Gas hydrate E&P: Dispelling the myths

Through the integration of information gained during the past 5 years, production of natural gas from hydrate should be viable in the near term using a petroleum systems' approach.

AUTHORS

Arthur H. Johnson, *Hydrate Energy International; and* ***Michael A. Smith,*** *US Minerals Management Service*

Natural gas hydrate is a solid, crystalline material that forms when gases, such as methane, combine with water under conditions of relatively high pressure and low temperature. The hydrate structure consists of an open latticework of water molecules that is stabilized by the gas molecules residing within regularly located voids or "cages." A single cubic foot of gas hydrate yields about 164 cf (4.6 cu m) of gas at atmospheric pressure along with about 0.8 cf of water.

The physical conditions under which gas hydrate is stable (Figure 1) have long been understood for pipelines, and the flow assurance aspects of gas hydrate have been studied for decades. However, these conditions also exist in sediments along continental margins throughout the world where water depths are greater than about 1,600 ft (487.8 m) and in sediments below permafrost in polar regions. Gas hydrate may occur in these locations at appropriate pressure and temperature conditions within a zone of hydrate stability that extends into the sediments to depths of up to many hundreds of feet. The base of the hydrate stability zone is primarily determined by the geothermal gradient, as the increasing temperature of the deeper sediments crosses the hydrate phase boundary. The thickness of the hydrate stability zone varies with factors including temperature, pressure, gas composition and salinity, and increases with greater water depths.

As the pressure and temperature conditions for hydrate stability occur along continental margins throughout the world, the potential for large accumulations of commercial gas hydrate deposits would appear to be enormous. Other factors, however, are also required. First among these is an adequate flux of methane (or other hydrocarbon gases) into the sediment. The gas may be biogenic or thermogenic, but with either source, there must be a mechanism for migration into the hydrate stability zone. Sulfate in sediment fluids can react with methane, and in locations with an insufficient methane flux, commercially viable gas hydrate deposits will not be present. The second factor is lithology. In most locations worldwide, the sediments within the hydrate stability zone are predominantly shales, and these comprise 3% to 5% of the sediment volume where hydrate is present. In contrast, sands within the hydrate stability zone typically have high hydrate saturations within the pore space of the sediment, exceeding 80% saturation in some locations.

During the past 20 years published literature on gas hydrates has debated the total volume of gas hydrate in the world, and significantly large numbers are typically cited. From an industry perspective, however, that discussion misses the point. What matters is the volume of gas that is concentrated in sediments that can be commercially recoverable. The vast amounts of hydrate dispersed in deepwater shales have little relevance to resource development.

Exploration for commercial gas hydrate resources must include assessments of the pressure/temperature conditions of a basin; hydrocarbon source, timing and migration; and sediment distribution. Many of the world's basins have the necessary components for commercial gas hydrate accumulations. One of the most promising is the deepwater Gulf of Mexico where prospect economics are enhanced by the presence of existing infrastructure.

The domestic oil and gas industry has largely avoided serious consideration of commercial gas hydrate development because of valid economic considerations based on early investigations. New information about hydrate formation and occurrence that has emerged in recent years has not yet been widely incorporated into industry planning. As a result, there are many outdated concepts (myths) about the resource potential of gas hydrate that need to be dispelled if the remaining challenges of gas hydrate development are to be addressed and overcome.

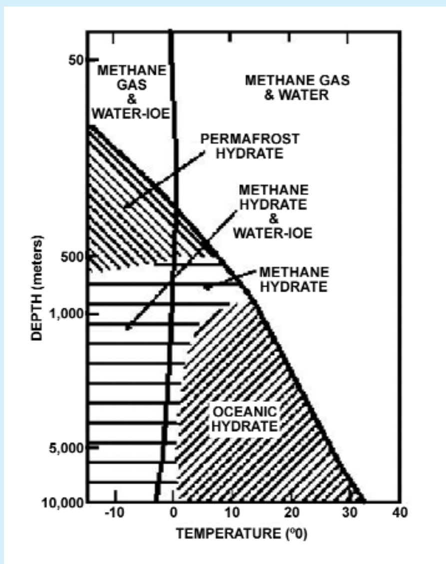

Figure 1. The above graphic is a phase diagram for methane hydrate, with permafrost and oceanic methane hydrate P-T fields delineated.

Myth No. 1 — A commercial gas hydrate deposit is always associated with a seismic 'Bottom Simulating Reflector'

The base of the hydrate stability zone may be identified on seismic data in some locations by a strong reflection

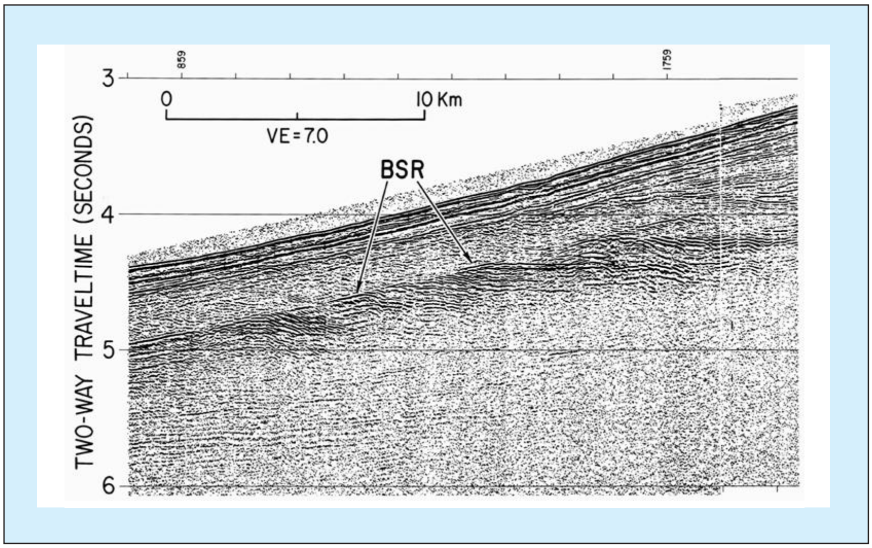

Figure 2. A seismic profile on the North Carolina continental rise illustrating a 'classic' Bottom Simulating Reflector.

with negative amplitude that results from the impedance contrast between hydrate-bearing sediments above the phase boundary and free gas-bearing sediments below (Figure 2). During the 1980s and 1990s, this seismic event, termed a "Bottom Simulating Reflector" (BSR) because it was observed paralleling seafloor topography and cutting across stratal boundaries in dipping sediments, was the primary means of identifying areas of interest for hydrate investigations. Cores recovered by Ocean Drilling Program and Integrated Ocean Drilling Program expeditions confirmed the presence of gas hydrate in sediments overlying the BSR.

By the late 1990s, hydrate exploration and assessment was commonly viewed as a BSR hunt. The most pronounced BSRs were off the Carolina coast on the Blake Outer Ridge, and that location became the focus of gas hydrate investigations for the United States. In contrast, few BSRs were found in the Gulf of Mexico and, where present, they tended to be far weaker than those along the Atlantic margin. As a result, hydrate studies in the Gulf of Mexico focused primarily on seafloor hydrate mounds and near-seafloor accumulations associated with gas vents instead of the potential of deeper hydrate reservoirs.

Worldwide drilling results during the past 5 years have significantly altered these models. While hydrate is present in the sediments at the Blake Outer Ridge, the concentrations are low, 5% of the rock volume or less. In addition, the sediments in the hydrate-bearing interval are uniformly composed of 60% clay. The poor reservoir lithology, the low hydrate concentrations and the lack of infrastructure make the Blake Outer Ridge an unlikely candidate for commercial hydrate development. A well-defined, mappable BSR is also present in Keathley Canyon at one of the sites the US Department of Energy (DOE) Gulf of Mexico Gas Hydrate Joint Industry Project drilled last year (Figure 3). In these wells, the sediment within the hydrate stability zone was predominantly shale and low volumes of hydrate occurred well above the BSR.

Underlying the problem of using a BSR is the nature of the BSR itself. When present, a BSR indicates the existence of minute gas bubbles within the sediment beneath the phase boundary but conveys little or no information about the overlying hydrate-bearing sediments. The BSR is useful in gas hydrate assessments for delineating the base of the hydrate stability zone but is absent in many prospective basins. In some basins, strong, continuous BSRs may delineate locations with poor reservoir lithologies. Much of the gas hydrate resource in the Gulf of Mexico occurs in discrete sands contained within the zone of hydrate stability and is unrelated to the presence of a BSR. Therefore, hydrate-bearing sands may be associated with a BSR, and where present, BSRs in sandy intervals often are discontinuous.

A successful exploration approach must consider gas hydrate reservoirs as part of the broader petroleum system and take into account sand deposition and hydrocarbon migration. Using this approach, the deepwater Gulf of Mexico has potential for commercial development of gas hydrate resources.

Myth No 2: The best gas hydrate deposits are in remote areas, far from current operations and under leasing and drilling moratoria

This myth grew out of the early emphasis on BSRs and the strong scientific focus on the Blake Outer Ridge and other remote locations. The large volume of publications focused on that location was seen to imply that the Atlantic margin was a primary site for future hydrate development, and that to be prospective, other areas should have comparable BSRs. Researchers studying the Pacific coast also identified gas hydrate locations offshore California and Oregon.

These areas were under moratoria. Future leasing and drilling programs could be expected to generate a hostile response from a significant segment of the public, and a natural assumption developed for many in the oil and gas industry that gas hydrate development would not be able to proceed for decades. In addition, most of the locations on the US Atlantic and Pacific margins are lacking in infrastructure, such as platforms or pipelines, severely impacting development economics.

With the information now available, commercially viable concentrations of gas hydrate are most likely to occur in basins where stratigraphy and hydrocarbon migration are optimal within the hydrate stability zone. These basins include the North Slope of Alaska and the deepwater Gulf of Mexico, where less political opposition to hydrate development should be expected. In addition, large volumes of existing seismic data in these basins can be utilized to assess hydrate potential, and the abundance of infrastructure significantly enhances the economics of development.

Myth No 3: Development is 20 or 30 years away and will require new methods of production

If the oil and gas industry's primary objective was to commercialize gas hydrate deposits comprised of a few percent of hydrate dispersed in shales (in 10,000 ft or 3,048 m of water), a new approach to development would be required, and a 30-year timeframe might be overly optimistic. However, the production of gas from hydrate-bearing sands will mainly entail the adaptation of existing industry technology.

In the simplest case, where a hydrate-bearing sand extends downdip across the phase boundary and includes free gas, simply producing the gas may lower reservoir pressures so hydrates dissociate (revert to gas and water), feeding more gas into the reservoir. This production approach involves little new technology. Other production scenarios involve heating or other forms of stimulation, which will yield higher production rates but increase operating expense. As with conventional gas reservoirs, hydrate-bearing reservoirs will involve a range of drive mechanisms, and the reservoir engineering aspects need additional study.

In 2002, an international consortium achieved a successful flow test from hydrate-bearing sands at the Mallik structure in the Canadian Arctic (Figure 4). While the rates of production were deliberately kept low, the test validated the producibility of natural gas from hydrate.

Because of increasing demand for natural gas, gas hydrate development programs are being undertaken in several nations, including the United States. The most ambitious programs are those of India and Japan, with India planning commercial production of gas from hydrate before the end of this decade. Successful development there will most likely accelerate development programs worldwide.

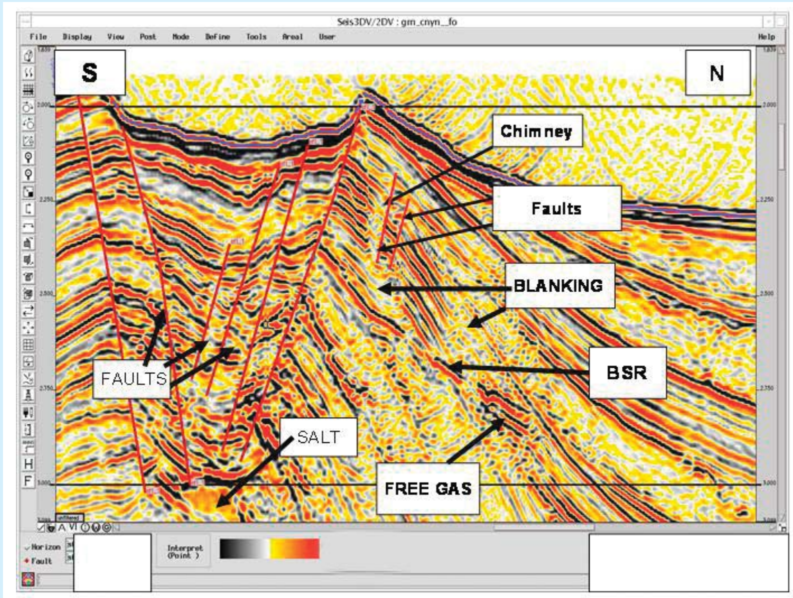

Figure 3. Three-dimensional time-migrated seismic section showing a Bottom Simulating Reflector (BSR) in the Green Canyon area. This example demonstrates the BSR (1) has high reflection amplitude, (2) has reversed polarity relative to the seafloor reflection, (3) has cross-cut bedding reflections and (4) is overlain by a blanking effect and underlain by free gas (from Kou and others, in press, The Leading Edge).

Myth No. 4: Hydrate resources in the Gulf of Mexico have no net present value, so they can be ignored in lease sales

In 1998, the Solicitor General of the US Department of the Interior determined that gas hydrate and associated free gas are included in the potential resources of deepwater Offshore Continental Shelf (OCS) oil and gas leases. The US Minerals Management Service recently completed a new assessment of technically recoverable gas hydrate reserves for the Gulf of Mexico and other offshore US basins. This assessment used 3-D multi-channel seismic, logging-while-drilling and electric logs, and other data to define sand fairways within the zone of hydrate stability and identify exploration wells that may have encountered hydrate within this sedimentary section. The DOE Gulf of Mexico Gas Hydrate joint industry project is currently evaluating locations likely to contain hydrate-bearing sands for a second drilling leg in the spring of 2008.

Significant technical, engineering and regulatory challenges will have to be overcome to delineate and begin production from Gulf of Mexico gas hydrate deposits. Shortages and increasing price and demand for natural gas, which could intensify from storm-related or politically caused supply interruptions, will increase pressure to fast-track hydrate exploration and production. Before commercial production from gas hydrate development programs in other countries appears to be imminent, the need to test production methods in the Gulf of Mexico may be unavoidable. Deepwater operators should already be considering accelerated hydrate research programs to be able to take advantage of the full value of some OCS leases.

Figure 4. Hydrate-derived gas is flared during the 2002 Mallik test in the Canadian Arctic.

For more information, refer to Max, M.D., Johnson, A., & Dillon, W.P. 2006. *Economic Geology of Natural Gas Hydrate.* Springer, Berlin, Dordrecht, 341pp E&P

To learn more about the issues that must be addressed and technologies that must be employed to move exploration for, and production of, methane hydrates forward, plan to attend the upcoming Commercializing Methane Hydrates conference Dec. 5 and 6 in Houston. For further details, please refer to the advertisement on page 48.