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Fire in the Ice

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The Gas Hydrates Resource Pyramid

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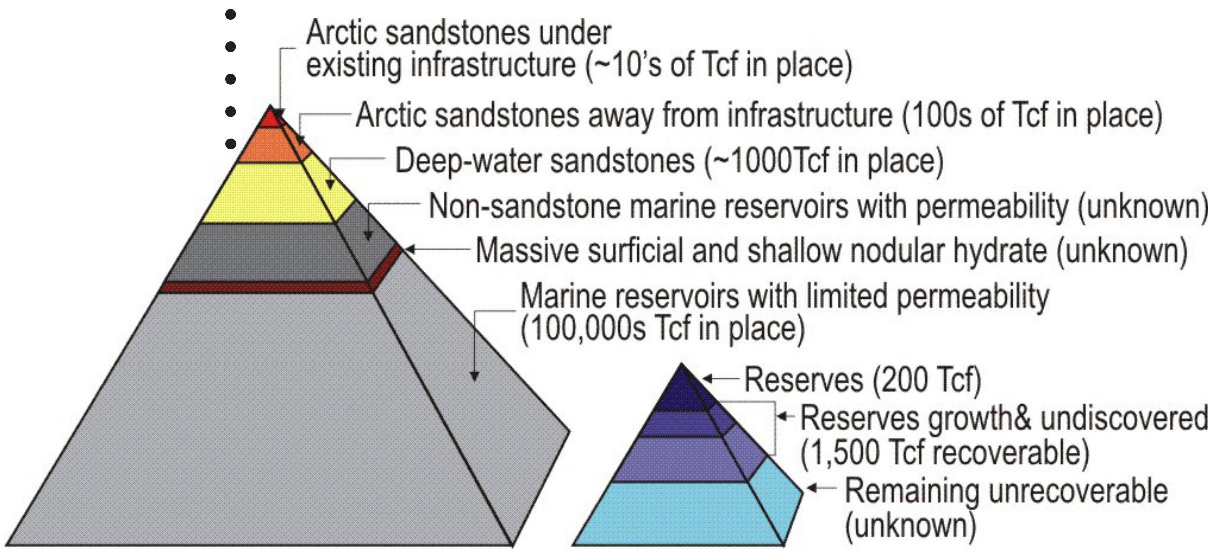
Over the past six years, the U.S. National Methane Hydrate R&D Program has worked to clarify the resource potential of gas hydrates by developing a fuller understanding of the occurrence of and natural controls on gas hydrate in nature. As a result of these efforts, we now recognize that the 1980s model (necessarily simplistic due to lack of field data) that portrayed subsurface gas hydrates as ubiquitous components of relatively uniform temperature and pressure-controlled stability zones is no longer viable. Instead, the Gas Hydrate Stability Zone (GHSZ) has been found to have a very complex geometry, with significant variability due to lateral and vertical changes in pore water salinity and heat flow. Furthermore, within the stability zone, the occurrence of gas hydrate is now recognized to be neither continuous nor random, but instead controlled by the complex interaction of factors unique to gas hydrate systems (necessary temperatures, pressures, and geochemical regimes) as well as many of the same parameters that industry has been using for decades to explore for more conventional resources (gas source, timing and pathways for water and gas migration, and suitable host reservoir).

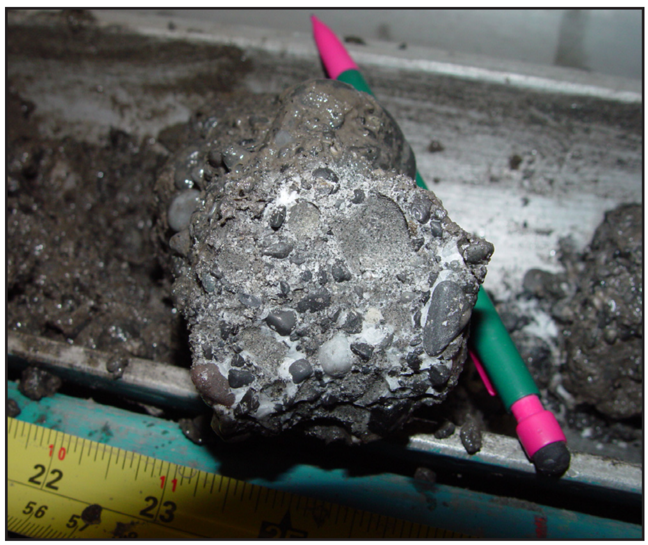
The recently-published Interagency R&D roadmap (see Announcements in this issue of *Fire in the Ice*) recognizes that the wide range of geological settings for gas hydrate will produce a variety of gas hydrate occurrences. With respect to their relative prospects for future production, we present several of these key



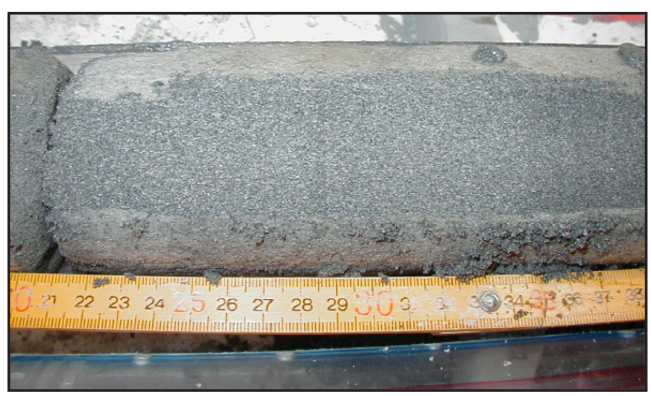
Gas Hydrates Resource Pyramid (left). To the right is an example gas resources pyramid for all non-gas-hydrate resources.

varieties (“gas hydrate prospect types”) within the context of a gas hydrates “resource pyramid.” Resource pyramids are commonly used to display the relative size and producibility of different elements within a category of resources, with the most promising resources at the top and the most technically challenging at the base. The pyramid shape results from the natural tendency for the most abundant elements of a resource group to also typically be the most difficult to profitably extract. A schematic resource pyramid for non-gas-hydrate natural gas resources is shown, at the appropriate scale with respect to the gas hydrates resource pyramid, in the figure below.

The peak of the Gas Hydrates Resource Pyramid (those resources that are closest to potential commercialization) is represented by gas hydrates that exist at high saturations within quality reservoirs rocks under existing Arctic infrastructure. This resource is currently estimated to be in the range of 33 trillion cubic feet (Tcf) of gas-in-place (in the “Eileen” trend of Alaska’s North Slope). Of that total, reservoir modeling conducted within the structure of the BP-DOE cooperative agreement on the North Slope suggests that as much as 12 Tcf of that volume may be technically recoverable. The next largest class of hydrate resources (shown in



Example of disseminated gas hydrate (white) within porous and permeable Arctic sandstone from the Mallik site, Northwest Canada (courtesy Mallik 2002 Gas Hydrate Project)



Example of disseminated gas hydrate (white specks) within porous and permeable marine sandstone from the Nankai Trough, offshore Japan (from Fujii, et al, 2005 ICGH Proceedings)

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Interested in contributing an article to *Fire in the Ice*?

This newsletter now reaches more than 700 scientists and other individuals interested in hydrates in sixteen countries. If you would like to submit an article about the progress of your methane hydrates research project, please contact Karl Lang at 301-670-6390 ext. 129 (klang@tms-hq.com) orange) are those less well-defined accumulations that exist in similar geologic settings (discretely trapped, high-saturation occurrences within high-quality sandstone reservoirs) on the North Slope, but away from existing infrastructure. The current USGS estimate for total North Slope resources is approximately 590 Tcf gas-in-place.

The next most challenging group of resources includes gas hydrates of moderate-to-high concentrations that occur within quality sandstone reservoirs in the marine environment. Because these resources will be challenged by the likely high costs of extraction from very deep water, the most favorable accumulations are those found in the Gulf of Mexico that lie in the vicinity of oil and gas production infrastructure. The scale of this resource is not well known, but is the subject of an ongoing assessment by the U.S. Minerals Management Service (MMS). Recent work by the MMS has revealed the occurrence of significant volumes of sandy sediments within the shallow section. In addition, the existence of high-quality reservoir sandstones with high gas hydrate saturation are known from the Gulf (see article on Alaminos Canyon 818 on page 12 of this issue of *Fire in the Ice*). Similar occurrences have also been reported by expeditions to the Nankai Trough offshore Japan and by the recent IODP Expedition 311 offshore Vancouver Island.

On the pyramid, below the resources associated with sand and sandstone-reservoirs, come massive deposits of gas hydrate, generally found encased in fine-grained muds and shales. Most promising among this group of gas hydrate occurrences are those with elevated gas hydrate saturations due primarily to extensive structural disturbance of the sediment. Such fractured reservoir accumulations may be common in certain areas, with thick sections exhibiting massive vein fills, or high concentrations of small hydrate nodules, smaller vein fills, and massive layers parallel to bedding planes. However,

Example of nodular gas hydrate from zone of intensely deformed fine-grained sediments (courtesy NGHP Expedition 01, India)

Example of massive sea-floor mound from Offshore Vancouver Island (courtesy Ross Chapman, U.Victoria) unlike the sand/sandstone systems where grain-supported reservoirs result in high matrix permeability and for which well-based production concepts are more plausible, extraction of methane from these shale-encased fractured accumulations will be very problematic. Major technological advancements beyond current production systems will be needed.

A special class of gas hydrate occurrences are massive gas hydrate mounds that lie exposed on the seafloor (or beneath a very thin layer of sediment) and extend to unknown depths. These features are possibly very dynamic and may be very common; however, the amount of gas resource represented is unknown. Recovery of methane from such features may be very difficult due to both their potentially limited size and the likelihood for significant disturbance of sensitive sea-floor ecosystems.

At the very base of the gas hydrate resource pyramid are those finely-disseminated accumulations, typified by the Blake Ridge accumulation offshore the Carolinas, in which large volumes of gas hydrate are relatively evenly distributed through vast volumes of fine-grained and relatively undeformed sediment at low (~10% or less) saturations. Perhaps the bulk of the world's global gas hydrate in-place resource (in the hundreds of Tcf gas-in-place) resides within this resource class. Unfortunately, the prospects for economic recovery of natural gas from this highly disseminated resource are very poor with current technologies. A major paradigm shift will be necessary to enable commercial extraction from such deposits.

In accord with this view of the gas hydrate resource base, the Interagency Program's effort to assess the future energy supply potential of gas hydrates recognizes the investigation of sand and sandstone reservoirs as it's highest priority. This work will focus on utilizing the natural laboratory of the Alaska North Slope to address questions of production technologies, with the near-term goal being the establishment of an extended production test facility. In the marine environment, the program will target exploratory drilling, the development of remote sensing systems, and the advancement of geologic models to better constrain the scale and nature of the marine gas hydrate resource, both in sandstones (highest initial priority) and in dense accumulations of massive forms associated with fracturing. The program will continue to support the development of the science and technology that will enable the reliable appraisal of gas hydrate prospects of all types by providing an improved understanding of the variety of natural geological systems that produce such deposits.