

Geochemical Assessment of Coastal Gas Hydrate Loading off the Coast of New Zealand*

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Abstract

Through world, coastal oceans there have been extensive surveys with the application of seismic data to predict deep sediment gas hydrate loading. Over the past 10 years comparisons of seismic data and geochemistry show there is a need to combine these data for a more thorough understanding of the deep sediment gas hydrate loading. Initial observations in predicting hydrate presence with integration of seismic and geochemistry data off the mid Chilean margin suggested gas hydrate loading could be greater at a location where seismic data showed moderate gas blanking. On the Atwater Valley in the Gulf of Mexico geochemical assessment showed a region with a strong vertical rise in the BSR to be a site where gas hydrate is likely not stable as a result of salt diapir intrusions creating gas hydrate instability and higher vertical methane advection. Here we present a series of data along the eastern coast of New Zealand that include seismic profiles, geochemistry, controlled source electromagnetics, and heat flow to assess gas hydrate loading. This comparison of locations shows remarkable inconsistencies in the data sets applied to gas hydrate predictions. Through these locations comparisons include: 1) The Porangahau Ridge in the Hikurangi Margin where geochemical profiles focusing anaerobic methane oxidation display moderate vertical gas migration in a region that strong seismic reflection, active heat flow, and controlled source electromagnetic data suggest deep gas hydrate loading and active fluid and gas advection. 2) Mahia Peninsula located further south from the Porangahau Ridge show strong similarity in geochemical and seismic data for assessment vertical methane fluxes in two different transects. However, porewater geochemical data from these transects compared to a location where seismic data indicates no gas hydrate loading are similar. A

more in-depth assessment of vertical fluid and gas migration in this area will be compared with porewater oxygen-18 stable isotope data. 3) Chatham Rise, a region where published seismic data was believed to contain gas hydrate loading was found to have a total absence of vertical methane migration. In this location, radiocarbon data of shallow sediment carbonate and organic carbon suggest a potential for carbon dioxide migration. This observation has resulted in plans for a paleo-geochemical study to understand vertical carbon dioxide migration over climate cycles.

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Coffin, R.B., L.J. Hamdan, J.P. Smith, P.S. Rose, R.E. Plummer, B.A. Yoza, I. Pecher, and M.T. Montgomery, 2014, Contribution of Vertical Methane Flux to Shallow Sediment Carbon Pools across Porangahau Ridge, New Zealand: *Energies*, v. 7/8, p. 5332-5356, <https://doi.org/10.3390/en7085332>

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Geochemical Assessment of Coastal Gas Hydrate Loading off the Coast of New Zealand

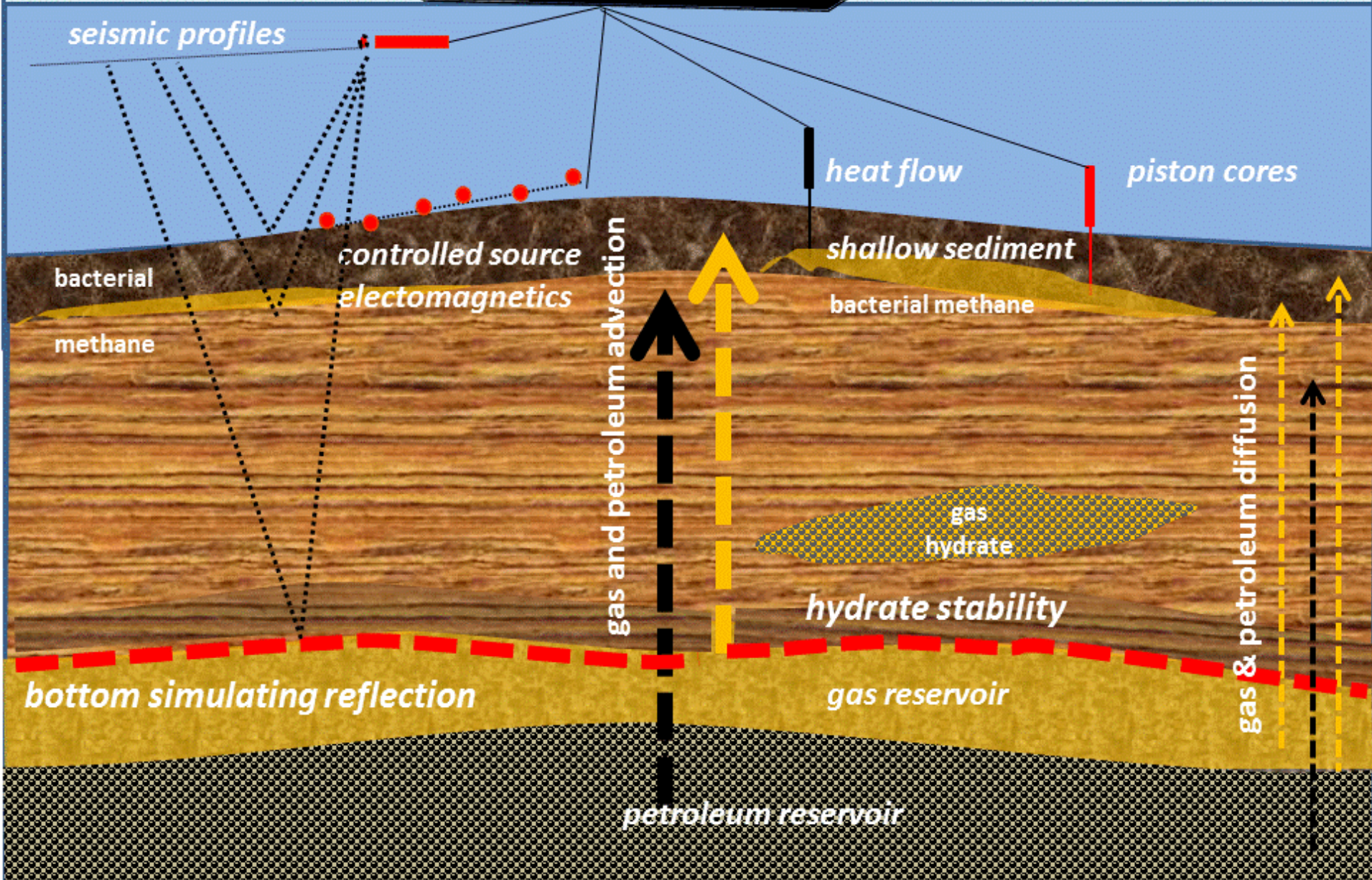


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Ingo Pecher, University of Auckland, Auckland, New Zealand
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Joshu Mountjoy, NIWA-Wellington, Wellington, New Zealand

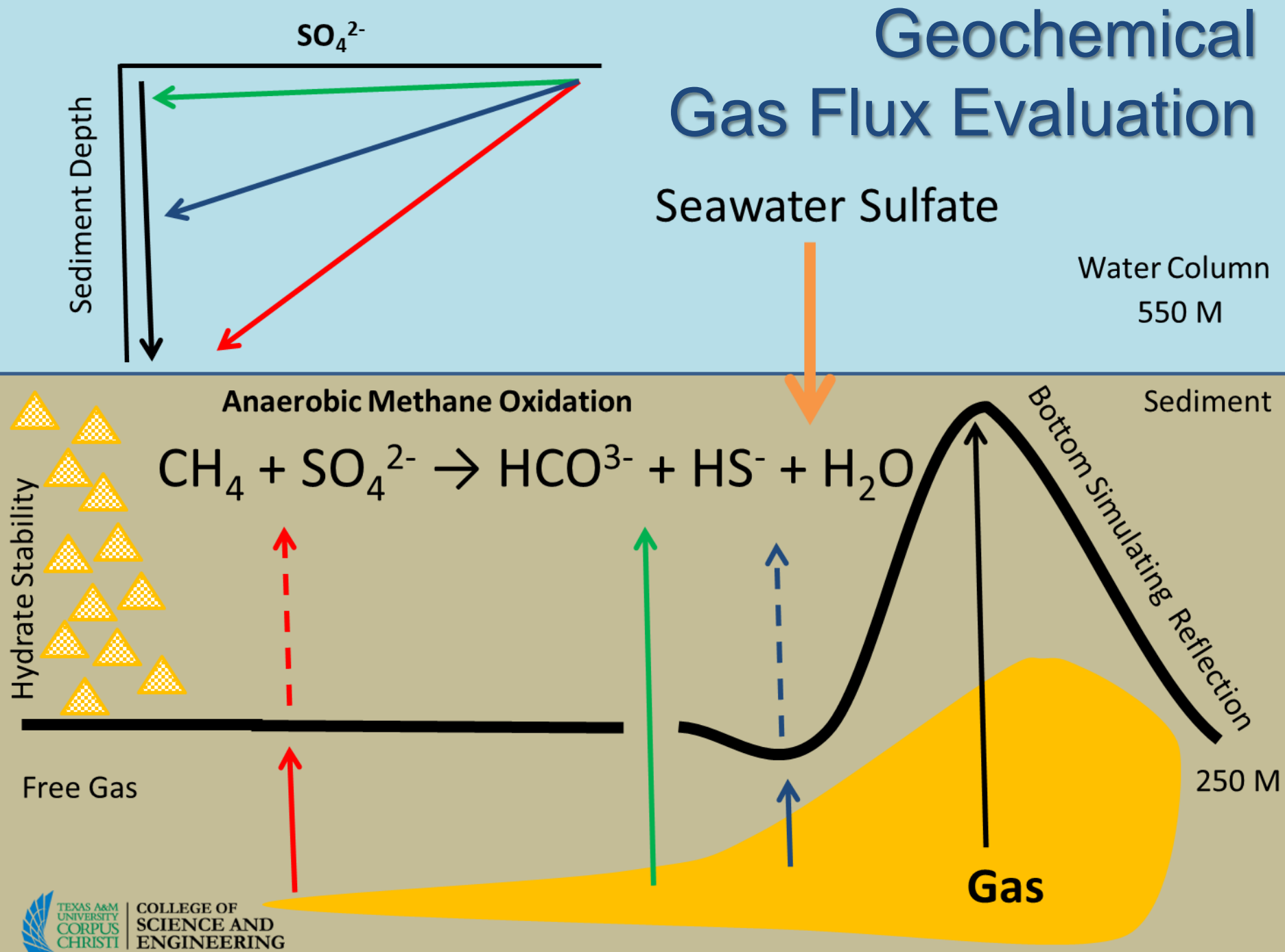
Acknowledgements

- Branden Yoza, University of Hawaii
- Jens Greinert, Geomar
- Joe Smith, US Naval Academy
- Kate Waghorn, University of Auckland
- Bryan Davy, GNS Wellington
- Lowell Stott, University of South Carolina

General Exploration Technology



Geochemical Gas Flux Evaluation



Carbon Source and Cycling

$$C_x = C_a + C_b$$

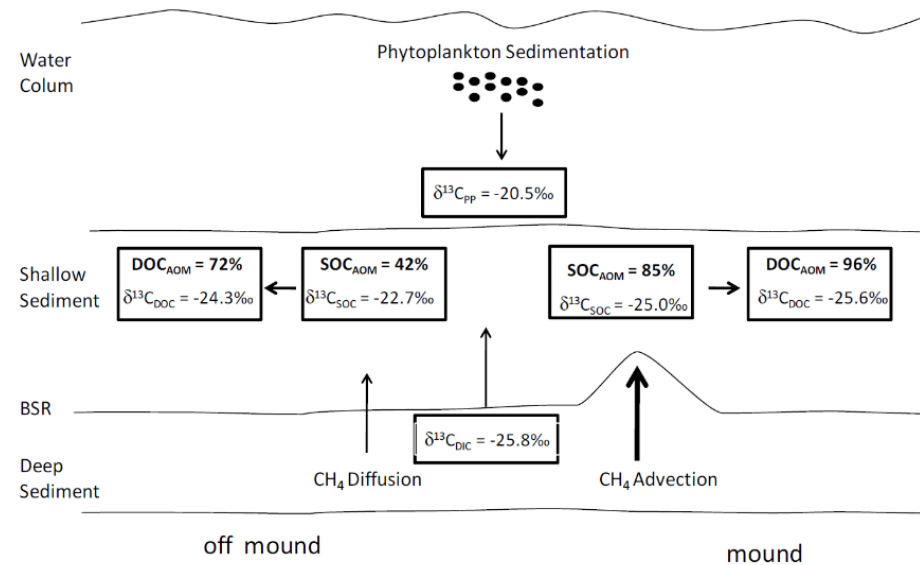
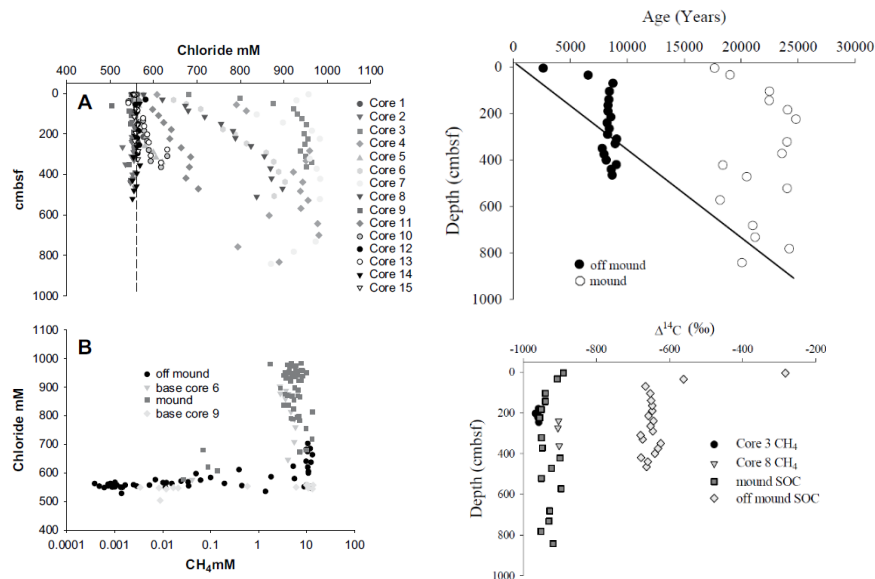
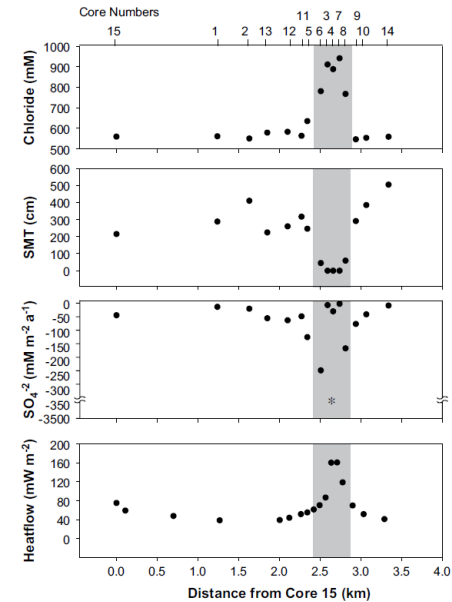
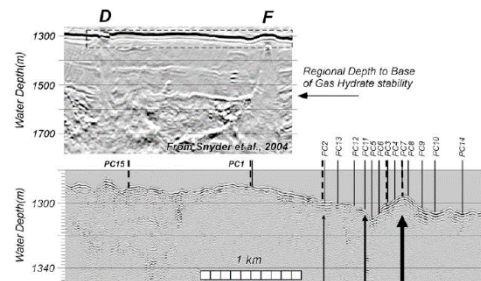
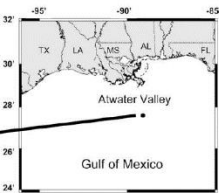
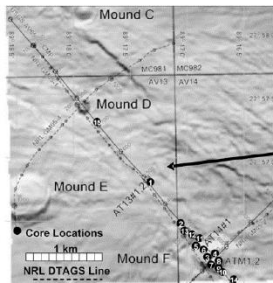
$$\delta^{13}C_x C_x = \delta^{13}C_a C_a + \delta^{13}C_b C_b$$

$$\delta^{13}C_x C_x = \delta^{13}C_a C_a + \delta^{13}C_b C_b + \delta^{13}C_{\Delta} \Delta C$$

$$\frac{d(\delta^{13}C_x C_x)}{dC} = \delta^{13}C_{\Delta} + \frac{d(\delta^{13}C_{\Delta})}{dC}$$

Coffin et al. 2013 . Spatial Variation in Shallow Sediment Methane Sources and Cycling on the Alaskan Beaufort Sea Shelf/Slope. 10.1016/j.marpetgeo.2013.05.002

Atwater Valley Gulf of Mexico

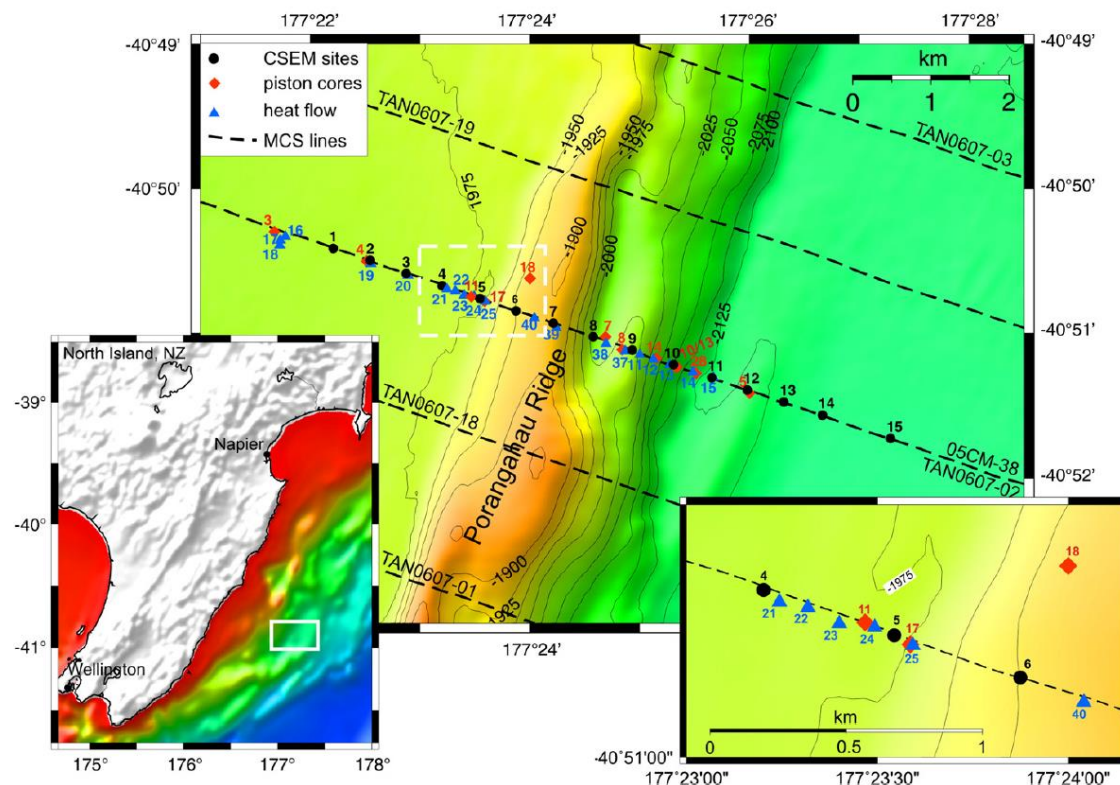


New Zealand Key Findings

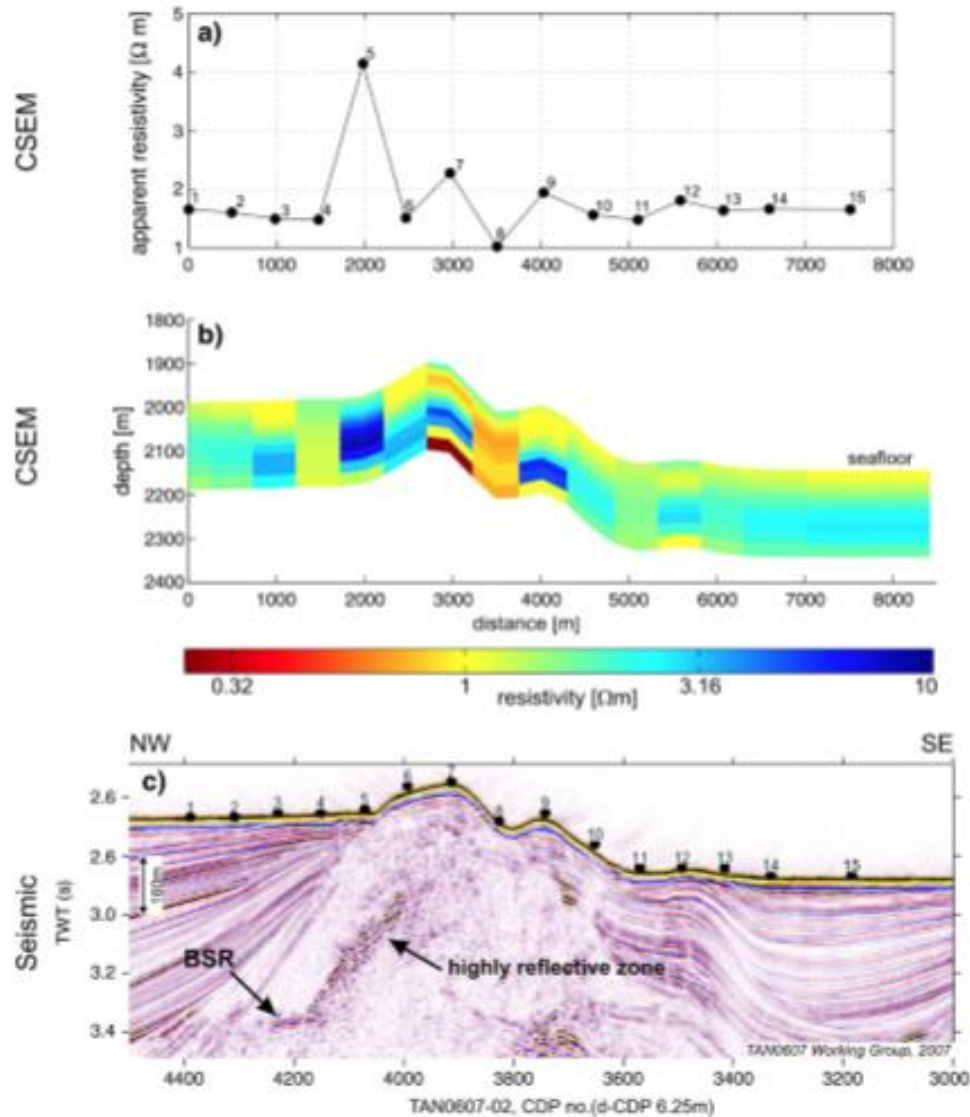
- Integration of seismic, geochemical, heatflow, and controlled source electromagnetic data on the Hikurangi Margin, New Zealand showed high vertical fluid and gas migration with low methane flux. – **2006**
- Observation of no vertical methane gas flux in regions across the Chatham Rise New Zealand, thought to have current and past hydrate loading. Current interpretation is deep system CO₂. – **2013**
- Presence in elevated gas flux at locations on the Hikurangi Margin where seismic data were interpreted to have low gas loading, no BSR was observed. – **2015**

Preliminary interpretation of electromagnetic, heat flow, seismic, and geochemical data for gas hydrate distribution across the Porangahau Ridge, New Zealand

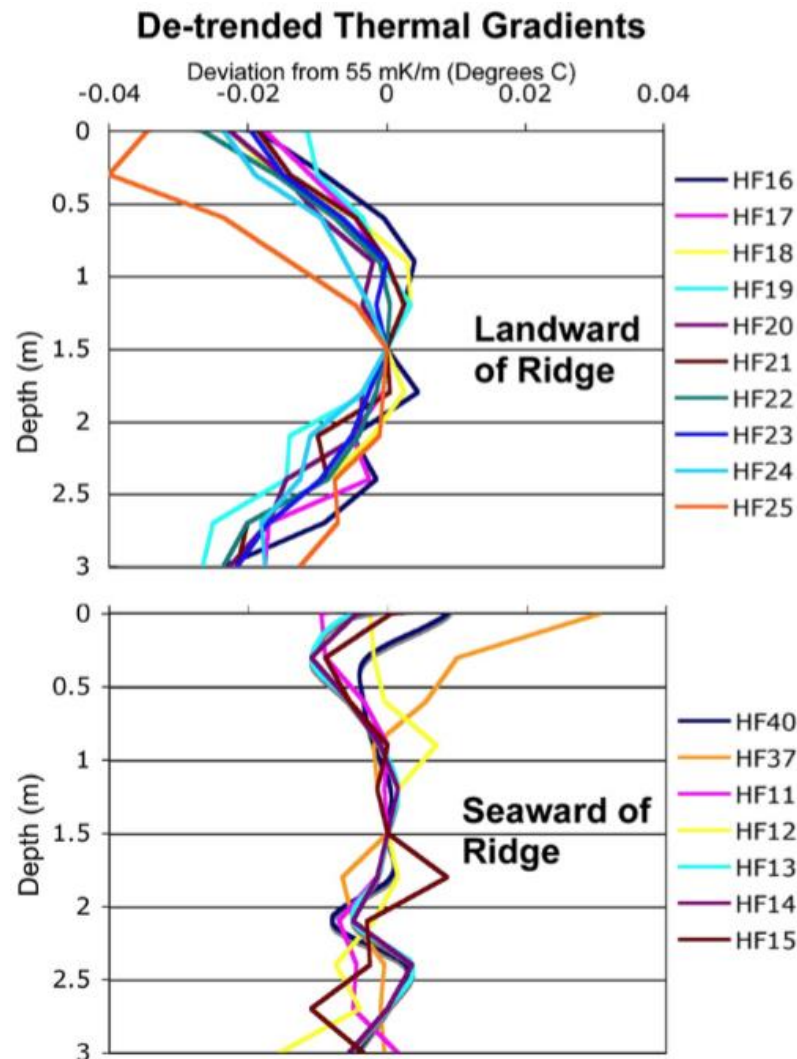
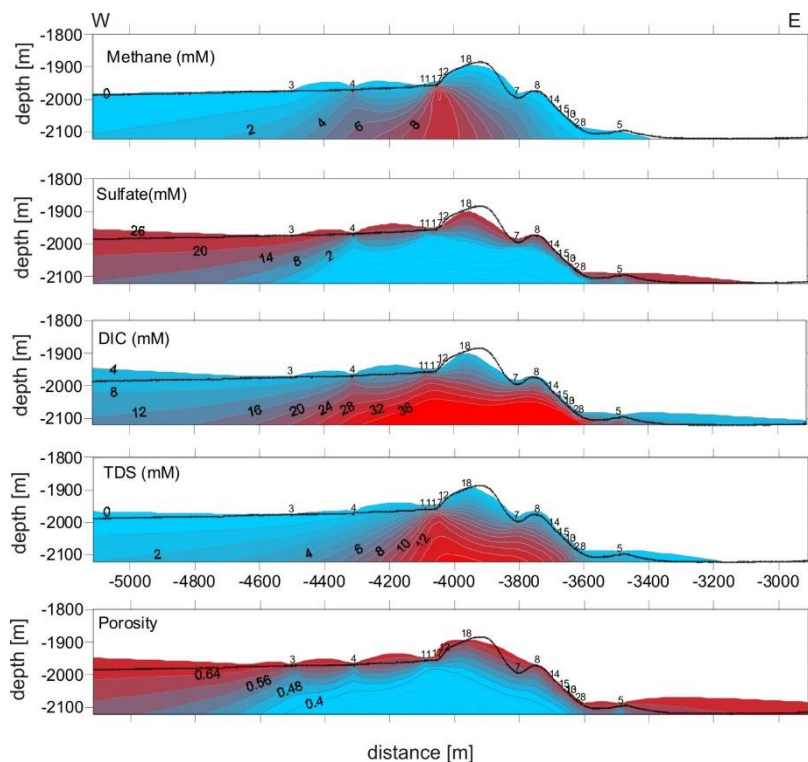
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Seismic and CSEM Data



Porangahau Ridge – Advection or Diffusion?

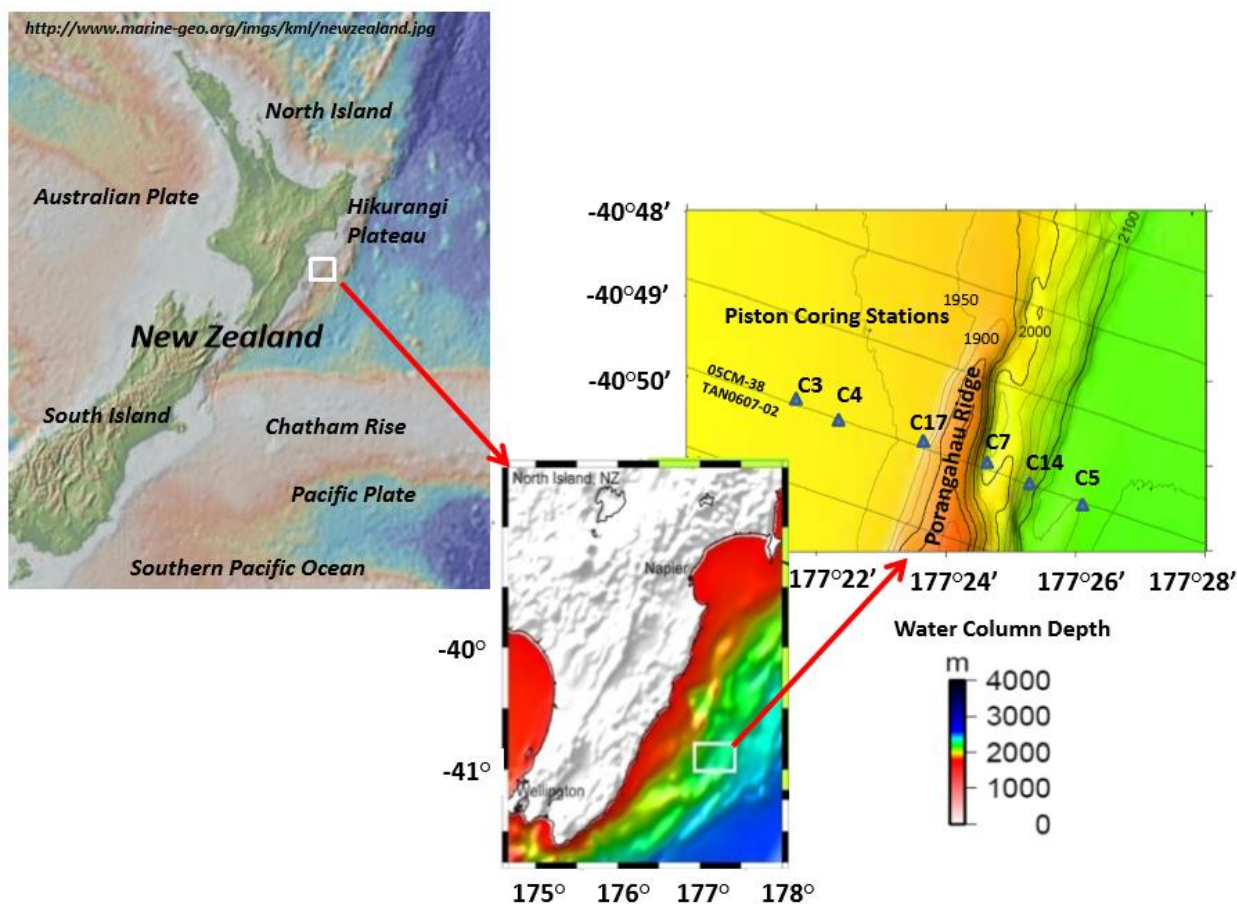


PC	SMT depth (mbsf)	Regional position
3	12.8	Landward of ridge
4	4.4	Landward of ridge
11	2.9	Landward of ridge
17	1.8	Landward of ridge
18	8.1	Apex of ridge
7	2.1	Seaward of ridge
8	3.6	Seaward of ridge
14	3.8	Seaward of ridge
10	Not calculated	Seaward of ridge
13	2.7	Seaward of ridge
28	3.2	Seaward of ridge
5	3.6	Seaward of ridge

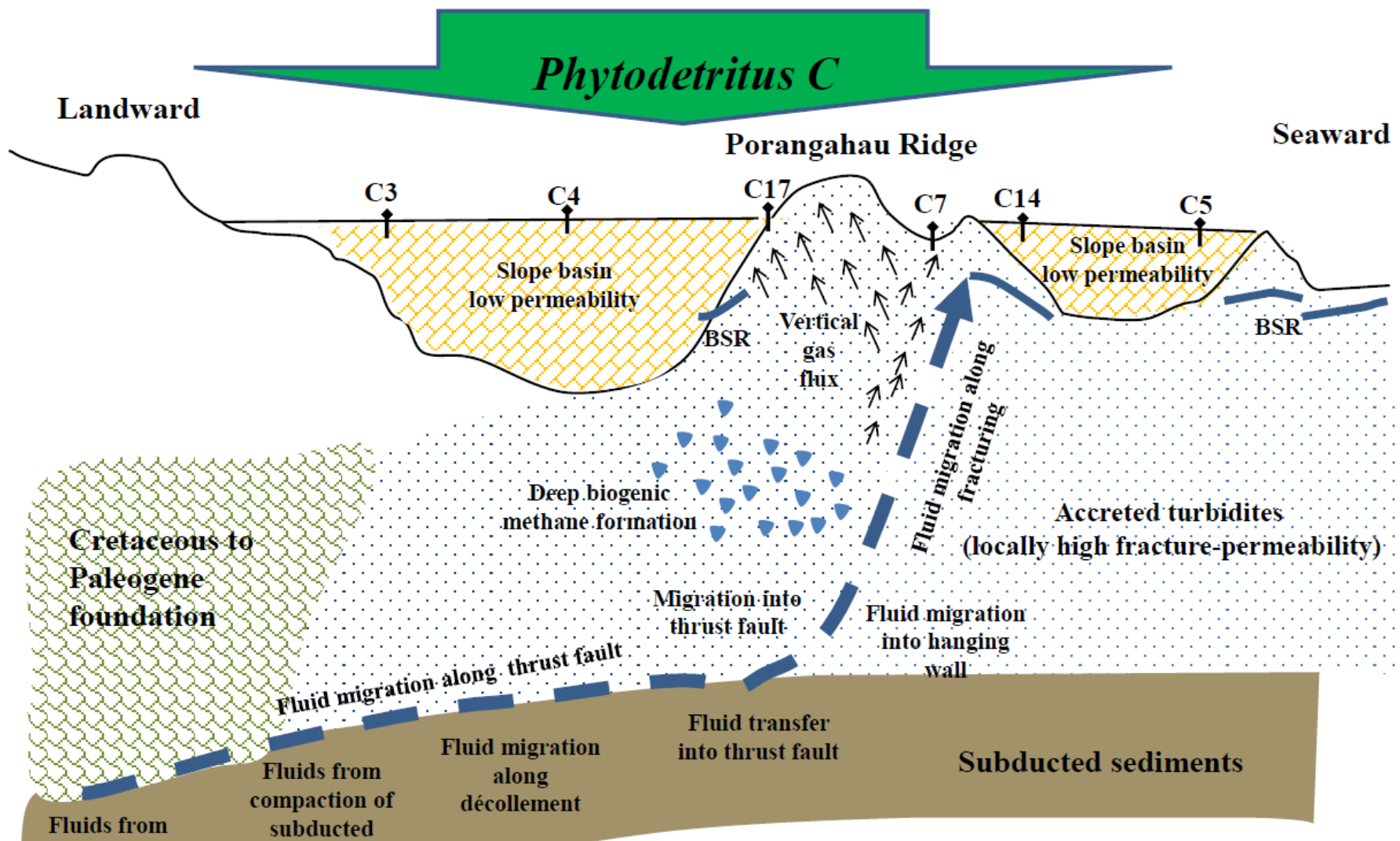
Contribution of Vertical Methane Flux to Shallow Sediment Carbon Pools across Porangahau Ridge, New Zealand

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 Rebecca E. Plummer ⁵, Brandon Yoza ⁶, Ingo Pecher ⁷ and Michael T. Montgomery ¹

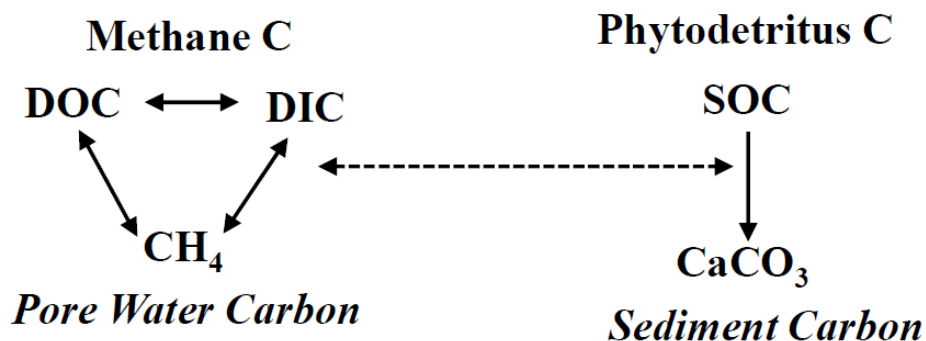
Energies **2014**, *7*, 5332–5356; doi:10.3390/en7085332



Porangahau Ridge – Advection or Diffusion?



Porangahau Ridge – Advection or Diffusion?



$$\frac{d(\delta^{13}\text{C} \times \text{C})}{d\text{C}} = \delta^{13}\text{C}_{\Delta} + \frac{d(\delta^{13}\text{C}_{\Delta})}{d\text{C}} \Delta\text{C}$$

Core	SOC			CaCO ₃			DOC			DIC		
	End members		Samples	End members		Samples	End members		Samples	End members		Samples
	PD	DIC *		PD	CH ₄		PD	DIC *		PD	CH ₄	
C4	-21.7	-41.5	-24.4	-0.3	-83.3	-2.7	-21.7	-41.5	-23.3	-21.7	-83.3	-41.5
C17	-21.7	-47.6	-24.7	-0.3	-83.3	-43.9	-21.7	-47.6	-42.8	-21.7	-83.3	-47.6
C7	-21.7	-38.5	-23.4	-0.3	-83.3	-15.0	-21.7	-38.5	-26.6	-21.7	-83.3	-38.5

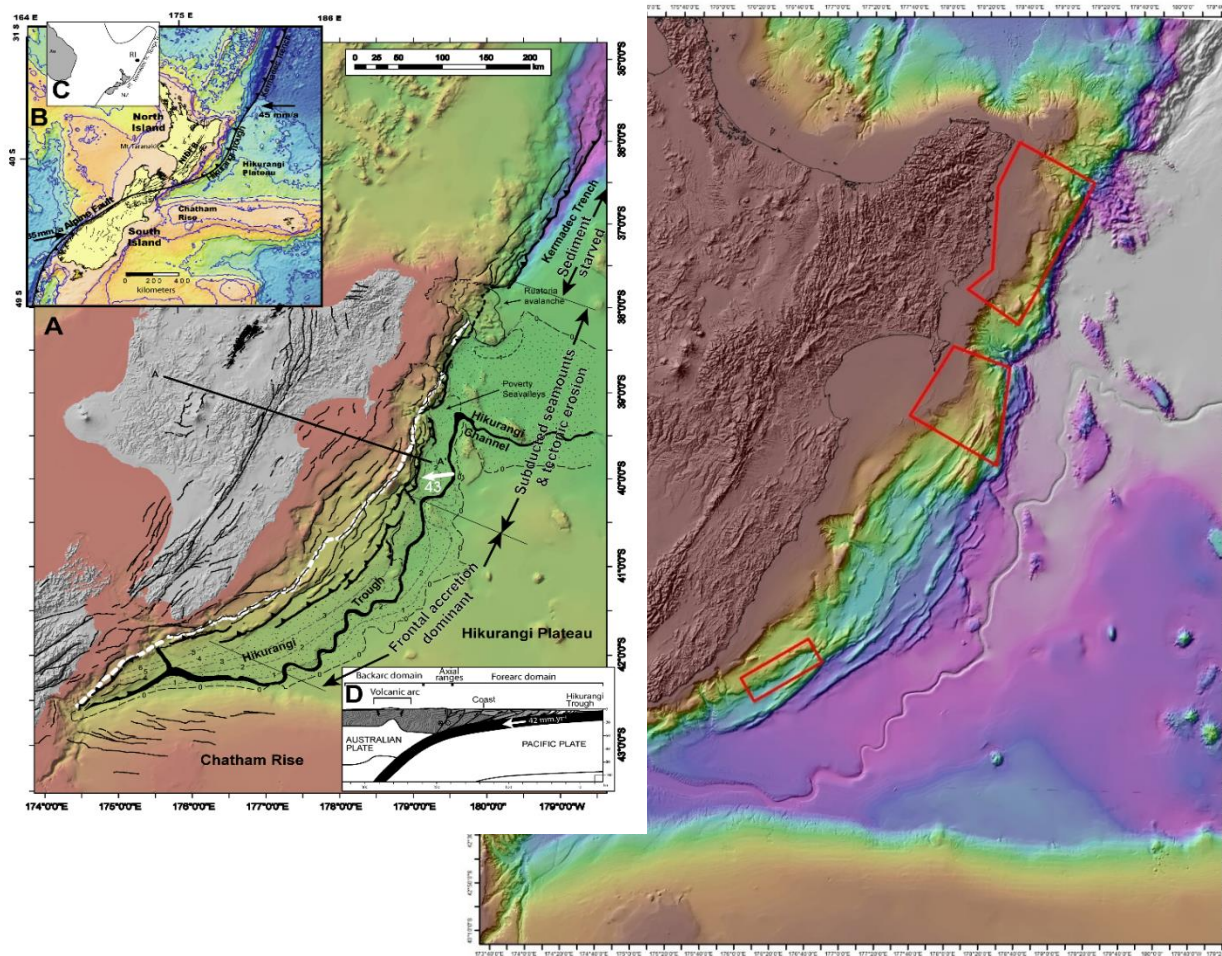
Core	DIC	DOC	CaCO ₃	SOC
C4	32%	7%	3%	12%
C17	47%	71%	55%	8%
C7	33%	24%	19%	8%

Vertical CH₄ Diffusion in Different Regions

Location	Minimum SMT (cmbsf)	Maximum SMT (cmbsf)	Minimum Diffusion (mM CH ₄ m ⁻² a ⁻¹)	Maximum Diffusion (mM CH ₄ m ⁻² a ⁻¹)	Reference
Beaufort Sea	147	2905	2.1	154.8	Coffin et al. 2013
Chatham Rise, New Zealand	1600	11700	-	-	Coffin et al., 2013
Hikurangi Margin, NZ, 2015	370	1136	16	73	Coffin et al., 2015
Mid Chilean Margin	33	1011	13.3	362.0	Coffin et al., 2006
Atwater Valley, Gulf of Mexico	0	410	20.4	249.1	Coffin et al., 2008
Kara, Chukchi and White Seas	-	-	0.44	47.4	Lein et al., 2011
Hikurangi Margin, New Zealand	183	1287	11.4	86.2	Coffin et al., 2009
Alaminos Canyon, Gulf of Mexico	308	1793	-	-	Coffin et al., 2009
Umitaka Spur, Japan	200	300	58	102	Snyder et al., 2007
Western Argentine Basin	370	22000	1	162.5	Hensen et al., 2003
GB & MC, Gulf of Mexico	~100	~250	-	-	Ruppel et al., 2005
Southern Chilean Margin	-	-	46	100	Treude et al., 2005
Bering Sea Slope	6	-	-	25.3	Wehrmann et al., 2011

Vertical Methane Migration on the Hikurangi Margin off the Mahia Peninsula, New Zealand

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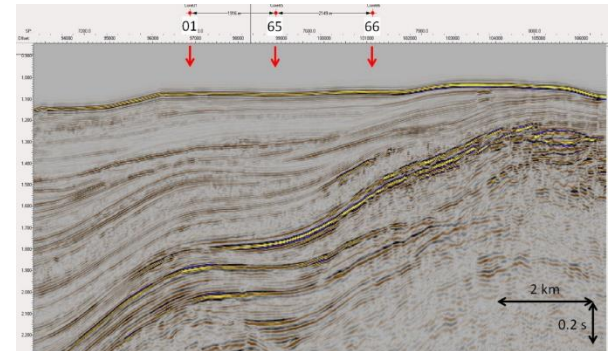


Core Sites

Control Cores

Station	SMT (cmbsf)	SO ₄ ²⁻ (mmol m ⁻² a ⁻¹)
1	257	-67.8
65	495	-31.5
66	468	-33.4

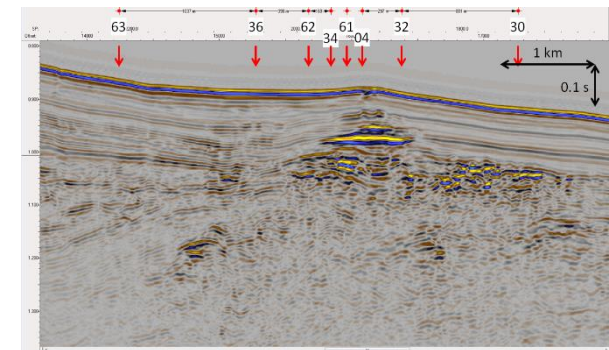
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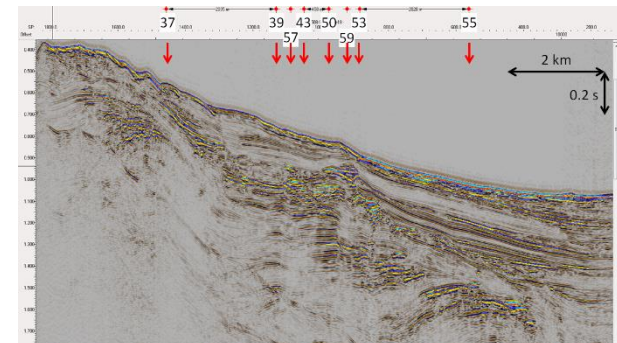
Mahia Transect 1

Station	SMT (cmbsf)	SO ₄ ²⁻ (mmol m ⁻² a ⁻¹)
37	366	-37.0
39	405	-47.5
57	357	-38.9
43	238	-69.8
50	1136	-15.8
59	621	-22.2
53	555	-25.6
55	732	-15.9

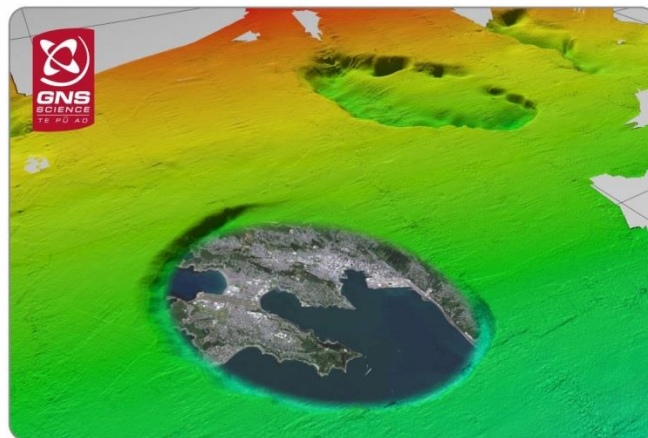
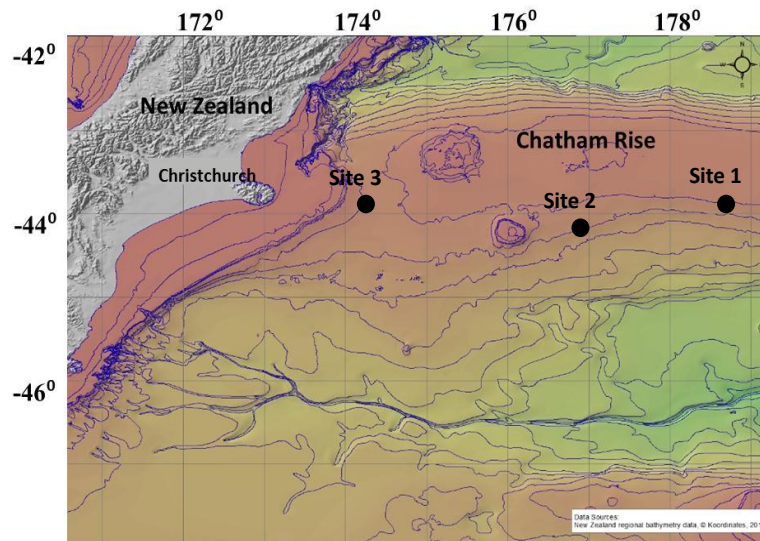
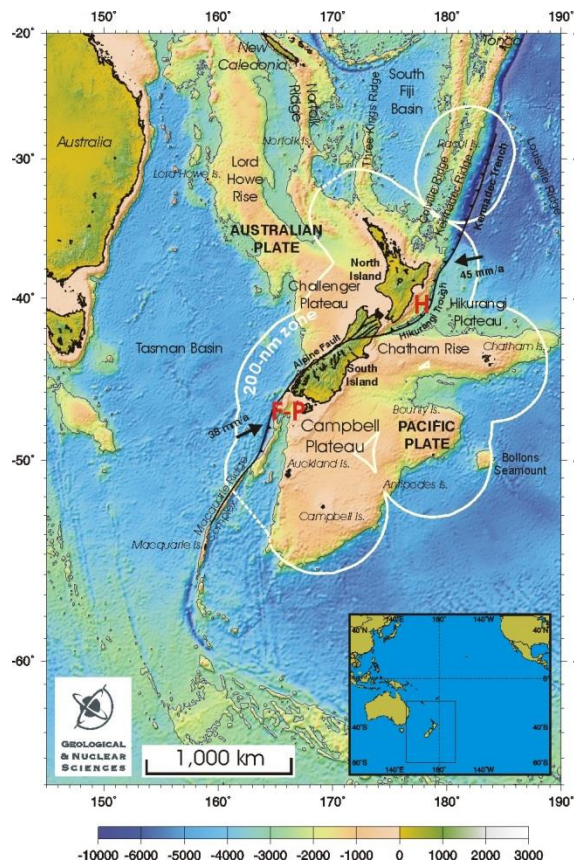
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Mahia Transect 2



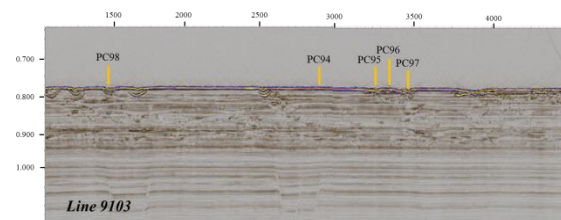
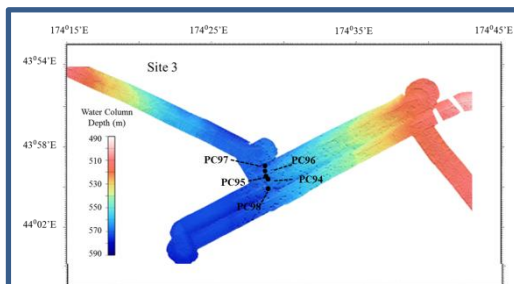
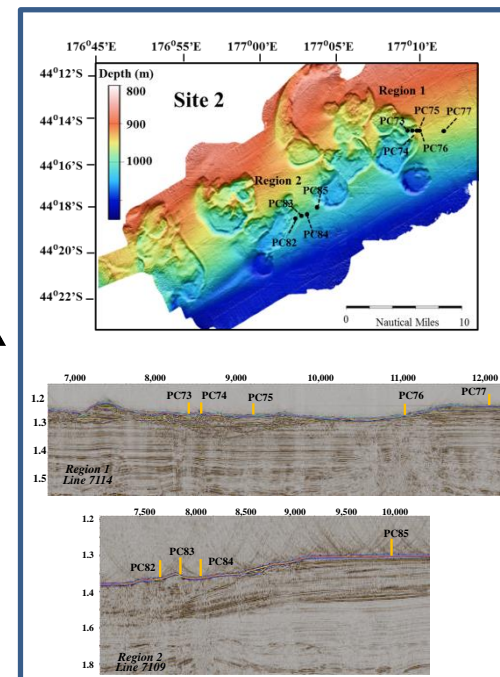
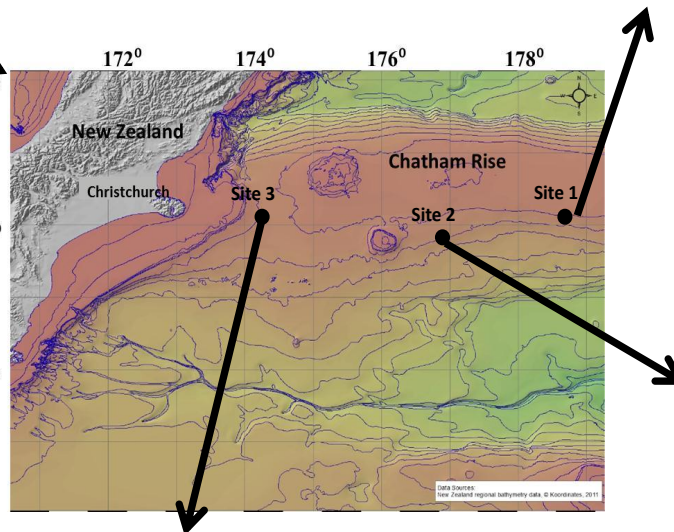
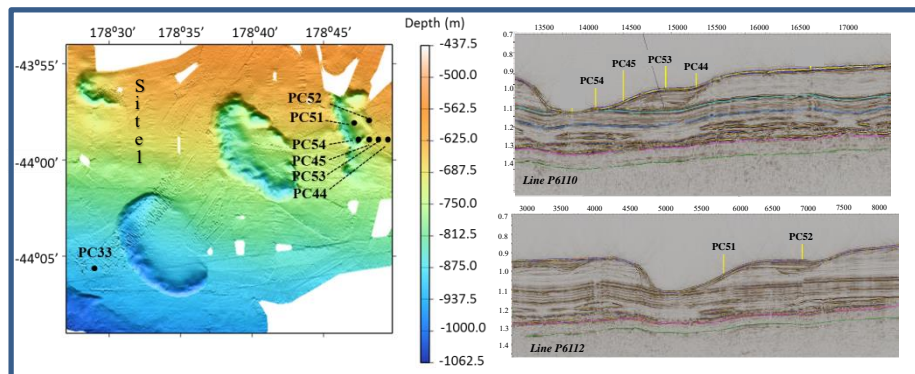
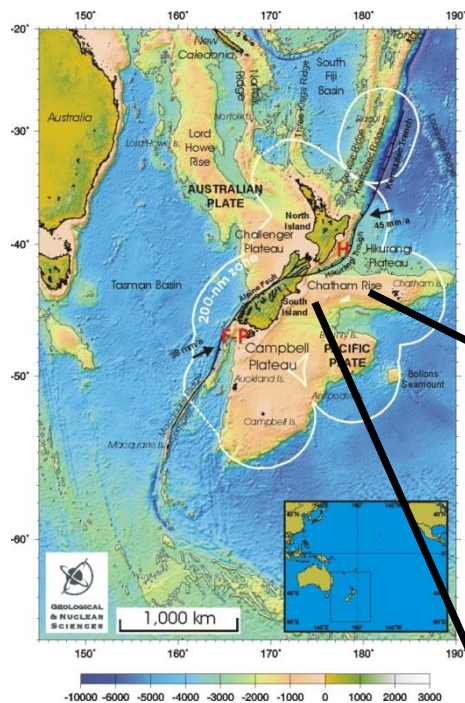
Geochemical Analysis of Vertical Methane Fluxes on the Chatham Rise, Eastern New Zealand





Te Whare Wānanga o Ōtago
NEW ZEALAND

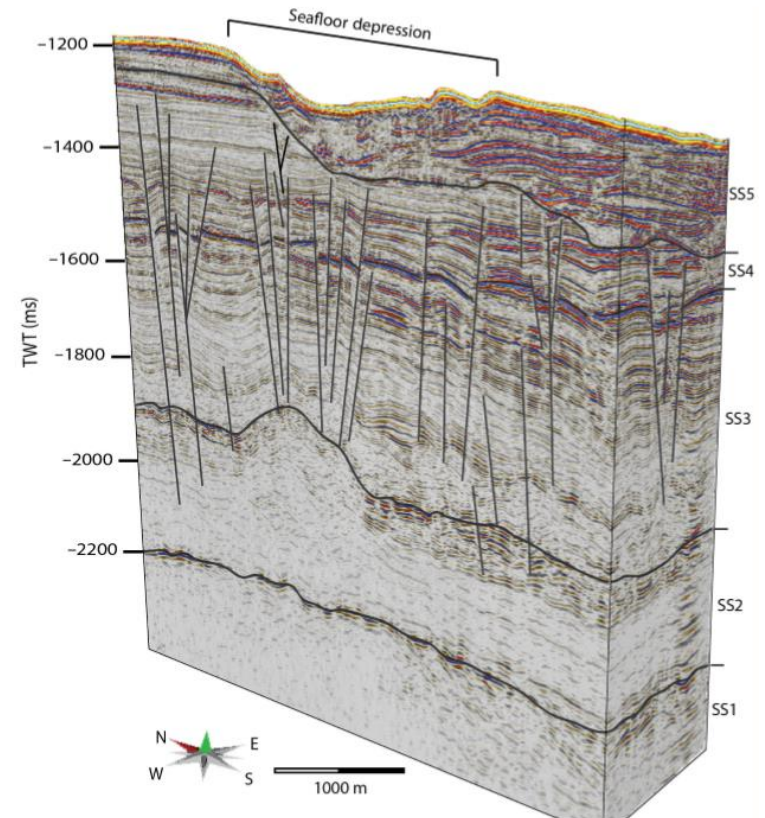
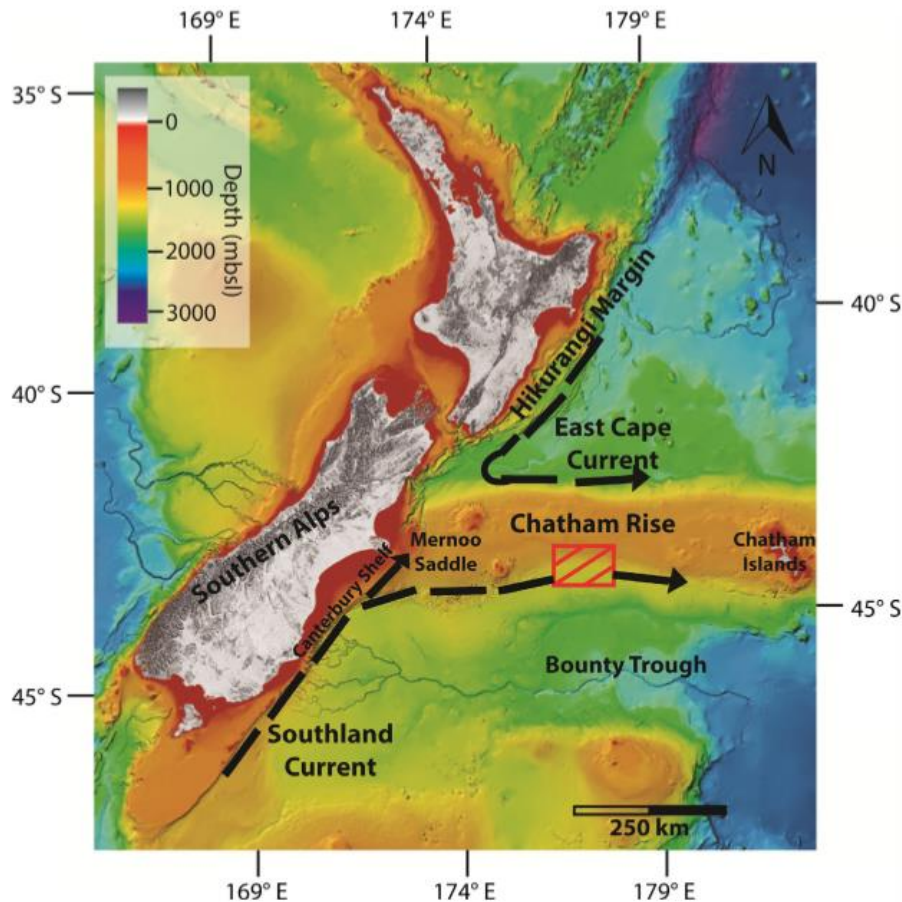


Chatham Rise – Methane Diffusion?

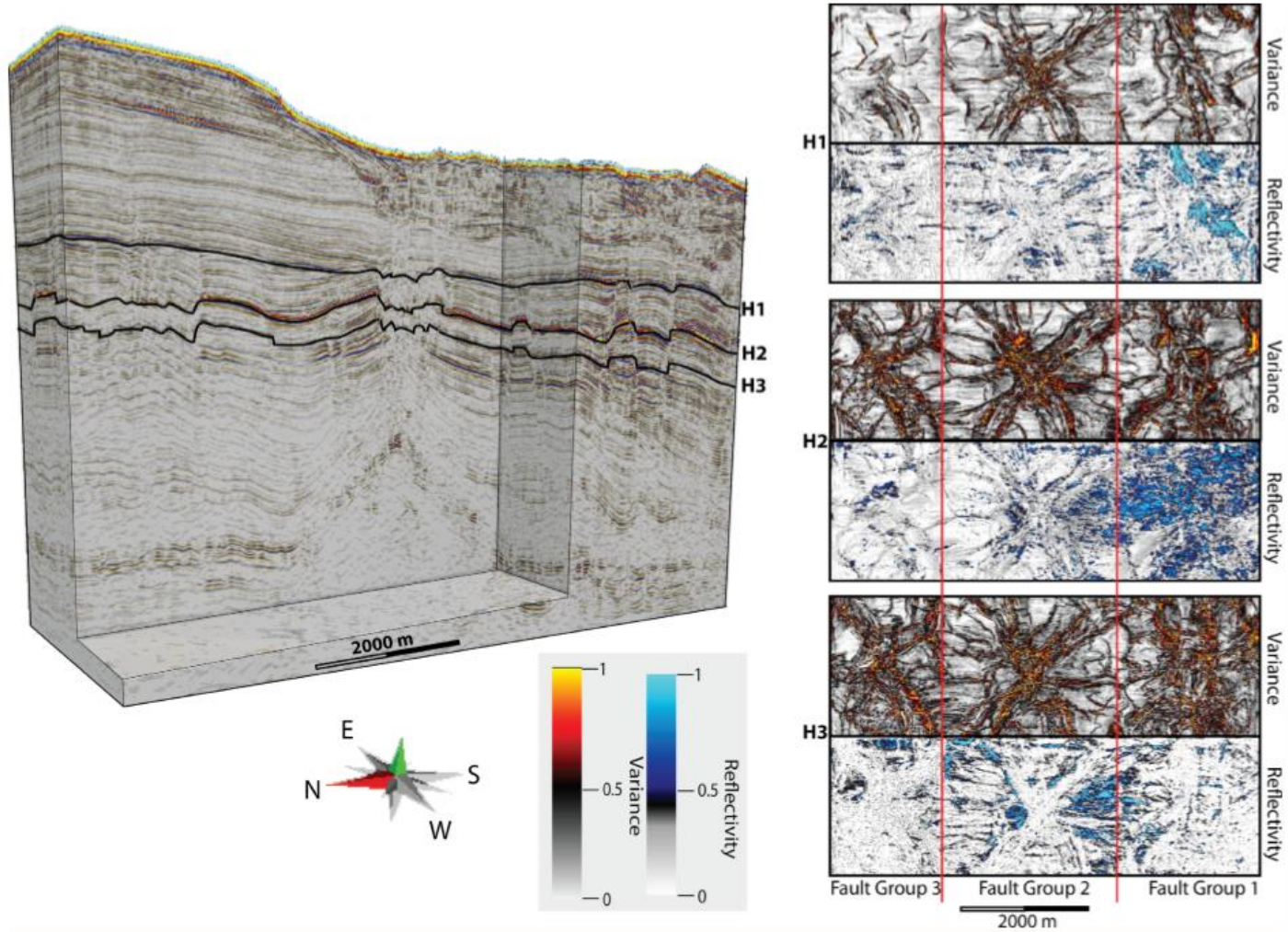


Paleo-fluid expulsion and contouritic drift formation on the Chatham Rise, New Zealand

Kate Alyse Waghorn,^{*,†}  Ingo Pecher,^{*} Lorna J. Strachan,^{*} Gareth Crutchley,[‡] Jörg Bialas,[§] Richard Coffin,[¶] ^{**} Bryan Davy,[‡] Stephanie Koch,[§]  Karsten F. Kroeger,[‡] Cord Papenberg,[§] Sudipta Sarkar[§] and SO.226 Scientific Party



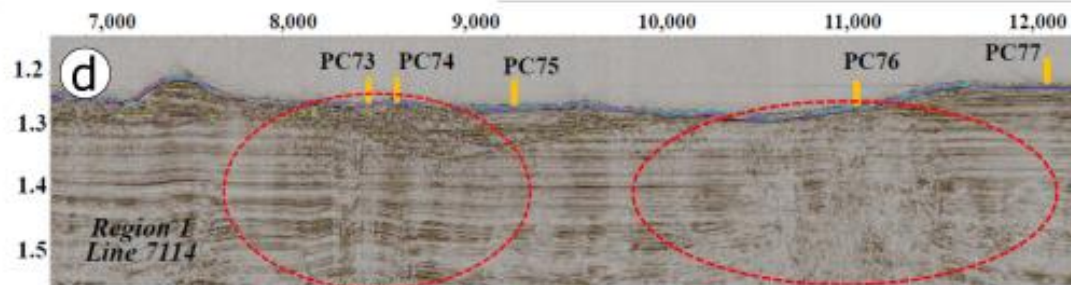
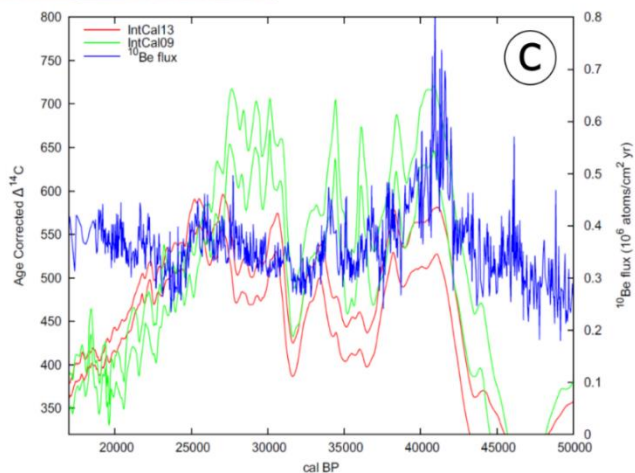
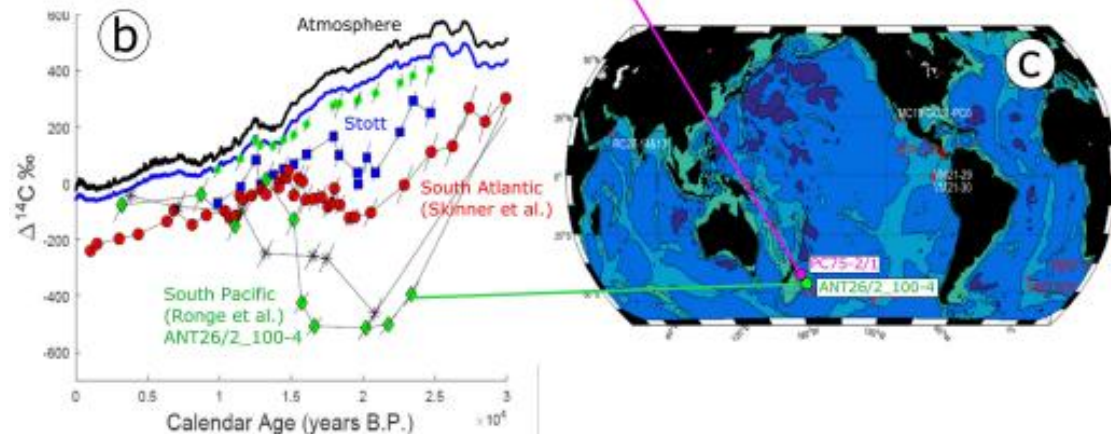
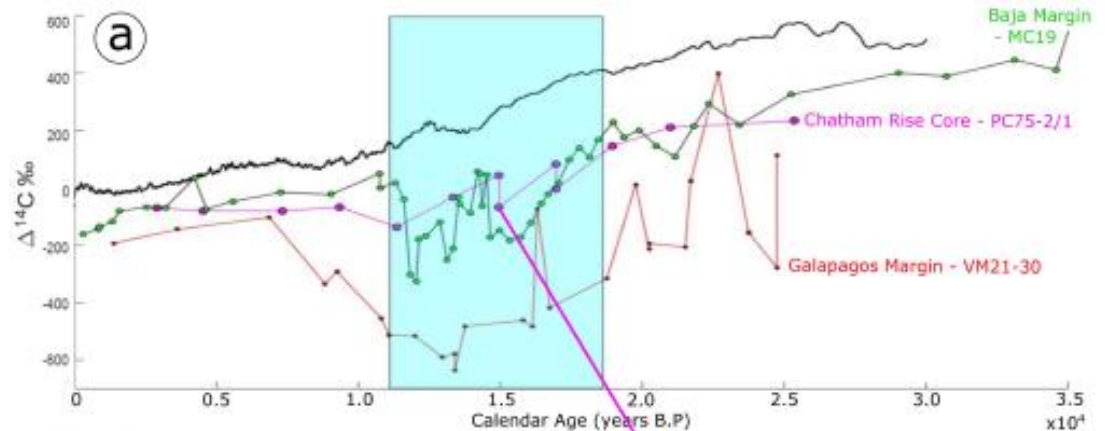
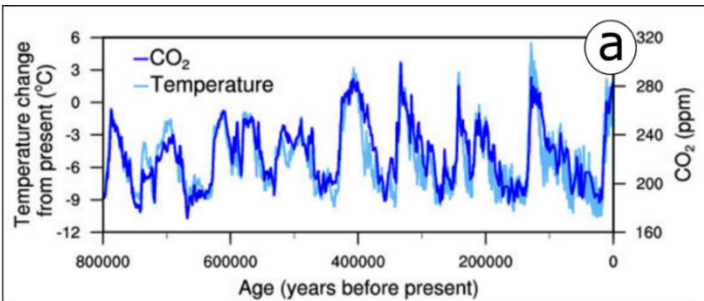
Paleo Depressions and Erosion



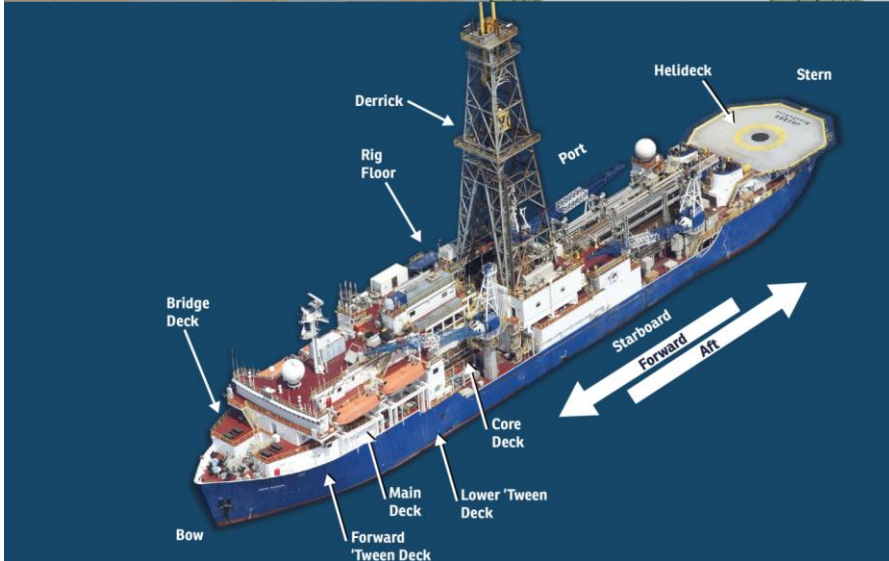
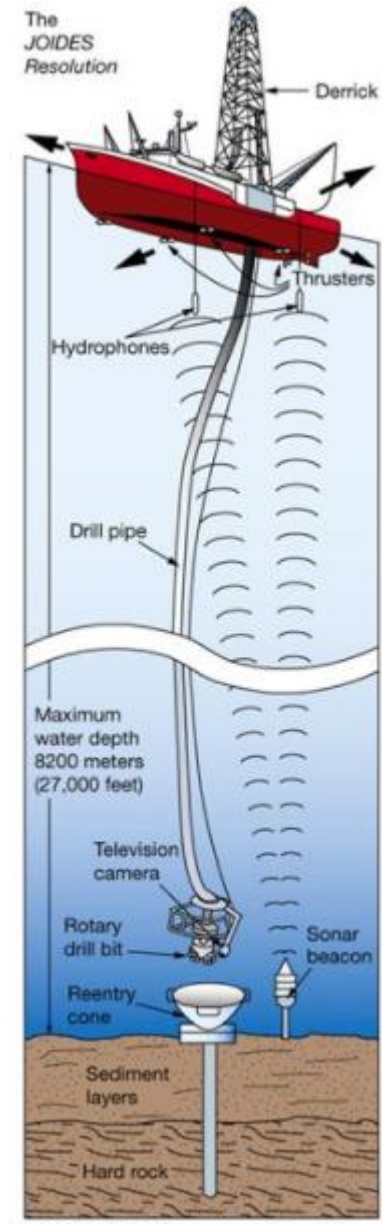
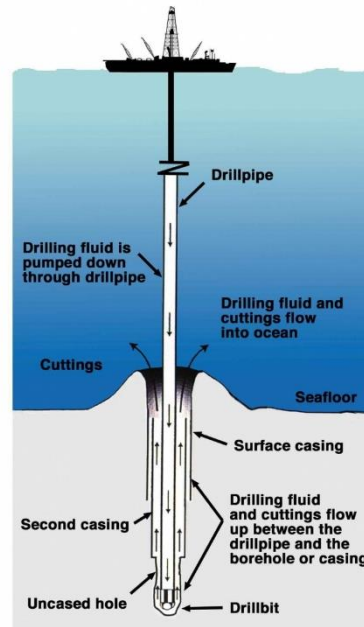
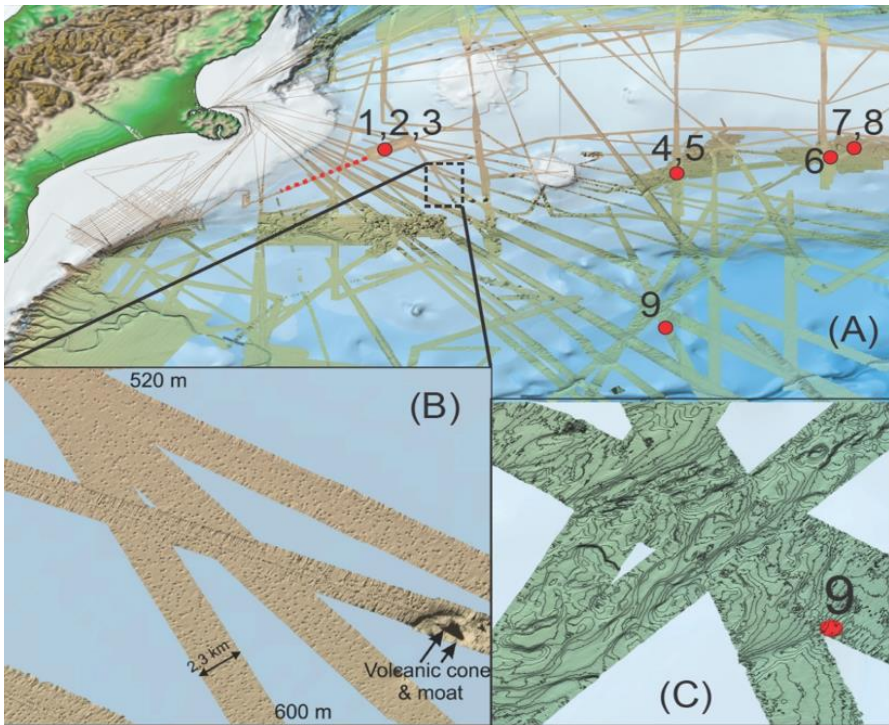
Chatham Rise – Methane Diffusion?

Site	Core ID	SO ₄ ²⁻ Minimum (mbsf)	R2, N
1	44-1-PC9	34.4	0.140, 18
1	45-1-PC9	101.8	0.829, 25
1	51-1-PC9	22.1	0.549, 21
1	52-1-PC9	69.0	0.607, 22
1	53-1-PC9	103.3	0.774, 25
1	54-1-PC9	100.2	0.763, 27
2A	73-2-PC9	51.5	0.955, 18
2A	74-1-PC9	77.2	0.936, 17
2A	75-2-PC9	16.2	0.988, 27
2A	76-1-PC9	50.5	0.962, 24
2A	77-2-PC9	37.5	0.920, 23
2B	82-3-PC9	23.5	0.958, 13
2B	83-1-PC9	38.0	0.760, 13
2B	84-1-PC9	33.6	0.957, 14
2B	85-2-PC9	51.6	0.859, 12
3	94-1-PC9	66.5	0.653, 24
3	95-1-PC9	55.4	0.201, 19
3	96-1-PC9	77.8	0.185, 21
3	97-1-PC9	no slope	n.d.
3	98-1-PC9	117.3	0.622, 18

Chatham Rise – CO₂ Diffusion?



Joides Resolution – Offshore Drilling



Conclusions, Future Needs

- Refined seismic data, focused 3D?
- More in depth water column analyses, ocean floor topography.
- Controlled source electromagnetic data development refining.
- Shallow sediment sensor probes for key geochemical profiles (sniffers)?