Marine Geology 272 (2010) 154–169

Contents lists available at ScienceDirect

Marine Geology

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

Acoustic and visual characterisation of methane-rich seabed seeps at Omakere Ridge on the Hikurangi Margin, New Zealand

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ARTICLE INFO

Article history:
Received 8 August 2008
Received in revised form 25 February 2009
Accepted 8 March 2009
Available online 24 March 2009

Keywords:
methane seeps
cold-water reef
Omakere Ridge
Hikurangi Margin
New Zealand
sidescan
seep-related biota

ABSTRACT

Six active methane seeps and one cold-water reef that may represent a relict seep were mapped at Omakere Ridge on New Zealand's Hikurangi Margin during cruises SO191 and TAN0616. Hydroacoustic flares, interpreted to be bubbles of methane rising through the water column were identified in the area. The seep sites and the cold-water reef were characterised by regions of high backscatter intensity on sidescan sonar records, or moderate backscatter intensity where the seep was located directly below the path of the sidescan towfish. The majority of sites appear as elevated features (2–4 m) in multibeam swath data. Gas blanking and acoustic turbidity were observed in sub-bottom profiles through the sites. A seismic section across two of the sites (Bear's Paw and LM-9) shows a BSR suggesting the presence of gas hydrate as well as spots of high amplitudes underneath and above the BSR indicating free gas. All sites were ground truthed with underwater video observations, which showed the acoustic features to represent authigenic carbonate rock structures. Live chemosynthetic biotic assemblages, including siboglinid tube worms, vesicomyid clams, bathymodiolin mussels, and bacterial mats, were observed at the seeps. Cold-water corals were the most conspicuous biota of the cold-water reef but widespread vesicomyid clam shells indicated past seep activity at all sites. The correlation between strong backscatter features in sidescan sonar images and seep-related seabed features is a powerful tool for seep exploration, but differentiating the acoustic features as either modern or relict seeps requires judicial analysis and is most effective when supported by visual observations.

1. Introduction

Seabed fluid flow is of fundamental importance to the marine environment and consequently influences the working of our planet (Judd and Hovland, 2007). It can occur in a variety of forms, and is widespread and dynamic. Although seabed fluid flow is essentially a geological process, it affects marine ecology, ocean chemistry, and the composition of the atmosphere (Kvenvolden and Rogers, 2005). Among the most widely documented seeping fluids are thermogenic hydrocarbons, in the form of natural gas, crude oil, and bitumens (Wilson et al., 1974; Judd and Hovland, 2007). Therefore, seeps can influence atmospheric concentrations of methane, particularly when the seeps occur in shallow water (<100 m) where gas bubbles can survive a journey to the sea surface without dissolving (Kvenvolden and Rogers, 2005; Schmale et al., 2005; McGinnis et al., 2006). Significant amounts of methane are also sequestered within gas hydrates, the global volumes of which vary with addition and withdrawal of free gas over geological time (Kvenvolden, 1988). Additionally, seabed fluid flow influences the composition of sediment pore water and the overlying water column, adding nutrients and substrates that can be oxidised by microbes and thus contributing to biological productivity (Kennicut et al., 1985).

Understanding the dynamics and distribution of seabed fluid flow, particularly of methane, is critical given the widespread, influential nature of the process. Marine geohazards may occur in association with shallow gas, including slope failures and drilling hazards (Hovland and Gudmestad, 2001). The energy potential of gas hydrates has encouraged significant research programmes (Max, 2000), and the oil industry makes use of seeps in petroleum exploration (Abrams, 2005). A more recent concern to marine science is the vulnerability of benthic ecosystems associated with methane seepage (Judd and Hovland, 2007).

Among the most effective tools for characterising seep sites are multibeam and sidescan sonar, which map the morphology and acoustic backscatter of the seafloor, detecting hardness contrasts between unconsolidated sediments and methane-derived authigenic carbonates, chemosynthetic 'cold seep' communities, water column

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doi:10.1016/j.margeo.2009.03.008

bubbles, or gas hydrates in the sediment (Orange et al., 2002; Niemann et al., 2005; Holland et al., 2006; Klaucke et al., 2006; Rollet et al., 2006; Naudts et al., 2008).

In this paper, we describe five seep sites and one cold-water reef with associated seepage on the mid-slope Omakere Ridge (Fig. 1) off Hawke Bay, New Zealand. Four of the seep sites (*Kea*, *Kaka*, *Kakapo*, and *Bear's Paw*) and the reef (*Moa*) are previously undocumented seabed features which were discovered at the southern end of Omakere Ridge where it bifurcates into parallel ridgelines. All of these sites, plus Lewis and Marshall's (1996) LM-9 site, are located towards the crests of the two ridgelines in approximately 1100–1170 m water depth. The data presented here were acquired during the course of two marine surveys: firstly the RENEWZ-1 NOAA-NIWA New Zeeps voyage (TAN0616) in November 2006, and then an IFM-GEOMAR survey aboard the RV SONNE (SO191) between January and March 2007. In this study, the seepage sites are characterised on the basis of sidescan sonar and multibeam swath data. Indicators of shallow gas in the region are also described in sub-bottom profile (SBP) data. Ground truthing of the seep sites was undertaken with underwater video and still cameras. The spatial relationship between high acoustic backscatter features in the sidescan sonar data and seabed characterisation from continuous underwater video observations is analysed quantitatively in a geographic information system (GIS). Our data and results suggest that seabed signatures of seepage can be identified with varying degrees of confidence depending on their morphology, but that definitive identification of modern seeps may require visual observations.

2. Study area

The Hikurangi Margin, off the east coast of New Zealand's North Island, is part of the Kermadec-Hikurangi subduction zone, which is a component of the boundary between the Pacific and Australian tectonic plates. The style of subduction tectonics varies along the

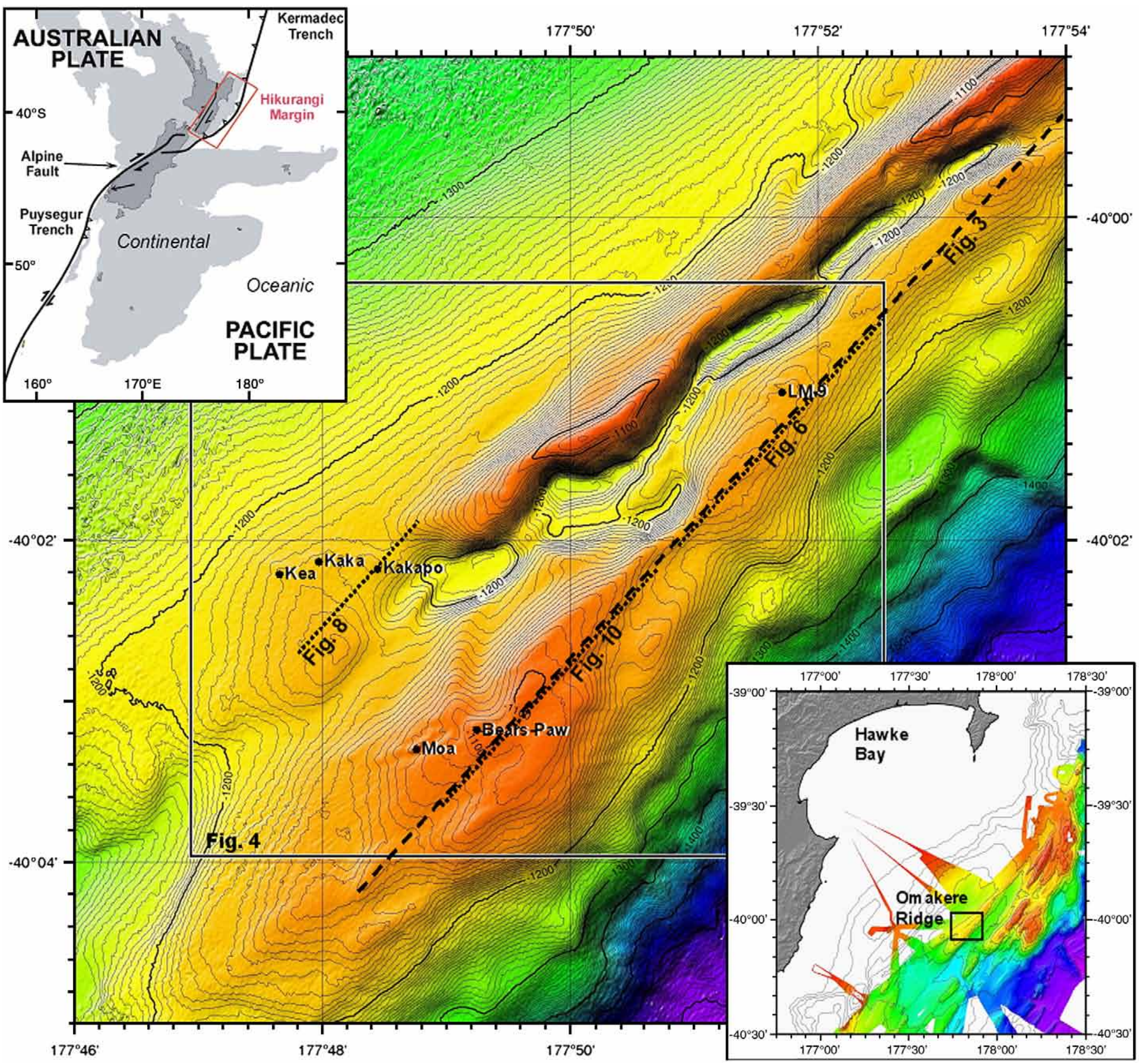

Fig. 1. Location and bathymetry of Omakere Ridge, including the location of seep sites described in this study.