Exploration and Production of Gas Hydrates

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Introduction

Knowledge gained during the past several years has greatly improved our understanding of gas hydrates in the natural environment. Drilling results from the Mackenzie Delta, Nankai Trough, and several ODP legs show that gas hydrates are widespread along continental margins and in Arctic regions although concentrations vary considerably. Shales typically have low concentrations of gas hydrate while coarse clastics can have pore space gas hydrate concentrations of over 80%. Due to this concentration and the inherent porosity and permeability of such reservoirs, commercial production of gas from hydrate is most feasible from coarse clastics.

The pronounced seismic signature commonly referred to as a “bottom simulating reflector” (BSR) is not a consistent gas hydrate indicator for commercial accumulations. While more subtle seismic indicators are often present, some gas hydrate accumulations may be seismically transparent. Improvements in seismic processing techniques, however, have recently made exploration for gas hydrate accumulations more feasible.

Which Gas Hydrates Will Be Produced?

Gas hydrates occur in a variety of forms in nature. These include gas hydrates dispersed in shales, filling fractures, in mounds at the seafloor, and as pore filling in sands and gravels. Each of these forms requires different considerations for commercial recovery, yet any consideration of commercial gas hydrate production should be based on sound principles of petroleum geology and engineering.

A commercial gas hydrate prospect requires all of the basic components of any conventional natural gas prospect. These include reservoir lithologies with appropriate porosities and permeabilities where the gas hydrate can be concentrated and that allow a well to recover gas over a sufficiently wide area. The reservoir must have appropriate traps and seals. In addition, hydrocarbon source and migration must be sufficient to charge the reservoirs. Taken together, these components comprise a petroleum system that is just as important for gas hydrate exploration as for any conventional petroleum venture.

Where in the U.S. Will Gas Hydrate Be Produced?

Gas hydrate development will be most viable in areas where existing conventional infrastructure (such as pipelines and platforms) may be leveraged so that the gas hydrate production does not have to support the full cost of development. As with conventional petroleum development, gas hydrate development will require access to prospective acreage. This includes leasing, drilling, and producing. Commercial development of gas hydrates also requires that cost effective production technology is available. Any production scenario that uses existing technology is inherently more viable than one that involves entirely new methods.

Given these considerations, most gas hydrate accumulations are clearly uneconomical. The Blake Outer Ridge off the Atlantic coast of the United States has poor reservoir lithology, low gas hydrate concentrations, no infrastructure, and is under a moratorium for commercial development. The Pacific margin of the U.S. may have some viable lithologies, but lacks infrastructure in most locations and is also off limits for commercial development.

The North Slope of Alaska has all of the requirements for gas hydrate development with the exception of a means to take produced gas to consumers. When a gas transmission line is built, gas hydrate production should soon follow. The Western and Central Gulf of Mexico also has the potential for reservoir-quality sands within the hydrate stability zone, along with well established conduits for migration and a growing deepwater infrastructure. Thus Alaska and the Gulf of Mexico are the prime U.S. exploration targets for gas hydrates.

Business Issues

While there are many aspects of gas hydrates that are interesting to study, the commercial development of this resource requires that several critical questions be answered, and these should be the focus of future research. First is the determination of the total volume of gas that can be recovered from a given well. Second is the rate at which these reserves can be produced. Third is the operating expense associated with establishing and maintaining production. To the extent that these remain unknown, economic decisions cannot be made and development is not possible.

The commercial viability of gas hydrates is further impacted by the price of natural gas, especially the forecast price over the life of a gas hydrate project. Competition from other gas sources (such as LNG) may also limit gas hydrate development.

Gas Hydrate Production Methods

Several approaches to gas hydrate production are under consideration. First is depressurization of the reservoir through the production of subjacent free gas. This approach has the advantage of using the most common existing production technologies and requires no energy input to the reservoir. It is limited, however, to reservoirs with subjacent free gas. The endothermic dissociation of gas hydrate may limit production due to ice formation in the pore space and by the cooling of the remaining gas hydrate. The second approach is thermal injection using either hot water or steam. While this method should effectively dissociate gas hydrate, a source of excess heat is required to maintain economic viability. Such a heat source could include the produced water from nearby conventional oil operations.

A third approach to gas hydrate production is inhibitor injection using a solvent such as methanol or glycol. This method is both expense and could lead to such rapid dissociation of gas hydrates that fracturing of adjacent shales could occur, breaching the reservoir. While inhibitor injection might be used to initiate production from a gas hydrate reservoir, it is unlikely that it could be used on an on-going basis. A fourth approach is CO_2 injection. Carbon dioxide can replace methane in the hydrate structure, and its heat of formation exceeds the heat lost in the dissociation of methane hydrate. It is not clear that such replacement is viable for entire reservoirs, and CO_2 injection would require a source of CO_2. The final production approach would involve the physical removal of the gas hydrate – essentially strip mining the seafloor. This approach is both economically unfeasible and environmentally unsound.

Gulf of Mexico Prospects

A zone of gas hydrate stability exists in the deepwater Gulf of Mexico where the necessary pressure and temperature conditions occur. The presence of gas hydrates depends on the pressure and temperature conditions being met as well as on sufficient concentration of natural gas. Gas hydrates are often absent from sediments near the seafloor due to the reaction of methane with sulfate from seawater. Thus, while gas hydrates are physically stable in this zone, they may be chemically unstable. The base of the hydrate stability zone may parallel the seafloor; however local variations in heat flow often result in an irregular base of the zone. Thus, attempting to identify the base of the stability zone with BSRs can yield inconsistent results.

The most obvious gas hydrate accumulations in the Gulf of Mexico are the hydrate mounds that occur on the seafloor near vents. Deeper hydrate-bearing sands are a more viable commercial target but these are (as yet) unevaluated. Much of the recent research on Gulf of Mexico gas hydrates has involved piston coring and visual observation with submarines. Yet, piston cores will find only the near-surface hydrates in the vicinity of vents and do not penetrate deep enough into the subsurface to evaluate hydrate-bearing sands. The same faults that serve as conduits for hydrocarbons to the vents may also result in a strong flux of gas into sands within the stability zone. Seismic data show that the base of the hydrate stability zone is warped upward beneath at least some of the vents, probably in response to both temperature and salinity. In those locations, the gas hydrates may extend only a short distance beneath the seafloor, minimizing the volume of gas hydrate present.

In the Gulf of Mexico, conventional drilling by the oil industry has penetrated sediment with the pressure and temperature conditions for gas hydrates over 1000 times without demonstrating the presence of gas hydrates. This is explained by the fact that hydrate-bearing sands are difficult to identify with conventional industry drilling methods. The shallow section is usually drilled rapidly with large drill bits and with drilling fluids that typically have high salinity and added solvents. If logged at all, these shallow sections logged with LWD tools that do not effectively detect gas hydrates. As a result, the potential for hydrate-bearing sands in the Gulf of Mexico is essentially unevaluated.

In many areas of the Gulf, shallow faulting does not extent to the seafloor, and the flux of natural gas will be more strongly directed to shallow sands. In this situation thus there would be no indication at the seafloor of any deeper hydrate-bearing sands.

Answering the Critical Business Questions

During 2004 a joint industry program (JIP) will conduct research drilling in the Gulf of Mexico. The JIP is led by ChevronTexaco and includes several U.S. companies as partners along with Japanese and Indian companies and the U.S. Minerals Management Service. Significant funding for the program is being provided by the U.S. Department of Energy. While the focus of the program is on safety related to conventional offshore facilities, the program will also provide information that will help answer the critical business questions regarding commercialization of gas hydrate.

The JIP will drill a series of boreholes in the Keathley Canyon and Atwater areas of the Gulf during the 2nd Quarter of 2004. In addition to an extensive logging program, the JIP intends to utilize a pressure-coring device. With the availability of this new data set, substantial progress is likely in the next few years to assess the commercial potential of gas hydrates in the Gulf of Mexico.