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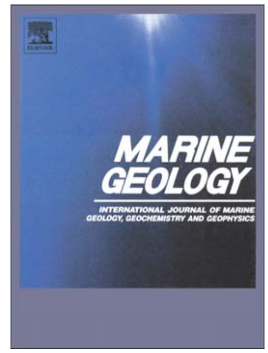

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Preface

Methane seeps at the Hikurangi Margin, New Zealand.

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Methane seeps are common at many active and passive continental margins around the world. They are characterized by the advection and expulsion of fluids generated in deeper sediment horizons. The fluids transport primarily CH_4, H_2S or Ba^{2+} along with other dissolved and gaseous compounds towards the seafloor and hence into oxic pore and bottom water conditions. During the last two decades, researchers gained significant knowledge about the biogeochemical processes that result in carbonate formation via the anaerobic oxidation of methane (AOM) or the interaction with gas hydrates and its role as temporal storage reservoir for methane. Scientists also learned how to detect active seep sites and realised that seeps are a window into the deeper geosphere as well as petroleum and gas systems. At the seafloor, seeps represent a biogeochemical oasis similar to hot vents. However, all the knowledge was gained in different areas and geological settings of the world ocean but left a regional gap in our knowledge about seeps in the SW Pacific.

Before the three cruises that delivered most of the data and observations discussed in this Special Issue (TAN0607 and TAN0616 with RV TANGAROA in 2006; SO191 with RV SONNE in 2007), a limited amount of reconnaissance information was available about methane-rich seepage around New Zealand. Occasional and mostly accidental findings of carbonate chimneys, chemosynthetic fauna and hydroacoustic anomalies pointed towards past and present seepage, mainly along the active Hikurangi Margin. A better database existed from seismic studies which imaged a wide spread BSR, free gas and fluid pathways in form of gas chimneys. The research strategy during the cruises in 2006 and 2007 employed geophysical mapping (seismic, multibeam and side-scan mapping, hydroacoustic flare imaging) followed by visual observations (video tows and ROV), sampling (water column, and sediment) and finally monitoring with landers and moorings that efficiently targeted interesting seeps. This proved to be a most efficient approach whereby the total insight gained was larger than the sum of individual investigations as detailed in the following chapters of the Special Issue.

The first paper by Greinert et al gives an overview of the seep studies undertaken in 2006 and 2007 along the Hikurangi Margin and presents bathymetric, visual and hydroacoustic evidence based on ‘flares’ of many of the 32 newly discovered seeps within the six different study areas. In a second overview paper, Barnes et al provide a detailed introduction to the morphological and tectonic differences between the study areas by combining existing bathymetric and seismic information with newly recorded data.

The following two papers focus on the geophysical reconnaissance of the southernmost study area, Opouawe Bank. Klaucke et al. present deep-towed sidescan data that image the scattered occurrence of chemoherm-like carbonate blocks and rising bubbles. In addition, they show visual evidence that the sidescan-inferred seep sites are indeed active seeps by merging geo-referenced seafloor observations with sidescan maps. Netzeband et al use seismic data to visualize the fluid migration pathways in the sediment below these sites. They found chimneys that are either characterised by high-amplitude reflections or by acoustic turbidity as well as faults acting as fluid pathways. Ocean Bottom Seismometer (OBS) data are used to calculate the sound velocity structure below the seafloor. The same OBS stations also carried methane sensors that recorded the changes in methane concentration of the bottom water during the 2-day deployment. These methane data, presented by Krabbenhoeft et al, show that methane seepage is episodic and linked to the tidal cycle. The localized occurrence of higher concentrations is most likely caused due the focussed release from deep-reaching faults and fissures closer to the seafloor. The final geophysical paper about Opouawe Bank by Schwalenberg et al. (a) reports about Controlled Source Electromagnetic measurements (CSEM) and postulates a layer of concentrated gas hydrate within the uppermost 100m of the sediment around the North and South Tower seep sites. The same paper also reports higher-than-normal heat flow and gas hydrate recovery from another nearby seep site (Takahe).

In a second paper, Schwalenberg et al. (b) report on CSEM measurements from the Porangahau Ridge which they link to geochemical pore water and heat flow data and conclude that the western rim of Porangahau Ridge is a zone of rising fluids that transport methane. Multi-channel seismic investigations by Pecher et al. also from Porangahau Ridge show high-amplitude reflections above the regional BSR level. Based on polarity and reflection strength, the authors interpret the high-amplitude reflections as being caused by free gas that may exist within the gas hydrate stability zone due to high advective heat flow from upward migrating fluids.

North of Porangahau Ridge at Rock Garden, Crutchley et al. identify several gas chimneys in seismic data functioning as fluid pathways. They feed seep sites at the seafloor that have been confirmed by hydroacoustic and visual data. The Rock Garden area is a peculiar, flat-topped ridge. Here Ellis et al show that the most likely mechanism for this shape is sediment weakening leading to seafloor erosion. They conclude that this process results from gas hydrate destabilization during tectonic uplift of the ridge that is caused by the subduction of a seamount. Based on bathymetric analyses around Rock Garden, Kukowski et al. show that the seamount subduction generates slopes of the accretionary ridges often steeper than 20°. Critical taper analysis, using realistic wedge geometries and fluid pressure scenarios, shows that much of the seaward slopes in the region are most likely outside the stability field and therefore subject to failure. The authors conclude "*that a thorough assessment of these features (seamounts) needs to be undertaken and its results incorporated into tsunami hazard models for the East Coast of New Zealand's North Island*".

Towards the west of Rock Garden lies Omakere Ridge. Here, Jones et al. use sidescan, sub-bottom, visual and hydroacoustic data to document six seep sites, five of which were newly discovered. Similar to Klaucke et al., their combined approach using multibeam and sidescan mapping with flare imaging proved to be a very successful and effective strategy. Camera tows across these seep sites confirmed the ongoing seep activity and revealed a flourishing cold water coral reef (Moa). Concentration and $\delta^{13}C$ data of methane as well as temperature and salinity data from a total of 90 water column casts at Omakere Ridge and other areas are reported by Faure et al. Apparently, no methane released from seeps escapes into the atmosphere but is diluted and distributed along specific density gradients, sometimes over large distances. Additional geochemical data from the water column at Opouawe Bank are reported by Law et al. They suggest, based on very low $\delta^{13}C$ methane data (-63 to -70 ‰ PDB), that the methane is biogenic which Faure et al. had also observed for other study areas. Law et al estimate an annual emission of 0.5 to 1 x 10^6 mol CH_4 into the water column from the 1056 m deep South Tower site based on hydroacoustic and geochemical data.

Linke et al. used the deep-sea Fluid Flux Observatory (FLUFO) to acquire current velocities, physical and geochemical flux data from two seep sites. Tidal-forced methane release was detected at Rock Garden by ADCP backscatter data as well as geochemically. Similar hydroacoustic anomalies were seen intermittently at Omakere Ridge. Here, plume modelling points to substantial amounts of dissolved methane that had been released during this event. From additional lander deployments also using the BioGeochemical Observatory (BIGO), Sommer et al. determined the overall respiration based on in-situ oxygen fluxes and ex-situ oxygen micro-profiles in conjunction with CH_4 and SO_4 measurements. This was done at a newly discovered seep habitat dominated by dense beds of heterotrophic ampharetide polychaetes. Towed video system and ROV observations were used by Naudts et al. to describe in detail the Faure Site and LM-3 Site at Rock Garden focussing on geological and biological habitats. They visually determined the bubble flux during an eruptive outburst (ca. 45 sec. long) to be 2.4 l/min corresponding to 7 mol/min of methane.

Seep biology is the subject of the two following papers. Baco et al. provide an initial characterization of cold seep faunal communities on the Hikurangi Margin based on visual observations and benthic sled- and multicorer-sampling carried out during TAN0616. Thurber et al. focus on the utilization of methane by different biological assemblages (e.g. polychaetes, sponges) using carbon and nitrogen stabile isotope signatures. They contrast the dominant symbiont-bearing mega fauna and heterotrophic mega- and macro-fauna from 10 methane-seep sites.

Linking biology and geology, Martin et al. present a foraminifera study to establish what effects, if any, methane-influenced pore waters have on benthic assemblages and the carbon isotopic signature of their tests. The data significantly differentiate between seep and non-seep sites based on the greater ^{13}C depletion and larger heterogeneity of $\delta^{13}C$ values in seep foraminifera. Campbell et al. in a comprehensive study evaluate the influence of methane seepage on sedimentological, biological, mineralogical and stable isotopic attributes of sediments. Based on box and multicorer samples and X-ray studies they show how the sediment fabric is affected by infaunal bivalves. Mineralogy and stable isotope studies as well as biomarker analyses of e.g. authigenic aragonite cemented carbonate nodules and rocks show $\delta^{13}C$ values as negative as -50 ‰ PDB, which demonstrate a methane-derived carbon source. Dolostones with $\delta^{18}O$ values of up to +7 ‰ PDB suggest pore fluids from gas hydrate dissociation.

To elucidate the geochronological framework, isotope geochemical signatures and structural environment of methane related authigenic carbonates, Liebetrau et al. use U/Th ages, $\delta^{234}U$ values and $^{230}Th/^{234}U$ activity ratios, together with $d^{13}C$ and $d^{18}O$ stabile isotope studies, to conclude that aragonite precipitations from Opouawe Bank, Uruti and Omakere Ridge reflect different generations of seep activity between 12,400 ± 160 and 2,090 ± 850 years BP. In studies on the adjacent land, Nyman et al. show that quite different forms of carbonate pipe and bulbous concretions, up to 5m long and 1 m in diameter, form as the plumbing systems for advecting methane-rich fluids. They record Miocene micritic dolomites with $\delta^{13}C$ values ranging from -22 to +13 ‰ PDB, which they interpreted to reflect carbonate precipitation from either the extensive anaerobic oxidation of methane and/or mixing of microbial methane and methanogenic CO_2.

In response to queries by reviewers, the following terminology with regards to terms ‘seep’, ‘vent’, ‘seep area’ or ‘flare’ is used. Flares are hydroacoustic manifestations of bubbles on an echogram. Elsewhere the term ‘plume’ is also used to describe the same hydroacoustic feature, but also to describe geochemical anomalies in the water column and the massive release of bubbles that initiates an upwelling flow of water together with the bubbles. To avoid misunderstanding with the latter, the term ‘flare’ is used to describe what is seen on an echogram. We consistently used the term ‘seep’ as a generic description of an ecosystem where methane-rich fluids are released from the seafloor without any implications about the size or number of fluid-releasing holes. Such mainly bubble releasing holes are called ‘vents’ not to be confused with hydrothermal vents (e.g. smokers). A ‘seep site’ is an area of several tens to a few 100s of meters in extent, with more or less continuous occurrences of typical seep features as authigenic ‘chemoherm’ carbonates, bacteria, clams, tube worms or bubble escapes. A ‘seep area’ represents the accumulation of two or more seep sites at a geologically or morphologically defined setting like a ridge (e.g. Uruti Ridge, Omakere Ridge) or bank (Opouawe Bank).

Finally, we would like to thank the Editor-in-Chief and journal manager of Marine Geology and in particular all the reviewers who put in an immense effort in providing valuable and critical comments on the manuscripts and tremendously helped to improve our entire effort to bring this Special Issue to publication.

We hope you enjoy reading about the findings at the Hikurangi Margin

Jens, Jörg, Keith and Erwin

Table 1: Sequence and studied seep areas of the presented papers.

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#	Author	Seep Areas
1	Greinert	Overview, all areas
	Seismic studies and geophysical reconnecense	
2	Barnes et al.	Overview, all areas
3	Klaucke et al.	Opouawe Bank
4	Netzeband et al.	Opouawe Bank
5	Krabbenhoeft et al.	Opouawe Bank
6	Schwalenberg et al. a	Opouawe Bank
7	Schwalenberg et al. b	Porangahau Ridge
8	Pecher at al.	Porangahau Ridge
9	Crutchley et al	Rock Garden,
10	Ellis et al.	Rock Garden
11	Kukowski et al.	Rock Garden
12	Jones et al.	Omakere Ridge

	Water and sediment chemistry / ROV and insitu observatories	
13	Faure et al.	Opouawe Bank, Rock Garden, Uruti Ridge, Omakere Ridge,
14	Law et al.	Opouawe Bank
15	Linke et al.	Rock Garden, Omakere Ridge
16	Sommer et al.	Opouawe Bank, Rock Garden, Omakere Ridge
17	Naudts et al.	Rock Garden
	Biology / Foraminifera	
18	Baco et al.	Opouawe Bank, Uruti Ridge, Rock Garden, Omakere Ridge, Ritchie Ridge
19	Thurber et al.	Opouawe Bank, Uruti Ridge, Rock Garden, Omakere Ridge, Ritchie Ridge
20	Martin et al.	Opouawe Bank, Rock Garden, Omakere Ridge
	Carbonates	
21	Campbell et al.	Opouawe Bank, Uruti Ridge, Rock Garden, Omakere Ridge
22	Liebetrau et al.	Opouawe Bank, Uruti Ridge, Omakere Ridge
23	Nyman et al.	Onshore, Hawke’s Bay region