University of Victoria | Graduate Studies

PROGRAMME

The Final Oral Examination
for the Degree of

DOCTOR OF PHILOSOPHY
(School of Earth and Ocean Sciences)

Subbarao Yelisetti

2008	University of Hyderabad, India (Mineral Exploration)	MTech
2006	University of Hyderabad, India (Physics)	MSc
2004	Acharya Nagarjuna University, India (Mathematics, Physics, Chemistry)	BSc

"Seismic structure, gas hydrate, and slumping studies on the Northern Cascadia margin using multiple migration and full waveform inversion of OBS and MCS data"

Thursday, October, 16, 2014
2:00 PM
Bob Wright Centre, Room A319

Supervisory Committee:
Dr. George Spence, School of Earth and Ocean Sciences, UVic (Supervisor)
Dr. Michael Riedel, School of Earth and Ocean Sciences, UVic (Member)
Dr. Roy Hyndman, School of Earth and Ocean Sciences, UVic (Member)
Dr. Joanne Wegner, Department of Mechanical Engineering, Uvic (Outside Member)

External Examiner:
Dr. Andrew Gorman, Department of Geology, University of Otago, New Zealand

Chair of Oral Examination:
Dr. Junling Ma, Department of Mathematics and Statistics, UVic

Abstract

The primary focus of this thesis is to examine the detailed seismic structure of the northen Cascadia margin, including the Cascadia basin, the deformation front and the continental shelf. The results of this study are useful in understanding sediment deformation and tectonics on this margin. They also have important implications for exploration of hydrocarbons (oil and gas) and natural hazards (submarine landslides, earthquakes, tsunamis, and climate change).

The first part of this thesis focuses on the role of gas hydrate in slope failure observed from multibeam bathymetry data on a frontal ridge near the deformation front off Vancouver Island margin using active-source ocean bottom seismometer (OBS) data collected in 2010. Volume estimates (~ 0.33 km^3) of the slides observed on this margin indicate that these are capable of generating large tsunamis. Velocity models from travel time inversion of wide angle reflections and refractions recorded on OBSs and vertical incidence single channel seismic (SCS) data were used to estimate gas hydrate concentrations using effective medium modeling. Results indicate a shallow high velocity hydrate layer with a velocity of 2.0 − 2.1 km/s that corresponds to a hydrate concentration of 40% at a depth of 100 m, and a bottom simulating reflector (BSR) at a depth of 265−275 m beneath the seafloor (mbsf). These are comparable to drilling results on an adjacent frontal ridge. Margin perpendicular normal faults that extend down to BSR depth were also observed on SCS and bathymetric data, two of which coincide with the sidewalls of the slump indicating that the lateral extent of the slump is controlled by these faults. Analysis of bathymetric data indicates, for the first time, that the glide plane occurs at the same depth as the shallow high velocity layer (100 ± 10 mbsf). In contrast, the glide plane coincides with the depth of the BSR on an adjacent frontal ridge. In either case, our results suggest that the contrast in sediments strengthened by hydrates and overlying or underlying sediments where there is no hydrate is what causing the slope failure on this margin.

The second part of this dissertation focuses on obtaining the detailed structure of the Cascadia basin and frontal ridge region using mirror imaging of few widely spaced OBS data. Using only a small airgun source (120 cu. in.), our results indicate structures that were previously not observed on the northern Cascadia margin. Specifically, OBS migration results show dual-vergence structure, which could be related to horizontal compression associated with subduction and low basal shear stress resulting from over-pressure. Understanding the physical and mechanical properties of the basal layer has important implications for understanding earthquakes on this margin. The OBS migrated image also clearly shows the continuity of reflectors which enabled the identification of thrust faults, and also shows the top of the igneous

oceanic crust at 5−6 km beneath the seafloor, which were not possible to identify in single-channel and low-fold multi-channel seismic (MCS) data. The last part of this thesis focuses on obtaining detailed seismic structure of the Vancouver Island continental shelf from MCS data using frequency domain viscoacoustic full waveform inversion, which is first of its kind on this margin. Anelastic velocity and attenuation models, derived in this study to subseafloor depths of ~ 2 km, are useful in understanding the deformation within the Tofino basin sediments, the nature of basement structures and their relationship with underlying accreted terranes such as the Crescent and the Pacific Rim terranes. Specifically, our results indicate a low-velocity zone (LVZ) within the Tofino basin sediment section at a depth 600 − 1000 mbsf over a lateral distance of 10 km. This LVZ is associated with high attenuation values and could be a result of over pressured sediments or lithology changes associated with a high porosity layer in this potential hydrocarbon environment. Shallow high velocities of 4 − 5 km/s are observed in the mid-shelf region at depths > 1.5 km, which is interpreted as the shallowest occurrence of the Eocene volcanic Crescent terrane. The sediment velocities sharply increase about 10 km west of Vancouver Island, which probably corresponds to the underlying transition to the Mesozoic marine sedimentary Pacific Rim terrane. High attenuation values of 0.03 − 0.06 are observed at depths > 1 km, which probably corresponds to increased clay content and the presence of mineralized fluids.

Awards, Scholarships, Fellowships

2009-2014 Graduate research assistantship
2013 - SEG grant award to attend SEG/Exxon Mobil Student Education Program and 2013 SEG Annual Meeting in Houston, USA.
2013 - EAGE student travel grant award to attend EAGE annual meeting in London, UK.
2013 - Chevron Canada outstanding student paper in seismology at Canadian geophysical union meeting.
2013 - CGU student travel grant award to attend CGU annual meeting in Saskatchewan, Canada.
2012 - SEG grant award to attend SEG/Chevron Student Leadership Symposium and 2012 SEG Annual Meeting in Las Vegas, USA.
2009-2012 University of Victoria fellowship
2006-2008 Baldota fellowship
2004-2006 Merit-cum-means scholarship
2001-2004 Sri Velgapudi Rama Krishna Memorial Prize

Selected Presentations

1. **Subbarao Yelisetti**, George. D. Spence. "Seismic velocity and attenuation structure beneath the Vancouver Island continental shelf using frequency domain visco-acoustic full waveform inversion of multichannel seismic data." Invited seminar at National Geophysical Research Institute, Hyderabad, India. July 2013. (oral)
2. **Subbarao Yelisetti**, George. D. Spence. "Seismic structure beneath the Vancouver Island continental shelf using full waveform inversion of multichannel seismic data." Expanded abstract, 75th EAGE meeting, London, UK. June 2013. (oral)
3. **Subbarao Yelisetti**, George. D. Spence. "Seismic velocity and attenuation structure beneath the Vancouver Island continental shelf using frequency domain visco-acoustic full waveform inversion of multichannel seismic data." Expanded abstract, CGU annual meeting, Saskatoon, Saskatchewan, Canada. May 2013. (oral)
4. **Subbarao Yelisetti**, George. D. Spence. "Seismic structure of the Vancouver Island continental shelf using waveform inversion of multichannel seismic data." Invited seminar at waveform tomography workshop, University of Western Ontario, London, Ontario, Canada. July 2012. (oral)
5. **Subbarao Yelisetti**, Spence, G.D. and Riedel, M. "Role of gas hydrates in slope failure on frontal ridge of northern Cascadia margin." AGU fall meeting, San Francisco, California, USA. Dec 2011. (poster)
6. **Subbarao Yelisetti**, George. D. Spence. "Seismic structure of the Vancouver Island continental shelf using tomographic and waveform inversion of multichannel seismic refraction data." AGU fall meeting, San Francisco, California, USA. Dec 2010. (oral)

Publications

1. **Subbarao Yelisetti**, Spence, G.D., Scherwath, M., Riedel, M., and Spiess, V.; "Dual-vergence structure from multiple migration of widely spaced OBSs from northern Cascadia margin." Draft ready for submission to *Geophysics*.
2. **Subbarao Yelisetti** and Spence, G.D.; "Seismic velocity and attenuation structure beneath the Vancouver Island continental shelf using frequency domain visco-acoustic full waveform inversion of multichannel seismic data." Draft ready for submission to *CJES*.
3. **Subbarao Yelisetti**, Spence, G.D. and Riedel, M.; "Role of gas hydrates in slope failure on frontal ridge of northern Cascadia margin." *Geophysical Journal International* **2014**, *199 (1)*, 441 - 458.