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Active venting sites on the gas-hydrate-bearing Hikurangi Margin, off New Zealand: Diffusive- versus bubble-released methane

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ABSTRACT

During the 'New Vents' SO191 cruise in 2007, the activity and distribution of seep sites on the gas-hydrate-bearing Hikurangi Margin, off northeastern New Zealand, were subjected to a highly detailed interdisciplinary study. Here we report on the visual observations and in situ measurements of physical properties performed with a ROV (remotely operated vehicle) and other video-guided platforms at two seep sites in the Rock Garden area; Faure Site and LM-3. The ROV allowed first ever visual observations of bubble-releasing methane seeps at the Hikurangi Margin. At Faure Site, bubble release was monitored during 4 dives, up to periods of 20 min. During the first dive, this resulted in the observation of six violent outbursts, each lasting 1 min over a three minute interval. These outbursts were accompanied by the displacement and resuspension of sediment grains, and the formation of small depressions, with a maximum diameter of 50 cm and depth of 15 cm, showing what is possibly an initial stage of pockmark formation. During subsequent dives at this bubble site, bubble release rates were rather constant and the previously observed outbursts could no longer be witnessed. At LM-3, the strongest manifestation of seep activity was a large platform (100 m^2), consisting of fresh authigenic carbonates, which was covered by seep fauna (live *Bathymodiolus* sp. mussels, *Calyptogena* sp. shells and live *Lamellibrachia* sp. tubeworms). Bubble activity near this platform was less prominent than at Faure Site. Our observations suggest that the two seep environments result from different types of methane release; mainly by bubble release at Faure Site and rather diffusive at LM-3. We propose a conceptual model where the different ways of methane release and seep environments may be explained by the depth of underlying hydrate occurrences and different tectonic histories of both seep sites.

1. Introduction

Gas seeps, i.e. locations of bubble release at the sea floor, are widespread on continental margins (Judd, 2003; Judd and Hovland, 2007). Their presence is commonly indicated by anomalies that are visible on different types of acoustic data, such as seismics, single-beam or multibeam echosounder or side-scan sonar (Greinert et al., 2006; Klaucke et al., 2006; Naudts et al., 2006; Schneider von Deimling et al., 2007; Gay et al., 2007; Judd and Hovland, 2007; Naudts et al., 2008; Greinert, 2008). While acoustic data are very useful to identify areas in which seeps occur, they usually fail to pinpoint the exact location of bubble release at the sea floor on meter or sub-meter scale. Seeps are often associated with distinct ecosystems with chemosynthetic fauna (bacterial mats, clams, tubeworms etc.) (Boetius and Suess, 2004; Judd and Hovland, 2007). Furthermore, seeps are often characterized by the presence of authigenic carbonates, which are easy to identify during near-bottom investigations, even without bubble release during the observations (Hovland et al., 1985; Paull et al., 1992; Peckmann et al., 2001; Orange et al., 2002; Greinert et al., 2002a; Judd and Hovland, 2007; Naudts et al., 2008). A very good method to observe and study seeps, their activity and the associated ecosystems is by detailed, visual, sea-floor observations in possible seep areas indicated by acoustic investigations.

Visual sea-floor observations can be made with a towed video sled, a manned submersible or a remotely operated vehicle (ROV). Towed video sleds make it possible to gain a regional overview of the sea-floor features by criss-crossing a target area (Greinert et al., 2002b; Sahling et al., 2008; Naudts et al., 2008). However, with video sleds it is not possible to stay on position, to move within small areas, to take samples or to perform measurements at a certain position over longer

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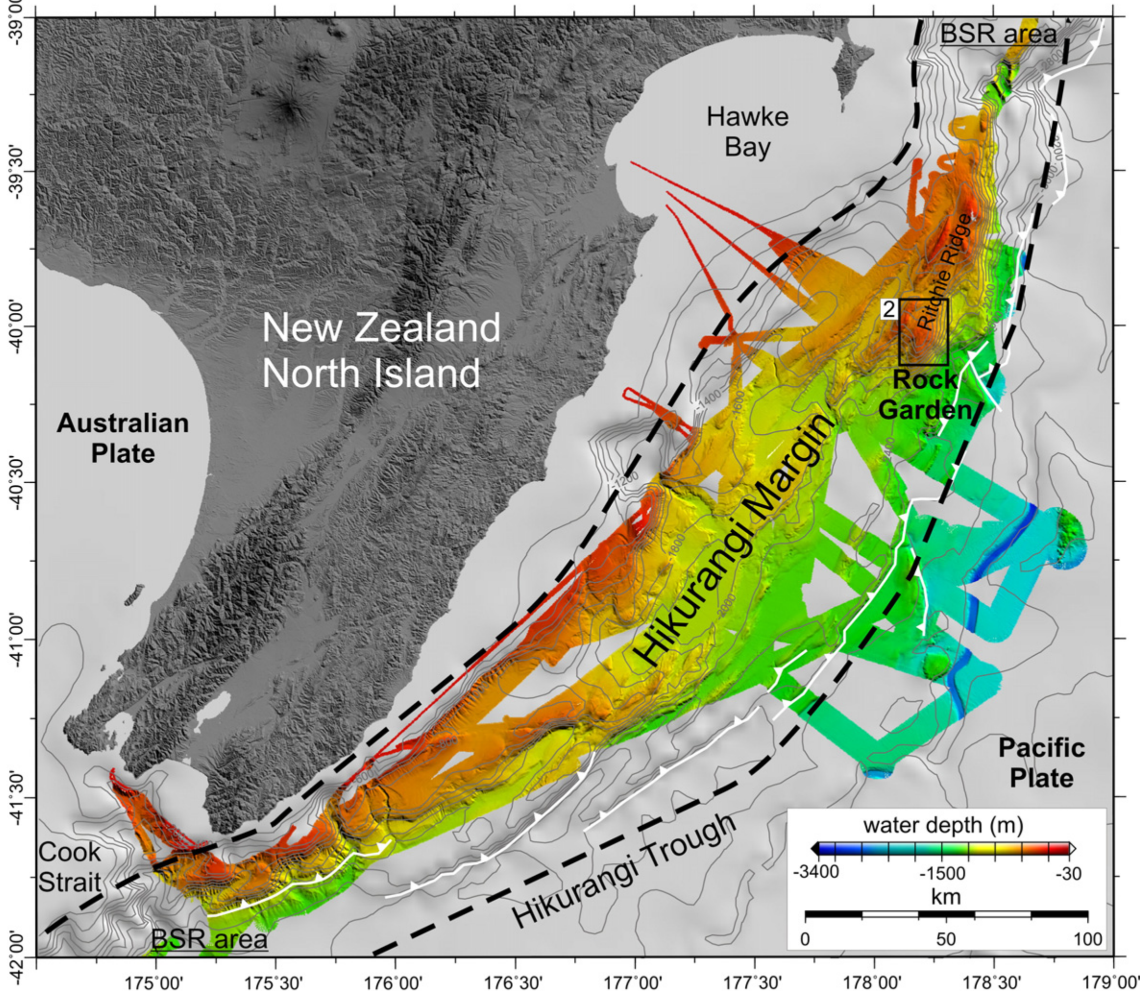

Fig. 1. Location map of the Hikurangi Margin, east of New Zealand's North Island, with acquired multibeam data (Greinert et al., 2010-this issue) and indication of the area with observed BSRs (black dashed line) and major tectonic features with the white lines indicating the deformation front (Lewis et al., 1998; Henrys et al., 2003; Barnes et al., 2010-this issue). Outline for Fig. 2 is also given. Land topography is derived from Shuttle Radar Topography Mission (SRTM) data. The bathymetry data is courtesy of NIWA.

time. Manned submersibles have the disadvantage that they are commonly very large and require a large ship and specialized crew. By contrast, ROVs are more adapted and have been used extensively in the last decade to study seep areas (Fujikura et al., 1999; Coleman and Ballard, 2001; Hovland, 2002; Orange et al., 2002; Ondréas et al., 2005; Paull et al., 2005; Sauter et al., 2006; Gay et al., 2006; Paull et al., 2007; Jerosch et al., 2007; Olu-Le Roy et al., 2007; Judd et al., 2007; Nikolovska et al., 2008).

In this paper, we present the first ever visual observations of bubble-releasing seeps at the Hikurangi Margin. In 2007, ROV and video-guided deployments enabled us to precisely locate the active methane seeps on the margin, and to perform detailed sea-floor observations, measurements and sampling at and around the seeps. Moreover, the use of ROV 'GENESIS' allowed us to investigate short-term temporal variations in seep activity, alternating from almost complete inactivity to violent outbursts, and to estimate bubble-release rates and methane flow rates.

2. Study area

The Hikurangi Margin, on the east side of New Zealand's North Island, is an accretionary margin related to the oblique subduction of the Pacific Plate underneath the Australian Plate (Barnes et al., 2010-this issue) (Fig. 1). Several areas with methane seeps and with bottom-simulating reflections (BSRs) visible on seismic recordings, possibly indicating the presence of gas hydrates, have already been described along this margin (Katz, 1982; Townend, 1997; Henrys et al., 2003; Pecher et al., 2004; Pecher et al., 2005; Faure et al., 2006; Greinert et al., 2010-this issue; Crutchley et al., 2010-this issue).

Here, we focus on Rock Garden, which is the southern termination of Ritchie Ridge, as our study area on the Hikurangi Margin, (Figs. 1 and 2). Rock Garden is an informal name, given by local fishermen, and refers to its rocky sea floor (Faure et al., 2006). The origin of Rock Garden's flat-topped relief and its uplift is still under debate. The uplift may be related to the subduction of a seamount or to major subduction-related thrust

Fig. 2. Multibeam bathymetry of Rock Garden (30 m grid) with indications of the known seep sites, video tracks (black lines) and acoustic flare locations (white dots) (see Fig. 1 for location) (Greinert et al., 2010-this issue). The possible depth limit for the GHSZ is indicated by the −630 m and −710 m isobaths (Faure et al., 2006). A. Multibeam bathymetry map of the LM-3 area with indications of ROV (red), TV-G (yellow) and OFOS tracks (black), flares (white dots) and the track line of the echosounder and seismic recordings (a–a′) (black dashed line). Outline for Fig. 6 is also indicated. B. Multibeam bathymetry map of the area around Faure Site with indications of ROV (red), TV-MUC (yellow) and OFOS video tracks (black), flares (white dots) and the track lines of the echosounder (b–b′) and seismic recording (c–c′) (black dashed lines). Outline for Fig. 8 is also indicated.