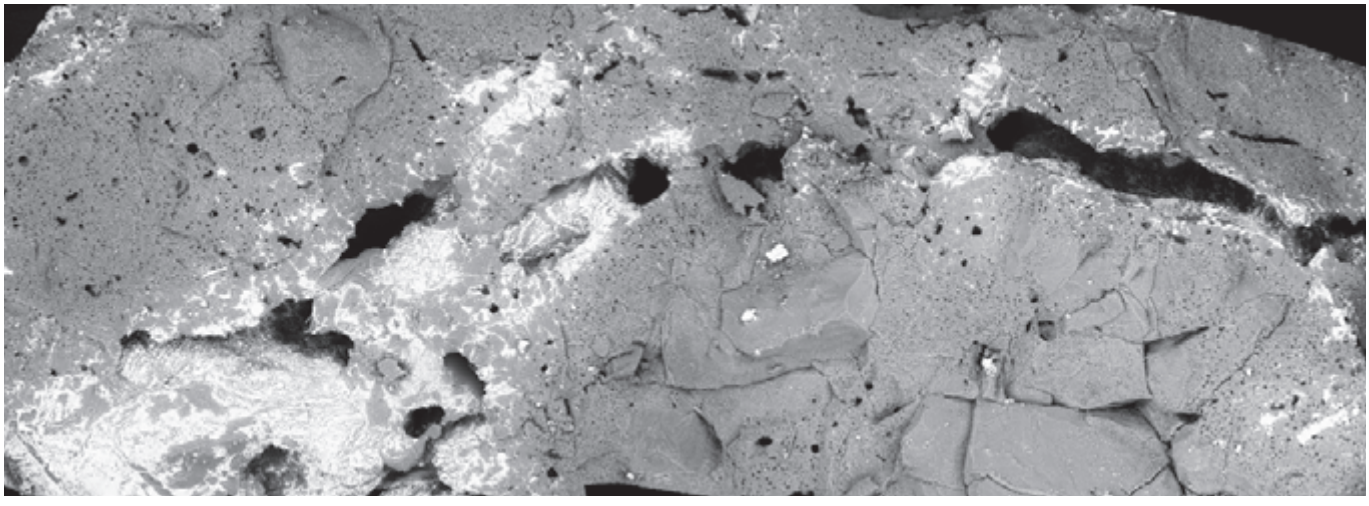
Methane hydrate deposits represent a potential source of energy, but exploiting this resource presents challenging hazards. The special drilling techniques required are reviewed by **Peter Jackson, Dave Long, Ali Skinner, Frank Williams*, Ameena Camps*, Mike Lovell*, Sarah Davies*, Tony Milodowski,** and **Chris Rochelle**. * University of Leicester

Investigating methane hydrates

Methane hydrates are ice-like substances in which gas molecules are held within 'cages' of water molecules. They form at low temperatures and high pressures where methane and water are available and are found beneath the sea floor in water depths greater than 500 metres. Large amounts of methane hydrate are thought to exist within sea-bed sediments, particularly beneath the continental slopes. The stability of this methane store may be sensitive to climate change, particularly in permafrost regions. This means that during global warming, hydrates constitute a geohazard especially where melting of the hydrate may significantly reduce the strength of the host sediment. Additionally, methane released during such events may itself contribute to global warming.

The methane hydrate reservoir is considered an unconventional petroleum gas resource but the instability of the host sediment during drilling operations has been identified as a potential hazard. The formation of hydrate deposits could be viewed as being analogous to the formation of mineral deposits: the hydrate growing in place in response to a supply of dissolved methane. Methane has been observed rising from the Hakon Mosby mud volcano in the Norwegian Sea. It travels close to the sea surface and is protected from dissolution by a membrane of hydrate; it may be concluded that a significant proportion of the methane reached the atmosphere.

We still have much to learn about methane hydrates below the sea floor. Geological and geotechnical interpretation of hydrate-bearing core is



SEM photomicrograph of methane hydrate showing gas channels, collected during IODP Expedition 311 to the Cascadia Margin NW USA.

difficult because the hydrates melt during conventional coring and sampling operations. Consequently, the core becomes 'soupy' or mousse-like in the presence of melting hydrate and expelled methane gas, and the fine-scale structure of the core tends to be destroyed.

To help overcome these problems the Integrated Ocean Drilling Program/Ocean Drilling Program (IODP/ODP) has identified special tools needed to investigate methane hydrate deposits. These include pressure coring and 'measurement while drilling' and 'logging while drilling' (MWD/LWD). On the Cascadia Margin (ODP Leg 204), these methods were used to drill and log vertical boreholes, while the petroleum industry uses MWD/LWD in horizontal wells.

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Loading logging while drilling (LWD) bottom hole assemblies on the scientific drill ship JOIDES Resolution.

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IODP Expedition 311 revisited the Cascadia Margin and took the same approach. Pressure coring developed by ODP and pressure coring and core logging under pressure developed by the European HYACE/HYACINTH consortia, were employed during these hydrate drilling efforts. The HYACINTH tool identified gas in the gas hydrate stability zone during ODP Leg 204 for the first time.

MWD/LWD technology is far less susceptible to poor hole conditions than conventional wireline logging in holes drilled using the riser-less technology employed on the JOIDES Resolution, where sea-water rather than mud is used as the drilling fluid. During IODP Expedition 311 hydrate MWD/LWD drilling operations, sea-water tended to cool the bottom hole assembly and adjacent sediment where the measurements were made.

Temperature increases with depth below the sea floor, due to geothermal heat flow, rising to approximately 20°C at target depths of 300 m. Consequently, the drilling fluid (sea-water) warms from the bottom-water temperature of approximately 4°C, in turn tending to warm the coldest (uppermost) sections of the hole during its return to the surface. This could lead to significant hole enlargement if the warming causes hydrates to melt.

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We consider our MWD/LWD measurements to be less disturbed by the drilling process than the conventional wireline ones and they have been employed to detect both the presence and concentration of hydrate in the sediment pore space. During IODP Expedition 311 it was not possible to obtain both core and MWD/LWD data in the same hole. As a result, we have not been able to directly calibrate the hydrate response seen in the LWD/MWD logs with core observations. However, having access to sediment-hosted hydrate samples will allow us to model pore space morphologies as an aid to calibrating the LWD/MWD resistivity data for IODP Expedition 311.

The results from both ODP Leg 204 and IODP Expedition 311 suggest gas hydrates on the Cascadia Margin are concentrated in relatively coarse-grained layers, such as sands within turbidite sequences. For example, it has been postulated that a coarse-grained volcanic ash deposit has acted as a conduit transporting methane from the accretionary complex to the summit of Hydrate Ridge. Consequently the hypothesis that hydrate forms preferentially in coarse-grained, more permeable sediment types, and is controlled by the supply of methane, continues to be attractive.

For further information, contact:

Peter Jackson, BGS Keyworth,
Tel: +44(0)115 936 3379
e-mail: pdj@bgs.ac.uk