Marine Geology 272 (2010) 170–188

Contents lists available at ScienceDirect

Marine Geology

journal homepage: www.elsevier.com/locate/margeo

# Methane seepage along the Hikurangi Margin of New Zealand: Geochemical and physical data from the water column, sea surface and atmosphere

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ARTICLE INFO

*Article history:*
Received 23 August 2008
Received in revised form 29 November 2009
Accepted 1 January 2010
Available online 11 January 2010

*Keywords:*
Methane
seepage
gas hydrate
water column
sea surface
carbon isotopes
Hikurangi Margin

ABSTRACT

The concentration and carbon isotope values of dissolved methane were measured in the water column at Rock Garden, Omakere Ridge and Wairarapa areas in the first dedicated cold seep investigation along the Hikurangi Margin of New Zealand. These measurements provide a high resolution impression of the methane distribution in the water column and show that these seep sites are actively venting methane with varying intensity. The highest concentrations (up to 3500 nM) measured in water samples obtained from Conductivity–Temperature–Depth (CTD) operations were at Faure Site of Rock Garden. Here, seafloor bubble release was observed by ROV. The Omakere Ridge area is actively venting over almost its entire length (~25 km), in particular at Bear's Paw, a newly discovered seep site. In the Wairarapa area another new seep site called Tui was discovered, where methane measurements often exceeded 500 nM. No evidence was obtained from water column or sea surface measurements along the Hikurangi Margin to indicate that methane from seeps is reaching the sea surface. In fact, a consistent upper boundary was observed at a density of 26.85 kg/m$^3$, which occurs at about 500 m below sea surface, above which methane decreased to background concentrations. No obvious oceanographic feature is associated with this 500 m $CH_4$ boundary. Bubble dissolution calculations show that about 500 m was also the model-derived maximum bubble rise height. A wide range of $\delta^{13}C_{CH4}$ values from −71 to −19‰ (VPDB) were measured, with the highest $CH_4$ concentrations having the lowest $\delta^{13}C_{CH4}$ values of about −71 to −68‰. Simple mixing and isotope fractionation calculations show that changes of $\delta^{13}C_{CH4}$ values are predominantly caused by the dilution of seep fluids with the seawater, with some anaerobic oxidation also occurring.



## 1. Introduction

There is general consensus that methane hydrates represent a significant methane reservoir (Milkov, 2004; Kvenvolden, 1988). Methane hydrates and hydrocarbon seepages (cold seeps) found at the world's continental margins (Judd and Hovland, 2007) have therefore drawn considerable attention because of their potential contribution to atmospheric methane levels (Judd, 2004; Kvenvolden and Rogers, 2005). However, quantitative seepage estimates are rare because submarine sources are difficult to find. Ongoing research at the continental slope off New Zealand enables us to better estimate the impact and distribution of $CH_4$ from seeps on oceanic and atmospheric $CH_4$ budgets.

Marine geophysical studies along the Hikurangi Margin have been ongoing since the 1970's, but have mainly focussed on regional tectonic features associated with the Pacific–Australian subduction plate boundary (Barnes et al., 2010-this issue and references therein). These studies have shown that wide-spread, bottom simulating reflectors (BSR), as indicators of free gas below gas hydrate cemented sediment horizons, are widespread along the Hikurangi Margin and that they are a potential target for gas hydrate exploration (Katz, 1982; Townend 1997; Henrys et al., 2003). The first indication of active fluid seepage of $CH_4$ and $H_2S$-rich fluids from an area called Rock Garden was made in 1994 by fishermen who obtained live specimens of mussels of the genus *Bathymodiolus* that are associated worldwide with $CH_4$ vents and seeps at depths from 400 to 3600 m (Lewis and Marshall, 1996; Von Cosel, 2002). Fishermen were also the first to observe hydroacoustic evidence for gas bubbles in the water

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doi:10.1016/j.margeo.2010.01.001

column (Lewis and Marshall, 1996), which has been confirmed by subsequent studies (Greinert et al., 2010-this issue; Naudts et al., 2010-this issue; Klaucke et al., 2010-this issue; Linke et al., 2010-this issue). Subsequent dredge sampling of the LM-3 site at Rock Garden confirmed seep fauna and flares rising 250 m above the seabed (Lewis and Marshall, 1996). Lewis and Marshall (1996) reported a total of four seep-related sites (LM-1, LM-3, LM-9, LM-10; Fig. 1) along the Hikurangi Margin.

With respect to seepage, methane distribution and related water column studies, Faure et al. (2006), published results of a 24 hour survey of Rock Garden area in 2004 that included the Lewis and Marshall LM-3 site (Fig. 1). At Rock Garden, elevated concentrations of methane (up to 10 nM, ~6 times background) were detected by onboard GC-based analyses and methane sensor (METS) measurements. The location of these higher concentrations is close to an area where a bottom simulating reflector (BSR) pinches out at the seafloor (~630 meters below sea level — mbsl).

Here, results of two surveys are presented (*RV TANGAROA* in 2006 and *RV SONNE* in 2007) that were dedicated to exploring the seep sites along the Hikurangi Margin. The water column studies described here concentrated on three different seep areas (Rock Garden, Omakere Ridge, Wairarapa; Fig. 1). The regional geological setting of the Hikurangi Margin is described in Barnes et al. (2010-this issue). A general overview of these cruises and, e.g., naming of seep sites, is given in Greinert et al. (2010-this issue).

## 2. Methods

### 2.1. Sample collection

Gas chromatograph (GC) based methane analyses, CTD casts, GC–mass spectrometer isotope measurements and ADCP-based current measurements were employed for this study. Physical parameters such as temperature and conductivity, as well as $CH_4$ data, measured by a METS sensor (formerly by CAPSUM, now Franatech GmbH, Lüneburg, Germany), were collected during CTD casts using a Seabird 911 plus system.

The CTD was deployed in two ways, as vertical casts and in short towed casts close to the seafloor. Tow casts are shown on the bathymetric maps with an additional letter added to CTD station numbers (e.g., CTD42a, 42b, etc. see Appendix Fig. 1). The positions indicate where the NISKIN bottles were closed. The underwater position of the CTD during the towed casts was determined by an IXSEA Posidonia (2nd Leg) and GAPS system (3rd Leg).

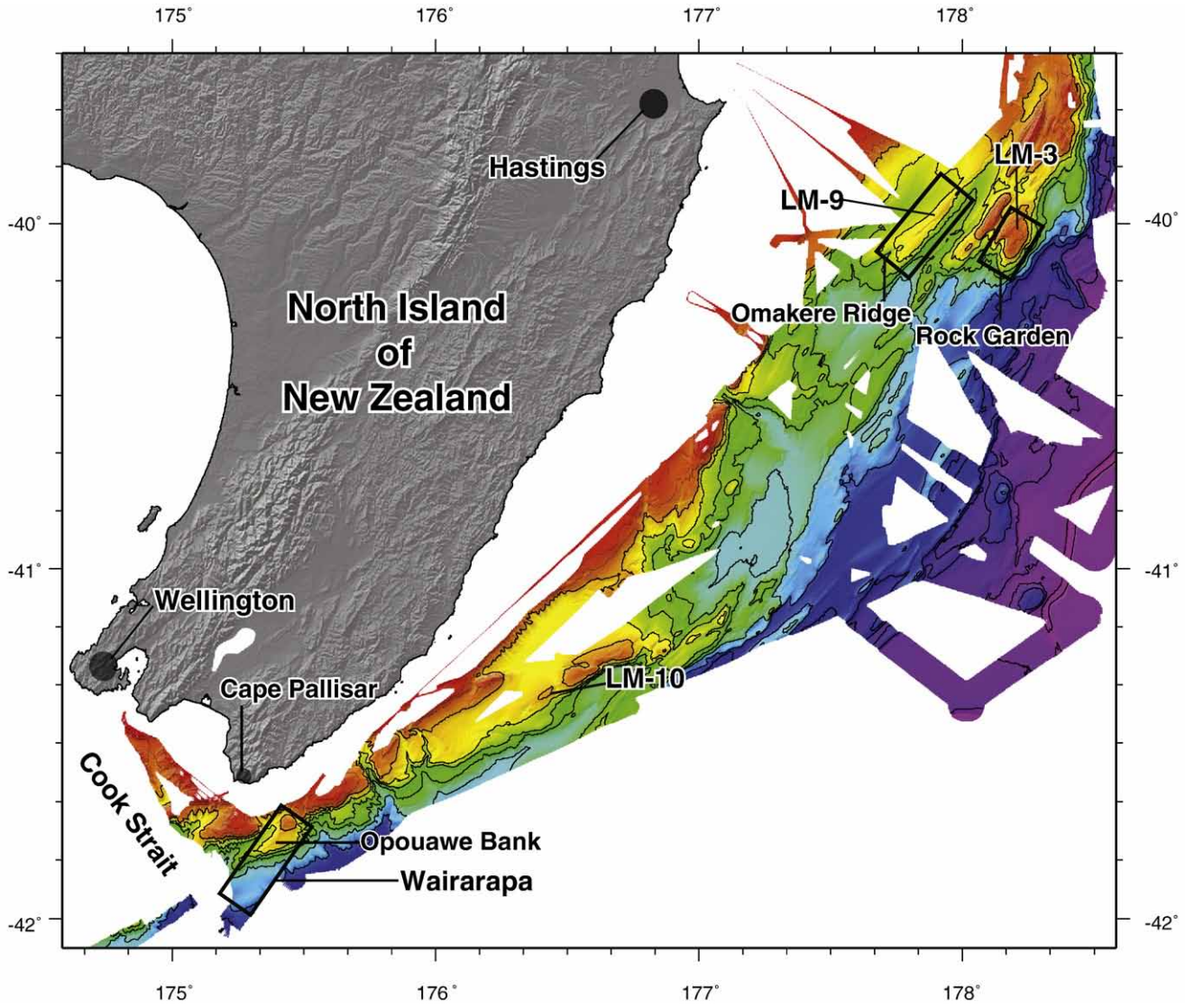


**Fig. 1.** Bathymetric map of the Hikurangi Margin showing the three study areas, Rock Garden, Omakere Ridge and Wairarapa. Also shown are the locations of the seep sites (named LM) reported by Lewis and Marshall (1996). LM-1 is not shown, because it is outside the area depicted here.