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Geologic Controls on Gas Hydrates in Arctic Environments

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Gas hydrates have the potential to provide an immense resource of natural gas from the world's oceans and polar regions. Gas hydrates are known to be widespread in permafrost regions and beneath the sea in sediments of outer continental margins. It is generally accepted that the volume of natural gas contained in the world's gas hydrate accumulations greatly exceeds that of known conventional gas reserves. Recent production tests in Alaska and northern Canada have also shown that natural gas can be produced from gas hydrates with existing conventional oil and gas production technology. Beyond a future energy resource, gas hydrates also represent a significant drilling and production hazard. Russian, Canadian, and American researchers have described numerous problems associated with the occurrence of gas hydrate in the Arctic, including well control difficulties and casing failures. Other studies also indicate that naturally destabilized gas hydrates may be contributing to the build-up of atmospheric methane, a significant greenhouse gas.

Gas hydrate accumulations in Arctic regions are associated with permafrost in Canada, Alaska, and northern Russia. Gas hydrate has also been recently discovered associated with alpine permafrost on the Qinghai Plateau in southern China. Onshore gas hydrates are present in the West Siberian Basin and are believed to be in other permafrost areas of northern Russia. Permafrost-associated gas hydrates are also present in the North American Arctic. Direct evidence for gas hydrates on the North Slope of Alaska comes from studies of cores from two gas hydrate research wells, and there is indirect evidence from drilling and open-hole industry well log for the probable presence of numerous gas hydrate layers in the area of the Prudhoe Bay, Kuparuk River, and Milne Point oil fields. Well-log responses attributed to the presence of gas hydrates have been obtained in about one-fifth of the wells drilled in the Mackenzie Delta. More than half of the wells in the Arctic Islands of Canada are inferred to contain gas hydrates. The combined

information from Arctic gas-hydrate studies shows that, in permafrost regions, gas hydrates may exist at subsurface depths ranging from about 130 to 2,000 m.

Two of the most studied permafrost-associated gas hydrate accumulations are those at the Mallik site in the Mackenzie River Delta of Canada and the Eileen gas hydrate accumulation on the North Slope of Alaska. The Mallik gas hydrate production research site has been the focus of three geologic and engineering field programs (1999/2002/2007-2008 Mallik GH Testing Projects) and yielded the first fully integrated production test of a natural gas hydrate accumulation. The science program in support of the U.S. Department of Energy (DOE) and BP-sponsored Mount Elbert gas hydrate test well project in northern Alaska generated one of the most comprehensive data sets on an Arctic gas hydrate accumulation along with critical gas hydrate reservoir engineering data. In 2011/2012, DOE partnered with ConocoPhillips and the Japan Oil, Gas and Metals National Corporation (JOGMEC) to investigate a new production method in which carbon dioxide injected into a gas hydrate-bearing rock unit can release methane while sequestering carbon dioxide in hydrate form. The field testing phase of the Ignik Sikumi gas hydrate production test well project was completed in 2012.

With the growing interest in natural gas hydrates as a source of energy, a geologic hazard, and a potential agent of climate change, it is becoming increasingly important to be able to understand the physical nature and the geologic controls on the formation and stability of gas hydrate in nature. Our knowledge of naturally occurring gas hydrates is growing and it can be concluded that: (1) a huge volume of natural gas is stored in gas hydrates; (2) production of natural gas from gas hydrates is technically feasible with existing technology; (3) gas hydrates hold the potential for natural hazards associated with seafloor stability and release of methane to the oceans and atmosphere; and (4) gas hydrates disturbed during drilling and petroleum production pose a potential safety problem.

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