[1]HYDRATE STUDIES OF NORTHERN CASCADIA MARGIN OFF VANCOUVER ISLAND: A REFERENCE SOURCE

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ABSTRACT

This article provides a comprehensive reference list to the extensive studies of marine natural gas hydrate surveys and studies on the northern Cascadia margin off Western Canada. The references are divided into each of the major study methods, surveys, analyses and conclusions. A number of MSc and PhD theses are included. We first refer to the articles that address the local tectonics and the sedimentary accretionary prism in which the hydrate forms, then those that describe the numerous geophysical and geological surveys and studies, and finally the articles that address the most important conclusions that have resulted from this work in the distribution, concentrations, and amounts of hydrate, and on the processes of hydrate formation and dissociation.

Keywords: gas hydrates, Cascadia, geophysical surveys

INTRODUCTION

The comprehensive surveys of natural gas hydrate on the northern Cascadia margin include a wide range of marine seismic surveys (conventional multichannel, ocean-bottom (OBS) studies, 3-D single-channel mapping, and very high resolution DTAGS multichannel towed near the seafloor. Other geophysical and geological studies include heat flow, electrical sounding (CSEM), seafloor compliance, sediment coring, and mapping gas plumes from the seafloor. A number of surveys and measurements have been carried out by remotely operated vehicle ROV observations of seafloor hydrate and carbonate. There have been two deep sea drilling programs. ODP 146 drilled several holes at a mid-slope site where there is a very strong hydrate BSR also a deep sea reference site just seaward of the deformation front. IODP 311 drilled holes and made downhole measurements at a series of sites across the margin from the seaward frontal ridge to the upper slope to examine the landward progression of hydrate formation and dissociation. This expedition also drilled a prominent local vent structure (Bullseye Vent),

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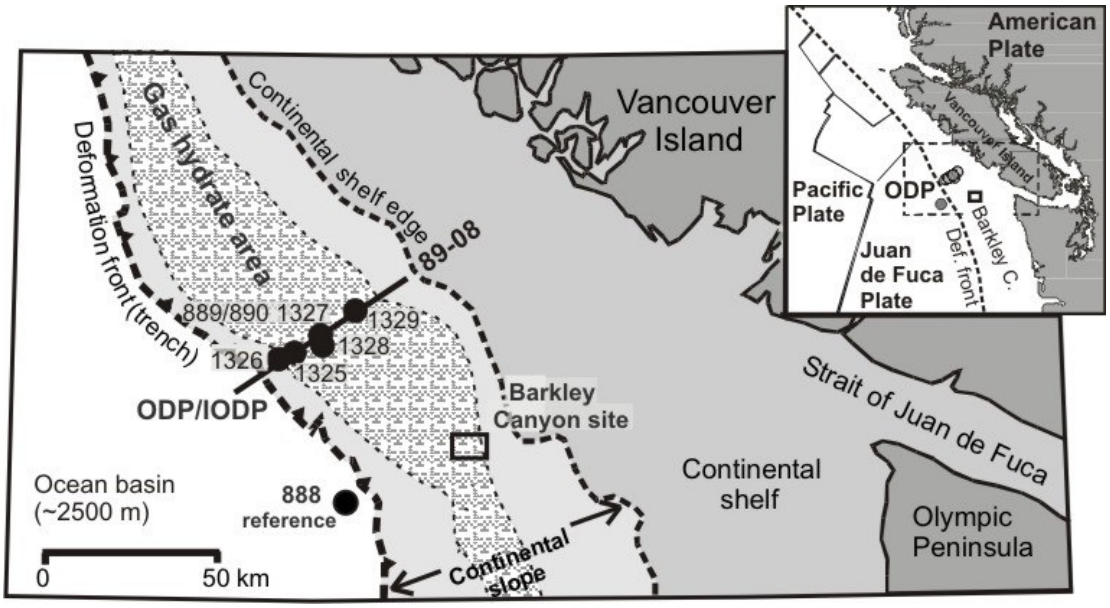

Figure 1. The northern Cascadia margin showing the region (stippled) where hydrate is indicated beneath the mid-continental slope by a widespread BSR, the main geophysical study areas along seismic line 89-08, ODP/IODP drill sites, and the Barkley Canyon seafloor hydrate study site.

that contains high concentrations of hydrate. Reviews of N. Cascadia hydrate work have been presented by Spence et al. (2000), Hyndman et al. (2001), and Riedel et al. (2006).

This compilation provides a comprehensive reference list to the extensive studies of marine natural gas hydrate surveys and studies on the northern Cascadia margin off Western Canada. An initial list of abbreviated references are divided into each of the major study methods, surveys, analyses and conclusions. A number of MSc and PhD theses are included. We first list to the articles that address the local tectonics and the sedimentary accretionary prism in which the hydrate forms, then those that describe the numerous geophysical and geological surveys and studies, and finally the articles that address the most important conclusions that have resulted from this work in the distribution, concentrations, and amounts of hydrate, and on the processes of hydrate formation and dissociation. The subdivided list is followed by a complete list of articles with reference details. This reference list focuses on the northern Cascadia margin. However, hydrate in a similar accretionary prism has been studied very extensively off Oregon (e.g., Tréhu et al., 2003; Tréhu et al., 2004 and references therein).

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The reference categories are:

1. GENERAL REVIEWS
2. REGIONAL TECTONIC FRAMEWORK FOR NORTHERN CASCADIA HYDRATE
3. PRISM SEDIMENT THICKENING, FLUID EXPULSION, AND HYDRATE FORMATION
4. SEISMIC SURVEYS
General
Conventional
Contract Multichannel Surveys
COAMS High-Resolution Multichannel
Single Channel Surveys, Including 3D Studies
DTAGS
Ocean-Bottom Seismographs
Special Processing and Analyses
5. OTHER GEOPHYSICAL SURVEYS
Heat flow

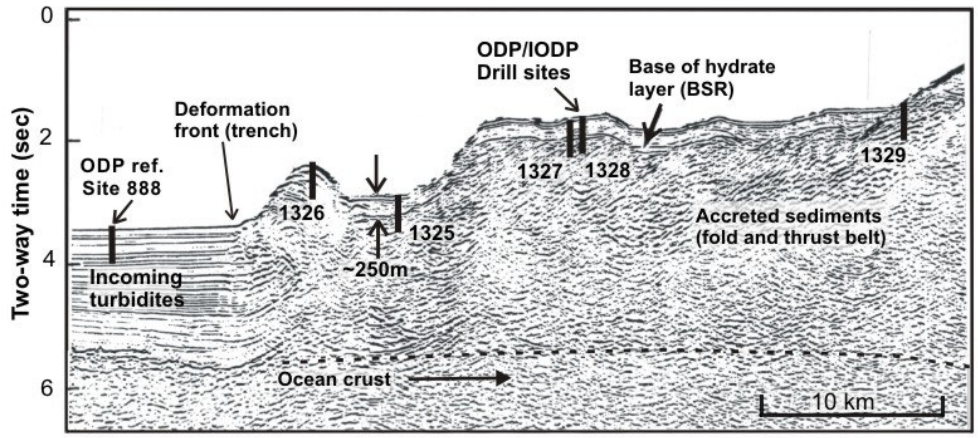

Figure 2. Multichannel seismic section 89-08 showing the very prominent BSR, the 2-3 km thick incoming turbidite sediments, and the landward thickening accretionary sedimentary prism. The ODP 146 and IODP 311 drill sites are also shown.

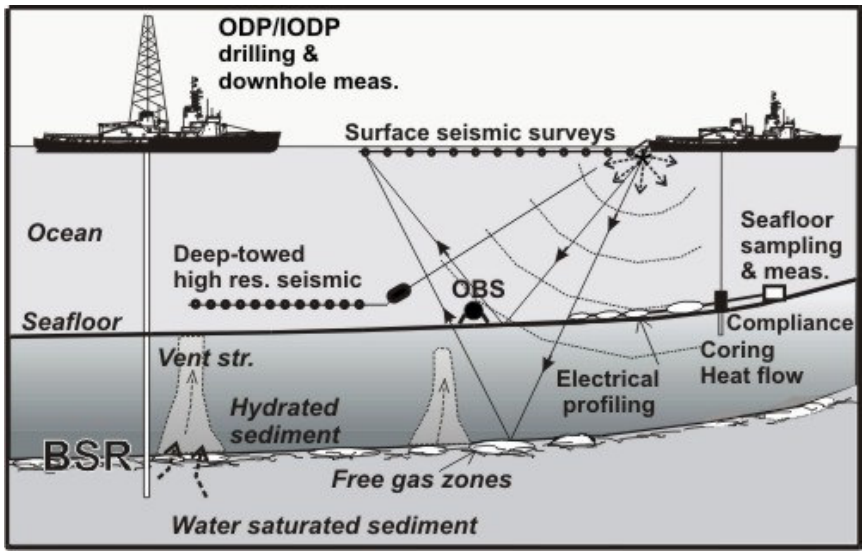

Figure 3. An illustration of the multidisciplinary geophysical and geological studies of hydrate on the northern Cascadia margin. The surveys include as wide range of seismic surveys (multichannel, ocean-bottom (OBS), high-resolution single-channel, and very high resolution deep towed DTAGS). Other studies include heat flow, electrical sounding (CSEM), seafloor compliance, sediment coring, water column gas plumes, surveys by ROV, and two deep sea drilling programs, ODP 146 and IODP 311.

1. GENERAL REVIEWS OF HYDRATE STUDIES IN THE AREA

Hyndman, and Dallimore, 2001. CSEG Recorder, May, p.11-20.

Hyndman, et al., 2001. AGU Monogr., Nat. Gas Hydrates: Occur., Distrib. & Dynam., 273-295.

Riedel, et al., 2006. In: Hedberg Res. Conf., Sept. 12-16, 2004, Vancouver, Canada.

Riedel, et al., 2006. In: Riedel et al., IODP Proc. Integ. Ocean Drill. Prog. V. 311, 1-28.

Spence et al., 2000. In: Nat. Gas Hydrates, Ed. Michael D. Max, Kluwer Acad. Publ., 183-198.

2. REGIONAL TECTONIC FRAMEWORK FOR NORTHERN CASCADIA HYDRATE

Clowes et al., 1987. Geophys. J. R. Astron. Soc, 89, 79-84.

Hyndman, 1995. Can. J. Earth Sci., 32, 1777-1802.

Hyndman et al., 1994. Proc. Ocean Drill. Prog., Initial Rep., 146, 399-419.

3. PRISM SEDIMENT THICKENING, FLUID EXPULSION, AND REGIONAL HYDRATE FORMATION

Davis et al., 1990. J. Geophys. Res., 95, 8869-8889.

Davis and Hyndman, 1989. Geol. Soc. Am. Bull., 101, 1465-1480.

He, 2002. MSc, Univ. Victoria, Victoria, B.C.

Hyndman and Spence, 1992. J. Geophys. Res, 97, 6683-6698.

Hyndman et al., 1993. J. Geophys. Res., 98, 21, 865-21,876.

Zühlsdorff et al., 2000. Internat. J. Earth Sci. 88, 655-667.

Zühlsdorff and Spieß, 2004. Geology, 32, 101-104.

4. SEISMIC SURVEYS

General

Riedel, 2001. PhD, Univ. Victoria.

Riedel et al., J. Geophys. Res., Solid Earth 107 (#B9), 2200.

Scherwath et al., 2006. In: Riedel et al., Proc. Integr. Ocean Drill. Prog. 311, 1-26.

Conventional Multichannel Surveys

Chen, 2006. Univ. Victoria, Victoria, B.C.

Clowes et al., 1987. Geophys. J. R. Astron. Soc, 89, 79-84.

Hyndman and Spence, 1992. J. Geophys. Res, 97, 6683-6698.

Spence et al., 1991a. Geol. Surv. Can., Open File Rep., 2391.

Yuan, 1996. Ph.D. Univ. Victoria, Victoria, B.C.

High-Resolution Multichannel COAMS and Single Channel Surveys, Including 3D Studies

Fink, 1995. Univ. Victoria, Victoria, B.C.

Fink and Spence, 1999. J. Geophys. Res., 104, 2909-2922.

He et al., 2007. Marine Geol. 239, 83-98.

Mi 1998. M.Sc. Univ. Victoria, Victoria, B.C.

Zühlsdorff and Spiess, 2004. Geology 32, 101-104.

Zuhlsdorff et al., 2002. In: Proc. Fourth Internat. Conf. Gas Hydrates, Yokohama, Japan, May 19-23, 13-18.

Zühlsdorff et al., 2000. Internat. J. Earth Sci. 88, 655-667.

DTAGS

Chapman et al., 2002. Geophysics 67, 1038-1047.

Gettrust et al., 1999. Eos, Trans. Am. Geophys. Un. 38, 439-440.

Gettrust et al., 2004. Leading Edge, 23 (April), 373-377.

Walia and Hannay, 1999. Geophys. Res. Lett., 26, 1993-1996.

Ocean-Bottom Seismographs

Dash, 2007. PhD, Univ. Victoria, Victoria, B.C.

Hobro, 1999. Ph.D., Univ. Cambridge, U.K.

Hobro et al., 2005. J. Geophys. Res. 110, B09102.

Hobro et al., 1998. Geol. Soc. Lond. Spec. Publ. 137, 133-140.

Lopez, 2008. MSc, Univ. Victoria, Victoria, B.C.

Spence et al., 1995. Proc. Ocean Drill. Progr., Sci. Results 146, 163-174.

Zykov, 2006. PhD, Univ. Victoria, Victoria, B.C.

Special Processing and Analyses

Chen, M-A. et al., 2007. Geophysics, 72, 31-43.

Chen, M.-A., 2006. MSc, Univ. Victoria, Victoria, B.C.

Dosso and Riedel, 2001. J. Acoust. Soc. Am. 110 (#2), 955-966.

Hyndman and Spence, 1992. Geophys. Res, 97, 6683-6698.
Riedel et al., 2003. Geophysics 68, 1485-1496.
Singh and Minshull, 1994. J. Geophys. Res. 99, 24,221-24,233.
Singh et al., 1993. Science, 260, 204-207.
Spence et al., 2008. Soc. Expl. Geophys. Spec. Vol., Seism. Studies of Nat. Gas Hydrate, in press.
Walia and Hannay, 1999. Geophys. Res. Lett., 26, 1993-1996.
Yuan et al., 1999. J. Geophys. Res. 104, 1179-1191.
Zühlsdorff et al., 2002. Proc. Fourth Int. Conf. Gas Hydrates, Yokohama, Japan, May 19-23, 13-18.

5. OTHER GEOPHYSICAL SURVEYS

Heat flow

Davis et al., 1990. J. Geophys. Res. 95, 8869-8889.
Ganguly et al., 2000. Marine Geol. 164, 53-68.
He et al., 2007. Marine Geol. 239, 83-98.
Heesemann et al., 2006. In: Riedel et al., *Proc. IODP,* 311: Washington, DC (IODP-MI, Inc.).

CSEM Electrical Profiling, Electrical Logs, and Core Samples

Edwards, 1997. Geophysics 62, 63-74.
Jarrard, et al., 1995. Proc. Ocean Drill. Progr., Sci. Results., 146, Ocean Drill. Progr., College Station, Texas.
Hyndman et al., 1999. Earth Planet. Sci. Lett., 172, 167-177.
Schwalenberg et al., 2008. In: Geophys. Methods Gas Hydrate Exploration, Eds. Riedel, Willoughby, Chopra, SEG Publications, Tulsa, in press
Schwalenberg et al., 2005. First Break , 23, 57-63.
Yuan, 2003. PhD, Univ. Toronto, Toronto, Ont.
Yuan and Edwards, 2000. Geophys. Res. Lett. 27, 2397-2400.

Seafloor Compliance

Willoughby et al., 2008. I: Geophys. Methods for Gas Hydrate Explor., Eds. Riedel, Willoughby, Chopra, SEG Publications, Tulsa, in press.
Willoughby, 2008. J. Geophys. Res., doi:10.1029/2005JB004136.
Willoughby, 2003. PhD, Univ. Toronto, Toronto, Ont.
Willoughby and Edwards, 2000. Geophys. Res. Lett., 27, 1021-1024.
Willoughby et al., 2000. In: Gas Hydrates: Challenges for the Future, Ann. N.Y. Acad. Sci., 912.

Sediment and Seafloor Magnetics

Novosel, 2002. MSc, Univ. Victoria, Victoria, B.C.
Novosel et al., 2005. Marine Geol. 216, 265-274.
Esteban et al. 2008. In: Soc. Expl. Geophys., Special Vol., Seismic Studies of Natural Gas Hydrate, in press.
Fink, 1995. MSc, Univ. Victoria, Victoria, B.C.

6. ROV STUDIES

Barkley Canyon

Chapman et al., 2004. Eos, Trans. Am. Geophys. Un. 85, 361.
Lu et al., 2007. Nature 445, 303-306.
Pohlman, 2006. PhD, College of William and Mary, Williamsburg, VA.
Pohlman et al., 2005. Organic Geochem. 36, 703-716.
Spence et al., 2001. Eos Trans. Am. Geophys. Un. 82, 623-627.
Udachin et al., 2007. Angew. Chem. Int. Ed. 46, 8220-8222.

Bullseye Area

Riedel, 2001. PhD, Univ. Victoria, Victoria, B.C.
Riedel et al, 2006. Geol. Soc. Am. Bull. 118, 23-38.
Tomaru et. al., 2007. J. Geochem. Explor. 95, 40-47.

7. CORING, SAMPLING, AND CHEMISTRY

Chapman et al., 2004. Eos, Trans. Am. Geophys. Un. 85, 361.
He, 2002. MSc, Univ. Victoria, Victoria, B.C.
He et al., 2007. Marine Geol. 239, 83-98.
Kastner et al., 1995. Proc. Ocean Drill. Progr., Sci. Results 146, 175-187.
Mi, 1998. Univ. Victoria, Victoria, Canada.
Pohlman, 2006. PhD, College of William and Mary, Williamsburg, VA.

Pohlman et al., 2005. Organ. Geochem. 36, 703-716.
Riedel et al., 2006. Marine Geol. 227, 215-225.
Solem et al., 2002. Proc. Fourth Internat. Conf. Gas Hydrates, Yokohama, Japan, May 19-23, 84-89.

8. ODP/IODP DRILLING PROGRAMS 146 AND 311

General

Chen, 2006. MSc, Univ. Victoria, Victoria, B.C.
Desmons, 1996. MSc, Univ. Victoria, Victoria, B.C.
Goldberg et al., 2000. Nat. Gas Hydrate in Oceanic and Permafrost Environments, Kluwer Acad. Publ., 295-310.
Hyndman et al., 1999. Earth Planet. Sci. Lett. 172, 167-177.
Hyndman et al., 1994. Proc. Ocean Drill. Prog., Initial Rep. 146, 399-419.
Lopez, 2008. MSc, Univ. Victoria, Victoria, B.C.
Novosel, 2002. MSc, Univ. Victoria, Victoria, B.C.
Novosel et al., 2005. Marine Geol. 216, 265-274.

ODP 146

Carson et al., 1995. Proc. Ocean Drill. Program, Scientific Rep., 146, Ocean Drill. Program, College Station, Tex., 477p.
Jarrard et al., 1995. Proc. Ocean Drill. Progr., Sci. Results. 146, Ocean Drill. Progr., College Station, Texas.
Kastner et al., 1995. Proc. Ocean Drill. Progr., Sci. Results 146, 175-187.
MacKay et al., 1994. Geology 22, 459-462.
Westbrook et al., 1994. Proc. Ocean Drill. Progr., Initial Rep. 146, 611p.

IODP 311

IODP Expedition 311 Scientists, 2005. *IODP Prel. Rept.,* 311 Washington, DC.

Jarrard et al., 1995. Proc. Ocean Drill. Progr., Sci. Results. 146, Ocean Drill. Progr., College Station, Texas.
Lu et al., 2006. Nature 445, doi:10.1038/nature05463.
Lu et al., 2005. J. Geophys. Res. 110, B10204.
Riedel et al., 2006. Marine Geol. 227, 215-225.
Riedel et al., 2006. Sci. Drill. 3, 18-24, doi:10.2204/iodp.sd.3.04.2006.
Riedel et al., 2006. Eos, 87 (#33).

Riedel et al., 2006. *Proc. IODP,* 311: Washington, DC, IODP-MI, Inc.

Riedel et al., 2006. Marine Geol. 227, 215-225.
Scherwath et al., 2006. In: Riedel et al., IODP Proc. Integr. Ocean Drill. Progr. 311, 1-26.
Tomaru et al., 2007. J. Geochem. Expl. 95, 40-47.

9. BULLS-EYE VENT

Novosel et al., 2005. Marine Geol. 216, 265-274.
Riedel et al., 2006. Geol. Soc. Am. Bull. 118, 23-38.
Riedel, 2001. PhD, Univ. Victoria, Victoria, B.C.
Schwalenberg, et al., 2008. In: Geophys. Methods for Gas Hydrate Explor., Eds: Riedel, Willoughby, Chopra, SEG Publications, Tulsa, in press.
Schwalenberg et al., 2005. First Break 23, 57-63.
Solem et al., 2002. Proc. Fourth Internat. Conference Gas Hydrates, Yokohama, Japan, May 19-23, 84-89.
Tomaru et al., 2007. J. Geochem. Explor. 95, 40-47.
Wood et al., 2002. Nature 420, 656-660.
Zühlsdorff et al., 2002. Proc. Fourth Internat. Conference Gas Hydrates, Yokohama, Japan, May 19-23, 13-18.

Zühlsdorff et al., 2000. Internat. J. Earth Sci. 88, 655-667.

Zühlsdorff and Spiess, 2004. Geology 32, 101-104.

10. FORMATION OF HYDRATE, CONCENTRATIONS, AND AMOUNTS

Haacke et al., 2007. Earth Planet. Sci. Lett. 261, 407-420.
Hyndman et al., 1992. J. Geophys. Res. 97, 7025-7041.
Hyndman and Dallimore, 2001. Can. Soc. Expl. Geophys., Recorder, May, 11-20.
Hyndman et al., 1999. Earth Planet. Sci. Lett. 172, 167-177.
Kastner et al., 1995. Proc. Ocean Drill. Program, Sci. Results 146, 175-187.
Lopez, 2008. MSc, Univ. Victoria, Victoria, B.C.
Riedel et al., Collett, 2006. Marine Geol. 227, 215-225.
Udachin et al., 2007. Angew. Chem. Int. Ed. 46, 8220-8222, doi: 10.1002/anie.200701821.

Yuan et al., 1996. J. Geophys. Res. 101, 13,655-13,671.

11. CLIMATE AND OTHER TOPICS

Taylor et al., 2005. In: Sci. Results Mallik 2002 Gas Hydrate Research Well Progr., Mackenzie Delta, Northwest Territories, Canada, Eds. Dallimore and Collett, Geol. Surv. Canada Bull. 585, p130 (abstract; full text in CD).

Taylor et al., 2002. Proc. Fourth Internat. Conf. Gas Hydrates, Yokohama, Japan, May 19-23, 63-70.

REFERENCES ALPHABETICAL

Carson, B., G.K. Westbrook, R.J. Musgrave, and E. Suess, 1995. Proc. Ocean Drill. Program, Scientific Rep., 146, Ocean Drill. Program, College Station, Tex., 477p.

Chapman, R., J. Gettrust, R. Walia, D. Hannay, G.D. Spence, W. Wood, and R.D. Hyndman, 2002. High resolution deep-towed multichannel seismic survey of deep sea gas hydrates off western Canada. Geophysics 67, 1038-1047.

Chapman, R., J. Pohlman, R. Coffin, J. Chanton, L. Lapham, Thermogenic Gas Hydrates in the Northern Cascadia Margin, 2004. Eos, Trans. Am. Geophys. Un. 85, 361.

Chen, M-A., M. Riedel, S.E. Dosso, 2007. AVO inversion of BSRs in marine gas hydrate studies, Geophysics, 72, 31-43.

Chen, M.-A., 2006. Northern Cascadia Marine Gas Hydrate: Constraints from Resistivity, Velocity, and AVO, MSc, University of Victoria, Victoria, B.C.

Clowes, R.M., C.J. Yorath, and R.D. Hyndman, 1987. Reflection mapping across the convergent margin of western Canada, Geophys. J. R. Astron. Soc. 89, 79-84.

Collett, T.S., Riedel, M., Malone, M.J., and the Expedition 311 Project Team, 2005. Cascadia margin hydrates. IODP Sci. Prosp. 311, Wash., DC, IODP-MI, Inc.

Dash, R.K., 2007. Crustal Structure and Marine Gas Hydrate Studies near Vancouver Island using Seismic Tomography, PhD, University of Victoria, Victoria, B.C..

Davis, E.E., and R.D. Hyndman, 1989. Accretion and recent deformation of sediments along the northern Cascadia subduction zone, Geol. Soc. Am. Bull. 101, 1465-1480.

Davis, E.E., R.D. Hyndman, and H. Villinger, 1990. Rates of fluid expulsion across the northern Cascadia accretionary prism: constraints from new heat flow and multichannel seismic reflection data, J. Geophys. Res. 95, 8869-8889.

Desmons, B., 1996. Integrated study of gas hydrates in marine sediments using geophysical and geochemical data, M.Sc. University of Victoria, Victoria, B.C., Canada.

Dosso, S. and M. Riedel, 2001. Array Element Localization for towed marine seismic arrays, J. Acoust. Soc. Am. 110, 955-966.

Edwards, R.N., 1997. On the resource evaluation of marine gas hydrate deposits using the sea-floor transient electric dipole-dipole method, Geophysics 62, 63-74.

Esteban, L., T.S. Hamilton, R.J. Hamilton, C. Lowe, and I Novosel, 2008. Gas hydrates and magnetism: Surveying and diagenetic analysis. Soc. Expl. Geophys., Special Vol., Seismic Studies of Natural Gas Hydrate, in press.

Fink, C.R., 1995. Methane hydrate distribution offshore Vancouver Island from detailed single channel seismic studies, MSc, University of Victoria, Victoria, B.C.

Fink, C.R., and G.D. Spence, 1999. Hydrate distribution off Vancouver Island from multi-frequency single channel seismic reflection data, J. Geophys. Res. 104, 2909-2922.

Ganguly, N., G.D. Spence, N.R. Chapman, and R.D. Hyndman, 2000. Heat flow variations from bottom simulating reflectors on the Cascadia margin. Marine Geol. 164, 53-68.

Gettrust, J., W. Wood, D. Lindwall, R. Chapman, R. Walia, D. Hannay, K. Louden, R. MacDonald, and R.D. Hyndman, 1999. New seismic study of deep sea gas hydrates results in greatly improved resolution, Eos, Trans. Am. Geophys. Un. 38, 439-440.

Gettrust, J.F., W.T. Wood and S.E Spychalski, 2004. High-resolution MCS in deepwater, Leading Edge 23 (April), 373-377.

Goldberg, D.S., T.S. Collett, and R.D. Hyndman, 2000. Ground truth: In-situ properties of hydrate. Natural Gas Hydrate in Oceanic and Permafrost Environments, Kluwer Acad. Publ., 295-310.

Haacke, R.R., G.K. Westbrook, and R.D. Hyndman, 2007. Gas hydrate, fluid flow and free gas: formation of the bottom-simulating reflector, Earth Planet. Sci. Lett. 261, 407-420.

He, T., G.D. Spence, M. Riedel, R.D. Hyndman, and N.R. Chapman, 2007. Fluid flow and origin of a carbonate mound offshore Vancouver Island: Seismic and heat flow constraints, Marine Geol. 239, 83-98.

He, T., 2002. Gas hydrates and fluid flow in Cascadia accretionary margin, MSc, University of Victoria, Victoria, B.C.

Heesemann, M., H. Villinger, A.T. Fisher, A.M. Tréhu, and S. Witte, 2006. Data report: testing and development of the new APC3 tool to determine in situ temperatures while piston coring. In: Riedel, et al., Proc. IODP 311: Washington, DC, IODP-MI, Inc.

Hobro, J.W.D., T.A. Minshull, S.C. Singh, and S. Chand, 2005. A three-dimensional seismic tomography study of the gas hydrate stability zone, offshore Vancouver Island, J. Geophys. Res. 110, B09102.

Hobro, J.W., S. Singh, and T. Minshull, 1998. Tomographic seismic studies of the methane hydrate stability zone in the Cascadia margin, Geol. Soc. Lond. Spec. Publ. 137, 133-140.

Hobro, J.W., 1999. Three-dimensional tomographic inversion of combined reflection and refraction travel-time data, PhD, University of Cambridge, U.K.

Hyndman, R.D., 1995. The Lithoprobe corridor across the Vancouver Island continental margin: The structural and tectonic consequences of subduction, Can. J. Earth Sci. 32, 1777-1802.

Hyndman, R.D., and S.R. Dallimore, 2001. Natural gas hydrate studies in Canada. Can. Soc. Expl. Geophys., Recorder, May, 11-20.

Hyndman, R.D., and E.E. Davis, 1992. A mechanism for the formation of methane hydrate and seafloor bottom-simulating reflectors by vertical fluid expulsion, J. Geophys. Res 97, 7025-7041.

Hyndman, R.D., and G.D. Spence, 1992. A seismic study of methane hydrate marine bottom-simulating reflectors, J. Geophys. Res. 97, 6683-6698.

Hyndman, R.D., T. Yuan, and K. Moran, 1999. The concentration of deep sea gas hydrates from downhole electrical resistivity logs and laboratory data, Earth Planet. Sci. Lett. 172, 167-177.

Hyndman, R.D., G.D. Spence, T. Yuan, and E.E. Davis, 1994. Regional geophysical and structure framework of the Vancouver Island margin accretionary prism, Proc. Ocean Drill. Prog., Initial Rep. 146, 399-419.

Hyndman, R.D., G.D. Spence, N.R. Chapman, M. Riedel, R.N. Edwards, 2001. Geophysical Studies of Marine Gas Hydrates in Northern Cascadia, AGU Monogr., Nat. Gas Hydrates: Occurr., Distribution, and Dynamics, 273-295.

Hyndman, R.D., K. Wang, T. Yuan, and G.D. Spence, 1993. Tectonic sediment thickening, fluid expulsion and the thermal regime of subduction zone accretionary prisms: the Cascadia margin off Vancouver Island, J. Geophys. Res. 98, 21, 865-21,876.

Jarrard, R.D., M.E. MacKay, G.K. Westbrook, and E.J. Screaton, 1995. Log-based porosity of ODP sites on the Cascadia accretionary prism. Proc. Ocean Drill. Program, Sci. Results., 146, Ocean Drill. Prog., College Station, Texas.

Kastner, M., K.A. Kvenvolden, M.J. Whiticar, A. Camerlenghi, and T.D. Lorenson, 1995. Relation between pore fluid chemistry and gas hydrate associated with bottom-simulating reflectors at the Cascadia margin, Proc. Ocean Drill. Program, Sci. Results 146, 175-187.

Lopez, C., 2008. Seismic Structure Associated with Gas Hydrate at the Frontal Ridge of Northern Cascadia Margin, MSc, University of Victoria, Victoria, B.C.

Lu, H., Y. Seo, J. Lee, I. Moudrakovski, J. Ripmeester, R. Chapman, R. Coffin, G. Gardner, and J. Pohlman, 2007. Complex gas hydrates from the Cascadia Margin. Nature 445, 303-306.

Lu, H., I. Moudrakovski, M. Riedel, G.D. Spence, R. Dutrisac, J. Ripmeester, F. Wright, and S.D. Dallimore, 2005. Occurrences and structural characterizations of gas hydrates associated with a cold vent field, offshore Vancouver Island, J. Geophys. Res. 110, B10204.

MacKay, M.E., R.D. Jarrard, G.K. Westbrook, R.D. Hyndman and the Shipboard Scientific Party of ODP Leg 146, 1994. Origin of bottom simulating reflectors: Geophysical evidence

from the Cascadia accretionary prism, Geology 22, 459-462.

Mi, Y., 1998. Seafloor sediment coring and multichannel seismic studies of gas hydrate, offshore Vancouver Island, MSc, University of Victoria, Victoria, B.C.

Novosel, I., 2002. Physical properties of gas hydrate related sediments, offshore Vancouver Island, MSc, University of Victoria, Victoria, B.C.

Novosel, I., G.D. Spence, and R.D. Hyndman, 2005. Reduced magnetization produced by increased methane flux at gas hydrate vent, Marine Geology 216, 265-274.

Pohlman, J.W. 2006, Sediment biogeochemistry of northern Cascadia margin shallow gas hydrate systems, PhD Thesis, College of William and Mary, Williamsburg, VA.

Pohlman, J.W., J.E., Bauer E.A. Canuel, K.S. Grabowski, D.L. Knies, C.S. Mitchell, M.J. Whiticar, and R.B. Coffin, 2008. Sources and fluxes of methane in gas hydrate cold-seep systems: Evidence from radiocarbon and stable isotopic signatures, Earth Planet. Sci. Lett., in press.

Pohlman, J.W., E.A. Canuel, N.R.. Chapman, G.D. Spence, M.J. Whiticar, and R.B. Coffin, 2005. The origin of thermogenic gas hydrates on the northern Cascadia Margin inferred from isotopic (13C/12C and D/H) and molecular composition of hydrate and vent gas. Organic Geochem. 36, 703-716.

Riedel, M., 2001. 3-D Seismic Investigations of Northern Cascadia Marine Gas Hydrates, PhD, University of Victoria, Victoria, B.C.

Riedel, M., I. Novosel, G.D. Spence, R.D. Hyndman, R.N. Chapman, R.C. Solem, T. Lewis, and L. Zuelsdorff, 2006. Geophysical and geochemical signatures associated with gas hydrate related venting at the northern Cascadia margin, Geol. Soc. Am. Bulletin 118, 23-38.

Riedel, M., E. Willoughby, R.D. Hyndman, G.D. Spence, N.R. Chapman, N. Edwards, I. Novosel, and K. Schwalenberg, 2006. Gas hydrates at the Northern Cascadia Margin, Gas Hydrates: Energy Resource Potential and Associated Geologic Hazards, In*:* Hedberg Res. Conf., Sept. 12-16, 2004, Vancouver, Canada.

Riedel, M., Collett, T.S., Malone, M.J., and the IODP Expedition 311 Scientists, 2006. Stages of gas-hydrate evolution on the northern Cascadia margin. Sci. Drill. 3, 18-24.

Riedel, M., E.C. Willoughby, M.A. Chen, T. He, I. Novosel, K. Schwalenberg, R.D. Hyndman, G.D. Spence, N.R. Chapman, and R.N. Edwards, 2006. Gas hydrate on the Northern Cascadia Margin: Regional geophysics and structural framework, In: Riedel et al., IODP Proc. Integr. Ocean Drill. Prog. 311, 1-28.

Riedel, M., Collett, T.S., Malone, M., and Expedition 311 Scientists, 2006. Gas Hydrate Transect Across Northern Cascadia Margin, Eos, 87 (#33).

Riedel, M., Collett, T.S., Malone, M.J., and the Expedition 311 Scientists, 2006. Proc. IODP 311: Wash., DC. IODP-MI, Inc.

Riedel, M., P.E. Long, and T.S. Collett, 2006. Estimates of in situ gas hydrate concentration from resistivity monitoring of gas hydrate bearing sediments during temperature equilibration, Marine Geol. 227, 215-225.

Riedel, M., Collett, T., Malone, et al., 2006. Gas hydrate transect across northern Cascadia margin. Eos, Trans. Am. Geophys. Union 87, 325.

Riedel, M., Collett, T.S., and Expedition 311 Scientists, 2005. Cascadia margin gas hydrates, IODP Prelim. Rept., 311 Washington, DC, IODP-MI Inc.

Riedel, M., T.S. Collett and R.D. Hyndman, 2005. Gas hydrate concentration estimates from chlorinity, electrical resistivity and seismic velocity, Geological Survey of Canada, Open File Report 4934.

Riedel, M., S.E. Dosso, and L. Beran, 2003. Uncertainty estimates in AVO inversion, Geophysics 68, 1485-1496

Riedel, M., R.D. Hyndman, G.D. Spence, and N.R. Chapman, 2002. Seismic Investigations of a Vent Field Associated with Gas Hydrates, Offshore Vancouver Island, J. Geophys. Res., Solid Earth 107 (#B9), 2200.

Riedel, M., G.D. Spence, N.R. Chapman and R.D. Hyndman, 2001. Deep Sea Gas Hydrates on the Northern Cascadia Margin, The Leading Edge, Jan 2001, 87-91.

Scherwath, M., M. Riedel, G.D. Spence, and R.D. Hyndman, 2006. Seismic structure beneath the north Cascadia drilling transect of IODP Expedition 311. In: Riedel et al., IODP Proc. Integr. Ocean Drill. Prog. 311, 1-26.

Schwalenberg,, K., R.N. Edwards, C. Scholl, E.C. Willoughby, K. Weitemeyer and S.C. Constable, 2008. The electrical signature of submarine gas hydrates derived from controlled source electromagnetics", In: Geophys. Methods Gas Hydrate Explor., Eds. Riedel et al., SEG Publ., Tulsa, in press.

Schwalenberg, K., E.C. Willoughby, R. Mir and R.N. Edwards, 2005. Marine gas hydrate signatures in Cascadia and their correlation with seismic blank zones, First Break 23, 57-63.

Singh, S.C., and T.A. Minshull, 1994. Velocity structure of a gas hydrate reflector at Ocean Drilling Program Site 889 from global seismic waveform inversion, J. Geophys. Res. 99, 24,221-24,233.

Singh, S.C., T.A. Minshull, and G.D. Spence, 1993. Velocity structure of a gas hydrate reflector, Science 260, 204-207.

Solem, R.C., G.D. Spence, D. Vukajlovich, R.D. Hyndman, M. Riedel, I. Novosel, and M. Kastner, 2002. Methane advection and gas hydrate formation within an active vent field offshore Vancouver Island. Proc. Fourth Internat. Conference on Gas Hydrates, Yokohama, Japan, May 19-23, 84-89.

Spence, G.D., R.R. Haacke, and R.D. Hyndman, 2008. Seismic indicators of natural gas hydrate and underlying free gas, Soc. Expl. Geophys., Special Volume, Seismic Studies of Natural Gas Hydrate, in press.

Spence, G.D., and R.D. Hyndman, 2001. The challenge of deep ocean drilling for natural gas hydrate. Geoscience Canada 28, 179-186.

Spence, G.D., R.D. Hyndman, N.R. Chapman, M. Riedel, N. Edwards, and J. Yuan, 2000. Cascadia Margin, Northeast Pacific Ocean: Hydrate. Distribution from Geophysical Observations, In: Natural Gas Hydrates (ed. by Michael D. Max), Kluwer Academic Publishers, 183-198.

Spence, G.D., R.D. Hyndman, N.R. Chapman, M. Riedel, N. Edwards, and J. Yuan, 2000. Cascadia margin, northeast Pacific Ocean: Hydrate distribution from geophysical observations. Natural Gas Hydrate in Oceanic and Permafrost Environments, Kluwer Acad. Publ., 183-198.

Spence, G.D., R. Chapman, and R.D. Hyndman, 2001. Fishing trawler nets massive "catch" of methane hydrates. Eos Trans. Am. Geophys. Un. 82, 623-627.

Spence, G.D., R.D. Hyndman, N.R. Chapman, R. Walia, J. Gettrust, and R.N. Edwards, 2000. North Cascadia deep sea gas hydrates. Gas Hydrates, Challenges for the Future, Annals of the New York Academy of Sci. 912, 65-75.

Spence, G.D., R.D. Hyndman, N.R. Chapman, M. Riedel, N. Edwards, and J. Yuan, 2000. Cascadia Margin, Northeast Pacific Ocean: Hydrate. Distribution from Geophysical Observations, In: Nat. Gas Hydrates, Ed: M.D. Max), Kluwer Academic Publishers, 183-198.

Spence, G.D., T.A. Minshull, and C. Fink, 1995. Seismic structure of methane gas hydrate, offshore Vancouver Island, Proc. Ocean Drill. Program, Sci. Results 146, 163-174.

Spence, G.D., R.D. Hyndman, E.E. Davis, and C.J. Yorath, 1991. Multichannel reflection profiles across the Vancouver Island continental shelf and slope, Geol. Surv. Can., Open File Rep., 2391.

Taylor, A.E., S.R. Dallimore, R.D. Hyndman, and F. Wright, 2005. Comparing the Sensitivity of Permafrost and Marine Gas Hydrates to Climate Warming, In: Sci. Results from Mallik 2002 Gas Hydrate Res. Well Prog., Mackenzie Delta, Northwest Territories, Canada, Eds. Dallimore and Collett, et al., Geol. Surv. Canada Bull. 585, p130 (abstract; text in CD).

Taylor, A.E., S.R. Dallimore, R.D. Hyndman, and F. Wright, 2002. Comparing the sensitivity of terrestrial and marine gas hydrates to climatic warming at the end of the last ice age. Proceedings of the Fourth International Conference on Gas Hydrates, Yokohama, Japan, May 19-23, 63-70.

Tomaru, H., R. Matsumoto, R. Coffin, J. Pohlman and G. Spence, 2007. Geochemical relation between gas hydrates and water venting in the seismic blanking zone in the northern Cascadia continental margin offshore Vancouver Island, Canada, J. Geochem. Explor. 95, 40-47.

Tréhu, A.M., P. E. Long, M. E. Torres, et al., 2004. Three-dimensional distribution of gas hydrate beneath southern Hydrate Ridge: constraints from ODP Leg 204, Earth Planet. Sci. Lett. 222, 845-862.

Tréhu, A.M., G. Bohrmann, F. Rack, M.E. Torres, Leg 204 Scientific Party, 2003, Proc. ODP, Initial Reports, 204 [CD-

ROM]. Ocean Drilling Program, Texas A&M University, College Station TX.

Udachin, K. A., H. Lu, G. Enright, C. I. Ratcliffe, J.A. Ripmeester, N. R. Chapman, M. Riedel, and G.D. Spence, 2007. Single-crystals of naturally occurring gas hydrates: the structures of methane and methane-mixed hydrocarbon hydrates, Angew. Chem. Int. Ed. 46, 8220-8222.

Walia, R., and D. Hannay, 1999. Source and receiver geometry corrections for deep towed multichannel seismic data, Geophys. Res. Lett. 26, 1993-1996.

Westbrook, G.K., B. Carson, R.J. Musgrave, and Shipboard Scientists, 1994. Proc. Ocean Drill. Program, Init. Rep. 146, 611p.

Willoughby, E., 2003. Resource Evaluation of Marine Gas Hydrates using the Compliance Method, PhD, University of Toronto, Toronto, Ont.

Willoughby, E.C., K. Latychev, R.N. Edwards, K. Schwalenberg and R.D. Hyndman, 2008. Review of Seafloor Compliance Studies of Marine Gas Hydrates, *in* Geophysical Methods for Gas Hydrate Exploration, Eds. Riedel, Willoughby, Chopra, Soc. Expl. Geophys. Pub., Tulsa, OK, in press.

Willoughby, E. C., K. Latychev, N. Edwards, K. Schwalenberg, and R. D. Hyndman, 2008. Seafloor compliance imaging of marine gas hydrate deposits and cold vent structures, J. Geophys. Res., doi:10.1029/2005JB004136, in press.

Willoughby, E.C., and R.N. Edwards, 2000. Shear velocities in Cascadia from seafloor compliance measurements, Geophys. Res. Lett. 27, 1021–1024.

Willoughby, E.C., K. Latychev, R.N. Edwards and G. Mihajlovic, 2000. Resource Evolution of Marine Gas Hydrate Deposits Using Seafloor Compliance Methods, in Gas Hydrates: Challenges for the Future, Ann. N.Y. Acad. Sci., 912.

Wood, W., J. Gettrust, N.R. Chapman, G.D. Spence, and R.D. Hyndman, 2002. Decreased stability of methane hydrates in marine sediments owing to phase-boundary roughness. Nature 420, 656-660.

Yuan, J., 2003. Electromagnetic Assessment of Off-Shore Methane Hydrate Deposits on the Cascadia Margin, PhD, University of Toronto, Toronto, Ont.

Yuan, J. and R.N. Edwards, 2000. The assessment of marine gas hydrate through electrical remote sounding: Hydrate without a BSR? Geophys. Res. Lett. 27, 2397-2400.

Yuan, T., 1996. Seismic studies of the northern Cascadia accretionary prism: Sediment consolidation and gas hydrate, Ph.D., University of Victoria, Victoria, B.C.

Yuan, T., G.D. Spence, and R.D. Hyndman, 1994. Seismic velocities and inferred porosities in the accretionary wedge sediments at the Cascadia margin, , J. Geophys. Res. 99, 4413-4427.

Yuan, T., R.D. Hyndman, G.D. Spence, and B. Desmons, 1996. Seismic velocity increase and deep-sea gas hydrate above a bottom-simulating reflector on the northern Cascadia continental slope, J. Geophys. Res. 101, 13,655-13,671.

Yuan, T., G.D. Spence, R.D. Hyndman, T.A. Minshull, and S.C. Singh, 1999. Seismic velocity studies of a gas hydrate bottom-simulating reflector on the northern Cascadia continental margin: Amplitude modeling and full waveform inversion, J. Geophys. Res. 104, 1179-1191.

Zühlsdorff, L., and V. Spiess, 2004. Three-dimensional seismic characterization of a venting site reveals compelling indications of natural hydraulic fracturing. Geology 32, 101-104.

Zuhlsdorff, L., V. Spiess, T. Schwenk, R. Chapman, M. Riedel, and R.D. Hyndman, 2002. Multi-frequency seismic data in the vicinity of a gas hydrate site at the northern Cascadia accretionary prism. Proc. Fourth Internat. Conf. Gas Hydrates, Yokohama, Japan, May 19-23, 13-18.

Zühlsdorff, L., V. Spieß, C. Hübscher, H. Villinger, A. Rosenberger, 2000. Implications for focused fluid transport at the northern Cascadia accretionary prism from a correlation between BSR occurrence and near-sea-floor reflectivity anomalies imaged in a multi-frequency seismic data set. Internat. J. Earth Sci. 88, 655-667.

Zykov, M.M., 2006. 3-D traveltime tomography of the gas hydrate area offshore Vancouver Island based on OBS data, PhD, University of Victoria, Victoria, B.C.