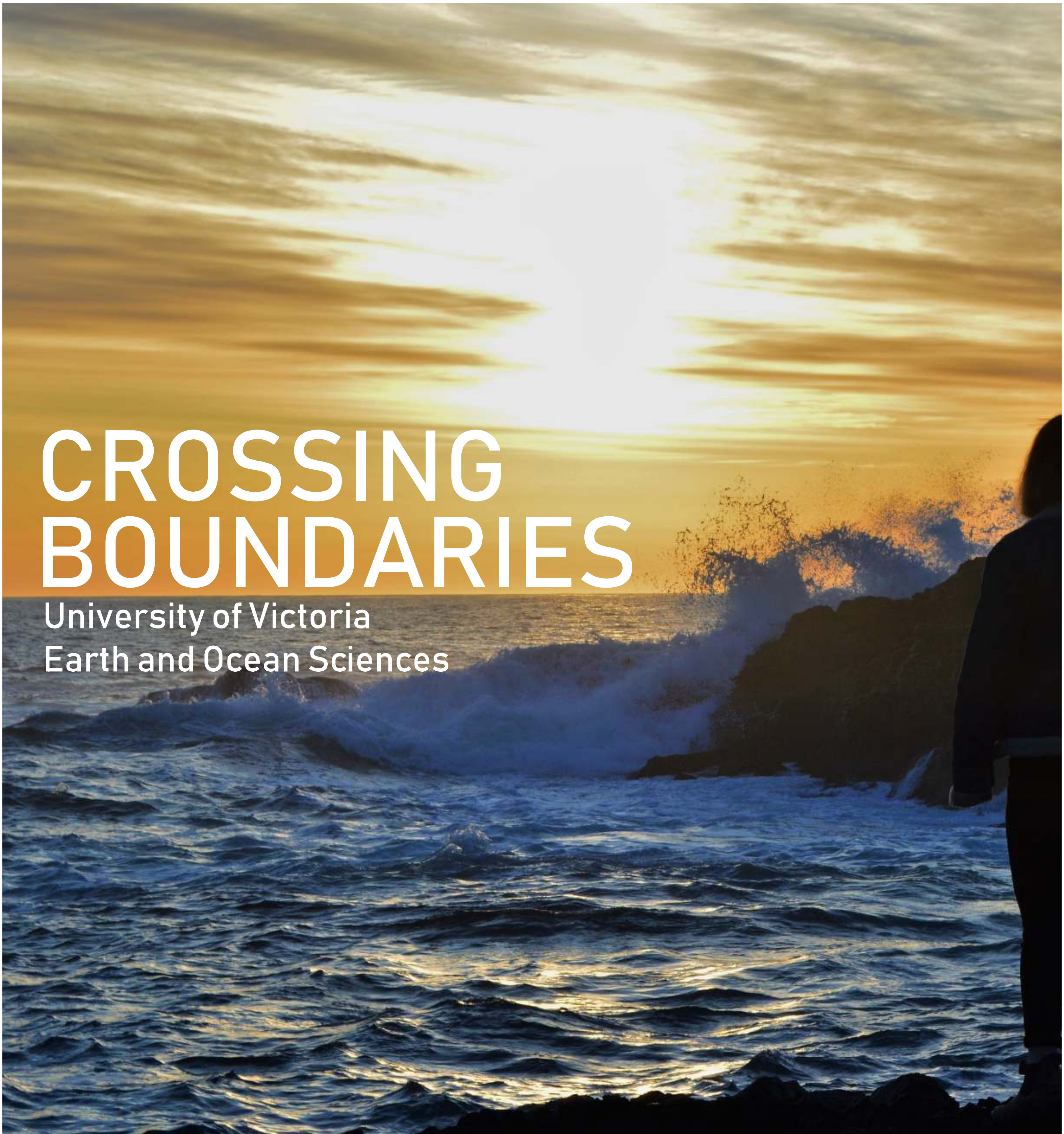

CROSSING BOUNDARIES

University of Victoria
Earth and Ocean Sciences

Graduate Student Magazine
Issue 1
Summer 2019
www.uvic.ca/science/seos/grad

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Geological field equipment on coastal outcrop, eastern Vancouver Island, Campbell River area, British Columbia. Photo by Sandy McLachlan.

Truck stuck in the mud on Anticosti Island during fieldwork. Photo by Mariko Capello.

Porthole rainbow at sea. Photo by Amanda Timmerman

Turbidite sequence on Pender Island. Photo by Jin-Si Over

From the Director

SEOS: A history of interdisciplinary excellence

It is both an honour and a pleasure to write a few words of introduction for this inaugural issue of *Crossing Boundaries*, a new annual journal by and for the graduate students of the School of Earth and Ocean Sciences (SEOS) at the University of Victoria. The name chosen for this journal, *Crossing Boundaries*, reflects nicely the Earth System Science philosophy of SEOS, which seeks to understand the processes and interactions of the atmosphere, hydrosphere, biosphere, lithosphere and deep earth, considering the planet as an integrated whole. While our expertise in SEOS can be categorized within core disciplines of geology, geochemistry, geophysics, oceanography and atmosphere/climate sciences, our research and education strengths lie in an inter-disciplinary approach to studying the Earth and its environments.

The student-written, student-edited research articles presented here convey some of the breadth of inquiry in the School, with topics including marine geophysics and inverse theory (Josée's "Clear as Mud - Estimating Seabed Geoacoustic Properties using Acoustic Remote Sensing"); radiometric dating of ancient ash falls to constrain the stratigraphic record of ice ages and mass extinctions in the Upper Ordovician (Marikò's "When did this Happen? Dating Ancient Volcanic Ash to Unravel the Past"); and micropaleontology of marine phytoplankton for climate and paleoenvironmental reconstructions (Sandy's "Dinoflagellate Cysts - Tiny Fossils lending Big Insights"). Common to all of these articles are clear and concise expositions (no mean feat in presenting specialized work to a broad scientific audience) and compelling figures and photographs. The additional photo galleries for field work, lab work and social events further illustrate some of the varied activities and adventures of the SEOS grad student experience.

Congratulations to Editor-in-Chief Amanda, the editorial team of Sheryl, Rebecca and Christiaan, and layout/print designer Jin-Si on producing this engaging and professional volume. And kudos on the inspiration and initiative in starting something new here to the benefit of SEOS and our present and future students.

Stan Dosso
Director of SEOS

Editor-in-Chief: Amanda Timmerman

Editors: Sheryl Murdock, Rebecca Scholtysik, and Christiaan Laureijs

Layout and Print Design: Jin-Si Over

Clear as Mud

Estimating seabed geoacoustic properties using acoustic remote sensing

Josée Belcourt

The ocean is opaque to electromagnetic radiation (light, radio waves) but transparent to sound, meaning that acoustic waves can propagate long distances through the ocean. The renowned oceanographer Walter Munk demonstrated this in 1960 when he and his team near Bermuda were able to detect sound from three controlled underwater detonations carried out near Perth, Australia, using underwater microphones (hydrophones) situated approximately 20,000 kilometers away (Munk et al. [1988]). Given the effectiveness of sound propagation in water, it is not surprising that many underwater applications like navigation, communication, and remote sensing utilize sound waves.

In shallow waters, sound waves are bounded above by the sea surface and below by the seafloor. Sound emitted from a source generally reflects from these boundaries many times before reaching a receiver; hence the sound field is greatly influenced by the properties of the sea surface and the seafloor, and contains information about these boundaries. Geoacoustic inversion is a remote sensing technique that uses measurements influenced by the seafloor to estimate the acoustic properties of the bottom boundary (i.e., layered seabed). This technique requires measurements of some sound-field quantity influenced by the seabed (e.g., reflection coefficients) and a model of the seabed, including model parameters (e.g., porosity, compressional-wave velocity, and density) and underlying physics (e.g., viscous grain shearing theory and spherical-wave reflection coefficients).

Estimating geoacoustic properties is an active area of underwater acoustic research because knowledge of seabed geoacoustic properties is often the limiting factor in modelling bottom-interacting sound fields, with many biological, geological, and geotechnical applications (to name a few). Moreover, the geoacoustic properties of soft, muddy seabeds have become of increasing interest to shallow-water acoustic research since they have been studied less and, as a result, are poorly understood in comparison to harder seabeds such as sands.

My work utilizes a remote sensing technique, trans-dimensional (trans-D) Bayesian inversion, to estimate geoacoustic properties and uncertainties of fine-grained (muddy) sediments from reflection-coefficient data in support of the United States Office of Naval Research 2017 Seabed Characterization Experiment. This experiment was a multi-institutional collaborative study on the New England Mud Patch with the aims of (1) understanding the physical mechanisms that control acoustic propagation in fine-grained (muddy) sediments, (2) quantifying uncertainties in estimated seabed parameters, and (3) assessing the resultant geoacoustic models and inversion methods (Knobles et al. [2018]).

How are seabed reflection coefficients measured?

The New England Mud Patch is a 13,000 km^2 area situated roughly 100 km south of Cape Cod, Massachusetts, USA. It is characterized by fine-grained (muddy) sediments, including clay and silt-sized particles, over coarse-grained (sandy) sediments. The seafloor over this large area is relatively smooth and flat making this an ideal location for the Seabed Characterization Experiment.

The experiment component I considered was designed to measure acoustic reflection coefficients (i.e., the ratio of the reflected acoustic wave energy to the energy incident on the seafloor, as a function of reflection angle and frequency). These measurements were made with a bottom-moored omni-directional receiver and a ship-towed broadband acoustic source as illustrated in Figure 1. The ship maintained a constant slow speed along a radial track with the centerline over the receiver position. The towed source emitted a short pulse with a broad bandwidth every second.

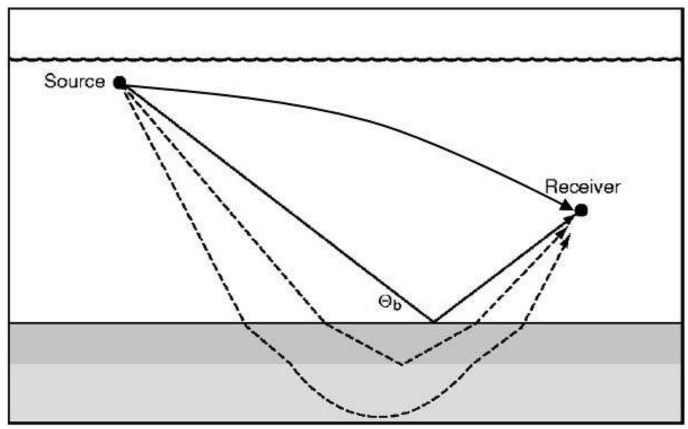

Figure 1. Experiment geometry showing the direct, bottom-reflected, and sub-bottom-reflected acoustic paths.

The reflection coefficients are computed from time-windowed direct and bottom-reflected acoustic arrival times, corrected for experimental effects including source directivity, geometric spreading and absorption (Holland et al. [2000]).

How are geoacoustic properties inferred from reflection-coefficient data?

In general, inverse problems use observed or measured data to estimate parameters of a postulated model that characterize a physical system. Conversely, forward problems compute or predict data that would be observed in an experiment given a model of the physical system (see Figure 2).

Here, the observed data are high-resolution seabed reflection coefficients. The seabed model consists of horizontally-stratified, homogeneous layers, with each layer characterized by viscous grain shearing (VGS) parameters (Buckingham 2007). VGS theory describes water-saturated sediments as a viscous fluid containing sediment grains in contact, including both friction and viscosity as loss mechanisms.

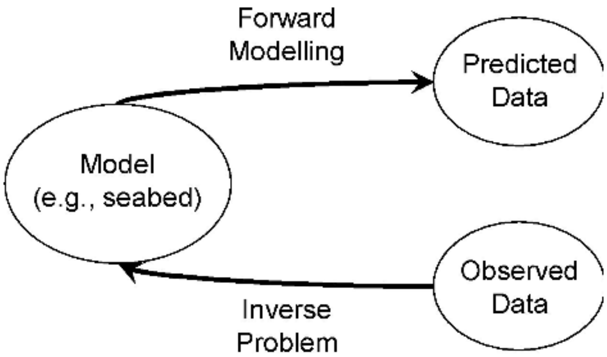

Figure 2. Diagram illustrating forward and inverse problems.

VGS parameters can be converted to more standard sediment properties such as compressional-wave velocity and density. These parameters can also be measured in the lab from sediment cores extracted at the site and compared to inversion results. Given the experiment geometry (sediment thickness and source-frequency bandwidth), data prediction are computed using spherical-wave (full-wave) reflection-coefficient theory as opposed to much-simpler plane-wave reflection-coefficient theory (Dettmer et al. 2007).

Inferring geoacoustic parameters requires solving an inherently nonlinear and non-unique inverse problem. The problem can be solved using a Bayesian approach that assumes the model is not deterministic but a random variable to be described probabilistically. In my work, a trans-D formulation is employed to sample probabilistically over an unknown number of seabed layers in addition to the geoacoustic parameters of each layer (Dettmer et al. 2010). The numerical method of parallel tempering reversible jump Markov-chain Monte Carlo is used to sample the posterior probability density, incorporating both data and prior information (physical parameter bounds). The solution is quantified in terms of marginal probability profiles for the geoacoustic properties, representing the uncertainty of the solution as a function of depth.

A look at inversion results

Inversion results for three depth-dependent parameters are shown in Figure 3. In this figure, the left-most panel illustrates the probability of occurrence of a layer interface as a function of sub-bottom depth. The next three panels show marginal probability profiles for porosity, sound (compressional-wave) speed, and density to a depth of 3.5 m. The profiles are normalized independently at each depth for display purposes. The dashed-line profiles represent measurements from a core taken near the experiment site. Core measurements are carried out by extracting a cylindrical sample of sediments to measure sediment properties in the lab. Coring provides direct measurements of sediment properties (compared to remote sensing), but are labour intensive and prone to errors/biases unless great care is taken. Nonetheless, core measurements (when available) can provide valuable ground-truth data for comparison with the inversion results. The agreement between the core measurements and inversion results is generally excellent here, particularly discounting the rapid fluctuations (spikes) that occur in the core values due to measurement artifacts. Here, the mud-base interface is estimated at 3.25 m depth. The most important VGS parameter, controlling the sediment geoacoustic properties, is porosity.

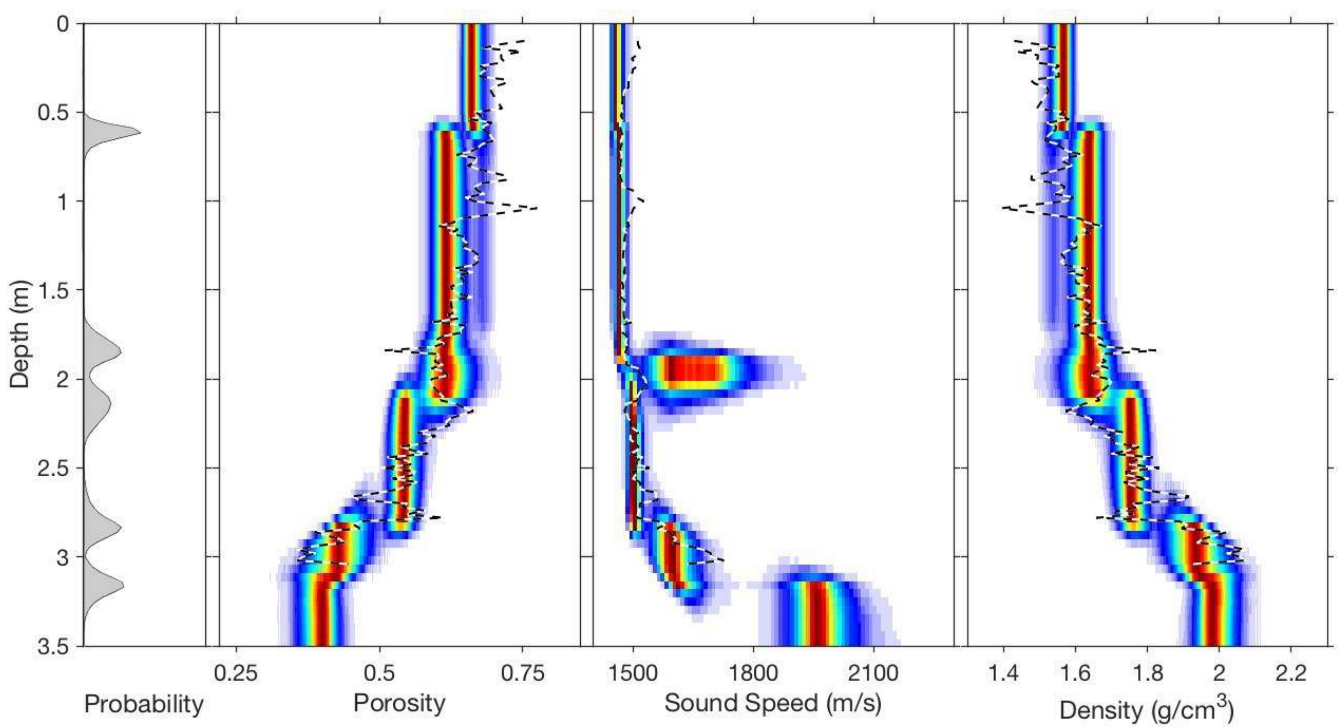

Figure 3. Inversion results in terms of marginal probability profiles for (from left to right) layer interface depth, porosity, sound speed, and density as a function of sub-bottom depth. Probability density is indicated by colour, with warm colours (e.g. red) indicating high probability and cool colours (blue) indicating low probability. Core measurements (dashed-line profiles) taken near the experiment site are plotted on the parameter plots.

The mean porosity estimate varies from 0.66 at 0.15 m depth (consistent with mud), to 0.54 at 2.5 m, to 0.40 (sand) at 3.5 m (below the mud base). Since the trans-D inversion presumes horizontally stratified, homogeneous layers, the stepwise porosity decrease may represent layered structure, a continuous gradient, or a combination of both. The complete analysis of inversion results can be found in Belcourt et al. (2019).

Lastly, the fit between the measured reflection-coefficient data and the data predicted for geoacoustic models obtained by inversion is illustrated in Figure 4. The predicted data are computed for a large number of model samples. The predicted reflection coefficients (red circles) generally fit the measured data (crosses) well across angles and frequencies.

Summary

Geoacoustic inversion represents an in-situ, non-intrusive, economical, alternative approach to direct core measurements. Trans-D inversion is a general and powerful approach to Bayesian geoacoustic inverse problems for depth-dependent seabed models. In my work, geoacoustic profiles are inferred from wide-angle frequency-domain reflection-coefficient data on the New England Mud Patch. These properties are important to understanding depositional processes and ocean acoustic waveguide propagation. The results from acoustic remote sensing of sediment properties using reflection-coefficient data agree well when compared to independent measurements, and provide a significant contribution to the Seabed Characterization Experiment.

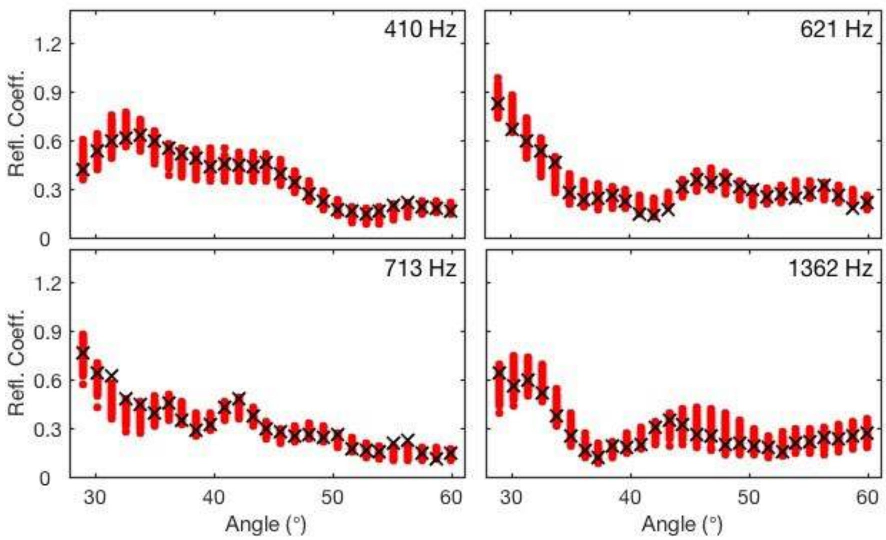

Figure 4. Comparison between observed reflection coefficient data (crosses) and predicted data probabilities from the trans-D inversion (red circles) at four (of nine) frequencies considered in the inversion.

This research was funded by the United States Office of Naval Research and the Canadian Department of National Defense.

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About the author: Josée Belcourt received her M.Sc. degree in Earth and Ocean Sciences at the University of Victoria in 2018. She is a Naval Warfare Officer in the Royal Canadian Navy and the Maritime Forces Pacific Formation Oceanographer at Canadian Forces Base Esquimalt. Her early naval career involved sailing in Her Majesty’s Canadian Ship (HMCS) OTTAWA as a Bridge Watchkeeper and HMCS CALGARY as the Underwater Warfare Officer.

Supervisor: Stan Dosso

When did this happen?

Dating ancient volcanic ash falls to unravel the past

Marikò Cappello

Reconstructing events
Geologists study Earth processes and make a constant effort to understand our planet and its history, from its origins up to today, and even modelling the future. One branch of geology that focuses on Earth history is stratigraphy. This discipline is concerned with sediments and rock deposits. Sediments and rocks are like the pages of a book, they tell us a story. They help us unravel the most significant events that have shaped the atmosphere, hydrosphere, biosphere and lithosphere of our planet. All that we know today about the timing, length and dynamics of events such as ice-ages and mass extinctions is thanks to stratigraphy as well as other branches of geology. The most common questions stratigraphers attempt to answer are: "When this this happen?", "How long did this event last?" and "What happened first/after?"

There are many approaches used by stratigraphers. For example, biostratigraphy focuses on the study of different types of fossils. As different species appear in different environments, prosper and become extinct at different times and under different conditions, it is possible to determine relative dates for sedimentary deposits containing fossils. This enables us to correlate fossil distribution around the world and to reconstruct a sequence of events by interpretation and deduction from the stratigraphic record.

Despite its tremendous usefulness, biostratigraphy remains a tool only for defining relative ages (e.g. are these rocks older/younger than those?) rather than absolute ages (actual dates). In order to have a more complete, precise and accurate timeline marked by a series of events, it is fundamental to have some absolute dates! This can be achieved by using radiogenic isotopes, especially considering the advances made in geochronology (the branch of geology concerned with determining numerical dates for rocks and past events) over the last decades.

One important time in the history of our planet is the Upper Ordovician epoch (458-444 million years ago), which is marked by profound perturbations, including an ice-age and a mass extinction. Even though there is copious biostratigraphic work, there is a severe lack of absolute ages for this time interval! My research addresses this by using radiometric dating of ancient ash falls to achieve a better understanding of the duration and the links between the different events that affected our planet during the late Ordovician time interval.

The combination of stratigraphy and geochronology is a very effective and well-rounded way to investigate the past. In order to understand more about absolute dating one must learn more about the basic principles of radiogenic isotopes and their applications.

Isotopes and radiogenic isotopes
Isotopes are atoms of the same element that have the same number of protons but different mass, due to having a different number of neutrons. Even though atoms of the same element must have the same number of protons, they can have a different number of neutrons, hence a different mass (Figure 1).

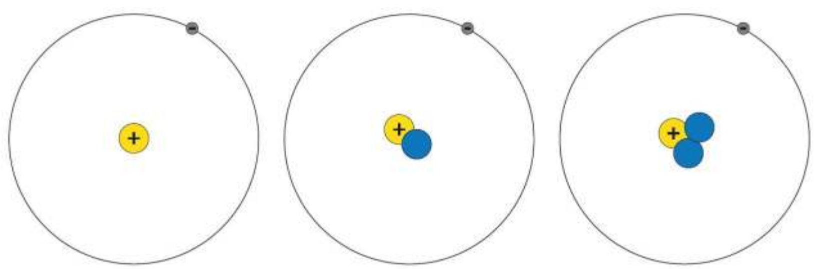

Figure 1. Illustration of the isotopes of hydrogen: ^{1}H (protium), ^{2}H (deuterium) and ^{3}H (tritium). Yellow circles represent the protons, blue circles represent the neutrons and the little grey circles represent the orbiting electrons.

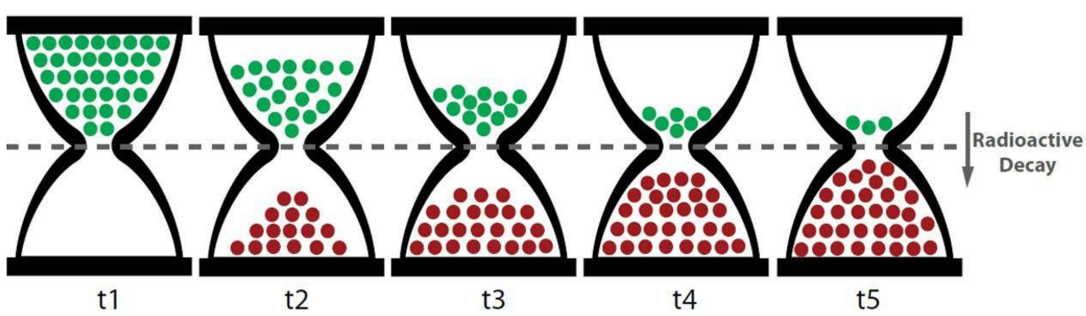

Figure 2. Simplified conceptual illustration of radioactive decay. From left to right one can observe that over time the number of parent atoms (indicated in green) decreases as the number of daughter atoms (indicated in red) increases. (t=time; t1=oldest, t5=most recent).

Figure 3. Cliff exposing Late Ordovician sediments, Anticosti Island (Quebec, Canada).

Most of the elements in the periodic table have at least two naturally occurring isotopes, while some have one only (monoisotopic elements). Isotopes can be either stable or unstable. Despite the numerous applications of stable isotopes, this article will focus on unstable isotopes. The nuclei of unstable atoms undergo radioactive decay; in other words they transform over time due to the emission of particles and energy. Radioactive decay is a process responsible for nuclei changes, resulting in the transformation of atoms from *parent* isotopes to different *daughter* isotopes. As time goes by, the parent isotope present in a sample decays into the daughter isotope. The longer the elapsed time, the more daughter isotope (and consequently less parent isotope) will be present (Figure 2). Therefore, by measuring the ratio between parent and daughter isotopes in a mineral (minerals are the building blocks of rocks), it is possible to determine dates.

Zircon U-Pb dating

There are different radiogenic isotopes and different minerals that can be dated, but zircon Uranium (U) - Lead (Pb) dating is one of the best and most suitable methods for my research.

Zircon is a mineral that is often a target for U-Pb dating because it concentrates U excluding Pb, and is very resistant to physical weathering, chemical weathering and metamorphism (change in structure and/or composition due to heat and/or pressure). Moreover this mineral has a further advantage: it contains two different radiogenic isotopes: ^{238}U and ^{235}U. Once the mineral is formed and there is no further exchange with the surrounding environment, there are two parent isotopes decaying into their respective daughter products (^{238}U decays into ^{206}Pb and ^{235}U decays into ^{207}Pb). This means that we can run two separate analyses on the same crystal and if the resulting dates are concordant (the same) we have a double confirmation of the absolute date being accurate! All these factors combined make zircon U-Pb dating a great tool in geochronology. As in any other system, there are several factors that can compromise zircon dating, resulting in two discordant dates (e.g. Pb loss).

"When we go back so far in time...volcanic eruptions are considered *instantaneous* events..."

There are different techniques adopted to measure the U-Pb ratios in zircons. Some of them are semi-invasive (zircon crystals are only partially damaged) and take only minutes, while the ID-TIMS (isotope dilution-thermal ion mass spectrometry) method is extremely invasive (zircons are completely dissolved) and it takes hours. Despite the evident disadvantages, the error is considerably lower with the ID-TIMS. With adequate sample preparation and pre-analysis treatments, the isotope ratios in zircons acquired with ID-TIMS can give very high precision dates. This is a very powerful tool to date geological material.

Dates: the more, the better

As I mentioned earlier, the Upper Ordovician, and in general the boundary between the end of the Ordovician-beginning of Silurian geologic periods (approximately 444 million years ago) is marked by major changes on our planet. The only way to unravel the nature of these transformations is to have more absolute dates to help us constrain the timing of each event. One of the most well preserved stratigraphic records (Figure 3) of this time is situated on Anticosti Island, Quebec (Canada).

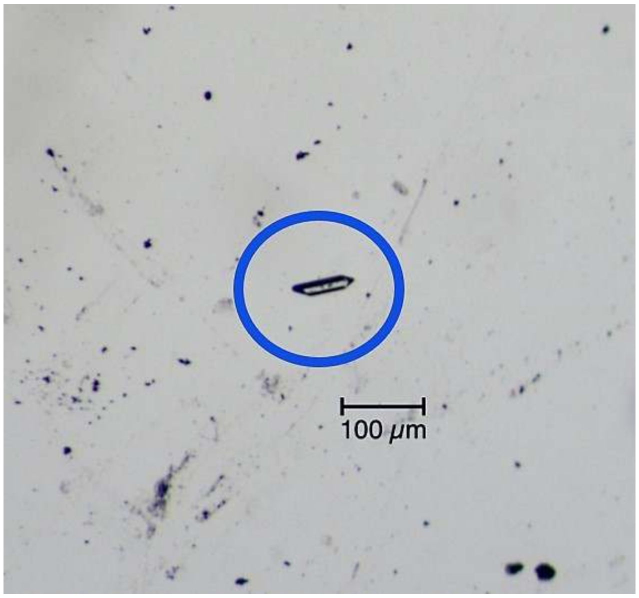

Figure 4. Micrograph taken during the process of isolating zircon crystals for ID-TIMS analysis. The elongated sharply edged crystal (circled in blue) comes from a sample collected on Anticosti Island (Quebec, Canada).

My research aims to improve on previous studies using the latest radiometric dating methods to provide more precise dates than those currently available. I went to Anticosti Island to collect samples of ancient volcanic ash falls, which are promising targets for U-Pb zircon dating. When we go so far back in time, volcanic eruptions can be considered as nearly *instantaneous* events in the stratigraphic record, hence they are perfect dating targets.

Due to chemical alteration, volcanic ash falls turn into bentonite (a type of clay) over long periods of time, so it can be hard to distinguish between a regular clay (non-volcanic origin) and a bentonite in the field. Of the 14 potential bentonites I collected, three bear zircons that have a morphology (shape) that suggests volcanic origin.

We are now dating single crystals (Figure 4) from the zircon bearing samples using U-Pb ID-TIMS. There is currently a scarcity of reliable radiometric ages for deposits close to the Ordovician-Silurian boundary, therefore it is relevant to conduct this type of analysis. Combining the new data with the existing geological data will allow for the development of a more refined age model. Furthermore, the new dates can be made easily available to other researchers if inserted in a geological database.

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About the Author: Marikò Cappello grew up on the slopes of Mt Etna (Sicily, Italy), the tallest active volcano in Europe. Volcanic eruptions, tremors and ashfalls were regular part of her life, igniting her passion for geology. As a child, she would always find new rocks to scrutinize, classify and add to her collection. Mariko pursued her passion by studying geology at an undergraduate level in Italy, and today she is an MSc student at the University of Victoria.

Supervisor: Jon Husson

Dinoflagellate Cysts

Tiny fossils lending big insights

Sandy McLachlan

What are dinoflagellate cysts and why are they useful?
Dinoflagellates are single-celled microscopic marine organisms, which are a major group of phytoplankton. Dinoflagellates exist throughout the world's oceans today and their success in both marine and aquatic environments is reflected in their cysts being highly abundant, widely distributed, and well-preserved in the fossil record. Dinoflagellate cysts are organic-walled structures produced when dinoflagellates enter a stage of dormancy following sexual reproduction. Dinoflagellates make their first unequivocal appearance in the fossil record during the Triassic Period (~235 Ma) and were largely unaffected on a global scale by the Cretaceous/Paleogene extinction event at 66 Ma (Fensome et al. 1996). The high quality of dinoflagellate cyst preservation is due to a unique, resilient carbohydrate-based biomolecule called dinosporin.

Given similarity in size, composition, and preservation environments, the study of dinoflagellate cysts falls within the discipline of palynology which encompasses research on other microscopic organic-walled structures such as pollen grains and spores. Data derived from dinoflagellate cyst assemblages help us to understand the responsiveness of phytoplankton communities to changing environmental conditions in Earth's past and their paleoecological significance. Their distinct shapes, physical characteristics, and prevalence in the fossil record make dinoflagellate cysts excellent tools for interpreting past environmental conditions over millions of years. Dinoflagellate cysts are widely used paleoenvironmental and primary productivity indicators in light of the known habitat preferences and ecological responses of modern species.

Basis of dinoflagellate cyst deep-time application
In order to gather quantitative data from both modern and fossil dinoflagellate cysts we must dissolve sediment samples in acid and count the individual cysts (Figure 1). Modern dinoflagellate cysts recovered from marine surface sediments and sediment trap apparatuses deployed to collect deposited sediment have produced a globally extensive body of data with precise, high-resolution records indicating species preferences for a range of environments (e.g., Marret & Zonneveld 2003) with discernible trends on decadal to centennial scales (e.g., Bringué et al. 2014). In turn, measures of species' responses to variations in environmental conditions as a function of their physical traits (called transfer functions) are used based on modern analogues for extrapolating similar marine conditions in studies of sediments deposited millions of years ago.

Deeper into the fossil record, dinoflagellate cyst association with other paleoenvironmental indicators is of greater necessity when making reliable inferences for a given spatial setting. These indicators may take the form of geochemical signals from elemental isotopes occurring either independently or obtained from microorganism remains composed of calcium carbonate (e.g., benthic foraminifera and nannofossils). Furthermore, rock age indication through records of paleomagnetic pole reversals, astronomical calibration of orbit-induced climate cyclicity (Milankovitch cycles), and other fossil index species enables trends in dinoflagellate cyst assemblage composition to be correlated within the context of generally accepted global conditions during a given time period.

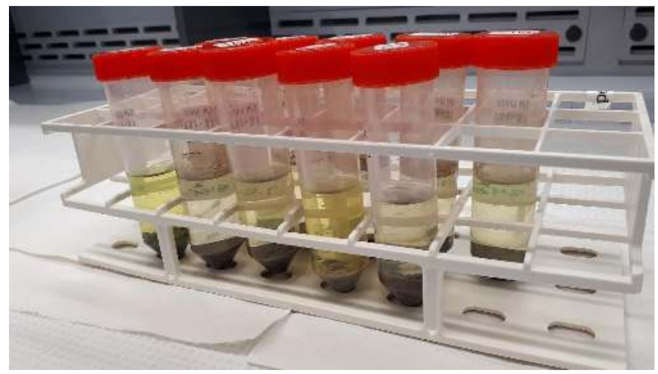

Figure 1. Sedimentary rock samples being treated with hydrochloric acid to break down carbonates prior to hydrofluoric acid treatment to dissolve the silicates, Paleoenvironmental and Marine Palynology Laboratory, SEOS, University of Victoria. The organic microfossils present within the rock matrix will be made visible for study by way of light transmitted microscopy following this procedure.

Dinoflagellates as primary producers
The process of photosynthesis whereby organisms take in carbon dioxide and produce oxygen is referred to as primary productivity. Primary productivity data carry implications for understanding trends in sea level fluctuation and by extension, global climate conditions. As one of the major phytoplankton groups in the world's oceans and pillars of the marine food web, dinoflagellates are paramount primary producers. In general terms, high dinoflagellate cyst concentrations and high species diversity are considered to be compelling indicators of dinoflagellate success.

These factors have been linked to high nutrient availability either from terrestrial runoff or upwelling conditions, and primary productivity in both modern and ancient marine settings (de Vernal 2009). When exposed to ultraviolet light, chlorophyll, the indicator molecule for an organism's ability to perform photosynthesis, will fluoresce. Present in dinoflagellate cysts with autotrophic capability, this photic response is used as an indication of past primary production capability owing to the remarkable long-term preservation potential of chlorophyll (Figure 2C) (Pospelova & Head 2002).

Beyond figures of assemblage diversity and absolute abundance, the ratio between cysts produced by primary producer and primary consumer dinoflagellates has also been applied in many Late Cretaceous and Paleogene studies as a paleo-upwelling signal. The basis of this ratio is the premise that greater numbers of primary consumer dinoflagellates occur as a result of conditions favourable to production if their preferable prey is other planktonic organisms such as diatoms and other primary producers.

Shore proximity and sea level change

In addition to establishing a paleo-upwelling signal, greater clarity in the discernment of marine paleoenvironmental shore proximity is possible through obtaining a ratio between dinoflagellate cysts with known nearshore and oceanic habitat preferences (Wall et al. 1977). Many modern marine taxa with known ecological niches are also common in the fossil record but where absent or underrepresented, morphologically analogous species have been utilized. Shore proximity paleoenvironmental reconstructions often draw on the concept of dinoflagellate cyst 'ecogroups' (Pross & Brinkhuis 2005) on the basis of apparent habitat preference.

Additionally, the establishment of spatial trends in cyst deposition can allow for inferences of sea level fluctuation based primarily on the ratio of oceanic to nearshore dinoflagellate cyst ecogroups across a continental shelf profile (Firth 1993).

Current research

Investigations being undertaken within the Paleoenvironmental and Marine Palynology Laboratory at the School of Earth and Ocean Sciences, University of Victoria, encompass projects with a focus on dinoflagellate cyst applications ranging from the Modern to the Mesozoic in the North Pacific realm over the last 80 million years. Work on climate and paleoenvironmental reconstructions based on high-resolution time series sampling within sediments of Quaternary age from the California Margin as well as from the South China Sea are ongoing. Research on dinoflagellate cyst assemblages from Upper Cretaceous and Paleogene sedimentary rocks collected along the eastern coast of Vancouver Island and the Gulf Islands are continuing to yield new findings with respect to relative dating, forearc basin depositional settings, and morphological variability as a function of marine paleoenvironmental parameters.

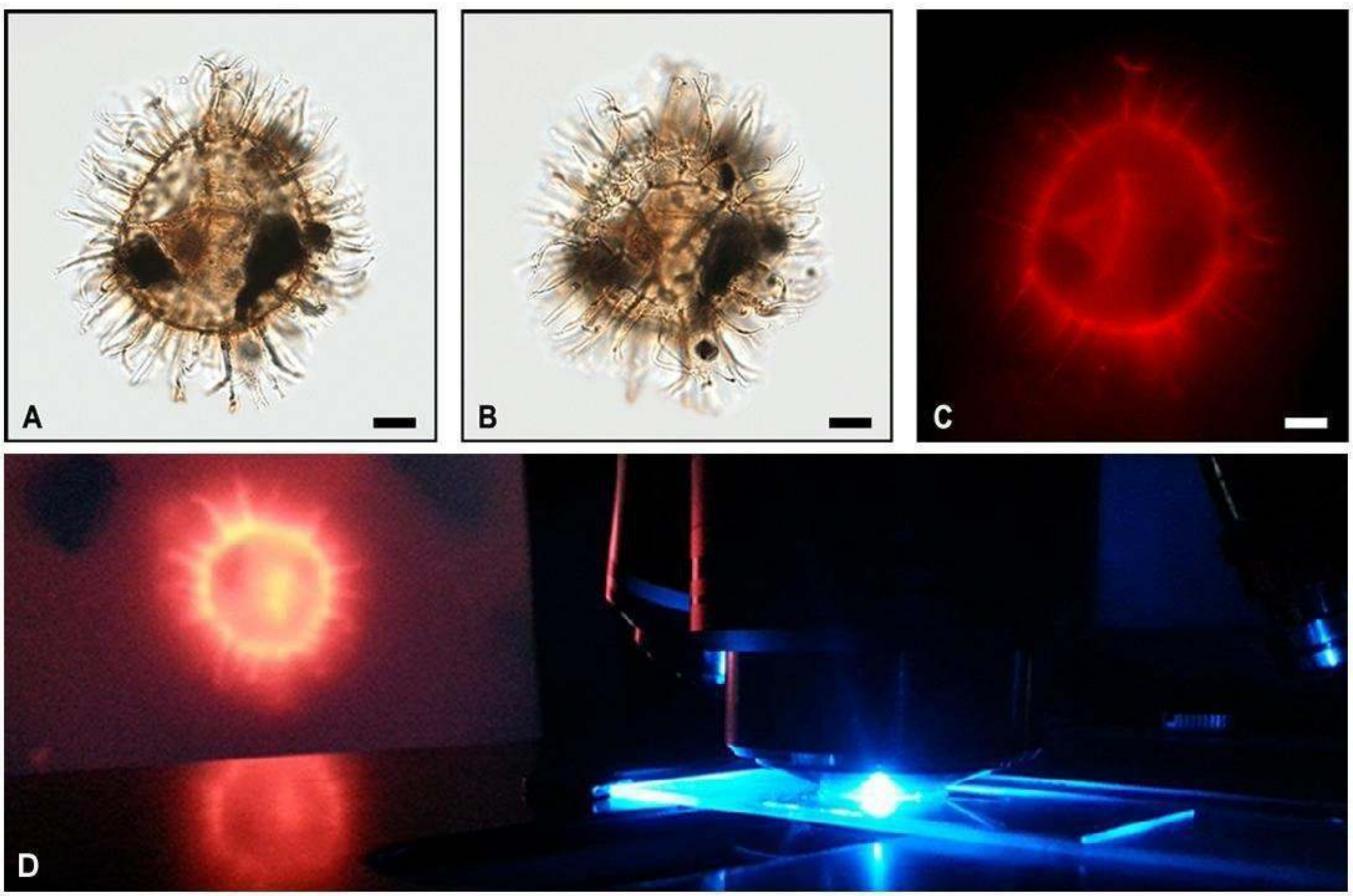

Figure 2. A, B, lateral views of the Cretaceous dinoflagellate cyst Coronifera oceanica as seen through a light transmitted microscope, Paleoenvironmental and Marine Palynology Laboratory, SEOS, University of Victoria. C, the same specimen illuminated through epifluorescence imaging. A–C, scale bar = 10 μm. D, ultraviolet light directed through microscope stage-mounted slide with illuminated specimen projected on monitor in background.

Active exploration into localized phytoplankton ecological turnovers following global extinction level events also promises to improve knowledge of how dinoflagellate cysts reflect shifting climate regimes and adapt to abrupt changes in marine conditions.

Conclusion

Dinoflagellate cysts remain crucial in their palynological and micropaleontological application. We are able to enhance our knowledge of global primary productivity, ocean oxygenation, and carbon cycling across time through gauging dinoflagellate cyst abundances and species diversity. As more data gets pooled, the correlation of dinoflagellate cyst events with other paleoenvironmental indicators throughout recent sedimentary history and the geological record stands to lend greater support to our understanding of climatic trends and Earth system dynamics impacting marine paleobiogeography. Methods of depositional setting reconstruction using taxa ratios are likely to lend further insight into specific regional conditions of limited duration. Data syntheses of dinoflagellate cyst records over broader geological periods will allow us to refine our understanding of phytoplankton responsivity to climate variability lending context for present global conditions in relation to times of warmer mean global temperatures.

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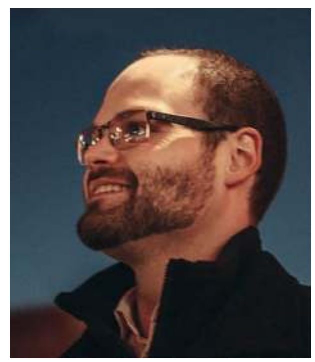
About the Author: Sandy is a PhD candidate in SEOS, where he also obtained his MSc in invertebrate paleontology and micropaleontology. A Vancouver Island resident for much of his life, he has collected fossils from the West Coast for over twenty years with the aim of elucidating British Columbia's paleontological heritage and its applications for answering questions of Earth History.

Supervisor: Vera Pospelova



SEOS Trivia!

1. How many countries do SEOS grad students represent?
2. How much rain does Victoria get annually on average?
3. Who in the SEOS department has 9 species named after them?
4. How many times a week can SEOS grad students get free coffee?

Answers: 1. About 10! (from 5 continents) 2. 58 cm a year, but up island is a temperate rainforest 3. Verena Tunnicliffe (mostly hydrothermal vent animals!) 4. At least 3 – Tuesdays and Thursdays on the 4th floor of Bob Wright and Wednesdays at the Grad House

Fresh Air

Graduate student adventures and field research

Matt Miller (PhD), in the Dower lab, stands on an ice flow in the Beaufort Sea. Matt spent one month aboard the Canadian Coast Guard Ship Louis S. St-Laurent looking for pteropods (small planktonic snails) in the Arctic to document how human-caused ocean acidification may be affecting their delicate shells.

Alex Geen (MSc) looks at pillow lavas at Sayward Beach along the Sidney peninsula; his research focuses on sulfide minerals in Vancouver Island rocks.

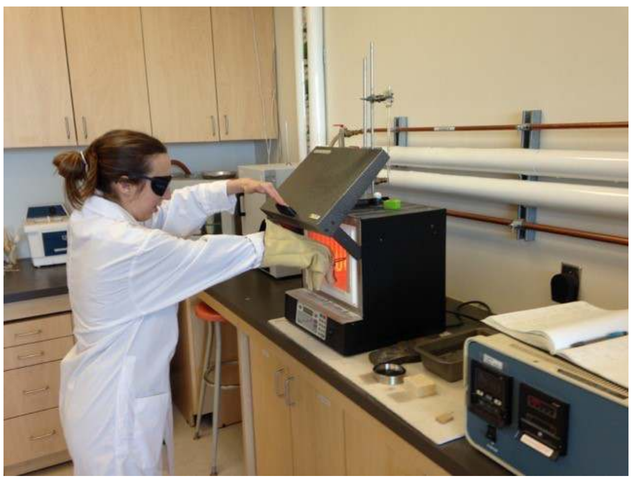
Sampling the last station of her PhD fieldwork, Theresa Venello, Dower lab, collects zooplankton samples from a vertical bongo net tow and water for chitobiase enzyme analysis along Line P (September 2018).

Julia Horne (PhD), Planetary Science with Colin Goldblatt, took this photo of SEOS instructor David Nelles and a student on the EOS 400 field school into the interior of British Columbia over the summer during wildfire season. Cool rocks were seen nonetheless.

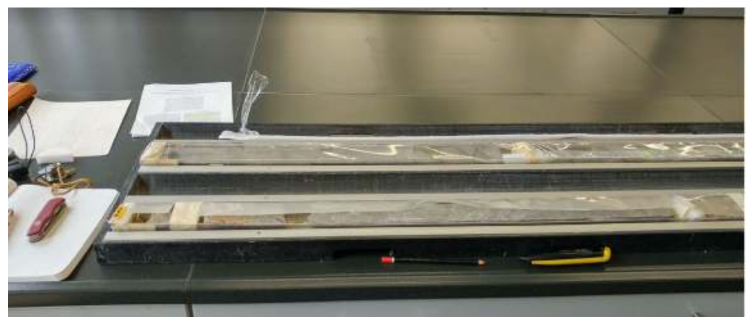
The Lab Bench

Graduate student inside activities

Mina SeyedAli (PhD), working with K. Gillis and L. Coogan, uses the column chromatography facilities for her research. The Teflon columns (look like straws) are filled with cation exchange resin to separate the cation of interest from a complex matrix of dissolved rocks. Part of her research focuses on lithium in rocks on the seafloor to determine what factors impact their isotopic composition over the last 120 million years.



Making a magma! Rebecca Scholtysik (PhD) synthesizing a magma melt composition at 900°C. It will be used in an experiment that investigates the behaviour of volatile trace metals that are emitted from volcanoes.



Christiaan Laureijs (PhD) examines and samples cores from the ocean drilling program. Using Rb/Sr age dating methods on secondary minerals that form between the interaction of seawater and basalt allows him to see how the composition has changed through time.

Brett Jameson (PhD), in the Juniper lab, works on a lab bench on the MSV Strickland in Saanich Inlet for his microbial ecophysiology research.

Shea Wyatt (PhD), in the Varela lab, filters seawater on-board the R/V Atlantic Explorer on a stint in Bermuda this past fall to collect data for his research on diatoms.

SEOS Events

Graduate students getting out there

SEOS has fun together too! Taking a break to go ice skating - Canadian or not - after some socializing and libations of Victoria's finest brews.

SEOS grad students represent at Victoria's March for Science

Summer "welcome back" SEOS grad picnic and meet-and-greet included stand up paddleboarding in Cadboro Bay.

Some of the SEOS graduate students we could wrangle together out of the 40 or so currently working towards their degrees.

Thank you!

From the Editor

To our readers,

The momentum for a magazine to showcase the research within our department was quickly shared by a few graduate students. We wanted something tangible to share with potential students, colleagues, and the general public. With the wide breadth of disciplines that are encompassed within the School of Earth and Ocean Sciences, 'Crossing Boundaries' is the perfect title for our magazine. Our department does indeed cross boundaries from atmosphere to oceans to rocks. Each article has been rigorously edited by someone within and outside the discipline. Part of the goal was to write the articles so a wider audience could understand - instead of writing only to people within our respective fields, and I believe the outcome is a perfect way to showcase our diverse and innovative research within the department.

I am proud to be a part of the team that took this idea to fruition and want to thank everyone who helped make this a reality. Thank you to the other editors who helped build a vision for the magazine. Their thoughtful edits and suggestions were greatly appreciated to create this first edition. Thank you to the authors for being patient as we explored this new venture and learned how to organize a magazine. I really appreciate all the time that went into writing articles in a style not always asked for in academia. Thank you to Jin-Si for doing the layout and making the final product reflect all of the hard work that went into this issue. Thank you to everyone who sent photos from the field or the lab. I also want to thank the Department for their support, especially Stan, Ed, Allison, and Terry. I am especially grateful to Lorenza Raimondi for her guidance in starting this magazine.

Hope you enjoy the first issue

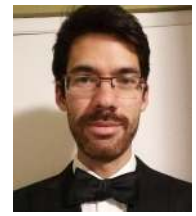
Editor-in-Chief

Amanda Timmerman

Meet the team!

Amanda Timmerman (PhD)
Lab: Gas Tracers
Advisor: Roberta Hamme
Fun fact: Has been on over 10 research cruises

Christiaan Laureijs (PhD)
Lab: Seafloor geochemistry
Advisor: Laurence Coogan
Fun fact: Plays the clarinet in the Don Wright Wind Orchestra



Sheryl Murdock (PhD)
Lab: Marine Microbial Ecology
Advisor: Kim Juniper
Fun fact: Has been in the submersible Alvin

Rebecca Scholtysik (PhD)
Lab: Experimental Petrology
Advisor: Dante Canil
Fun fact: Lived in Iceland

Jin-Si Over (MSc)
Lab: Paleo-environments
Advisor: Vera Pospelova
Fun fact: Likes to ride a unicycle around.

If you are interested in writing a piece, editing, or submitting photos for future issues please send your info to uvic.crossingboundaries@gmail.com