss of the *Gaul* attracted attention because no distress call was ever received, and the wreck, which was discovered in 1997, appears to be in good condition.

Such claims are greeted with scepticism by most hydrates researchers. In the case of the *Gaul*, an investigation by the British Marine Accident Investigation Branch, released in 1999, suggested that high waves had caused the vessel to capsize, although the issue is being further investigated by a government inquiry. But engineers say that gas releases can sink ships — although it has nothing to do with buoyancy.

Energy companies, for example, have lost ships when large amounts of methane have been released from conventional reservoirs during drilling projects. The force of the escaping gas tips the boat, causing it to capsize and fill with water through open hatches. "Poor seamanship, together with a very large hydrate release, could provide conditions conducive to sinking," says Jerome Milgram, an ocean-engineering researcher at the Massachusetts Institute of Technology who has studied such accidents.

Only time will tell whether the uncertainties surrounding the extraction of methane from hydrates can be cleared up. Even the most optimistic advocates concede that lack of knowledge about the distribution of hydrates, and the methods needed to extract them, present large obstacles. But many researchers remain hopeful. They point out that other commercial energy sources, such as the pockets of methane gas found alongside coal, initially seemed impossible to exploit. Necessity is the mother of invention, after all. If the need for natural gas continues to increase, some of the problems will undoubtedly seem less daunting. ■

David Adam is a news and features writer for *Nature*.

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US National Methane Hydrate Program
➧ **www.netl.doe.gov/scng/hydrate**

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