EARTH MATTERS

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COVER PHOTOS Front: ESB Atrium by Martin Dee, UBC Communications & Marketing. Back: Arctic Seascape by Kristina Brown.

From the Editor

This year has been one of surprises. Pokemon GO delighted nerds and novices alike. Apple, the longtime industry leaders of product design, unveiled "courageous" changes. After 108 years, the Chicago Cubs finally won the World Series. England voted to leave the European Union. Not least of all, the US election outcome shook the world.

Substantial changes occurred in EOAS, too. Six giants of the department announced their retirement this year. We mourned the loss of the energetic, sometimes quirky, always generous Professor Kurt Grimm. The Public and Internal Relations Committee hosted a public talk by climate legend Paul Hoffmann (page 6) to the delight of EOASers, UBC alumni, and the general public. With applications in for a new department faculty hire in, unknown and exciting opportunities are at our doorstep.

My own path also took a surprising turn when I was hired to rebuild EOAS' website. Several hundred Google searches, video tutorials, black coffees, and curses under my breath (or not) later, I'm grateful for the faith my superiors and peers invested in me.

Other aspects of the department are slower to change. The Public and Internal Relations Committee recently surveyed department members on their attitudes towards the department's sense of community. Many shared the belief that EOAS remains divided according to specialty; some dismissed that a department our size could be unified. Yet, survey responses were included a wellspring of suggestions to build community. A large proportion of respondents called for designated common spaces and purely social events, while others in all too frequently marginalized roles cried out for deserved recognition.

Building community will not be instantaneous or spontaneous, nor will it be impossible. The process can begin with conscious recognition of members of all roles within our department. To this important end, you'll find this volume of Earth Matters has been significantly expanded to include profiles of many more RAs, PDFs, and graduate students than prior editions. I hope you read this volume and learn something about "that person you always see in the hallway." You might be surprised.

Chuck Kosman
Earth Matters Editor-in-Chief

From the Head

EOAS is a dynamic community of people, each with their own remarkable story of learning, inquiry, service and discovery. On the shortest time scale, each year about 9200 students enrol in a 3-credit course in EOAS. Many of those enrolments will be from the 560 or so undergraduates who spend their last three years in our programs. On slightly longer time scales, approximately 200 graduate students pursue degrees in EOAS, evenly split between masters and PhD degrees. Faculty and staff have the longest time scales of all.

This spring we celebrated five faculty and one staff member who retired (or will retire) this year after long careers in EOAS. There is a good chance that almost every geologist and geological engineer who has graduated from UBC in the last 23 years learned much of his or her fundamental geology from Mary Lou Bevier. Her enthusiasm for field geology has inspired several generations of students. Oldrich Hungr was a pillar of our Geological Engineering program. A world leader in debris-flow research and hazard assessment, Oldrich had the engineer's talent to cut to the essentials of a problem, and the technical agility to produce both fundamental insights and solutions to practical problems. Jim Mortensen was a titan of the Cordillera of northern British Columbia, the Yukon and Alaska. Sought after by industry, he contributed selflessly on numerous student committees, was heavily active in the Mineral Deposit Research Unit and taught a wide variety of courses. In recognition of his career in research, exploration and student mentorship, he was this spring awarded the Canadian Institute of Mining's J.C. Sproule Northern Exploration Award. Leslie Smith, the most senior and distinguished member of the Geological Engineering's hydrogeology group leaves after 43 years' affiliation with UBC, starting when he enrolled for his PhD in 1973. Winner of numerous awards, he was a role-model scientist, colleague and instructor. We will miss his gentle humour and wit in the classroom, but hope to enjoy him as he continues research as an Emeritus Professor. Paul Smith, who retires at the end of 2016, was a leader in both his discipline and also in EOAS. Paul was Department Head during a critical phase when the culture of the then relatively new department was established. His enthusiastic support for science-based education has revolutionized our teaching methods, and his vision and energy were instrumental in the construction of the Earth Sciences Building. John Amor was the dedicated leader of our computer support staff "compstaff" and an excellent hockey goalie. He embodied the notion of selfless service to help others. Indeed, he established our IT helpdesk. I will miss each one of these colleagues, and wish them well.

We also experienced the tragic death in February of our colleague Kurt Grimm. Kurt started as an assistant professor in Geology in 1992 and retired in December 2015. An engaging, passionate polymath, he was unconventional, sincere and genuine. And he was taken from this world far too young.

Several faculty members have taken leadership positions outside of EOAS this year. Susan Allen was appointed as Associate Dean of Science. Philippe Tortell has assumed the leadership of the Peter Wall Institute Advanced Studies. Evgeny Pakhomov is the first Director of the new Institute for Oceans and Fisheries. Lee Groat has been the Director of the Integrated Sciences Program since 2007.

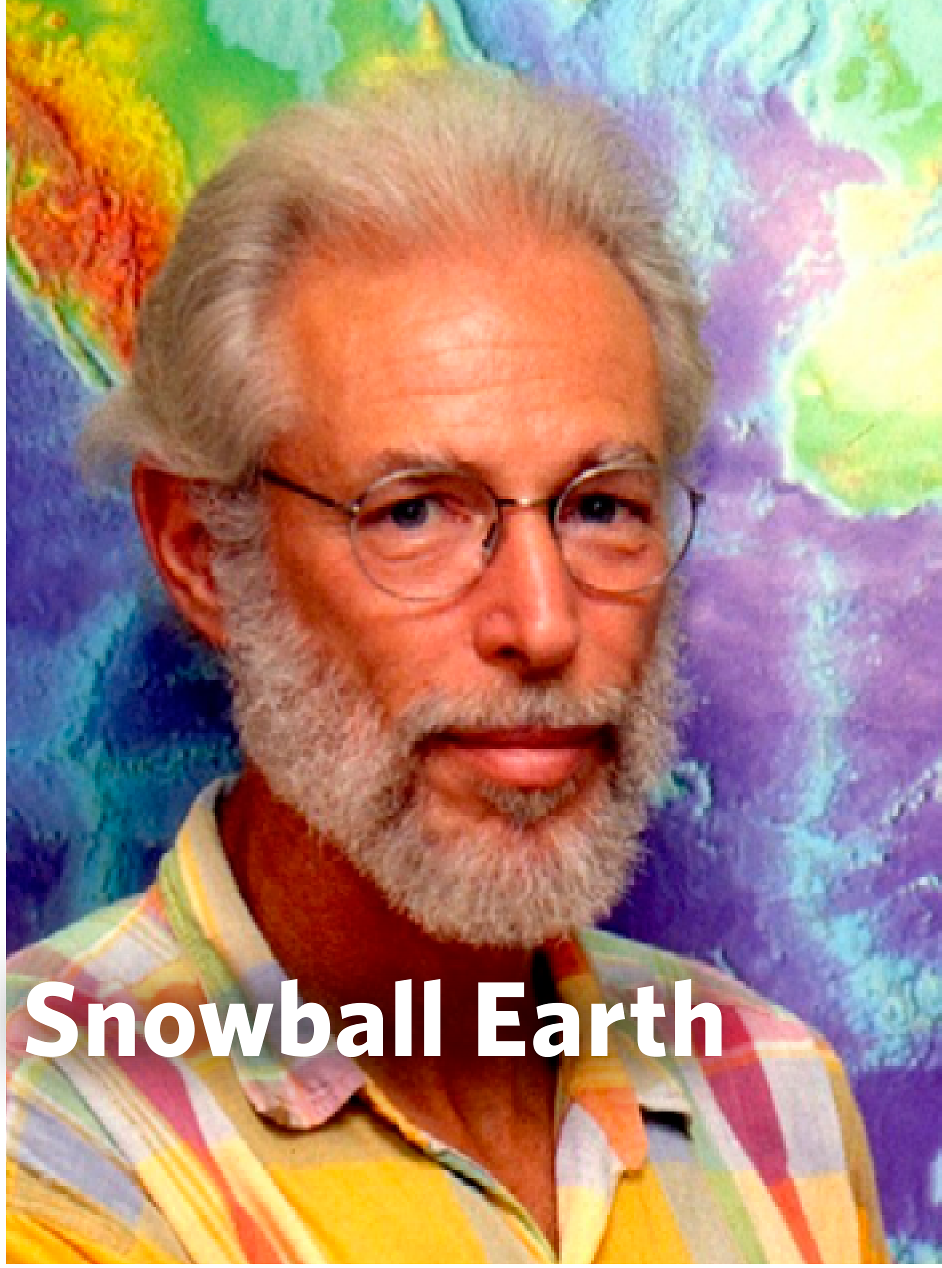
These changes have left a hole in the faculty complement in EOAS that we are beginning to address with new hiring. In July we were very pleased to welcome Scott McDougall back to EOAS as a professor after 10 years in industry. A natural hazards expert, Scott brings much needed fresh blood to our Geological Engineering Program. We are presently searching for a position in Earth Systems Evolution, and have received over 220 applications. This position is a "big tent" area meant to identify exciting people in new emerging areas of geoscience inquiry. The position was defined in the hiring plan developed by junior faculty. The plan was an attempt to balance what I view are the two key drivers in a world-class research department like EOAS: 1) building upon established disciplinary strengths and 2) forging into emerging areas. In our new hires, we need a balance of both. Science moves forward as new tools and techniques are applied to disciplines. Think of the impact of computation on geophysics and geological engineering, oceanography and atmospheric sciences, the impact of instrumentation on geochemistry and the impact of remote sensing on planetary sciences and geology.

Similarly, to ensure that our graduates are able to most effectively address societal problems, and understand the modern challenges that define the Earth sciences, we need our programs and curriculum to keep pace with these new tools and techniques. I see our curriculum evolving in the future with the goal that our graduates are able to effectively use the ever increasing flood of data flowing from the advances in instrumentation, networking and remote sensing, and apply process-based models to test and understand hypotheses. Although hard to imagine 30 years ago, tools from genomics and microbiology are changing the way we interpret geologic history, clean up contaminated sites and prospect for ores. As Elizabeth Kolbert describes in her excellent book, *The Sixth Extinction*, this type of evolutionary change has been literally and metaphorically present in the Earth sciences since the time of Cuvier, Lyell and Darwin. These are exciting times for our science.

Beyond the job search in Earth Systems Evolution, when are we going to hire again? That depends upon our budget. On the cost side, most of our budget is committed to salaries for faculty, staff and teaching assistants. Under the university's activity-based budgeting, our revenues depend upon the number of students we teach in classes, the number of students in our programs, the number of graduate students and our research funding. It is sometimes called the "bums in seats" model. We have been doing well by most of these measures, and I am optimistic that we will be hiring new faculty again next year. In the meantime, I am grateful to my hardworking colleagues, and the cadre of non-tenure track faculty who put in tremendous effort to support our teaching.

Roger

Professor Roger Beckie
Head of Earth, Ocean and Atmospheric Sciences



The Story of Snowball Earth

Presented by Dr. Paul Hoffman, Himself

by Rachel Maj and Meghan Sharp

With current concerns about climate change, the evolution of Earth's climate history is a topic in which many are interested, but only few understand. Last November, an expert among these few was invited to be the first feature presentation of the EOAS department's annual Brock Talks. This year's guest of honour was Dr. Paul Hoffman, a sedimentary field geologist at Harvard University. Dr. Hoffman gave a total of four talks at UBC, three of which were directed towards faculty and students in the department, and the fourth open to the public. He also set aside time for discussion sessions with graduate students and PDFs.

Dr. Hoffman led listeners on a journey that explored his best-known hypothesis: Snowball Earth. The Snowball Earth hypothesis suggests that Earth was once in a state of global glaciation, which shut off most biological activity. Earth is thought to have escaped these intense conditions through volcanic outgassing that rapidly transformed the planet to the opposing extreme: a global greenhouse. In this Brock Talk, titled "Earth's Astonishing Climate History", Dr. Hoffman discussed the detailed story of Snowball Earth, the abrupt rise of complex life that succeeded it and the connection between the two.

Dr. Hoffman began the series of four talks with "Dates and dynamics: Snowball Earth comes of age". He went on to present "What caused the Cryogenian climate crises?" and "Snowball ocean acidification and cap carbonates". The entire EOAS department was invited to attend these three talks, and immerse themselves in the story of Snowball Earth through the description of the methods of data collection, analysis of data, and interpretation of Dr. Hoffman's many years of research. He invited scientists at UBC to question and contribute to the proposed story. Audience members from a variety of specializations and with various levels of geological knowledge asked questions, providing an interesting and complete perspective. To put all these pieces together, the final talk was open to the public and examined Snowball Earth more generally from its rise to its termination.

After the presentation, EOAS hosted a reception where Dr. Hoffman stayed in the ESB atrium to chat and answer further questions people had about his work. An inspiring scientist, Dr. Hoffman's talks captivated all who attended. This year's Brock Talk adventure was a very successful initiation for the series. Stay tuned to find out who we will explore with next!

A Visit from a World-Class Role Model: Susan Solomon talks at UBC

by Rachel Maj and Meghan Sharp

Models are a key component of science and its evolution, but one of the most important (and often forgotten) kind of models are role models. Susan Solomon, a world leader in atmospheric science at the Massachusetts Institute of Technology, is a role model for many young scientists. Last November, UBC students seized the opportunity to speak to Solomon about her journey as an influential woman in science and some of the challenges she has faced. Preceding this question period, Solomon gave a seminar on "Emerging Signals of Climate Change, and Getting Past International Gridlock".

Her talk consisted of two parts: the first focused on discussing what research has been done to identify indicators of climate change in various locations around the world. She discussed the factors affecting climate change and the potential effects it may have on the future of our planet. In the second part of her presentation she described the implications of climate change for different nations across the planet with emphasis on the importance of a global perspective. Solomon provided her take on the upcoming Paris negotiations, (which she participated in just three days later), and her expectations for other international climate change conferences to take place in the future.

A group of undergraduate and graduate students were able to stay after the seminar for some more personal time with Solomon. She opened up about her experiences and journey to becoming a successful female scientist. This was a time for the students to let their curiosity take over, and find out information that can't be found in a textbook or on Google. They asked questions from "How did you develop an interest in Earth science?" to "What was your proudest moment?". This was a truly unique and rare opportunity for aspiring Earth scientists.

Student Life

Online TAing

by Rhy McMillan

Many graduate students in EOAS are Teaching Assistants (TAs). These assistantships are one of the few ways that graduate students obtain instructional experience, with the other options being the Teaching and Learning and Graduate Seminar courses (EOSC 516) and Instructional Skills Workshops. TAing classically involves interacting with students face-to-face during labs and in the classroom; however, these interactions are more and more commonly taking place online, or 'screen-to-screen,' as opposed to 'face-to-face.' For example, in 2007 there were 325 students taking one distance education (DE) course in EOAS; now, there are over 3500 students per year that take eight different DE courses in the department. With the increasing popularity of online courses and the ever-evolving interface between students and their instructors, TAing for some courses has changed forever. TAs are now regularly interacting indirectly with students over the internet, and working to develop online content instead of verbal lab introductions.

Although the fundamentals of how people learn don't change with different methods of delivery, details of how to support learning vary with different media. This has presented EOAS TAs with a number of challenges. Genna Patton, a PhD Candidate in UBC EOAS who has TAed numerous online courses explains:

"When TAing a course online, it's impossible to tell when students stumble unless they post a question on the discussion board or they send an email. Some students have trouble expressing exactly what it is that they find confusing in online forums, so as a TA, when you receive a question from a student, you really have to try to put yourself in their shoes and think about the material from their point of view. It's very easy to make unconscious assumptions when a student posts a question online and those assumptions can often lead to answering a question that the student didn't ask. So there has to be a lot of back and forth to hone in on exactly how to phrase what it is that you need to say to help them. It really takes a lot of patience to teach and TA these courses, because there is no immediate feedback"

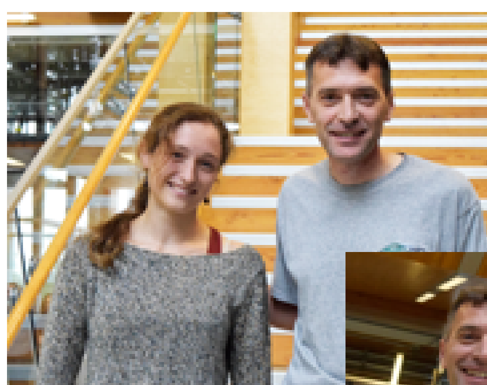
Instructors committed to thriving distance education courses will often prompt students for their opinions on new activities and assignments as much as possible to try and fill the void between 'screen-to-screen' and 'face-to-face' learning and to get more immediate feedback.

Although it represents a change in pace for many students, instructors, and TAs, online learning will no doubt become more common in the future. Due to the influx of online courses and the contributions to DE made by EOAS faculty, TAing online courses is a great opportunity for EOAS graduate students to experience screen-to-screen interaction with learners, preparing them for the teaching environments of tomorrow.

TA Awards

by Johan Gilchirst

Teaching Assistants (TAs) just grade homework and tests right? Not quite. In the EOAS department, they teach classes and laboratory sections, hold office hours, co-teach field schools and meet with instructors to construct lesson plans. TAs are indispensable to the department and they bridge the generation gap between professor and undergraduate student. Two TAs have stood out in the past year; Rhy McMillan and Anna Mittelholz. Both received awards for their outstanding TA work, Rhy for assisting with EOSC 222 and Anna for assisting with EOSC 211. Congratulations to both Rhy and Anna for their dedicated work and our sincerest thanks to them for helping to foster a friendly learning environment for the hard-working undergraduates of the EOAS department.



Graduate Poster Corral

by Georgia Peterson

Every year the department holds an evening showcasing current graduate research. Graduate students present their work with a poster, which allows peers and faculty to become quickly acquainted with recent research within the department. The event allows for discussions and feedback and promotes cross-disciplinary interaction.

Prizes are awarded to the best poster submissions in the following three categories: best poster design, most exciting research, and people's choice. Judges are composed of a committee of both faculty and graduate students and the attendees vote for the people's choice category. This year's winners are:

BEST POSTER DESIGN: MELANIE CHANONA

Melanie is researching the mechanisms driving variabilities in the arctic ocean's circulation pattern. Melania has begun quantifying how bathymetry, atmospheric forcing and tidal energy influences arctic circulation both spatially and temporally by using internal wave field modelling.

MOST EXCITING RESEARCH: CRAIG RICHARDSON

Craig Richardson has confirmed the presence of a large Mo-Cu porphyry deposit in the Syarung–Dok Yong Fault Corridor in Cambodia. Craig showed that a combination of geological mapping, termite mound geochemistry, shortwave infrared alteration mapping, and aeromagnetics can successfully identify new mineral deposits in a cost effective manner.

PEOPLE'S CHOICE: TIM HAYWARD

Tim has identified several repeating earthquake (a series of repeating seismic events rupturing in the same fault patch) along the right lateral strike slip portion of Queen Charlotte plate boundary. The mechanism for these repeating earthquakes is largely not understood, however, Tim has shown that repeating earthquakes exhibit a range of magnitudes and pulse durations with no apparent scaling relationship. This suggests a non-self-similar process.

Professor Michael Bostock inspects a Salish Sea model during the Poster Corral. Photo by Meghan Sharp.

GeoRox Excursions: Explosions and Landslides

by Rachel Maj and Meghan Sharp

This year, UBC's undergraduate geological engineering club GeoRox organized two educational and inspiring field trips to gain some insight into some of the engineering operations and issues in British Columbia.

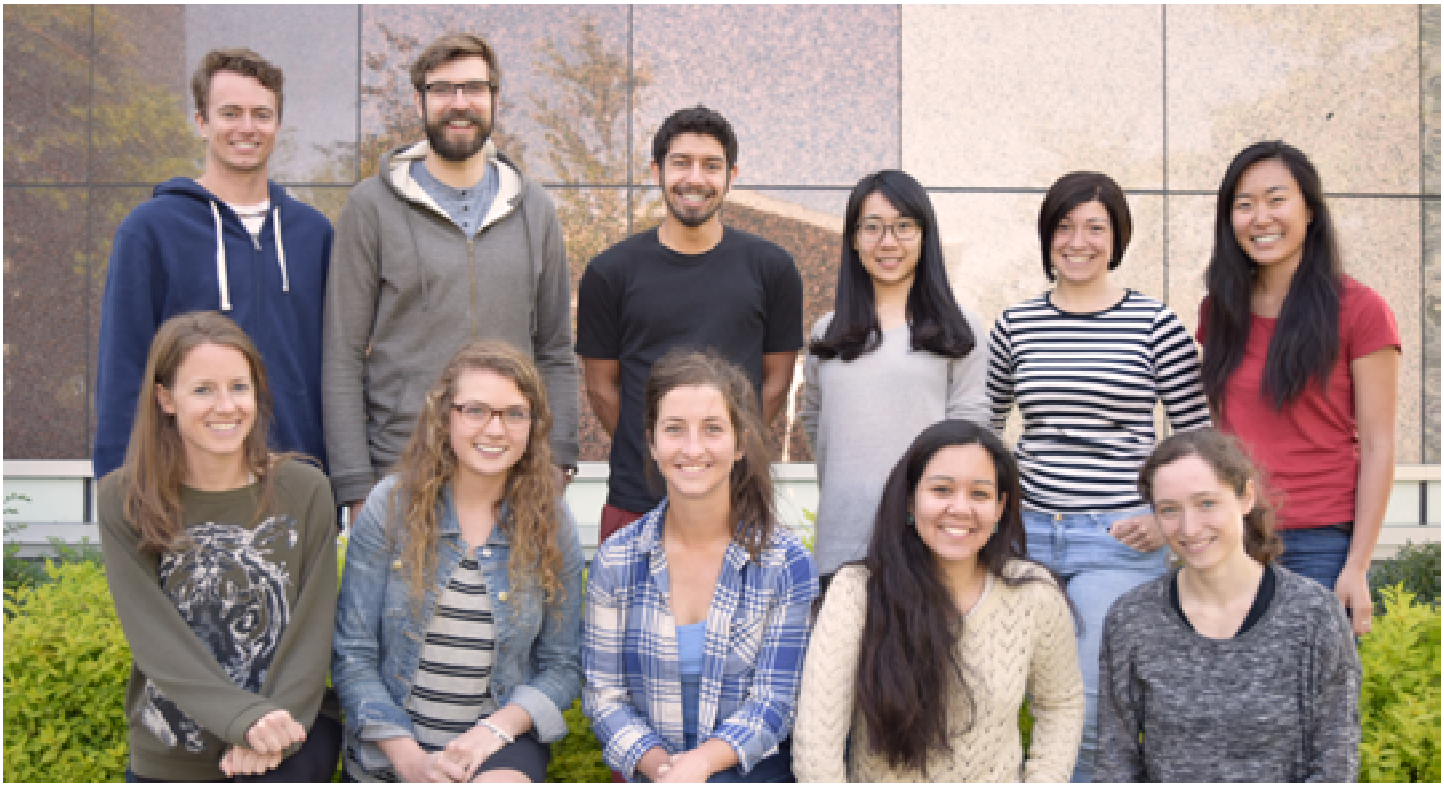
Twenty students attended the first trip in October 2015 at the Upper Lillooet Hydro Project. On their way to the drill and blast tunnelling project, the students stopped at Canada's second largest landslide, the Mount Meager Landslide, and a separate debris flow where they received an in-depth and engaging explanation of the sites' hazards. The students witnessed active drilling and a blast from the outside of one of the tunnels. The attendees also received a full site tour and safety orientation by two working engineers. The engineering students observed how the blasts were generated as well as how debris was cleared following a blast. The engineers showed UBC students how rock bolt designs and steel set supports were used to reinforce the rocks after the explosion. The trip was an educational experience highlighting many aspects of the geological engineering industry. GeoRox also made sure that students who were unable to attend the trip could still benefit from the knowledge that was shared with them by giving a short presentation at the GeoRox club meeting following the outing to discuss what they learned. In addition to providing students with a wealth of knowledge, it also allowed club members of all ages to socialize and connect at the beginning of the year.

Ten students attended the second field trip on March 28th, 2016. The purpose of the trip was to investigate local engineering problems and attempts by engineers to mitigate the risks they posed. Carrying on with the theme of landslides, GeoRox members visited the Riverside Landslide and studied the response to the slide by the district of North Vancouver. The students then travelled to the Seymour Valley Rockslide and discussed failure mechanisms before concluding with a hike of the Mosquito Creek Debris Flow barrier where they discussed its unique design and operation.

The two field trips provided GeoRox students with an insight into various geo-hazards affecting Vancouver and surrounding municipalities as well as a renewed enthusiasm for geological engineering.

Graduate Student Council
Going Beyond

by Rhy McMillan and Johan Gilchirst



Graudate council officers. Back row, (left to right): Tim Hayward, Rhy McMillan, Johan Gilchrist, Cindy Yu, Anna Grau, Rachel Kim. Front row, left to right: Lauren Harrison, Olenka Forde, Keelin Scully, Brenda D'Acunha, Anna Mittelholz.

Graduate students have many responsibilities, such as teaching assistantships, applying for funding and scholarships, coursework, attending laboratory group meetings, and, of course, conducting research and writing theses. For many, this leaves little time for anything else; others choose to spend their spare time making the experience for graduate students in our department the best it can be.

In recent years, the EOAS Graduate Student Council (GSC) has dramatically increased its presence in the department, establishing a great community and voice in EOAS and the university as a whole. The EOAS GSC ensures that graduate students in the department can focus on their work and not miss out on the other important aspects of student life. The committee members volunteer their time to organize many different events and activities. These include social events, such as a camping trip to Salt Spring Island, bowling night, the annual Whistler weekend trip, curling night, and the twice monthly coffee hour. The sports committee on the council provides opportunities to join intramural teams each semester and has started a weekly lunchtime sports hour every Friday on the ESB main lawn. The council has also continued organizing annual events, like the Poster Corral, in collaboration with the Mineral Deposit Research Unit, Dawson Club, and Environmental Science Student Association, as well as the EOAS 3 Minute Thesis competition, promoting a sharing of research within the graduate student community at EOAS.

It is not all fun and games for the committee, however. Representatives from the council make sure that grad students are represented in the hiring process and in department meetings at EOAS. Representatives also attend Teaching Assistant union meetings, coordinate with the Pacific Museum of the Earth, participate in the UBC Graduate Student Society, and ensure the wellbeing of EOAS grad students. They have also successfully campaigned for a shared space designated solely for graduate students. An autonomous graduate student space will foster greater interaction and community among graduate students while also bringing grads up to par with the various undergraduate clubs who already have lounges.

The EOAS GSC is indispensable and makes the lives of graduate students a bit easier and more fun. The new guard of graduate students who run the council are more motivated than ever before to have a voice within the department and develop a greater sense of community. It's a trend that hopefully will continue in the future, allowing graduate students in EOAS to keep have a more well-rounded experience at UBC.

Ocean Odysseys

Photo: Arctic sun by Kristina Brown

MEOPAR

by Alex Wilson

Established in 2012, the Marine Environmental Observation and Response Network (MEOPAR), is a multi-disciplinary research program dedicated to meeting the challenges of our changing ocean. The pan-Canadian, interdisciplinary team of researchers collaborate on large-scale projects that work to understand and predict the impact of marine hazards on human activities and ecosystems, and improve the response when hazards do occur.

The Oceanography team at UBC (headed by Professor Susan Allen) play a key role in the MEOPAR projects in western Canada. The team has been dedicated to developing a high-resolution, real-time 3D model of the Salish Sea. Their model predicts everything from ocean currents, temperature and salinity to plankton blooms and storm surge sea-level height.

Climate change and the impact of a growing global population hold a wealth of unknowns for the world. It's exciting to know that organizations such as MEOPAR are at the forefront of tackling the impacts of these wide-reaching issues.

Read more about MEOPAR through Nancy Soontiens' work, page 40.

Towuti Lake

by Kohen Bauer

During the months of May and June 2015, members of the Crowe laboratory ventured to a remote lake system on Sulawesi Island, Indonesia, for an opportunity to go swimming in the Archean ocean. These ferruginous and virtually sulphate free lakes are excellent modern analogues to the conditions hypothesized to exist in the first oceans that formed on our planet, making them exceptional windows into early earth development. These very unique environmental controls also mean that there is a high level of species endemism in the region and the lakes support a niche group of microbes with distinctive metabolic capacities. The Towuti Drilling (TDP) project was an international collaboration between a number of research groups with the overall goal of drilling lake Towuti's subsurface, and in doing so producing the longest existing climate record of the region known as the Indo-Pacific warm pool. During our stay in Indonesia the TDP team collected a plethora of lake water samples and recovered over 1 km worth of drill core from 3 sites. The mission now is to connect climatic variations in the western equatorial Pacific to the geochemical, sedimentological and microbial properties of the ~1 million year sedimentary record contained within the cores.

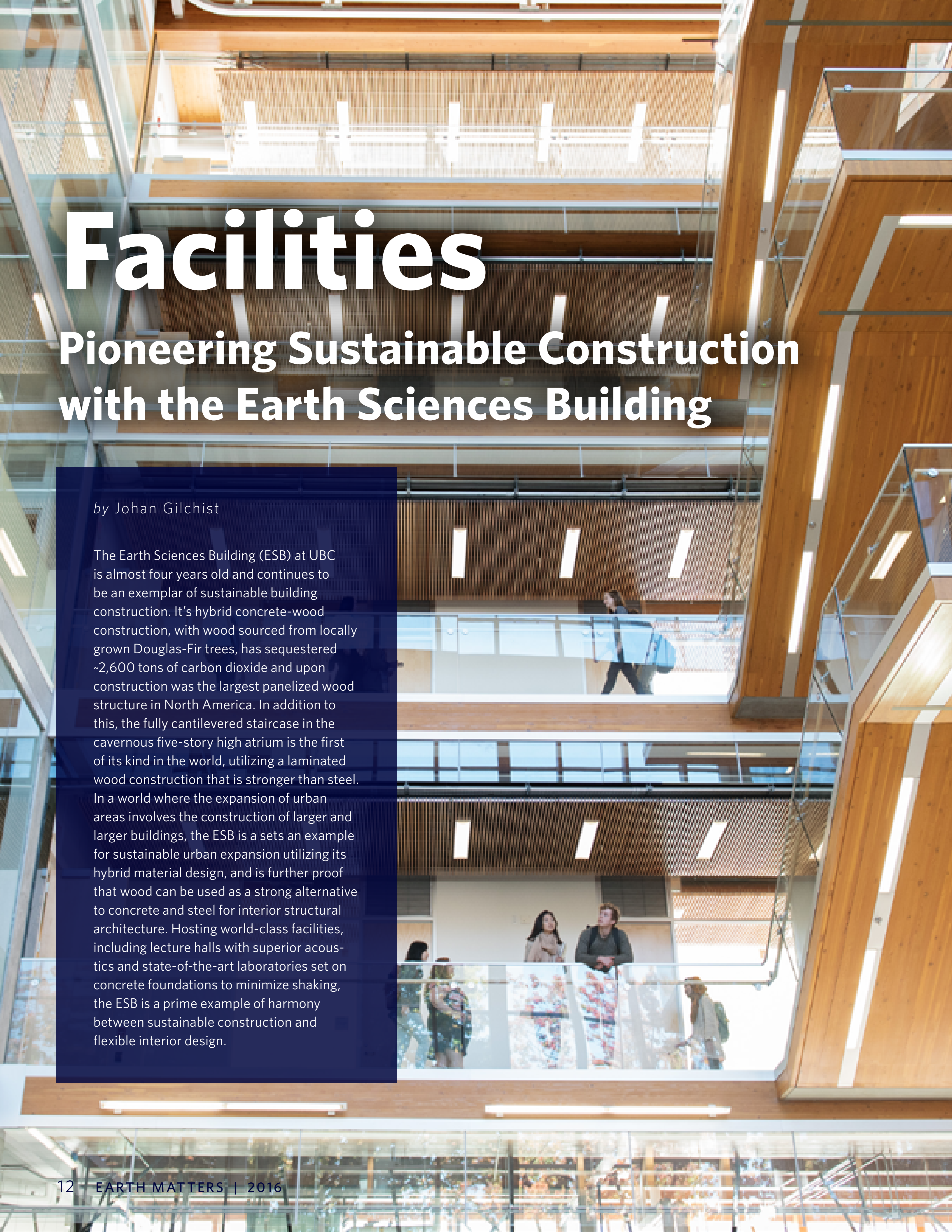
GEOTRACES

by Alex Wilson

Many trace elements are critical for marine life, and therefore influence the functioning ocean ecosystem and the global carbon cycle. GEOTRACES, an international collaborative effort involving 35 countries, is dedicated to better understanding the distribution of trace elements and isotopes, filling a critical gap in our knowledge of the global marine biogeochemical cycle. The project aims to identify the processes that control trace element distributions across the global ocean. At UBC, Professor Roger Francois is heading a team of researchers dedicated to this endeavour.

Data collection is accomplished through a series of ocean cruises that are designed to target and eventually map the global ocean. This year, the Canadian UBC team along with collaboration from Germany and American researchers successfully mapped the dangerous Arctic passage stretching across the northern border of Alaska and Canada, to Baffin Bay, near Greenland in the east.

Read more about GEOTRACES through the work of faculty members Roger Francois and Kristin Orians, pages 26 and 30.



Facilities

Pioneering Sustainable Construction with the Earth Sciences Building

by Johan Gilchist

The Earth Sciences Building (ESB) at UBC is almost four years old and continues to be an exemplar of sustainable building construction. It's hybrid concrete-wood construction, with wood sourced from locally grown Douglas-Fir trees, has sequestered ~2,600 tons of carbon dioxide and upon construction was the largest panelized wood structure in North America. In addition to this, the fully cantilevered staircase in the cavernous five-story high atrium is the first of its kind in the world, utilizing a laminated wood construction that is stronger than steel. In a world where the expansion of urban areas involves the construction of larger and larger buildings, the ESB is a sets an example for sustainable urban expansion utilizing its hybrid material design, and is further proof that wood can be used as a strong alternative to concrete and steel for interior structural architecture. Hosting world-class facilities, including lecture halls with superior acoustics and state-of-the-art laboratories set on concrete foundations to minimize shaking, the ESB is a prime example of harmony between sustainable construction and flexible interior design.

Facility Spotlight:
Pacific Centre for Isotopic and Geochemical Research (PCIGR)

Spring Research Internships

by Diane Hanano and Rhy McMillan

PCIGR recently partnered with STEM Fellowship, a federal non-profit organization that connects and empowers young innovators in the sciences. Together, they coordinated the Spring Research Internship Program designed to facilitate passion for multidisciplinary scientific inquiry and help high school students interested in research develop the necessary skills to realize this goal. In this inaugural year, competition was strong, with over 45 motivated and enthusiastic students vying for a spot in the program.

PCIGR hosted 6 high school interns over two weeks during Spring Break (March 14-24, 2016). The grade 11 and 12 students came from Gladstone, Lord Byng, and Sir Winston Churchill secondary schools in Vancouver. The interns were mentored by PCIGR graduate students and Multidisciplinary Applied Geochemistry Network (MAGNET) trainees Catherine Armstrong, Rhy McMillan, and Nichole Moerhuis.

In Catherine's project on Hawaiian volcanism, the students looked at basaltic rocks and thin sections under the microscope to identify minerals, textures, and alteration. They also analyzed whole-rock major element data, leached rock powders in the clean lab, and prepared samples for X-ray diffraction. At the end of the week, the interns presented their research on a "big picture" question about ocean island basalts.

Rhy introduced his interns to archaeology and paleoanthropology though a study of the geochemistry of bones from Scladina Cave, Belgium. After cutting the bones into cross-sections, the students set to work mixing resin to mount the samples, then sanding and photographing them. They spent the last day of their internship using the microscopes looking at bone histology, discussing bone diagenesis, and analyzing laser ablation trace element data from previously sampled bones.

During Nichole's week, the students determined the age of a granophyric sill that cross-cuts the Skaergaard Intrusion in East Greenland. They experienced every stage of processing and analysis required to turn a hand sample into a concentrated mineral separate, and then establish the crystallization age. This included mechanical and magnetic separation, zircon picking and mount preparation, scanning electron microscopy, laser ablation mass spectrometry analysis, and finally data reduction.

PCIGR was pleased to participate in this program and support the training and mentorship of young scientists in geochemistry, an important part of its philosophy. Both the mentors and interns learned and benefited significantly from this experience. We look forward to seeing this initiative develop and grow over the coming years!

Photo: PCIGR nUBC Nu instruments MC-ICP-MS NP II and Nu 1700 by Dominique Weis

MAGNET 3rd Annual Workshop

by Jamie Cutts & Rhy McMillan

Multidisciplinary collaboration is becoming more and more sought after in modern research. The Multidisciplinary Applied Geochemistry Network (MAGNET) is a research group of students and faculty members from universities across Canada (including UBC) who are united in their common interest of applying geochemical methods to address scientific questions, both big and small. Research topics include (but aren't limited to) archaeology, mantle and lithosphere research, differentiation and crystallization in the Earth's crust, volcanology, paleoceanography, mine-site and groundwater contamination and remediation, and ore deposit genesis. With such diverse research interests and because the 20+ trainees are spread across our huge country, members of MAGNET get together once a year to catch-up for a field trip and professional development workshop.

At each workshop, the location and general theme varies. This year it was in Ottawa and was focused on using stable isotope geochemistry to track groundwater flow and paleoclimates. The trip began with 3 days at the University of Ottawa during which members of MAGNET took part in professional development workshops on industry opportunities, publication writing, networking, science policy, and increasing online exposure as scientists. They were also given an ethics seminar by the Association of Professional Geoscientists of Ontario. The visit also included a tour of the phenomenal laboratory facilities at the new Accelerator Mass Spectrometer (AMS) and its associated labs at the University of Ottawa. During the stay in Ottawa members of MAGNET took part in team building exercises, which included tours of beautiful Gatineau Park, zip-lining, and caving, all while learning about the more than 1 billion year geological history of the Ottawa area.

To cap off the trip, the group went to the Canadian Nuclear Laboratories (CNL) in Chalk River to tour the active nuclear reactor, waste burial sites and contamination remediation systems. The CNL does not generate electricity; instead, they produce a large proportion of the world's medical isotopes and do a lot of materials testing with neutron beams. Unfortunately, the nuclear reactor is slated for decommission in the near future and there are no plans to replace it. As such, it was a unique opportunity to have been given a tour by the very knowledgeable scientists that run reactor.

This workshop was not only a great learning opportunity but it was a fantastic way for members of MAGNET to interact with each other in person. It is easy to become blinded to anything outside of your own research, and such a collaborative experience is refreshing.

How Clean is Clean?

by Rhy McMillan

Researchers at the Pacific Centre for Isotopic and Geochemical Research (PCIGR) measure very small things in a very big world. This type of research needs extremely high-precision instrumentation and calls for avoiding contamination during every step of sample preparation, which requires a very clean and well-maintained work environment. Thankfully, the Earth and Ocean Sciences Main (EOS-M) building, where the PCIGR is hosted, a team of cleaners have been keeping the building sparkling throughout the more than a decade of PCIGR analyses. These cleaning staff have been contributing,in their own way, to the fantastic analytical reputation of the labs. As much as it seems like the geochemists do most of the heavy lifting, none of their high-precision results would be possible if their workspace was dirty, and the confidence in their results would diminish if samples were potentially contaminated. Thus, members of the EOS-M cleaning team have become, more or less, honorary PCIGR lab mates; like the researchers in the lab, they never seem to think that something can be too clean or done too carefully, and they are also great company late at night when analyses run long. So, from all of us at the PCIGR: Thanks!

Facility Spotlight: Mineral Deposit Research Unit

MDRU Takes On Exploration Geochemistry

by Rachel Kim

The Mineral Deposit Research Unit (MDRU) is a collaborative partnership between the Department of Earth, Ocean and Atmospheric Sciences and the mining industry. Since its establishment 25 years ago, the MDRU has gained considerable international recognition in the mineral exploration and mining industry. Projects and research are supported by mineral exploration companies, government research councils, geological surveys, and other agencies. The Exploration Geochemistry Initiative (EGI), in collaboration with ACME Analytical Laboratories (now Bureau Veritas Minerals) and Natural Sciences and Engineering Research Council of Canada, is one of the latest major projects at the MDRU led by Dr. Peter Winterburn. The EGI is focused on applying geochemistry and new techniques to detect anomalies within the soil and till coverings that may hinder exploration efforts. With mineral exploration projects often seeking out concealed mineralization under transported cover (like glacial deposits), finding cost- and time-effective methods to help expose prospective areas is of the utmost importance. Having a concrete understanding of how organic and inorganic geochemical anomalies develop over and around areas of mineralization is important for exploration targeting efforts. The main objectives of the EGI are: (1) to better understand how anomalous geochemical signals develop in transported till cover above mineralization; (2) to identify optimal methodologies that can be effectively applied to their detection; and (3) to filter out ambient environmental background variability to ensure identification of such anomalies. The attainment of these objectives will aid in the development of sampling and processing protocols to help develop industry-appropriate geochemical tools, and applications for future exploration and resource targeting efforts.

Dr. Winterburn is currently the primary supervisor for 5 MDRU MSc students whose projects are focused on active exploration and mining sites around the world. At present, his students are conducting work around Volcanogenic Massive Sulphide (VMS), porphyry, and kimberlite deposits. Partnerships with the MDRU's Discovery Tools for Buried Copper Deposits in the Atacama Desert Project and NSERC-funded CMIC Footprints Project have brought MDRU researchers Dr. Thomas Bissig and Dr. Rob Lee to the EGI team in the past year.

Moving forward, the EGI plans to expand research into organic applications and add two Ph.D. positions to the EGI: one to study the application of molecular biology as an exploration technique in overburden, and one to evaluate the application of hydrocarbons in mineral exploration for non-petroleum exploration targets.

Western Tethys

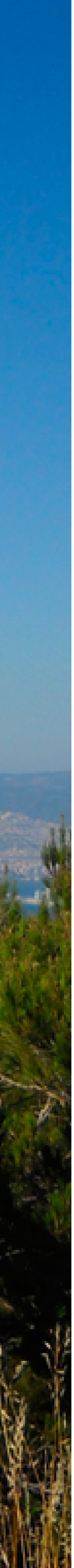
Ancient Processes, Modern Opportunities

Tectonic processes on the Earth's surface have produced important opportunities for human civilization: mineral resources. So rely on the expertise of MDRU exploration geologists to perform extensive and detailed geologic mapping that reveals the formation history of these complex terranes. *by Johan Gilchrist and Rachel Maj*

The Mineral Deposit Research Unit (MDRU) is partnered with industry on projects in countries all over the world, including Colombia, Ecuador, Mongolia, Yukon, Alaska, Eastern Canada, and more. The origins of their largest international collaboration, the Western Tethyan Project (WTP), began at ground zero for great ideas: a coffee shop on UBC campus, fittingly called Bean Around the World.

The Western Tethyan region, spanning 7,000 km from Romania to Pakistan and extending north to Georgia and Armenia, is now one of the most well-known hosts of metal deposits in the world. Clues about the origins of this region lie in its name: Western Tethys. This region formed in the Mesozoic (~250 Mya) as result of numerous collisional events between Eurasia and Africa that lasted until the Eocene (~34 Mya). These events devoured multiple Tethys ocean basins and island arcs to create the Tethys metallogenic belt. During the Oligocene and Miocene (~34-5 Mya), periods of crustal extension produced many hydrothermal deposits in the area. Tension in the Earth's crust related to the region's subduction events formed new pathways for hot water and vapour bearing economic metals to flow through. These fluids deposited metals including gold and copper and altered minerals along their pathways, producing deposits known as epithermal and porphyry.

MDRU's previous work in Turkey laid the foundation for the WTP. Due to increasing interest in the economic value of the region, Dr. Craig Hart, Director of the MDRU, began to sow the seeds for the WTP by soliciting the interest of several companies to commence an extensive mapping project around Turkey. Craig has a lot on his plate with the global distribution of the MDRU's projects. Dr. Aleksandar (Alex) Miskovic, originally from Eastern Europe and recently finished with a diamond geologist job for the Canadian government in the Northwest Territories, was brought on to build this project from the ground up. Having begun with six corporate sponsors, the project has since grown in both the size of the area being mapped and the number of people involved. There are now sixteen sponsors, ten graduate students, five research associates and five professors involved in the project, representing Greece, Turkey, Bulgaria and Canada.



Fabien Rabayrol (left) and Kaleb Boucher (right) in perfect hammer form collecting rock samples from the Bornova Flysch ophiolitic melange that may host epithermal mineralization in the Izmir District, Turkey.

Dr. Alexsandar (Alex) Miskovic, Western Tethyan Project coordinator

THE MAN FOR THE JOB

Craig's general role with MDRU projects is to be a facilitator. Using his experience to secure the necessary funding and personnel, he is the reason any new MDRU project is able to make the jump from coffee shop idea to fully funded project. On top of supervising his team of graduate students and research associates at the MDRU, he has limited time left to manage MDRU's projects, especially the ones that grow far beyond expectation. As Project Manager and Chief Researcher, Dr. Miskovic is the heart and soul of the WTP. "The key to this has been Alex Miskovic. We hired him as the senior researcher on the project, so all of the components revolved around him," says Dr. Hart. Dr. Miskovic kept track of multiple revenue streams, expense accounts, maintained relationships with many labs for geochemistry and geological surveys, co-supervised seven graduate students, spent nine months out of his three years on the project in the field, and still got some mapping and data analysis done. Supervising graduate students from MDRU, University of Athens in Greece, University of Belgrade in Serbia, and Mugla University in Turkey, was deemed as a priority for Dr. Miskovic and Dr. Hart. The students were actively engaged in fieldwork, producing reports and presenting their work to researchers from academia and industry.

Kaleb Boucher was one of the students heavily involved in the WTP, having recently completed a Master's thesis on an epithermal gold deposit in Turkey. His project focused on understanding the structural controls of the Efemçukuru Gold Deposit near Izmir, Turkey. Sometimes fault activity creates vacuum pockets in the Earth's crust,

Drill core sample from a gold bearing vein at the Efemçukuru Gold deposit. The sample shows a "cockade texture", which forms when brecciated clasts in a vein are overgrown by minerals such as quartz (white), rhodochrosite (pink), and sulfosalts (black), which can often contain high-grade gold mineralization.

attracting fluid to them due to their low pressure. When the fluid arrives, it may rapidly boil and immediately deposit any metals dissolved in it, a process called flash boiling. By mapping the various vein structures surrounding his deposit and using carbon and oxygen isotopic analyses to figure out how many different water sources contributed to its formation, he created a dataset that characterized his deposit, concluding that most of the gold was deposited by the flash boiling process. With sole access to his dataset, sponsors of his project have high quality data to expedite their exploration and extraction of the gold. Kaleb's dataset will prove vital in determining if there are more economically viable metal deposits near his study site. This provides his sponsors with a jump-start on their competition for deciding where to prospect next.

AN ACADEMIC INDUSTRY

Dr. Miskovic is extremely proud of the work performed by graduate students, post-doctoral Fellows, and research associates throughout the project. Dr. Miskovic is also a firm believer in spreading knowledge, particularly between industry and academia. During the WTP, the MDRU led five short courses for the industry sponsors and the other universities involved, rounding out a complete, international transfer of knowledge. While it is important to provide results for industry, Dr. Miskovic stresses that the MDRU is an academic institution whose end goal is to train future economic geologists.

While the academic benefits are important, a project of this size requires a large amount of funding and the interests of industry are still a priority. The timing of this project coincided with a lull in the mineral exploration global market when most mineral exploration operations were cutting back financially. Despite these challenges, Alex and Craig's hard work and the support of their industry sponsors allowed the project to persevere through the economic lull. Though now successfully completed, many industry sponsors are keen to expand the project further as the full economic potential of this region has yet to be determined.

TIMELESS MAPS

Geological mapping performed with the precision and spatial resolution of the WTP will prove useful for decades to come. Geologists still use maps that are decades old in current research projects. Dr. Miskovic oversaw the integration of old and new data in the Western Tethyan region, constructing a database that is one of the grand results of the project. Dr. Miskovic noted that "the Persians, Trojans, Romans, and others have explored this land for millennia, yet it still has much to be discovered." For Kaleb Boucher, his Masters project was an experience he'll take away for the rest of his life, concluding, "I'm very lucky to have been working with such an awesome group of people."

Facility Spotlight:
Centre for Experimental Study of the Lithosphere

Staring into the "Fish Bowl"

by Georgia Peterson and Alex Wilson

The Centre for Experimental Study of the Lithosphere (CESL) at the base of the new Earth Sciences Building is on display for the whole world to see. The space is one of two EOS 'fishbowl' laboratories, and forms a world-class, highly equipped platform for experimental research. Here, a myriad of equipment is devoted to understanding the rheological properties of earth forming materials. Machines such as the Large Sample Rig, Low Temperature Deformation Rig and Volcanic Deformation Rig enable rock strength testing through deformation under both uniaxial and triaxial loads. Samples can be melted or foamed in the high-temperature furnaces, and then analyzed using a wide variety of 3D scanning, porosity, permeability and ultrasonic imaging equipment.

Understanding the strength of rocks under a variety of physical conditions (temperature, confining pressure, pore fluid pressure, etc.) is essential for a diverse range of geophysical disciplines. Dr. Kelly Russell, a professor of volcanology, uses the fishbowl laboratory to host experiments designed to investigate the rheological controls on volcanic processes. Professor Erik Eberhardt, a geological engineer, combines numerical models with physical experiments that help predict rock behaviour during catastrophic geologic events such as mine pit wall failures in deep mines. Professor Lori Kennedy, a structural geologist, applies rock deformation experiments to further understand the brittle and ductile mechanics of large fault systems such as the Queen Charlotte and San Andres faults.

The unique open laboratory space has also allowed a wealth of cross-disciplinary collaboration. Dr. Erik Eberhardt, for example, has begun collaboration with Dr. Hallam Crowe (a geomicrobiologist) to produce "first-of-their-kind" experiments investigating the interaction between microorganisms and the permeability of fractured rock systems deep in the earth.

Experimental research is the core of a wide range of geophysical disciplines. In EOAS, we are lucky to boast a world-class facility dedicated to providing cutting-edge scientific insight.

Faculty Profiles

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Garry Clarke

The mountain glaciers of Western Canada are beautiful to behold, but are currently under threat by climatic influences. Emeritus Professor Garry Clarke has spent much of his life observing and measuring alpine glaciers in order to refine geophysical models used for predicting glacier response under different climate change scenarios.

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Roger Francois

The circulation of Earth's oceans is of paramount importance to regulating global climate. Professor Roger Francois uses isotopes to quantify the strength and geometry of past and present ocean circulation and its response to a changing Arctic environment.

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Kristin Orians

Elements that occur in very low abundances in the ocean have a lot to say about the changing environments they traverse during their journey to and through the water. Associate Professor Kristin Orians uses these trace elements to determine the origin and fate of ocean water.

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by Kohen Bauer & Genna Patton

Garry Clarke was born into Earth science. As a young child, he spent many summers on the shores of Lake Louise at his grandparents' summer camp viewing his first mountain glaciers from afar. Since that time, Garry's connection to our planet has not ceased and his career has revolutionized the field of glaciology and our perception of climate change.

However, Garry wasn't always a glaciologist; he was initially trained broadly as a geophysicist. His unique background has allowed him to incorporate geophysical techniques into the field of glaciology and has provided many great advances in glacier flow dynamics. Garry obtained both his master's and doctoral degrees from the University of Toronto, having been a part of the first generation of the prestigious Massey College, where some of his graduate courses were instructed by the emblematic Canadian geophysicist and leading contributor to plate tectonic theory: John Tuzo Wilson.

It was during his masters that he first studied glaciers. Garry recollects an unforgettable field season spent in Greenland at the Camp Century ice field in 1964, during the Vietnam War. "We lived in a city that was run by the military and excavated out of the ice, similar to a salt mine, and the settlement included everything from a library to a movie theatre." The goal was to complement research conducted by a group of Cambridge glaciologists working on measuring ice thickness via radar, by ground-truthing the measurements using an "active source" seismic reflection technique where the seismic source was C4 explosive supplied by the military. "Talk about a kid's dream!" Garry laughs, "Greenland was good fun, a confluence of so many things from world's best radar to the drilling of the first major ice core which had huge paleoceanographic impacts."

GLACIERS BECOME THE FOCUS

Upon completing his MSc Garry continued in geophysics. "At the time of my PhD, geophysics was a good balance between a sure-fire job in the oil exploration industry and academic opportunities." Thus his PhD was focused on seismic signal processing and statistical communication theory. Garry puts it plainly; "seismic data is a message from the earth, and your task is to decode that message." In geophysics the secret message is the underlying structure of the earth.

Amazingly, Garry was only twenty-five years old when he arrived at UBC for the assistant professor position. "The mission sort of presented itself at my doorstep in Toronto," he recalls, having not even applied for the job. Garry decided to turn down a post-doc position in Uppsala, Sweden, in order to cross Canada and join UBC. It was only once he was settled in Vancouver that Garry's focus shifted fully to glaciology. Garry mentions that it was the "why" and "how" questions regarding glacier behaviour and dynamics that sparked a transition away from a typical geophysical characterization approach to glaciology. "Glaciers seem simple on one level, but are such intricate systems," he says.

MOUNTAIN GLACIERS IN THE YUKON

In glaciology of the 60s and 70s, the technology available to study the interior structure of glaciers was limited. Measuring simple variables like temperature through the depth of a glacier required "hot point drills which melted through about 1 m of ice per hour and the glaciers were 100 m thick." The instruments that traversed these holes needed to be simple and inexpensive, because it was possible they weren't making a return trip back to the surface. Despite limited access to the icy interior, Garry and others were still able to piece together important information about the thermal structure of mountain glaciers. This allowed Garry to develop theories about the mechanisms that control not just the slow flow of ice but the emergence and importance of intermittent powerful surges, when glaciers flow at up to 100 times their normal rate. "Rather than just demonstrating stability, we could watch them switch from one driver to another driver and it gives you a sense of the processes that are competing."

During one field season, Garry witnessed the draining of a lake that had been damned by a surging glacier. He and his field research team found that the lake would seasonally drain as the glacier melted and turned their attention to this phenomenon. Outburst floods, as they're called, are now known to have played a role in dramatic climate change events of the past, and Garry had a front row seat to observe the processes involved. Returning the next season to the field site in the Yukon, "the pivotal moment came when we had really big plans for studying the lake, but found it had already drained, earlier than ever," he recalls. Needing to change the plan for that summer's field season, Garry looked to nearby glaciers. "We looked around and saw Trapridge Glacier looking absolutely ready to burst."

Taking field notes on Trapridge Glacier, July 2004

AN INTENSELY STUDIED GLACIER

Thus began a twenty-six year observational record of Trapridge Glacier. By this time, drilling holes into the ice was a relatively routine task, and with a hot water jet, 5-7 holes could be carved out per day. With a fully instrumented glacier, and the ability to rapidly drill new holes, Garry and his team developed a variety of instruments to lower through the glacier. "We were doing a lot of instrumentation invention," he says smiling. "And every time we came up with a new instrument, we'd learn more about the glacier." It was an intensely studied glacier and from 1980 to 2006 Garry and his research team watched Trapridge Glacier pass in and out of parts of the surge cycle.

Now retired, Garry thinks about glaciers somewhat more remotely, using regional glaciation models. In 2015, Garry and several other authors detailed the fate of Canadian glaciers in the 21st century in an article in Nature Geoscience. Representing what he refers to as "10 years" of his own work and "40 person years," this study is the culmination of his work, with help from several other glaciologists, modeling mountain glaciers. "They're beautiful things. The mountains don't look quite right without the glaciers on them," he remarks fondly. "If we can hold to 1.5 °C of warming, we'll have some ice to admire in Canada. Not as much as you'd want, but it won't be completely gone."

Garry drilling through Trapridge Glacier with a hotwater jet drill, July 2003.

Garry and Lawrence McCandless erecting the structure that will serve as a kitchen, living room, office and laboratory for the summer field season on Trapridge Glacier, July 2007.

Roger Francois

The circulation of Earth's oceans is of paramount importance to regulating global climate. Professor Roger Francois uses isotopes to quantify the strength and geometry of past and present ocean circulation and its response to a changing Arctic environment.

by Chuck Kosman and Alex Wilson

After growing up in Belgium and studying engineering during his undergraduate, Roger was faced with a choice: complete mandatory service in the military or spend two years working abroad. Roger opted for the latter, and began work as a textile engineer in the Republic of Zaire (now the Democratic Republic of Congo). "At that point", he laughs, "I was not very serious about having a career." He decided to go to England to pursue a MSc in oceanography (where he also learned to speak English).

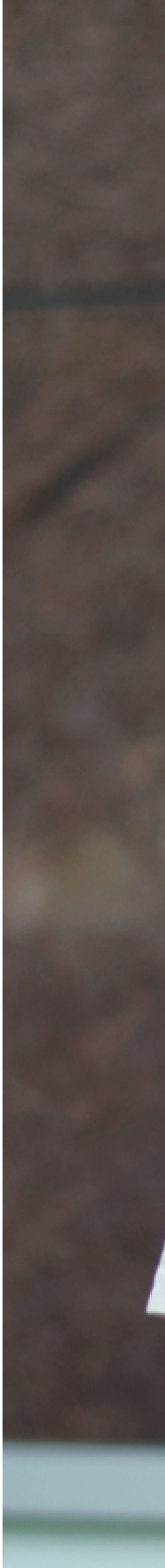
Roger came to UBC in 1980 to embark on a PhD and after seven years of great skiing, he moved onto a postdoctoral fellowship at the University of New Hampshire. In 1988, he undertook another postdoctoral fellowship at the Woods Hole Oceanographic Institution in Massachusetts, where he continued to work as a scientist for 17 years. Roger returned to UBC as a professor in 2005, intent on studying the chemistry and dynamics of the Earth's oceans.

A GLOBAL CONVEYOR BELT

The ocean is far from homogeneous. Ocean water is stratified according to variation in salinity and temperature. Cold, dense, saline water occupies the deepest areas, while warmer and fresher water stays at the surface. The oceans are also dynamic. Water is constantly moving along a global looped "conveyor belt" completing a full cycle once every 1000 years. This thermohaline circulation plays a key role in redistributing heat across the planet. In the northern Atlantic, warm, saline surface water from the equator gradually cools as it moves towards the polar regions and eventually becomes dense enough to sink, providing one of the driving forces behind the entire global circulation system.

"All of that links to climate and deglaciation." Roger has shown that at the end of the last glacial maximum, large quantities of fresh meltwater derived from the continental ice sheets that covered North America and Europe shutdown the conveyor belt. This had a profound effect on the global climate, cooling the northern latitudes and significantly warming the equatorial ones.

Roger cannot study the ocean's past circulation by measuring temperature and salinity, however. Instead, Roger relies on isotopes. Studying the relative proportions of different neodymium (Nd) isotopes, for example, allows Roger to trace the source of different water masses. Isotopes of other elements, such as protactinium (Pa) and thorium (Th), are useful for determining how strong the ocean overturning process was.



Two of Roger's current Ph.D. students, Aram Goodwin and Genna Patton, use Nd isotopes to reconstruct past ocean circulation patterns. While Aram investigates how the oceans acquire their Nd isotopic signature, Genna is examining ancient sediments to see whether Nd isotope concentrations fluctuate as a result of deglaciation. Research cruises to conduct fieldwork in the Arctic, Pacific, and Atlantic are just part of the fun.

THE BELG-O-MATIC

Over the last five years, Roger has supervised a Ph.D. project which could revolutionize the way that mineral dissolution is investigated. He and his student Bart De Baere (also a Belgian) developed a new technology aimed at examining mineral dissolution kinetics through the use of a flow-through, time-resolved analysis technique (FT-TRA). Bart designed, built and tested the patriotically named "Belg-o-matic". Originally designed to investigate the magnesium (Mg) to calcium (Ca) ratio in foraminifera, this small flow-through cell allows a tiny aliquot of sample (single mineral grain or foram) to be concentrically analysed from the rim to the core. The machine passes a solution over the sample to gradually dissolve it, allowing for real-time, trace-element analysis via a mass spectrometer of the different compositional layers, "like the layers on a onion". Mineral dissolution kinetics are also important outside of the field of oceanography. Already Bart and Roger are expanding the machine's range of applications to include industrial work examining mine tailings with Professor Greg Dipple, and forsterite (olivine) dissolution with Professor Ulrich Mayer. In the future, Roger hopes to employ atomic force microscopy to allow this clever gizmo to image mineral surfaces dissolving in real time.

Above: On the deck of CCGS *John P. Tully*, North Pacific, February 2014.

Right: Genna Patton (PhD student) readying the UBC multicorer to collect sediment samples in the Strait of Georgia.

Unidentified fossil found on Somerset Island during a sampling expedition of Arctic Rivers. On board CCGS *Amundsen* in the Canadian Arctic Archipelago, August 2015.

INTERNATIONAL WATERS

Beyond UBC, Roger is also a commanding force within the GEOTRACES program. This international collaboration, started in 2000, maps the distribution of trace metals and isotopic compositions throughout the entire ocean. A major part of Rogers work since returning to UBC has been to try and build a Canadian contribution to this project, in which over 35 countries are currently involved. It hasn't been easy, however. Oceanographic fieldwork in the Canadian Arctic is notoriously expensive. Only a small number of large icebreaker ships owned by the Canadian coast guard are available for charter. Research time exceeds $50,000 per day, commonly forcing academic programs to "piggyback" on preexisting governmental or industrial work. Despite these challenges, the collaboration is rewarding. Last summer, Roger and his postdoctoral student, Dr. Melanie Grenier teamed up with more than 20 colleagues from multiple Canadian universities and international teams from America and Germany. Together, they achieved a great milestone in their work: they collected data and samples that will effectively map the periodic table across the Arctic.

Although he jokes that it has all just been "serendipity", Roger's broad expertise and skills as a researcher have produced a wealth of essential contributions to the field of oceanography and beyond.

Kristin Orians

Elements that occur in very low abundances in the ocean have a lot to say about the changing environments they traverse during their journey to and through the water. Associate Professor Kristin Orians uses these trace elements to determine the origin and fate of ocean water.

by Rhy McMillan and Johan Gilchrist

When your childhood adventures involve travelling the world during your father's research sabbaticals, it's hard to not follow such a path yourself. It was these childhood experiences that originally motivated Dr. Kristin Orians, jointly appointed as Associate Professor of Chemical Oceanography in the EOAS and Chemistry Departments at UBC, to seek a career in scientific research. Her father's work as a biologist inspired her, and she recalls, "I think I always knew I wanted to be a scientist, and I started out thinking I would be a biologist." But while going to high school in Seattle, Kristin discovered something important about herself: she didn't want to become a biologist. "By studying different things that were new to me, I got turned on to chemistry," recalls Kristin.

That discovery spawned her academic career and guided her along a pathway toward graduate school. "I took a course in chemical oceanography in my fourth year that I really liked, and that professor ended up being my PhD supervisor," recalls Kristin. "It wasn't a discipline I was aware of. I always liked water, I liked to sail, I like to swim, but I had no idea that you could combine chemistry and oceans into a discipline," says Kristin.

After taking a year off between her undergraduate degree and her PhD to work in industry, she returned to UCSC to complete her doctoral degree with Dr. K.W. Bruland, followed up by a postdoctoral fellowship at MIT.

TRACING THE OCEANS

Kristin succinctly describes chemistry as, "a way to explain things that I don't already understand." In her current research at UBC, Kristin measures trace elements in seawater to answer questions about how phytoplankton interact with them, where the water in the arctic comes from, and how the chemical speciation of an element affects how it behaves. "A trace element is any element that's below a certain concentration. From one to another, the controls for their distribution in the ocean are extremely variable, and they are present in low enough concentrations that they can tell you something about how it functions," explains Kristin. Such trace elements in the ocean include aluminum, iron, gallium, copper, and manganese, which all serve slightly different purposes when addressing her research questions.

Because each element behaves differently, Kristin must choose wisely. "You can look at sources and cycling of ocean water through elements that are removed quickly. The trace elements I am interested in have very short residence times, on the order of 50 to 100 years, and often only spend a few weeks near the surface."

The distribution of trace elements in the ocean varies greatly with time and space, a valuable characteristic that can be used resource for tracking various ocean processes. "Some of the trace elements I study are actually major elements in the Earth's crust, but are very insoluble in the ocean. This leads to them having quite low concentrations in the ocean, making them good for tracing the source of elements from land because they are removed rapidly and are only found near where they originate from," she describes. This attribute of some trace elements is integral to answering her research questions, but it also poses a problem for her in the field. If an element is very low in concentration in the ocean and highly concentrated on land, contamination during sampling is a huge concern. This has led to some interesting field experiences with unique instrumentation, some including close encounters with polar bears!

Curious polar bears inspect a conducting Kevlar cable connected to sampling equipment 3500m below the sea surface. Fortunately, they did not chew through the cable!

Kristin in a survival suit, ready to board a helicopter to the research ice breaker CCGS *Amundsen*. There are no deep water ports in the Arctic for ships to dock, so scientists and equipment are transferred by helicopter.

A CHANGING ENVIRONMENT

Kristin's research with trace elements has myriad applications, but the focus of her research is the GEOTRACES program in the Arctic. Using trace elements and isotopes, the GEOTRACES program's mission is to track processes in the ocean and how they respond to environmental change.

"The Arctic is a place of which we know very little about where things come from and where things are going and it's changing really fast. Any extra tracers we can find that helps us figure out how the arctic circulates and how it's responding to climate change is very important," explains Kristin. As part of this research, Kristin has developed some big-picture questions, such as: "can you use trace elements to figure out where the water comes from and where it goes to in the Arctic, how it's changing with the ice melting, and how it's reacting to new channels being opened up as the ice recedes?" As distant as the Arctic may be, the answers to these questions have dramatic implications in the context of climate change for us father south.

Through many expeditions and much undergraduate, graduate, and postdoctoral work, Kristin has learned to read the story of the ocean through the lens of trace elements. Kristin's investigations of the oceans with GEOTRACES, including compiling a massive database of oceanographic data, and as part of other projects will provide information to help us better understand one of the final frontiers on our planet: the ocean.

A chilly sunrise over the icescape at 77 °N in the Canada Basin (-13 °C at 4:39am Sept 13, 2015).

Marghaleray Amini

The advent of mass spectrometers revolutionized the Earth Sciences, and the addition of micro-sampling techniques to them have opened up yet more opportunities. Research Associate Marghaleray (Marg) Amini is the operator of PCIGR's sophisticated laser-equipped model, allowing her to work with a stunning variety of research questions, materials, and people.

by Chuck Kosman

A Research Associate in the Pacific Centre for Isotopic and Geochemical Research (PCIGR), Marg is a jack-of-all-trades. Beginning with her BSc and MSc at the Max-Planck Institute for Chemistry in Mainz, Germany (studying Martian meteorites and hotspot volcanoes), Marg became committed to geochemistry. She continued on with a PhD at GEOMAR-Helmholtz Centre for Ocean Research in Kiel, Germany researching hydrothermal activity on the ocean floor, a postdoctoral fellowship at the University of Saskatchewan examining the sediment-water interface in anoxic basins, and then onto studying carbonate shelled marine invertebrates back at the Johannes Gutenberg University of Mainz, Germany. As a Scientific Advisor at Kabul University in her home country of Afghanistan, Marg came to value higher education's importance to society.

Marg's repertoire has only grown while at PCIGR. One of the projects Marg is involved in dates ancient mineral grains from the world's richest deposit of platinum. She also works on the trace element composition of bones—those from long gone cave bears, laboratory mice, and the otoliths of several migrating fish species (each for very different reasons). Metals are on the menu, too: copper & zinc contained in soil, molybdenum of mine tailings, and radioactive material created in the TRIUMF particle accelerator. The list goes on; at any given time Marg is collaborating with five or more research groups—whose members include PCIGR students, other EOAS and UBC personnel, and researchers worldwide—to address their highly specialized research questions.

TOOLS OF THE TRADE

The secret to Marg's powers: a tiny laser beam and a subatomic race track. The laser blasts micrometre sized craters into solid material; the ejected material is ionized in a plasma as hot as the sun's surface, then propelled by high voltage into an instrument called a mass spectrometer. "A mass spectrometer is to matter as a prism is to light," Marg describes it; the spectrum of elements contained within a sample are sorted precisely according by mass. The ability to quantify the chemical and isotopic composition of just a 10 micrometre spot (or less) in real time revolutionized observational sciences and is what affords Marg the opportunity to work on as diverse a set of research questions as she does.

THE SPICE OF LIFE

Nothing is cut and dry in Marg's world. The variety of materials and research questions Marg's collaborators pose to her precludes a one-size-fits-all solution. She must customize each project from start to finish, from the sample collection methods, to sample preparation, laser beam optics, detector calibration, and data interpretation. It is only through sweating the small stuff of the analytical world that Marg's collaborators can answer their big questions. "Nothing is routine," she says, "only more or less simple."

Nor is anything absolute (as she notes it is outside of science, too). Accuracy is only relative to standards established by the community. "If everyone agrees, you have in your little relative world an absolute," she smiles.

The variety and the opportunity to shape the big picture through analytics drives Marg. "It's maybe a blessing or a curse but I find everything interesting. I personally gain a lot of insight into fields that I otherwise would never have the chance to."

Mark Halverson

Investigating the physics of the universe need not be confined to working on a computer or performing experiments in a windowless basement lab. This epiphany led Research Associate Mark Halverson along a sinuous path to first investigating how stars, galaxies, and the universe evolve ultimately to researching how water flows and mixes in the coastal ocean.

by Rhy McMillan

Mark, a Research Associate with Dr. Richard Pawlowicz, studies circulation and mixing in the coastal waters of British Columbia. His academic career started far from the ocean, however, at a small land-locked state school in Wisconsin studying industrial management. "I remember taking a course called Joining and Fastening. That's when I knew it wasn't for me," recalls Mark. "I liked math and physics, so I upgraded to engineering," he adds. Still not satisfied, he changed university and completed a bachelor's in Astrophysics and Physics at the University of Minnesota, and then a master's in Astronomy at the University of Wisconsin.

THE TIDE CHANGES

However, the way he looked at the world was about to be turned upside down. While taking courses during his masters, he stumbled upon a way to combine a passion for the outdoors and physics: physical oceanography.

Mark isn't alone in such a shift of focus. "It isn't until later in their academic careers that engineering and physics students become aware that physical oceanography exists," says Mark. "I want students to know that there are research opportunities other than tinkering away in a lab for the rest of your life; you can go out on boats and airplanes to do your work."

WATER, LIFE, AND RADIO WAVES

Completing a PhD in Oceanography at UBC in 2009, Mark continued his research in Prince William Sound, Alaska, before returning to UBC. Mark uses observations to study coastal ocean circulation, in particular how the buoyant and turbid plume formed by the Fraser River flows, mixes, and affects life in the Salish Sea.

The movement of water in coastal environments has substantial implications for us on land. "The ocean flows, mixes, and changes in response to weather and climate. But then there is life within it that is, to a very large degree, controlled by the physical environment. This begins at the bottom of the marine trophic pyramid with phytoplankton, and is connected all the way up to salmon and other things that are important to us," he explains.

Mark's research also addresses a technological challenge: he evaluates the ability of high-frequency radio wave instruments to trace currents. These methods have applications in search and rescue operations and pollutant dispersal studies. In a nutshell, these tools bounce radio waves off of the ocean surface to make maps of the surface currents. This technology is used widely in the USA, where the Coast Guard uses the data to guide search and rescue operations. In Canada, however, there are only a handful of these instruments, although organizations such as Ocean Networks Canada are rapidly expanding the coverage.

In addition to engaging with the local community by contributing to the EOAS PDF/RA council, Mark's research also extends north to the central BC coast where he works with researchers at the Hakai Institute to establish baselines of oceanographic data. Beyond everything else, Mark is happy to spend his days above ground studying the depths below.

Daniele Pedretti

To maintain a clean environment near mines, it is necessary to understand the chemical products of water interacting with leftover uneconomic rock. Postdoctoral Fellow Daniele studies the origin and evolution of drainage at the Antamina Mine in the Andes Mountains to improve its long term waste management plans.

by Georgia Peterson

Almost 99% of the rocks dug up by mining are economically useless. "These waste rocks are stored outside the main mine pit and left to build up as mountains," Daniele Pedretti explains. Mining companies are concerned about the quality of the drainage that results when rainwater percolates through these piles of waste rock. If the mine has sulfidic ores, there is a possibility to produce acidic drainage which could affect downhill water supplies if not properly treated. Understanding how drainage from waste rock evolves and whether it will be good quality is vital for making informed decisions about long term waste management.

IN THE ANDES

Daniele has been working as a post doctoral fellow with Roger Beckie and Uli Mayer for the past 2 ½ years. He previously completed his PhD at the Technical University of Catalonia in Barcelona, Spain, researching stochastic methods applied to different aspects of hydrogeology. His current research project focuses on the Antamina mine located in the Andes Mountains of Peru, one of the largest copper–zinc mines in the world. Antamina mine waste is dominated by carbonates, so most drainage is neutral pH. However, for some rock types with higher sulfide and lower carbonate contents, the quality is less certain. Daniele asks, "how likely it is that poor-quality drainage form? When will this occur? How long shall managed water treatment facilities be expected to work in the future to minimize the impact of polluted drainage?"

STOCHASTIC MODELING

The key difficulty in answer these questions is the heterogeneity of the waste rocks. To make progress, his research uses "stochastic" reactive transport modeling. This approach contrasts with traditional "deterministic" modeling methods where the information input to a model is exact. For example, in deterministic models a specific amount of sulfide might be initially specified, while in stochastic models one would provide an average and variance of sulfide concentrations found in rocks. Stochastic methods quantitatively estimate the probability that a certain amount of aqueous byproducts will form as the water percolates through the waste rock pile. Additionally, when used to make predictions for the continuous temporal evolution of the polluted water, stochastic methods are less prone to errors because they can account uncertainty in the geochemical and hydraulic properties.

OTHER STREAMS

Daniele's model can predict the probability that acidification of the percolating water at Antamina Mine will continue over the next 100 years, or if a certain amount of sulfide concentrations will exceed a specific threshold at the base of the pile. However, Daniele's model is not limited to a specific waste rock configuration. Indeed, when properly tuned based on site-specific information, the model can be applied as a predictive tool in any mining context.

In the future, Daniele hopes to apply stochastic reactive modeling in other hydrogeological contexts, such as to understand impacts of urban developments on hydrogeological processes, a field called "urban hydrology". He is particularly interested in how stormwater basins, which are built to store water to prevent seasonal flooding, negatively affect groundwater reservoirs.

Nancy Soontiens

The future of oceanographic forecasting will rely heavily on large-scale, three-dimensional fluid dynamic modelling. At UBC, a team of researchers are at the forefront of the field, with a newly developed model tailored to predicting temperature, salinity, ocean currents and storm surges in the Salish Sea.

by Alex Wilson

Nancy Soontiens, a postdoctoral Oceanography researcher is EOAS, bridges the gap between three-dimensional oceanographic modelling and useful, everyday application. Nancy's Ph.D. investigated internal waves - the propagation of energy within a fluid medium. Although these waves cannot be seen, they are common features of our stratified oceans, atmosphere and lakes. After completing her Ph.D. in applied mathematics at the University of Waterloo, Ontario, Nancy found herself searching for a relevant way of applying her highly specialized skillset.

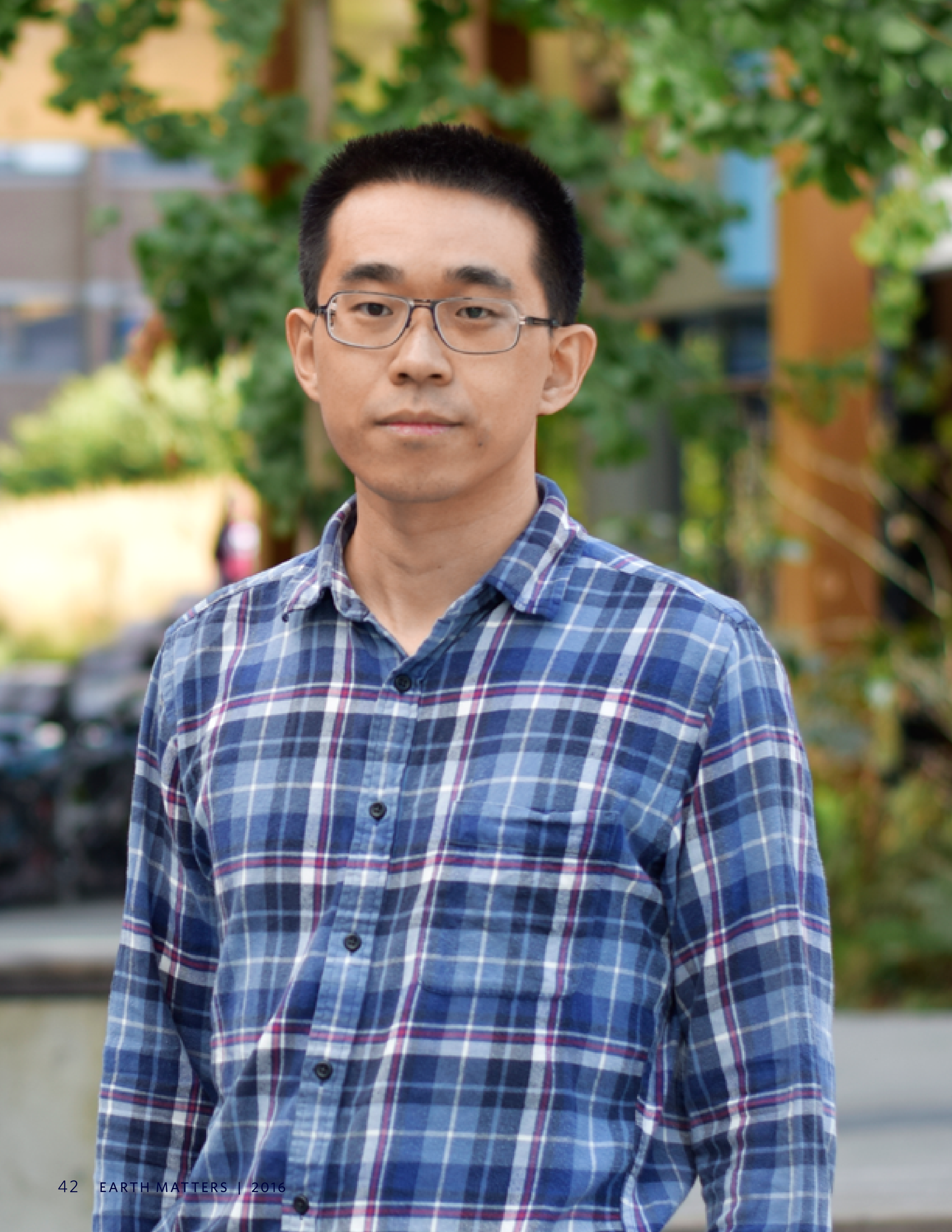
PUTTING IT ALL TOGETHER

Working alongside EOAS Professor Susan Allen, Nancy plays an integral role in the Salish Sea NEMO project. Armed with MEOPAR funding (Marine Environmental Observation Prediction and Response Network), the team has developed a three-dimensional ocean model of the Salish Sea, the body of water stretching between the mainland of Washington and British Columbia. The model is based on the NEMO (Nucleus for European Modeling of the Ocean) framework, and by inputting the average results of a wider, long-term global ocean model, it solves a complex set of equations that monitor temperature, salinity, ocean currents, and sea level.

PREDICTION AND WARNING

Nancy and Susan's model gives accurate predictions of sea-level-rise during storm surges - crucial information for the many residents living in low-lying coastal communities that border the Salish Sea (the city of Vancouver among them). Her model is constantly updating, giving high-resolution predictions: "We actually run the model everyday, three times in fact". The live results are freely available to residents via a dedicated website: www.salishsea.eos.ubc.ca. You're probably thinking "three-dimensional models requiring super computing power – that mustn't come cheap." Well, that's where you would be wrong. Nancy's team does utilize a supercomputer (hosted by Ocean Networks Canada) to process the model three times per day, but this computing time is now automated and free, offered to the UBC team as a trial-run.

Although confident in the integrity of their model, Nancy is constantly striving to update and improve it. Her current focus is on the Strait of Juan de Fuca, the narrow inlet situated between Victoria and the Washington mainland. Understanding the passage of a stratified fluid over a topographic feature (such as a sill), and the role of mixing and internal waves during this process is crucial to her success. One constant problem is that many of these processes occur at a scale that is smaller than the grid size of the model. At 898 cells long, 398 cells wide and 40 cells deep, her model is by no means small (these dimensions correspond to a typical cell size of 500 m x 500 m horizontally and 1-27 m vertically). To get around this issue, Nancy is working to incorporate the effects of this fine-scale mixing by parameterizing the process. With each step, she brings the model closer to reality, helping her understand the complex role of internal waves, mixing, and topography within a large-scale ocean model.



Dikun Yang

Identifying economically viable resource deposits in earth's subsurface is no easy task. Dikun Yang, a Postdoctoral Fellow at the UBC Geophysical Inversion Facility, makes this possible by using cutting edge geophysical modelling techniques. The technique he uses, known as inverse modelling, is a cost effective way to employ geophysical measurements in order to produce 3D models of mineral deposits.

by Kohen Bauer

Human civilization is reliant on a plethora of commodities that are hidden out of sight, buried deep underground in earth's subsurface. Our society depends on our ability to extract these commodities - economically important materials such as metals, groundwater and petroleum. However, to do this, we first must have a detailed idea about the geometry of deposits and reservoirs and where they reside at depth. Dikun Yang, a postdoctoral researcher who is a part of the UBC Geophysical Inversion Facility is able to create such a picture, using geophysical data, a computer and an approach known as inverse modelling.

PAINTING A PICTURE OF THE SUBSURFACE

The Geophysical Inversion Facility is where Dikun's strong theoretical physics background becomes practical. The inverse modelling approach is the integration of geophysical field data into a computer model, which allows Dikun to create and visualize a 3D snapshot of what lies underground. By using geophysical measurements and field observations to constrain his models, his algorithms produce pictures of the subsurface, which highlight the structure of the deposit of interest. Using this approach Dikun is able to interpret abstract geophysical data in a geologically tangible way. This makes inverse modelling a key tool in determining viable targets both in terms of future exploration and extraction. The implications of Dikun's efforts are particularly valuable because the method is extremely cost-effective. Inverse modelling of the subsurface can paint a picture of a deposit in minutes or hours, whereas spatially confined drilling and geochemical sampling might require months or even years and great expense.

DO THE RESULTS MAKE SENSE?

"You need to be careful", warns Dikun, "if used incorrectly, the inverse model can produce results that are completely imaginary." The last thing exploration companies' want is to be drilling for a non-existent ore body that a computer invented. What Dikun is referring to with his cautioning, is the issue of non-uniqueness. A challenging feature of most of Dikun's inverse problems is that many different earth models can arise from the same set of geophysical observations: His algorithms spit out many possible solutions for what the ore body could look like. Choosing the best possible model ultimately comes down to a delicate balance between the number of geophysical observations as inputs, and what constraints are placed on the model. Ultimately, Dikun is an expert in interpreting if the model output is viable. He is able to run and decipher multiple different simulations and obtain the most realistic model solution.

WHEN IT WORKS, IT REALLY WORKS

Dikun describes a particular study where he employed the inverse modelling technique to characterize a volcanogenic massive sulphide (VMS) deposit. These ore bodies are typically small, deeply buried and highly electrically conductive. However, these distinguishing qualities also make them difficult to discover using standard ground sampling techniques. By continuously refining his model simulations by updating initial conditions and interpreting electromagnetic data, Dikun was able to describe the structure of a deposit with incredible accuracy, demonstrating the utility of the inverse approach.

The real world applications of inverse modelling are vast. The Geophysical Inversion Facility even has a project identifying land mines and unexploded artillery in war-ravaged countries, the first step in safely removing them. Whether you're a private mining company hoping to strike it big, or a non-profit organization eager to locate a source of groundwater for a local town, Dikun is the man behind the method who is dedicated to helping you visualize your goal, literally.

Anna Grau & Anna Mittelholz

RED PLANET

For PhD students Anna Mittelholz and Anna Grau, Mars is a place very close to home. The red planet some of the highest potential for discovering evidence of extraterrestrial life in our solar system, but there's more allure than the prospect of discovering aliens. The two use their study of Mars to answer some challenging questions about our own planet.

by Rhy McMillan and Meghan Sharp

Mars wasn't always a cold and desolate planet. "A series of events shaped Mars into its present state" explains Anna Mittelholz, "and figuring out what these events were and why they happened brings us closer to understanding what really matters during the formation of the Earth and other terrestrial planets." Most of the major events over the geological history of Mars—impacts, the formation of the northern hemisphere lowlands and southern hemisphere highlands and valley networks, the generation of a strong internally-generated magnetic field, and a protracted period of volcanism—occurred only within the first billion years of the planet's evolution. But why?

This enigmatic feature of Mars' history distinguishes it from Earth and fires the imaginations of the two Annas beyond measure. "You have evidence of a remnant magnetic field, an unusual topographic dichotomy between the northern and southern hemispheres, unexpected river valleys...all these different data sets. For me, it's like a big puzzle and you're trying to solve it," says Anna Mittelholz. Anna Grau shares her sentiments;"what happened to change a planet that was potentially so similar to Earth very early on into the cold and dry desert it is today?"

WHO ARE 'THE ANNAS'?

Anna Grau studied theoretical physics for her undergraduate degree and Geophysics for her master's degree in Barcelona, Spain. During this time she was faced with the decision of whether to study pure, theory-based physics or physics applied to Earth. She was fascinated by "how physics could solve problems like no other science," and decided to apply this passion to her PhD under the supervision of Dr. Mark Jellinek. Her work on the geomorphology and climate history of Mars provides a compromise to her difficult decision, and a ready outlet to her passion for learning.

Anna Mittelholz completed her bachelor's degree in Munich, Germany, studying geophysics. During her degree, she held an engineering job building a satellite. Her undergraduate honours thesis dealt with seismicity on Mars and the challenges of using a single seismometer to gain information for the InSight lander, a stationary robot designed to study Mars' interior. Anna came to UBC to do her MSc with Dr. Catherine Johnson, who is on the InSight Science team, and got involved in the mission herself. Due to her dedication to her subject and academic excellence, Anna transferred to a PhD shortly thereafter.

THEIR MARTIAN PUZZLE PIECES

Although both of the projects being carried out by Anna and Anna are focused on the same planet, the questions they are trying to answer are quite different.

Anna Grau is exploring how to use the intricate and varied patterns characteristic of Martian valley systems to reconstruct Mars' early climate. Anna has shown that, whereas some valleys were probably carved by rivers, many were produced as a result of the advance and retreat of glaciers and by the subglacial flow of melt water. Rather than a tropical beginning, Anna sees early mars increasingly as being like modern day Greenland.

Anna Mittelholz wants to know what the magnetic field of Mars is like now, as well as what it was like before it almost completely disappeared about 4 billion years ago. On Earth, our magnetic field is the first line of defense against solar winds ripping away our atmosphere. The demise of the magnetic field may be what caused the Martian atmosphere to disintegrate so long ago. Anna is able to use measurements of the magnetic field preserved in the rocks, as well as the external magnetic fields induced by the sun, to explore the past and present Martian magnetic field.

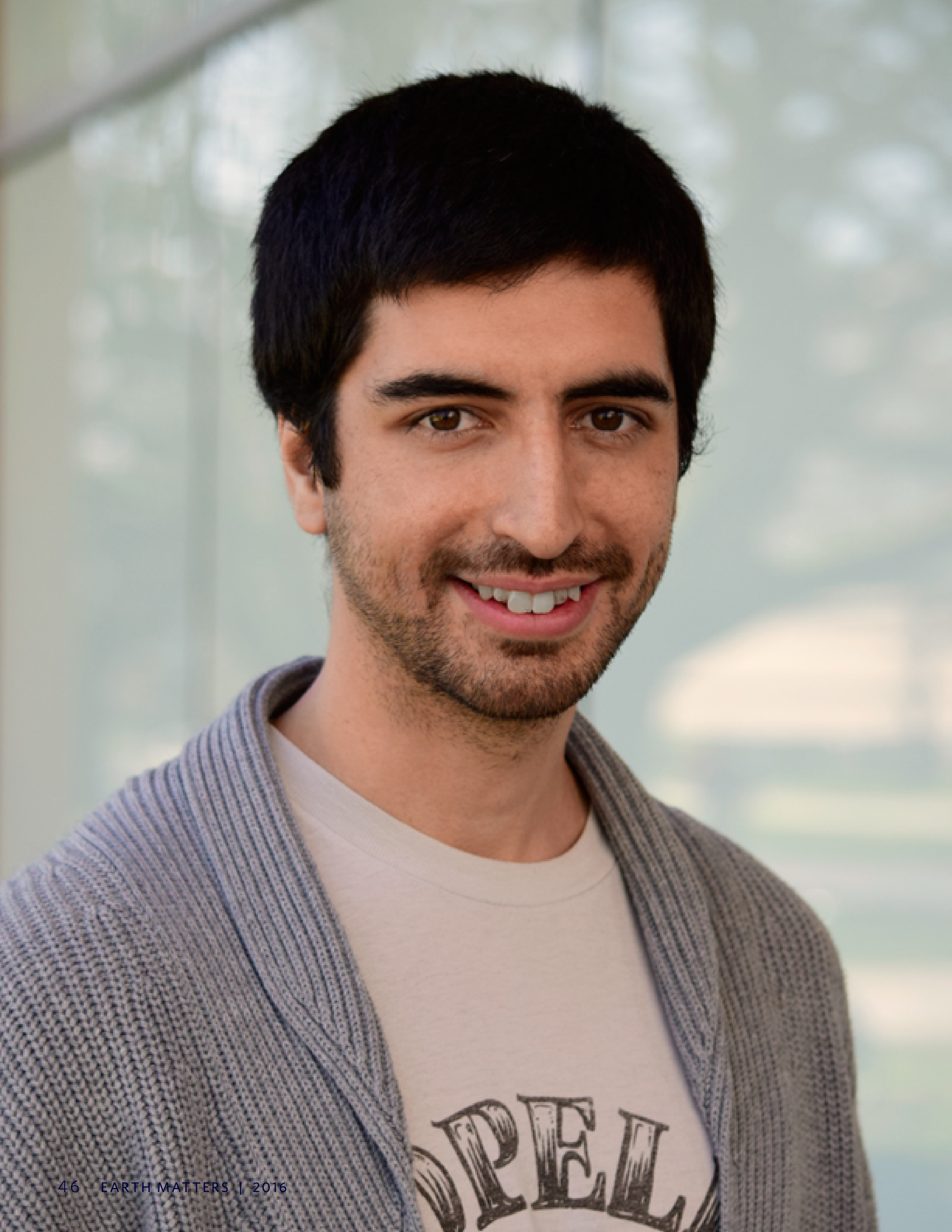
FITTING THEIR PIECES TOGETHER

As disparate as their work appears, the projects are actually quite closely related. "The magnetic field was possibly key to protecting the Martian atmosphere, and the Martian atmosphere basically provided the conditions for water stability on the surface," explains Anna Mittelholz. Both Annas use satellite data to make observations in hopes of answering their questions. Anna Grau has developed her own technique for categorizing the kinds of valleys on the surface and connecting them to particular erosional phenomena using satellite imagery and topography data. Anna Mittelholz uses data collected by the Mars Global Surveyor satellite (MGS) and the Mars Atmosphere and Volatile Evolution mission (MAVEN), two NASA projects intended to study the interplanetary magnetic field, ionosphere, and crustal magnetic field. Although their questions probe different aspects of the Mars puzzle, they will provide pieces to help better view the planet as a whole.

ONWARDS, BUT MOSTLY UPWARDS

Anna Grau and Anna Mittelholz are doing an astronomical job in their respective fields, and in the process they are providing inspiration to many future scientists through outreach programs, and writing for publications such as the one that you are currently reading. The big question is: who is going to get to the Red Planet first; Anna or Anna?

Background photo: Topographic shaded relief map of the Martian surface. Credit: MOLA Science Team.



Jordan Aaron

Landslides are immensely destructive natural hazards, having the potential to wipe out infrastructure and endanger human lives. Jordan Aaron's goal is to model and predict the movement and motion of landslides in order to reduce the risk associated with these extreme events.

by Kohen Bauer

Jordan Aaron is a geo-engineer and PhD candidate whose work with supervisor Oldrich Hungr focuses on numerical modelling of "extremely rapid flow-like landslides". To get a better idea of what one of these natural hazards looks like, he shows me a video on his computer. The video opens and we are looking at a serene tree-covered slope in Italy. Seconds pass, and it appears as though a few trees disappear from view, as if melting off the landscape. In a flash, the entirety of the slope wastes away in a whirlwind of debris, rock, dust and rubble, all of which catastrophically flow down onto a roadway below. Even through the video footage, it is apparent that these types of landslide carry immense destructive power. Fortunately for us, there are researchers like Jordan, who work to predict the flow behaviour and direction of such landslides, a crucial factors in the assessments of hazards as well as in strategies for landslide mitigation.

PAST IS THE KEY TO THE PRESENT

Capturing the complex mechanical interactions among particles and fluids in a rapidly flowing landslide is a daunting challenge for numerical modelling studies. "There are so many factors to consider in characterizing a landslide," says Jordan, "so data collection is a key process in refining the models." In order to improve and parameterize his models, Jordan meticulously examines the history books and characterizes past landslides. He collects as much information as possible for each unique incident, everything from the type of materials involved, such as organic ground cover and lithology, to the climate record of the landslide region. All of these properties have important, but understudied affects on how a landslide is generated and ultimately where it flows. Having such a database of historic landslides allows Jordan to identify common variables when comparing separate events. Finding systematic properties or behaviours shared by these landslides is a vital part of predicting their flow regimes and characters. Jordan's models incorporate only the most essential constraints, simulating the landslide movement by integrating only a few of the intrinsic properties, leading to a streamlined approach in determining which factors were ultimately responsible for slope failure. This allows him to model the propensity of slope failure for a wide range of initial conditions and predict the landslide behaviour that emerges, in turn.

REPRODUCIBLE RESULTS

One of the best things about Jordan's research is that it is extremely practical. He is honing algorithms that are important tools in a geotechnical engineer's workflow. "It's really motivating when the model correctly predicts the path of a landslide. The model becomes an essential part of risk analysis." One particular model success story is the Frank Slide, which occurred in 1903 in the North West Territories, and still remains Canada's deadliest landslide with an estimated 70-90 casualties. The important model parameter in the Frank Slide simulation was the friction between the slide material and the slope over which it traveled. By accurately parameterizing this factor, Jordan's model precisely reproduced the slide direction, and so testing a the model where the initial conditions and final results are well constrained is an excellent way to assess its accuracy.

Jordan's research on landslides has the power to save human lives through hazard identification. The information produced through Jordan's modelling, can be used to make better decisions regarding infrastructure and land use. Ultimately, Jordan is working to make the chaos of Mother Nature more systematically predictable.

Dave Capelle

The oceans are changing quickly and scientists like Dave Capelle have to work fast to keep up. Newly designed instruments combined with an ideal natural laboratory will give Dave a preview of how the world's oceans will change in response to climate change.

by Johan Gilchrist and Meghan Sharp

After completing a BSc in Geography and Climatology, Dave Capelle found himself working on an icebreaker ship in the Arctic Ocean conducting research on an oceanography expedition. To take his passion to the next level, he accepted an offer from UBC to work with Dr. Philippe Tortell on the fate of methane and nitrous oxide gases in the ocean and their response to climate change.

A NATURAL LABORATORY

Dave's journey into graduate school began with data collection. Philippe led him into a cold room, filled from floor to ceiling with seawater samples, many from Saanich Inlet, BC. The samples were waiting to be analyzed as part of a collaborative research effort with colleagues from the Department of Microbiology and Immunology at UBC.

According to Dave, Saanich Inlet is a "natural laboratory". It goes through a seasonal oxygen cycle, providing a case study for how a body of seawater responds to the growth of oxygen-minimum zones (OMZs). OMZs are predicted to expand in the oceans as a response to climate change. Their expansion will have a large but uncertain effect on the fate of the dissolved greenhouse gases (GHGs) methane (CH_4) and nitrous oxide (N_2O), the climate consequences of which motivate Dave's work.

FLIRTING WITH ENGINEERING

To fully characterize the seasonal oxygen cycling of Saanich Inlet, Dave's group has been collecting 40 bottles of seawater samples monthly for many years. However, processing and analyzing that number of samples would normally be time-consuming to the point of impossibility. In part to help Dave overcome this forbidding technical hurdle, Philippe developed an idea for an instrument that can analyze multiple samples simultaneously. With the help of Dr. John Dacey at Woods Hole Oceanographic Institute in Massachusetts, Dave and Philippe developed the "Purge and Trap Gas Chromatography Mass Spectrometer" (PTGCMS) after two years of work. The innovative PTGCMS is capable of analyzing 50 samples per day with only around an hour of setup, which is many times more efficient than the previous hand-sampling method. With the data flooding in from the PTGCMS, Dave currently focuses on analyzing the CH_4 and N_2O concentrations in his samples. "We have nearly ten years of data now, which is really amazing. There are only a handful of places in the world with data sets like this," says Dave.

DISSOLVED GREENHOUSE GASES

"CH_4 is produced during the anoxic decomposition of organic matter, a process that is largely confined to sediments but also occurs inside sinking particles in well-oxygenated waters," Dave explains. Warming of these sediments causes them to release even more CH_4; scientists like Dave are concerned that climate change will cause excess methane to be released into the oceans and subsequently into the atmosphere before it can be consumed naturally by bacteria. This would amplify the greenhouse effect and warm the planet further through a CH4-warming positive feedback cycle.

Dave is also studying a similar feedback for the effect of N_2O concentration on climate change. In OMZs, where most available oxygen has been used up, nitrate (NO_3^-, a vital nutrient for most primary producers) is converted to nitrous oxide and other gases that are unavailable for biological uptake. Less nitrate means less primary productivity, which results in less carbon dioxide uptake by organisms and more warming of the Earth's surface.

A PROXY FOR CHANGE

The magnitudes of these effects are hard to predict and due to climate change, the CH_4 and N_2O feedbacks may already be in motion, hence Dave's urgency in analyzing his samples. By using the PTGCMS to keep up with the high sampling rate of Saanich Inlet, Dave is building a CH_4 and N_2O database that may provide insight into how large ocean basins will respond to climate change and the expansion of OZMs.

Jenn Fohring

Computational geophysics relies on complex and demanding numerical computations to characterize the subsurface. Jenn Fohring uniquely exploits geophysical data coupled with an inverse model to answer key questions about the subsurface flow of fluids.

by Genna Patton

Jenn Fohring is all about the math. She's a PhD candidate specializing in computational geophysics at UBC—with a strong emphasis on the computations. "It's more about the math than the rocks for me. I fell in love with computer science and linear algebra," she says smiling. Jenn works with Eldad Haber in our Earth, Ocean and Atmospheric Sciences department and builds inverse problems that utilize geophysical data. Ultimately, Jenn is predicting the subsurface evolution of fluid flow in a reservoir through time, be it anything from oil to water.

USING GEOPHYSICAL DATA IN A NEW AND UNIQUE WAY

Historically, geologists would use physical measurements of borehole material from an aquifer to constrain parameters like hydraulic conductivity and hydraulic pressure that can then be used to estimate how subsurface fluid will flow in a reservoir. "But this won't necessarily accurately characterize square kilometers of rock," says Jenn. "You have sparsely populated boreholes throughout an aquifer and not much data to work with". Instead of only relying on physical measurements that can be obtained from borehole material to attempt to constrain fluid flow, she combines a flow model and a geophysical survey model to answer this question. "By incorporating geophysical data into this problem, we can get a much more accurate estimate of the hydraulic conductivity and how the fluid will flow," says Jenn.

SEISMIC DATA IN A FLOW MODEL

Taking seismic measurements between boreholes a known distance apart, she can accurately parameterize the time and distance over which the seismic waves travel. The inverse aspect of this problem is then to estimate the inverse of the velocities of the seismic waves. Inversion of the geophysical data allows her to characterize the changes in the composition of the rock in the aquifer. Without a known relationship between the seismic velocities and hydraulic conductivities, it's difficult to estimate the hydraulic conductivity for rocks in the reservoir. Therefore, Jenn forms a coupled inverse problem to estimate fluid velocities directly from seismic data. "Instead of solving two different partial differential equations, we just jam them all together into one problem," explains Jenn.

In the real world version of this problem, the aquifer is then pumped with an inert tracer. The idea is that the presence of the tracer will change the speed of the seismic waves travelling through the reservoir; comparing the geophysical data before and after the tracer is added will provide more information to constrain the model's predictions of the flow. "You want a distinct contrast in the velocities between these two scenarios," she says. The more distinct these two independent geophysical surveys, the more tightly constrained the initial distribution of the tracer.

SOLVING FOR THE SUBSURFACE FLOW

Using the seismic travel time data and inverse methods, Jenn solves for two variables: the initial distribution of the tracer within the reservoir and the flow field calculated from the geophysical data. The model is then able to predict the evolution of the subsurface flow. In the mathematical world that Jenn lives in, her model is linear and two-dimensional and she creates the initial borehole experiment that her model tries to recreate. "I invent a situation and can run the model to make sure everything works. Real data is way more difficult," she says laughing. Jenn claims to run a simple model with a simple version of reality, but she's enthusiastic to test more complicated scenarios. "Reactive transport, advection diffusion, multiple phase flow; these things in physical models, they're definitely something that would be fun to look at."

Lauren Harrison

The Hawaiian seamount chain is driven by a mantle plume that originates at the core-mantle boundary. Lauren Harrison has shown that the plume's lithium isotope signature can be explained by mantle material mixed with oceanic crust, implying that old subducted plates move throughout the entire mantle and collect at the-mantle boundary to later be sampled by plumes.

by Georgia Peterson

Lauren obtained her undergraduate degree from the University of Wyoming, where she majored in Geology with minors in Chemistry and Honors. "It was only natural that eventually I became a geochemist," she recalls. Her desire for studying the Hawaiian volcanoes came from living on the Island of Hawaii, where she was able to dip a rock hammer into a lava flow.

As a PhD candidate, Lauren Harrison is interested in the evolution of the Hawaiian-Emperor volcanic chain: a complex seamount chain produced by the movement of the Pacific Plate over a mantle plume. Working with Dominique Weis at the Pacific Centre for Isotopic and Geochemical Research (PCIGR), Lauren studies how the geochemical composition of the Hawaiian mantle plume has evolved throughout the past 47 million years using isotopes and trace elements that she describes as "the geochemical fingerprints of the mantle source."

NOW TRENDING

Isotopes are atoms of the same element with different numbers of neutrons, which results in slight variations in their masses. Geochemical processes such as melting and fluid-rock interactions naturally fractionate some isotopes, including those of the element lithium, due to their differences in weight. Different parts of the mantle, termed reservoirs, bear different lithium isotopic signatures because of their different histories; they vary from relatively pristine, "primordial" compositions, to "heavy" from concentrated ^{7}Li riverine runoff, to "light" as a result of fluid-rock interactions having removed the heavier isotope.

Lavas of the Hawaiian Islands bears two distinctive geochemical trends: the Kea and the Loa trends. Decades of research have demonstrated that the Kea and Loa trends are different geochemically as a result of sampling mantle reservoirs with different time-integrated histories. Lauren has been studying the isotopes of lithium (^{6}Li and ^{7}Li) which have not previously been examined in many Hawaiian basalts, as well as those of lead, hafnium, neodymium and strontium to constrain the source reservoirs of the two trends. Her analyses indicate that the Kea trend is similar to primordial mantle, while the source of the Loa trend is more complex due to crustal recycling.

CITING SOURCES

The lithium isotopic signature that Lauren has observed in the Loa trend provides compelling evidence that the Hawaiian mantle plume is recycling ancient, subducted ocean crust back to Earth's surface. It has previously been suggested from geophysical studies that subducting oceanic crust can sink through the entire length of the mantle (all 2900 km) and collect near the core-mantle boundary, sometimes referred to as "the slab graveyard." The Hawaiian mantle plume itself arises from a thermal instability at the core-mantle boundary, which causes hot material to upwell towards the surface. Lauren suggests that the isotopic signature of several different types of geologic material brought down with a subducting slab, including marine sediments, oceanic crust, subduction-eroded lower continental crust, could explain the observed isotopic heterogeneity.

Though this bilateral trend is known to occur on the exposed Hawaiian island, it is unknown whether the two trends continue on the older sections of the Hawaiian–Emperor chain. In addition to her work on determining the source reservoirs, Lauren is performing high precision isotopic analysis of basalt samples from an older section of the Hawaiian-Emperor chain, the Northwest Hawaiian Ridge, in order to constrain the distribution and onset of the double trend. In all, Lauren has shown that lithium isotopes are capable of providing powerful information about the dynamics of Earth's mantle.

Anna Hippmann

Phytoplankton produce half of the world's oxygen and are therefore an extremely important part of Earth's climate and ocean ecology. Anna is conducting experiments to research how phytoplankton adapt and survive in low nutrient conditions.

by Georgia Peterson

"Every second breath of oxygen we take is provided by phytoplankton. They are extremely important single celled organisms who influence cycles of silica, oxygen, carbon dioxide, nitrate, phosphate worldwide!" Anna Hippmann exclaims. As a biological oceanographer, Anna studies how the availability of the trace metal elements, iron and copper, affect productivity, physiology, and the proteomic response (the set of proteins a cell uses at any given moment) of phytoplankton in the open ocean. These trace metals are cycled into the upper ocean from rivers, ocean upwellings, and through the deposition of dust from continents and volcanic eruptions. Currently, it is estimated that phytoplankton growth is limited by a shortage of iron in about 30% of the ocean. The onset of global climate change may significantly alter both spatial distribution and quantity of these essential nutrients. Without a comprehensive understanding of phytoplankton adaptations to these changing conditions, researchers will be unable to predict potentially vast changes in ocean ecology. Furthermore, as producers of nearly half the world's oxygen and an extremely important sink for carbon dioxide, understanding these adaptations is essential to predicting future global climate.

SURVIVAL TECHNIQUES

Anna is particularly interested in diatoms, which are one of the largest classes of eukaryotic phytoplankton in the ocean. Many proteins involved in photosynthesis require iron. So, how do diatoms survive in low metal environments? Two main adaptative strategies have been postulated: 1) decreasing the amount of iron containing proteins and 2) increasing the ability to take up iron. Evidence has been found that diatoms employ both strategies by making use of copper. Diatoms can use a copper containing protein in photosynthesis instead of one containing iron and they can improve their iron uptake through the use of a multi-copper oxidase.

Anna conducts experiments where she cultures diatoms in an artificial seawater medium, subjected to three different scenarios: low Fe, low Cu, and both low Fe and Cu concentrations. In this way she can begin to tease apart the intricate dance of copper and iron physiology in diatoms.

DIFFERENCES IN ADAPTATION

Hippmann's initial results show that even within the same species different strains of diatoms are responding differently to the imposed scenarios. "Currently, I am looking at two different strains of the same diatom species. One strain was extracted from the ocean in 1958, and the other in 1977." Traditionally, single celled organisms are considered exact clones and should theoretically respond to stresses in an identical manner. However, Anna's initial findings are suggestive that even single celled organisms can be quite unique in nature. The 1958 strain is less resistant and needs 10% more copper to sustain its minimum growth rate and 40% more to reach its maximum growth rate. Anna has only begun analyzing the protein response of each strain, but the 1977 strain, which can handle much lower copper concentrations, seems to remodel a bigger portion of its metabolic pathways to alleviate the low copper conditions. It is also producing less of the main copper containing protein (plastocyanin) and has increased production of other proteins not yet identified. These unknown proteins have the potential to be a new group of copper responsive proteins (CuSIPs – Cu starvation induced proteins) that could warrant further exploration. Overall, Anna's experiments have furthered our understanding of adaptation strategies of diatoms, with important implications for future climate change and ocean ecology.

Maria Eliana Lorca Ugalde

Establishing how mining activities impact the surrounding environment and mitigating these impacts is a critical aspect of the mining industry. Maria's work serves to identify the impacts of the Antamina open pit mine on local fresh water cycling.

by Genna Patton

Sometimes we don't have enough of it, sometimes we have way too much of it, and sometimes it's poisonous; all over the world people experience the complicated relationship between freshwater and the environment. Maria Lorca, now studying at UBC, grew up in Chile where water scarcity is a big problem. "I think understanding how to use water in the most effective way was one of the things that drew me to hydrogeology," says Maria.

WASTE ROCK AND THE ENVIRONMENT

Maria is a PhD candidate working with Roger Beckie and Uli Mayer in EOAS. Her research examines the role of air supply in waste rock piles and how this could ultimately impact metal transport through natural water cycling. Metals are more soluble in acidic conditions, so the higher the acidity, the more likely it is that metals will be transported from waste rock piles through to the surrounding environment. "The main process that produces acidity in waste rock is pyrite oxidation. The increased presence of oxygen enhances this process and that's not something that you want to happen," explains Maria. Her study site, the Antamina mine, is also a unique environment to study because of the presence of carbonate rocks, which can neutralize acidic conditions. "It's really interesting from a geochemical point of view to understand which waste rock conditions will allow neutralization and which won't."

MARIA AND HER WASTE ROCK PILES

Maria's study and an array of other studies examining waste rock interactions are being conducted at the Antamina open pit mine in Peru. "The Antamina mine waste rock exists in a very wet environment, so a lot of water is affected by the mining activities." Maria has been studying five different waste rock piles that vary in both physical and chemical composition. The test piles were wired with sampling lines that extract samples of pore gas from within the piles every night, resulting in a two-year time series of O_2 and CO_2 data. The piles are also wired to collect temperature and moisture content which are parameters that can affect air flow and also be indicative of chemical reactions. Maria finds that these parameters vary quite dramatically between the piles. In the waste rock pile in which pore gas differed the most from atmospheric gas composition, "O_2 concentration is seven percent, so two-thirds of atmospheric oxygen is being consumed by reactions."

TAKING SHAPE

Scaling her smaller waste rock piles up to the full scale dump sites suggests that the size, shape and other physical characteristics of the pile will have pronounced effects on the reactions occurring within the pile. "The full scale waste rock dumps are built by what's called end-dumping, so the waste rock is just pushed over the closest edge of the pit mine; finer rock stays at the top and the coarser rock goes to the bottom so air moves more freely through the waste rock at the base," says Maria. The expectation of the full scale piles was that oxygen wouldn't penetrate very far through the pile's surface. Maria's findings show, however, that oxygen enters the center of the pile due to the size segregation of the rock. "Dumping sites will always build their waste rock piles in a way that is most cost efficient, but they can try to reshape their piles to reduce air flow at the base and plan their closure with this information in mind."


ANTAMINA


OR

Camilo Rada Giacaman

Understanding how glaciers flow is critical to answering many of the front page questions in glacier dynamics. Camilo Rada Giacaman, a mountaineer-turned-glaciologist, is undertaking a field-based operation that may hold the key towards accurately modeling and predicting global ice retreat rates and climate change.

by Alex Wilson

Not many in our generation can lay claim to an Antarctic peak, nor boast the title of "best Chilean mountaineer of 2011". Camilo Rada Giacaman, EOAS PhD student and the namesake of Rada Peak, has achieved both these feats. Camilo's love of the mountains started at a young age, and as a keen outdoorsman, he naturally gravitated to mountaineering. Over the 18 years Camilo has been climbing, he has reached over 240 summits, conquered 24 first ascents, and explored some of the most remote regions of Patagonia and Antarctica.

Mountaineering is not the only spike in Camilo's crampons; he's also a highly talented glaciologist. Camilo began his career with an undergraduate degree in Astronomy. Realizing he didn't want to spend his life with an eye glued to a telescope, Camilo then turned to a subject rich in field-based observation – Earth Science. After completing his Master's degree in geophysics at Universidad de Chile, Camilo became interested in glaciology, ultimately pursuing a Ph.D. under the guidance of Dr. Christian Schoof.

IT'S ALL ABOUT BASAL SLIDING

Camilo has focused his work at UBC towards understanding the processes involved during glacier basal sliding. "Out of the models dedicated to understanding the front page questions in glacial dynamics such as sea level rise or water availability, one of the major uncertainties is in the nature of basal sliding." The problem lies in a poor understanding of how water is drained from the base of a glacier. Water under a glacier acts as a lubricant, but more importantly it can partially support a glacier's weight, promoting sliding at the glacier-rock interface. Current models tend to incorporate this process as an evenly distributed, diffusive process. In reality however, water drainage may be pulsatile and localized to a number of specific drainage channels and shallow pools in cavities beneath the ice.

To address these issues, Camilo and Christian have been drilling holes down to the base of a small glacier located in the Saint Elias Mountain Range, near the border of the Yukon and Alaska. Using his wealth of field-based skills, Camilo has revolutionized the field operation. To date, the pair have drilled over 300 holes to measure water pressure at the base of the glacier. The work has produced a unique and invaluable dataset spanning nearly 10 years of glaciological observation. Camilo has also been instrumental in bringing glaciological data acquisition into the digital age. Using instruments that he designed and programmed himself, Camilo now measures a number of new variables including conductivity and instrument tilt, in addition to the original water pressure.

"A SYSTEM OF TAPS BEING SWITCHED ON AND OFF"

So far Christian and Camilo's work has determined that it is exceptionally uncommon to find an example of a glacier displaying clear diffusive water flow. Their data suggests that water drainage can be described as a "complex system of taps being switched on and off". This system of channels and pockets is highly dynamic, often showing very little correlation between water pressures in different cavities or channels.

The observations that Camilo and Christian have made have significant implications for current models of glacier flow. Together, they are studying basal sliding from a "data-backed approach, not just a theoretical one." Armed with his unique dataset, Camilo is poised to provide some of the critical pieces of information that modellers need to fully understand the complex dynamics during glacier movement. His work may hold the key to open door towards accurately modeling and predicting global ice retreat rates and climate change in general.

Aranildo Rodrigues de Lima

Weather forecasting relies on unraveling patterns contained within enormous datasets using limited time and resources. Aranildo is investigating machine learning approaches that directly address the challenges facing forecasting agencies and professionals.

by Chuck Kosman and Rachel Maj

"You know the Roomba?" Aranildo pauses our discussion to ask us about the robotic vacuum cleaner that has become textbook example of machine learning. "I have one -- they're really good! They save a lot of time." A PhD candidate under Dr. William Hsieh, Aranildo Rodrigues de Lima was exposed to the concept of machine learning during his BSc in computer science in Brazil as it was just emerging as a field. Looking for a way to directly apply the theory he learned in his MSc in applied statistics, Aranildo came to EOAS to tackle real-world problems. But he has a goal more complex than sweeping the floor. "What I'm trying to do is make machine learning methods usable for weather forecasting."

LEARNING THE ROPES

How does one teach a machine? With training and tests, of course. Learning machines are fed artificial datasets from which they construct models; the measure of their success is how well they can navigate real world ones. What distinguishes machine learning (ML) from traditional programming is that the computer comes up with the relationships between input and outputs through an error minimization process, rather than having them explicitly programmed in.

Machine learning is particularly useful for characterizing relationships between inputs and outputs that are "non-linear", meaning there is not a unique one-to-one relationship, or otherwise very complex -- like the relationship between past and future weather. Because machine learning approaches trade off between computation time, user intervention time, and accuracy, a human is still required to determine which machine approach is most useful for the task at hand, or if one is even required at all.

I CHOOSE YOU

Environment Canada provided Aranildo with three years worth of past weather data from 13 weather stations across Canada, including measurements of variables like precipitation, temperature, and wind speed, in addition to live daily data. Making sense of a dataset that large and in real time is far from "plug and play," Aranildo cautions. Yet the main challenge in implementing ML is, perhaps unsurprisingly, the human resources cost. "The first thing any client wants to know is 'how long is it going to take to train me?'" Aranildo explains. Currently, adopting ML would require a weather forecasting agency, such as Environment Canada, to take on the expensive task of training their staff.

To meet these specific challenges, Aranildo is investigating three machine learning approaches: support vector regression with evolutionary strategy (SVR-ES), extreme learning machines (ELM), and most recently online methods. He is packaging complex models in a way that makes them more user-friendly by exploring machine learning methods that help automate input choice (SVR-ES). Aranildo is working to bring his ML methods "online", meaning the machine can adjust its computed relationships based on new data right as it comes in, rather than the model periodically requiring retraining. Aranildo combines these with techniques that simplify the relationship between inputs and outputs to dramatically cut down computation time (ELM).

Aranildo envisions machine learning techniques replacing the more traditional approaches very soon, within the next 5-10 years, when testing is complete and the methods are proven. Machine learning methods not only present the advantage of the use of real-time data but also greatly improve the accuracy of the results obtained by unraveling patterns a human simply could not. Perhaps one day forecasting the weather will be as easy as cleaning the floor.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Schudel G., Lai V., Gordon K., Weis D. Trace Element Characterisation of USGS Reference Materials by HR-ICP-MS and Q-ICP-MS. Chem. Geol. 410, 223-236, 2015.

Awards and Distinctions*

Allen, Susan
President's Prize, Canadian Meteorological and Oceanographic Society, 2015

Andersen, Raymond
Norman R. Farnsworth Research Achievement Award, American Society of Pharmacognosy, 2015
UBC Faculty of Science Service Award 2016

Crowe, Sean
Peter Wall Institute for Advanced Studies Scholar, 2015
Fischer Canadian Society of Microbiologists Award in Microbiology Research, 2015

Dipple, Greogry
NSERC Discovery Accelerator Supplement

Eberhardt, Erik
UBC-EOAS Undergraduate Instructor of the Year Award

Francois, Roger
Fellow of the Royal Society of Canada, 2015
Timothy R. Parsons Medal, 2016 (Department of Fisheries and Oceans, Canada)

Jellinek, Mark
Commendation from Dean Peacock for EOSC 212 and EOSC 453

Mortensen, James
J.C. Sproule Award for "Excellence in Northern Exploration and Mentoring", Canadian Institute of Mining, Metallurgy and Petroleum (CIM), 2016

Oldenburg, Doug
Best Paper in Geophysics SEG 2014: McMillan, M., Oldenburg, D., (2014), Co-operative constrained inversion of multipleelectro-magnetic data sets, Geophysics, 79, 4, B173–B185

Pakhomov, Evgeny
Dean's commendation for receiving outstanding teaching evaluation, 2015

Scoates, James
Blaustein Visiting Professor, Stanford University, 2016
International Research Chair, Université Libre de Bruxelles, Brussels, Belgium, 2016

Smit, Matthijs
Canadian Research Chairs Tier II Award of Position, 2015

Smith, Paul
Excellence in Leadership and Service Award, EOAS, 2015

Stull, Roland
Killiam Teaching Prize, 2015

Tortell, Philippe
Scholar in Residence, Peter Wall Institute for Advanced Studies, UBC

Waterman, Stephanie
Alfred P. Sloan Fellowship in Ocean Sciences, 2015
Early Career Ocean Scientist Award, Canadian National Committee for the International Scientific Committee on Ocean Research (SCOR) 2016

Weis, Dominique
Blaustein Fellowship, University of Stanford, Spring 2016

*Includes only honours distributed May 1st, 2015 – April 30th, 2016.

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