Gas Hydrates in New Zealand

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Gas hydrates have been studied extensively in the past two decades with significant government and industry interest in gas hydrates as a possible natural-gas resource (e.g., Boswell, 2009) and as a potential geohazard for deep-water infrastructure (e.g., McConnell et al., 2012). While strong progress has been made addressing these objectives, many fundamental questions related to gas hydrates are still unresolved, in particular their role in the global carbon cycle and climate change (e.g., Dickens, 2003) as well as their effect on seafloor stability (e.g., Bangs et al., 2010; Mountjoy et al., submitted). Furthermore, many questions related to the distribution of gas hydrates have yet to be answered, such as sources of gas, gas-supply for hydrate formation, and emplacement of gas hydrates in sediments.

Gas Hydrates offshore New Zealand: The Hikurangi Margin (Figure A) is the only area offshore New Zealand in which gas hydrates have been sampled (e.g., Bialas et al., 2007). Indirect evidence for gas hydrates is provided by the presence of bottom simulating reflections (BSRs) on the Fiordland-Puysegur Margin (Townend, 1997) and indications for gas within the hydrate stability zone in the Northland and Taranaki Basins (Ogebule and Pecher, 2010). Pockmarks on the Chatham Rise may be caused by gas hydrate dissociation during glacial sealevel lowstands (Davy et al., 2010). The New Zealand government is funding a program to assess gas hydrates as a possible energy resource, focusing on the Hikurangi Margin. Drilling is now required to calibrate geophysical reservoir characterisation, perhaps as part of a government-backed Complementary Project Proposal to IODP. The economic case for gas hydrates in New Zealand is unique because of the depletion of known conventional gas fields, New Zealand's remoteness resulting in high cost for LNG import, and relatively small rates of gas consumption suggesting hydrates could provide New Zealand with gas for several decades. New Zealand's gas hydrate deposits are also ideally suited to address several key basic-science questions.

Seafloor Stability: Studies of the effect of gas hydrates on seafloor failure have generally focused on gas hydrate dissociation, assuming that solid gas hydrates strengthen sediments. Observations on the Hikurangi Margin may now lead to a paradigm shift: the gas hydrate zone itself may be a region of sediment weakness. Creeping of submarine landslides and seafloor erosion appear to be linked to a thin zone of gas hydrates. Seafloor weakening could be caused either by elevated pore pressures transmitted through hydrofractures into the hydrate zone

(Crutchley et al., 2010) or by plastic deformation of ice-like gas hydrates similar to rock glaciers (Mountjoy et al., submitted) (Figure B). Remote drilling off the R/V *Sonne* is now planned to sample sediments from the creeping landslides. Acquisition of 3-D seismic data has been proposed to extend results from remote drilling. Ultimately, drilling through the entire creeping slide mass, collection of pressure cores, and borehole logging are needed to confirm the presence of hydrates, investigate their pore-scale distribution, and quantify their effect on sediment physical properties. The D/V *JOIDES Resolution* is ideally suited for these investigations which has led to plans for the submission of an Ancillary Program Letter to the proposed IODP leg in the study area (proposal 781A).

Cold seeps, link to fluid migration, and gas hydrate emplacement: Fluid migration into and through the gas hydrate stability zone on the Hikurangi Margin is thought to be highly focused with vigorous gas expulsion at cold seeps (Coffin et al., submitted; Greinert et al., 2010) and pronounced local thermal anomalies marked by upwarping of BSRs (Pecher et al., 2010). Seismic reflection profiles show that known seep sites are closely associated with major thrust faults through the accretionary wedge. It has been proposed that gas hydrate formation may be caused by cooling of gas-bearing sediments following a decrease of fluid advection, a novel model of hydrate emplacement in sediments (Toulmin et al., 2010). Furthermore, a strong link between BSR occurrence and fluid migration from underthrusted sediments has been shown and it has been suggested that this link is caused by enhanced rates of microbial and possibly thermogenic methane transport into the hydrate stability field in addition to in-situ generation of methane (Plaza-Faverola et al., 2012). Deep sediment cores in those areas may help to unravel the methane generation process, as well as the transport mechanism of free gas through the gas hydrate stability field. A study has recently been proposed to design coring and drilling programs aimed at investigating focused fluid flow on the Hikurangi Margin and its effect on the local gas hydrate system near sites of fluid expulsion. Answering these questions will provide new insights into the mechanisms that control gas hydrate formation as well as more globally, methane cycling in subduction zones.

Response of gas hydrates to sealevel lowering: Seafloor pockmarks have been detected over a >20,000 km^2 area on the Chatham Rise (Davy et al., 2010). These pockmarks appear to be controlled by bathymetry and are situated in a seafloor-depth range that is predicted to have moved out of hydrate stability during glacial-stage sealevel lowstands. Buried pockmarks in seismic data are present at reflections that appear to mark sealevel lowstands (Figure C). It has therefore been suggested the pockmarks formed following gas hydrate dissociation during glacial sealevel lowering. Because of a bathymetric locking of currents, parts of the Chatham Rise are thought to not have experienced any significant bottom-water temperature changes during glacial cycles, making the study area ideally suited to investigate the effect of sealevel-lowering on gas hydrate-bearing sediments. Evaluation of data acquired during a recent seismic and coring survey of the R/V *Sonne* is expected to shed more light onto these findings.

With the very recent success of offshore production testing off Japan, hydrates may become a promising gas resource. However, many basic-science aspects related to gas hydrates have yet to be resolved. New Zealand offers excellent opportunities for gas hydrate research, which will ultimately require ocean drilling.

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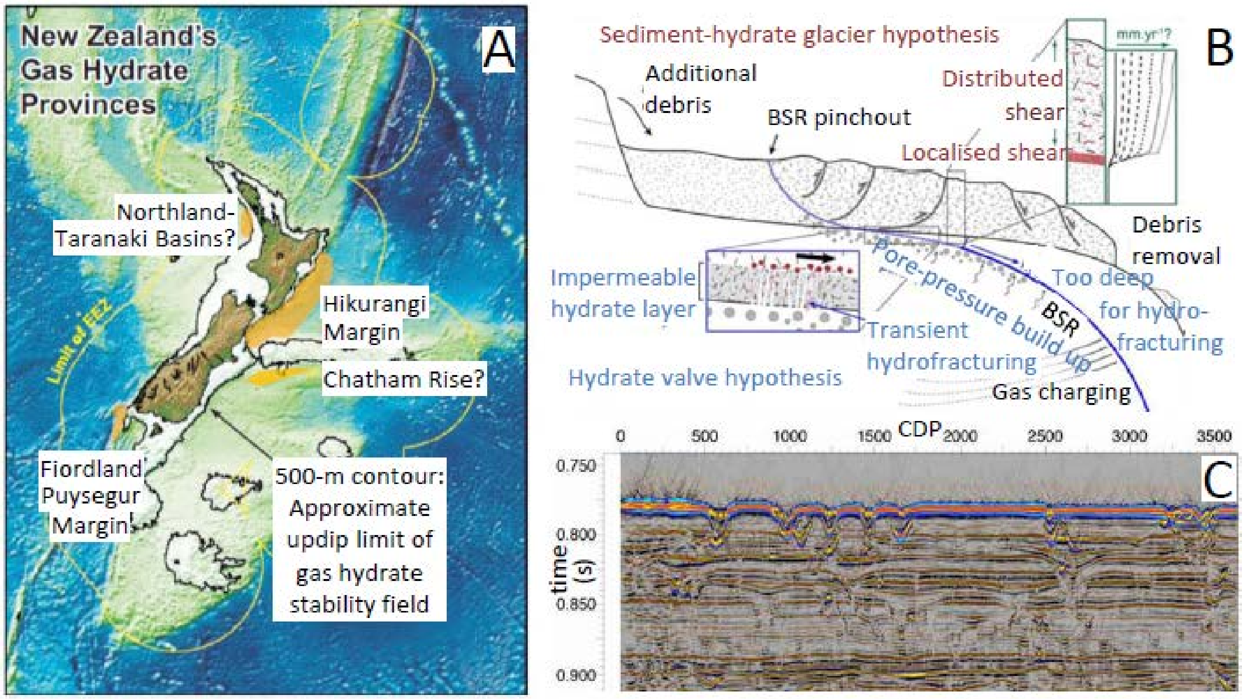

Figure A. Gas hydrate provinces offshore New Zealand. Figure B. Hypotheses for gas-hydrate-related creeping of sediments (after Mountjoy et al., submitted). Figure C. Seismic images of seafloor and buried pockmarks on the Chatham Rise (R/V Sonne voyage SO-226)