First Sampling of Gas Hydrate From the Vøring Plateau

Methane hydrate is a clathrate, an ice-like solid formed from methane and water, that is stable under conditions of pressure and temperature found in most of the world’s oceans at depths greater than a few hundred meters below the seabed. The hydrate occurs in depositional settings where there is sufficient methane to exceed its solubility in water within the hydrate stability field. It has been speculated that methane released fromhydrate by climate-induced changes in pressure and temperature escapes into the ocean and into the atmosphere, where its acts as a greenhouse gas.

Recent sampling from a large field of pockmarks (shallow crust depressions in the seabed tens of hundreds of meters across) in the southeastern part of the Vøring plateau on the continental margin of Norway has revealed the presence of methane hydrate, less than a meter below the seafloor (Figure 1). Although many marine geological and geophysical investigations have explored different aspects of the pockmarks, which are related to the focused discharge of methane and other gases [Kenyon et al., 1995; Brouillet et al., 2000; Hovland and Svenen, 2006], the presence of gas hydrate had never been verified by sampling in this region. This is significant because although gas flow from methane through these features was recognized, clear evidence for active flow was lacking. The very large number of these features gives them the potential to be important for the delivery of methane to the seabed to support communities of chemosynthetic biota, and, possibly, to sparsely release large quantities of methane into the ocean and atmosphere.

Samples of hydrate were collected by the ROV Professor Logachev during Leg 3 of the sixteenth cruise of the United Nations Educational, Scientific, and Cultural Organization’s Intergovernmental Oceanographic Commission/UNESCO/IFREMER (http://www.ner- hermes.net/) Training Research (TTR) program, which took place 8 June through 2 July 2006. This cruise was part of the European Union’s Sixth Framework Programme (F6P) integrated project HERMES (http://www.ner-hermes.net/). The principal task of Leg 3 was to investigate the three-dimensional structure and properties of two fluid-gas escape chimneys beneath pockmarks showing different states of seep/vent activity, with the aim of discovering whether the chimneys are lined with hydrate and whether any free gas exists in the chimneys, to provide evidence for the chimneys’ origin.

Vøring Plateau’s Pockmark Field

Log 3 of the Professor Logachev’s cruise was preceded by an investigation of the surface geology, vent activity, chemistry, and biological communities of pockmarks, using the remotely operated vehicle Victor, deployed from the research vessel Pourquoi pas? during its Vicking cruise, part of the HERMES program, in May–June 2006. Similar investigations with the same purpose were conducted from the Professor Logachev at six pockmarks, CN03, G11, Tobic, Sharic, Bobic, and Doda (Figure 2), using seismic reflection profiling with mini-gas-injection air guns, a deep-towed 100-kilohertz side-scan sonar and 5-kilohertz subbottom profiler, a gravity corer, and a television-guided grab.

As shown by the side-scan sonar images, the pockmarks are roughly oval in shape, with diameters between 100 and 300 meters, and have a complex structure with several mounds and depressions within them (Figure 2). The subbottom profiler records show variation in the relief of the seabed up to 15 meters across these features. Seismic sections display vertical zones beneath these complex pockmarks, narrower than the feature formed at the seafloor, in which coherent reflectors are locally absent and often show scattering and acoustic turbidity, consistent with heterogeneity and the possible presence of free gas (Figure 3). A local brightening of some reflectors and attenuation of others beneath them indicates the widespread presence of free gas deeper than 250 meters below the seabed.

Television observation and sampling of the seafloor revealed widespread evidence for methane seepage through the seafloor smalls, jets, and cracks, dense debris of biotries—including those dependent on chemosynthesis—two types of tube worms, and several kinds of carbonate precipitate. After many hours of television observation, however, we are convinced that the peak in venting activity by these structures occurred sometime between periods of higher activity, based on the observation of a number of chemosynthetic biota. Methane was observed bubbling from decomposing hydrate and collected tabular-shaped crystals up to 3 centimeters in size. In the second core, at the same location, was able to penetrate about 20 centimeters into hydrate-rich sediment. The whole of this interval, at the bottom of the chimney, was occupied by a layer that was saturated and strongly cemented with microcrystalline hydrate, by subvertical veins filled with hydrate, and by thin (millimeters in thickness) plates of hydrate 12–14 centimeters wide. This chimney was extended across the whole width of the core, implying that its side, the plates are larger and were truncated by coting. These plates imparted a thin kind of stratification (Figure 1a) that is likely to depend on variation in the composition and texture of the host sediment, but, unfortunately, we were not able to identify the cause of the stratification, because the pockmark sediment became liquefied and mixed after the composition of the hydrate was removed by the dissociating hydrate within a sample of the core burned for several minutes, suggesting a very high concentration of hydrate in the sediment (Figure 1b).

The samples of hydrate were found at or near the tops of features with positive relief from which seepage of methane is observed. Seeps were at local mounds inside larger depressions or faults expressed in the small-scale topography of the seabed. It is likely that many of the several hundred pockmarks on the Vøring plateau that have similar morphologies and are underlain by chimneys with similar seismic characteristics also contain shallow accumulations of hydrate.

Gas Hydrate and Methane Seepage

Gas hydrate-bearing sediment is difficult to core when inflowed and cemented by a high concentration of gas, which may be why hydrate has not been recovered before from these features. These highly cemented accumulations of hydrate are different from the more disseminated ones that were cored during TTR cruises in the Black Sea, the Mediterranean, and the Gulf of Cadiz and at the Haakon Mosby mud volcano (located between Norway and Svalbard), but similar to shallow hydrate recovered by Leg 311 of the Integrated Ocean Drilling Program (IODP) from a chimney off Vancouver Island [Bielik et al., 2006].

Gas Hydrate

The methane seepage from the pockmarks is presently at a low level. The presence of hydrate, however, indicates that methane is being brought to the complex pockmarks at an average rate that over time is sufficiently high enough to prevent the hydrate from disappearing under the combined effects of diffusion to the ocean and anaerobic oxidation of methane. In the intervals between periods of higher activ-

ity, the methane hydrate can act as a reservoir, methane seepage, supporting the community. The potential for this supply is more rapid if free gas can migrate upward through the chimneys beneath the pockmark.
factor is required to prevent the gas from forming hydrate, such as insufficient pore water locally to turn all the gas to hydrate, locally high salinity, or a narrow plume of warm water in which the gas can migrate or be carried to the seabed. The potential significance of the confirmation of the activity of these chimneys is high, because although they are individually less active in discharge of methane to the seafloor, which, from the deformation of chimneys, which, from the deformation of their status as active methane seeps with gas plumes in different parts of the ocean, their combined effect in supplying methane to the seafloor could be many times that of, for example, the large and active Mariana Ridge mud volcano.

The discovery of hydrate in pockmarks of the Vøring plateau has provided confirmation of the status of active methane seeps or vents. Whether the hydrate is sustained by methane in solution in pore water flow or vents. Whether the hydrate is sustained by methane in solution in pore water flow up the chimneys and reaching saturation near the seabed or whether the hydrate is created during intermittent episodes of expulsion of free gas is a question still to be answered. To understand the global significance of these features for Earth’s methane budget and their impact on climate, it is important to establish the origin of the chimneys, which, from the deformation of the sedimentary layers through which the chimneys intrude, appears to have been of a catastrophic nature. Understanding the nature of the chimneys’ subsequent development can be approached through the analysis of high-resolution seismic images calibrated by the analysis of samples from cores and, possibly, by future ocean drilling.

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References


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logachev@geol.msu.ru; Graham K. Westbrook, Centre, Southampton University, Southampton, U.K.; Adriano Mazzini, Physics of Geological Processes, School of Geography, Earth and Environmental Sciences, Birmingham University, Birmingham, U.K.; Michael Ivanov, UNESCO/Moscow State University Center for Marine Geology and Geophysics, Faculty of Marine Geology and Geophysics, Moscow State University, Moscow, Russia; Kon Mosby mud volcano.

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