MARINE RESERVES

Offshore gas hydrates begin to add up

Several projects are under way to study this potentially huge natural resource.

By Reservoir & Resources Editor KARL LANG

With gas hydrates it's easy to get lost in the numbers. To begin with, the units of choice are 10^{15} cu/m, or about 35,000 Tcf. Gas hydrates are thought to hold twice the energy available in the world's entire complement of coal, oil and conventional gas.

Combine that with the range in estimates of worldwide gas hydrate resources, which differ by a factor of nearly 40,000 for the submarine hydrate category alone, and recognize that only relatively small samples of gas hydrate have been obtained, at great difficulty and expense, and that most of these essentially disappeared within a few seconds.

Such orders of magnitude make it impossible to ignore the potential of gas hydrates, but the uncertainty surrounding their character and accumulation makes it difficult to decide just how much attention they deserve. During the past 5 years, efforts have increased to gain a better understanding of gas hydrates: where and how they are found, how they behave and what we need to learn to either avoid or extract them. The role of gas hydrates in the natural environment, in particular how they might affect global climate over time, also is of increasing interest to several governments.

In the United States, the effort has been driven by an increase in funding behind a coordinated effort among national labs, universities and industry partners. In fiscal year1999, the US Department of Energy (DOE) spent US $500,000 on methane hydrate research. During fiscal year 2001, $17 million was invested, $10 million by DOE and another $7 million by other government entities. Coordinated by the Strategic Center for Natural Gas at the National Energy Technology Laboratory (NETL), the research program involves 13 government labs or agencies – including the US Geological Survey (USGS), the Minerals Management Service and the National Oceanographic and Atmospheric Administration – 10 universities and at least seven exploration and production companies. As might be expected, while the results have begun to answer some questions, they also have identified additional unknowns regarding the extent and character of this potentially enormous resource.

Character of natural gas hydrates

Gas hydrates are a form of energy mineral found in onshore sediments in polar regions and in offshore sediments under certain conditions of seafloor temperature and gas composition. Hydrates consist of water molecule cages that surround and trap hydrocarbon molecules in a lattice network. (Another term for hydrates, *clathrates*, is derived from the Latin word for "lattice.") With a structure and appearance similar to ice, 1 cu ft of solid hydrate contains between 150 cu ft and 180 cu ft of gas at standard conditions. Hydrate crystalline architecture follows three basic forms, depending on the amounts of heavier hydrocarbons present. Within sediments, depending on the geothermal gradient and the depth of water or permafrost, there can be a region of several hundred meters where hydrates exist as stable solids. Deeper, the increased temperature precludes their formation.

Hydrates, particularly those found in the Gulf of Mexico, can be more accurately thought of as a vein-filling mineral deposit than a pore-filling alternative to conventional gas. Samples of hydrate collected from seafloor accumulations in the Gulf are quite hard and appear as dirty white bands within cores.

Occurrences of gas hydrates have been recorded worldwide along the continental margins and in Arctic Alaska, Canada and Siberia. Onshore, hydrates have been observed or inferred in several areas, more recently in the Alaskan North Slope and in the Mackenzie Delta of Canada's Northwest Territories. In Canada, an international collaborative effort resulted in the drilling of the **Mallik 2L-38** well in early 1998. Logs in this well inferred the presence of gas hydrate at a fairly high concentration over several hundred meters. In February and March, a follow-up test was drilled in the same area. Japan National Oil Co., one of the project partners, reported methane gas was successfully extracted from hydrates in the deeper than 3,000-ft (915-m) well using warm water to dissociate the hydrate layer. Other efforts to drill, core and test similar wells on the North Slope are under way.

Significant known offshore occurrences include the Nankai Trough southeast of Japan, Hydrate Ridge off the coast of the US Pacific Northwest, Blake Ridge off the coast of South Carolina and a wide deepwater area in the northwestern Gulf of Mexico. With the exception of Hydrate Ridge, which is smaller, each of these areas has an estimated areal extent on the order of 10,000 sq miles to 20,000 sq miles (25,900 sq km to 51,800 sq km).

Offshore accumulations of gas hydrates can be categorized as structural, stratigraphic or combinations of the two. Structural accumulations can be associated with a fault system, where gas migrates from depth along the faults to the surface, or with mud volcanoes. (The Haakon Mosby mud volcano in the North Sea is a classic example.) Such accumulations often exhibit hydrate mounds on the seafloor, chemosynthetic communities of sea life surrounding these mounds and gas plumes escaping into the water column.

Stratigraphic accumulations occur as laterally extensive lenses of hydrates in relatively permeable sediment zones. In this case, the hydrate is generally less concentrated, occurring as smaller crystals in the pore spaces, and more widely disseminated. The Blake Ridge and Nankai Trough accumulations are examples. In both of these areas, bottom-simulating reflectors

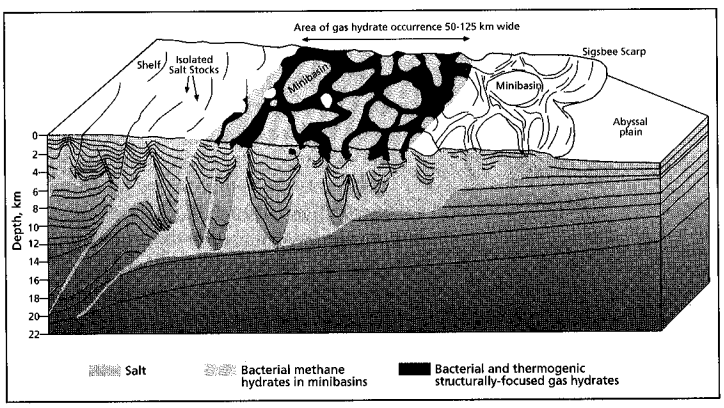


Figure 1. A schematic of gas hydrates localities in Gulf of Mexico reveals biogenic methane hydrate is formed in mini-basins. (After Milkov and Sassen, 2001).

(BSRs) seen on seismic sections are indicators of hydrates in the subsurface sediments. BSRs are strong seismic reflectors that parallel the seafloor but cut across other reflectors and are believed to be associated with the base of hydrate-bearing sediments.

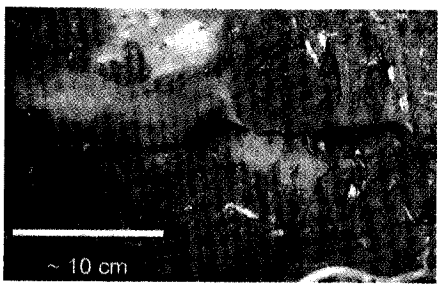
Gulf of Mexico hydrates

While stratigraphic and structural accumulations exist in the Gulf of Mexico, most gas hydrates are focused along structures formed by ongoing salt deformation and active faulting. Venting of thermogenic gas along faults and through fractured, unconsolidated shallow sediments leads to hydrate concentrations of 20% to 30% of the sediment volume in some places. Cores showing 100% gas hydrate intervals have been observed.

Biogenic (bacterial) methane hydrate is also formed in the mini-basins between the salt-induced ridges (Figure 1). This type of hydrate, crystallized in lower-permeability sediments from methane generated *in situ* or migrated from depth over a long time, exhibits lower concentrations (no more than 1% to 2% of sediment volume).

As shown in Figure 2, Gulf of Mexico gas hydrate accumulations have been located across an area roughly 300 miles (480 km) long, 60 miles (95 km) wide and encompassing more than 20,000 sq miles (51,800 km) at water depths from 1,450 ft to 7,900 ft (445 m to 2,400 m). More than 3,000 piston cores have been retrieved, and gas hydrate has been recovered from such cores and from submersibles at more than 53 sites. Most hydrate is found within the first 20 ft (6 m) of sediment and often is observed outcropping on the seafloor. The most studied localities include the Bush Hill hydrate mound at **Green Canyon 184/185** (near the **Jolliet** platform), a location at **Mississippi Canyon 852/853** (between the **Mars** and **Ursa** developments) and sites at **Green Canyon 234** and **Atwater 425**.

Dr. Alexei Milkov, a gas hydrates researcher with Dr. Roger Sassen and the Geochemical and Environmental Research Group at Texas A&M University, said gas hydrates may be present in the Gulf of Mexico beyond the northwestern region, but accumulations are likely to be small examples of the biogenic sort since hydrocarbon venting from mature petroleum systems is uncommon beyond that region.



Outcroppings of gas hydrates are common on the Gulf of Mexico seafloor.

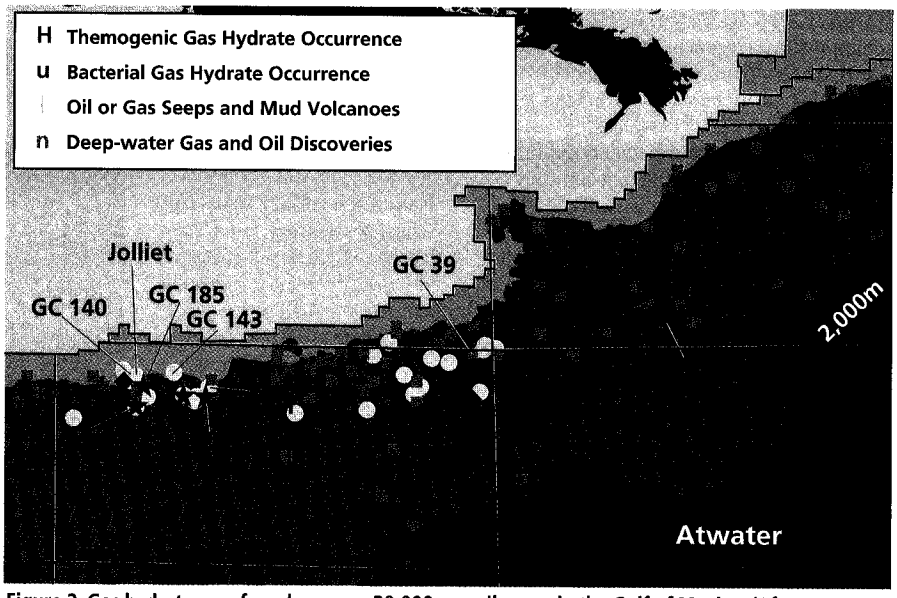


Figure 2. Gas hydrates are found across a 20,000-sq. mile area in the Gulf of Mexico. (After R. Sassen, *et al*, 2001.)

"Structurally focused gas hydrate accumulations in the Gulf of Mexico could contain about 280 Tcf to 390 Tcf, while the stratigraphic accumulations in mini-basins could contain another 70 Tcf to 100 Tcf," Milkov said. "But even if we consider only the highly concentrated accumulations present near the venting gas localities, that is still a number one or two times the current conventional gas reserves of the United States. If gas hydrate production ever makes economic sense, it most probably will be the gas hydrate 'elephants' associated with structurally focused accumulations and the surrounding production and transportation infrastructure in the Gulf of Mexico that will make it possible."

In comparison, the Blake Ridge area off the Atlantic coast has been sampled at 19 sites during Ocean Drilling Program and Deep Sea Drilling Project voyages. Gas hydrate has been recovered in four cases at depths to 1,100 ft (335 m) subbottom. Indirect evidence of gas hydrates (BSRs) has been used to extrapolate their lateral and vertical distribution within the sediments. These seismic indicators together with the core information have been used to estimate that more than 1,000 Tcf of methane could be dispersed across the area. The low concentration, however, would appear to be a significant barrier to recovery.

Next steps in data gathering

In July 2002, a research cruise, organized and co-funded by DOE and the USGS, will collect giant piston cores – up to 160 ft (50 m) long – to determine the lateral distribution of gas and gas hydrate in-basin sediments with ambiguous gas hydrate indicators at depth and near known hydrate accumulations. Another important objective is to determine the strength of sediment to assess the hazards of placing drilling platforms on the seafloor where slumping is common. The information obtained in this sampling cruise will be used to help guide drilling in 2003 and 2004 to obtain more information about hydrate accumulations.

The cruise will be carried out on the French research vessel *Marion Dufrense* as part of the Images program, an international effort to understand the mechanisms and consequences of climatic changes using oceanic sedimentary records that also will be assessing cores for this purpose. A multiton core barrel is dropped from the vessel and retrieved by cable. Five transects constituting 22 sites have been tentatively chosen in the Gulf of Mexico. The first is a slump feature east of the Ursa tension-leg platform (TLP) in **Mississippi Canyon 810/854**. The second is an area with some seismic indication of hydrates in **Garden Banks 423/554**, southwest of the **Auger** TLP. Third is a feature north of the **Cooper** development in **Garden Banks 344/345**. The fourth is a midbasin test in the **Garden Banks 301/302/345** area. And the final site is north of the **Baldpate** platform, at **Garden Banks 215/216/239**.

The drilling site to be chosen based in part on the data obtained by these piston cores will provide the first opportunity to calibrate geophysical data with hydrate occurrence in the Gulf of Mexico. It is hoped there also will be an opportunity to obtain and study core from a massive hydrate accumulation.

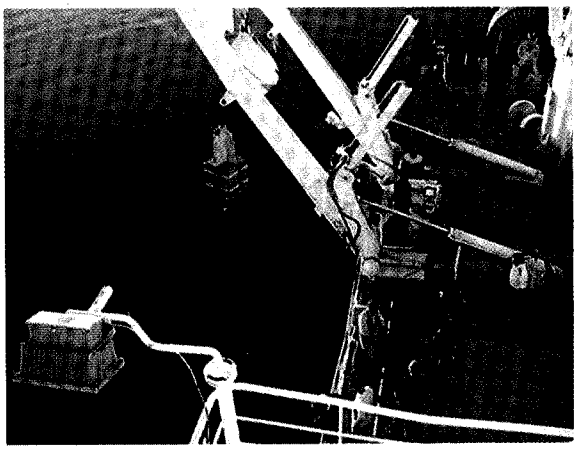
Drilling a test well into a hydrate accumulation is a goal of the Gulf of Mexico Gas Hydrates Joint Industry Project (JIP). This JIP, which includes ChevronTexaco, Schlumberger, Phillips Petroleum, Halliburton and Conoco in collaboration with NETL and DOE, is investigating naturally occurring gas hydrates in the Gulf of Mexico. The primary goals include:

- characterization of sediments containing hydrates;
- understanding potential safety hazards associated with drilling and pipeline laying through sediments containing gas hydrates;
- developing a database of existing seismic, core, log, thermophysical and biogeochemical data to identify hydrate-containing sites in the deepwater Gulf of Mexico;
- implementing a drilling and sample collection program to collect data and obtain cores; and
- developing wellbore and seafloor stability models pertinent to hydrate-containing sediments.

Phase one of this multiphase, multiyear project will be devoted to data collection, analysis, model development and protocol generation to detect and characterize hydrate-containing sediments. Results will be used to plan and execute the drilling, sampling and data collection field program to be conducted in the second phase.

Research effort growing

Whatever the final label for methane hydrates – huge resource of clean-burning gas to be tapped when conventional resources dwindle or subsea hazard to be carefully avoided when drilling or laying pipelines – the data being gathered is valuable and timely. While the US research investment is substantial, it is still significantly less than that of some other countries (in particular, Japan). Accordingly, the volume of scientific information available and the number of papers published on the topic should continue to grow. While not a near-term solution to energy demand, the hydrate research programs under way are good examples of long-term planning and collaboration on the part of government and industry. E&P



A Piston core apparatus is dropped from the French research vessel *Marion Dufresne*. (Photo courtesy of IFREMER).

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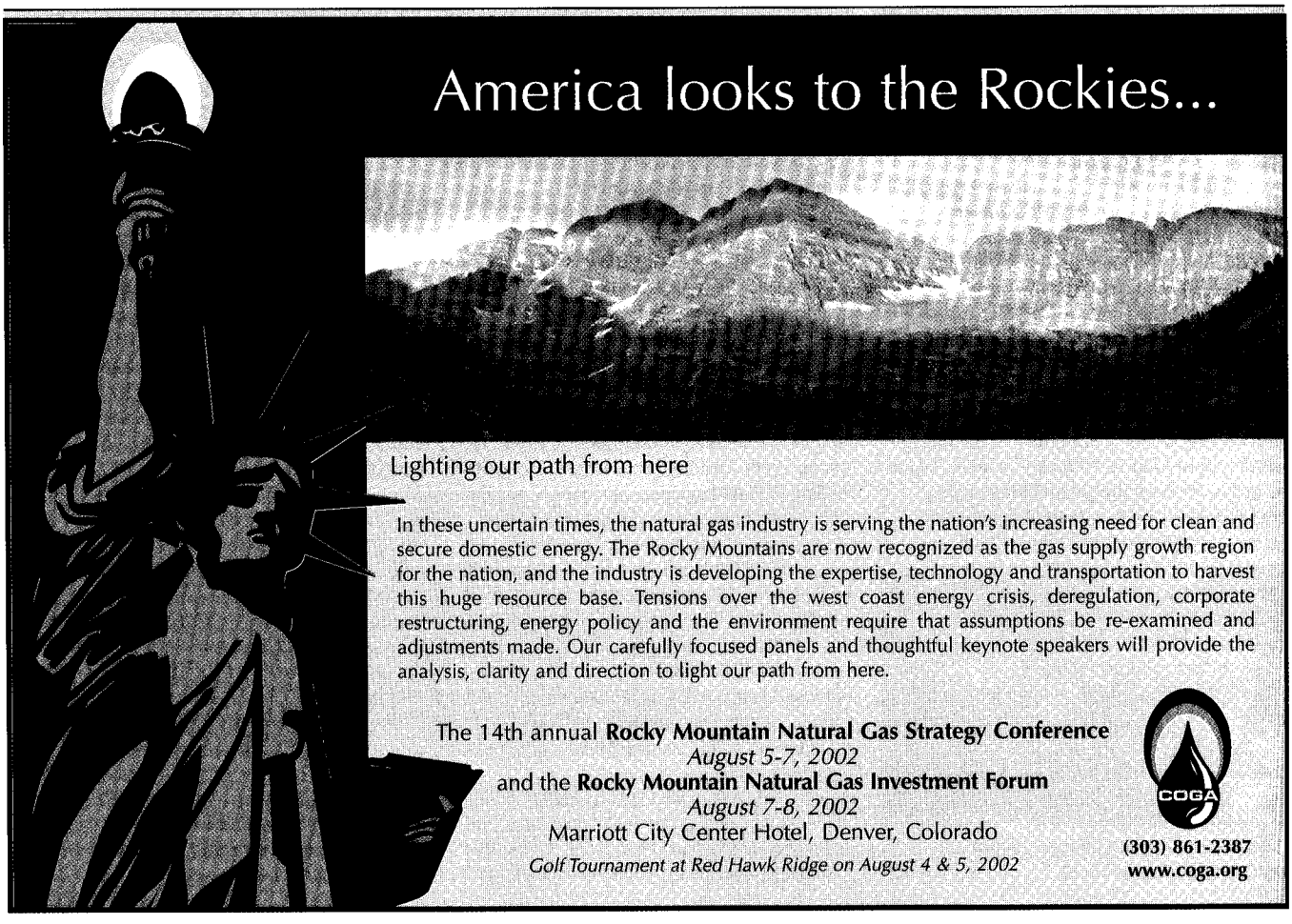

Lighting our path from here

In these uncertain times, the natural gas industry is serving the nation's increasing need for clean and secure domestic energy. The Rocky Mountains are now recognized as the gas supply growth region for the nation, and the industry is developing the expertise, technology and transportation to harvest this huge resource base. Tensions over the west coast energy crisis, deregulation, corporate restructuring, energy policy and the environment require that assumptions be re-examined and adjustments made. Our carefully focused panels and thoughtful keynote speakers will provide the analysis, clarity and direction to light our path from here.

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